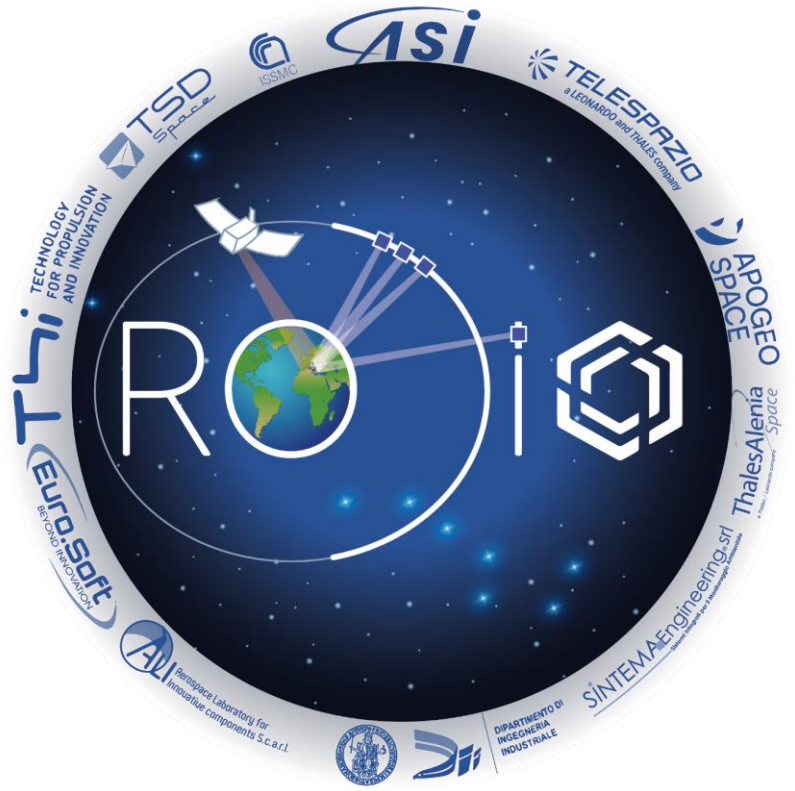
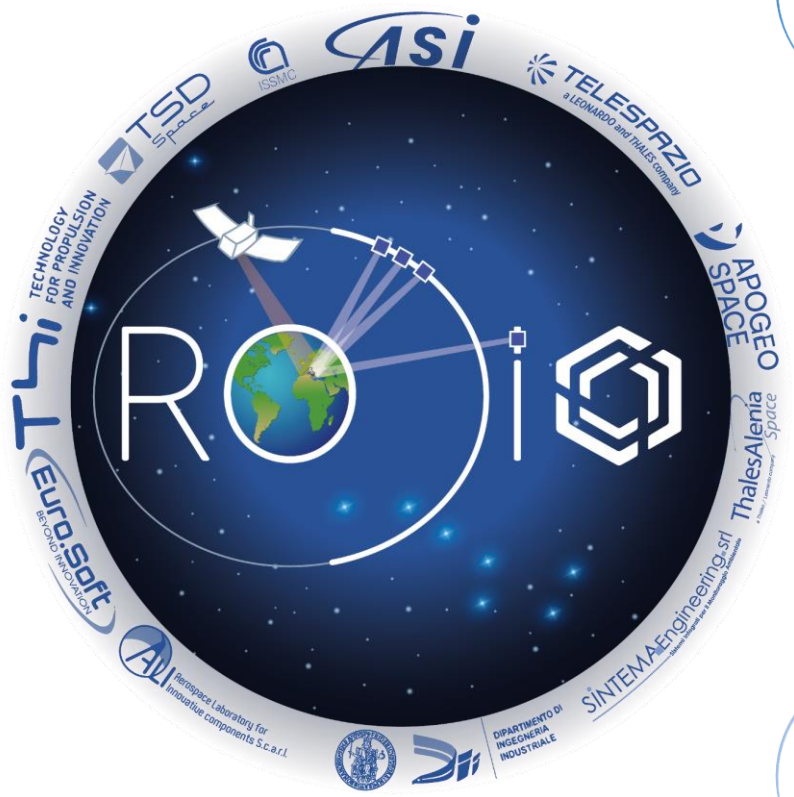


RODiO
Dimostrazione in orbita di un radar ad apertura sintetica distribuito su una formazione di cubesat

Maria Daniela Graziano
University of Naples Federico II

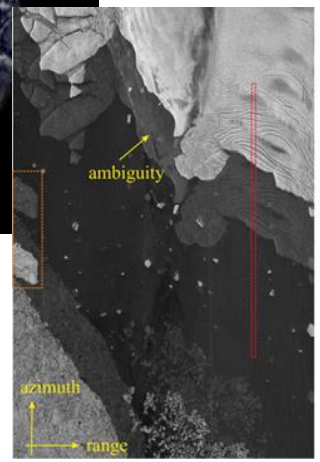
Outline

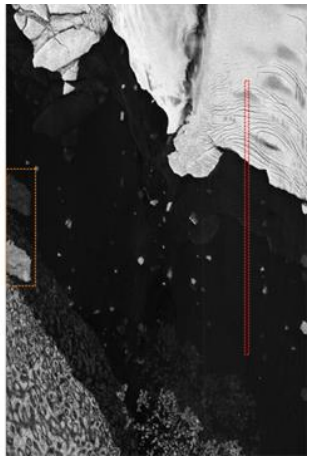


- Objectives
- Mission Analysis
- System and subsystems challenges
- RODiO in a nutshell

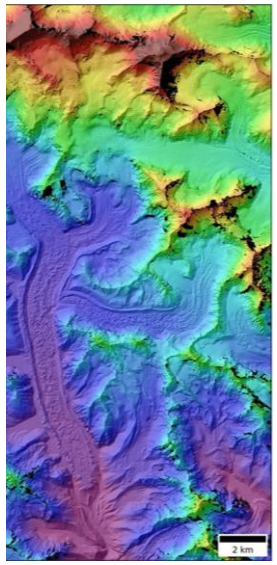
Objectives

In-orbit-demonstration of the concept of Distributed Synthetic Aperture Radar (DSAR) using PLT-1 as an illuminator of opportunity

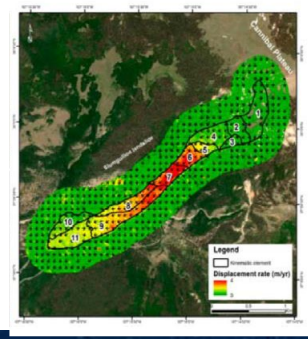


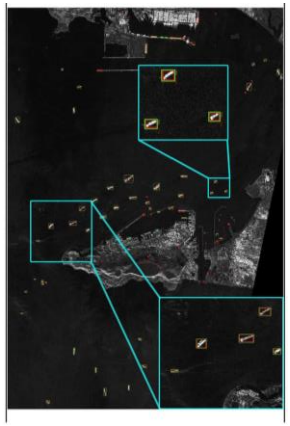


In-orbit-demonstration of a novel hybrid rocket propulsion system for long baseline formation reconfiguration



