HEMERA – Constellation of passive SAR-based micro-satellites for a Master/Slave configuration

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SAPIENZA
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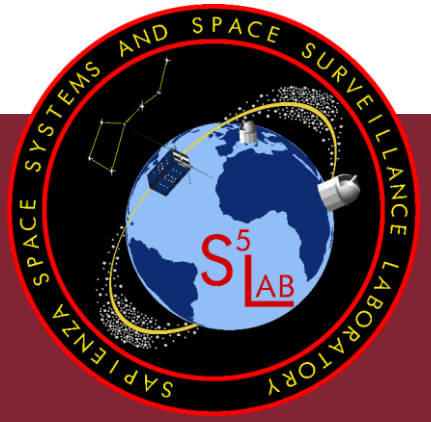

HEMERA Team

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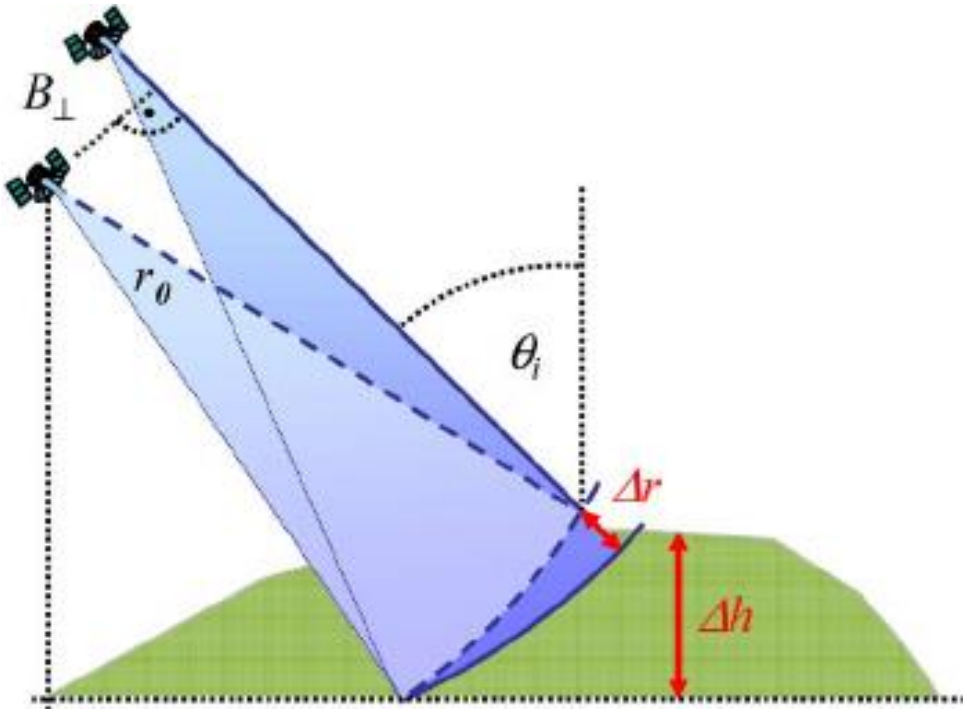
State of the Art

X-Band COSMO-SkyMed Constellation (2007-2010)

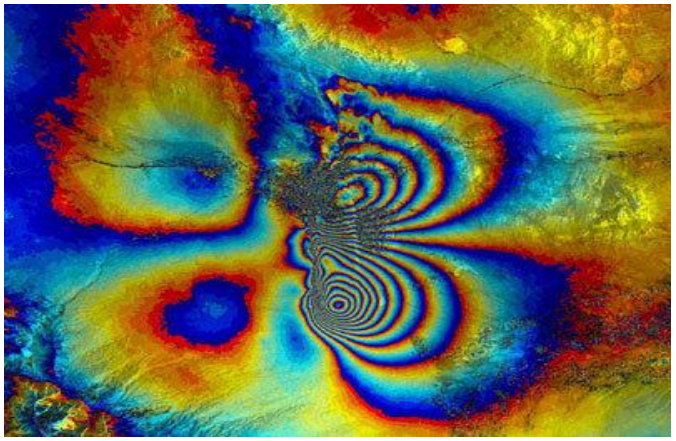
- The **SAR Technology** is currently used for different EO applications (InSAR, DinSAR, etc.) due to their **24/7 availability**
- **Several active SAR constellations are currently operating** in Low Earth Orbit (LEO) in **monostatic configuration** for EO purposes
- **Large Earth Observation (EO) satellites** are very expensive, massive and characterized by high volume and power consumption
- **Smaller platforms** offer the possibility to **fulfill similar mission objectives by reducing the cost and the weight** of the spacecraft without reducing the system reliability

