Formation Flying for Astrophysics

SIMBOL-X : An X Ray Mission

~ [0,5keV – 70 to 80keV]

~ [1.2 10^{17}Hz – 1.7 10^{19}Hz]

~ [2480 pm – 17.7 pm]

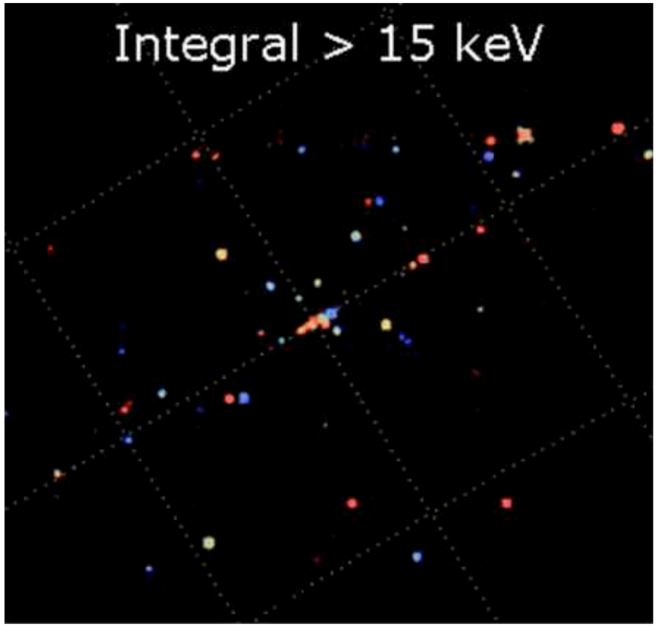
(Target Launch : 2012)

SIMBOL-X is one of the 4 formation flying astrophysics mission studied by CNES in 2005

Why hard-X rays ?

Non thermal emissions in X and γ rays are unique signatures needed to answer fundamental questions in modern astrophysics :

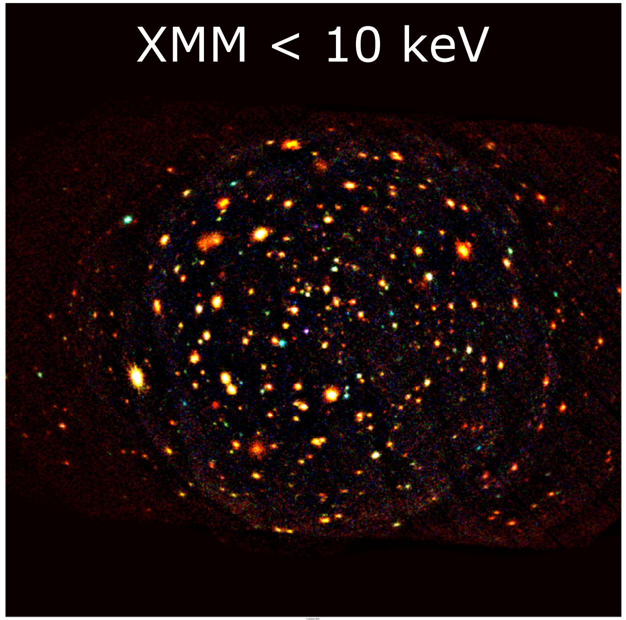
- How works the dynamics of the universe at all scales ? From star formation to cosmological large structure formation, this is driven by accretion power, particularly on Black Holes, and violent non thermal phenomena (as jets)
- How good are our physics laws in extreme conditions, of gravity, pressure, magnetic field ? Do we need new physics ?
- How and where are accelerated the cosmic rays at the highest energies ?



30 degrees

Why Simbol-X ?

Large FOV instruments have unveiled the richness of the domain, but insufficient for doing the physics, and for seeing obscured sources…

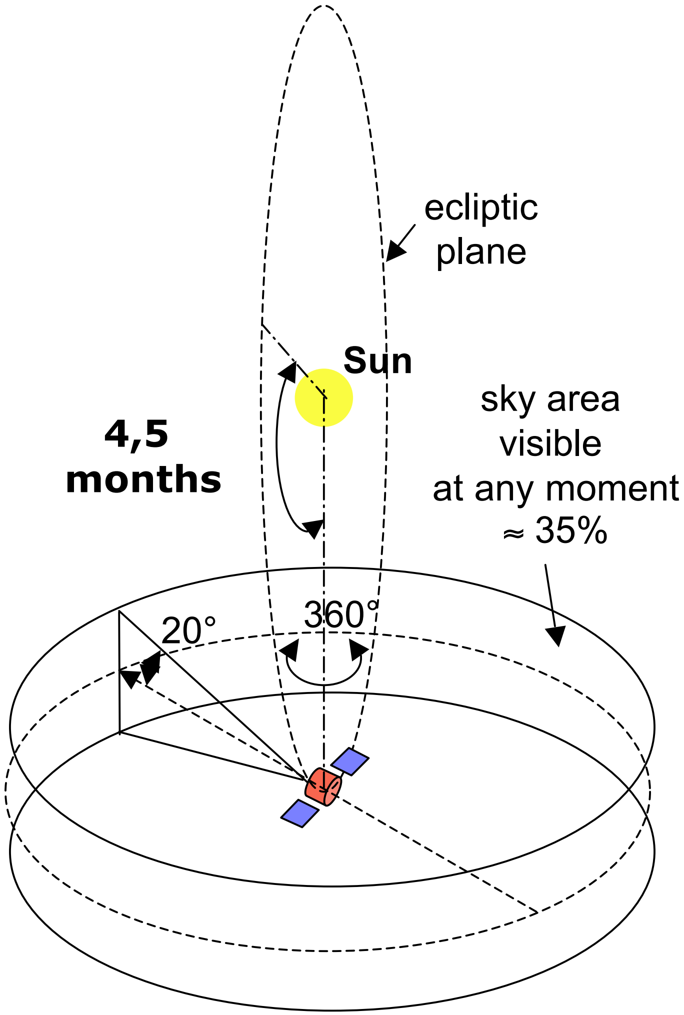


30 arcmin

Focusing (telescope !) revolution needed in hard X-rays, like was done in optical and soft X-rays, to get "astronomical" sensitivity and angular resolution, and have access to relevant dynamical scales…

Now feasible by extension of the soft X-ray optics to the hard band, thanks to the long focal length offered by the Formation Flight !

