→ THE ESA EARTH OBSERVATION Φ-WEEK

EO Open Science and FutureEO

12–16 November 2018 | ESA–ESRIN | Frascati (Rome), Italy

"HORUS Cluster: the S5Lab CubeSat-based multi-angle and multi-spectral Earth Observation system"

Alice Pellegrino, Fabio Santoni, Federico Curianò, Andrea Gianfermo, Francesco Feliciani

Mission Rationale

17 Sustainable Development Goals

HORUS cluster

SAPIENZA UNIVERSITÀ DI ROMA

Mission Rationale

5 addressed UN SDGs

Atmospheric aerosols/dust and Air Pollution

Top-of-the-atmosphere and bidirectional albedo

Detection of cloud features

Land surface characteristics

Main Targets

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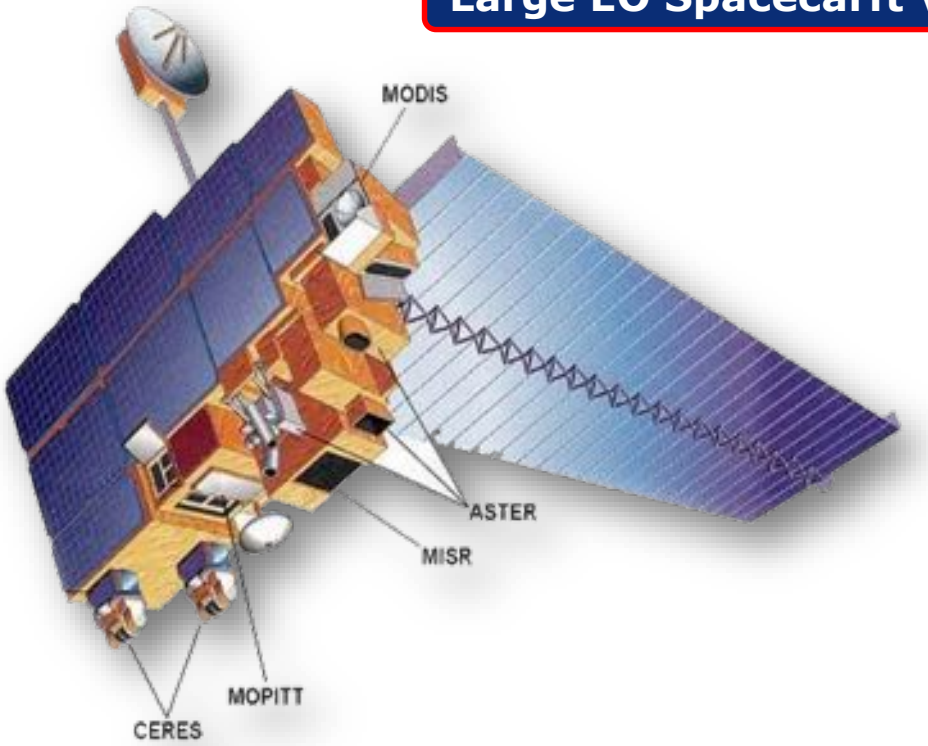
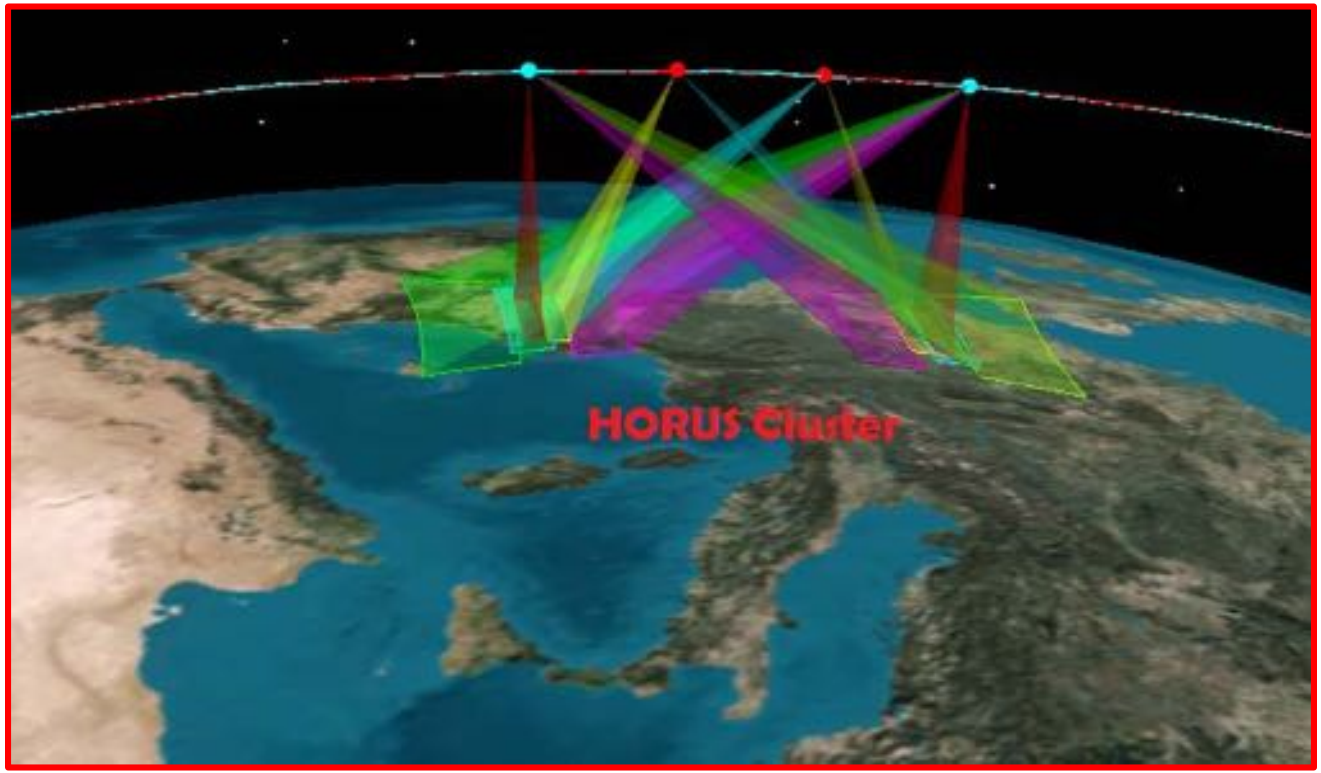
Large EO Spacecarft VS Small EO Platforms

