

SAOCOM-CS Phase A

PAYLOAD ANALYSIS OF PASSIVE BI-STATIC SYNTHETIC APERTURE RADAR

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Executive Summary

Airbus DS (CASA Espacio)

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AIRBUS
DEFENCE & SPACE

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SCOPE & BACKGROUND

This document is the Executive Summary of Saocom Companion Satellite (CS) L-band Rx-only SAR Payload Phase A/B1 study performed by Airbus DS (CASA Espacio) & the Universidad Politecnica de Cataluña (UPC) from July 2014 until April 2015.

Saocom-CS payload is aimed at being mounted onboard a dedicated satellite that will flight in formation with Saocom-1B satellite., the L-band SAR satellite property of CONAE (Comisión Nacional de Actividades Espaciales, Argentina).

Saocom-1B will be put in orbit by Space-X Falcon-9 launcher, which will be equipped with a Multiple Payload Adapter (MAS-5, built by Airbus DS Spain), allowing the launch of 5 additional satellites simultaneously, one of them being Saocom-CS. This is how Saocom-CS entered into scene in 2013, and since then, ESA has been working in the definition of the mission, together with the space industry that has collaborated in different related topics.

Airbus DS Spain started working with ESA in 2013 based on the knowledge of MAS-5 adapter and a predevelopment that was made for TERRASAR-L in 2004 and can be reused for Saocom-CS.



2002

For LARSAR mission, CASA developed a qualified L-band subarray

2004

Subarray adaptation to TERRASAR-L mission

2013

CONAE signs the contract with CASA for a MAS-5 Launcher Payload Adapter to flight Saocom-1B with 5 secondary passengers on-board Falcon-9. Thus, volume and Mass are limiting factors.

ESA starts Saocom-cs Phase-0 Feasibility study

CASA participates in CDF with the following responsibilities:

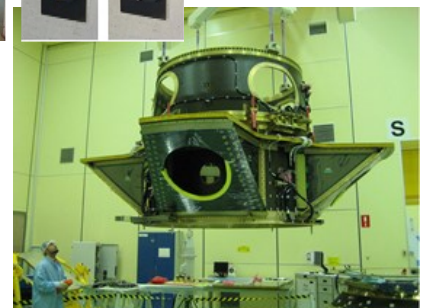
- Adaptation of existing L-band antenna subarray for Bi-static SAR applications
- L-band SAR antenna design
- Accommodation of the L-band antenna on the satellite platforms and on the launcher



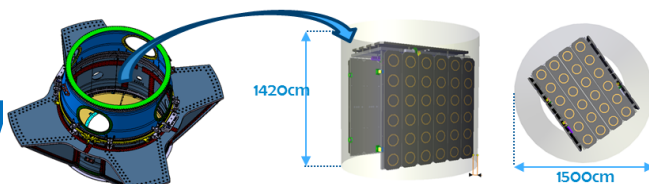
MAS-5 adapter



LARSAR/TERRASAR-L subarrays



2014-2015



Maximum Mass Allowed
= 400kg (CoG 1m)

Payload Phase A/B1

Rx-only SAR payload design & analyses

L-band antenna design & analyses

Definition of payload interfaces

Definition of the Design, Development & Validation plan (DDVP) of the payload

Generation of technical specifications for next project phases

Antenna RF predevelopments:

Adaptation of the Subarray to Saocom-CS: slight frequency tuning and adapted thermal design

Development of L-band power divider

PAYLOAD OVERVIEW & PERFORMANCE

SAOCOM-CS will be flying in formation with SAOCOM-1B as companion satellite. This will allow the acquisition of single-pass interferometric and tomographic measurements. The system will be operated in the following sequence of mission phases:

Launch and Early Orbit phase (LEOP), from launch ignition to the point where the space segment is in such a state that the platform and instrument commissioning can begin.

