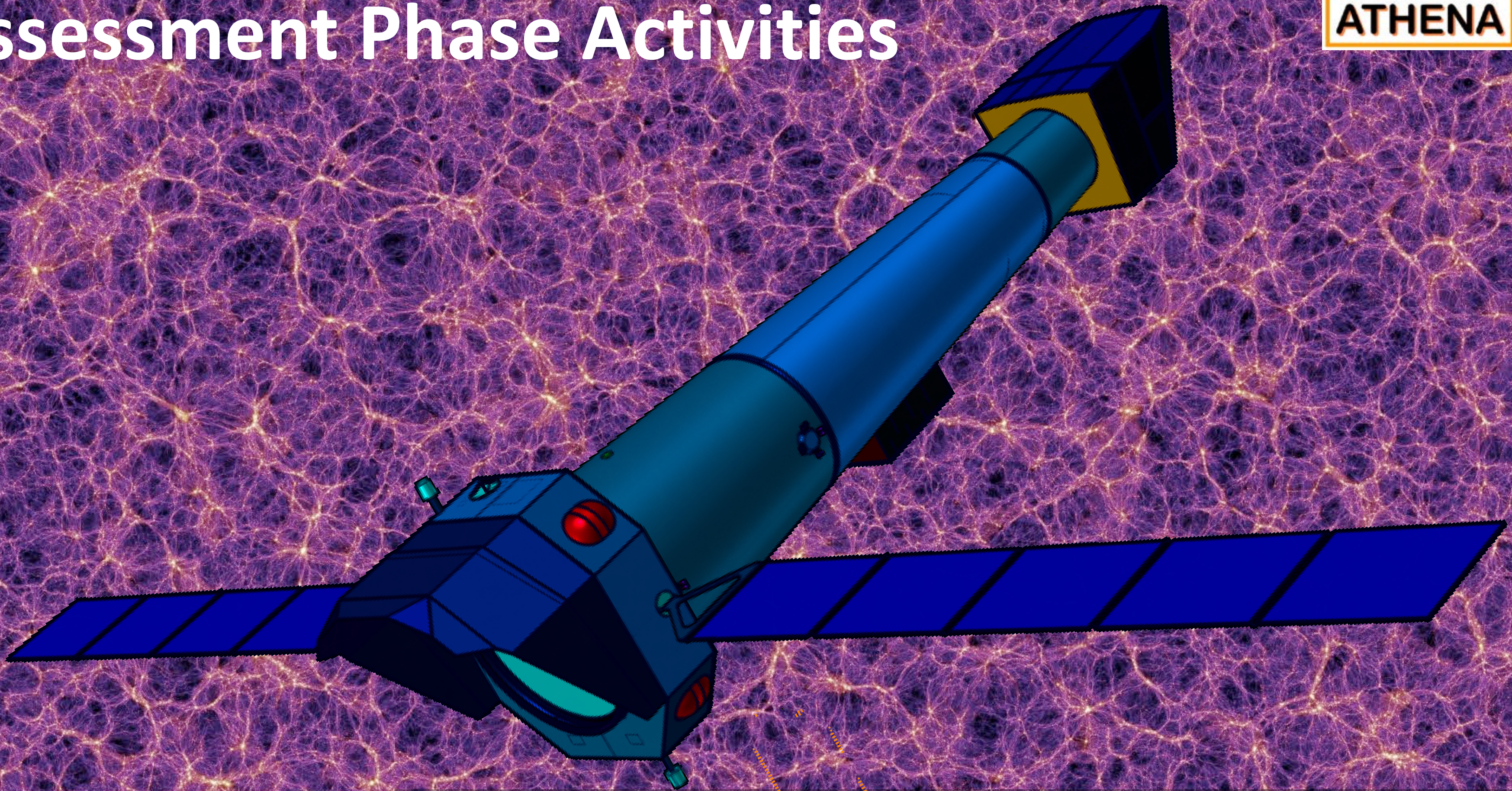
Athena:
Assessment Phase Activities



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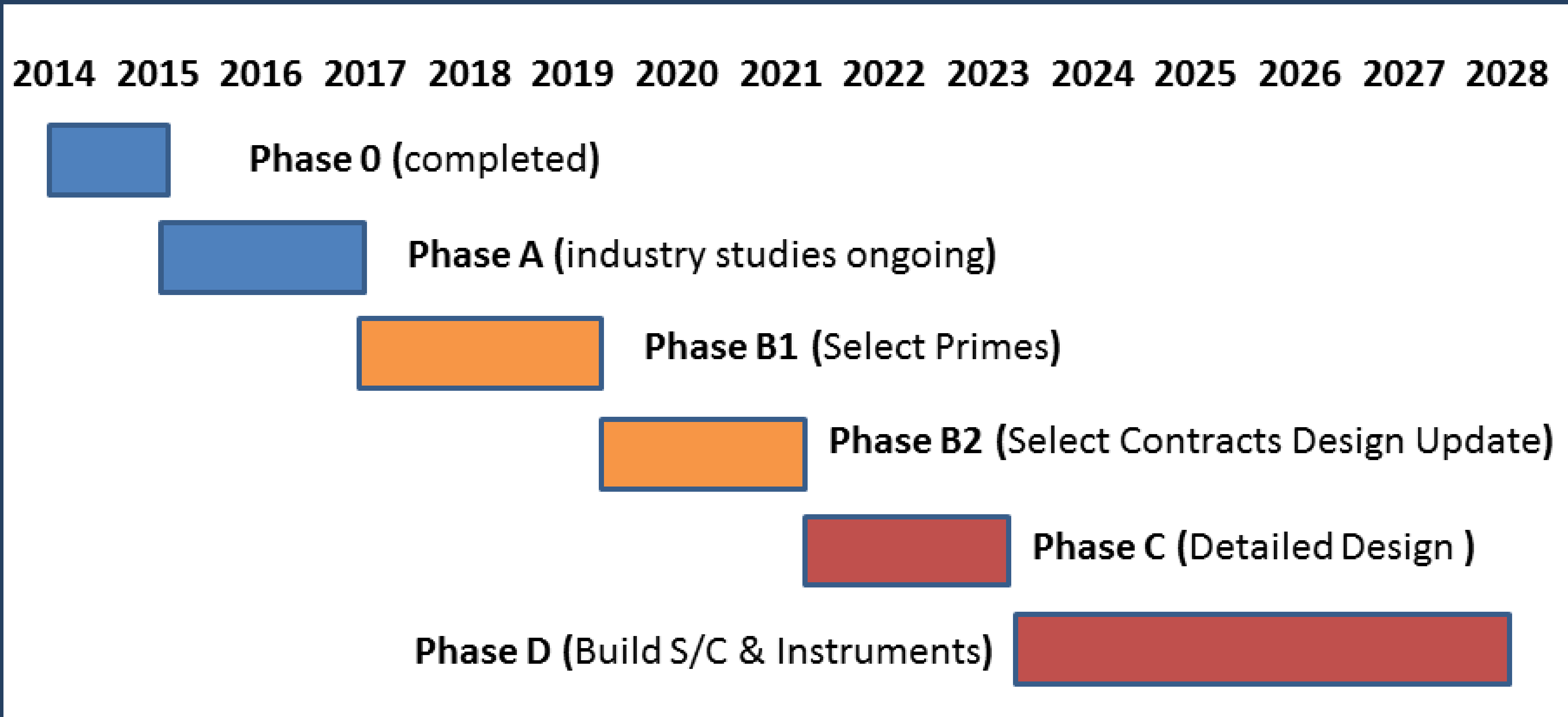
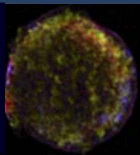
ESA ESTEC

Overall Schedule



Key Date: SPC Adoption 2020

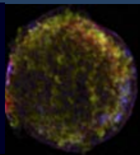


Starting Point

The initial mission architecture and S/C design produced during Phase 0 of the ATHENA study

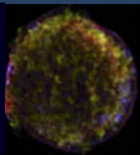
Primarily by the CDF, over a 6 week period in September/October 2014

Building on significant study heritage from previous concepts (IXO, ATHENA_L1), and the on-going SPO and instrument developments