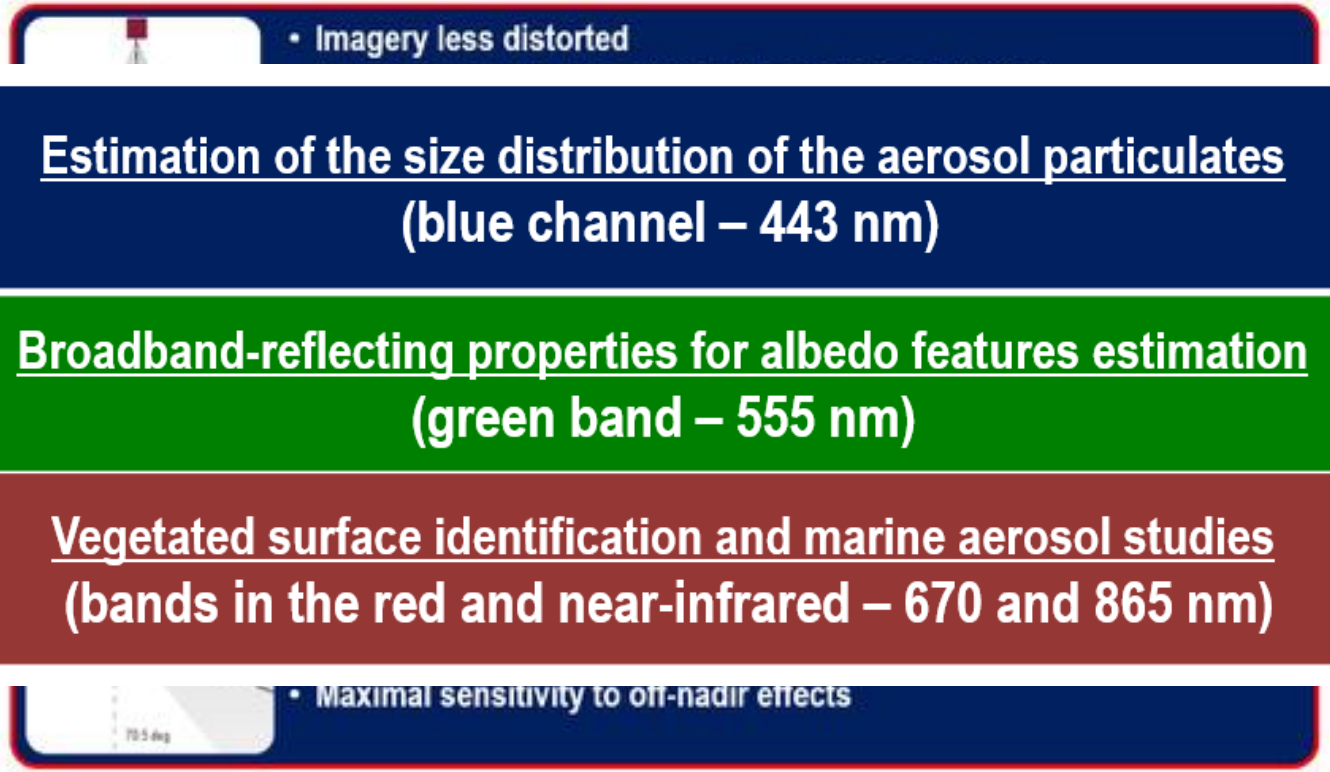


Mission Rationale



- 6U-based Cluster
- 8 Off-nadir Angles
- Redundancy on Nadir view
- 4 Spectral Bands

Mission Rationale

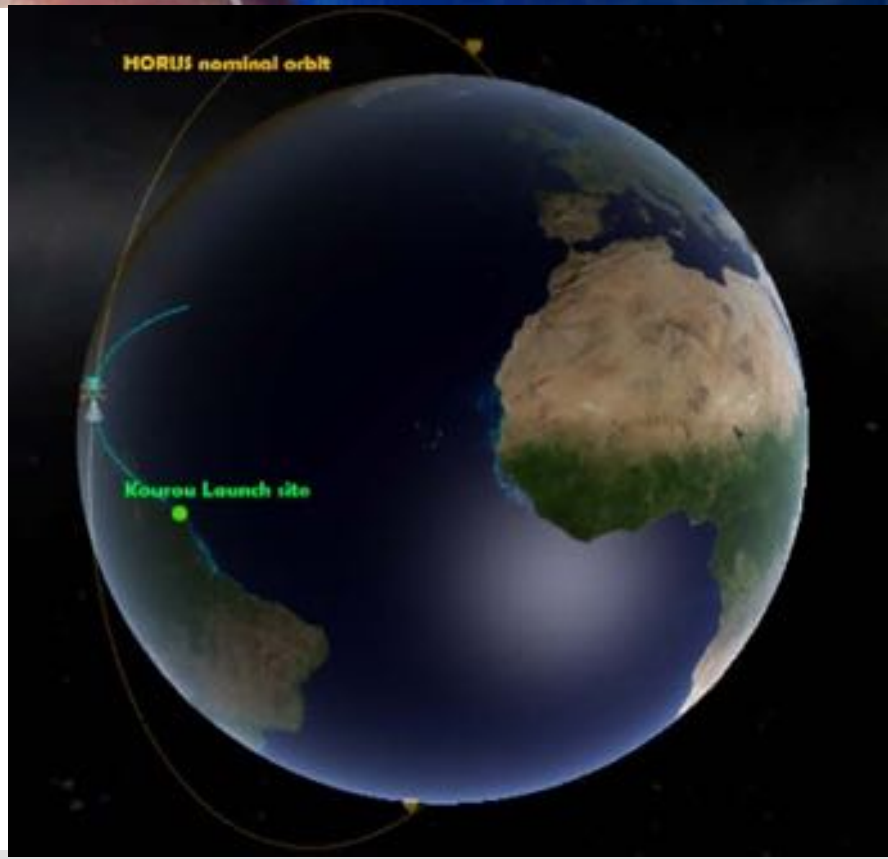


Mission Requirements

Spectral Performances	**Four spectral bands** (R, G, B, and NIR)
Off-nadir sampling capability	**Eight different view-angle** forward and afterward the Nadir (±26.1°, ±45.6°, ±60.0°, ±70.5°) with **redundancy on Nadir views**
Radiometric performances	**High sensitivity** is needed for a wide range of scene reflectance (2% to 100%) **without any change in gain**
Spatial performances	**Sub-km Spatial Resolution**
Stable Pointing	**Three-axis stabilization** and On-board Orbit Control System
Cluster Downlink Capacity	The **maximum needed data rate is around 50 Mbits/s**

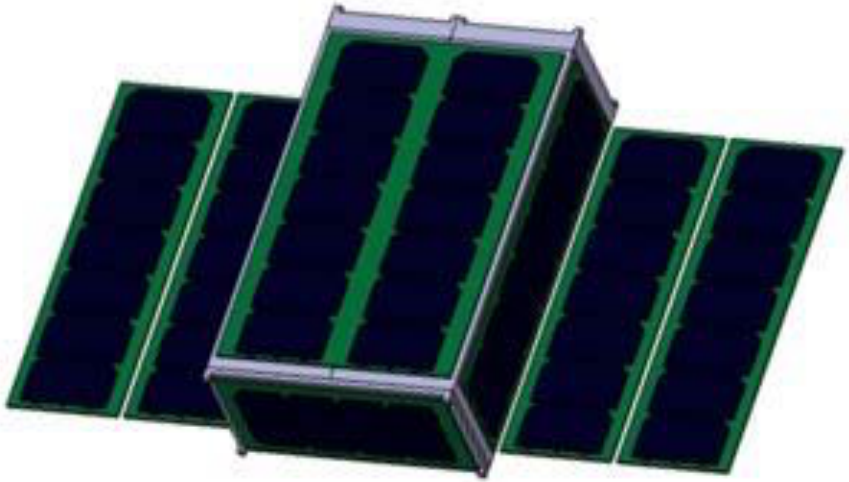
Orbital Parameters

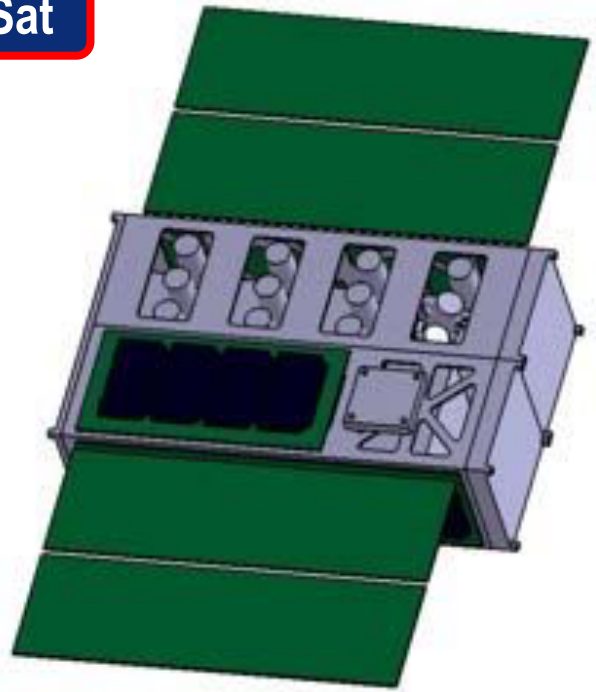
Orbit	SSO - circular
Semiaxis	6856.99 km
Inclination	97.41 deg
Argument of Perigee	68.13 deg
RAAN	200.00 deg
Shift in True Anomaly	2.32 deg
Mean Local Solar Time at DN	10:30 am
Orbital Period	94.18 min
Eclipse Time	35.12 min



