DustCube

2016 CubeSat Developers' Workshop
Cal Poly

(04/21/2016)

Universidad de Vigo

micos
Engineering for Remote Sensing

A 3U Cubesat to Characterize the natural dust environment and microscopic ejecta due to DART high speed impact on the Binary asteroid 65803 Didymos.

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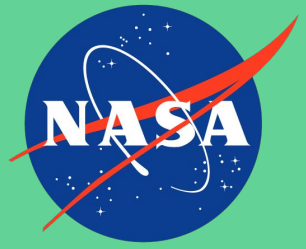
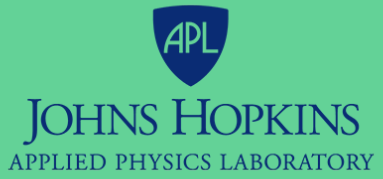
University of Vigo

University of Bologna

Micos Engineering





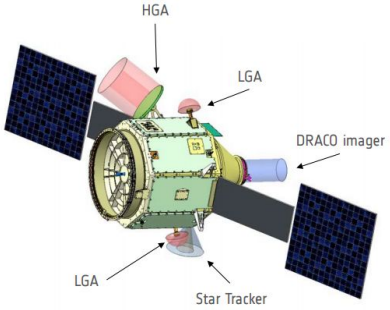
AIDA Mission

AIDA Mission (Asteroid Impact and deflection assessment)

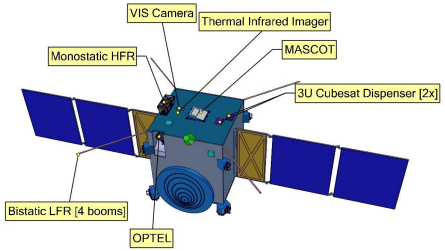
dart (Double Asteroid Redirection Test)

