National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Beyond ASTER: Future VNIR-SWIR and TIR Hyperspectral Instruments

Michael Abrams
Jet Propulsion Laboratory, California Institute of Technology

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Outline of Presentation

- Status of NASA
- Landsat Data Continuity Mission
- ASTER
- Hyperspectral missions

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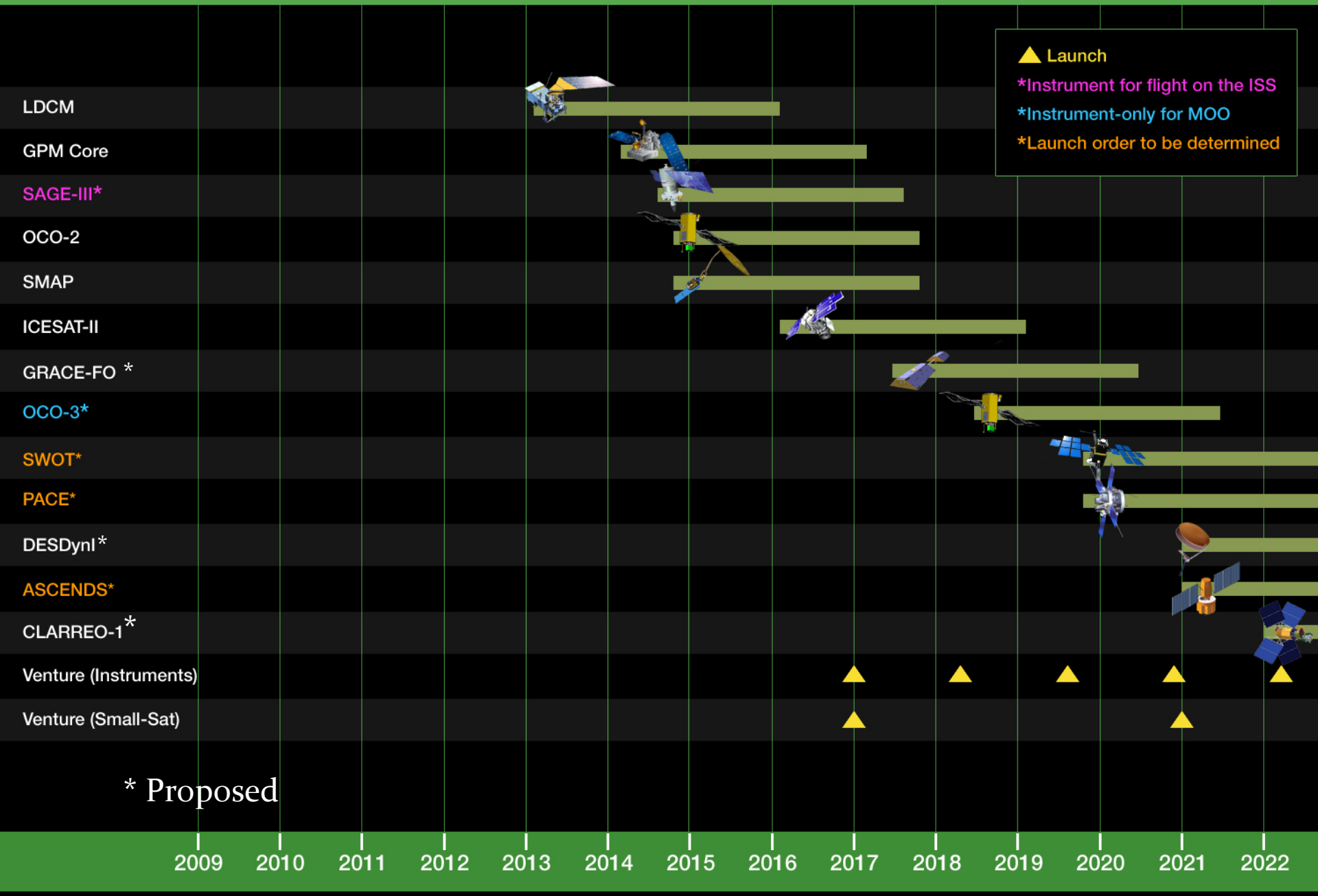
Launch-CY2011
Launch-CY2012
Launch-CY2013
Aquarius
OSTM/Jason 2 (NOAA)
Jason
QuikSCAT*
TRMM
EO-1
Landsat-7 (USGS)
Aqua
ACRIMSAT
Terra
SORCE
LDCM
Aura
GRACE (2)
CALIPSO
CloudSat
Suomi-NPP

Proposed Future Mission Timelines



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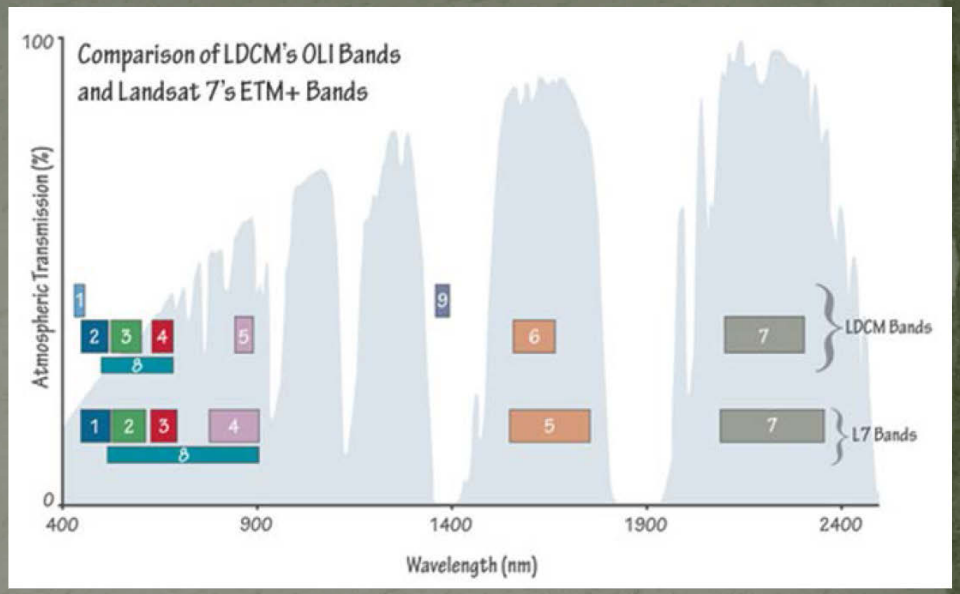
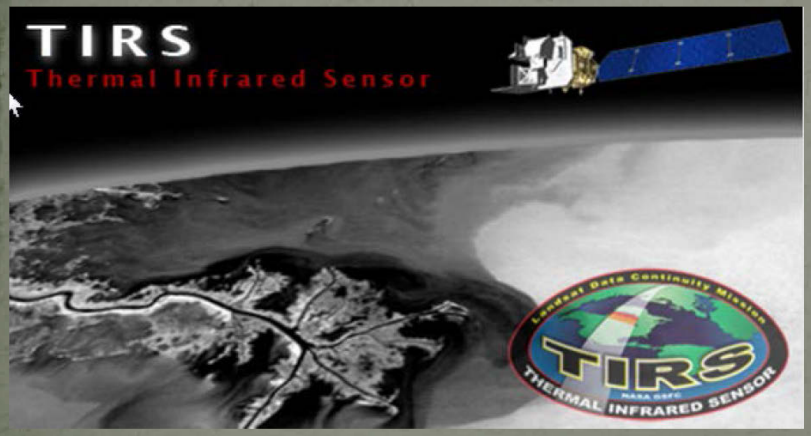
LDCM Update

- Landsat Data Continuity Mission (LDCM) is on schedule for a February 2013 launch; the Thermal Infrared Sensor (TIRS) has completed environmental testing with spacecraft integration in February 2012; (the Operational Land Imager (OLI) is already integrated

LDCM at Orbital Sciences, Arizona, March





2 Channels @ 100m IFOV
10.6-11.2 um
11.5-12.5 um

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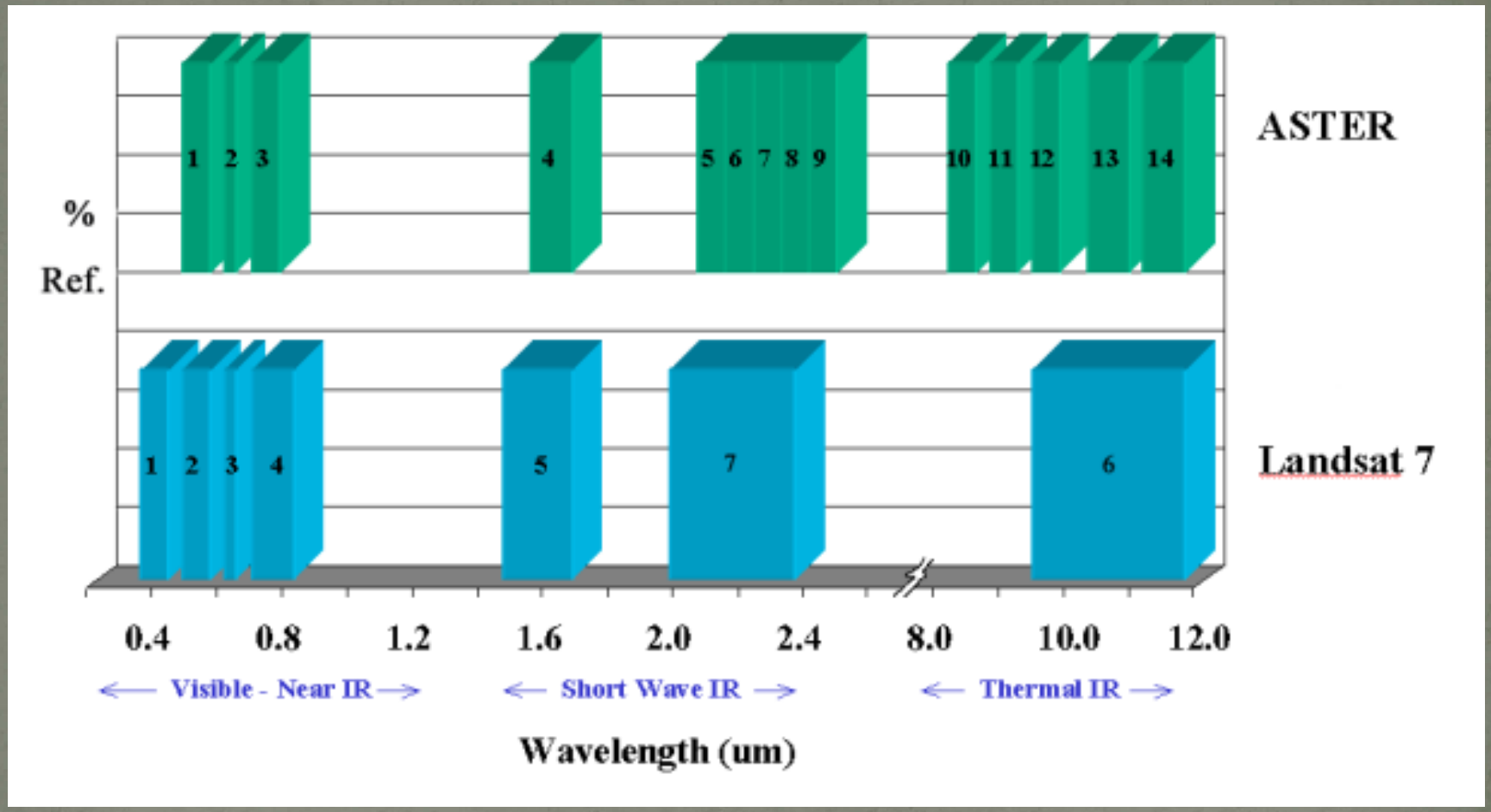
ASTER

