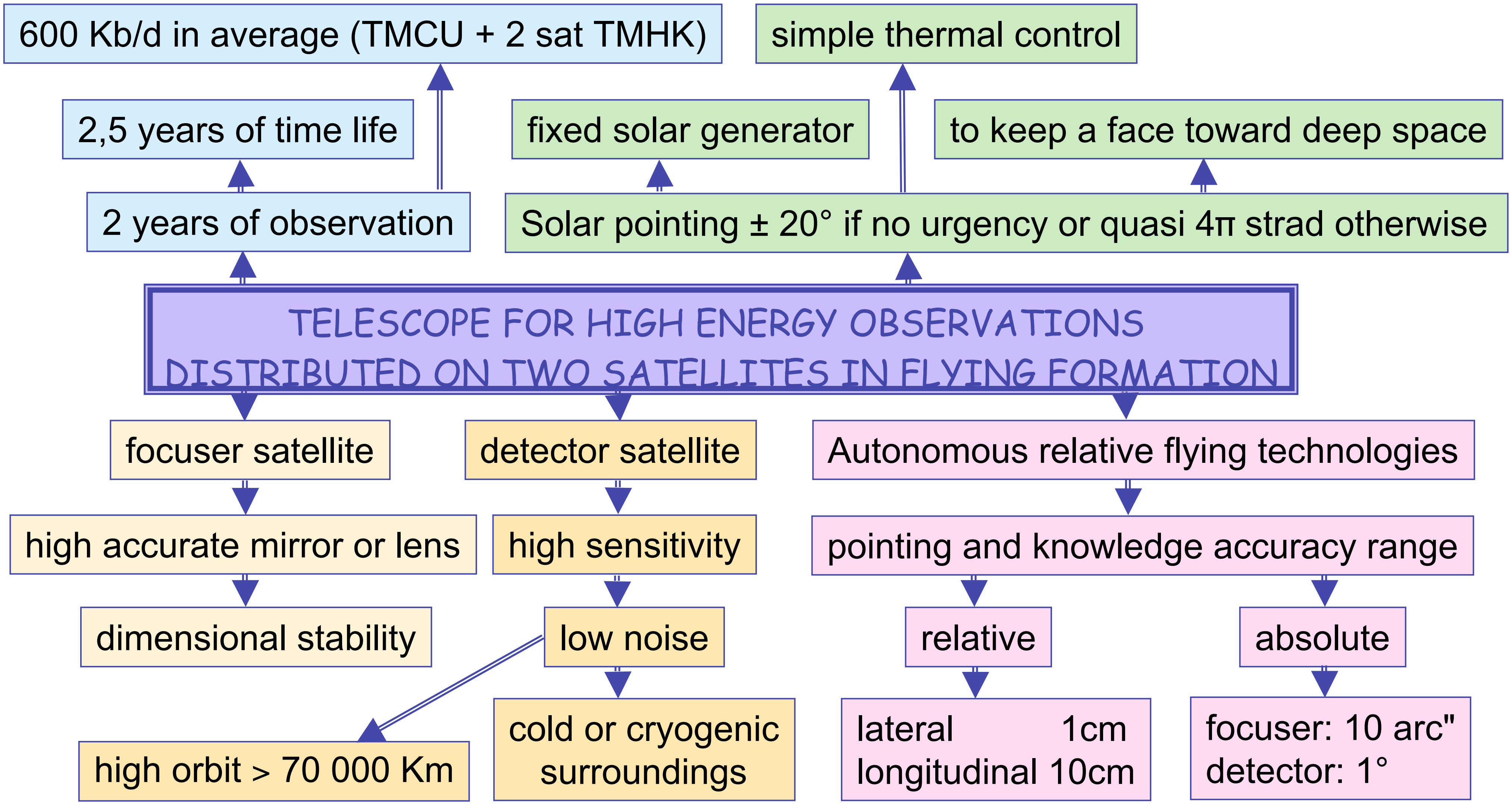
During the year 05 CNES has studied 4 Formation Flying missions
including 2 of them for High Energy Astrophysics : MAX and SIMBOL-X

Based on this background and from a pure technical point of view,
this report presents a lot of similarities between the two High Energy Astrophysics missions.

The major specificities come from the payload of course,
but here again, the engineering and technical solutions are the same.