OBSERVATION AREA AND TECHNICAL CONSTRAINTS



Pointing type XMM and INTEGRAL:

allows a sun pointing:
- Fixed Solar Arrays
- Simplified Thermal Control

the celestial vault is scanned in 4,5 months (≈ 35% at any moment)

Minimal life duration : 2,5 years with 2 years for science

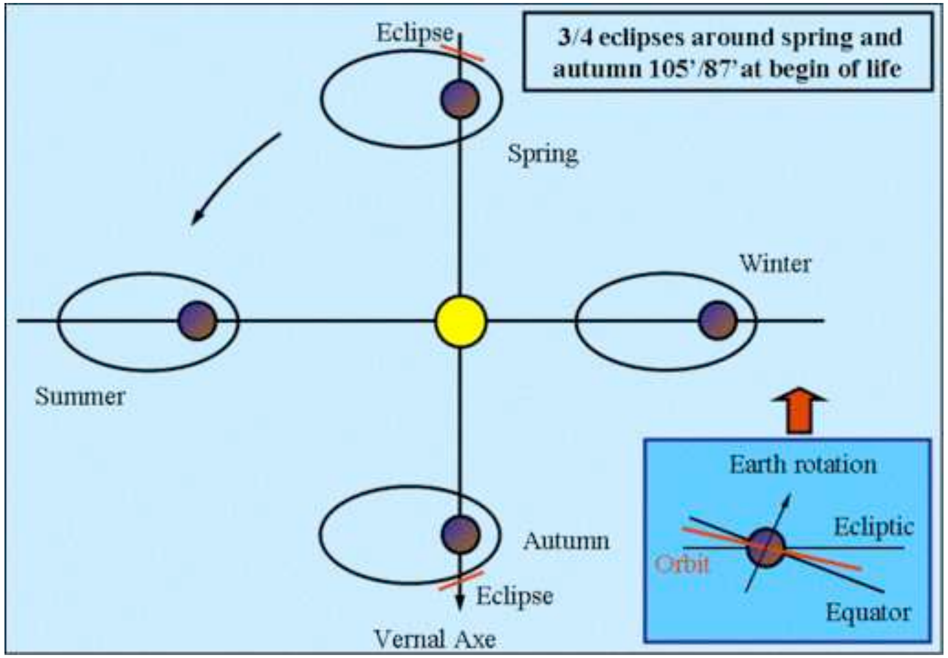
Scientific Orbit : 44 000 km / 253 000 km / 7 sidereal days / Low initial inclination

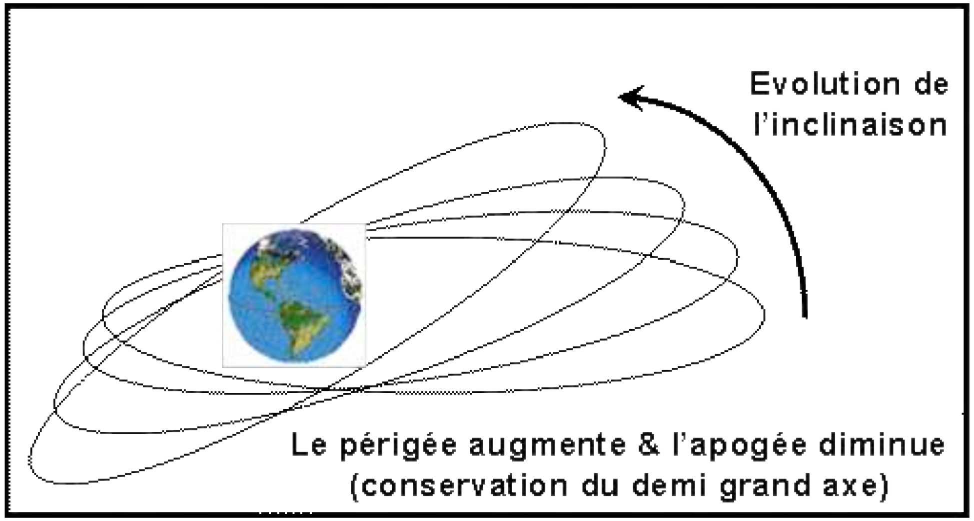
Has been chosen to give 90% time above 73 000 km which maximizes the science

Satellites ΔV around 500 m/s (hydrazine)

Daily visibility : ~12 hours per station with a maximum of 2 hours hole

At perigee the visibility is permanent (24 hours) for the chosen station

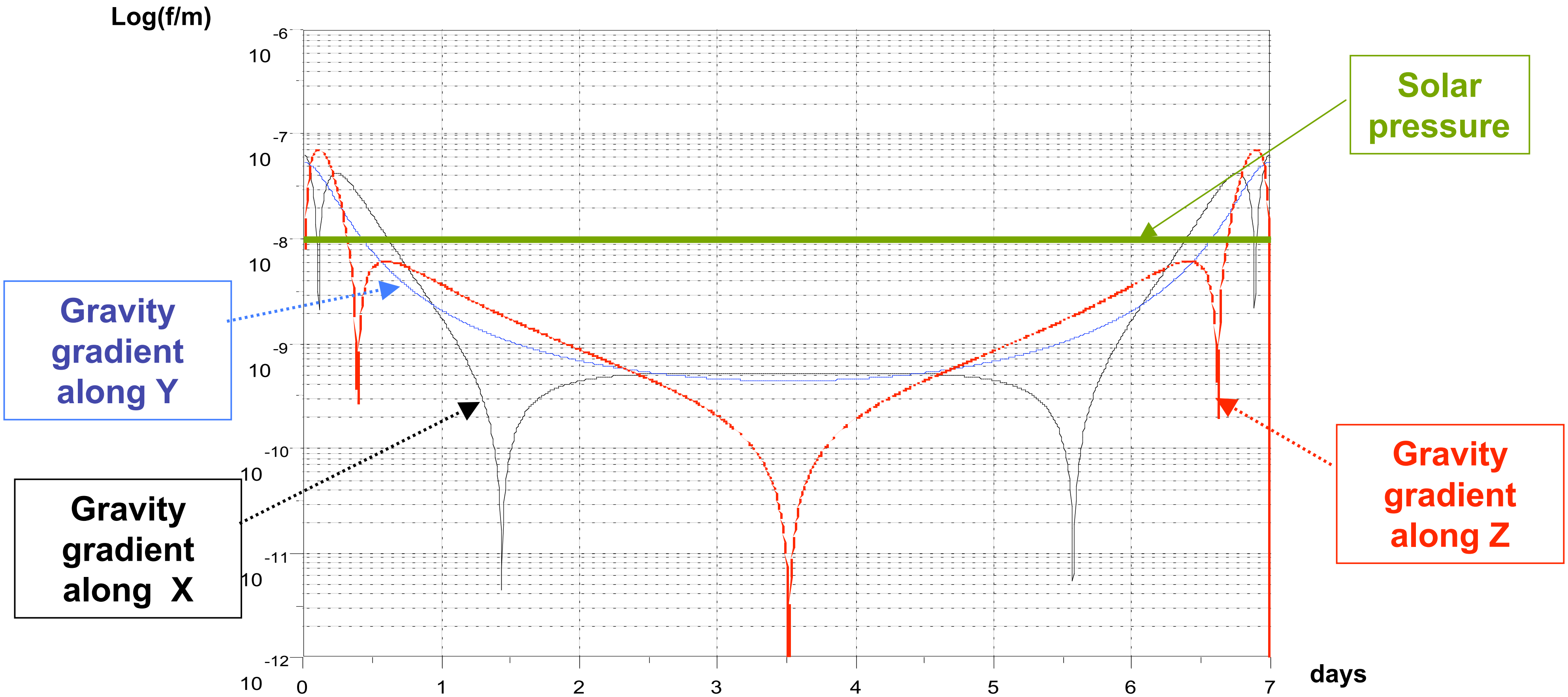




Perigee will increase to ~70 000 km after 2 years due to lunar effects combined to semi major axis conservation

