A Reproduced Copy

OF

NASA-TM-85274 19830013211

Reproduced for NASA

by the

NASA Scientific and Technical Information Facility

LIBRARY COPY

JUL 29 1983

LANELEY RESEARCH CENTER
LIBRARY, NASA
HAMP'TON, VIRGINIA

FFNo 672 Aug 65
LANDSAT-D Investigations Workshop

May 13-14, 1982

Goddard Space Flight Center

Day 1
Agenda

John Barker
Agenda
LANDSAT-D INVESTIGATIONS WORKSHOP -
BLDG. 26, ROOM 205

Thursday, 13 May 1982

8:30 am  Agenda                                      Barker
8:35 am  Welcome, Science Organization and
          Introduction of Investigators                  Salomonson
9:00 am  Landsat-D Project Status                   Busse
9:15 am  Landsat-D Ground Segment                   Webb
10:15 am BREAK (Photo Session)                     Lyon
10:45 am Early Access TM Processing                Lyon
11:00 am Landsat-D Data Acquisition and
          Availability                                   Freden
11:30 am Landsat-D Performance Characterization    Barker
12:00 pm Introduction of Technical Experts
          and Science Representatives
12:30 pm Lunch and Informal Investigations
          Team Interaction
Thursday, 13 May 1982 (Cont.)

2:00 pm  Introduction to MSS Pre-NOAA Characterization
          Alford

2:15 pm  MSS Radiometric Sensor Performance
          Barker
          • Spectral Information
          • Absolute Calibration
          • Ground Processing

3:30 pm  MSS Geometric Sensor Performance
          Banks

4:00 pm  MSS Geometric Processing and Calibration
          Brooks

5:00 pm  Closing Remarks
          Barker

5:30 pm  Dinner and Informal Investigations
          Team Interaction

1-3
Thursday, 13 May 1982 (Cont.)

TOURS, etc., Building 28

(Five Tours/Presentations Offered Each Half Hour)

1. Landsat Assessment System (LAS)  Lyon/Fischel
2. Image Generation Facility (IGF)   GE
3. MSS and TM Sensored Pictures      Barker
4. Control and Simulation Facility (CSF) GE
5. End-to-End System Analysis Study Highlights Billingsley
Agenda

LANDSAT-D INVESTIGATIONS WORKSHOP

Friday, 14 May 1982

8:00 am  Informal Investigations Team Interaction

8:30 am  Introduction to TM Characterization

  TM Radiometric Sensor Performance
  • Spectral Information
  • Absolute Calibration
  • Ground Processing

  Barker

10:15 am  BREAK

10:30 am  TM Geometric Sensor Performance

11:30 am  TM Geometric Processing — Flight Segment

  Engel
  Beyer

12:30 pm  Lunch and Informal Investigations Team Interaction
Friday, 14 May 1982 (Cont.)

1:45 pm  TM Geometric Processing — Ground Segment  Beyer
3:00 pm  Early Access TM Processing  Fischel
3:45 pm  Wrap-Up Panel Discussion  Science Team
4:15 pm  Informal Investigations Team Interaction
Welcome, Science Organization and Introduction of Investigators

Vince Salomonson
Distributed Responsibilities

PROJECT SCIENTIST
- Overall Management and Direction of Project Science Activities
- Representation of Science Objectives and Activities to NASA Headquarters, GSFC and the User Community
  - Chairman of Landsat-D Technical Users Working Group

ASSOCIATE PROJECT SCIENTIST
- Day to Day Representation to the Project
- Systems Performance for Flight and Ground Segments
- Systems Contractor Management (Santa Barbara Research Center (SBRC), GE) for Science Contracts
Distributed Responsibilities (Cont.)

ASSISTANT PROJECT SCIENTIST

- Science Monitor
- Science Resources
  - Manpower
  - Dollars

MISSION UTILIZATION MANAGER

- Scene/Data Selection
  - Acquisition
  - Processing
  - Distribution

- Out-of House Investigators Management
  - Contracts
  - Grants
  - MOU’s
  - Scientific Monitors
  - Contract Monitors

All Responsibilities Require Close Contact and Frequent Communication with All Elements of the Project: e.g. LAS, ADDS, Software Manager, Mission Operations Manager, etc.
Landsat-D Project Status

Jon Busse
Landsat-D Key Events

SCRUNGE Available
Start OPS Readiness Period

Ground Segment Integrated Test (67 MSS Scenes/Day Processing Capability)

133 MSS Scenes/Day Processing Capability

TVM Acquisition Archive

200 MSS Scenes/Day Processing Capability

1982

Mission Operations Review
D-Launch Readiness

Flight Readiness Review

1983

Ground Segment Acceptance

MSS System Transition to NOAA

1984

1985

TDRSS/NCC Capability

TM-12 Scenes/Day

TM-100 Scenes/Day Transition to NOAA
## Flight Segment Status

**COMPLETED THERMAL VACUUM TEST MARCH 11, 1982**

<table>
<thead>
<tr>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>24</td>
<td>25</td>
<td>26</td>
<td>27</td>
<td>28</td>
<td>29</td>
</tr>
<tr>
<td>30</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Thermal Vacuum
- TM/MSS Performance
- Appendage Installation
- Deployments
- Alignment
- Vibration
- Acoustic
- Alignment
- Deployments
- Mass Properties
- Flight Readiness RVW
- Box/Pack
- Ship

*Original page is of poor quality*
Landsat-D Ground Segment

Bill Webb
Landsat-D System Overview

- System Requirements
- Flight Segment
- Ground Segment
Landsat-D System Requirements

- Orbit
  - Altitude: 705.3 km
  - Descending Node: 9:30-10:00 a.m.
- Launch Vehicle
  - Delta 3920
- Instruments
  - Multispectral Scanner
    - 4 Band
    - 80 Meter IFOV
  - Thematic Mapper
    - 7 Band
    - 30 Meter IFOV
- Flight Segment
  - Uses Multimission Modular Spacecraft
  - Shuttle Retrievable
- Mission Life
  - 3 Years
- 1 Spacecraft Operation at a Time
- Ephemeris Data
  - Global Positioning System
  - Predicted/Uplink
- Coverage
  - Ground Station Tracking Data Network
    - Initially
  - Tracking and Data Relay Satellite System
    - When Available
- Scenes/Day — Flight Segment
  - NASA (200 MSS; 100 TM)
  - Foreign (337 MSS; 150 TM)
- Data Quantity — Ground Segment
  - MSS
    - Archival Data — 200 Scenes/Day
  - TM
    - TM Evaluation—Begins July 30, 1982
      - 1 Scene/Day
    - TM R&D—Begins July 30, 1983
      - Archive Data—12 Scene/Day
      - Fully Processed—12 Scene/Day
    - TM Operational—Begins January 31, 1985
      - Archive Data—100 Scene/Day
      - Fully Processed—50 Scene/Day Film/HDT
      - 10 Scene/Day CCT
- Products Through Ground Segment
  - 48 Hours
    - High Density Tapes
    - Computer Compatible Tapes
    - TM Film
- Data Quality
  - Geodetic Accuracy: 0.5 Pixel, 90% of the Time
  - Temporal Registration: 0.3 Pixel, 90% of the Time
  - Radiometric Correction to ± 1 Quantum Level
LANDSAT D FLIGHT SEGMENT

GLOBAL POSITIONING SYSTEM ANTENNA

ATTITUDE CONTROL MODULE

PROPULSION MODULE

POWER MODULE

S-BAND ANTENNA

THEMATIC MAPPER

WIDEBAND MODULE

MULTISPECTRAL SCANNER

SUN SENSORS

SOLAR ARRAY PANEL

MULTI-MISSION MODULAR SPACECRAFT

INSTRUMENT MODULAR

1-18
Multispectral Scanner (MSS) Sensor

MSS Detector Details

<table>
<thead>
<tr>
<th>Bands</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Scan Mirror

4 Bands
6 Detectors Per Band

Along Track Direction

West → East

Scan Direction

Band | Spectral Ranges μm
-----|---------------------
1    | .5 – .6
2    | .6 – .7
3    | .7 – .8
4    | .8 – 1.1

Ground IFOV
All Bands – 83 Meters
Data Rate – 15.06 Mbps
Quantization Levels – 64

Orbit Direction N to S

Swath Width 185 km
THEMATIC MAPPER (TM) SENSOR

Scan Mirror

Along Track Direction

Silicon Detectors and Filters
Bands 1 2 3 4

Cooled Detectors and Filters
Bands 5 6 7

Scan Direction

Ground IFOV
Bands 1-5 & 7 30 Meters
Band 6 120 Meters

Data Rate - 04.9 Mbps
Quantization Levels - 256

Incorporates Angular Displacement Sensor (ADS)
Measures Angle of Motion from 2 to 125 Hz
Source of Jitter Compensation Data
PARTITIONING THE GROUND SEGMENT

TYPICAL GROUND SYSTEM ELEMENTS

- OPERATIONS CONTROL CENTER (OCC)
- DATA MANAGEMENT SYSTEM (DMS)

LANDSAT-D ELEMENTS

- TRANSPORTABLE GROUND STATION (TGS)
- CONTROL & SIMULATION FACILITY (CSF)
- MISSION MANAGEMENT FACILITY (MMF)
- IMAGE GENERATION FACILITY (IGF)
- LANDSAT ASSESSMENT SYSTEM (LAS)

- FLIGHT SEGMENT CONTROL & MONITORING
- MANAGEMENT CONTROL
- PRODUCTION CONTROL
- DATA BASE
- IMAGE ACQUISITION
- PRODUCT GENERATION

1-27
Mission Management Facility and Image Generation Facility Partitioning

- **Landsat Assessment System**
- **Control & Simulation Facility (CSF)**
- **Transportable Ground Station (TGS)**
- **Image Generation Facility (IGF)**
- **Mission Management Facility (MMF-M)**
- **Mission Management Facility (MMF-T)**

**NASA Owned**

**Transfer to NOAA at D+6 Months**

**Transfer to NOAA on January 31, 1985**

1-28
LANDSAT-D GROUND SEGMENT
Mission Management Facility
Major Functions

- **Data Acquisition**
  - PROCESS REQUESTS for Data Acquisition
  - PROVIDE CANDIDATE Scene Data ACQUISITION LISTS for Satellite Operations Planning and Scheduling
  - ACCOUNT FOR TELEMETRY Data Acquisition
  - ACCOUNT FOR IMAGE Data Acquisition

- **Data Archive**
  - SCHEDULE Archival Processing
  - MAINTAIN Archival DATA BASE and Produce Image Catalogs

- **Product Generation**
  - PROCESS REQUESTS for Product Generation
  - SCHEDULE Product Generation

- **Ground Segment Management**
  - Maintain Ground Segment SUPPLIES INVENTORY
  - TRACK Ground Segment PROBLEMS
  - Provide VERIFICATION AND SELF TEST Capability
  - Provide MANAGEMENT REPORTS
IMAGE GENERATION FACILITY

- DATA RECEIVE, RECORD TRANSMIT SYSTEM
- MSS IMAGE PROCESSING SYSTEM
- TM IMAGE PROCESSING SYSTEM
DATA RECEIVE, RECORD, TRANSMIT SYSTEM
MAJOR FUNCTIONS

- RECORD MSS AND TM DATA
- GENERATE TAPE DIRECTORIES
- COPY HIGH DENSITY TAPES
- ARCHIVE HIGH DENSITY TAPES
- TRANSMIT MSS DATA TO EROS DATA CENTER
MSS IMAGE PROCESSING SYSTEM
MAJOR FUNCTIONS

- PROCESS IMAGE RELATED TELEMETRY
  (ATTITUDE AND EPHEMERIS)

- GENERATE 28-TRACK ARCHIVAL TAPES
  - RADIOMETRICALLY CORRECTED
  - GEOMETRIC CORRECTIONS APPENDED

- CREATE QUALITY ASSURANCE PRODUCTS
  - COMPUTER COMPATIBLE TAPES
  - REPORTS
  - FULLY CORRECTED HIGH RESOLUTION FILM
MSS IMAGE PROCESSING SYSTEM
HARDWARE

HIGH DENSITY (DIGITAL Recorder (spare))

HIGH DENSITY DIGITAL RECORDER

TAPE CONTROL, TIME CODE

MATRIX SWITCH

SERIAL TO PARALLEL DATA INPUT

MSS DECOM

PARALLEL TO SERIAL DATA OUTPUT

VAX 11/780

DATA OUTPUT

DICOMED 70MM FILM RECORDER

ON LINE DISPLAY

CONTROL POINT IMAGE DISPLAY

PROCESS CONTROL

IMAGE DATA

176 MBYTE SYSTEM DISKS (2)

800/1600 BPI COMPUTER COMPATIBLE TAPE (3)

176 MBYTE IMAGE DISKS (8)

AP-180V ARRAY PROCESSOR

1-36
MULTISPECTRAL SCANNER
IMAGE GENERATION PROCESS FLOW

TRANSPORTABLE GROUND STATION

MODEM (FROM WHITE SANDS VIA DOMSAT)

DOMSAT INTERFACE FACILITY (BLOG. 23)

DATA RECEIVING RECORDING

HDT_R

DATA INPUT & REFORMATTING

IMAGE DISKS

COMPUTE
- GEOMETRIC CORRECTION MATRICES
- RADIOMETRIC CORRECTION FUNCTIONS
- ANNOTATION DATA

RADIOMETRIC CORRECTION

HDT_A

GEOMETRIC CORRECTION DATA
- ATTITUDE
- EPHemeris
- MSS UNIQUE

DATA RECEIVE, RECORD, TRANSMIT SYSTEM

CONTROL POINT LIBRARY BUILD

PERFORMANCE EVALUATION AND QUALITY ASSURANCE

MSS IMAGE PROCESSING STRINGS
MSS IMAGE PROCESSING SYSTEM
INTERFACES

MISSION MANAGEMENT FACILITY

PROCESS FEEDBACK & CONTROL POINT CHIPS

PROCESS REQUESTS

DATA RECEIVE RECORD TRANSMIT SYSTEM

TM, MSS VIDEO DATA TAPES

PROCESSED FILM

PHOTO LAB

LATENT FILM

ORIGINAL PAGE IS OF POOR QUALITY

1=38
TM IMAGE PROCESSING SYSTEM
MAJOR FUNCTIONS

- PROCESS IMAGE RELATED CORRECTION DATA
  - GYRO
  - ANGULAR DISPLACEMENT SENSOR
  - MIRROR SCAN CORRECTION
  - EPHEMERIS

- GENERATE 28-TRACK ARCHIVAL TAPES
  - RADIOMETRICALLY CORRECTED
  - GEOMETRIC CORRECTIONS APPENDED

- GENERATE 28-TRACK FULLY CORRECTED TAPE

- GENERATE HIGH RESOLUTION FILM AND COMPUTER COMPATIBLE TAPE PRODUCTS

- CREATE QUALITY ASSURANCE REPORTS
THEMATIC MAPPER IMAGE GENERATION PROCESS FLOW

GEOMETRIC CORRECTION DATA
- ATTITUDE
- EPSIMENIS
- TM UNIQUE

COMPUE
- GEOM CORRECTION MATRICES
- RADIO CORRECTION FUNCTIONS
- ANNOTATION DATA

DATA RECEIVING RECORDING

INPUT SCREENING DATA EXTR

RADIOMETRIC AND CONTROL POINT DATA

RADIOMETRIC CORRECTION

GEOMETRIC CORRECTION

PRODUCT GENERATION

EROS DATA CENTER

TRANSPORTABLE GROUND STATION

MODEM (FROM WHITE SANDS VIA DOMSAT)

DATA RECEIVE, RECORD, TRANSMIT SYSTEM

TM IMAGE PROCESSING SYSTEM

CONTROL POINT LIBRARY BUILD

PERFORMANCE EVALUATION AND QUALITY ASSURANCE
TM IMAGE PROCESSING SYSTEM INTERFACES

MISSION MANAGEMENT FACILITY

PROCESS FEEDBACK & CONTROL POINT CHIPS

PROCESS REQUESTS

DATA RECEIVE, RECORD, TRANSMIT SYSTEM

TM, MSS VIDEO DATA TAPES

LATENT FILM

PROCESSED FILM

PHOTO LAB
Processing

CAPABILITY – SCENES/DAY
MSS 133 MIPS – AT LAUNCH
200 MIPS – SEPT 30, 1982
TM 1 SCRUNGE – AT LAUNCH
12 TIPS – JULY 31, 1983
100 TIPS – JAN 31, 1985

FULL CAPABILITY DEMONSTRATION

OPERATIONS READINESS TESTING AND EXERCISES

INSTRUMENT ACTIVATION

PLANNED PROCESSING FOR USERS

MSS

TM-SCRUNGE

ORIGINAL PAGE 13
OF POOR QUALITY

1-43
CONTROL AND SIMULATION FACILITY
MAJOR FUNCTIONS

• PLAN AND SCHEDULE FLIGHT SEGMENT OPERATIONS

• SCHEDULE LINK SUPPORT WITH NETWORK CONTROL CENTER

• COMMAND FLIGHT SEGMENT

• ACQUIRE FLIGHT SEGMENT TELEMETRY

• MONITOR, EVALUATE, AND REPORT FLIGHT SEGMENT PERFORMANCE

• SIMULATE FLIGHT SEGMENT OPERATION

• REPROGRAM ON BOARD COMPUTER

• PERFORM SELF TEST
TRANSPORTABLE GROUND SYSTEM
MAJOR FUNCTIONS

- ACQUIRE TM/MSS VIDEO DATA
  - OPERATIONALLY IN PRE-TDRSS ERA
  - SUPPORT EVALUATION IN POST-TDRSS ERA

- PROVIDE TM/MSS VIDEO DATA TO THE IMAGE GENERATION FACILITY

- PROVIDE CAPABILITY TO RECEIVE NARROWBAND TELEMETRY
LANDSAT ASSESSMENT SYSTEM
MAJOR FUNCTIONS

- PERFORM DATA QUALITY AND IMAGE SCIENCE TESTS OF TM AND MSS
- COMPARE TM AND MSS SENSORS
- COMPARE LANDSAT-D TO PREVIOUS LANDSAT MISSIONS
- PERFORM LIMITED APPLICATIONS INVESTIGATIONS IN SELECTED DISCIPLINES
La at
NASA Boundary
To Gate #2 (Parkway Gate)
Bldg. 28 Landsat-D Ground Segment
Road #4

Landsat-D Transportable Ground Station Location
10 Meter Antenna
Electronics Van
Road #10
Road #8

Gate #4

Soil Conservation Rd.

Main Gate
Greenbelt Rd.

150 Foot Collimation Tower
Network Training and Test Facility Bldg. #25

La at-D Ground Segment Location
Landsat-D Performance Characterization

John Barker
Landsat-D Performance Characterization Activities

- Introduction
- Objectives
- Structure
- Engineering Verification
- Science Characterization
- Activities Schedule
- Investigations Workshop
Introduction

Landsat-D Performance Characterization is a Cooperative, Two-Part Engineering and Scientific Analysis Effort Designed to Foster the Effective Accomplishment of Overall Project Goals.

- Thematic Mapper (TM) Capability Assessment
- Multispectral Scanner (MSS) to TM Transition
- Operational System Feasibility Demonstration
- Continuity of MSS Imagery
- Continued Foreign Access
Objectives

ENGINEERING:
- Verify Instrument, Data Processing Facility and Total System Performance to Specifications
- Establish Equipment and Operations Reliability
- Verify Product Quality Standards

SCIENCE:
- Characterize Accuracy and Precision of Sensor and Spacecraft Performance
- Characterize Accuracy and Precision of Image Data Quality
- Characterize Accuracy and Precision of Derived Information
- Recommend Landsat-D System Improvements
- Communicate Results to Research Community
Structure

LANDSAT-D SYSTEM

ENGINEERING VERIFICATION
- RELIABILITY
- SPECIFICATIONS
- QUALITY ASSURANCE
  - END-TO-END SYSTEM PERFORMANCE
  - TM SYSTEM PERFORMANCE
  - MSS SYSTEM PERFORMANCE
  - INSTRUMENT PERFORMANCE

SCIENCE CHARACTERIZATION
- SENSOR AND SPACECRAFT PERFORMANCE
- IMAGE DATA QUALITY
- APPLICATIONS INFORMATION

- Recommend Landsat-D System Improvements
- Communicate Results to Research Community
Engineering Verification
Engineering Verification Organization

LANDSAT-D PROJECT
  L. Gonzales

RELIABILITY VERIFICATION
  W. Webb

SPECIFICATIONS VERIFICATION

INSTRUMENTS
  O. Weinstein

MSS SYSTEM
  L. Gonzales

TM SYSTEM
  L. Gonzales

PRODUCT QUALITY VERIFICATION
  Webb

MSS
  G. Banks

TM
  O. Weinstein

END-TO-END SYSTEM
  W. Webb

Jet Propulsion Laboratory
  F. Billingsley

* MDOD Mission and Data Operations Directorate
** SBRC Santa Barbara Research Center

1-58
- Recommend Landsat-D System Improvements
- Communicate Results to Research Community
**Instrument Performance Analysis**

(SENSOR SYSTEM LEVEL TESTS)

<table>
<thead>
<tr>
<th>RESPONSIBILITIES</th>
<th>REPORTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSS-Protoflight and Flight (PF and F)</td>
<td>• Technical Memos</td>
</tr>
<tr>
<td></td>
<td>• Pre-Ship Review</td>
</tr>
<tr>
<td>Hughes</td>
<td>• Final Report</td>
</tr>
<tr>
<td></td>
<td>• Technical memos</td>
</tr>
<tr>
<td>TM (PF and F)</td>
<td>• Pre-Ship Review</td>
</tr>
<tr>
<td>Santa Barbara Research Center (SBRC)</td>
<td>• Post-Launch Support</td>
</tr>
</tbody>
</table>
# MSS and TM System Performance Analysis

<table>
<thead>
<tr>
<th>Ge Responsibilities</th>
<th>Reports</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-Launch</strong></td>
<td>• Technical Memos</td>
</tr>
<tr>
<td>TM Radiometric Testing and Data Reduction</td>
<td>• Pre-Ship Review</td>
</tr>
<tr>
<td>TM Geometric Testing</td>
<td>• Processing White Papers and Data Reduction</td>
</tr>
<tr>
<td><strong>Post-Launch</strong></td>
<td>• Technical Memos</td>
</tr>
<tr>
<td>Radiometric Calibration and Validation</td>
<td>• Post-Launch Support</td>
</tr>
<tr>
<td>Geometric Calibration and Validation</td>
<td>• Processing Parameter Update</td>
</tr>
</tbody>
</table>
End-to-End System Performance Analysis

RESPONSIBILITY
Fred Billingsley, JPL

REPORTS
Pre-Launch Publication of Landsat-D End-to-End System Performance Study

STUDY OBJECTIVES
• Determine to What Extent Intended System Performance is Possible
• Estimate Image Technical Performance to be Expected
• Determine if Adequate Ancillary Information is Present
• Trace Effects of System Functions and Operations Through the System
  • Determine End-to-End System Operability
  • Estimate Cumulative Errors
Structure

LANDSAT-D SYSTEM

ENGINEERING VERIFICATION

RELIABILITY

SPECIFICATIONS

QUALITY ASSURANCE

END-TO-END SYSTEM PERFORMANCE

TM SYSTEM PERFORMANCE

MSS SYSTEM PERFORMANCE

INSTRUMENT PERFORMANCE

SCIENCE CHARACTERIZATION

SENSOR AND SPACECRAFT PERFORMANCE

IMAGE DATA QUALITY

APPLICATIONS INFORMATION

• Recommend Landsat-D System Improvements
• Communicate Results to Research Community
# Reliability Verification

<table>
<thead>
<tr>
<th>RESPONSIBILITY (ONGOING)</th>
<th>REPORTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSFC Mission Operations Manager (Webb)</td>
<td>Maintenance Plan</td>
</tr>
<tr>
<td>GE Engineering Support Organization</td>
<td>Configuration Management Plan</td>
</tr>
<tr>
<td>GE Quality Assurance Organization</td>
<td>Equipment Service Reports (ESR)</td>
</tr>
<tr>
<td></td>
<td>Problem Defect Reports (PDR)</td>
</tr>
<tr>
<td></td>
<td>Management Reports</td>
</tr>
<tr>
<td></td>
<td>• Utilization</td>
</tr>
<tr>
<td></td>
<td>• Mean Time to Repair</td>
</tr>
<tr>
<td></td>
<td>• Inventory and Supplies</td>
</tr>
<tr>
<td></td>
<td>• Production Statistics</td>
</tr>
<tr>
<td></td>
<td>• Maintenance Histories</td>
</tr>
</tbody>
</table>
# Quality Assurance Verification

<table>
<thead>
<tr>
<th>RESPONSIBILITY (ONGOING)</th>
<th>REPORTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSFC Mission Operations Manager (Webb)</td>
<td>Quality Assurance Reports</td>
</tr>
<tr>
<td>GE Quality Assurance Organization</td>
<td>Processing Summary Reports</td>
</tr>
<tr>
<td>• Product Evaluation</td>
<td>Automated PDR and ESR Management Reports</td>
</tr>
<tr>
<td>• Process Evaluation</td>
<td>System Audit Reports</td>
</tr>
<tr>
<td></td>
<td>Special Management Reports (Trend Analyses &amp; Current Quality Problem Daily Report)</td>
</tr>
</tbody>
</table>

1-65
# Quality Verification Supporting Information

<table>
<thead>
<tr>
<th>INFORMATION</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Approaches to Satisfying Landsat Data User Concerns&quot;</td>
<td>The Operational Landsat-D Quality Assurance/ Performance Evaluation Plan Review Meeting, February 1982 (Final Report)</td>
</tr>
<tr>
<td>Operational Quality Assurance</td>
<td>MOR, April 6-7, 1982</td>
</tr>
<tr>
<td>USER CONCERNS</td>
<td>REQUIREMENTS</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>TIMELINESS OF DATA: Throughput Turnaround Time</td>
<td>0 200 New MSS Scenes/Day 0 48 Hours from Receipt of Data</td>
</tr>
<tr>
<td>COMPLETENESS OF DATA: Treatment of Data Dropouts, Errors</td>
<td>0 Replace Lost Data with Last Good Data 0 Detect and Correct Bad Time Codes 0 Report All Substitutions on Digital Products</td>
</tr>
</tbody>
</table>
| RADIOMETRIC QUALITY OF DATA: Absolute and Relative | ±1 Quantum Level over Entire Detector Range (6 Bit Data) within each Band | • Calibration on Wedge for Absolute and Band-to-Band Fidelity • Nominal Calibration Wedge for Back-Up • Scene Content for Detector-to-
### TABLE 1: APPROACHES TO SATISFYING LANDSAT DATA USER CONCERNS (Cont'd)

**ORIGINAL PAGE IS OF POOR QUALITY**

<table>
<thead>
<tr>
<th>USER CONCERNS</th>
<th>REQUIREMENTS</th>
<th>APPROACH TO SATISFYING REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RADIOMETRIC QUALITY OF DATA (Cont'd):</td>
<td></td>
<td>Detector Ranging (Destriping)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Techniques Demonstrated on LS-2 Data:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Meet ±1 Quantum Level Detector Range</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Means and Variances of Radiance Population Preserved for each Sweep</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Automated Assessment of Performance Part of Processing System</td>
</tr>
<tr>
<td>GEOMETRIC QUALITY OF DATA:</td>
<td></td>
<td>Systematic Correction Data (SCD):</td>
</tr>
<tr>
<td>Absolute and Temporal</td>
<td></td>
<td>• Models of Spacecraft/Sensor/Earth System</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ephemeris, Attitude Measurements</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Residuals Include Measurement Errors, Unmeasured Attitude Components (All Frequencies), Scanner Alignment, Scan Repeatability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Geodetic or Temporal Correction Data (GCD):</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- From Automatic Control Point/Control Point Neighborhood (CPN) Registration (After Systematic Correction of CPN)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Techniques for Detecting False Correlations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Filtering of Systematic Control Point (CP) Location Errors to Update SCD to GCD</td>
</tr>
<tr>
<td>AVAILABILITY OF DATA QUALITY MEASURES:</td>
<td></td>
<td>Quality Measures for All Phases of Processing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Daily and Continuing Readiness for Operations (Quality Assessment)</td>
</tr>
<tr>
<td>USER CONCERNS</td>
<td>REQUIREMENTS</td>
<td>APPROACH TO SATISFYING REQUIREMENTS</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------</td>
<td>-----------------------------------</td>
</tr>
</tbody>
</table>
Standard MSS Processing