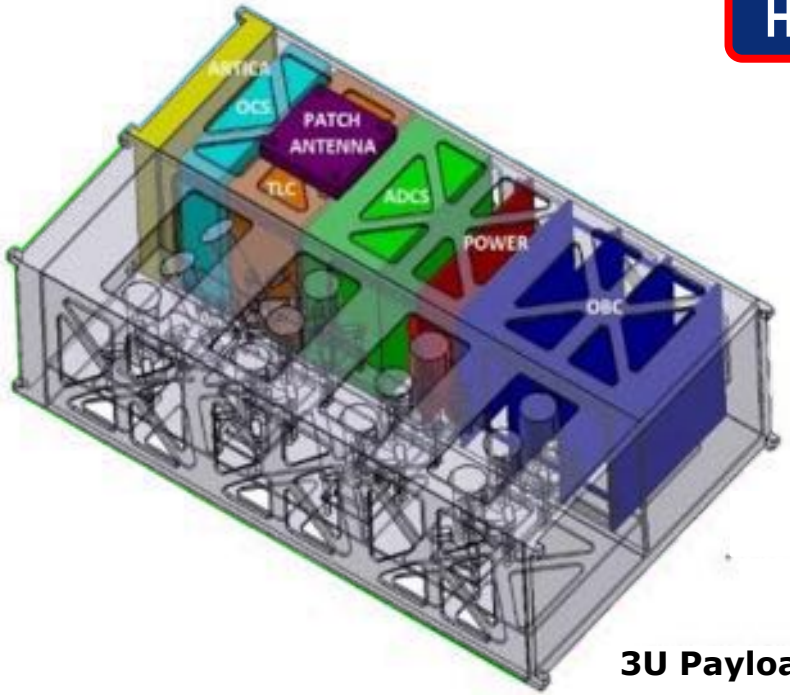
Spacecraft Design

HORUS 6U CubeSat





HORUS 6U CubeSat



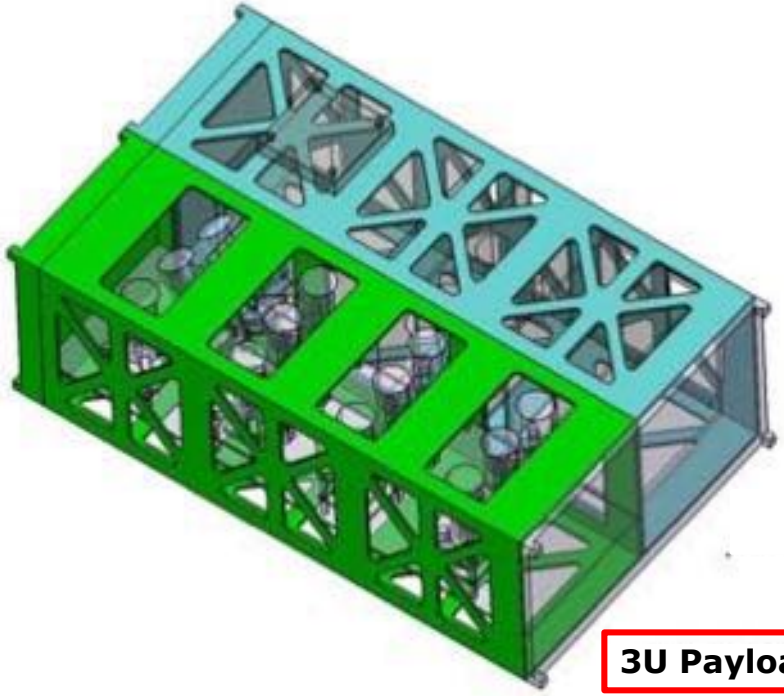
3U Payload Module

3U Service and Control Module

Subsystems

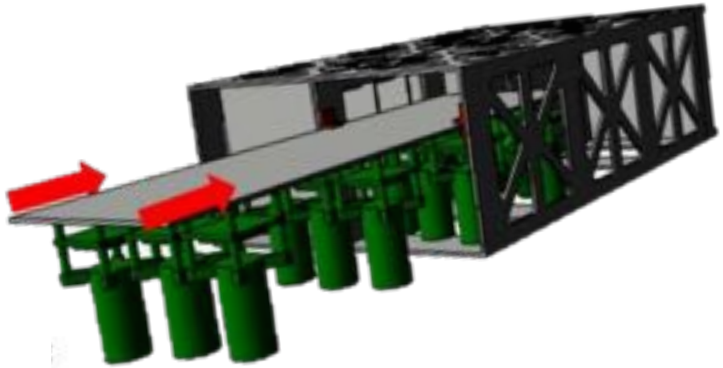
- OBDH
- EPS/Solar Panels
- ADCS
- TT&C
- OCS
- Deorbiting

Rail-based Integration System for the Payload



3U Payload Module

3U Service and Control Module



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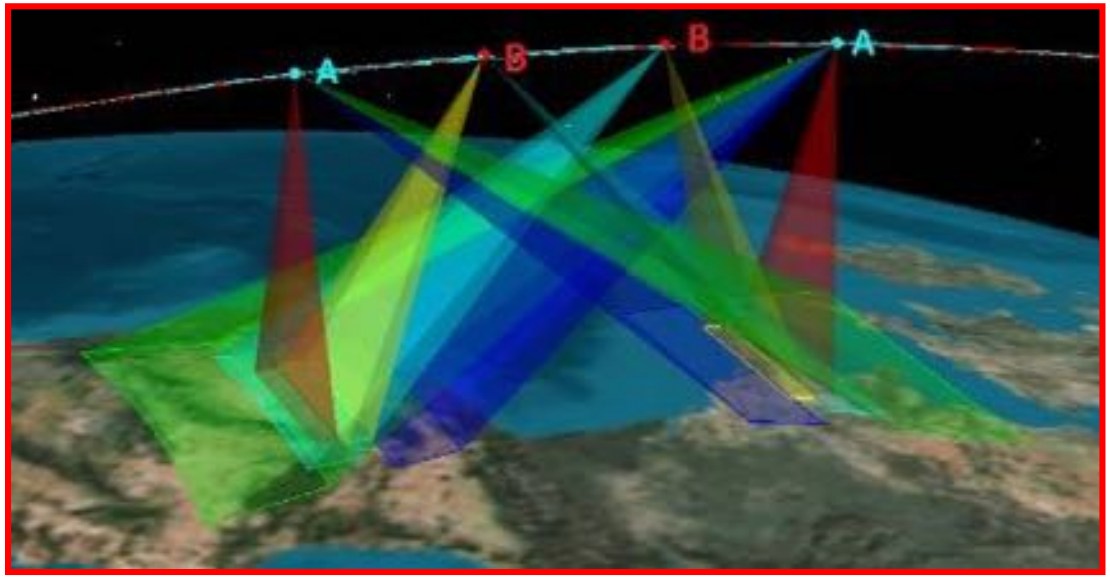
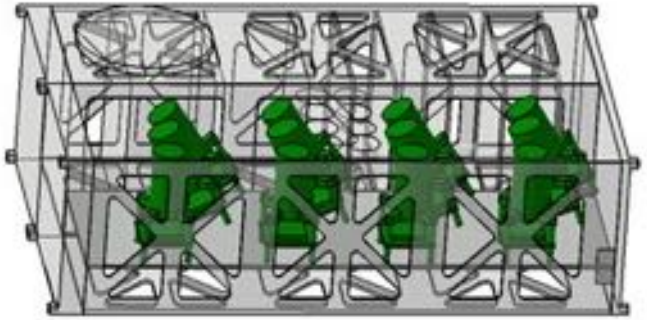
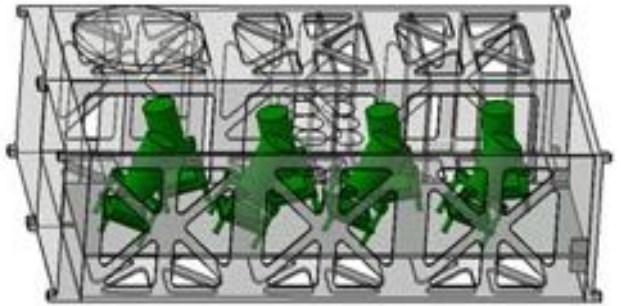
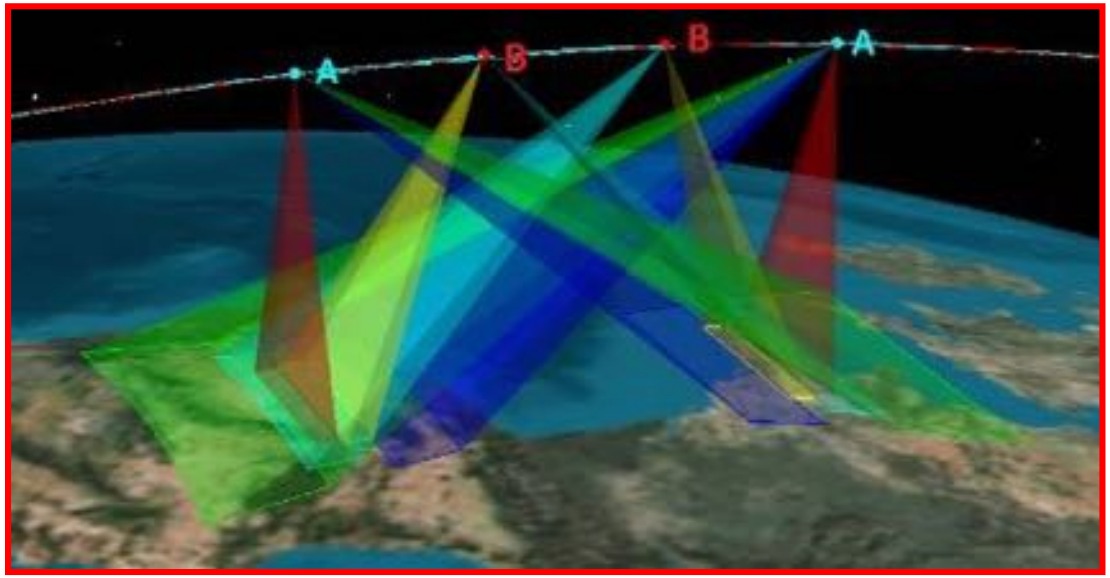




