Landsat 7: Early On-Orbit Performance

by

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Introduction

- The Landsat 7 mission began after a spectacularly successful Delta 2 launch on April 15, 1999 from the Vandenberg Air Force Base in California.
  - weather was so clear that cameras tracked it down range ~ 500 miles
- The first images were acquired on Sunday, April 18, just three days after launch
  - purely by “luck of the draw” the first usable image included Sioux Falls/EDC (honest!)
  - Level 1 systematically corrected products were generated via the Image Assessment System (IAS) @ EDC within a few hours
  - this first image was officially released on Earth Day, Thursday, April 22
  - Normal post launch engineering checkout activities are continuing according to the on-orbit independent verification plan (OIVP)
  - it will take ~ 75 days to complete OIVP ==> plan to be “operational” **on/about July 1**
  - during OIVP, numerous activities such as “out-gassing” are required to acclimate the instrument to its space environment; “out-gassing” was successfully completed on April 30, and the collection of 8-band imagery, for engineering checkout purposes, commenced according to the OIVP
  - as of last Friday, May 14, we had acquired ~ 1600 images of engineering data
    - this engineering data will not be distributed to the public

Introduction *(cont)*

- Additional OIVP activities include preparation to underfly Landsat 5. Meticulous planning is required to position the Landsat 7 spacecraft in proximity to the Landsat 5 spacecraft using orbit adjust maneuvers to raise the Landsat 7 orbit and slow down its drift rate. Once this proximity has been achieved, the two Landsat's will collect selected observations simultaneously over a 3 day period to permit cross-calibration, thus establishing a base line for understanding the respective imaging characteristics of the two instruments. We expect the underfly to occur June 1 - 3.
- Upon completion of the Landsat 5 underfly maneuver, Landsat 7 will be positioned in its nominal operational orbit (an altitude of 705 km vs. the current ~ 680 km) by mid-June.
- Landsat 7 will be positioned to collect observations consistent with the Landsat 4 / 5 WRS, but phased eight paths to the East of Landsat 5.
- 8 day repeat coverage will exist as long as Landsat 5 remains operational

Why No Distribution of Engineering Data

- It is important to note that until final orbital positioning is completed (~ mid-June), Landsat 7 will not begin to collect data for the global archive, and subsequent production operations.

- All data acquired prior to that time will be considered “engineering” checkout data. All engineering data have certain “abnormalities” due to the fact that the spacecraft is flying lower and faster than normal, and it is drifting across the WRS paths -- all these factors yield non-standard scenes and data
- Please be assured that all data abnormalities are well understood and will not exist once the satellite reaches it’s final orbital altitude

- Selected scenes, subscenes, or swaths acquired during this period will be extracted and used for evaluation and/or release of photographic imagery for PR or other non-scientific interests, but it will not be offered as “standard” products for sale
  - also during this period, selected data will be extracted and provided to international ground station cooperators and system developers for testing purposes, but with caveats pertaining to their use.

Image Assessment System

- An Image Assessment System (IAS) has been implemented at EROS Data Center in concert with the Landsat Project Science Office at NASA Goddard to perform on-orbit radiometric and geometric calibration and daily image quality assessments throughout the life of the mission
- the IAS at EDC has been responsible for processing all of the Landsat 7 imagery that has been released so far
  - once EDC goes operational, the Landsat Product Generation System (LPGS) will be responsible for routine generation of products for distribution
  - the IAS will be operated in the background to look at a random subsample of imagery each day to look for any data anomolies and to perform radiometric and geometric calibration functions
- The early performance results to be reported in the following charts are representative examples of the capabilities and functions of the IAS

Some Spacecraft Performance Highlights

- OIVP Requirements Verification Status (as of 5/13/99):
  - Total on-orbit verification requirements:153
  - Total on-orbit requirements verified to date: 66
  - On-Orbit requirements to be verified: 87
- attitude subsystem is in precision pointing mode

  – working with the IAS / ground geometric calibration group at EDC to quantify precision *(early results indicate locational accuracies of ~ 100 m vs. the spec of 250 m)*
- power subsystem is operating nominally; solar array fully operational and tracking the sun; battery temp's are stabilized and battery charge control is under software management; no power problems during imaging day or night
- solid state recorder has successfully recorded and played back both wideband and narrowband data
- we have fully exercised all three gimballed x-band antennas and all four x-band frequencies, using the Landsat Ground Station at EROS Data Center and the stations at Svalbard, Norway and Poker Flat, Alaska

Some Instrument Performance Highlights

ETM+ Noise Performance:

- **Initial on-orbit data is consistent with pre-launch thermal vacuum (T/V) test data there is no evidence of instrument change going into orbit**
- **Several detectors in Bands 1 and 8 show coherent noise in the shutter region only -- *this noise is not present in the image data* -- hence the higher standard deviations for the "shutter" vs "image" data as shown in the Table**
- **no on-orbit data yet acquired in Band 8 high gain mode**
- **Bands are generally in specification except for some Band 8 detectors**
- **Performance, in general, seems to be slightly better in both T/V and on-orbit environments than under ambient (i.e., room temperature) testing conditions.**
- **Noise specification is at 2 non-zero signal levels. A model fit to these two data points was used to extrapolate the specification to zero signal level**

