TM/TC specifications

for the nano-satellite CASAA-Sat

Technical Document

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Summary

Introduction

1 – Object

This document describe the specifications of the TM/TC communication of the nano-satellite CASAA-Sat.

2 – Scope

This document is intended for the radio-amateur community, to be able to receive and request data from CASAA-Sat.

3 – Dictionary

Acronym / Symbol	Definition
CASAA-Sat	CArtography of the South Atlantic Anomaly, the name of the nano-satellite.
TM/TC	Telemetry / Telecommand
FSK	Frequency Shift Keying
BPSK	Binary Phase Shift Keying

I – CASAA-Sat mission

Aix-Marseille University (AMU), through the Laboratoire d'Astrophysique de Marseille (LAM), has been involved since 2013 in the CNES program for the development of Nano-satellites by higher education students, initially the JANUS program, and now Nanolab Academy.

This mission has a strong pedagogical vocation. It has trained around 200 students, including 32 on their end of studies project, from a variety of disciplines and levels (DUT, License, Master's and Engineering schools), welcomed at Aix-Marseille University's Spatial Center, integrated into the LAM.

The initial scientific objective of CASAA-Sat is to CArtograph the South Atlantic Anomaly (SAA) for its one year mission, that is, to probe relevant parameters of the SAA with the aim of correlating them. These are irradiations and magnetic field, to be measured, and luminous phenomena at the poles, to be photographed.

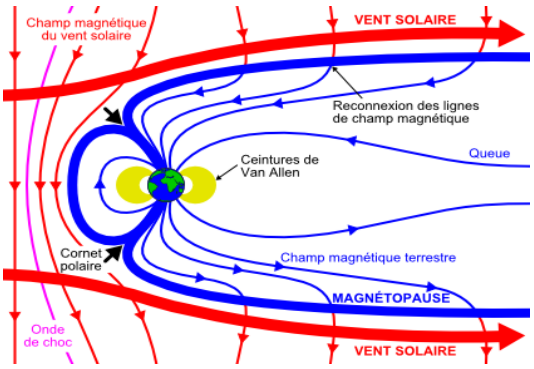
CASAA-Sat will orbit at an altitude of 528 km, using a sun synchronous orbit (SSO) with an inclination of 97.46° and an LTAN of 19h30.

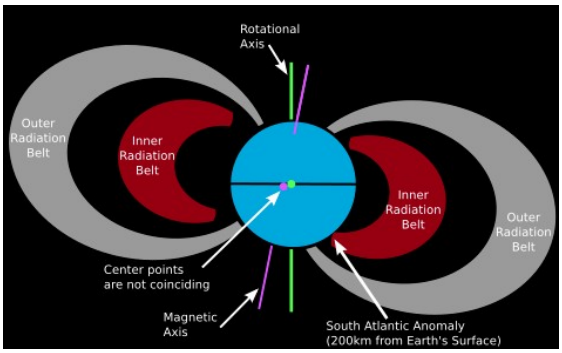
The orbital parameters given by the launcher are:

- Injection time: 2024-12-26 01:16:07 UTC
- Semi-major axis: 6906.4753 km
- Eccentricity: 0.00043
- Orbital Inclination: 97.4637°
- Right Ascension of ascending node: 27.2171°
- Argument of perigee: 173.5024°
- True Anomaly: 357.7322°
- Mean Anomaly: 357.7341°

I.1 – 1st objective: measuring the deposited doses in the SAA

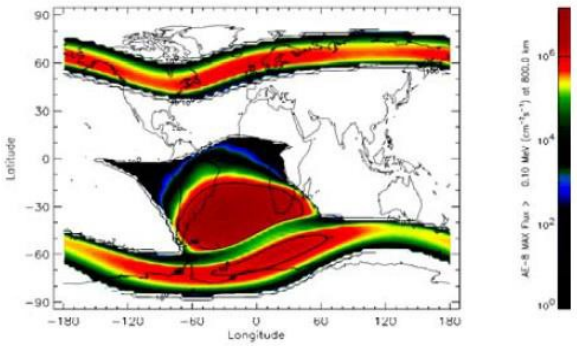
Our planet is bombarded by cosmic radiations, notably by the Sun, like during solar flares. These radiations are can be distinguished into two categories: the charged particles (like electrons and protons), and the neutral particles (like photons).





