



# NASA missions and their role in commercial remote sensing

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# Introduction

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- NASA operates a relatively large number of earth remote sensing sensors and plans to continue this with Decadal Survey Missions.
  - Past sensors typically, viewed as science endeavors
  - Relationship to commercial sector is tenuous
- Talk highlights those missions and NASA activities that
  - Had impacts on commercial activities
  - Emphasis on calibration activities for high-resolution sensors.
  - Upcoming missions that may be of interest to commercial remote sensing
    - ◆ Landsat follow-on mission
    - ◆ Near-term Decadal Survey Missions.
- Discussion is based on the views of a former university professor being a civil servant for three months



# JACIE

## NASA was an original member of Joint Agency Commercial Image Evaluation (JACIE) team

- Several U.S. Government agencies purchased commercial data products for research and applications
  - Required knowledge of data quality
  - JACIE team formed to leverage capabilities of separate agencies
- Three original agencies with unique characterization expertise
  - NASA - Systems Characterization (radiometric, spatial, geometric)
  - NGA (was NIMA)- Photogrammetry and Image Interpretability
  - USGS - Cartographic Assessments



## NASA's original role

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NASA's primary efforts were for radiometric and geometric calibration

- Stennis Space Center organized activities from multiple groups
  - University of Arizona
  - South Dakota State University
  - University of Maryland
- Emphasis was on high resolution imagers (Ikonos, QuickBird, Orbview)
- More recent activities related to the use of commercial sensors as a supplement to Landsat data
- Other activities related to NASA data buys



## Early work

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NASA's primary efforts were for radiometric and geometric calibration

- Joint characterization of Space Imaging's (now part of GeoEye) Ikonos and DigitalGlobe's QuickBird imagery using various sites nationwide
  - MTF and spatial resolution
  - Image interpretability
  - Feature extraction utility
  - Geometric properties of imagery
  - Radiometric accuracy assessment
  - Comparison with Landsat 7 and other satellite imagery
- Four JACIE High Spatial Resolution Commercial Imagery Workshops (2001-2004)



# Example – radiometric calibration

Measurements of surface reflectance of a homogeneous test site



Measurements of atmospheric conditions

Predict at-sensor radiance for a selected area of the site and compare to imagery

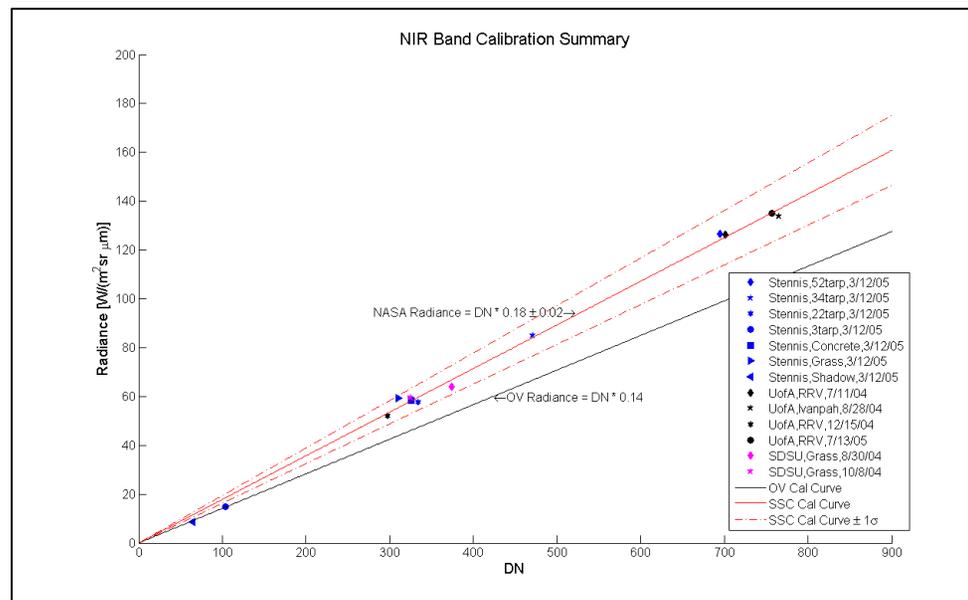
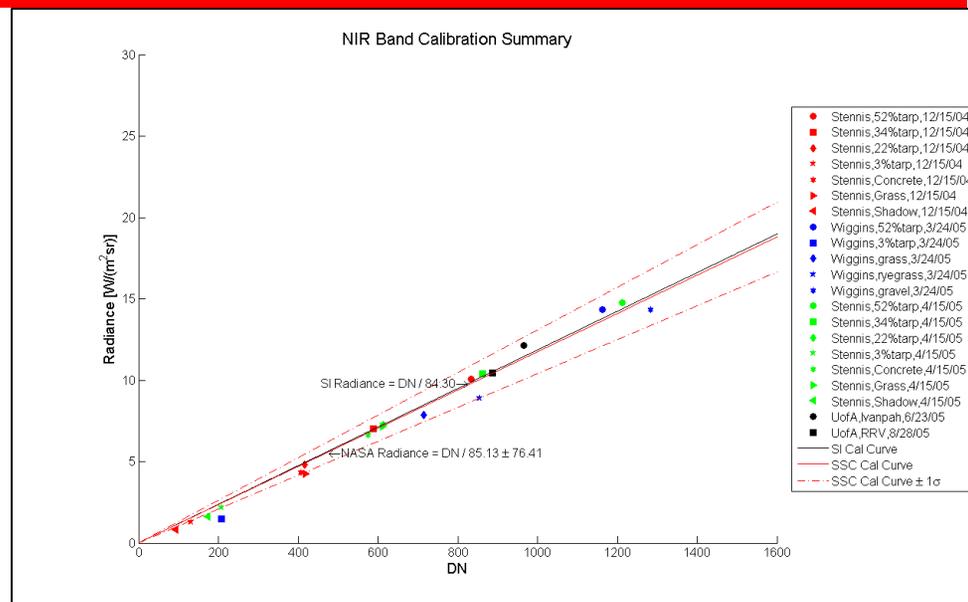
RTC Code