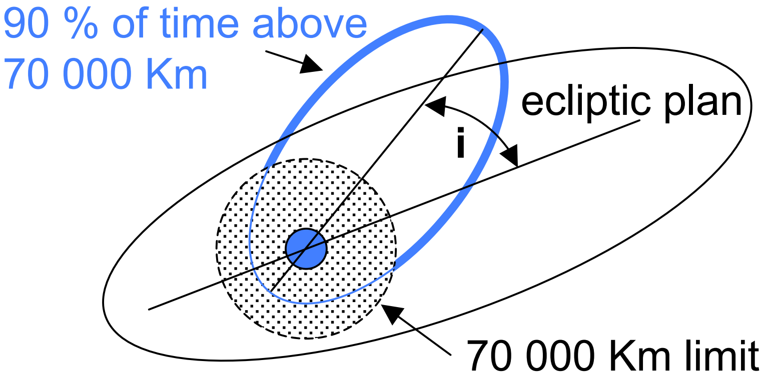
Summary:
- similarities of the scientific need
- same solutions for
  + orbit
  + communications
  + propulsion
  + formation flying
- payload specificities but same engineering treatment
  + detector
  + focuser
- resulting common architecture
- conclusion

BASIC MISSIONS: commonalities for technical aspects



ORBIT

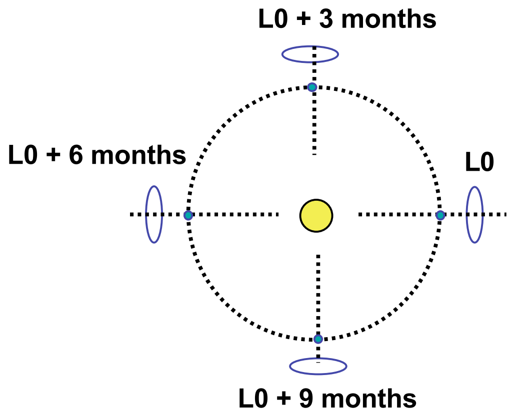
HEO: 7 sidereal days : apogee 253000 km
perigee 44000 km



i chosen for - eclipse and orbit control limitation
- launcher performance optimization

- easy to operate and easy coms
- large ΔV on board for
+ perigee ascent after Soyuz injection
+ more perturbations on FF

L2: **transfer duration: 4 months roughly**
positioning: 2 months
scientific orbit: Lissajous



- X band + MGA with pointing for coms.
- complicated to operate: L2 + FF

- much less energetic than a circular orbit above 70 000 Km
- same Soyuz launcher performance for both cases (for i=45° in HEO)

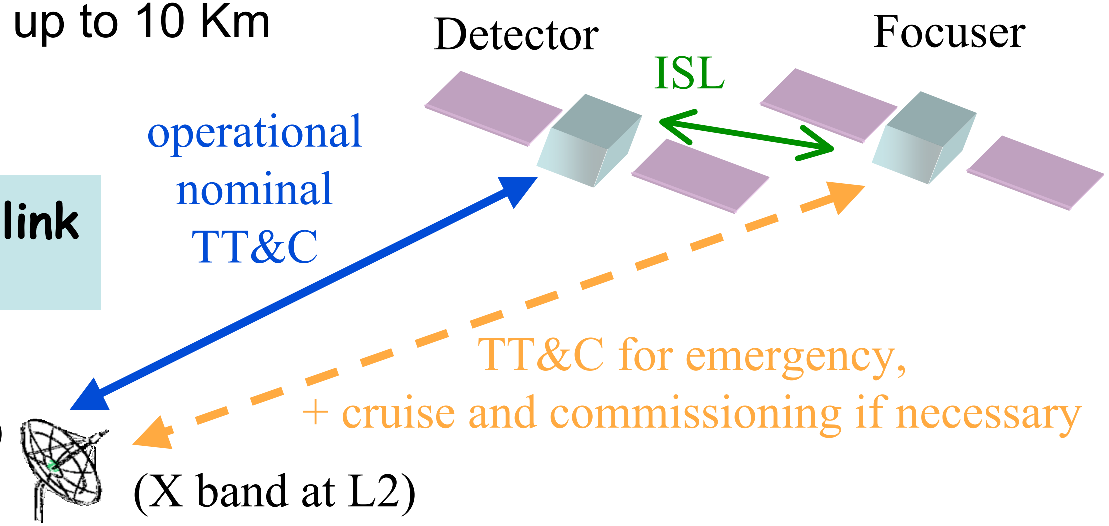
As a result the HEO is more accessible for these types of missions