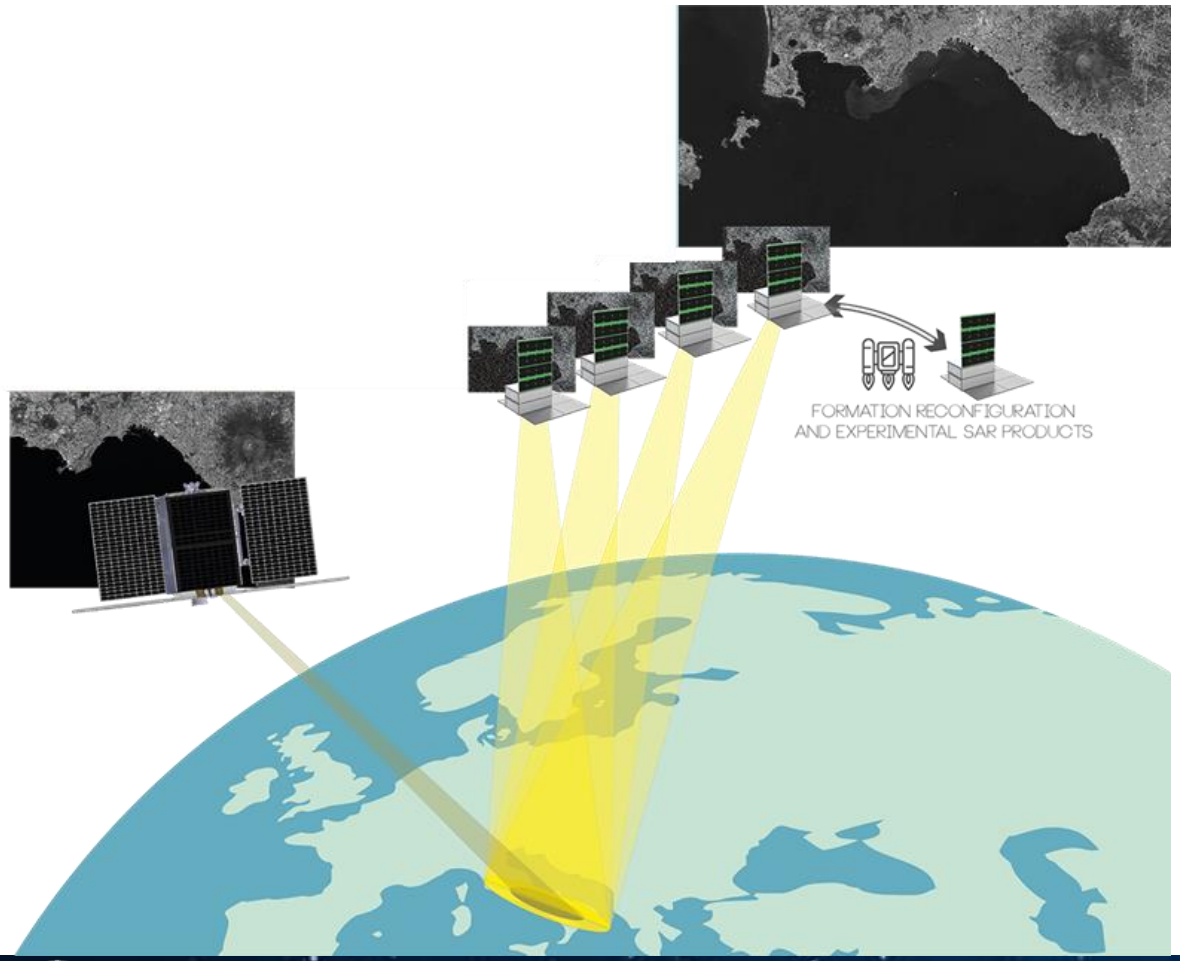
Demonstration of SAR products for scientific and commercial downstream





Mission Idea and Scenario

RODiO - Radar for earth Observation by synthetic aperture Distributed on a cluster of CubeSats equipped with high-technology micro-propellers for new Operative services



- RODiO is a cluster of 4 CubeSats **flying in formation among them and with PLT-1** at about 410 km altitude
- Each CubeSat embarks a **receiving-only X-band SAR** instrument able to collect bistatic echoes exploiting PLT-1 as an opportunity illuminator
- One CubeSat is provided with a flight demonstrator of an innovative **hybrid rocket propulsion** unit

Constraint:

PLT-1 is not cooperative

*RODiO mission **empowers** PLATiNO-1 (PLT-1) scopes and application fields*

Mission Idea and Scenario

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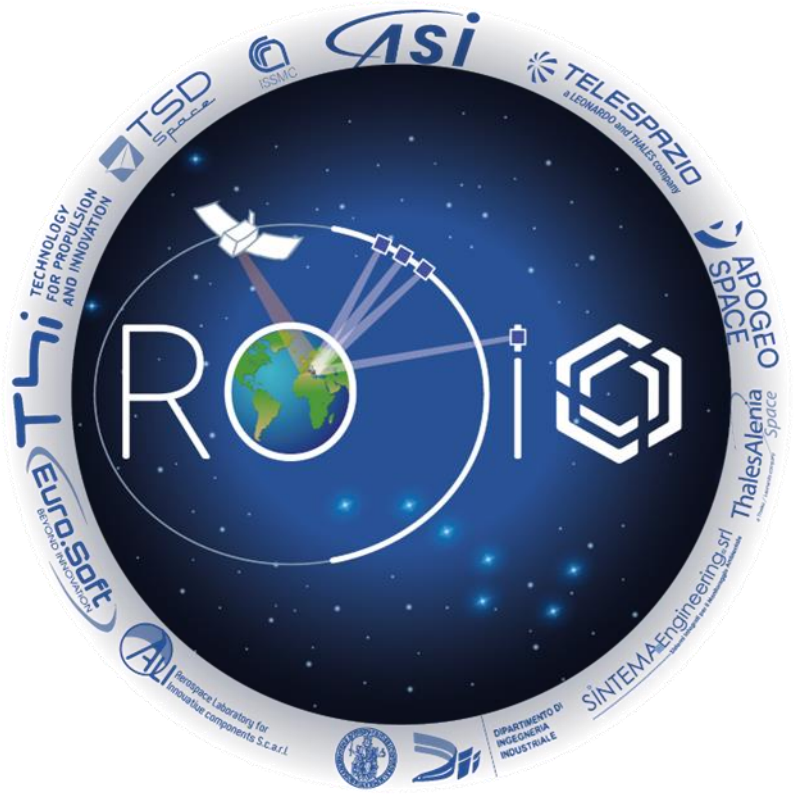

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People

Dipartimento di Ingegneria Industriale

Università degli Studi di Napoli Federico II

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

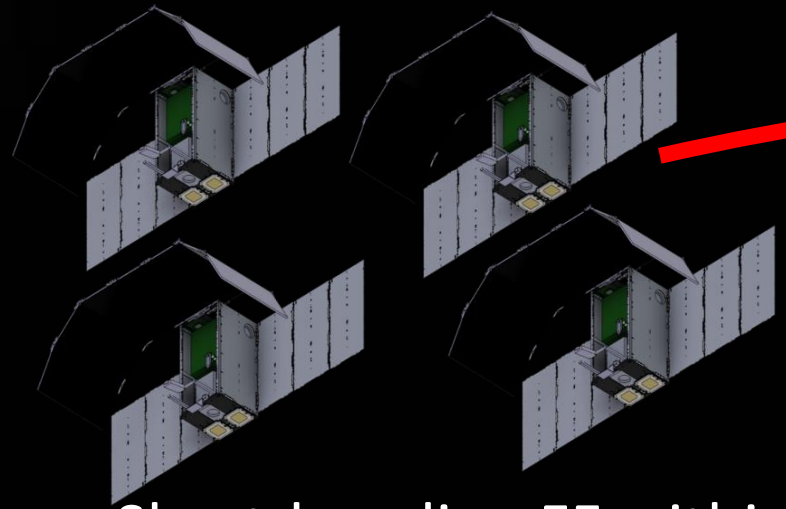
- Thales Alenia Space – Italia
- Apogeo Space
- Techno System Developments
- ALI
- Technology For Propulsion and Innovation
- CNR-ISSMC
- Sintema Engineering
- Euro.Soft
- Telespazio

Phase A: Concluded

Phase B: Approved

Mission Analysis

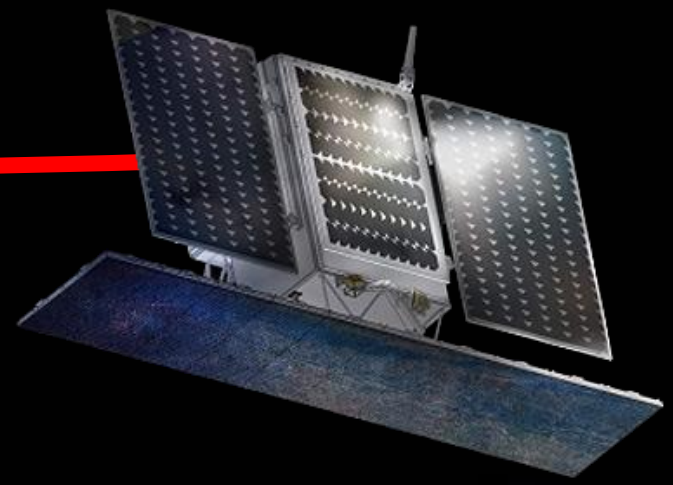
Cluster of receivers
(hundreds of meters)



