AlSAT-1N

AMSAT Briefing

Briefing on the AlSat-1N spacecraft for the Amateur Satellite community.

Version	Date	Changes
1	24th Sept 2016	First Issue

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1 Scope

This document provides a briefing to the AMSAT community on the AlSat-Nano mission in relation to the AlSat-1N spacecraft. The document provides an overview of the spacecraft, the mission and provides the telemetry formats. The document provides a point of contact for feeding data back to the mission.

2 Mission Overview

2.1 Mission Goals

The main goals of this programme are:

- To provide education and support allowing development of space technologies and applications which are of practical use to Algeria, at a competitive cost which will help to create sustainable growth in the country.
- To offer a flight opportunity for payloads and/or bus elements to the UK nanosatellite & CubeSat community to be selected for flight through an open competition issued by UKSA in collaboration with SSC and ASAL.

The overarching aim of the programme is to foster an enhancement of collaboration in space programmes between the UK and Algeria, in line with intentions expressed in a MoU [AD-03]. In particular this programme has been developed to help tackle some of the Algerian developmental challenges and therefore the payloads will have to demonstrate some contribution towards meeting these objectives. The programme operates at three different levels, i) Education, ii) Research and iii) Production and field deployment of applications, which are interconnected to create synergy within the programme. The various activities will be brought together by the development of the nanosatellite and its deployment, which are an integral part of the joint programme.

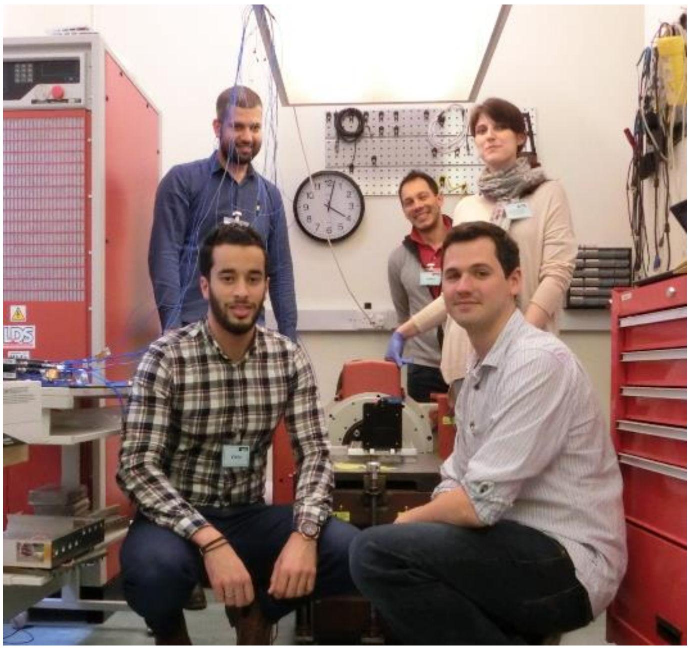

Figure 1 – The FM Vibe test team

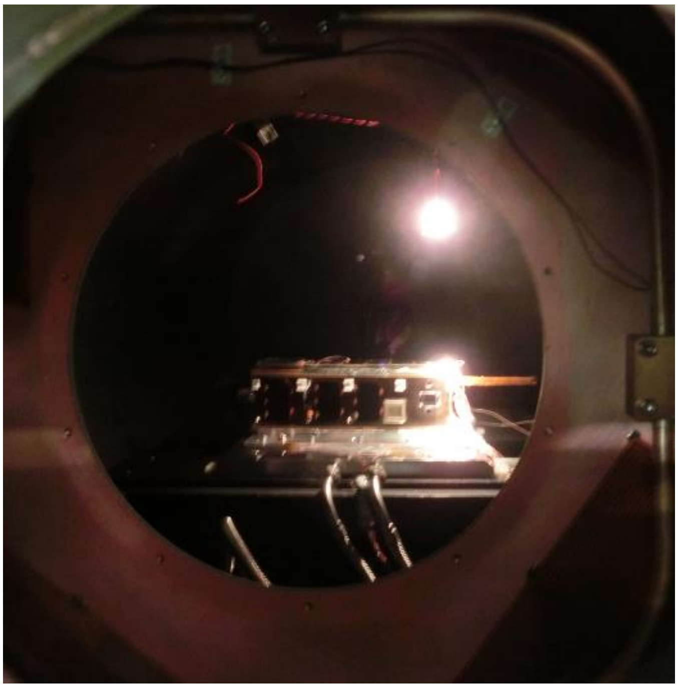

Figure 2 – AlSat-1N undergoing Thermal vacuum testing

Figure 3 – AlSat-Nano operator training

Figure 4 – AlSat-1N Flight Readiness Review inspection

2.2 Mission Orbit Parameters

Pre-launch TLEs are given below; parameters shall be updated as information becomes available.