State of the Art

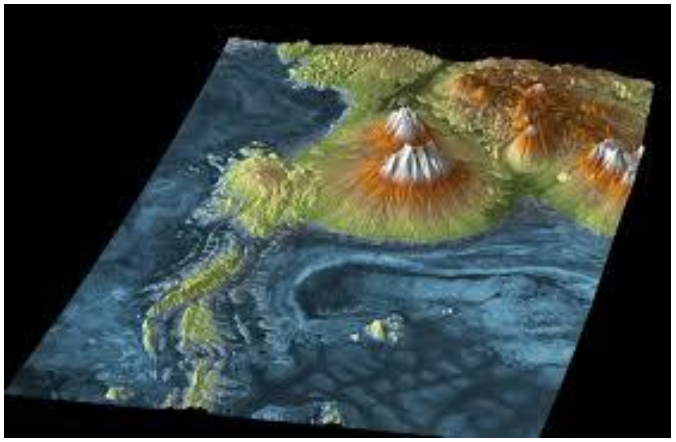


Across-Track Interferometry

Interferometry

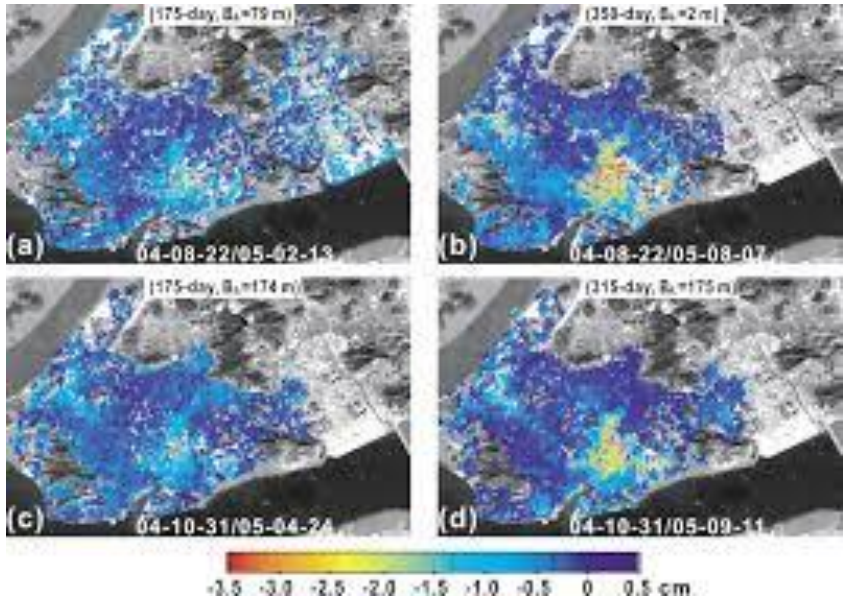


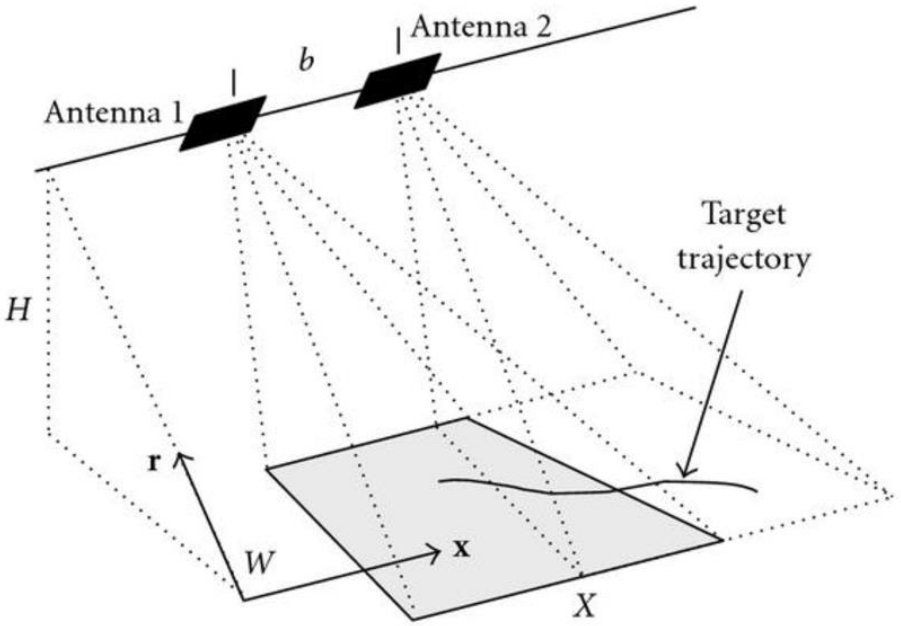
Digital Elevation Model (DEM)



State of the Art

Differential Interferometry





Along-Track Interferometry

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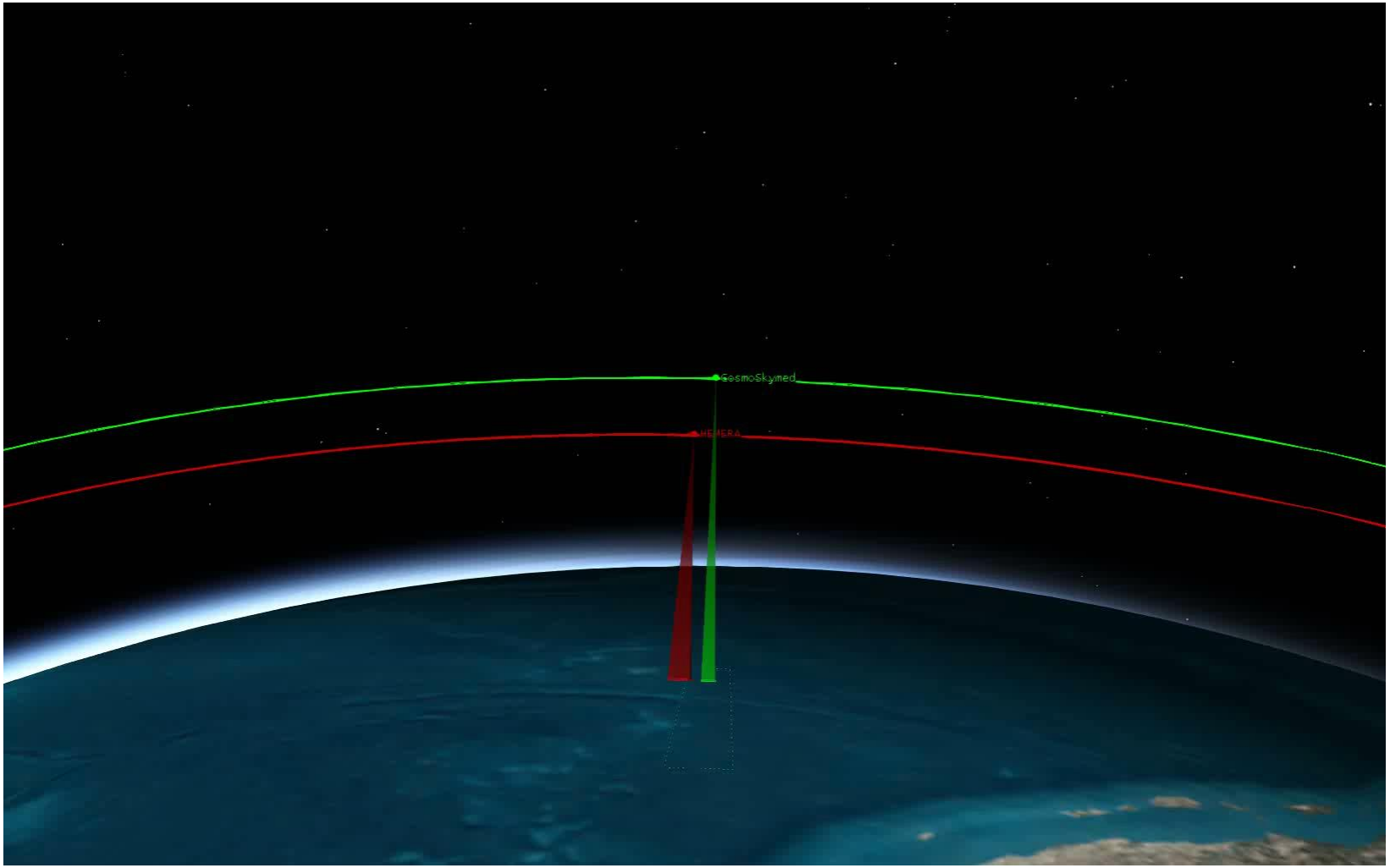
Mission Concept



Mission Concept

17 Sustainable Development Goals

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Mission Objectives

PRIMARY

- To **increase** the COSMO-SkyMed **Synthetic Aperture of 40%**
- To **guarantee at least 10 x 10 m of Ground Resolution** in Stripmap mode

SECONDARY

- Monitoring and mitigation of natural disasters
- Monitoring Structural failures
- Subsidence control
- Monitoring Earth plates movement

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Key Performance Parameters

Master/Slave synchronization	Slaves satellites activated on **scheduled time**
Resolution	**1.7 m x 0.5 m**
Interferometry	Increase the **quality** and the **number of perspectives**
Attitude control and system stability	**SAR antenna look angle of 39.8 deg** (±0.01 deg) **off-nadir**