# Example results - radiometric

- Data from all of the groups were gathered and analyzed at Stennis Space Center
- Technical interchange meetings with data vendors allowed the development of consistent radiometric calibrations
- NIR results from two sensors over the same time period



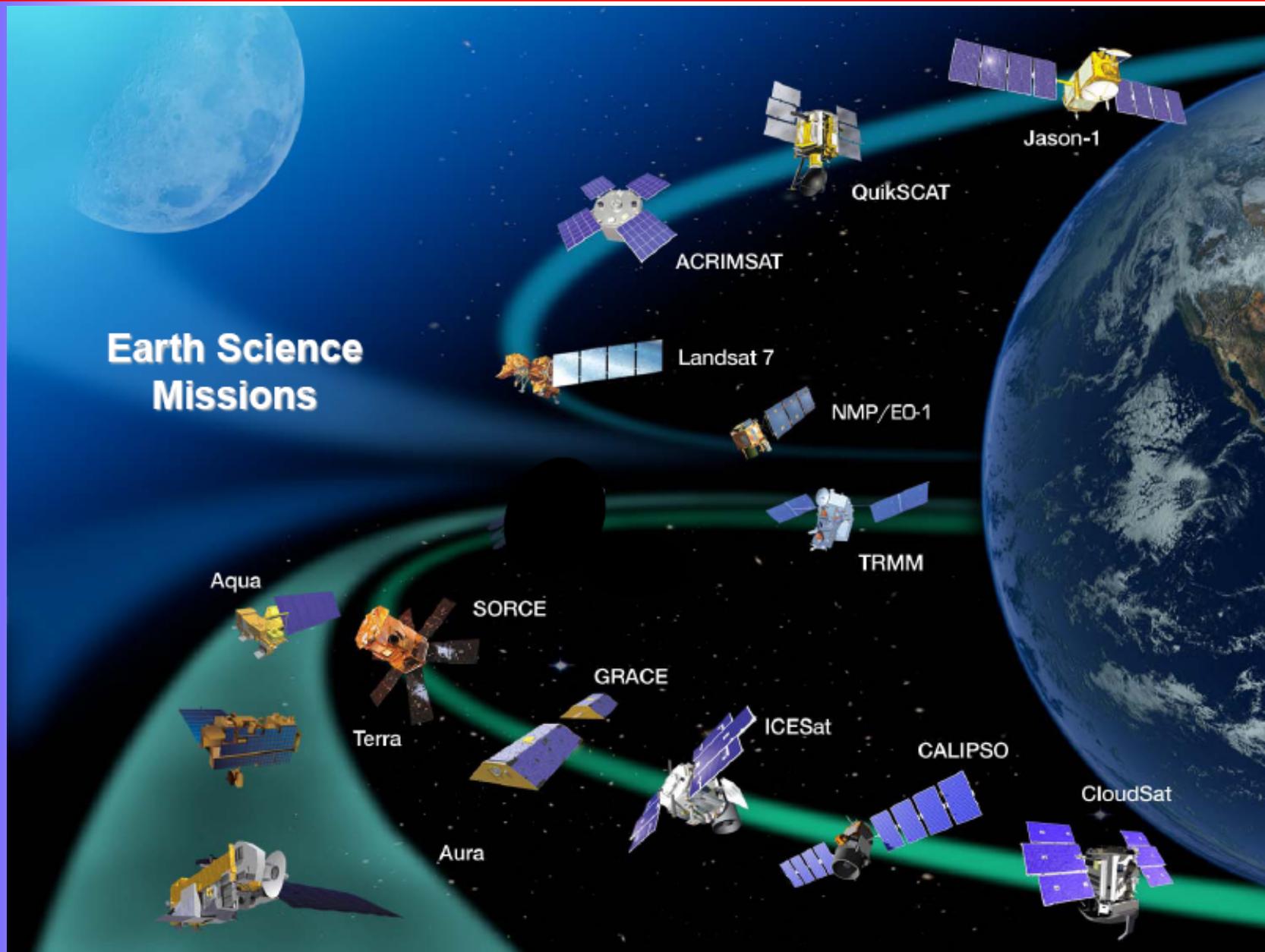


# 2004 JACIE Talk





# Current platforms





# Future missions

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Planned Landsat follow-on and Decadal Survey missions should be of interest to this workshop

- Opted to discuss those missions related to
  - Optical imagers
  - Shortwave and longwave IR parts of spectrum
  - Multispectral and hyperspectral
- Landsat Data Continuity Mission (LDCM) is the result of many years of effort to continue the Landsat program
- Decadal Survey Missions are a response by NASA to a National Research Council report
  - NRC made 29 different recommendations in many areas for Earth Science
  - NASA is working to address the many of these recommendations



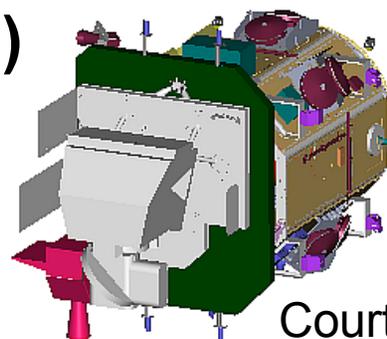
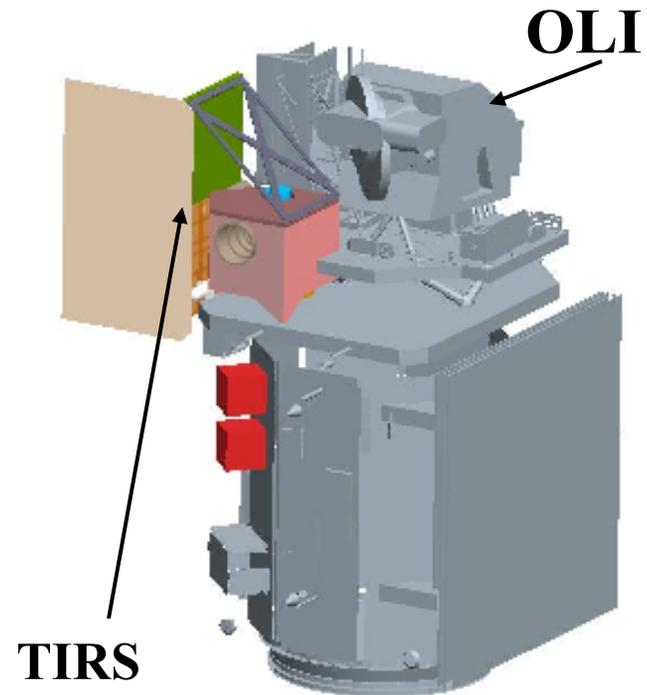
# LDCM

Launch date December 2012

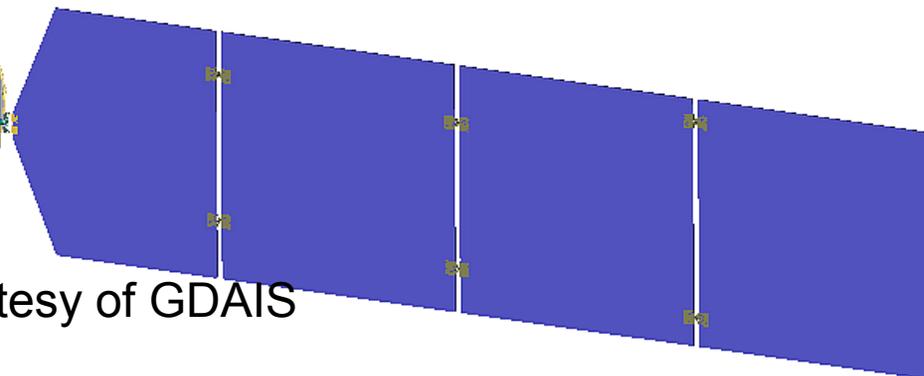
Operational Land Imager being built by Ball Aerospace and Technology Corp.

