A Reproduced Copy

OF

NASA TM-85274

Reproduced for NASA

by the

NASA Scientific and Technical Information Facility

LIBRARY COPY

JUL 29 1983
LANGLEY RESEARCH CENTER
LIBRARY, NASA
HAMPTON, VIRGINIA

FFNo 672 Aug 65
LANDSAT-D Investigations Workshop

May 13-14, 1982

Goddard Space Flight Center

Day 1
Agenda
# Agenda

**LANDSAT-D INVESTIGATIONS WORKSHOP - BLDG. 26, ROOM 205**

**Thursday, 13 May 1982**

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

TOURS, etc., Building 28

(Five Tours/Presentations Offered Each Half Hour)

1. Landsat Assessment System (LAS)  Lyon/Fischel
    8:30 pm

2. Image Generation Facility (IGF)  GE
    9:00 pm

3. MSS and TM Sensored Pictures  Barker
    9:30 pm

4. Control and Simulation Facility (CSF)  GE
    9:30 pm

5. End-to-End System Analysis Study Highlights  Billingsley
    10:00 pm
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
Science Office Organization

Project Scientist
- V. SALOMONSON (920)

Associate Project Manager
- J. BARKER (923)

Assistant Project Scientist
- D. WILLIAMS (923)

Mission Utilization Manager
- S. FREDEN (902)
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**
- **200 MSS Scenes/Day Processing Capability**
- **1982**
- **1983**
- **1985**
- **TDRSS/NCC Capability**
- **Mission Operations Review**
- **Flight Readiness Review**
- **D-Launch Readiness**
- **Ground Segment Acceptance**
- **MSS System Transition to NOAA**
- **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></th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>25</td>
<td>26</td>
<td>27</td>
<td>28</td>
<td>29</td>
</tr>
<tr>
<td></td>
<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 13 of Poor Quality*
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 Within 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
LANDSAT D FLIGHT SEGMENT

GLOBAL POSITIONING SYSTEM ANTENNA

ATTITUDE CONTROL MODULE

PROPULSION MODULE

POWER MODULE

MULTI-MODAL MODULAR SPACECRAFT

INSTRUMENT MODULAR MODULE

S-BAND ANTENNA

THEMATIC MAPPER

WIDEBAND MODULE

MULTISPECTRAL SCANNER

SUN SENSORS

SOLAR ARRAY PANEL

X-BAND ANTENNA

HIGH GAIN ANTENNA

ANTENNA MAST

(2) OMNI ANTENNA
FLIGHT SEGMENT INTERFACES

- NAVIGATION SATELLITES
- TRACKING & DATA RELAY SATELLITE SYSTEM
- GROUND BASED SPACE FLIGHT TRACKING & DATA NETWORK
- GROUND SEGMENT
- TRANSPORTABLE GROUND STATION
- MULTIMISSON MODULAR SPACECRAFT
- THEMATIC MAPPER
- MULTISPECTRAL SCANNER
- GLOBAL POSITIONING SYSTEM RECEIVER/PROCESSOR ASSEMBLY
- WESTERN TEST RANGE
- DELTA
- SPACE TRANSPORTATION SYSTEM
- FOREIGN GROUND STATIONS
- INTEGRATION & TEST GROUND STATION
**Multispectral Scanner (MSS) Sensor**

**MSS Detector Details**

<table>
<thead>
<tr>
<th>Bands</th>
<th>Spectral Ranges $\mu m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.5 - .6</td>
</tr>
<tr>
<td>2</td>
<td>.6 - .7</td>
</tr>
<tr>
<td>3</td>
<td>.7 - .8</td>
</tr>
<tr>
<td>4</td>
<td>.8 - 1.1</td>
</tr>
</tbody>
</table>

Ground IFOV
All Bands - 83 Meters
Data Rate - 15.06 Mbps
Quantization Levels - 64
THEMATIC MAPPER (TM) SENSOR

Scan Direction

Along Track Direction

Silicon Detectors and Filters

Bands 1 2 3 4

Cooled Detectors and Filters

Bands 5 6 7

Incorporates Angular Displacement Sensor (ADS)

Measures Angle of Motion from 2 to 125 Hz

Source of Jitter Compensation Data

Scan Mirror

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

Data Rate — 04.9 Mbps
Quantization Levels — 256

<table>
<thead>
<tr>
<th>BAND</th>
<th>SPECTRAL RANGES $\mu$m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>45 — 52</td>
</tr>
<tr>
<td>2</td>
<td>52 — 60</td>
</tr>
<tr>
<td>3</td>
<td>63 — 69</td>
</tr>
<tr>
<td>4</td>
<td>76 — 90</td>
</tr>
<tr>
<td>5</td>
<td>1.55 — 1.75</td>
</tr>
<tr>
<td>6</td>
<td>10.4 — 12.5</td>
</tr>
<tr>
<td>7</td>
<td>20.8 — 23.5</td>
</tr>
</tbody>
</table>

Bands 1-5 & 7

185 km

Swath Width

Orbit Direction

Scan Direction
GROUND SEGMENT INTERFACES

FLIGHT SEGMENT

WHITE SANDS

DOMSAT

DOMSAT INTERFACE FACILITY

GSTDN

FOREIGN STATIONS

EROS DATA CENTER

DOMSAT

NETWORK CONTROL CENTER

NATIONAL WEATHER SERVICE

PROJECT OFFICE

TAPE SUPPORT FACILITY

OPERATION SUPPORT COMPUTING FACILITY

PHOTO LAB

MISSION SUPPORT COMPUTING & ANALYSIS DIVISION
PARTITIONING THE GROUND SEGMENT

TYPICAL GROUND SYSTEM ELEMENTS

OPERATIONS CONTROL CENTER (OCC)

DATA MANAGEMENT SYSTEM (DMS)

TRANSPORTABLE GROUND STATION (TGS)

CONTROL & SIMULATION FACILITY (CSF)

MISSION MANAGEMENT FACILITY (MMF)

IMAGE GENERATION FACILITY (IGF)

LANDSAT-D ELEMENTS

LANDSAT ASSESSMENT SYSTEM (LAS)

FLIGHT SEGMENT CONTROL & MONITORING

MANAGEMENT CONTROL

PRODUCT 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)

Landsat Assessment System

Control & Simulation Facility (CSF)

Transportable Ground Station (TGS)

Data Receive, Record, Transmit System (DRRTS)

MSS Image Processing System (MIPS)

TM Image Processing System (TIPS)

MSS Mission Management Facility (MMF-T)

NASA Owned

Transfer to NOAA at D + 6 Months

Transfer to NOAA on January 31, 1985
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

MATRIX SWITCH

SERIAL TO PARALLEL DATA INPUT

MSS DECOM

PARALLEL TO SERIAL DATA OUTPUT

TAPE CONTROL, TIME CODE

AP-180V ARRAY PROCESSOR

VAX 11/780

176 MBYTE SYSTEM DISKS (2)

176 MBYTE IMAGE DISKS (8)

800/1600 BPI COMPUTER COMPATIBLE TAPE (3)

DICOMED 70MM FILM RECORDER

ON LINE DISPLAY

CONTROL POINT IMAGE DISPLAY

PROCESS CONTROL

IMAGE DATA

MMF-M DECNET

ONE OF THREE
MULTISPECTRAL SCANNER
IMAGE GENERATION PROCESS FLOW

TRANSPORTABLE GROUND STATION

MODEM (FROM WHITE SANDS VIA DOMSAT)

DOMSAT INTERFACE FACILITY (BLOCK 23)

DATA RECEIVE, RECORD, TRANSMIT SYSTEM

DATA TRANSMIT

DATA READING RECORDING

HDT

DATA INPUT & REFORMATTING

IMAGE DISKS

GEOMETRIC CORRECTION DATA

- ATTITUDE
- EPHemeris
- MSS UNIQUE

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

RADIOMETRIC CORRECTION

HDT A

CONTROL POINT LIBRARY BUILD

PERFORMANCE EVALUATION AND QUALITY ASSURANCE

MSS IMAGE PROCESSING STRINGS

ORIGINAL PAGE IS OF POOR QUALITY
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

DATA RECEIVING RECORDING

INPUT SCREENING DATA EXTR

RADIOMETRIC AND CONTROL POINT DATA

DATA RECVIEVING RECORDING

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

PRODUCT GENERATION

CCT

EROS DATA CENTER

GEOMETRIC CORRECTION DATA

- ATTITUDE
- EPHemeris
- TM UNIQUE

COMPUTE

- GEOM CORRECTION MATRICES
- RADIO CORRECTION FUNCTIONS
- ANNOTATION DATA

ORIGINAL PAQ: 13
OF POOR QUALITY

1-41
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
MSS  200 MIPS - SEPT 30, 1982
TM   1 SCROUNGE - 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

TM-SCROUNGE

MSS

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
Landsat-D Ground Segment Location

To Gate #2 (Parkway Gate)

Bldg. 28 Landsat-D Ground Segment

Road #4

Main Gate

Greenbelt Rd.

Road #8

Soil Conservation Rd.

Gate #4

Electronics Van

10 Meter Antenna

NASA Boundary

Bore Sight Antenna

150 Foot Collimation Tower

Network Training and Test Facility Bldg. #25

ORIGINAL PAGE IS OF POOR QUALITY
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
Structure

LANDSAT-D SYSTEM

ENGINEERING VERIFICATION
- RELIABILITY
- SPECIFICATIONS
- QUALITY ASSURANCE

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

END-TO-END SYSTEM PERFORMANCE
- TM SYSTEM PERFORMANCE
- MSS SYSTEM PERFORMANCE
- INSTRUMENT PERFORMANCE

- 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>Hughes</td>
<td>- Pre-Ship Review</td>
</tr>
<tr>
<td></td>
<td>- Final Report</td>
</tr>
<tr>
<td>TM (PF and F)</td>
<td>- Technical memos</td>
</tr>
<tr>
<td>Santa Barbara Research Center (SBRC)</td>
<td>- Pre-Ship Review</td>
</tr>
<tr>
<td></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></td>
</tr>
<tr>
<td>TM Radiometric Testing and Data Reduction</td>
<td>• Technical Memos</td>
</tr>
<tr>
<td>TM Geometric Testing</td>
<td>• Pre-Ship Review</td>
</tr>
<tr>
<td><strong>Post-Launch</strong></td>
<td></td>
</tr>
<tr>
<td>Radiometric Calibration and Validation</td>
<td>• Processing White Papers and Data Reduction</td>
</tr>
<tr>
<td>Geometric Calibration and Validation</td>
<td>• Technical Memos</td>
</tr>
<tr>
<td></td>
<td>• Post-Launch Support</td>
</tr>
<tr>
<td></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

1-63
## 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

## Responsibility (Ongoing)

<table>
<thead>
<tr>
<th>GSFC Mission Operations Manager (Webb)</th>
<th>GE Quality Assurance Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Product Evaluation</td>
<td>• Process Evaluation</td>
</tr>
</tbody>
</table>

## Reports

- Quality Assurance Reports
- Processing Summary Reports
- Automated PDR and ESR Management Reports
- System Audit Reports
- Special Management Reports (Trend Analyses & Current Quality Problem Daily Report)

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>• Performance Evaluation Product Generation</td>
<td>• Landsat-D Mission Operations Review (MOR), April 6-7, 1982</td>
</tr>
<tr>
<td>• Operational Quality Assurance</td>
<td>• MOR, April 6-7, 1982</td>
</tr>
</tbody>
</table>
### Table 1: Approaches to Satisfying Landsat Data User Concerns

#### Original Page 12

**OF POOR QUALITY**

<table>
<thead>
<tr>
<th>USER CONCERNS</th>
<th>REQUIREMENTS</th>
<th>APPROACH TO SATISFYING REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TIMELINESS OF DATA:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Throughput</td>
<td>• 200 New MSS Scenes/Day</td>
<td>• High Level of Back Up in Design</td>
</tr>
<tr>
<td>Turnaround Time</td>
<td>• 48 Hours from Receipt of Data</td>
<td>• Most Equipment Off-the-Shelf, Proven Performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Availability/Reliability-Maintenance, Spares Philosophy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• General Purpose System Simulator (GPSS) Model:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Timeliness, Utilization,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Failure Mode Effects Analysis,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Optimization of Operating Scenarios</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Automatic Monitoring, Reporting of Performance</td>
</tr>
<tr>
<td><strong>COMPLETENESS OF DATA:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment of Data Dropouts, Errors</td>
<td>• Replace Lost Data with Last Good Data</td>
<td>• Request Retransmission of Bad Data Transfers from White Sands</td>
</tr>
<tr>
<td></td>
<td>• Detect and Correct Bad Time Codes</td>
<td>• Provision to Skip Bad Data on Scene Basis</td>
</tr>
<tr>
<td></td>
<td>• Report All Substitutions on Digital Products</td>
<td>• Repetition of Last Good Video Data for Lost Video Line</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Insertion of Flywheel Times for Bad Time Code</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Automatic Reporting of Substitute Video Data in Line Quality Maps</td>
</tr>
<tr>
<td><strong>RADIOMETRIC QUALITY OF DATA:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute and Relative</td>
<td>• ±1 Quantum Level over Entire Detector Range (6 Bit Data) within each Band</td>
<td>• Calibration on Wedge for Absolute and Band-to-Band Fidelity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Nominal Calibration Wedge for Back-Up</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Scene Content for Detector-to-</td>
</tr>
</tbody>
</table>
### TABLE 1: APPROACHES TO SATISFYING LANDSAT DATA USER CONCERNS (Cont'd)

<table>
<thead>
<tr>
<th>USER CONCERNS</th>
<th>REQUIREMENTS</th>
<th>APPROACH TO SATISFYING REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RADIOMETRIC QUALITY OF DATA (Cont'd):</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></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><strong>GEOMETRIC QUALITY OF DATA:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute and Temporal</td>
<td>• 0.3 Pixel Temporal Registration Accuracy (90%)</td>
<td>• Systematic Correction Data (SCD):</td>
</tr>
<tr>
<td></td>
<td>• 0.5 Pixel Geodetic Accuracy (90%)</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),</td>
</tr>
<tr>
<td></td>
<td></td>
<td>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</td>
</tr>
<tr>
<td></td>
<td></td>
<td>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><strong>AVAILABILITY OF DATA QUALITY MEASURES:</strong></td>
<td>• Daily and Continuing Readiness for Operations (Quality Assessment)</td>
<td>• Quality Measures for All Phases of Processing</td>
</tr>
</tbody>
</table>
### TABLE 1: APPROACHES TO SATISFYING LANDSAT DATA USER CONCERNS (Cont'd)

<table>
<thead>
<tr>
<th>USER CONCERNS</th>
<th>REQUIREMENTS</th>
<th>APPROACH TO SATISFYING REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVAILABILITY OF DATA QUALITY MEASURES (Cont'd):</td>
<td>• Assurance Quality of Products</td>
<td>• Some Quality Measures Evaluated Against Thresholds to Determine:</td>
</tr>
<tr>
<td></td>
<td>• Evaluation and Enhancement of Performance</td>
<td>- Rework</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Rejection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Long Term Evaluation and Enhancement of System</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