1 99911U 58056A 16270.26346165 .00000000 00000-0 +80011-4 0 335

99911 98.2043 327.8094 0027727 264.5366 95.3533 14.63819911213958

Start of beacon transmission is anticipated for 06:57UTC 26/09/2016.

2.3 Satellite Registration

As the mission is to be operated by Algerian students and staff, and from Algeria, the spacecraft was co-ordinated as shown.

The International Amateur Radio Union

Since 1925, the Federation of National Amateur Radio Societies
Representing the Interests of Two-Way Amateur Radio Communication

IARU Amateur Satellite Frequency Coordination

Back to List of Sats whose Frequencies have been coordinated

Alsat-1N	Updated: 21 Jan 2016		Responsible Operator	Djamel Eddine Baba Hamed 7X4TS
Supporting Organisation	Centre de Développement des Satellites			
Contact Person	debabahamed@cds.asal.dz.nospam			

Headline Details: A: Commissioning The 3U CubeSat satellite must first perform key tasks for communications, power safety, and commanding of payloads via the on-board computer (OBC). After this, the attitude determination and control system will perform key maneuvers for power safety via B-dot (Y-Thompson) and 3-axis pointing modes. B: Educational Mission The satellite is being built in collaboration between Surrey Space Centre staff and Algerian students as a technology transfer and demonstrator for Algeria. C: U.K. Payload Hosting The satellite is also hosting three U.K. payloads from various institutions to increase the technology readiness level (TRL) for D: Outreach The satellite aims increase widening participation of satellite technologies for engineering and science within Algeria and the UK. Additionally, the satellite aims to take images of the Earth and send back data from the UK payloads. E: Extended Mission It is planned that the satellite will continue after 1 year with further Algerian depts. (to be clarified). Proposing a 9k6 FSK downlink using FSK as Strand-1. Planning an SSO launch by ISRO, no launch date has been provided.**A Downlink on 437,650 MHz has been coordinated**

Application Date:	16 Nov 2015	Freq coordination completed on	11 Jan 2016

The IARU Amateur Satellite Frequency Coordination Status pages are hosted by AMSAT-UK as a service to the world wide Amateur Satellite Community

2.4 Community Data

Any downlinked data will be gratefully received to alsatnano@gmail.com. Both decoded hex files and recordings would be greatly appreciated. Richard Duke (M0GSN) is transmission authority in the UK under SSC Club callsign M0GKK.