Charged particles, due to their electric nature, have a trajectory influence by magnetic fields. The Earth magnetic field will trap these charged particles in the magnetosphere, like in the Van Halen belt, where they will create a very strong irradiation environment. We are particularly interested by the inner radiation belt, at an altitude between 1000 and 12000 km, where the South Atlantic Anomaly (SAA), a region of the earth magnetic dipole where the field is weaker, concentrate these particles in lower LEO altitudes.

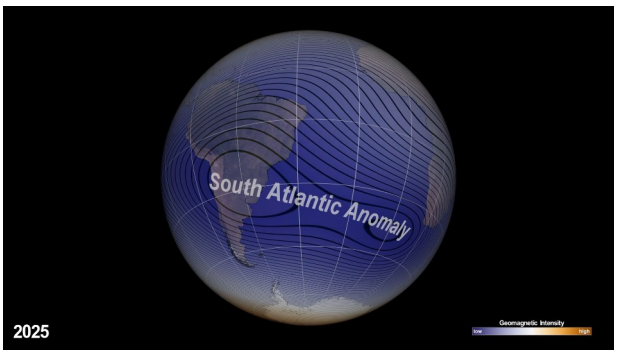
CASAA-Sat first objective is to measure the deposited doses from those radiations, especially at the poles and the SAA where a higher flux is expected. For this, it possesses six dosimeters, two in each axis, able to record the irradiation they receive over time.

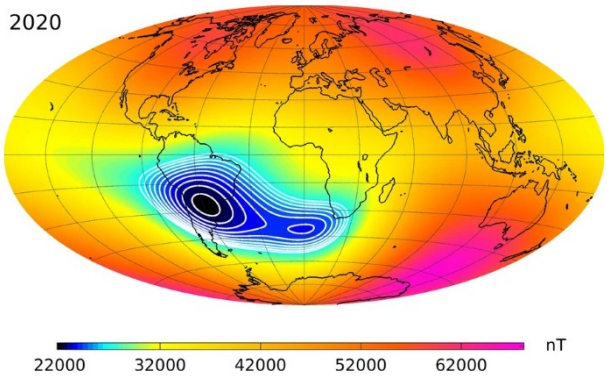


600 km

I.2 – 2nd objective: the magnetic field in the SAA

The measurement of the earth magnetic field is also important since it is that magnetic field that trap charge particles, notably in the South Atlantic Anomaly.



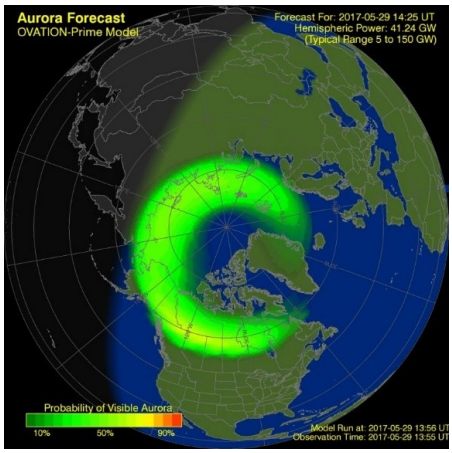


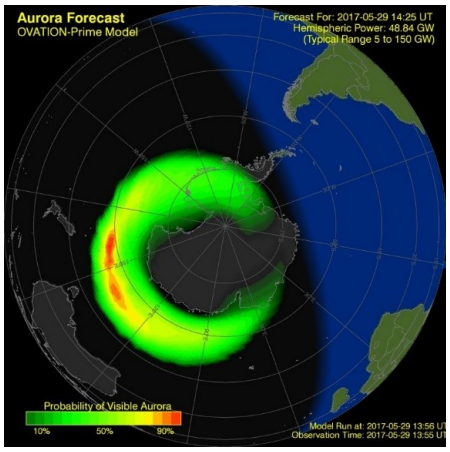
The second objective of CASAA-Sat is to measure the local magnetic field and correlate it with the irradiations. This field will then be compared with existing models like the IGRF 13.

