Section 9

Introduction to the ALI Instrument and Data Processing

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Overview

- ***Introduction***
- ***ALI Design and Calibration Overview***
- ***Instrument Characteristics***
- ***Flight Data***
- ***Summary***

EO-1 Advanced Land Imager

- ***Primary instrument on EO-1***
- ***Validating new technologies***
  - ***Landsat data continuity, improved performance, and cost reduction***
  - ***Innovative approaches to land imaging***
- ***Designed, developed, and tested by MIT Lincoln Laboratory with NMP instrument team members***
  - ***Raytheon SBRS for the focal plane system***
  - ***SSGPO, Inc. for the optical system***
- ***Measurement requirements were developed***
  - ***From the bottom up by the instrument team***
  - ***In collaboration with the earth science community***

Key ALI Performance Requirements

- ***Meet or exceed ETM+ performance (without thermal band) at minimum size, weight, schedule, and cost***
  - ***3 degree field of view***
  - ***10 m panchromatic GSD***
  - ***30 m multispectral GSD***
  - ***Pushbroom imaging***
  - ***On-orbit internal calibration and stability monitoring system***
- ***Spectral band suite was augmented for science reasons***
  - ***Split band # 4 into two sub-bands***
  - ***Add bands at 442 nm and 1244 nm***
  - ***Reduce spectral width on the Pan band***
- ***Pan band GSD reduced to 10m***
- ***Dynamic range to cover >100% albedo with one gain state***
- ***SNR four to ten times ETM+ values, depending on band***
- ***Demonstrate spatial, spectral, and radiometric calibration for large detector arrays***
- ***Other performance goals guided by Landsat-7***

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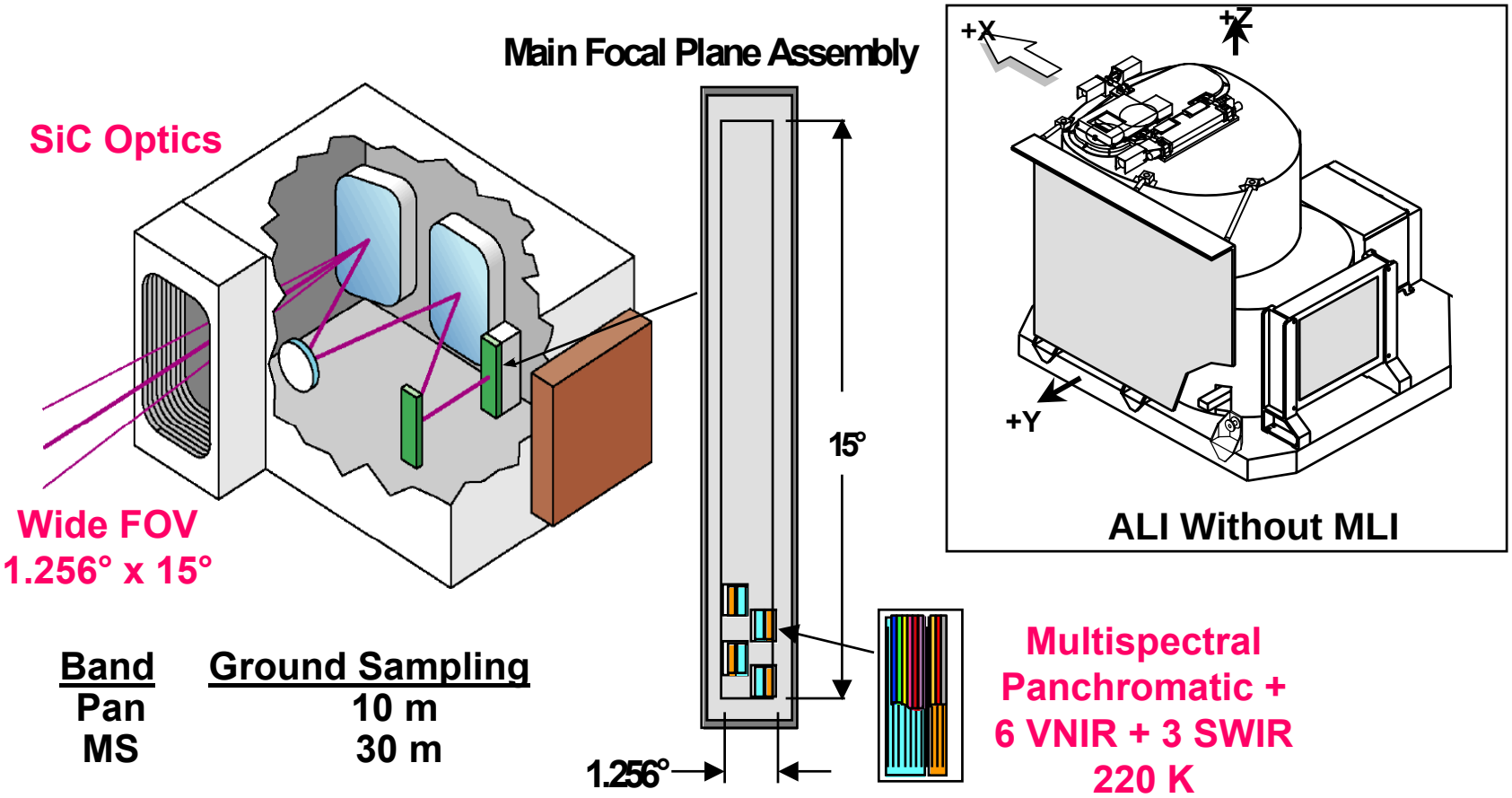
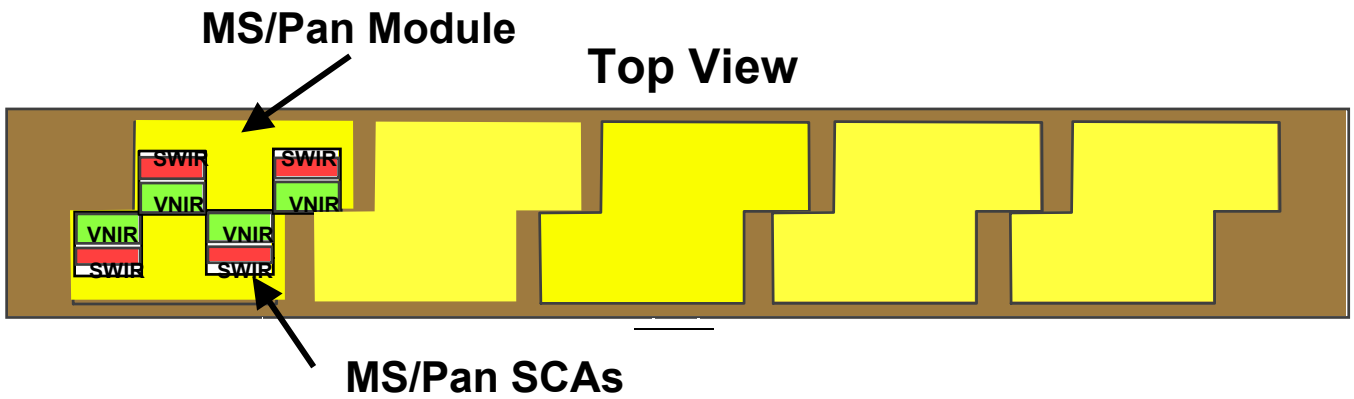
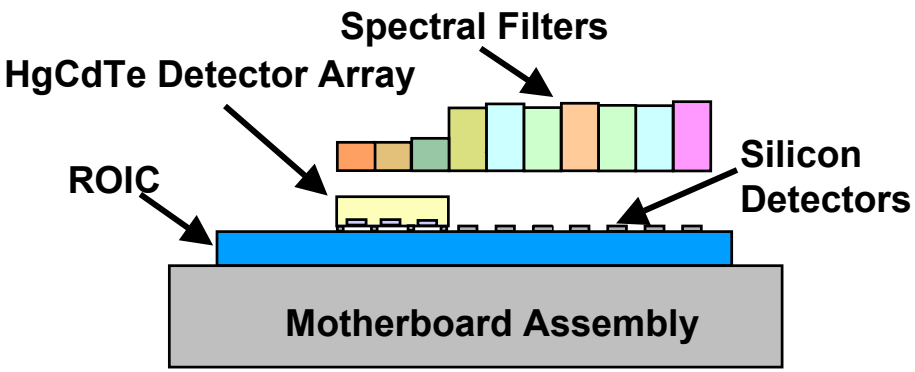
Advanced Land Imager (ALI)