- User Request Processing
- Spacecraft Scheduling
- Telemetry Processing
- Image Acquisition
- Systematic Correction Data Generation
- Archive Generation
- Performance Evaluation Product Generation
- Uplink
PEPG—HDT-AM Evaluation

- Ingest Display
- Image Display
- VT 100
- PEPG
- HDT-AM
- MMF
- Process Requests
- TAS
- Input Source/Process Request
- How/Manual Selection Via Menu for Automatic Processing
- Who/Computer Operator Using Standard Procedures
- Where/Any MIPS String

Every Scene Will Be Evaluated Before Uplink
HDT-AM Evaluation—Sequence of Events

- Display Available Work
- Start Product Evaluation
- Operator Prompted for:
  - HDT-AM Mount
  - HDT-AM Dismount
- Ingest and Scene Summary Reports Generated Automatically
- Selected Scenes Stored on Disk for Evaluation by Quality Assurance
  - Formatted Dumps
  - Image Display
PEPG Product Generation

Input Source/Process Request

- **How/Manual Selection Via Menu**
  for Automatic Processing

- **Who/Computer Operator Using**
  Standard Procedures

- **Where/MIPS for CCT (2 Scenes/Day)**
  TIPS for 241 mm
  (9 Scenes/Day)
Operational Quality Assurance
Quality Assurance—Responsibilities

Assure Performance — Measurement
— Evaluation
— Adjustment
— Enhancement

Problem Management — Prevention
— Detection
— Investigation
— Solution
— Reporting
Quality Assurance Implementation

- Quality Assurance Concepts
- Product Evaluation
- Process Evaluation
Quality Assurance Concepts

- Quality Assurance Features Designed Into System
- System is Fault Tolerant—Thruputs All Processable Data
- Fault Detection Built in, Limits Initially Set High
- System Captures Quality Indicators
  - Stored in MMF Data Base
  - Available in Many Computer Reports
- Quality Screening Responsibility Shared With Other Operators
- Quality Personnel Allocated for Problem Identification and Solution
  - Supported by Automated PDR/ESR System
- High Visibility to Management of Problem and Quality Reports
System is Fault Tolerant

**DRRTS**

ECC's—Count Limit Checked $\leq 10$ Uncorrectable (MSS) $\leq 1000$ Correctable (TM)

— If Exceeded, Alarms for Operator; Summary in QA Report

Major Frame Sync Loss—If $>10$ Consecutive, Automatically Breaks Interval

Bad Time Code—Identified in Directory

— Operator Instructed Via SOP to Re-Dub Good Time Code Data

Recording Quality From TGS—Displayed in Moving Window Display (Read After Write)

— Operator Response
  - Notify TGS if Transmission Bad
  - Switch Recorders if Recorder Problem

**MMF**

Quality Checks ECC's and Sync Loss Against Limits—Limits Initially Same as DRRTS/MIPS

**MIPS**

ECC's—Same Alarms as DRRTS

Time Code—Substitutes if Can't Read

Sweep Substitution—Limit Checks—if Sync Loss for 10 Consecutive Major Frames, Declares Partial and Continues to Next Scene
QA Scenerio for Normal Processing
(HDT-AM Generation)

- Observe Telemetry Data Displays
- Observe Video on QLM

Telemetry

CSF

PCS

- Observe Video
- Observe Video on MWD
- Receive Messages on ECC Limits Exceeded
- Examine Sample of HDT and Video Error Files
- Examine QA Reports

DRRTS Data Capture

Archive Generation

- Observe Video During Ingest, Output, Cloud Cover Analysis
- Receive Error Messages on ECC Limits Exceeded
- Examine 70 mm Film
- Examine Dump Reports
- Receive Error Messages on ECC Limits Exceeded
- Examine 241 mm Film

PEPG

- Examine QA Reports
- Random Sample Defined by QA
- Specific Scenes Selected

Scene Selection

- Receive Messages on ECC Limits Exceeded
- Examine Sample of HDT Error Files

DRRTS Uplink

- Receive Messages

- Perform by Operators
- Perform by QA

QLM: Quick Look Monitor
MWD: Moving Window Display
ECC: Error Correcting Code
Product Evaluation

Assess Image Quality
- Real Time by Quality Analysts Using Visual and Data Evaluation Techniques
- Real Time by CSF/DRRTS Operators Using Moving Window Display, Quick Look Monitor, and Evaluators Consoles
- Off Line by Image Processing Analysts Using Visual and Data Evaluation Techniques

Authorize Uplinking of Acceptable Products
- By Quality Analysts Following PEPG Process
- By Image Processing Analysts Following Detailed Evaluation of Rejected/Reprocessed Data

Establish Accept/Reject/Reprocess Criteria
- By Image Processing Analysts With Concurrence of Engineering Review Board
- Update Using Pre and Post Launch Experience

Investigate User Feedback
- By Image Processing Analysts With Response Thru Project Office
Image Quality Assessment—Visual Techniques

- Each Scene—Scrolling Video Display (PEPG)

  **Evaluation Criteria**
  - Video Present
  - Anomalies in Video Data
  - Correlate Video Data With Operator Messages

- 1 Band/Scene to 70 mm Film Product

  **Evaluation Criteria**
  - Presence of All Characteristics (E. G., Video, Annotation, Tick Marks, Scene ID)
  - Anomalies in Video Data (Striping, Line Starts, Sync Loss)
  - Correlation With QA Reports

- PEPG —Upon Request by Image Processing Analyst

  - Detailed Evaluation Using Comtal Display and 241 mm Film
  - Typically Used for—
    - More Thorough Evaluation of Apparent Problems Observed During Process
    - Investigation of PDR’s
    - Precise Measurements to Support Performance Analysis
Image Quality Assessment—Data Analysis Techniques

- Uses "Quality Indicators" Designed Into System
- Data Available From:
  - Various Processing Reports
  - Tape Annotation Records
  - QA Reports
  - MMF Quality Files

Quality Indicators Used Real Time

- Limit Checks in Software
- Correlate to Video Display During PEPG
- Accept/Reject/Reprocess Criteria Established in SOP's
- Annotate Products for Users

Used Off Line

- To Aid in Problem Investigation
- To Support Performance Trend Analysis
- To Support Adjustments in Criteria—Accept/Reject/Reprocess
- To Support Changes in S/W Limit Checks
Typical Quality Indicators

**DRRTS** — Image Quality Data File

- Location: DECNET Header Record (DRRTS → MMF)
- Data: Major Frames Out of Sync, Minor Frame Sync Loss, Minor Frame Sync Bit Errors, Bit Slips

**MAG QA Report** — By Scene

- Radiometric Quality: Detector Data Summary by Band

**MAG Processing Summary Report** — By Scene

- Band Quality Indicators: Derived From
  - Minor Frame Sync Loss
  - Major Frame Sync Loss
  - Line Substitutions
  - Missing Line Starts
Typical QA Report
Overall and Quality Code

- Located in Byte 146 of HDT Header Data
- Ranges From 0 - 9, A,B,C
  - 0 — Acceptable
  - C — Best
- Geometric Correction Quality
  - Code | Parameters Modeled
  - A — No Parameter Modeled
  - G — Along Track, Across Track (Uses Control Points for Translation Errors)
  - E — Along Track, Across Track, Yaw, Altitude
- Radiometric Correction Quality (RCA — Max. Difference Between Detector Means for Image)
  - Code | Criteria
  - E 0 < Relative Calibration Accuracy < 1.0
  - G 1.0 < RCA < 2.0
  - A 2.0 < RCA
- Image Data Quality
  - \( DQI = \frac{MJ \cdot FSL + MiFSL + \text{Unrecov. ECC}}{20} + \frac{\text{Unrecov. ECC}}{20} \)
  - Code | Criteria
  - E 0 < DQI < 1.5
  - G 1.5 < DQI < 4.5
  - A 4.5 < DQI
Process Evaluation

Problem Investigation
- PDR Investigations by Quality Analysts and Image Processing Analysts
- PDR Processing and Management Reports by PDR Coordinator
- Problem Trend Analysis By Image Processing Analysts Using PDR's and ESR's and Data Base

Process Quality Assessment
- Processing Success Evaluation by Image Processing Analyst Using Processing and QA Reports
- Operation Audits of All Functions by Quality Analysts
- Refinement of Use of Quality Indicators by Quality Analysts
- Processing Enhancement Recommendations
- Line Tests
  - Evaluate Results and Authorize Processing—Quality Analysts
  - Criteria Development and Evaluation—Image Processing Analysts (Approved by ERB)

Management Reporting
- Automated Management Reports for PDR's and ESR's
- Audit Reports
  - Immediate Reports to Responsible Manager
  - Corrective Action Reports Required
  - Management Report
- Special Management Reports
  - Problem Trend Analysis (Monthly)
  - Current Quality Problems (Daily)
Accept/Reject/Reprocess Flow

Criteria

Video Displays QA Reports Processing Reports

Quality Analysts

Accept

Continue Processing

PDR Reject/Reprocess

Production Control MMF

Image Processing Analysts

Adjust Criteria

ERB → On Line SOP's

User Feedback

- Management Reports
  - PDR—Daily
  - ESR—Daily
- Processing Enhancement Recommendations
- Problem Trend Analysis (Monthly)
- Current Quality Problems (Daily)
Structure

LANDSAT-D SYSTEM

ENGINEERING VERIFICATION

- RELIABILITY
- SPECIFICATIONS
- QUALITY ASSURANCE

SCIENCE CHARACTERIZATION

- SENSOR AND SPACECRAFT PERFORMANCE
- IMAGE DATA QUALITY
- APPLICATIONS INFORMATION

INSTRUMENT PERFORMANCE

END-TO-END SYSTEM PERFORMANCE

TM SYSTEM PERFORMANCE

MSS SYSTEM PERFORMANCE

• Recommend Landsat-D System Improvements
• Communicate Results to Research Community
Sensor and Spacecraft Performance Characterization

AREAS OF INVESTIGATION

RADIOMETRY

A. Spectral Resolution
   1. Filter
   2. Detectors
   3. System

B. Radiometric Resolution
   1. Absolute Integrating Sphere Calibration (Dynamic Range Linearity, S/N)
   2. External Calibration (Precision)
   3. Internal Calibration (Precision, S/N)
   4. Flooding Lamp Calibration (Uniformity Over Scan)
Sensor and Spacecraft Performance Characterization

AREAS OF INVESTIGATION (CONT.)

GEOMETRY

A. Geometry of Pixel
1. Rise Time and Delay Time
2. Bright Target Recovery Time
3. MTF (IFOV) or Frequency Response Time
4. Bowtie Scan Angle Effect
5. Altitude Effects

B. Geometry of Image (Pixel Location)
1. Sensor Effects
   A. Scan Profile for Reference Detector
      • Along and Across Scan
      • Forward and Reverse Scan
   B. Detector Location Relative to Reference Detector
      • Band-to-Band Registration
      • Forward and Reverse Scan
   C. Between Scan Alignment
      • Reference Detector Forward and Reverse Offset
      • Along and Across Scan

2. Ephemeris
   A. Orbital Support Computing Division (OSCD)
   B. Global Positioning System (GPS)

3. Attitude
   A. Angular Displacement Sensor (ADS)
   B. Inertial Reference System (DRIRU)
   C. Attitude Control System (ACS)
   D. Alignment to Sensor (ADS, DRIRU and ACS)
Recommend Landsat-D System Improvements

• Communicate Results to Research Community
Image Data Quality Performance Characterization

AREAS OF INVESTIGATION

RADIOMETRY

A. Spectral Information
   1. Detector Replacement Algorithms
   2. Band Compression Algorithms

B. Radiometric Information
   1. Internal Calibration Algorithms
      A. Channel-to-Channel
      B. Band-to-Band
   2. Scene Histogram Calibration Algorithms
      (Radiometric Destriping)
   3. Absolute Scene Radiance Calibration Algorithms
      A. Reflective Band
      B. Thermal Band
   4. Noise Correction Algorithms
Image Data Quality Performance Characterization

AREAS OF INVESTIGATION (CONT.)

GEOMETRY

A. Geometry of Pixel (Ground IFOV)
B. Geometry of Image (Pixel Location)
   1. Systematic Correction
      A. Scan Profile
      B. Detector Location (Forward and Reverse Scan Alignment, Gap and Overlap)
      C. Between Scan Alignment
      D. Ephemeris
      E. Attitude
   2. Geodetic Correction with Ground Control Points (GCPs)
      A. Reference Library Build (Scene-to-Map Rectification)
      B. Scene-to-Reference Scene Registration
   3. Resampling
Recommend Landsat-D System Improvements
Communicate Results to Research Community
# Applications Information — MSS and TM

## Areas of Interest

<table>
<thead>
<tr>
<th>RENEWABLE RESOURCES</th>
<th>NON-RENEWABLE RESOURCES</th>
<th>PLANNING/ENVIRONMENTAL MANAGEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>Geology</td>
<td>Regional/Urban Lane Use</td>
</tr>
<tr>
<td>Inventory</td>
<td>Structure</td>
<td>Cover Classification</td>
</tr>
<tr>
<td>Yield</td>
<td>Landforms</td>
<td>Cover Change</td>
</tr>
<tr>
<td>Condition</td>
<td>Lithology</td>
<td>Environmental Impact</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Thermal Anomalies</td>
<td>Coastal Zone</td>
</tr>
<tr>
<td>Episodal Event</td>
<td>Geobotanical Anomalies</td>
<td>Monitoring</td>
</tr>
<tr>
<td>Soils</td>
<td>Topography (Stereo)</td>
<td>Hydrology</td>
</tr>
<tr>
<td>Classification</td>
<td>Episodal Event</td>
<td>Drainage Patterns</td>
</tr>
<tr>
<td>Erosion</td>
<td></td>
<td>Inland Water Inventory</td>
</tr>
<tr>
<td>Moisture</td>
<td></td>
<td>Snow Pack Parameters</td>
</tr>
<tr>
<td>Forests</td>
<td>Image-Science</td>
<td>Ice — Inland &amp; Near Shore</td>
</tr>
<tr>
<td>Inventory</td>
<td>Pattern Recognition</td>
<td>Water Quality — Inland &amp; Near Shore</td>
</tr>
<tr>
<td>Stand Evaluation</td>
<td>Information Extraction</td>
<td>Wetland/Estuaries Inventory</td>
</tr>
<tr>
<td>Condition</td>
<td></td>
<td>Episodal Event</td>
</tr>
<tr>
<td>Episodal Event</td>
<td></td>
<td>Wildlife Habitat</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td>Inventory</td>
</tr>
<tr>
<td>Vegetation Inventory</td>
<td></td>
<td>Evaluation</td>
</tr>
<tr>
<td>Condition</td>
<td></td>
<td>Oceans</td>
</tr>
<tr>
<td>Episodal Event</td>
<td></td>
<td>Currents (Near Shore)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tides</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bathymetric Charts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ocean Pollution (Near Shore)</td>
</tr>
</tbody>
</table>
# Sensor and Spacecraft Performance Characterization — MSS

<table>
<thead>
<tr>
<th>Name</th>
<th>Colwell</th>
<th>Barnstein</th>
<th>Anuta</th>
<th>Malia</th>
<th>Bodner</th>
<th>Price</th>
<th>Slater</th>
<th>Wingley</th>
<th>Malta</th>
<th>Zobeiri</th>
<th>Erickson</th>
<th>Hock</th>
<th>Lauer</th>
<th>Schott</th>
<th>Kefter</th>
<th>Welch</th>
<th>Proser</th>
<th>Guernay</th>
<th>Hill</th>
<th>Everett</th>
<th>MacDonald</th>
<th>Anderson</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSFC No.</td>
<td>AN 3</td>
<td>AN 8</td>
<td>AN 12</td>
<td>AN 14</td>
<td>AN 15</td>
<td>AN 18</td>
<td>AN 20</td>
<td>AN 23</td>
<td>AN 25</td>
<td>AN 26</td>
<td>AN 29</td>
<td>AN 31</td>
<td>AN 32</td>
<td>AN 35</td>
<td>AN 37</td>
<td>AN 39</td>
<td>AN 41</td>
<td>AN 42</td>
<td>AN 44</td>
<td>AN 46</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Radiometry**
  - Spectral Matching
    - Filter
    - Detectors
    - System
  - Absolute Integrating Sphere Calibration
  - External Calibration
  - Internal Calibration
    - Precision
    - Signal-to-Noise
  - Flooding Lamp Calibration
  - Rise Time & Delay Time
  - Bright Target Recovery Time
  - MTF (IFOV) or Frequency Response Time
  - Bowtie Scan Angle Effect
  - Altitude Effects

- **Geometry**
  - Geometry of Image
    - Pixel Location
  - Sensor Effects
    - Scan Profile, Reference Detector
    - Detector Location Relative to Reference Detector
    - Between Scan Alignment
  - Ephemeris
    - Orbital Support Competing Div.
    - Global Positioning System (GPS)
  - Attitude
    - Angular Displacement Sensor (ADS)
    - Inertial Reference System (IDIRU)
    - Attitude Control System (ACS)
    - Alignment to Sensor
# Sensor and Spacecraft Performance Characterization — TM

<table>
<thead>
<tr>
<th>Name</th>
<th>Calwell</th>
<th>Barretta</th>
<th>Anita</th>
<th>Malia</th>
<th>Bender</th>
<th>Price</th>
<th>Slater</th>
<th>Wingley</th>
<th>Zobrist</th>
<th>Erickson</th>
<th>Hoovers</th>
<th>Laier</th>
<th>Schott</th>
<th>Keillet</th>
<th>Welch</th>
<th>Potter</th>
<th>Guernay</th>
<th>Hill</th>
<th>Everett</th>
<th>MacDonald</th>
<th>Anderson</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSFC No</td>
<td>AN 3</td>
<td>AN 8</td>
<td>AN 14</td>
<td>AN 15</td>
<td>AN 18</td>
<td>AN 20</td>
<td>AN 23</td>
<td>AN 25</td>
<td>AN 26</td>
<td>AN 29</td>
<td>AN 31</td>
<td>AN 32</td>
<td>AN 35</td>
<td>AN 37</td>
<td>AN 41</td>
<td>AN 42</td>
<td>AN 44</td>
<td>AN 46</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Spectral Matching
- **Filter**
- **Detectors**

## Radiometric Resolution
- **Absolute Integrating Sphere Calibration**
- **External Calibration**
- **Internal Calibration**
  - **Precision**
  - **Signal to Noise**
- **Flood Lamp Calibration**

## Geometry
- **Rise Time & Delay Time**
- **Bright Target Recovery Time**
- **MTF (IFOV) or Frequency Response Time**
- **Bowtie Scan Angle Effect**
- **Altitude Effects**

## Sensor Effects
- **Scan Profile, Reference Detector**
- **Detector Location Relative to Reference Detector**
- **Between Scan Alignment**

## Ephemeris
- **Orbital Support Computing Div**
- **Global Positioning System (GPS)**

## Attitude
- **Angular Displacement Sensor (ADS)**
- **Inertial Reference System (DIRIUI)**
- **Attitude Control System (ACS)**
- **Alignment to Sensor**

---

**Page 101**
# Image Data Quality Performance Characterization – TM

<table>
<thead>
<tr>
<th>Name</th>
<th>Coswell</th>
<th>Bernstein</th>
<th>Anuta</th>
<th>Melia</th>
<th>Bender</th>
<th>Price</th>
<th>Slater</th>
<th>Wrigley</th>
<th>Melia</th>
<th>Zobrist</th>
<th>Erickson</th>
<th>House</th>
<th>Fuller</th>
<th>Schott</th>
<th>Keefler</th>
<th>Welch</th>
<th>Guernsey</th>
<th>Hill</th>
<th>Everett</th>
<th>MacDonald</th>
<th>Anderson</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSFC No.</td>
<td>AN 3</td>
<td>AN 9</td>
<td>AN 12</td>
<td>AN 14</td>
<td>AN 15</td>
<td>AN 18</td>
<td>AN 20</td>
<td>AN 23</td>
<td>AN 26</td>
<td>AN 29</td>
<td>AN 31</td>
<td>AN 32</td>
<td>AN 35</td>
<td>AN 36</td>
<td>AN 37</td>
<td>AN 41</td>
<td>AN 42</td>
<td>AN 44</td>
<td>AN 46</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiometric</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geometry of Pixel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systematic</td>
<td>Scan Profile</td>
<td>Detector Location</td>
<td>Between Scan Alignment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pixel Location</td>
<td>Geodetic Correction</td>
<td>Reference Library Build</td>
<td>Scene-to-Reference Registration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>of Image</td>
<td>with GCPs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resampling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: The table indicates different detection and replacement algorithms for various image data types.*
# Applications Information — MSS & TM

<table>
<thead>
<tr>
<th>Name</th>
<th>Colewell</th>
<th>Bernstein</th>
<th>Anuta</th>
<th>Malia</th>
<th>Bender</th>
<th>Price</th>
<th>Slater</th>
<th>Wiggley</th>
<th>Mallia</th>
<th>Zobrist</th>
<th>Erickson</th>
<th>Hovis</th>
<th>Lauer</th>
<th>Schott</th>
<th>Keifler</th>
<th>Welch</th>
<th>Pozier</th>
<th>Guernsey</th>
<th>Hill</th>
<th>Everett</th>
<th>MacDonald</th>
<th>Anderson</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSFC No.</td>
<td>AN 3</td>
<td>AN 8</td>
<td>AN 12</td>
<td>AN 14</td>
<td>AN 15</td>
<td>AN 18</td>
<td>AN 20</td>
<td>AN 23</td>
<td>AN 25</td>
<td>AN 26</td>
<td>AN 29</td>
<td>AN 31</td>
<td>AN 32</td>
<td>AN 35</td>
<td>AN 36</td>
<td>AN 37</td>
<td>AN 39</td>
<td>AN 41</td>
<td>AN 42</td>
<td>AN 44</td>
<td>AN 46</td>
<td></td>
</tr>
</tbody>
</table>

## Renewable Resources
- Agriculture
- Soils
- Forests
- Range
- Other

## Non-Renewable Resources
- Geology
- Image Science
- Other

## Planning/Environmental Management
- Regional/Urban Land Use
- Coastal Zone
- Hydrology
- Wildlife Habitat
- Oceans
- Other
Investigations Workshop Schedule

FIRST WORKSHOP TIMING

TODAY IS TOO EARLY:
- Still in AN Contract Negotiation
- Much More Landsat-D Information Still to Come

TODAY IS TOO LATE:
- Less Than Two Months to Launch
- Already Buried in Data!
- Already More Questions Than Answers!
Investigations Workshop Objectives

• Provide Pre-Requisite Information on:
  - MSS & TM Radiometry and Geometry
  - Data Acquisition, Processing and Availability
  - Nature and Direction of Investigations Program

• Create the Investigations Team

• Get Help:
  - Review of Draft Reports
  - Refinement of AN Areas of Investigation
  - Identification of AN Data and Information Requirements
Investigations Workshop Activities

PROVIDING INFORMATION

- Workshop Presentations
- Thursday Evening Tours
  - Five Offered (1/2 Hour Each)
  - Select up to Four During 2 Hours Allotted
- Supporting Documentation (Tape Formats, Draft Reports, etc.)
  - Order Via Form Provided
  - Limited Quantity Available Today
  - Remainder of Order Filled by Mail

CREATING TEAM

- Investigations Team Interaction Opportunities
- Principal Investigator Meetings with Science Representatives
Investigations Workshop Activities (Cont.)

ASKING FOR HELP, PLEASE:

• Identify Specific Additional Information Required, When Desired and When Needed (Via Workshop Return Form)

• Review Indicated Draft Reports (Via Workshop Return Form)

• Locate Individual Investigation Area Within Matrix (Via X on Matrix in Meeting with Science Representative)
Early Access TM Processing

John Lyon
Landsat-D Assessment System

SYSTEM OBJECTIVES

TM EARLY ACCESS PROGRAM (SCROUNGE)

- Provide, In Concert with the Applications Developmental Data System and Components of the Ground Segment, the Only TM Products Available in the First Year of Orbital Operations
  - One Scene/Day Using A Priori Corrections
  - Standard Products: P Film and Digital Data on 6250 BPI Tapes
  - Also Available: A and "B" Data Sets as Necessary

RESEARCH/ANALYSIS DATA SYSTEM ALLIED WITH GROUND SEGMENT

- Open Ended/Flexible
- To Accommodate Meaningful Data Quality and Interpretation Studies v. Instruments, Emphasizing TM
- Available for AN Support with Some Resource Contention with Scrounge

1-109
Overall Configuration

A/N
CARD
PRINT
UNIBUS

VAX11/780
CCT (2)
PDP11/34

AP-180 V
ARRAY PROCESSOR

HDT (2)
CCT (3)

DISK (8)

HIGH SPEED BUS

DICOMED D47
OPTRONICS L5500
(FILM RECORDERS)

IMAGE ANALYSIS TERMINALS

IAT 1
CONTROL

IAT 2

IAT 3
CONTROL

SCANNER/DIGITIZER

1-110
Image Data Quality Analysis/Science Support Program
End-to-End Scrounge Data Flow

Imagery

DRRTS → TAS → ADDS → TAPE LIBRARY → PRODUCT SUPPORT & DISTRIBUTION FACILITY

Telemetry

CSF → MMF → LAS → FILM LIBRARY

ACQUISITION

Acquisition Requests
21 Scenes/Week Ordered for Processing

PRODUCT GENERATION

≥10 Scenes Per Week
7 Scenes Per Week

Standing Order Film for Evaluation and Completed Work Order

Product Request

Product Distributed Notification

SCIENCE OFFICE

21 Scenes Per Week
10 Scenes Per Week
7 Scenes Per Week

Products to Users

Acquisition Requests and Scheduling
Imagery & Image Data Products
Telemetry and Product Ancillary Information
Processing Work Order and Product Request
End to End Scrounge — LAS

ACQUISITION

PRODUCT GENERATION

SCIENCE OFFICE

ALL 3 IS C: B ARE ARCHIVED IN LAS LIBRARY

1-113
LAS Functions

• Receive a Minimum of 10 and up to 21 TM Scenes Per Week in CCT-B Format
• Receive Corresponding Work Orders and Scene Priorities
• Apply Radiometric and Geometric Corrections to TM Data as Required to Produce CCT-A and P Products
• Produce TM P-Film Master and Associated Products for 7 Scenes Per Week
• Forward Standing Order Film Products and Updated Work Orders to Science Office
• Store Tape and Film Master in Respective Libraries
• Supply Film and Tape Masters to Products Support and Distribution Facility (According to Product Requests) for Preparation of Output Products
• Provide Science Office with Weekly Processing Summary Report
TM Early Access Program Functional Data Flow

REQUIRED PERFORMANCE LEVEL 1 TM SCENE/DAY

MSS CORRELATIVE DATA AVAILABLE: IGF AND IPF

MAJOR FUNCTIONAL DATA FLOW

- TM PROCESSING -

*NOT REQUIRED
LAS interfaces

FROM ADDS

WO

CCT B

CCT A

CCT P

TAPE LIBRARY

PRODUCT REQUEST

TO PRODUCT SUPPORT AND DISTRIBUTION FACILITY

A AND B ALSO AVAILABLE

FROM SCIENCE OFFICE

PRODUCT REQUESTS

FROM SCIENCE OFFICE

PRODUCT REQUESTS

FILM LIBRARY

FILM MASTER

FILM PRODUCTS

WO

WEEKLY PROCESSING REPORT

STANDING ORDER FILM PRODUCTS

WO

TO SCIENCE OFFICE

TO SCIENCE OFFICE

FOR CLOSE OUT OF UNSUCCESSFUL SCENES

TO SCIENCE OFFICE
Landsat-D Data Acquisition and Availability

Stan Freden
Landsat-D Data Acquisition and Availability

- MSS Acquisition and Availability
- TM Acquisition and Availability
- AN Mission Options
MSS Data Acquisition and Availability

FIRST YEAR

Acquisition Capability: 200 Scenes/Day
All US Except Hawaii

Acquisition Priorities:
First 6 Months—All Possible Data
of US Consistent with Landsat-3/
Landsat-D Station Conflicts
After 6 Months—NOAA
Responsibility, NASA Engineering/
Special Requirements will be Met

Acquisition Requests:
All Go Through the EROS Data
Center (EDC)
AN Requirements Come to GSFC
Science Office → EDC

Processing Capability/Priority: 200 Scenes/Day Soon After Launch
All Data Processed and Distributed
by EDC
Some Engineering Data Available
Through GSFC
Priorities for Loading Landsat-D MSS GCP Library (U.S.)

