GMV CubeSat Subsystems, Products and Technologies

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INNOVATING SOLUTIONS

GMV Strategic lines for CubeSats

- Products
  - GNSS Receiver for Space Applications
  - AIR hypervisor
  - Ground Segment products for cubesat applications

- Participation in operational missions:
  - OPS-SAT
  - RACE
  - JUVENTAS
  - INFANTE

Products

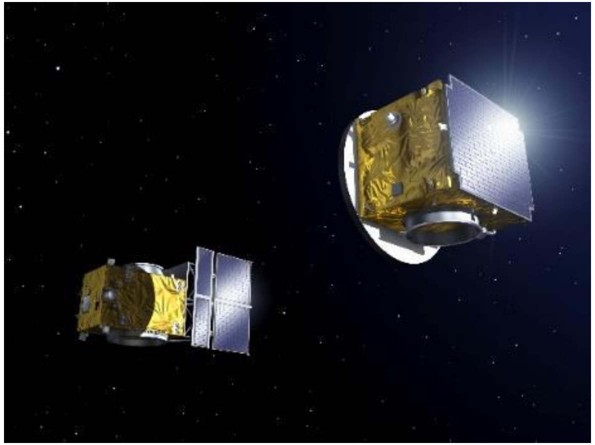
GNSS Receivers and Technologies

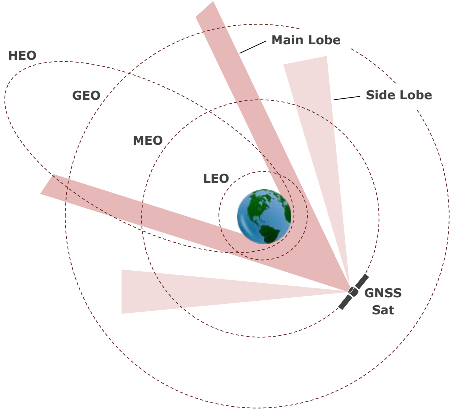
Air in CubeSat

Ground Segment Solutions

GNSS receivers and technologies

- GNSS what for
  - GNSS Receiver
  - Relative GNSS & Formation Flying SW
  - High Altitude GNSS: HEO, GEO and beyond





GNSS receivers and technologies

GMV GNSS SDR Receiver development overview (GNSSW)

GNSSW v1 (2015) → GNSSW-LEON4 v2 (2019) → GNSSW-MLMSC v3 (2019-2020)

GNSSW v1 (2015)

- LEO applications
- GPS L1 C/A
- Embedded on PowerPC750
- TRL4

GNSSW-LEON4 v2 (2019)

- LEO applications
- GPS L1 C/A, Galileo E1 pilot and data
- E1/L1 Front-End prototype
- Embedded on LEON4 quad-core (GR740)
- TRL5

GNSSW-MLMSC v3 (2019-2020)

- Launcher & LEO applications
- GPS L1 C/A, Galileo E1 pilot and data (prototype of GPS L5 & Galileo E5a pilot processing for LEO)
- TRL8
- On-going activity

GNSSW-LEON4 v2 (2019) → GNSSW-LEO (2021)

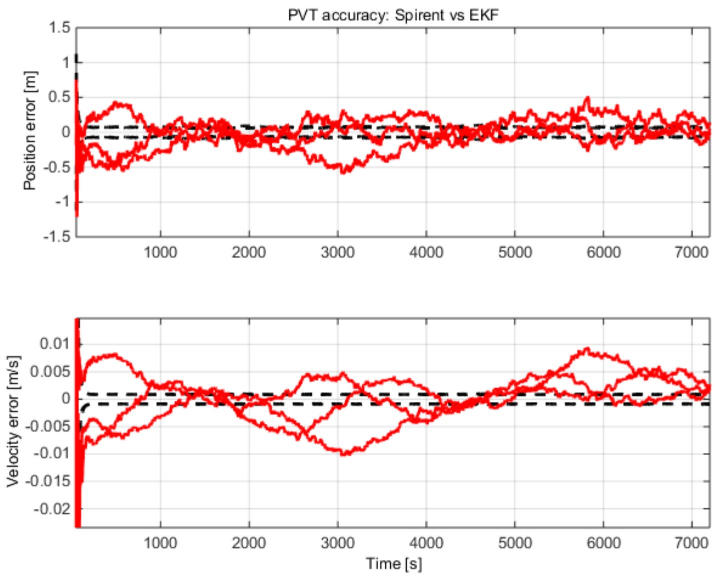
GNSSW-LEO (2021)