Thermal InfraRed Sensor from Goddard Space Flight Center

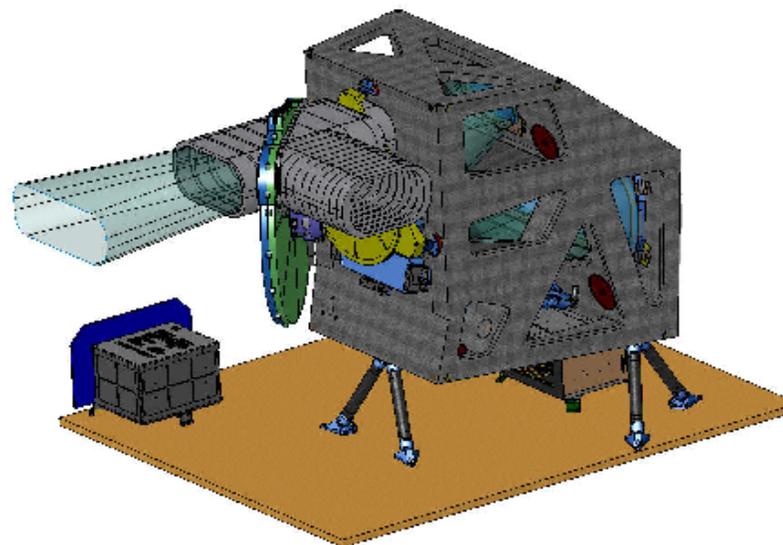
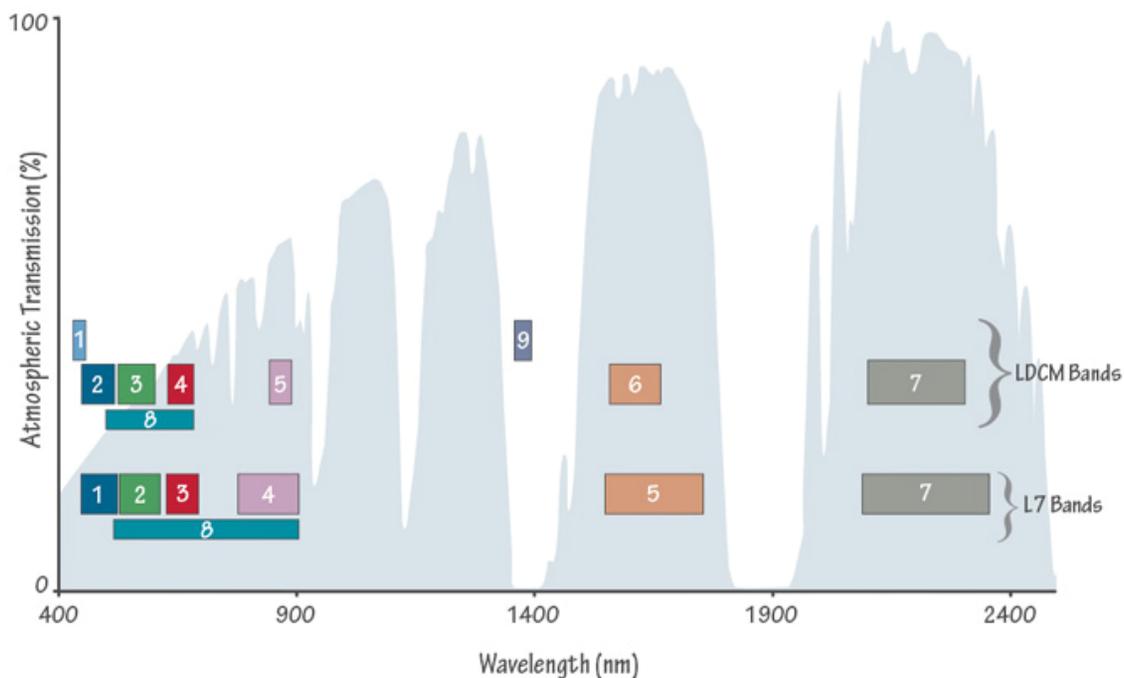
Spacecraft being from General Dynamics Advanced Information Systems (GDAIS)