<table>
<thead>
<tr>
<th>AREA</th>
<th>PATH/ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washington, DC</td>
<td>15/33</td>
</tr>
<tr>
<td>Lubbock, TX area</td>
<td>29, 30, 31/36, 37</td>
</tr>
<tr>
<td>Grand Canyon, AZ</td>
<td>37, 38/35</td>
</tr>
<tr>
<td>Phoenix, AZ</td>
<td>37/37</td>
</tr>
<tr>
<td>Lake Powell, UT</td>
<td>37/34</td>
</tr>
<tr>
<td>San Francisco, CA</td>
<td>44/34</td>
</tr>
<tr>
<td>Los Angeles, CA</td>
<td>41/36</td>
</tr>
<tr>
<td>Chicago, IL</td>
<td>22, 23/31</td>
</tr>
<tr>
<td>White Sands, NM</td>
<td>33/37</td>
</tr>
<tr>
<td>Pennsylvania (especially Lancaster area)</td>
<td>(15/32)</td>
</tr>
<tr>
<td>Florida</td>
<td></td>
</tr>
<tr>
<td>Midwest Agricultural Area (Iowa, Kansas, North Dakota, etc.)</td>
<td></td>
</tr>
<tr>
<td>Eastern United States</td>
<td></td>
</tr>
<tr>
<td>Western United States</td>
<td></td>
</tr>
<tr>
<td>Rest of United States (48 states)</td>
<td></td>
</tr>
<tr>
<td>Alaska</td>
<td></td>
</tr>
<tr>
<td>Hawaii</td>
<td></td>
</tr>
</tbody>
</table>
## MSS Tape Products

<table>
<thead>
<tr>
<th>FACILITY</th>
<th>PROCESSING LEVELS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NONE</td>
</tr>
<tr>
<td></td>
<td>RAW</td>
</tr>
<tr>
<td>MIPS</td>
<td></td>
</tr>
<tr>
<td>CCT-AM</td>
<td></td>
</tr>
<tr>
<td>CCT-PM</td>
<td></td>
</tr>
<tr>
<td>EDC</td>
<td></td>
</tr>
<tr>
<td>CCT-PM</td>
<td></td>
</tr>
</tbody>
</table>

Note: Available as Soon as GCP Library can be Loaded
TM Data Acquisition and Availability

FIRST YEAR

Acquisition Capability: 30 Scenes/Day Average
Eastern and Central 48 Prior to TDRSS
Total 48 + Some Alaska/Hawaii and Some
Foreign After TDRSS

Acquisition Priorities: Disasters
A/N Requirements
US Agricultural Requirements
Other Specials/PAO, etc.

Acquisition Requests: Data Request Forms
Inputs to Science Office
— AN Requirements go to Technical Representatives
— Others to Dr. Stanley C. Freden
NASA/Goddard Space Flight Center
Code 902
Greenbelt, MD 20771
344-5818
LANDSAT-D DATA REQUIREMENTS

THEMATIC MAPPER (TM) AND MULTISPECTRAL SCANNER (MSS)

PRINCIPAL INVESTIGATOR NAME ____________________________

ADDRESS _____________________________________________

_____________________________________________________

_____________________________________________________

_____________________________________________________

_____________________________________________________

TELEPHONE NUMBER (US AND CANADA) ______________________

INVESTIGATION NUMBER _________________________________

TEST SITE NUMBER ____________________________________

LOCATION ____________________________________________

COORDINATES:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>A.</th>
<th>B.</th>
<th>C.</th>
<th>D.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>D.M.S.</td>
<td>D.M.S.</td>
<td>D.M.S.</td>
<td>D.M.S.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LANDSAT-D WRS (Do not complete)

<table>
<thead>
<tr>
<th>PATH</th>
<th>ROW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DATA ACQUISITION SCHEDULE:

<table>
<thead>
<tr>
<th>DAY</th>
<th>NIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FIRST YEAR: (82) JUL AUG SEP OCT NOV DEC</td>
</tr>
<tr>
<td></td>
<td>(83) JAN FEB MAR APR MAY JUN</td>
</tr>
<tr>
<td></td>
<td>SECOND AND THIRD YEARS: (83/84) JUL AUG SEP OCT NOV DEC</td>
</tr>
<tr>
<td></td>
<td>(84/85) JAN FEB MAR APR MAY JUN</td>
</tr>
</tbody>
</table>

CLOUD COVER RESTRICTION: _______________ %

ARE IN SITU DATA BEING COLLECTED CONCURRENTLY? YES NO

ANTICIPATED DATE(S)

DATA PRODUCTS:

THEMATIC MAPPER:

<table>
<thead>
<tr>
<th>BAND</th>
<th>TAPES</th>
<th>FILM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCT-A</td>
<td>CCT-P</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Principal Investigator must order Multispectral Scanner data from the ERUS Data Center. These data will be paid for by the Principal Investigator.
TM Data Acquisition and Availability (Cont.)

FIRST YEAR

Processing Capability = 1 Scene/Day = 7 Scenes/Week

Processing Priorities:
- Disasters
- A/N Requirements—Commonality, etc.
- US Agricultural Programs
- Other Specials

Processing Selection and Data Distribution:
- Screen and Select 21 "Cloud Free", "High Quality" Scenes Each Week in Priority Order
- Produce = 10 CCT-B's in ADDS for LAS
- Produce 7 "Processed" Scenes/Week in LAS
  - Provide Tape and Film Copying
  - Provide Tape and Film Distribution

Expected Data Product Availability:
- ≈ 1 Scene/Cycle/AN Average
- Tapes and Film as Required
- Availability of First Processed Scene Upon Request for Analysis Systems Checkout
## TM Tape Products

<table>
<thead>
<tr>
<th>FACILITY</th>
<th>PROCESSING LEVELS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NONE</td>
</tr>
<tr>
<td></td>
<td>RAW</td>
</tr>
<tr>
<td>SCROUNGE (BEFORE JULY 83)</td>
<td>X</td>
</tr>
<tr>
<td>CCT-BT</td>
<td></td>
</tr>
<tr>
<td>CCT-AT</td>
<td>X</td>
</tr>
<tr>
<td>CCT-PT</td>
<td>X</td>
</tr>
<tr>
<td>TIPS</td>
<td>X</td>
</tr>
<tr>
<td>CCT-AT</td>
<td></td>
</tr>
<tr>
<td>CCT-PT</td>
<td>X</td>
</tr>
</tbody>
</table>

Note: Available as Soon as GCP Library can be Loaded
Examples of AN Landsat-D Mission Options

- MSS On Alone
- TM On Alone
- MSS and TM On Together
- Daytime and Nighttime
- Choice of MSS Configuration
- Choice of TM Configuration
Introduction of Technical Experts and Science Representatives

John Barker
Introduction to MSS
Pre-NOAA Characterization

Bill Alford
OBJECTIVES

- Characterize Accuracy and Precision of Imagery
- Characterize Accuracy and Precision of Derived Information
- Recommend Landsat-D System Improvements
- Communicate Capabilities to Research Community
Landsat-D Science Office Pre NOAA MSS Characterization

AREAS OF INVESTIGATION

- Sensor Performance
- Image Data Quality
- Applications Information

SUPPORT

- Landsat-D Project
  - GE
  - Hughes Aircraft
  - CSC
  - ORI

- GSFC MSS Characterization Support
- Application Notice Investigations

1-133
Sensor and Spacecraft Performance Characterization

Radiometry of MSS

<table>
<thead>
<tr>
<th>Spectral Resolution</th>
<th>Filter</th>
<th>Detectors</th>
<th>System</th>
<th>Anuta</th>
<th>Bender</th>
<th>Slater</th>
<th>Malina</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral Matching</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute Integrating Sphere Calibration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External Calibration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal Calibration</td>
<td>Precision</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flooding Lamp Calibration</td>
<td></td>
<td>Signal-to-Noise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1-134
## Sensor and Spacecraft Performance Characterization

### Geometry of MSS

<table>
<thead>
<tr>
<th>Geometry of Image (Pixel Location)</th>
<th>Sensor Effects</th>
<th>Bernstein</th>
<th>Anuta</th>
<th>Bender</th>
<th>Keiffer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan Profile, Reference Detector</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detector Location Relative to Reference Detector</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Scan Alignment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ephemeris</td>
<td>Orbital Support Competing Div.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Global Positioning System (GPS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude</td>
<td>Angular Displacement Sensor (ADS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inertial Reference System (DRIRU)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Attitude Control System (ACS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alignment to Sensor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Sensor and Spacecraft Performance Characterization

#### Geometry of MSS (con’t)

<table>
<thead>
<tr>
<th>Geometry of Pixel</th>
<th>Colewell</th>
<th>Anuta</th>
<th>Zobrist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise Time &amp; Delay Time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bright Target Recovery Time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MTF (IFOV) or Frequency Response Time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bowtie Scan Angle Effect</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Altitude Effects</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

ORIGINAL PAGE IS OF POOR QUALITY
# Image Data Quality Performance Characterization

## Radiometry of MSS

<table>
<thead>
<tr>
<th>Spectral Information</th>
<th>Colewell</th>
<th>Bernslein</th>
<th>Anuta</th>
<th>Bender</th>
<th>Slater</th>
<th>Malia</th>
<th>Zobrist</th>
<th>Hovis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector Replacement Algorithms</td>
<td></td>
<td></td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bar-J Compression Algorithms</td>
<td></td>
<td></td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal Calibration Algorithms</td>
<td>Channel-to-Channel</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Band-to-Band</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scene Histogram Calibration Algorithms (Radiometric Destriping)</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Absolute Scene Radiance Calibration Algorithms</td>
<td>Reflective Band</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td></td>
<td>Thermal Band</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Noise Correction Algorithms</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
</tbody>
</table>
# Image Data Quality Performance Characterization

## Geometry of MSS

<table>
<thead>
<tr>
<th>Geometry of Image (Pixel Location)</th>
<th>Bernstein</th>
<th>Anuta</th>
<th>Beverley</th>
<th>Wrigley</th>
<th>Manila</th>
<th>Zobrist</th>
<th>Keiffer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground IFOV</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systematic Correction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scan Profile</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Detector Location</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Between Scan Alignment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ephemeris</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geodetic Correction with GCPs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference Library Build</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Scene-to-Scene Registration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Resampling**
# Applications Information -- MSS and TM

## Areas of Interest

<table>
<thead>
<tr>
<th>RENEWABLE RESOURCES</th>
<th>NON-RENEWABLE RESOURCES</th>
<th>PLANNING/ENVIRONMENTAL MANAGEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>Geology</td>
<td>Regional/Urban Lane Use</td>
</tr>
<tr>
<td>Inventory</td>
<td>Structure</td>
<td>Cover Classification</td>
</tr>
<tr>
<td>Yield</td>
<td>Landforms</td>
<td>Cover Change</td>
</tr>
<tr>
<td>Condition</td>
<td>Lithology</td>
<td>Environmental Impact</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Thermal Anomalies</td>
<td>Coastsal Zone</td>
</tr>
<tr>
<td>Episodal Event</td>
<td>Geobotanical Anomalies</td>
<td>Monitoring</td>
</tr>
<tr>
<td>Soils</td>
<td>Topography (Stereo)</td>
<td>Hydrology</td>
</tr>
<tr>
<td>Classification</td>
<td>Episodal Event</td>
<td>Drainage Patterns</td>
</tr>
<tr>
<td>Erosion</td>
<td></td>
<td>Inland Water Inventory</td>
</tr>
<tr>
<td>Moisture</td>
<td></td>
<td>Snow Pack Parameters</td>
</tr>
<tr>
<td>Forests</td>
<td>Image-Science</td>
<td>Ice – Inland &amp; Near Shore</td>
</tr>
<tr>
<td>Inventory</td>
<td>Pattern Recognition</td>
<td>Water Quality – Inland &amp; Near Shore</td>
</tr>
<tr>
<td>Stand Evaluation</td>
<td>Information Extraction</td>
<td>Wetland/Estuaries Inventory</td>
</tr>
<tr>
<td>Condition</td>
<td></td>
<td>Episodal Event</td>
</tr>
<tr>
<td>Episodal Event</td>
<td></td>
<td>Wildlife Habitat</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td>Inventory</td>
</tr>
<tr>
<td>Vegetation Inventory</td>
<td></td>
<td>Evaluation</td>
</tr>
<tr>
<td>Condition</td>
<td></td>
<td>Oceans</td>
</tr>
<tr>
<td>Episodal Event</td>
<td></td>
<td>Currents (Near Shore)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tides</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bathymetric Charts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ocean Pollution (Near Shore)</td>
</tr>
</tbody>
</table>
GSFC Radiometric Characterization

- Destriping Analysis
  - Detector Histogram Comparisons
  - Bright to Dark Area Comparisons
  - Visual, Clustering and Classification Qualitative Tests

- Dynamic Range

- Signal-to-Noise
GSFC Geometric Characterization

- Geodetic Rectification Accuracy
  Compare with Intense Array of Verification Points

- Temporal Registration Accuracy
  Cross Correlate Temporal Scene with Geodetic Verified Scene

- Systematic Correction Accuracy
  - Cross Correlate With Geodetic Verified Scene
  - Band to Band Correlation to Measure Band Offsets
  - Analysis of MIPS Derived Parameters for Attitude/Ephemeris (GE)
  - Define Scan Non-Linearity (GE)
Landsat-D vs. Landsat 2/3
Geometric Accuracy

- Within Scene Comparisons as a Function of WRS Offset

- Adjacent Scene Overlap Area Comparisons

Landsat-2/3 Overlap
(Smaller Than for 2/3)
## Landsat-D

### Pre-NOAA MSS Characterization Reports & Schedules

<table>
<thead>
<tr>
<th>REPORTS</th>
<th>1982</th>
<th>1983</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hughes MSS Final Report</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>GE Geometric Calibration Report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE Radiometric Calibration Report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE Geometric Evaluation Report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE Radiometric Evaluation Report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSC MSS Radiometric Calibration Report</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>ORI MSS Geometric Correction Report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GSFC MSS Characterization Report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applications Notice Investigations MSS</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Applications Notice Investigations MSS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applications Notice Investigations MSS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characterization Report</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Final = \( \triangle \)
Draft = \( O \)
LANDSAT-D MSS RADIOMETRY

OBJECTIVES

TODAY

DOCUMENT SPECTRAL CHARACTERISTICS

DOCUMENT ABSOLUTE RADIOMETRIC LAMP CALIBRATION

DOCUMENT POST-LAUNCH RADIOMETRIC PREPROCESSING PROCEDURE

FUTURE

RECALIBRATE AND VALIDATE POST-LAUNCH

ESTIMATE THE ACCURACY AND PRECISION OF RADIOMETRIC CALIBRATIONS
### FILTER SPECIFICATIONS FOR LANDSAT MULTISPECTRAL SCANNERS

<table>
<thead>
<tr>
<th>BAND</th>
<th>BAND EDGE (nm)</th>
<th>BAND SLOPE INTERVAL (nm)</th>
<th>SPECTRAL FLATNESS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LOWER</td>
<td>UPPER</td>
<td>FROM 5% TO 50% LOWER</td>
</tr>
<tr>
<td>1</td>
<td>500 ± 10</td>
<td>600 ± 10</td>
<td>&lt;20</td>
</tr>
<tr>
<td>2</td>
<td>600 ± 10</td>
<td>700 ± 10</td>
<td>&lt;20</td>
</tr>
<tr>
<td>3</td>
<td>700 ± 10</td>
<td>800 ± 10</td>
<td>&lt;20</td>
</tr>
<tr>
<td>4</td>
<td>800 ± 10</td>
<td>1100a ± 10</td>
<td>&lt;35</td>
</tr>
</tbody>
</table>

a — UPPER BAND EDGE NOT FILTER DETERMINED — FILTER SPECIFICATION NECESSARY FOR FLATNESS DETERMINATION
KEY TO FIGURES 2 AND 3

1-147
### MSS-D Spectral Characterization by Channel: Band 2 (600-700 nm)

<table>
<thead>
<tr>
<th>Scanner Channel Band Edge (nm)</th>
<th>Width&lt;sup&gt;a&lt;/sup&gt; (nm)</th>
<th>Slope Interval (nm)</th>
<th>Spectral Flatness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td>Lower</td>
</tr>
<tr>
<td><strong>Proto-Flight</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>603</td>
<td>708&lt;sup&gt;*&lt;/sup&gt;</td>
<td>105&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
<tr>
<td>8</td>
<td>602</td>
<td>696</td>
<td>34</td>
</tr>
<tr>
<td>9</td>
<td>603</td>
<td>696</td>
<td>92</td>
</tr>
<tr>
<td>10</td>
<td>603</td>
<td>696</td>
<td>94</td>
</tr>
<tr>
<td>11</td>
<td>604</td>
<td>698</td>
<td>94</td>
</tr>
<tr>
<td>12</td>
<td>602</td>
<td>695</td>
<td>93</td>
</tr>
<tr>
<td><strong>Flight</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>603</td>
<td>697</td>
<td>94</td>
</tr>
<tr>
<td>8</td>
<td>603</td>
<td>696</td>
<td>93</td>
</tr>
<tr>
<td>9</td>
<td>603</td>
<td>696</td>
<td>94</td>
</tr>
<tr>
<td>10</td>
<td>602</td>
<td>696</td>
<td>93</td>
</tr>
<tr>
<td>11</td>
<td>603</td>
<td>697</td>
<td>94</td>
</tr>
<tr>
<td>12</td>
<td>603</td>
<td>697</td>
<td>94</td>
</tr>
</tbody>
</table>

- **a** — No filter specification
- **b** — Fails to meet filter specification
- *— Rejectable as outlier: \( \alpha = 0.01 \)
# Band 2 (600-700nm) Spectral Characterization

## By Means and Standard Deviations: MSS 1, 2, 3, PF, F

<table>
<thead>
<tr>
<th>Scanner</th>
<th>Band Edge (nm)</th>
<th>Width (nm)</th>
<th>Slope Interval (nm)</th>
<th>Spectral Flatness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td>Width</td>
<td>Lower</td>
</tr>
<tr>
<td>PF*</td>
<td>603</td>
<td>698</td>
<td>95</td>
<td>12</td>
</tr>
<tr>
<td>PF**</td>
<td>603</td>
<td>696</td>
<td>93</td>
<td>12</td>
</tr>
<tr>
<td>F</td>
<td>603</td>
<td>697</td>
<td>94</td>
<td>12</td>
</tr>
</tbody>
</table>

### Means

<table>
<thead>
<tr>
<th></th>
<th>Lower</th>
<th>Upper</th>
<th>Width</th>
<th>Lower</th>
<th>Upper</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>603</td>
<td>701</td>
<td>97</td>
<td>15</td>
<td>26</td>
<td>9.0*</td>
<td>13.3*</td>
</tr>
<tr>
<td>2*</td>
<td>607</td>
<td>710</td>
<td>103</td>
<td>14</td>
<td>30</td>
<td>7.9*</td>
<td>18.0*</td>
</tr>
<tr>
<td>2**</td>
<td>607</td>
<td>710</td>
<td>103</td>
<td>14</td>
<td>29</td>
<td>7.8*</td>
<td>16.8*</td>
</tr>
<tr>
<td>3</td>
<td>606</td>
<td>705</td>
<td>100</td>
<td>14</td>
<td>31</td>
<td>7.2</td>
<td>17.2*</td>
</tr>
</tbody>
</table>

### Standard Deviations

<table>
<thead>
<tr>
<th></th>
<th>Lower</th>
<th>Upper</th>
<th>Width</th>
<th>Lower</th>
<th>Upper</th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.5</td>
<td>2.2</td>
<td>2.8</td>
<td>1.7</td>
<td>3.4</td>
<td>3.4</td>
<td>2.8</td>
</tr>
<tr>
<td>2*</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
<td>1.2</td>
<td>3.6</td>
<td>1.1</td>
<td>4.5</td>
</tr>
<tr>
<td>2**</td>
<td>0.6</td>
<td>0.9</td>
<td>1.1</td>
<td>1.2</td>
<td>1.0</td>
<td>1.2</td>
<td>3.8</td>
</tr>
<tr>
<td>3</td>
<td>0.9</td>
<td>1.2</td>
<td>0.8</td>
<td>0.8</td>
<td>2.0</td>
<td>2.0</td>
<td>4.8</td>
</tr>
</tbody>
</table>

*With outlier channel included

**With outlier channel excluded

- a — No filter specification
- b — Fails to meet filter specification

Boxes indicate characteristics where differences between PF or F and all previous scanners (1,2,3) were greater than differences between two sets of PF measurements.
## SIMULATED MSS BAND MEANS

<table>
<thead>
<tr>
<th>TARGET</th>
<th>SENSOR SYSTEM</th>
<th>BAND 1&lt;sup&gt;b&lt;/sup&gt;</th>
<th>MEANS&lt;sup&gt;a&lt;/sup&gt; (DIGITAL MSS COUNTS)</th>
<th>BAND 2&lt;sup&gt;b&lt;/sup&gt;</th>
<th>BAND 3&lt;sup&gt;b&lt;/sup&gt;</th>
<th>BAND 4&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LSD-PF</td>
<td>19.36</td>
<td>14.89 (14.76)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>80.82&lt;sup&gt;*&lt;/sup&gt;</td>
<td>45.80&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LSD-F</td>
<td>19.25</td>
<td>14.72</td>
<td>82.81&lt;sup&gt;*&lt;/sup&gt;</td>
<td>45.39&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>SOYBEANS</td>
<td>LS1</td>
<td>19.46 (19.55)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>15.43</td>
<td>76.95</td>
<td>47.14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LS2</td>
<td>19.58</td>
<td>16.24 (16.13)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>78.58</td>
<td>47.24</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LS3</td>
<td>19.77</td>
<td>15.36</td>
<td>73.93</td>
<td>47.55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LSD-PF</td>
<td>28.39</td>
<td>34.75&lt;sup&gt;d&lt;/sup&gt;</td>
<td>41.02</td>
<td></td>
<td>18.61</td>
</tr>
<tr>
<td></td>
<td>LSD-F</td>
<td>28.39</td>
<td>34.75</td>
<td>41.05</td>
<td></td>
<td>18.48</td>
</tr>
<tr>
<td>SOIL</td>
<td>LS1</td>
<td>28.32&lt;sup&gt;d&lt;/sup&gt;</td>
<td>34.73</td>
<td>41.04</td>
<td>19.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LS2</td>
<td>28.34</td>
<td>34.66&lt;sup&gt;d&lt;/sup&gt;</td>
<td>41.05</td>
<td>19.07</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LS3</td>
<td>28.33</td>
<td>34.66</td>
<td>41.10</td>
<td>19.15</td>
<td></td>
</tr>
</tbody>
</table>

**a** — AT SATELLITE SENSOR RESPONSE, NADIR—LOOKING FOR 40° SOLAR ZENITH ANGLE AND 20 km VISIBILITY; UNITS ARE SIMULATED NON-TRUNCATED MSS DIGITAL COUNTS WITH MAXIMUM SPECIFIED RADIANCE SCALED TO 127.99 FOR BANDS 1, 2, 3 AND 63.99 FOR BAND 4.

**b** — LANDSAT-D BANDS 1, 2, 3 AND 4 CORRESPOND TO BANDS 4, 5, 6 AND 7, RESPECTIVELY ON PREVIOUS LANDSATs.

**c** — MEAN IN PARENTHESES IS WITH OUTLIER CHANNEL EXCLUDED

**d** — EXCLUSION OF OUTLIER DID NOT CHANGE BAND MEAN

'PF, F DIFFERENCE EXCEEDS: (1) DIFFERENCE BETWEEN SIMULATIONS RUN WITH EACH SET OF PF MEASUREMENTS SEPARATELY AND (2) 0.30 DIGITAL COUNTS.