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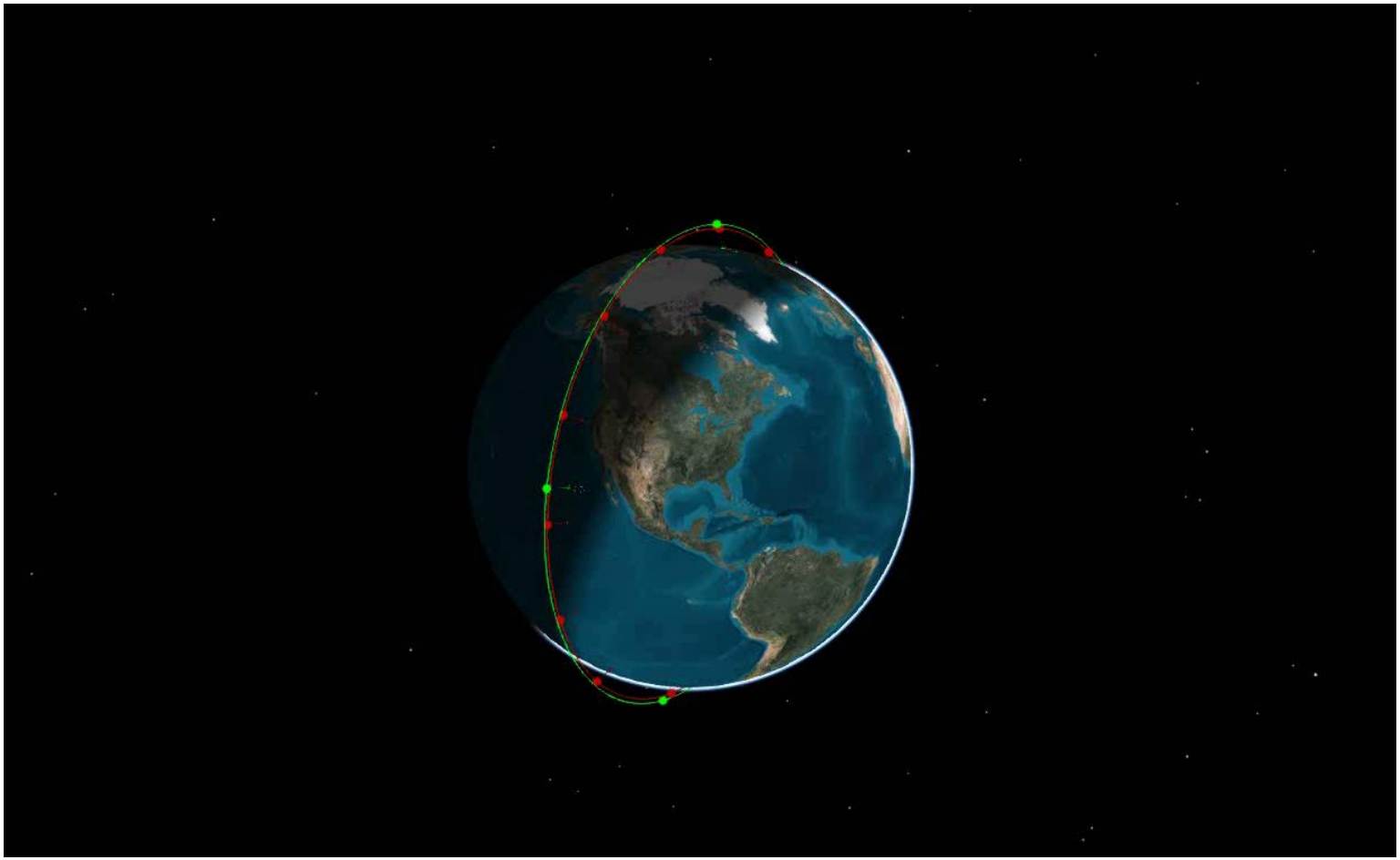
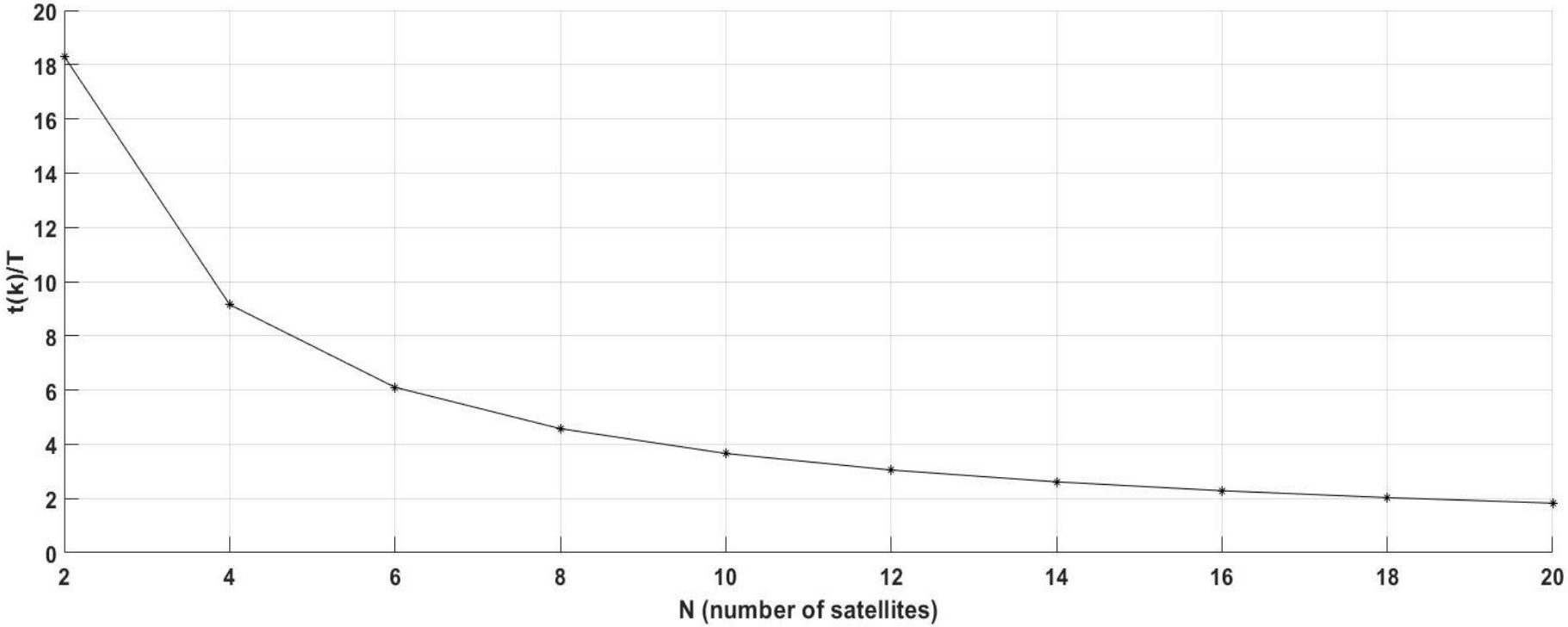
Space Segment