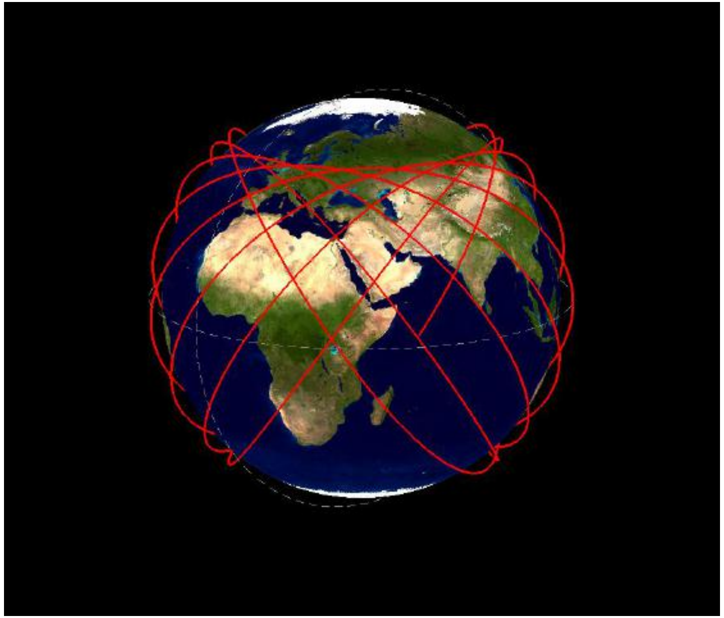
- LEO IOD on GOMX-5

GNSS receivers and technologies

Performance

- Fast start (<5 min in cold and <2 min in warm)
- High accuracy (position <1m and velocity <1cm.s-1) no iono simulated
- 21 tracking channels on LEON4 quad core





GNSS receivers and technologies

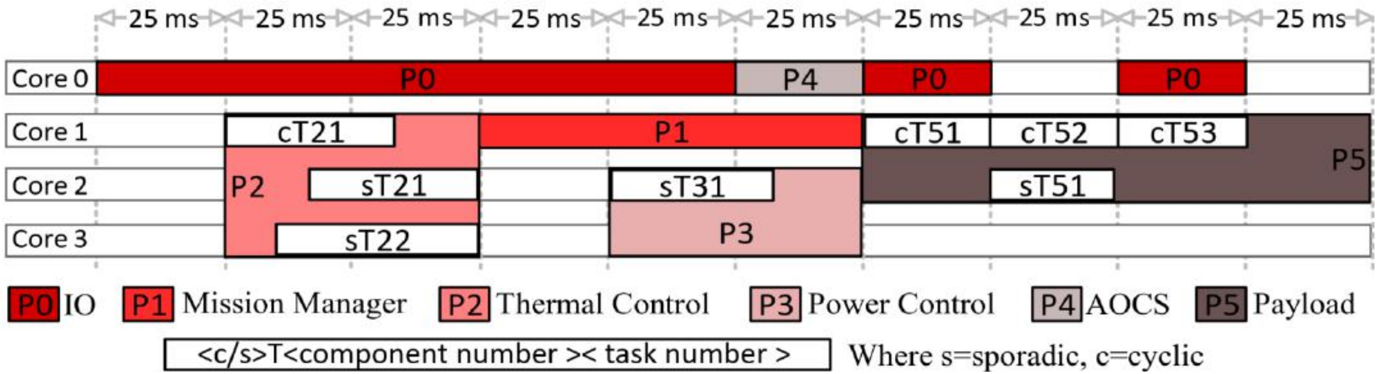
GNSSW on Miura

- GNSSW on Miura microlauncher (estimated launch date 2020-2021)
  - E1/L1 signal processing
  - Launcher dynamics
- GNSSW on GOMX-5 (estimated launch date 2021)
  - E1/L1 signal processing
  - LEO dynamics high accuracy
- GNSSW on cubesats around Moon?
  - High sensitivity tracking and acquisition