Band	Ground Sampling
Pan	10 m
MS	30 m

Main Focal Plane Assembly

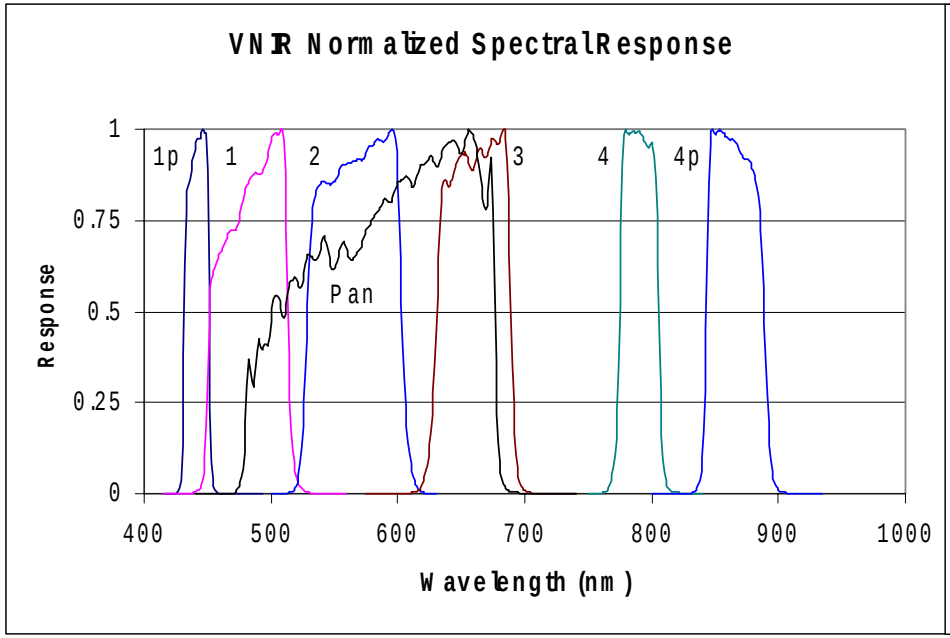


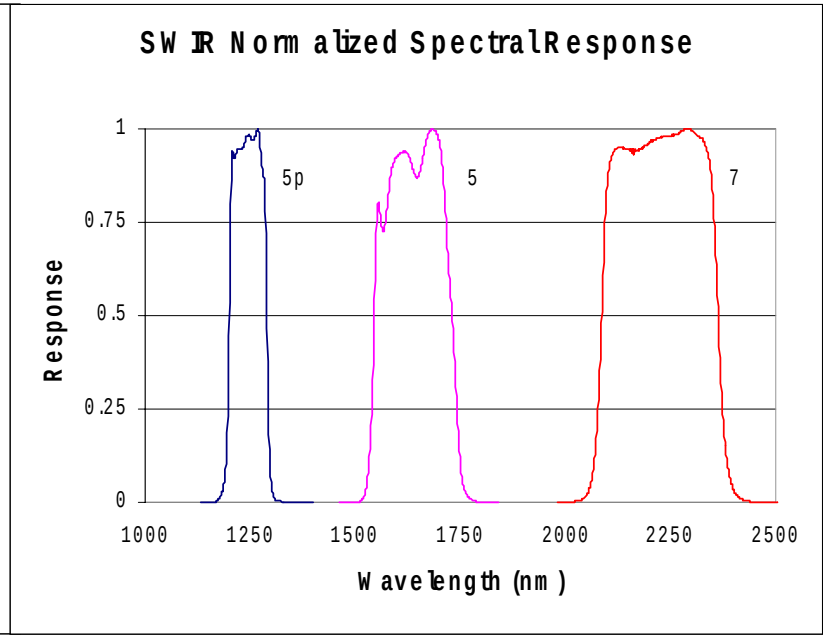


MS/Pan SCA

MS : Multispectral
Pan : Panchromatic
ROIC : Read-out Integrated Circuit
SCA : Sensor Chip Assembly
SWIR : Short Wave Infrared
VNIR : Visible Near Infrared

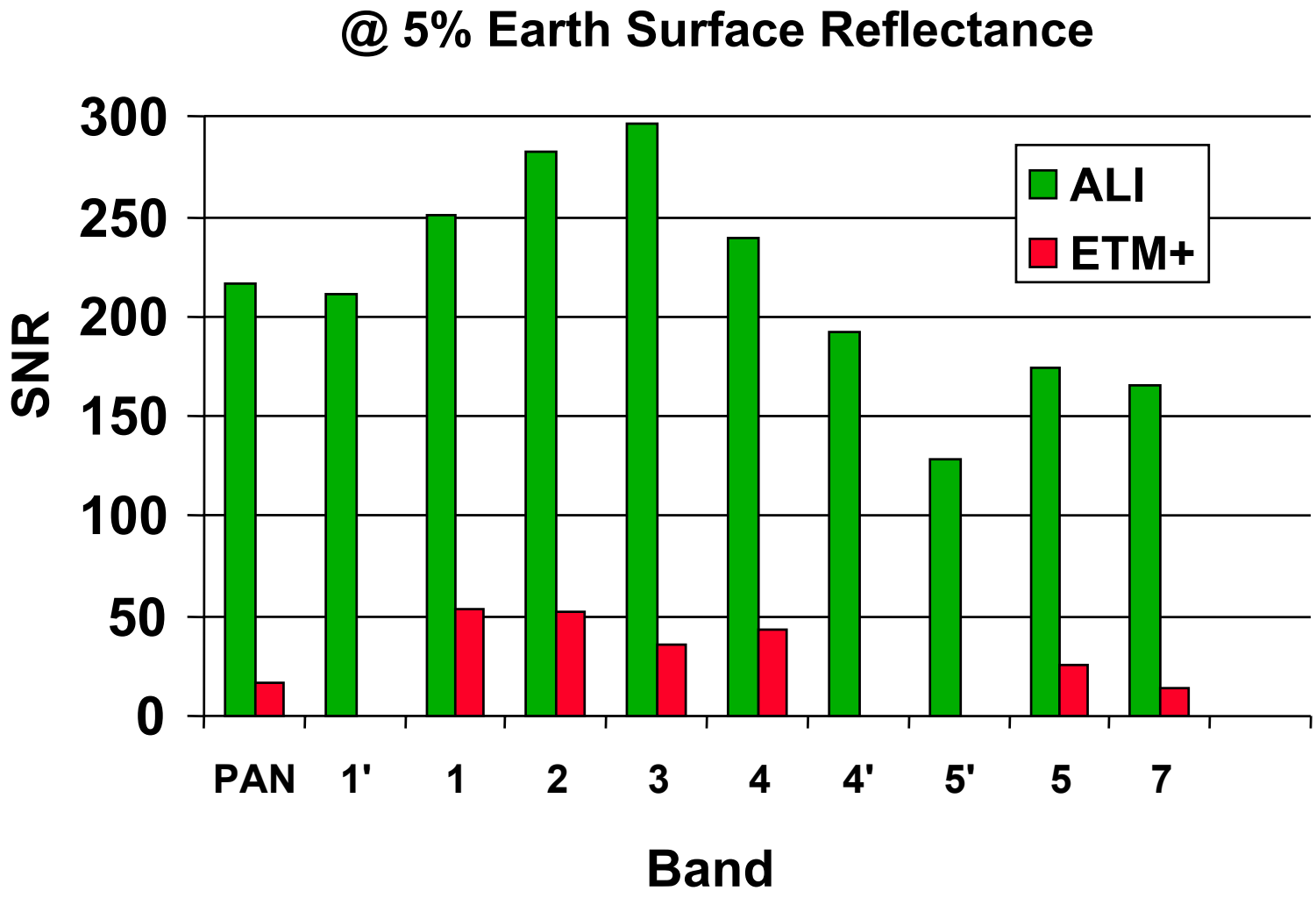
ALI Spectral Response Functions



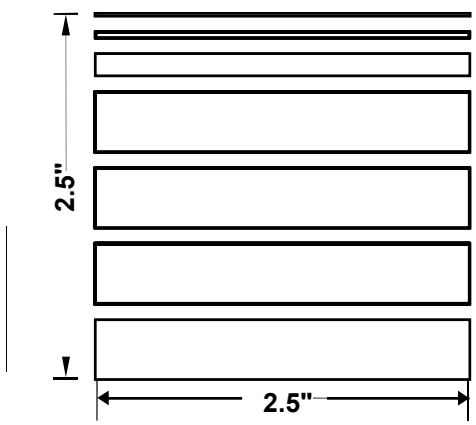


ALI Bands	1p	1	2	PAN	3	4	4p	5p	5	7
Wavelength (nm)	442	485	567	592	660	790	866	1244	1640	2226
Bandwidth (nm)	19	53	70	144	56	31	44	88	171	272

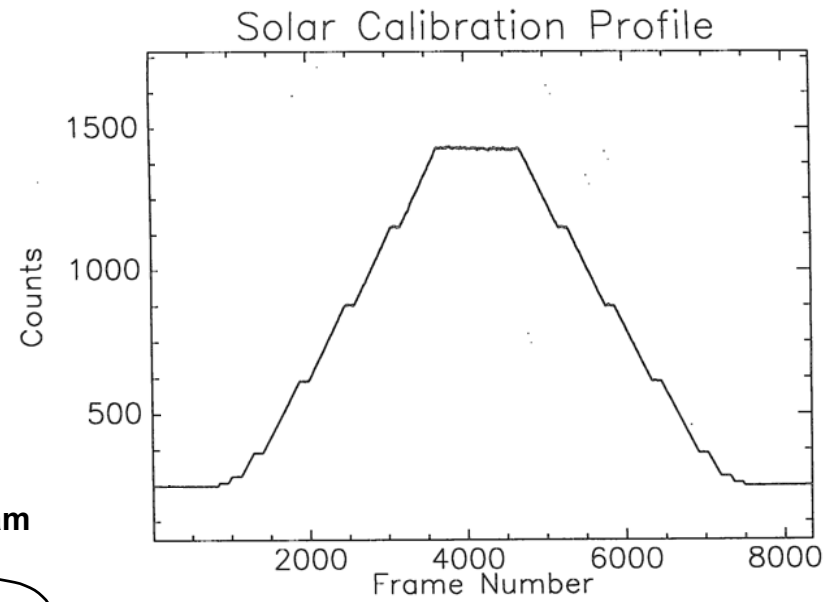
ALI SNR Performance

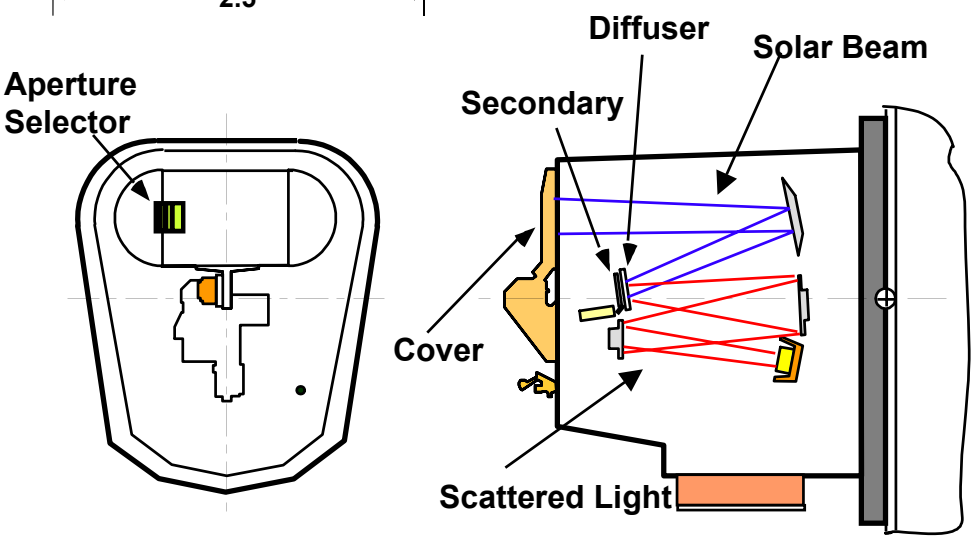


Solar Calibration



Signal Level	Cumulative Signal
1%	1%
2%	3%
7%	10%
20%	30%
20%	50%
20%	70%
20%	90%





