POLITECNICO
MILANO 1863

HERMES SP

Scientific Workshop, November 18-19, 2020

H.E.R.M.E.S.

High Energy Rapid Modular Ensemble of Satellites

Spacecraft

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The overall project fundamentals

- **Scientific goal** → accurate and prompt localisation of ***bright hard X-ray/soft γ-ray transients*** such as γ-ray bursts (GRBs)

- **Technological goal** → implementation of a ***fractionated space assets*** by means of ***small satellites*** to:
  - Provide ***short time*** to orbit
  - Provide agility and mission **flexibility**
  - Contain **costs**

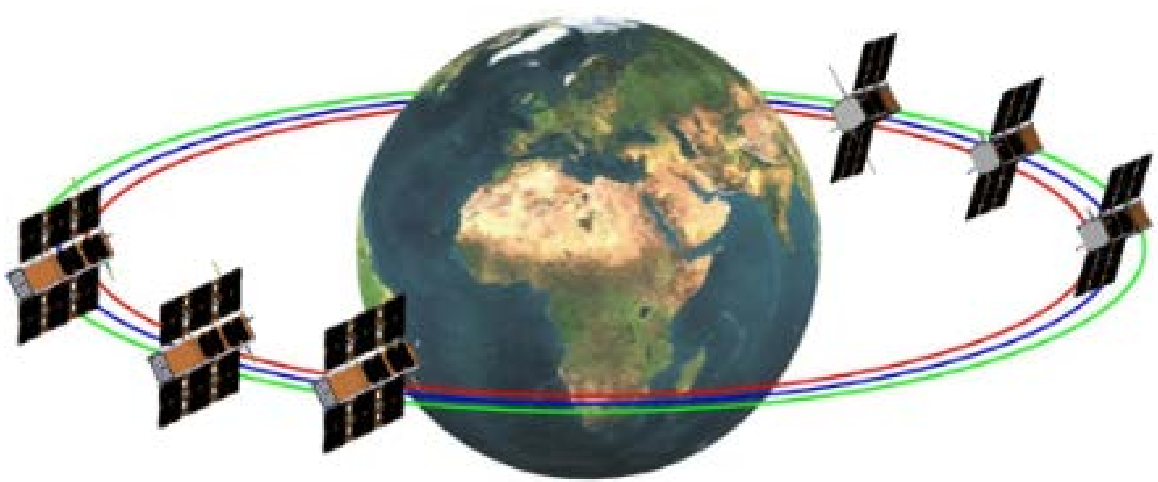
The mission architecture

Service Module

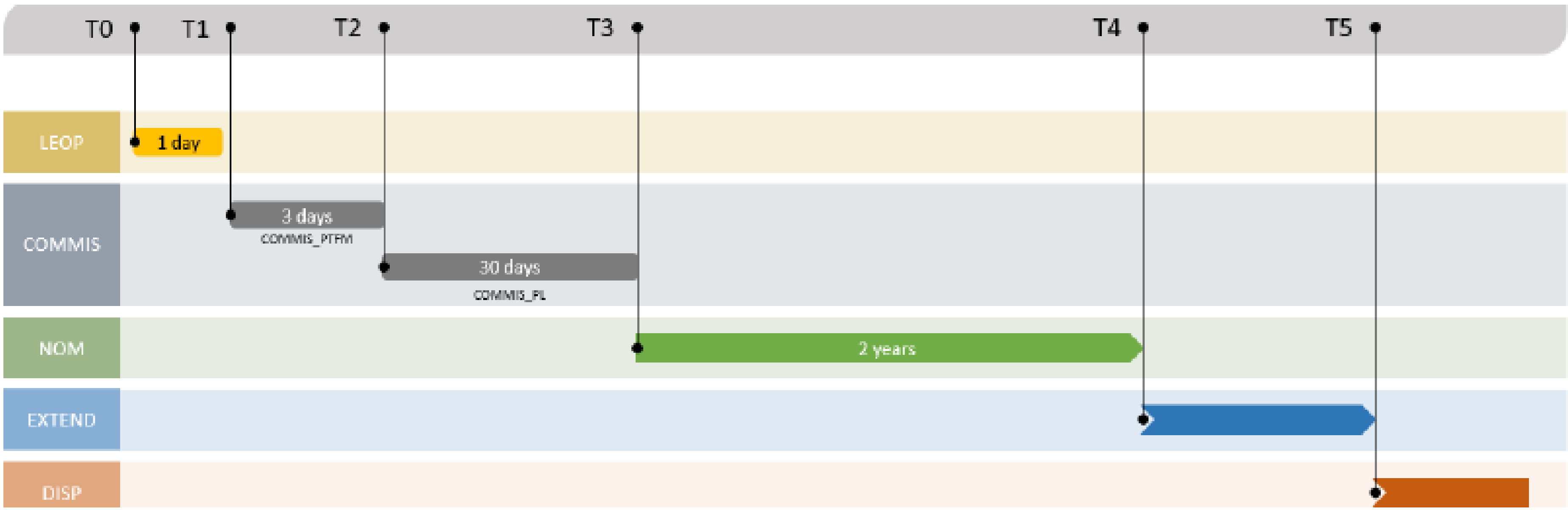
Constraints

- Triangularisation→ ***sats triplets***
- Fast comms
- large data volume
- control authority needed
- limited cost

→ ***6 - 3U form factor cubesats class***



The on orbit timeline



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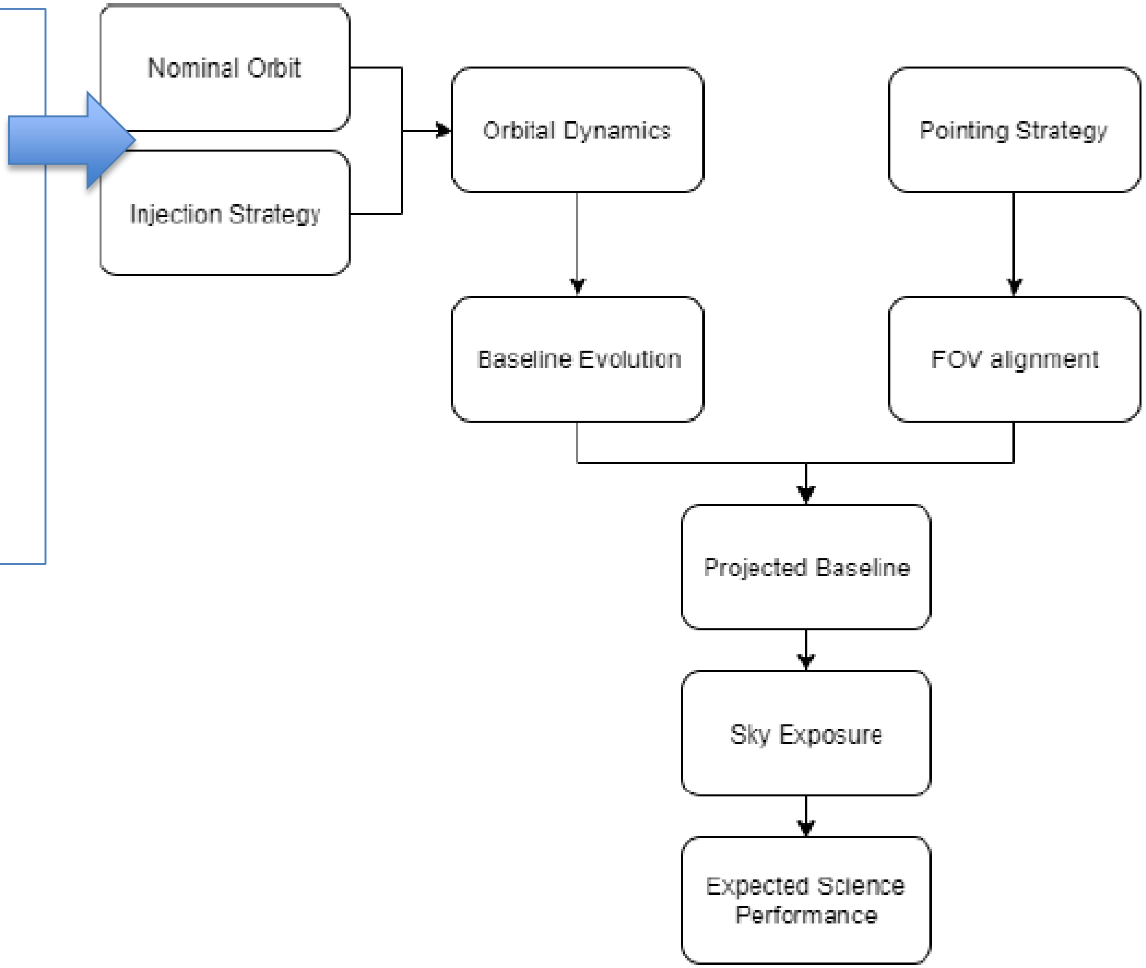
Sizing the orbits