Air in CubeSat

air

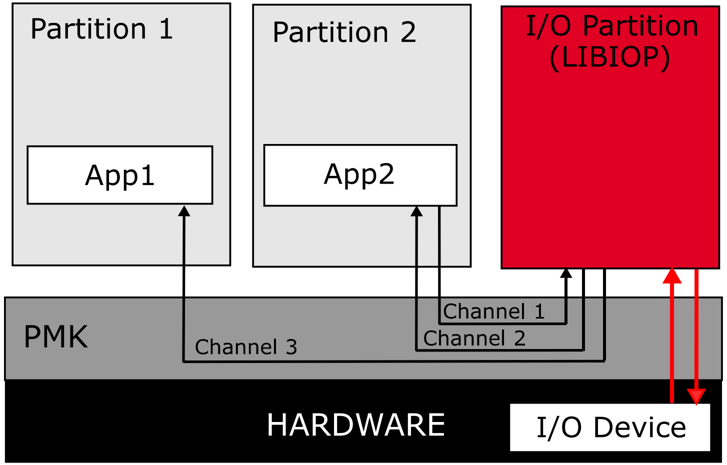
THE ROBUST PARTITION SAFETY CRITICAL REAL TIME OPERATING SYSTEM
IMPLEMENTING ARINC 653 APEX



- Applications with **different criticality levels** can co-exist in the same processing hardware. Sharing processes affect performance at HW level
- Avionics functions using the same resource, **safely isolated** in time and space

Air in CubeSat

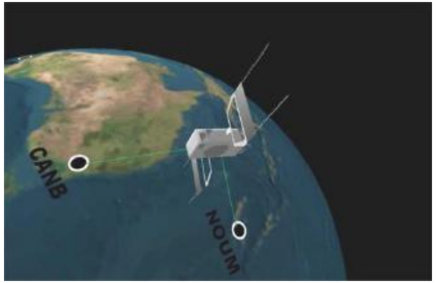
- AIR is a type-1 hypervisor that guarantees **Time & Space Partitioning (TSP)**
- The TSP paradigm allows multiple payload applications, with **different criticalities**, to be executed, in the same hardware resource, while ensuring their isolation, i.e. guaranteeing that any **potential failure will not propagate** and compromise the mission.
- Use of standards promotes **software reuse**, portability and modularity
- Less hardware, thus **less weight and power consumption**
- Overall: **more capabilities, less costs**

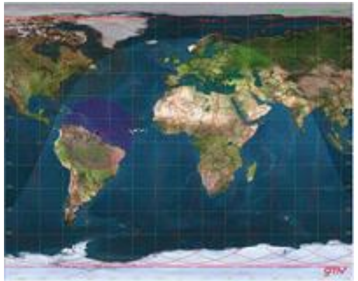


- RTEMS 4.8i and 5
- Multicore SPARC and ARM

Ground segment solutions

- Down-sized version of GMV's traditional products for ground segment:
  - Flight Dynamics Systems: ***focussuite*** (covering all FD functions, including constellation management and collision avoidance services)
  - Mission Control Systems: ***hifly*** (satellite control system)
  - Mission Planning System: ***flexplan*** (mission planning and scheduling)
  - Orchestrator: ***flyplan*** (comprehensive on-ground operations automator)
- Main Objectives of the down-sized versions
  - Cost reduction (both system provision cost and operations cost) with respect to traditional infrastructure
  - Enhanced flexibility
  - Multi-platform capability
  - Improved maintainability