Installation of ALI into Thermal Vacuum Chamber

ALI Calibration

- ***ALI well calibrated during ground testing at Lincoln Laboratory with the instrument in a thermal vacuum chamber at expected operation temperatures***
  - ***Focus***
  - ***Modulation Transfer Function***
  - ***Pixel Lines of Site***
  - ***Spectral Response***
  - ***Absolute Radiometry***

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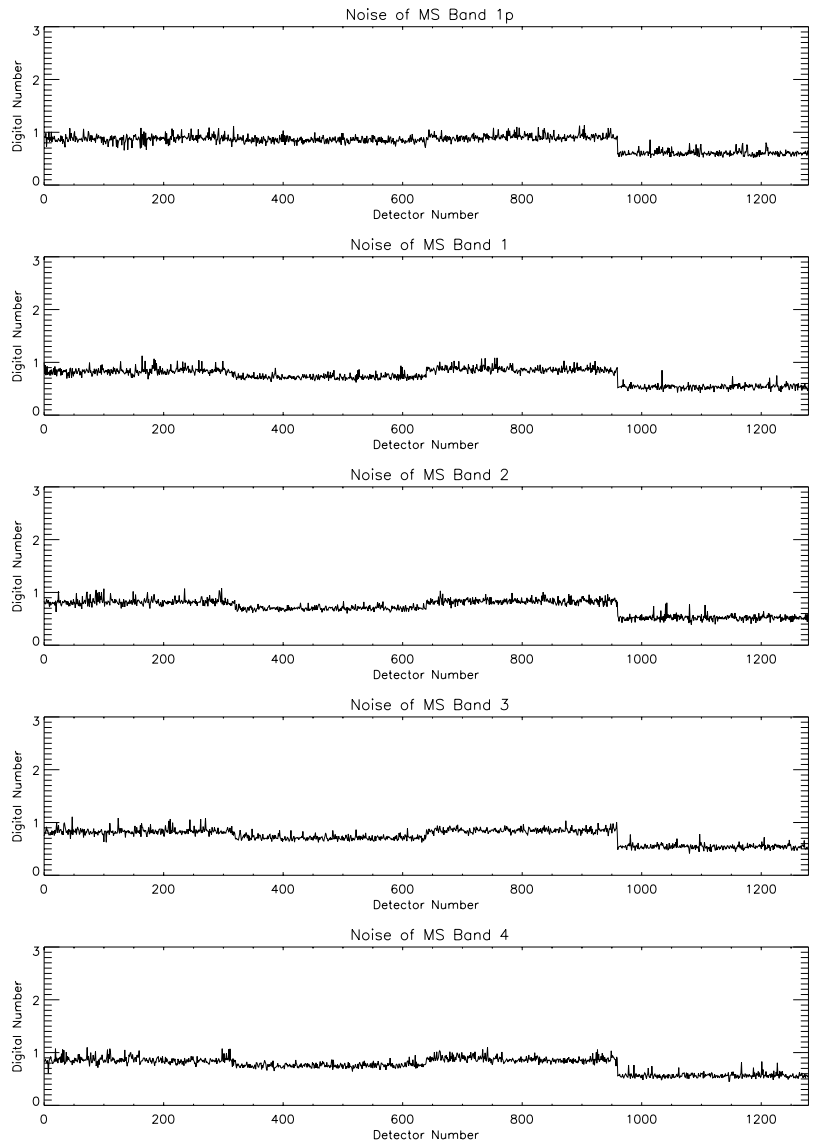
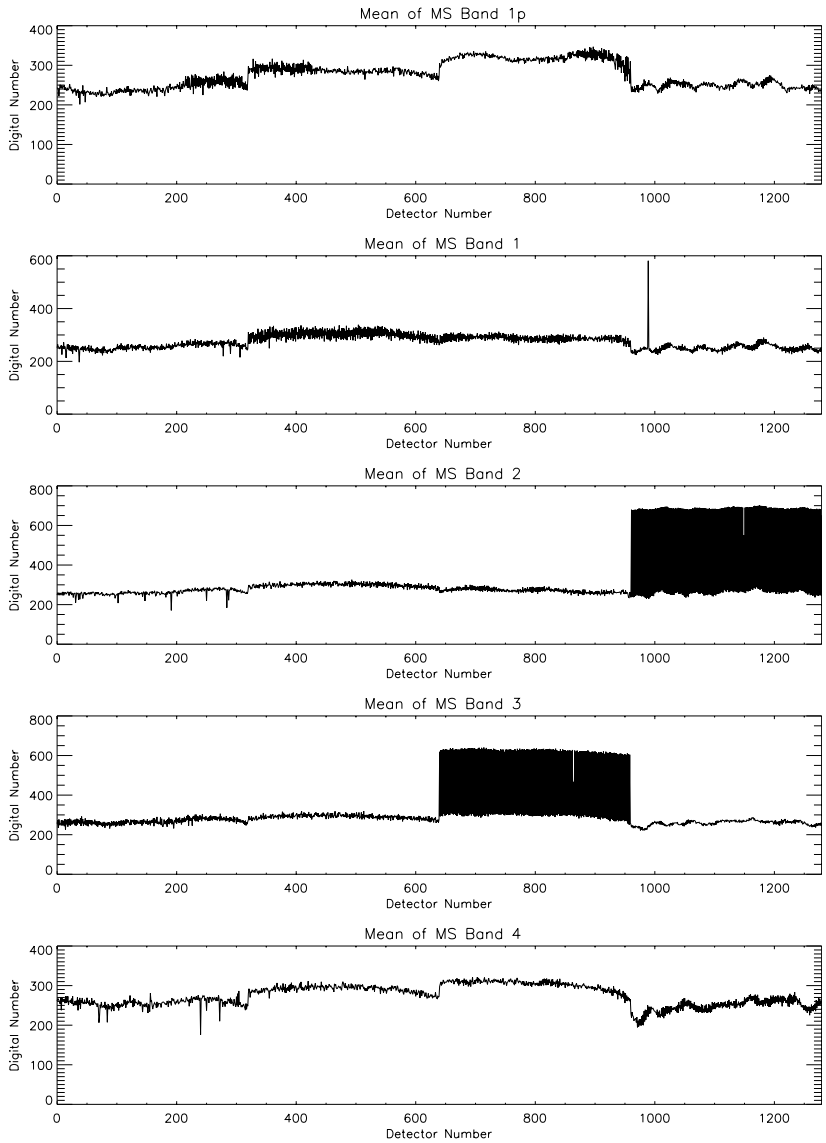
White Noise at 220 K



Dark Current at 220 K



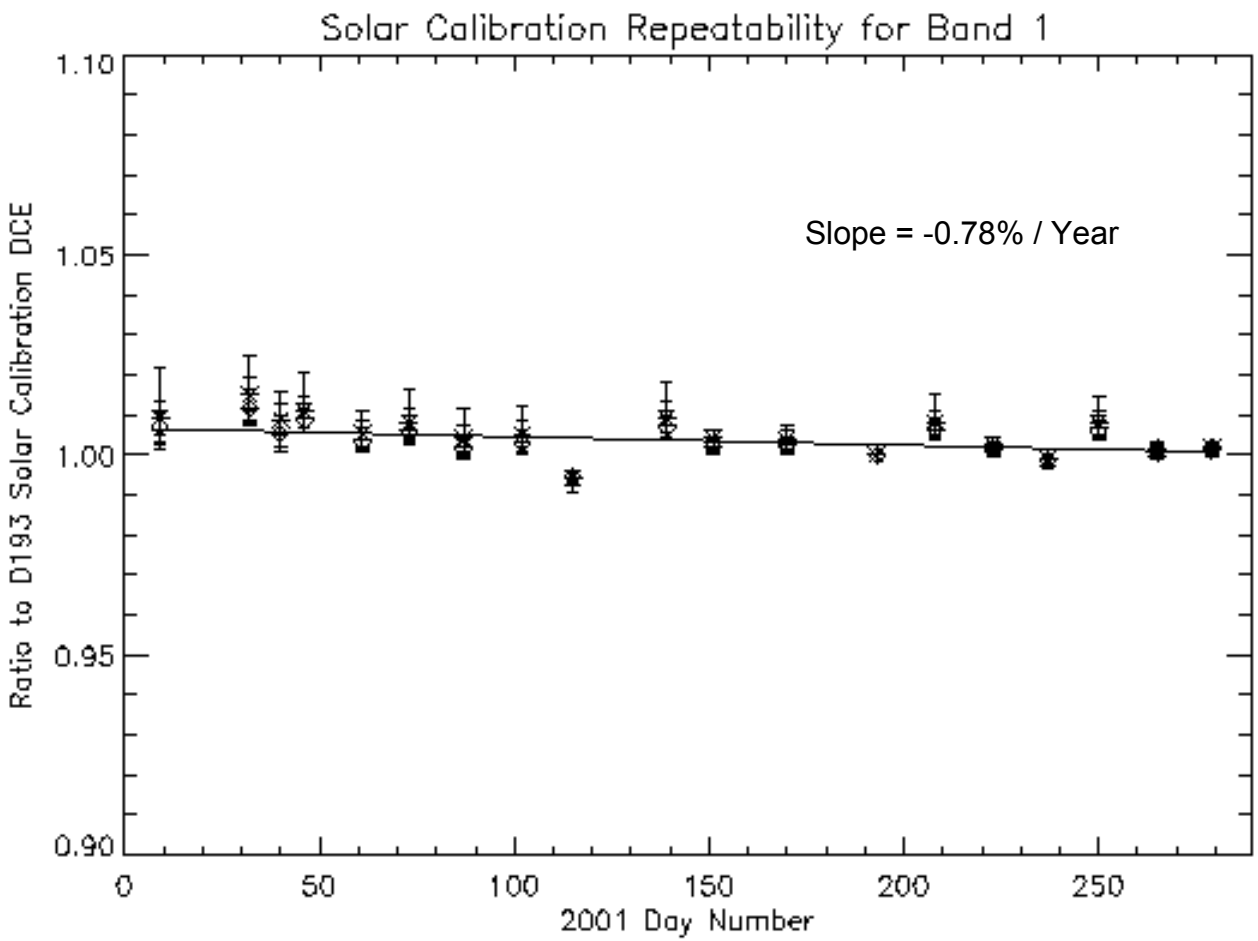
Anomalous Detectors

- ***Inoperable***
- ***Excessive noise (3X mean noise for SCA)***
- ***Excessive dark current (1.25X mean for SCA)***
- ***Anomalous gain***
- ***Cross-talk***
- ***99.96% of focal plane functional***
  - ***6 inoperable***
  - ***21 with degraded performance***
- ***99.82% of focal plane has excellent performance***