aida

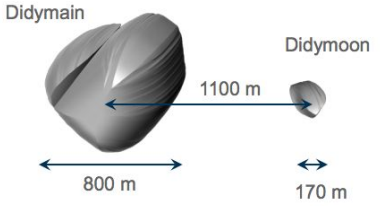
NASA

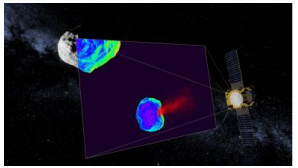


esa

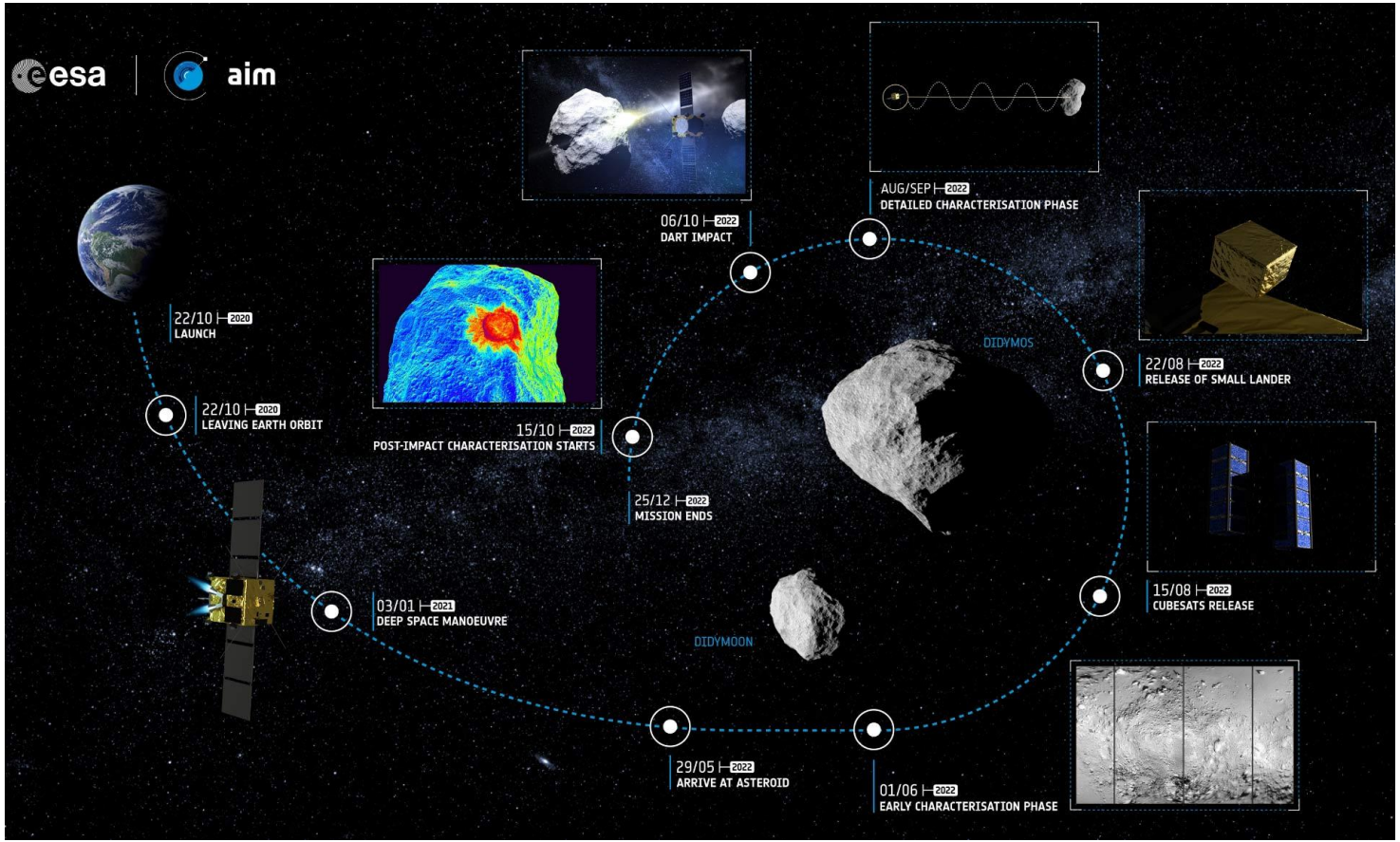


aim



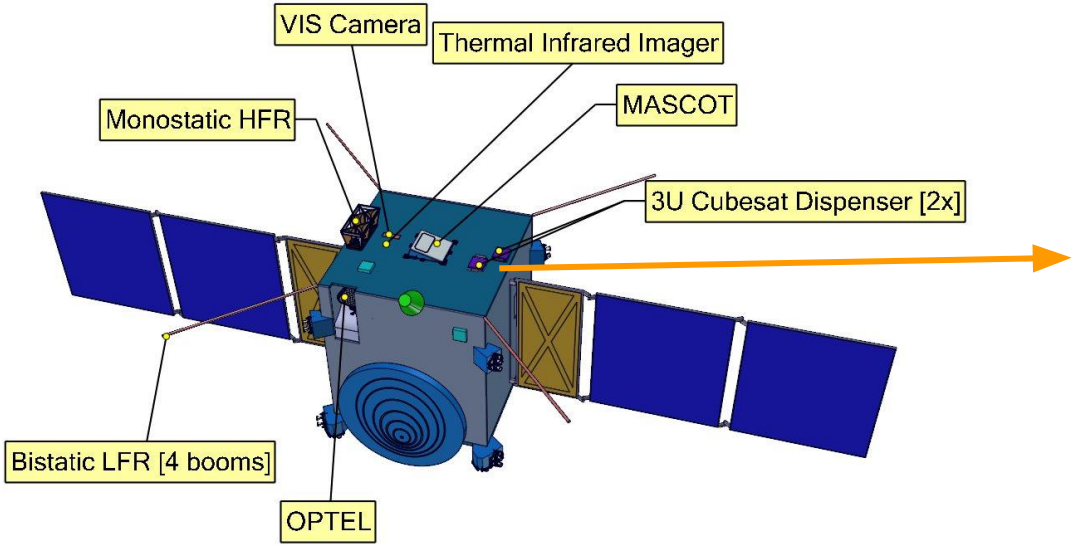


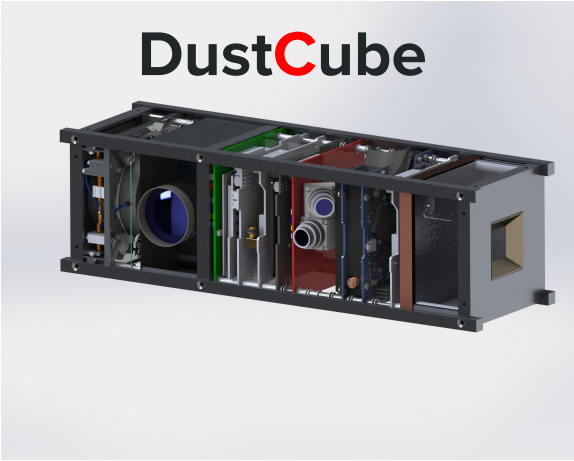
AIM CONOPS (Concept of Operations)



AIM (Asteroid Impact Mission)

aim





DustCube

TEAM

DustCube Project Consortium

University of Bologna

Universidad de Vigo

Engineering for Remote Sensing

- Orbit Dynamics
- Attitude Control Systems
- Navigation Control Systems

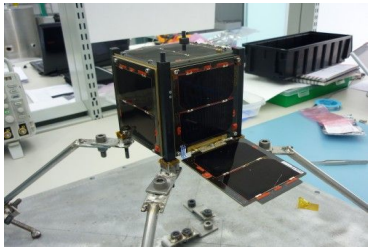
- Project Management
- System Engineering
- SC Platform
- SC Operations

- Optical Payload Design
- Scientific analysis
- Environmental Testing
- Scientific data processing

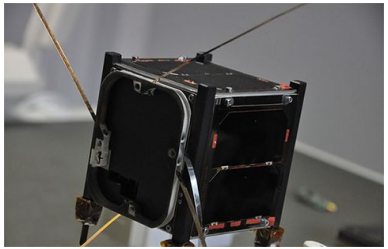
DustCube Project Consortium (1 / 3)

Universidade Vigo

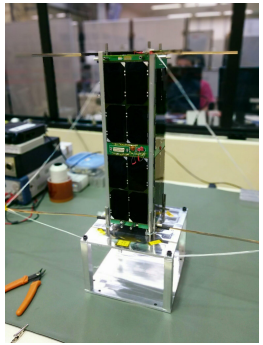
- **UVIGO CubeSats Experience in 8 years:** 3 CubeSats launched and operated until 2016



Xatcobeo: 1U
(**Operated for 2.5 years**,
Launched on (13/02/2012)
Re-Entered on 01/09/2014)
Launched with **ESA Vega**



HUMSAT-D: 1U
(**Operated for 1.2 years,**
OPS Finalized on 02/2015)
Launched with **Dnepr/GAUSS**
11/2013



SERPENS: 3U
(**Mission finalized on April 1, 2016 Re-Entered**)
Launched with JAXA, through the **ISS**
19/08/2015

- **On-going developments:**

FemtoXat ⅓ U (Modular Cubesat)

HumSat2.0 Payload:
Second Generation SDR payload for HUMSAT. (**End of 2016**)

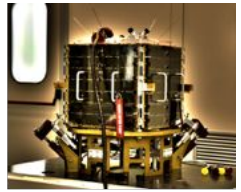
SatNet: Open Source Ground station network
(Final testing. **Operative on 03/2016**)

- **ESA ESEO** Satellite - Ground Station Node
- Pontevedra **Smart City Sensors Network** deployment.
- Development of H**ighly adaptable EGSE tools** for SC Testing
- Developments of **CubeSats Telemetry analysis tools**