- 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 Organization

Quality Assurance Manager

Secretary

Quality Engineering
- Quality Engineer
- Image Processing Analyst (2)

Quality Assurance
- Quality Assurance Supervisor
- Quality Analysts (6)
- PDR Coordinator

Configuration Management
- Supervisor
- Configuration Management Analyst
- Librarian
- Data Management Specialists (2)
# Quality Assurance—Responsibilities

<table>
<thead>
<tr>
<th><strong>Assure Performance</strong></th>
<th><strong>Problem Management</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement</td>
<td>Prevention</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Detection</td>
</tr>
<tr>
<td>Adjustment</td>
<td>Investigation</td>
</tr>
<tr>
<td>Enhancement</td>
<td>Solution</td>
</tr>
<tr>
<td></td>
<td>Reporting</td>
</tr>
</tbody>
</table>
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

1-79
QA Scenario for Normal Processing
(HDT-AM Generation)

- Observe Telemetry Data Displays
- Observe Telemetry Signal Quality
- Observe Video on QLM
- Examine QA Reports

Telemetry

CSF

PCS

Video

DRRTS Data Capture

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

Archive Generation

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

PEPG

- Examine Dumps and Reports
- Observe Video
  - During Ingest
  - Individual Scenes From Disk
- Receive Messages on ECC Limits Exceeded
  - Examine 241 mm Film

Scene Selection

- Random Sample Defined by QA
- Specific Scenes Selected

DRRTS Uplink

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

Release Decision

Yes

Reject/ Reprocess

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

- Performed by Operators
- Performed by QA
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

1-83
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

1-84
Typical QA Report

Band Quality Indicators
Launch Baseline Criteria - All Quality Levels Acceptable
With Operating Experience - Acceptable Threshold May Be Established

Acceptable Limit For Uncorrected -10
Criteria given To QA For Uplink Decision

Radiometric Indicators
Max Difference Between
Detectors Within Each Band
= 3 Initially

1-85
Overall and Quality Code

- Located in Byte 146 of HDT Header Data

- Ranges From 0 - 9, A,B,C
  0 — Acceptable
  C — Best

- f (Geometric Correction Quality, Radiometric Correction Quality, Image Data Quality

- 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
  \[ DQI = \frac{MJ \text{ FSL} + MiFSL + \text{Unrecov. ECC}}{20} \]
  Code Criteria
  E 0< DQI <1.5
  G 1.5< DQI <4.5
  A 4.5< DQI

1-86
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

Video Displays
QA Reports
Processing Reports

Criteria

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)
Science Characterization
**Science Organization**

- **SCIENCE OFFICE**
  - V. Salomonson

- **GSFC SUPPORT STUDIES**
  - D. Williams

- **SCIENCE EVALUATION**
  - J. Barker

- **APPLICATIONS NOTICE INVESTIGATIONS**
  - S. Freden

- **MSS**
  - W. Alford

- **SENSOR PERFORMANCE**
  - LAS
    - CSC
    - ERRSAC

- **IMAGE DATA QUALITY**
  - USGS
  - GE

- **APPLICATIONS INFORMATION**
  - CSC

- **SENSOR PERFORMANCE**
  - TM
    - J. Barker

- **IMAGE DATA QUALITY**
  - RMS
  - RDS
  - SASC
  - CSC

*Eastern Regional Remote Sensing Application Center*
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>Yield</td>
<td>Structure</td>
<td>Cover Classification</td>
</tr>
<tr>
<td>Condition</td>
<td>Landforms</td>
<td>Cover Change</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Lithology</td>
<td>Environmental Impact</td>
</tr>
<tr>
<td>Episodal Event</td>
<td>Thermal Anomalies</td>
<td>Coasts Zone</td>
</tr>
<tr>
<td>Soils</td>
<td>Geobotanical Anomalies</td>
<td>Monitoring</td>
</tr>
<tr>
<td>Classification</td>
<td>Topography (Stereo)</td>
<td>Hydrology</td>
</tr>
<tr>
<td>Erosion</td>
<td>Episodal Event</td>
<td>Drainage Patterns</td>
</tr>
<tr>
<td>Moisture</td>
<td></td>
<td>Inland Water Inventory</td>
</tr>
<tr>
<td>Forests</td>
<td>Image-Science</td>
<td>Snow Pack Parameters</td>
</tr>
<tr>
<td>Inventory</td>
<td>Pattern Recognition</td>
<td>Ice — Inland &amp; Near Shore</td>
</tr>
<tr>
<td>Stand Evaluation</td>
<td>Information Extraction</td>
<td>Water Quality — Inland &amp; Near Shore</td>
</tr>
<tr>
<td>Condition</td>
<td></td>
<td>Wetland/Estuaries Inventory</td>
</tr>
<tr>
<td>Episodal Event</td>
<td></td>
<td>Episodal Event</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td>Wildlife Habitat</td>
</tr>
<tr>
<td>Vegetation Inventory</td>
<td></td>
<td>Inventory</td>
</tr>
<tr>
<td>Condition</td>
<td></td>
<td>Evaluation</td>
</tr>
<tr>
<td>Episodal Event</td>
<td></td>
<td>Oceans</td>
</tr>
<tr>
<td></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>GSFC No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colwell</td>
<td>AN 3</td>
</tr>
<tr>
<td>Bernstein</td>
<td>AN 8</td>
</tr>
<tr>
<td>Malin</td>
<td>AN 9</td>
</tr>
<tr>
<td>Bender</td>
<td>AN 12</td>
</tr>
<tr>
<td>Price</td>
<td>AN 14</td>
</tr>
<tr>
<td>Slater</td>
<td>AN 15</td>
</tr>
<tr>
<td>Wogluy</td>
<td>AN 18</td>
</tr>
<tr>
<td>Malin</td>
<td>AN 20</td>
</tr>
<tr>
<td>Zobrist</td>
<td>AN 75</td>
</tr>
<tr>
<td>Ericson</td>
<td>AN 26</td>
</tr>
<tr>
<td>Hovis</td>
<td>AN 29</td>
</tr>
<tr>
<td>Schott</td>
<td>AN 31</td>
</tr>
<tr>
<td>Keffler</td>
<td>AN 32</td>
</tr>
<tr>
<td>Welch</td>
<td>AN 35</td>
</tr>
<tr>
<td>Proctor</td>
<td>AN 37</td>
</tr>
<tr>
<td>Guernsey</td>
<td>AN 39</td>
</tr>
<tr>
<td>Hill</td>
<td>AN 41</td>
</tr>
<tr>
<td>Everett</td>
<td>AN 42</td>
</tr>
<tr>
<td>MacDonald</td>
<td>AN 44</td>
</tr>
<tr>
<td>Anderson</td>
<td>AN 46</td>
</tr>
</tbody>
</table>

## Radiometry

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

## Geometry of Image (Pixel Location)

<table>
<thead>
<tr>
<th>Effects</th>
<th>Scan Profile, Reference Detector</th>
<th>Sensor Location Relative to Reference Detector</th>
<th>Between Scan Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Ephemeral

<table>
<thead>
<tr>
<th>Effects</th>
<th>Orbital Support Competing Div.</th>
<th>Global Positioning System (GPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Attitude

<table>
<thead>
<tr>
<th>Effects</th>
<th>Angular Displacement Sensor (ADS)</th>
<th>Inertial Reference System (DRIRU)</th>
<th>Attitude Control System (ACS)</th>
<th>Alignment to Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Image Data Quality Performance
Characterization — MSS


| Geometry | Spectral Information | Detector Replacement Algorithms
|          | Band Compression Algorithms
|          | Internal Calibration Algorithms
|          | Channel to Channel
|          | Band to Band
|          | Scene Histogram Calibration Algorithms (Radiometric Striping)
|          | Absolute Scene Radiance Calibration Algorithms
|          | Reflective Band
|          | Thermal Band
|          | Noise Correction Algorithms
|          | Ground IFOV
|          | Radiometrically Corrected Image Location
|          | Scan Profile
|          | Detector Location
|          | Systematic Correction
|          | Between Scan Alignment
|          | Ephemera
|          | Attitude
|          | Geodetic Correction
|          | Reference Library Build
|          | with GCs
|          | Scene to Reference Registration
|          | Resampling

1-100
# Sensor and Spacecraft Performance Characterization — TM

<table>
<thead>
<tr>
<th>Name</th>
<th>Colwell</th>
<th>Barratton</th>
<th>Arletta</th>
<th>Malia</th>
<th>Bender</th>
<th>Price</th>
<th>Slater</th>
<th>Wingley</th>
<th>Zobrist</th>
<th>Ericksen</th>
<th>Haavre</th>
<th>Lauer</th>
<th>Schott</th>
<th>Kellner</th>
<th>Welch</th>
<th>Poster</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 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 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>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Radiometric Spectral Resolution**
- Filter
- Detectors
- System
- Absolute Integrating Sphere Calibration
- External Calibration
- Internal Calibration
- Precision
- Signal to Noise
- Flooding Lamp Calibration

**Geometry of Image Pixel Location**
- Scan Profile, Reference Detector
- Detector Location Relative to Reference Detector
- Between Scan Alignment
- Orbital Support Computing Div
- Global Positioning System (GPS)
- Angular Displacement Sensor (ADS)
- Inertial Reference System (DRIRU)
- Attitude Control System (ACS)
- Alignment to Sensor
# Image Data Quality Performance

## Characterization — TM

<table>
<thead>
<tr>
<th>Name</th>
<th>Coswell</th>
<th>Bernstein</th>
<th>Anuta</th>
<th>Malia</th>
<th>Bender</th>
<th>Price</th>
<th>Slater</th>
<th>Whigley</th>
<th>Malia</th>
<th>Zobrist</th>
<th>Erickson</th>
<th>Horve</th>
<th>Lauer</th>
<th>Schott</th>
<th>Keffer</th>
<th>Welch</th>
<th>Guerney</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 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 41</td>
<td>AN 42</td>
<td>AN 44</td>
<td>AN 46</td>
<td></td>
</tr>
</tbody>
</table>

## Spectral Information
- **Detector Replacement Algorithms**
- **Band Compression Algorithms**
  - **Internal Calibration Algorithms**
    - Channel-to-Channel
    - Band to Band
  - **Scene Histogram Calibration Algorithms (Radiometric Destriping)**
  - **Absolute Scena Fruance Calibration Algorithms**
    - Reflective Band
    - Thermal Band
  - **Noise Correction Algorithms**

## Geometry
- **Geometry of Pixel**
  - **Ground IFOV**

## Radiometric Information
- **Geometry of Image (Pixel Location)**
  - **Systematic Correction**
    - Scan Profile
    - Detector Location
    - Between Scan Alignment
    - Ephemeral
    - Attitude
  - **Geodetic Correction**
    - Reference Library Build
    - Scene-to-Reference Registration
  - **Resampling**
# Applications Information — MSS & TM

<table>
<thead>
<tr>
<th>Name</th>
<th>Agriculture</th>
<th>Soils</th>
<th>Forests</th>
<th>Range</th>
<th>Other</th>
<th>Geology</th>
<th>Image Science</th>
<th>Other</th>
<th>Regional/Urban Land Use</th>
<th>Coastal Zone</th>
<th>Hydrology</th>
<th>Wildlife Habitat</th>
<th>Oceans</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSFC No.</td>
<td>AN 3 AN 8 AN 9 AN 12 AN 14 AN 15 AN 18 AN 20 AN 23 AN 25 AN 26 AN 29 AN 31 AN 32 AN 35 AN 36 AN 37 AN 39 AN 41 AN 42 AN 44 AN 46</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>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- This table lists various applications information for MSS & TM, categorizing them under Renewable Resources, Non-Renewable Resources, and Planning/Environmental Management.
- Each row represents an application field, and the columns correspond to different names associated with those fields.
- The GSFC No. column indicates the associated numbers for each name.

**Original Page Quality:** Poor

**Page:** 1-103
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 (½ 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
Overall Configuration

VAX11/780

UNIBUS

A/N
CARD
PRINT

HDT (2)
CCT (2)
DISK (8)

CCT (3)

AP-180 V
ARRAY PROCESSOR

PDP11/34

DICOMED D47

OPTRONICS L5500
(FILM RECORDERS)

CONTROL

IAT 1

IMAGE ANALYSIS TERMINALS

IAT 2

IAT 3

CONTROL

SCANNER/DIGITIZER

HIGH SPEED BUS
End-to-End Scrounge Data Flow

Imagery

DRRTS → TAS → ADDS → LAS → TAPE LIBRARY

≥10 Scenes Per Week

Telemetry

CSF → MMF → ADDS

21 Scenes/Week Ordered for Processing

Acquisition Requests

≥10 Scenes Per Week

Standing Order Film for Evaluation and Completed Work Order

7 Scenes Per Week

FILM LIBRARY

PRODUCT SUPPORT & DISTRIBUTION FACILITY

21 Scenes Per Week

Ordered for Processing

STANDING ORDER

Film for Evaluation and Completed Work Order

ACQUISITION | PRODUCT GENERATION

Acquisition Requests and Scheduling

Imagery & Image Data Products

Telemetry and Product Ancillary Information

Processing Work Order and Product Request

SCIENCE OFFICE

PRODUCT DISTRIBUTION

Products to Users

PRODUCT REQUEST

PRODUCT DISTRIBUTED NOTIFICATION

ORIGINAL PAGE 13 OF FOUR
End to End Scrounge — LAS
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

CCT B

CCT P

LAS

TAPE LIBRARY

CCT B

CCT A

PRODUCT REQUEST

TO PRODUCT SUPPORT AND DISTRIBUTION FACILITY

A AND B ALSO AVAILABLE

PRODUCT REQUESTS

FROM SCIENCE OFFICE

PRODUCT REQUESTS

FROM SCIENCE OFFICE

TO PRODUCT SUPPORT AND DISTRIBUTION FACILITY

FILM MASTER

FILM PRODUCTS

WO

WEEKLY PROCESSING REPORT

FOR CLOSE OUT OF UNSUCCESSFUL SCENES

TO SCIENCE OFFICE

STANDING ORDER FILM PRODUCTS

WO

TO SCIENCE OFFICE

WO

FILM LIBRARY

FILM MASTER

PRODUCT REQUESTS

FROM SCIENCE OFFICE

ORIGINAL PAGE IS OF POOR QUALITY
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.)

### AREA
- Washington, DC
- Lubbock, TX area
- Grand Canyon, AZ
- Phoenix, AZ
- Lake Powell, UT
- San Francisco, CA
- Los Angeles, CA
- Chicago, IL
- White Sands, NM
- Pennsylvania (especially Lancaster area)
- Florida
- Midwest Agricultural Area (Iowa, Kansas, North Dakota, etc.)
- Eastern United States
- Western United States
- Rest of United States (48 states)
- Alaska
- Hawaii

### PATH/ROW
- 15/33
- 29, 30, 31/36, 37
- 37, 38/35
- 37/37
- 37/34
- 44/34
- 41/36
- 22, 23/31
- 33/37
- (15/32)
# 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>X</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:

A

B

C

D

LATITUDE

LONGITUDE

D.M.S.

D.M.S.