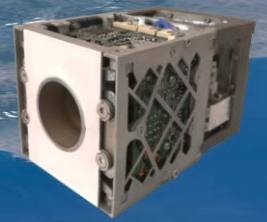
Short-baseline FF within
RODiO Cluster

Along-track baseline (tens of km)

Long-baseline keeping
with PLT-1



Formation Reconfiguration by
HPS in Phase #2

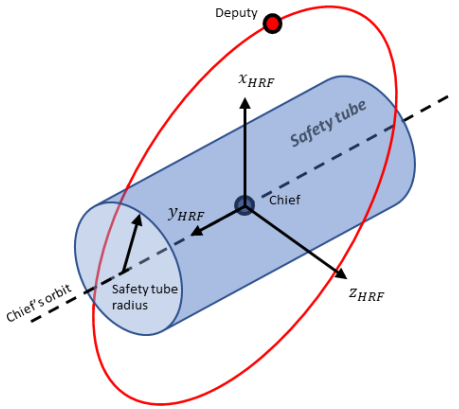


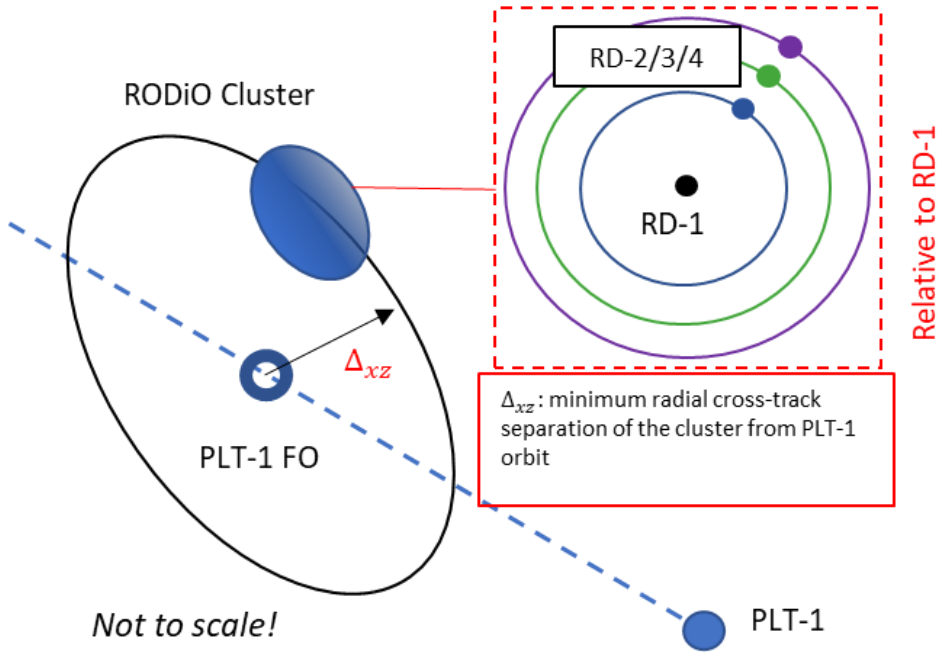
Constraints:

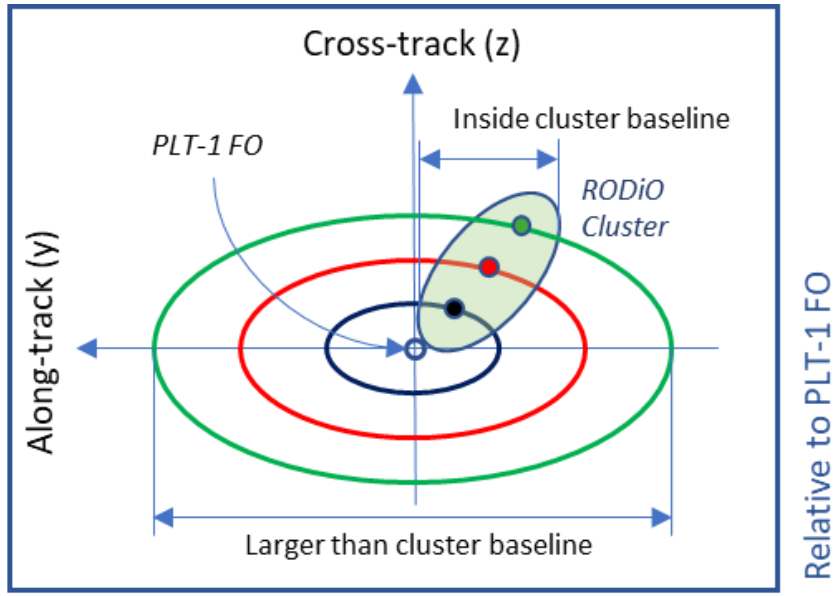
- PLT-1 is not cooperative
- REGULUS-50-I2 by T4i as the only propulsion system for short-baseline FF and long-baseline keeping

Short-baseline FF within RODiO Cluster

- PLT-1 safety as the main driver
- **Multiple safety levels**
  - RODiO ballistic coefficient larger than PLT-1 ➔ RODiO CubeSats must lead PLT-1
  - RODiO CubeSats are not just lead PLT-1, horizontal/vertical separations established
  - RODiO Cluster designed according to safe ellipse principle, i.e. safety tubes





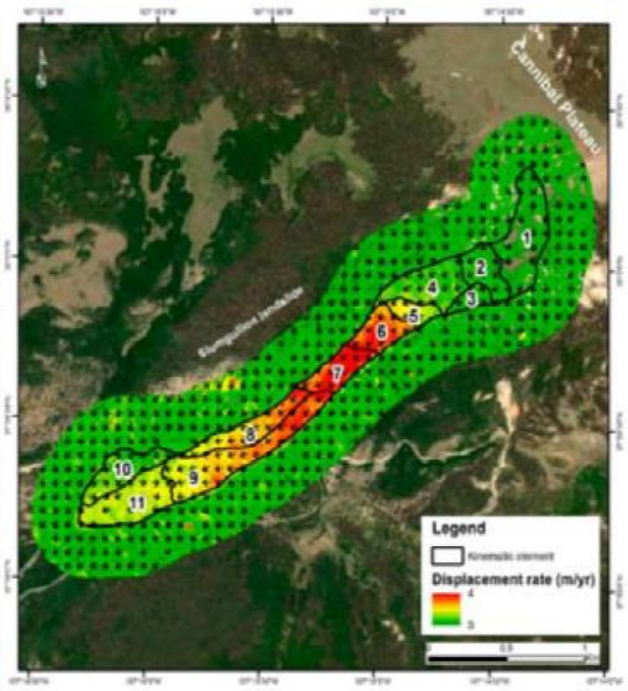


Long-baseline keeping with PLT-1

- *Demonstration of SAR products for scientific and commercial downstream*
  - RODiO CubeSats cover the same scene as PLT-1 but from a different perspective

An image couple, 1 from PLT-1 and 1 from the cluster (4 CubeSats) before and after the event

Product Name	RODiO Added Value
Infrastructure Monitoring	Greater detail in the evaluation of the magnitude of the events investigated
Land Deformation Map	Expanding the coverage of phenomena to be monitored
Flood Map	Improved flood mapping and risk assessment