Evolving Requirements

Parameter	IXO	ATHENA_L1	ATHENA
System Requirements			
# Instruments	6	2	2
On-axis A_eff (~1keV)	2.5m² (@1.25keV)	1m² (@1.25keV)	2m² (@1keV)
On-axis A_eff (6keV)	0.65m²	0.5m²	0.25m²
PSF HEW (on axis, <~8keV)	5''	10''	5''
AKE (a posteriori)	1'' (3σ)	1.5'' (3σ)	1'' (3σ)
ToO reaction time	<24h	<8-12h	<4h 80% of cases
Inst. Funct. Requirements			
X-IFU ΔE	2.5eV	3eV	2.5eV
X-IFU FoV	2' diameter	3' diameter	5' diameter
WFI ΔE	150eV	150eV	150eV
WFI FoV	18'x18'	24'x24'	40'x40'
Inst. Resource Requirements			
X-IFU (inc. CC)	(all instruments)		
Mass*	663 kg	409 kg	583 kg
Power*	1621 W	1005 W	1500 W
WFI			
Mass*	-	83 kg	288 kg
Power*	-	187 W	570 W



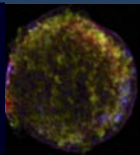
Boundaries & Requirements

• Launch 2028, 1Bn€ CaC

A pre-CDF study cost and risk assessment indicated that:

- **Targeting an ATHENA_L1-class SC (standard launcher I/F, no deployable focal plane) would be necessary to constrain the cost (for an ESA-only mission), and that even with this measure the ESA CaC would be likely to significantly exceed the limit**
- **Given the programmatic uncertainty on the Ariane programme, the proposed SC would not be compatible with A6 (as it was then defined)**

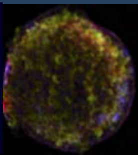
Therefore, to constrain cost and size, the study was based on the premise of using the largest standard 2624 mm Launch Vehicle Adaptor (LVA) on Ariane 5 ECA



CDF Costing Analysis

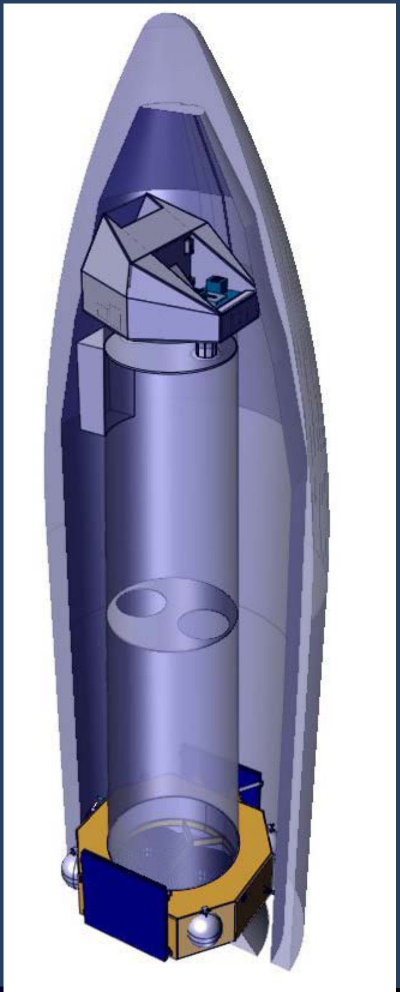
- The as proposed mission would be unaffordable respecting geo-return, an ESA-funded cooler, and no international involvement

- De-scoping to an L1-class mission (~1.5m^2 telescope, best-effort ToO, standard LVA but JAXA supplying the cryo-cooler to the X-IFU Consortium (avoids ESA management I/F cost for the CC) is ~1Bn€