Mission Analysis

The mission analysis logic

The baseline trajectory design shall consider:

- 6 satellites in ***loose formation***
- ***Co-pointing*** requirements for GRB localisation
- Payload ***sensitivity to environment***
- ***No CoM control*** on board



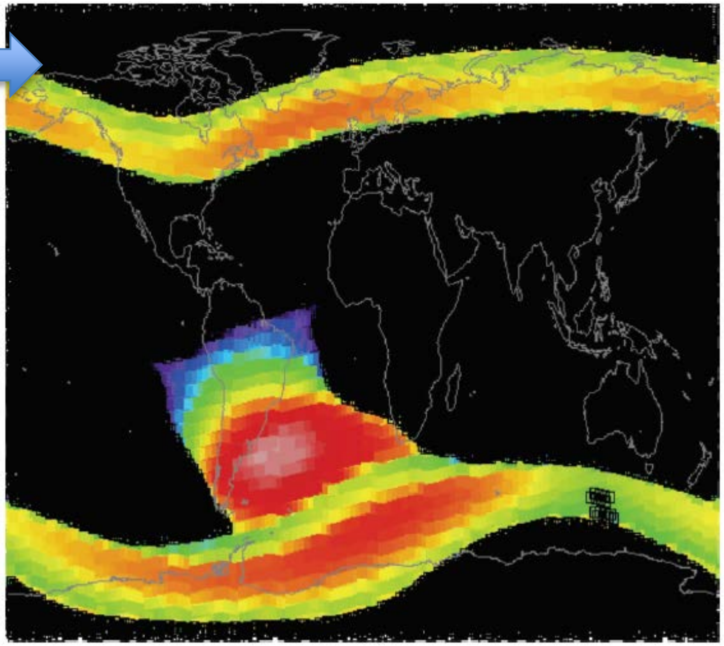
Orbit selection- tradeoff

Polar and South Atlantic Anomaly forbidden

Continuous sky survey *(galactic center avoidance)*

0<Orbit plane inclination<20 deg; >70deg

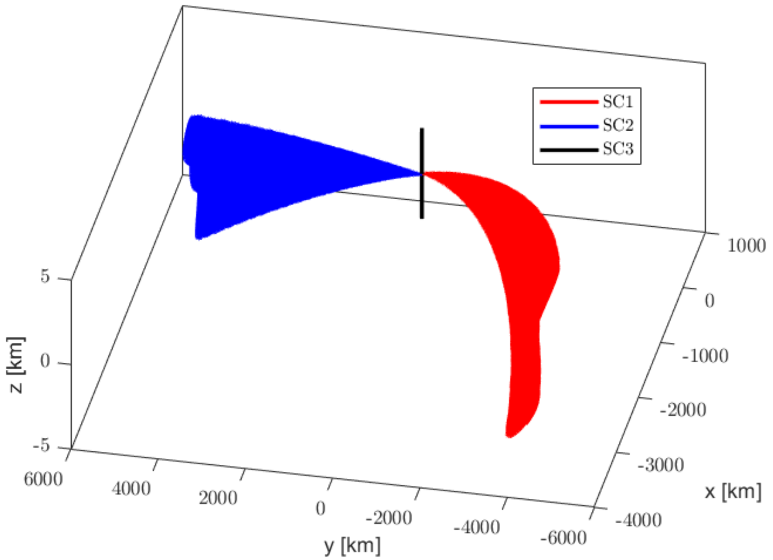
Orbit altitude<600 km



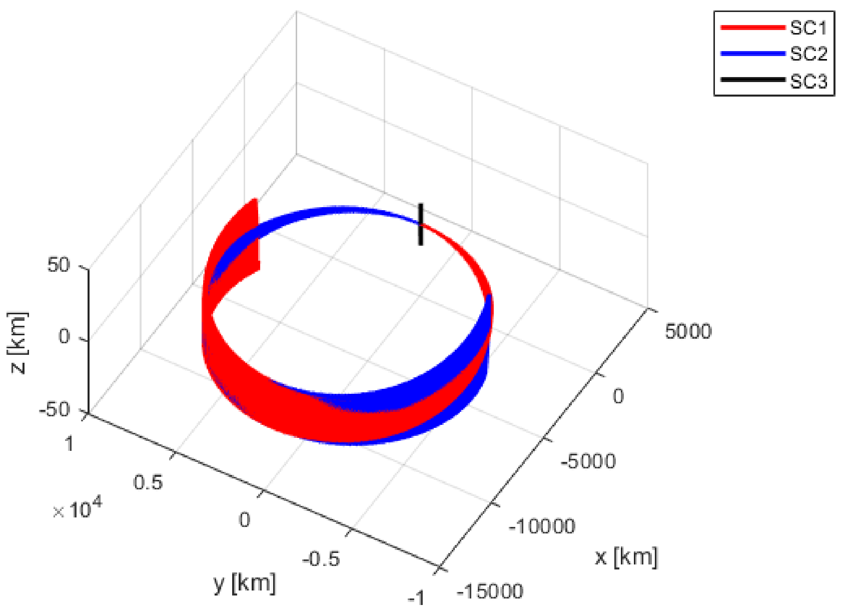
parameter	LEO equatorial	Sun Syncronous
Height (km)	500-550	
Eccentricity	0 (circular)	
Inclination (deg)	0	98
RAAN (LTN)	-	6am/12am