BOXES INDICATE BANDS WHERE OUTPUT DIFFERENCES BETWEEN PF OR F AND ALL PREVIOUS SCANNERS (1,2,3) EXCEED: (1) AND (2) AS ABOVE.
RELATIVE SPECTRAL RESPONSE, RSR

BAND 1 MSS-D DIFFERENCES

SPECTRAL RADIANCE, \( L(\lambda) \) (W/m² cm² ster • \( \mu \)m)

WAVELENGTH, \( \lambda \) (nm)

PF, F AVERAGE
LS1, 2, 3 AVERAGE
SOIL
SOYBEANS

ORIGINAL PAGE IS OF POOR QUALITY
ORIGINAL PAGE IS
OF POOR QUALITY

( % )

RELATIVE SPECTRAL RESPONSE

BAND 4 MSS-D APPARENT DIFFERENCES

SPECTRAL RADIANCE, L \lambda (W/m^2 cm^{-2} ster^{-1} nm^{-1})

WAVELENGTH, \lambda (nm)

PF. F AVERAGE JUNE 81
SOYBEANS
LS 1, 2, 3 AVERAGE
SOIL
### Simulated Maximum Within-Band Sensor Output Differences

<table>
<thead>
<tr>
<th>Target</th>
<th>Sensor</th>
<th>Digital Counts</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Band 1</td>
<td>Band 2</td>
<td>Band 3</td>
</tr>
<tr>
<td></td>
<td>Band 1</td>
<td>Band 2</td>
<td>Band 3</td>
</tr>
<tr>
<td>Soybeans</td>
<td>LSD-PF</td>
<td>0.11</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>LSD-F</td>
<td>0.17</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>LS1</td>
<td>0.75</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>LS2</td>
<td>0.16</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>LS3</td>
<td>0.30</td>
<td>0.16</td>
</tr>
<tr>
<td>Soil</td>
<td>LSD-PF</td>
<td>0.03</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>LSD-F</td>
<td>0.01</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>LS1</td>
<td>0.10</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>LS2</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>LS3</td>
<td>0.07</td>
<td>0.09</td>
</tr>
</tbody>
</table>

*PF, F difference exceeds: (1) difference between simulations run with each set of PF measurements separately and (2) 0.30 digital counts. Boxes indicate bands where output differences between PF or F and all previous scanners exceed (1) and (2) as above.
Landsat-D System Overview

Cmd, Tlm, TM & MSS

TORS

DOMSAT

GSFC

TORS GROUND STATION

DOMSAT GROUND STATION

EROS DATA CENTER

LANDSAT ASSESSMENT SYSTEM

DATA MANAGEMENT SYSTEM

GSFC

TGS

NTTF

FOREIGN GROUND STATION

OPERATIONS CONTROL CENTER

Command & Timing

Processed Data

TM & MSS HARDWARE LINK

TM & MSS

Processed Data

Command & Timing
MSS Landsat-D Preprocessing

S-Band Telemetry Stream (15 Mbps)

Bulk Video Scene Data (57 x 83m)
4 Reflective Bands (6 Detectors/Scan)
2340 Lines x 3240 Pixel/Line = 7.6 x 10^6 Pixels

Spacecraft Data

Attitude \( \theta_x, \theta_y, \theta_z \)
Ephemeris \( \alpha, \beta, r \)

Scene Histograms 0-63
1 Cal. Lamp Wedge

30° Sphere 1-9 Levels

External Data

Control Point Chips 32 x 32

Control Point Neighborhood 128 x 128

Systematic Grid

Radiometric Look-Up Table (RLUT)
3 Bands (0-127) + 1 Band (0-63)

Geodetic Grid

4 Pre-Processing Output Images

3240 Lines x 3240 Pixels (57 x 57 m)/Line = 10.5 x 10^6 Pixels

--- Radiometric Pre-Processing

--- Geodetic Pre-Processing

1-157
Landsat-D Protoflight Multispectral Scanner (MSS)

MSS SCANNING ARRANGEMENT

MSS Detector Details

<table>
<thead>
<tr>
<th>Band</th>
<th>Spectral Range nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>495 - 605</td>
</tr>
<tr>
<td>2</td>
<td>603 - 698</td>
</tr>
<tr>
<td>3</td>
<td>701 - 813</td>
</tr>
<tr>
<td>4</td>
<td>808 - 1023</td>
</tr>
</tbody>
</table>

Ground IFOV
All Bands - 82.7 x 57m
Data Rate - 15.06 Mbps
Quantization Levels - 64

Swath Width 185 km
Landsat MSS Absolute Radiometric Calibration

Fiber Bundle Ends at Focus

Detectors (1 to 24)

24 Video Outputs

Secondary Mirror

Scan Mirror

Primary Mirror

View to Earth 14.9°

Know Radiance

Integrating Sphere

Source Assemblies

Neutral Density Filter

Telescope Optical Axis

Folding Mirror

Rotating Shutter Wheel

Optical Fiber Array

Lamp Calibration System

1-159
MSS CALIBRATION: DEFINITION OF VARIABLES

\[ R_{JK} = \text{INTEGRATING SPHERE RADIANCE FOR SPHERE LEVEL } J \]
\[ \text{AND MSS CHANNEL } \kappa \]

\[ R_{JK} = \frac{\int R_{WJ} RSR_{K} \, d\lambda}{\int RSR_{K} \, d\lambda} \]

\[ BW_{K} = \text{MEASURED BANDWIDTH OF CHANNEL } \kappa \]

\[ RSR_{K} = \text{MEASURED RELATIVE SPECTRAL RESPONSE FOR CHANNEL } \kappa \]

\[ RW_{J} = \text{SPECTRAL RADIANCE FOR } 76 \text{ cm INTEGRATING SPHERE FOR SPHERE LEVEL } J \]
Spectral Radiant Emittance Plot for 76 cm Integrating Sphere

![Graph showing spectral radiant emittance plot for a 76 cm integrating sphere. The plot illustrates the radiant emittance as a function of wavelength, with values ranging from 0 to 200 mW cm\(^{-2}\) \(\mu\text{m}^{-1}\) across the wavelength range of 0.4 to 1.2 \(\mu\text{m}\).]
Illustrative MSS/PF Lamp Calibration Wedge

\[ Q = \text{Average Digital Count for All 9 Sphere Levels} \]

\[ Q = \frac{1}{n} \sum_{j=1}^{n} Q_{ij} \]

\[ n = 9 \]

e.g. for \( i = 230 \)

<table>
<thead>
<tr>
<th>( j )</th>
<th>( Q_{ij} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>98.65</td>
</tr>
<tr>
<td>2</td>
<td>99.94</td>
</tr>
<tr>
<td>3</td>
<td>101.75</td>
</tr>
<tr>
<td>4</td>
<td>99.98</td>
</tr>
<tr>
<td>5</td>
<td>101.51</td>
</tr>
<tr>
<td>6</td>
<td>105.24</td>
</tr>
<tr>
<td>7</td>
<td>97.03</td>
</tr>
<tr>
<td>8</td>
<td>97.89</td>
</tr>
<tr>
<td>9</td>
<td>88.72</td>
</tr>
</tbody>
</table>
Systematic MSS Video and Wedge Level Timing Sequence

1st Known Radiance Run

2nd Known Radiance Run

jth Known Radiance Run

Telemetry Words →
MSS CALIBRATION: DEFINITION OF VARIABLES (CONT'D.)

\[ V_J = \text{SCENE AVERAGES VIDEO LEVEL FOR SPHERE LEVEL } J \]

\[ V_J = \frac{1}{390} \sum_{L=1}^{390} \frac{1}{N} \sum_{S=1}^{N} V_{JSL} \]

\[ V_{JSL} = \text{RAW VIDEO LEVEL IN DIGITAL COUNTS OF PIXEL } s \text{ ON LINE } L \text{ FOR SPHERE LEVEL } J \]

\[ S = \text{INDEX FOR SUM OF PIXELS IN A LINE} \]

\[ L = \text{INDEX FOR SUM OF LINES IN A SCENE} \]

\[ Q_{IJ} = \text{AVERAGE WEDGE LEVEL AT WORD } i \text{ AFTER SPHERE LEVEL } J \]

\[ Q_{IJ} = \frac{1}{390} \sum_{L=1}^{390} q_{iJL} \]

\[ q_{iJL} = \text{RAW DIGITAL COUNTS FOR WEDGE WORD } i \text{ ON LINE } L \text{ AFTER SPHERE LEVEL } J \]

\[ i = \text{WORD NUMBER} \]

\[ J = \text{SPHERE RADIANCE LEVEL} \]

\[ L = \text{LINE NUMBER} \]
MSS/PF ILLUSTRATIVE ABSOLUTE CALIBRATION TRANSFER FROM SPHERE TO CALIBRATION LAMP WEDGE WORD (230) FOR BAND 1, CHANNEL 1 (15TH SEPT., 1981, AT GE, VALLEY FORGE)

<table>
<thead>
<tr>
<th>INTEGRATING SPHERE RADIANCE LEVEL</th>
<th>AVERAGED VIDEO LEVEL (DIGITAL COUNTS)</th>
<th>AVERAGED WEDGE LEVEL (390 SCANS) (DIGITAL COUNTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_j ) (mW cm(^{-2}) sr(^{-1}))</td>
<td>( V_j )</td>
<td>( Q_{i,j} )</td>
</tr>
<tr>
<td>0.04</td>
<td>2.1</td>
<td>97.03</td>
</tr>
<tr>
<td>0.09</td>
<td>3.5</td>
<td>97.89</td>
</tr>
<tr>
<td>0.12</td>
<td>5.5</td>
<td>98.72</td>
</tr>
<tr>
<td>0.17</td>
<td>7.7</td>
<td>98.65</td>
</tr>
<tr>
<td>0.33</td>
<td>15.4</td>
<td>99.94</td>
</tr>
<tr>
<td>0.48</td>
<td>22.2</td>
<td>101.75</td>
</tr>
<tr>
<td>0.64</td>
<td>29.4</td>
<td>99.98</td>
</tr>
<tr>
<td>0.96</td>
<td>46.6</td>
<td>101.51</td>
</tr>
<tr>
<td>1.95</td>
<td>96.6</td>
<td>105.24</td>
</tr>
</tbody>
</table>

\[
\bar{Q}_1 = \frac{1}{9} \sum_{j=1}^{9} Q_{1,j} = 100.08
\]

ILLUSTRATES HYSTERESIS DEPENDENCY OF WEDGE VALUE ON PRECEDING RADIANCE LEVEL
CORRECTION PROCEDURE FOR HYSTERESIS EFFECT

- MODEL EXPECTED CAL WEDGE VALUE FOR WORD $i$ AFTER SPHERE LEVEL $J$ AS A FUNCTION OF AVERAGE VALUE FOR ALL SPHERE LEVELS
  
  $$ Q_{ij} = A_j + B_j \bar{Q}_i $$

- ADJUST VIDEO VALUE FOR SPHERE LEVEL $J$ ASSUMING THE HYSTERESIS TIME CONSTANT IS LONG RELATIVE TO THE 73 MSEC SCAN TIME

  $$ V_J = A_j + B_j V_{A,j} $$

  $$ V_{A,j} = \frac{V_J - A_j}{B_J} $$
LINEAR HYSTERESIS MODEL FOR LAMP
CALIBRATION WEDGE VALUES FOR MSS/PF
BAND 1, CHANNEL 1

<table>
<thead>
<tr>
<th>I</th>
<th>$\overline{Q}_I$ (DIGITAL COUNTS)</th>
<th>$Q_{1J}$ (DIGITAL COUNTS)</th>
<th>LEAST SQUARES FIT TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>220</td>
<td>106.7</td>
<td>112.9</td>
<td>$Q_{1J} = A_J + B_J \overline{Q}_I$</td>
</tr>
<tr>
<td>230</td>
<td>100.1</td>
<td>105.2</td>
<td>FOR BRIGHTEST SPHERE</td>
</tr>
<tr>
<td>240</td>
<td>95.1</td>
<td>99.7</td>
<td>LEVEL J WITH</td>
</tr>
<tr>
<td>250</td>
<td>90.0</td>
<td>94.6</td>
<td>$R_J = 1.95 \text{ MW cm}^{-2}\text{sr}^{-1}$</td>
</tr>
<tr>
<td>260</td>
<td>85.7</td>
<td>90.7</td>
<td>HYSTERESIS OFFSET</td>
</tr>
<tr>
<td>270</td>
<td>81.3</td>
<td>85.9</td>
<td>$A_J = .02$</td>
</tr>
<tr>
<td>280</td>
<td>77.5</td>
<td>81.6</td>
<td>HYSTERESIS GAIN</td>
</tr>
<tr>
<td>290</td>
<td>73.0</td>
<td>77.1</td>
<td>$B_J = 1.054$</td>
</tr>
<tr>
<td>300</td>
<td>68.9</td>
<td>73.2</td>
<td></td>
</tr>
<tr>
<td>310</td>
<td>65.5</td>
<td>68.7</td>
<td></td>
</tr>
<tr>
<td>810</td>
<td>4.1</td>
<td>4.3</td>
<td></td>
</tr>
<tr>
<td>820</td>
<td>3.9</td>
<td>4.1</td>
<td></td>
</tr>
<tr>
<td>850</td>
<td>3.2</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>860</td>
<td>3.0</td>
<td>3.2</td>
<td></td>
</tr>
</tbody>
</table>

$R^2 = .99996$
## ADJUSTMENT OF SPHERE VIDEO LEVELS FOR HYSTERESIS EFFECT FOR MSS/PF BAND 1, CHANNEL 1

<table>
<thead>
<tr>
<th>AVERAGED VIDEO VALUE FOR INTEGRATING SPHERE LEVEL J $V_J$ (DIGITAL COUNTS)</th>
<th>LINEAR REGRESSION COEFFS $Q_{iJ} = A_J + B_J \bar{Q}_i$</th>
<th>ADJUSTED VIDEO LEVEL $V_{A_J} = \frac{V_J - A_J}{B_J}$ (DIGITAL COUNTS)</th>
<th>SPHERE RADIANCE $R_J$ (mWcm$^{-2}$sr$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>.01</td>
<td>.971</td>
<td>2.15</td>
</tr>
<tr>
<td>3.5</td>
<td>-.08</td>
<td>.980</td>
<td>3.65</td>
</tr>
<tr>
<td>5.5</td>
<td>-.01</td>
<td>.984</td>
<td>5.60</td>
</tr>
<tr>
<td>7.7</td>
<td>.00</td>
<td>.986</td>
<td>7.81</td>
</tr>
<tr>
<td>15.4</td>
<td>.00</td>
<td>1.000</td>
<td>15.39</td>
</tr>
<tr>
<td>22.2</td>
<td>.01</td>
<td>1.014</td>
<td>21.89</td>
</tr>
<tr>
<td>29.4</td>
<td>.03</td>
<td>.997</td>
<td>29.47</td>
</tr>
<tr>
<td>46.6</td>
<td>.01</td>
<td>1.014</td>
<td>45.96</td>
</tr>
<tr>
<td>96.6</td>
<td>.02</td>
<td>1.054</td>
<td>91.61</td>
</tr>
</tbody>
</table>
CALIBRATION PROCEDURE FOR LAMP RADIANCE
TRANSFER OF SPHERE RADIANCE TO DETECTOR VIDEO VALUE

LEAST SQUARES FIT: \( V_{Aj} = p + qR_j \)

MSS/PF BAND 1, CHANNEL 1, SPHERE TO DETECTOR

OFFSET \( p = -0.21 \) (DIGITAL COUNTS)

GAIN \( q = 47.17 \) (DIGITAL COUNTS/MWcm\(^{-2}\)sr\(^{-1}\))

ASSUME LAMP RADIANCE CAN BE CALCULATED FROM \( p, q \)

\[
\bar{Q}_1 = p + qR_1
\]

\[
R_1 = \frac{\bar{Q}_1 - p}{q}
\]
CALCULATION OF LAMP RADIANCE FOR SIX OPERATIONAL WEDGE WORDS FOR MSS/PF BAND 1, CHANNEL 1

<table>
<thead>
<tr>
<th>WEDGE WORD NUMBER</th>
<th>OBSERVED AVERAGE WEDGE LEVEL</th>
<th>CALCULATED RADIANCE FOR WEDGE WORD</th>
</tr>
</thead>
<tbody>
<tr>
<td>230</td>
<td>100.08</td>
<td>2.126</td>
</tr>
<tr>
<td>240</td>
<td>95.05</td>
<td>2.020</td>
</tr>
<tr>
<td>250</td>
<td>90.04</td>
<td>1.913</td>
</tr>
<tr>
<td>260</td>
<td>85.67</td>
<td>1.821</td>
</tr>
<tr>
<td>810</td>
<td>4.07</td>
<td>0.091</td>
</tr>
<tr>
<td>820</td>
<td>3.85</td>
<td>0.086</td>
</tr>
</tbody>
</table>

\[ R_I = \bar{Q}_I - P \]

(DIGITAL COUNTS) (mWcm\(^{-2}\)sr\(^{-1}\))
CALCULATION OF LAMP RADIANCE FOR SIX OPERATIONAL WEDGE WORDS FOR MSS/PF BAND 1, CHANNEL 1

<table>
<thead>
<tr>
<th>WEDGE WORD NUMBER</th>
<th>OBSERVED AVERAGE WEDGE LEVEL</th>
<th>CALCULATED RADIANCE FOR WEDGE WORD</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>( \bar{Q}_I )</td>
<td>( R_I = \frac{\bar{Q}_I - P}{q} ) (MW cm(^{-2}) sr(^{-1}))</td>
</tr>
<tr>
<td>230</td>
<td>100.08</td>
<td>2.126</td>
</tr>
<tr>
<td>240</td>
<td>95.05</td>
<td>2.020</td>
</tr>
<tr>
<td>250</td>
<td>90.04</td>
<td>1.913</td>
</tr>
<tr>
<td>260</td>
<td>85.67</td>
<td>1.821</td>
</tr>
<tr>
<td>810</td>
<td>4.07</td>
<td>0.091</td>
</tr>
<tr>
<td>820</td>
<td>3.85</td>
<td>0.086</td>
</tr>
</tbody>
</table>

1-171
<table>
<thead>
<tr>
<th>CHANNEL</th>
<th>230</th>
<th>240</th>
<th>250</th>
<th>260</th>
<th>810</th>
<th>820</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.126</td>
<td>2.020</td>
<td>1.913</td>
<td>1.821</td>
<td>.091</td>
<td>.086</td>
</tr>
<tr>
<td>2</td>
<td>2.056</td>
<td>1.952</td>
<td>1.857</td>
<td>1.763</td>
<td>.085</td>
<td>.081</td>
</tr>
<tr>
<td>3</td>
<td>2.099</td>
<td>1.992</td>
<td>1.899</td>
<td>1.808</td>
<td>.089</td>
<td>.084</td>
</tr>
<tr>
<td>4</td>
<td>2.047</td>
<td>1.944</td>
<td>1.849</td>
<td>1.760</td>
<td>.086</td>
<td>.080</td>
</tr>
<tr>
<td>5</td>
<td>2.062</td>
<td>1.966</td>
<td>1.854</td>
<td>1.766</td>
<td>.089</td>
<td>.083</td>
</tr>
<tr>
<td>6</td>
<td>2.058</td>
<td>1.950</td>
<td>1.856</td>
<td>1.770</td>
<td>.087</td>
<td>.082</td>
</tr>
</tbody>
</table>

INTERNAL LAMP RADIANCE VALUES FOR SIX CALIBRATION WORD LOCATIONS FOR MSS/PF BAND 1

1-172
CALCULATION OF GAIN AND OFFSET USING LAMP RADIANCE VALUES AT SIX OPERATIONAL WEDGE WORDS

LINEAR REGRESSION: \( \bar{Q}_i = \alpha + \beta R_i \)

CHANNEL OFFSET = \( \alpha = \sum_{i=1}^{6} C_i \bar{Q}_i \)

CHANNEL GAIN = \( \beta = \sum_{i=1}^{6} D_i \bar{Q}_i \)

CALIBRATION REGRESSION COEFFICIENTS:

\[
C_i = \frac{\left[ \sum R_i^2 - R_i \sum R_i \right]}{k}
\]

\[
D_i = \frac{\left[ 6R_i - \sum R_i \right]}{k}
\]

\[
K = 6 \sum R_i^2 - (\sum R_i)^2
\]
BAND NORMALIZATION OF MSS CHANNEL GAINS AND OFFSETS

\[ \bar{Q} = p + q R_i \]

\[ V_c = \frac{V_{\text{Max}}}{(R_{\text{Max}}-R_{\text{Min}})} (R-R_{\text{Min}}) \]

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.48</td>
<td>2.5</td>
<td>.02</td>
</tr>
<tr>
<td>2</td>
<td>2.00</td>
<td>1.8</td>
<td>.04</td>
</tr>
<tr>
<td>3</td>
<td>1.76</td>
<td>1.5</td>
<td>.04</td>
</tr>
<tr>
<td>4</td>
<td>4.60</td>
<td>4.0</td>
<td>.10</td>
</tr>
</tbody>
</table>
ILLUSTRATIVE MSS/PF LINEAR REGRESSION COEFFICIENTS
FOR BAND 1

<table>
<thead>
<tr>
<th>WORD 230</th>
<th>WORD 240</th>
<th>WORD 250</th>
<th>WORD 260</th>
<th>WORD 810</th>
<th>WORD 820</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>C1</td>
<td>D2</td>
<td>C2</td>
<td>D3</td>
<td>C3</td>
</tr>
<tr>
<td>.1641</td>
<td>-.054</td>
<td>.1418</td>
<td>-.024</td>
<td>.1195</td>
<td>.006</td>
</tr>
<tr>
<td>.1689</td>
<td>-.053</td>
<td>-.1457</td>
<td>-.023</td>
<td>.1244</td>
<td>.005</td>
</tr>
<tr>
<td>.1648</td>
<td>-.052</td>
<td>.1420</td>
<td>-.022</td>
<td>.1220</td>
<td>.005</td>
</tr>
<tr>
<td>.1691</td>
<td>-.052</td>
<td>.1461</td>
<td>-.022</td>
<td>.1247</td>
<td>.005</td>
</tr>
<tr>
<td>.1688</td>
<td>-.053</td>
<td>.1474</td>
<td>-.025</td>
<td>.1225</td>
<td>.007</td>
</tr>
<tr>
<td>.1690</td>
<td>-.053</td>
<td>.1450</td>
<td>-.022</td>
<td>.1240</td>
<td>.005</td>
</tr>
</tbody>
</table>
BAND NORMALIZED EQUATIONS

BAND NORMALIZED CHANNEL OFFSET \[ \alpha' = \sum C'_{i} \bar{Q}_{i} = B = \text{CHANNEL BIAS} \]

BAND NORMALIZED CHANNEL GAIN \[ \beta' = \sum D'_i \bar{Q}_{i} = G = \text{CHANNEL GAIN} \]

WHERE BAND NORMALIZED REGRESSION COEFFICIENTS

\[ C'_i = C_i + R_{\text{MIN}} D_i \]
\[ D'_i = (R_{\text{MAX}} - R_{\text{MIN}}) D_i \]

BAND NORMALIZED VIDEO VALUE, \( VB \), IS:

\[ VB = \frac{127}{\beta'} (V - \alpha') \]

WHERE \( V \) IS THE RAW DIGITAL VIDEO VALUE AND THIS IS THE DIMENSIONLESS ABSOLUTE CALIBRATION EQUATION
### BAND NORMALIZED LINEAR REGRESSION COEFFICIENTS
FOR MSS BAND 1

<table>
<thead>
<tr>
<th>CHANNEL</th>
<th>$D_1$</th>
<th>$C_1$</th>
<th>$D_2$</th>
<th>$C_2$</th>
<th>$D_3$</th>
<th>$C_3$</th>
<th>$D_4$</th>
<th>$C_4$</th>
<th>$D_5$</th>
<th>$C_5$</th>
<th>$D_6$</th>
<th>$C_6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.403</td>
<td>-0.051</td>
<td>0.352</td>
<td>-0.021</td>
<td>0.296</td>
<td>0.008</td>
<td>0.248</td>
<td>0.034</td>
<td>-0.652</td>
<td>0.514</td>
<td>-0.653</td>
<td>0.515</td>
</tr>
<tr>
<td>2</td>
<td>0.419</td>
<td>-0.049</td>
<td>0.361</td>
<td>-0.020</td>
<td>0.309</td>
<td>0.008</td>
<td>0.257</td>
<td>0.034</td>
<td>-0.671</td>
<td>0.513</td>
<td>-0.674</td>
<td>0.514</td>
</tr>
<tr>
<td>3</td>
<td>0.409</td>
<td>-0.049</td>
<td>0.352</td>
<td>-0.019</td>
<td>0.303</td>
<td>0.007</td>
<td>0.254</td>
<td>0.032</td>
<td>-0.657</td>
<td>0.513</td>
<td>-0.660</td>
<td>0.515</td>
</tr>
<tr>
<td>4</td>
<td>0.419</td>
<td>-0.049</td>
<td>0.362</td>
<td>-0.019</td>
<td>0.309</td>
<td>0.008</td>
<td>0.260</td>
<td>0.033</td>
<td>-0.674</td>
<td>0.513</td>
<td>-0.677</td>
<td>0.515</td>
</tr>
<tr>
<td>5</td>
<td>0.419</td>
<td>-0.050</td>
<td>0.366</td>
<td>-0.022</td>
<td>0.303</td>
<td>0.009</td>
<td>0.255</td>
<td>0.035</td>
<td>-0.670</td>
<td>0.513</td>
<td>-0.674</td>
<td>0.515</td>
</tr>
<tr>
<td>6</td>
<td>0.420</td>
<td>-0.050</td>
<td>0.360</td>
<td>-0.019</td>
<td>0.307</td>
<td>0.008</td>
<td>0.260</td>
<td>0.033</td>
<td>-0.671</td>
<td>0.513</td>
<td>-0.675</td>
<td>0.515</td>
</tr>
</tbody>
</table>
MSS/PF ABSOLUTE RADIOMETRIC ACCURACY

CONCLUSIONS

- INTEGRATING SPHERE RADIANCE CORRECT TO 10%
  RELATIVE TO NBS STANDARD

- ERRORS FROM USE OF NOMINAL BAND WIDTHS
  (PRIOR TO RECALIBRATION BY GE)

<table>
<thead>
<tr>
<th>BAND</th>
<th>RANGE OF RADIANCE ERROR</th>
<th>RADIANCE BIAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.8 %</td>
<td>-9 %</td>
</tr>
<tr>
<td>2</td>
<td>12.9 %</td>
<td>7 %</td>
</tr>
<tr>
<td>3</td>
<td>2.6 %</td>
<td>-12 %</td>
</tr>
<tr>
<td>4</td>
<td>19.5 %</td>
<td>28 %</td>
</tr>
</tbody>
</table>
MSS RADIOMETRIC PRE-PROCESSING PROCEDURES
(MIPS = MSS IMAGE PROCESSING SYSTEM)

PURPOSE: CONVERT OBSERVED VIDEO DIGITAL COUNTS, V, INTO COUNTS WHICH ARE PROPORTIONAL TO RADIANCE, VA, BY USING RADIOMETRIC LOOK-UP TABLES (RLUTs)

STEPS:  
- COLLECT SCENE SEGMENT DATA
- CALCULATE BAND NORMALIZED GAIN, BIAS, AND RESULTING RLUT BY SEGMENT USING INTERNAL CALIBRATION LAMP DATA
- MODIFY GAIN AND BIAS USING SCENE HISTOGRAMS (OPTIONAL)
- GENERATE RLUT FOR EACH SUBSEGMENT BY BLENDING SEGMENT-LEVEL GAIN AND BIAS
Radiometric Pre-Processing Data Flow

Raw Segmented Scene and Calibration Data

Apply Band Normalized RLUT

Optionally Apply Histogram Normalized RLUT

Radiometrically Calibrated Subsegmented Scene
COLLECT MSS SCENE SEGMENT DATA

DURING INITIAL INGEST OF RAW DATA INTO MIPS:

DIVIDE EACH SCENE INTO SEGMENTS (CAN BE ONE, TWO, FOUR, OR EIGHT)

COLLECT SCENE HISTOGRAMS OF DIGITAL VIDEO VALUES, \( V \), FOR EACH SEGMENT.

COLLECT SIX DIGITAL CALIBRATION WEDGE WORDS, \( Q \), FROM EVERY OTHER LINE FOR EACH SEGMENT.
CALCULATE 24 BAND NORMALIZED RLUTs

FOR EACH SEGMENT FROM SELECTED CALIBRATION WEDGE DATA

1. CALCULATE SIX AVERAGE CALIBRATION WEDGE VALUES, $\bar{Q}$, FOR EACH CHANNEL
2. CALCULATE INITIAL GAIN (G) AND BIAS (B) FOR EACH CHANNEL
3. CALCULATE POST-LAUNCH MODIFIERS
4. CALCULATE A BAND NORMALIZED RLUT BY CHANNEL
CALCULATE SIX AVERAGE CALIBRATION WEDGE VALUES
FOR EACH CHANNEL IN THE SEGMENT

- Decompress the six calibration wedge digital values, \( Q \), acquired on every other scan, from \((0 - 63)\) to \((0 - 127)\).

- Calculate average calibration wedge value, \( \bar{Q} \), for each word.

<table>
<thead>
<tr>
<th>Word Number</th>
<th>Word Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>230</td>
</tr>
<tr>
<td>2</td>
<td>240</td>
</tr>
<tr>
<td>3</td>
<td>250</td>
</tr>
<tr>
<td>4</td>
<td>260</td>
</tr>
<tr>
<td>5</td>
<td>810</td>
</tr>
<tr>
<td>6</td>
<td>820</td>
</tr>
</tbody>
</table>

\( \bar{Q} = \frac{1}{6} \sum_{i=1}^{6} Q_i \)
CALCULATE INITIAL GAIN (G) AND BIAS (B)

FOR EACH CHANNEL IN THE SEGMENT

RETRIEVE ABSOLUTE LAMP CALIBRATION LINEAR REGRESSION COEFFICIENTS, C' AND D'

FROM DATA BASE.