3 System Description

3.1 System Architecture

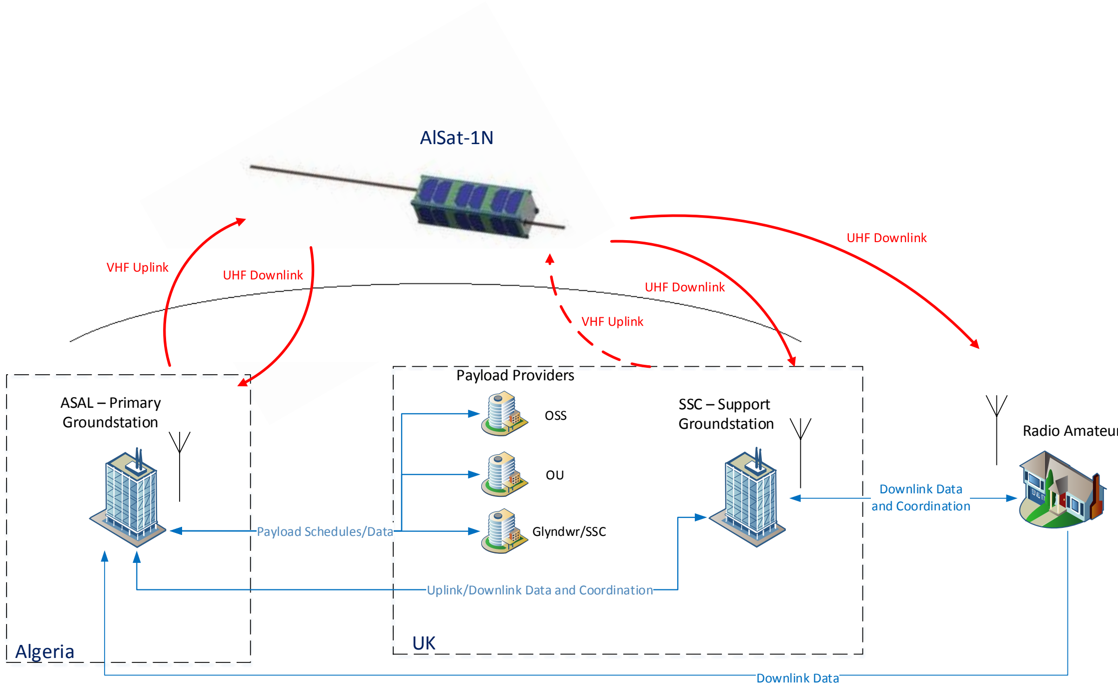

Figure 5 – Top level system interactions

The AlSat-1N spacecraft is a 3U CubeSat 10x10x34 cm. The design philosophy is to keep the platform as simple as possible and minimize the new development. That is achieved with the usage of COTS components as well as the ones with flight heritage.

The AlSat-1N spacecraft is a 3U CubeSat utilising VHF/UHF amateur frequency bands. The spacecraft is controlled by an On-Board Computer that interfaces with an on-board transceiver. The OBC interprets and acts on uplinked telecommands and sends beacon and requested telemetry and files. The spacecraft is operated by the mission primary ASAL ground station. The SSC Support groundstation and radio amateur community can receive transmitted data from the spacecraft. Data from SSC and Radio amateurs can be supplied to the ASAL groundstation data centre.

All Telemetry Channels are available for reference and are appended to this document.

3.2 Space Segment Description

The spacecraft is a 3U CubeSat 10 x 10 x 34 cm:

Figure 6 – AlSat-1N CubeSat

The platform avionics is composed by:

- Stellenbosch ADCS that additionally acts as an OBC. This subsystem is expected to be capable exceed requirements for the Pointing and Stability Capability as well as timing requirements.
- The power system, with the ClydeSpace 3rd gen 3U EPS, and custom solar panels (with cells Azur Space 28% of efficiency) with the same cut-out of the structure and standalone battery 30Whr.
- The communications with the ground station are executed through the STRaNDceiver ('STRx'), using the UHF band to transmit and the VHF to receive, aided by a gain stage between the VHF and the STRx.
- An SIB and a Power switch board, both made in SSC, will provide it interface with the EGSE and with the payload respectively.

The spacecraft uses a novel Copper-Beryllium tape form antenna system, with the UHF Tx and VHF Rx antennas deploying from opposite facets of the spacecraft

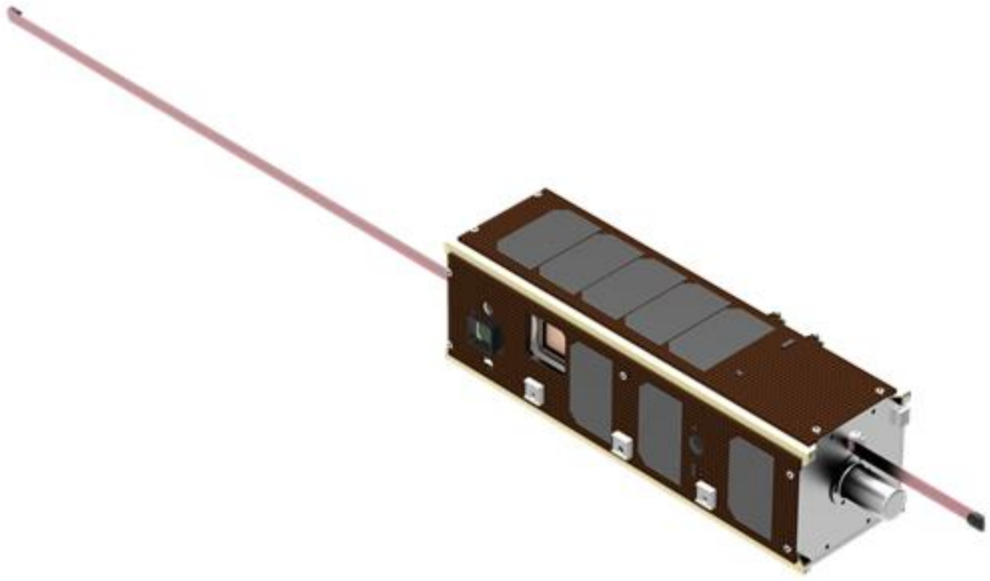

Figure 7 – AlSat-1N CubeSat rendering with deployed antennas

The selected payloads are:

- The AstroTube™ Boom from Oxford Space Systems[1]
- Thin Film Solar Cell supplied by Glyndwr University
- Compact CMOS Camera Demonstrator 2 (C3D2) from Open University

The S/C uses the I2C protocol and/or CAN for telemetry and telecommand depending on the payloads specification. During the Payload operation, the S/C will store and downlink. All platform subsystem communication is via I2C with the OBC as master.