Orbit selection – triangularisation: FF natural evolution

Baseline natural drift evolution: 3 days to D=1000km



Baseline natural drift evolution log term



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Sizing the orbits

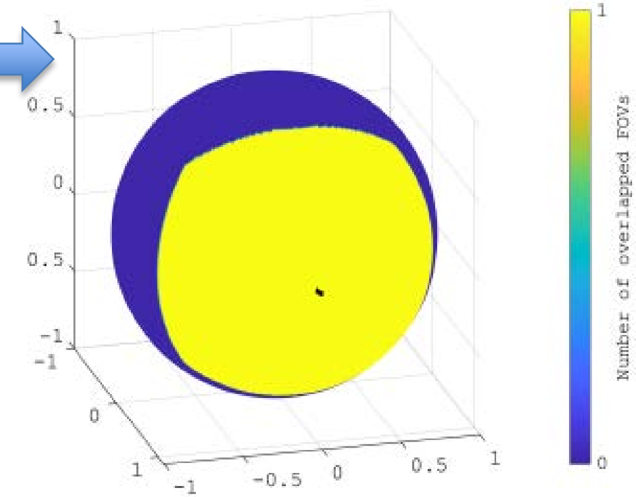
Mission Analysis – FF & poiting strategy

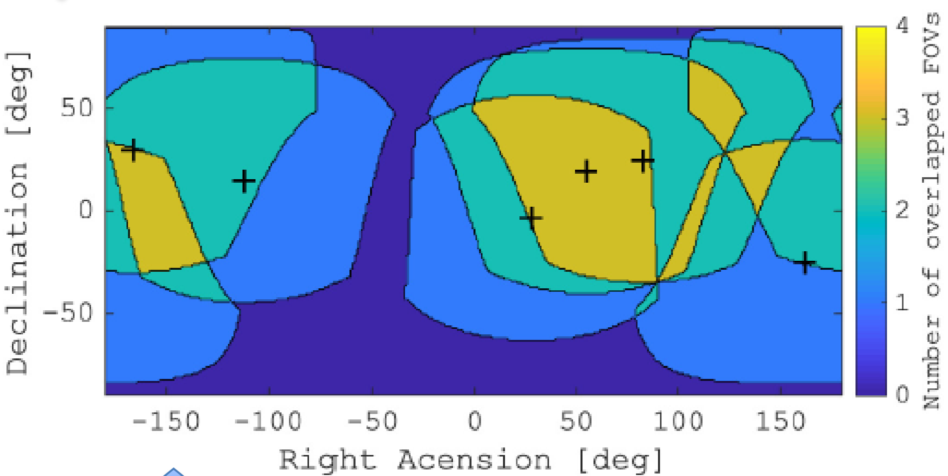
Orbit selection – FOV & triangularisation

Instrument FOV = 60 deg

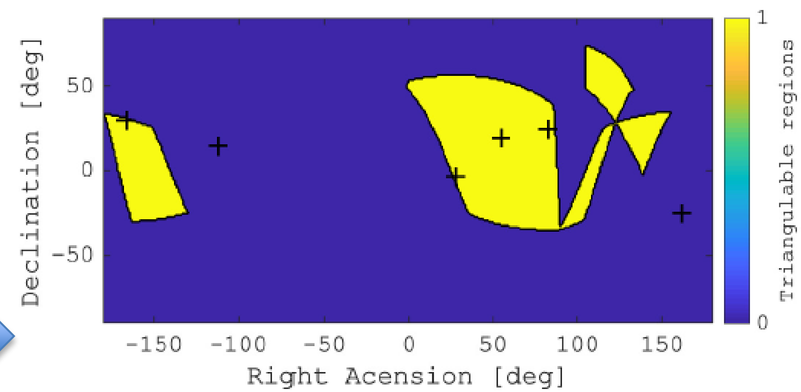
Min 3 sats simultaneous FOV <20 deg

Baseline>420 km





6 s\c active

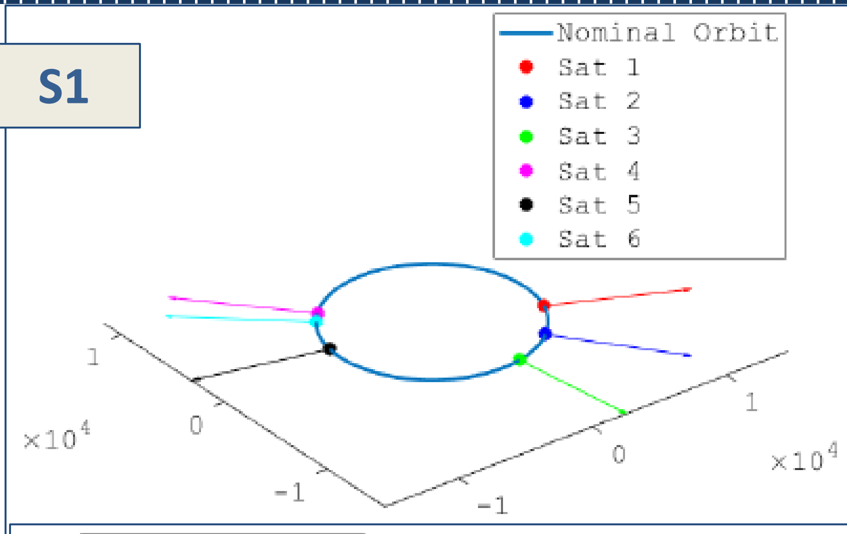


Orbit selection – triangularisation: pointing strategy

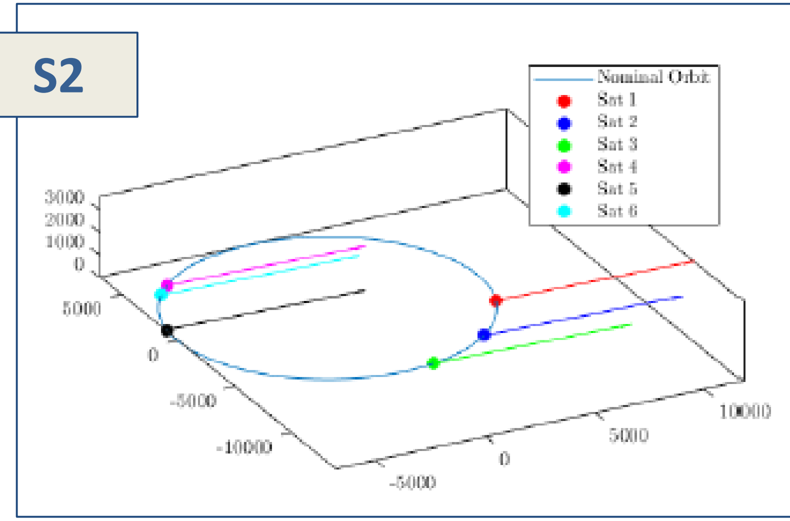
1. ***Zenith pointing for each payload LoS***
   - No maneuver required
   - Earth in the field of view→shadowing
2. ***Co-alignment of n 3 payload LoSs on an Inertial-selected direction***
   - maneuvers required
   - Earth in the field of view→shadowing
3. ***Co-alignment of n 3 payload LoSs on a LVLH-selected direction*** (i.e. LoSs aligned on the zenith direction of a specific satellite in the fleet).
   - Reduced maneuvering required
   - Sun\galactic center in the field of view
4. ***Co-alignment of n 3 payload LoSs on a LVLH-optimized direction*** (i.e. LoSs aligned on a optimal direction, defined in the LVLH frame, selected and computed on-ground).
   - Optimized field of view
   - Sun\galactic center easy avoidance
   - Maneuvering required