CALCULATE GAIN AND BIAS FOR EACH CHANNEL:

\[ G = \sum C'Q \]
\[ B = \sum D'Q \]
CALCULATE POST-LAUNCH MODIFIERS
(AS NECESSARY)

BASED ON HISTOGRAMING OF REAL SCENE DATA,
CALCULATE MODIFIER (M) AND ADDER (A) TERMS TO CORRECT FOR RESIDUAL
STRIPING AND ATMOSPHERIC EFFECTS BY UPDATING THE ABSOLUTE CALIBRATION
EQUATION TO:

\[ VC = \frac{127}{MG} (V-B) - A = G'V + B' \]

\[ M = 1 \text{ AND } A = 0 \text{ UNTIL TIME OF UPDATE} \]
CALCULATE A BAND NORMALIZED RLUT
( FOR EACH CHANNEL )

COMPUTE A SEGMENT SPECIFIC RLUT:

\[ \text{RLUT} = \text{INTEGER } \left( \frac{(i - 1) - B}{G} \right) \]

MAP RLUT INTO COMMON RANGE FROM 0 TO 127 TO AVOID STRIPING FROM DETECTORS WITH DIFFERENT SENSITIVITY
MODIFY BAND NORMALIZED GAIN AND BIAS USING SCENE HISTOGRAMS FOR EACH CHANNEL IN THE SEGMENT

0 DECOMPRESS THE RAW SCENE HISTOGRAMS FROM (0 - 63) TO (0 - 127) (CONVERTS V-VALUES TO VD-VALUES IN ORDER TO CORRECT FOR NON-LINEARITY OF PHOTOMULTIPLIER TUBES)

0 CREATE CALIBRATED SCENE HISTOGRAMS BY APPLYING BAND NORMALIZED RLUT TO DECOMPRESSED SCENE HISTOGRAMS

0 CREATE A BAND AVERAGE SCENE HISTOGRAM FROM THE SIX INDIVIDUAL HISTOGRAMS

0 MODIFY EACH CHANNEL HISTOGRAM, \( rh \), SO THAT IT HAS THE SAME MEAN, \( \text{MEAN}(rh) \), AND STANDARD DEVIATION, \( \text{SD}(rh) \), AS THE BAND AVERAGE HISTOGRAM, \( \bar{rh} \), USING THE FOLLOWING FORMULA
HISTOGRAM NORMALIZATION (CONTINUED)

\[
\bar{RH} = G \cdot RH + b
\]

\[
g = \frac{SD(\bar{RH})}{SD(RH)}
\]

\[
b = MEAN(\bar{RH}) - g \cdot MEAN(RH)
\]

CALCULATE A HISTOGRAM NORMALIZED GAIN, \( G'' \), AND BIAS, \( B'' \)

\[
G'' = G' / g
\]

\[
B'' = B - G' \cdot b
\]
Scene Segment Blending

Example of Segment Blending With Number
Of Segments = 4
Number of Sub-Segments/Segment = 3
## Protoflight MSS-D

### Geometric Performance Summary

<table>
<thead>
<tr>
<th></th>
<th><strong>SPEC</strong></th>
<th><strong>ACTUAL</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Line Length Variation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TM off</td>
<td>42 μrad (rms)</td>
<td>12-19 μrad (rms)</td>
</tr>
<tr>
<td>TM on</td>
<td>42 μrad (rms)</td>
<td>109-113 μrad (rms)</td>
</tr>
<tr>
<td><strong>Line Length (Average)</strong></td>
<td>31.5-34 ms</td>
<td>32.3 ms</td>
</tr>
<tr>
<td><strong>Total Scan Angle</strong></td>
<td>.26 ± .001 rad</td>
<td>.2603 rad</td>
</tr>
<tr>
<td><strong>Scan Repeatability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TM off</td>
<td>24 μrad (rms)</td>
<td>&lt; 3 μrad (rms)</td>
</tr>
<tr>
<td>TM on</td>
<td>24 μrad (rms)</td>
<td>&lt; 7 μrad (rms)</td>
</tr>
<tr>
<td><strong>Cross Scan</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systematic</td>
<td>±200 μrad</td>
<td>&lt; ±42 μrad</td>
</tr>
<tr>
<td>Random</td>
<td>24 μrad (10)</td>
<td>&lt; 3 μrad</td>
</tr>
<tr>
<td><strong>MTF (10)2 μrad bars</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Band 1</td>
<td>&gt; .36</td>
<td>.49-.54</td>
</tr>
<tr>
<td>Band 2</td>
<td>&gt; .36</td>
<td>.47-.54</td>
</tr>
<tr>
<td>Band 3</td>
<td>&gt; .36</td>
<td>.47-.52</td>
</tr>
<tr>
<td>Band 4</td>
<td>&gt; .36</td>
<td>.45-.48</td>
</tr>
</tbody>
</table>

1-192
Scan Mirror Angle vs. Time Trajectory

Scan Period 73.42 ms (NOM)

Active Scan Period 32.3 ms (NOM)

Beginning of Scan (BOS) Bumper

Scan Center Line

Reverse Scan

Active Scan

Reverse Scan

Time

SMP1

SMP3

End of Scan (EOS) Bumper Position

SMP = Scan Monitor Pulse
MSS Detector Sampling Sequence

Band

4  3  2  1

Fiber Optics

A,19  A,13  A,7  A,1
B,20  B,14  B,8  B,2
C,21  C,15  C,9  C,3
D,22  D,16  D,10  D,4
E,23  E,17  E,11  E,5
F,24  F,18  F,12  F,6

Sequence Indicator

ORIGINAL PAGE 3 OF POOR QUALITY
MSS Scan Mirror Co-ordinate System

Telescope Axis

Local Horizontal

Telescope

BOS Bumper

EOS Bumper

Scan Mirror

Local Vertical

45°

Mirror Normal

Line of Sight

H = View Angle \ (H = 2Y \text{ if } X = 0)

Y = Mirror Angle

X = Jitter Angle

Local Vertical

1-196
Scan Profile Equations

\[ \ddot{y} + v \dot{y} + k(y - x) = 0 \]

\[ y = Ae^{-Rt} \sin (\omega (t + F) + B \sin (\omega_0 t - \phi) + C \cos (\omega_0 t + \phi) \]

\[ H = 2y - x \]

Where:
- \( I \) = Mirror Moment of Inertia
- \( y \) = Mirror Angle
- \( v \) = Damping Coefficient
- \( K \) = Flex Pivot Spring Constant
- \( x \) = Jitter Angle = \( A_0 \sin (\omega_0 t + \phi) \)
- \( H \) = View Angle
- \( t \) = Time from Beginning of Scan (BOS)
SCAN PROFILE EQUATIONS DEFINITION

\[ A = \frac{-S_0 - A_0 \sin \phi + B \sin \phi + C \cos \phi}{\sin \omega F} \]

\[ R = \frac{\omega_1^2}{2 q} \]

\[ F = \frac{1}{\omega} \tan^{-1} \left[ \frac{\sin \omega p}{x(p) - y_p(p) - S_0} \right] \]
\[ \frac{y_p(0) - x(0) - S_0}{e^{\omega p} + \cos \omega p} \]

\[ x(p) = A_0 \sin (\omega_0 p + \phi) \]
\[ x(0) = A_0 \sin \phi \]
\[ y_p(p) = B \sin (\omega_0 p + \phi) + C \cos (\omega_0 p + \phi) \]
\[ y_p(0) = B \sin \phi + C \cos \phi \]

\[ B = \frac{A_0 \left(1 - \frac{\omega_0^2}{\omega_1^2}\right)}{\left(1 - \frac{\omega_0^2}{\omega_1^2}\right)^2 + \left(\frac{\omega_p}{q}\right)^2} \]

\[ C = \frac{-A_0 \left(\frac{\omega_p}{q}\right)}{\left(1 - \frac{\omega_0^2}{\omega_1^2}\right)^2 + \left(\frac{\omega_p}{q}\right)^2} \]

\[ \omega = \omega_1 \left[1 - \left(\frac{\omega_0}{2q}\right)^2\right]^{1/2}, \quad \omega_1 = \sqrt{\frac{k}{I}}, \quad q = \frac{k}{v} \]
Scan Profile
Zero Damping, Zero Jitter Case

\[ x = v = 0 \]
\[ y = \frac{-S_o}{\sin \omega p} \sin (t - p/2) \]
\[ H = 2y \]

Where:
\( S_o = \) Half of Mirror Scan Angle
\( p = \) Active Scan Period
MSS Active Scan Mirror Profile

- Beginning of Scan (BOS)
- SMP1 (First Scan Monitor Pulse)
- Scan Center Line
- SMP3 (Third Scan Monitor Pulse)
- End of Scan (EOS)

View Angle, H, (Radians)

Time, t, (Milliseconds from BOS)
Landsat-D MSS/PF Calculated Deviation from Linear Scan

(ASSUMES NO DAMPING)

Deviation from Linear Scan, $V_2$, ($\alpha$ Radians)*

+631

0

-631

Time, $t$, (Milliseconds from BOS)

0  5  10  15  20  25  30

*Nominal (Linear) Scan Profile Minus Actual Profile
(Scale to be Calibrated During System Level Tests)
Landsat-D MSS/PF
Deviations from Linear Scan
(Assumes damping, based on engineering model measurements)

Deviation from Linear Scan, \( V_2 \) (\( \mu \) radians)*

Time, \( t \), (Milliseconds from BOS)

*Scale to be calibrated during system level tests
Protoflight MSS-D Scan Profiles
(with and without damping)

Definitions and physical values
T - time in seconds from BOS (SMP-1)
Y - mirror angle in radians
H - view angle in radians
P - active scan time (.03230 seconds)
K - flex pivots spring constant (26.6 in lbs/rad)
I - mirror inertia (.0923 in 16 sec^2)
S_o - half of mirror angle from SMP-1 to SMP-3 (.065075 rad)
### Scan Profile with Damping Coefficient $v = 0$

<table>
<thead>
<tr>
<th>$T$(SEC)</th>
<th>$H$(RAD)</th>
<th>$Y$(RAD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.13015000</td>
<td>6.5075000E-02</td>
</tr>
<tr>
<td>0.0008075</td>
<td>0.12379434</td>
<td>6.1897171E-02</td>
</tr>
<tr>
<td>0.001615</td>
<td>0.11741542</td>
<td>5.8707711E-02</td>
</tr>
<tr>
<td>0.0024225</td>
<td>0.11101444</td>
<td>5.5507218E-02</td>
</tr>
<tr>
<td>0.00323</td>
<td>0.10459259</td>
<td>5.2296296E-02</td>
</tr>
<tr>
<td>0.0040375</td>
<td>0.9315091E-02</td>
<td>4.9075546E-02</td>
</tr>
<tr>
<td>0.004845</td>
<td>0.91691147E-02</td>
<td>4.5845574E-02</td>
</tr>
<tr>
<td>0.0056525</td>
<td>0.85213975E-02</td>
<td>4.2606987E-02</td>
</tr>
<tr>
<td>0.00646</td>
<td>0.78720786E-02</td>
<td>3.9360393E-02</td>
</tr>
<tr>
<td>0.0072675</td>
<td>0.72212807E-02</td>
<td>3.6106403E-02</td>
</tr>
<tr>
<td>0.008075</td>
<td>0.65631256E-02</td>
<td>3.2845629E-02</td>
</tr>
<tr>
<td>0.0088825</td>
<td>0.59157364E-02</td>
<td>2.9578682E-02</td>
</tr>
<tr>
<td>0.00969</td>
<td>0.52612354E-02</td>
<td>2.6306177E-02</td>
</tr>
<tr>
<td>0.0104975</td>
<td>0.46057457E-02</td>
<td>2.3026729E-02</td>
</tr>
<tr>
<td>0.011305</td>
<td>0.39493906E-02</td>
<td>1.9746953E-02</td>
</tr>
<tr>
<td>0.0121125</td>
<td>0.32922933E-02</td>
<td>1.6461466E-02</td>
</tr>
<tr>
<td>0.01292</td>
<td>0.26345773E-02</td>
<td>1.3172887E-02</td>
</tr>
<tr>
<td>0.0137275</td>
<td>0.19763663E-02</td>
<td>9.8818316E-03</td>
</tr>
<tr>
<td>0.014535</td>
<td>0.13177839E-02</td>
<td>6.5889195E-03</td>
</tr>
<tr>
<td>0.0153425</td>
<td>0.65895386E-03</td>
<td>3.2947693E-03</td>
</tr>
<tr>
<td>0.01615</td>
<td>-1.5154374E-10</td>
<td>-7.5771868E-11</td>
</tr>
<tr>
<td>0.0169575</td>
<td>-6.5895389E-03</td>
<td>-3.2947694E-03</td>
</tr>
<tr>
<td>0.017765</td>
<td>-1.3177839E-02</td>
<td>-6.5889196E-03</td>
</tr>
<tr>
<td>0.0185725</td>
<td>-1.9763663E-02</td>
<td>-9.8818317E-03</td>
</tr>
<tr>
<td>0.01938</td>
<td>-2.6345774E-02</td>
<td>-1.3172887E-02</td>
</tr>
</tbody>
</table>
\begin{align*}
T(\text{SEC}) &= 0.201875 & H(\text{RAD}) &= -3.2922933E-02 & Y(\text{RAD}) &= -1.6461467E-02 \\
T(\text{SEC}) &= 0.203355 & H(\text{RAD}) &= -3.943906E-02 & Y(\text{RAD}) &= -1.9746353E-02 \\
T(\text{SEC}) &= 0.210250 & H(\text{RAD}) &= -4.6057458E-02 & Y(\text{RAD}) &= -2.3028729E-02 \\
T(\text{SEC}) &= 0.2261 & H(\text{RAD}) &= -5.2612354E-02 & Y(\text{RAD}) &= -2.6306177E-02 \\
T(\text{SEC}) &= 0.234175 & H(\text{RAD}) &= -5.9157864E-02 & Y(\text{RAD}) &= -2.957882E-02 \\
T(\text{SEC}) &= 0.24225 & H(\text{RAD}) &= -6.5691258E-02 & Y(\text{RAD}) &= -3.2845629E-02 \\
T(\text{SEC}) &= 0.250325 & H(\text{RAD}) &= -7.2212807E-02 & Y(\text{RAD}) &= -3.6196404E-02 \\
T(\text{SEC}) &= 0.2584 & H(\text{RAD}) &= -7.8720787E-02 & Y(\text{RAD}) &= -3.9360393E-02 \\
T(\text{SEC}) &= 0.266475 & H(\text{RAD}) &= -8.5213973E-02 & Y(\text{RAD}) &= -4.260687E-02 \\
T(\text{SEC}) &= 0.27455 & H(\text{RAD}) &= -9.1691147E-02 & Y(\text{RAD}) &= -4.5845574E-02 \\
T(\text{SEC}) &= 0.282625 & H(\text{RAD}) &= -9.8151091E-02 & Y(\text{RAD}) &= -4.9075546E-02 \\
T(\text{SEC}) &= 0.2907 & H(\text{RAD}) &= -1.0459259 & Y(\text{RAD}) &= -5.2296296E-02 \\
T(\text{SEC}) &= 0.298775 & H(\text{RAD}) &= -1.1101444 & Y(\text{RAD}) &= -5.5507218E-02 \\
T(\text{SEC}) &= 0.30685 & H(\text{RAD}) &= -1.1741542 & Y(\text{RAD}) &= -5.8707711E-02 \\
T(\text{SEC}) &= 0.314925 & H(\text{RAD}) &= -1.2379434 & Y(\text{RAD}) &= -6.1897171E-02 \\
T(\text{SEC}) &= 0.323 & H(\text{RAD}) &= -1.3015000 & Y(\text{RAD}) &= -6.5075000E-02
\end{align*}

\textit{ORIGINAL PAGE IS OF POOR QUALITY}
Scan Profile with Damping Coefficient $v = 107 \times 10^{-6}$ ft. - 16 - sec/rad

<table>
<thead>
<tr>
<th>$T$(SEC)</th>
<th>$H$(RAD)</th>
<th>$Y$(RAD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>.13015000</td>
<td>6.5075000E-02</td>
</tr>
<tr>
<td>.0003075</td>
<td>.12339288</td>
<td>6.1896439E-02</td>
</tr>
<tr>
<td>.001613</td>
<td>.11741256</td>
<td>5.8786282E-02</td>
</tr>
<tr>
<td>.0024225</td>
<td>.11101026</td>
<td>5.5505130E-02</td>
</tr>
<tr>
<td>.00323</td>
<td>.10456717</td>
<td>5.2293583E-02</td>
</tr>
<tr>
<td>.0040375</td>
<td>9.8144493E-02</td>
<td>4.9072246E-02</td>
</tr>
<tr>
<td>.004845</td>
<td>9.1683448E-02</td>
<td>4.5841724E-02</td>
</tr>
<tr>
<td>.0056525</td>
<td>8.5205248E-02</td>
<td>4.2602624E-02</td>
</tr>
<tr>
<td>.00646</td>
<td>7.8711110E-02</td>
<td>3.9355553E-02</td>
</tr>
<tr>
<td>.0072675</td>
<td>7.2202253E-02</td>
<td>3.6101127E-02</td>
</tr>
<tr>
<td>.008075</td>
<td>6.5679902E-02</td>
<td>3.2839951E-02</td>
</tr>
<tr>
<td>.0088825</td>
<td>5.9145282E-02</td>
<td>2.9572641E-02</td>
</tr>
<tr>
<td>.00969</td>
<td>5.2599622E-02</td>
<td>2.6293811E-02</td>
</tr>
<tr>
<td>.0104975</td>
<td>4.6044150E-02</td>
<td>2.3022075E-02</td>
</tr>
<tr>
<td>.011305</td>
<td>3.9480101E-02</td>
<td>1.9740050E-02</td>
</tr>
<tr>
<td>.0121125</td>
<td>3.2908735E-02</td>
<td>1.6454353E-02</td>
</tr>
<tr>
<td>.01292</td>
<td>2.6331201E-02</td>
<td>1.3165600E-02</td>
</tr>
<tr>
<td>.0137275</td>
<td>1.9748822E-02</td>
<td>9.874408E-03</td>
</tr>
<tr>
<td>.014535</td>
<td>1.3162805E-02</td>
<td>6.5814027E-03</td>
</tr>
<tr>
<td>.0153425</td>
<td>6.5743898E-03</td>
<td>3.2871949E-03</td>
</tr>
<tr>
<td>.01615</td>
<td>-1.5187312E-05</td>
<td>-7.5936560E-06</td>
</tr>
<tr>
<td>.0169575</td>
<td>-6.6046875E-03</td>
<td>-3.3023638E-03</td>
</tr>
<tr>
<td>.017765</td>
<td>-1.3192873E-02</td>
<td>-6.5964363E-03</td>
</tr>
<tr>
<td>.0185725</td>
<td>-1.9778505E-02</td>
<td>-9.8892523E-03</td>
</tr>
<tr>
<td>.01933</td>
<td>-2.6360346E-02</td>
<td>-1.3180173E-02</td>
</tr>
<tr>
<td>.0201875</td>
<td>-3.2937160E-02</td>
<td>-1.6465800E-02</td>
</tr>
<tr>
<td>T (SEC)</td>
<td>H (RAD)</td>
<td>Y (RAD)</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>0.020995</td>
<td>-3.9507711E-02</td>
<td>-1.9753855E-02</td>
</tr>
<tr>
<td>0.0218025</td>
<td>-4.6070764E-02</td>
<td>-2.3035302E-02</td>
</tr>
<tr>
<td>0.02261</td>
<td>-5.2625086E-02</td>
<td>-2.3312543E-02</td>
</tr>
<tr>
<td>0.0234175</td>
<td>-5.9169445E-02</td>
<td>-2.9584723E-02</td>
</tr>
<tr>
<td>0.024225</td>
<td>-6.5702517E-02</td>
<td>-3.2851306E-02</td>
</tr>
<tr>
<td>0.0250325</td>
<td>-7.2223300E-02</td>
<td>-3.6111680E-02</td>
</tr>
<tr>
<td>0.02584</td>
<td>-7.8730463E-02</td>
<td>-3.9365231E-02</td>
</tr>
<tr>
<td>0.0266475</td>
<td>-8.5222698E-02</td>
<td>-4.2611345E-02</td>
</tr>
<tr>
<td>0.027455</td>
<td>-9.1698845E-02</td>
<td>-4.5849423E-02</td>
</tr>
<tr>
<td>0.0282625</td>
<td>-9.8157689E-02</td>
<td>-4.9078845E-02</td>
</tr>
<tr>
<td>0.02907</td>
<td>-1.0459802</td>
<td>-5.2295088E-02</td>
</tr>
<tr>
<td>0.0300775</td>
<td>-1.1101861</td>
<td>-5.5509307E-02</td>
</tr>
<tr>
<td>0.030685</td>
<td>-1.1741328</td>
<td>-5.8709133E-02</td>
</tr>
<tr>
<td>0.0314925</td>
<td>-1.2379591</td>
<td>-6.1897903E-02</td>
</tr>
<tr>
<td>0.0323</td>
<td>-1.3015000</td>
<td>-6.5075000E-02</td>
</tr>
</tbody>
</table>

*ORIGINAL PAGE IS OF POOR QUALITY*
Line Length Variation Effects on Scan Mirror Profile

Line Length Error = -78 μsec.
$V_0$ = Error Remaining after "Rubberband" Correction
$V_1$ = Error Resulting from Shortened Line Length if Baseline Profile is Used
$V_2$ = Deviation from Linear Scan
MSS Geometric Processing and Calibration

Joan Brooks
GEOMETRIC CORRECTION AGENDA

- REQUIREMENTS
- OVERVIEW OF CORRECTION DATA GENERATION
- SYSTEMATIC CORRECTION DATA GENERATION
- GEODETIC CORRECTION DATA GENERATION
- GEOMETRIC CORRECTION CALIBRATION
SUMMARY OF KEY GEOMETRIC CORRECTION REQUIREMENTS

- COMPLETE GEOMETRIC CORRECTION CALCULATION
  - EXCEPT NO TERRAIN RELIEF COMPENSATION
- USE EPHemeris FROM GPS OR ORBIT SUPPORT COMPUTING DIVISION (2 DAY PREDICT)
- MAP PROJECTIONS
  - UNIVERSAL TRANSVERSE MERCATOR/POLAR STEREoGRAPHIC
  - SPACE OBLIQUE MERCATOR
- INTERACTIVE CONTROL POINT LIBRARY BUILD
  - SELECT CONTROL POINTS FROM MAPS AND PHOTOGRAPHIC IMAGERY
  - 100 CONTROL POINTS/DAY
  - CAPABILITY TO USE THE EXISTING LANDSAT 2/3 LIBRARY
  - ELEVATION OF CONTROL POINTS MUST BE USED
- SCENE FRAMING BASED UPON A WORLD REFERENCE SYSTEM (WRS)
- FULLY CORRECTED MSS IMAGERY
  - FOR SENSOR AND PROCESS QUALITY ASSESSMENT
  - RESAMPLING USING NEAREST NEIGHBOR OR CUBIC CONVOLUTION
  - CCT AND 241 MM FILM OUTPUTS
- MSS ARCHIVAL HIGH DENSITY TAPE
  - FORMAT AND CONTENT MUST CONFORM WITH IPF-ICD-201
  - DEFINES MSS GEOMETRIC CORRECTION DATA
SUMMARY OF KEY GEOMETRIC CORRECTION REQUIREMENTS (ACCURACY)

GEODE蒂C RECTIFICATION

- 0.5 PIXEL (90% OF THE TIME)
- REFERENCE TO STANDARD MAP
- ASSUME ACCURATE GROUND CONTROL POINTS
- VERIFIED OVER AREAS WITH NO TOPOGRAPHICAL VARIATIONS

TEMPORAL REGISTRATION

- 0.3 PIXEL (90% OF THE TIME)
- ADEQUATE INSTRUMENT PERFORMANCE
GEOMETRIC ACCURACY SPECIFICATIONS

GEOMETRIC CORRECTION REQUIREMENTS
90% OF THE TIME

GEODETIC
TEMPORAL
0.5 PIXEL

TEMPORAL REGISTRATION WITH REGISTRATION CONTROL POINTS

REFERENCE SCENE
BAND K

GEODETIC
CONTROLS
POINTS

STANDARD
MAP
(NO ERRORS)

GEODETIC
RECTIFICATION

PASS N
BAND L

BAND TO BAND

PASS N
BAND K

PASS N + 1
BAND L

BAND TO BAND

PASS N + 1
BAND K

GEODETIC
RECTIFICATION

ORIGINAL PAGE IS OF POOR QUALITY

1-213
TEMPORAL REGISTRATION REQUIREMENT INTERPRETATION

- TEMPORAL REGISTRATION REQUIREMENT: 0.3 PIXEL, 90% OF THE TIME

- CLARIFICATIONS
  - SPECIFICATION APPLIES PER AXIS OF THE OUTPUT SCENE (X, Y)
  - PIXEL DEFINED AS INPUT PIXEL SIZE
    - 42.5 μRadian FOR TM
    - 117.2 μRadian FOR MSS
    (AVOIDS ALTITUDE EFFECTS AND RESTRAINT OF REDUCED TM OUTPUT PIXEL SIZE, 28.5 METER)
  - ADEQUATE NUMBER AND DISTRIBUTION OF CONTROL POINTS
  - ELEVATION OF CONTROL POINTS MUST BE KNOWN
  - VERIFIED OVER AREAS WITH NEGLIGIBLE EARTH TOPOLOGICAL VARIATIONS
TEMPORAL REGISTRATION VERIFICATION

- CATEGORIES OF ERRORS

  - BIASES: "FIXED" OFFSET BETWEEN REFERENCE AND SUBSEQUENT PASS. RESULTS PRIMARILY FROM ATTITUDE, ALIGNMENT AND EPHEMERIS UNCERTAINTY. RANDOM OVER THE ENSEMBLE OF ESTIMATION EVENTS. ENSEMBLE VARIANCE \( \sigma_B^2 \).

  - RANDOM: INTERNAL ERRORS WITHIN ONE SCENE. RESULTS FROM SCAN MIRROR NON-REPEATABILITY, RESIDUAL JITTER, PROCESSING LINEARIZATION AND COMPUTATIONAL LIMITATIONS. ONE SCENE VARIANCE \( \sigma_R^2 \).