COMMUNICATIONS

Data downloading - payload data only on detector satellite
- house keeping on both satellites + ranging

> ISL: Inter Satellite Link allows 10 Kb/s up to 10 Km
- GNC
- Focuser HK

> Only one Detector / Earth TT&C link in nominal operational case
- 2 sat HK
- payload data



with one ground station: on HEO > 24h high rate every 7 days and ≈ 12 h low rate every day
at L2: 8h low rate every day with X band and on board MGA

Because detectors are small with a low imagery capability, the amount of data is reasonable
⟹ The ground station capability can be reduced in time to save money

PROPULSION

Mission, operation and command/control need:
- satellites positioning and orbit maintenance mainly for ground station phasing
- on formation putting and anti-collisions maneuvers

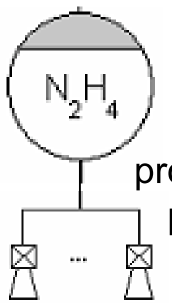
Scientific Mission need: repointing on different targets
- Focuser satellite attitude changing with reaction wheels and associated unloading thrusters
- Detector satellite follows the Focuser using different manouver strategies with thrusters

Formation Flying GNC need: Minimum Impulse Bit (MIB) = 0.5 to 1 mNs
with a good repetitiveness accuracy, independently on 6 DoF, only on Detector satellite

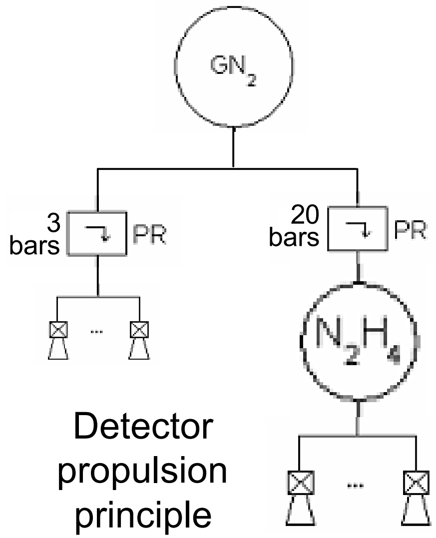
- Cold Nitrogen micro thrust propulsion is simple and really appropriate for this last need
- Higher Isp propulsion is better appropriate for all other needs: Hydrazine system, vs. bi propellant one, is sufficient and simple

<u>Consequence:</u>

- Only N2H4 system on Focuser satellite
- N2H4 and GN2 systems on Detector satellite



Focuser propulsion principle



Detector propulsion principle

FORMATION FLYING (autonomous relative flying)

THE NEED

Relative positioning : - lateral / LoS. :+/- 1 cm , knowledge : 0.5 mm (3'' LoS)
- longitudinal : +/- 10 cm

Detector attitude control: Pointing:1 degree with no Stability constraint

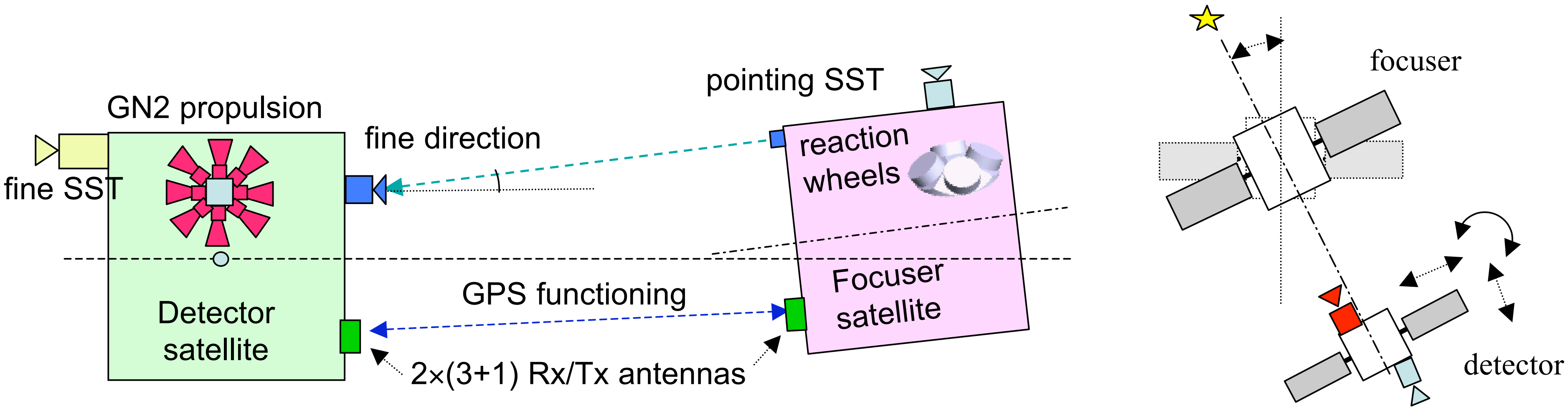
Focuser attitude control: Pointing:10 arcsec with no Stability constraint