HEMERA is a 14 micro-satellites Constellation

Space Segment

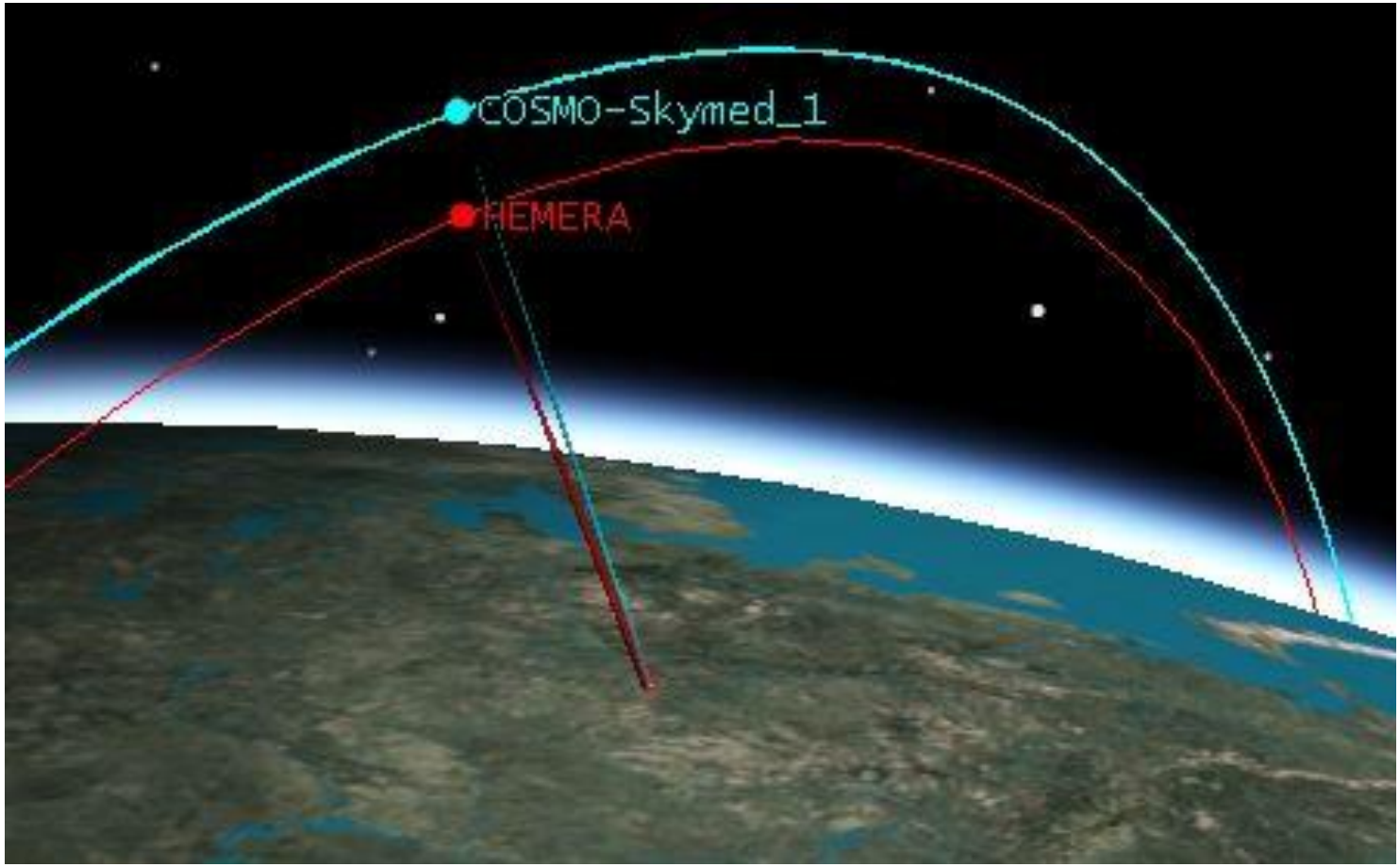


HEMERA is a 14 micro-satellites Constellation

Space Segment

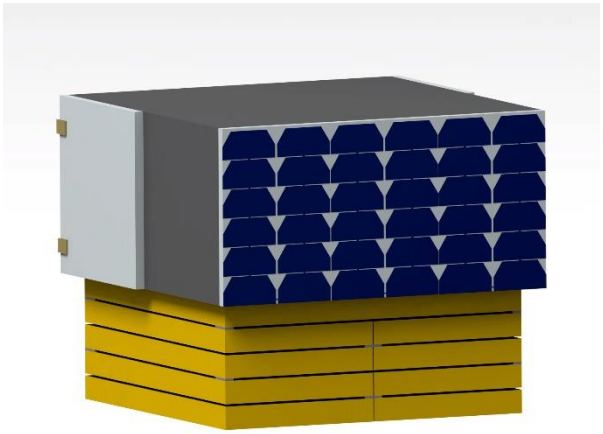
	Orbital Parameters
Inclination	97.86 deg
Semi-Major Axis	6873 km
Eccentricity	~ 0
RAAN	133 deg
Orbital Period	94.51 min
Revolutions per Day	15.19
Phasing (true anomaly)	25 deg