PERTURBATIONS ON HEO ORBIT

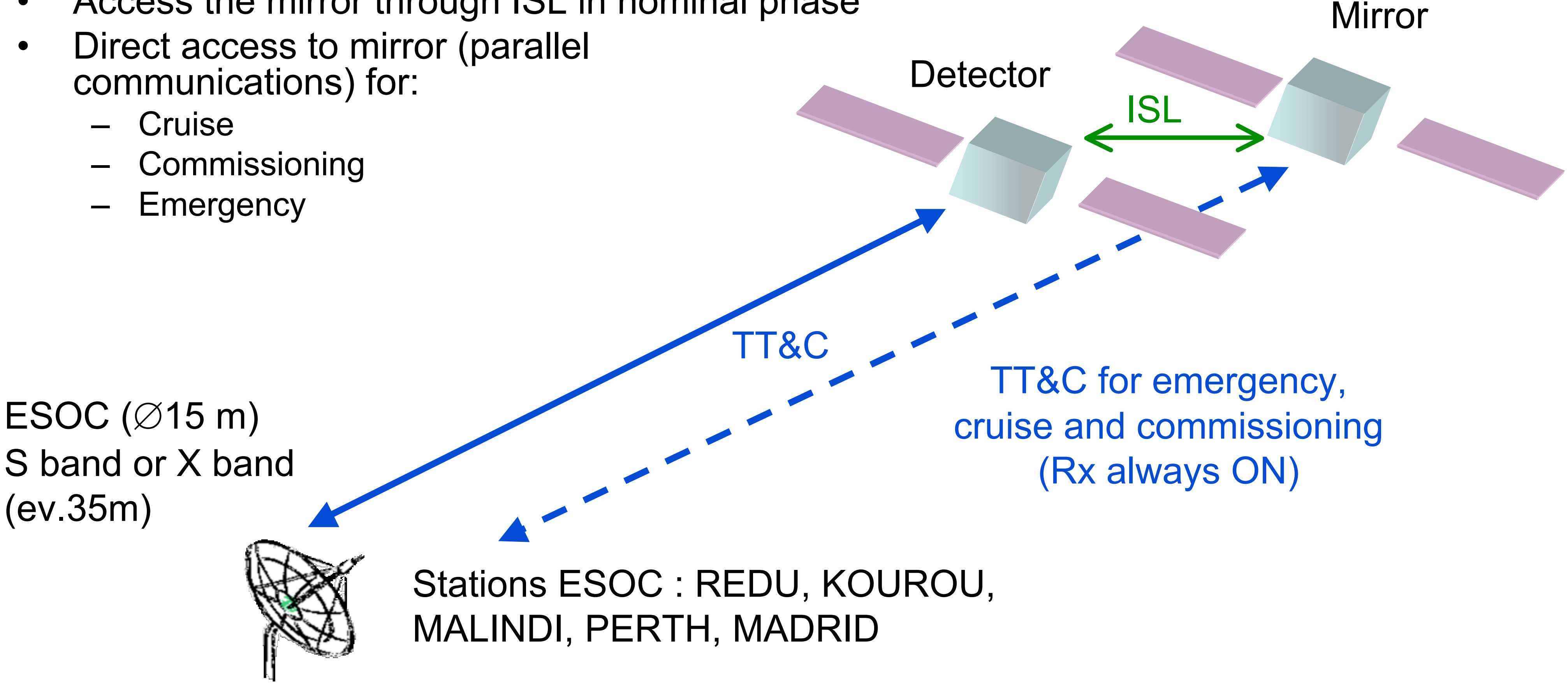
Orbit: 46000 – 253000 km - formation inclined 45° / orbit plane



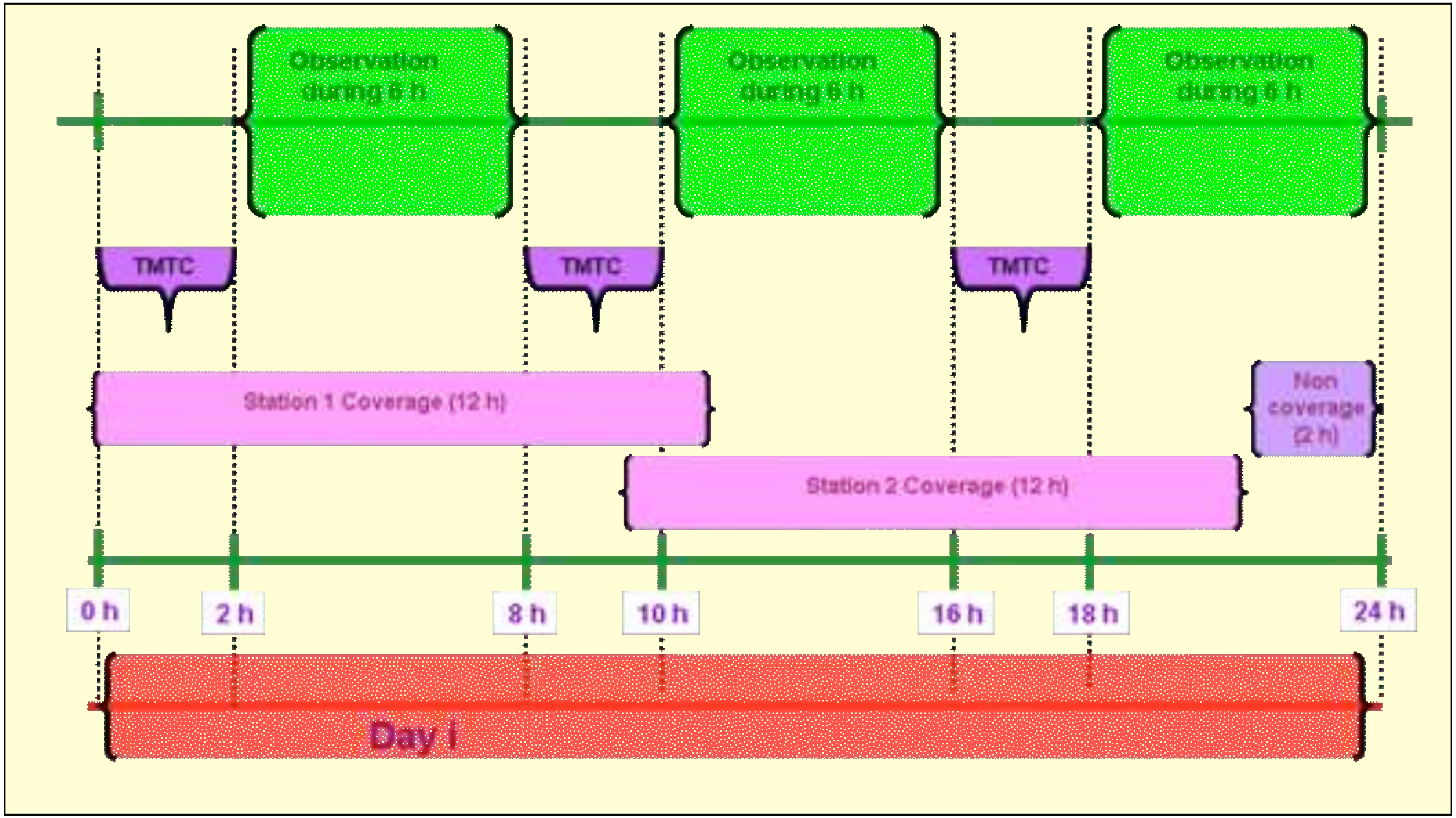
Solar radiation pressure is dominant most of the time (h > 70000 km ; like L2)