LANDSAT-D WRS
(Do not complete)

PATH | ROW

|     |     |

|     |     |

|     |     |

|     |     |
DATA ACQUISITION SCHEDULE:

NIGHT JUSTIFICATION: __________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________

FIRST YEAR:  (82) JUL AUG SEP OCT NOV DEC
__________
(83) JAN FEB MAR APR MAY JUN
__________
SECOND AND THIRD YEARS:  (83/84) JUL AUG SEP OCT NOV DEC
__________
(84/85) JAN FEB MAR APR MAY JUN
__________

CLOUD COVER RESTRICTION: ______________%    

ARE IN SITU DATA BEING COLLECTED CONCURRENTLY?   YES NO

ANTICIPATED DATE(S) _______________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________

DATA PRODUCTS:

THEMATIC MAPPER:

<table>
<thead>
<tr>
<th>TAPES</th>
<th>FIlM</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BAND</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>
MULTISPECTRAL SCANNER:

<table>
<thead>
<tr>
<th>BAND</th>
<th>TAPES</th>
<th>FILM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCT-A</td>
<td>+P</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>+T</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>-T</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</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>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NONE</td>
<td>RADIOMETRIC</td>
<td>GEOMETRIC (NN OR CC RE-SAMPLING)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RAW</td>
<td>INTERNAL CALIBRATION</td>
<td>SCENE HISTOGRAM</td>
<td>SYSTEMATIC</td>
<td>GEODETiC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCROUNGE (BEFORE JULY 83)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCT-BT</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NOTE</td>
</tr>
<tr>
<td>CCT-AT</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCT-PT</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>NOTE</td>
<td></td>
</tr>
<tr>
<td>TIPS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NOTE</td>
</tr>
<tr>
<td>CCT-AT</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>NOTE</td>
<td></td>
</tr>
<tr>
<td>CCT-PT</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>NOTE</td>
<td></td>
</tr>
</tbody>
</table>

Note: Available as Soon as GCP Library can be Loaded

1-127
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
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>Absolute Integrating Sphere Calibration</th>
<th>External Calibration</th>
<th>Internal Calibration</th>
<th>Flooding Lamp Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Precision</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Signal-to-Noise</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anuta</th>
<th>Bender</th>
<th>Slater</th>
<th>Mallia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
### Sensor and Spacecraft Performance Characterization

#### Geometry of MSS

<table>
<thead>
<tr>
<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>
</tr>
<tr>
<td>Detector Location Relative to Reference Detector</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Between Scan Alignment</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ephemeris</th>
<th>Bernstein</th>
<th>Anuta</th>
<th>Bender</th>
<th>Keiffer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbital Support Competing Div.</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Global Positioning System (GPS)</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attitude</th>
<th>Bernstein</th>
<th>Anuta</th>
<th>Bender</th>
<th>Keiffer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angular Displacement Sensor (ADS)</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Inertial Reference System (DRIRU)</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Attitude Control System (ACS)</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<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>3right 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>
## Image Data Quality Performance Characterization

### Radiometry of MSS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Channel-to-Channel</td>
<td>Band-to-Band</td>
<td>Reflective Band</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Thermal Band</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Colewell</th>
<th>Bernstein</th>
<th>Anuta</th>
<th>Bender</th>
<th>Slater</th>
<th>Malila</th>
<th>Zobrist</th>
<th>Hovis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<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>
<td></td>
</tr>
<tr>
<td></td>
<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>
<td></td>
</tr>
<tr>
<td></td>
<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>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1-127
## Image Data Quality Performance Characterization

### Geometry of MSS

<table>
<thead>
<tr>
<th>Geometry of Image (Pixel Location)</th>
<th>Geometry of Pixel</th>
<th>Bernstein</th>
<th>Anuta</th>
<th>Bember</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>
<td></td>
</tr>
<tr>
<td>Scan Profile</td>
<td></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>
<td></td>
</tr>
<tr>
<td>Between Scan Alignment</td>
<td></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>
<td></td>
</tr>
<tr>
<td>Attitude</td>
<td></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>
<td></td>
</tr>
<tr>
<td>Reference Library Build</td>
<td></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>
<td></td>
</tr>
<tr>
<td>Resampling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# 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></td>
</tr>
<tr>
<td>Episodal Event</td>
<td>Geobotanical Anomalies</td>
<td></td>
</tr>
<tr>
<td>Soils</td>
<td>Topography (Stereo)</td>
<td></td>
</tr>
<tr>
<td>Classification</td>
<td>Episodal Event</td>
<td></td>
</tr>
<tr>
<td>Erosion</td>
<td></td>
<td>Coastal Zone</td>
</tr>
<tr>
<td>Moisture</td>
<td></td>
<td>Monitoring</td>
</tr>
<tr>
<td>Forests</td>
<td>Image-Science</td>
<td></td>
</tr>
<tr>
<td>Inventory</td>
<td>Pattern Recognition</td>
<td></td>
</tr>
<tr>
<td>Stand Evaluation</td>
<td>Information Extraction</td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Episodal Event</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation Inventory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Episodal Event</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1-139
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**
  - Minimum WRS Offset
  - Maximum WRS Offset

- **Adjacent Scene Overlap Area Comparisons**
  - Landsat-2/3 Overlap
  - Landsat-D 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></td>
<td>○ △</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>○</td>
<td>△</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</td>
<td></td>
<td>○ △</td>
</tr>
<tr>
<td>MSS Applications Information Report</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applications Notice Investigations</td>
<td></td>
<td>○ △</td>
</tr>
<tr>
<td>MSS Characterization Report</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Final = △
Draft = ○
John Barker

Ground Segmentation

Absolute Calibration

Spectral Information

Performance

MSS Radiometric Sensor
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 WIDTH (nm)</th>
<th>SLOPE INTERVAL (nm) FROM 5% TO 50%</th>
<th>SPECTRAL FLATNESS (%) OVER CENTRAL 70%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HALF POWER POINTS LOWER</td>
<td>UPPER</td>
<td>LOWER</td>
<td>UPPER</td>
</tr>
<tr>
<td>1</td>
<td>500 ± 10</td>
<td>600 ± 10</td>
<td>—</td>
<td>&lt;20</td>
</tr>
<tr>
<td>2</td>
<td>600 ± 10</td>
<td>700 ± 10</td>
<td>—</td>
<td>&lt;20</td>
</tr>
<tr>
<td>3</td>
<td>700 ± 10</td>
<td>800 ± 10</td>
<td>—</td>
<td>&lt;20</td>
</tr>
<tr>
<td>4</td>
<td>800 ± 10</td>
<td>1100± ± 10</td>
<td>—</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$^a$ (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>7</td>
<td>603</td>
<td>708*</td>
<td>105*</td>
</tr>
<tr>
<td>8</td>
<td>602</td>
<td>696</td>
<td>34</td>
</tr>
<tr>
<td>PROTO-FLIGHT</td>
<td>9</td>
<td>603</td>
<td>696</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>FLIGHT</td>
<td>7</td>
<td>603</td>
<td>697</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 (600-700 nm) 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(^{a}) (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>
<td>UPPER</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>
<tr>
<td><strong>MEANS</strong></td>
<td>603</td>
<td>701</td>
<td>97</td>
<td>15</td>
</tr>
<tr>
<td>1</td>
<td>603</td>
<td>701</td>
<td>97</td>
<td>15</td>
</tr>
<tr>
<td>2*</td>
<td>607</td>
<td>710</td>
<td>103</td>
<td>14</td>
</tr>
<tr>
<td>2**</td>
<td>607</td>
<td>710</td>
<td>103</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>606</td>
<td>705</td>
<td>100</td>
<td>14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>LOWER</th>
<th>UPPER</th>
<th>LOWER</th>
<th>UPPER</th>
<th>POSITIVE</th>
<th>NEGATIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PF*</td>
<td>0.7</td>
<td>4.7</td>
<td>4.8</td>
<td>0.5</td>
<td>1.9</td>
<td>1.4</td>
</tr>
<tr>
<td>PF**</td>
<td>0.8</td>
<td>0.8</td>
<td>0.6</td>
<td>0.5</td>
<td>1.4</td>
<td>1.5</td>
</tr>
<tr>
<td>F</td>
<td>0.4</td>
<td>0.6</td>
<td>0.5</td>
<td>0.4</td>
<td>0.9</td>
<td>1.2</td>
</tr>
<tr>
<td><strong>STANDARD DEVIATIONS</strong></td>
<td>1</td>
<td>3.5</td>
<td>2.2</td>
<td>2.8</td>
<td>1.7</td>
<td>3.4</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>
</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>
</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>
</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.

1-149
**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>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>SOYBEANS</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*</td>
<td>45.80</td>
</tr>
<tr>
<td></td>
<td>LSD-F</td>
<td>19.25</td>
<td>14.72</td>
<td>82.81*</td>
<td>45.39</td>
</tr>
<tr>
<td></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>
</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>
</tr>
<tr>
<td></td>
<td>LS3</td>
<td>19.77</td>
<td>15.36</td>
<td>73.93</td>
<td>47.55</td>
</tr>
<tr>
<td>SOIL</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>18.61</td>
</tr>
<tr>
<td></td>
<td>LSD-F</td>
<td>28.39</td>
<td>34.75</td>
<td>41.05</td>
<td>18.48</td>
</tr>
<tr>
<td></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>
</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>
</tr>
<tr>
<td></td>
<td>LS3</td>
<td>28.33</td>
<td>34.66</td>
<td>41.10</td>
<td>19.15</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 (1,2,3) EXCEED: (1) AND (2) AS ABOVE.*

---

**NOTES:**

- 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.
- LANDSAT-D BANDS 1, 2, 3 AND 4 CORRESPOND TO BANDS 4, 5, 6 AND 7, RESPECTIVELY ON PREVIOUS LANDSATS.
- MEAN IN PARENTHESES IS WITH OUTLIER CHANNEL EXCLUDED.
- EXCLUSION OF OUTLIER DID NOT CHANGE BAND MEAN.

---

*Page 1 of 2*
BAND 1 MSS-D DIFFERENCES

SPECTRAL RADIANCE, $L_{\lambda}$ (mW/cm² • ster • µm)

WAVELENGTH, $\lambda$ (nm)

RELATIVE SPECTRAL RESPONSE, RSR (%)

PF, F AVERAGE

LS 1, 2, 3 AVERAGE

SOIL

SOYBEANS

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

RELATIVE SPECTRAL RESPONSE, RSR

BAND 4 MSS-D APPARENT DIFFERENCES

 Spectral Radiance, L(\nu) (\text{W cm}^{-2} \text{ster}^{-1} \text{um}^{-1})

WAVELENGTH, \lambda (\text{nm})
### SIMULATED MAXIMUM WITHIN-BAND SENSOR OUTPUT DIFFERENCES

<table>
<thead>
<tr>
<th>TARGET</th>
<th>SENSOR</th>
<th>BAND 1</th>
<th>BAND 2</th>
<th>BAND 3</th>
<th>BAND 4</th>
<th>BAND 1</th>
<th>BAND 2</th>
<th>BAND 3</th>
<th>BAND 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DIGITAL COUNTS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PERCENT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOYBEANS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD-PF</td>
<td>0.11</td>
<td>0.91</td>
<td>2.23</td>
<td>[1.43]</td>
<td>0.6</td>
<td>6.2</td>
<td>2.8</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>LSD-F</td>
<td>0.17</td>
<td>0.10</td>
<td>[0.78]</td>
<td>1.04</td>
<td>0.9</td>
<td>0.7</td>
<td>0.9</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>LS1</td>
<td>0.75</td>
<td>0.12</td>
<td>2.39</td>
<td>0.63</td>
<td>3.9</td>
<td>0.8</td>
<td>3.1</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>LS2</td>
<td>0.16</td>
<td>0.77</td>
<td>3.63</td>
<td>0.39</td>
<td>0.8</td>
<td>4.8</td>
<td>4.6</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>LS3</td>
<td>0.30</td>
<td>0.16</td>
<td>4.01</td>
<td>0.80</td>
<td>1.5</td>
<td>1.0</td>
<td>5.4</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOIL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD-PF</td>
<td>0.03</td>
<td>0.07</td>
<td>0.10</td>
<td>0.46</td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>LSD-F</td>
<td>0.01</td>
<td>0.05</td>
<td>0.02</td>
<td>0.32</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>LS1</td>
<td>0.10</td>
<td>0.09</td>
<td>0.04</td>
<td>0.21</td>
<td>0.3</td>
<td>0.3</td>
<td>0.1</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>LS2</td>
<td>0.05</td>
<td>0.03</td>
<td>0.06</td>
<td>0.12</td>
<td>0.2</td>
<td>0.1</td>
<td>0.2</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>LS3</td>
<td>0.07</td>
<td>0.09</td>
<td>0.13</td>
<td>0.26</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
<td>1.4</td>
<td></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.
**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
\( \theta_y, \theta_p, \theta_r \)

Ephemeris
\( \alpha, \beta, \gamma \)

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
Landsat-D Protosflight 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
Landsat MSS Absolute Radiometric Calibration

- Fiber Bundle Ends at Focus
- Secondary Mirror
- Scan Mirror
- Primary Mirror
- Detectors (1 to 24)
- 24 Video Outputs
- Shutter Wheel
- 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
MSS CALIBRATION: DEFINITION OF VARIABLES

\( R_{jk} = \) INTEGRATING SPHERE RADIANCE FOR SPHERE LEVEL \( j \) AND MSS CHANNEL \( k \)

\[
R_{jk} = BW_k \frac{\int RW_j RSR_k \, d\lambda}{\int RSR_k \, d\lambda}
\]

\( BW_k = \) MEASURED BANDWIDTH OF CHANNEL \( k \)

\( RSR_k = \) MEASURED RELATIVE SPECTRAL RESPONSE FOR CHANNEL \( k \)

\( RW_j = \) SPECTRAL RADIANCE FOR 76 cm INTEGRATING SPHERE FOR SPHERE LEVEL \( j \)
Spectral Radiant Emittance Plot for 76 cm Integrating Sphere
Illustrative MSS/PF Lamp Calibration Wedge

Q = 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>98.72</td>
</tr>
</tbody>
</table>

Cal Wedge Word i (Number)
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.)