Courtesy of GDAIS



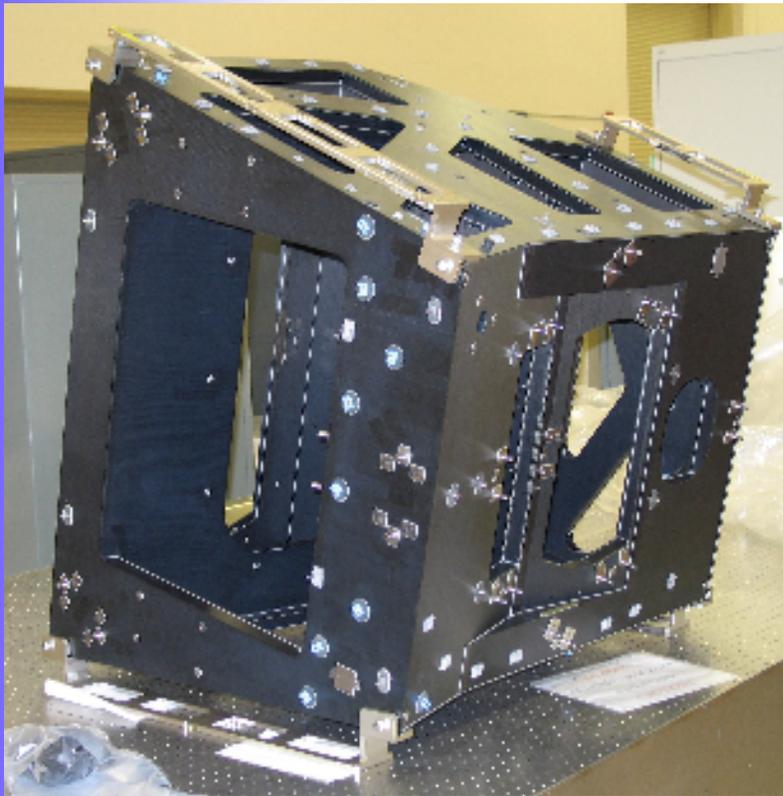
- Pushbroom VIS/SWIR sensor
- Four-mirror telescope with front aperture stop
- FPA consisting of 14 sensor chip assemblies, passively cooled
- Aperture 135 mm
- F number 6.4
- 36  $\mu\text{m}$  / 18  $\mu\text{m}$  detectors (MS / Pan)