DustCube Project Consortium (2 / 3)

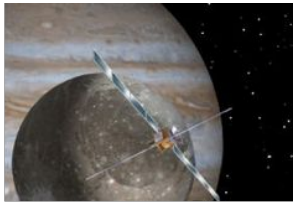
University of Bologna

- **ALMASat (ALma MAter Satellite)**
  Demonstrator, successfully launched on February 13th, 2012

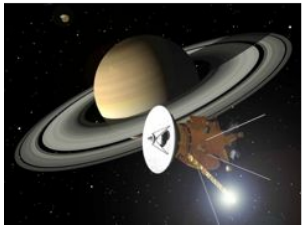


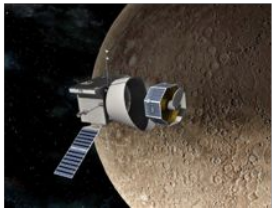
- **ESEO satellite**
  GPS Receiver and OD, as part of the payload package (in collaboration with SITAEL)
  Ground Stations design.

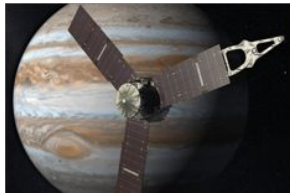
- **Target research areas:**
  Micropropulsion systems
  Cold-gas, flown on ALMASat-1 in 2012
  Monopropellant warm-gas, under development
  GPS Receivers and Autonomous Navigation Systems
  Ground Segment/Station Technologies and Mission Control Centers
  AODCS simulation tools



- <u>RadioScience Experiments</u>
  - Juno **(NASA)**,
  - Cassini-huygens (**NASA/ESA/ASI)**
  - Juice **(ESA)**
  - Bepi-Colombo **(ESA)**



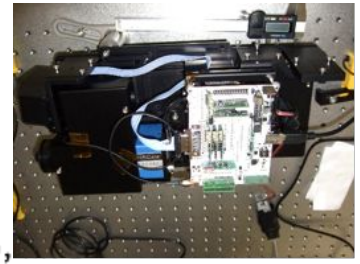


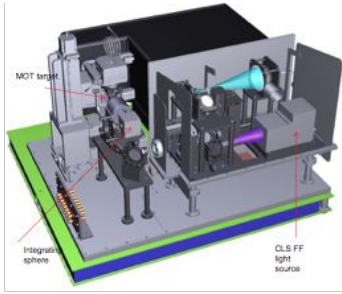


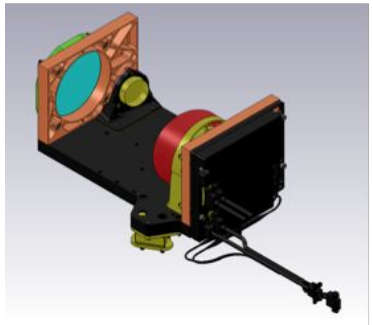
Micos Engineering GmbH
Company competences and SysNova team

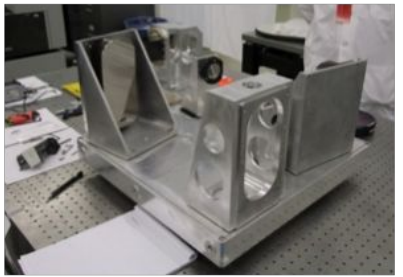
Engineering for Remote Sensing

- Operational since April 2011 (www.micos.ch)
- Hosted by Empa (Swiss Materials Science Federal laboratory) incubator
- Focus on system engineering for opto-mechanical systems
- Independently owned (100% by 5 shareholders)
- 20 employees (16 engineers/physicists, 6 PhDs)
- Clean room (15m² ISO7, 45m² ISO6, 9m² ISO5), ESD lab, TVAC procured
- E.g. instrumentation for Sentinels (S4: AIT-OGSE, S5: Calibration Subsystem), COM-Blackbodies, Proba-3: High Accuracy Metrology Optical Head Unit, and technology developments such as Optical Encoders









Micos Competencies:

- System Engineering
- Optical Engineering
- Mechanical Engineering
- Algorithms, Processing and SW
- AIT
- PA/QA

DustCube S/C

It is a **CubeSat for deep space exploration** which main technical and scientific objectives are:

Technical:

