Back to The Future

Incorporating HyspIRI-like VSWIR on a SmallSat

HyspIRI 2003 Workshop

Presented by

Steve Ungar

BASED ON

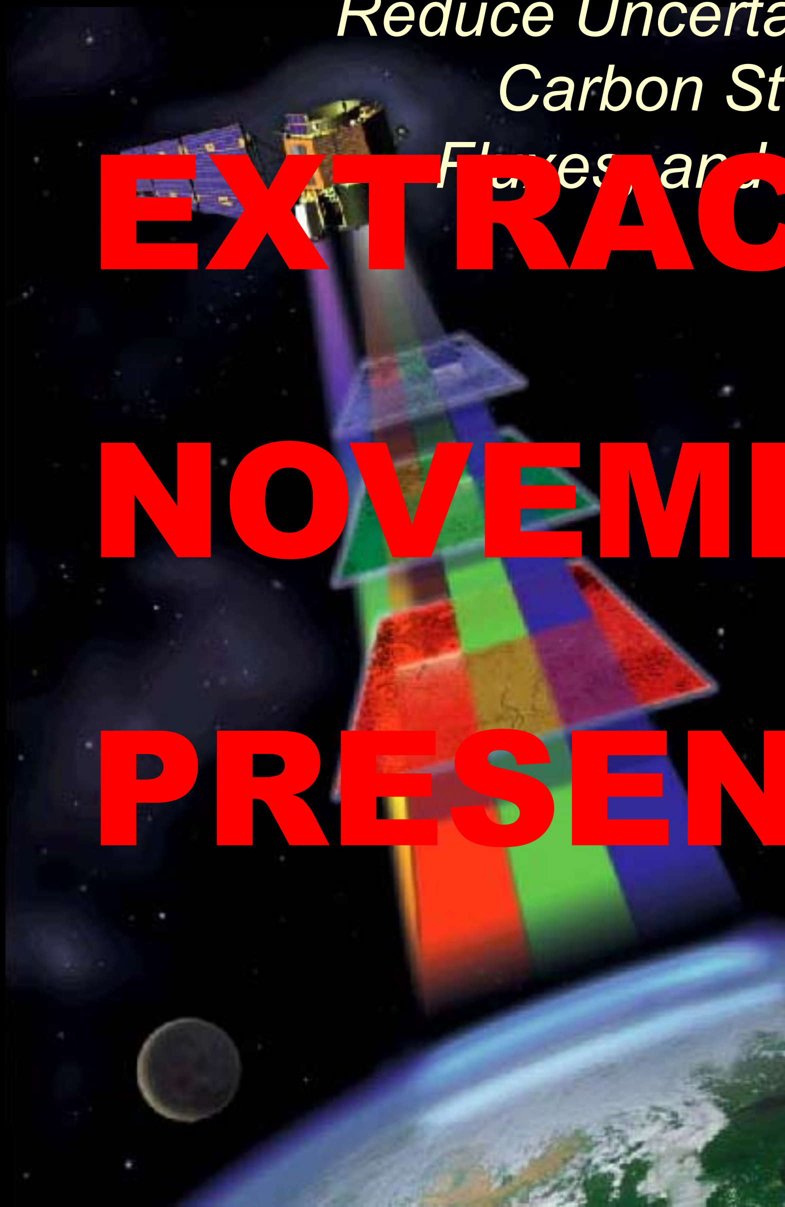
HyspIRI precursor mission proposals terminating in the *Flora White Paper*

SLIDES FROM

Greg Asner
Rob Green
Steve Ungar

Flora Mission Overview

Reduce Uncertainty in Carbon Storage, Fluxes and States



OBSERVIG PLATFORM

Imaging Spectrometer

400 – 2500 nm with 10 nm spectral resolution

60 KM swath / 30 M IFOV

ORBIT

705 Km altitude Sun-synchronous, circular orbit inclined at 98.2°

Descending node with an equatorial crossing at 11 am local time

Flora Mission Objectives

Flora's scientific goal is to dramatically reduce uncertainty in carbon storage, fluxes, and state in biospheric models.

The Flora mission makes global measurements of:

- **Fractional carbon cover** (photosynthetic material and non-photosynthetic material) versus bare soil, snow/ice, or water;
- Abundance of **functionally distinct plant types**;
- **Vegetation condition** and ecosystem **responses to disturbance**.

Imaging spectroscopy is a proven technology for these measurements.

Flora Project Formulation Team

Project Scientist
Stephen Ungar, GSFC
Mission Science
and Technology

University PI
Gregory Asner,
Carnegie/Stanford
Science Team Leader

Instrument Science and Calibration
Robert Green, JPL

Project Manager, GSFC
Systems Engineer, GSFC
Operations Manager - Dan Mandl (GSFC)