Although the payloads are not intended to interact which each other, one of the cameras of the C3D2 Payload is focused on the length of the Boom, to capture images of this after the deployment. No other interactions exist.

RF communications are achieved using the STRaNDceiver ('STRx'). The STRx operates at amateur band frequencies and is a two-board, modular VHF up/UHF down RF transceiver designed for CubeSats. It consists of a digital modem, two IF stages (for uplink and downlink) and an analogue frontend. The IF stages are single-chip RF modems with a fixed IF in the 70 cm band. The digital modem hosts an I2C slave node, which provides the main bus interface to the module.

Because of the fixed IF, the analogue frontend acts as a combined LNA and frequency converter, shifting the VHF signal to the UHF-band IF. This is done in a single stage, using a non-tuneable local oscillator of 312.5MHz. Fine tuning is achieved within the IF chain of the modem. The downlink stage consists of a single, switched, high-power amplifier with a gain of approximately 30dB with a maximum output power of 31dBm. Input drive level, fine-tuning of the IF, data modulation & demodulation, and similar operations are all performed by the digital modem by setting parameters in the RF modem chips via a SPI interface.

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[1] Since project inception, the SpaceMag boom has been renamed AstroTube to ensure consistency with communication from OSS

3.3 Hosted payloads

3.3.1 AstroTube™ Boom

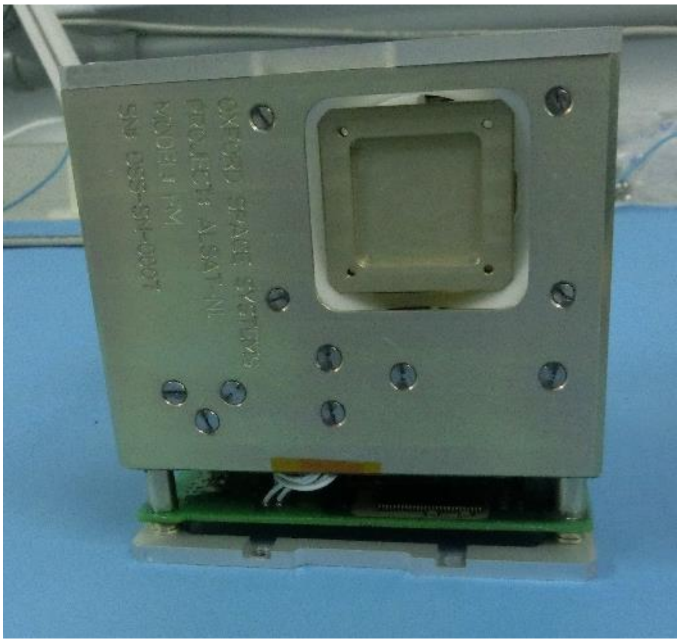

Figure 8 – AstroTube™ Boom Payload

The AstroTube™ Boom payload is divided into 3 elements: the main PCB, the boom mechanism and the secondary (sub payload) PCB.

The AstroTube™ OSS payload comprises the following sub-systems:

- 1.5m long extendible rolled composite boom, boom mechanism, and associated main PCB.
- Magnetometer and associated electronic circuit (AstroTube™-Lite)
- 2x RADFET (Radiation-Sensing Field-Effect Transistor) and associated electronic circuit

The extendible element of the boom sub-system is a 20mm diameter open-section flexible composite member with a 224° subtended angle and 0.3mm thickness. Epoxy-based plain weave carbon fibre prepreg has been used in the manufacturing of the boom as this material type has low outgassing characteristics and relatively high radiation tolerance. The boom element itself can be fully or partially deployed; it can be retracted and stowed from either of these two states.

The SpaceMag-Lite is a three axis, lightweight, fluxgate magnetic sensor, offering measurement performance from DC to 1kHz, for field strengths up to ±60µT.

The RADFETs (Radiation-Sensing Field-Effect Transistor) are microminitaure silicon pMOSFET transistors which act as an integrating dosimeter, measuring dose in rad or Gy(Si).