Space Segment

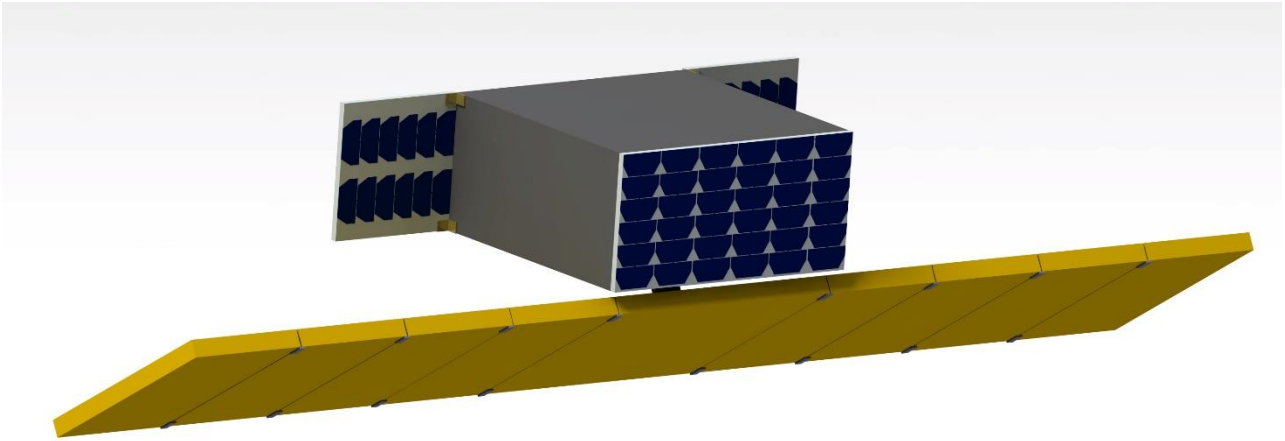


HEMERA Operative time per day of 26 minutes

Structural Design



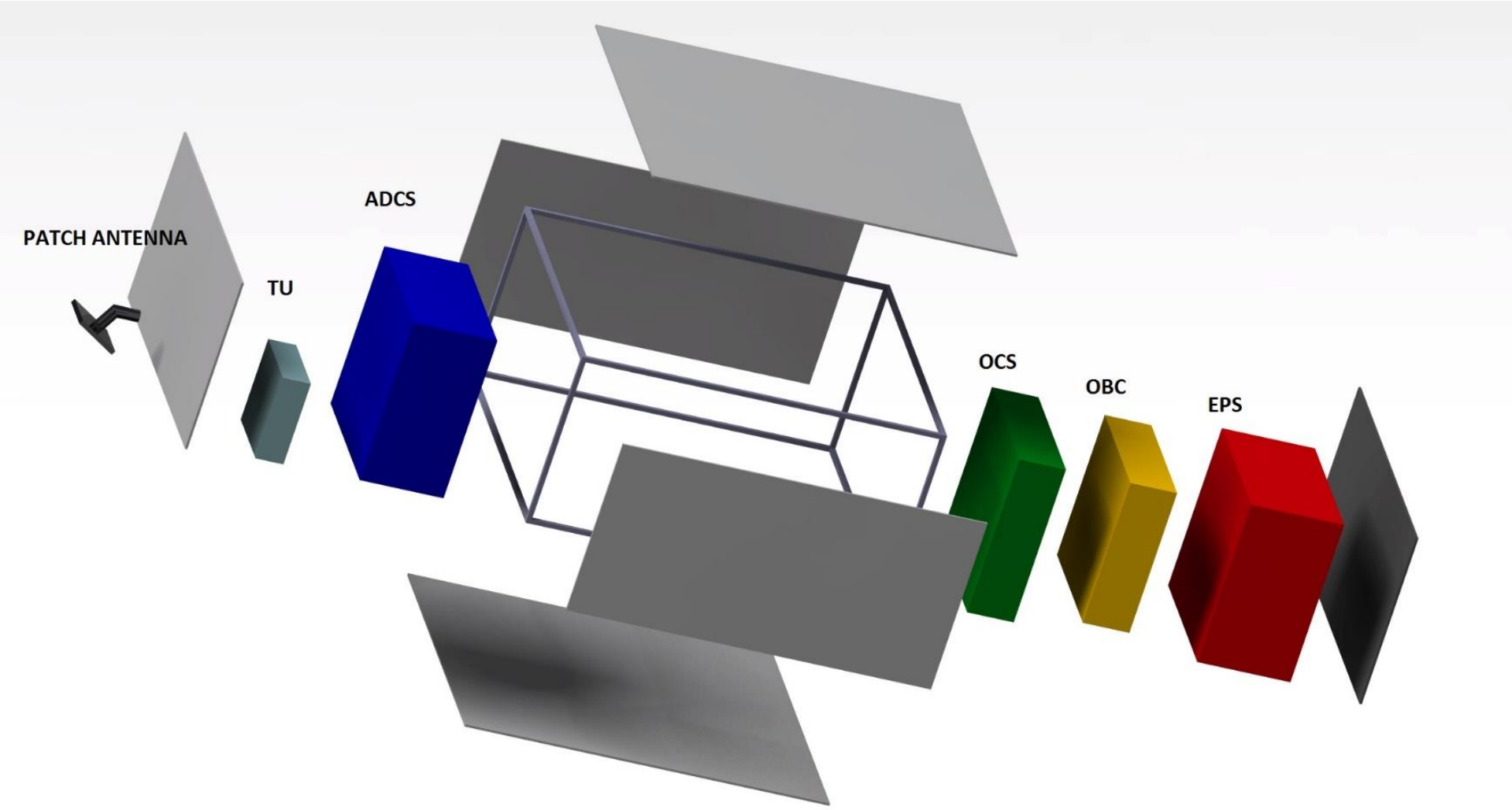
Folded configuration



Unfolded configuration

- **Material:** aluminum alloy 6061-T6 (**thickness of 4 mm**)
- **Volume** (without the antenna): 0.109 m^3
- **Volume** (with the antenna): 0.123 m^3

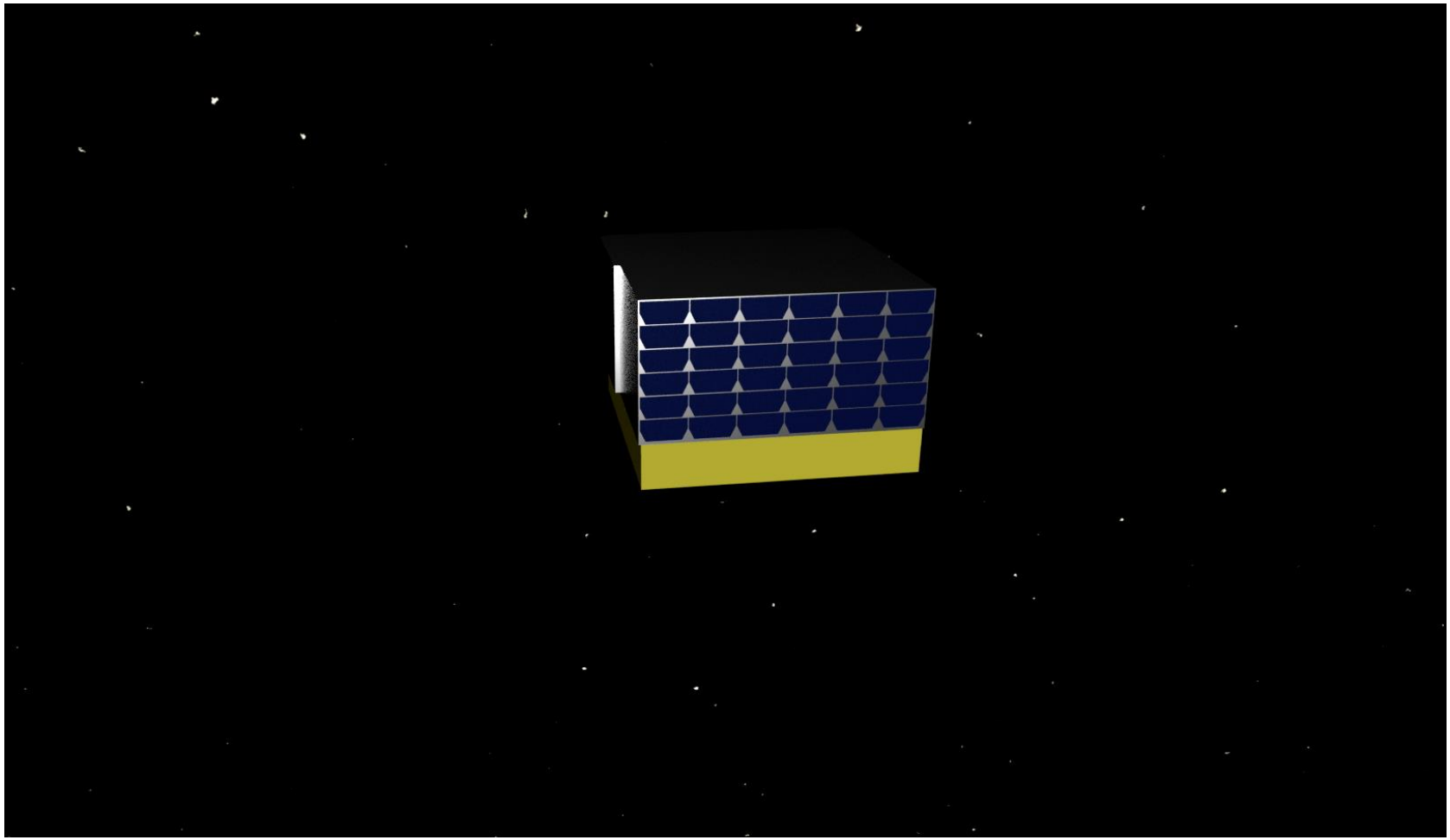
Exploded View



Mass Budget

Mass Budget	
Components	**Weight**
SAR antenna	11.6 kg
OBC	1.5 kg
On-Board Recorder	1.7 kg
ADCS	2.9 kg
Solar panels	5.2 kg
Batteries	1.08 kg
Structure	12 kg
Harness	0.4 kg
OCS	(3.8 kg)
Telecommunication unit	0.7 kg
Total (with a 5% of safety margin)	39.98 kg (43.97 kg)