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

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

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

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

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

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

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

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

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

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

\[ L = \text{LINE NUMBER} \]
INTEGRATING SPHERE RADIANCE LEVEL

<table>
<thead>
<tr>
<th>$R_J$ (mW cm$^{-2}$ sr$^{-1}$)</th>
<th>$V_J$ (DIGITAL COUNTS)</th>
<th>$Q_{iJ}$ (DIGITAL COUNTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>.04</td>
<td>2.1</td>
<td>97.03</td>
</tr>
<tr>
<td>.09</td>
<td>3.5</td>
<td>97.89</td>
</tr>
<tr>
<td>.12</td>
<td>5.5</td>
<td>98.72</td>
</tr>
<tr>
<td>.17</td>
<td>7.7</td>
<td>98.65</td>
</tr>
<tr>
<td>.33</td>
<td>15.4</td>
<td>99.94</td>
</tr>
<tr>
<td>.48</td>
<td>22.2</td>
<td>101.75</td>
</tr>
<tr>
<td>.64</td>
<td>29.4</td>
<td>99.98</td>
</tr>
<tr>
<td>.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>

$$\bar{Q}_1 = \frac{1}{9} \sum_{j=1}^{9} Q_{1j} = 100.08$$

ILLUSTRATES HYSTERESIS DEPENDENCE 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

$$Q_{i,j} = A_j + B_j \bar{Q}_i$$

- 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></th>
<th>(Q_1) (DIGITAL COUNTS)</th>
<th>(Q_{ij}) (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_{ij} = A_j + B_j \bar{Q}_i)</td>
</tr>
<tr>
<td>230</td>
<td>100.1</td>
<td>105.2</td>
<td></td>
</tr>
<tr>
<td>240</td>
<td>95.1</td>
<td>99.7</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>90.0</td>
<td>94.6</td>
<td></td>
</tr>
<tr>
<td>260</td>
<td>85.7</td>
<td>90.7</td>
<td></td>
</tr>
<tr>
<td>270</td>
<td>81.3</td>
<td>85.9</td>
<td></td>
</tr>
<tr>
<td>280</td>
<td>77.5</td>
<td>81.6</td>
<td></td>
</tr>
<tr>
<td>290</td>
<td>73.0</td>
<td>77.1</td>
<td></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>

**For brightest sphere level J with**

\[ R_j = 1.95 \text{ MW cm}^{-2} \text{ sr}^{-1} \]

**Hysteresis Offset**

\[ A_j = .02 \]

**Hysteresis Gain**

\[ B_j = 1.054 \]

\[ R^2 = .99996 \]
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 $v_j$</th>
<th>LINEAR REGRESSION COEFFS $Q_{ij} = A_j + B_j \bar{q}_i$</th>
<th>ADJUSTED VIDEO LEVEL $v_{aj} = \frac{v_j - A_j}{B_j}$</th>
<th>SPHERE RADIANCE $R_i^j$ (mWcm⁻²sr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$v_j$ (DIGITAL COUNTS)</td>
<td>$A_j$</td>
<td>$B_j$</td>
<td>$v_{aj}$ (DIGITAL COUNTS)</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>-------------</td>
<td>-------------</td>
<td>--------------------------</td>
</tr>
<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 \( p, q \)

\[ Q_1 = p + qR_1 \]

\[ R_1 = \frac{Q_1 - p}{q} \]
**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>I</td>
<td>( \bar{Q}_I )</td>
<td>( \frac{\bar{Q}_I - P}{q} )</td>
</tr>
<tr>
<td></td>
<td>(Digital Counts)</td>
<td>(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>

1-170
### 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 (Digital Counts)</th>
<th>Calculated Radiance for Wedge Word (MW cm⁻² sr⁻¹)</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>.091</td>
</tr>
<tr>
<td>820</td>
<td>3.85</td>
<td>.086</td>
</tr>
</tbody>
</table>
INTERNAL LAMP RADIANCE VALUES FOR SIX CALIBRATION WORD LOCATIONS FOR MSS/PF BAND 1

<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>
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>

Equivalent Lamp Calibration Radiance, \( R_i \) (mW cm\(^{-2}\) ster\(^{-1}\))
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>0.1641</td>
<td>-0.054</td>
<td>0.1418</td>
<td>-0.024</td>
<td>0.1195</td>
<td>0.006</td>
</tr>
<tr>
<td>0.1689</td>
<td>-0.053</td>
<td>-0.1457</td>
<td>-0.023</td>
<td>0.1244</td>
<td>0.005</td>
</tr>
<tr>
<td>0.1648</td>
<td>-0.052</td>
<td>0.1420</td>
<td>-0.022</td>
<td>0.1220</td>
<td>0.005</td>
</tr>
<tr>
<td>0.1691</td>
<td>-0.052</td>
<td>0.1461</td>
<td>-0.022</td>
<td>0.1247</td>
<td>0.005</td>
</tr>
<tr>
<td>0.1688</td>
<td>-0.053</td>
<td>0.1474</td>
<td>-0.025</td>
<td>0.1225</td>
<td>0.007</td>
</tr>
<tr>
<td>0.1690</td>
<td>-0.053</td>
<td>0.1450</td>
<td>-0.022</td>
<td>0.1240</td>
<td>0.005</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
<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>.403</td>
<td>-.051</td>
<td>.352</td>
<td>-.021</td>
<td>.296</td>
<td>.008</td>
<td>.248</td>
<td>.034</td>
<td>-.652</td>
<td>.514</td>
<td>-.653</td>
<td>.515</td>
</tr>
<tr>
<td>2</td>
<td>.419</td>
<td>-.049</td>
<td>.361</td>
<td>-.020</td>
<td>.309</td>
<td>.008</td>
<td>.257</td>
<td>.034</td>
<td>-.671</td>
<td>.513</td>
<td>-.674</td>
<td>.514</td>
</tr>
<tr>
<td>3</td>
<td>.409</td>
<td>-.049</td>
<td>.352</td>
<td>-.019</td>
<td>.303</td>
<td>.007</td>
<td>.254</td>
<td>.032</td>
<td>-.657</td>
<td>.513</td>
<td>-.660</td>
<td>.515</td>
</tr>
<tr>
<td>4</td>
<td>.419</td>
<td>-.049</td>
<td>.362</td>
<td>-.019</td>
<td>.309</td>
<td>.008</td>
<td>.260</td>
<td>.033</td>
<td>-.674</td>
<td>.513</td>
<td>-.677</td>
<td>.515</td>
</tr>
<tr>
<td>5</td>
<td>.419</td>
<td>-.050</td>
<td>.366</td>
<td>-.022</td>
<td>.303</td>
<td>.009</td>
<td>.255</td>
<td>.035</td>
<td>-.670</td>
<td>.513</td>
<td>-.674</td>
<td>.515</td>
</tr>
<tr>
<td>6</td>
<td>.420</td>
<td>-.050</td>
<td>.360</td>
<td>-.019</td>
<td>.307</td>
<td>.008</td>
<td>.260</td>
<td>.033</td>
<td>-.671</td>
<td>.513</td>
<td>-.675</td>
<td>.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

0 CALCULATE SIX AVERAGE CALIBRATION WEDGE VALUES, Q, FOR EACH CHANNEL
0 CALCULATE INITIAL GAIN (G) AND BIAS (B) FOR EACH CHANNEL
0 CALCULATE POST-LAUNCH MODIFIERS
0 CALCULATE A BAND NORMALIZED RLUT BY CHANNEL
CALCULATE SIX AVERAGE CALIBRATION WEDGE VALUES
FOR EACH CHANNEL IN THE SEGMENT

0 DECOMPRESS THE SIX CALIBRATION WEDGE DIGITAL VALUES, \( Q \), ACQUIRED ON EVERY OTHER SCAN, FROM (0 - 63) TO (0 - 127)

0 CALCULATE AVERAGE CALIBRATION WEDGE VALUE, \( \bar{Q} \), FOR EACH WORD

<table>
<thead>
<tr>
<th>SCANNING</th>
<th>WORD NUMBER</th>
<th>WORD LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCAN N</td>
<td>I</td>
<td>( N_i )</td>
</tr>
<tr>
<td>SCAN 3</td>
<td>1</td>
<td>230</td>
</tr>
<tr>
<td>SCAN 5</td>
<td>2</td>
<td>240</td>
</tr>
<tr>
<td>SCAN 1</td>
<td>3</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>810</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>820</td>
</tr>
</tbody>
</table>

\[
\overline{Q}_{230} \quad \overline{Q}_{240} \quad \overline{Q}_{250} \quad \overline{Q}_{260} \quad \overline{Q}_{810} \quad \overline{Q}_{820}
\]

AVERAGE \( Q \)
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:

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

M = 1 AND A = 0 UNTIL TIME OF UPDATE
CALCULATE A BAND NORMALIZED RLUT
(FOR EACH CHANNEL)

COMPUTE A SEGMENT SPECIFIC RLUT:

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

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, MEAN(RH), AND STANDARD DEVIATION, SD(RH), AS THE BAND AVERAGE HISTOGRAM, RH, USING THE FOLLOWING FORMULA

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

\[ \bar{R}_H = G \cdot R_H + b \]
\[ g = \frac{SD(\bar{R}_H)}{SD(R_H)} \]
\[ b = MEAN(\bar{R}_H) - g \cdot MEAN(R_H) \]

CALCULATE A HISTOGRAM NORMALIZED GAIN, G'', AND BIAS, B''

\[ G'' = \frac{G'}{g} \]
\[ B'' = B - G' \cdot b \]
Scene Segment Blending

Example of Segment Blending With Number
Of Segments = 4
Number of Sub-Segments/Segment = 3

\[ \frac{1}{2} G_1 + \frac{1}{2} G_2, \frac{1}{2} B_1 + \frac{1}{2} B_2 \]
\[ \frac{1}{2} G_1 + \frac{1}{2} G_2, \frac{1}{2} B_1 + \frac{1}{2} B_2 \]
\[ \frac{1}{2} G_2 + \frac{1}{2} G_1, \frac{1}{2} B_2 + \frac{1}{2} B_1 \]

\[ \frac{1}{2} G_3 + \frac{1}{2} G_2, \frac{1}{2} B_3 + \frac{1}{2} B_2 \]
# Protoflight MSS-D
## Geometric Performance Summary

<table>
<thead>
<tr>
<th></th>
<th>SPEC</th>
<th>ACTUAL</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>**MTF (10</td>
<td>2 μrad bars)**</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

Beginning of Scan (BOS) Bumper

Scan Center Line

Reverse Scan

Active Scan

Scan Period 73.42 ms (NOM)

Active Scan Period 32.3 ms (NOM)

End of Scan (EOS) Bumper Position

SMP = Scan Monitor Pulse

SMP1

SMP3

Original page is of poor quality
MSS Detector Sampling Sequence

Band

4 3 2 1

A,19 ↔ A,13
B,20 ↔ B,14
C,21 ↔ C,15
D,22 ↔ D,16
E,23 ↔ E,17
F,24 ↔ F,18

A,7 ↔ A,1
B,8 ↔ B,2
C,9 ↔ C,3
D,10 ↔ D,4
E,11 ↔ E,5
F,12 ↔ F,6

Fiber Optics

Sequence Indicator

1-195
MSS Scan Mirror Co-ordinate System

Telescope Axis

Local Horizontal

Telescope

BOS Bumper

EOS Bumper

Scan Mirror

Local Vertical

45°

Y

Mirror Normal

H = View Angle (H = 2Y if X = 0)

Y = Mirror Angle

X = Jitter Angle

Line of Sight

Local Vertical

1-196
Scan Profile Equations

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

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

\[ H = 2y - x \]

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

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

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

\[ F = \frac{1}{\omega} \tan^{-1} \left[ \frac{\sin \omega P}{x(P) - y_p(P) - S_0} \right] \]

\[ x(P) = A_0 \sin (\omega_0 P + \phi) \]

\[ x(0) = A_0 \sin \phi \]

\[ y_p(P) = B \sin (\omega_0 P + \phi) + C \cos (\omega_0 P + \phi) \]

\[ y_p(0) = B \sin \phi + C \cos \phi \]

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

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

\[ \omega = \omega_1 \left[1 - \left(\frac{\omega_1}{2q}\right)^2\right]^{1/2}, \quad \omega_1 = \sqrt{\frac{k}{I}}, \quad q = \frac{k}{\nu} \]
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

![Graph showing the active scan mirror profile with markers for Beginning of Scan (BOS), SMP1 (First Scan Monitor Pulse), Scan Center Line, End of Scan (EOS), SMP3 (Third Scan Monitor Pulse). The graph plots View Angle, H, (Radians) against Time, t, (Milliseconds from BOS).]
Landsat-D MSS/PF Calculated Deviation from Linear Scan

(ASSUMES NO DAMPING)

Deviation from Linear Scan, V_2, (μ Radians)*

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)

Deviations from Linear Scan, \( V_2 \) (\( \mu \)Radians) *

<table>
<thead>
<tr>
<th>Time, t, (Milliseconds from BOS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>30</td>
</tr>
</tbody>
</table>

*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>0.9851091E-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>0.8521397E-02</td>
<td>4.2606987E-02</td>
</tr>
<tr>
<td>0.00646</td>
<td>0.7872078E-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>0.65631258E-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>0.01105</td>
<td>0.3949306E-02</td>
<td>1.9746953E-02</td>
</tr>
<tr>
<td>0.011125</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>9.8816316E-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>0.65893536E-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>0.0163575</td>
<td>-6.5835389E-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>
<tr>
<td>T(SEC)</td>
<td>H(RAD)</td>
<td>Y(RAD)</td>
</tr>
<tr>
<td>--------</td>
<td>--------------</td>
<td>----------------</td>
</tr>
<tr>
<td>0.0201875</td>
<td>-3.2922933E-02</td>
<td>-1.6461467E-02</td>
</tr>
<tr>
<td>0.020995</td>
<td>-3.943906E-02</td>
<td>-1.9746953E-02</td>
</tr>
<tr>
<td>0.0219025</td>
<td>-4.6057458E-02</td>
<td>-2.3028729E-02</td>
</tr>
<tr>
<td>0.02261</td>
<td>-5.2612354E-02</td>
<td>-2.6306177E-02</td>
</tr>
<tr>
<td>0.0234175</td>
<td>-5.915764E-02</td>
<td>-2.9578682E-02</td>
</tr>
<tr>
<td>0.024225</td>
<td>-6.5691258E-02</td>
<td>-3.2845629E-02</td>
</tr>
<tr>
<td>0.0250325</td>
<td>-7.2212807E-02</td>
<td>-3.6196404E-02</td>
</tr>
<tr>
<td>0.02584</td>
<td>-7.8720787E-02</td>
<td>-3.9360393E-02</td>
</tr>
<tr>
<td>0.0266475</td>
<td>-8.5213973E-02</td>
<td>-4.2606987E-02</td>
</tr>
<tr>
<td>0.027455</td>
<td>-9.1691147E-02</td>
<td>-4.5845574E-02</td>
</tr>
<tr>
<td>0.0282625</td>
<td>-9.8151091E-02</td>
<td>-4.9075546E-02</td>
</tr>
<tr>
<td>0.02907</td>
<td>-1.0459259</td>
<td>-5.2296296E-02</td>
</tr>
<tr>
<td>0.0298775</td>
<td>-1.1101444</td>
<td>-5.5507218E-02</td>
</tr>
<tr>
<td>0.030685</td>
<td>-1.1741542</td>
<td>-5.8707711E-02</td>
</tr>
<tr>
<td>0.0314925</td>
<td>-1.2379434</td>
<td>-6.1897171E-02</td>
</tr>
<tr>
<td>0.0323</td>
<td>-1.3015000</td>
<td>-6.5075000E-02</td>
</tr>
</tbody>
</table>
Scan Profile with Damping Coefficient $v = 107 \times 10^{-6}$ ft. - 16 - ser/rad