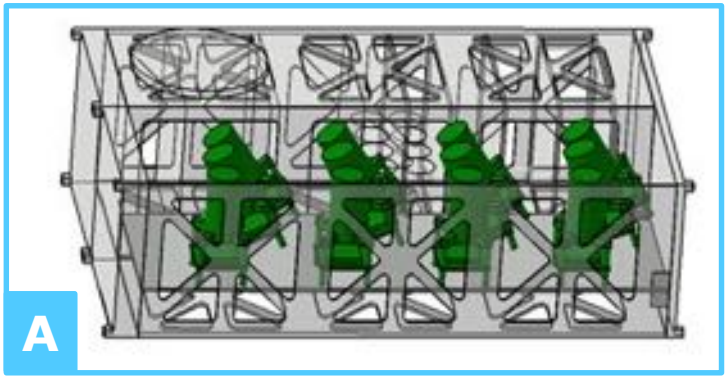


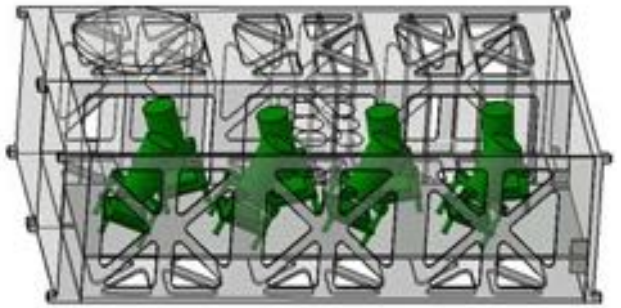
2 Main On-board Configurations

Spacecraft Design

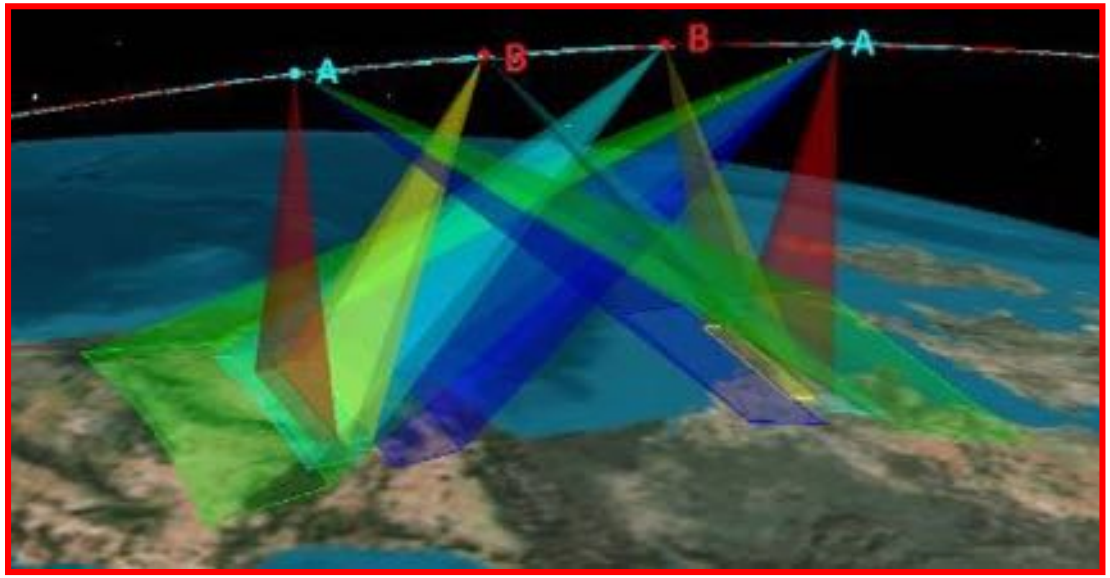


Configuration A

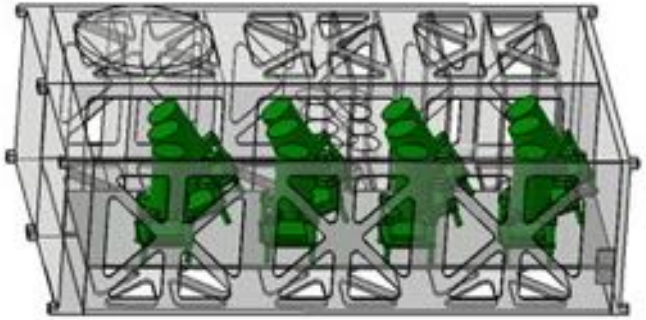


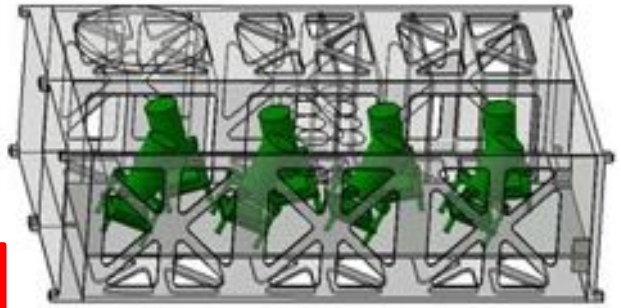


Spacecraft Design



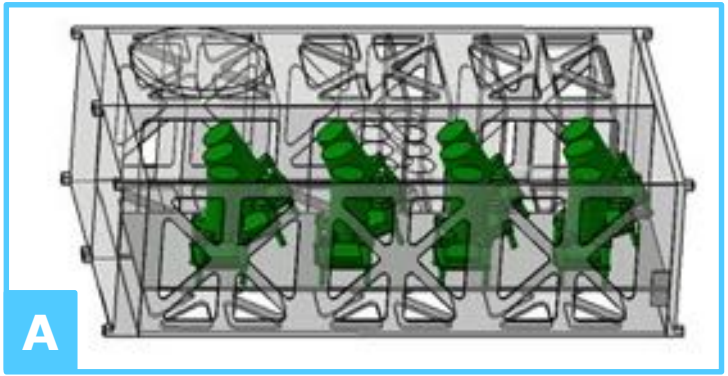
Configuration B

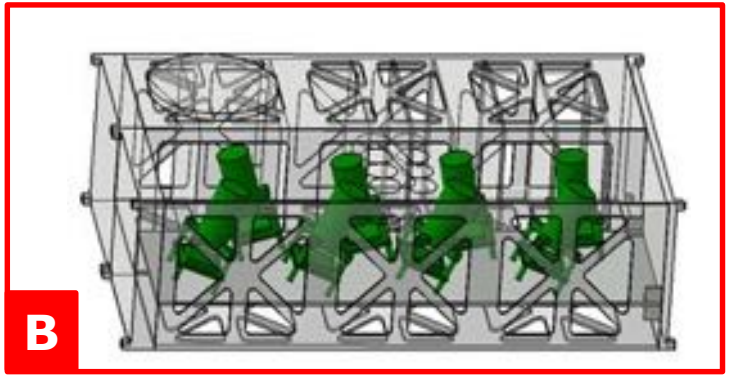




Mass Budget

Components	Configuration A	Configuration B
Aluminium structure	0.97 kg	
Optical payload	3.0 kg	2.0 kg
ARTICA System	0.40 kg	
OCS	0.30 kg	
TLC	0.20 kg	
Power Control Unit	0.15 kg	
Battery Pack and Aluminium support system	0.60 kg	
OBC	0.40 kg	
ADCS	0.50 kg	
Solar Panels	1.4 kg	
Connections	0.30 kg	
Antenna	0.17 kg	
TOTAL MASS	9.40 Kg	8.40 Kg