Commissioning phase (COM), from beginning to end of commissioning operations for the platform and payload

Nominal observation phase (NOM) from the end of the commissioning phase to the End-of-Life phase, aiming to obtain scientific observations and consists of the following sub-phases:

- **Tomographic phase (TOM)** This phase is aimed at retrieving information on boreal forest structure and biomass by exploiting a series of equidistant interferometric acquisitions
- **Bi-static phase (BiStat)** This phase is aimed at retrieving information on bistatic surface motion, persistent scatterers and bistatic radiometric signatures
- **Specular phase (SPEC)**. This phase is aimed at retrieving information on soil moisture and radiometric signatures.

End-of-Life phase (EOL), where the satellite shall be passivated in accordance with space debris mitigation requirements.

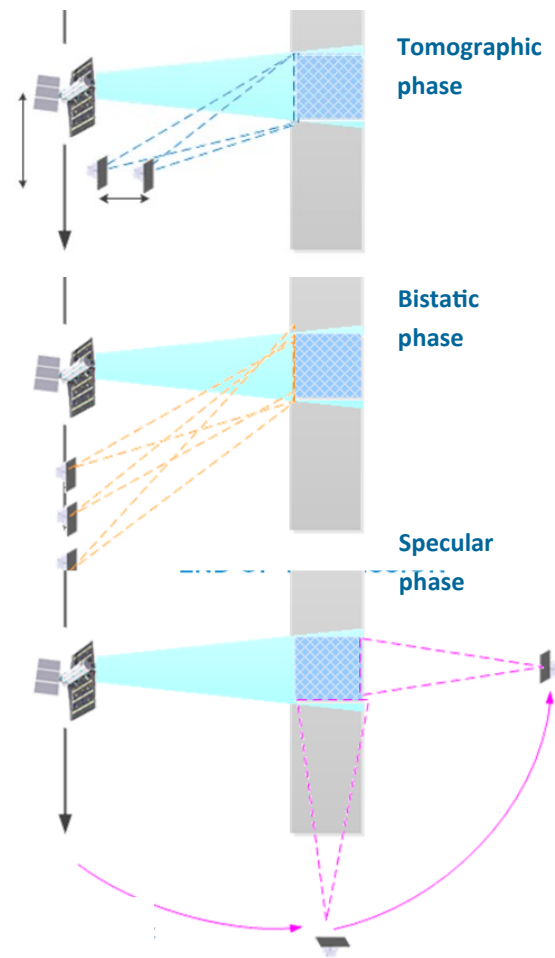
SAOCOM-CS payload, as already specified, is a receive-only SAR instrument that uses as transmitted signal that of Saocom-1B satellite.

Therefore, the characteristic of the chirp transmitted will contribute significantly to the bi-static system performance. The main characteristics of the signal are:

- Central Frequency = 1275 MHz
- Polarization: H, V
- Maximum bandwidth: 44.7 MHz

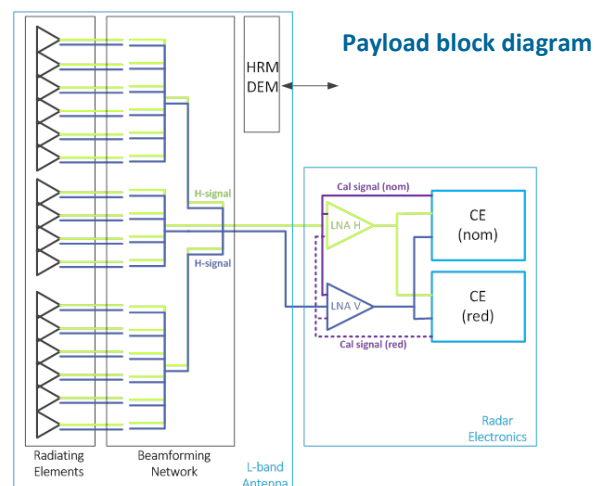
The table on the side shows the different swaths of Saocom and their respective bandwidths.