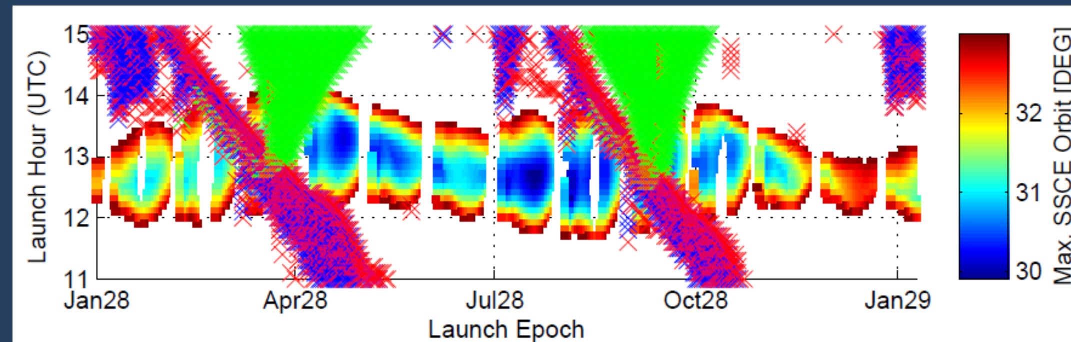
From CDF to Phase A

- The preliminary baseline configuration was established in the CDF study. Compatibiliy with the L mission budget (1 B€, e.c. 2013), still needs confirmation
  - Industrial studies are needed for enabling reliable cost estimates
  - Consolidation of international collaboration scheme (JAXA and NASA provisions)
  - Consolidation of Member States provision
- Although CDF design point (~1.5m^2) was perceived as a realistic target, the "optimum" definition point within boundary conditions will be reached through the Phase A1
- Determine collecting area we could afford, and resources that can be allocated to the instruments



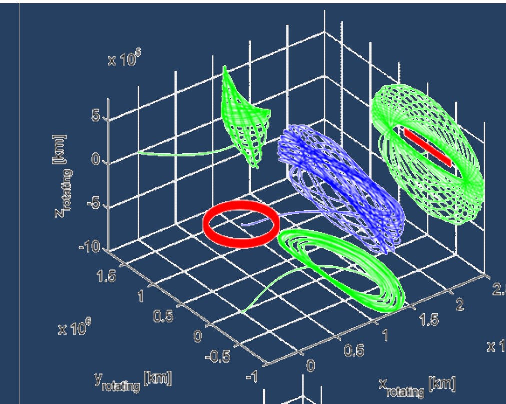
Mission Architecture (i)

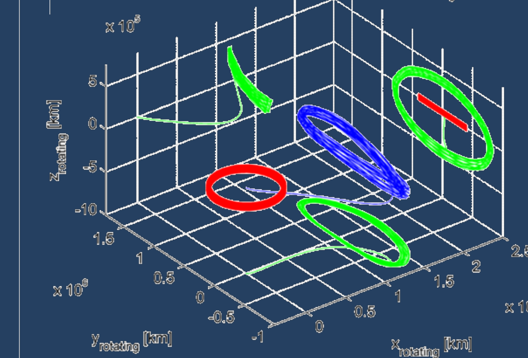
Launch using A-64, direct transfer and free-insertion in to a large amplitude (measured from the Sun-Earth-line ~0.75×10^6 km) Halo orbit at L2



Constraints imposed on the trajectory:

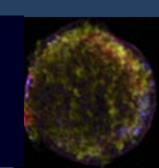
- Sun-SC-Earth (SSCE) angle less than 33°
- No Earth/Moon eclipses during transfer or operations
- Orbit shape highly dependent upon launch time/date
- ΔV ~$75 ms^{-1}$:
- Periodic small station-keeping manoeuvres
- EoL disposal to deep-space
- 3h daily downlink to New Norcia
- Additional uplink stations for ToO





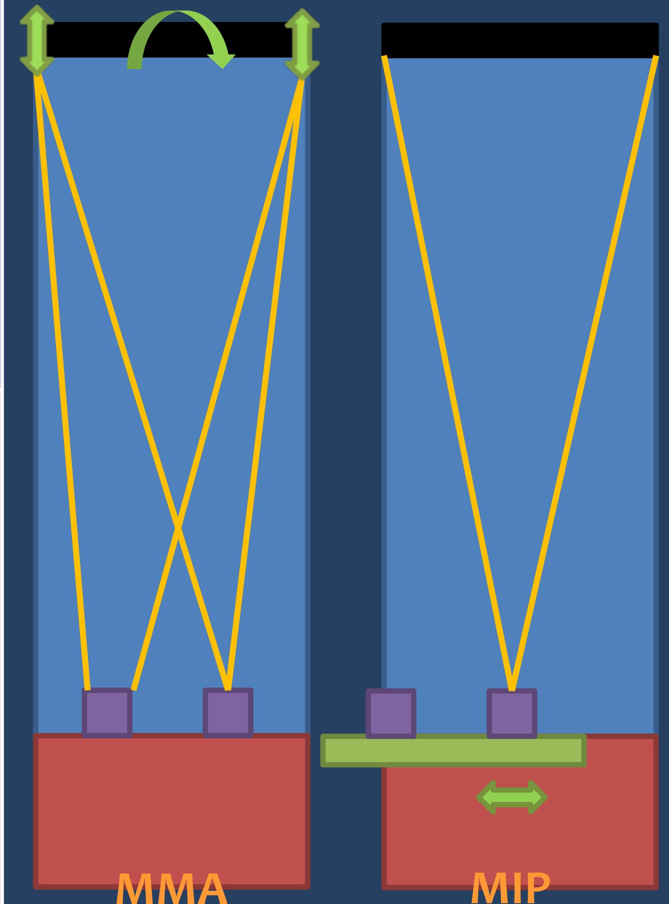
Mission Architecture (ii)