Figure 9 – AstroTube™ Boom Payload fully deployed from AlSat-1N

3.3.2 C3D2

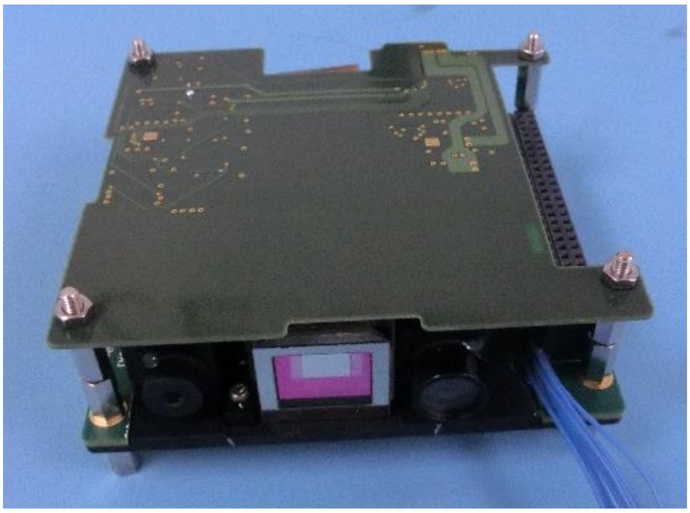

Figure 10 – C3D2 Imager Payload

C3D2 is based on the C3D imager that has been previously flown on UKube-1.

C3D2 hosts three (3) e2v 'Sapphire' CMOS imaging sensors, each capable of implementing multiple imaging modes, in a three (3) imager arrangement; two (2) wide field imagers (WFI) and one (1) experimental narrow field imager (NFI). C3D2 can also perform thermometry and radiation dose measurements using a suite of distributed sensors on an experiment support system (ESS).

One of the wide field imagers is focused to be able to image the Boom payload during deployment.

The majority of images downloaded by C3D2 will be made publically available.

3.3.3 Thin Film Solar Cell

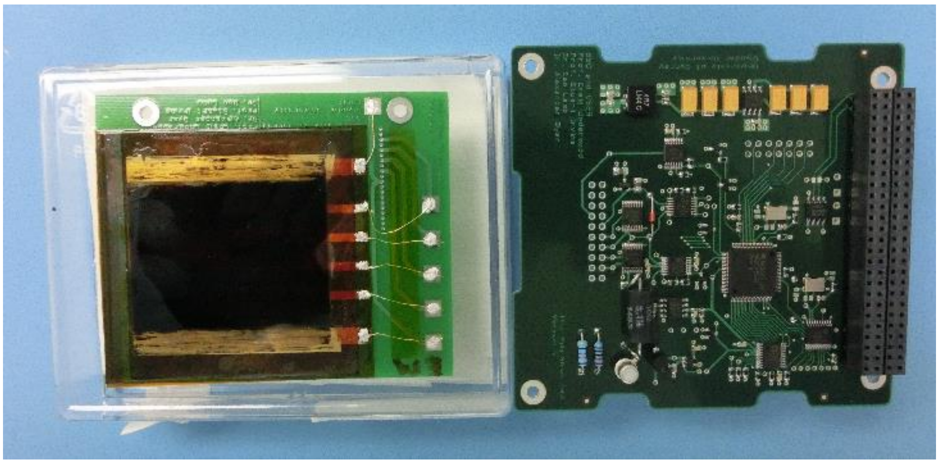

Figure 11 – Thin Film Solar Cell Payload

Glyndwr University are demonstrating a novel thin film solar cell structure. The structure is the first to utilise from Qioptiq Space Technology Ltd's (QST) ultra-thin and flexible cover glass as both the substrate and radiation protection for the solar cell.

The Thin Film Solar Cell (TFSC) payload is designed to measure the (non-linear) current-voltage (I-V) response of 4 experimental thin-film solar cells in orbit when illuminated by the Sun.

The TFSC payload consists of two elements: An externally mounted board, which is mounted on a solar-irradiated surface and an internally mounted controller board. The solar cell test has 4 test cells with a mounted LM35 temperature sensor.

3.4 Ground Segment Description

The Figure 12 depicts the ground station system diagram. A primary PC maintained within the Ground Segment control centre interfaces with both the RF chain and rotator systems. Groundstation software and interfaces are discussed in the Ground Station Specification document. The RF chain is based around an ICOM-9100 transceiver controlled via the ground segment control PC via a Kantronics TNC (KWM-9612+). Doppler frequency control of the ICOM is via the control PC. The ICOM Tx line is routed to the 144MHz antenna – an optional HPA can be included in the system on the transmit chain if found to be needed. The ICOM Rx is connected to the 434 MHz antenna through a masthead mounted UHF LNA (SP-70). The Antennas are mounted on a mast at the ground segment site. Tracking rotation in Azimuth/Elevation is via Yaesu G-5500 rotators controlled with Yaesu GS-232 interfaced to the groundstation PC.