Communications strategy

- 2 communications modes
  - Housekeeping mode (TC + HKTM + ranging)
  - TMCU download (TC + TM high rate, detector only)
- Access the mirror through ISL in nominal phase
- Direct access to mirror (parallel communications) for:
  - Cruise
  - Commissioning
  - Emergency

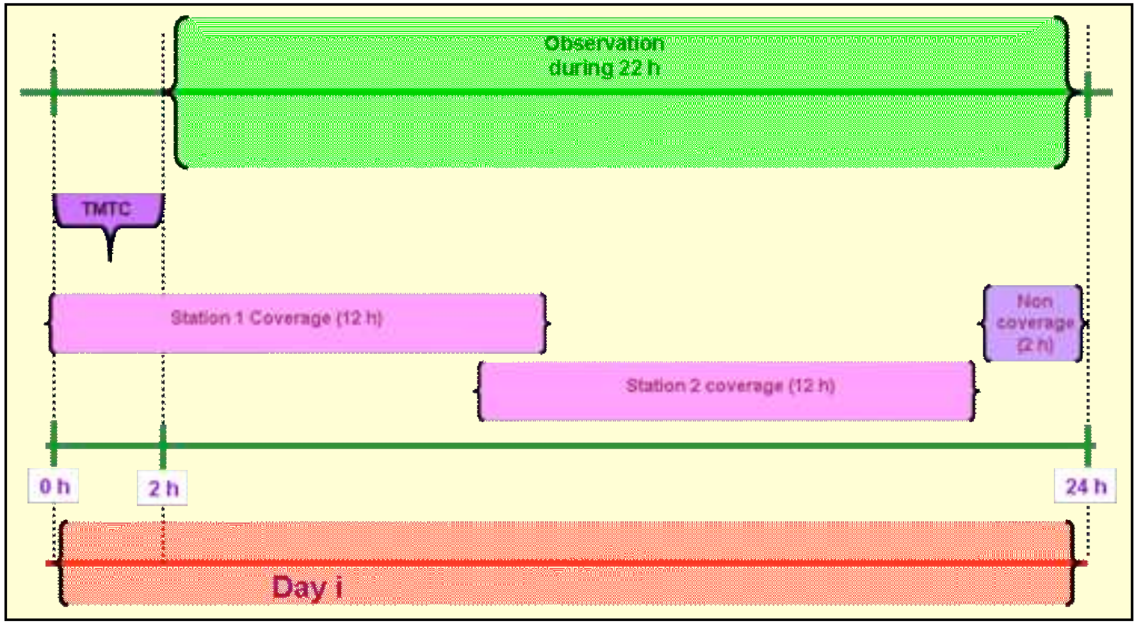


OPERATIONS : SEVERAL HARD SOURCES (22 ks ; > 1 mCrab)

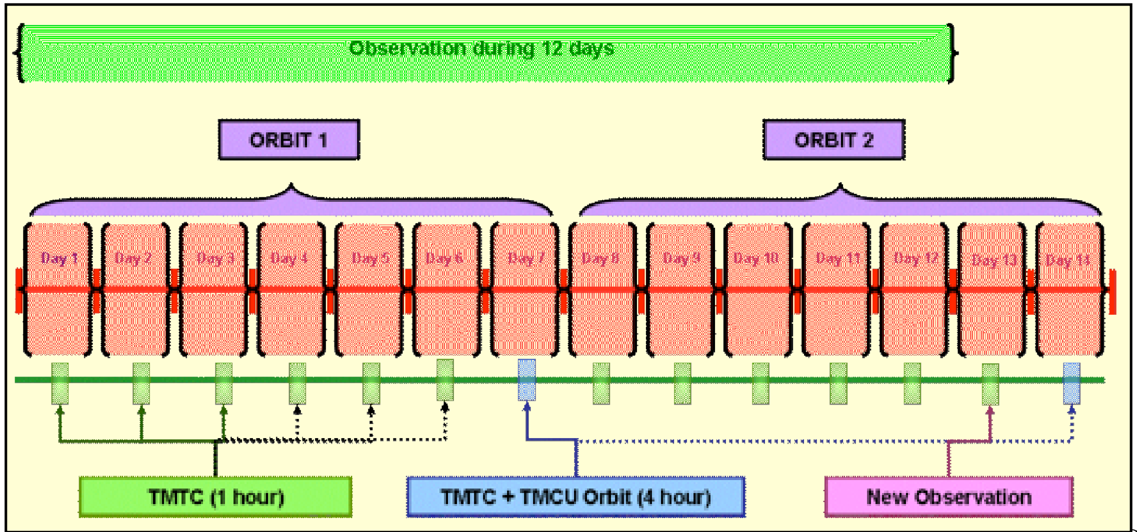


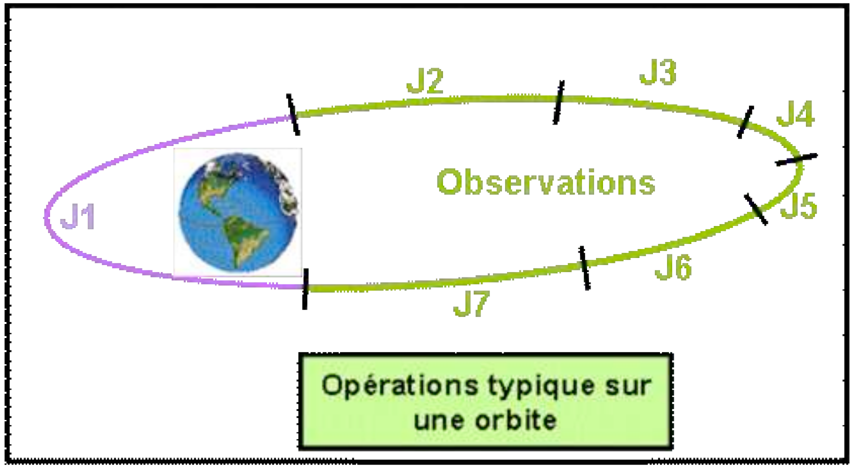
OPERATIONS (Cont'd)

EXAMPLE 2
ONE WEAK SOURCE
(79 ks ; < 50 µCrab)



EXAMPLE 3
DEEP FIELD (~1 Ms)