Orbit selection – triangularisation: pointing strategy

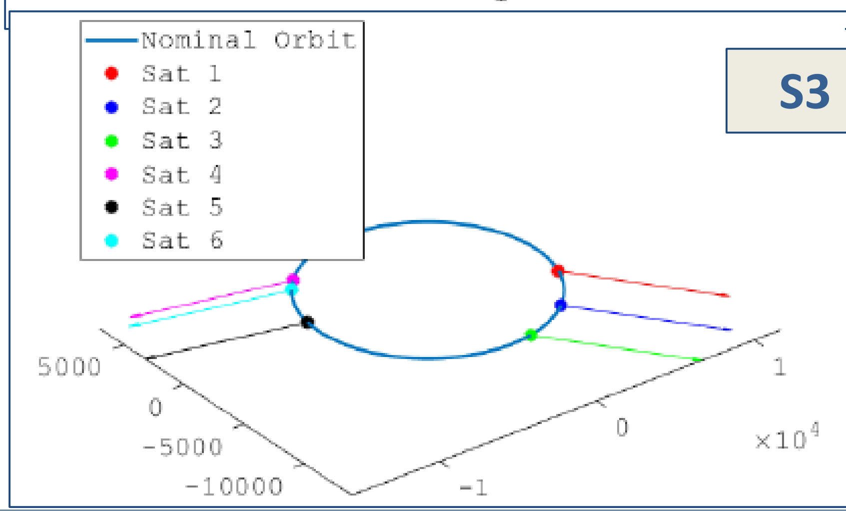
S1



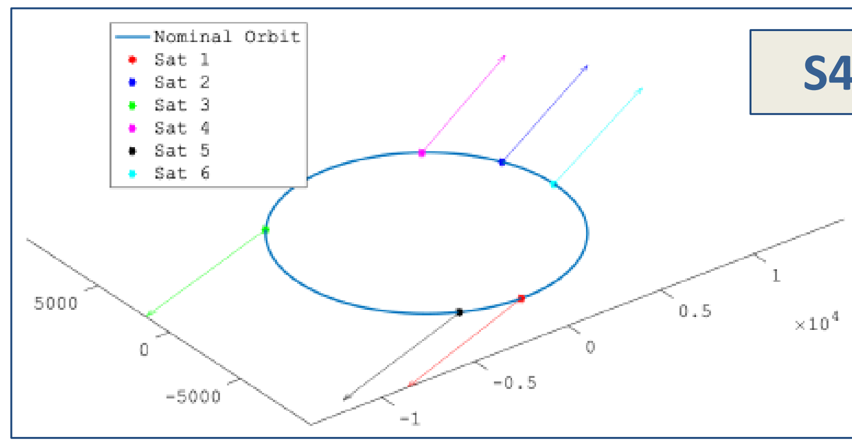
S2



S3

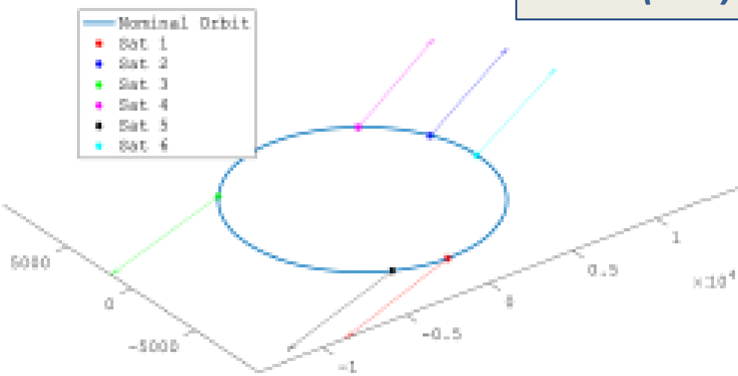


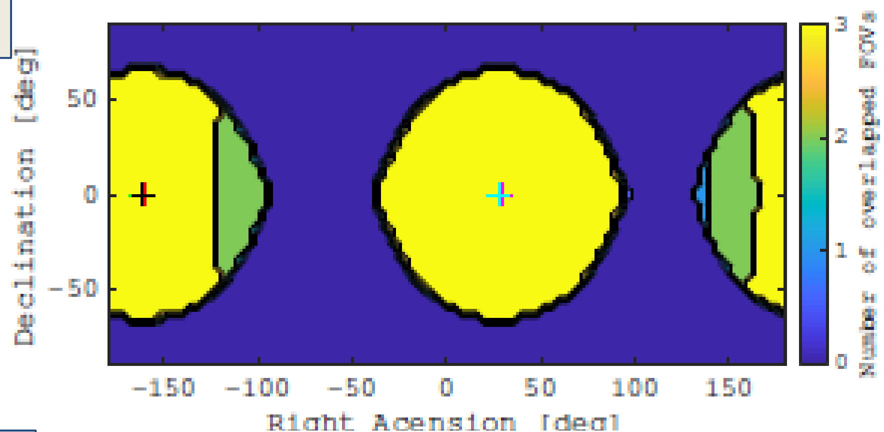
S4



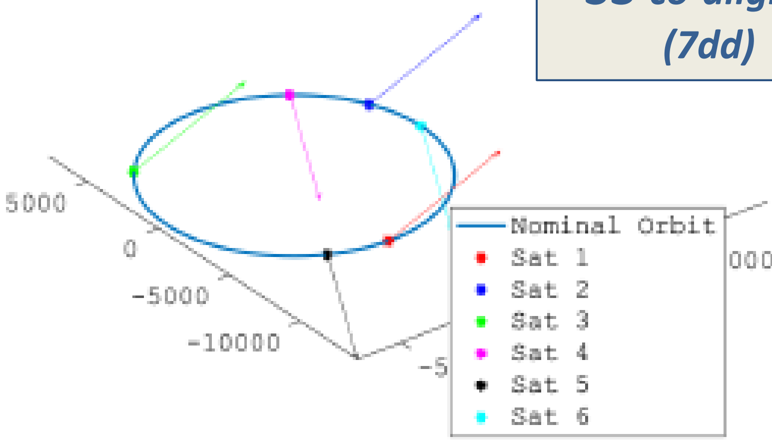
Orbit selection – triangularisation: pointing strategy 4

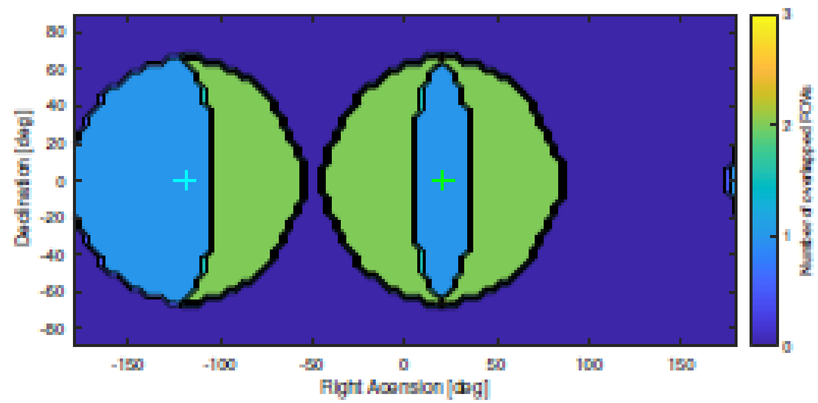
S4-optimized* *(7dd)