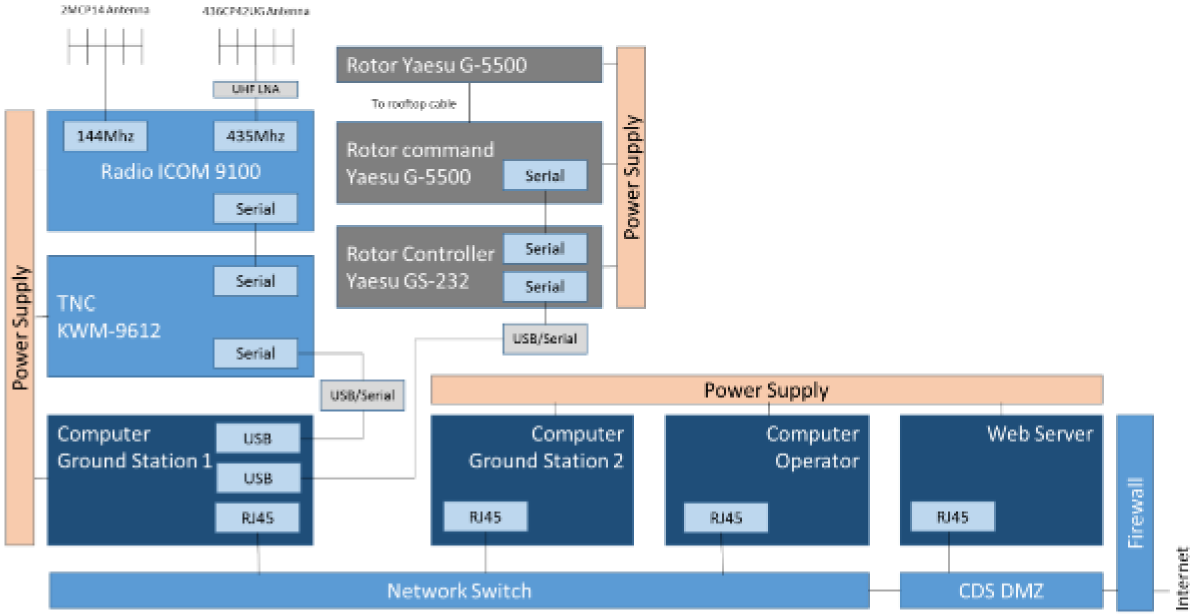

Figure 12 – ASAL ground-station system diagram

3.5 Definitions

Table 1 provides definitions of terms used in this document.

Table 1 – Definition of terms used in this document

Message	Any message that gets sent between the spacecraft and mission control system. This is a standard SSC message structure that is common to all communications to the spacecraft and between on board systems. The Message is self-contained and is addressed to a single node (subsystem/payload).
Telecommand	A message sent to the spacecraft which is intended to cause an action / change on the spacecraft. A single telecommand message can contain one or more channels of data in the ground to space direction, and one or more channels as a reply in the space to ground direction.
Telemetry Request	A message sent from the spacecraft to the ground that returns data related to the health or operation of the spacecraft. A single telemetry request message can contain one or more channels of data in the ground to space direction, and one or more channels as a reply in the space to ground direction.
Channel	A part of a message that has been set to contain a specific value. (Also known as a 'data field')
Mission Control	Mission Control System is the ground-segment spacecraft commanding software. This consists of a database and associated programs to allow

System (MCS)	spacecraft controllers to efficiently control both the groundstation and spacecraft.
Packet	A packet is a unit of data that is sent between two systems. The packet usually contains a header that contains address information used to route the packet to its intended destination, and a payload or data frame which contains the telecommands or telemetry data.
WOD / Schedule Entry	Unit of data in a file which uses a similar structure to the transmission protocols
File	A File consists of a set of data. This can be composed of a set of WOD or Schedule Entries or payload formatted data

4 Radio Frequency Interface

RF Interface parameters for the AlSat-1N spacecraft are given in Table 2.

Table 2 – RF Downlink interface parameters

Direction	**Frequency** (MHz)	**Band**	**Data rate**	**Modulation**	**Bandwidth**	**Data format**	**Power**
Downlink	437.646	UHF	9600 bps	G3RUH filtered FSK	12.5 kHz	NRZI, scramble (G3RUH)	Max. +31dBm

All baseband operations, including filtering, pulse-shaping, bit encoding etc. are handled by the modem ICs within the STRx transceiver.

The STRx has a maximum power output of +31 dBm (not counting feed/antenna losses). The downlink modem signal power can be reduced to +10 dBm in two steps via telecommand.

4.1 STRx HDLC

Data are transmitted via RF within HDLC-like frames – the HDLC encapsulation does not fully meet the I-frame definition standard however the point-to-point nature of the link allows for this variance. HDLC encapsulation and strip-out, G3RUH data scrambling/descrambling and all other baseband operations (including bit stuffing) are handled by the modem automatically on both uplink and downlink.