GMV participation in CubeSat missions

OPS-SAT

RACE

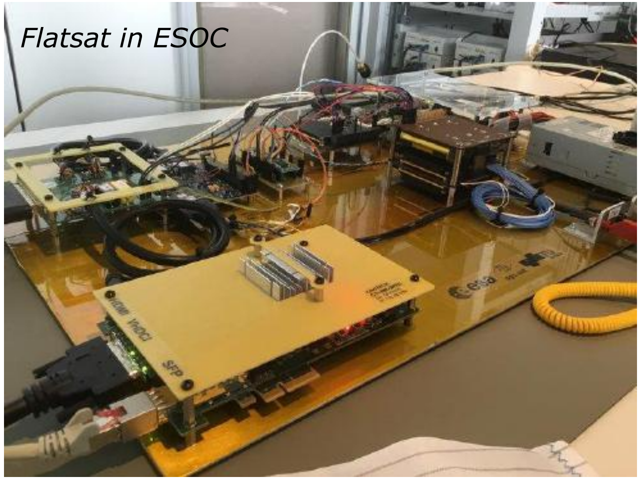
JUVENTAS

INFANTE

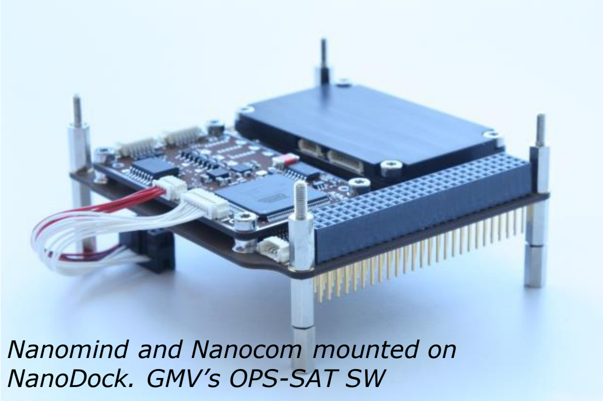
OPS-SAT: ADCS, OBSW and FDIR

GMV tasks:

- To develop (design, implementation, tests) On-Board Software of the satellite's platform On-Board Computer
- To implement Nadir-Pointing ADCS
- To develop (design, implementation, tests) the FDIR system
- To develop Software Validation Facility



Flatsat in ESOC

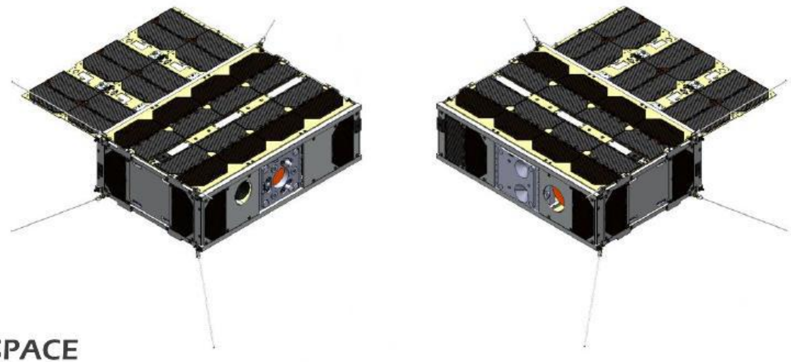


Nanomind and Nanocom mounted on NanoDock. GMV's OPS-SAT SW

OPS-SAT mockup

RACE: AOCS-GNC

- **R**endezvous **A**utonomus **C**ubeSats **E**xperiment
- In-orbit demonstration of inspection and docking of two 6U CubeSats
- Autonomous GNC and Robust Control
- Use of 6DoF propulsion system
- Autonomous and robust FDIR for CubeSat formation
- Consortium with GomSpace, Almatech and MICOS



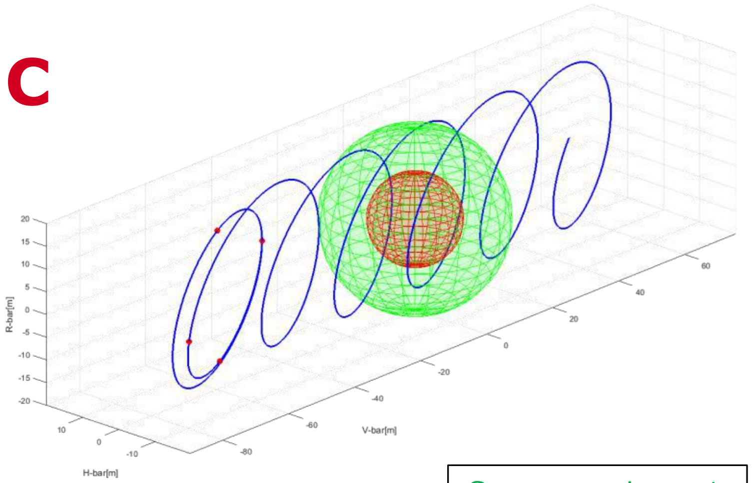
RACE: AOCS & GNC

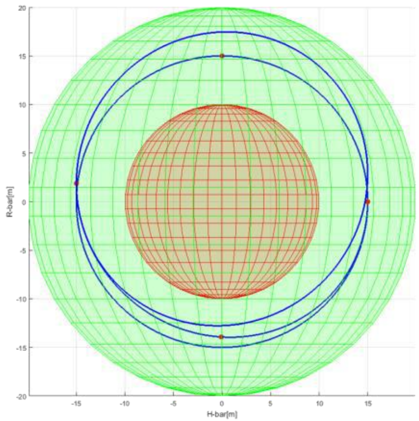
Close Fly Around GNC with non cooperative tumbling SC

- Navigation based on Center of Brightness IP
- 3D Attitude control
- Multi-impulsive Maneuvers