- ToO alerts isotropic random in time/space
- Monday to Friday, 09.00–17.00 working hours at ESAC/ESOC, 120m commutes twice a day (ESAC staff able to perform their functions remotely at home if a ToO-request arrives out-of-hours)
- Uplink at New Norcia, Malargüe
- Agile SC (4°/minute slew & settle)
- 10min instrument swap-out should the ToO-request arrive when WFI is observing
- 40h X-IFU cooling cycle period, with 32h cool-time and 8h regeneration time (primary constraint)



Payload Architecture (ii)

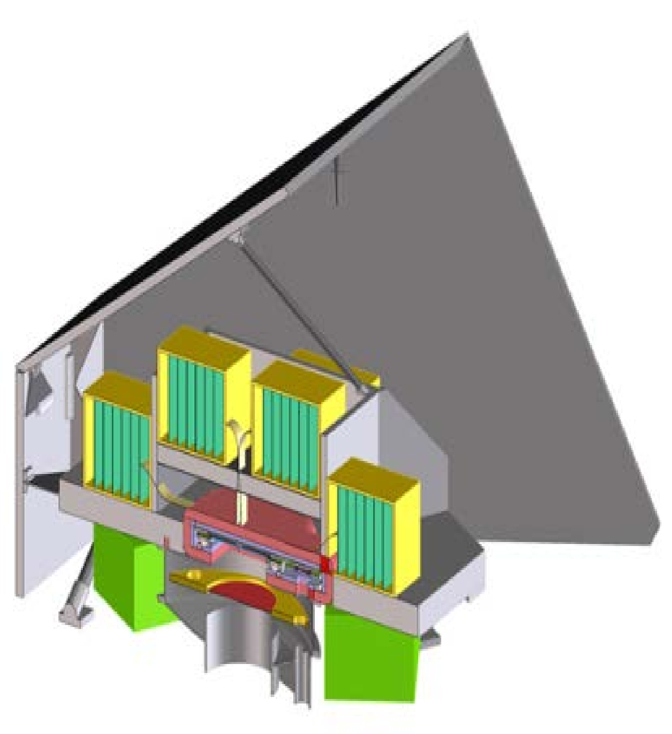
	MIP	MMA
PROS	- Misalignment of star trackers is minimized (placed on the mirror)	- Reduced inertia for slewing the S/C - Range of motion - Less stringent in terms of position stability (only affects vignetting function)
CONS	- X-IFU instrument requires cryogenic chain (vibration) - Harness would need to allow moving ~0.75 m - Heat pipes restricted - Proximity to regeneration X-IFU (possibly lower position accuracy) - Possible additional risk of locking on black spot, avoiding it reduces focal length	- Effective area reduction - Attachment of MMA to FMS is critical (8 points were considered so far). Locked during launch. Stress transmission (shocks) - Baffle configuration will probably require two holes (depending on position on FMS) => worse for straylight



ATHENA – Payload Overview

- Wide Field Imager (WFI) - Silicon Depleted P-channel Field Effect Transistor (DEPFET) Active Pixel Sensor camera with two separate detector arrays, ~17 cm apart

- X-ray Integral Field Unit (X-IFU) - Actively-shielded X-ray micro-calorimeter spectrometer for high-spectral resolution (2.5 eV), single narrow FoV (5’ Ø, ~17.4 mm^2) detector array composed of ~3840 super-cooled TES



	X-IFU (inc. CC)	WFI
energy range [keV]	0.2 - 12	0.1 - 15
Energy resolution [eV]	2.5	150
FoV [']	5 Ø	40 x 40
Pixel size [µm]	250	130
Detector op. temp [K]	<100 mK	210
Mass [kg]	583	288
Power [W]	1500	684

Phase A – Part 1

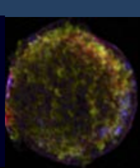
- **Expected duration: ~ 12 months**
- **Configurations will be studied by the Industrial contractors:**
  - **From CDF baseline to maximum resource compatible**
  - **Preliminary definition of the spacecraft for both configurations**
  - **Preliminary development plan and costing for both configurations**

- **The Phase A.1 is closed by a dedicated review** *(Mission Consolidation Review)*, **which includes the Cost at Completion estimate for both configurations.**
- **The baseline will be defined following the MCR and leads to Payload AO**

Note: The selected baseline may differ from the two configurations as studied.