SENSORS

- RF metrology with ISL : all formation maneuvers and first level of formation flying accuracy
- lateral sensor + star tracker with 1 arcsec accuracy range
- classical navigation SST for the focuser pointing

ACTUATORS

- reaction wheels for focuser pointing
- 8×10 mN GN2 thrusters for 6 DoF relative positioning control on the Detector



COLD OR CRYOGENIC SURROUNDING DETECTOR

small size and mass (focused signal)
slightly dissipative (front electronics beside)

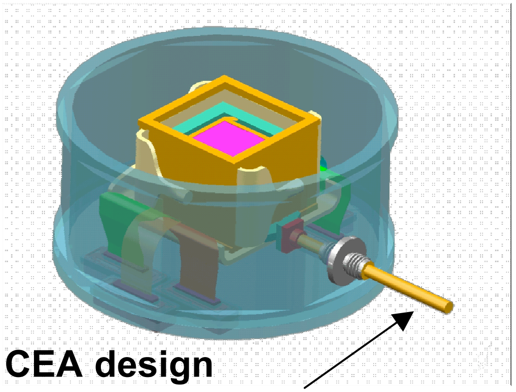
pointing allows a cold surface continuously facing deep space without any perturbation

allow a passive thermal concept

no coolers,
no mechanisms,
no vibrations,
no consumption

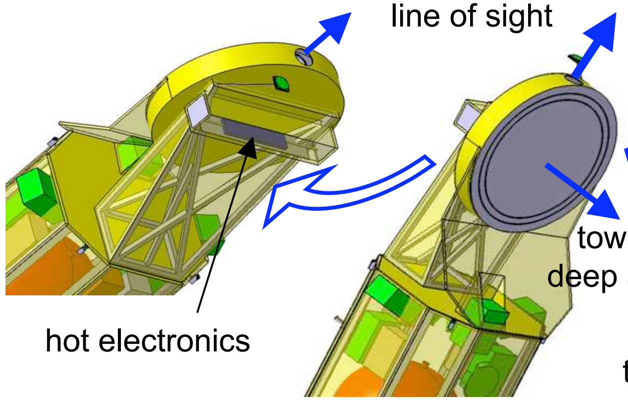
but very specific design for each case

cold detection

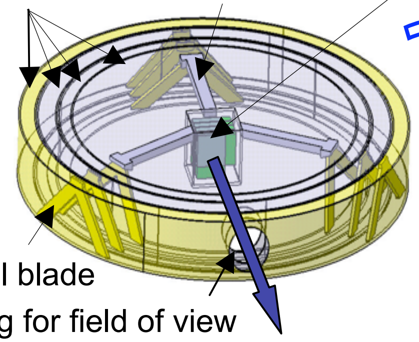


CEA design
heat pipe connected to a classical radiator

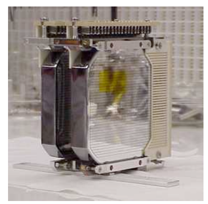
cryogenic detection



multi stages cryostat
with detection and pre amps

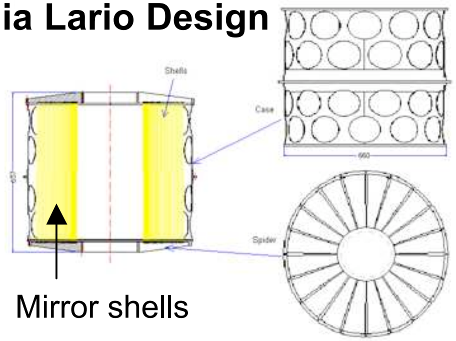