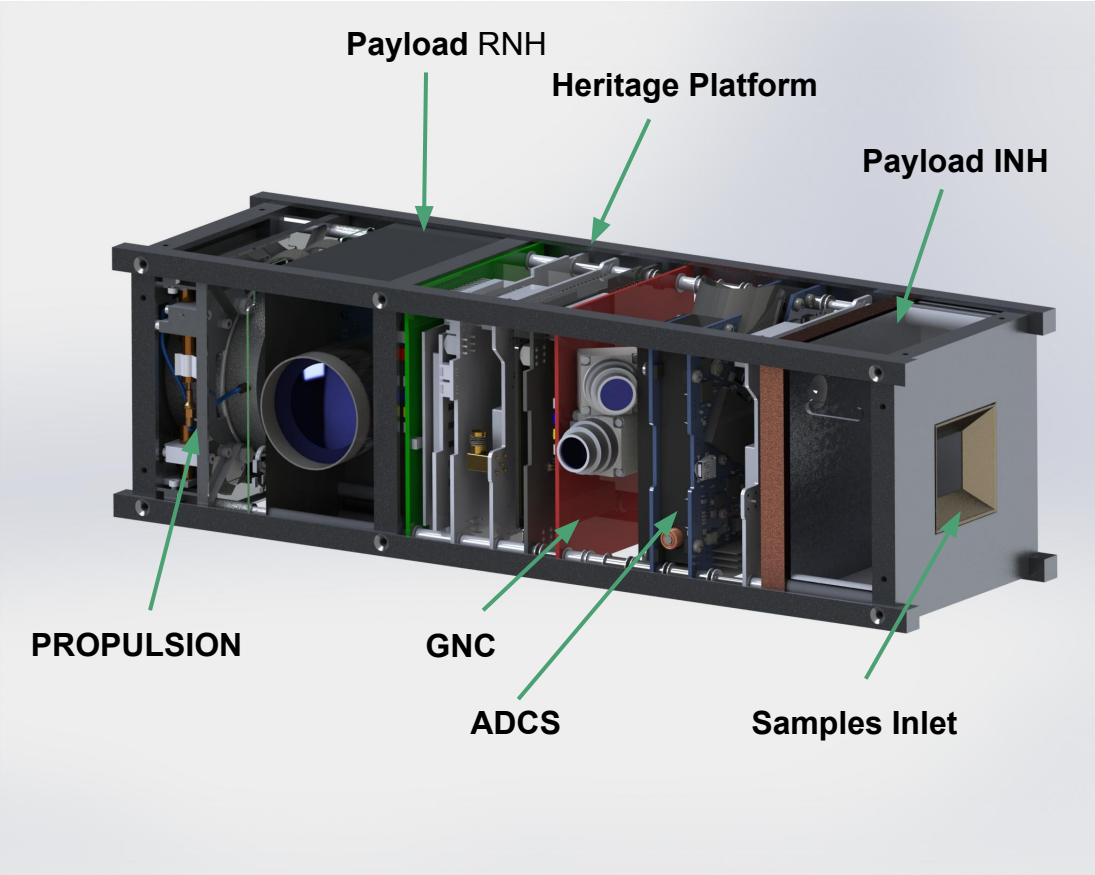
- **Test an Intersatellite-link** (network of 2 cubesats + lander + AIM mother S/C) in deep space.
- **Deploy a cubesat on an asteroid vicinity**.
- **Test laser altimetry** on a miniaturized system onboard a Cubesat.

Scientific:

- **Characterize (shape, size, speed, refractive index,etc) the asteroid particles** environment:
  - Natural environment Dust
    - **Vicinity, L4/L5**
  - Characterization of the **asteroid ejecta plume** due to DART **Impact**
    - Plume cloud physical properties (composition, size, shape, distribution)
    - Plume evolution after impact
    - Surface regolith characterization

- **Imaging** of the Didymoon
  - **Before** Impact
  - **During** Impact
  - **After** Impact

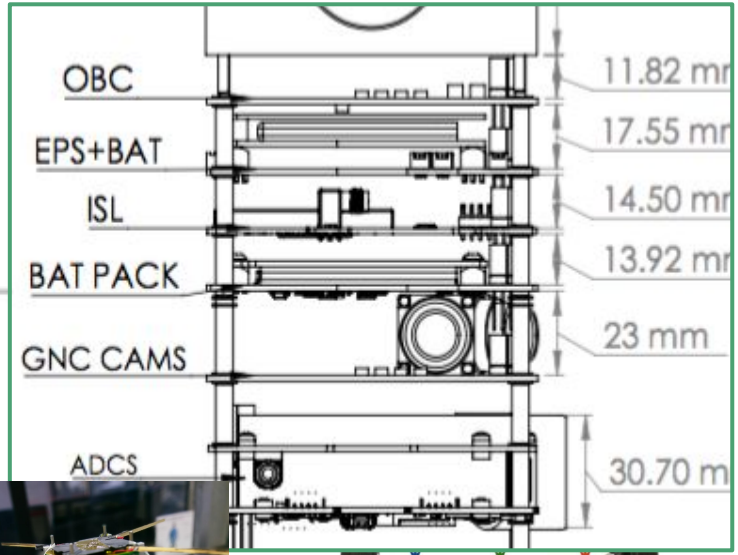
S/C Configuration

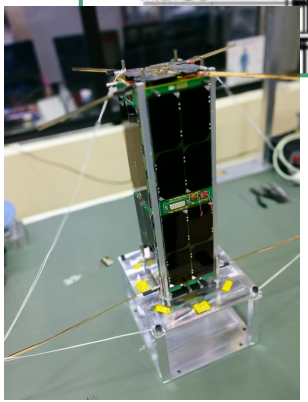


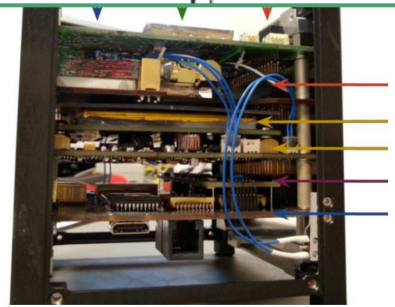
1 x 3U CubeSat

- Optical Navigation
  - (TIR Cameras)
- Cold Gas Propulsion
  - Multiple Thrusters configuration
- ADCS (3-axis pointing)
  - Reaction wheels
  - Start-trackers
  - Sun-sensors
- Payloads
  - INH (In-Situ Nephelometer)
  - RNH (Remote Nephelometer)
- Two deployable solar panels
  - Estimated power generation of 15W