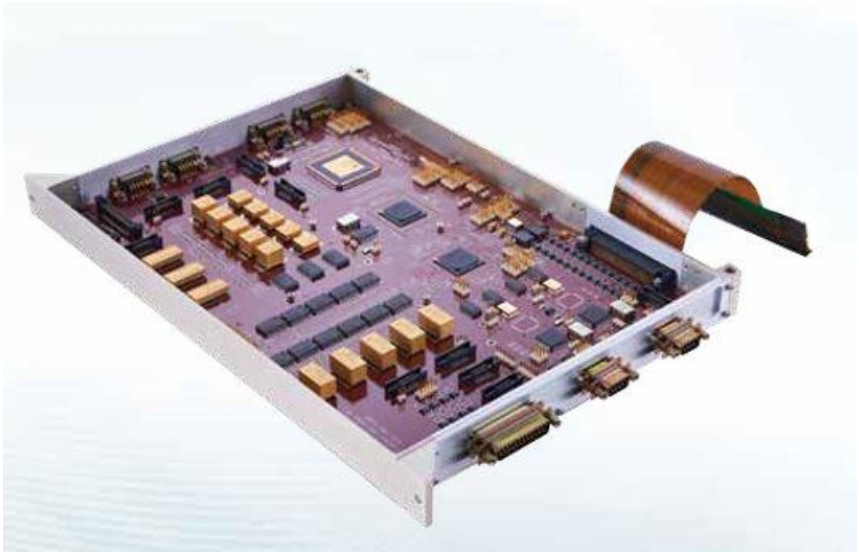
HEMERA in-orbit Configuration



Antenna main Features

Feature	Value
Carrier Frequency	9.65 GHz
Signal Bandwidth	300 MHz
Incidence Angle	21.8 deg to 60.8 deg
Azimuth Resolution	1.75 m
Variable Ground Range Rsolution	1.346 m to 0.553 m
Signal Noise Ratio (SNR)	1.4262 dB to 9.9754 dB
Radar Cross Section	20 dB
Antenna Gain	43.167 dB
Ground Swath Width	40 km
Synthetic Aperture	4.7 km
Dimensions	3.5 m x 0.7 m x 0.05 m
Mass	11.6 kg

On-Board Computer



On-Board Recorder:
Storage Capacity: 16 GBytes

On-Board Computer:
ERC32 processor chip

ADCS

Attitude Control Actuators for the 3-axis Stabilization

- **Three reaction wheels**:
  - Maximum Torque: ~10^{-5} Nm
  - Momentum: 0.4 Nms
- **Three magnetorquers for the desaturation**

Attitude Determination Sensors

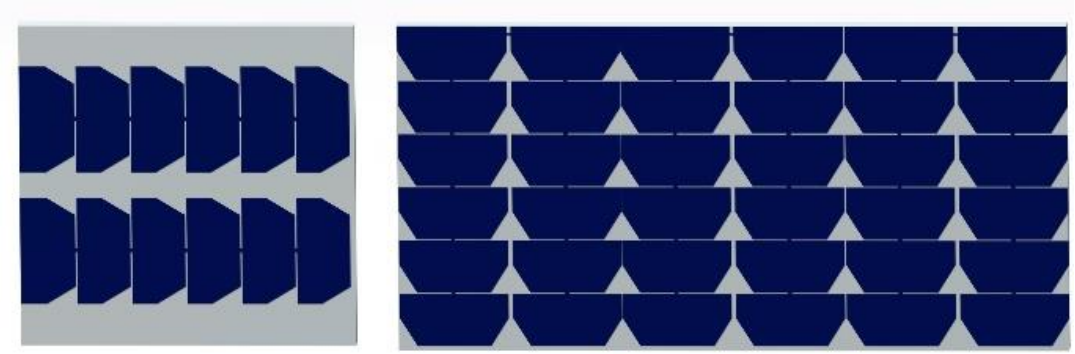
- One Star Tracker
- Four coarse Sun Sensors
- One fine Sun Sensor
- One Magnetometer

Energy Budget

Main Results:

- The performed analyses proved that each **HEMERA spacecraft** is characterized by the **higher power consumption during the operations of the on-board antenna** (Operative Mode)
- The **on-board Solar Arrays** have been sized by **referring to** the total power consumption during the **Operative Mode**

EPS



- **Number of cells: 60**
- **Power generated: 154.5 W**
- **Total mass: 5.2 kg**

- **Number of batteries: 8**
- **Bus Voltage: 28 V**
- **Total mass: 1.08 kg**

Telecommunication Unit

Main Features

- **S-band antenna:**
  - 2.025-2.11 GHz for uplink (2 kbit/s)
  - 2.2-2.3 GHz for downlink (8 kbit/s)
- **DPSK Modulation**
- **Prevention from phase disturbances but high Eb/N0**