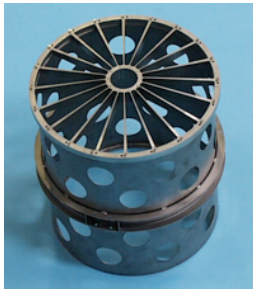
3 stages stripped
Ge detector



FOCUSERS DIMENSIONAL STABILITY

Media Lario Design

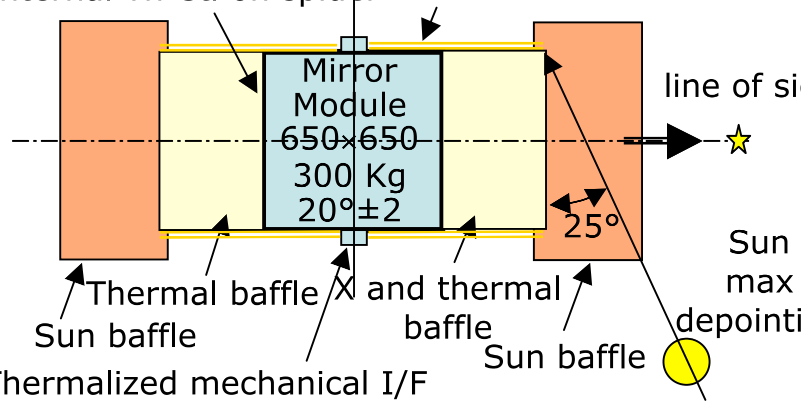




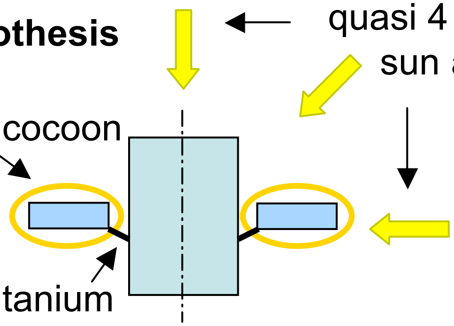
XMM background **thermal control: 20 ± 2°**

but here with 2 faces open toward deep space

working hypothesis



hypothesis



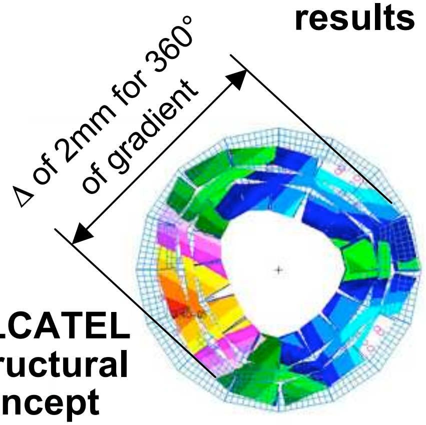
natural thermal behaviour

about 3 d° max gradient without lens thermal control

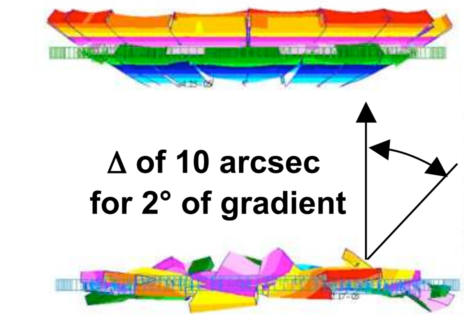
specification

2mm in plan, 0.1mm out of plan, 10 arc" crystal misalignment

results



ALCATEL structural concept



conclusion: thermal control: 20 ± 2°

ARCHITECTURE 1/2

The reliability degree of the system must be in accordance with the global cost of the mission. Because this cost is quite significant
(2 satellites, FF package and associated operations, complex payload, …),
the reliability of the global system must be quite high.

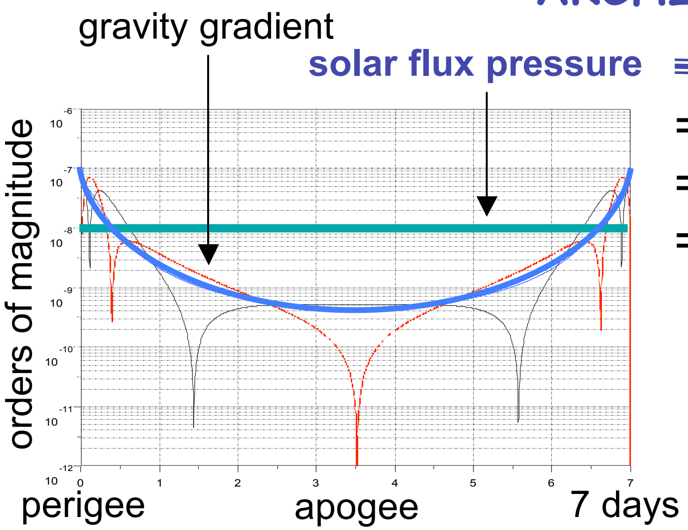
The base to consider is "no single point failure"