Proposed flight-proven Platform for DustCube



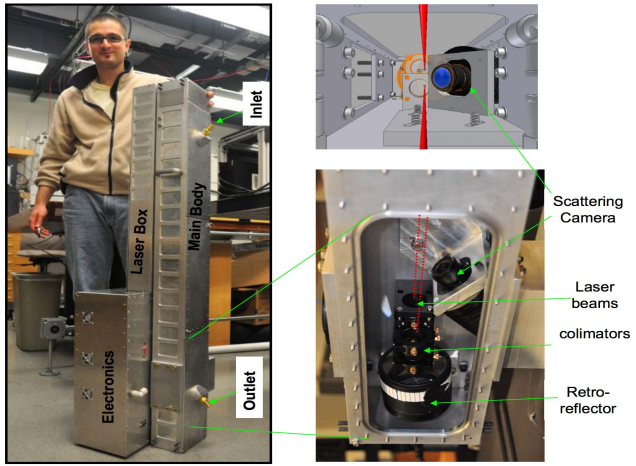


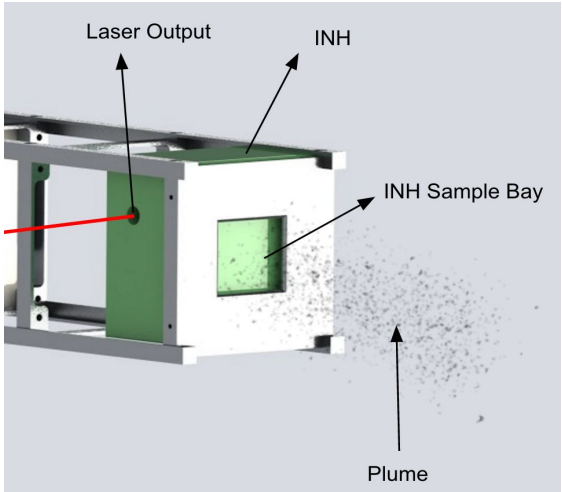


- **System Reliability:**
  - **> 4 Years** in Orbit, more than **100.000 EXECUTED COMMANDS**
  - Inhouse subsystems development + COTS
  - Critical components = RAD-HARD
  - **Inhouse OBSW:** On Board SW
    - FDIR implementation (Failure detection, isolation and recovery)
    - High level of autonomy
    - High modularity for new payloads
  - **40 different Telemetries**
  - **84 Telecommands** direct and scheduler programming
  - Exhaustive system engineering effort and AIT:
    - TLYF (Test Like you Fly)
    - E2E
    - EMC Testing
    - ECCS Tailored Methodology for CubeSats developments
  - **LOW COST! (**Lowering the cost, without compromising reliability)
- **GSSW** (Ground Segment Software) based on ESA **PUS** (Packet Utilization Standard)

(INH) In-situ Nephelometer

- INH: In situ NepHelometer is a miniature design of the PI-Neph (NASA airborne missions)



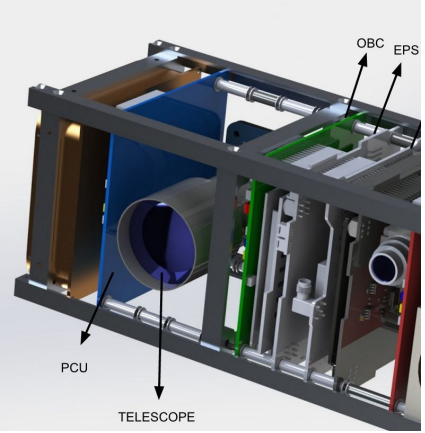


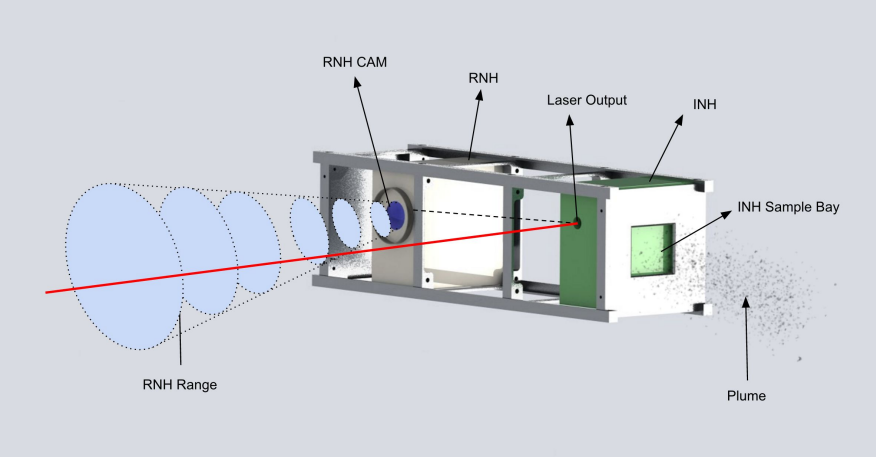
Polarized Imaging Nephelometer Development and Applications on Aircraft, Dissertation, **Dolgos, G.**, 298 pages, 2014

- The particles are deposited in the INH Sample Bay
  - Trapped on a charged surface
- The laser beam passes in front of the camera twice while, the camera takes samples of the impact of the laser with the particles,
  - On the first pass, the forward **scattered light** reaches the camera on a family of scattering angles
  - On the second pass the **backscattered light** reaches the camera in the complementary scattering angle range.
- The laser beam reaches the output of the SC to execute remote measurements of particles.
- Ongoing instrument miniaturization for a 1U CubeSat volume equivalent, based on Micos heritage, is being performed.

RNH Design (Remote Nephelometer)

- RNH: Instrument enhancement for remote sensing
  - Scattering data from remote particles