At least 10 header bytes are transmitted first as a preamble to facilitate the operation of bit recovery loops in digital receivers. The preamble bytes are followed by a number of HDLC flags to ensure a receiver is able to distinguish the start of a valid packet.

Packets include 4 bytes of HDLC address (8-bit coded ASCII characters representing a call-sign), STRx Transceiver header consisting of Sequence (1 byte), Length (2 bytes) and ID (2 bytes). The packet then provide context for the payload data in the SSC Header consisting of Payload ID (1 byte), Message ID (1 byte) and Response Code (1 byte). The data is then provided in the frame with variable length as defined by the SSC Header with relation to the TLM spreadsheet.

Figure 13 overleaf shows the AlSat-1N packet structure in a KISS frame with a worked example of the EPS critical telemetry (Payload ID: 0x2E, Message ID: 0xF0) as outputted by a TNC.

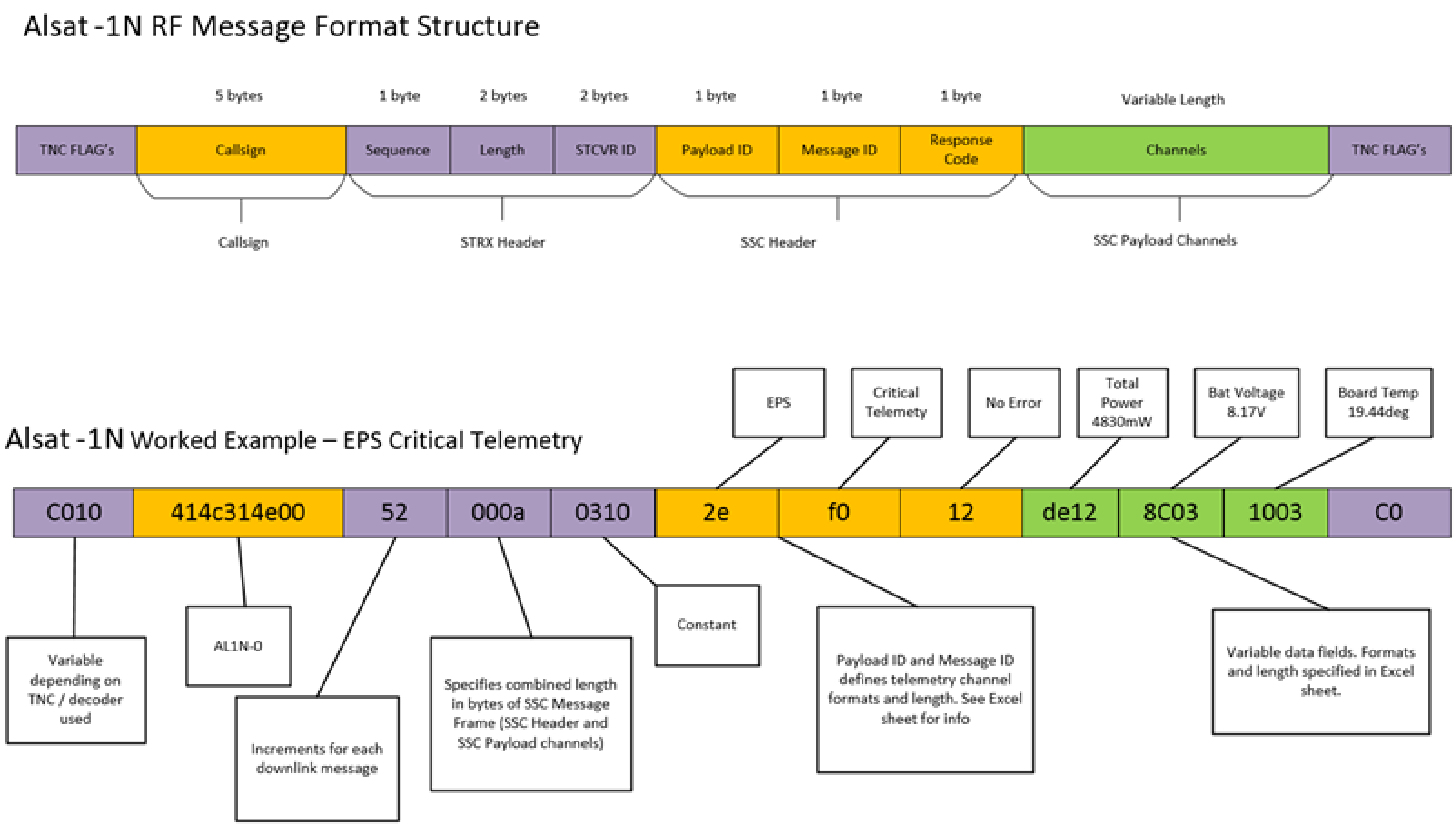

Figure 13 – Overview of AlSat-Nano HDLC packet structure

5 Spacecraft Beacon

Platform housekeeping can be collected via the regular telemetry beacons, and also through the collection of WODs. Further collection is anticipated from amateur secondary stations.