Science Team

External Science Advisory Group

Instrument Manager
James Kenny, JPL

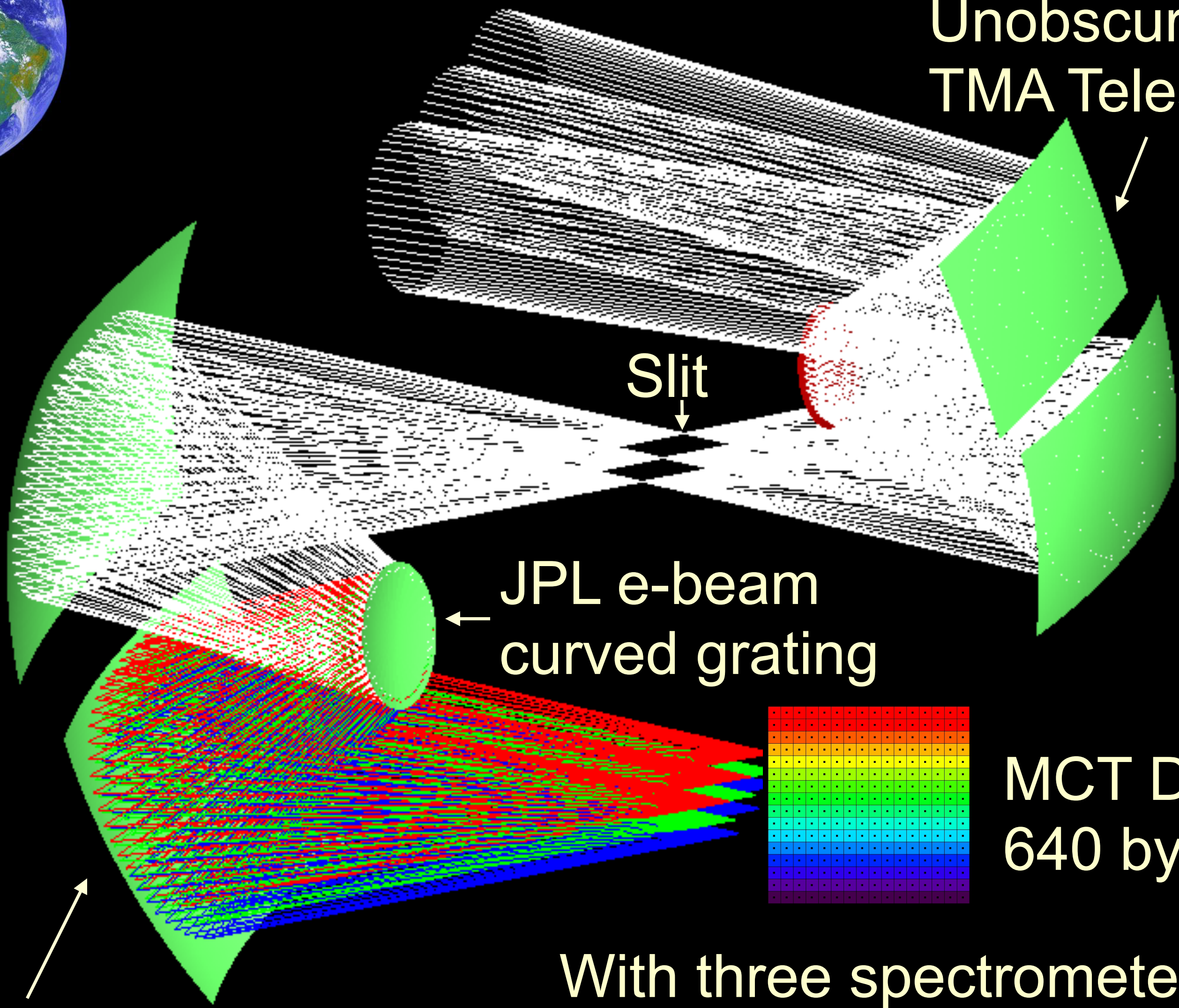
Deputy Mission Scientist
Robert Knox, GSFC

Flora

Science Requirement Imaging Spectrometer

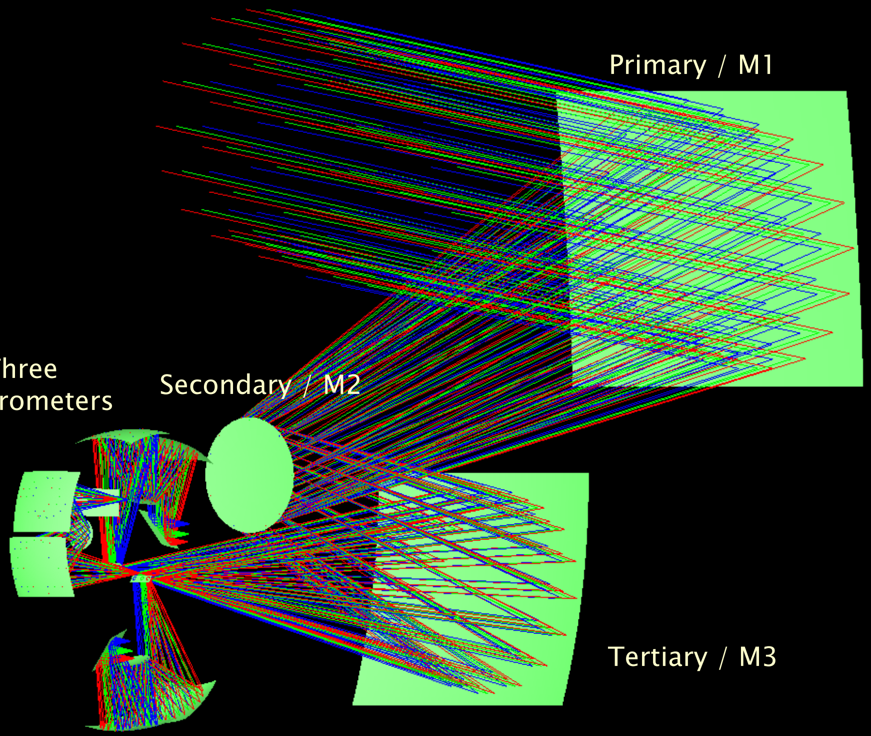
Spectral	400 to 2500 at 10 nm	
Spatial	60 km swath at 30 m	
Radiometric	12 bits, 0 to 1.2 Max Lamb.	
Radiometric Calibration	3 to 5% absolute	
SNR (ZA = 45, R = 50%)	600 (700 nm)	300 (2200 nm)
SNR (ZA = 45, R = 5%)	200 (700 nm)	60 (2200 nm)
Spectral Calibration	< 0.5 nm	
Spectral uniformity	> 95% cross track	
Spectral IFOV Shift	<5% down wavelength	