Pol Mode	Saocom-1B Swath TX BW
Dual-pol	1) 38,3 MHz
	2) 32,2 MHz
	3) 27,9 MHz
	4) 24,4 MHz
Quad-pol	1) 44,7 MHz
	2) 40,5 MHz
	3) 37,1 MHz
	4) 34,4 MHz



Considering all the limitations of the program (schedule constraints, subarray predevelopment and available launch volume), the payload idesign is composed of three parts:

- SAR antenna: a passive RX antenna with a fixed beam at 1275 MHz and with 50 MHz of bandwidth.
- Mechanism for hold-down and deployment of the antenna
- Radar electronics that includes the low-noise amplifiers and performs the signal processing and packaging



PAYLOAD OVERVIEW & PERFORMANCE



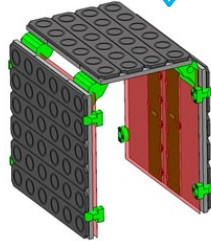
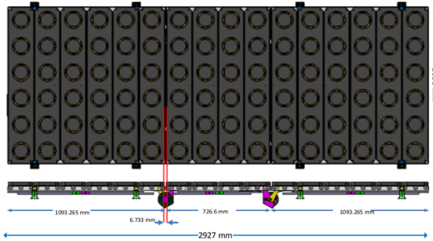
SAR ANTENNA:
Passive RX antenna
Fixed beam at 1275 MHz
BW 50 MHz



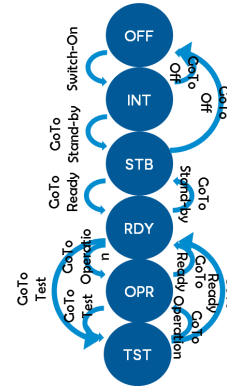
MECHANISMS
Deployment
Hold-down & Release



RADAR ELECTRONICS
Low-noise amplification
Signal processing
Signal packaging



8 Hold-down mech (HRM)
2 Deployment mech. (DEM)



Payload
operational
modes

16 Subarrays in 3 panel (6, 6, 4)
Beamforming network
Harness and thermal hardware

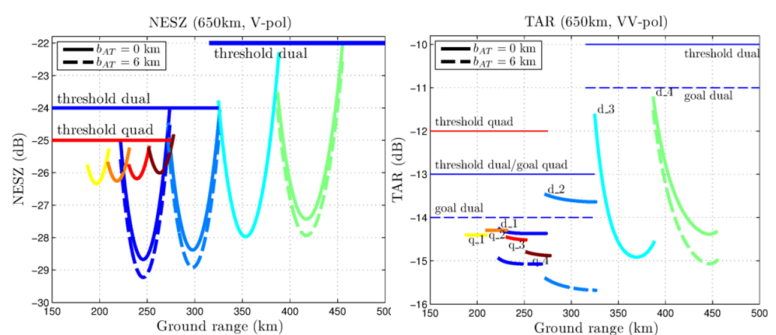
The instrument performance analysis ensures the feasibility of the mission during the satellite lifetime and throughout all its phases. The emphasis in this study is given to the tomographic phase, in which interferometric measurements for boreal forests studies will drive the mission objectives and requirements. Next study phases will complete the performance analysis with dedicated bi-static and synchronization studies. The main mission and instrument performance parameters are shown in the table on the right.

Most of the performance parameters will depend on the geometry setting of both satellites, as well as the antenna patterns and other instrument parameters between transmitter and receiver.

The figures on the right show the sensitivity (NESZ) and total ambiguity ratios, as expected for V-polarization and highest orbital altitude (650 km), as a worst case example. The numbers are provided for 0 km and 6 km along-track baselines (bAT), as this is the nominal expected range during the tomographic phase. As observed, all requirements are within ESA SRD specification, with only some very marginal exceptions. It is worth noting that ambiguity ratios are mainly driven by azimuth ambiguities, which are being revisited in terms of the PRF distribution set by CONAE.