It means a complete level of redundancy for all equipments.
- for some of them, as the OBC for instance, It can be met with internal additional boards
- for GNC and propulsion, a perfect symmetric architecture between both satellites is possible

The command / control aspect is new for this type of mission
- sharing control between autonomy and ground for the 2 satellites management
- internal hierarchical organization to secure the failure modes and anti-collision management

Once established, it is the same for all these kinds of missions.

ARCHITECTURE 2/2



the Δ between both satellites must be minimized

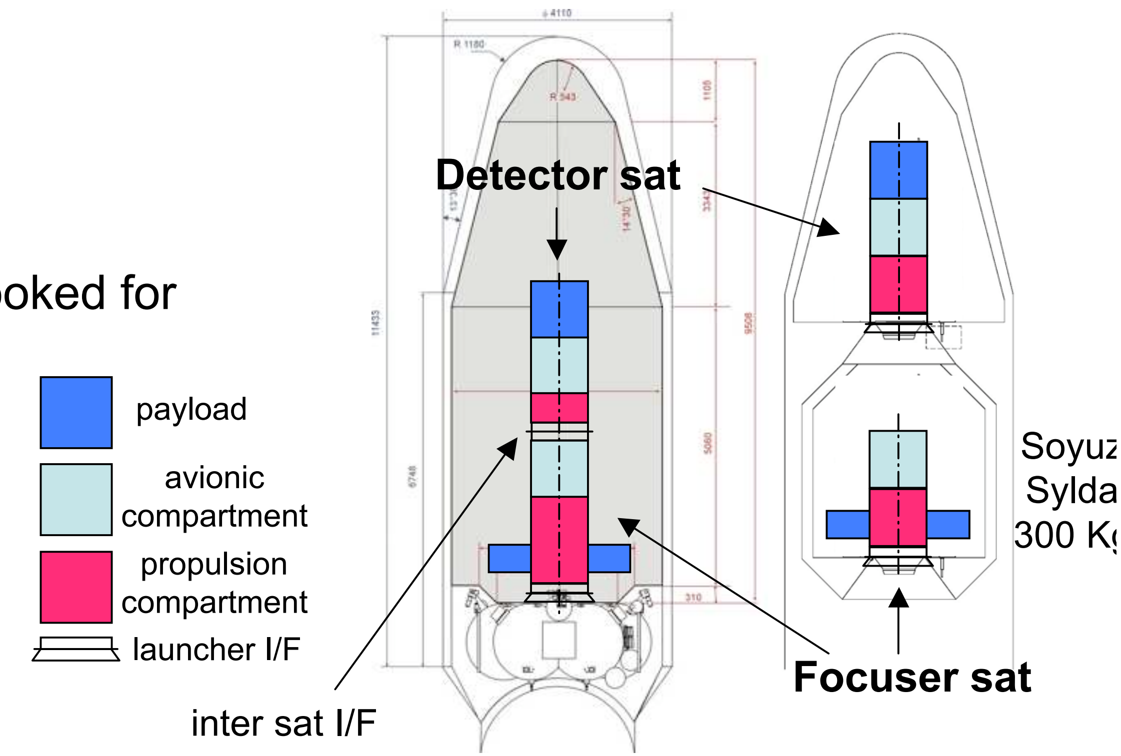
=> their ballistic coefficient must be as close as possible

=> same S / M and very symmetrical geometry

=> solar generator with 2 symmetrical wings

At last a modular accommodation is looked for

It allows the highest level of recurrence for each sub system including structure independently of the configuration for satellites and launch



CONCLUSION

The main conclusion is that it could be possible to imagine
a sort of common couple of spacecrafts which could be reused for different missions
as it was the case for XMM and INTEGRAL.

In the next stages, it could be interesting to take into account that point
during possible further activities in that field of space science.

An other point is that MAX and SIMBOL-X present a similar degree of complexity
which is not extremely high except the fact that Formation Flying is new.

Taken into account the previous comments,
the global cost of both missions could range between the half and the third
of the previous generation of missions.