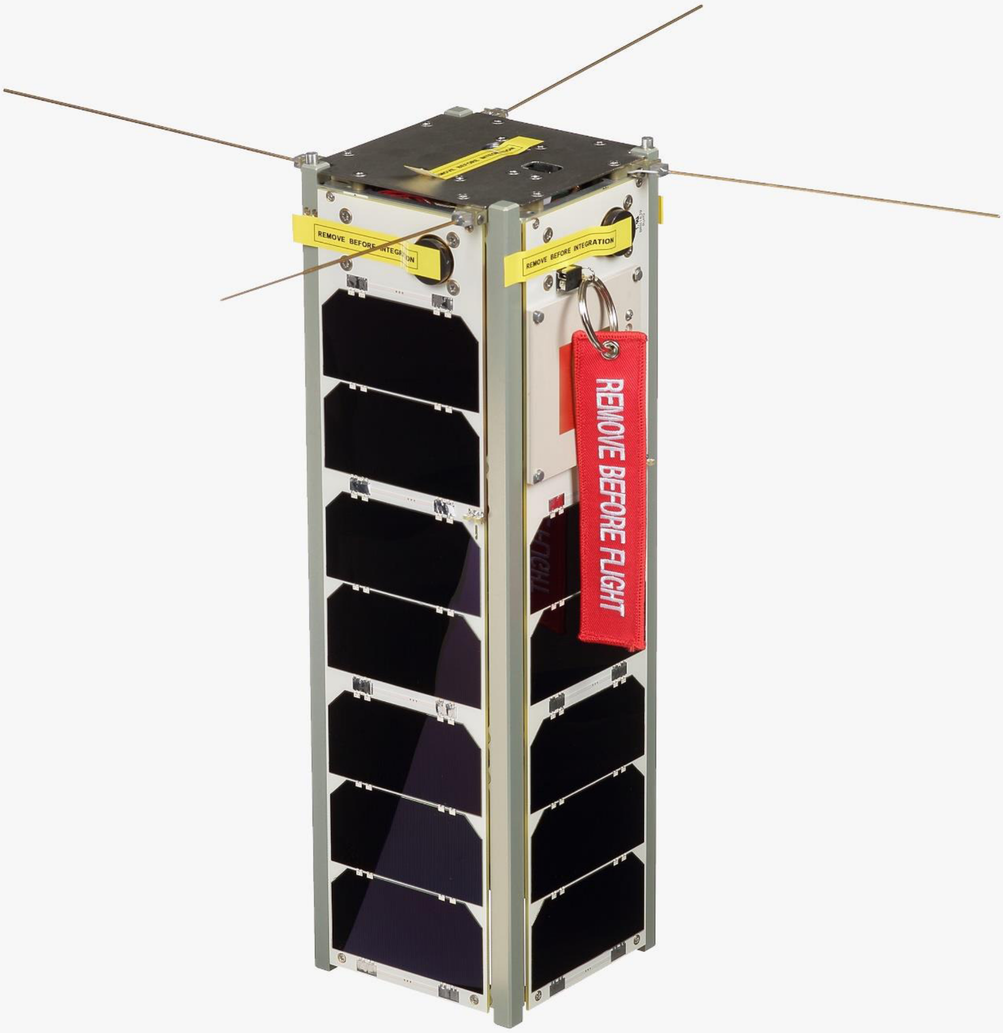

Lacuna 3U Satellite

Space Debris Mitigation Report

NA-LS3-SDMR-R0

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1. Introduction

This document aims to describe the measures, verification methods and possible implementations to be taken in order to reduce the probability of fragmentation events and collisions, and minimize the probability of hazard occurrence in orbit and in case of re-entry as described in ECSS-Q-40B document for the Lacuna 3U satellite (LacunaSat-3). This document was prepared by NanoAvionics by following ESA Space Debris Compliance Verification Guidelines.

2. Scope of the Document

This document provides information on how the ESA Space Debris Requirements are met by LacunaSat-3 satellite.

3. Reference Documents

1. EXO_LacunaSat_ICD
2. *ESA Space Debris Mitigation Compliance Verification Guidelines*

4. LacunaSat-3 satellite Summary

The mission of M3P platform is to safely and cost efficiently launch the satellite into its orbit and to operate there with integrated customers payload.

Standard configuration of the satellite hardware layout allows the maximization of volume available for the payload and ensures robust power properties and thermal control for sensitive payloads, such as measurement and remote sensing instruments. To ensure the practical reliability of the satellite, radiation-resistant components and design implementations are involved to support critical systems such as the Flight Computer, Payload Controller, Electric Power System and Communication System.