Earth Imaging Spectrometer

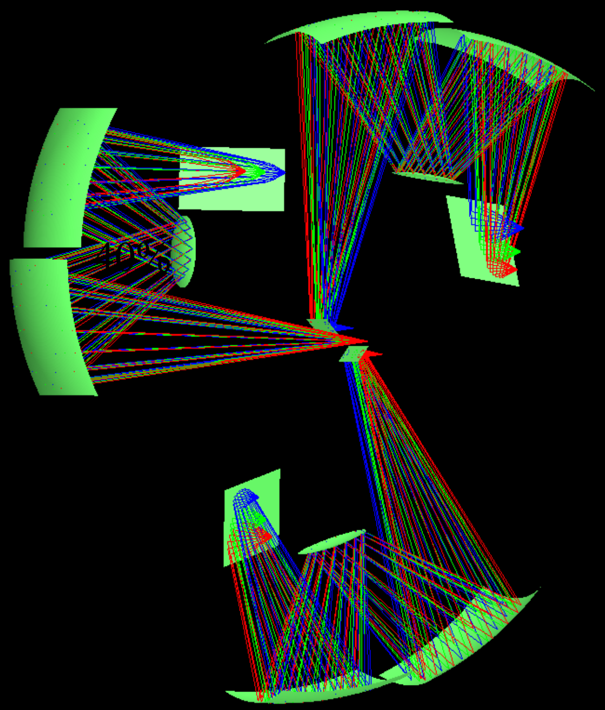


With three spectrometers:
Spectral: 400 to 2500 nm @ 10 nm
Spatial: 60 km swath @ 30 m

FLORA Shaded Model



Spectrometer Detail



Key Flora-Instrument Parameters

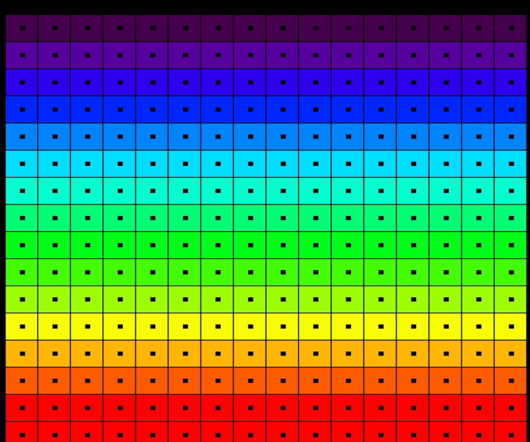
- Mass: 70 Kg CBE
  - 8.4 kg two stage radiator on spacecraft
- Power: 130 W CBE
  - Imaging over sunlit Earth (5 to 40% of orbit)
  - Plus upto 5% imaging top and bottom of night side
  - No image in eclipse
- Volume: 1.2 X 0.8 X 0.6 meters
- Data rate 6 lines of 60.2 mbps lossless or 9.2 mbps lossy
  - Lossless only over 60 by 60 km target sites 2 per orbit
  - Lossy over remainder of orbit
  - Imaging over only sunlit/land portion of Earth
- Cost $40m