I.3 – 3rd objective: the luminous phenomena at the poles

Auroras borealis (in the north) and australis (in the south) are luminous phenomena in the sky appearing around the geomagnetic poles, in a region called the "auroral zone", particularly during high solar activity. They are the result of charged particles interacting with the upper atmosphere.

The two figures below show the appearance probability of an aurora based on the current solar wind activity.

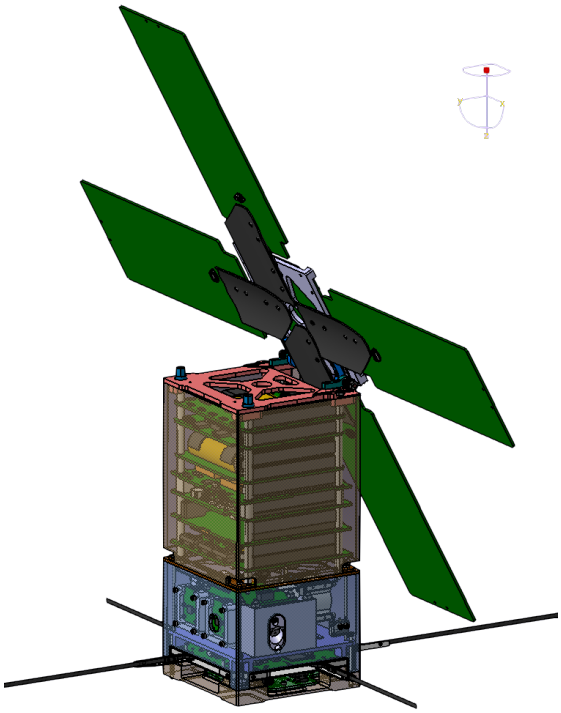




The third objective of CASAA-Sat is to capture these luminous phenomena by taking pictures and correlate them with the irradiation and the magnetic field.

II – Nano-satellite specification

II.1 – Flight Model



The nano-satellite CASAA-Sat is a 2U Cube-Sat (100×100×227 mm) of 2.7 kg.

II.2 – Radio link

The frequencies used by the satellite to communicate to the ground are:

- Up-link: VHF 9600 baud FSK G3RUH at 145.900 MHz
- Down-link: UHF 9600 baud BPSK G3RUH at 436.500 MHz

The satellite uses the AX.25 protocol UI (Unnumbered Information) frames to communicate. CASAA-Sat call-sign is “CASAA-1”. The satellite will send a periodic beacon using a AX.25 frame.

Every AX.25 frame Info section start with a header with a frame id, followed by one or more telemetry/telecommand (TM/TC).

The maximum size of the Info section of the AX.25 frame is 200 bytes in up-link and 235 bytes in down-link.

Some telecommands are authenticated and are not accessible by non authorized users.

III – Payload format

The frame payload is the Info section of the AX.25 UI (Unnumbered Information) frame.

Flag	Address	Control	Info	FCS	Flag
01111110	112/224 Bits	8/16 Bits	N*8 Bits	16 Bits	01111110

Figure 3.1a. U and S frame construction.

The followings formats are shown in a number like representation (LSB on the right and MSB on the left). The number on top show the byte offset.

TM payload format:

6	5	4	3	2	1	0
… TM ...	Check Sum				Frame Id	

TC payload format:

10	9	8	7	6	5	4	3	2	1	0
… TC ...	Check Sum				Date				Frame Id	

The date format is the number of 1/10 seconds since the 01/01/2020.