- 1999 launch on Terra
- Joint Japan/US effort
- 15 m VNIR, 30 m SWIR, 90 m TIR
- Stereo capability
- 60 km swath
- < 16 day repeat cycle

ASTER


ASTER
Landsat 7
% Ref.
1 2 3
4
5 6 7 8 9
10 11 12
13 14
1 2 3 4
5
7
6
0.4
0.8
1.2
1.6
2.0
2.4
8.0
10.0
12.0
Visible - Near IR
Short Wave IR
Thermal IR
Wavelength (um)

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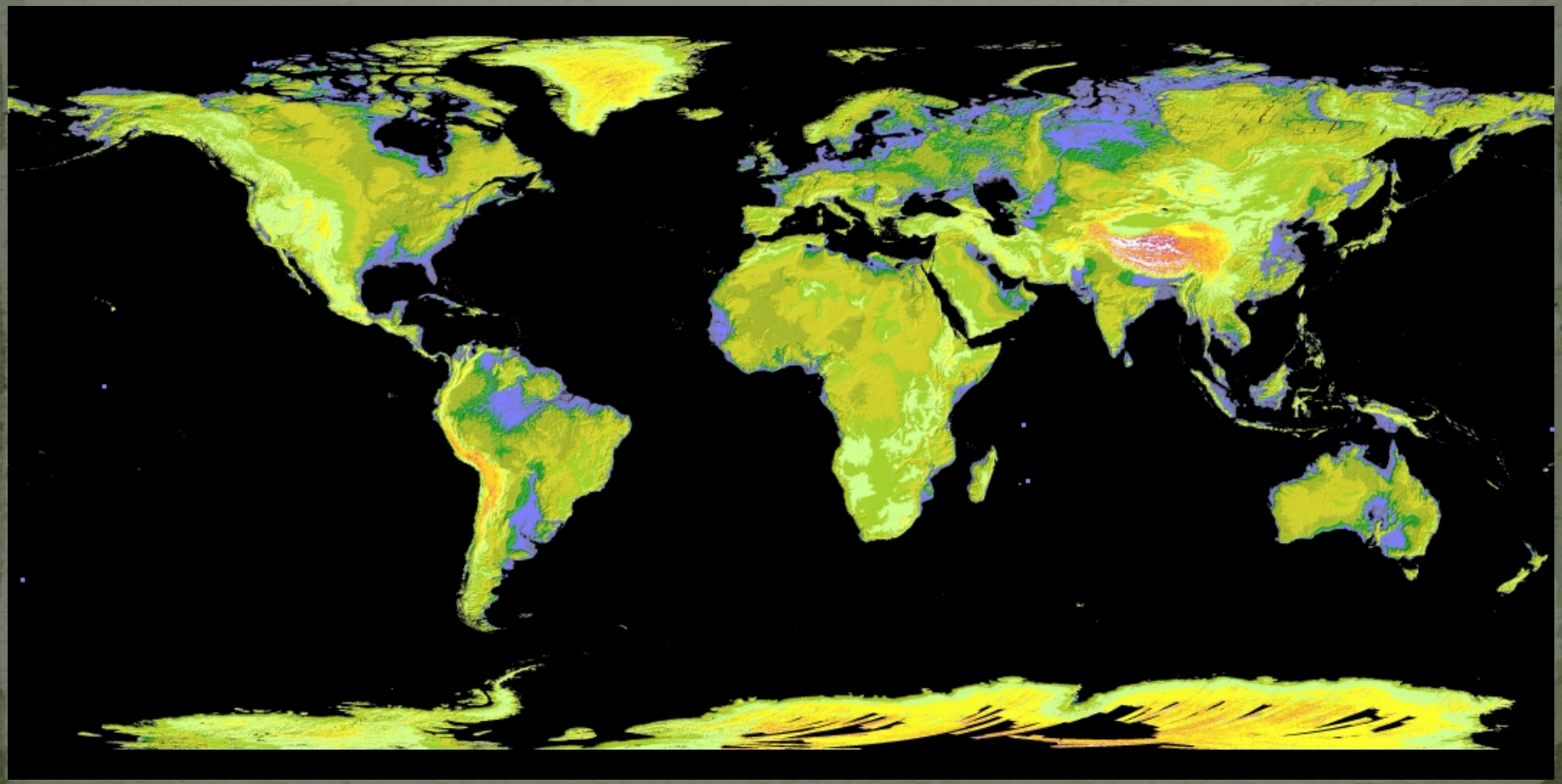
ASTER

Global DEM (GDEM V2) free for all users. 30m postings, ~22,000 1x1 degree tiles



Current Scanners

Sensor	**Hyperion**	**CHRIS**	**HySI**	**HJ-1A**	**HICO**
Country and Organization	USA NASA	UK ESA	India ISRO	China CAST	USA NASA/ONR
GSD (m)	30	17/34	506	100	90
Swath at Nadir (km)	7.65	13 (nominal)	129.5	≥50	42
Wavelength Coverage (nm)	357-2576	400-1050	400 - 950	450 - 950	353 - 1081
Number of Bands	242	18/37/6	64	110 - 128	128
Spectral Res. (nm @ FWHM)	10	5.6-32.9	~ 10	5	5.7
Launch Date	2000	2001	2008	2008	2009

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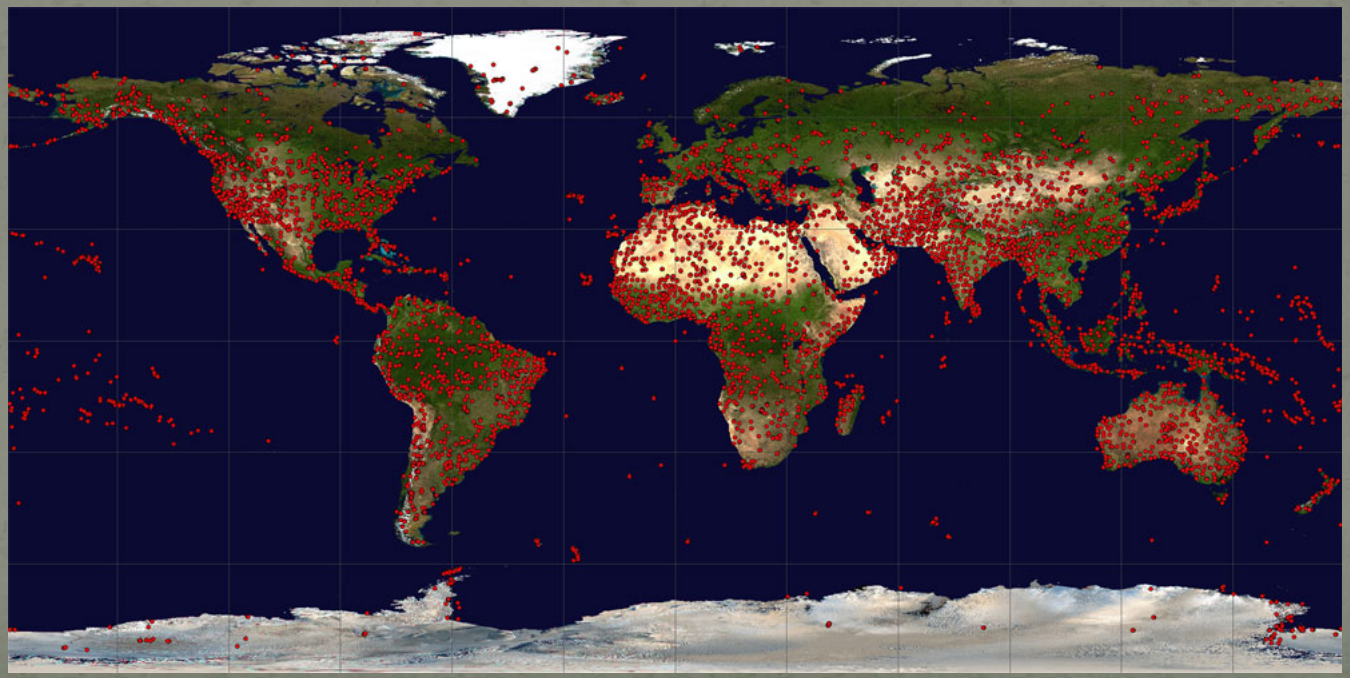
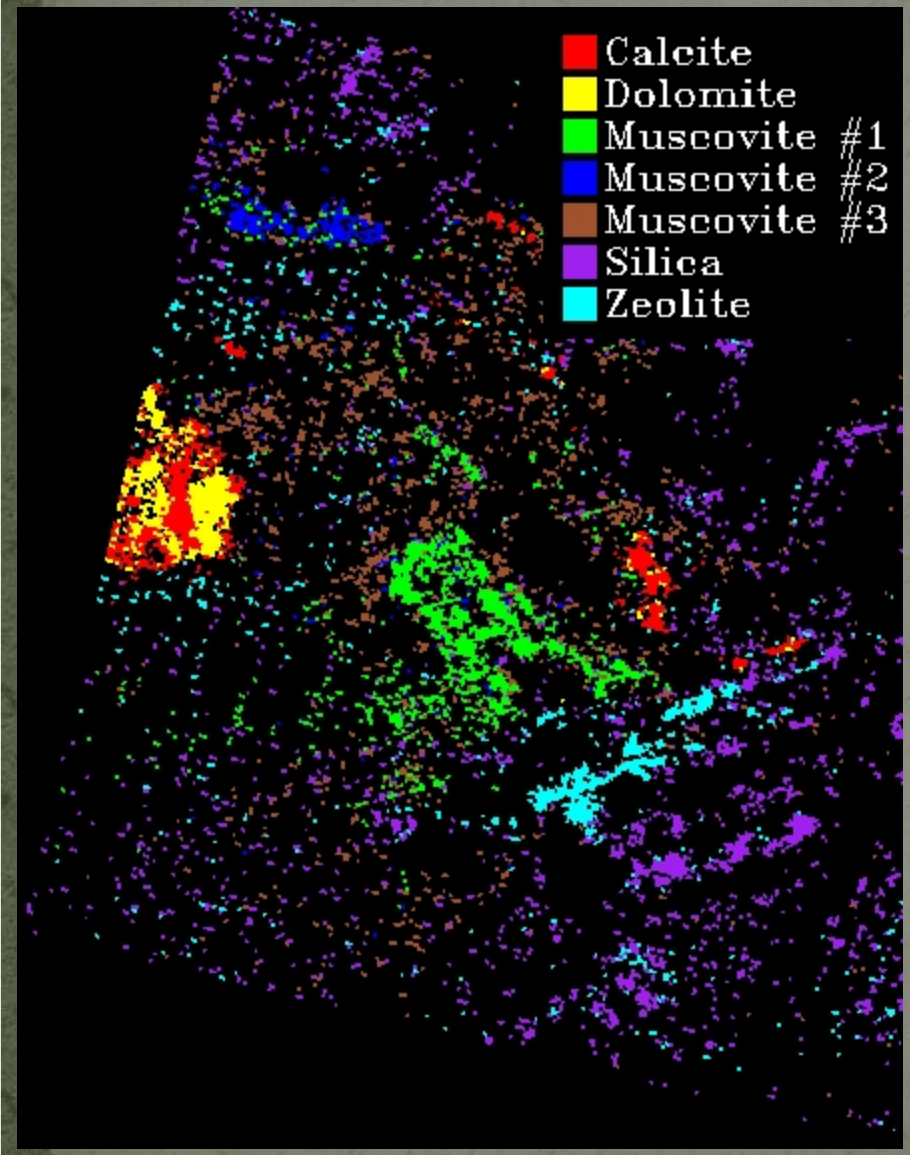
Hyperion