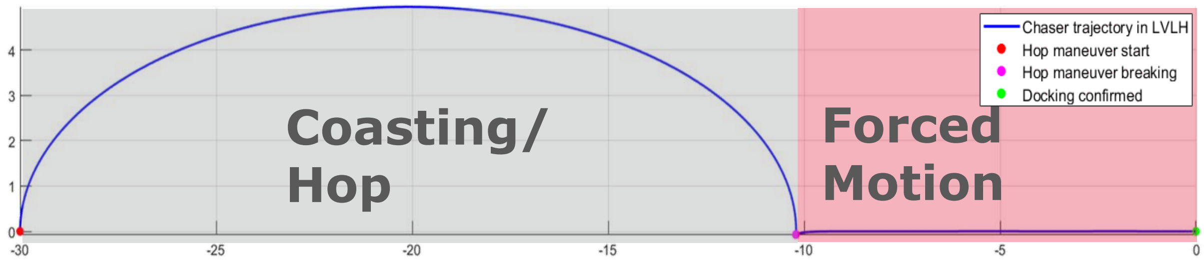
Cooperative rendez-vous and docking

- Navigation based on Vision based navigation with LEDS
- 6D Attitude and position control



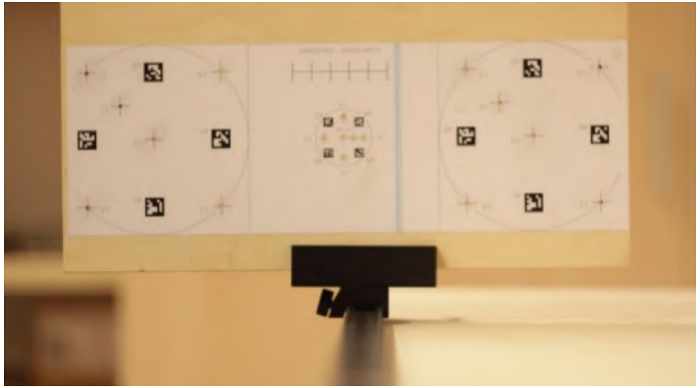


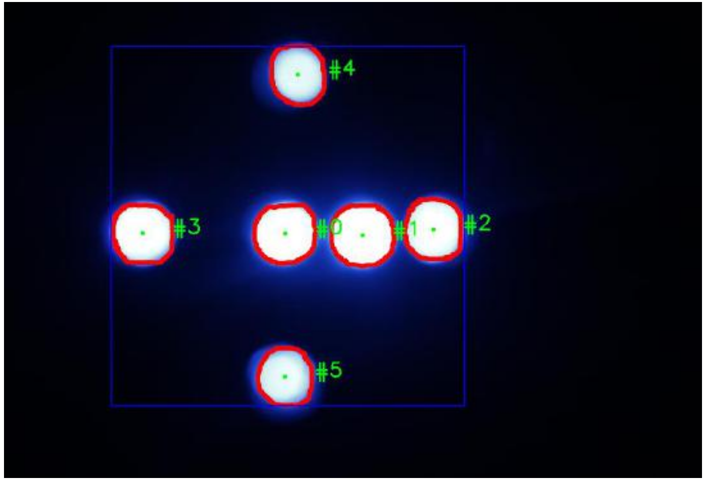
Green – requirement fulfillment zone
Red – keep-out zone



RACE: AOCS-GNC

- LED detection and relative 6DoF pose estimation
  - EKF/UKF Kalman filter
  - Careful consideration of delays and handling of lost measurements
- Narrow-angle camera observes large pattern
  - Camera on target, pattern on chaser
- At close range switch to wide-angle camera and small pattern
  - Camera on chaser, pattern on target





JUVENTAS: MA & GNC

- JUVENTAS is one of the two CubeSats piggybacked by HERA.
- GMV is responsible for the Mission analysis and GNC/AOCS.
- JUVENTAS mission:
  - Perform radar science on Didymain
  - Perform radio science on Didymoon
  - Take images of DART impact crater