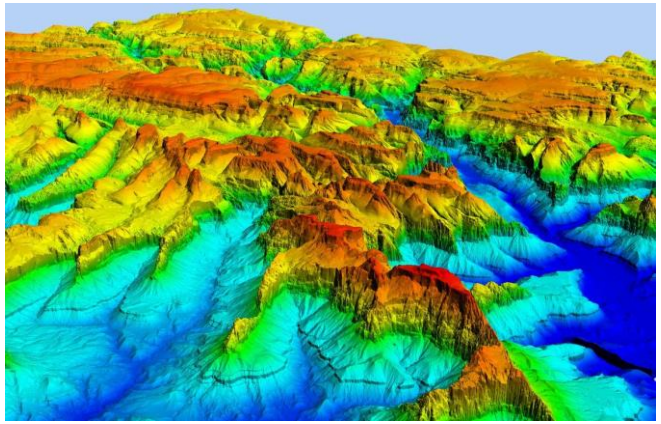
SINTEMA Engineering srl

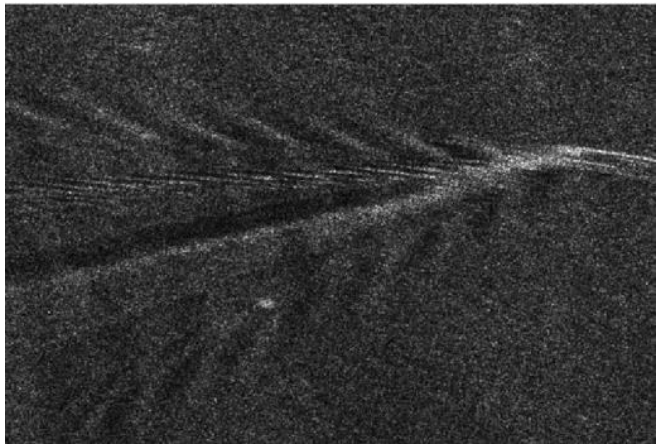
Long-baseline keeping with PLT-1

- *Demonstration of SAR products for scientific and commercial downstream*
  - RODiO CubeSats cover the same scene as PLT-1 but from a different perspective

Single-pass image couple, 1 from PLT-1 and 1 from the cluster (4 CubeSats)

Product Name	RODiO Added Value
Radargrammetric DEM	Accurate DEM generation with radargrammetric techniques without time lag between the two acquisitions
Ship detection	Discrimination of azimuth ambiguity
Wake Analysis	Different wake features are visible owing to the bistatic geometry.





Euro.Soft BEYOND INNOVATION

Formation Reconfiguration by HPS in Phase #2

High-thrust (up to 10N) propulsion system (HPS) using polymeric fuel and liquid oxidizer

Validation of a key enabling technology to provide miniaturized satellites with green, low-cost, low-complexity propulsion capability for in-orbit maneuvers

Average parameters

$\dot{m}_{ox}$	3 g/s	3.5 g/s	4 g/s
Isp [s]	288.1	289.8	291.3
Thrust [N]	10.2	11.9	13.6
O/F	5.01	5.19	5.35
P_c [bar]	10.6	12.4	14.2
D_p [mm]	24.3	23.8	23.6
$\dot{r}$ [mm/s]	0.27	0.31	0.35
$\dot{m}_{fuel}$[g/s]	0.61	0.68	0.76
G_{ox} [kg/m^2 s]	8.57	10.26	11.98

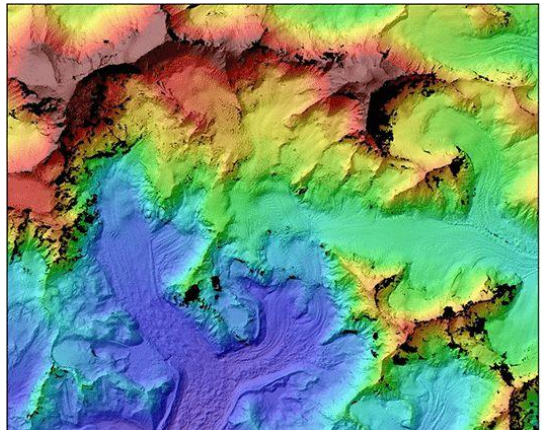
Novel multistatic SAR data collections enabled, e.g a **triplet of acquisitions** over the same area at three different observation angles.

Formation Reconfiguration by HPS in Phase #2

- *Demonstration of SAR products for scientific and commercial downstream*
  - RODiO CubeSats cover the same scene as PLT-1 but from a different perspective

Single-pass image triplet, 1 from PLT-1 and 1 from the cluster (3 CubeSats) and from the escaped CubeSat

Product Name	RODiO Added Value
Multi-baseline Radargrammetric DEM	Accurate DEM generation exploiting three different lines of sight and radargrammetric techniques.
Multi-baseline Ship Velocity Map	Velocity measurement based on radargrammetric and stereo SAR techniques

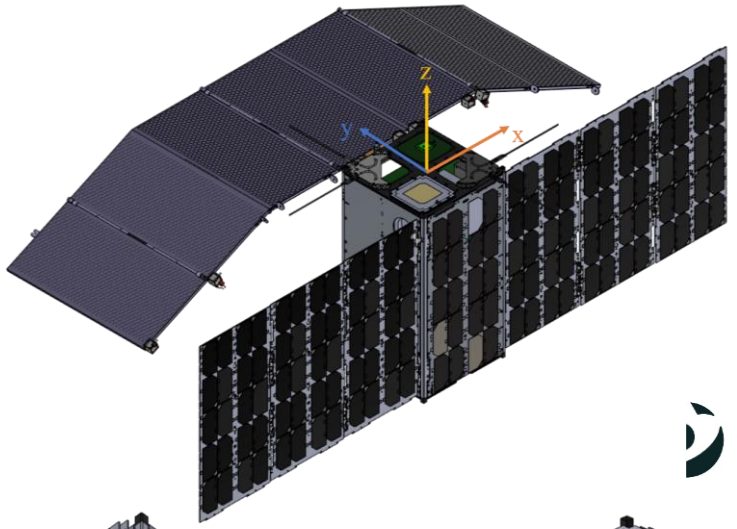


High complexity at system and subsystem level

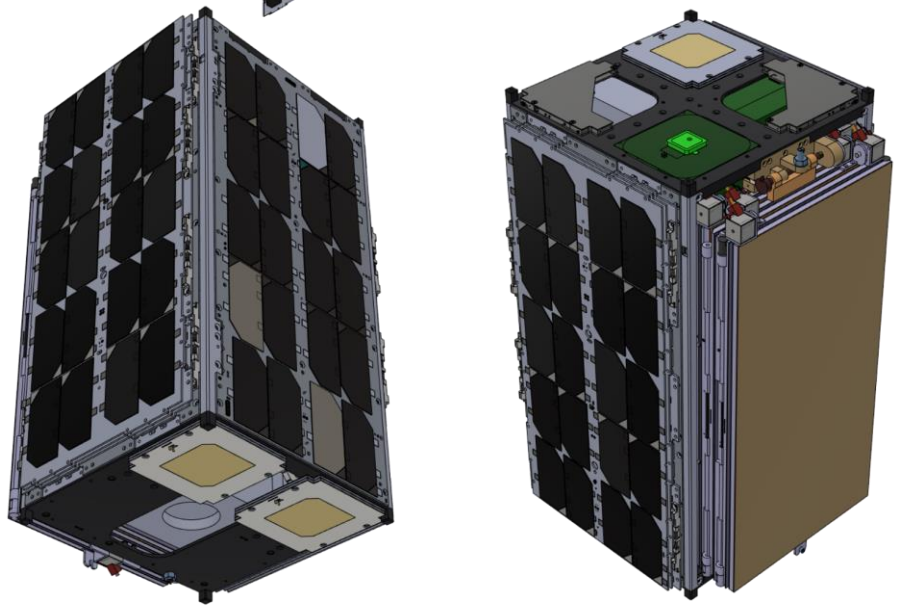
- The satellites share the same 16U platform and components
  - HPS replaced with dummy mass or additional battery pack (TBC) on 3 out of 4 sats, ensuring the preservation of both the inertia matrix and the ballistic coefficient.