Partial Aperture Solar Calibrator

- Partial aperture solar calibrator reflects sunlight through a small 0.16 inch diameter aperture and auxillary optics into ETM+.
- Image *(next vu-graph)* is stretched along scan about 9:1 as orbital pitch (360°/99 minutes) determines sun scanning rate.
- Imaging occurs before terminator is reached (i.e. superimposed on a dark earth background).
- Typically we receive 3 images (off of three different sets of optics) per acquisition at different along track and across track positions -- the PAC image shown in the next vu-graph represents the first of the 3 images.
- Image is scalloped due to the scan line corrector

Landsat-7 ETM+ Partial Aperture Solar Calibrator Image

Creating and Refreshing a Global Archive

- Working with the Landsat Science Team, the Landsat Project Science Office established the concept and mechanism for acquiring a U.S.-held archive of ETM+ images covering the global continental surfaces on a "seasonal" basis
  - created a **Long Term Acquisition Plan (LTAP)** to optimize scene acquisitions
  - promoted the incorporation of cloud cover predict into the daily acq. scenario
  - implemented an improved automatic cloud cover assessment (ACCA) algorithm
  - advocated the concept of acquiring all scenes when flying over all 50 states, not just the lower 48 *(except mid-winter, low light scenes in Alaska)*

Long Term Acquisition Plan -- Overview

- Goal: to optimize use of the on-orbit asset to create a U.S.-held archive of sunlit, cloud-free, ETM+ data providing global coverage of the Earth's continental and coastal surfaces, refreshed on a periodic (seasonal) basis

- Problem: how to schedule ETM+ data acquisition, on-board storage, transmission, and ground processing in light of satellite-system resource limitations
  - satellite power and ETM+ duty cycle
  - data transmission rates (150 Mbps from each of 3 X-band antennas)
  - contact time with U.S.-operated ground station antennas
  - capacity of the on-board solid-state recorder (100 ETM+ scenes)
  - ground data processing system capacity and performance

- Ground Rules: the ETM+ will acquire data every time Landsat 7 passes over all 50 states, irregardless of cloud cover, and the data will be down-linked (or shipped) to the Landsat Ground Station at EDC for archival; EDC will be capable of capturing and archiving 250 ETM+ scenes/day

Long Term Acquisition Plan -- Overview*(cont)*

- LTAP Land Data Base identifies every WRS scene containing land within its boundaries:
  - all continents, with Antarctica starting at minimum ice pack limits
  - Arctic islands
  - inland seas and bays to extent that the WRS scene contains any land
  - unnamed islands, shoals, reefs, rocks, banks
  - within vast shallow coastal areas (<200m deep)
  - scenes close to continental coasts and well within the shallows
- Our current land data base contains approximately 14,000 WRS scenes out of a total of 57,784 scenes
- The scheduling algorithm uses LTAP to assign priorities to the WRS scenes within view of the ETM+ on any particular day. The ETM+ and Landsat 7 satellite will then schedule the acquisition, storage, and transmission of those 250 scenes assigned the highest priorities.

Long Term Acquisition Plan Simulations

- Many 80-day scenarios (i.e., five 16 day cycles) have been run to understand the interplay between archive requests and Int'l Ground Station (IGS) requests
  - working with USGS/EDC to maximize IGS acquisitions and support MOU negotiations
  - trying different combinations of priorities and stations to understand the LTAP/scheduler

    software behavior

- Recent simulation results
  - simulation runs show that 90% of the land scenes defined in the data base are acquired

    within 3 months; dependent on cloud cover since we avoid taking scenes with above

    average cloud cover
  - these runs also show that IGS's, on average, receive 95% coverage of their national

    boundaries and 75% coverage of territory outside their national boundaries

Long Term Acquisition Plan -- Summary

- Given the implementation of LTAP, the need for considering special requests for specific scene acquisitions is minimized -- basically, if an area is highly likely to be cloud-free, it will probably be scheduled for acquisition (also, IGS' will be collecting full coverage within their acquisition range)
- ***Thus, the ground data system at EDC has not been configured to accept individual acquisition requests, at least during the first year of operations.***

Summary

- The Landsat 7 system (spacecraft, instrument, and ground system) is performing well, and we are delighted with the quality of the early results.
- However, we are not in production mode, and will not be, until we have completed the on-orbit verification plan. If activities proceed as we have planned, Landsat 7 data products should be available for sale & distribution on or about July 1, 1999.
  - be assured that the Landsat 7 Team will provide ample notification prior to beginning production operations so that users can plan their orders for Landsat 7 digital data products
- The Long Term Acquisition Plan assures periodic refresh coverage of all major land masses of the world. Therefore, the ground data system at EDC has not been configured to accept individual acquisition requests, at least during the first year of operations.

Summary *(cont)*

- With the Long Term Acquisition Plan and the Image Assessment System, we have put in place two totally new system components that should enhance significantly the quality of the data to be acquired and archived
- The fundamental goal of the Landsat 7 mission is to maintain Landsat data continuity and we feel that there is not doubt that Landsat 7 will meet that objective.
- We feel that the Landsat 7 ETM+, along with LTAP, the IAS, and the rest of ground processing system at EDC, will dramatically enhance the use of remotely sensed data in our daily lives, as well as stimulate the commercial, value-added and education communities.

Upcoming NASA Earth Observation Missions

by

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