<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>0.0003075</td>
<td>0.12379288</td>
<td>6.1896439E-02</td>
</tr>
<tr>
<td>0.001613</td>
<td>0.11741256</td>
<td>5.8766282E-02</td>
</tr>
<tr>
<td>0.0024225</td>
<td>0.11101026</td>
<td>5.5505130E-02</td>
</tr>
<tr>
<td>0.00323</td>
<td>0.10458717</td>
<td>5.2293583E-02</td>
</tr>
<tr>
<td>0.0040375</td>
<td>0.9814493E-02</td>
<td>4.9072246E-02</td>
</tr>
<tr>
<td>0.004845</td>
<td>0.91683448E-02</td>
<td>4.5841724E-02</td>
</tr>
<tr>
<td>0.0056525</td>
<td>0.85205248E-02</td>
<td>4.2602624E-02</td>
</tr>
<tr>
<td>0.00646</td>
<td>0.78711118E-02</td>
<td>3.9355555E-02</td>
</tr>
<tr>
<td>0.0072675</td>
<td>0.72202253E-02</td>
<td>3.6101127E-02</td>
</tr>
<tr>
<td>0.008075</td>
<td>0.65679902E-02</td>
<td>3.2839951E-02</td>
</tr>
<tr>
<td>0.0088825</td>
<td>0.59145282E-02</td>
<td>2.9572641E-02</td>
</tr>
<tr>
<td>0.00969</td>
<td>0.52996222E-02</td>
<td>2.6298111E-02</td>
</tr>
<tr>
<td>0.0104975</td>
<td>0.46044150E-02</td>
<td>2.3022075E-02</td>
</tr>
<tr>
<td>0.011305</td>
<td>0.39480101E-02</td>
<td>1.9740050E-02</td>
</tr>
<tr>
<td>0.0121125</td>
<td>0.32908715E-02</td>
<td>1.6454353E-02</td>
</tr>
<tr>
<td>0.01292</td>
<td>0.26331201E-02</td>
<td>1.3165600E-02</td>
</tr>
<tr>
<td>0.0137275</td>
<td>0.19748822E-02</td>
<td>9.8744108E-03</td>
</tr>
<tr>
<td>0.014535</td>
<td>0.13162805E-02</td>
<td>6.5814027E-03</td>
</tr>
<tr>
<td>0.0153425</td>
<td>0.65743898E-03</td>
<td>3.2871349E-03</td>
</tr>
<tr>
<td>0.01615</td>
<td>-1.5187312E-05</td>
<td>-7.5936560E-06</td>
</tr>
<tr>
<td>0.0169575</td>
<td>-6.6046875E-03</td>
<td>-3.3023438E-03</td>
</tr>
<tr>
<td>0.0177635</td>
<td>-1.3192873E-02</td>
<td>-6.5964363E-03</td>
</tr>
<tr>
<td>0.0185725</td>
<td>-1.9778505E-02</td>
<td>-9.8892523E-03</td>
</tr>
<tr>
<td>0.01933</td>
<td>-2.6360346E-02</td>
<td>-1.3180173E-02</td>
</tr>
<tr>
<td>0.0201875</td>
<td>-3.2937168E-02</td>
<td>-1.6465580E-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>-3.95077711E-02</td>
<td>-1.9753855E-02</td>
</tr>
<tr>
<td>0.0218025</td>
<td>-4.6070764E-02</td>
<td>-2.3033382E-02</td>
</tr>
<tr>
<td>0.02261</td>
<td>-5.2625088E-02</td>
<td>-2.3312543E-02</td>
</tr>
<tr>
<td>0.0234175</td>
<td>-5.9163445E-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>-7.2223360E-02</td>
<td>-3.6111680E-02</td>
</tr>
<tr>
<td>0.02584</td>
<td>-7.3730463E-02</td>
<td>-3.9365231E-02</td>
</tr>
<tr>
<td>0.0266475</td>
<td>-8.5222698E-02</td>
<td>-4.2611349E-02</td>
</tr>
<tr>
<td>0.027455</td>
<td>-9.1698845E-02</td>
<td>-4.5849432E-02</td>
</tr>
<tr>
<td>0.0282625</td>
<td>-9.8157899E-02</td>
<td>-4.9078845E-02</td>
</tr>
<tr>
<td>0.02907</td>
<td>-1.0459802</td>
<td>-5.2295008E-02</td>
</tr>
<tr>
<td>0.0298775</td>
<td>-1.1101861</td>
<td>-5.550307E-02</td>
</tr>
<tr>
<td>0.030685</td>
<td>-1.1741328</td>
<td>-5.8703139E-02</td>
</tr>
<tr>
<td>0.0314925</td>
<td>-1.2379581</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 \mu\text{sec.}

\begin{align*}
V_0 &= \text{Error Remaining after "Rubberband" Correction} \\
V_1 &= \text{Error Resulting from Shortened Line Length if Baseline Profile is Used} \\
V_2 &= \text{Deviation from Linear Scan}
\end{align*}
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

GEODETIC RECTIFICATION

TEMPORAL REGISTRATION WITH REGISTRATION CONTROL POINTS

GEODETIC CORRECTION REQUIREMENTS
90% OF THE TIME

GEODETIC
0.5 PIXEL

TEMPORAL
0.3 PIXEL (REGISTRANT TO REFERENCE)
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

- **CATAGEORIES 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 $\sigma_M^2$. 

1-215
# Multispectral Scanner Temporal Registration Error

## In Pixel (117.2 μm) 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√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√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>0.269</td>
<td>0.318</td>
</tr>
<tr>
<td>• Systematic Correction Data Generation</td>
<td>0.030√2</td>
<td>0.030√2</td>
</tr>
<tr>
<td>• Geodetic Correction Data Generation</td>
<td>0.030√2</td>
<td>0.030√2</td>
</tr>
<tr>
<td>• Correction Data Interpolation</td>
<td>0.030√2</td>
<td>0.030√2</td>
</tr>
<tr>
<td>• Resampling</td>
<td>0.014√2</td>
<td>0.014√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
OVERVIEW OF GEOMETRIC CORRECTION (CONTINUED)

- REFORMATTTING 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

1-219
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

\[ f(i) = 2 \cdot e^{-\beta(t-t_0)} \left\{ a \sin \omega(t_0 + [i-1] \Delta t) \right\} \]

- \( f \) = Scan Angle
- \( i \) = Pixel Number
- \( \Delta t \) = Sampling Time
- \( t_0 \) = Line Start 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)

![Diagram depicting the coordinate system with labels for WRS Scene Center and Ground Track (Nominal).]
Oblique Mercator Coordinates For The Sphere

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

\[ y = R_e \cdot \alpha \]

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

- Highly Conformal With Scene
- Good Local Approximation to Space Oblique Mercator

\[ 1-223 \]
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 \((\phi, \lambda')\)

\[
\hat{R}_{LP} (\phi, \lambda') = \hat{R}_{S/C}(t) + d\hat{\omega}(t)
\]

- From Pixel Number \(i\)

- Scan Line \(j\)

- Scene Center Time

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

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

- Transform to ECEF Coordinates

\[
\lambda (i, \hat{\omega}) \text{ From } \lambda', \text{ Earth Spin}
\]

- Transform \((\phi, \lambda)\) 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)

\[
\begin{align*}
X₀ &= f₀(i, j) \\
Y₀ &= g₀(i, j)
\end{align*}
\]

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

• Highly Linear in Spacecraft Parameter Biases

\[
\begin{align*}
    x(i, j, \theta) &= x_0(i, j) + \frac{\lambda}{2} \frac{\partial x(i, j)}{\partial \theta} \delta \theta(i, j) \\
y(i, j, \theta) &= y_0(i, j) + \frac{\lambda}{2} \frac{\partial y(i, j)}{\partial \theta} \delta \theta(i, j)
\end{align*}
\]

• Analytic Expressions for Partial Derivatives Defined Over Entire Grid

• Spacecraft Parameter Biases

- \( \delta \lambda \) - Bias in Oblique Longitude
- \( \delta \beta \) - Bias in Oblique Latitude
- \( \delta \rho \) - Bias in S/C Radial Location
- \( \delta \phi \) - Pitch Angle
- \( \delta \alpha \) - Roll Angle
- \( \delta \gamma \) - Yaw Angle

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

- $\text{SCF}_0$ 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 Sufficient
- 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 (Tast on Angular Momentum)
- Bad Data Point Count/Residuals for Quality
- Mean Residual Error (Exclusive of Bias) — approximately 10M
Source of Ephemeris

NASA GSFC OCC

Fourier Series Coefficients

Telemetry $x, y, z$

Every 0.192 Secs

GPS $x_o, y_o, z_o$

S/C OBC $x_1, y_1, z_1$

$x_2, y_2, z_2$

$\vdots$

$x_j, y_j, z_j$

$\vdots$
Ephemeris Data Smoothing

- Outlier rejection criterion: angular momentum error > 0.002 $\times$ 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

Validity Check

△θ

512 M3

Amplitude/Phase Compensation

Last DRIRU Driit Estimate in Interval

First Quaternion in the Interval

DRIRU Measurement Compensation

Euler Parameter Integration

MSS Attitude (Roll, Pitch, Yaw)

612 MS Grid

Example of Quaternion
In Small Angle Approximation

\[
\begin{align*}
\theta_1 & \approx \frac{1}{2} \theta_r \\
\theta_2 & \approx \frac{1}{2} \theta_r \\
\theta_3 & \approx \frac{1}{2} \theta_r \\
\theta_4 & \approx 1.0
\end{align*}
\]
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:
- Scene Center
- Nominal Ground Track
- WRS Scene Center
- Midscan Ground Trace
- Intersection
- Earth Center
MSS Data Flow In GCDG

1. Locate CP in Video Data

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

3. Filter

4. Scene Center and SCF Updates/Map Projections

CPN Extraction Parameters

MSS Data Extraction
- Radiometric Correction Data Dept

RLUT

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

Band Line Adjustment (BLA) MSCD

CP Data

\[ \Delta x(t_k^i, j_k^i, \tau_k) \]
\[ \Delta y(t_k^i, j_k^i, \tau_k) \]

\[ \tau_k = 1/NCP \]

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

Geodetic Correction Functions (GCF)
Properties/Effects Of $\delta$ For Landsat-D MSS

(Single Scene)

- Constant $\delta$

- $\delta_\omega, \delta_\Theta$  - Along Track Displacement

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

- $\delta_\Theta$  - Along Track Asymmetry

- $\delta_\eta$  - 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

- $S_L$ and $S_{\theta_p}$ Hard to Separate — Represented by Single Variable — $S_{AT}$, For Along Track Translations
- $S_{\beta}$ and $S_{\theta_R}$ Hard to Separate — Represented by Single Variable $S_{CT}$, 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>$S_{AT}$</td>
<td>Along Track Shift</td>
<td>$&gt; 10$</td>
</tr>
<tr>
<td>$S_{CT}$</td>
<td>Cross Track Shift</td>
<td>$&gt; 10$</td>
</tr>
<tr>
<td>$S_L$</td>
<td>Cross Track Magnification</td>
<td>$\sim 0.1$</td>
</tr>
<tr>
<td>$S_{\theta_y}$</td>
<td>Along Track Skew</td>
<td>$\sim 0.8$</td>
</tr>
<tr>
<td>$S_{AT}$</td>
<td>Along Track Magnification</td>
<td>$\sim 0.1$</td>
</tr>
<tr>
<td>$S_{CT}$</td>
<td>Cross Track Skew</td>
<td>$\sim 0.1$</td>
</tr>
</tbody>
</table>
Basis Of The MSS Filter

- Linearity of SCF with $\delta = (\delta_x, \delta_y, \delta_z, \delta_{\theta_x}, \delta_{\theta_y}, \delta_{\theta_z})$

- Availability of Analytic Partial Derivatives

$$\mu_{x_{\epsilon}}(i,j) = \frac{\partial X(i,j)}{\partial \delta_\epsilon}$$
$$\mu_{y_{\epsilon}}(i,j) = \frac{\partial Y(i,j)}{\partial \delta_\epsilon}$$

$$\Delta X(i,j) = \sum_{\epsilon} \mu_{x_{\epsilon}}(i,j) \cdot \Delta \delta_\epsilon(i,j)$$
$$\Delta Y(i,j) = \sum_{\epsilon} \mu_{y_{\epsilon}}(i,j) \cdot \Delta \delta_\epsilon(i,j)$$

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

$$\frac{N_{CP}}{\sigma_x^2} \left( \frac{\bar{e}_x^2}{\sigma_x^2} + \frac{\bar{e}_y^2}{\sigma_y^2} \right) \equiv \frac{F(\delta)}{\sigma_x^2}$$

Where

$$\bar{e}_\delta^2 = \frac{1}{N_{CP}} \sum_{k=1}^{N_{CP}} \left( \Delta \delta_k - \sum_{l} \mu_{x_{\epsilon}}(i_l^k, j_l^k) \cdot \Delta \delta_{\epsilon}(i_l^k, j_l^k) \right)^2$$

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: $sCT, sR, s\dot{CT}$
  - COMPUTE X-QUALITY FOR
    1. ALL 3 VARIABLES
    2. $sCT$ AND EACH OF 2 INDIVIDUALS
    3. $sCT$ ALONE
  - RETAIN VARIABLE SET THAT PRODUCES BEST QUALITY

• Y CORRECTING BIASES: $sAT, s\dot{e}_Y, s\dot{AT}$
  - PROCEED AS FOR X, USING Y-QUALITY
  - RETAIN VARIABLE SET THAT PRODUCES BEST QUALITY

• REPORT VARIABLE SET USED, X- AND Y- QUALITY
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 \( (\mathbf{x}) \)
- 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
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>ADMS</td>
<td>Applications Developmental Data System</td>
</tr>
<tr>
<td>ADPS</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>ADPE</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>AF1HC</td>
<td>Air Force Global Weather Central</td>
</tr>
<tr>
<td>AFOS</td>
<td>Automation of Field Operations and Services</td>
</tr>
<tr>
<td>APFRO</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>AGSPO</td>
<td>Aerospace Group Strategic Planning and Programs 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>APFO</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 Program Representation</td>
</tr>
<tr>
<td>ASPRS</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>Apollo Telescope Mount</td>
</tr>
<tr>
<td>AFP</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>
</tbody>
</table>