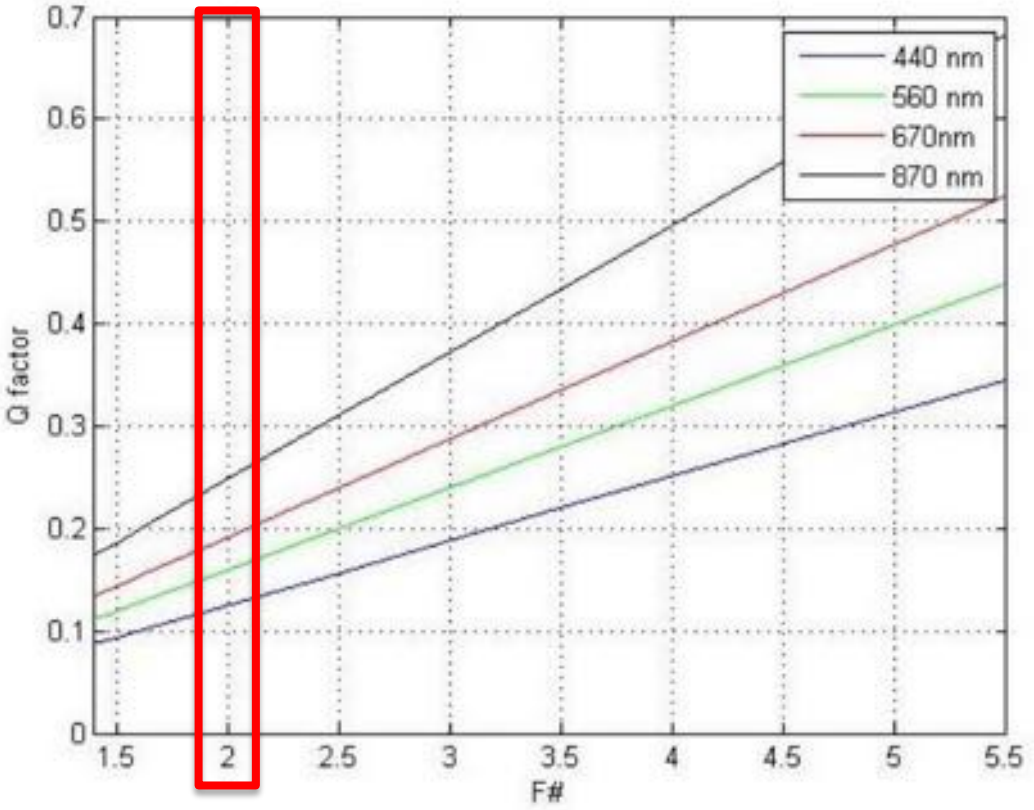


Feasibility Study

- **Sub-kilometer spatial resolution**
- **8 Off-nadir angles plus redundancy on the Nadir view**
- **Matrix imagers configuration**
- **Common focal length (21 mm)**
- **Pixel dimension of 7µmx7µm**
- **CMOS sensor (2048x1536 pixels)**
- **COTS filters (RGB and NIR)**
- **MISR Optical Quality Factor (Q) ∈ [0.1,0.25]**

Main Hypotheses

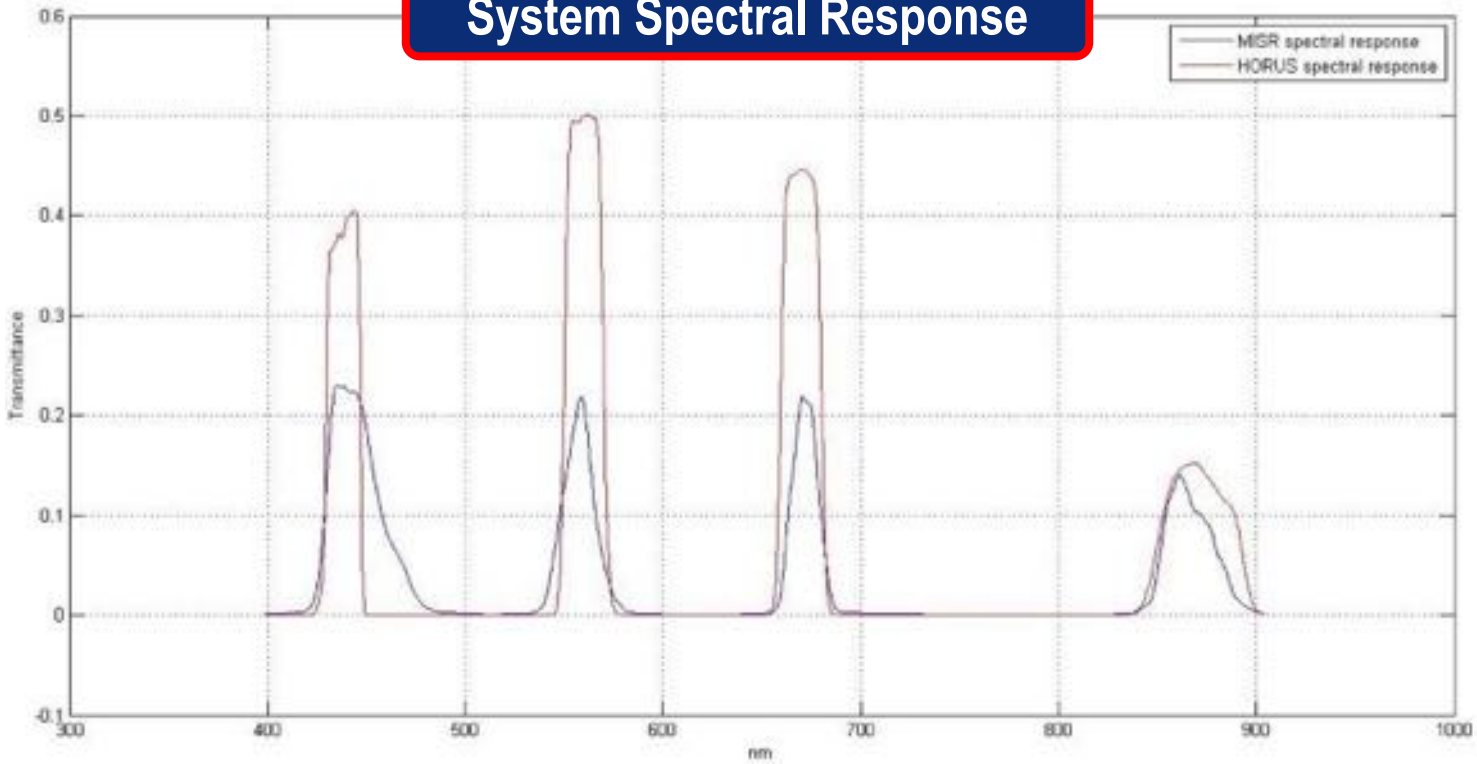
Feasibility Study



F# = 2

10.5 mm as Sensor Dimension

System Spectral Response



Radiometric Analysis Results

Equivalent reflectance %	Minimum SNR	HORUS			
		Blue	Green	Red	NIR
100	700	861.8	868.7	862.9	865
70	600	719.5	725.3	720.4	722.3
50	450	606.4	611.3	607.2	608.7
20	300	378	381	378.5	379.5
2	100	100	101	100	100