Formation Flying Requirements

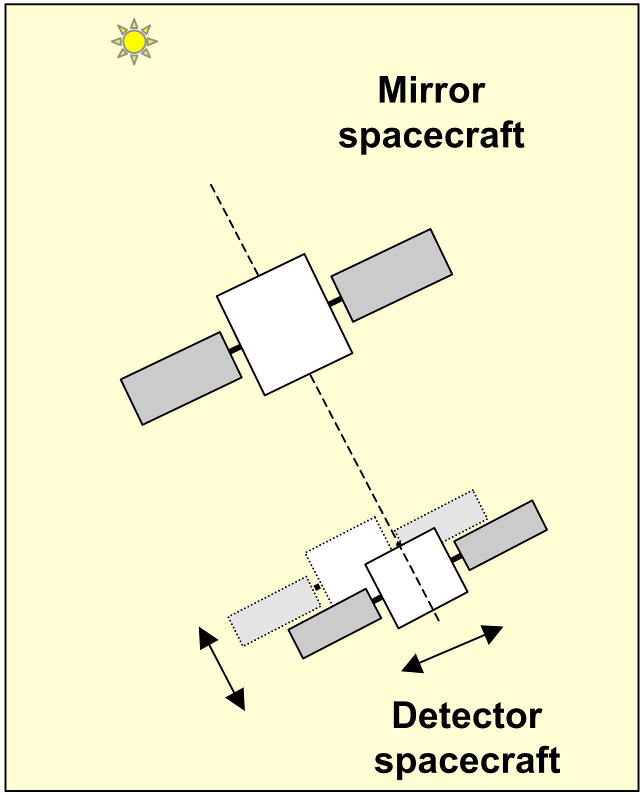
Relative positioning :
- **lateral / L.O.S. :+/- 1 cm**
- longitudinal : +/- 10 cm
- **lateral position knowledge : 0.5 mm (or 3'' LOS)**

➔ Constraint on inertial and relative metrology
lateral sensor + star tracker with 1 arc sec accuracy range

Mirror attitude control:
- Pointing : 10 arc sec
- Stability : no constraint

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

➔ Low constraints on attitude control



GNC HARDWARE

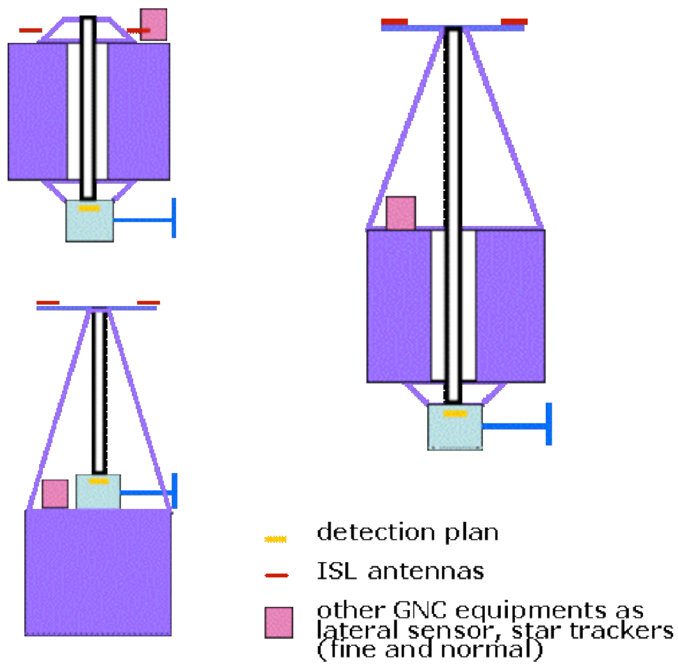
	Mirror Spacecraft	*Detector spacecraft*
Metrology	- standard SST (x2) + 1 gyro bloc **- RF terminal + 1 antenna** **- corner cubes or diodes**	- Fine SST (1'') + standard SST or - standard SST + precise gyrometers **- RF terminal RF + 3 antennas** **- Lateral sensor**
Actuation	• Reaction wheels (x4) > 1 Nm.s • 5 N Hydrazine thrusters (orbit transfer & maintenance; wheels off-loading)	• Cold gas thrusters (8 x 2) for attitude & fine position control (5.4 kg) •1 N Hydrazine thrusters (orbit transfer & maintenance; formation slew)

FF equipment : no critical technology in metrology (currently in development or R&D studies) and propulsion (already available)

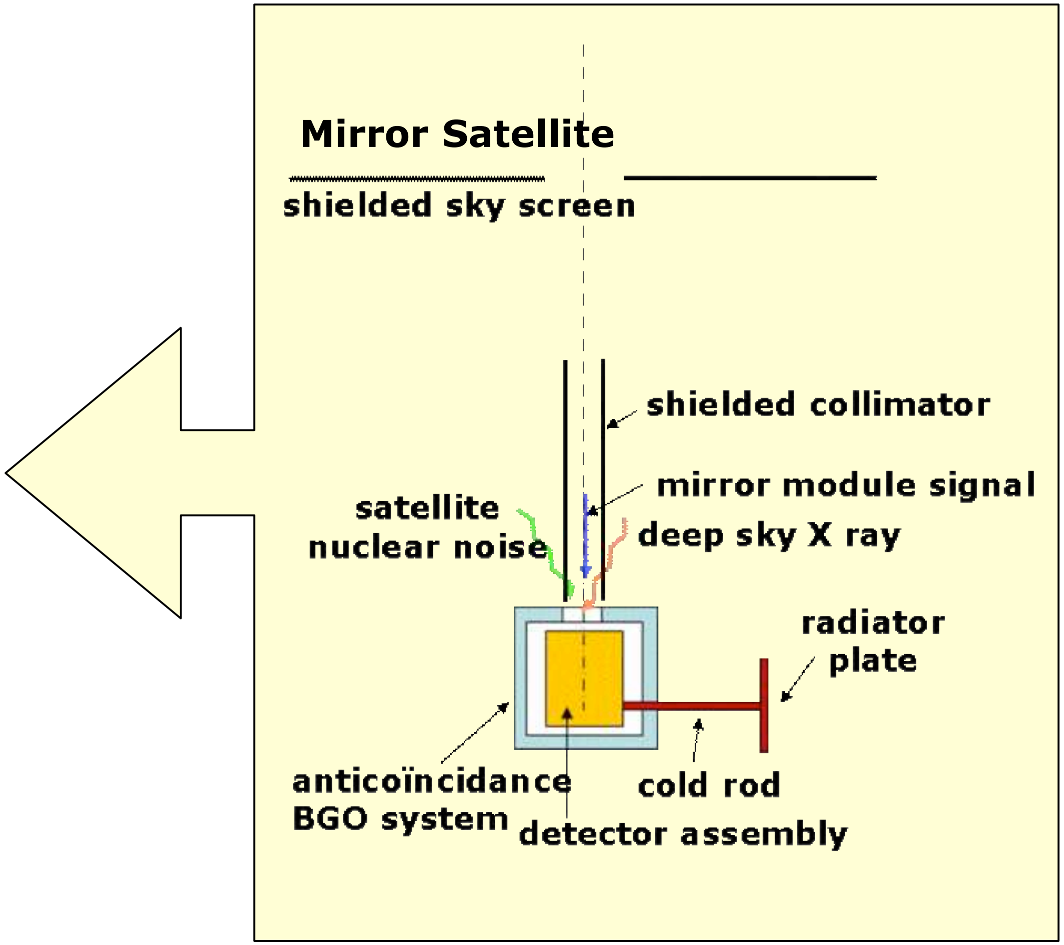
DETECTOR REFERENCE PLANS

To optimize the global pointing accuracy management,
GNC sensors and detection plan must be nearby one to each other
as much as possible to avoid all possible structural deformations.