Link Budget

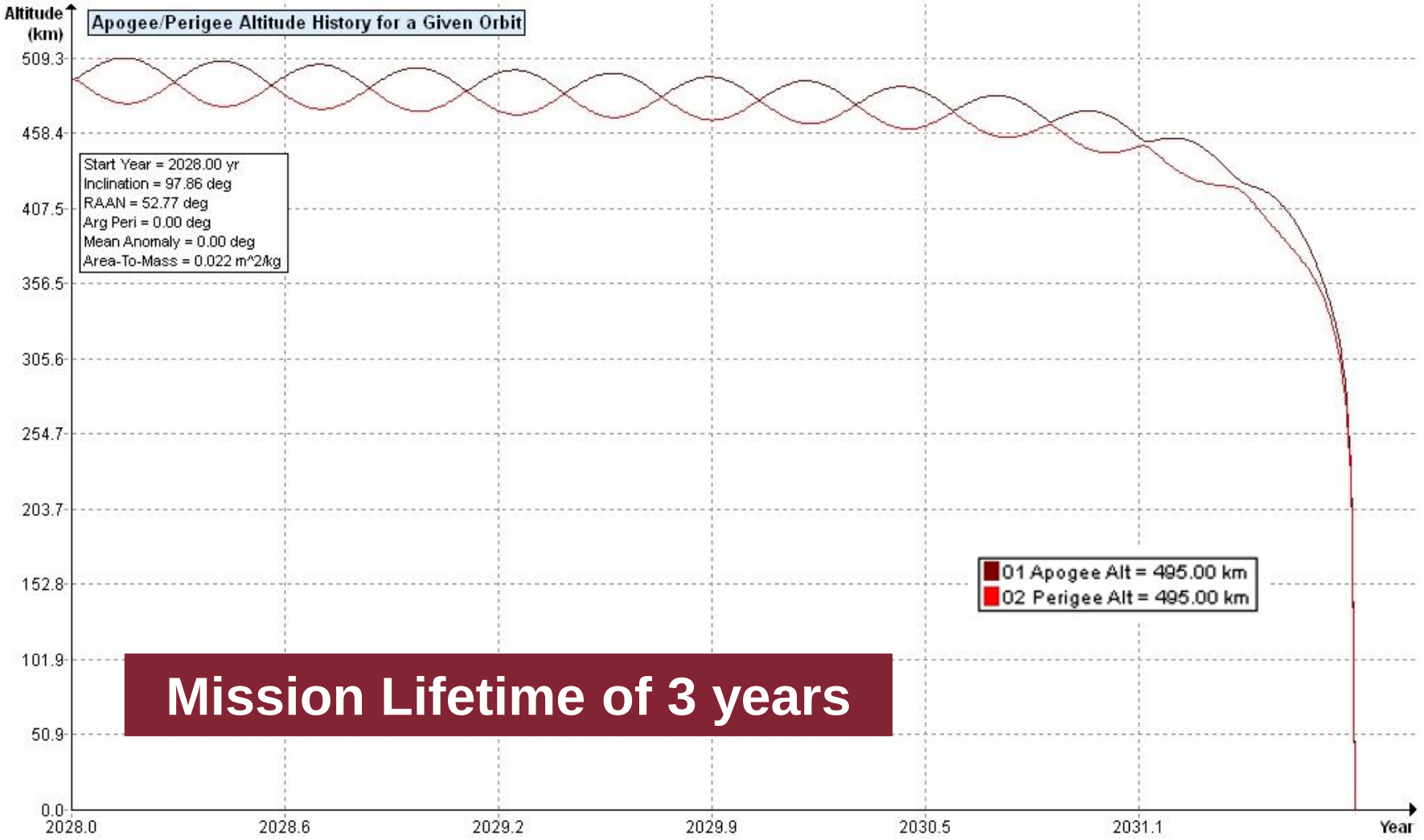
Parameters	Data, Telemetry and Tracking (downlink)	Command (uplink)
Frequency (S-band)	2.250 GHz	2.068 GHz
Transmitter Power	3.0 dB	3.0 dB
Transmit Antenna Gain	1.5 dB	20.4 dB
Receive Antenna Figure of Merit	18.8 dBK^{-1}	0.9 dBK^{-1}
Path Loss	164 dB	163.3 dB
Atmospheric Loss	2.5 dB	2.5 dB
Polarization Loss	0.2 dB	0.2 dB
Additional Loss	3 dB	3 dB
Data Rate	5 Mbps	0.1 Mbps
E_b/N_0	15.2 dB	33.9 dB
Required E_b/N_0	10.4 dB	12 dB
Margin	4.8 dB	21.9 dB

Thermal Control Subsystem

- The performed Thermal Analysis permits to estimate the **operative temperatures** in the **Worst Hot** and **Cold cases**:
    - Maximum temperature: **45 ºC** (@ Qint= 160 W)
    - Minumum temperature: **-10 ºC** (@ Qint = 95 W)

Passive TCS

Orbital Decay Analysis



Mission Lifetime of 3 years

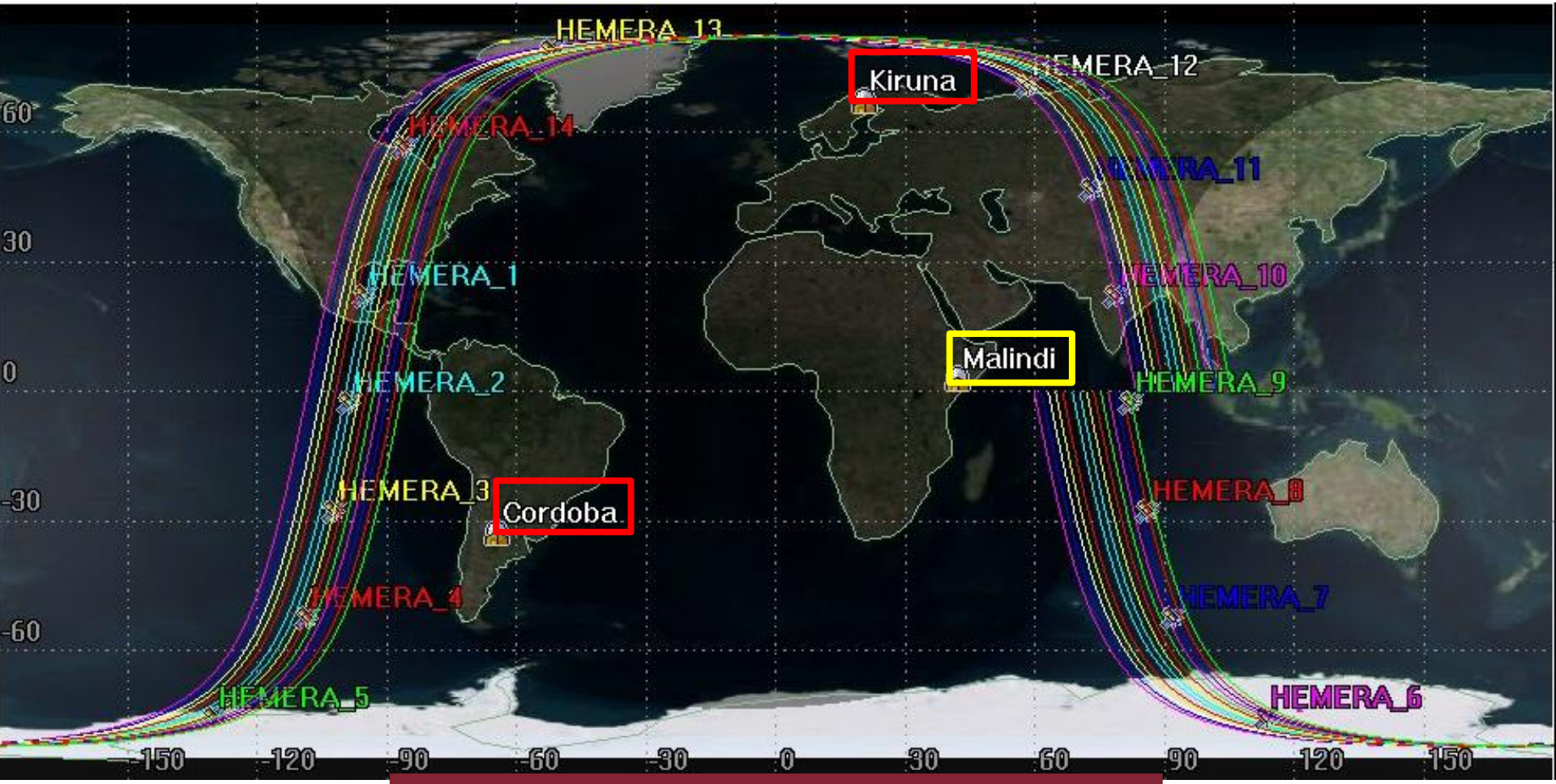
Orbit Control Subsystem

- **Specific Impulse**: 2200 s (Pulsed Plasma Thrusters)
- **Needed ΔV** = 42.8 m/s per year
- **Mission Extension**: three years
- **Propellant Mass**: 0.4 kg
- **OCS total Mass**: 3.8 kg