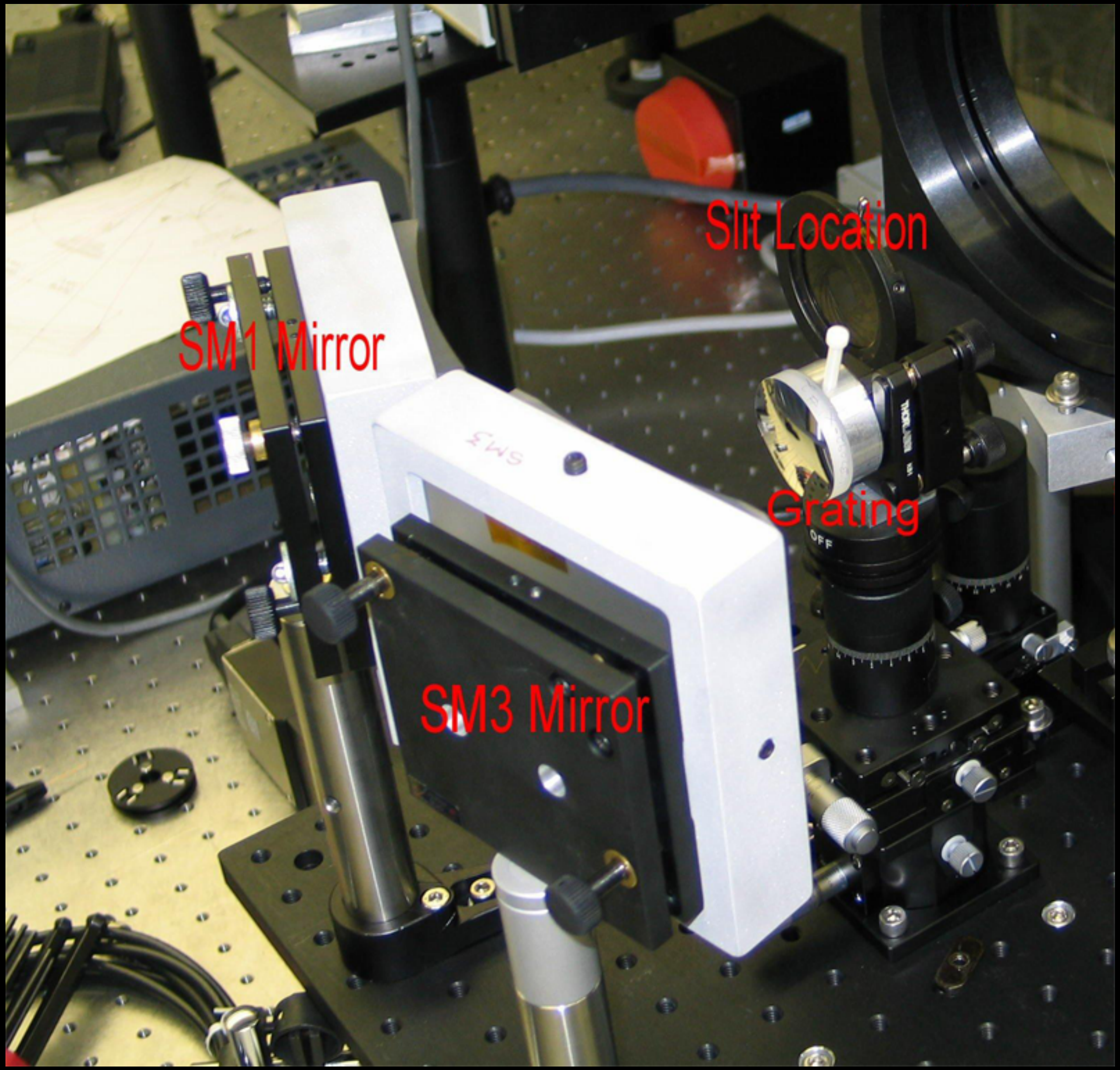
Flora Technology Readiness
Offner f/2.7 Spectrometer, May 2004

Bench test of fabricated components

f/2.7 Offner Spectrometer
- Spectrometer mirror SM1
- Convex dual blazed grating
- Spectrometer mirror SM3

Measured cross-track uniformity
- <3% of spectral sampling





Flash-Forward

- The Flora White Paper, forwarded to the NAS committee responsible for creating the NASA Decadal Survey, increased pixel size to 45 meter, accommodating:
  - Higher SNR
  - Larger FOV
- The white paper was used by the NAS as the basis for the VSWIR portion of their proposed HyspIRI mission.
- The NASA HyspIRI Concept team, consistent with objectives as stated in the Decadal Survey, has further increased the pixel size to 60 meters allowing for exploitation of larger focal plane arrays to reduce the number of spectrometers, as well as providing:
  - Still higher SNR
  - Much larger FOV
  - More frequent re-visit time

Flora
Carbon Science

Proposed Mission Overview

Stephen Ungar
Mission Scientist

IGARSS- 2004
Anchorage, AK
Sept. 26, 2004

SpectraSat measurements enable global change science.

Fractional Vegetation Cover

- Global carbon cycle
  - Sink activity & feedbacks
  - Aboveground C stocks
  - C management
- Ecosystem responses to global change
- Land surface energy exchanges
  - Climate variability and change
  - Global water cycle

Plant Functional Types

- Global carbon cycle
  - Sink activity & feedbacks
  - C stocks and turnover
- Ecosystem responses to global change
- Biodiversity/biocomplexity

Disturbance Responses & Vegetation Condition

- Global carbon cycle
  - Regional C sources and sinks
- Ecosystem responses to global change
- Land use/land cover change
- Sustainability of ecosystem services

SpectraSat "Flora" Mission Objectives

The Flora mission scientific goal is to reduce uncertainty in carbon storage, fluxes, and state.

The Flora mission makes global measurements of:

- Fractional vegetation cover (photosynthetic or green vegetation and non-photosynthetic tissues/plant litter) versus bare soil, snow/ice, or water;
- Abundance of functionally distinct plant types;
- Vegetation condition and ecosystem responses to disturbance.

This information will be uniquely valuable in understanding the land biosphere components of the global carbon cycle.

Imaging spectroscopy is a proven technology for these measurements.

