Mission Description

In this chapter several aspects relating to the ^{Po}Cat are described. Do note that these are intended to serve as a reference and may not be representative of your own mission.

- Statement and Objectives
- Data Products
- Mission Phases
- Satellite Operational Modes

Statement and Objectives

Mission Statement

The ^{Po}Cat-Lektron is a mission resulting from the *IEEE OpenPocketQube Kit* initiative, developed at the UPC NanoSat Lab. The mission has been selected in the 4^{th} call of the ESA Fly Your Satellite! (FYS) program. The mission analysis presented corresponds to the ^{Po}Cat-Lektron mission. It consist of two 1P PocketQubes, the ^{Po}Cat-2 and the ^{Po}Cat-3, developed as a part of the *IEEE OpenPocketQube Kit*. This mission aims to demonstrate the feasibility of PocketQube platforms for remote sensing applications. The payloads on board of the PocketQubes are two passive radiometers to be use for RFI purposes on K and L bands. Apart from the remote sensing nature of the mission, this mission also aims to demonstrate the feasibility of the PocketQube platforms to create, manage and join Federated Satellite Systems. To do so, the FSS Experiment will be reproduced as a part of the experiments of the mission.

Mission Objectives

1. Demonstration of Scientific Viability: Demonstrate the feasibility of conducting scientific missions using PocketQube platforms. To do so, the mission proposes collecting valuable RFI data through a K-Band and L-Band passive radiometers (One for each PocketQube). The payloads will monitor interferences on these bands. This data will facilitate enhanced detection and the generation of heatmaps indicating RFI distribution across the globe. In this experiment we aim to obtain data on the K-Band to see the impact on the atmospheric water vapor measurements, and in the L-Band the interferences over the Position Navigation and Timing (PNT) signals.

2. Satellite Federation Concept: To establish and demonstrate that PocketQube platforms can create, manage and join Federated Satellite System (FSS). This proof of concept for this resource-limited platforms is based on the reproduction of the FSS Experiment conducted at the UPC NanoSat Lab. The demonstration consist on create a federation between 2 PocketQubes, in order to download data. Previous missions such as the FSS-Cat from the UPC NanoSat Lab demonstrated the feasibility of this opportunistic collaboration using 6U CubSats.

3. Educational Development: As a mission developed at the UPC NanoSat Lab, the mission is oriented for undergraduated students to gain experience and get involved in real space missions. In addition, several Bachelor and Master Thesis had been done from this project, apart from the academic papers that this project has produced.

Data Products

This section will cover the pata products generated by the Lektron mission. Consider these will vary depending on the P/L. The following information is presented in relation to ^{Po}Cat 1, ^{Po}Cat 2 and ^{Po}Cat 3.

1. Mission Data Products

The satellite mission will provide time-tagged, geolocated spectrograms and statistical data on Radio Frequency Interference (RFI) for both K-Band and L-Band. These bands are integral to a variety of critical applications:

- L-Band is primarily used for environmental monitoring, including soil moisture measurement, ocean salinity estimation, and sea ice thickness determination, all performed via microwave radiometry. It is also crucial for satellite navigation and GNSS reflectometry applications.
- K-Band supports atmospheric water vapor monitoring, short-range radar systems, and newly added 5G services.

The mission will also provide images on the visual spectrum, serving as a proof of concept for future PocketQube payload development and allowing the monitoring of large areas in critical enviromental states such as giant ice masses are rainforests. This task is performed by a VGA camera.

1.1. Scientific and Technological Questions to be Answered

The mission aims to enhance the understanding of electromagnetic spectrum occupancy in space. By providing RFI detection data, it will address key challenges related to spectrum interference regarding the impact of RFI on both communication and remote sensing. The data will also inform strategies for interference mitigation and spectrum optimization, ensuring the continued viability of K and L-Band applications.

The mission also aims to prove the feasibility of optical imaging by PQs.