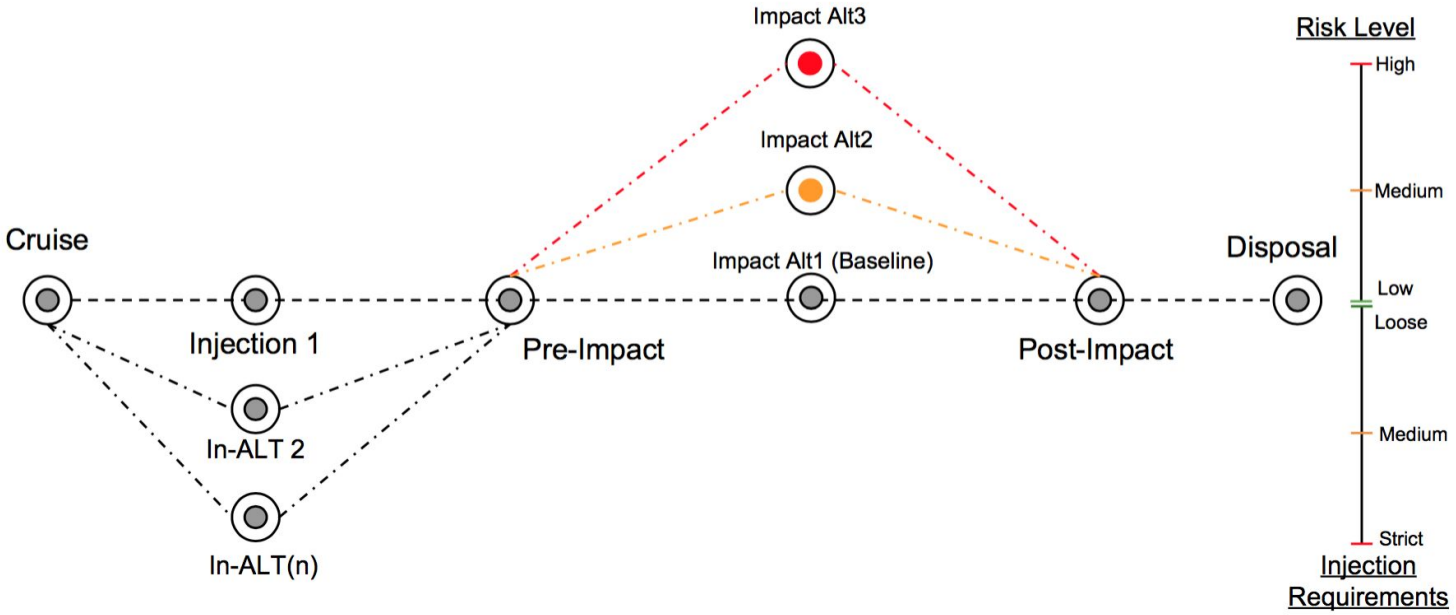




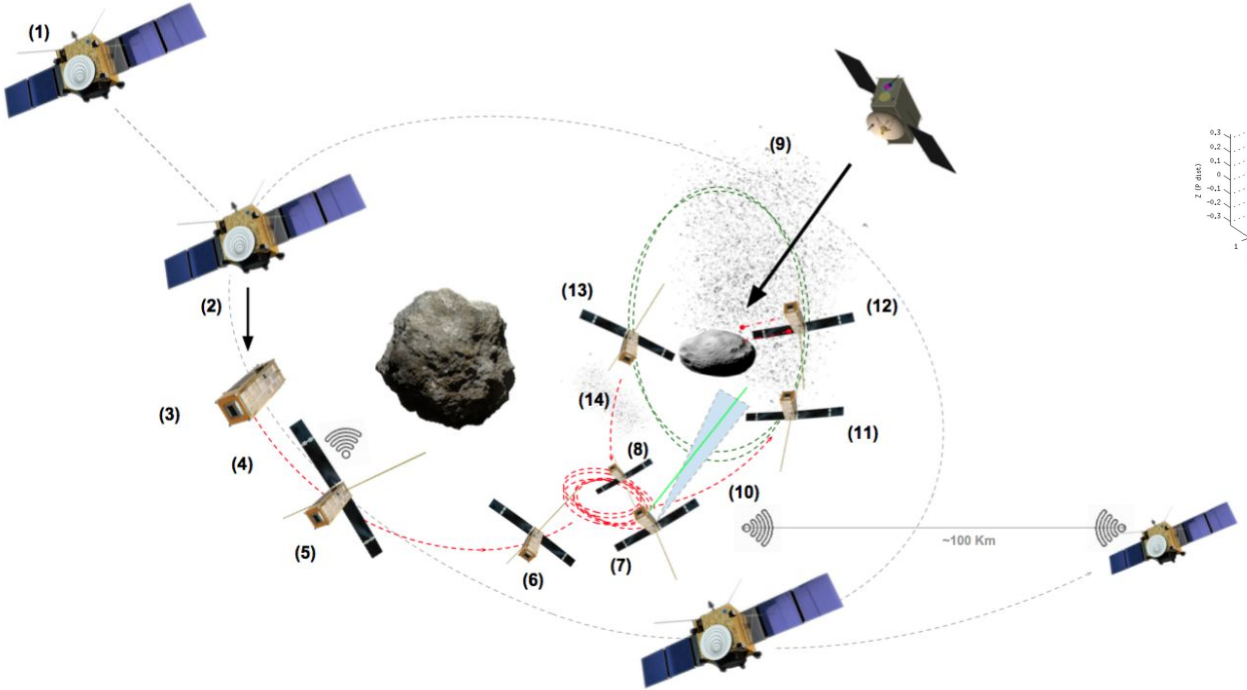
- Technology validation of an altimetry laser (TOF) system used for both surface recognition and navigation.