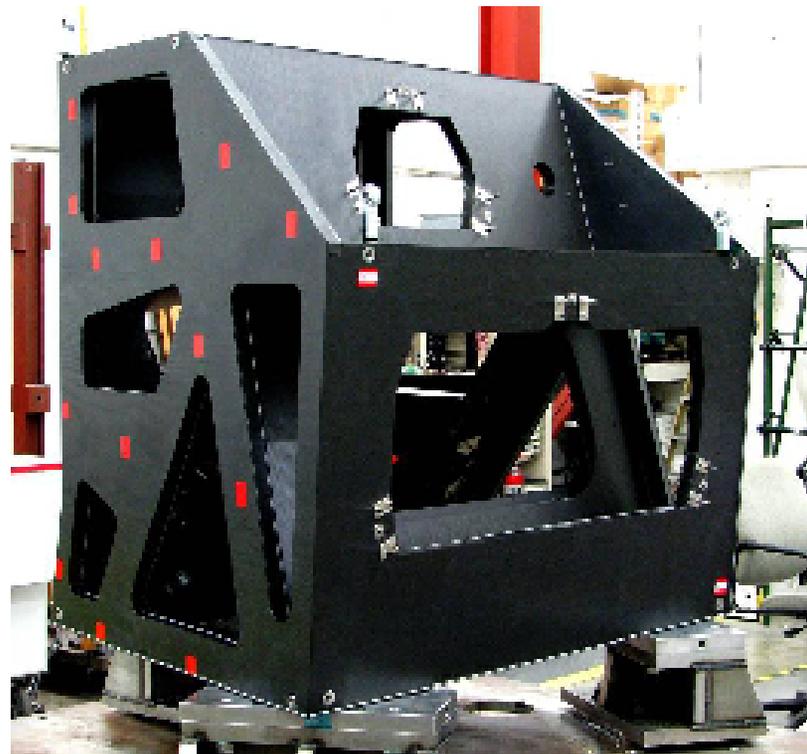
Courtesy of BATC



# OLI Main Bench Assembly



Side View of Bench



Back View of Bench

Courtesy of BATC



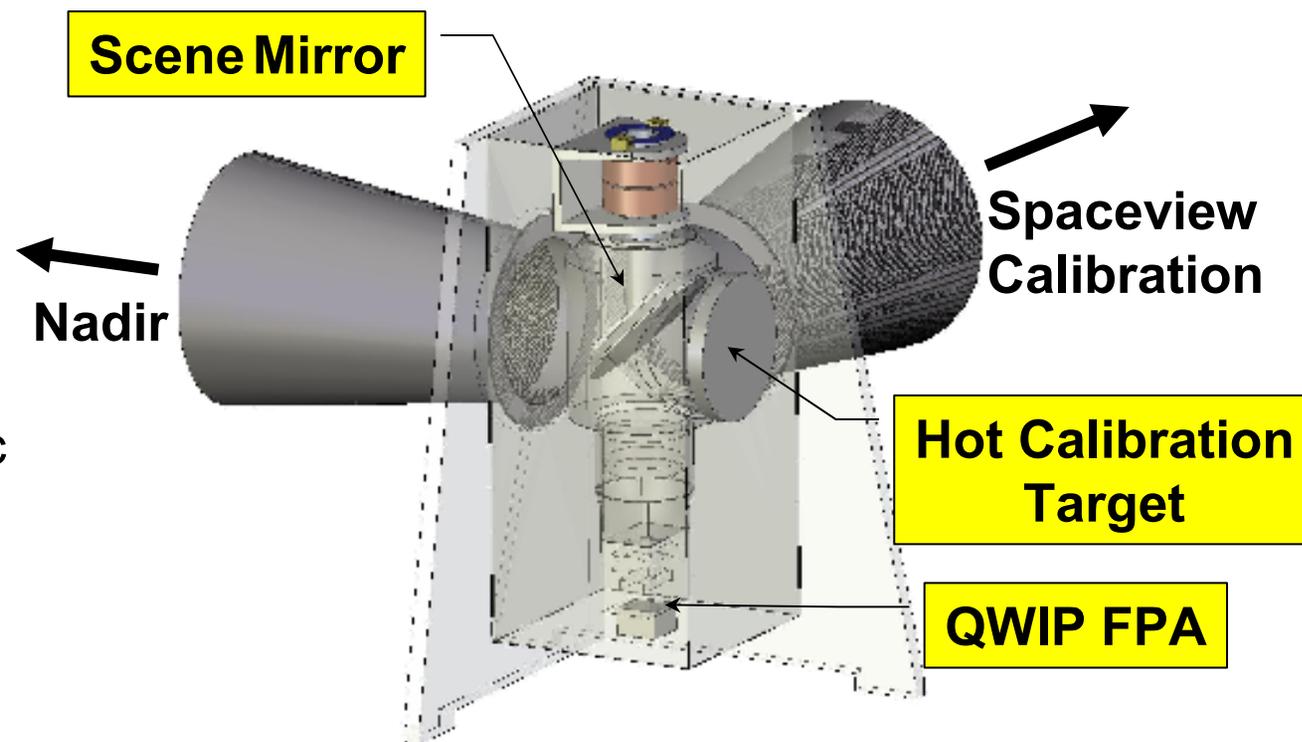
# TIRS Status

## NASA Authorization Act of 2008 included wording for continuity of Landsat thermal data

- A Phase A Study was initiated July 1, 2008.
  - The Purpose of this study was to investigate the implementation of a Thermal Infrared Sensor for LDCM and provide risk mitigation to the Dec. 2012 launch readiness date.
    - ◆ Evaluate / Allocate LDCM requirements.
    - ◆ Create a feasible concept design.
    - ◆ Assess the programmatic implementation including the schedule and early procurements needed prior to PDR.
    - ◆ Begin the instrument development activities.
- Concept design developed, meets or exceeds the TIRS performance requirements.
  - System Concept Review held October 17, 2008
  - Independent Review of the current TIRS concept.

- 120 m resolution sufficient to resolve most center-pivot irrigation fields in Western U.S.
- Landsat satellites provide 16 day repeat imaging -- sufficient for water consumption estimation
- A two band instrument to enable atmospheric correction

Band	Center Wave length (micrometers)	Spatial Resolution At Nadir (m)	NE $\Delta T$ Requirements	
			At T <sub>Typical</sub>	At T <sub>High</sub>
Thermal 1	10.8	120	0.4K	0.35K
Thermal 2	12.0	120	0.4K	0.35K





# Decadal Survey Missions – Tier 1

Tiers indicate development schedule

<b>Mission</b>	<b>Mission Description</b>	<b>Orbit</b>	<b>Instruments</b>
CLARREO (NASA portion)	Solar and Earth radiation: spectrally resolved forcing and response of the climate system	LEO, Precessing	Absolute, spectrally-resolved interferometer
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer
ICESat-II	Ice sheet height changes for climate change diagnosis	LEO, Non- SSO	Laser altimeter
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health	LEO, SSO	L-band InSAR Laser altimeter