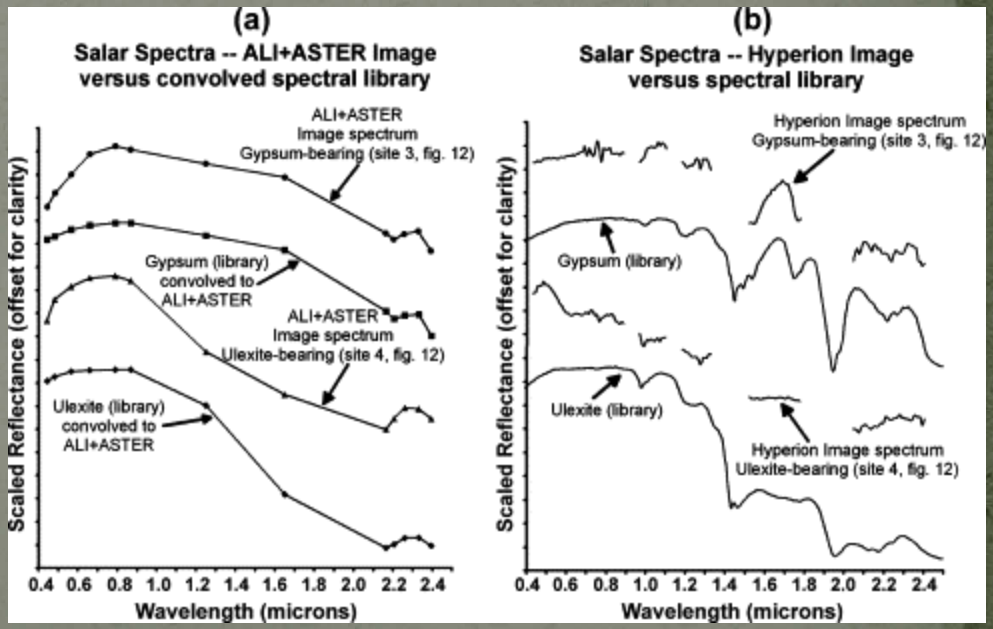
Hyperion operates on NASA's EO-1 spacecraft since 2000. It is a VSWIR hyperspectral scanner, accompanying the ALI multispectral instrument. Hyperion was a technology demonstration, explaining its 7.5 km swath width, and very limited data acquisition capability. Over 11 years, numerous scenes have been acquired, and are available free to users.



Hyperion



An example of Hyperion's mineral mapping capability relying on full spectrum hyperspectral imaging from 0.4 to 2.45 µm.



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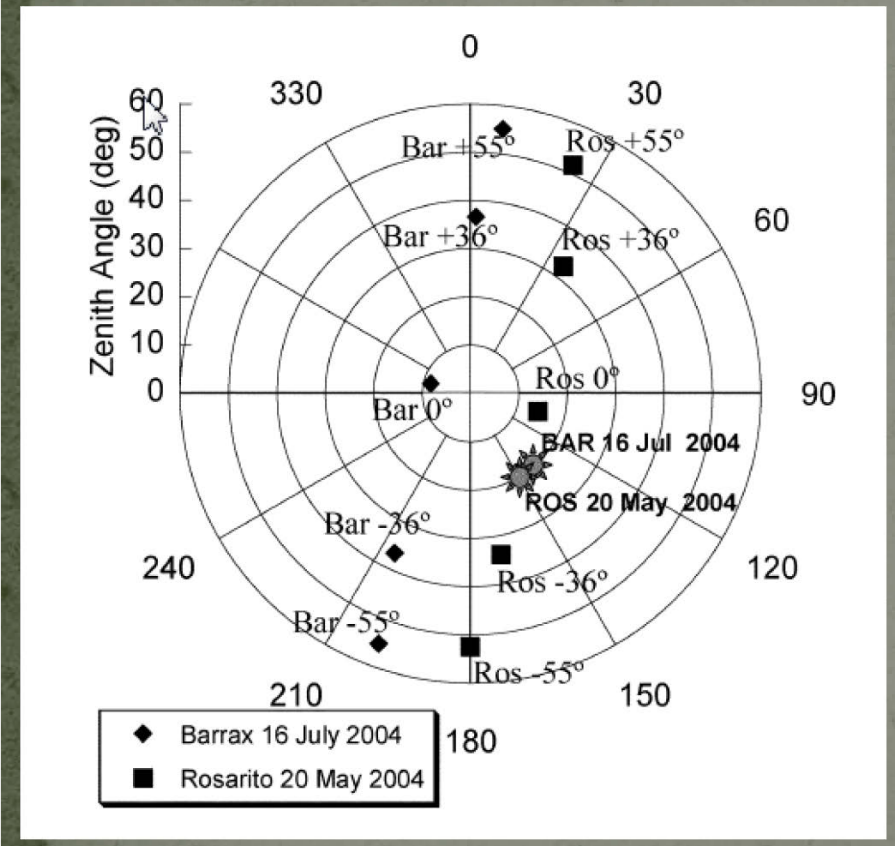
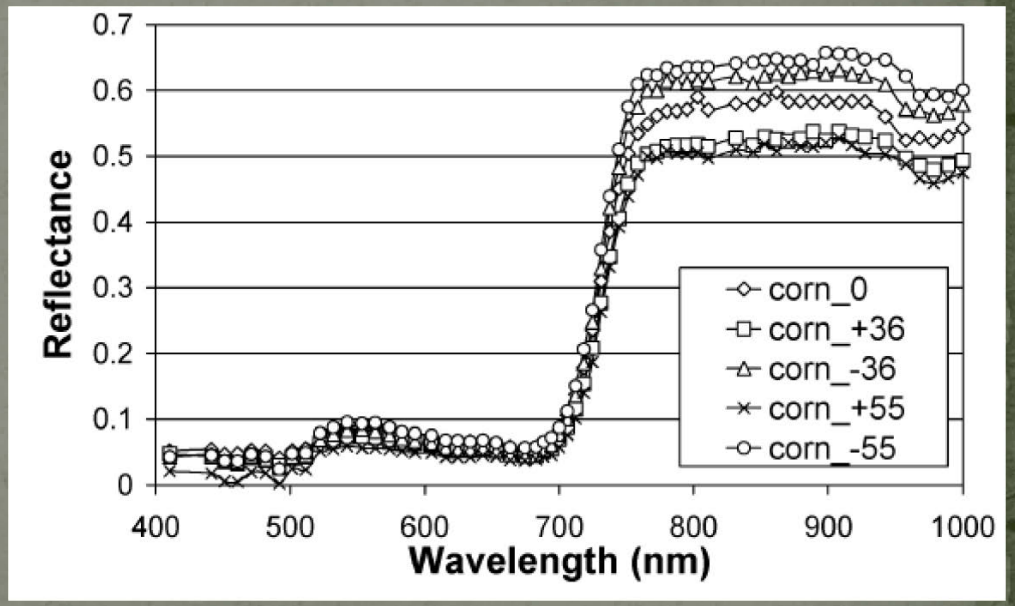
CHRIS

Compact High Resolution Imaging Spectometer on ESA's PROBA platform



CHRIS acquires 13 x 13 km images with 5 different viewing angles for BRDF studies.



CHRIS

All CHRIS data are available through ESA's online EOLI catalogue.

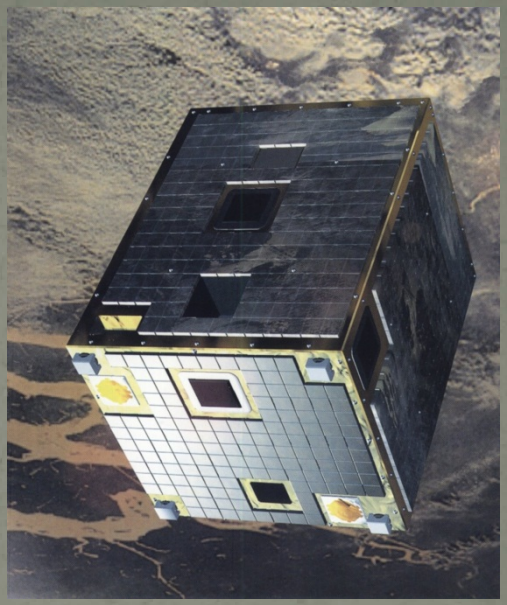
MODE 1: Full swath width, 62 spectral bands, 773nm / 1036nm, nadir ground sampling distance 34m @ 556km

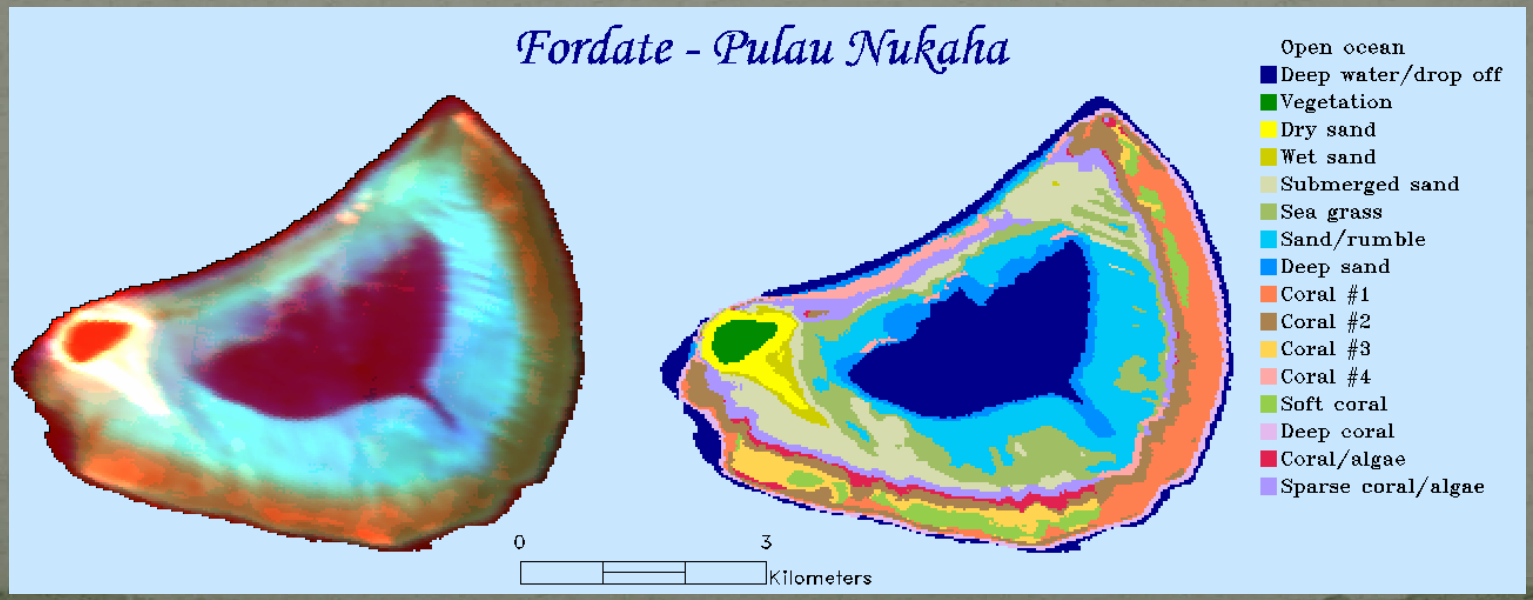
MODE 2 WATER BANDS: Full swath width, 18 spectral bands, nadir ground sampling distance 17m @ 556km