Height	475 km	455 km
Suitable Incidence Angle	22 deg to 62 deg	23 deg to 63 deg
Variable Ground Range	1.302 m to 0.549 m	1.258 m to 0.545 m
Work Time per Day	108.174 s	104.387 s

Variation of SAR antenna performances with the height

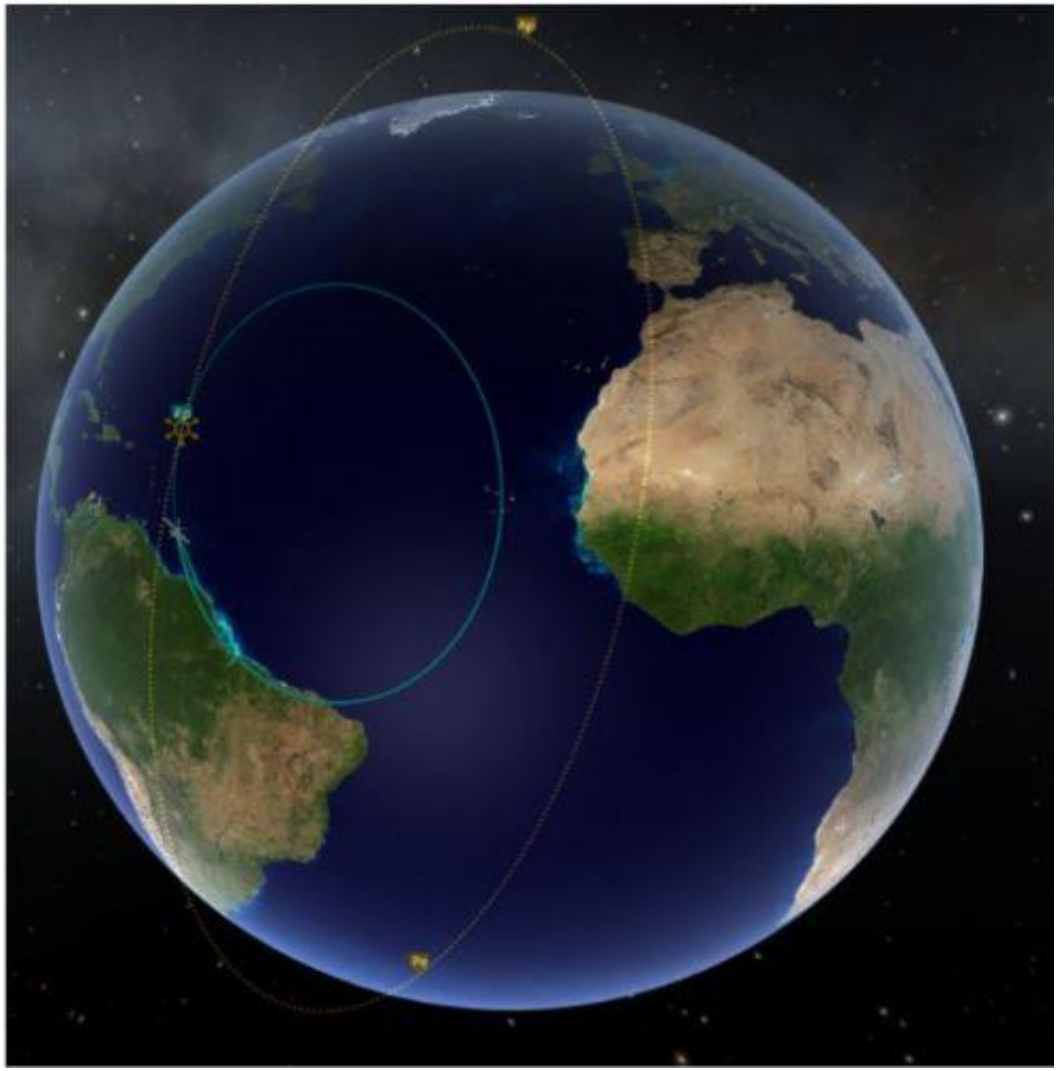
Ground Segment



Three main Ground Stations

User Segment

Launch Segment



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Risk Analysis

Risk
Lack in synchronization with the Master for data acquisition
Lack in acquisition of data about the same target if the proper attitude is not guaranteed
Memory saturation on-board the spacecraft
Failure in reaching the nominal orbit
Problems in achieving the required stability in the spacecraft pointing
Delay in components procurement

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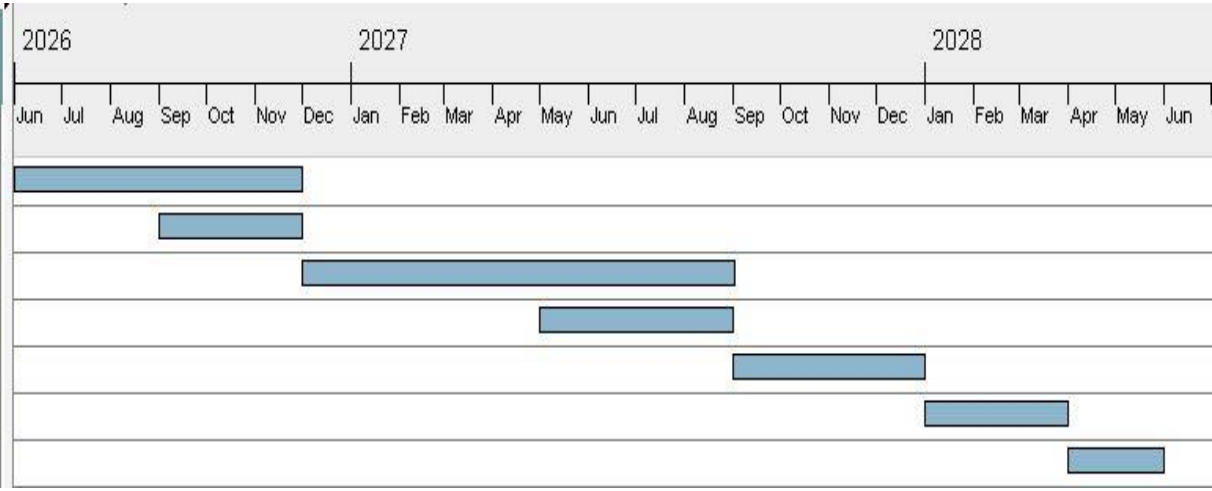
Implementation Plan

Name	Begin date	End date
HEMERA Mission Design Phase	01/06/26	30/11/26
Agreement Implementation Phase	01/09/26	30/11/26
SAR antenna development	01/12/26	01/09/27
Subsystems development	01/05/27	31/08/27
Assembly and Integration	01/09/27	31/12/27
Testing phase	01/01/28	31/03/28
Launcher Integration	01/04/28	31/05/28



$6.57M ($14k per kg)

Thank you for listening!

For further information, please contact:

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- **giulia.broggi.14@gmail.com**

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The 5th
Mission Idea Contest
Micro/Nano Satellites for Global Sustainable Development