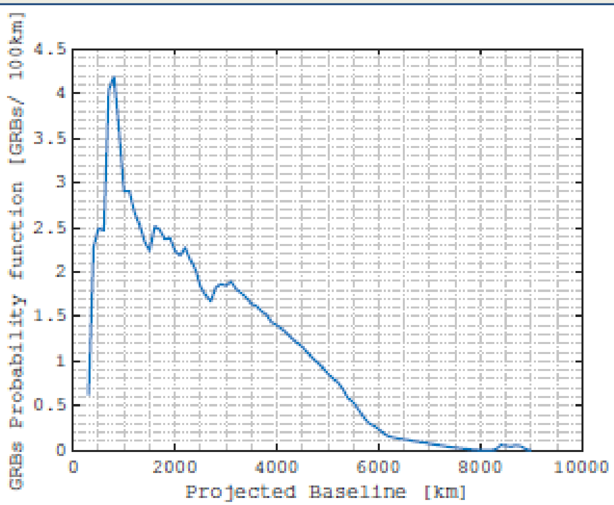
S3-co-aligned* *(7dd)

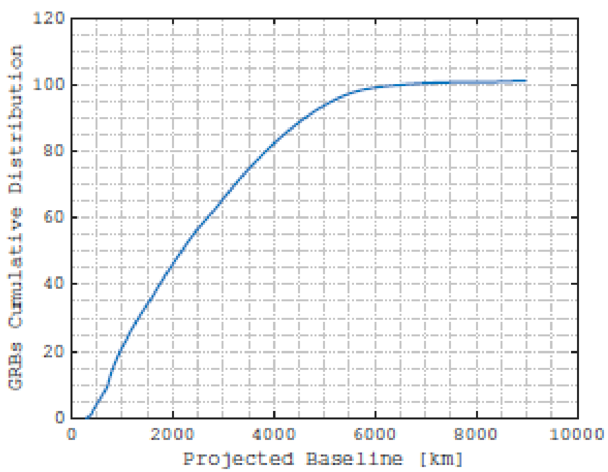




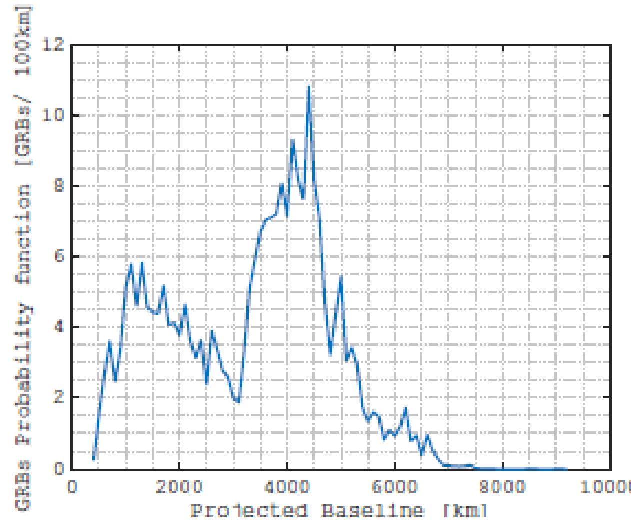
Baseline evolution with pointing strategy

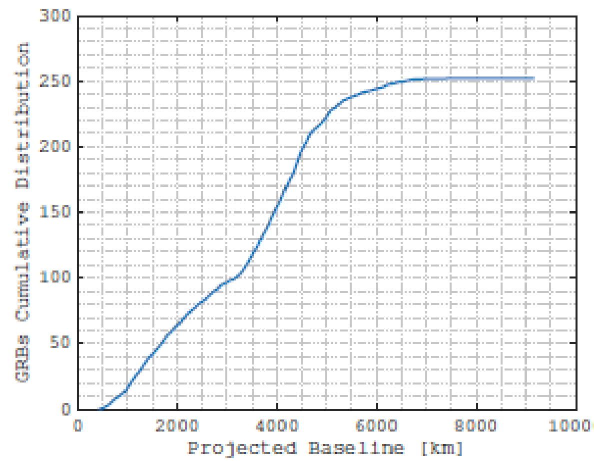
S3 – baseline evolution





S4 – baseline evolution





Baseline evolution with pointing strategy summary

Case			Results			
S/C [-]	h [km]	Strategy	μ [GRB]	3σ [GRB]	SE_μ [GRB]	SE_σ [GRB]
6	500	*co-alignment*	120.26	13.6	0.14	0.09
6	550	*co-alignment*	124.19	15.86	0.16	0.11
3	500	*co-alignment*	49.67	8.7	0.19	0.13
3	550	*co-alignment*	52.11	8.8	0.19	0.13
6	550	*optimized*	234.80	57.03	1.94	1.39
5	550	*co-alignment*	82.02	15.08	0.34	0.24
5	550	*optimized*	135.48	13.29	0.40	0.28

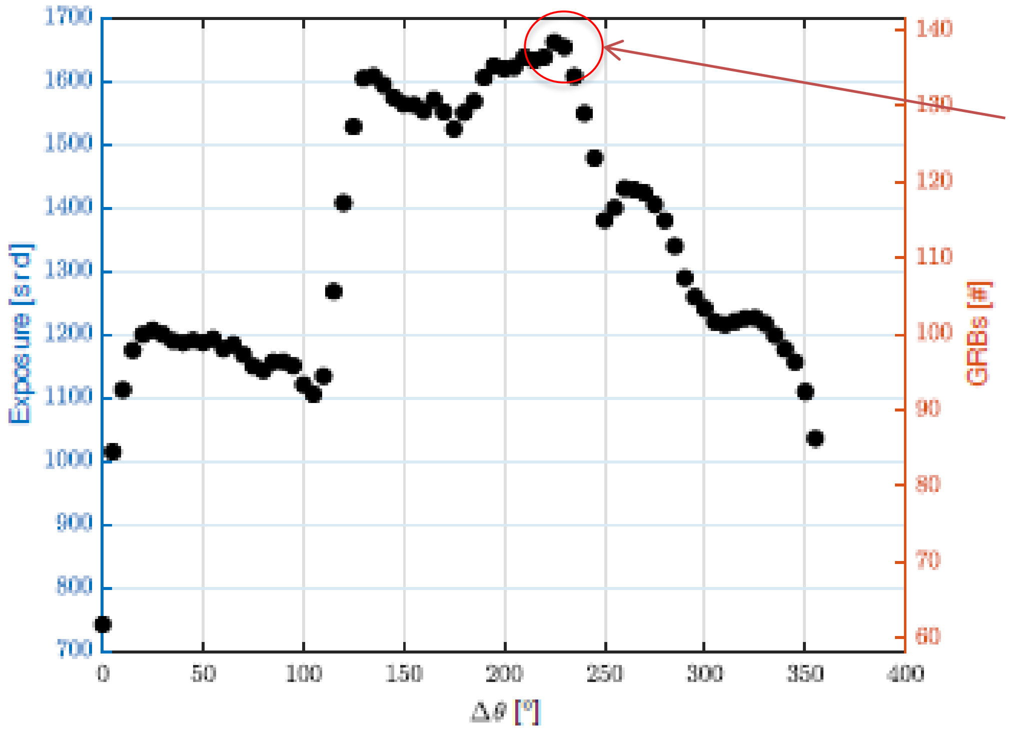
Sizing the orbits

Mission Analysis – orbit injection strategy

Orbit selection – sensitivity to on orbit insertion

Launcher's injection conditions of the 6 s\c are

fundamental for the FF\constellation evolution



Best angular separation between triplets at insertion
→ $\Delta\theta_0$=220 deg

Sizing the orbits

Data transfer & Nav

TTM&TC requirements and design synthesis

Scientific requirements on scientific data transfer

***GRB early warning*: communication relay network**

- ***Short burst of data at request*** (generally outside comm window).
- ***Max 30 min latency***