MODE 3 LAND CHANNELS: Full swath width, 18 spectral bands, nadir ground sampling distance 17m @ 556km

MODE 4 CHLOROPHYL BAND SET: Full swath width, 18 spectral bands, nadir ground sampling distance 17m @ 556km

MODE 5 LAND CHANNELS: Half swath width, 37 spectral bands, nadir ground sampling distance 17m @ 556km





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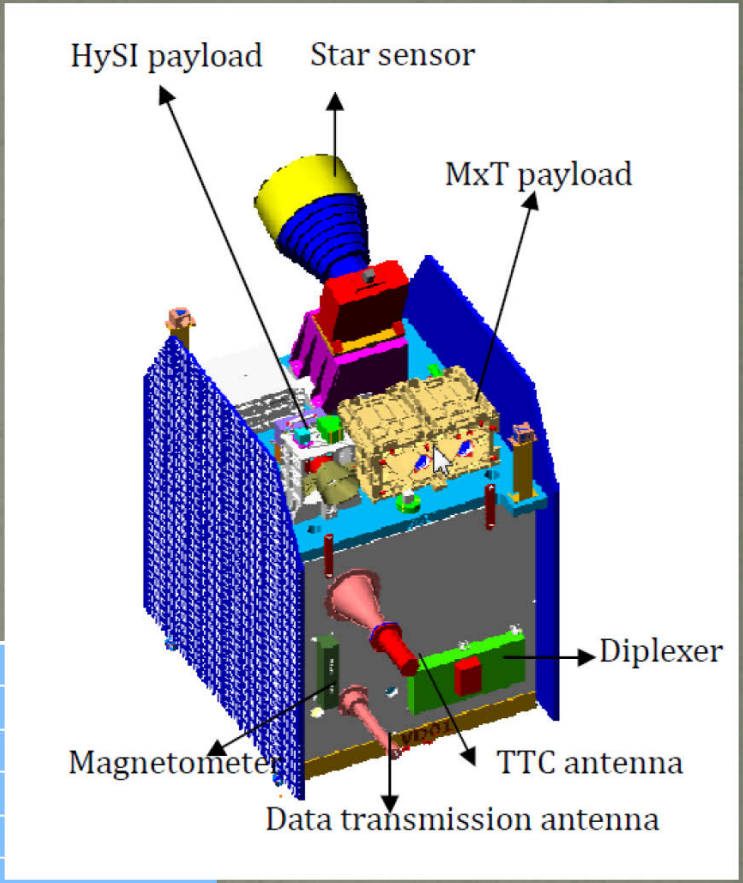
HySI

HySI (Hyperspectral camera), is one of two instruments on IMS-1 (Indian Mini Satellite-1), previously called TWSat (Third World Satellite), a small earth observing satellite developed by Indian Space Research Organization (ISRO). It has about 500m IFOV and 129 km swath. Data are made available to developing countries.



Nation:	India
Type / Application:	Earth Observing
Operator:	ISRO
Contractors:	ISRO
Equipment:	
Configuration:	Microsatellite-SSB (SSB-2)
Propulsion:	?
Power:	2 deployable solar arrays, batteries
Lifetime:	2 years
Mass:	83 kg
Orbit:	630 km × 630 km, 97.9°

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HJ-1A
Huan-Jing (=Environment) Constellation

HJ-1A is also the Small Multi-Mission Satellite (SMMS) of Asia Pacific Space Cooperation Organization (APSCO) and it will be the important data resources of APSCO space application. SMMS is a joint venture payload between China, Iran, South Korea, Mongolia, Pakistan, Thailand and Bangladesh under the Asian-Pacific organization.

Nation:	China
Type / Application:	Earth observation
Operator:	CAST
Contractors:	DFH Satellite Co. Ltd of CAST
Equipment:	
Configuration:	CAST968B Bus
Propulsion:	
Power:	2 deployable solar arrays, batteries
Lifetime:	
Mass:	
Orbit:	

HJ-1A

Fourier Transform hyperspectral imager

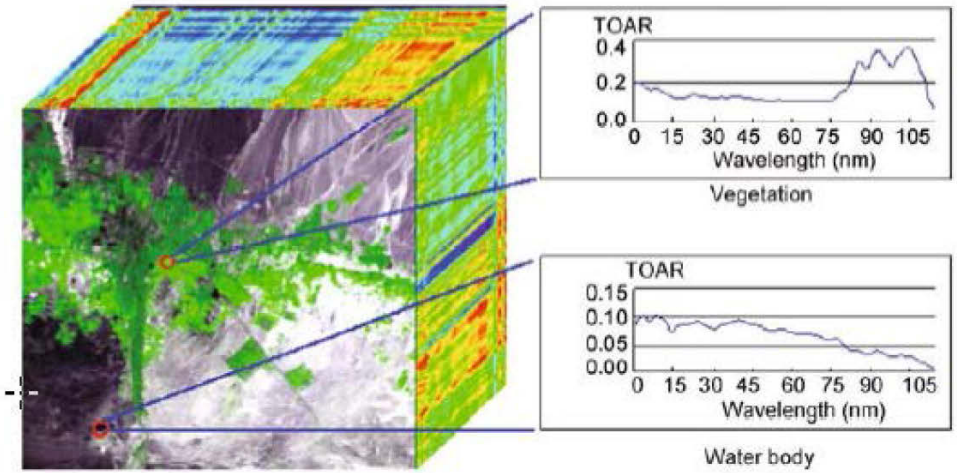
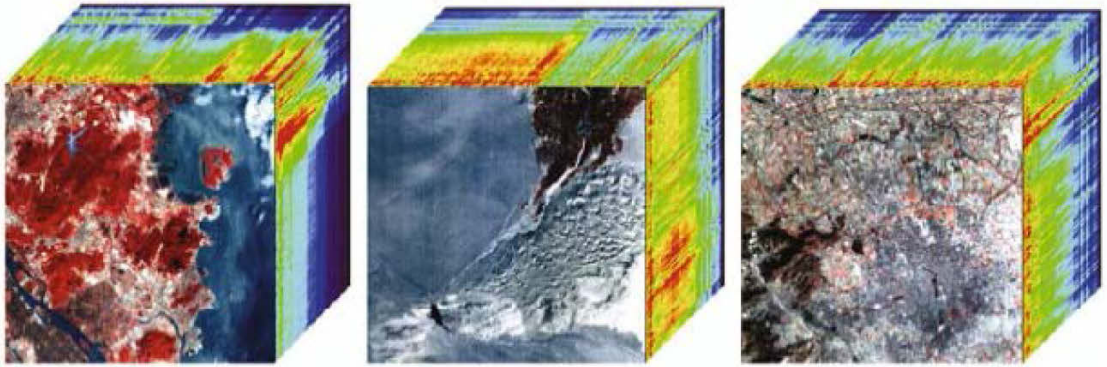


Figure 3 First orbit hyperspectral image of HJ-1A.



(a) (b) (c)

Figure 4 HJ-1A hyperspectral image cubes.

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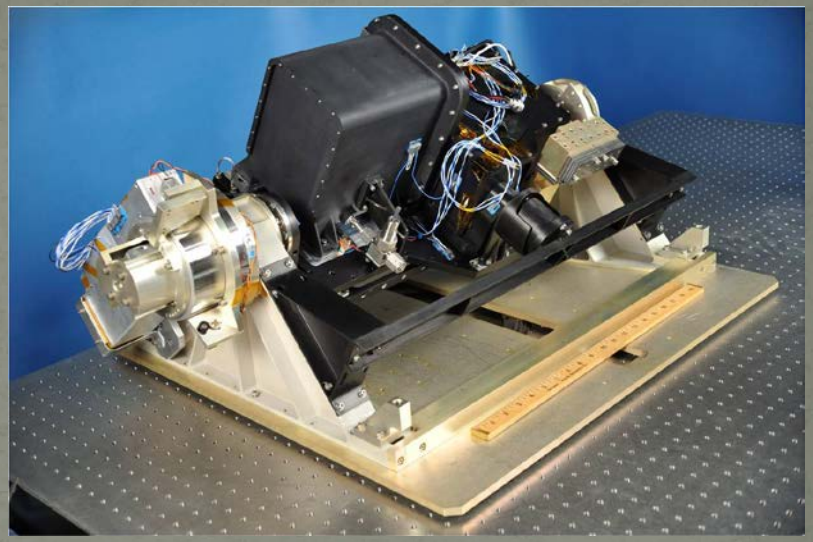
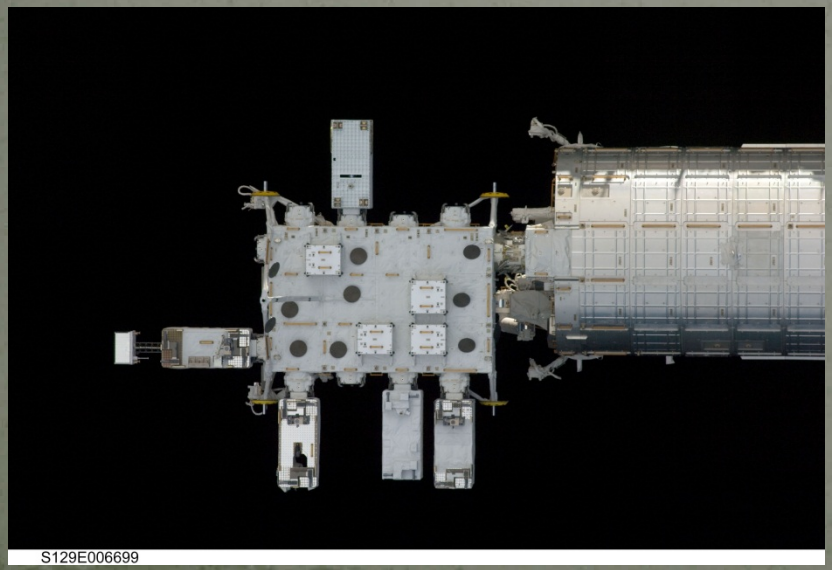
HICO
Hyperspectral Imager for the Coastal Ocean

HICO is operated on the Space Station by the US NASA and Navy. The data system is done by Oregon State University. HICO is designed for ocean observations