## Decadal Survey - Tier 2

<b>Mission</b>	<b>Mission Description</b>	<b>Orbit</b>	<b>Instruments</b>
HypIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health	LEO, SSO	Hyperspectral spectrometer
ASCENDS	Day/night, all-latitude, all-season CO <sub>2</sub> column integrals for climate emissions	LEO, SSO	Multifrequency laser
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics	LEO, SSO	Ka-band wide swath radar C-band radar
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	GEO	High and low spatial resolution hyperspectral imagers
ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry	LEO, SSO	Backscatter lidar Multiangle polarimeter Doppler radar



# Venture Class

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NRC recommended a “Venture Class” line of small, cost- and schedule-constrained missions

- Competitively selected “missions” to complement the identified strategic missions
  - Single string instruments allowed
  - High risk, high return demonstration technology a consideration
  - Creative spacecraft & launch options considered
- FY09 budget does allow a “Mission of Opportunity” with start in FY10 and launch NET FY14 -- with only a small amount of money
- The named missions in the Decadal Survey will not be Venture Class, but will be executed through the Earth Systematic Missions Program Office



# HySpIRI

Hyperspectral Infrared Imager is a Tier 2 mission for the 2013-2016 timeframe

- Hyperspectral imager in visible to SWIR & thermal multispectral scanner
- Goals
  - **Global** ecosystem (terrestrial & aquatic) condition & change
  - **Global** surface temperature & emissivity measures for hazards, water use & availability, urbanization, & land surface composition & change
- Decadal Survey recommendations set boundary conditions for mission design efforts
- Should not stray from guidance and only do so for most compelling reasons of science, cost, mission design, etc.