2 planes 3 planes



COLLIMATION CONSTRAINTS

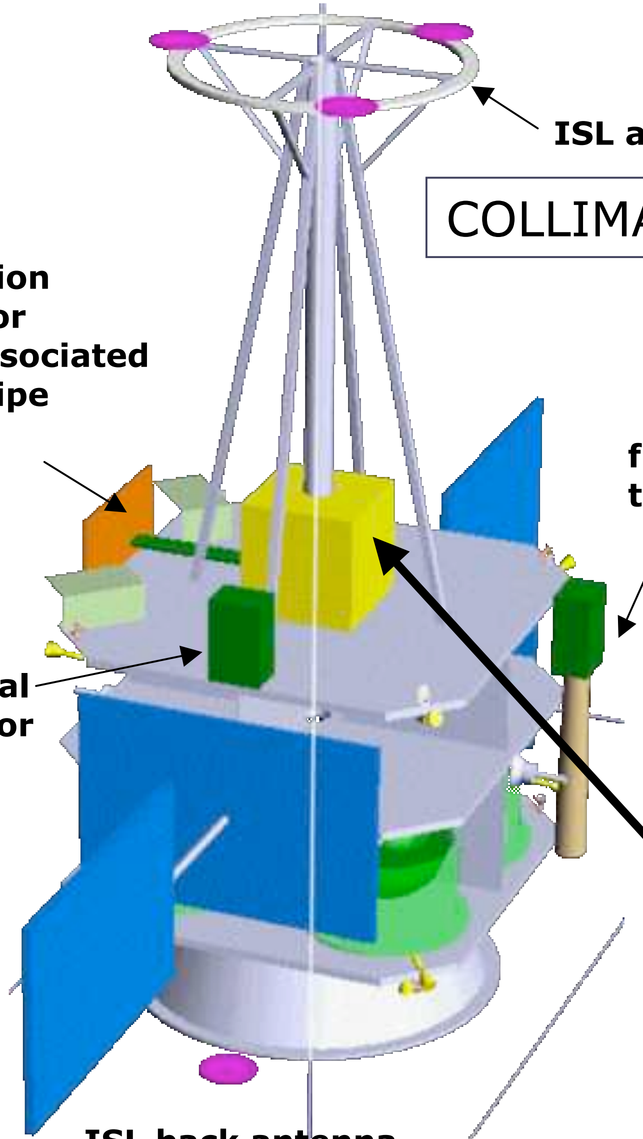


SIMBOL-X Mission

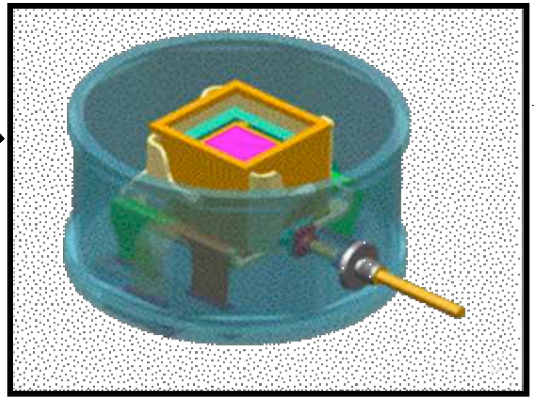
DETECTOR SATELLITE

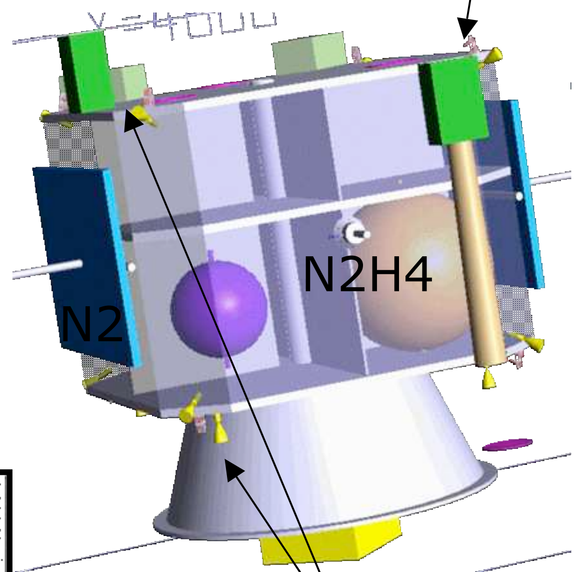
~530 kg ***(with 30% margin)***

Platform dry mass : ~250 kg (no margin)