Possible solution →Intersatellite link required

- Not practically achievable by the HERMES constellation until HERMES-CC

  → Commercial network needed (Orbcomm, Globalstar, Iridium).

Adopted solution→ **IRIDIUM network:**

- Flight Heritage (TechEdSat missions)
- Low Data latency

TTMTC requirements and design synthesis

UHF/VHF link

- High reliability, flight heritage for CubeSat
- Omnidirectional, low datarate (~ 10 kbps), allows operation without ADCS poiting
- Baseline for **TC** in each phase and for **TM** in LEOP, Commissioning and Safe mode
- Can operate as a backup for scientific data (with reduced performances)

S-Band

- Flight heritage in CS market
- Low directionality (60 deg cone), still it requires slew maneuver
- Minimum datarate: 500 kbps, going up to ~2000 kbps
- Baseline for **P/L** data and for **TM** in nominal phases after Commissioning.
- Can act as a backup for **TC**.

Attainable data volume dumping/dd→1237 Mb/dd

TTMTC requirements and design synthesis

GS	Latitude (deg)	Longitude (deg)
Malindi	-2.995713889	40.19495556
Katherine	-14.3755	132.152

GS	Malindi	Katherine	Malindi + Katherine
Mean contact duration (min)	10.25	6.48	16.73
Number of passages per year	5146	5146	5146
Mean revisiting time	102.15	102.15	102.15
Mean comm-free time	91,9	95,67	67,72
Cumulative time with 1 sat in visibility	143.26	107.93	251.19
Cumulative time with 2 sat in visibility	32.55	13.51	46.06
Cumulative time with 3 sat in visibility	3.79	1.35	5.14

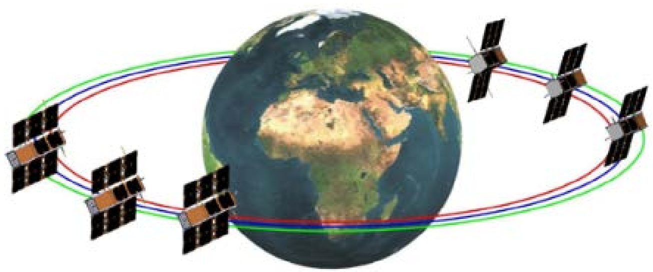
Always

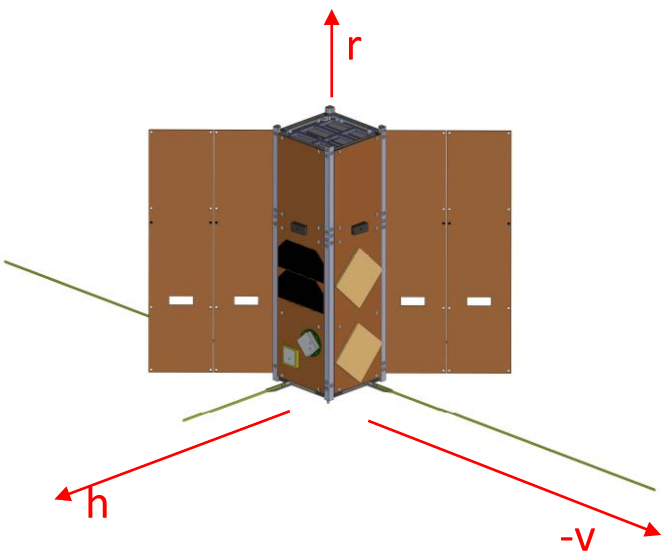
Only eclipse

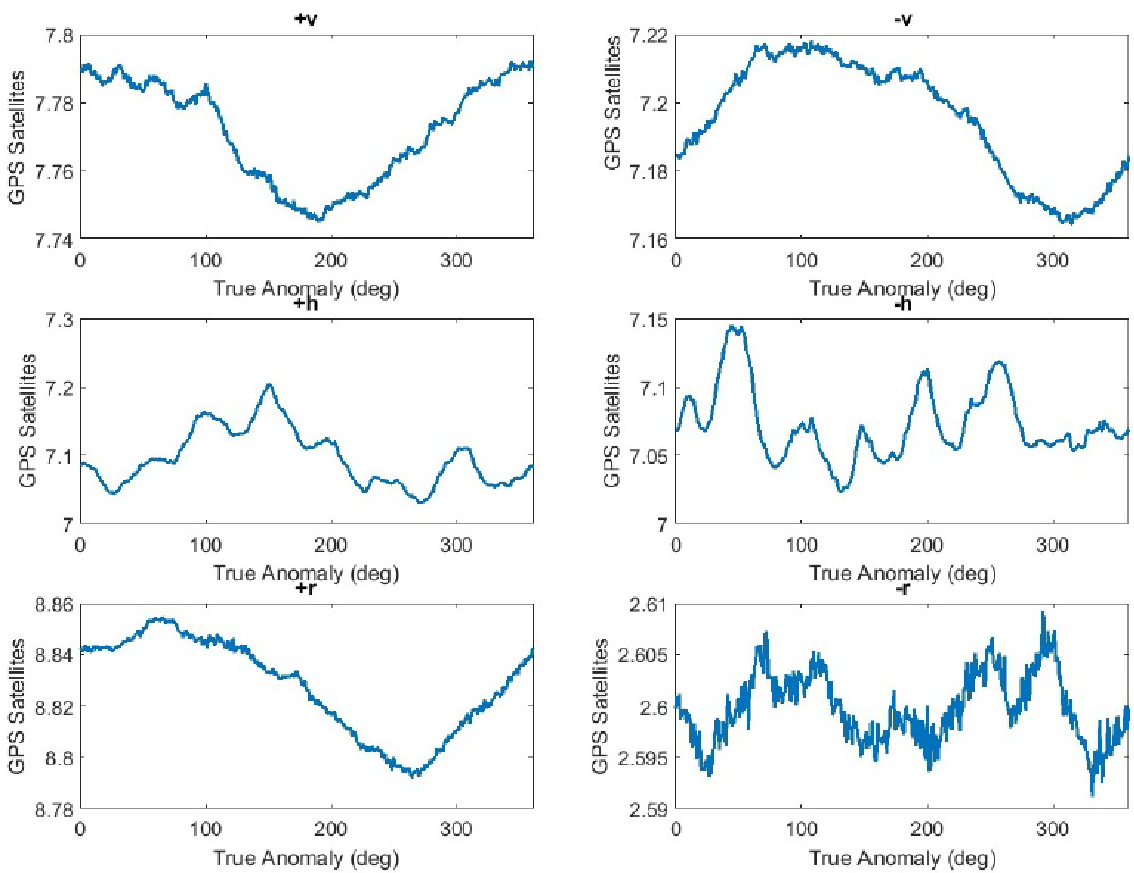
GS	Malindi	Katherine	Malindi + Katherine
Mean contact duration (min)	10.25	6.48	16.73
Number of passages per year	1891	1891	1095
Mean revisiting time shadow/sunlight	102.15/1013	102.15/1013	102.15/1100
Mean comm-free time shadow/sunlight	91,9/1000	95,67/1000	67,72/1100
Cumulative time with 1 sat in visibility	55.11	40.30	56
Cumulative time with 2 sat in visibility	10.96	4.71	9
Cumulative time with 3 sat in visibility	1.24	0.45	1