- Multi-criteria trade-off analysis carried out
  - mechanism complexity, mechanical interferences among appendages, interaction of the solar panels with the SAR FoV, ballistic coefficient, interaction among thrusters' plume and satellite appendages, thrusters' misalignment with the P/F CoM

- Mass and geometry compliant with Cubesat deployer
  - About 35 kg margined wet mass
  - maximum protrusion from the rails smaller than 39 mm

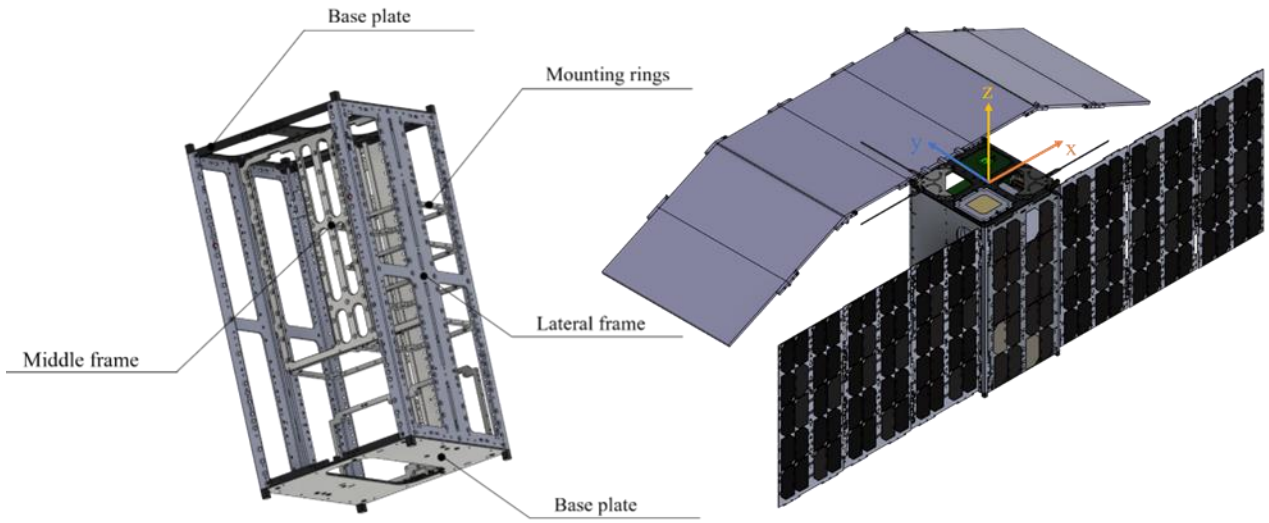


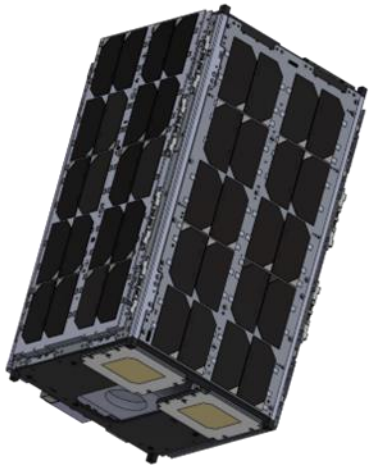
APOGEO SPACE

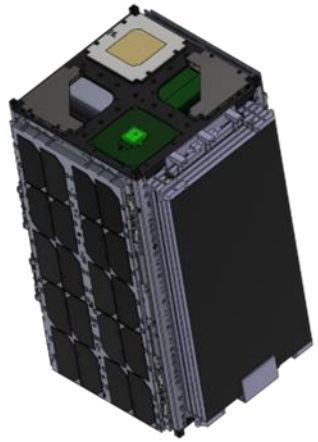


High complexity at system and subsystem level

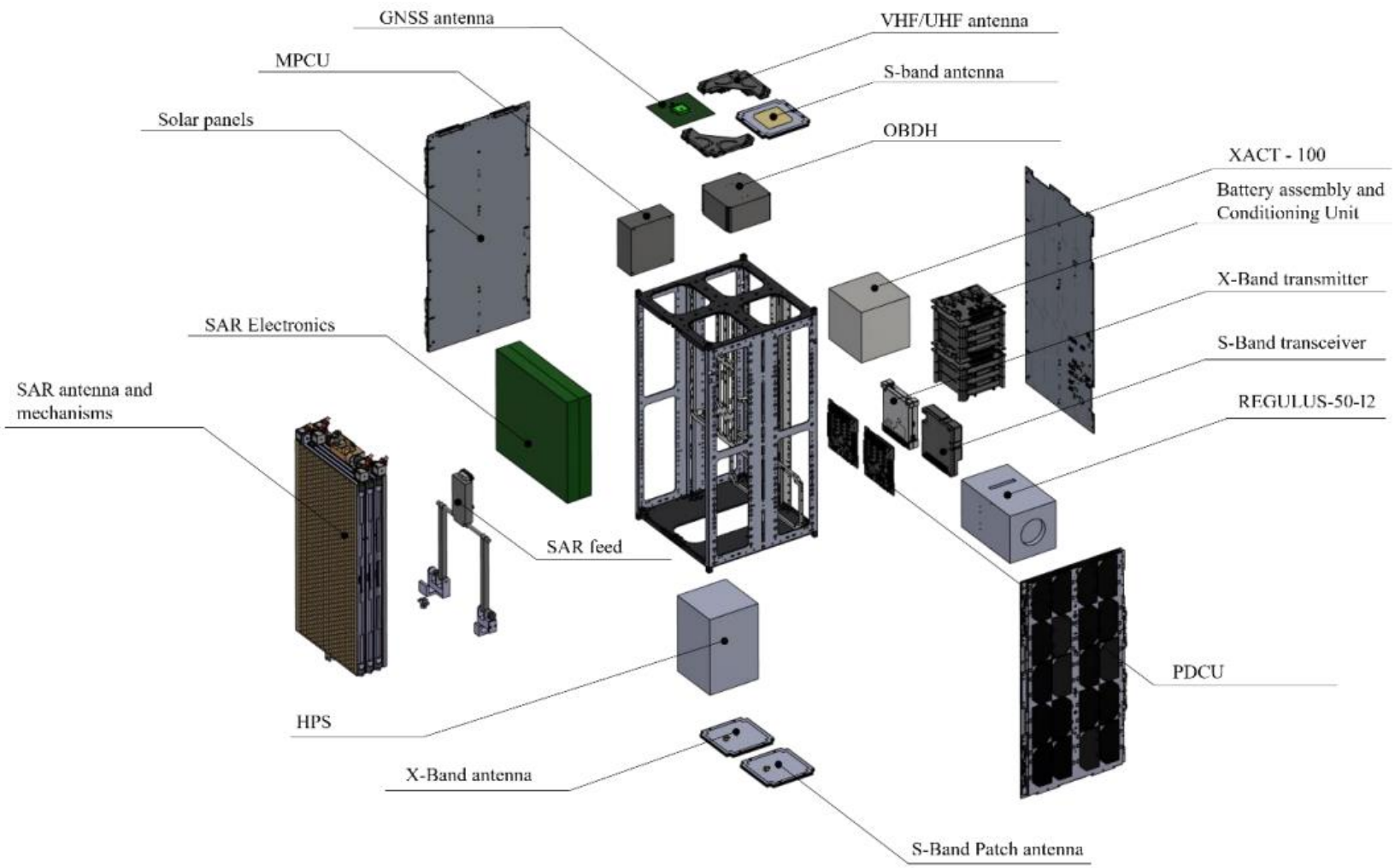
- The thrusters are accommodated orthogonally with respect to each other (alignment trust direction vs Center of mass)
- Miniaturized payloads (SAR reflect array technology and 1.5U Hybrid Propulsion systems)
- Electric Propulsion as the only system for short-baseline FF and long-baseline keeping
- Intersatellite link guaranteed
- Ground Segment design to meet data volume requirements