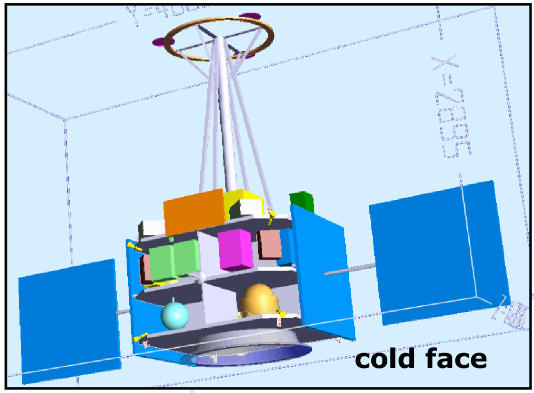
Detection payload

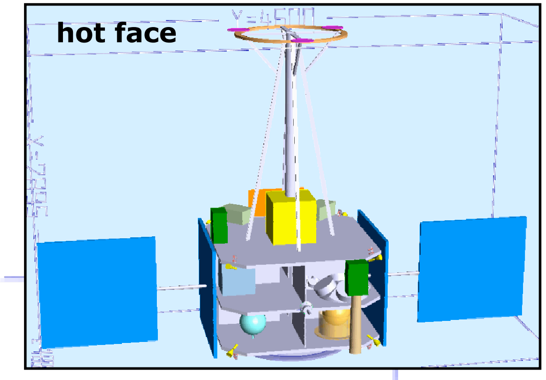


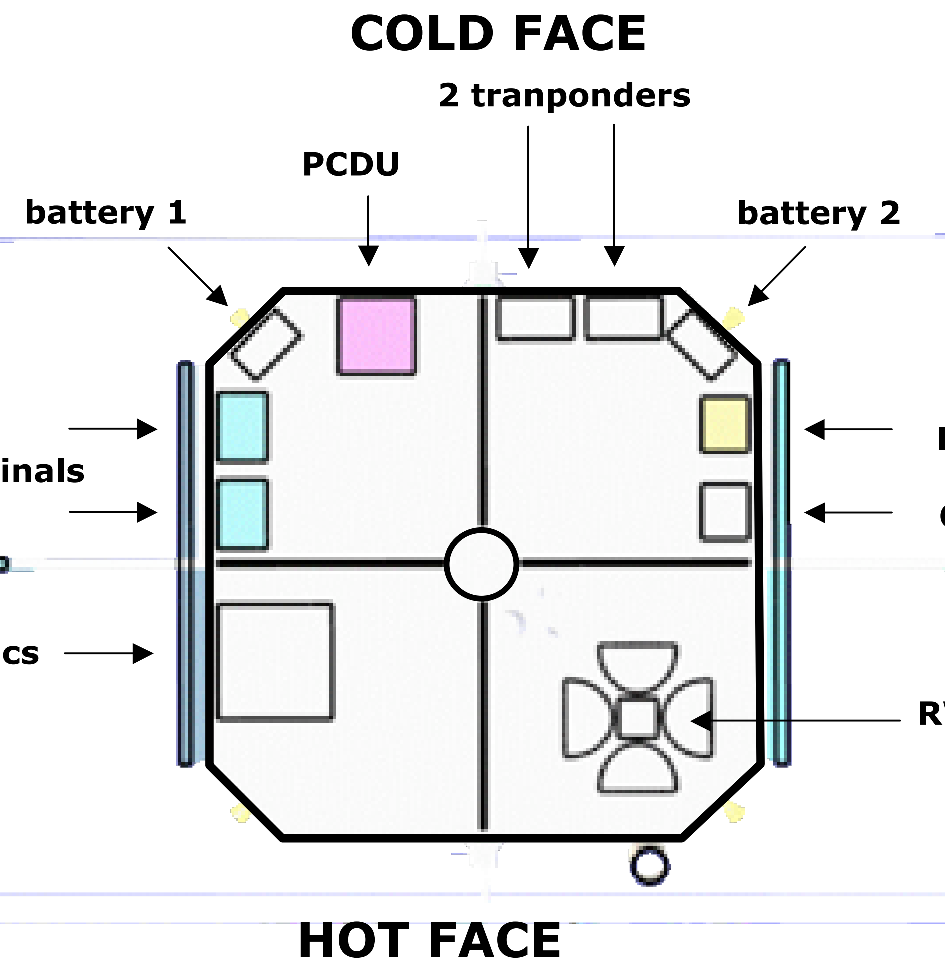


DETECTOR SATELLITE : AVIONICS

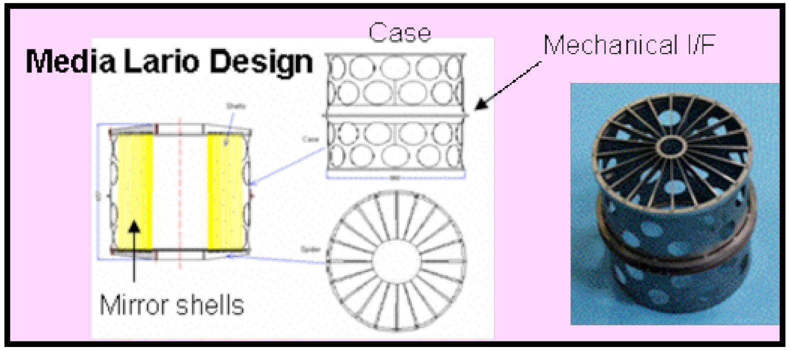
(Use of some Myriade equipment enhanced or not)