Orbit selection – GPS visibility

of GPS sats in view







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Sizing the platform

Attitude determination & Control

Pointing performance – attitude system sizing

Performance	Value
APE	5 deg
ARE	0.1 deg/s
AKE	3 deg
Positioning	30 m
Jitter	$<$1 deg
Agility	$>$100 deg in 600s
Stability	6dB and 30deg stability margins

Component	unit	COTS/ Custom
IMU	1	COTS
GYROSCOPE 3 axis	1	*COTS*
GPS	1	COTS
MAGMTR 3 axes	1	COTS
SUNSENSOR fine	4	COTS
SUNSENSOR coarse	12	COTS
IMU	1	
MTORQ	3	COTS
Reaction wheels	4	COTS
TOTAL ADCS		

ADCS Mode	MAGMTR	FSSXX	CSSXXX	IMU	MTORQ	RWL-ASM
Detumbling	ON	OFF	OFF	OFF	ON	OFF
Sun Pointing	ON	OFF	ON	ON	BACKUP	ON
Science Pointing	ON	ON	BACKUP	ON	ON	ON
Maneuvering	ON	ON	ON	ON	BACKUP	ON
Telecommunications	ON	ON	ON	ON	BACKUP	ON

Sizing the platform

Power Supply

Power supply architecture

OBS MODE - sunlit

Parameter	Value [W]
Battery recharge power demand	4.07
System power demand	13.36
Total power demand	**17.43**
Solar arrays generated power	**20.75**

OBS MODE – sunlit, man &comm

Parameter	Value [W]
Battery recharge power demand	4.65
System power demand	13.36
Total power demand	**18.01**
Solar arrays generated power	**20.75**

OBS MODE – sunlit, man&comm in eclipse

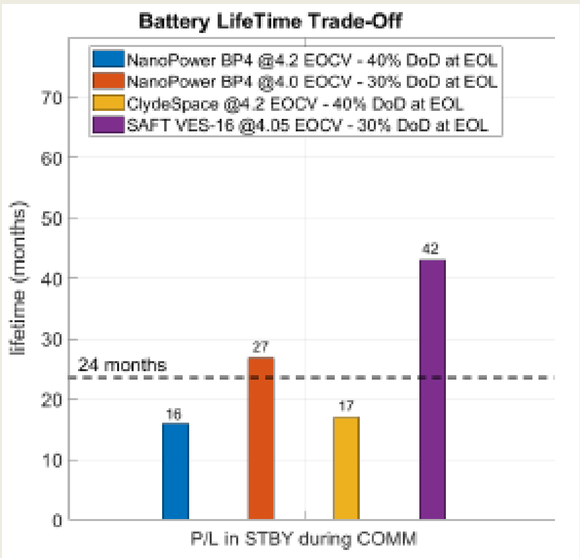
Parameter	Value [W]
Battery recharge power demand	4.41
System power demand	13.36
Total power demand	**17.50**
Solar arrays generated power	**20.75**

LEOP– charging battery

Parameter	Value [W]
Battery recharge power demand	11.21
System power demand	5.83
Total power demand	**17.43**
Solar arrays generated power	**25.00**

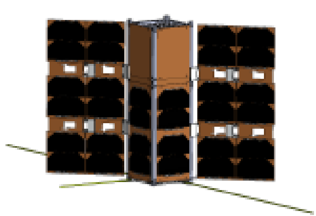
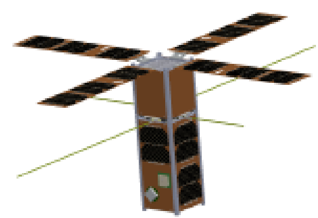
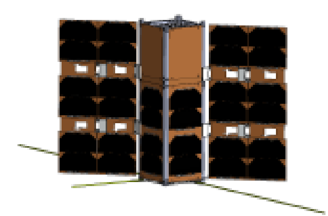
Orbit	Battery cycles	Max duration [min]
Equatorial	11030*	36
SSO	4500**	23

Battery critical trading off



Power supply architecture

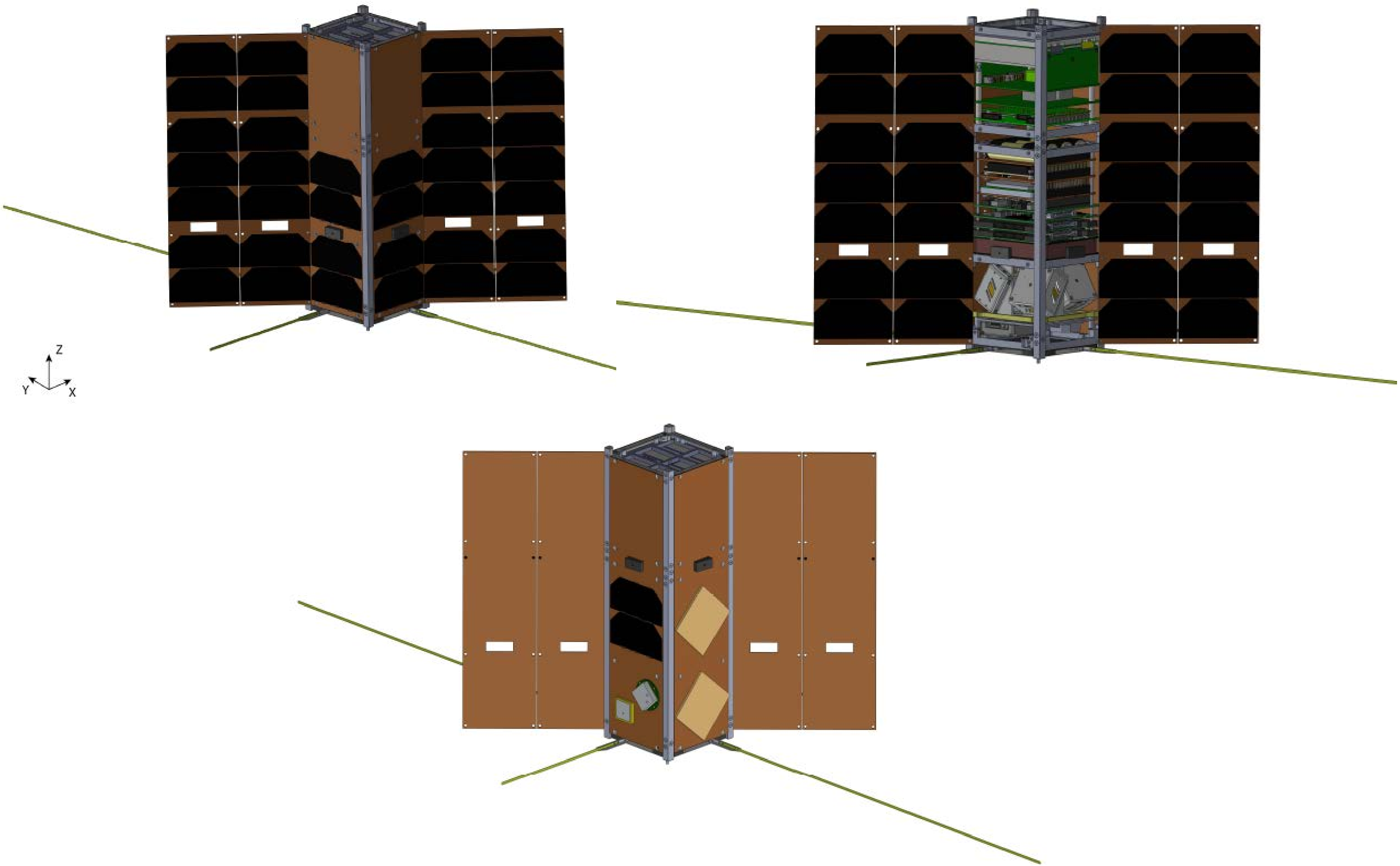
1. **Equatorial orbit** with Inertial Pointing - Wing Panels.
2. **Equatorial orbit** with Zenith Pointing: Petals Panels.
3. **Equatorial orbit** with Zenith Pointing: Wing Panels.
4. **SSO orbit** with Inertial Pointing: Wing Panels.