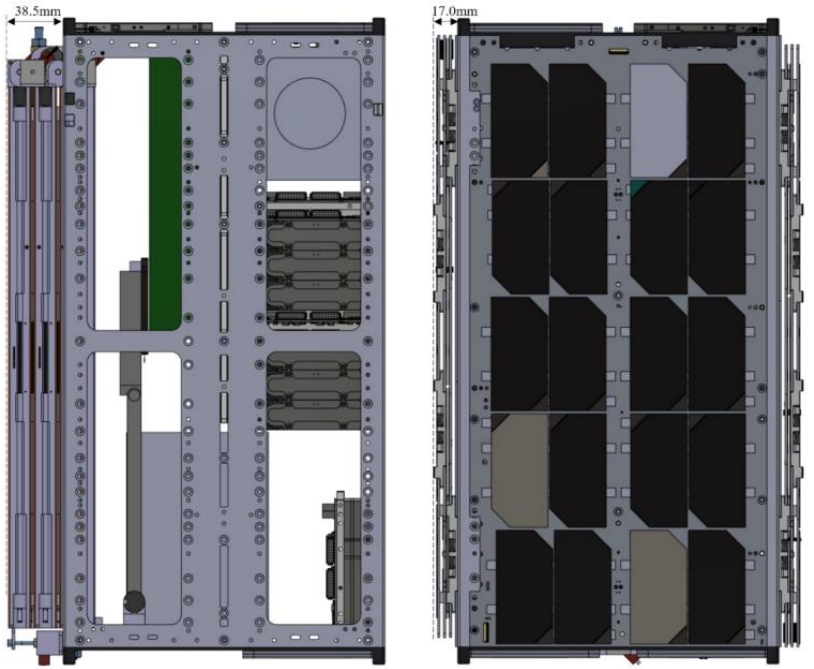






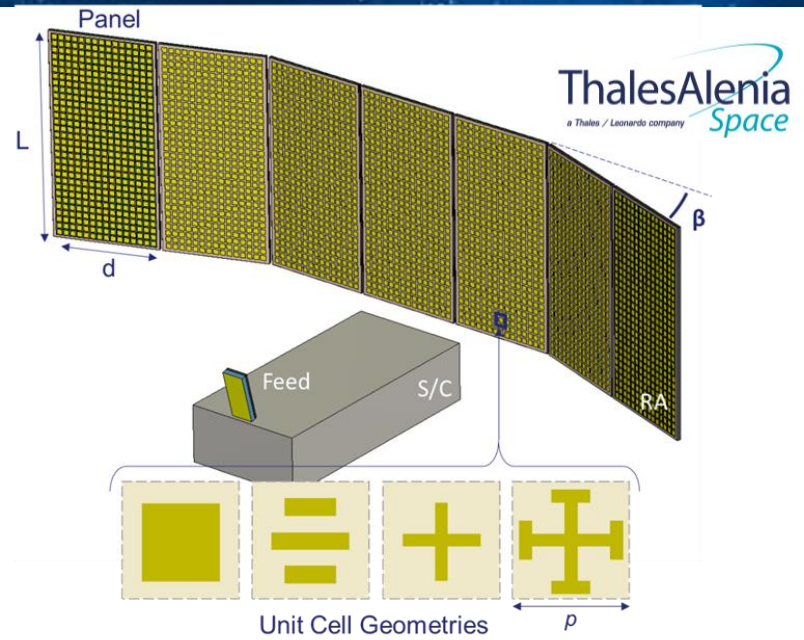
High complexity at system and subsystem level

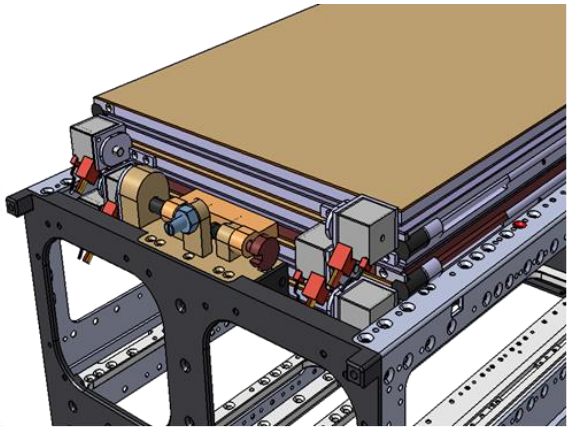




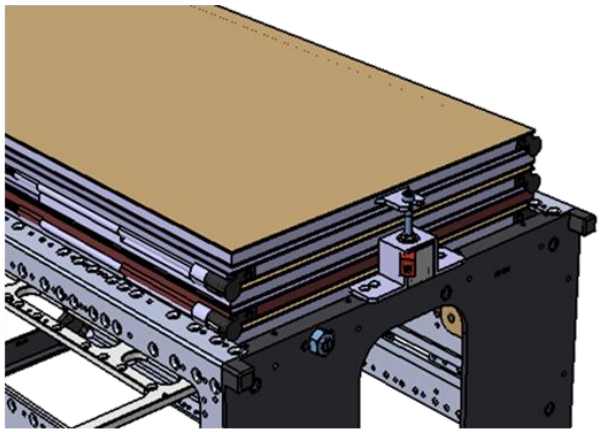
SAR Payload

- **Reflect-array Antenna** with deployable reflecting panels in planar PCB technology and feed element in slotted waveguide
  - 7 panels with dimensions of 0.38 m x 0.19 m each
  - **Less than 3.2 kg**
- The pack of 7 panels is attached to the satellite structure through the **main hinge**, fixed at the central panel.
- The **feed assembly** is mounted on a two-leg support, to not interfere with the propulsion subsystem
- The **rotations** and proper **deployment** are ensured by several features integrated into each subsystem: HDRM upon command, torsion springs, rotary damper, adjustable end-stop.

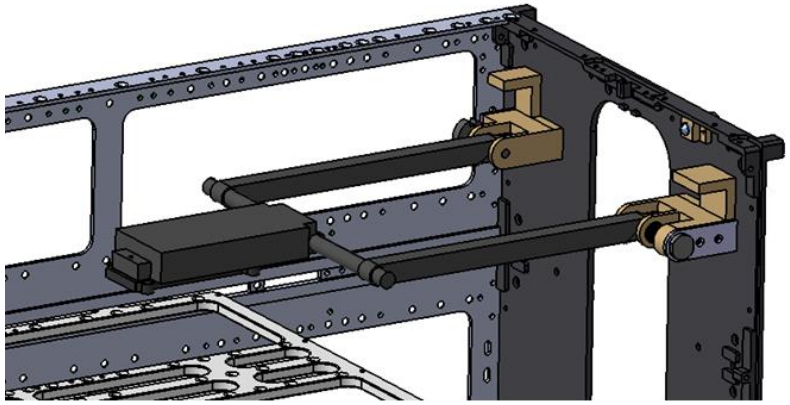




View of the main hinge



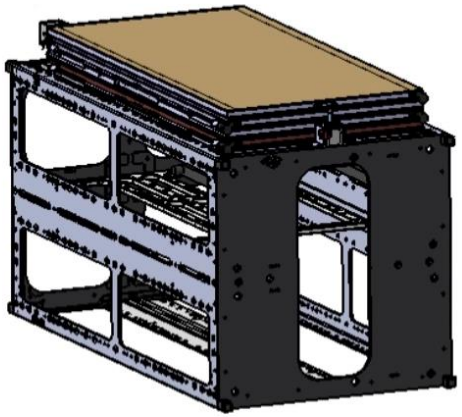
View of the HDRM position



View of the feed assembly

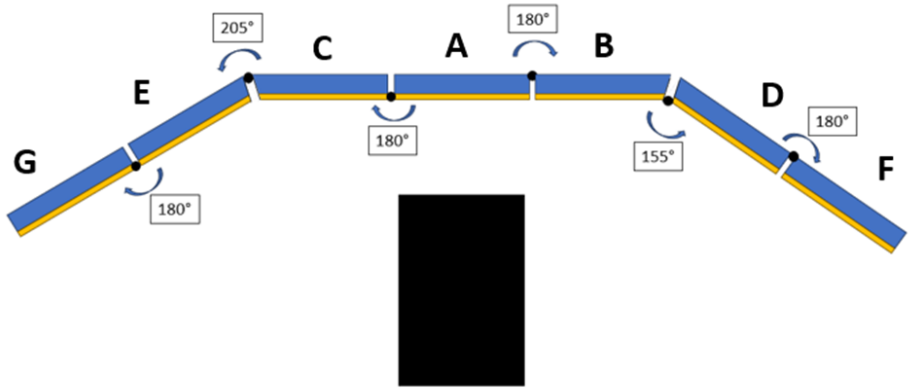
SAR Payload

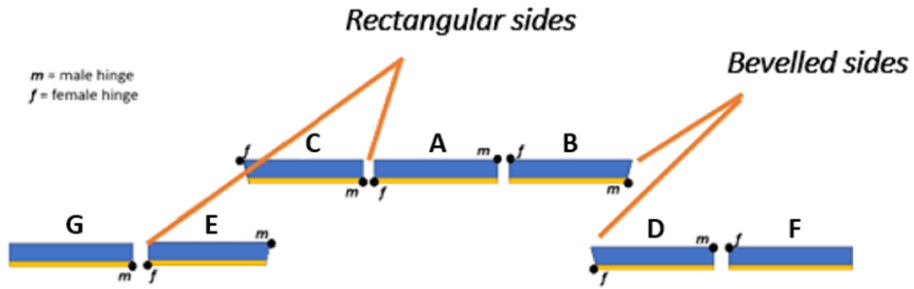
- *hinge of the panels integrated into the panel frame*