The first byte of every TM/TC is the TM/TC code.

III.1 – Images

Images are send in 32 bytes chunks, from 1 to 7 chunks per TM frames. The 7 chunk TM uses a more compact version to fit in a frame.

...	36	...	5	4	3	2	1	0
(Count Chunks)	Chunk Data (32 bytes)			Chunk Index		Image Id (12 bits)	Count (4 bits)	0x90

Image 7 chunks TM format (7 contiguous chunks starting at 1st Chunk Index):

...	36	...	5	4	3	2	1	0
(Count Chunks)	Chunk Data (32 bytes)			1st Chunk Index		Image Id (12 bits)	Count (4 bits)	0x91

To request a missed image chunk, the following TC can be sent:

...	5	4	3	2	1	0
(Count Chunk Indices)	Chunk Index		Image Id		Count	0x90

Images can be retrieved using their id:

Get image metadata TC:

2	1	0
Image Id		0x8F

And the response:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Date				Size (in bytes)				Height		Width		Type	Image Id		0x8F

III.2 – Deposited doses

The six dosimeters are measured regularly. Below is the TM to get back the measurement logs:

...	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
(Count Logs)	Dosim Y2		Dosim Y1		Dosim Z2		Dosim Z1		Dosim X2		Dosim X1		Date				Count	0x8A

They can also be requested by the TC:

5	4	3	2	1	0
Count	Start Date				0x8A

III.3 – Magnetic field

Measure logs of the magnetic field:

...	24	...	6	5	4	3	2	1	0
(Count Logs)	Magnetic field measure (19 bytes)			Date				Count	0x8B

24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6
gain	raw -Z		raw -X		raw -Y		Field -Z (nT)				Field +X (nT)				Field +Y (nT)			

They can also be requested by the TC:

5	4	3	2	1	0
Count	Start Date				0x8B

IV – First visibilities

Using the orbital parameters given by the launcher, the first ground visibilities with the satellite at Marseille, France (43°20'15.0"N 5°26'03.6"E) are the following:

Date 1 le 26/12/2024 à 08:22:59 (UTC+1).
Duration 1 : 9.531515 min.

Date 2 le 26/12/2024 à 09:58:39 (UTC+1).
Duration 2 : 5.524505 min.

Date 3 le 26/12/2024 à 19:05:21 (UTC+1).
Duration 3 : 9.238392 min.

Date 4 le 26/12/2024 à 20:40:47 (UTC+1).
Duration 4 : 7.264588 min.

Date 5 le 27/12/2024 à 08:11:07 (UTC+1).
Duration 5 : 9.456013 min.

Date 6 le 27/12/2024 à 09:46:26 (UTC+1).
Duration 6 : 6.370053 min.

Date 7 le 27/12/2024 à 18:53:37 (UTC+1).
Duration 7 : 9.004738 min.

Date 8 le 27/12/2024 à 20:28:31 (UTC+1).
Duration 8 : 7.874793 min.

Date 9 le 28/12/2024 à 07:59:16 (UTC+1).
Duration 9 : 9.319197 min.

Date 10 le 28/12/2024 à 09:34:17 (UTC+1).
Duration 10 : 7.058056 min.

Date 11 le 28/12/2024 à 18:41:55 (UTC+1).
Duration 11 : 8.709041 min.

Date 12 le 28/12/2024 à 20:16:19 (UTC+1).
Duration 12 : 8.363923 min.

Date 13 le 29/12/2024 à 07:47:27 (UTC+1).
Duration 13 : 9.117221 min.

Date 14 le 29/12/2024 à 09:22:11 (UTC+1).
Duration 14 : 7.628759 min.

Date 15 le 29/12/2024 à 18:30:15 (UTC+1).
Duration 15 : 8.346235 min.

Date 16 le 29/12/2024 à 20:04:11 (UTC+1).
Duration 16 : 8.754242 min.