The LacunaSat-3 satellite is split into following subsystems:

- **Electrical Power Supply (EPS)**: the system that delivers the power to all other subsystems as regulated power on individual channels. These channels are also monitored and turned on/off by the EPS. The EPS also controls the satellite operational modes.
- **Communications (COM)**: the COM subsystem takes care of communication with earth over UHF-based radio link. The system is able to send and receive telemetry data and establish a two way communication with the ground station
- **Flight Computer (FC)**: this system is responsible for system level services such as mission planning, telemetry logging, power management and payload control. Additionally it provides power and data interface to other subsystems, as well as performs automatic or manual thermal control.
- **Payload Controller (PC)**: provides an interface with the other subsystems and allows to monitor and control the payload.
- **Structure**: responsible for the overall structure of the satellite. This includes subsystem placement and fastening, deployables and material selection.
- **Solar Panels (SP)**: the solar panels are used to charge the batteries, which helps to ensure safe operating conditions even in the eclipse.
- **Attitude Determination and Control Subsystem (ADCS)**: this system is responsible for detumbling the satellite as well as provides accuracy and stability of the satellite, payload and antennas. This is done by the use of various sensors and actuators.
- **S-Band**: is used for payload data uplink and downlink, due to higher data throughput capabilities.

- **Payloads:** IoT transceiver consisting of receiver, transmitter and low-profile antenna, capable of sending and receiving LoRa messages send by IoT devices on the ground in the ISM/SRD bands (notionally 868 MHz and 915 MHz).

5. Procured Launch Service Description

NanoAvionics will use the offer for a piggyback-launch opportunity to Low Earth Orbit (LEO) with the Soyuz-2 launch vehicle as has been offered by ExoLaunch. All the technical information about the launch vehicle and deployer can be found in EXO_LacunaSat_ICD document.

6. Mission Overview

The LacunaSat-3 is brought to a 543-568 km altitude, Sun Synchronous Orbit (SSO) orbit by the Fregat US, which is itself a commonly used upper stage for the Soyuz-2 launch vehicle.

The Lacuna payload is an efficient transmitter that sends satellite almanac and device operating frequency information to LoRa IoT devices on the ground in the ISM/SRD bands (notionally 868 MHz and 915 MHz). It also has the ability to receive IoT signals in the same bands. Transmit and Receive is achieved via a separately connected and mounted single low-profile passive antenna.

7. Space Debris Requirements

The space debris requirements will be met by verification methods, which include test, analysis, review-of-design and inspection. Debris Assessment Software 3.1 (DAS3.1.1) was used in order to analyze the change in the satellites orbit due to natural decay as well as to see if the orbit debris requirements are met. Atmospheric drag, solar and lunar gravity, solar radiation pressure, and Earth's gravity field with Zonal harmonics (J2, J3 and J4) are the perturbations included in the DAS orbit propagator. The atmospheric model used in DAS was the Jachia 1976 Standard Model. The coefficient of drag is assumed to be 2.2 and coefficient of reflectivity is assumed to be 1.25.

8. Space Debris Mitigation Implementation and Verification

8.1. Space System Mission-Related Objects (MROs)

The requirement aims at limiting the spacecraft Mission-Related Objects (MROs), larger than 1 mm, which can be intentionally separated or unintentionally released during the launch and operational phases. The requirement aims as well at limiting the risk of collision of MROs with the parent space system or any other operating space system since most of these mission-related objects are released with low relative velocity and, therefore, remain in close proximity to the operational orbit of the parent body.

8.1.1. Mitigation Measures

The M3P platform satellite bus was designed such that there are no unintentional MROs released. This was done by choosing materials and system technologies that are able to withstand the environmental degradation, before atmospheric re-entry.

8.2. Space System Fragmentation and Explosion Risk

This section covers all potential causes of break-up during deployment and mission operations.

8.2.1. Mitigation Measure

To minimize and eliminate the presence of MROs in LEO the M3P satellite bus was designed in such a way that no MROs are released during the satellite deployment or mission operations. The LacunaSat-3 satellite has no propulsion system nor any pressurized vessels. Lithium Ion batteries are used on board the satellite, which have previously flown on other satellite missions such as NanoAvionics LithuanicaSAT-2, M6P, BlueWalker1 and others.

8.3. Space System Small Particles Release

The requirement aims at preventing the release of randomly dispersed small particles (> 1 mm) in Earth orbit. These particles, although small, can damage operational space systems.

8.3.1. Mitigation Measures

The LacunaSat-3 satellite has four burn out wires used in its design, all of which are used for UHF antennas deployment.

To eliminate the release of small particles, the wires are secured in such a way, that when they are burned, they are not released to the outer space or to the inside the system, rather the wires are tied down to the subsystems to ensure that they are not released.

8.4. Space System On-Orbit Collision Risk Assessment

NASA DAS software was used in order to assess on-orbit collision risk. For each spacecraft and launch vehicle orbital stage in or passing through LEO, the program or project shall demonstrate that, during the orbital lifetime of each spacecraft and orbital stage, the probability of accidental collision with space objects larger than 10 cm in diameter is less than 0.001.