Anomalous Detectors

Band	Detector	Inoperable	Excess Dark Current	Excess Noise		High Cross-Talk	Anomalous Gain
				White	PRF		
1	989		X				
2	1149					X	
3	864					X	
5p	2				X		
5p	82			X	X		
5p	83				X		
5p	92			X	X		
5p	99			X	X		
5p	365		X	X	X		X
5p	372			X			
5p	374	X	X	X			
5p	636			X	X		
5p	638	X	X	X			
5	119				X		
5	911		X	X	X		X
5	913		X	X	X		X
5	982	X					X
5	1202	X	X	X			
5	1204	X	X				
5	1206	X	X	X			
7	4				X		
7	11			X	X		
7	17				X		
7	126				X		
7	307				X		
7	382			X	X		
Pan	1631			X			

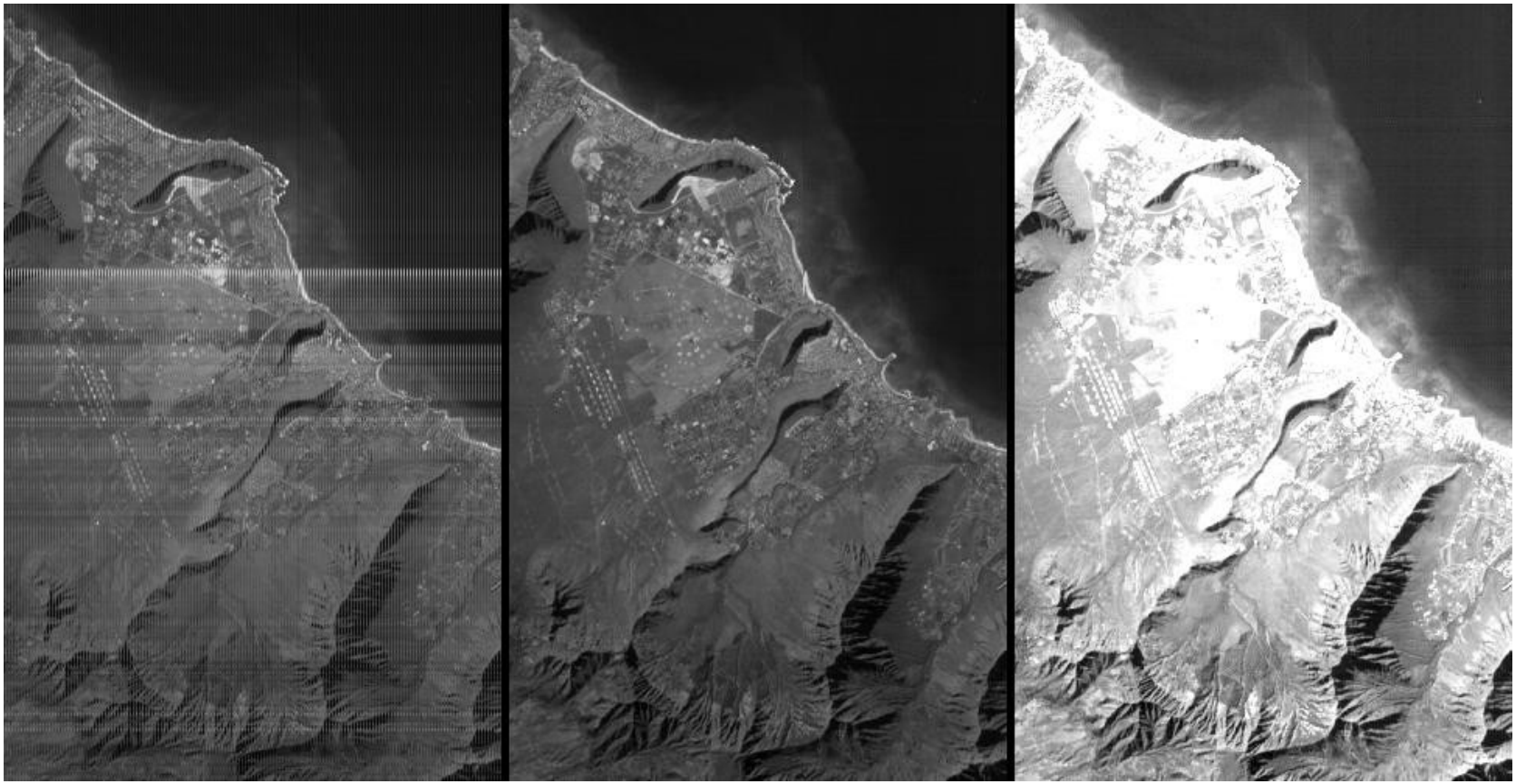
Stability - Band 1



Leaky Detector Correction

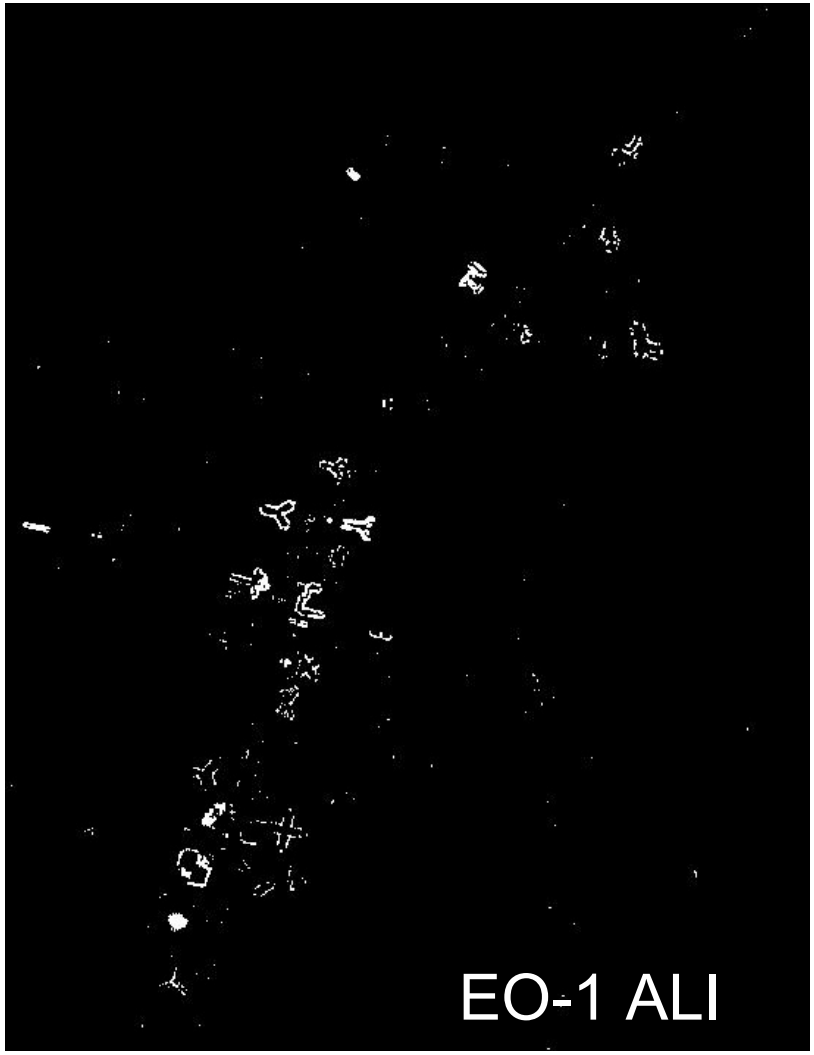
Oahu, 2000:354, Detail

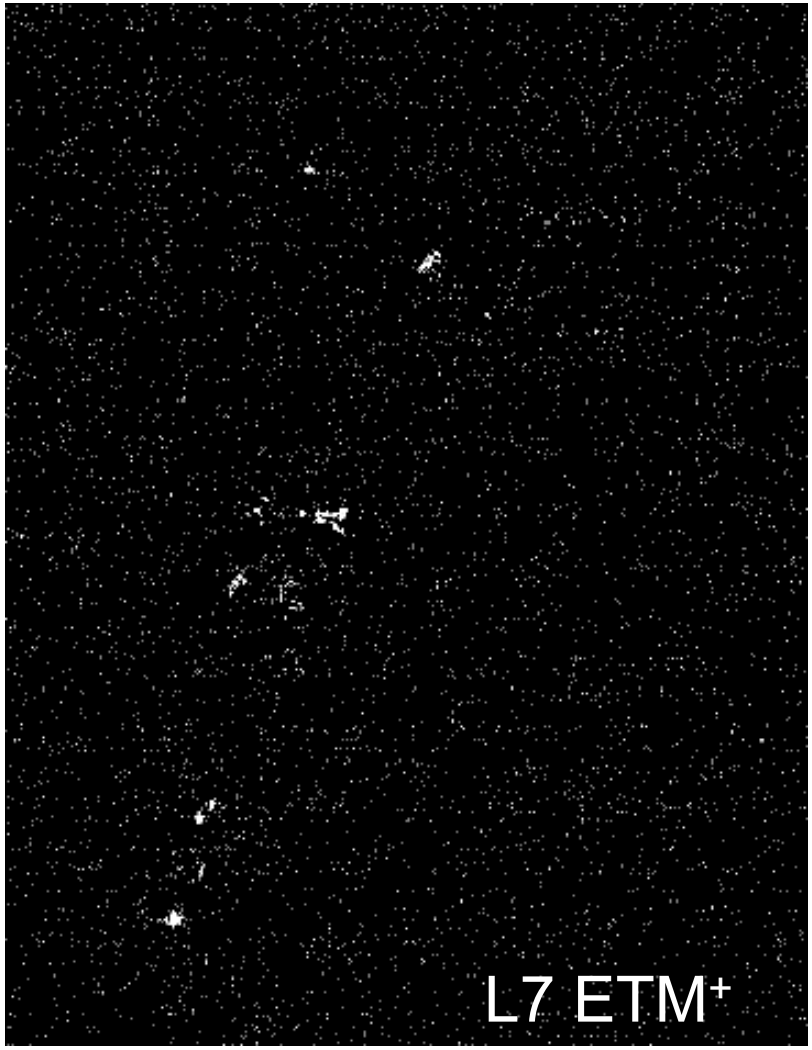
Original **Corrected** **Corrected, high contrast**