- **List of Acronyms**
- **Acceptance Test**
- **Applications Technology Laboratory**
- **Antenna Test Model**
- **Apollo Telescope Mount**
- **Acceptance Test Plan**
- **Applications Technology Satellite**
- **American Wire Gauge**
- **Boom Antenna Retention Deployment and Jetison Assembly**
- **Bench Acceptance Test**
- **Build Baseline**
- **Bus Coupling Unit**
- **Block Data Format**
- **Bit Error Rate**
- **Biological Experiment Scientific Satellite**
- **Browse Film Recorder**
- **Band Interleaved by Cylinder**
- **Band Interleaved by Line**
- **Band Interleaved by Pixel**
- **Band Interleaved by Word**
- **Beginning of Life**
- **Beginning of Scan**
- **Beginning of Tape**
- **Bid and Proposal**
- **Bus Protection Assembly**
- **Bits per Inch**
- **Bytes per Inch**
- **Bits per Second**
- **Bytes per Second**
- **Broadcast Satellite Experimental**
- **Band Sequential**
- **Back Surface Radiator**
- **Bench Test Cooler**
- **Bench Test Equipment**
- **Backup**
- **Black and White**
- **Configured Articles List**
- **Calibration**
- **Central Atlantic Regional Ecological Test Site**
- **Catalog of Available and Standard Hardware**
- **Catalog**
- **Cloud Cover Assessment**
- **Configuration Control Board**
- **Camera Controller Combiner**
DMSP  Defense Meteorological Satellite Program
DOC  Data Operations Control
DOD  Department of Defense
DOE  Department of the Interior
DOE/OE  Domestic Communications Satellite
DPM  Drafting Practices Manual
DPR  Design Problem Report
DPS  Data Processing System
DPS  DRRS Process Software
DPSE  DRRS Process Software Executive
DPU  Digital Processing Unit
DR11C  Programmed Input Output Interface Device for DEC
DR70  Digital Memory Access Interface Device for DEC
DR780  Direct Memory Access Interface Device for DEC
VAX-11/780
DR1RU  Dry Rotor Inertial Reference Unit
DRRTS  Data Receive, Record and Transmit System
DS  Dimension (Telephone) System
DSC  Data Collection System
DSCS  Defense Satellite Communications System
DSCS  Desk Side Computer System
DSI  Digital Subsystem Interface Unit
DSL  Data Service Laboratory
DSCM  Downlink Synchronization Module
DSSCI  Data Stripper-Serial Controller Interface
DSU  Digital Switching Unit
DOT  Digital Terrain Data
DTS  Digital Terrain Map
DTS  Digital Tape Generation
DTR  Daily Test Report
DSI  Digital Transmission System
DV  Digital Voltmeter
DX20  DEC Peripheral Interface Device
DXFP  Data Extraction and Formatting Process
EAGE  Electrical Aerospace Ground Equipment
EBCDIC  Extended Binary Coded Decimal Interchange Code
EBA  Electron Beam Recorder
EBRIC  Electron Beam Recorder Image Correction
ECC  Error Correction Capability (HIDR)
ECEF  Earth-Centered-Earth-Fixed
ECL  Earth-Centered-Inertial
ECI  Emitter Coupled Logic
EDC  EROS Data Center
EDPS  Electronic Digital Processing System
EDPS  EDC Digital Image Processing System
EDP  Electronic Data (Digital) Processing
EDPS  Electronic Data Processing System
EDP  Electro-Explosive Device
EFC  Electronic Flxed Coordinate System
EGRET  Explorer Gamma Ray Experiment Telescope
EGSE  Electrical Government Supplied Equipment
EI  Engineering Instruction
EIA  Electronic Industries Association
ELE  Elevation at Entry
ELS  End-of-Line Sync
ELX  Elevation at Exit
EMC  Electromagnetic Compatibility
ENI  Electromagnetic Interference
ENA/DISA  Enable/Disable
EOB  End-of-Buffer
EOP  End-of-File
EOX  End-of-Life
EOF  End-of-Mission
EOP  Earth Observation Program
EOF  End-of-Process
ECRT  End-of-Roll Target
EOT  End-of-Scan
EOS  Earth Observation Systems
EOS  Earth Observations Satellite
EOF  End-of-Set
EOSP  Earth Observation and Shuttle Programs
EOV  End-of-Vacation
EPA  Equipment FOC
EPC  Electrical Power Conditioner
EPF  Euler Parameter Integration
EPS  Electrostatic Plotting Software
ER  Equipment Room
ERE  Earth Resources Equipment Package
EROS  Earth Resources Observation System or Satellite
ERS  Earth Resources Survey
ERS  Earth Resources Technology Satellite
ESA  European Space Agency
ESR  Equipment Service Report
EU  European Space Research and Technology Center
ET  Expander Unit
EVA  Extra-Vehicular Activity
EVAL  Earth Viewing Applications Laboratory
EWO  Engineering Work Order
FAIRS  Full Aperture Infrared Source
FAO  Financial and Administrative Operations
FAS  Foreign Agricultural Service
FCS  File Control Service
FOO  Fixed (Cartridge) Diablo Disk (Drive)
FDR  Final Design Review
FFP  Federation of Functional Processors
FGS  Fine Guidance System
FHIST  Fixed-Head Star Tracker
FID  Final Instrument Definition
FIFD  First-In, First-Out
FIPS  Federal Information Processing Standards
FM  Frequency Modulation
FL  Flight Model
FMEA  Failure Mode and Effects Analysis
FMS  Flight (Segment) Management Subsystem
FO  Flight Operations
FOC  Fault Object Camera
FORTRAN  Formula Translation
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICCD</td>
<td>Intensified Charge Coupled Device</td>
</tr>
<tr>
<td>ICD</td>
<td>Interface Control Document</td>
</tr>
<tr>
<td>ICS</td>
<td>Image Correction Support Software</td>
</tr>
<tr>
<td>ICS</td>
<td>Interactive Computer Simulator</td>
</tr>
<tr>
<td>ID</td>
<td>Identification</td>
</tr>
<tr>
<td>IDA</td>
<td>Image Data Acquisition</td>
</tr>
<tr>
<td>IDB</td>
<td>Identification Bus</td>
</tr>
<tr>
<td>IDBS</td>
<td>International Data Base Systems</td>
</tr>
<tr>
<td>IDS</td>
<td>Image Data System</td>
</tr>
<tr>
<td>IDT</td>
<td>Investigation Definition Team</td>
</tr>
<tr>
<td>IDT</td>
<td>Image Display Terminal</td>
</tr>
<tr>
<td>IDT</td>
<td>Industrial Data Terminal Corporation</td>
</tr>
<tr>
<td>IDT</td>
<td>Image Data Transmission</td>
</tr>
<tr>
<td>I/F</td>
<td>Interface</td>
</tr>
<tr>
<td>IF</td>
<td>Intermediary Frequency</td>
</tr>
<tr>
<td>IFD</td>
<td>In-Flight Disconnect</td>
</tr>
<tr>
<td>IFHV</td>
<td>Instantaneous Field-of-View</td>
</tr>
<tr>
<td>IG</td>
<td>Initial Gap</td>
</tr>
<tr>
<td>IGF</td>
<td>Image Generation Facility</td>
</tr>
<tr>
<td>IIGS</td>
<td>Initial Image Generation Subsystem</td>
</tr>
<tr>
<td>IRV</td>
<td>Improved Inter-Range Vectors</td>
</tr>
<tr>
<td>IS</td>
<td>International Imaging Systems</td>
</tr>
<tr>
<td>IM</td>
<td>Information Management</td>
</tr>
<tr>
<td>IM</td>
<td>Instrument Module</td>
</tr>
<tr>
<td>IMAC</td>
<td>Image Processing and Analysis Center</td>
</tr>
<tr>
<td>IMS</td>
<td>Information Management Subsystem</td>
</tr>
<tr>
<td>IMS</td>
<td>Information Management Subsystem Computer</td>
</tr>
<tr>
<td>IMSFCC</td>
<td>Information Management Subsystem FFP Control Computer</td>
</tr>
<tr>
<td>IMU</td>
<td>Image Memory Unit</td>
</tr>
<tr>
<td>InSb</td>
<td>Indium Antimonide</td>
</tr>
<tr>
<td>INTRALAB</td>
<td>Information Transfer Laboratory</td>
</tr>
<tr>
<td>I/O</td>
<td>Input/Output</td>
</tr>
<tr>
<td>IPC</td>
<td>Initial Product Creation</td>
</tr>
<tr>
<td>IPSC</td>
<td>Information Production Control System</td>
</tr>
<tr>
<td>IPD</td>
<td>Information Processing Division</td>
</tr>
<tr>
<td>I/PF</td>
<td>Image Processing Facility</td>
</tr>
<tr>
<td>IPS</td>
<td>Inches per Second</td>
</tr>
<tr>
<td>IPS-1</td>
<td>IPS String No. 1 Computers</td>
</tr>
<tr>
<td>IPS-2</td>
<td>IPS String No. 2 Computers</td>
</tr>
<tr>
<td>IPSC</td>
<td>IPS Computer</td>
</tr>
<tr>
<td>IQ</td>
<td>Interactive Query Language</td>
</tr>
<tr>
<td>IR</td>
<td>Infrared</td>
</tr>
<tr>
<td>IRR</td>
<td>Integrated Requirements Bldg</td>
</tr>
<tr>
<td>IRRD</td>
<td>Independent Research and Development</td>
</tr>
<tr>
<td>IRRD</td>
<td>Interface Requirements Document</td>
</tr>
<tr>
<td>IRPA</td>
<td>Infrared Focal Plane Assembly</td>
</tr>
<tr>
<td>IRG</td>
<td>Inter-Record Gap</td>
</tr>
<tr>
<td>IRIG</td>
<td>Inter-Range Instrumentation Group Time Code</td>
</tr>
<tr>
<td>IRIG-A</td>
<td>IRIG Time Code Series A</td>
</tr>
<tr>
<td>IRP</td>
<td>Infrared Photometer</td>
</tr>
<tr>
<td>IRD</td>
<td>Interrupt Request</td>
</tr>
<tr>
<td>IRU</td>
<td>Inertial Reference Unit</td>
</tr>
<tr>
<td>IS</td>
<td>Input Subsystem</td>
</tr>
<tr>
<td>ISA</td>
<td>Instrument Standard of America</td>
</tr>
<tr>
<td>ISAM</td>
<td>Index Sequential Access Method</td>
</tr>
<tr>
<td>ISM</td>
<td>Interface Switching Module</td>
</tr>
<tr>
<td>ISS</td>
<td>Image Generation Facility Software Sunset</td>
</tr>
<tr>
<td>ISU</td>
<td>Input Scanner Unit</td>
</tr>
<tr>
<td>IT</td>
<td>Integration Test</td>
</tr>
<tr>
<td>I&amp;T</td>
<td>Integration and Test</td>
</tr>
<tr>
<td>ITO</td>
<td>Inception-to-Date</td>
</tr>
<tr>
<td>ITD</td>
<td>Incurred-to-Date</td>
</tr>
<tr>
<td>ITP</td>
<td>Integration Test Plan</td>
</tr>
<tr>
<td>IU</td>
<td>Interface Unit</td>
</tr>
<tr>
<td>IUE</td>
<td>International Ultraviolet Explorer</td>
</tr>
<tr>
<td>IUS</td>
<td>Interim Upper Stage</td>
</tr>
<tr>
<td>JPL</td>
<td>Jet Propulsion Laboratory</td>
</tr>
<tr>
<td>JSC</td>
<td>Johnson Space Center</td>
</tr>
<tr>
<td>K</td>
<td>A Thousand</td>
</tr>
<tr>
<td>K</td>
<td>IOA (Memory Usage Only)</td>
</tr>
<tr>
<td>Kb</td>
<td>Kilobit</td>
</tr>
<tr>
<td>KB</td>
<td>Kilobyte</td>
</tr>
<tr>
<td>KBps</td>
<td>Kilobits per Second</td>
</tr>
<tr>
<td>Kbps</td>
<td>Kilobits per Second</td>
</tr>
<tr>
<td>KCRT</td>
<td>Keyboard Cathode Ray Tube</td>
</tr>
<tr>
<td>KCPU</td>
<td>CPU for DEC-10 Computer</td>
</tr>
<tr>
<td>km</td>
<td>Kilometer</td>
</tr>
<tr>
<td>KS</td>
<td>Key Station</td>
</tr>
<tr>
<td>KSA</td>
<td>Ku-Band Single Access</td>
</tr>
<tr>
<td>KSC</td>
<td>Kennedy Space Center</td>
</tr>
<tr>
<td>KW</td>
<td>Kilowords</td>
</tr>
<tr>
<td>KOC</td>
<td>DEC Hardcopy Terminal</td>
</tr>
<tr>
<td>LANDSAT</td>
<td>Large Area Crop Inventory Equipment</td>
</tr>
<tr>
<td>LaRC</td>
<td>Land Satellite</td>
</tr>
<tr>
<td>LARC</td>
<td>Langley Research Center</td>
</tr>
<tr>
<td>LAS</td>
<td>Landsat-D Assessment System</td>
</tr>
<tr>
<td>LAT</td>
<td>Latitude</td>
</tr>
<tr>
<td>LBP</td>
<td>Library Build Process</td>
</tr>
<tr>
<td>LBR</td>
<td>Laser Beam Recorder</td>
</tr>
<tr>
<td>LCP</td>
<td>Left-hand Circularly Polarized</td>
</tr>
<tr>
<td>LEO</td>
<td>Light-Emitting Diode</td>
</tr>
<tr>
<td>LFC</td>
<td>Left-Fill Code</td>
</tr>
<tr>
<td>LIDU</td>
<td>Large Image Display Utility</td>
</tr>
<tr>
<td>LIFD</td>
<td>Last-In, First-Out</td>
</tr>
<tr>
<td>LLA</td>
<td>Adjusted Line Length</td>
</tr>
<tr>
<td>LLC</td>
<td>Line Length Code</td>
</tr>
<tr>
<td>LM</td>
<td>Library Maintenance</td>
</tr>
<tr>
<td>LM</td>
<td>Line Monitor</td>
</tr>
<tr>
<td>LMM</td>
<td>Landsat Mission Management</td>
</tr>
<tr>
<td>LMSC</td>
<td>Lockheed Missile and Space Corporation</td>
</tr>
<tr>
<td>LOE</td>
<td>Level of Effort</td>
</tr>
<tr>
<td>Longitude</td>
<td>Longitude</td>
</tr>
<tr>
<td>LOS</td>
<td>Line of Sight</td>
</tr>
<tr>
<td>LOS</td>
<td>Loss of Signal</td>
</tr>
<tr>
<td>LPC</td>
<td>Longitudinal Parity Check</td>
</tr>
<tr>
<td>LPM</td>
<td>Line Point Marker</td>
</tr>
<tr>
<td>LPM</td>
<td>Line Point Marker</td>
</tr>
<tr>
<td>LPM</td>
<td>Lines Per Minute</td>
</tr>
<tr>
<td>LRA</td>
<td>Laser Retrodirector Array</td>
</tr>
</tbody>
</table>
Longitudinal Redundancy Check
Laser Retrodirector
Least Significant Bit
Landsat-0
Landsat 3
Light Transfer Characteristics
Long-Term Tape Storage Facility
Line Test Unit
Logical Unit Number
Launch Vehicle
Mega-
M
Million
Multiple Access
Modular Attitude Control System
MSS Archival Product Generation
Macro Array Processor
High-Speed Bus for DEC Equipment
Management and Technical Services Company
Mega-
Mb
Megabyte
MA
Mega-
Mbps
Megabits per Second
MCC
Mission Control Center
MCCA
Manual Cloud Cover Assessment Package
MCR
Monitor Console Routine
MCTF
Mission Contractor Test Facility
MADDO
Mission and Data Operations Directorate
MHP
High Speed Bus
MHP
Master Data Processor
Module Exchange Mechanism
Marshall Earth Resources Information Transfer System
METSAT
Meteorological Satellite
MFB
Major Frame Buffer
MD
Master File Directory
MFS
Major Frame Synchronization
MGSE
Mechanical Government Supplied Equipment
MSS
MSS/HDR Service
MH
Multi-Hundred Watt
MHz
Mega-
HF
Megahertz (10^6)
MIF
Master Information File
MIP
Management Information Process
MIPS
MIPS Image Processing System
MIPS
Mega-Instructions per Second
MIS
Mission Interface Subsystem
MIT
Master Information Table
MJF
Major Frame
mm
Millimeter
Miles
Mission Management Facility
MMFC
Mission Management Facility Control Computer
MMF
MSS Mission Management Facility
MMF-T
TM Mission Management Facility
MMS
Mission Management System
MMSS
Multi-Mission Modular Spacecraft
Memory Management Unit
Minor Frame Synchronization
Maintenance and Operations
Modulator/Demodulator
Moments of Inertia
Manned Orbiting Laboratory
Mission Operations Manager
Mega-Operations per Second
Mission Operations Review
Memorandum of Understanding
MSS Preprocessor
Mission Planning System
Modular Power Subsystem
Maximum Power Tracker
Multiplex
Maintenance Requirements Analysis
Maintenance Requirements Analysis Matrix
Master Reference Cube
Module Reference System
Mirror Sweep
Most Significant Bit
Manned Space Center
MSS Mirror Scan Correction Data
MSSD
TM Mirror Scan Correction Data
MSC
Mission Support Coordination Office
MSC
Matrix Switch Control
Millisecond
Marshall Space Flight Center
Monthly Status Review
Module Support Structure
Multispectral Scanner
MSS-A
MSS Archival Data
MSC
Matrix Switch
MT
Magnetic Tape
Mean Time Between Failures
Modulation Transfer Function
Material
Mechanical Test Module
MSS Telemetry Processor
Mean Time to Repair
Magnetic Tape Unit
Multiplexer
Mega-
MIPS
Megawords
M Purified and Filtered Gaseous Nitrogen
Not Applicable
Negative Acknowledgement
Nimbus/AEM Preprocessor System
National Aeronautics and Space Administration
NASA Communications Network
NASA Structural Analysis (Program)
NASA Transient Analysis System
Narrow Band Tape Recorder
National Climatic Center
Network Control Center
Network Control Center Subsystem
National Cartographic Information Center
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</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>POO</td>
<td>Project Operations Directors</td>
</tr>
<tr>
<td>POP</td>
<td>Project Operating Plan</td>
</tr>
<tr>
<td>PORS</td>
<td>Preliminary Operations Requirements and Testing Support</td>
</tr>
<tr>
<td>PWO</td>
<td>Purchasing 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 System</td>
</tr>
<tr>
<td>PRN</td>
<td>Pseudo Random Noise</td>
</tr>
<tr>
<td>PRR</td>
<td>Payload Receiving 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>PSSO</td>
<td>Parallel-to-Serial Data Output Device</td>
</tr>
<tr>
<td>PSS</td>
<td>Photo/Shipping Support Facility</td>
</tr>
<tr>
<td>PSM</td>
<td>Phase Shift Keying</td>
</tr>
<tr>
<td>PST</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>QA</td>
<td>Qualification and Acceptance</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 Program</td>
</tr>
<tr>
<td>QAP</td>
<td>Quality Control Program</td>
</tr>
<tr>
<td>QCP</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>QLP</td>
<td>Quick Look Processing System</td>
</tr>
<tr>
<td>QPS</td>
<td>Quadrature Phase Shift Keyed</td>
</tr>
<tr>
<td>QRD</td>
<td>Quick-Response Work Order</td>
</tr>
<tr>
<td>QSL</td>
<td>Quarter Scan Line</td>
</tr>
<tr>
<td>RAA</td>
<td>Refactoring 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>RCP</td>
<td>Radiometric Corrected Process</td>
</tr>
<tr>
<td>RCPP</td>
<td>Radiometric Function Calculation Process</td>
</tr>
<tr>
<td>RDT</td>
<td>Raw Data Tape</td>
</tr>
<tr>
<td>REC</td>
<td>Record</td>
</tr>
<tr>
<td>REM</td>
<td>Rotary 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>RFH</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>RGO</td>
<td>Massbus Adaptor for DEC VAX-11/780</td>
</tr>
<tr>
<td>RIO</td>
<td>Review Item Discrepancy</td>
</tr>
<tr>
<td>R1U</td>
<td>Remote Interface Unit</td>
</tr>
<tr>
<td>RLU</td>
<td>Radiometric Lookup Table</td>
</tr>
<tr>
<td>RMD</td>
<td>Remote Manipulator System</td>
</tr>
<tr>
<td>RMS</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>RPOS</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>RPN</td>
<td>Revolutions Per Minute</td>
</tr>
<tr>
<td>RPS</td>
<td>RDV Preprocessor</td>
</tr>
<tr>
<td>RROA</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>R/T</td>
<td>Real-Time</td>
</tr>
<tr>
<td>RUG</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>SADAPA</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 Jettison 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>S/C</td>
<td>Spacecraft</td>
</tr>
<tr>
<td>SC</td>
<td>Signal Conditioning</td>
</tr>
<tr>
<td>SCA</td>
<td>Signal Conditional Assembly</td>
</tr>
<tr>
<td>SCADA</td>
<td>Switching, Conferencing and Monitoring Arrangement</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>SCCB</td>
<td>Software Change Control Board</td>
</tr>
<tr>
<td>SCD</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>SCII</td>
<td>Serial Control Interface for Input (now SPDI)</td>
</tr>
<tr>
<td>SCIO</td>
<td>Serial Control Interface for Output (now PSSO)</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>SGD</td>
<td>Space Division</td>
</tr>
<tr>
<td>SDF</td>
<td>Software Development Facility</td>
</tr>
<tr>
<td>SDHS</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>SED</td>
<td>Secondary Electron Conduction Orthicon</td>
</tr>
<tr>
<td>SEOPS</td>
<td>Standard Earth Observation Package Satellite</td>
</tr>
<tr>
<td>SEOS</td>
<td>Synchronous Earth Observation Satellite</td>
</tr>
<tr>
<td>S1</td>
<td>Science Instruments</td>
</tr>
<tr>
<td>SIAT</td>
<td>Special Image Annotation Tape</td>
</tr>
<tr>
<td>SION</td>
<td>Science Instrument Central Module</td>
</tr>
<tr>
<td>SIDU</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 Requirement 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>SLR</td>
<td>Scan Line Corrector</td>
</tr>
<tr>
<td>SLER</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>SLS2</td>
<td>Start-of-Line Sync</td>
</tr>
<tr>
<td>SMA</td>
<td>S-Band Multiple Access</td>
</tr>
<tr>
<td>SMA</td>
<td>Scan Mirror Assembly</td>
</tr>
<tr>
<td>SMN</td>
<td>Solar Maximum Mission</td>
</tr>
<tr>
<td>SMNO</td>
<td>Support Maintenance and Operations</td>
</tr>
<tr>
<td>SMM</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>S/NP</td>
<td>Signal-to-Noise Ratio</td>
</tr>
<tr>
<td>SNR</td>
<td>Signal-to-Noise Ratio</td>
</tr>
<tr>
<td>SQA</td>
<td>Space Oblique Mercator</td>
</tr>
<tr>
<td>SOP</td>
<td>Standard Operating Procedure</td>
</tr>
<tr>
<td>SOM</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>SPDI</td>
<td>Serial-to-Parallel Data Input Device</td>
</tr>
<tr>
<td>SPN</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>
<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>SRRD</td>
<td>Software Requirements and Conceptual Design Review</td>
</tr>
<tr>
<td>SROD</td>
<td>Software Requirements Document</td>
</tr>
<tr>
<td>SRODS</td>
<td>Site Preparation Requirements Document</td>
</tr>
<tr>
<td>SRT</td>
<td>Support Systems Module</td>
</tr>
<tr>
<td>SSS</td>
<td>Space System Operations</td>
</tr>
<tr>
<td>SSSR</td>
<td>Systems Software Requirements Review</td>
</tr>
<tr>
<td>SST</td>
<td>Synchronous System Trap</td>
</tr>
<tr>
<td>ST</td>
<td>Space Telescope</td>
</tr>
<tr>
<td>STAC</td>
<td>Standard Telemetry and Command Components</td>
</tr>
<tr>
<td>STAC-CU</td>
<td>STAC Central Unit</td>
</tr>
<tr>
<td>STAC-STINT</td>
<td>STAC 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>STDI</td>
<td>Standard System Test and Operation Language</td>
</tr>
<tr>
<td>STDL</td>
<td>Space Flight Tracking and Data Network</td>
</tr>
<tr>
<td>STDP</td>
<td>Space Technology Engineering Program</td>
</tr>
<tr>
<td>STINT</td>
<td>Standard Interface for Onboard Computer</td>
</tr>
<tr>
<td>STT</td>
<td>STAC Interface Unit</td>
</tr>
<tr>
<td>STTOC</td>
<td>Space Telescope Operations Control Center</td>
</tr>
<tr>
<td>STOL</td>
<td>System Test and Operation Language</td>
</tr>
<tr>
<td>STP</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>STR</td>
<td>Space Transportation System</td>
</tr>
<tr>
<td>STR</td>
<td>Shuttle Transportation System</td>
</tr>
<tr>
<td>STR</td>
<td>Space Telescope Scientific Operations Center</td>
</tr>
<tr>
<td>SUC</td>
<td>Switching Unit</td>
</tr>
<tr>
<td>SVS</td>
<td>Space Vehicle Specification</td>
</tr>
<tr>
<td>S/W</td>
<td>Software</td>
</tr>
<tr>
<td>SMA</td>
<td>Science Working Group</td>
</tr>
<tr>
<td>SVD</td>
<td>System Corrected Images</td>
</tr>
<tr>
<td>S/W</td>
<td>System Corrected Images</td>
</tr>
<tr>
<td>S/W</td>
<td>System Corrected Images</td>
</tr>
<tr>
<td>S/W</td>
<td>System Corrected Images</td>
</tr>
<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 Archival 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 Determined</td>
</tr>
<tr>
<td>TBD</td>
<td>To Be Defined</td>
</tr>
<tr>
<td>TBR</td>
<td>To Be Resolved</td>
</tr>
</tbody>
</table>