  - MEASUREMENT: ERROR IN CORRELATING TWO CONTROL POINTS. VARIANCE \( \sigma_M^2 \).
## Multispectral Scanner Temporal Registration Error

In Pixel (117.2 μ") 90% of the Time

<table>
<thead>
<tr>
<th>Error Source</th>
<th>MSS-D Performing at Spec Level</th>
<th>MSS-D Performing at MSS-3 Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cross Track</td>
<td>Along Track</td>
</tr>
<tr>
<td></td>
<td>Bias</td>
<td>Random</td>
</tr>
<tr>
<td>Multispectral Scanner</td>
<td>-</td>
<td>0.337 (\sqrt{2})</td>
</tr>
<tr>
<td>Scan Repeatability</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Band-to-Band</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Scan Underlap/Overlap</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Worst Case 45°N</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>81.8°S</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Spacecraft</td>
<td>-</td>
<td>0.102 (\sqrt{2})</td>
</tr>
<tr>
<td>Jitter</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ground Processing</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>• Attitude/Ephemeris Residual</td>
<td>-</td>
<td>0.269</td>
</tr>
<tr>
<td>• Systematic Correction Data Generation</td>
<td>-</td>
<td>0.030 (\sqrt{2})</td>
</tr>
<tr>
<td>• Geobetic Correction Data Generation</td>
<td>-</td>
<td>0.030 (\sqrt{2})</td>
</tr>
<tr>
<td>• Correction Data Interpolation</td>
<td>-</td>
<td>0.030 (\sqrt{2})</td>
</tr>
<tr>
<td>• Resampling</td>
<td>-</td>
<td>0.014 (\sqrt{2})</td>
</tr>
<tr>
<td>RSS Subtotal</td>
<td>0.269</td>
<td>0.505</td>
</tr>
<tr>
<td>Random + Bias RSS</td>
<td>0.572</td>
<td>0.768 (81.8°S)</td>
</tr>
<tr>
<td>System Specification</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>
OVERVIEW OF CORRECTION DATA GENERATION

SYSTEMATIC CORRECTION DATA - THREE STAGES

- OFFLINE DEVELOPMENT OF NOMINAL CORRECTION DATA
- ONLINE ATTITUDE/EPHEMERIS PROCESSING, SCENE CENTER DETERMINATION
- ONLINE UPDATE OF NOMINAL CORRECTION DATA USING PROCESSED ATTITUDE/EPHEMERIS

GEODETIC CORRECTION DATA - ONLINE

- EXTRACTION AND CORRECTION OF CONTROL POINT NEIGHBORHOODS USING SYSTEMATIC CORRECTION DATA
- CORRELATION OF CONTROL POINT LIBRARY CHIPS TO CONTROL POINT NEIGHBORHOODS
- FILTERING OF CONTROL POINT DISLOCATION TO DETERMINE EPHEMERIS/ATTITUDE CORRECTIONS
- UPDATE OF SYSTEMATIC CORRECTION DATA USING FILTER OUTPUTS

1-217
OVERVIEW OF GEOMETRIC CORRECTION (CONTINUED)

- REFORMATTING OF CORRECTION DATA TO HORIZONTAL AND VERTICAL RESAMPLING MATRICES (HRS/VRS)
Overview of MSS Geometric Correction
Data Generation for a Scene

Legend
HRS: Horizontal Resampling
VRS: Vertical Resampling
SOM: Space Oblique Mercator
UTM: Universal Transverse Mercator
PS: Polar Stereographic
Systematic Correction of Imagery: Effects Modeled

- Spacecraft Ephemeris (Input)
- Spacecraft Attitude (Input)
- Scanner Misalignment (Parameters)
- Scan Angle Profile (Parameterized Model)
- Earth Geoid (Parameterized Model)
- Earth Rotation (Parameterized Model)
- World Reference System Scene Centers

Calculations Performed for Single Detector in Center of Detector Array —

- Band-Line Adjustments (BLA) Applied Separately
- Line Length Corrections Applied Separately
MSS Mirror Model for SCDG

\[ f(i) = 2 \cdot e^{-B(t-t_0)} \{ A \sin \omega (t_0 + [i-1] \Delta t) \} \]

- \( f \) = Scan Angle
- \( i \) = Pixel Number
- \( \Delta t \) = Sampling Time
- \( \omega \) = Mirror Frequency
- \( A \) = Amplitude
- \( B \) = Damping Constant
- Along Scan Only (Roll Axis)
- Need Shape for Cross Scan (Pitch/Yaw vs \( i \))
Coordinate System For Basic Calculations

Standard Coordinate System:

- Origin at WRS Scene Center
- X-Axis Along S/C Nominal Angular Momentum Vector
- Z-Axis Earth Center Pointing
- Y-Axis Completes Right Hand Coordinate System
  (Parallel to S/C Nominal Inertial Velocity)
Oblique Mercator Coordinates For The Sphere

\[ X = \frac{R_e}{2} \ln \left( \frac{1 + \sin \beta}{1 - \sin \beta} \right) \]

\[ Y = R_e \cdot \lambda \]

- Oblique Longitude of \( P \)
- Oblique Latitude of \( P \)
- Local Earth Radius at WRS Scene Cent

- Highly Conformal With Scene
- Good Local Approximation to Space Oblique Mercator
Systematic Correction Functions (SCF)

Objective: Associate \((X, Y)\) in Processed Image with \((i, j)\) in Raw Video

\[ i = \text{Pixel Number (Sample Time)} \]
\[ j = \text{Line Number (Scan Time)} \]

\((i, j)\) Defines Unique Time \(t\) Relative to Scene Center Time

Result: \(X = f(i,j)\) \(\{\) \(Y = g(i,j)\) \(\}\) For Given Ephemeris and Attitude
Systematic Corrections Functions: The Lookpoint Calculation

- In ECI Coordinates, solved for \((\theta, \lambda')\)
  \[
  \hat{\mathbf{R}}_{LP}(\theta, \lambda') = \hat{\mathbf{R}}_{S/C}(t) + d\hat{\mathbf{\omega}}(t)
  \]
  \(t\) From Pixel Number \(i\)
  Scan Line \(j\)
  Scene Center Time

- \(\hat{\mathbf{R}}_{S/C}(t)\) From Ephemeris

- \(\hat{\mathbf{\omega}}(t)\) From Scan Profile, Alignment, Attitude Data

- Transform to ECEF Coordinates
  \[
  \lambda'(i, \hat{J}) \text{ From } \lambda', \text{ Earth Spin}
  \]

- Transform \((\theta, \lambda)\) to \((\lambda', \beta)\)

- Transform \((\lambda, \beta)\) to \((x, y)\)
Nominal Systematic Correction Functions (SCF₀)

- Spacecraft in Orbit that Determines WRS Scene Centers (Nominal Orbit)
- Spacecraft and Sensor have Nominal Pointing (Nominal Attitude Data)

\[
\begin{align*}
X₀ &= \phi₀(i,j) \\
Y₀ &= \theta₀(i,j)
\end{align*}
\]

\(X₀, Y₀\) Independent of Spacecraft Ephemeris and Attitude
Properties Of Systematic Correction Functions

- Highly Linear In Spacecraft Parameter Biases

\[ x(i, j, \delta) = x_0(i, j) + \frac{\delta}{2} \frac{\partial x(i, j)}{\partial \delta} S_\varepsilon(i, j) \]

\[ y(i, j, \delta) = y_0(i, j) + \frac{\delta}{2} \frac{\partial y(i, j)}{\partial \delta} S_\varepsilon(i, j) \]

- Analytic Expressions for Partial Derivatives Defined Over Entire Grid

- Spacecraft Parameter Biases

- \( S_\lambda \) – Bias in Oblique Longitude
- \( S_\beta \) – Bias in Oblique Latitude
- \( S_r \) – Bias in S/C Radial Location
- \( S_\theta_p \) – Pitch Angle
- \( S_\theta_r \) – Roll Angle
- \( S_\theta_y \) – Yaw Angle

- Biases Generally Functions of Time
Offline Generation of Nominal Systematic Correction Functions/Partial Derivatives

- SCFO Generated on Grid 41 (Along Scan) x 11 (Along Track)
- Partial Derivatives (PD) Generated on Grid 5 (Along Scan) x 3 (Along Track)
- Linear Interpolation Suffices
- Functions of WRS Scene Center Latitude Only
- Stored for Single Reference Path, Along with Nominal Ephemeris and WRS Scene Center Data
- Total Data Base <1.5 MBytes
Ephemeris Processing

- Received Ephemeris has been Processed on the OBC
- May Be Contaminated By
  - Noise
  - Outliers (Transmission Errors)
  - Bias (Ground Truth Required for Removal)
- Smoothing to Remove Noise (J2 Model with Drag)
- Outlier Detection/Removal (Test on Angular Momentum)
- Bad Data Point Count/Residuals for Quality
- Mean Residual Error (Exclusive of Bias) — approximately 10M
Source of Ephemeris

GPS → S/C OBC

Telemetry: \( \dot{x}, \dot{y}, \dot{z} \)

Every 0.192 Secs

Fourier Series Coefficients

NASA GSFC OCC

\[
\begin{align*}
\ldots & x_0 \quad y_0 \quad z_0 \quad \dot{x}_0 \quad \dot{y}_0 \quad \dot{z}_0 \\
\ldots & x_1 \quad y_1 \quad z_1 \quad \dot{x}_1 \quad \dot{y}_1 \quad \dot{z}_1 \\
\ldots & x_2 \quad y_2 \quad z_2 \quad \dot{x}_2 \quad \dot{y}_2 \quad \dot{z}_2 \\
\ldots & x_j \quad y_j \quad z_j \quad \dot{x}_j \quad \dot{y}_j \quad \dot{z}_j
\end{align*}
\]
Ephemeris Data Smoothing

- Outlier rejection criterion: angular momentum error > 0.002 x angular momentum
Attitude Data Processing

- Received from the Spacecraft
  - Quaternions on a 4.096 Second Grid
  - Angular Increments (Pitch, Roll, Yaw) on a 0.512 Second Grid, Filtered (Frequencies less than 0.5 Hz)
  - Data in Earth Centered Inertial Coordinate System

- Required Processing
  - Phase and Amplitude Compensation for Angular Increments
  - Limit Checking to Remove Outliers (Transmission Error)
  - Integration of Euler Parameters (Rates from Angular Increments)
  - Quality Checks
Data Flow in MSS Attitude Data Processing

- 8 K bite TLM
- Validity Check
- Pre-launch Calibration Data
- 512 M
- Amplitude/Phase Compensation
- Scale Factors/Alignment Data
- Euler Parameter Integration
- Euler Parameter Transformation
- MSS Attitude (Roll, Pitch, Yaw) 612 MS Grid
- Last DRIRU Drift Estimate in Interval
- First Quaternion in the Interval

Example of Quaternion in Small Angle Approximation:

\[
\begin{align*}
\phi &= \frac{1}{2} \theta_p \\
\beta &= \frac{1}{2} \theta_r \\
\gamma &= \frac{1}{2} \theta_f \\
\eta &= 1.0
\end{align*}
\]
Scene Center Calculation

- Scene Center Time: Time at which X-axis of Standard Coordinate System is intersected by a Radius Vector Through Midscan Ground Trace

[Diagram showing the intersection of the Scene Center, Nominal Ground Track, Midscan Ground Trace, WRS Scene Center, and Earth Center.]
MSS Data Flow In GCDG

1. Locate CP in Video Data

2. 
   - R/C CPN
   - G/C CPN
   - Enhance CPC/CPN
   - Cross-Corr. CPC-CPN

3. Filter

4. Scene Center and SCF Updates/Map Projections

CPN Extraction Parameters

MSS Data Extraction
   - Radiometric Correction Data Dev't

RLUT

HRS/VRS in O.M. C.S.

Band Line Adjustment (BLA) MSCD

CP Data

\[ \Delta X(i, \xi, \eta, k) \]
\[ \Delta Y(i, \xi, \eta, k) \]
\[ k = i, NCP \]

CPC - Control Point Chip (32 x 32)
CPC - Control Point Neighborhood
\[ (i, \xi, \eta) \] - Location in Raw Data of k th Control Point

ORIGINAL PAGE IS OF POOR QUALITY
Properties/Effects Of $\delta$ For Landsat-D MSS
(Single Scene)

- Constant $\delta$

- $\delta_\alpha, \delta_\theta$  
  - Along Track Displacement

- $\delta_\beta, \delta_\eta$
  - Cross Track Displacement

- $\delta_\theta$
  - Along Track Asymmetry

- $\delta_\gamma$
  - Cross Track Asymmetry (Magnification)

- Asymmetries Almost Linear and Odd Functions of $X$

- Displacements Large

- Asymmetries Small But Detectable (0.25 - 1.5 Pixel)
Rates - All Asymmetric Image Distortions

- $\delta x, \delta \theta_p$ — Along Track Asymmetry (Magnification)
- $\delta \beta, \delta \theta_r$ — Cross Track Asymmetry (Rotation or Yaw Plus Cross Track Skew)
- $\delta \theta_y$ — Growth of Along Track Skew
- $\delta h$ — Growth of Cross Track Magnification

- Asymmetries Almost Linear and Odd Functions of $Y$.
- Asymmetries Marginally Detectable (Less Than 0.1 Pixel, 90%)
Filter Variables

- $S\lambda$ and $S\theta_p$ Hard to Separate — Represented by Single Variable — $S\lambda T$, For Along Track Translations
- $S\beta$ and $S\theta_r$ Hard to Separate — Represented by Single Variable $S\theta$, for Cross Track Translations

Hence a 6-Variable Filter:

<table>
<thead>
<tr>
<th>Bias Name</th>
<th>Effect in Image</th>
<th>90% Error at Worst Point (Pixels)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S\lambda T$</td>
<td>Along Track Shift</td>
<td>&gt; 10</td>
</tr>
<tr>
<td>$S\theta$</td>
<td>Cross Track Shift</td>
<td>&gt; 10</td>
</tr>
<tr>
<td>$S\beta$</td>
<td>Cross Track Magnification</td>
<td>~ 0.1</td>
</tr>
<tr>
<td>$S\theta_y$</td>
<td>Along Track Skew</td>
<td>~ 0.8</td>
</tr>
<tr>
<td>$S\lambda T$</td>
<td>Along Track Magnification</td>
<td>~ 0.1</td>
</tr>
<tr>
<td>$S\theta$</td>
<td>Cross Track Skew</td>
<td>~ 0.1</td>
</tr>
</tbody>
</table>
Basis Of The MSS Filter

- Linearity of SCF with $\delta = (s_x, s_y, s_z, s_{rp}, s_{rq}, s_{rt})$

- Availability of Analytic Partial Derivatives

$$
\mu_x e(i,j) = \frac{\partial x(i,j)}{\partial x e}
$$

$$
\mu_y e(i,j) = \frac{\partial y(i,j)}{\partial y e}
$$

- $\Delta x(i,j) = \frac{\mu_x e(i,j) \cdot S_e(i,j)}{x}$

- $\Delta y(i,j) = \frac{\mu_y e(i,j) \cdot S_e(i,j)}{y}$

- Above Suggests an Optimal Least Squares Filter, Based on Function:

$$
NCP \left( \frac{\epsilon_x^2}{\sigma_x^2} + \frac{\epsilon_y^2}{\sigma_y^2} \right) \equiv \frac{F(\delta)}{\sigma_x^2}
$$

Where

$$
\epsilon_\delta^2 = \frac{1}{NCP} \sum_{k=1}^{NCP} \left[ \Delta Q_k - \frac{\mu_y e(i_k,j_k) \cdot S_e(i_k,j_k)}{x} \right]^2
$$

and

$$
\sigma_\delta^2 = \text{Variance of Image Noise/Measurements}
$$
CHOOSING THE OPTIMAL VARIABLE SET

• X CORRECTION AND Y CORRECTION ARE ALMOST INDEPENDENT

• X CORRECTING BIASES: $CT$, $R$, $CT,$
  - COMPUTE X-QUALITY FOR
    1. ALL 3 VARIABLES
    2. $CT$ AND EACH OF 2 INDIVIDUALS
    3. $CT$ ALONE
  - RETAIN VARIABLE SET THAT PRODUCES BEST QUALITY

• Y CORRECTING BIASES: $AT$, $EY$, $AT$
  - PROCEED AS FOR X, USING Y-QUALITY
  - RETAIN VARIABLE SET THAT PRODUCES BEST QUALITY

• REPORT VARIABLE SET USED, X- AND Y- QUALITY

1-240
Quality Of Correction

- Definition of X-Quality:
  Residual Error in X at Worst Points in Scene (Corners)

- Definition of Y-Quality:
  Residual Error in Y at Worst Points in Scene (Corners)

- Semi-Analytic Functions for X and Y Quality
  Deduced for Given NCP and Spatial Distribution of CPs — Also Depend on $\sigma_x, \sigma_y$ Directly

- X- and Y-Quality Deduced Dynamically and Used to Select Optimal Variable Set

- Outliers Removed in Usual Way
FILTER OUTPUTS

- STATE VECTOR ($\hat{x}$)
- COVARIANCE MATRIX
- ALONG TRACK, CROSS TRACK QUALITY MEASURES
- RESIDUALS AT CONTROL POINTS
- OUTLIER ENUMERATION
- VARIABLES ESTIMATED
GEOMETRIC CORRECTION CALIBRATION

• PURPOSE: IMPROVE SYSTEMATIC CORRECTION FOR SCENES LACKING CONTROL POINTS

• PARAMETERS TO BE CALIBRATED
  - MIRROR MODEL PARAMETERS
  - INSTRUMENT MISALIGNMENTS
  - IMAGE NOISE MATRIX ELEMENTS
  - A PRIORI STATISTICS OF THE SPACECRAFT PARAMETER BIASES

• CALIBRATION DATA - LONG TERM MEANS AND VARIANCES
  - MEAN AND VARIANCE OF LINE LENGTHS
  - MEANS AND VARIANCES OF SPACECRAFT PARAMETER BIASES
  - RESIDUALS AT CONTROL POINTS - MEANS AND VARIANCES OF RESIDUALS SORTED ON CROSS TRACK LOCATION
GEOMETRIC CORRECTION CALIBRATION (CONTINUED)

CALIBRATION APPROACH

- EFFECTS MIXED ON THE GROUND - SELECT SINGLE PARAMETER TO BE UPDATED

- NON-ZERO MEANS OF SPACECRAFT PARAMETER BIASES POINT TO MISALIGNMENTS, MIRROR AMPLITUDE OR MIRROR VELOCITY ERRORS

- VARIANCES OF SPACECRAFT PARAMETER BIASES PROVIDE STATISTICS FOR SELECTING OPTIMAL VARIABLE SET

- CROSS TRACK PATTERNS IN THE RESIDUALS POINT TO MIRROR VELOCITY PROFILE ERRORS

- DEVIATION OF MEAN LINE LENGTH FROM NOMINAL - MIRROR SPEED CORRECTION - NO IMPACT
Closing Remarks

John Barker
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAT</td>
<td>Archival Ancillary (Data) Tape</td>
</tr>
<tr>
<td>ACCA</td>
<td>Automatic Cloud Cover Assessment</td>
</tr>
<tr>
<td>ACE</td>
<td>Attitude Control Electronics</td>
</tr>
<tr>
<td>ACS</td>
<td>Attitude Control System</td>
</tr>
<tr>
<td>ACT</td>
<td>Application Concept Test</td>
</tr>
<tr>
<td>A/D</td>
<td>Analog to Digital</td>
</tr>
<tr>
<td>ADCP</td>
<td>See ANOP</td>
</tr>
<tr>
<td>ADDS</td>
<td>Applications Developmental Data System</td>
</tr>
<tr>
<td>ADFS</td>
<td>Automated Digital Facsimile System</td>
</tr>
<tr>
<td>ADL</td>
<td>Applications Development Laboratory</td>
</tr>
<tr>
<td>ADP</td>
<td>Automatic Data Processing</td>
</tr>
<tr>
<td>AOPE</td>
<td>Automatic Data Processing Equipment</td>
</tr>
<tr>
<td>ADS</td>
<td>Aerospace and Data Systems</td>
</tr>
<tr>
<td>ADS</td>
<td>Angular Displacement Sensor or Angle Detector Sensor</td>
</tr>
<tr>
<td>ADT</td>
<td>Ancillary Data Tape</td>
</tr>
<tr>
<td>AEM</td>
<td>Applications Exploratory Mission</td>
</tr>
<tr>
<td>AFGC</td>
<td>Air Force Global Weather Central</td>
</tr>
<tr>
<td>AFOS</td>
<td>Automation of Field Operations and Services</td>
</tr>
<tr>
<td>AFPRO</td>
<td>Air Force Plant Representative Office</td>
</tr>
<tr>
<td>AG</td>
<td>Archive Generation</td>
</tr>
<tr>
<td>AGC</td>
<td>Automatic Gain Control</td>
</tr>
<tr>
<td>AGE</td>
<td>Aerospace Ground Equipment</td>
</tr>
<tr>
<td>AGS&amp;PO</td>
<td>Aerospace Ground Equipment and Program Office</td>
</tr>
<tr>
<td>Ahr</td>
<td>Ampere-hour</td>
</tr>
<tr>
<td>ALU</td>
<td>Algorithm Logic Unit</td>
</tr>
<tr>
<td>AMS</td>
<td>Attitude Measurement System</td>
</tr>
<tr>
<td>AN</td>
<td>Applications Notice</td>
</tr>
<tr>
<td>ANCP</td>
<td>See ANOP</td>
</tr>
<tr>
<td>ANDP</td>
<td>Ancillary Data Calculation Process</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>ANT</td>
<td>Ascending Node Table</td>
</tr>
<tr>
<td>AO</td>
<td>Announcement of Opportunity</td>
</tr>
<tr>
<td>AOIPS</td>
<td>Atmospheric and Oceanographic Image Processing System</td>
</tr>
<tr>
<td>AOP</td>
<td>Advanced Onboard Processor</td>
</tr>
<tr>
<td>ADS</td>
<td>Acquisition of Signal</td>
</tr>
<tr>
<td>AP</td>
<td>Applications Processor</td>
</tr>
<tr>
<td>AP</td>
<td>Array Processor</td>
</tr>
<tr>
<td>APOF</td>
<td>Aerial Photography Field Office</td>
</tr>
<tr>
<td>APL</td>
<td>Applied Physics Laboratory (John Hopkins Univ.)</td>
</tr>
<tr>
<td>APS</td>
<td>Antenna Positioning System</td>
</tr>
<tr>
<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
</tr>
<tr>
<td>ASPR</td>
<td>Aerospace Strategic Programs Representation</td>
</tr>
<tr>
<td>ASPR</td>
<td>Armed Services Procurement Regulations</td>
</tr>
<tr>
<td>ASR</td>
<td>Automatic Send/Receive</td>
</tr>
<tr>
<td>AST</td>
<td>Asynchronous System Trap</td>
</tr>
<tr>
<td>ASVT</td>
<td>Applications System Verification and Transfer Project</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT</td>
<td>Acceptance Test</td>
</tr>
<tr>
<td>ATL</td>
<td>Applications Technology Laboratory</td>
</tr>
<tr>
<td>ATM</td>
<td>Antenna Test Model</td>
</tr>
<tr>
<td>ATM</td>
<td>Antenna Telescope Mount</td>
</tr>
<tr>
<td>ATP</td>
<td>Acceptance Test Plan</td>
</tr>
<tr>
<td>ATS</td>
<td>Applications Technology Satellite</td>
</tr>
<tr>
<td>AWG</td>
<td>American Wire Gauge</td>
</tr>
<tr>
<td>BARDA</td>
<td>Boom Antenna Retention Deployment and Jiettison Assembly</td>
</tr>
<tr>
<td>BAT</td>
<td>Bench Acceptance Test</td>
</tr>
<tr>
<td>BB</td>
<td>Build Baseline</td>
</tr>
<tr>
<td>BCU</td>
<td>Bus Coupling Unit</td>
</tr>
<tr>
<td>BDF</td>
<td>Block Data Format</td>
</tr>
<tr>
<td>BER</td>
<td>Bit Error Rate</td>
</tr>
<tr>
<td>BES</td>
<td>Biological Experiment Scientific Satellite</td>
</tr>
<tr>
<td>BFR</td>
<td>Browse Film Recorder</td>
</tr>
<tr>
<td>BIC</td>
<td>Band Interleaved by Cylinder</td>
</tr>
<tr>
<td>BIL</td>
<td>Band Interleaved by Line</td>
</tr>
<tr>
<td>BIP</td>
<td>Band Interleaved by Pixel</td>
</tr>
<tr>
<td>BIW</td>
<td>Band Interleaved by Word</td>
</tr>
<tr>
<td>BOL</td>
<td>Beginning of Life</td>
</tr>
<tr>
<td>BOS</td>
<td>Beginning of Scan</td>
</tr>
<tr>
<td>BOT</td>
<td>Beginning of Tape</td>
</tr>
<tr>
<td>B&amp;P</td>
<td>Bid and Proposal</td>
</tr>
<tr>
<td>BPA</td>
<td>Bus Protection Assembly</td>
</tr>
<tr>
<td>bpi</td>
<td>Bits per Inch</td>
</tr>
<tr>
<td>BPI</td>
<td>Bytes per Inch</td>
</tr>
<tr>
<td>bps</td>
<td>Bytes per Second</td>
</tr>
<tr>
<td>BPS</td>
<td>Bytes per Second</td>
</tr>
<tr>
<td>BSE</td>
<td>Broadcast Satellite Experimental</td>
</tr>
<tr>
<td>BSQ</td>
<td>Band Sequential</td>
</tr>
<tr>
<td>BSR</td>
<td>Back Surface Radiator</td>
</tr>
<tr>
<td>BTC</td>
<td>Bench Test Cooler</td>
</tr>
<tr>
<td>BTE</td>
<td>Bench Test Equipment</td>
</tr>
<tr>
<td>B/U</td>
<td>Backup</td>
</tr>
<tr>
<td>B&amp;W</td>
<td>Black and White</td>
</tr>
<tr>
<td>CAL</td>
<td>Configured Articles List</td>
</tr>
<tr>
<td>CAR</td>
<td>Calibration</td>
</tr>
<tr>
<td>CARETS</td>
<td>Central Atlantic Regional Ecological Test Site</td>
</tr>
<tr>
<td>CASH</td>
<td>Catalog of Available and Standard Hardware</td>
</tr>
<tr>
<td>CAT</td>
<td>Catalog</td>
</tr>
<tr>
<td>CCA</td>
<td>Cloud Cover Assessment</td>
</tr>
<tr>
<td>CCB</td>
<td>Configuration Control Board</td>
</tr>
<tr>
<td>CCC</td>
<td>Camera Controller Combiner</td>
</tr>
</tbody>
</table>
Field Operations Service
Field Operations Subsystem
Field Object Spectrograph
Field-of-View
Focal Plane Assembly
Final Product Generation
Floating Point Processor
Focal Plane Structure
Facilities Requirement Document

Flight Segment
Federal Supply Code For Manufacturers
Flight Segment Development Facility
Fairchild Space and Electronics Company
Frequency Shift Keying
Flight Scheduling Subsystem
Flight Segment Simulator
Flight Support System
Fine Sun Sensor
Flight Segment Simulator Software
Fourier Transform
Federal Telephone System
Fiscal Week
Fiscal Year
For Your Information

Geometric Correction
Geocentric Correction Data or Geometric Correction Data
Geodetic Correction Data Generation
Geometric Correction Matrices
Geometric Correction Matrix
Geometric Correction Operator
Geodetic Verification System
Geodetic Control Point
Ground Control Point
Ground Data Handling System
Graphics Display Terminal
General Electric
General Interface Device for DRS 780
Geometric Correction Process
Geographic Reference
Ground Electronics Specification
General Electric Technical Service Company
Government Furnished Equipment
Godard Film Inventory Tape
Government Furnished Property
Godard HDT Inventory Tape
Gigahertz (10^9)
General Instruction
Government Inspection Agency
General Manager
GEO Microcode File
Geometric Correction Matrix Calculation Process
Ground (Segment) Management Subsystem

Greenwich Mean Time
Geostationary Operational Environmental Satellite
General Purpose Console
Ground Processing Equipment
General Purpose Information Processor
Global Positioning System
General Purpose Transformation
Gamma Ray Explorer
Graphite Filed Epoxy
Ground Segment
Ground Support Equipment
Godard Space Flight Center
Ground Support System Software
Ground Spaceflight Tracking and Data Network

Header, Ancillary, Annotation, Trailer
GATT for Library Maintenance
HDDR Assignment and Control
Imager Annotation, Trailer
High-Order Aerospace Language
Heat Capacity Mapping Mission
HDT Duplication
High Density Digital Recorder
HDTD High Density Digital Tape
HDE High-Density Tape Generator
HDT-HD High Density Tape
HDT-A HDT-Archive Format (Partially corrected radiometrically but not geometrically)
HDT-A1 HDT-A for MSS Sensor Data
HDT-A10 Copy of HDT-A for MSS Sensor Data
HDT-AT HDT-A for TM Sensor Data
HDT-ATC Copy of HDT-A for TM Sensor Data
HDT-1 HDT (Data) Interval
HDT-1F HDT-Product Format (Fully corrected)
HDT-P HDT-P for MSS Sensor Data
HDT-PT Copy of HDT-P for TH Sensor Data
HDT-TP High Density Tape Recorder
HDT-W High Density Radar Data Recorder
HDT-WM HDT-W Data as recorded in DRRTS
HDT-RM HDT-R for MSS Sensor Data
HDT-RH HDT-R for TM Sensor Data
HDT-S HDT-S Grain Element Tape Recorder
HDT-SN HDT-S at White Sands
HDT-ST High Density Tape Generator
HgCdTe Mercury Cadmium Telluride
Hierarchy Input Process: Output
High Resolution Film Recorder
HiRi High Speed Control Element
High Speed Interface
Host Vehicle (Landsat-D)
Hardware
Hertz (cycles per second)

Image Analyzer Console
Integrated Analysis Plan
Image Analysis Terminal
Image Annotation Tape
Integration Baseline