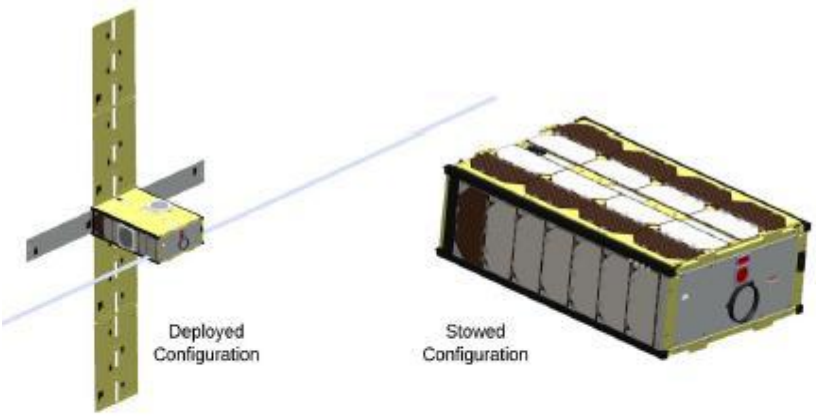
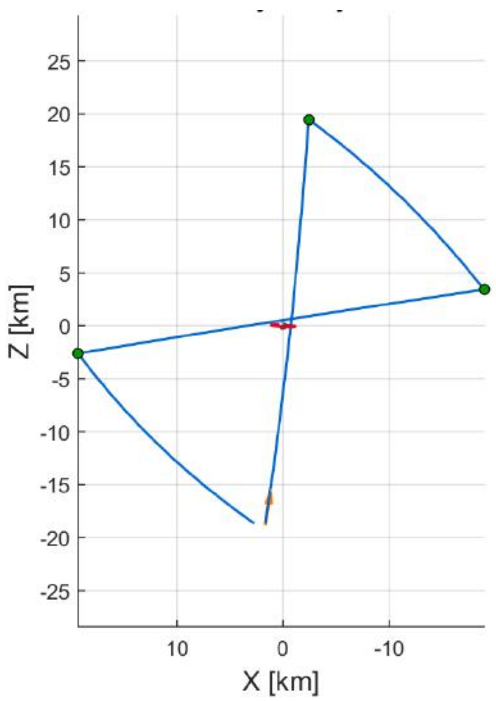


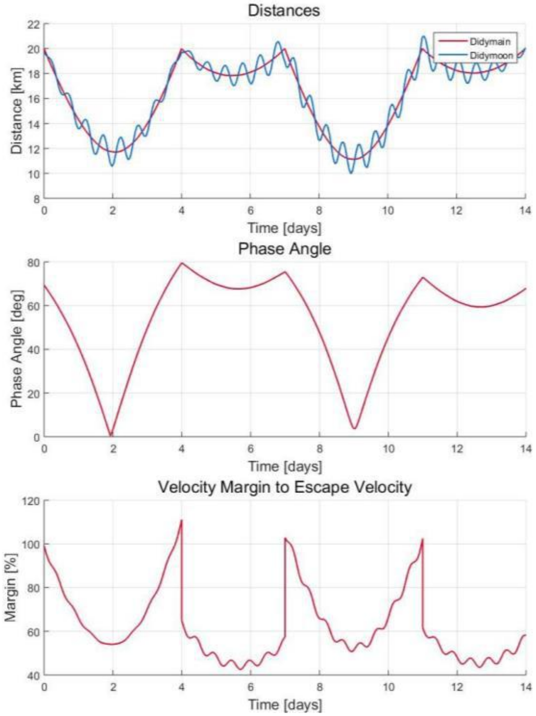
Figure 4: Juventas Cubesat deployed (left), stowed (right)

ADCS&GNC	3-axis stabilized	
	ADCS Sensors	6x Fine Sun Sensors IMU 2x star trackers
	GNC Sensors	Navigation Camera (w/payload) Laser altimeter
	Actuators	4x GSW600-4P RCS prop