Technology Developments

- Reach TRL ≥ 5/6 before mission adoption (Q1 2020)
- Some technologies are highly critical and require dedicated development activities during Phase A/B1 since they carry significant risk to the project:
  - *SPO Mirror Modules (MM) & Mirror Assembly (MA) related technology developments*
  - *The X-IFU Cryogenic Chain (CC) related technology developments*
  - *Instrument Switching Mechanism (ISM)*
  - *ATHENA radiation and background modelling*



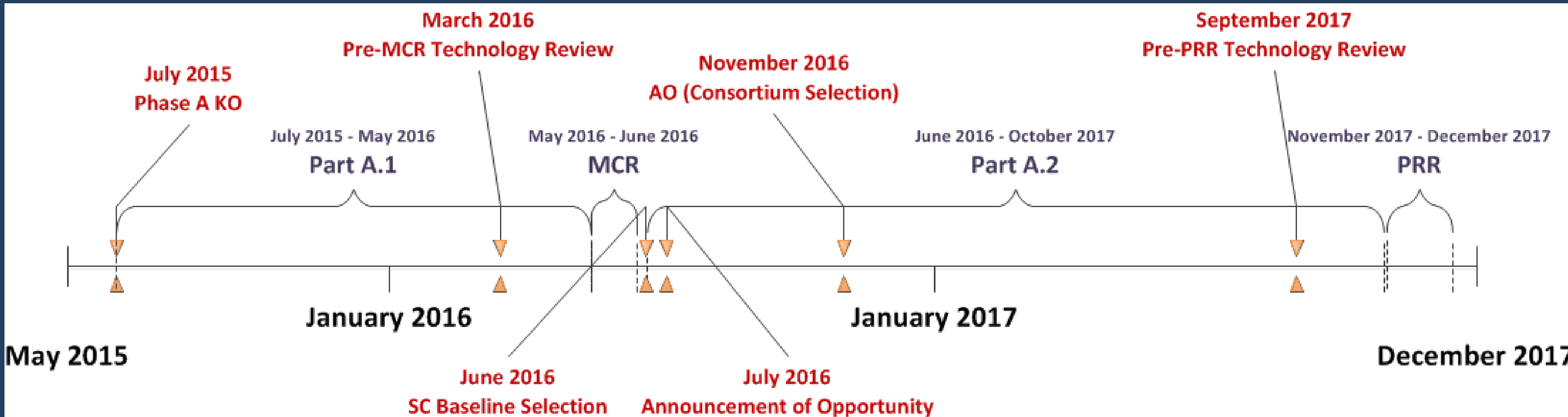
Technology Developments (ii)

- Areas considered moderately critical and some technology development during Phase A/B1 is :
  - *MM shock suppression*
  - *On-board Metrology (OBM)*
  - *SC Mirror Contamination Cover (MCC)*
  - *Planning S/W & Fast Timeline Generation.*
  - *High accuracy star tracker*

TOO and cryo regeneration

- TOO response time driven by cryo-cooler availability
- Recycling time is based on the Safari cooler, but some growth potential.
- The 2K cooler performance can e.g. be increased by operating the 15K cooler at full power during the recycling time (operating the 15K I/F at ~12K),
- Similar for the 4K stage, it might be possible to increase the cooling power, taking into account that the JAXA JT coolers are sized for 40mW (depending on the failure modes) or to consider some Energy storage
- Need to examine margin philosophy for the cooling chain. E.g. need to be conservative on the parasitic loads and consider some system margins for the coolers to be sure to have a working system. can be a little bit more relaxed on the recycling time/hold time

Phase A – schedule



Phase A.1 kick-offs (parallel contracts):	July 2015
MCR data package (2 configurations):	April 2016
MCR completed:	May 2016
Baseline selection :	June 2016
Phase A.2 kick-off:	June 2016
AO for science instruments:	Early July 2016
Selection of Instrument consortia:	November 2016
PRR data package:	November 2017
PRR completed (end of Phase A):	Dec 2017