SNR ≥ 100

Resolution at Ground

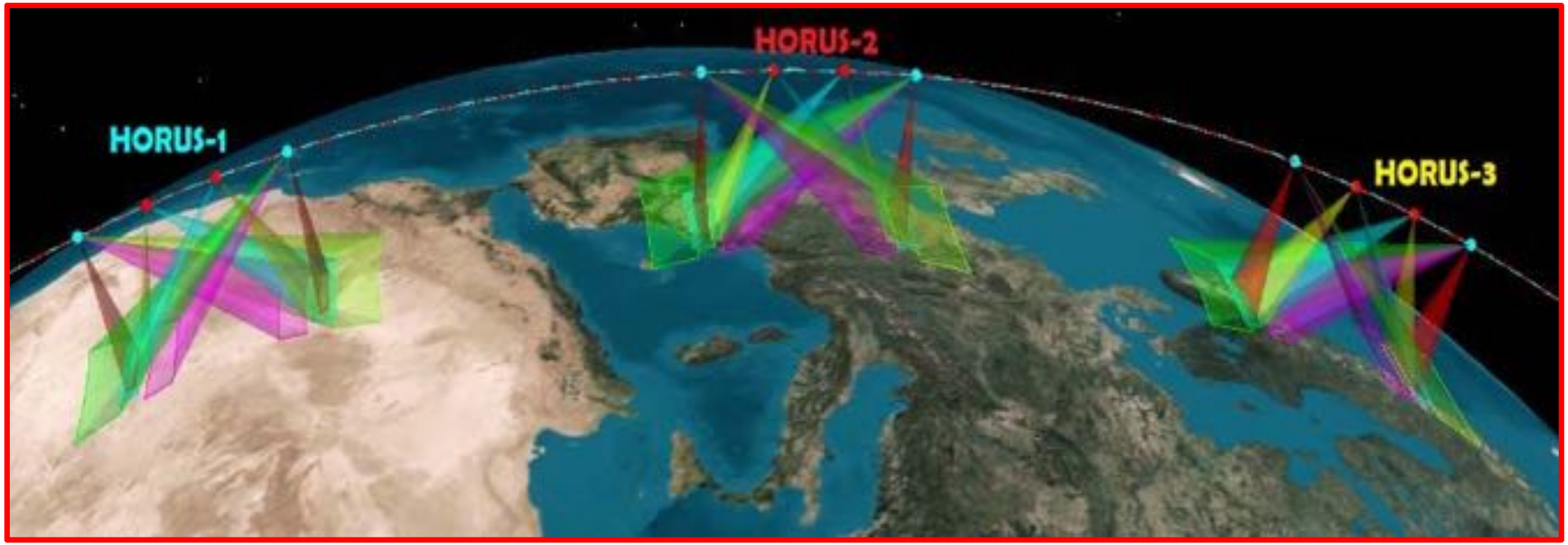
		Observing angles				
		0 deg	26.1 deg	45.6 deg	60.0 deg	70.5 deg
Spectral bands	blue (446 nm)	27.2 m	30.2 m	38.8 m	54.4 m	81.4 m
	green (558 nm)	34.0 m	37.8 m	48.6 m	68.0 m	102.0 m
	red (672 nm)	41.0 m	45.6 m	58.6 m	82.0 m	122.8 m
	IR (866 nm)	53.0 m	59.0 m	75.8 m	106.0 m	158.8 m

Main Hypotheses:

- **Diffraction limited device**
- **Aberration free estimation**

Synergy with existing EO spacecraft

Scalable Configuration



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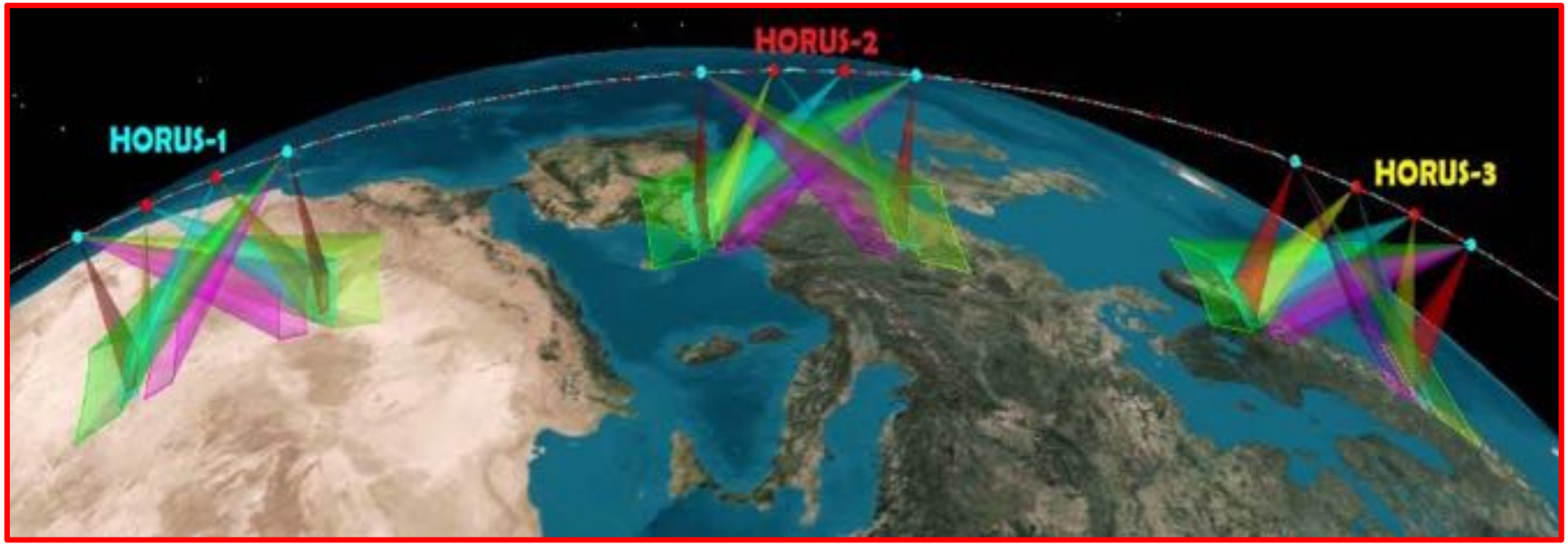


Conclusions

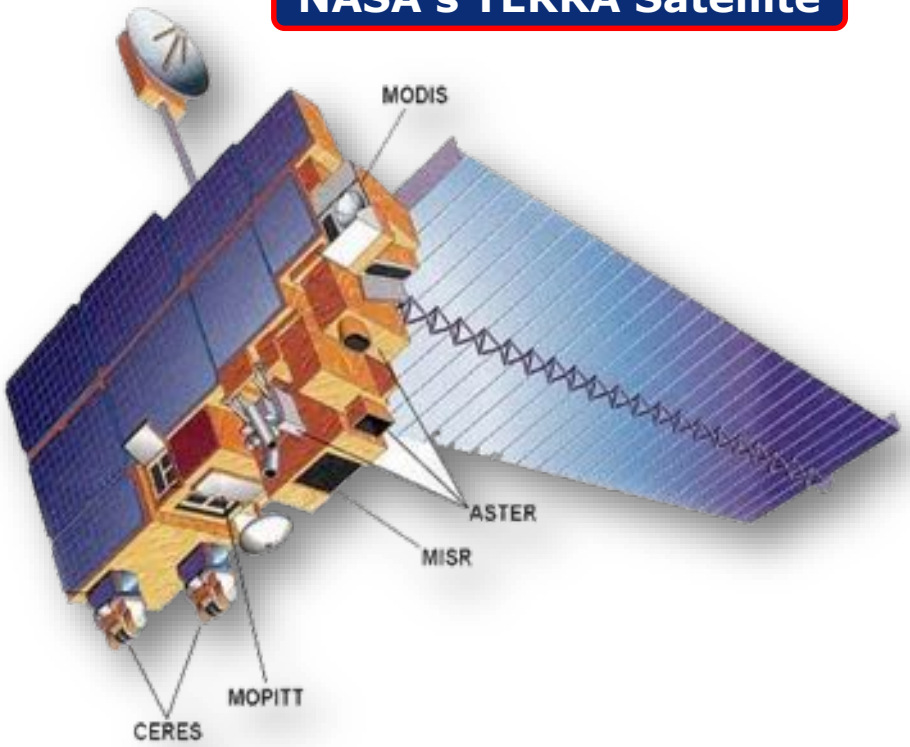
- The **HORUS Cluster Mission** has been designed at **Sapienza Space Systems and Space Surveillance Laboratory (S5Lab)** to define a new EO concept able to acquire multi-spectral and multi-angle imagery
- The **design** has been **consolidated** and the **Feasibility Study performed** allowed defining the main features of the spacecraft and on-board payload
- The **main requirements and key performance parameters of the mission have been defined** by considering the performances offered by the NASA's TERRA satellite
- The **Synergy between the HORUS Cluster and already existing EO large/small satellites constellation and spacecraft** is currently under evaluation

Questions?