Science Team Members

Greg Asner, Stanford	– PI, Science Team Leader – fractional cover, condition
Stephen Ungar, GSFC	– Project Scientist
Robert O. Green, JPL	– Inst. Science, calibration
Forrest Hall, UMBC	– global data products, disturbance
Alfredo Huete, U of Arizona	– cover and condition
Robert Knox, GSFC	– Deputy Project Scientist – ecosystem dynamics
Mary Martin, UNH	– function and condition (biochemistry)
Betsy Middleton, GSFC	– function and condition (photobiology)
Dar Roberts, UCSB	– functional type and condition
Susan Ustin, UC-Davis	– functional type & condition, wetlands

Others TBD - atmospheric characterization, coastal zone

FLORA Mission

Architecture is inherently scalable - the JPL Flora Instrument consists of 3 spectrometer modules.

Each module contains a processor which can perform simple operations on data (e.g. linear transformation, spectral convolution) as it passes it to the spacecraft bus providing redundancy.

Modules can perform dissimilar operations – the only constraint being that the combined data flow not violate the spacecreaft bus rate.

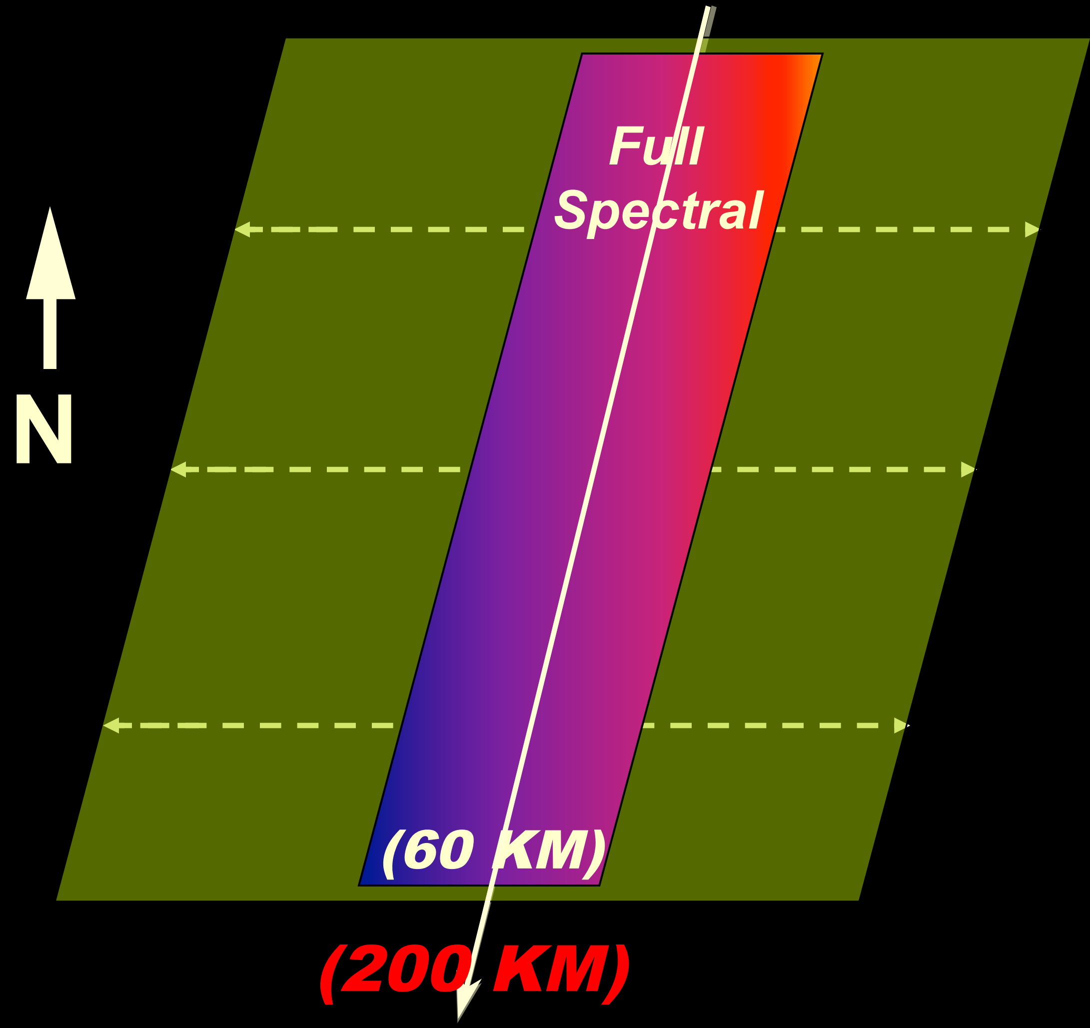
FullSpectral Landsat Swathwidth

Basic Imaging Spectrometer Characteristics

	Module	Observatory
Spectral Range	0.4 – 2.5 µm	210 Channels
Sampling Interval	10 nm	10 nm/Ch
Swath Width	20 km (640 pixels)	10 modules (200 km)
Pixel Size	31.25 m	31.25 m
SNR (ZA=60º, R=30%)	VNIR - 600 SWIR - 450	VNIR - 600 SWIR - 450
Digitization	12 bit	12 bit
Radiometric Range	-0.1 to 1.1 L_{max}	-0.1 to 1.1 L_{max}
Spectral Uniformity	>95%	>95%
Spatial Uniformity	>95%	>90%