Regarding spatial resolution, while ground range resolution is in the order of 10 m in all the swaths, notably the azimuth resolution decreases with increasing along-track baseline as a result of a reduction in the Doppler bandwidth. Analyses show that especially for dual-pol swaths the expected 5 m resolution can reach up to 8.5 m, depending on the baseline; but it is compliant in quad-pol swaths and lower baselines.

Orbit type	Sun-synchronous dawn-dusk 97.9° inclination
Orbit ref. altitude	619.6 km
Repeat cycle	16 days (14 + 13/16)
Mission lifetime	5 years
Instrument frequency band	L-Band (1275 MHz +/- 50 MHz) full-pol
Spatial resol.	10 m (range) x 5 – 6 m (azimuth)
Inc angle	17.6° - 38.3°
Swath width	21 km – 68 km depending on swath and pol.
Baseline	2 km – 250 km along-track 0 km – +/- 12 km across-track
Pol. modes	Dual-pol/Quad-pol
NESZ	-25 dB – -22 dB depending on swath and pol.
Radiom. stability/accuracy	0.5 dB / 0.2 dB

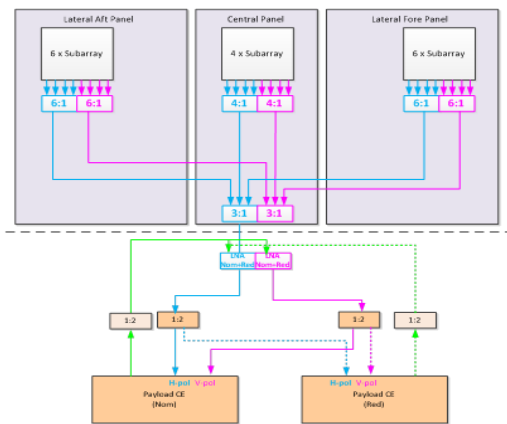


SAOCOM/-CS NESZ-V dual-pol/quad-pol (left) and TAR-V (right) for 650 km altitude

The overall antenna RF architecture is suitable in terms of the expected RF budget levels and phase performance. Dedicated analysis show that the system dynamic range (40 dB) is well covered by the antenna and payload electronics, depending upon the final selection of the ADC. Phase stability is also consistent with expected 6 deg change in 10 min (long-term), and 3 deg in 10 s (short-term).

PAYLOAD DESIGN

RF ARCHITECTURE



The signal received by each of the 16 subarrays are combined to produce a unique RF signal at the output of the antenna for each polarisation, H and V.

These two signals are fed to the radar electronics (CE), both nominal and redundant parts.

The nominal/redundant signal distribution is performed inside the CE, as well as the low-noise amplification of each polarisation.

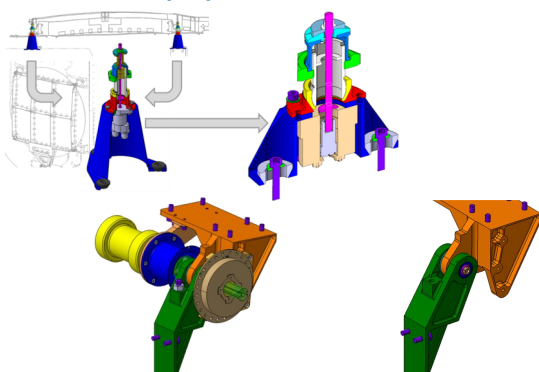
The CE down-convert the signal, digitise it and pre-process it before storing the data in the mass memory of the instrument.