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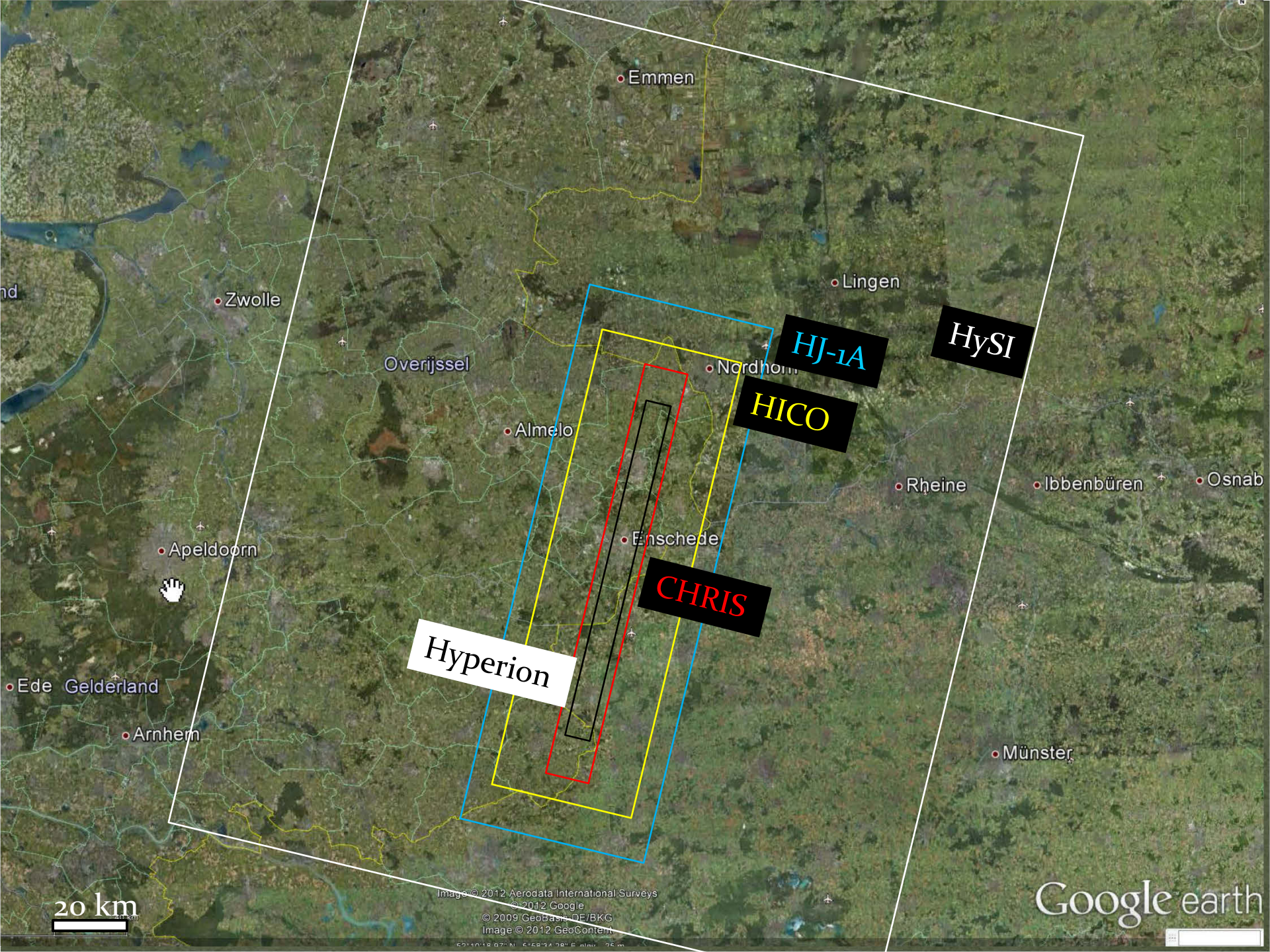

Emmen
Zwolle
Overijssel
Lingen
Nordhorn
Almelo
Rheine
Ibbenbüren
Osnab
Enschede
Apeldoorn
Ede
Gelderland
Arnhem
Münster
HJ-1A
HySI
HICO
CHRIS
Hyperion
20 km
Image © 2012 Aerodata International Surveys
© 2012 Google
© 2009 GeoBasis-DE/BKG
Image © 2012 GeoContent
Google earth

Spectral Coverage

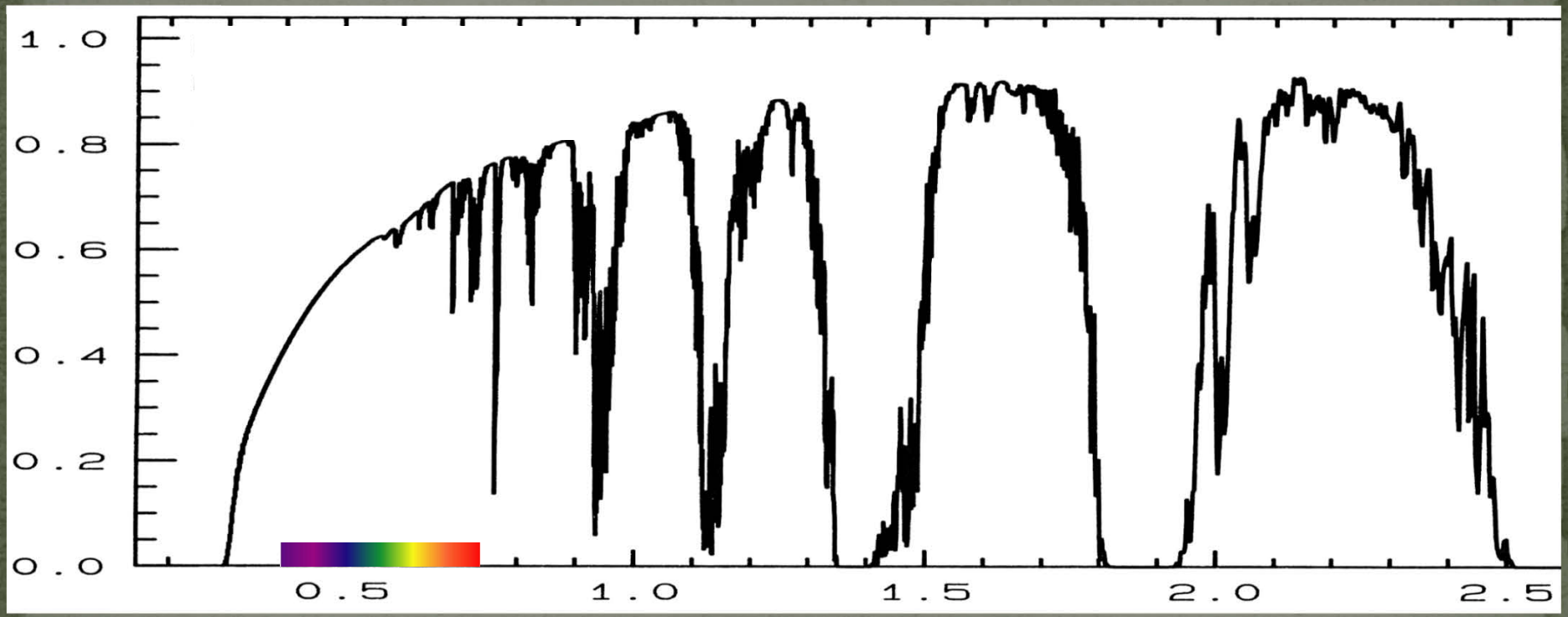
HJ-1A

HySI

Chris

HICO

Hyperion



Ready Scanners

Sensor	**EnMAP**	**PRISMA**	**MSMI**
Country and Organization	Germany GFZ/DLR	Italy ASI	S. Africa SunSpace
GSD (m)	30	30	~15
Swath at Nadir (km)	30	30	~ 15
Wavelength Coverage (nm)	420 - 2450	400 - 2500	440 - 2350
Number of Bands	218	237	200
Spectral Res. (nm @ FWHM)	5/10 VNIR 10 SWIR	~12	10
Launch Date	2015	2013/14	?

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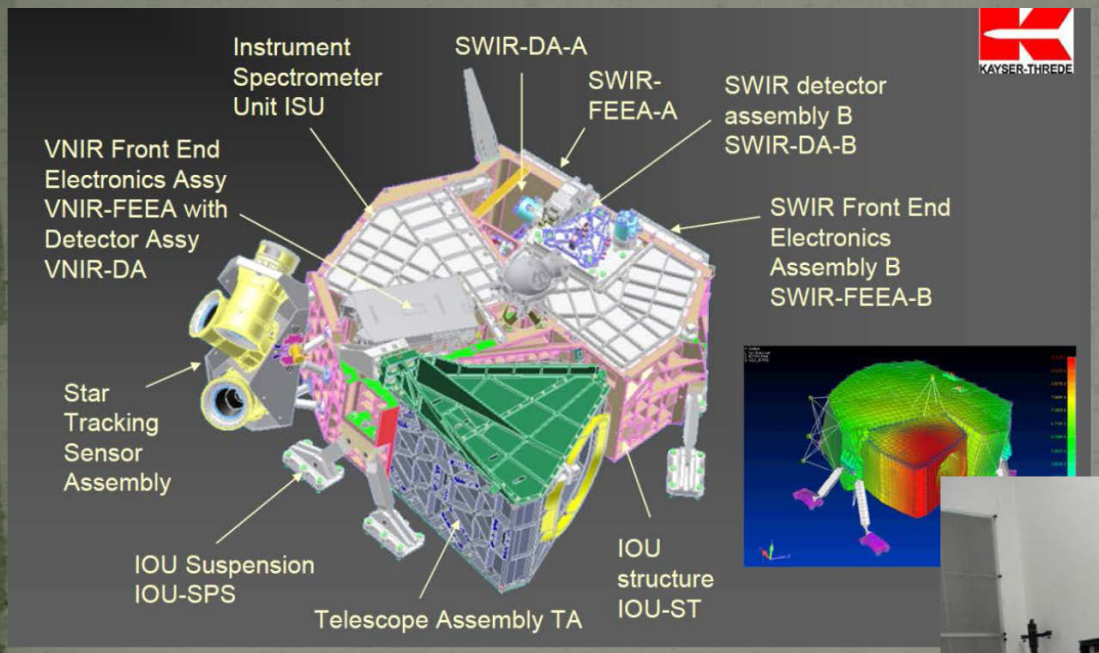
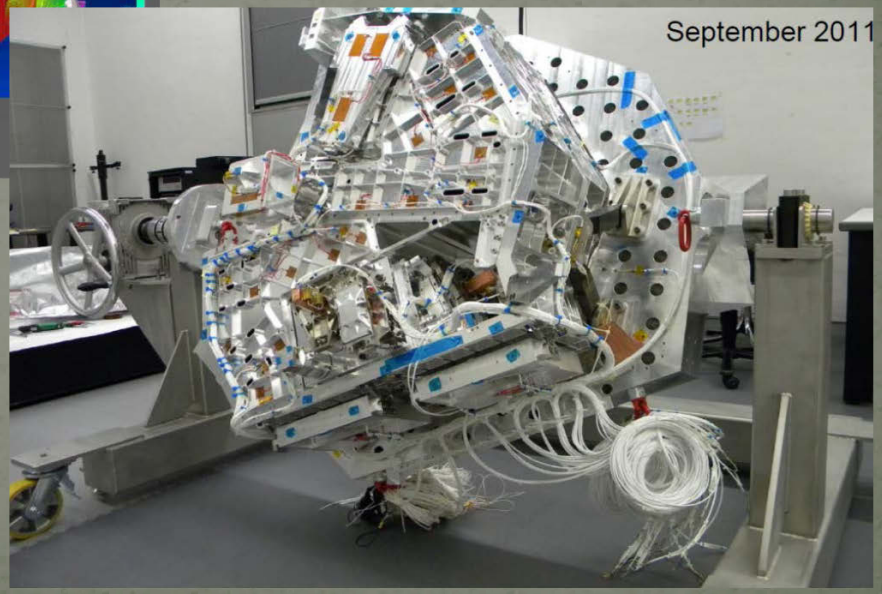
EnMAP Hyperspectral Imager