SpectraSat Observing Strategy

HSI may point anywhere within 16.5º FOV



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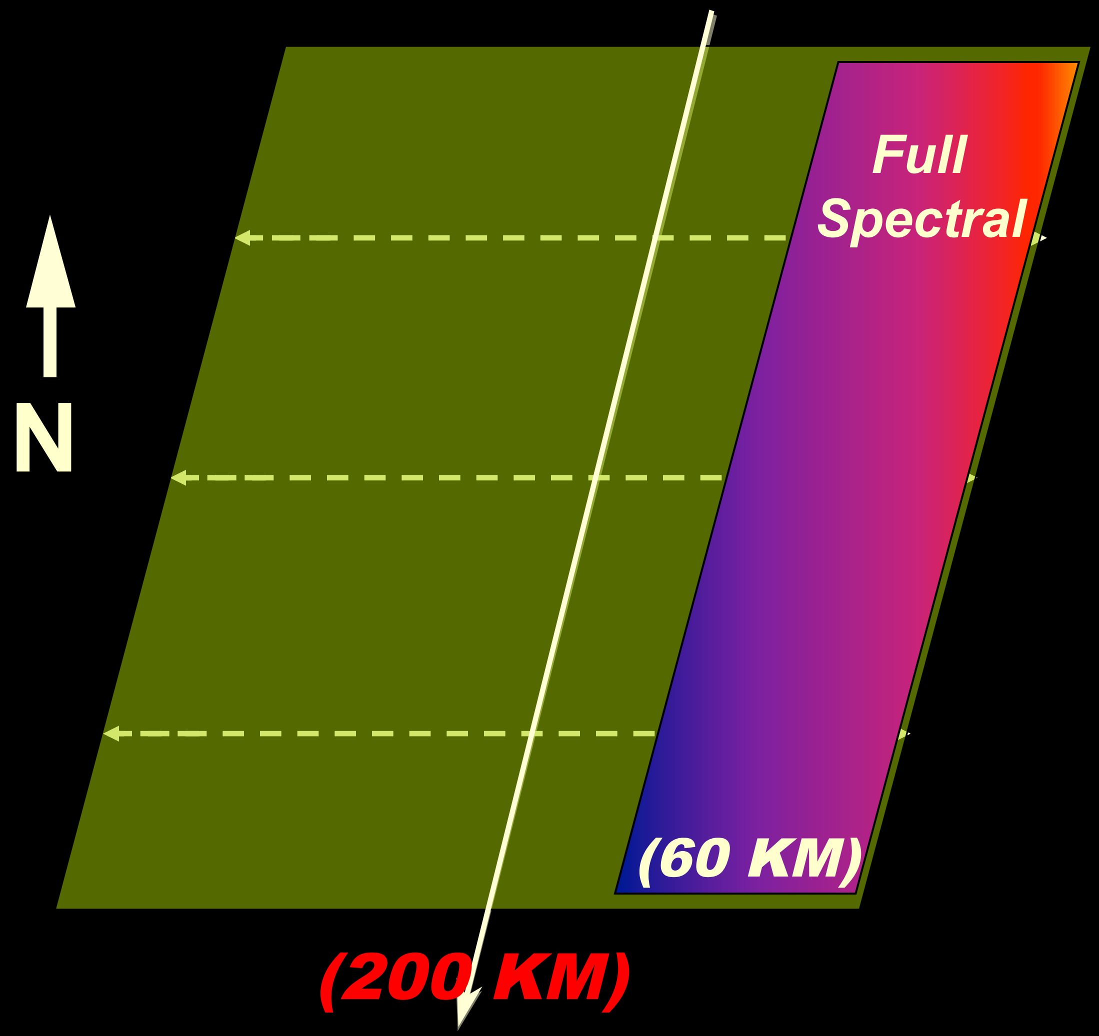
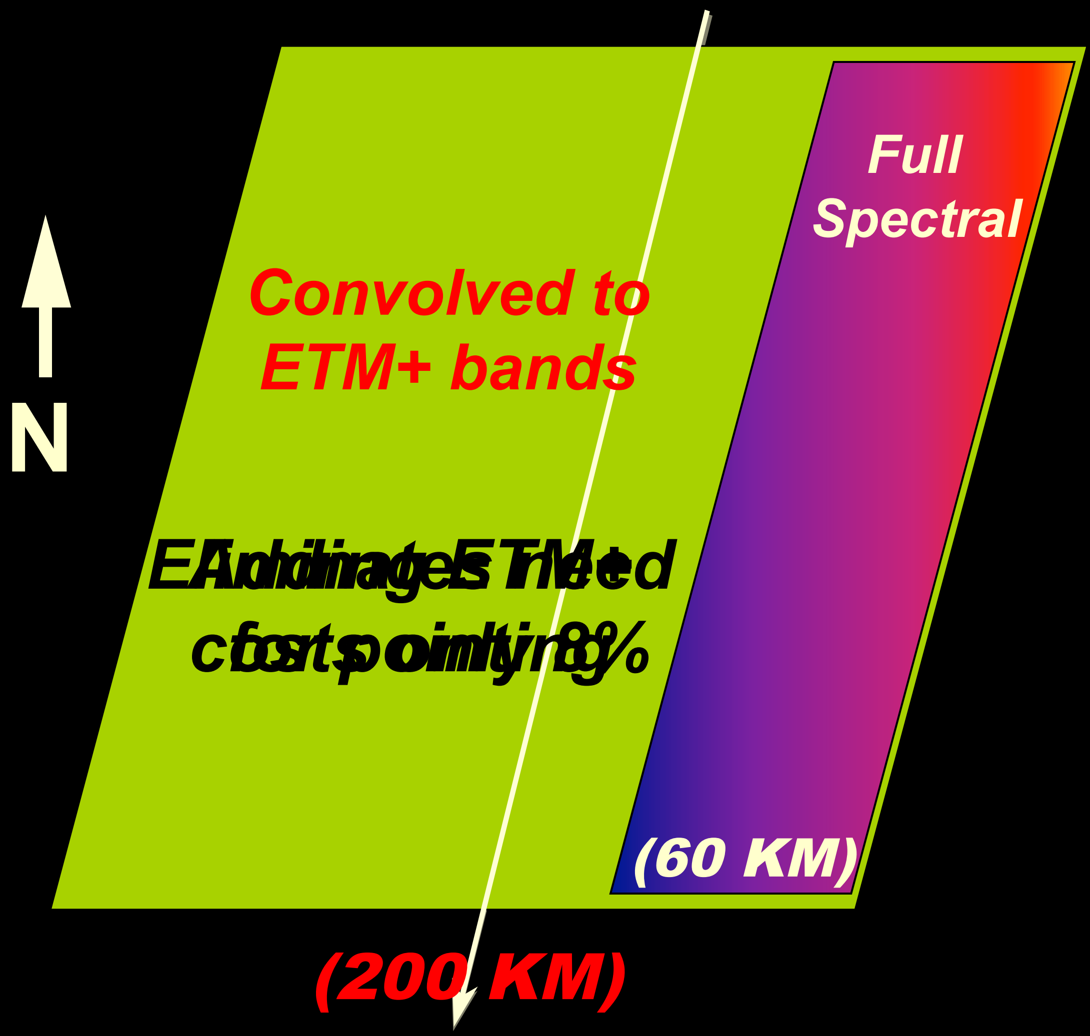
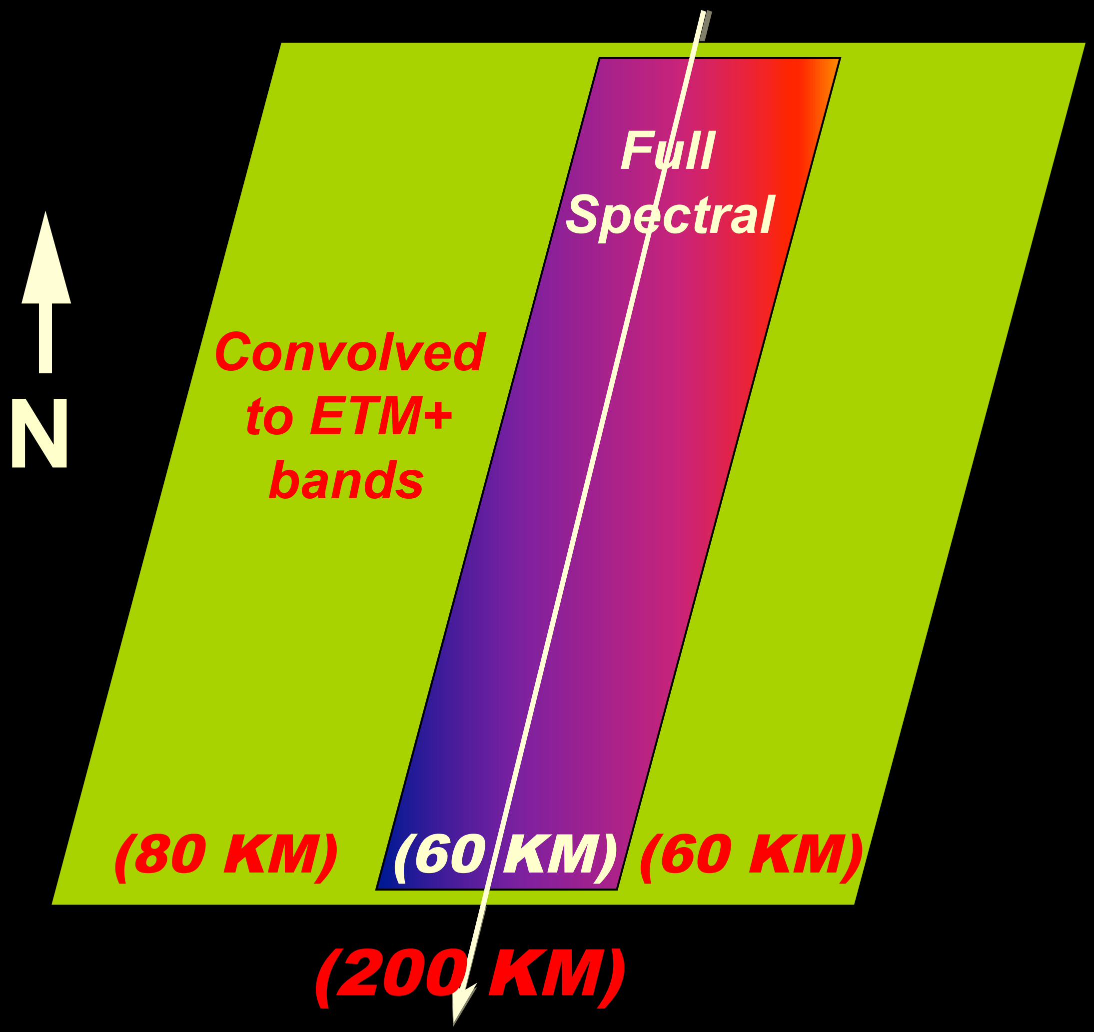