- *panels frame shaped to reach the specified angle upon deployment*

Deployment Sequence





- *a pre-defined sequence can be commanded with any decided time and can be monitored by a binary telemetry signal from each single Nano Pin Puller (nD3PP)*

HPS Payload

The main subsystems are:

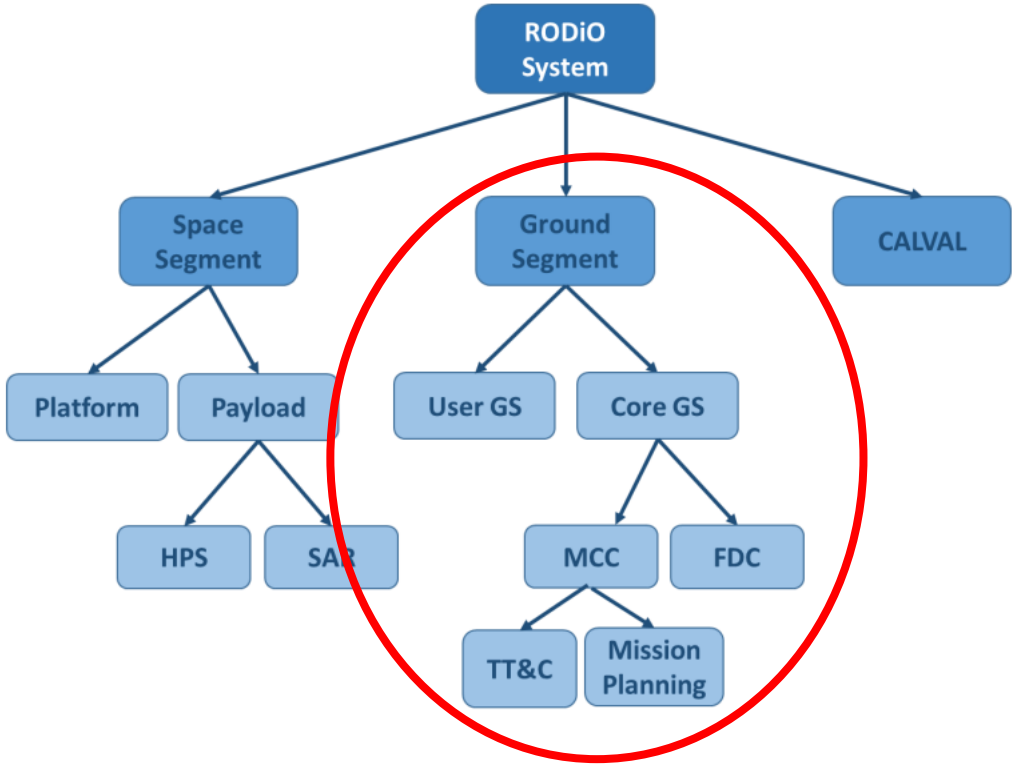
- Thruster (Combustion chamber + nozzle)
- Catalytic bed
- HTP tank
- N2 tank
- Fluidics

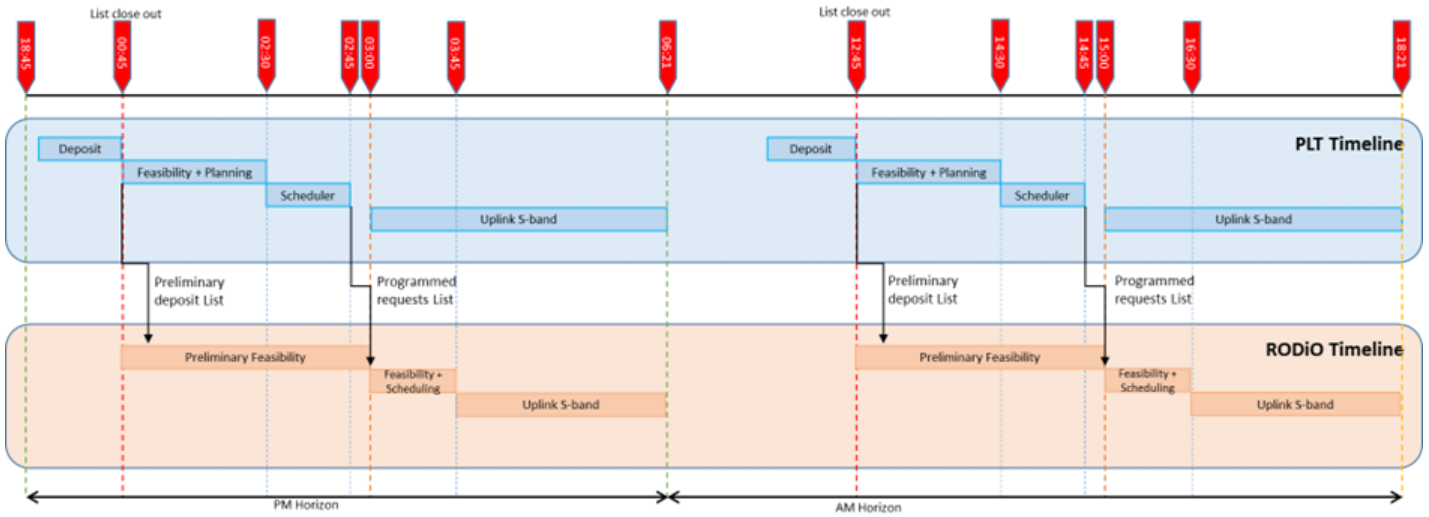
Configuration	Total height
1	189.2 mm
2	148.2 mm
3	159.8 mm
4	140.3 mm