MECHANISMS DESIGN

HRM

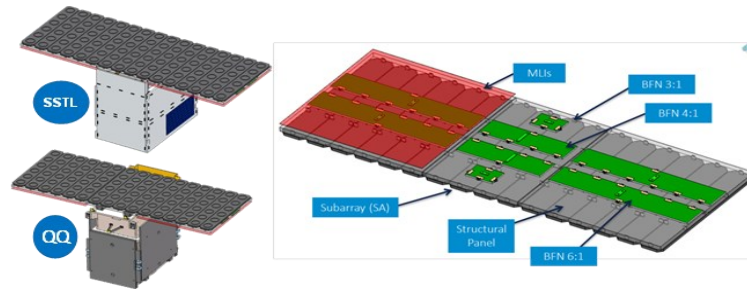
Trade-offs have been made in order to find already qualified solutions directly compatible with this mission but allowed envelope within the launcher adaptor in addition to the antenna panel shape (squared) and its impossibility to be drilled hardly constraints not only the HRMs available locations but also its allowed envelope. These facts lead to a compact specific design for the mission.

CASA HRM proposed solution



DEM proposed solution (active & passive parts)

MECHANICAL DESIGN



Antenna mechanical features:

- ✓ **Mass 63.12kg (incl. Margins)**
- ✓ **Compliant with stiffness requirements (stowed & deployed), of both platforms**
- ✓ **Strenghts: Comfortable margins of Safety in all the cases analyzed for both platforms**

The L-band Antenna has been designed to be compatible with two different platforms (SSTL & Qinetiq platforms). For both platforms, the antenna fits in the available dynamic volume of the launcher (cylinder of 1.5m in diameter & 1.4m in height).

The top antenna panel is fixed to the platform structure by means of 4 brackets. Each lateral panel interfaces with 4 HDRM with the platform. Between the lateral panels and the top panel there are 2 DEM that will deploy the antenna once in orbit.

DEM

Two panels of approximately 25 [kg] and 5 [kgm²] have to be deployed 90 [°] once in orbit. Additionally a couple of RF cables have to be routed to each panel. To fulfil these needs a spring and damped mechanism is the solution to implement.

Some already qualified solutions have been studied and the most reliable solution proposed by CASA consists on the use of the spring motor design implemented in SMOS plus an off-the-shelf damper. This design takes advantage of a smart design that provides redundancy (i.e. higher reliability) even for the sliding surfaces of the deployment axes. CASA has also made emphasis on thermo-elastic aspects and has included the relevant isostatics joints in the design while the needed stiffness values are guaranteed.

PAYLOAD DESIGN

THERMAL DESIGN

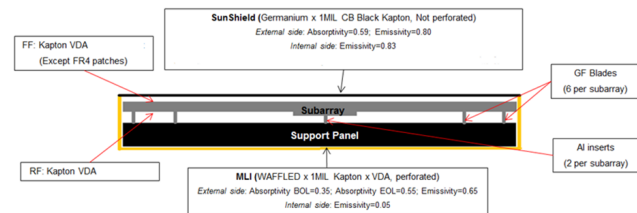
SAOCOM-CS Antenna thermal control provides an adequate thermal environment for the antenna isolating it and minimizing the impact of it in the S/C. It is based on passive thermal control elements only.

The radiating face of the Antenna is covered by a SunShield to avoid direct solar fluxes in the front face of the subarrays. The RF losses due to this SunShield are lower than 0.1 dB. In addition, both faces of the subarrays (front and rear) are covered by VDA kapton foil glued to the surface, which provides a low emissivity to the subarrays, isolating them from the temperatures of the SunShield that is viewing to the space.

The rear and lateral parts of the Antenna are covered by Kapton MLI to isolate the Antenna from external environment.

The subarrays are mounted over the sandwich panel by glass fibre blades that provide a very low conductivity between the subarrays and the panel. BFNs below the sandwich panel are mounted in the same way, by means of fibre

Thermal design concept for Saocom-CS antenna



glass blades with a very low conductivity between them.

The mechanisms (HRMs and DEMs) are covered by the same Kapton MLI used to cover the rear side of the antenna to isolate them from external environment.

THERMAL ANALYSIS

A representative TMM of the Antenna has been built to analyse the different thermal scenarios presented to study the thermal behaviour of the Antenna in Nominal (deployed position) and non-operative (stowed position) mode.