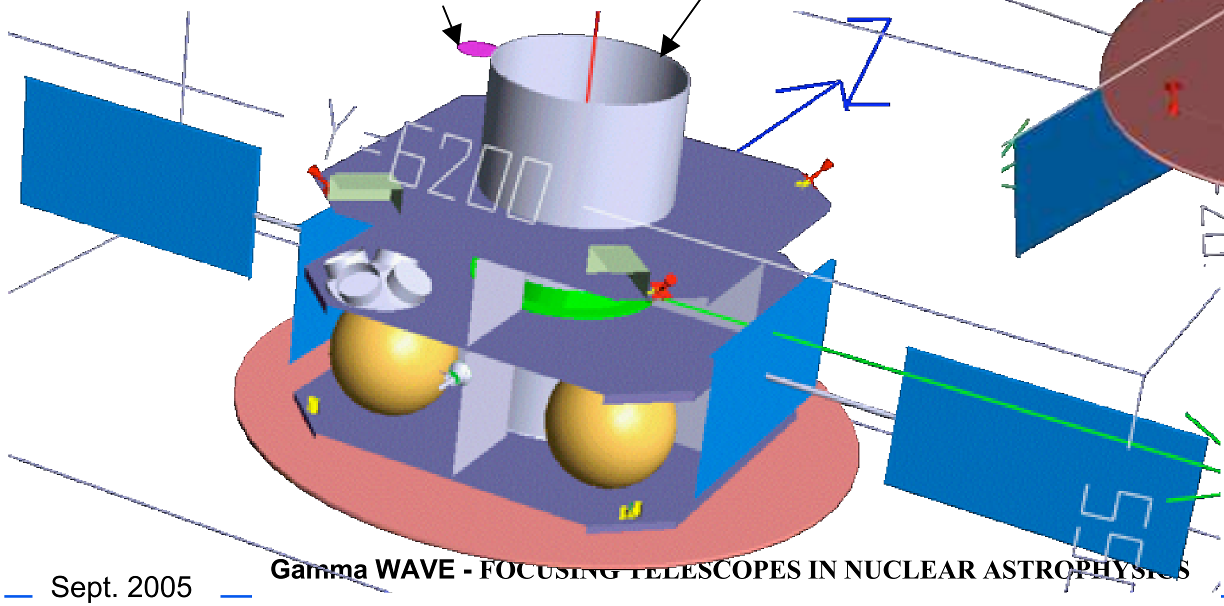
Wolter-I Mirror

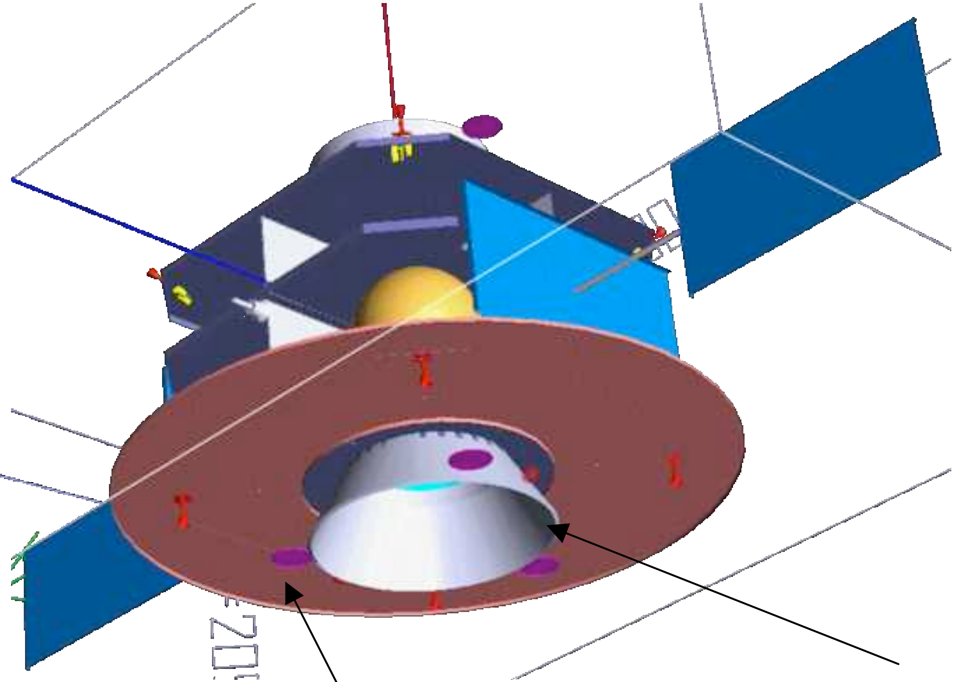


MIRROR SATELLITE

~1250 kg ***(with 30% margin)***

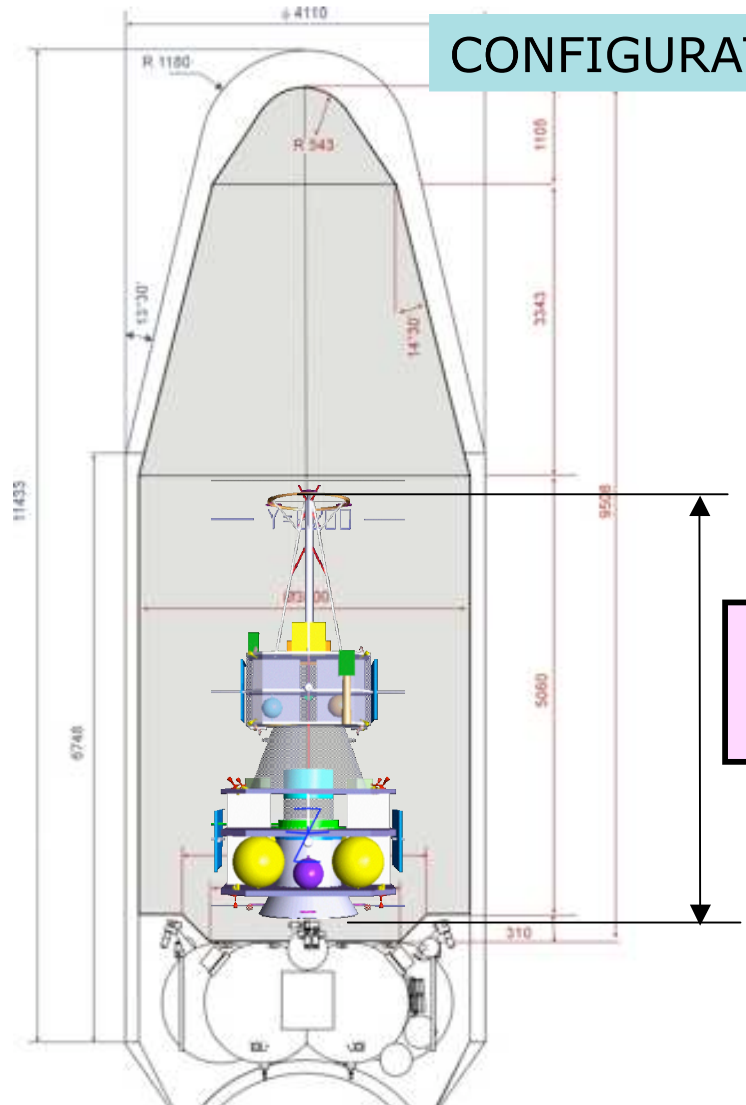
Platform dry mass : 320 kg (no margin)





SIMBOL-X Mission

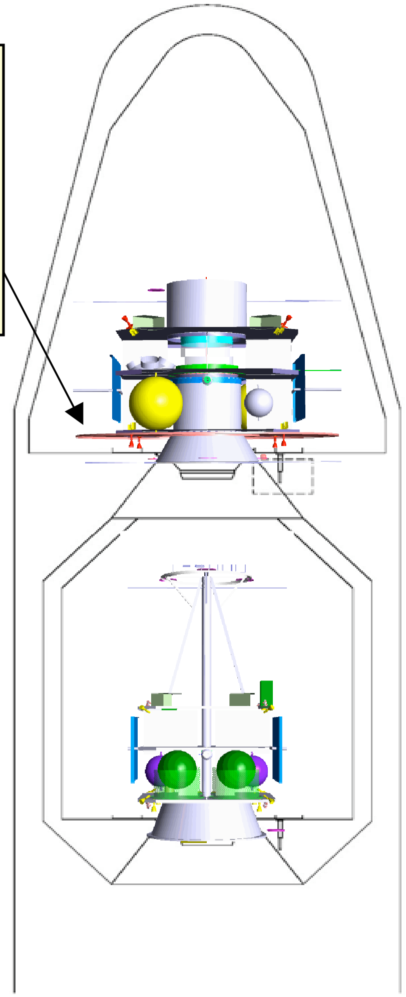
CONFIGURATIONS UNDER SOYUZ FAIRING



the 3m sky screen is too large for SYLDA

➔ Upper position on launcher for the mirror satellite

the composite is 5m high !



Composite on one launcher I/F

2 independent I/F with SYLDA

Synthesis & recommendations

- **SIMBOL-X is a "permanent observatory" which propose a great number of observations (~500 per year) and a great variety of these sources.**
- **The short duration of the observation times (less than a day in general) authorizes a great scheduling flexibility or a short term redefinition of the objectives,**
- **The substantial spacecraft mass margins allows to envisage several mirror options (with adapted focal between 25 m and 30 m) :**
  - **Mirror thickness similar to XMM mirror,**
  - **Thinner mirrors,**
  - **mirrors with multilayer,**

⇒ These options shall have to be studied during phase A and the choice confirmed at the end of this one

Synthesis & recommendations (Cont'd)

- **The decrease of the transmission at low energy (20% at 1,5keV) should permit to decrease the necessary resources for the mirror module thermal control (addition of insulating layers at the entrance & exit), it is an important simplification with respect to XMM constraints,**
- **The necessity of including a collimator in front of the detector (perturbations due to diffuse X-ray emission), led to deep modifications of the detector satellite configuration and at a lower level of the mirror satellite one. Nevertheless, a broad space for optimization of the satellite configurations exists,**
- **In addition, a fairly detailed definition of the detector payload and a strong technical support by CEA allowed to identify suitably the constraints imposed by this one on the space segment.**

⇒ The result of this is that the mission and space system are, then, strong & robust (detection function).