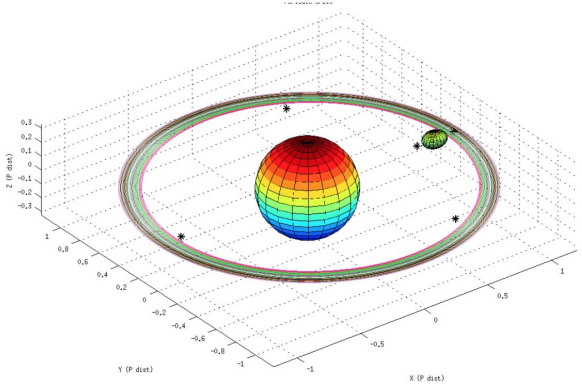
DustCube
CONOPS

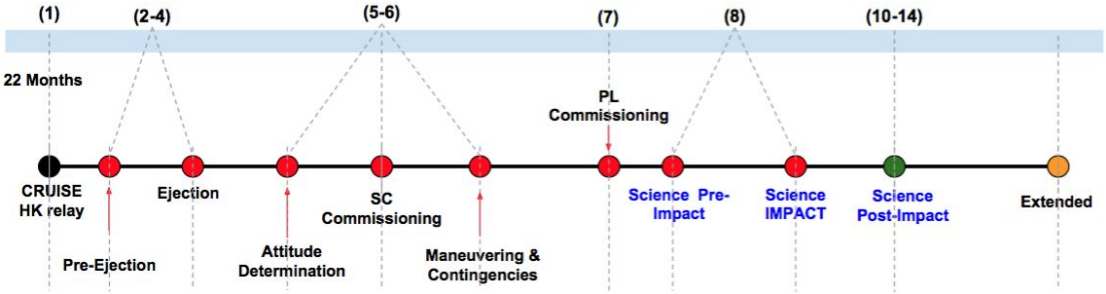
Concept of operations

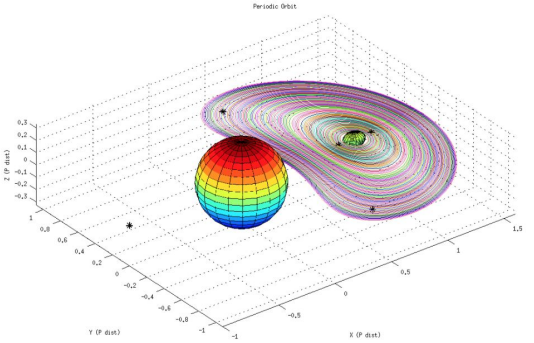


- Set of alternatives for INJECTION Phase, based on injection complexity (Backed-up with numerical models)
- Set of alternatives for IMPACT Phase, based on probability to be impacted by ejected plume, and navigation complexity (Backed-up with Orbital and Environmental analysis)


(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
(11)
(12)
(13)
(14)
~100 Km


Z (P dist)
Y (P dist)
X (P dist)


(1)
(2-4)
(5-6)
(7)
(8)
(10-14)
22 Months
PL Commissioning
CRUISE HK relay
Pre-Ejection
Ejection
Attitude Determination
SC Commissioning
Maneuvering & Contingencies
Science Pre-Impact
Science IMPACT
Science Post-Impact
Extended


Periodic Orbit
Z (P dist)
Y (P dist)
X (P dist)

DustCube

SCIENCE

SCIENCE CONOPS and Objectives

COPINS Phase	Orbit Position	Duration	Payload Activities
COPINS Deployment	Platform activities @Km	6 days	Commissioning
	Orbit Manouvering (Parking orbit)	1 day	Didymos system imaging

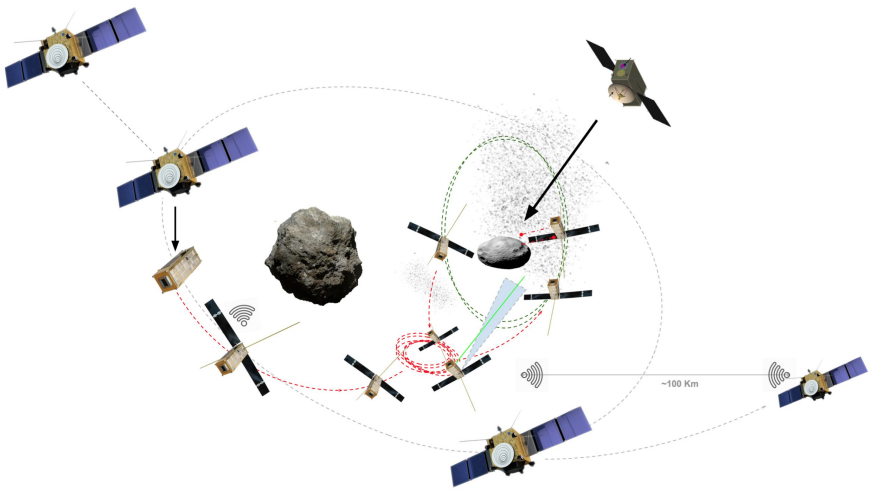
Pre-Impact	SCIENCE @L4/L5	21 days	- Natural dust environment characterization
			  - Particles counting
			  - Particles deposition
			- Didymoon surface Imaging

DART Impact	SCIENCE @L4/L5	1 day	- Impact Imaging
			- Plume concentration evolution
			- Particles characterization
			  - PSD (Particles Size distribution)
			  - Particles speeds
			  - Shape
			  - Refractive Index

	SCIENCE @Rendezvous	(TBD) hrs	- Didymoon surface Imaging - Laser altimetry validation (TOF)

	SCIENCE @DRO Low altitutde	24 days	- Particles charcaterization
			  - Sphericity
			  - BRDF
			  - PSD (Particles size distribution)
			- Surface Imaging

Post-Impact	SCIENCE @L4/L5	~20 days	Extended Science objectives



DustCube Conclusions

- International Consortium (Research institutions + Industry)
- Very valuable science return for the community (INH + RNH)
- Validation of technology for future missions with CubeSats (Laser altimetry)
- Reliable Technology (flight proven platform)
  - FDIR
  - Autonomy
  - 3 Launched and Operated CubeSats Missions
- Experience on autonomous navigation system, space optical payloads and autonomous OBSW
- Tailored ECSS Methodology on CubeSats developments
  - i.e PUS (Packet Utilization standard)