# Hyperspectral imager



Imaging spectrometer: 87kg / 38W

Schedule: 4 year phase A-D, 3 years operations

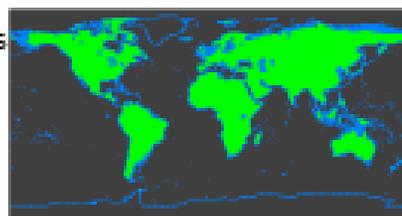
All components have flown in space

## Science Questions:

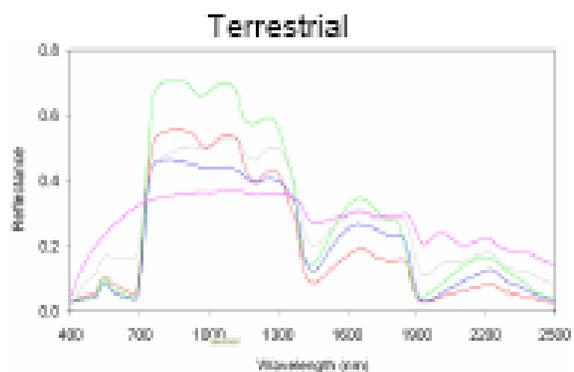
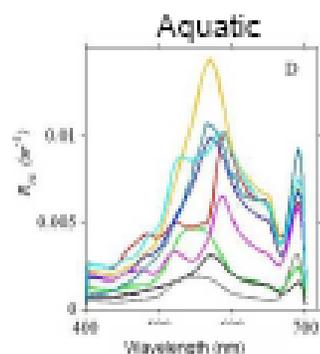
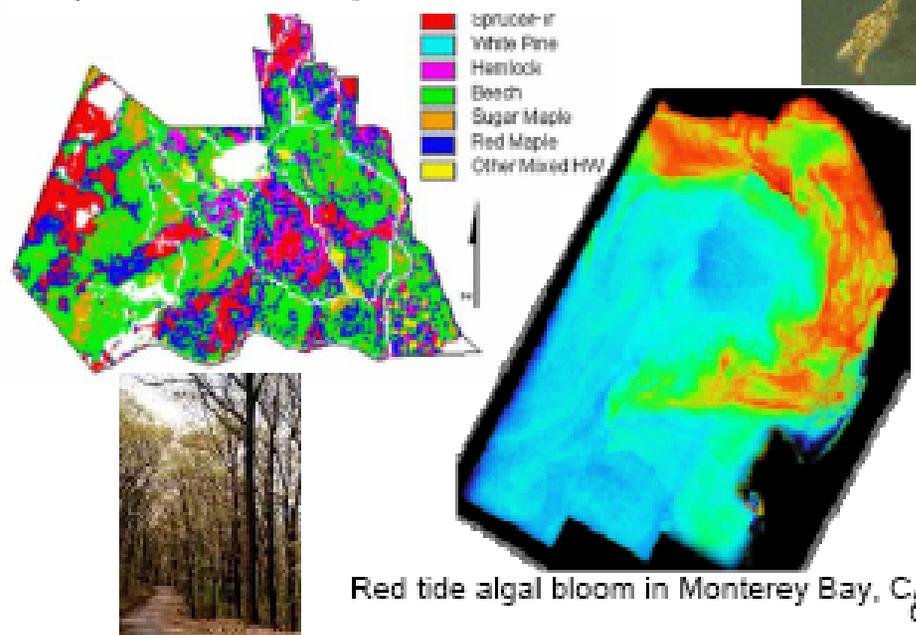
- *What is the composition, function, and health of land and water ecosystems?*
- *How are these ecosystems being altered by human activities and natural causes?*
- *How do these changes affect fundamental ecosystem processes upon which life on Earth depends?*

## Measurement:

- 380 to 2500 nm in 10nm bands
- Accurate location 60m spatial
- 19 days revisit
- Global land and shallow water

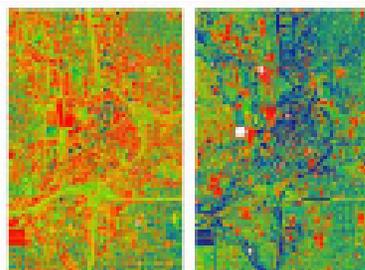
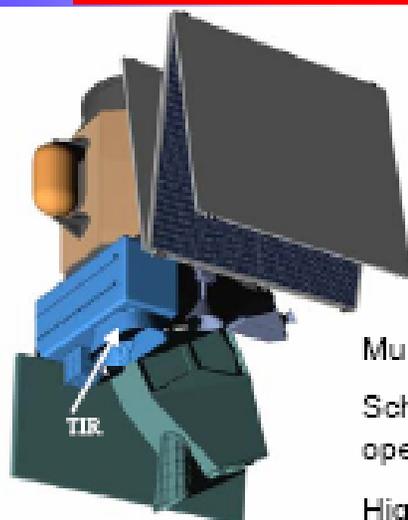