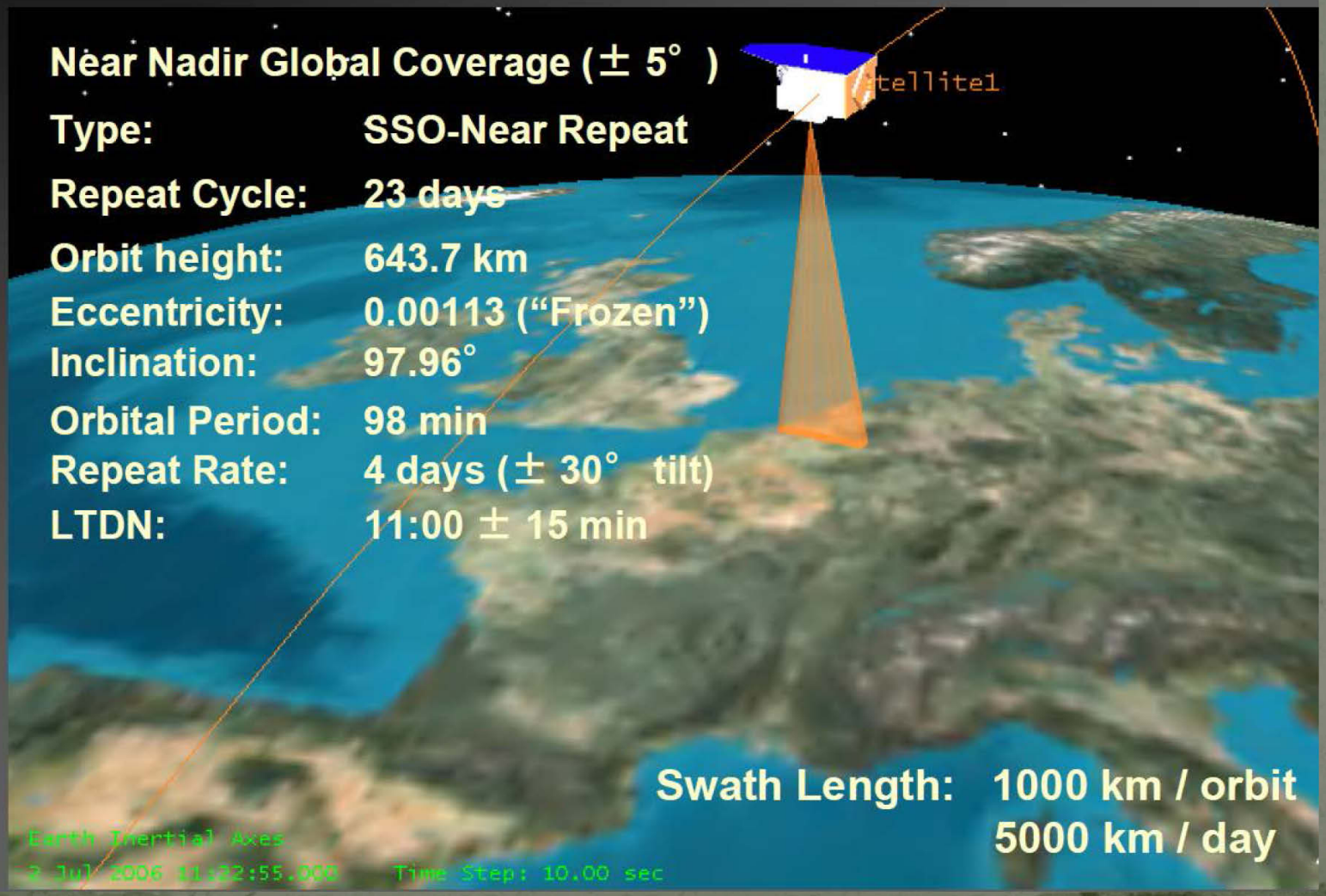
ENMAP





ENMAP

Main Orbit Parameters



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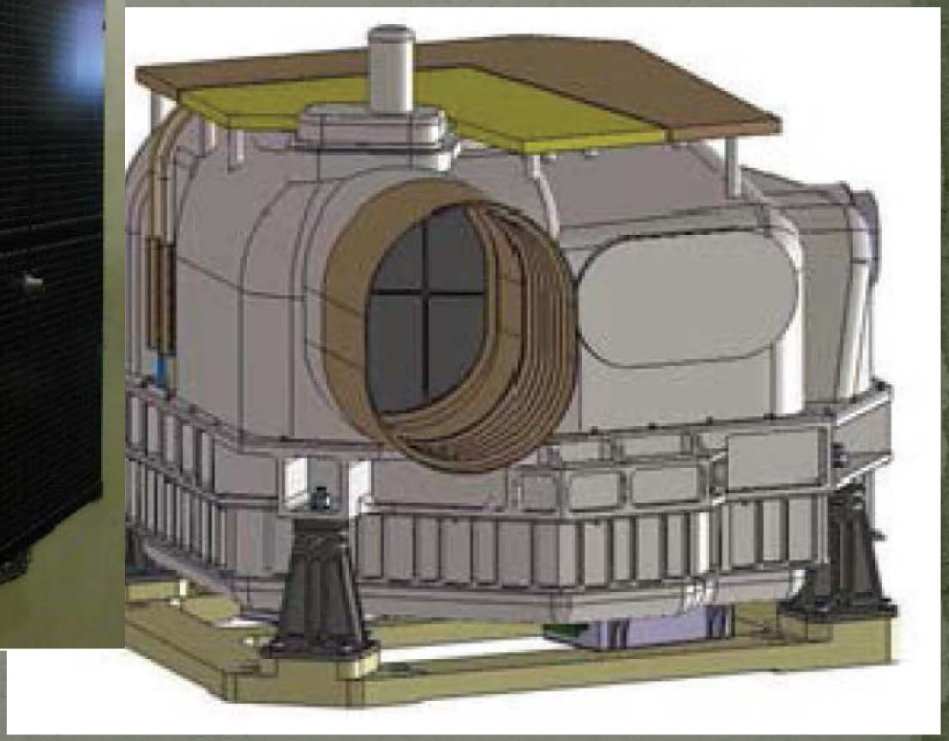
PRISMA

Italian Space Agency: ~2015 launch(?)



PRISMA
Italian Space Agency: ~2015 launch(?)

1. Development of algorithms and products for applications in agriculture and land monitoring supporting
the PRISMA mission (to be realised by CNR IMAA)
2. Synergic use of PRISMA products with high spatial resolution meteo-chimical simulation and ground
validation (to be realised by CETEMPS)
3. hyperspectral system analysis for integrated geophysical applications (to be realised by INGV)
4. advanced methods for analysis, integration and optimization of level 1 and level 2 PRISMA products (to
be realised by IFAC CNR)
5. Coasts and Lake Assessment and Monitoring by PRISMA HYperspectral Mission (to be realised by
ISMAR CNR).

Ready Scanners

Multi-Sensor Microsatellite Imager (MSMI)

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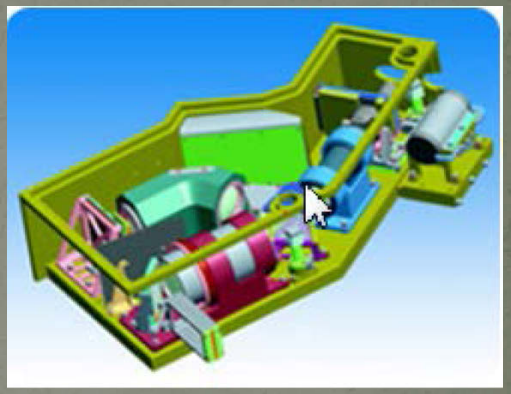

Optical SpectroMeter Unit (OSMU) is a hyperspectral imaging spectrometer integrated in a South-African Multi-Sensor Microsatellite Imager (MSMI) onboard of the second generation SUNSAT satellite ZASat2. OSMU contains two spectral channels: one in the visible and one in the infrared range. It has a field of view of 1,25° imaged on a detector of 1000 by 400 pixels. About 200 spectral bands are recorded in the wavelength area between 350 and 2350nm, with a spectral resolution of 5-14nm and at a spatial ground resolution of 15m (seen from height of 600km).

South Africa will provide the satellite bus for the first – indeed, probably for both – of the satellites in the recently announced India Brazil South Africa Dialogue Forum (Ibsa) satellite programme.

Planned Scanners

Sensor	HyspIRI*	HISUI-ALOS-3	HYPXIM CA
Country and Organization	USA JPL, NASA	Japan METI	France CNES
GSD (m)	60	30	15
Swath at nadir (km)	145	15	30
Wavelength Coverage (nm)	380 – 2500	400 - 2500	400 - 2500
Number of bands	> 200	185	> 200
Spectral Res. (nm @ FWHM)	10	10 VNIR 12 SWIR	≤ 14 VIS ≤ 10 NIR/SWIR
Launch Date	Baseline > 2020	≥ 2015	~ 2019

*Proposed instrument –Pre-decisional for planning and discussion purposes only

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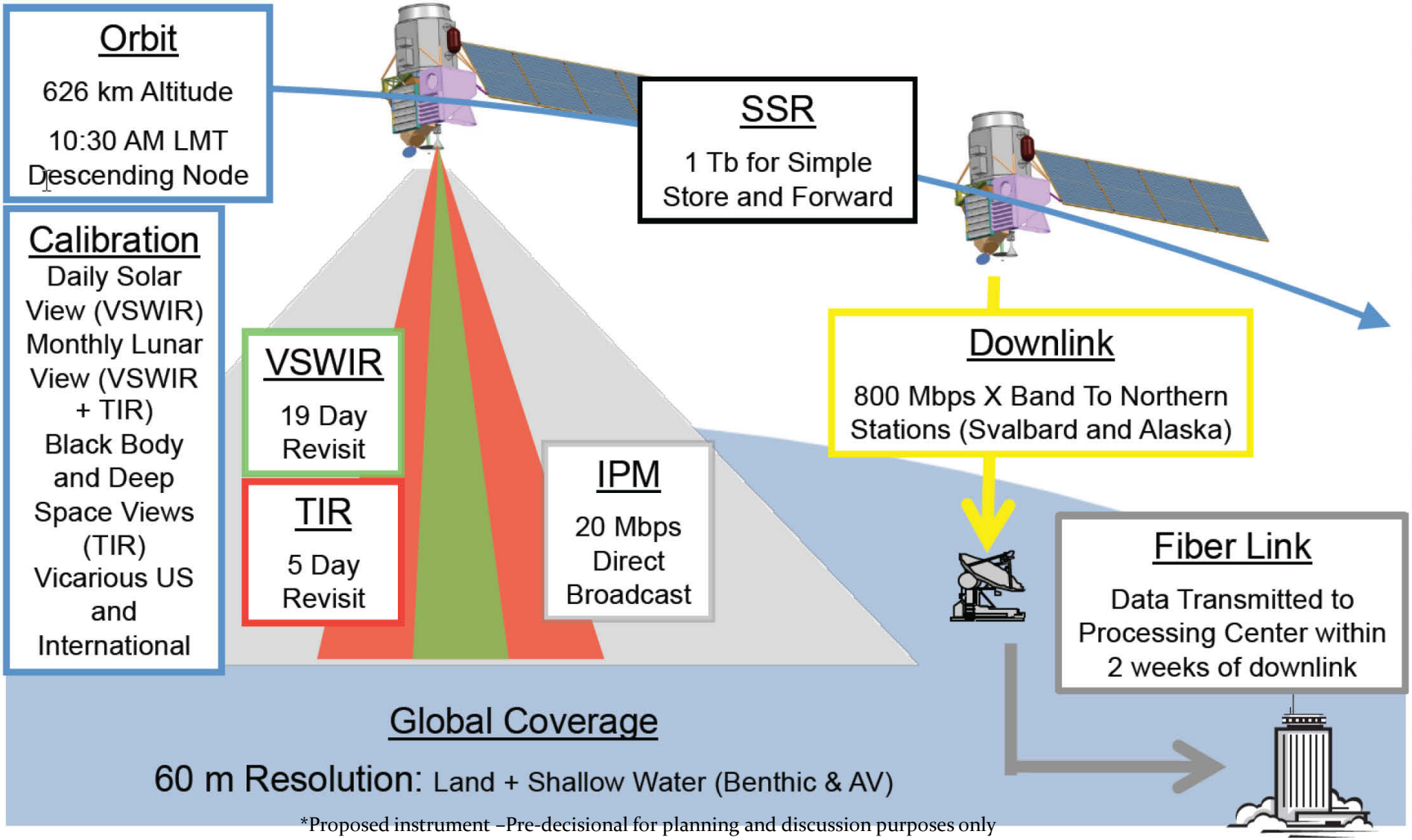
Hyperspectral Infrared Imager – HyspIRI*