1-249
ICCD
Intensity-Coupled Device
ICD
Image Control Document
ICS
Image Correction Support Software
ICS
Interactive Computer Simulator
ID
Identification
IDA
Image Data Acquisition
IDBD
Identification Bus
IDBSS
Intersystem Data Base System
IDS
Image Data System
IDT
Investigation Definition Team
IDT
Image Display Terminal
IDT
Industrial Data Terminal Corporation
IDT
Image Data Transmission
I/F
Interface
IF
Intermediacy Frequency
IFD
In-Flight Disconnect
IFSV
Instantaneous Field-of-View
IG
Initial Gap
IGF
Image Generation Facility
IIGS
Initial Image Generation Subsystem
IIRV
Improved Inter-Range Vectors
IIS (j^2S)
International Imaging Systems
IM
Information Management
IM
Instrument Module
IMAC
Image Processing and Analysis Center
IMG
Information Management Subsystem
IMSC
Information Management Subsystem Computer
IMSCC
Information Management Subsystem FFP Control Computer
IMU
Image Memory Unit
IN5b
Indium Antimonide
INTRALAB
Information Transfer Laboratory
I/O
Input/Output
IPC
Initial Product Creation
IPCS
Information Production Control System
IPD
Information Processing Division
IPF
Image Processing Facility
IPS
Inches per Second
IPS
Image Processing Subsystem
IPS-1
IPS String No. 1 Computers
IPS-2
IPS String No. 2 Computers
IPSC
IPS Computer
IQL
Interactive Query Language
IR
Infrared
IRB
Integrate Requirements Bureaucracy
IRD
Independent Research and Development
IRD
Interface Requirements Document
IRFPA
Infrared Focal Plane Assembly
IRG
Inter-Record Gap
IRG
Inter-Range Instrumentation Group Time Code
IRIG-A
IRIG Time Code Series A
IRP
Infrared Photometer
IRD
Interrupt Request
IRU
Inertial Reference Unit
IS
Input Subsystem
ISA
Instrument Standard of America
ISAM
Index Sequential Access Method
ISM
Interface Switching Module
ISS
Image Generation Facility Software Subset
ISU
Input Scanner Unit
IT
Integration Test
IT&T
Integration and Test
ITD
Inception-to-Date
ITD
Inception Test Plan
IUS
Interface Unit
IUE
International Ultraviolet Explorer
IUS
Interim Upper Stage
JPL
Jet Propulsion Laboratory
JSC
Johnson Space Center
K
Kilobit
KB
Kilobyte
Kbps
Kilobits per Second
KBPS
Kilobytes per Second
KCBR
Keyboard Cathode Ray Tube
KLIO
CPU for DEC-10 Computer
km
Kilometer
KS
Key Station
KSA
Ku-Band Single Access
KSC
Kennedy Space Center
KW
Kilowords
LA36
DEC Hardcopy Terminal
LACIE
Large Area Crop Inventory Equipment
LANDSAT
Land Satellite
LaRC
Langley Research Center
LAS
Landsat-D Assessment System
LAT
Latitude
LBP
Library Build Processor
LBR
Library Beam Recorder
LCP
Left-hand Circularly Polarized
LED
Light-Emitting Diode
LCF
Left-Fill Computer
LIDU
Large Image Display Utility
LIFO
Last-In, First-Out
LLA
Adjusted Line Length
LLC
Line Length Code
LM
Library Maintenance
LM
Line Monitor
LMSC
Lockheed Missions and Space Corporation
LOE
Level of Effort
LON
Longitude
LOSE
Line of Sight
LOS
Loss of Signal
LPC
Longitudinal Parity Check
LPM
Line Point Marker
LPM
Lines Per Minute
LPM
Load Point Marker
LRA
Laser Retrodirector Array
LA36
DEC Hardcopy Terminal
LACIE
Large Area Crop Inventory Equipment
LANDSAT
Land Satellite
LaRC
Langley Research Center
LAS
Landsat-D Assessment System
LAT
Latitude
LBP
Library Build Processor
LBR
Library Beam Recorder
LCP
Left-hand Circularly Polarized
LED
Light-Emitting Diode
LCF
Left-Fill Computer
LIDU
Large Image Display Utility
LIFO
Last-In, First-Out
LLA
Adjusted Line Length
LLC
Line Length Code
LM
Library Maintenance
LM
Line Monitor
LMSC
Lockheed Missions and Space Corporation
LOE
Level of Effort
LON
Longitude
LOSE
Line of Sight
LOS
Loss of Signal
LPC
Longitudinal Parity Check
LPM
Line Point Marker
LPM
Lines Per Minute
LPM
Load Point Marker
LRA
Laser Retrodirector Array
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM/FL</td>
<td>Performance Monitor/Fault Location</td>
</tr>
<tr>
<td>PPM</td>
<td>Program Maintenance Manual</td>
</tr>
<tr>
<td>PMP</td>
<td>Premodulation Processor</td>
</tr>
<tr>
<td>PHT</td>
<td>Photomultiplier Tube</td>
</tr>
<tr>
<td>PN</td>
<td>Pseudo Noise</td>
</tr>
<tr>
<td>PO</td>
<td>Project Office</td>
</tr>
<tr>
<td>POO</td>
<td>Project Operations Directors</td>
</tr>
<tr>
<td>POP</td>
<td>Project Operating Plan</td>
</tr>
<tr>
<td>PORTS</td>
<td>Preliminary Operations Requirements and Testing</td>
</tr>
<tr>
<td>POWO</td>
<td>Purchase Order Work Order</td>
</tr>
<tr>
<td>PPL</td>
<td>Photo Processing Lab</td>
</tr>
<tr>
<td>PPL</td>
<td>Preferred Parts List</td>
</tr>
<tr>
<td>PPO</td>
<td>Program Participation/Opportunities System</td>
</tr>
<tr>
<td>PPS</td>
<td>Photographic Processing Subsystem</td>
</tr>
<tr>
<td>PRMIS</td>
<td>Printing Resource Management Information</td>
</tr>
<tr>
<td>PRN</td>
<td>Pseudo Random Noise</td>
</tr>
<tr>
<td>PRQ</td>
<td>Payload Recording Operations</td>
</tr>
<tr>
<td>PROM</td>
<td>Programmable Read-Only Memory</td>
</tr>
<tr>
<td>PRP</td>
<td>Performance Recognition Program</td>
</tr>
<tr>
<td>PRU</td>
<td>Power Regulator Unit</td>
</tr>
<tr>
<td>PS</td>
<td>Polar Stereographic</td>
</tr>
<tr>
<td>PSDO</td>
<td>Parallel-to-Serial Data Output Device</td>
</tr>
<tr>
<td>PSC</td>
<td>Photo/Shipping Support Facility</td>
</tr>
<tr>
<td>PSK</td>
<td>Phase Shift Keying</td>
</tr>
<tr>
<td>PSM</td>
<td>Programmable Sync Module</td>
</tr>
<tr>
<td>PSR</td>
<td>Project Status Review</td>
</tr>
<tr>
<td>PSU</td>
<td>Power Supply Unit</td>
</tr>
<tr>
<td>PSU</td>
<td>Power Switching Unit</td>
</tr>
<tr>
<td>PVS</td>
<td>Pressure Vessel Spacecraft</td>
</tr>
<tr>
<td>PWB</td>
<td>Printed Wiring Board</td>
</tr>
<tr>
<td>PWN</td>
<td>Pulse Width Modulated</td>
</tr>
<tr>
<td>QQA</td>
<td>Qualification and Acceptance</td>
</tr>
<tr>
<td>QA</td>
<td>Quality Assurance/Assessment</td>
</tr>
<tr>
<td>QAF</td>
<td>Quality Assessment Film</td>
</tr>
<tr>
<td>QAP</td>
<td>Quality Assessment Process</td>
</tr>
<tr>
<td>QAP</td>
<td>Quality Assurance Procedure</td>
</tr>
<tr>
<td>QAP</td>
<td>Qualification and Acceptance Program</td>
</tr>
<tr>
<td>QC</td>
<td>Quality Control</td>
</tr>
<tr>
<td>QFP</td>
<td>Quality Assurance Film Generation Process</td>
</tr>
<tr>
<td>QID</td>
<td>Queued Request for Input/Output</td>
</tr>
<tr>
<td>QIO</td>
<td>Queue Input/Output Process</td>
</tr>
<tr>
<td>QLD</td>
<td>Quick Look Display</td>
</tr>
<tr>
<td>QLM</td>
<td>Quick-Look Monitor Unit</td>
</tr>
<tr>
<td>QLP</td>
<td>Quick-Look Processor</td>
</tr>
<tr>
<td>QLPS</td>
<td>Quick-Look Processing System</td>
</tr>
<tr>
<td>QPSK</td>
<td>Quadrant Phase Shift Keyed</td>
</tr>
<tr>
<td>QPD</td>
<td>Quick-Phase Display</td>
</tr>
<tr>
<td>QWO</td>
<td>Quick-Work Order</td>
</tr>
<tr>
<td>QSL</td>
<td>Quarter Scan Line</td>
</tr>
<tr>
<td>RAA</td>
<td>Reformatting Ancillary Annotation</td>
</tr>
<tr>
<td>RAM</td>
<td>Random Access Memory</td>
</tr>
<tr>
<td>RBV</td>
<td>Return Beam Vidicon</td>
</tr>
<tr>
<td>RC</td>
<td>Radiometric Correction</td>
</tr>
<tr>
<td>RCFP</td>
<td>Radiometric Correction Function Calculation Process</td>
</tr>
<tr>
<td>RCHP</td>
<td>Right-Hand Circularly Polarized</td>
</tr>
<tr>
<td>RCP</td>
<td>Registration or Relative Control Point</td>
</tr>
<tr>
<td>RCP</td>
<td>Right-Hand Circularly Polarized</td>
</tr>
<tr>
<td>RCV</td>
<td>Receive</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>RDQ</td>
<td>Radiometric Corrected Process</td>
</tr>
<tr>
<td>RCP</td>
<td>Radiometric Function Calculation Process</td>
</tr>
<tr>
<td>RDU</td>
<td>Raw Data Tape</td>
</tr>
<tr>
<td>REC</td>
<td>Record</td>
</tr>
<tr>
<td>REN</td>
<td>Rocket Engine Module</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>RFC</td>
<td>Right-Fill Count</td>
</tr>
<tr>
<td>RFO</td>
<td>Request for Hire</td>
</tr>
<tr>
<td>RFOV</td>
<td>Resolution Field-of-View</td>
</tr>
<tr>
<td>RFP</td>
<td>Request for Proposal</td>
</tr>
<tr>
<td>RFP</td>
<td>Massbus Adaptor for DEC VAX-11/780</td>
</tr>
<tr>
<td>RLO</td>
<td>Review Item Discrepancy</td>
</tr>
<tr>
<td>RIU</td>
<td>Remote Interface Unit</td>
</tr>
<tr>
<td>RLUT</td>
<td>Radiometric Lookup Table</td>
</tr>
<tr>
<td>RMS</td>
<td>Remote Manipulator System</td>
</tr>
<tr>
<td>RNS</td>
<td>Root Mean Square</td>
</tr>
<tr>
<td>RNS</td>
<td>Record Management Services</td>
</tr>
<tr>
<td>ROM</td>
<td>Read-Only Memory</td>
</tr>
<tr>
<td>ROW</td>
<td>Geographic Frame Reference</td>
</tr>
<tr>
<td>RPS</td>
<td>DEC 176 MB Disk or Removable Disk Storage Unit</td>
</tr>
<tr>
<td>RPO</td>
<td>DEC 293 MB Disk</td>
</tr>
<tr>
<td>RPA</td>
<td>Receiver/Processor Assembly (GPS)</td>
</tr>
<tr>
<td>RPA</td>
<td>Reliability and Product Assurance</td>
</tr>
<tr>
<td>RPH</td>
<td>Revolutions Per Minute</td>
</tr>
<tr>
<td>RPR</td>
<td>RBV Preprocessor</td>
</tr>
<tr>
<td>RQA</td>
<td>Reliability and Quality Assurance</td>
</tr>
<tr>
<td>RSE</td>
<td>Receiving Site Equipment</td>
</tr>
<tr>
<td>RSE</td>
<td>Remote Site Equipment</td>
</tr>
<tr>
<td>RSX-1M</td>
<td>Multi-Tasking Operating System Software</td>
</tr>
<tr>
<td>RTX</td>
<td>Real-Time</td>
</tr>
<tr>
<td>RTG</td>
<td>Radiosotope Thermoelectric Generator</td>
</tr>
<tr>
<td>RTTS</td>
<td>Real-Time Test System</td>
</tr>
<tr>
<td>RX</td>
<td>Receive</td>
</tr>
<tr>
<td>RCP</td>
<td>Radiometric Correction Function Calculation Process</td>
</tr>
<tr>
<td>RCHP</td>
<td>Right-Hand Circularly Polarized</td>
</tr>
<tr>
<td>RCP</td>
<td>Registration or Relative Control Point</td>
</tr>
<tr>
<td>RCP</td>
<td>Right-Hand Circularly Polarized</td>
</tr>
<tr>
<td>RCV</td>
<td>Receive</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>RDQ</td>
<td>Radiometric Corrected Process</td>
</tr>
<tr>
<td>RCP</td>
<td>Radiometric Function Calculation Process</td>
</tr>
<tr>
<td>RDU</td>
<td>Raw Data Tape</td>
</tr>
<tr>
<td>REC</td>
<td>Record</td>
</tr>
<tr>
<td>REN</td>
<td>Rocket Engine Module</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>RFC</td>
<td>Right-Fill Count</td>
</tr>
<tr>
<td>RFO</td>
<td>Request for Hire</td>
</tr>
<tr>
<td>RFOV</td>
<td>Resolution Field-of-View</td>
</tr>
<tr>
<td>RFP</td>
<td>Request for Proposal</td>
</tr>
<tr>
<td>RFP</td>
<td>Massbus Adaptor for DEC VAX-11/780</td>
</tr>
<tr>
<td>RLO</td>
<td>Review Item Discrepancy</td>
</tr>
<tr>
<td>RIU</td>
<td>Remote Interface Unit</td>
</tr>
<tr>
<td>RLUT</td>
<td>Radiometric Lookup Table</td>
</tr>
<tr>
<td>RMS</td>
<td>Remote Manipulator System</td>
</tr>
<tr>
<td>RNS</td>
<td>Root Mean Square</td>
</tr>
<tr>
<td>RNS</td>
<td>Record Management Services</td>
</tr>
<tr>
<td>ROM</td>
<td>Read-Only Memory</td>
</tr>
<tr>
<td>ROW</td>
<td>Geographic Frame Reference</td>
</tr>
<tr>
<td>RPS</td>
<td>DEC 176 MB Disk or Removable Disk Storage Unit</td>
</tr>
<tr>
<td>RPO</td>
<td>DEC 293 MB Disk</td>
</tr>
<tr>
<td>RPA</td>
<td>Receiver/Processor Assembly (GPS)</td>
</tr>
<tr>
<td>RPA</td>
<td>Reliability and Product Assurance</td>
</tr>
<tr>
<td>RPH</td>
<td>Revolutions Per Minute</td>
</tr>
<tr>
<td>RPR</td>
<td>RBV Preprocessor</td>
</tr>
<tr>
<td>RQA</td>
<td>Reliability and Quality Assurance</td>
</tr>
<tr>
<td>RSE</td>
<td>Receiving Site Equipment</td>
</tr>
<tr>
<td>RSE</td>
<td>Remote Site Equipment</td>
</tr>
<tr>
<td>RSX-1M</td>
<td>Multi-Tasking Operating System Software</td>
</tr>
<tr>
<td>RTX</td>
<td>Real-Time</td>
</tr>
<tr>
<td>RTG</td>
<td>Radiosotope Thermoelectric Generator</td>
</tr>
<tr>
<td>RTTS</td>
<td>Real-Time Test System</td>
</tr>
<tr>
<td>RX</td>
<td>Receive</td>
</tr>
<tr>
<td>SA</td>
<td>Single Access</td>
</tr>
<tr>
<td>SA</td>
<td>Solar Array</td>
</tr>
<tr>
<td>SAD</td>
<td>Solar Array Drive</td>
</tr>
<tr>
<td>SADAPTA</td>
<td>Solar Array Drive and Power Transfer Assembly</td>
</tr>
<tr>
<td>SAIL</td>
<td>Space Applications and Information Library</td>
</tr>
<tr>
<td>SARSA</td>
<td>Solar Array Retention, Deployment and Jeftison Assembly</td>
</tr>
<tr>
<td>SB</td>
<td>Stage Baseline</td>
</tr>
<tr>
<td>SBC</td>
<td>Single Board Computer</td>
</tr>
<tr>
<td>SBI</td>
<td>Synchronous Backplane Interconnect</td>
</tr>
<tr>
<td>SRC</td>
<td>Santa Barbara Research Center</td>
</tr>
<tr>
<td>SBS</td>
<td>Space Background Simulator</td>
</tr>
<tr>
<td>SBU</td>
<td>Strategic Business Unit</td>
</tr>
<tr>
<td>SC</td>
<td>Spacecraft</td>
</tr>
<tr>
<td>SCA</td>
<td>Signal Conditioning</td>
</tr>
<tr>
<td>SCA</td>
<td>Signal Conditional Assembly</td>
</tr>
<tr>
<td>SCAMA</td>
<td>Switching, Conferencing and Monitoring Arrangement</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>SCCB</td>
<td>Software Change Control Board</td>
</tr>
<tr>
<td>SCDD</td>
<td>Systematic Correction Data</td>
</tr>
<tr>
<td>SCHS</td>
<td>Spacecraft Hardware Simulator (MSS Simulator)</td>
</tr>
<tr>
<td>SCI</td>
<td>Serial Control Interface</td>
</tr>
<tr>
<td>SCI1</td>
<td>Serial Control Interface for Input (now SPD1)</td>
</tr>
<tr>
<td>SCI0</td>
<td>Serial Control Interface for Output (now PSD0)</td>
</tr>
<tr>
<td>SCL</td>
<td>Subcontract Labor</td>
</tr>
<tr>
<td>SCM</td>
<td>Systematic Correction Matrix</td>
</tr>
<tr>
<td>SCP</td>
<td>Sun Calibration Process</td>
</tr>
<tr>
<td>SCR</td>
<td>Scaler Control Register</td>
</tr>
<tr>
<td>SRC</td>
<td>Software Change Request</td>
</tr>
<tr>
<td>SCASU</td>
<td>Signal Conditioning and Switching Unit (SU)</td>
</tr>
<tr>
<td>SCT</td>
<td>System Control Terminal</td>
</tr>
<tr>
<td>SD</td>
<td>Space Division</td>
</tr>
<tr>
<td>SDF</td>
<td>Software Development Facility</td>
</tr>
<tr>
<td>SDS</td>
<td>Satellite Data Handling System</td>
</tr>
<tr>
<td>SDISS</td>
<td>Satellite Data Ingest and Storage Subsystem</td>
</tr>
<tr>
<td>SDB</td>
<td>Satellite Data Services Branch</td>
</tr>
<tr>
<td>SEAM</td>
<td>Software Engineering and Management Program</td>
</tr>
<tr>
<td>Sec</td>
<td>Seconds of Arc</td>
</tr>
<tr>
<td>SEECO</td>
<td>Secondary Electron Conduction Orthonic</td>
</tr>
<tr>
<td>SEOPS</td>
<td>Standard Earth Observation Package Satellite</td>
</tr>
<tr>
<td>SEQOS</td>
<td>Synchronous Earth Observation Satellite</td>
</tr>
<tr>
<td>SII</td>
<td>Science Instruments</td>
</tr>
<tr>
<td>SIA</td>
<td>Special Image Annotation Tape</td>
</tr>
<tr>
<td>SION</td>
<td>Science Instrument Central Module</td>
</tr>
<tr>
<td>SIOU</td>
<td>Small Image Display Utility</td>
</tr>
<tr>
<td>SIF</td>
<td>Simulation Image File</td>
</tr>
<tr>
<td>SIM</td>
<td>Simulator</td>
</tr>
<tr>
<td>SIP</td>
<td>System Image Preservation</td>
</tr>
<tr>
<td>SIRD</td>
<td>Support Instrumentation Requirements Document</td>
</tr>
<tr>
<td>SIU</td>
<td>Sectorizer Ingest Unit</td>
</tr>
<tr>
<td>SLAT</td>
<td>Spacecraft Location and Attitude Tape</td>
</tr>
<tr>
<td>SLC</td>
<td>Scan Line Corrector</td>
</tr>
<tr>
<td>SLE</td>
<td>Synch Loss Error Rate</td>
</tr>
<tr>
<td>SLP</td>
<td>Source Language Input Program</td>
</tr>
<tr>
<td>SLS</td>
<td>Scan Line Sync</td>
</tr>
<tr>
<td>SLS5</td>
<td>Start-of-Line Sync</td>
</tr>
<tr>
<td>SMD</td>
<td>S-Band Multiple Access</td>
</tr>
<tr>
<td>SMM</td>
<td>Scan Mirror Assembly</td>
</tr>
<tr>
<td>SMM</td>
<td>Solar Mirror Mission</td>
</tr>
<tr>
<td>SMSO</td>
<td>Support Maintenance and Operations</td>
</tr>
<tr>
<td>SMP</td>
<td>Scan Monitor Pulse</td>
</tr>
<tr>
<td>SMR</td>
<td>Software Modification Record</td>
</tr>
<tr>
<td>SMSA</td>
<td>Standard Metropolitan Statistical Area</td>
</tr>
<tr>
<td>SNH</td>
<td>Signal-to-Noise Ratio</td>
</tr>
<tr>
<td>SNO</td>
<td>Signal-to-Noise Ratio</td>
</tr>
<tr>
<td>SO4</td>
<td>Space Oblique Mercator</td>
</tr>
<tr>
<td>SGP</td>
<td>Standard Operating Procedure</td>
</tr>
<tr>
<td>SOW</td>
<td>Statement of Work</td>
</tr>
<tr>
<td>SP</td>
<td>Stack Pointer</td>
</tr>
<tr>
<td>SPC</td>
<td>Small Peripheral Controller</td>
</tr>
<tr>
<td>SPD</td>
<td>DEC Software Product Description</td>
</tr>
<tr>
<td>SPD</td>
<td>Serial-to-Parallel Data Input Device</td>
</tr>
<tr>
<td>SPJ</td>
<td>Sub-Project Manager</td>
</tr>
<tr>
<td>SPP</td>
<td>Special Purpose Processor</td>
</tr>
<tr>
<td>SPR</td>
<td>Software Problem Report</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPRD</td>
<td>Site Preparation Requirements Document</td>
</tr>
<tr>
<td>SPS</td>
<td>Segment Processing Subsystem</td>
</tr>
<tr>
<td>SPU</td>
<td>Scene Processing Unit</td>
</tr>
<tr>
<td>SQA</td>
<td>Software Quality Assurance</td>
</tr>
<tr>
<td>SPRR</td>
<td>Software Requirements and Conceptual Design Review</td>
</tr>
<tr>
<td>SCLS</td>
<td>Software Requirements and Conceptual Design Specification</td>
</tr>
<tr>
<td>SRR</td>
<td>System Requirements Specification</td>
</tr>
<tr>
<td>SRS</td>
<td>System Requirement Specification</td>
</tr>
<tr>
<td>SRT</td>
<td>Supporting Research and Technology</td>
</tr>
<tr>
<td>SS</td>
<td>Seconds</td>
</tr>
<tr>
<td>S/S</td>
<td>Subsystem</td>
</tr>
<tr>
<td>SSA</td>
<td>S-Band Single Antenna</td>
</tr>
<tr>
<td>SSC</td>
<td>Science Support Center</td>
</tr>
<tr>
<td>SDDA</td>
<td>Sequential Similarity Detection Algorithm</td>
</tr>
<tr>
<td>SSM</td>
<td>Support System Module</td>
</tr>
<tr>
<td>SSD</td>
<td>Space System Operations</td>
</tr>
<tr>
<td>SSR</td>
<td>Systems Software Requirements Review</td>
</tr>
<tr>
<td>SSTD</td>
<td>Synchronous System Trap</td>
</tr>
<tr>
<td>ST</td>
<td>Space Telescope</td>
</tr>
<tr>
<td>STCC</td>
<td>Standard Telemetry and Command Components</td>
</tr>
<tr>
<td>STACC</td>
<td>STACC Central Unit</td>
</tr>
<tr>
<td>STACCU</td>
<td>STACC Interface Unit</td>
</tr>
<tr>
<td>STC</td>
<td>System Test Console</td>
</tr>
<tr>
<td>STD</td>
<td>System Test Director</td>
</tr>
<tr>
<td>STD</td>
<td>Standard</td>
</tr>
<tr>
<td>STDL</td>
<td>System Test and Operation Language</td>
</tr>
<tr>
<td>STDN</td>
<td>Spaceflight Tracking and Data Network</td>
</tr>
<tr>
<td>STEP</td>
<td>Space Technology Engineering Program</td>
</tr>
<tr>
<td>STINT</td>
<td>Standard Interface for Onboard Computer</td>
</tr>
<tr>
<td>STINT</td>
<td>STACC Interface Unit</td>
</tr>
<tr>
<td>STOCC</td>
<td>Space Telescope Operations Control Center</td>
</tr>
<tr>
<td>STOL</td>
<td>System Test and Operations Language</td>
</tr>
<tr>
<td>STR</td>
<td>System Test Plan</td>
</tr>
<tr>
<td>STR</td>
<td>Standard S/C Telemetry Recorder</td>
</tr>
<tr>
<td>STR</td>
<td>Standard Tape Recorder</td>
</tr>
<tr>
<td>STR</td>
<td>System Test Review</td>
</tr>
<tr>
<td>STS</td>
<td>Space Transportation System</td>
</tr>
<tr>
<td>STS</td>
<td>Shuttle Transportation System</td>
</tr>
<tr>
<td>STSOC</td>
<td>Space Telescope Scientific Operations Center</td>
</tr>
<tr>
<td>SU</td>
<td>Switching Unit</td>
</tr>
<tr>
<td>SVS</td>
<td>Space Vehicle Specification</td>
</tr>
<tr>
<td>SW</td>
<td>Space Vehicle Command</td>
</tr>
<tr>
<td>SYCG</td>
<td>System Corrected Images</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA</td>
<td>Transistor Adaptor</td>
</tr>
<tr>
<td>TAC</td>
<td>Telemetry and Command</td>
</tr>
<tr>
<td>TAC</td>
<td>TM Adaptive Capability</td>
</tr>
<tr>
<td>TAG</td>
<td>TM Archive Product Generation</td>
</tr>
<tr>
<td>TAM</td>
<td>Three Axis Magnetometer</td>
</tr>
<tr>
<td>TAS</td>
<td>Tape Archive and Storage</td>
</tr>
<tr>
<td>TBA</td>
<td>To Be Announced</td>
</tr>
<tr>
<td>TBD</td>
<td>To Be Defined</td>
</tr>
<tr>
<td>TBR</td>
<td>To Be Resolved</td>
</tr>
</tbody>
</table>
### LAS Software Functions (Partial Listing)