## Map of dominant tree species, Bartlett Forest, NH





# TIR sensor



Temperature  
Moisture  
Atlanta, GA - May 1997

Multispectral Scanner: 66kg / 78W

Schedule: 4 year phase A-D, 3 years operations

High Heritage

### Science Questions:

TQ1. Volcanoes/Earthquakes (MA, FF)

- How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?

• TQ2. Wildfires (LG, DR)

- What is the impact of global biomass burning on the terrestrial biosphere and atmosphere, and how is this impact changing over time?

• TQ3. Water Use and Availability, (MA, RA)

- How is consumptive use of global freshwater supplies responding to changes in climate and demand, and what are the implications for sustainable management of water resources?

• TQ4. Urbanization/Human Health, (DQ, GG)

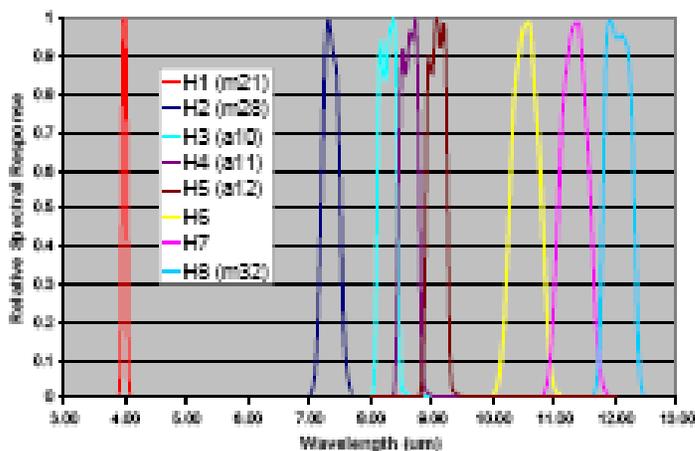
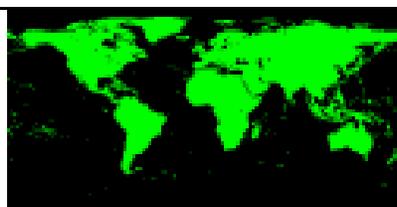
- How does urbanization affect the local, regional and global environment? Can we characterize this effect to help mitigate its impact on human health and welfare?

• TQ5. Earth surface composition and change, (AP, JC)

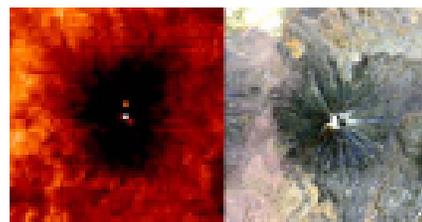
- What is the composition and temperature of the exposed surface of the Earth? How do these factors change over time and affect land use and habitability?

### Measurement:

- 7 bands between 7.5-12  $\mu\text{m}$  and 1 band at 4  $\mu\text{m}$
- 60 m resolution, 5 days revisit
- Global land and shallow water

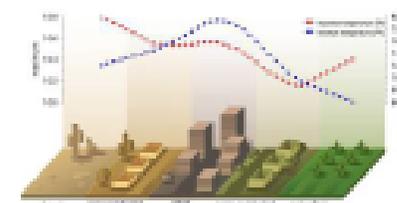


### Andean volcano heats up

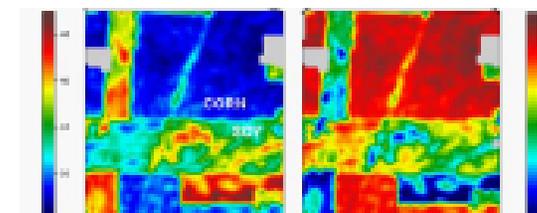


Volcanoes

### Urbanization



### Water Use and Availability



Surface Temperature

Evapotranspiration



# Summary

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## Ambitious future ahead for terrestrial remote sensing at NASA

- NASA is still trying to understand its role with the commercial side of remote sensing
  - Better understanding of how to avoid conflicts with the sensor developers
  - Interactions with commercial, international providers will still require a bit of sensitivity
- Coupling NASA sensors with the broader community is critical
  - JACIE
  - GEOSS, CEOS, and other international collaborations
  - Provide supplemental data to commercial providers
- Calibration and validation role will continue to be a key role of NASA with current and future sensors