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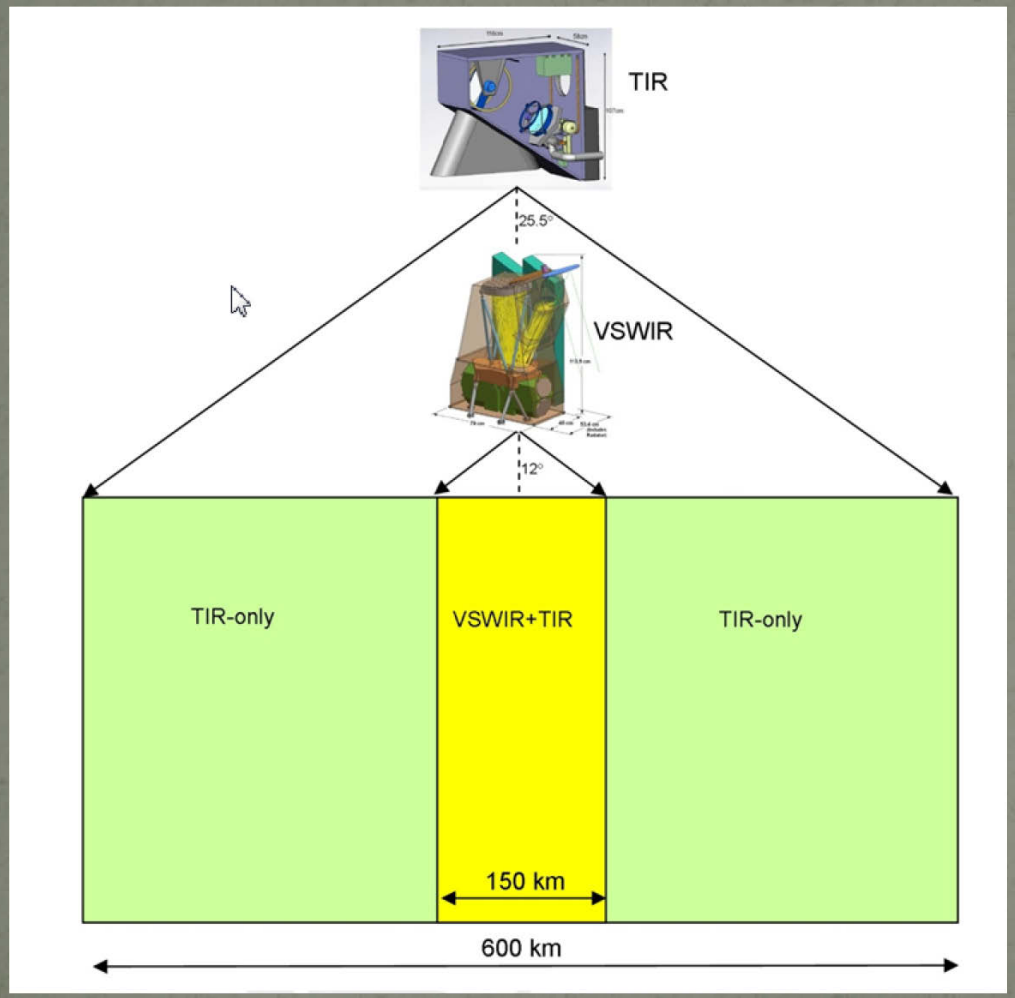
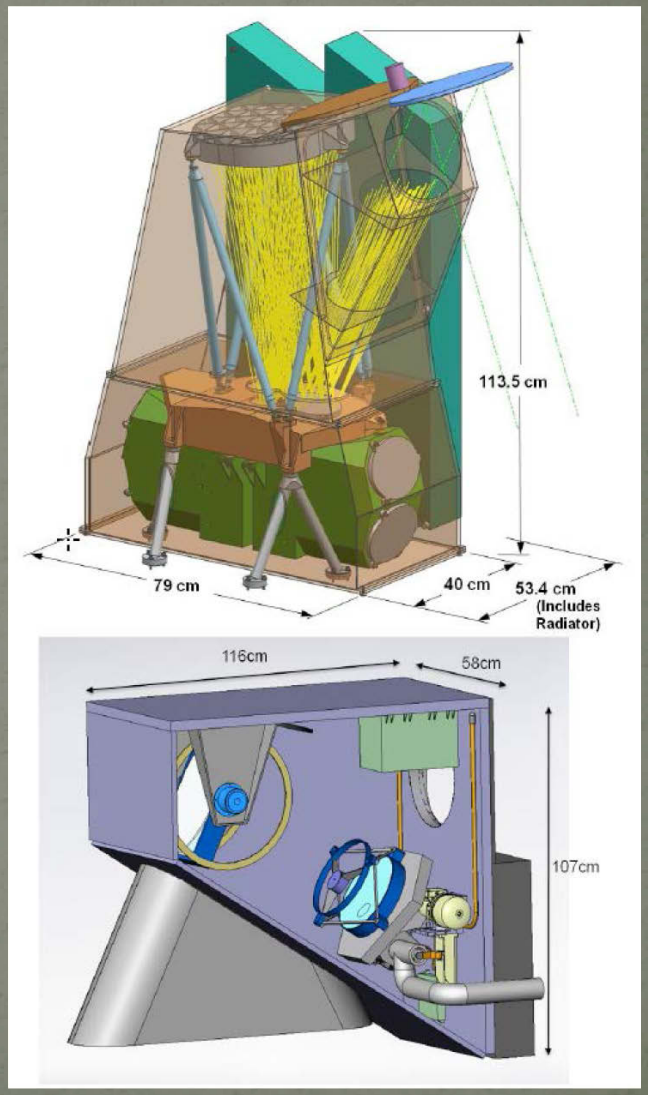
Hyperspectral Infrared Imager – HyspIRI*





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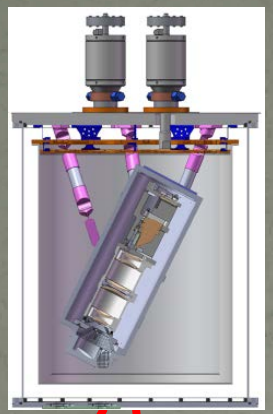
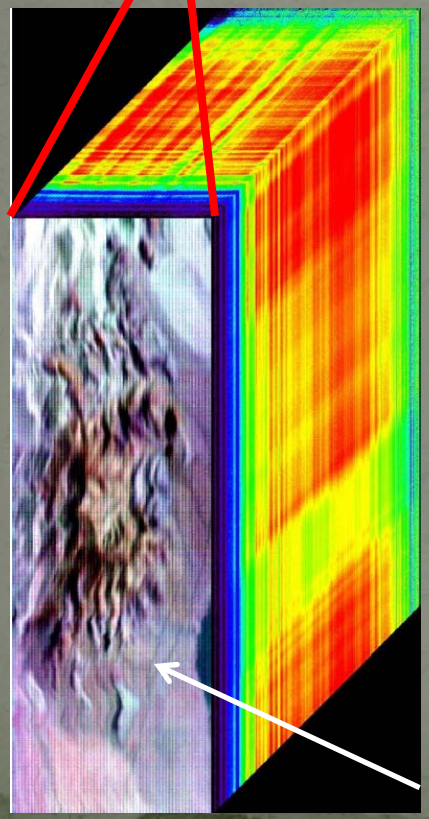
First Flight of HyTES

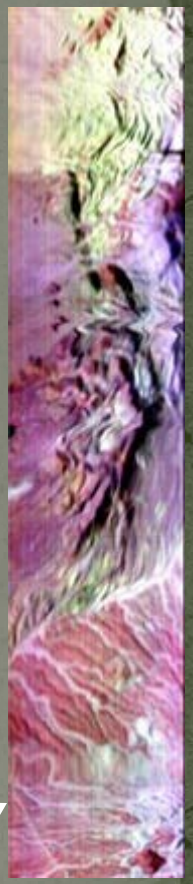
PI Simon J. Hook



The Hyperspectral Thermal Emission Spectrometer (HyTES) was developed at JPL with support from the NASA Instrument Investigator Program. HyTES would provide high spatial and spectral resolution thermal infrared data for the proposed HyspIRI* Decadal Survey mission.



HyTES first flights occurred in July 2012 over various sites in the western U.S.