A total of 7 cases have been analysed, 4 nominal and 3 non-operative. The results are summarized in the table below.

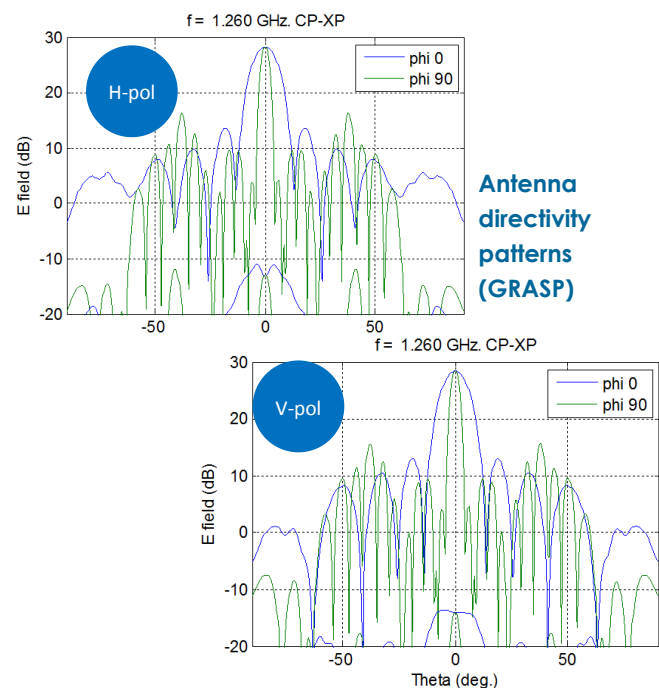
	Description of cases	Temperature range (with 20°C qualification margins)	Temperature ranges obtained for the different elements of the Antenna considering all the cases
Nominal Thermal cases	Hot EOL Winter Solstice Firing +X Hot EOL Winter Solstice Imaging Scenario 04: Payload ON/OFF Scenario 14: Payload OFF Cold Case	Subarrays: +85°C/-55°C Sandwich Panel: +70°C/-50°C BFNs: +60°C/-49°C	Subarrays: +85°C/-74°C Sandwich Panel: +70°C/-59°C
Cold Non-Operative Thermal cases	S5A: Winter Solstice Tumbling case BOL S8C: Vernal Equinox 3 Weeks case BOL S4C: Vernal Equinox Y-Thompson case BOL	Subarrays: +38°C/-74°C Sandwich Panel: +32°C/-59°C BFNs: +30°C/-58°C HRMs: +51°C/-33°C DEMs: +33°C/-20°C	BFNs: +60°C/-58°C HRMs: +51°C/-33°C DEMs: +33°C/-20°C

RF DESIGN

Considering the measured patterns of the subarray, the antenna directivity patterns have been obtained using GRASP model. The patterns at 1260 MHz are shown in the figures in this page, in which XPI is 38.4 dB for H polarization (average in the bandwidth) and 41.2 dB for V polarization (average in the bandwidth).

Simulated results of the antenna S-parameters have been obtained. Input matching at antenna level is better than -17 dB for H polarization and -20 dB for V polarization. Predicted isolation between H and V ports at antenna level is better than -34 dB.

Also, loss budget has been done, and including 10 % margin in all the components, losses better than 2 dB are achieved.