JUVENTAS: Deployment phase

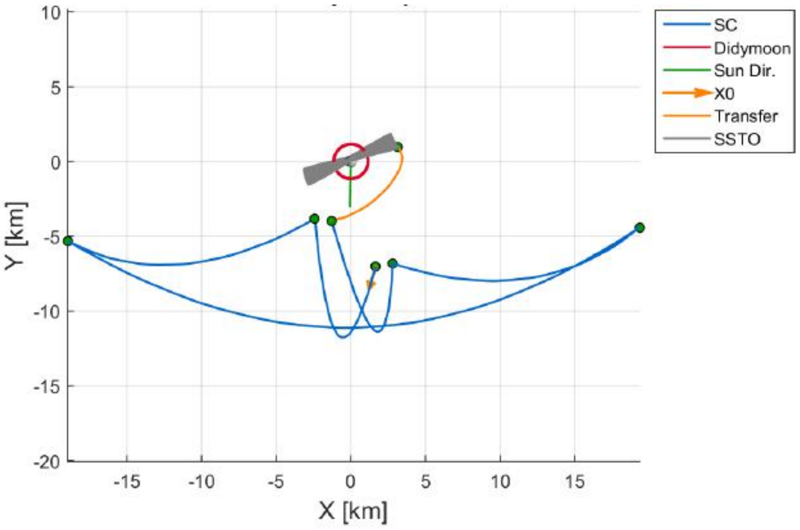
- JUVENTAS will be released from HERA in a hyperbolic arc trajectory
  - Minimum distance of 10 km.
  - Phase angle below 90º.
  - Velocity margin above 40% the local escape velocity.
  - One polar hyperbolic arc.
- The objective is to perform a rehearsal phase of the operations of the CubeSat
  - Perform necessary checks.
  - Test manoeuvres, telecommands, ISL, among others systems.

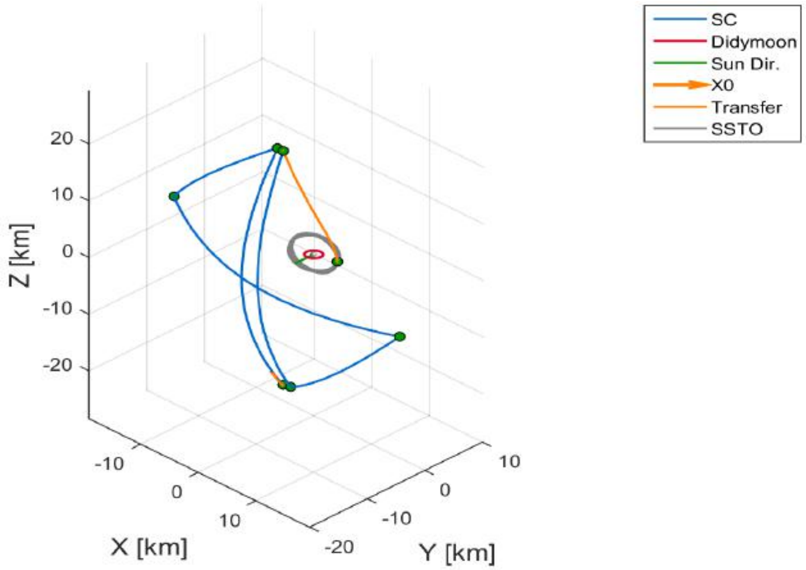




JUVENTAS: Transfer to SSTO

- Operations shall be performed from a Self stabilized terminator orbit (SSTO).
- The injection into the SSTO is achieved through a passively **safe 2-day hyperbolic arc**.
- **Velocity margin** must be ensured **above 40%**