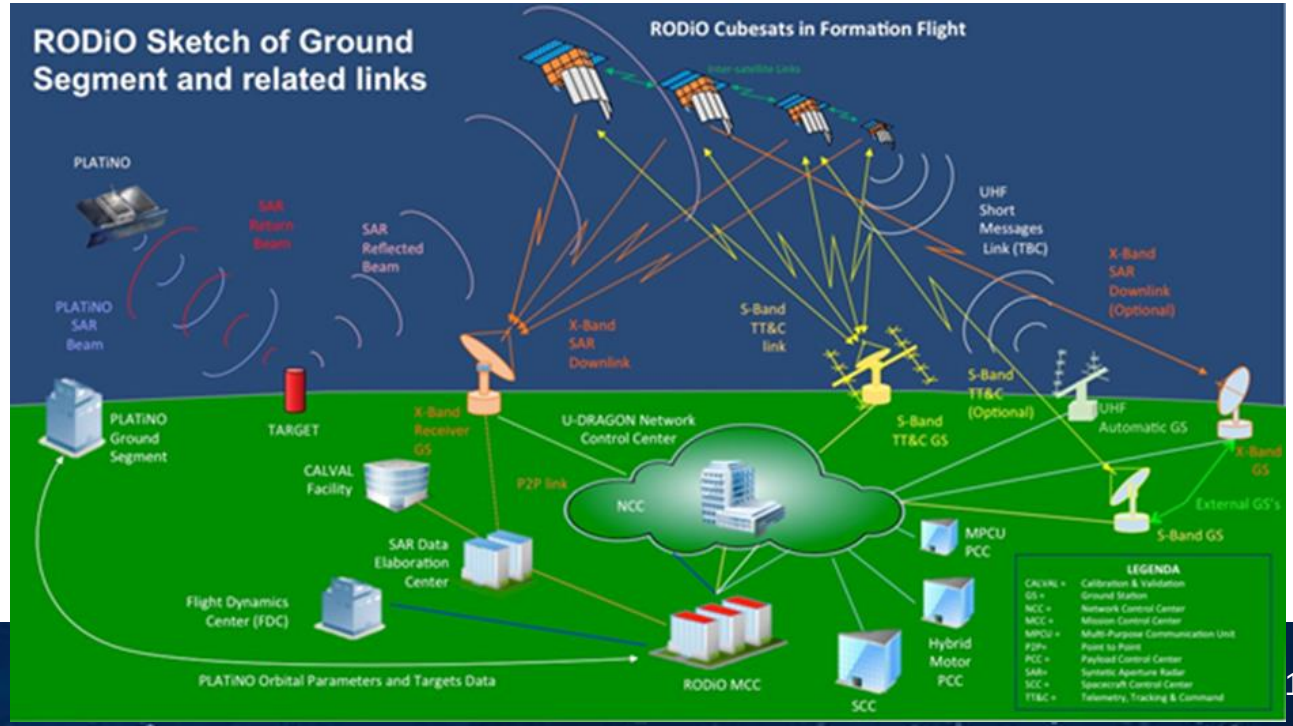
TECHNOLOGY FOR PROPULSION AND INNOVATION

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

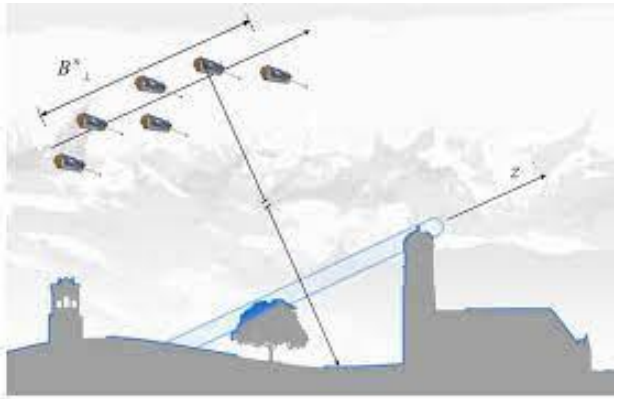
High complexity at system and subsystem level

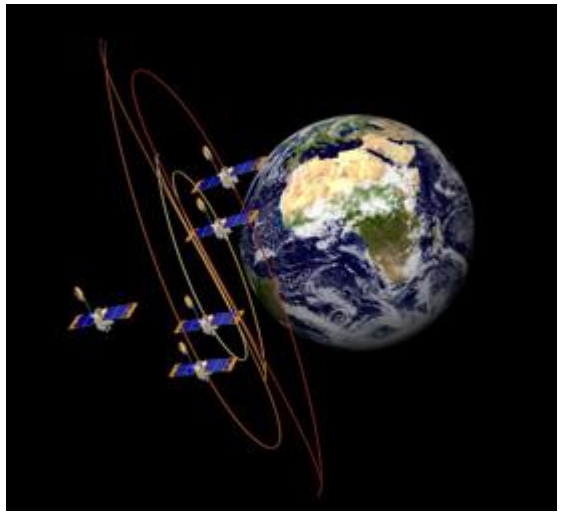


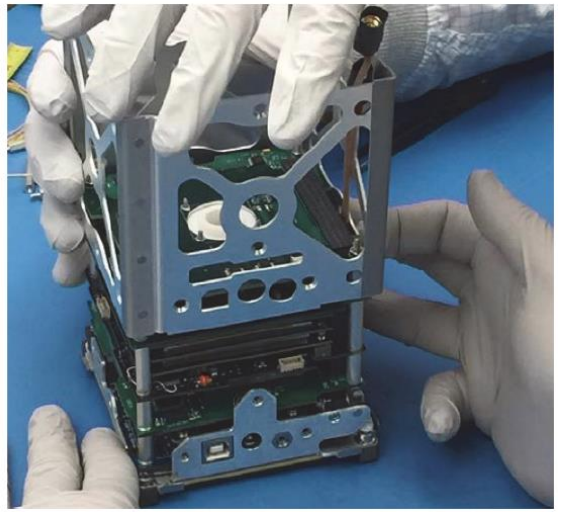


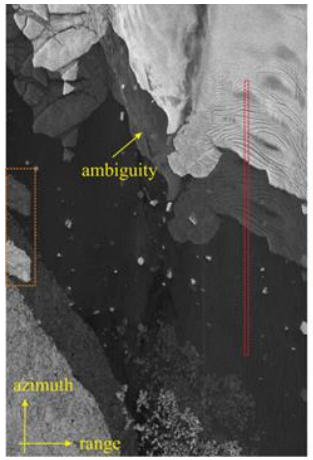


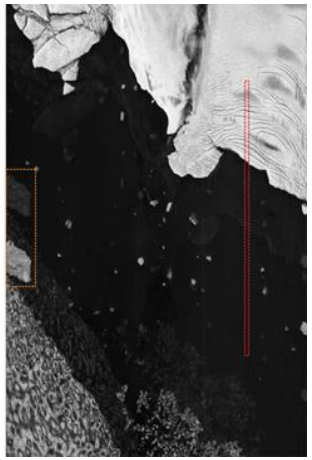
RODiO in a nutshell











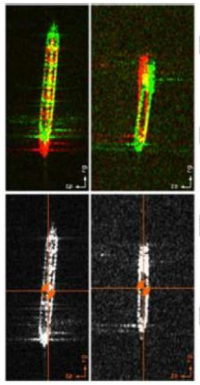
Formation flying and propulsion

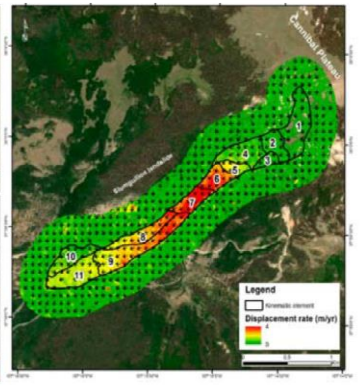
Satellite and payload miniaturization

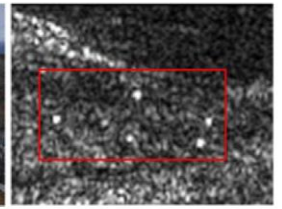
RODiO

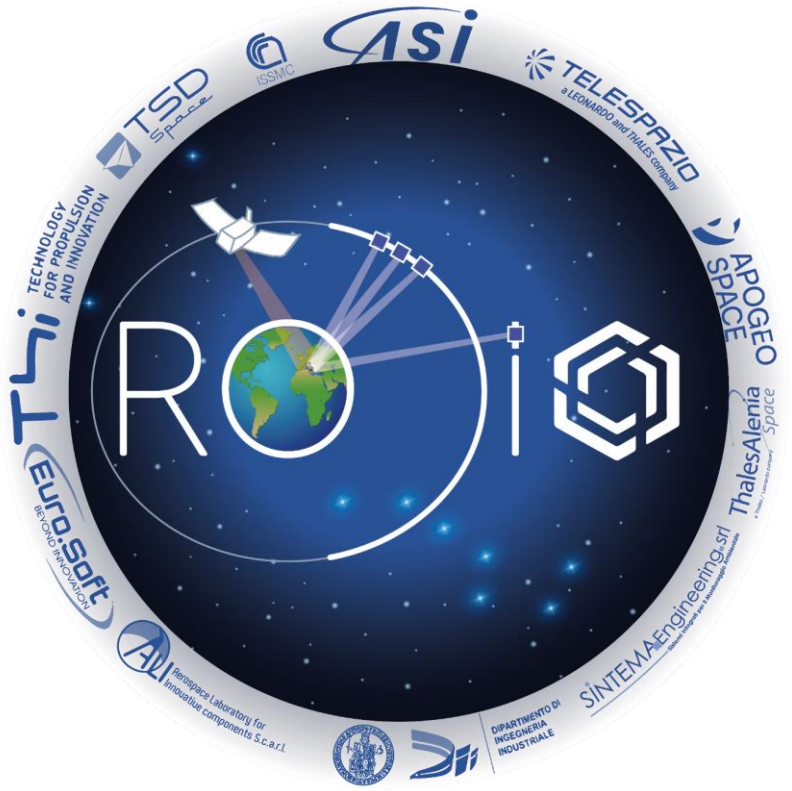
Distributed SAR imaging

New applications









Thank you for your attention

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