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAYES</td>
<td>Max. Likelihood Classification</td>
</tr>
<tr>
<td>BINARY</td>
<td>7 Functions: +, -, *, /, and, or, XOR</td>
</tr>
<tr>
<td>CALAMP</td>
<td>Analyze CAL Lamp Data</td>
</tr>
<tr>
<td>CANAL</td>
<td>Canonical Analysis</td>
</tr>
<tr>
<td>CHARGOT</td>
<td>Writes Annotation to Bit Plane</td>
</tr>
<tr>
<td>CLASSMAP</td>
<td>Generate Class Map Film Product</td>
</tr>
<tr>
<td>CLUSTER</td>
<td>Clustering</td>
</tr>
<tr>
<td>COLGEN</td>
<td>Generate Pseudo Color Table</td>
</tr>
<tr>
<td>COLSLIC</td>
<td>Movable Zero Band In Color LUT</td>
</tr>
<tr>
<td>CONCAT</td>
<td>Combine Class</td>
</tr>
<tr>
<td>CONTOUR</td>
<td>Concatenate Images</td>
</tr>
<tr>
<td>CONVOLVE</td>
<td>Convolve Image (Smoothing)</td>
</tr>
<tr>
<td>COPY</td>
<td>Copy or Subset Image</td>
</tr>
<tr>
<td>COVAR</td>
<td>Covariance Matrix</td>
</tr>
<tr>
<td>CORSTK</td>
<td>Figure Drawing with a Cursor (Graphics Proc.)</td>
</tr>
<tr>
<td>DESPIKE</td>
<td>Remove Spikes</td>
</tr>
<tr>
<td>DISCRIM</td>
<td>Discrimant Analysis</td>
</tr>
<tr>
<td>DROPCLS</td>
<td>Delete Class</td>
</tr>
<tr>
<td>DROPSITE</td>
<td>Delete Training Site</td>
</tr>
<tr>
<td>EDGE</td>
<td>Extract Edges in Image</td>
</tr>
<tr>
<td>EDGECORR</td>
<td>Register Images by Edge Correlation</td>
</tr>
<tr>
<td>EDITSITE</td>
<td>Edit Training Site Coordinates</td>
</tr>
<tr>
<td>FFT1</td>
<td>1-Dimensional Fourier Transform</td>
</tr>
<tr>
<td>FFT1FL</td>
<td>1-Dimensional Fourier Transform Filter</td>
</tr>
<tr>
<td>FFT2</td>
<td>2-Dimensional Fourier Transform</td>
</tr>
<tr>
<td>FFT2FL</td>
<td>2-Dimensional Fourier Transform Filter</td>
</tr>
<tr>
<td>FIGLEFEN</td>
<td>Figure Drawing with a Light Pen (Graphics Proc.)</td>
</tr>
<tr>
<td>FILM</td>
<td>Generate Film Product</td>
</tr>
<tr>
<td>FIT</td>
<td>Scale Image by Histogram</td>
</tr>
<tr>
<td>FLICKER</td>
<td>Blink Mode Display</td>
</tr>
<tr>
<td>FROMTV</td>
<td>Quick Copy of IAT to Disk</td>
</tr>
<tr>
<td>FTP2IX</td>
<td>Generate 2-Dimensional Fourier Display</td>
</tr>
<tr>
<td>FTLIPX</td>
<td>Generate 1-Dimensional Fourier Display</td>
</tr>
<tr>
<td>GDG</td>
<td>Generate Geometric Transformation Data</td>
</tr>
<tr>
<td>GEOM</td>
<td>Perform Geometric Transformation (Rubber Sheet) for LAS</td>
</tr>
<tr>
<td>GRAPHICS</td>
<td>Graphic Functions Via Console Button</td>
</tr>
<tr>
<td>GREYREG</td>
<td>Register Images by Grey Level Correlation</td>
</tr>
<tr>
<td>GRSLIC</td>
<td>Movable Zero Band in LUT</td>
</tr>
<tr>
<td>HINDU</td>
<td>Histogram Inspired Cluster</td>
</tr>
<tr>
<td>HISTEQ</td>
<td>Histogram Equalization LUT Generation</td>
</tr>
<tr>
<td>JITTER</td>
<td>Analyze Jitter Effects</td>
</tr>
<tr>
<td>KARLOV</td>
<td>Karhunen-Loeve Transform</td>
</tr>
<tr>
<td>LINESPR</td>
<td>Repair Bad Lines</td>
</tr>
<tr>
<td>LIST</td>
<td>List and Histogram Image Window</td>
</tr>
<tr>
<td>LISTSAT</td>
<td>List Stats File</td>
</tr>
<tr>
<td>LUTEDIT</td>
<td>Edits LUT File</td>
</tr>
<tr>
<td>LUTO</td>
<td>Load Specified LUT from LUT Disk File</td>
</tr>
<tr>
<td>LUTSAV</td>
<td>Save LUT on Disk File</td>
</tr>
<tr>
<td>MASKSTAT</td>
<td>Statistics of Mask Image</td>
</tr>
<tr>
<td>MEDIT</td>
<td>Perform Median Filtering</td>
</tr>
<tr>
<td>MINDIST</td>
<td>Minimum Distance Classification</td>
</tr>
<tr>
<td>MOSAIC</td>
<td>Mosaic Images</td>
</tr>
<tr>
<td>MSA2P</td>
<td>Resample MSS A-Image to P-Image</td>
</tr>
<tr>
<td>PARALL</td>
<td>Parallelized Classification</td>
</tr>
<tr>
<td>PFILE</td>
<td>Generate P-Type Film Product</td>
</tr>
<tr>
<td>POLYSITE</td>
<td>Polygonal Site Selections</td>
</tr>
<tr>
<td>PSEUDO</td>
<td>Load Pseudo Color Tables (LUTO. Proc.)</td>
</tr>
<tr>
<td>RADION</td>
<td>Apply LUT to Image</td>
</tr>
<tr>
<td>RECORD</td>
<td>Copies TV to TV (Thru LUT Optional)</td>
</tr>
<tr>
<td>RELOAD</td>
<td>Rename Class</td>
</tr>
<tr>
<td>RLUT</td>
<td>TM A-Priori RLUT Generation</td>
</tr>
<tr>
<td>SAVIAT</td>
<td>Saves IAT B/W Configuration</td>
</tr>
<tr>
<td>SCALE</td>
<td>Convert Halfword Image to BYTE Image</td>
</tr>
<tr>
<td>SCANNER</td>
<td>Read Scanner/Digitizer</td>
</tr>
<tr>
<td>SCFT</td>
<td>Perform Fourier Analysis of SCD HFM</td>
</tr>
<tr>
<td>SCROLL</td>
<td>Scroll Disk Image to IAT's</td>
</tr>
<tr>
<td>SEGNOFF</td>
<td>Segment Offset Correction</td>
</tr>
<tr>
<td>SEQRPR</td>
<td>Renair Image Blemish</td>
</tr>
<tr>
<td>SETTV</td>
<td>Redefines IAT B/W Configuration</td>
</tr>
<tr>
<td>SHADE</td>
<td>Shade Plot of Image Window</td>
</tr>
<tr>
<td>SITES</td>
<td>Rectangular Site Selections</td>
</tr>
<tr>
<td>SPLIT</td>
<td>Split Screen Operation</td>
</tr>
<tr>
<td>STATS</td>
<td>Generate Stats File (Training Site)</td>
</tr>
<tr>
<td>STRETCH</td>
<td>Stretch Image Contrast</td>
</tr>
<tr>
<td>TESTGEN</td>
<td>Generate Test Images</td>
</tr>
<tr>
<td>TIEPTS</td>
<td>Generate Control Grid for Resampling</td>
</tr>
<tr>
<td>TM2P</td>
<td>Resample TM A-Image to P-Image</td>
</tr>
<tr>
<td>TUMB</td>
<td>Histograms of TM Image for Resampling</td>
</tr>
<tr>
<td>TOTV</td>
<td>Quick Copy of 'TV-Size' Image to IAT</td>
</tr>
<tr>
<td>TRANS</td>
<td>Transform Divergence</td>
</tr>
<tr>
<td>USAP</td>
<td>Uniformity Mapping</td>
</tr>
<tr>
<td>UNARY</td>
<td>Vegetative Index</td>
</tr>
<tr>
<td>VEGGIN</td>
<td>Weight Generator for FFT2FL</td>
</tr>
<tr>
<td>VGEN</td>
<td>Transfer Training Site</td>
</tr>
<tr>
<td>XFERSITE</td>
<td>Enlarge or Reduce Image</td>
</tr>
</tbody>
</table>

**Note:** The document contains a table listing software functions, which includes commands and their descriptions. The table is structured to provide a clear and concise overview of the functions available in the software.
INVITEES

Addess, Stan
Code 435
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-6449

Aepli, Ted, M-7235
GE Space Division
P.O. Box 8555
Philadelphia, PA 19101
(215) 962-3870

Alberts, Larry
ORI, Inc.
14CO Spring Street
Silver Spring, MD 20910
(301) 588-6180

Alford, Bill
Code 932
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-5586

Anderson, James
Code HA20, Bldg. 1100
NASA/National Space
Technology Laboratories
NSTL Station, MS 39529
(601) 688-3830

Anuta, Paul
LARS/Purdue University
W. Lafayette, IN 47906
(317) 494-6305

Ball, Dave
CSC
8728 Colesville Road
Silver Spring, MD 20910
(301) 344-6589

Balla, John
Code 726
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-6091

Banks, Gary
Code 726
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-5558

Barker, John
Code 923
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-8978/8881

Beaver, Jud
ORI, Inc.
1400 Spring Street
Silver Spring, MD 20910
(301) 588-6180

Bender, Lee
U.S. Geological Survey
730 National Center
12201 Sunrise Valley Drive
Reston, VA 22092
(703) 860-6273

Bernstein, Ralph
IBM Palo Alto Scientific Center
P.O. Box 10500
1530 Page Mill Road
Palo Alto, CA 94303-0821
(415) 855-3126

Beyer, Eric, M-7235
GE Space Division
P.O. Box 8555
Philadelphia, PA 19101
(215) 962-3572

Billingsley, Fred
Code 198-231
Jet Propulsion Laboratories
Pasadena, CA 91103
FTS 792-2325

Blodget, Herb
Code 902
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-8997
Bly, Beldon
CSC
8728 Colesville Rd.
Silver Spring, MD 20910
(301) 589-1545

Bracken, Peter
Code 500
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-9688

Brandshaft, Don
Hughes Aircraft Corp.
Santa Barbara Research Center
75 Coromar Drive
Santa Barbara, CA 93317
(805) 968-3511 x343

Brooks, Joan
General Electric Space Division
4701 Forbes Boulevard
Lanham, MD 20706
(301) 459-2900, Ext. 455

Brown, Lottie
Code 435
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-8520

Buhler, Lynn
ORI, Inc.
1400 Spring Street
Silver Spring, MD 20910
(301) 588-6180

Busse, Jon
Code 435
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-6142

Campbell, William J.
Code 744
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-8116

Carr, Jim
ORI, Inc.
1400 Spring Street
Silver Spring, MD 20771
(301) 588-6180

Cicone, Richard
Environmental Research Institute of Michigan
P.O. Box 8618
Ann Arbor, MI 48107
(313) 994-1200

Clark, Bill
CSC
8728 Colesville Road
Silver Spring, MD 20910
(301) 589-1545

Clark, Judy
ORI, Inc.
1400 Spring Street
Silver Spring, MD 20910
(301) 588-6180

Colwell, Robert
Associate Director
Space Sciences Laboratory
University of California, Berkeley
Berkeley, CA 94720
(415) 643-2351

Connors, Kathy
ORI, Inc.
1400 Spring Street
Silver Spring, MD 20910
(301) 588-6180

Cox, Scott
Code 902
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-8909

Cressy, Phil
Code 902
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-7658
<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Address</th>
<th>City, State, Zip</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crone, Larry</td>
<td>NOAA National Earth Satellite Service</td>
<td>4701 Forbes Blvd., Lanham, MD 20706</td>
<td>(301) 459-2900</td>
<td></td>
</tr>
<tr>
<td>Dallam, William</td>
<td>General Electric Space Division</td>
<td>4701 Forbes Blvd., Lanham, MD 20706</td>
<td>(301) 459-2900</td>
<td></td>
</tr>
<tr>
<td>Dasgupta, Rangit</td>
<td>CSC</td>
<td>8728 Colesville Road, Silver Spring, MD 20910</td>
<td>(301) 509-1545, Ext. 722</td>
<td></td>
</tr>
<tr>
<td>DeGloria, Stephen</td>
<td>Space Sciences Laboratory</td>
<td>University of California, Berkeley, CA 94720</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dietz, Jim</td>
<td>NASA/Goddard Space Flight Center</td>
<td>Greenbelt, MD 20771</td>
<td>(301) 344-9456</td>
<td></td>
</tr>
<tr>
<td>Dozier, Jeffrey</td>
<td>Associate Professor of Geography</td>
<td>University of California, Santa Barbara, CA 93106</td>
<td>(805) 961-2309 or 2109</td>
<td></td>
</tr>
<tr>
<td>Dunker, Chris</td>
<td>NASA/Goddard Space Flight Center</td>
<td>Greenbelt, MD 20771</td>
<td>(301) 344-4931</td>
<td></td>
</tr>
<tr>
<td>Dykstra, John</td>
<td>Earth Satellite Corp.</td>
<td>7222 47th St., Chevy Chase, MD 20815</td>
<td>(301) 652-7130</td>
<td></td>
</tr>
<tr>
<td>Eng, Kenneth</td>
<td>Systems &amp; Applied Sciences Corp.</td>
<td>5809 Annapolis Rd., Hyattsville, MD 20784</td>
<td>(301) 699-5400</td>
<td></td>
</tr>
<tr>
<td>Engel, Jack</td>
<td>Hughes Aircraft Corp.</td>
<td>Santa Barbara Research Center, Santa Barbara, CA 93317</td>
<td>(805) 968-3511, Ext. 6145</td>
<td></td>
</tr>
<tr>
<td>Erickson, Jon</td>
<td>Earth Resources Applications Division</td>
<td>Mail Code SH, NASA/Johnson Space Center</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Everett, John</td>
<td>Earth Satellite Corp.</td>
<td>7222 47th Street, Chevy Chase, MD 20815</td>
<td>(301) 652-7130</td>
<td></td>
</tr>
<tr>
<td>Fischel, David</td>
<td>NASA/Goddard Space Flight Center</td>
<td>Greenbelt, MD 20771</td>
<td>(301) 344-9534</td>
<td></td>
</tr>
<tr>
<td>Foote, Harlan</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foster, James</td>
<td>NASA/Goddard Space Flight Center</td>
<td>Greenbelt, MD 20771</td>
<td>(301) 344-9135</td>
<td></td>
</tr>
<tr>
<td>Freden, Stan</td>
<td>NASA/Goddard Space Flight Center</td>
<td>Greenbelt, MD 20771</td>
<td>(301) 344-5818</td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>Code</td>
<td>Address</td>
<td>Phone</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>------</td>
<td>----------------------------------------------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>Gervin, Janette</td>
<td>902</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-7061</td>
<td></td>
</tr>
<tr>
<td>Gonzales, Lou</td>
<td>435</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-5161</td>
<td></td>
</tr>
<tr>
<td>Gordon, Frederick</td>
<td>902</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-8037</td>
<td></td>
</tr>
<tr>
<td>Goward, Samuel</td>
<td></td>
<td>NASA/Goddard Institute for Space Studies</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2880 Broadway</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>New York, NY 10025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grebowski, Gerry</td>
<td>564.3</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-6386</td>
<td></td>
</tr>
<tr>
<td>Gurney, Charlotte</td>
<td></td>
<td>Systems &amp; Applied Sciences Corp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5809 Annapolis Road</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hyattsville, MD 20784</td>
<td>(301) 699-6137</td>
<td></td>
</tr>
<tr>
<td>Hahn, Jerold</td>
<td>435</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-6568</td>
<td></td>
</tr>
<tr>
<td>Haight, Steve</td>
<td></td>
<td>ORI, Inc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1400 Spring Street</td>
<td>(301) 588-6180</td>
<td></td>
</tr>
<tr>
<td>Hallada, Wayne</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heffner, Paul</td>
<td>564.3</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-6263</td>
<td></td>
</tr>
<tr>
<td>Heinig, Joe</td>
<td>564.3</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-7506</td>
<td></td>
</tr>
<tr>
<td>Hill, Charles</td>
<td></td>
<td>Test &amp; Evaluation Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NASA/Earth Resources Lab</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NSTL Station, MS 39529</td>
<td>(FTS) 494-2042</td>
<td></td>
</tr>
<tr>
<td>Hlauka, Chris</td>
<td></td>
<td>Ames Research Center</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>NASA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moffett Field, CA 94035</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horn, Tim</td>
<td>435.9</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-7876</td>
<td></td>
</tr>
<tr>
<td>Horseman, Martha</td>
<td>920</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-8671</td>
<td></td>
</tr>
<tr>
<td>Hovis, Warren</td>
<td></td>
<td>Director, Satellite Experiment Lab</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>National Oceanic &amp; Atmospheric Administration</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>National Earth Satellite Service</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>FB NO. 4-Room 0135</td>
<td>(301) 763-7381</td>
<td></td>
</tr>
<tr>
<td>Imhoff, Marc</td>
<td>902</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-7095</td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>Code</td>
<td>Organization</td>
<td>Address</td>
<td>Phone</td>
</tr>
<tr>
<td>-----------------------</td>
<td>------</td>
<td>------------------------------------</td>
<td>----------------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Irons, James</td>
<td>923</td>
<td>NASA/Goddard Space Flight Center</td>
<td>Greenbelt, MD 20771</td>
<td>(301) 344-5240</td>
</tr>
<tr>
<td>Jackson, Michael J.</td>
<td></td>
<td>Natural Environment Research Council</td>
<td>Polaris House North Star Avenue Swindon Wiits. SN2 IEU UNITED KINGDOM Telex: 444293 (ENVRE G)</td>
<td></td>
</tr>
<tr>
<td>Johnson, Robert</td>
<td></td>
<td>Hughes Aircraft Space &amp; Communications Group</td>
<td>El Segundo, CA</td>
<td></td>
</tr>
<tr>
<td>Kaufman, Lynn</td>
<td>902</td>
<td>ORI, Inc. 1400 Spring Street Silver Spring, MD 20910</td>
<td>(301) 588-6180</td>
<td></td>
</tr>
<tr>
<td>Kerber, Arlene</td>
<td></td>
<td>NASA/Goddard Space Flight Center</td>
<td>Greenbelt, MD 20771</td>
<td>(301) 344-5355</td>
</tr>
<tr>
<td>Kieffer, Hugh</td>
<td></td>
<td>Branch of Astrogeologic Studies U.S. Geological Survey 2255 North Gemini Drive Flagstaff, AZ 86001 (FTS) 261-1357</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kiepp-Baker, Nick</td>
<td>M-7226</td>
<td>GE Space Division  P.O. Box 8555 Philadelphia, PA 19101</td>
<td>(215) 962-2238</td>
<td></td>
</tr>
<tr>
<td>Koffler, Russ</td>
<td>435</td>
<td>NASA/Goddard Space Flight Center</td>
<td>Greenbelt, MD 20771</td>
<td>(301) 344-5207</td>
</tr>
<tr>
<td>Kreibiel, John</td>
<td>733</td>
<td>NASA/Goddard Space Flight Center</td>
<td>Greenbelt, MD 20771</td>
<td>(301) 344-5777</td>
</tr>
<tr>
<td>Krueger, Don</td>
<td>5118</td>
<td>NASA/Goddard Space Flight Center</td>
<td>Greenbelt, MD 20771</td>
<td>(301) 344-5118</td>
</tr>
<tr>
<td>Kugelmann, Diane</td>
<td>902</td>
<td>NASA/Goddard Space Flight Center</td>
<td>Greenbelt, MD 20771</td>
<td>(301) 344-8146</td>
</tr>
<tr>
<td>Labovitz, Mark</td>
<td>922</td>
<td>NASA/Goddard Space Flight Center</td>
<td>Greenbelt, MD 20771</td>
<td>(301) 344-5600</td>
</tr>
<tr>
<td>Lansing, Jack</td>
<td></td>
<td>Hughes Aircraft Corp. Santa Barbara Research Center 75 Coromar Drive Santa Barbara, CA 93317</td>
<td>(805) 968-3511</td>
<td></td>
</tr>
<tr>
<td>Latty, Rick</td>
<td>923</td>
<td>NASA/Goddard Space Flight Center</td>
<td>Greenbelt, MD 20771</td>
<td>(301) 344-9256</td>
</tr>
<tr>
<td>Lauer, Donald</td>
<td></td>
<td>Applications Branch U.S. Geological Survey EROS Data Center Sioux Falls, SD 57198 (FTS) 784-7111</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lauritson, Levin</td>
<td>435</td>
<td>NASA/Goddard Space Flight Center</td>
<td>Greenbelt, MD 20771</td>
<td>(301) 344-5223</td>
</tr>
<tr>
<td>Name</td>
<td>Code</td>
<td>Address/Location</td>
<td>Phone</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>------</td>
<td>-------------------------------------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>Linstrom, Loren</td>
<td>435</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-5223</td>
<td></td>
</tr>
<tr>
<td>Lu, Yun-chi</td>
<td></td>
<td>CSC, 8728 Colesville Rd. Silver Spring, MD 20910</td>
<td>(301) 589-1545</td>
<td></td>
</tr>
<tr>
<td>Lyon, John</td>
<td>932</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-8744</td>
<td></td>
</tr>
<tr>
<td>MacDonald, Robert</td>
<td></td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-8744</td>
<td></td>
</tr>
<tr>
<td>Malherbe, Pete, M-7222</td>
<td></td>
<td>GE Space Division</td>
<td>(215) 962-4699</td>
<td></td>
</tr>
<tr>
<td>Malila, William</td>
<td></td>
<td>Environmental Research Institute of Michigan, P.O. Box 8618, Ann Arbor, MI 48107</td>
<td>(313) 994-1200</td>
<td></td>
</tr>
<tr>
<td>Manheimer, Harry</td>
<td></td>
<td>NASA Headquarters</td>
<td>(202) 755-1201</td>
<td></td>
</tr>
<tr>
<td>Markham, Brian</td>
<td>923</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-5240</td>
<td></td>
</tr>
<tr>
<td>Martucci, Louis M.</td>
<td></td>
<td>DOE Pacific Northwest Laboratory</td>
<td>(202) 252-2146 (temporary)</td>
<td></td>
</tr>
<tr>
<td>Maxwell, Marvin</td>
<td>920</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-8036</td>
<td></td>
</tr>
<tr>
<td>Middleton, Elizabeth</td>
<td>902</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-8403</td>
<td></td>
</tr>
<tr>
<td>Moore, Jesse</td>
<td></td>
<td>NASA Headquarters</td>
<td>(202) 755-3728</td>
<td></td>
</tr>
<tr>
<td>Mowe, Ed</td>
<td>435</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-6978</td>
<td></td>
</tr>
<tr>
<td>Mulligan, Patricia</td>
<td>902</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-5515</td>
<td></td>
</tr>
<tr>
<td>Murphy, Bob</td>
<td>923</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-7282</td>
<td></td>
</tr>
<tr>
<td>Nelson, Ross</td>
<td>923</td>
<td>NASA/Goddard Space Flight Center</td>
<td>(301) 344-4926</td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>Code</td>
<td>Address</td>
<td>Phone</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>------</td>
<td>-------------------------------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>Nieman, Ron</td>
<td></td>
<td>CSC 8728 Colesville Road</td>
<td>(301) 589-1545</td>
<td></td>
</tr>
<tr>
<td>Ormsby, James</td>
<td>924</td>
<td>NASA/Goddard Space Flight Center Greenbelt, MD 20771</td>
<td>(301) 344-6908</td>
<td></td>
</tr>
<tr>
<td>Oseroff, Harold</td>
<td>902</td>
<td>NASA/Goddard Space Flight Center Greenbelt, MD 20771</td>
<td>(301) 344-8933</td>
<td></td>
</tr>
<tr>
<td>Podwysocki, Mel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price, John</td>
<td></td>
<td>Hydrology Laboratory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prokop, Ed</td>
<td>564.3</td>
<td>NASA/Goddard Space Flight Center Greenbelt, MD 20771</td>
<td>(301) 344-3490</td>
<td></td>
</tr>
<tr>
<td>Quann, John</td>
<td>500</td>
<td>NASA/Goddard Space Flight Center Greenbelt, MD 20771</td>
<td>(301) 344-7506</td>
<td></td>
</tr>
<tr>
<td>Ramipriyan, H. K.</td>
<td>932</td>
<td>NASA/Goddard Space Flight Center Greenbelt, MD 20771</td>
<td>(301) 344-9496</td>
<td></td>
</tr>
<tr>
<td>Rango, Al</td>
<td>924</td>
<td>NASA/Goddard Space Flight Center Greenbelt, MD 20771</td>
<td>(301) 344-5480</td>
<td></td>
</tr>
<tr>
<td>Robinson, Jon</td>
<td></td>
<td>CSC 8728 Colesville Rd.</td>
<td>(301) 589-1545</td>
<td></td>
</tr>
<tr>
<td>Royal, Al</td>
<td></td>
<td>General Electric Space Division 4701 Forbes Blvd. Lanham, MD 20705</td>
<td>(301) 459-2900</td>
<td></td>
</tr>
<tr>
<td>Salomonson, Vince</td>
<td>920</td>
<td>NASA/Goddard Space Flight Center Greenbelt, MD 20771</td>
<td>(301) 344-6481</td>
<td></td>
</tr>
<tr>
<td>Schmetzler, Charles</td>
<td>922</td>
<td>NASA/Goddard Space Flight Center Greenbelt, MD 20771</td>
<td>(301) 344-5213</td>
<td></td>
</tr>
<tr>
<td>Schott, John</td>
<td></td>
<td>School of Photographic Arts &amp; Sciences Rochester Institute of Technology One Lomb Memorial Drive Rochester, NY 14623</td>
<td>(716) 475-2783</td>
<td></td>
</tr>
<tr>
<td>Sehn, George</td>
<td>M-7235</td>
<td>GE Space Division</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sheffield, Charles</td>
<td></td>
<td>Farnum Satellite Corp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7222 47th St.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chevy Chase, MD 20815</td>
<td>(301) 652-7130</td>
<td></td>
</tr>
</tbody>
</table>
Short, Nick
Code 922
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-7870

Slater, Philip
Optical Sciences Center
University of Arizona
Tucson, AZ 85721
(602) 626-4242

Staskowski, Ron
Earth Satellite Corp
7222 47th St.
Chevy Chase, MD 20815
(301) 652-7130

Stauffer, Mark
Code 923
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771

Strome, W. M.
Canada Center for Remote Sensing
2464 Sheffield Road
Ottawa, Ontario, Canada K1A 0X7

Stuart, Locke
Code 902
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-6987

Sudey, John
Code 716
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-9907

Thomondguyard, June
EROS Data Center
Sioux Falls, SD 57198
(605) 594-6555

Thompson, R. J.
EROS Data Center
Sioux Falls, SD 57198
(605) 594-6555

Toll, Dave
Code 923
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-9256

Townshend, J.
Natural Environment Research Council
Polaris House
North Star Avenue
Swindon
Wilts, SN 2 1EU
UNITED KINGDOM
Telex: 444293 (ENVRE G)

Ungar, Steve
NASA/Goddard Institute for
Space Studies
2880 Broadway
New York, NY 10025

Van Wie, Pete
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-7605

Waltz, Fred
EROS Data Center
Sioux Falls, SD 57198
(605) 594-6555

Warriner, Howard

Watt, Bill
Code 435
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-9437

Webb, William
Code 435
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-9308

Weinstein, Oscar
Code 435
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-8108
Welch, Jim
NASA Headquarters
Exploration Division, OSSA
600 Independence Ave., S.W.
Washington, DC 20546
(202) 755-8458

Welch, Roy
Department of Geography
University of Georgia
Athens, GA 30602
(404) 542-2856

Wescott, Tom
GE Space Division
4701 Forbes Blvd.
Lanham, MD 20706
(301) 459-2900

Whitman, Ruth
ORL, Inc.
1400 Spring Street
Silver Spring, MD 20910
(301) 588-6160

Williams, Darrel
Code 923
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-8860

Witt, Ronald
Code 902
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-5042

Wrigley, Robert
MS242-4
Ames Research Center
NASA
Moffett Field, CA 94035
(FTS) 448-6060

Wukelic, George
Zobrist, Albert
MS 168-514
Jet Propulsion Laboratory
California Institute of
Technology
4800 Oak Grove Drive
Pasadena, CA 91109
(FTS) 792-3237