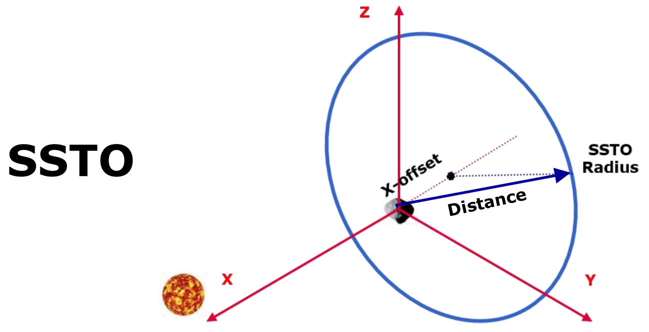


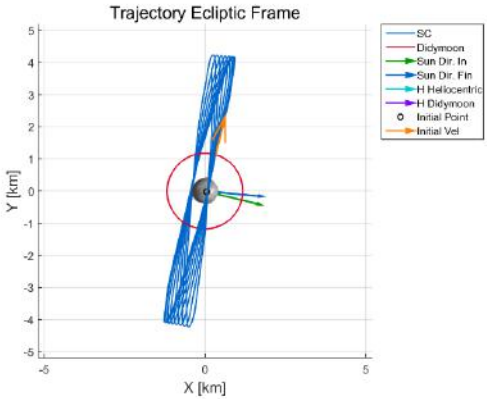


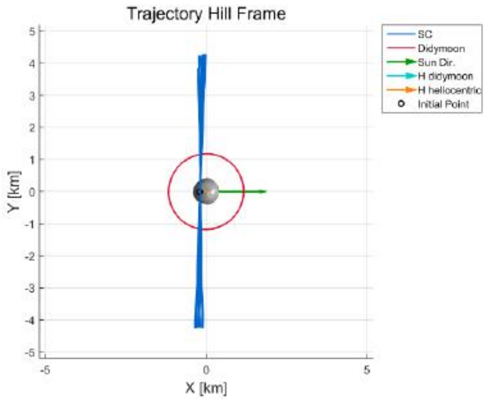
JUVENTAS: Observation phase

- **Equilibrium circular orbits** perpendicular to Sun direction in the Hill dynamics Frame.
  - **X-axis:** Sun Direction.
  - **Y-Axis:** Completes the right handed system.
  - **Z-axis:** Parallel to Didymos heliocentric orbit.

- **Two SSTO required.**
  - Proximity Global Observation phase (2.5 – 5 km).
  - Observation phase (1.5 - 2.5 km)

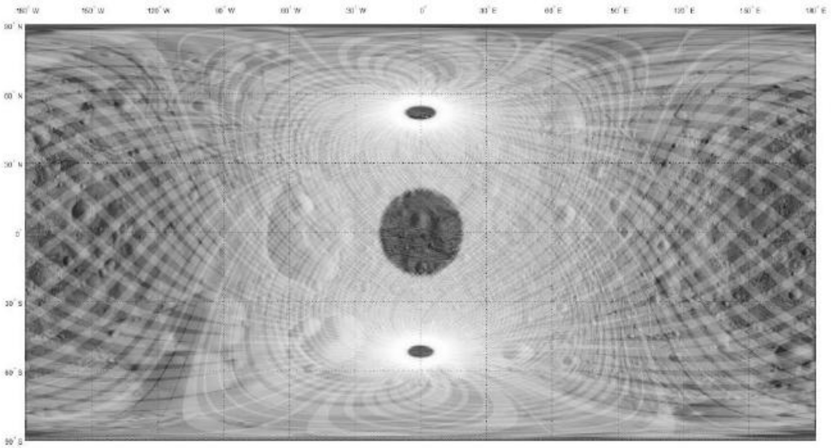




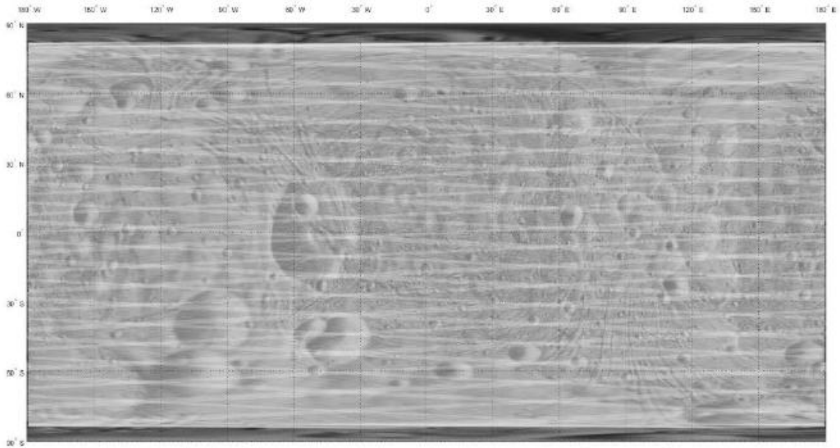


JUVENTAS: Coverage of the system

- **Didymoon** ground track for a 1.5 km SSTO during 60 days.



- **Didymain** ground track for a 3 km SSTO during 60 days.



INFANTE

- **INFANTE** is a 10M€ project funding from FCT/ANI and Portuguese industry led by Tekever
- Microsatellite
- Precursor for a EO & Comms Constellation
- SAR
- Multispectral Camera
- Scientific Experiments
- To operate in 2021

- AIR will operate as a hypervisor of scientific experiments payloads
- Ensures **isolation** and **robustness** of main mission against experiments

CONCLUSIONS

Conclusions

- Developing products
  - GNSS Receiver for Space Applications
  - AIR hypervisor
  - Ground Segment products for cubesat applications
- Enabling complex missions with cubesats:
  - Mission Analysis & GNC & IP
  - OBSW
  - Ground segment
  - FPGA programming and powerful processor use (SDR in particular) for Image processing, GNSS & GNC
- Applying expertise & technologies traditionally used for larger missions with cubesat and microsats

Thank you

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INNOVATING SOLUTIONS