For further details: ali.Pellegrino.92@gmail.com

Mission Background

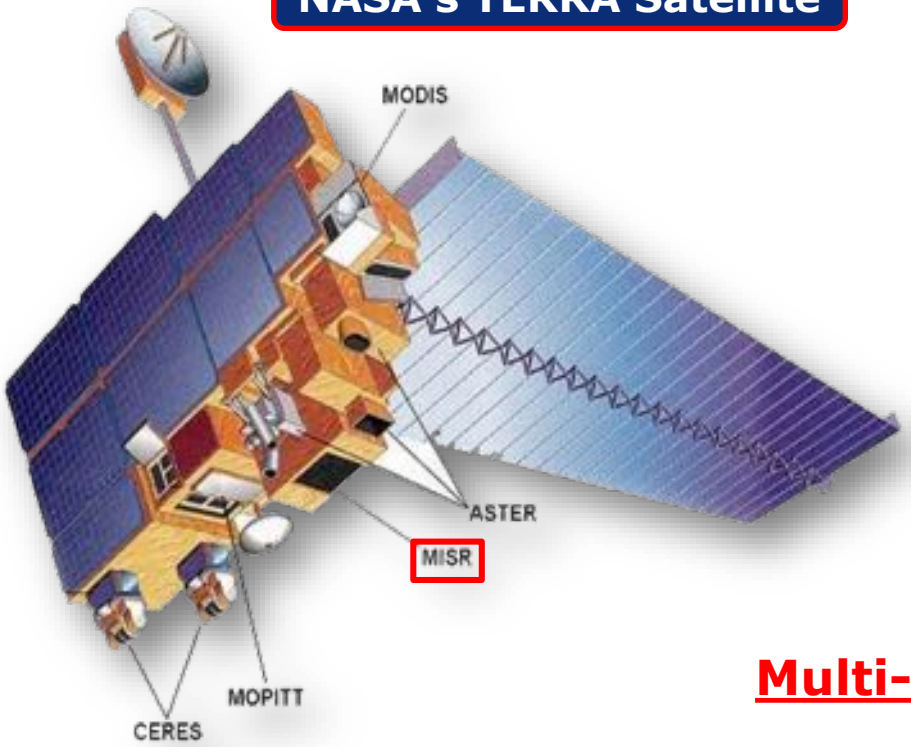
NASA's TERRA Satellite



- It was launched on on December 18, 1999
- Its size is comparable to a **small school bus**
- It carries **five instruments** taking **measurements of the Earth system**
- Terra has a **strong chance of operating successfully into the early 2020**