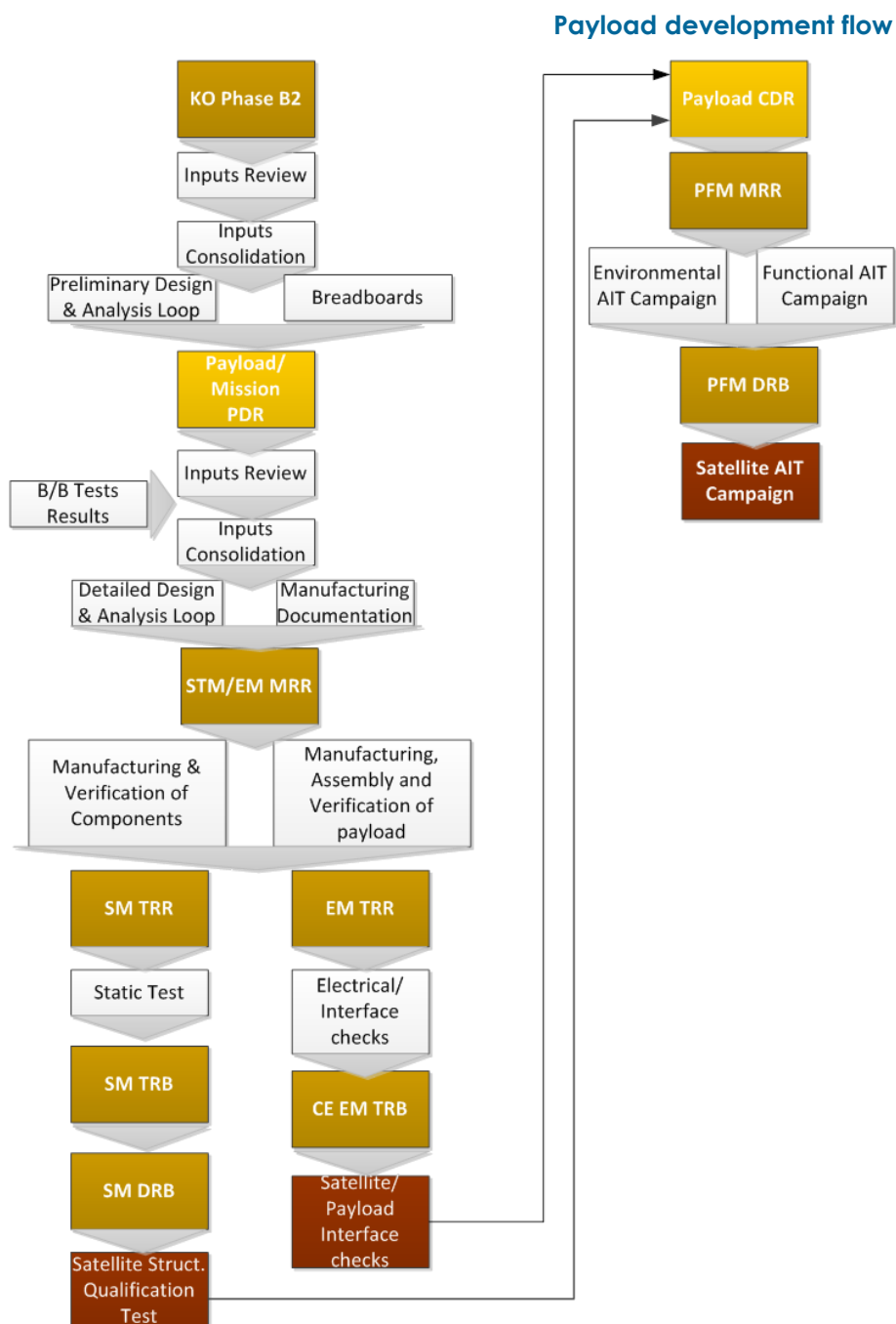
DEVELOPMENT PLAN

The development flow considered takes into account those of the radar electronics, the antenna and the platforms, being compatible also with the schedule of the SAOCOM-1B mission.

The figure below shows the proposed development flow for the payload, considering a kick-off after a bridging phase of 10 months to consolidate the mission programmatic and to achieve the adequate TRL of all the technologies involved.

The payload model philosophy proposed includes:

- A Structural Model (SM), to early check the mechanical behaviour and the mechanisms qualification
- An Engineering Model (EM), for early check of the instrument performance
- A Proto-Flight Model (PFM) that is the complete flight instrument that will be submitted to a full test campaign





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