University of Bologna

Universidade Vigo

Engineering for Remote Sensing

DustCube Project

Diego Nodar

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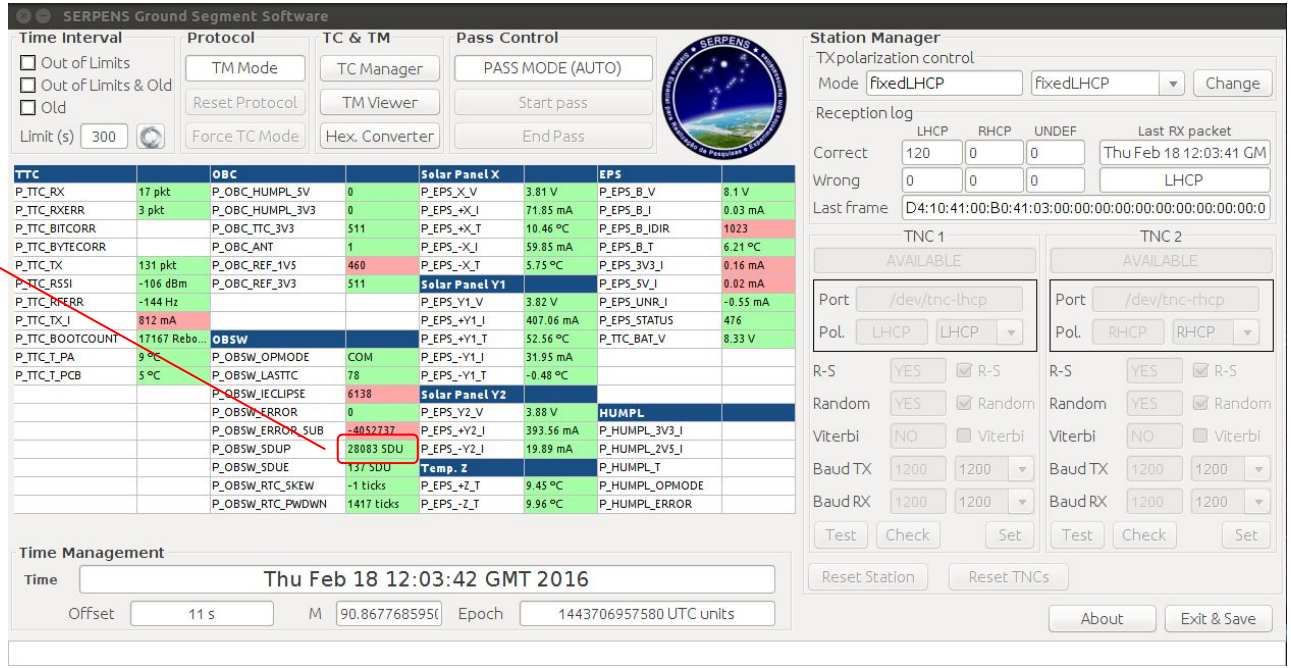
SERPENS S/C
Fresh Data

(Backup slides)

Fresh data from SERPENS Cubesat (Proposed Platform)

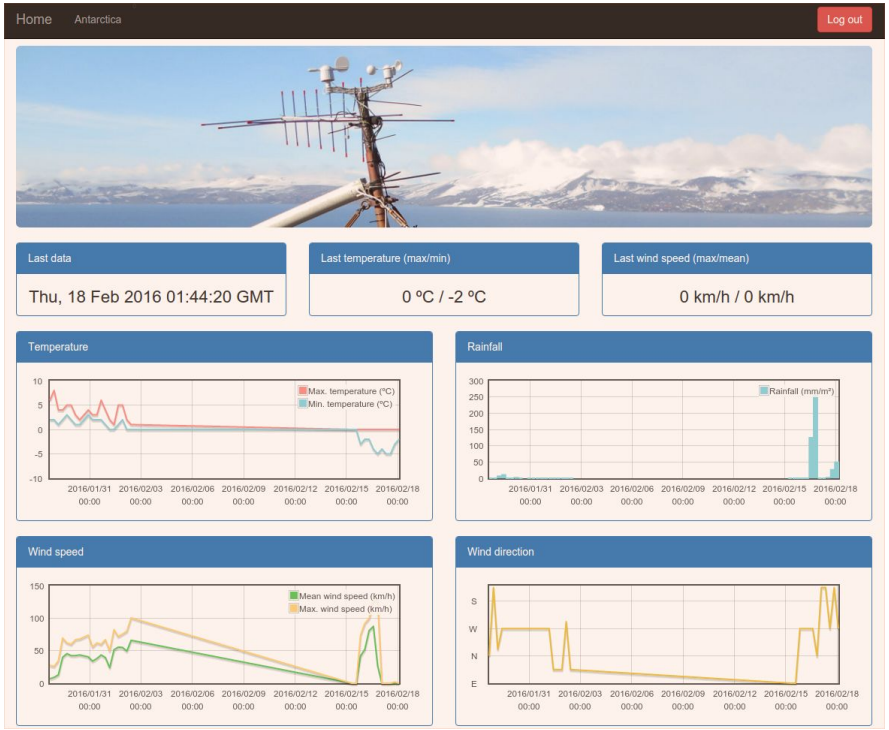
- Snap shot of SERPENS TM Viewer during S/C pass over Vigo (Thursday 18/02/2016)

28083
Executed Commands on scheduler (since 09/2015)



- Downloaded Data in the communication pass:
  - Environmental data collected from HUMSAT sensors deployed in **ANTARCTICA + Chile + Spain.**
  - Payload measurements of Global VHF radio interference on the Amateur band to globally map the jamming sources.

Fresh data from SERPENS (Antarctica data and sensors)



Figurs. Data gathered from Antarctica sensors

Figure. Humsat sensor

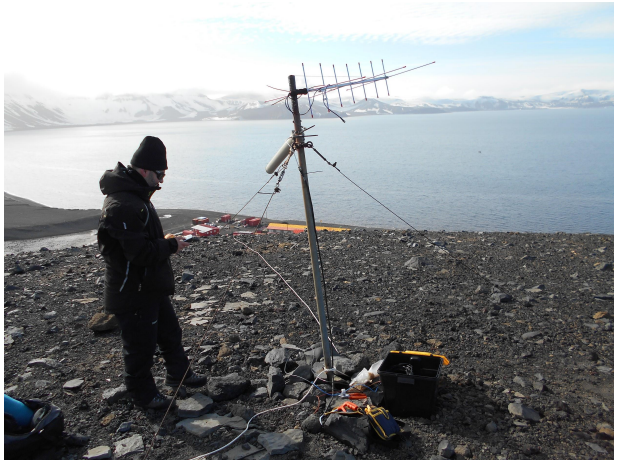


Figure. Antarctica spanish base sensor location