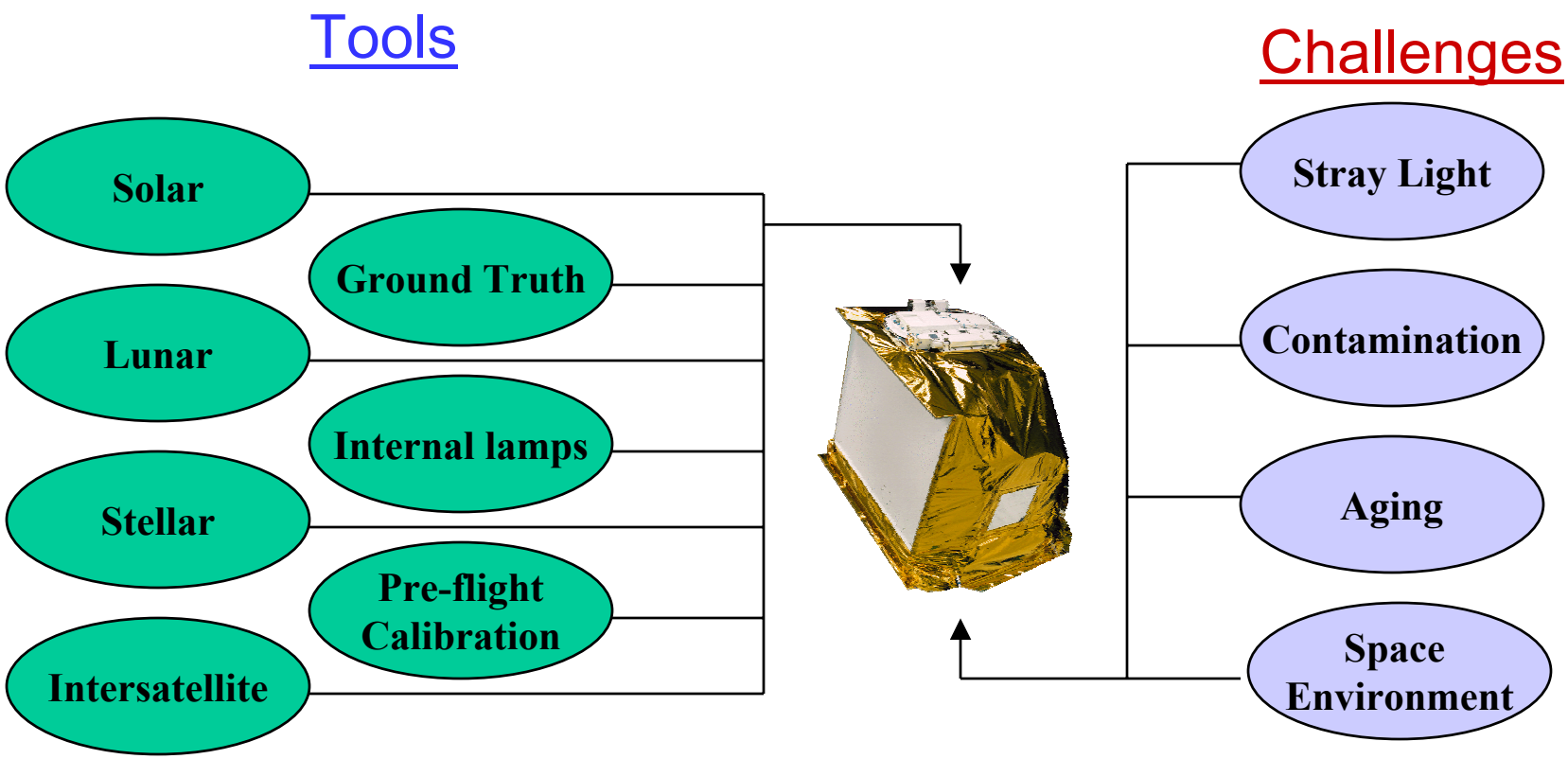
Sensitivity

Las Vegas at night 2001:093, Pan

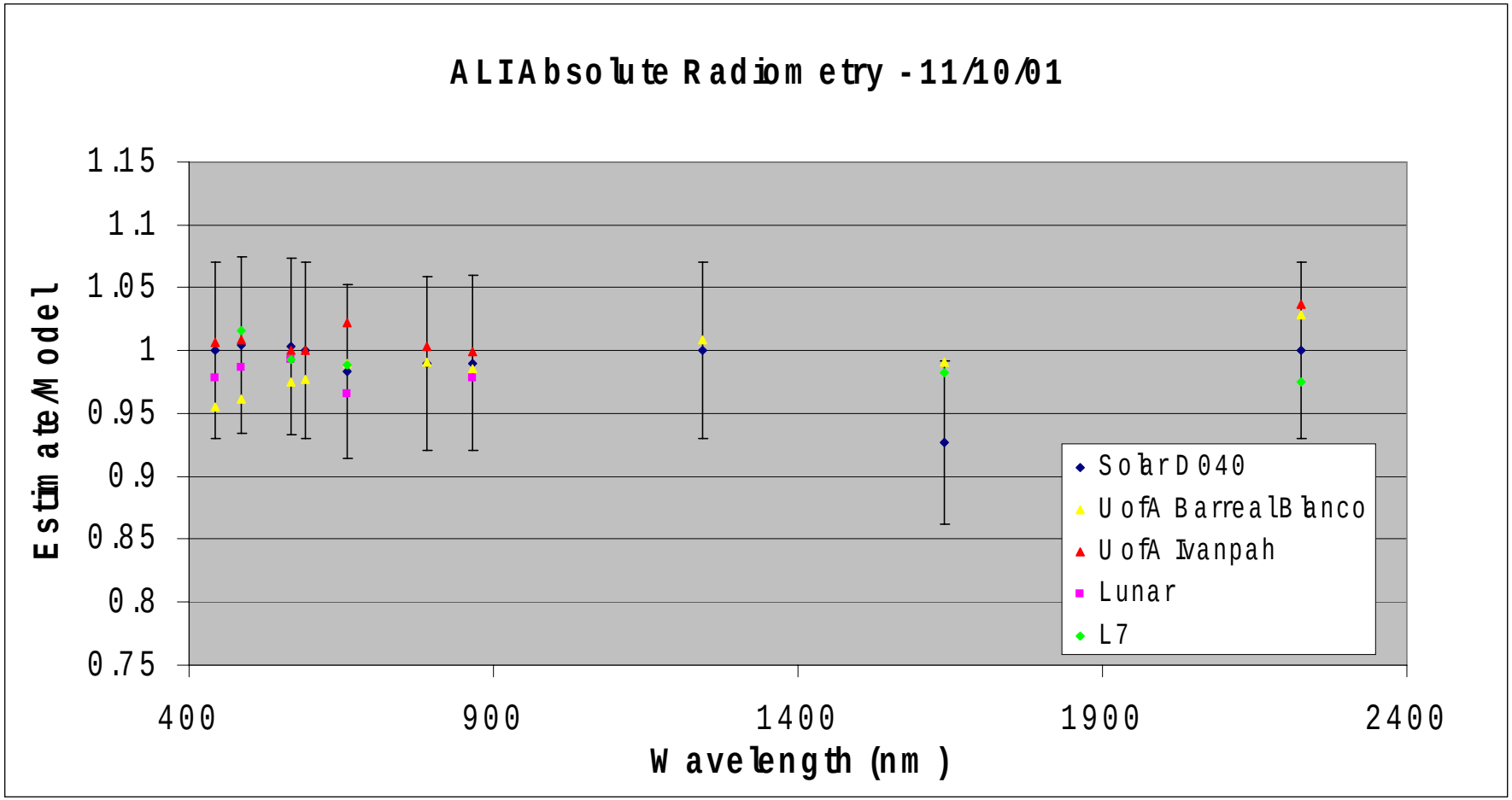




On-orbit Calibration



Absolute Radiometry



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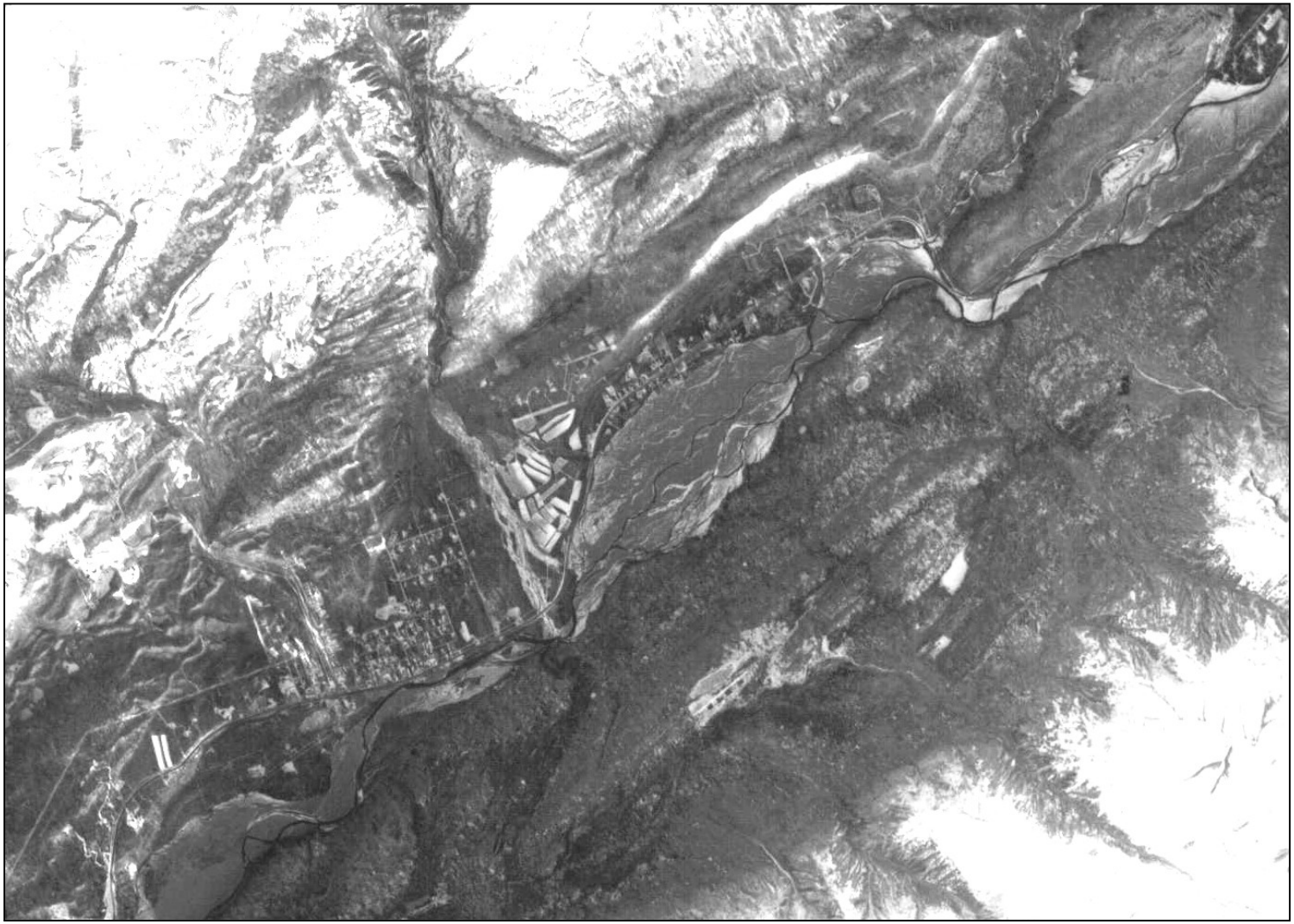
Earth Observing-1 S/C

First ALI Image: Sutton, AK

(2000:330, Pan zoom)



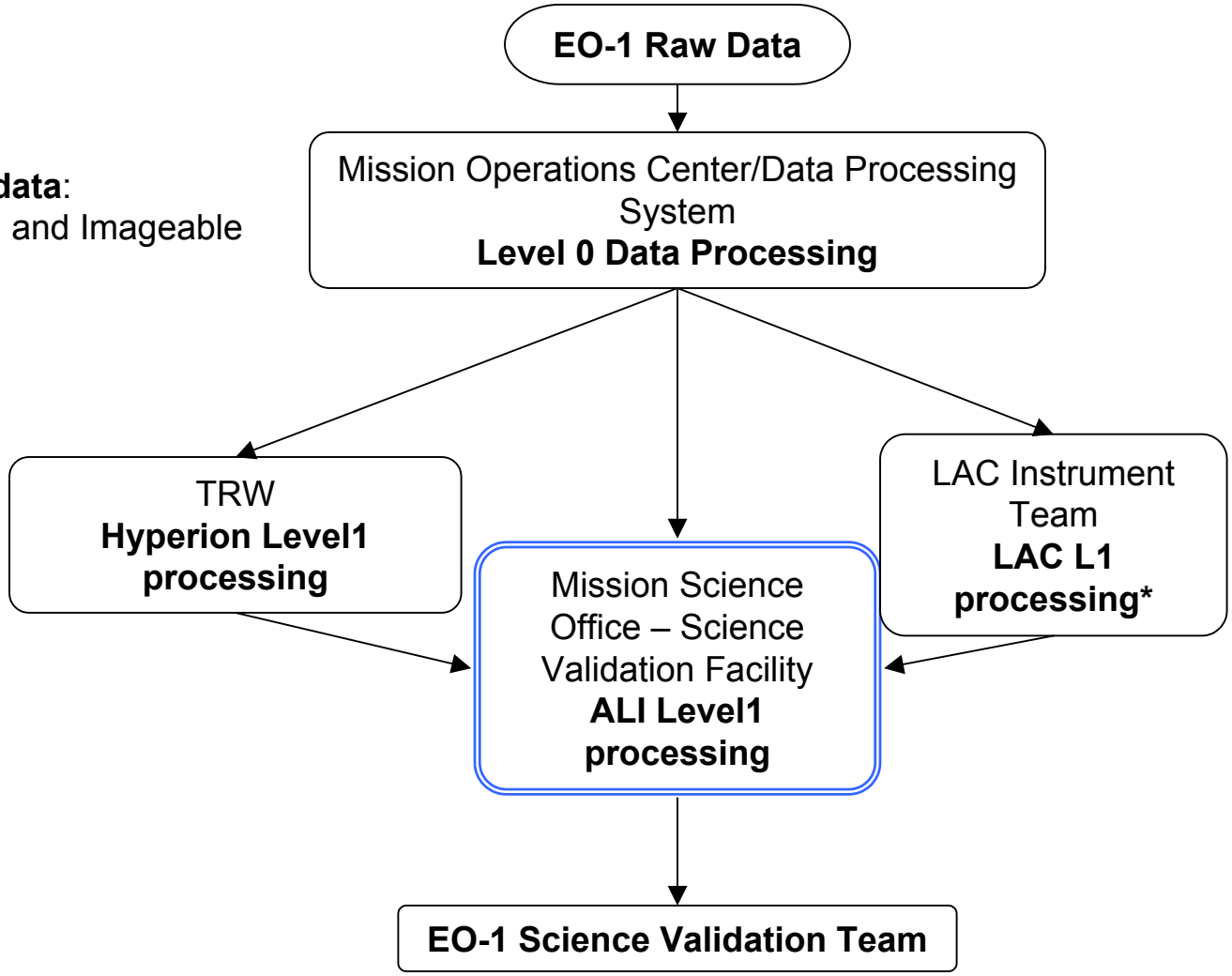
Landsat-7 & ALI Comparison (Sutton, AK)

Level 1 Processing

EO-1 Data Path

Level 0 data:
Decoded and Imageable data.

Level 1 data:
Radiometrically corrected, removal of selected instrument artifacts.



ALI Files

- ALI data files are in EOS-HDF Format
- One file per SCA
- Data attributes are embedded in the files
- Filenames:
  - Level0: **EO1***yyyydddhhmmss*.**M***n***Z**
  - Level1: **EO1***yyyydddhhmmss*.**M***n***R**

    n=1..4 (SCA's)

    y=year, *d*=day of year, *h*=hour, *m*=minutes, *s*=seconds

ALI Level 0 File Description

- ***ALI Level 0 HDF file contents:***
  - ***HDF file attributes:***
    - *Filename, Datalevel, LZP version number, SceneID, Scene description, Data Endian, File generation time, etc.*
  - ***Each file has 6 to 8 datasets depending on whether lamp calibrations was performed***