1-254
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBS</td>
<td>To Be Supplied</td>
</tr>
<tr>
<td>TBV</td>
<td>To Be Verified</td>
</tr>
<tr>
<td>T/C</td>
<td>Time Code</td>
</tr>
<tr>
<td>TCG</td>
<td>Time Code Controller</td>
</tr>
<tr>
<td>TCN</td>
<td>Time Code Generator</td>
</tr>
<tr>
<td>TCI/OSC</td>
<td>Time Code In/Oscillator</td>
</tr>
<tr>
<td>TCM</td>
<td>Army Test and Evaluation Command</td>
</tr>
<tr>
<td>TCC/PAN</td>
<td>Time Code Out/Panel</td>
</tr>
<tr>
<td>TCS</td>
<td>Thermal Control System</td>
</tr>
<tr>
<td>TCU</td>
<td>Time Code Unit</td>
</tr>
<tr>
<td>T&amp;D</td>
<td>Test and Diagnostic</td>
</tr>
<tr>
<td>TDE</td>
<td>Test Directives</td>
</tr>
<tr>
<td>TDRS</td>
<td>Tracking and Data Relay Satellite</td>
</tr>
<tr>
<td>TDS</td>
<td>Tracking and Data Relay Satellite System</td>
</tr>
<tr>
<td>T&amp;E</td>
<td>Test and Evaluation</td>
</tr>
<tr>
<td>TEP</td>
<td>Telemetry Extraction Process</td>
</tr>
<tr>
<td>TGS</td>
<td>Transporable Ground Station</td>
</tr>
<tr>
<td>TIPS</td>
<td>TM Image Processing System</td>
</tr>
<tr>
<td>TIPSS</td>
<td>Television Infrared Observation System</td>
</tr>
<tr>
<td>TIS</td>
<td>Technical Information Series</td>
</tr>
<tr>
<td>TLM</td>
<td>Telemetry</td>
</tr>
<tr>
<td>TM</td>
<td>Thematic Mapper</td>
</tr>
<tr>
<td>TMV</td>
<td>Telemetry Volts</td>
</tr>
<tr>
<td>TOD</td>
<td>True-of-Date</td>
</tr>
<tr>
<td>TP</td>
<td>Telemetry Processor</td>
</tr>
<tr>
<td>TPG</td>
<td>Test Pattern Generator</td>
</tr>
<tr>
<td>TPL</td>
<td>Test Plan</td>
</tr>
<tr>
<td>TR</td>
<td>Tape Recorder</td>
</tr>
<tr>
<td>TRB</td>
<td>Test Review Board</td>
</tr>
<tr>
<td>TRF</td>
<td>Tracking and Receiving Facility</td>
</tr>
<tr>
<td>TRK</td>
<td>Track (HOUR)</td>
</tr>
<tr>
<td>TKG</td>
<td>Tracking Program</td>
</tr>
<tr>
<td>TRW</td>
<td>TRW Defense and Space Systems Group</td>
</tr>
<tr>
<td>T/S</td>
<td>Thermal/Structural</td>
</tr>
<tr>
<td>TSM</td>
<td>Test and Simulation Subsystem</td>
</tr>
<tr>
<td>TSSC</td>
<td>Technical Support Services Company</td>
</tr>
<tr>
<td>TSSF</td>
<td>Tape Staging and Storage Facility</td>
</tr>
<tr>
<td>TTA</td>
<td>Triangular Transition Adaptor</td>
</tr>
<tr>
<td>T&amp;T&amp;C</td>
<td>Telemetry Tracking and Command</td>
</tr>
<tr>
<td>TIL</td>
<td>Transistor Logic Device</td>
</tr>
<tr>
<td>TTY</td>
<td>Teletype Operator Console</td>
</tr>
<tr>
<td>TUS</td>
<td>1600 bpi Magnetic Tape Unit</td>
</tr>
<tr>
<td>TU72</td>
<td>6250 bpi Magnetic Tape Unit</td>
</tr>
<tr>
<td>TU75</td>
<td>6250 bpi Magnetic Tape Unit</td>
</tr>
<tr>
<td>TV</td>
<td>Television</td>
</tr>
<tr>
<td>TW</td>
<td>Travelling Wave Tube</td>
</tr>
<tr>
<td>TWTA</td>
<td>Travelling Wave Tube Amplifier</td>
</tr>
<tr>
<td>TX</td>
<td>Transmit</td>
</tr>
<tr>
<td>UARS</td>
<td>Upper Atmosphere Research Satellite</td>
</tr>
<tr>
<td>UBA</td>
<td>Unibus Adapter</td>
</tr>
<tr>
<td>UBC</td>
<td>Unit Block Controller</td>
</tr>
<tr>
<td>UDPM</td>
<td>Unload DDP Module</td>
</tr>
<tr>
<td>UDF</td>
<td>Unit Development Folder</td>
</tr>
<tr>
<td>UFD</td>
<td>User File Directory</td>
</tr>
<tr>
<td>UHF</td>
<td>Ultra High Frequency</td>
</tr>
<tr>
<td>UIC</td>
<td>User Identification Code</td>
</tr>
<tr>
<td>U/L</td>
<td>Uplink</td>
</tr>
<tr>
<td>UNIBUS</td>
<td>Universal Bus</td>
</tr>
<tr>
<td>UQPSK</td>
<td>Unbalanced Quadrature</td>
</tr>
<tr>
<td>UASR</td>
<td>Universal Synchronous Asynchronous Receiver Transmitter</td>
</tr>
<tr>
<td>USB</td>
<td>Upper Side-Band</td>
</tr>
<tr>
<td>USDA</td>
<td>United States Department of Agriculture</td>
</tr>
<tr>
<td>USGS</td>
<td>United States Geological Survey</td>
</tr>
<tr>
<td>UTC</td>
<td>Universal Time Coordinated</td>
</tr>
<tr>
<td>UTM</td>
<td>Universal Transverse Mercator</td>
</tr>
<tr>
<td>VA</td>
<td>Value Analysis</td>
</tr>
<tr>
<td>VAC</td>
<td>Volts, Alternating Current</td>
</tr>
<tr>
<td>VAP</td>
<td>Verification Acceptance Program</td>
</tr>
<tr>
<td>VAX-11/780</td>
<td>Virtual Address Extension DEC Model Computer 11/780</td>
</tr>
<tr>
<td>VCO</td>
<td>Voltage-Controlled Oscillator</td>
</tr>
<tr>
<td>VCI</td>
<td>Verification Cross-Reference Index</td>
</tr>
<tr>
<td>VDC</td>
<td>Volts, Direct Current</td>
</tr>
<tr>
<td>VE</td>
<td>Value Engineering</td>
</tr>
<tr>
<td>VHF</td>
<td>Very High Frequency</td>
</tr>
<tr>
<td>VHR</td>
<td>Very High Resolution Radiometer</td>
</tr>
<tr>
<td>VICAR</td>
<td>Video Image Communication and Retrieval</td>
</tr>
<tr>
<td>VIP</td>
<td>Virtually Interfaced Peripheral</td>
</tr>
<tr>
<td>VM</td>
<td>Value Management</td>
</tr>
<tr>
<td>VMS</td>
<td>Virtual Memory (Operating) System</td>
</tr>
<tr>
<td>VPA</td>
<td>Video Processor and Sync Separator</td>
</tr>
<tr>
<td>VPC</td>
<td>Video Processor/Image Recorder</td>
</tr>
<tr>
<td>VPT</td>
<td>Vacuum Thermal</td>
</tr>
<tr>
<td>VBT</td>
<td>Verification Test</td>
</tr>
<tr>
<td>VTR</td>
<td>Intelligent CRT Terminal</td>
</tr>
<tr>
<td>VTR</td>
<td>Non-Intelligent CRT Terminal</td>
</tr>
<tr>
<td>VTR</td>
<td>Video Tape Recorder</td>
</tr>
<tr>
<td>W/B</td>
<td>Wideband</td>
</tr>
<tr>
<td>WBM</td>
<td>Wideband Module</td>
</tr>
<tr>
<td>WBBS</td>
<td>Work Breakdown Structure</td>
</tr>
<tr>
<td>WBS</td>
<td>Wideband Subsystem</td>
</tr>
<tr>
<td>WBSS</td>
<td>Wide Band Video Tape</td>
</tr>
<tr>
<td>WBT</td>
<td>Wide Band Video Tape Recorder</td>
</tr>
<tr>
<td>WBS</td>
<td>Writeable Control Store</td>
</tr>
<tr>
<td>WFT</td>
<td>Wide-Field Camera</td>
</tr>
<tr>
<td>WO</td>
<td>Work Order</td>
</tr>
<tr>
<td>WFC</td>
<td>Word Processor Center</td>
</tr>
<tr>
<td>WP</td>
<td>Work Package Manager</td>
</tr>
<tr>
<td>WR</td>
<td>World Reference System</td>
</tr>
<tr>
<td>WS</td>
<td>White Sands Missile Range</td>
</tr>
<tr>
<td>WTR</td>
<td>Western Test Range</td>
</tr>
<tr>
<td>WTR</td>
<td>Transmit</td>
</tr>
<tr>
<td>WTR</td>
<td>Transmitter</td>
</tr>
<tr>
<td>Z</td>
<td>Zulu Time (GMT)</td>
</tr>
<tr>
<td>ZTS</td>
<td>Zoom Transfer Scoop</td>
</tr>
<tr>
<td>ZWC</td>
<td>Zero Word Count</td>
</tr>
<tr>
<td>μ</td>
<td>Micro-</td>
</tr>
<tr>
<td>μm</td>
<td>Micrometer (10^-6 meter)</td>
</tr>
<tr>
<td>μp</td>
<td>Microprocessor</td>
</tr>
<tr>
<td>μs</td>
<td>Microsecond</td>
</tr>
</tbody>
</table>
LAS Software Functions (Partial Listing)