	Case 1	Case 2	Case 3	Case 4
				
Mean Generated Power in light [W]	33.3	17.2	25.0	30.0

Sizing the platform

Assembly

Space segment baseline configuration



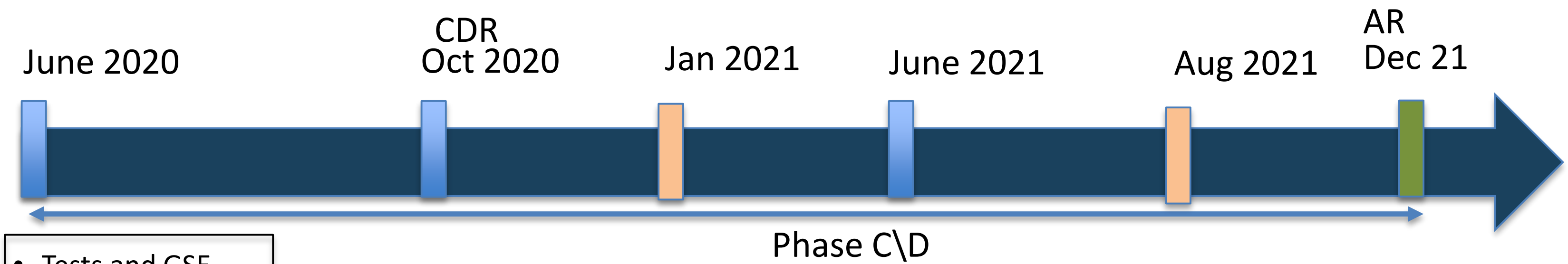
Mass budget

Name	Description	V	Mass [g]	M%	M.Mass [g]
PFM/FM0 (with system margin)					7281.5
System margin				10%	
PFM/FM0	Hermes SP Proto-Flight Model		6035.2		6619.5
STR	Structure and Mechanisms		343.0		380.6
STR-PRM	Primary Structure		310.0	10%	341.0
STR-SUP1	IMU/Iridium support		33.0	20%	39.6
EPS	Electric Power System		1649.0		1911.5
DOCK-EPS	EPS docking board		80.0	5%	84.0
ACU	Array Conditioning Unit		54.0	5%	56.7
PDU	Power Distribution Unit		57.0	5%	59.9
W-SArray-ASM	Wing Solar Array Assembly		700.0	20%	840.0
B-SArray-ASM	Body-mounted Solar Array Assembly		500.0	20%	600.0
BATT	Battery Assembly		258.0	5%	270.9
ADCS	Attitude Determination and Control System		1188.0		1289.0
DOCK-ADCS	ADCS Docking Board		64.0	5%	67.2
OBC-ADCS	ADCS Controller		24.0	5%	25.2
MAGMTR	Main Magnetometer		8.0	5%	8.4
GPS	GPS board		31.0	5%	32.6
MTORQ	3-axis Magnetorquers		156.0	5%	163.8
RWL-ASM	Reaction wheels assembly		830.0	10%	913.0
GPS-ANT	GPS antenna		50.0	5%	52.5
IMU	Inertial Measurement Unit (6DOF)		25.0	5%	26.3
TT&C	Telemetry, Telecommands, and Control		629.0		689.2
TR-SBAND	S-band transmitter		106.0	10%	116.6
ANT-S-TX	S-band antenna TX		136.0	10%	149.6
TRX-UHF	UHF transceiver		106.0	10%	116.6
ANT-UHF	UHF antenna		85.0	5%	89.3
IRD-MDM	Iridium modem		30.0	5%	31.5
IRD-ANT	Iridium antenna		10.0	20%	12.0
IRD-IF	Iridium interface board		20.0	20%	24.0
ANT-S-RX	S-band antenna RX		136.0	10%	149.6
OBDH	On-Board Data Handling		97.0		110.7
OBC-MAIN	Main OBC module		57.0	10%	62.7
IF-BRD	Interface board		40.0	20%	48.0
TCS	Thermal Control System		5.0		5.3
PNT-ARGLZ	Paint payload panels		5.0	5%	5.3
HARNESS	Platform harness		545.0	20%	654.0
SCI-PL	Scientific Payload		1579.2	0%	1579.2

Timeline

The mission development plan

All 6 satellites development\assembly & acceptance tests run @PoliMI-DAER labs



- Tests and GSE setup
- Procurement
- SW development

- p/l integration and assembly testing

- Platform equipment testing
- Platform assembly/integration
- Platform testing
- p/l platform IF preliminary tests
- SW implementation\integration

•2-6 Platform assembly/integration
•2-6 Platform testing

- p/l integration and assembly testing

Launch is under discussion for Q2 2022

Final remarks

- **HERMES** represents an innovative approach to **perform space science** in terms of:
  - Exploitation of ***miniaturized*** new generation scientific ***payloads***
  - ***Enhancement of cubesat class performance*** & technology to cope with challenging operational requirements
  - ***New lifecycle paradigm*** with research centers and academy to cover from conceptual phase to flight

- **HERMES** s\c is applicable for **space exploration missions** for Moon and Asteroids mineralogy characterization
- **HERMES** ***Service Module*** is a general purpose platform which offers to PL:

  - 100x100x100 mm volume
  - 1.5 kg mass
  - 5 W power
  - 1Gb data/d