    - *Pre-image dark*
    - *Image*
    - *Post-image dark*
    - *Lamp (not always present)*

ALI Level 0 File Description *(Continued)*

- ***Each dataset includes 13 attributes***
  - *Sensor ID: MS1, MS2, MS3, MS4, PN1,PN2,PN3, or PN4.*
  - *Dataset Type: Dark, Image or Lamp*
  - *Data start time: eg. 2001333093000*
  - *Data duration [seconds]*
  - *Integration Time [seconds]*
  - *Frame Rate [Frames/seconds]*
  - *Data Gate Open time*
  - *Data Gate Close time*
  - *Number of bytes Prior to Frame sync.*
  - *Number of Cross-Track pixels*
  - *Number of along-track pixels*
  - *Number of Bands: 9 (MS), 1 (Pan)*
  - *Percent Missing data*

ALI Level 1R File Description

- **ALI Level1R are in EOS-HDF format**
- **Level1 filename: EO1***yyyydddhhmmss*.**M***n***R**
  - *n*=1..4 (SCA's)
  - *y*=year, *d*=day of year, *h*=hour, *m*=minutes, *s*=seconds
- There are **4 HDF datasets** in each ALI Level1 file:
  - MS **Level1R** Image(Array: 320 x nframes x 9)
  - MS **Offset** (Array: 320 x 1 x 9)
  - MS **Response** Coefficients(Array: 320 x nframes x 9)
  - PAN **Level1R** Image(Array 960 x nframes x 1)
  - Pan **Offset** (Array 960 x 1 x 1)
  - Pan **Response** Coefficients(Array: 960 x nframes x 1)