<table>
<thead>
<tr>
<th>Function</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>CHARCUT</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>CORSTRIK</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>Discriminant Analysis</td>
</tr>
<tr>
<td>DROPCL</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>FFT</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>FIGURE</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>FT2PIX</td>
<td>Generate 2-Dimensional Fourier Display</td>
</tr>
<tr>
<td>FI1PIX</td>
<td>Generate 1-Dimensional Fourier Display</td>
</tr>
<tr>
<td>GCDG</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>KASLOV</td>
<td>Karhunen-Loeve Transform</td>
</tr>
<tr>
<td>LINEOFF</td>
<td>Line Offset Correction</td>
</tr>
<tr>
<td>LINEREPR</td>
<td>Repair Bad Lines</td>
</tr>
<tr>
<td>LIST</td>
<td>List and Histogram Image Window</td>
</tr>
<tr>
<td>LISTSTAT</td>
<td>List Stats File</td>
</tr>
<tr>
<td>LUTEDIT</td>
<td>Edits LUT File</td>
</tr>
<tr>
<td>LUTLDD</td>
<td>Load Specified LUT from LUT Disk File</td>
</tr>
<tr>
<td>LUTSAVE</td>
<td>Save LUT on Disk File</td>
</tr>
<tr>
<td>MASKSTAT</td>
<td>Statistics of Mask Image</td>
</tr>
<tr>
<td>MEDFIL</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>Parallelepiped Classification</td>
</tr>
<tr>
<td>PFI LM</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 (LUTLOD Proc.)</td>
</tr>
<tr>
<td>RADON</td>
<td>Apply RLUT to Image</td>
</tr>
<tr>
<td>RECORD</td>
<td>Copies TV to TV (Thru LUT Optional)</td>
</tr>
<tr>
<td>REMOLD</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>SCF</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>SEGNOFF</td>
<td>Segment Offset Correction</td>
</tr>
<tr>
<td>SETTV</td>
<td>Renam Image Blemish</td>
</tr>
<tr>
<td>SHADE</td>
<td>Redefines IAT B/W Configuration</td>
</tr>
<tr>
<td>SHADER</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>TMA2P</td>
<td>Resample TM A-Image to P-Image</td>
</tr>
<tr>
<td>TMBIB</td>
<td>Histograms of TM Image for RLUT</td>
</tr>
<tr>
<td>TOTV</td>
<td>Quick Copy of 'TV-Size' Image to IAT</td>
</tr>
<tr>
<td>TRANSDIV</td>
<td>Transform Divergence</td>
</tr>
<tr>
<td>USGAP</td>
<td>Uniformity Mapping</td>
</tr>
<tr>
<td>UHARY</td>
<td>Vegetative Index</td>
</tr>
<tr>
<td>VEGGIN</td>
<td>Weight Generator for FFT2FL</td>
</tr>
<tr>
<td>WINTER</td>
<td>Transfer Training Site</td>
</tr>
<tr>
<td>XFERSITE</td>
<td>Enhance or Reduce Image</td>
</tr>
</tbody>
</table>
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.
1400 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, Judi
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) 64-2351

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
Crone, Larry  
NOAA  
National Earth Satellite Service  
FB No. 4- Room 0135  
Washington, DC 20233

Dallam, William  
General Electric  
Space Division  
4701 Forbes Blvd.  
Lanham, MD 20706  
(301) 459-2900

Dasgupta, Rangit  
CSC  
8728 Colesville Road  
Silver Spring, MD 20910  
(301) 589-1545, Ext. 722

DeGloria, Stephen  
Space Sciences Laboratory  
University of California, Berkeley  
Berkeley, CA 94720

Dietz, Jim  
Code 435.9  
NASA/Goddard Space  
Flight Center  
Greenbelt, MD 20771  
(301) 344-9456

Dozier, Jeffrey  
Associate Professor of Geography  
University of California  
Santa Barbara, CA 93106  
(805) 961-2309 or 2109

Dunker, Chris  
Code 435  
NASA/Goddard Space  
Flight Center  
Greenbelt, MD 20771  
(301) 344-4931

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

Eng, Kenneth  
Systems & Applied Sciences Corp.  
5809 Annapolis Rd.  
Hyattsville, MD 20784  
(301) 699-5400

Engel, Jack  
Hughes Aircraft Corp.  
Santa Barbara Research Center  
75 Coromar Drive  
Santa Barbara, CA 93317  
(805) 968-3511, Ext. 6145

Erickson, Jon  
Earth Resources Applications Division  
Mail Code SH  
NASA/Johnson Space Center  
Houston, TX 77058  
(FTS) 525-4017

Evrett, John  
Earth Satellite Corp.  
7222 47th Street  
Chevy Chase, MD 20815  
(301) 652-7130

Fischel, David  
Code 932  
NASA/Goddard Space  
Flight Center  
Greenbelt, MD 20771  
(301) 344-9534

Foote, Harlan  
Foster, James  
Code 924  
NASA/Goddard Space  
Flight Center  
Greenbelt, MD 20771  
(301) 344-9135

Freden, Stan  
Code 902  
NASA/Goddard Space  
Flight Center  
Greenbelt, MD 20771  
(301) 344-5818
Gervin, Janette
Code 902
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-7061

Gonzales, Lou
Code 435
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-5161

Gordon, Frederick
Code 902
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-8037

Goward, Samuel
NASA/Goddard Institute for Space Studies
2880 Broadway
New York, NY 10025

Grebowsky, Gerry
Code 564.3
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-6386

Gurney, Charlotte
Systems & Applied Sciences Corp.
5809 Annapolis Road
Hyattsville, MD 20784
(301) 699-6137

Hahn, Jerold
Code 435
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-6568

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

Hallada, Wayne

Heffner, Paul
Code 564.3
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-6263

Heinig, Joe
Code 564.3
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-7506

Hill, Charles
Test & Evaluation Group
NASA/Earth Resources Lab
NSL Station, MS 39529
(FTS) 494-2042

Hlauka, Chris
Ames Research Center
NASA
Moffett Field, CA 94035

Horn, Tim
Code 435.9
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-7876

Horseman, Martha
Code 920
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-8671

Hovis, Warren
Director, Satellite Experiment Lab
National Oceanic & Atmospheric Administration
National Earth Satellite Service
FB NO. 4-Room 0135
Washington, DC 20233
(301) 763-7381

Imhoff, Marc
Code 902
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-7095
Irons, James
Code 923
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-5240

Jackson, Michael J.
Natural Environment Research Council
Polaris House
North Star Avenue
Swindon
Wilts. SN2 IEU
UNITED KINGDOM
Telex: 444293 (ENVRE G)

Johnson, Robert
Hughes Aircraft
Space & Communications Group
El Segundo, CA

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

Kerber, Arlene
Code 902
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-5355

Kieffer, Hugh
Branch of Astrogeologic Studies
U.S. Geological Survey
2255 North Gemini Drive
Flagstaff, AZ 86001
(FTS) 261-1357

Koep-Baker, Nick M-7226
GE Space Division
P.O. Box 8555
Philadelphia, PA 19101
(215) 962-2238

Koffler, Russ
Code 435
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-5207

Krehbiel, John
Code 733
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-5777

Krueger, Don
Code 5118
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-5118

Kugelmann, Diane
Code 902
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-8146

Labovitz, Mark
Code 922
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-5600

Lansing, Jack
Hughes Aircraft Corp.
Santa Barbara Research Center
75 Comorar Drive
Santa Barbara, CA 93317
(805) 968-3511

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

Lauer, Donald
Applications Branch
U.S. Geological Survey
EROS Data Center
Sioux Falls, SD 57198
(FTS) 784-7111

Lauritson, Levan
Code 435
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-5223
Linstrom, Loren
Code 435
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-5223

Martucci, Louis M.
DOE Pacific Northwest
Laboratory
Richland, WA 99352
(202) 252-2146 (temporary)

Lu, Yun-chi
CSC
8728 Colesville Rd.
Silver Spring, MD 20910
(301) 589-1545

Maxwell, Marvin
Code 920
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-8036

Lyon, John
Code 932
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-8744

Middleton, Elizabeth
Code 902
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-8403

MacDonald, Robert
Earth Resources Research
Division
NASA/Johnson Space Center
Mail Code SG
Houston, TX 77058
(713) 525-6141

Moore, Jesse
NASA Headquarters
600 Independence Ave., S.W.
Washington, DC
(202) 755-3728

Malherbe, Pete, M-7222
GE Space Division
P.O. Box 8555
Philadelphia, PA 19101
(215) 962-4699

Mowle, Ed
Code 435
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-6978

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

Mulligan, Patricia
Code 902
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-5515

Manheimer, Harry
NASA Headquarters
600 Independence Ave., S.W.
Washington, DC
(202) 755-1201

Murphy, Bob
Code 923
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-7282

Markham, Brian
Code 923
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-5240

Nelson, Ross
Code 923
NASA/Goddard Space
Flight Center
Greenbelt, MD 20771
(301) 344-4926
Nieman, Ron
CSC
8728 Colesville Road
Silver Spring, MD 20910
(301) 589-1545

Ormsby, James
Code 924
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-6908

Oseroff, Harold
Code 902
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-8933

Podwysocki, Mel

Price, John
Hydrology Laboratory
Beltsville Agriculture Research Center, West
Beltsville, MD 20705
(301) 344-3490

Prokop, Ed
Code 564.3
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-7506

Quann, John
Code 500
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-8768

Ramipriyan, H. K.
Code 932
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-9496

Rango, Al
Code 924
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-5480

Robinson, Jon
CSC
8728 Colesville Rd.
Silver Spring, MD 20910
(301) 589-1545

Royal, Al
General Electric Space Division
4701 Forbes Blvd.
Lanham, MD 20705
(301) 459-2900

Salomonson, Vince
Code 920
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-6481

Schmetzler, Charles
Code 922
NASA/Goddard Space Flight Center
Greenbelt, MD 20771
(301) 344-5213

Schott, John
School of Photographic Arts & Sciences
Photographic Science & Instrumentation Division
Rochester Institute of Technology
One Lomb Memorial Drive
Rochester, NY 14623
(716) 475-2783

Sehn, George, M-7235
GE Space Division
P.O. Box 8555
Philadelphia, PA 19101
(215) 962-3652

Sheffield, Charles
Fantom Satellite Corp.
7222 47th St.
Chevy Chase, MD 20815
(301) 652-7130
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) 344-6997

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

Thomodsky, 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 C)

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

Van Wee, 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

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

Weber, William  
Code 435  
NASA/Goddard Space Flight Center  
Greenbelt, MD 20771  
(301) 344-8308

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  
ORI, 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