HyTES Parameters:

- 512 cross-track pixels
- 256 spectral bands between 7.5-12 μm
- FOV 50 degrees
- 3.4 m pixel @2000 m

Bands 150 (10.08 μm), 100 (9.17 μm), 58 (8.41 μm) displayed as RGB

*Proposed instrument –Pre-decisional for planning and discussion purposes only

Planned Scanners

Sensor	HyspIRI*	HISUI-ALOS-3	HYPXIM CA
Country and Organization	USA JPL, NASA	Japan METI	France CNES
GSD (m)	60	30	15
Swath at nadir (km)	145	15	30
Wavelength Coverage (nm)	380 – 2500	400 - 2500	400 - 2500
Number of bands	> 200	185	> 200
Spectral Res. (nm @ FWHM)	10	10 VNIR 12 SWIR	≤ 14 VIS ≤ 10 NIR/SWIR
Launch Date	Baseline > 2020	≥ 2015	~ 2019

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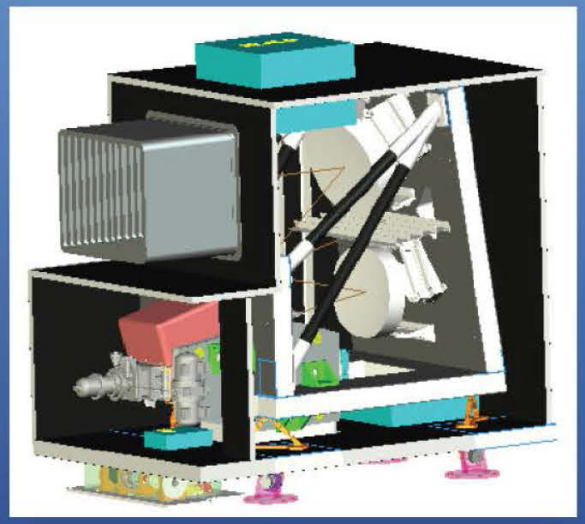
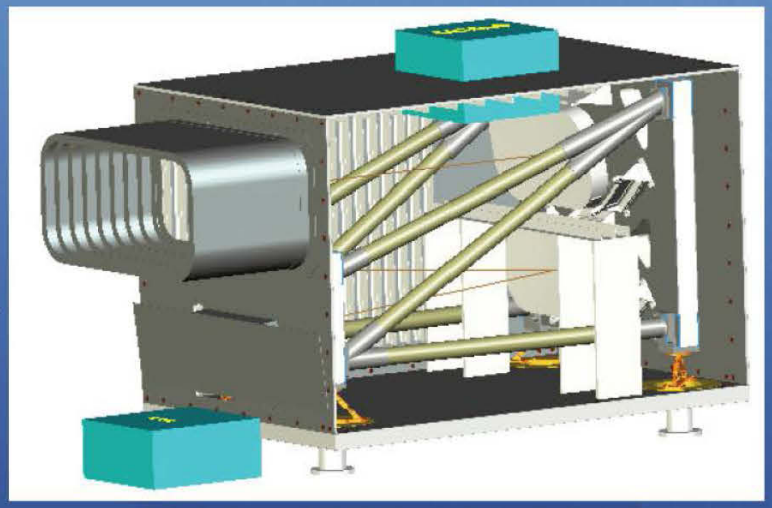
JAXA's ALOS-3 and HISUI (Hyperspectral Imaging Suite)

HISUI



Hyperspectral Imager



Multispectral Imager

HISUI

Parameter		Requirement
Spatial Resolution and Swath Width		30 m and 30 km
Spectral	Bands	185 (VNIR:57 SWIR:128)
	Range	0.4 - 2.5 µm VNIR:0.4-0.97 µm SWIR:0.9-2.5 µm
	Resolution	10 nm (VNIR), 12.5 nm (SWIR)
Signal to Noise Ratio (30% albedo)		≥ 450 @620 nm ≥ 300 @2100 nm
MTF		≥ 0.2
Dynamic Range		≥ 10 bits (current design=12bit)
Data Compression		Lossless (70%)
Pointing Capability		≈ ±3 ° (±30 km)

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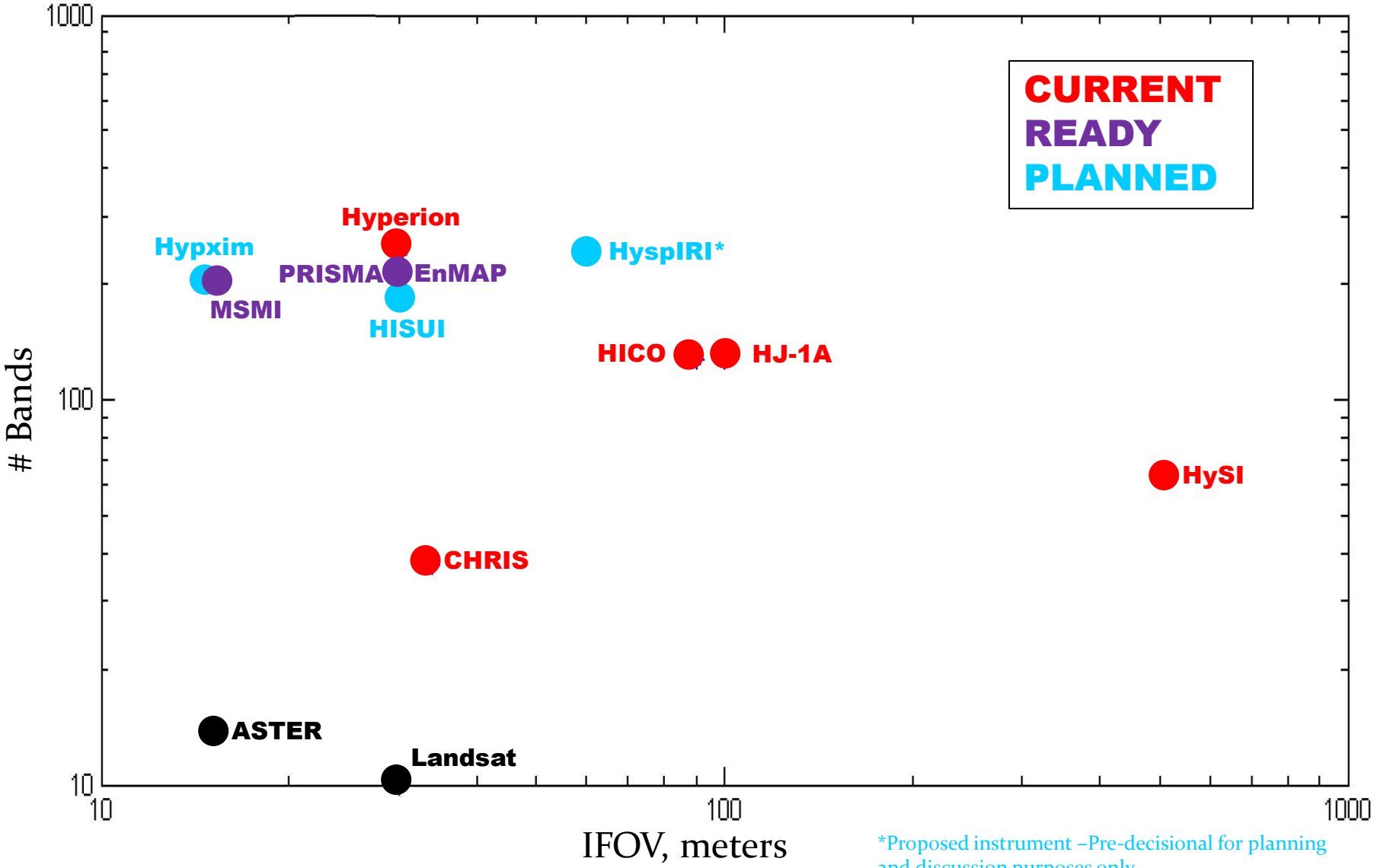
HYPXIM

- France's CNES sponsored a mission study to investigate hyperspectral scanners for civilian and military applications
- This resulted in plans for three instrument concepts: HYPXIM-C, HYPXIM-CA and HYPXIM-P Hyper-performance

- HYPXIM-C: 2 satellites, 15 km swath, 15 m resolution, 200 kg weight
- HYPXIM-CA: 30 x 30 km images, 60 kg weight

- HYPXIM-P: 16 km swath, 3-day revisit with pointing, 8 m resolution; 40 bands in TIR with 100 m resolution

IFOV vs Number Bands



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Spectral Coverage and Swath Width

	VNIR	SWIR	TIR	Swath
Landsat	4	2	1	180
ASTER	3	6	5	60
CHRIS	37			13
HYSI	64			130
Hyperion	85	135		7
HJ-1A	110			50
HICO	128			42
MSMI	80	120		15
EnMAP	85	135		30
PRISMA	90	145		30
HISUI	85	100		15
HYPXIM-P	65	135	40	30
HyspIRI*	85	135	8	145/600

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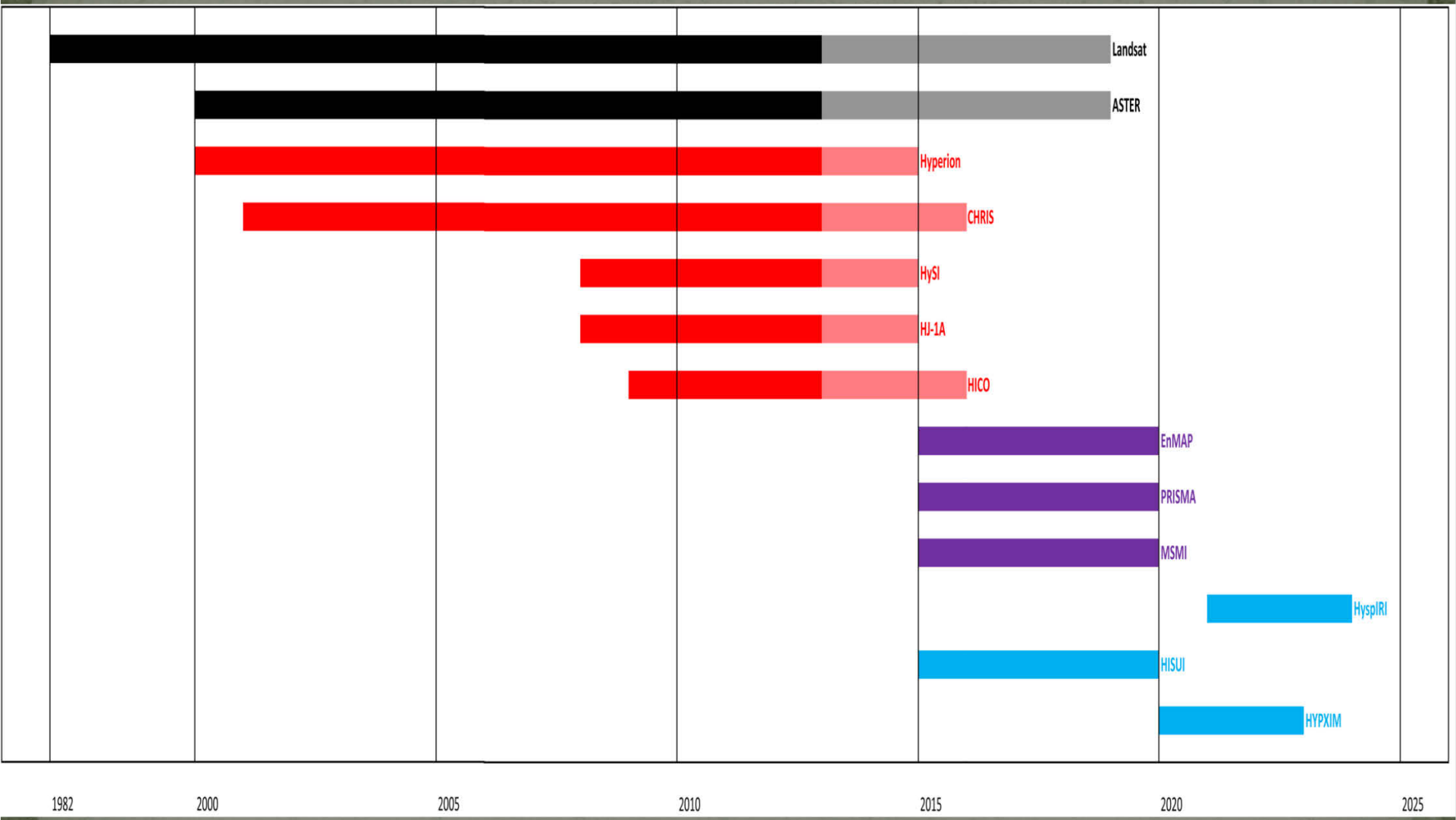
Instrument Lifetimes