Full Spectral Landsat Swathwidth Descending Orbit Ground Tracks

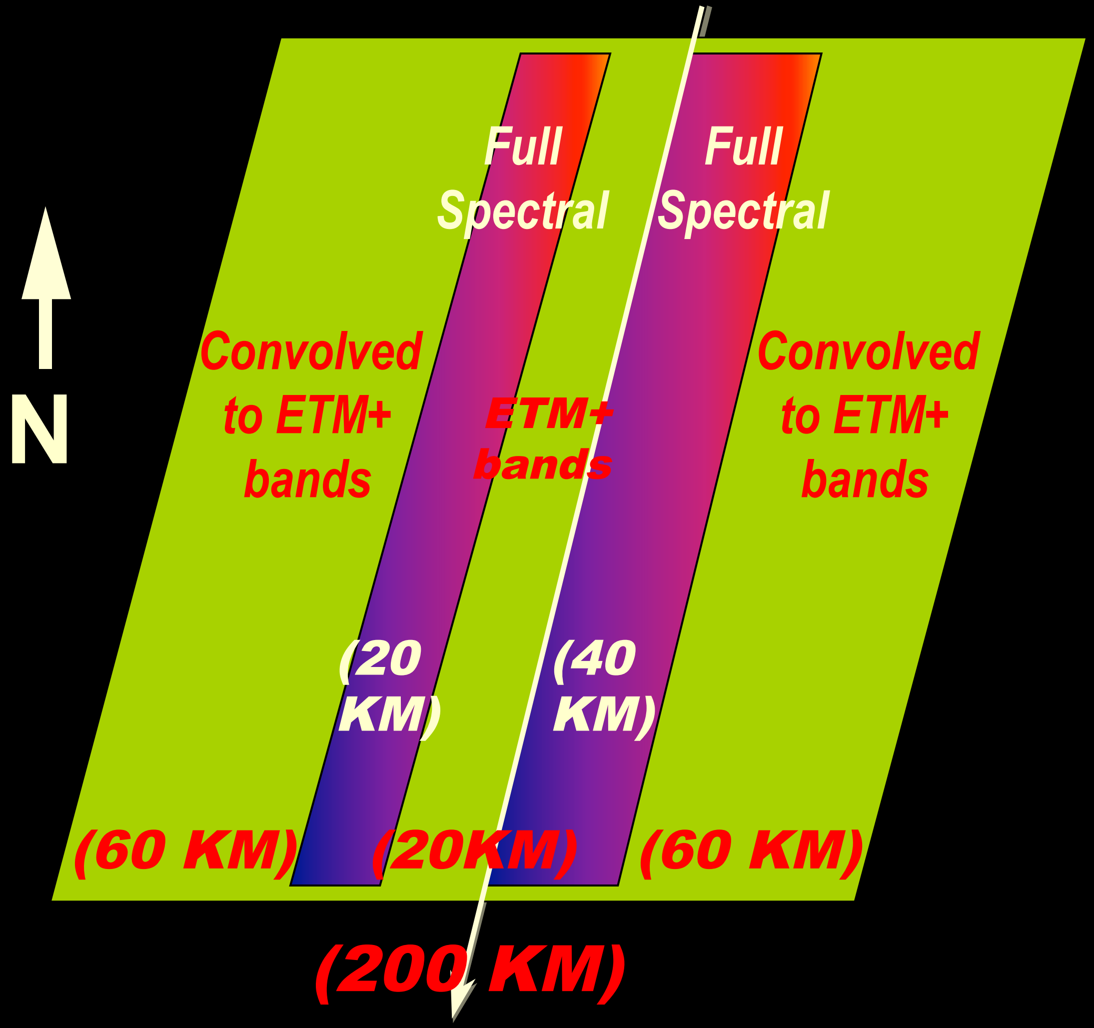


Full Spectral Landsat

HSI may be positioned at 20 KM intervals



Full Spectral Landsat
HSI for any 20 KM module combination



New Directions for LSI

- Reduction in download volume for Full-Spectral land imager can be realized by spatial aggregation of pixels
  - 90 meter pixels will reduce download by almost an order of magnitude, but will still meet HyspIRI objectives
  - preserves ability to download full swath Landsat-like bands at 30 meter pixel size
  - provides for selected areas areas at full spectral 30 meters
- Formation flying of multiple SmallSats allows for unprecedented flexibility and potential the other cost reduction
  - Two identical spectrometers, on identical platforms, with reduced FOV telescopes, observing adjacent swaths 15 seconds apart
  - Optical-comm link can provide greater reliability/redundancy
  - If one platform fails, the other can still do the entire global mapping in 32 (as opposed to 16) days
  - Provides opportunity for coordinated thermal measurements