ALI Level 1R File Description *(Continued)*

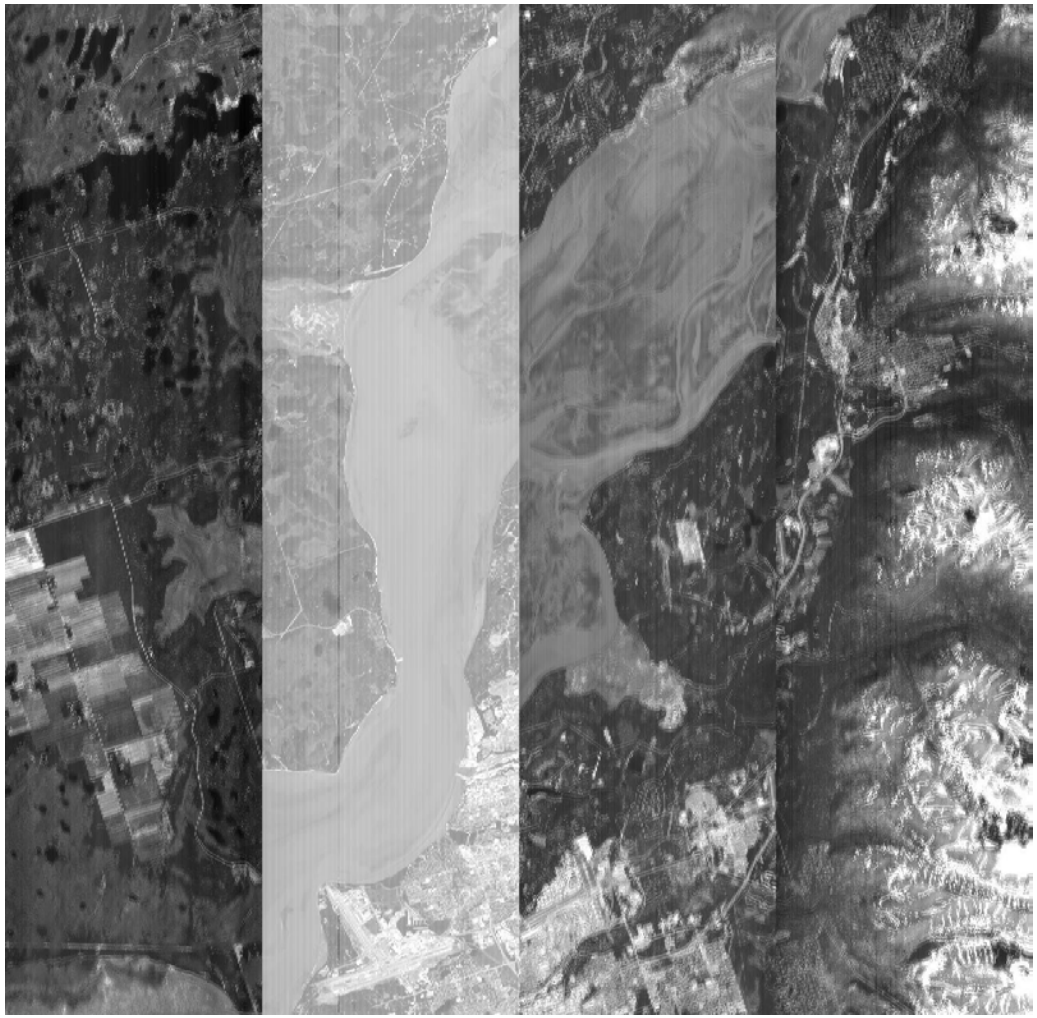
- ***ALI Level 1R File Attributes:***
  - ***All of Level0 File attributes plus calibration software version number (v4.6), Calibration database set (Apr 04, 2001)***
  - ***Frame shifts used to align the images are also included in the attributes lists***
  - ***Data stored as 16bit integers***
  - ***Units are in mW / (cm^2.sr.micron)***
  - ***Scaling Factor = 300***

Level 1R Process

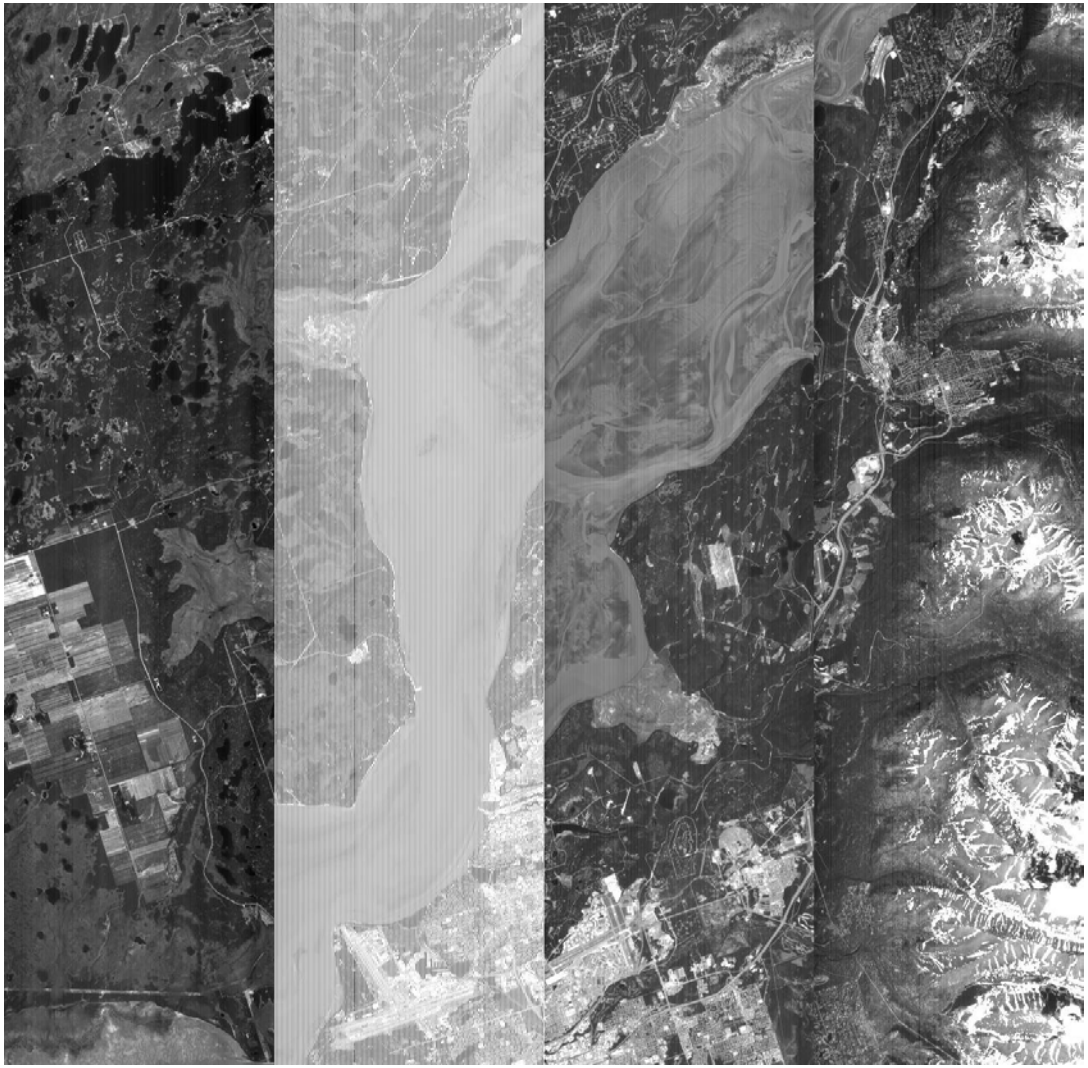
- ***Level0 image (odd-even offset applied)***
- ***Average post-image dark data***
- ***Subtract average dark offset from Level0 image***
- ***Apply calibration coefficients***
- ***Perform leaky pixel corrections for Band 2 - SCA 4 and Band 3 - SCA 3***

Level 1R Process

- ***Raw Image***



Level 1R Process



- ***Raw Image***
- ***Shift odd pixels - Level 0 Product***

Level 1R Process

- ***Raw Image***
- ***Shift odd pixels – Level0 Product***

-----Level 1 Process-----

- ***Subtract dark current***

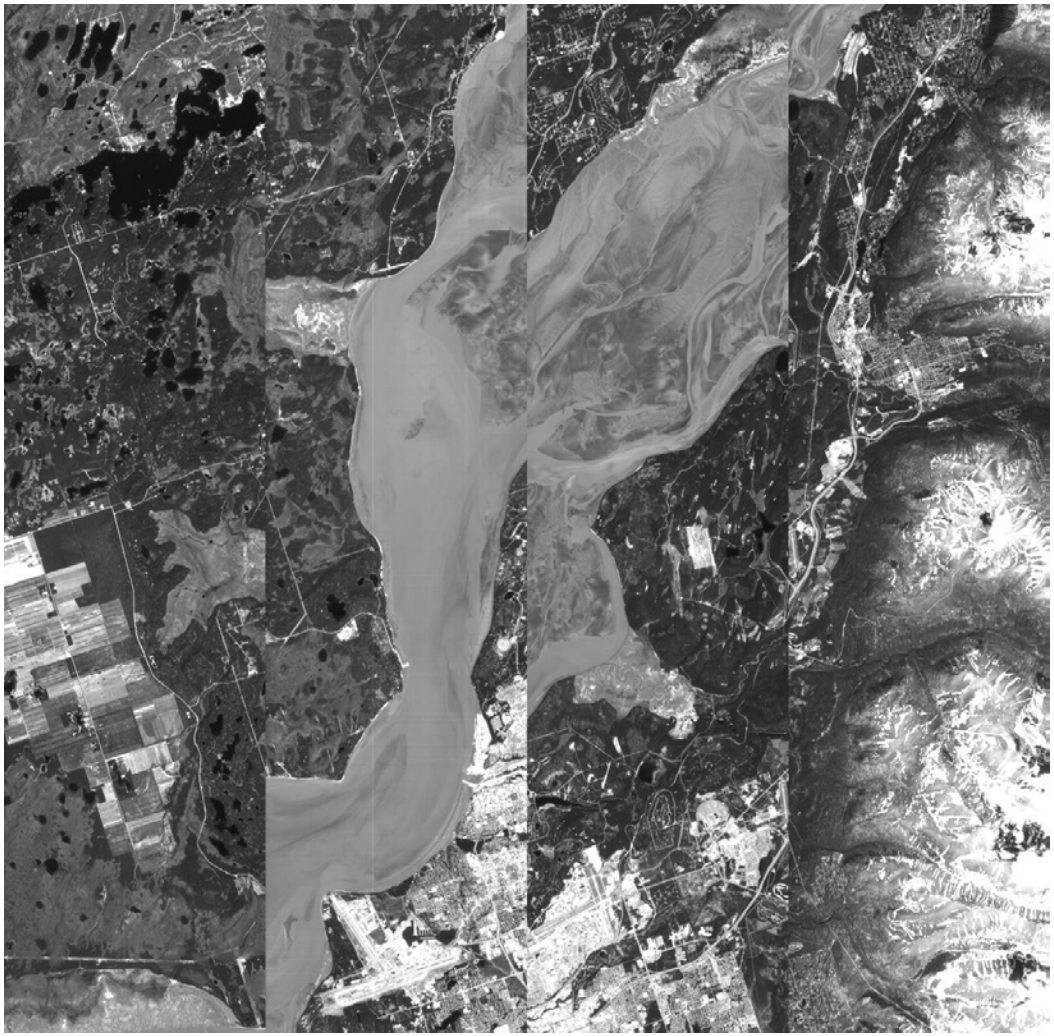
Level 1R Process

- ***Raw Image***
- ***Shift odd pixels – Level0 Product***

-----Level 1 Process-----

- ***Subtract dark current***
- ***Calibrate radiometrically***

Level 1R Process



- ***Raw Image***
- ***Shift odd pixels***

-----Level 1 Process-----

- ***Subtract dark current***
- ***Calibrate radiometrically***
- ***Correct for cross talk; Leaky pixels***