The spacecraft beacon in a nominal state shall transmit spacecraft health data at 15 second intervals. The interval of the beacon is however modified by the battery voltage within four categories:

Table 3 – Beacon interval

Battery Voltage	Beacon Interval
Highest	90s
High	120s
Normal	180s
Low	300s
Lowest	540s

5.1 Beacon

The beacon is configurable, but by in nominal mode by default all consist of the following data:

- OBC parameters:
  - **Software Version (OBC)**
  - **Software Boot Location (OBC)**
- Power parameters:
  - **Battery voltage (EPS)**
  - **Battery current (EPS/Battery)**
  - BCR inputs from Solar Panels (EPS)
  - Bus currents (3.3V, 5V, V_BAT)(EPS)
  - Switched power line state (PDM)
  - Switched power line voltage (PDM)
  - Switched power line current (PDM)
  - Solar Panel Sun presence (EPS)
- FDIR parameters
  - EPS reset counter (EPS)
  - **Up-time (OBC)**
  - **Unix Time (OBC)**
  - Fault register (OBC)
- Comms parameters
  - **Traffic counter (OBC)**
  - **RSSI (STRx)**
  - **Doppler (STRx)**
- ADCS parameters:
  - ADCS estimation mode (OBC)
  - ADCS control mode (OBC)

- Estimator Attitude (OBC)
- Estimator Rates (OBC)

- Temperature data:
  - **Battery (Battery)**
  - BCR (EPS)
  - Solar Panels (EPS)
- Amateur Radio Text Message
- Miscellaneous
  - Configurable registers (OBC)
    - Eg: raw ADCS data, payload tlm, etc.

A safety critical subset (in **bold**) of these are used during safe-mode and start-up ops to reduce transmit power and to reduce OBC and I2C data throughput.

Beacons can be configured to be a burst transmission of all packets one after the other or round-robin whereby an interval exists between each packet. Nominal operations would use burst transmission a low power state shall use the round robin system.

Configurable Slots exist in the beacon for operator selected additional telemetry above the baseline.

The beacon can be commanded to beacon with a user defined period should it be desired.

5.2 Beacon Alterations

The content of the beacon may be altered during operations to include a limited set of pre-defined parameters or to react to operations as they happen.

5.3 End of Life Capabilities

Three months prior to scheduled end of life, a plan will be constructed that safely puts the spacecraft into a silent non-operational mode. This will include steps such as depleting the batteries and making sure that un-wanted transmission does not occur.

6 Mission Timeline

The mission timeline gives an estimated guide to the key phases within the mission. This starts from LEOP where power and safety needs to be stable for a prolonged period of time. And ends with the radio silence and deorbiting (or handover to the amateur radio community for further experimentation).

The following phases are planned:

Phase	**Phase**	**Activity**

A - Launch and Early Operations (Platform Commissioning)	A1	• Launch
		• Confirmation of deployment from launch vehicle
		• Automated deployment of antennas
		• Monitor Radio Amateur community
		• Receive beacon data from spacecraft during groundstation passes to verify:
		    ○ Power safety
		    ○ Thermal safety
		    ○ OBC uptime
		• Receive ranging TLEs from JPSOC – confirm spacecraft orbit

	A2	• Request telemetry during groundstation passes including:
		    ○ BCR currents
		    ○ Solar Panel temperatures
		    ○ RF parameters
		• Nominal ops safe mode and start of processes
		• Command downlink of WOD files
		• Characterise safe mode state
		• Establish operational constraints

B - Payload Commissioning	B1	• Commission TFSC payload • Commission C3D2 payload • Commission Boom payload **Minimum mission success criteria achieved**
	B2	• Command turn on of ADCS and verify system stability • Activate estimation mode • Command downlink of WOD files • Establish operational constraints
	B3	• Command Detumbling mode into Y-thompson spin • Downlink of ADCS WOD
C - Payload Operations	C1	**Payload Operations to achieve full mission success criteria**
	C2	• Enter 3-axis stabilisation **Payload Operations to achieve extended mission success criteria**
D - End of Life	D1	• If appropriate, assign an AO-status allowing the amateur radio community to operate and receive the beacons to end of life • Maximise drag area • Passivate battery • Deactivate radio transmitter **Nominal End of Mission**

Table 4 – Operational Phases of the AlSat-1N mission