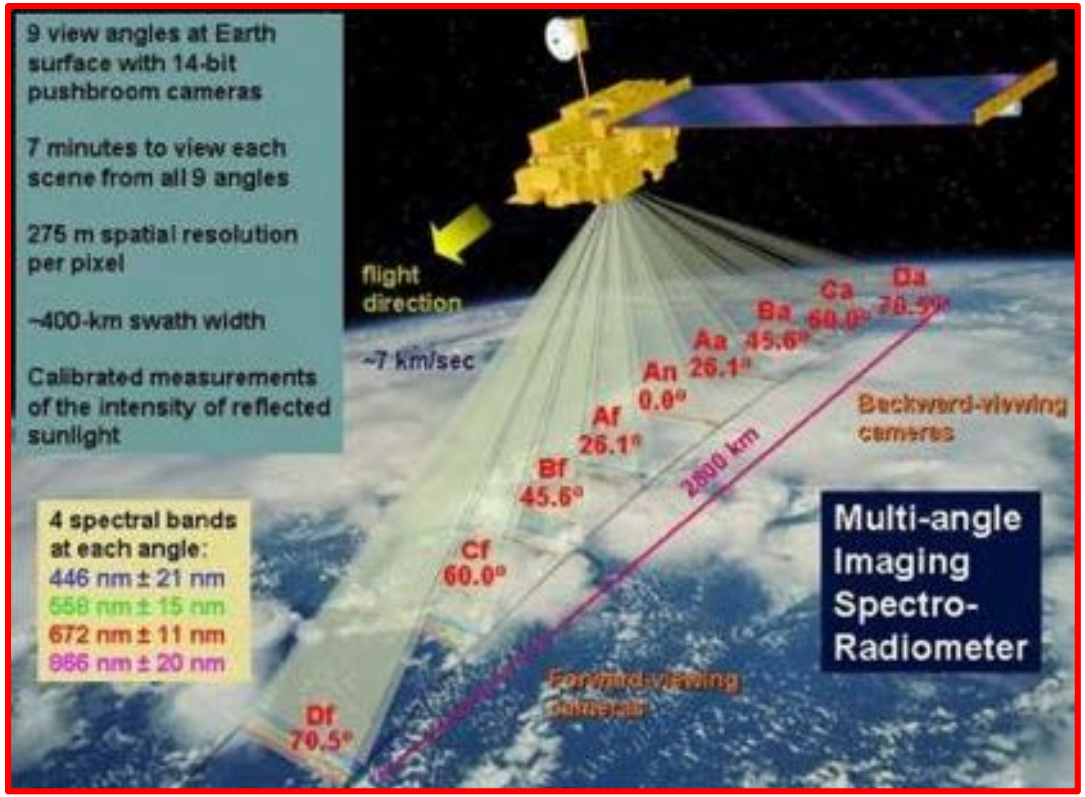
Mission Background

NASA's TERRA Satellite



Multi-angle Imaging SpectroRadiometer

Mission Background



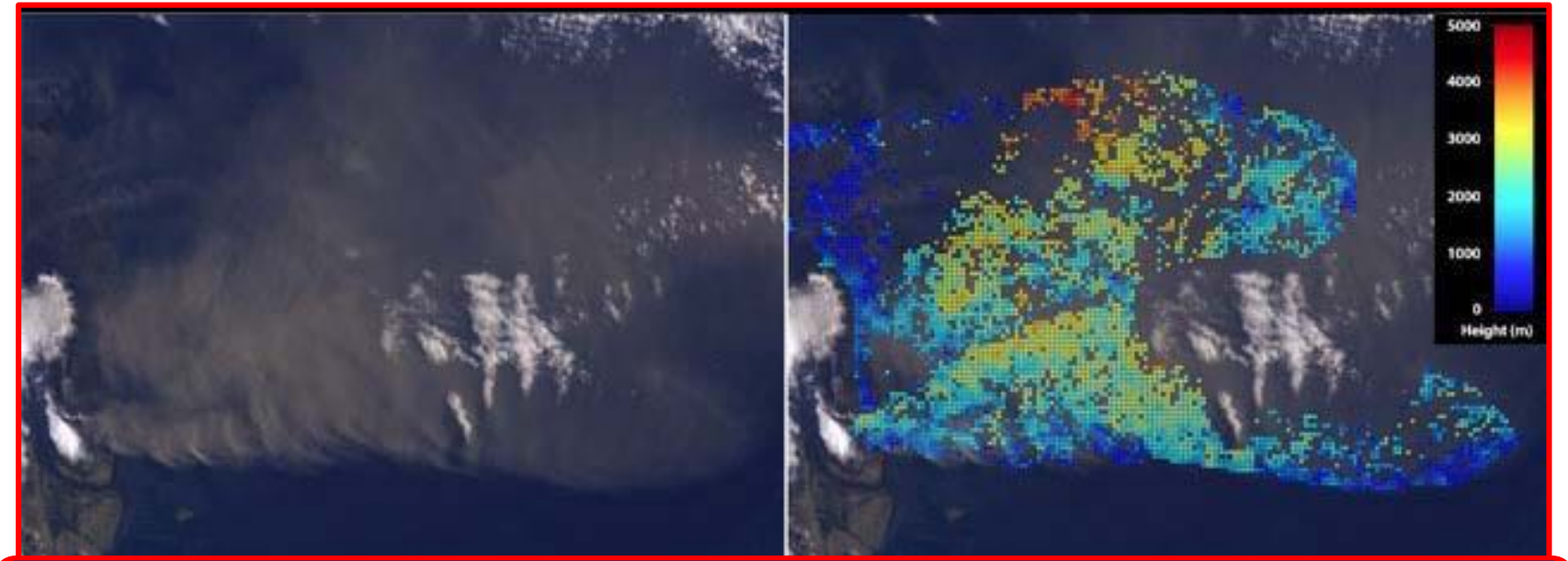
9 Pushbroom Cameras

4 Spectral Bands

9 view angles

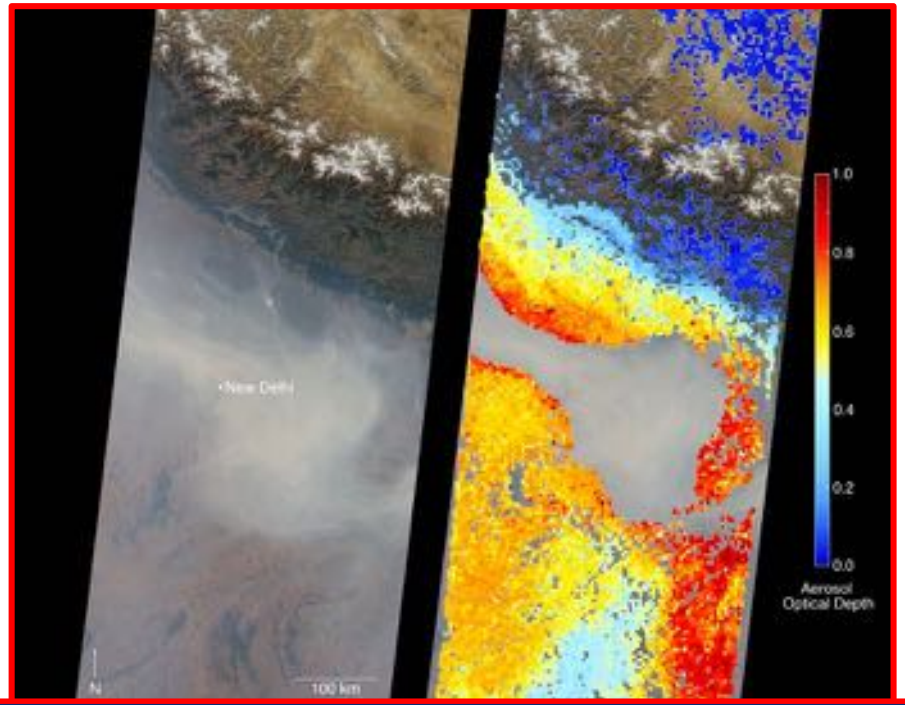
275 m of Spatial Resolution per pixel

Mission Background



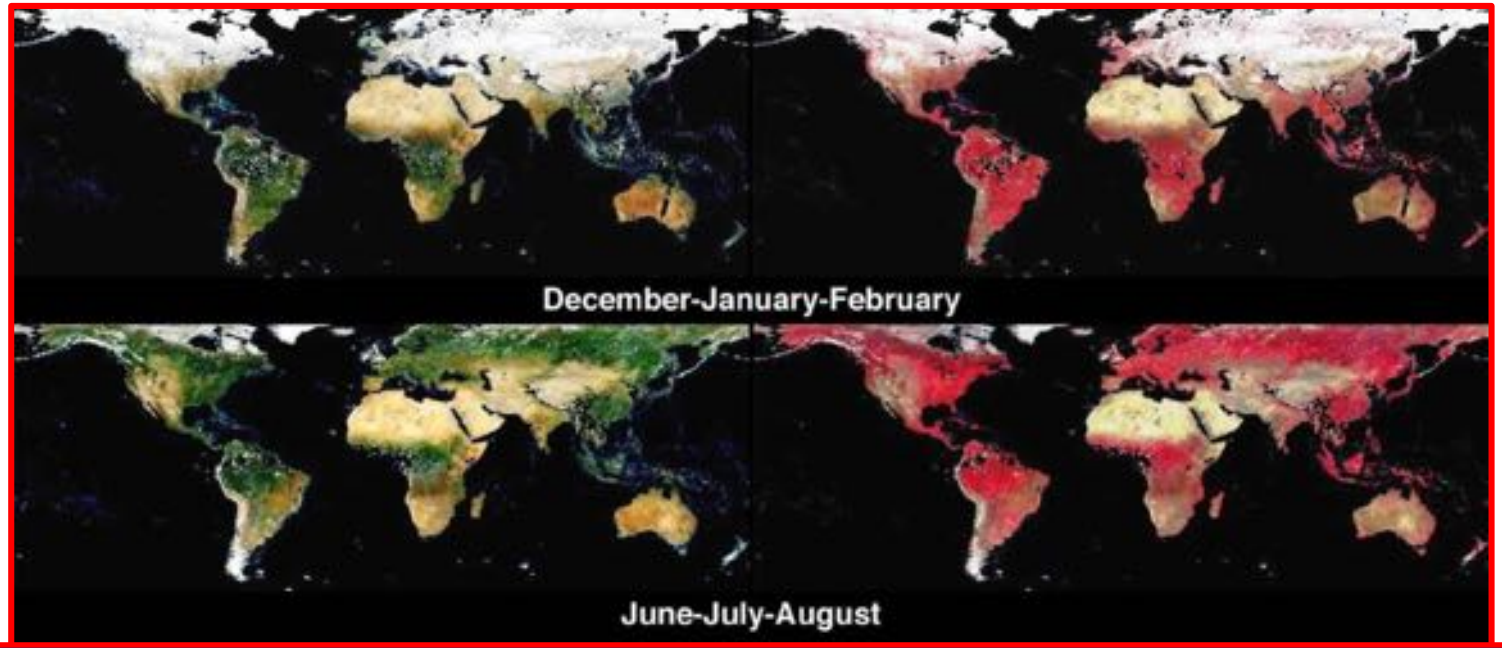
View of the ash plume from Iceland's Eyjafjallajokull volcano

Mission Background



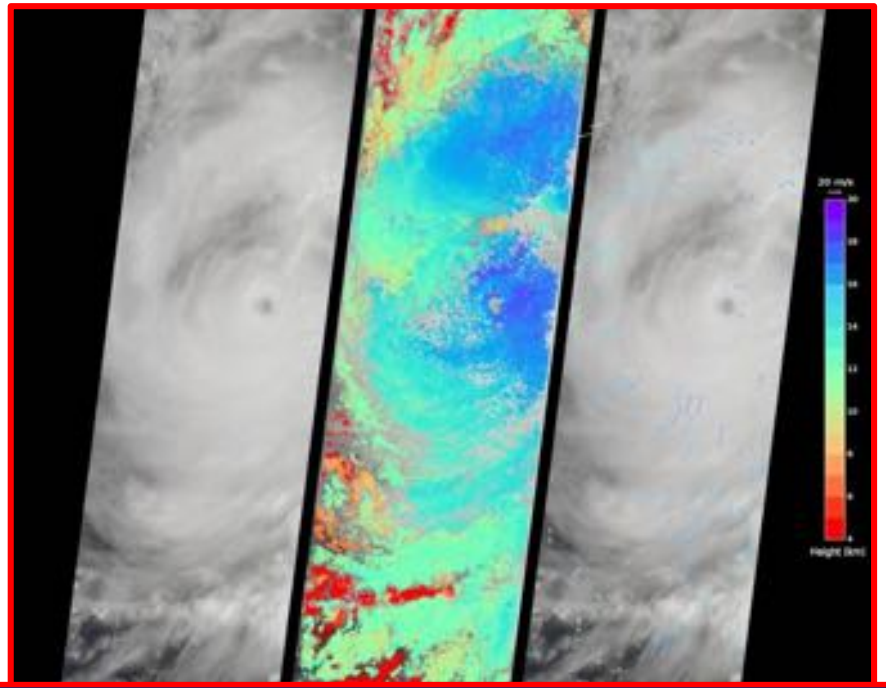
Severe Air Pollution in New Delhi

Mission Background



Global, seasonal summaries of Directional Hemispherical Reflectance (DHR), the "black-sky" albedo

Mission Background



Estimate of the amounts, types and heights of clouds

Link Budget

Features	Symbol	Data	Result
RF Output Power	P_t	3 dBW	
Antenna Gain	G_t	0 dBi	
Free Space Path Loss	L_p	175 dB	
Additional Loss	L_a	5 dB	
Receiver Antenna Figure of Merit	G/T	30 dBK^{-1}	
Boltzmann's Constant	k	-228.6 dBW/(Hz*K)	
Data Rate	R	70 Mbps	
E_b/N_0	E_b/N_0	-	11.6 dB
E_b/N_0 Required for BER= 10^{-5}	$E_b/N_{0\,min}$	4.4 dB	
Link Margin	-	$E_b/N_0 - E_b/N_{0\,min}$	**7.2 dB**

Solar Arrays and Required Power

Average Power	30W
Power peak	~ 41W

- **Zenith-pointing face**: 6U body-mounted solar panel (triple junction cells) equipped with a double deployable system;
- **CubeSat base**: 2U body-mounted recovery panels;
- **Nadir-pointing 6U face**: 2U body-mounted recovery panels