DAS software showed that for the LacunaSat-3 satellite, this probability is less than 0.001. The following parameters were used:

- Perigee Altitude: 543 km
- Apogee Altitude: 568 km
- Inclination: 97.6818 degrees
- RAAN: 324.4347 degrees
- Argument of Perigee: 196.6457 degrees
- Area-to-Mass ratio: 0.01969
- Launch date: 2020.09.28

8.5. Space System Disposal

The LacunaSat-3 satellite will naturally decay to the Earth's atmosphere within 25 years. This analysis was carried out using DAS software with the following parameters:

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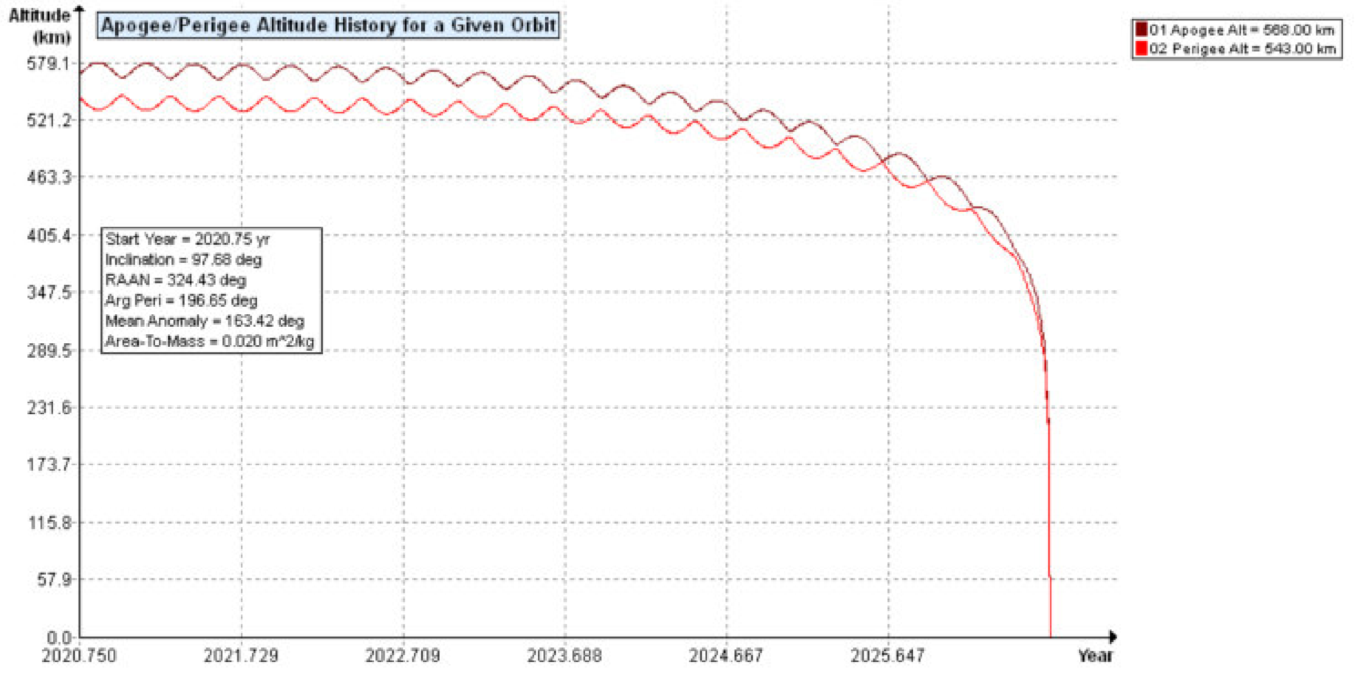

Figure 1. Apogee/Perigee Altitude History for the LacunaSat-3 satellite Orbit

The analysis showed that the lifetime of the LacunaSat-3 mission from original altitude is 5.864 years.

8.6. Space System Passivation

The requirement aims at preventing accidental break-ups of the space system in Earth orbit after the completion of its mission operations and post-mission disposal by depleting energy or making safe all on-board sources of energy.

8.6.1. Mitigation Measure

Mitigation measure to minimize risk related to store energy after the disposal phase are summarized in Annex E, *ESA Space Debris Mitigation Compliance Verification Guidelines* document, such as:

- Disconnect ADCS sensors and actuators from power supply source
- The batteries are discharged to keep the voltage between 6.0 – 6.4 V
- MPPT Software set point set to low voltage value
- Telemetry transmission is switched off

8.7. Space System Re-Entry

This requirement addresses with a maximum risk figure each spacecraft, launch vehicle stage, and MRO, which can re-enter in controlled or uncontrolled way, the casualty risk shall not exceed 1 in 10000 for any re-entry event (controlled or uncontrolled)

8.7.1. Mitigation Measure

The M3P satellite bus was designed to ensure that all the components and materials can demise during re-entry. What is more an analysis was carried out on DAS software which confirmed that the risk does not exceed 1 in 10000.

8.8. Space System Hazardous Materials

LacunaSat-3 satellite contains no hazardous materials.