Level 1R Process

- ***Raw Image***
- ***Shift odd pixels***

-----Level 1 Process-----

- ***Subtract dark current***
- ***Calibrate radiometrically***
- ***Correct for cross talk***
- ***Shift odd SCAs***

Level 1R Process

- ***Raw Image***
- ***Shift odd pixels***

-----Level 1 Process-----

- ***Subtract dark current***
- ***Calibrate radiometrically***
- ***Correct for cross talk***
- ***Shift odd SCAs***

----- Post Process -----

- ***Overlay bands***

Washington, DC

(2000:336, Pan)

Boston

(2001:042, Pan)

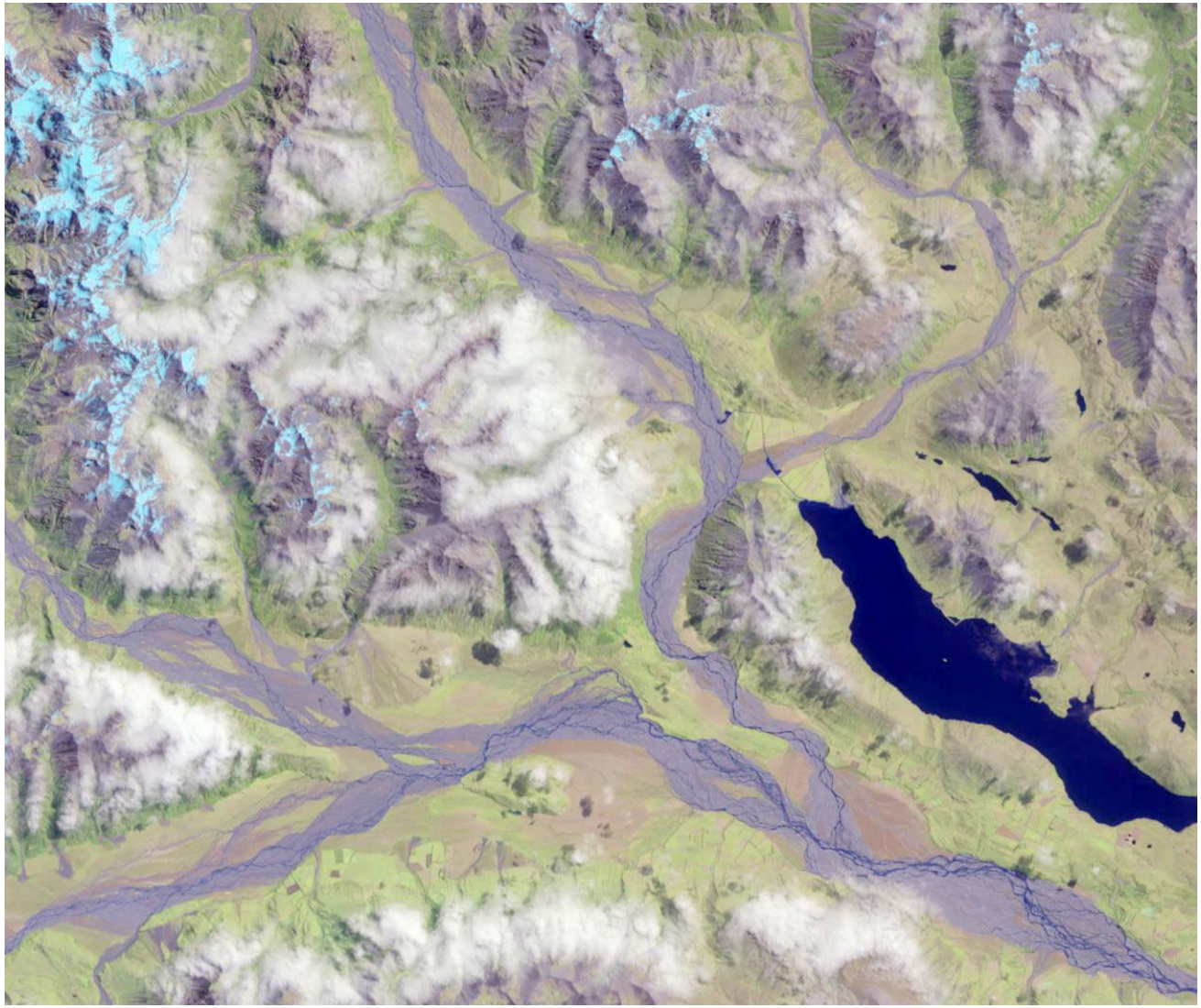
Cape Canaveral

(2001:013, MS 4-3-2)

Oahu, HI

New Zealand

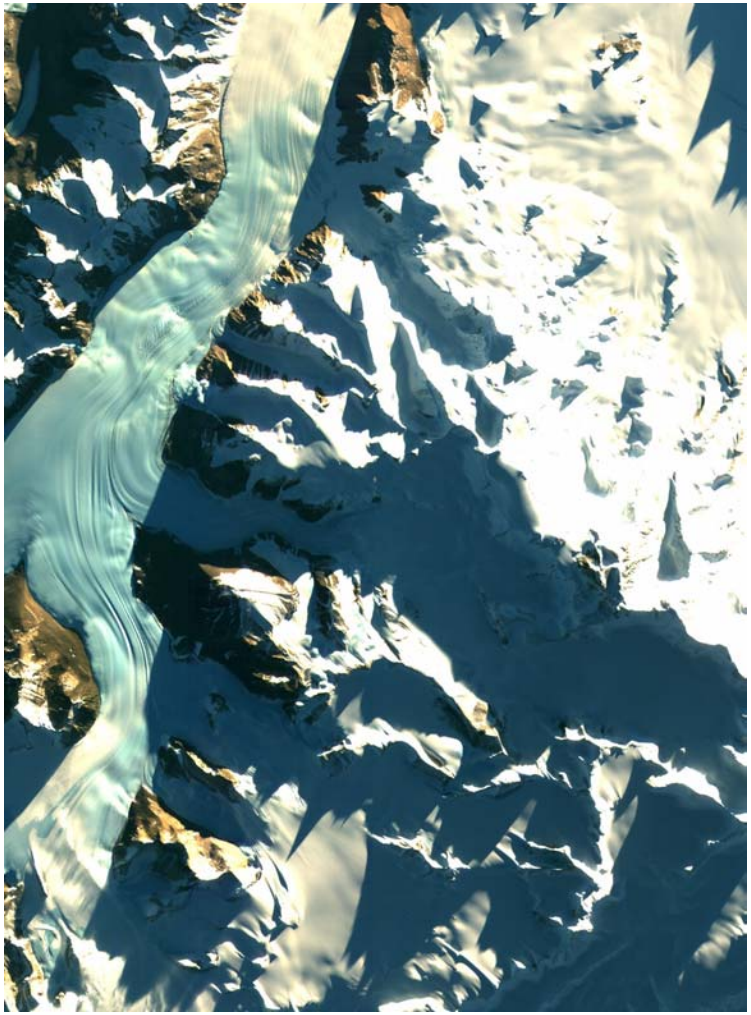
2001:049, MS 7,4,2



Lambert Glacier, Antarctica

2001:044, MS 4-3-2

2001:076, MS 4-3-2



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Summary

- ***ALI performance assessment during Laboratory ground testing closely matches on orbit measurements***
- ***Only handful of detectors (0.18%) show anomalous behavior***
- ***Two leaky detectors with cross-talk have been problematic but an algorithm that removes this effect has been developed and implemented***
- ***On-orbit calibrations proving to be valuable tools***
  - ***Establish ALI absolute radiometric accuracy to within ± 5% (except for water regions)***
  - ***Demonstrate excellent repeatability/stability of the instrument***

MIT / Lincoln Laboratory Reports

◆ EO-1-1:	Instrument and Flight Operations Overview	Released
◆ EO-1-2:	Spectral Calibration	Released
◆ EO-1-3:	Radiometric Calibration	Released
◆ EO-1-4:	Detector Lines of Sight	Released
◆ EO-1-5:	Dark Current and Noise Characterization & Anomalous Detectors	Released
◆ EO-1-6:	Dark Current Stability Over One-half Orbit Period During First 60 Days	Released
◆ EO-1-7:	Dark Current and Noise Trending for the First 60 Days	Released
	MIT/LL Technical Report 1061: EO-1 ALI Modulation Transfer Function	Released
◆ EO-1-8:	Flight Stability During First Year	In Review
◆ EO-1-9:	Leaky Detector Characteristics and Correction	In Progress
◆ EO-1-10:	Flight Spatial Performance Assessment	In Progress
◆ EO-1-11:	Flight Radiometric Performance Assessment	In Progress