Framework for Processing Mission Data Products:

RFI Data:

- Characteristics: Time-tagged geolocated spectrograms for K and L-Band frequencies.
- Sampling Frequency: High enough to allow detailed interference analysis and mitigation strategies. Specifically allowing for a high-resolution interference heatmap on ground.
- Ground Infrastructure: Data will be processed through a dedicated ground segment with advanced RFI detection capabilities, enabling both real-time and post-mission analysis.
- Data Volume:
  - **K-Band:** 2.8KB per measurement.
  - **L-Band:** 0.7KB per measurement.
- Accessibility: Data will be made available to certain stakeholders involved in the scientific sector like FARS and GRSS, promoting the collaborative development of spectrum usage strategies.

Optical Data:

- Characteristics: Time-tagged geolocated images of different Earth regions.
- Sampling Frequency: As defined by the operator.
- Ground Infrastructure: Data will be processed through a dedicated ground segment, enabling both real-time and post-mission analysis.
- Data Volume: Ranging from 2KB to 48KB. (more information provided here)
- Accessibility: Data will be made available to certain stakeholders involved in the scientific sector like FARS and GRSS.

Telemetry Data:

The satellite will generate telemetry data, including measurements of voltage, current, temperature, angular speeds, light intensity, and the Earth’s magnetic field. This data, although not commercially valuable, will be critical for assessing the operational state of the satellite and gaining insights into its long-term performance. The telemetry will be processed in near real-time and used to ensure optimal satellite functionality.

Services Provided:

The primary service offered by the mission will be comprehensive RFI data for K and L-Bands, enabling stakeholders to mitigate interference effectively, as well as close to real time Earth imaging. Additionally, the mission will provide operational health data for satellite performance monitoring, which will benefit satellite designers and operators for future missions.

Mission Phases

The mission is segmented into five distinct phases: **1) Prelaunch**, **2) Launch and Early Orbit Phase (LEOP)**, **3) In-orbit Commissioning**, **4) Operations**, and **5) Post-mission**. Throughout each phase, various procedures are carried out, either commanded from the ground or autonomously performed by the satellite. This section delineates the expected duration of each phase and specifies the actions performed and how they are executed.

1) Prelaunch Phase: This preliminary stage, will take place between one and six months prior the launch, and is estimated to span approximately two days. Involves performing tests and validation processes to guarantee the proper functionality of all subsystems, right up until the satellite is integrated into the deployer. Moreover, meticulous visual examinations will be performed on the satellite's outer components to confirm they are in good conditions and have not suffered any damage. Upon completion of these final checks, the final software configuration parameters are uploaded, and all counters are reset to initialize the satellite in its initial flight conditions.

2) Launch and Early Operations Phase: This phase, which lasts about 10 hours, is autonomously handled by the spacecraft, starting after the launch, with the satellite being dispatched into space. Following deployment, the satellite's kill switches are deactivated, and it powers on automatically. Initially, the satellite remains in standby mode for the first 30 minutes to prevent collisions with other satellites or debris. Subsequently, the satellite may initiate Attitude and Determination Control Subsystem (ADCS) activities to stabilize itself while concurrently attempting to deploy the communication antenna. However, it will delay initiating periodic beacon transmissions until 15 minutes later (45 minutes post-deployment), adhering to requirements prohibiting radio emissions beyond this time. These periodic beacons facilitate ground tracking of the satellite.

3) In-orbit Commissioning Phase: This phase begins after the ground station receives the first beacon from the satellite which means that commanding from the ground can start. Is estimated to last less than a week. The telemetry data contained in the beacon allows operators to verify the satellite's and all subsystems' correct operation and the successful execution of LEOP autonomously by the satellite. Assuming no issues arise, operators can start sending specific commands such as ”PING” to acknowledge signal reception and initiate communication, ”UPDATETIME” to synchronize the satellite's clock, and ”UPLOAD TLE” for orbital data proposes. Additional configurations and checks are performed, including payload antenna deployment. Once stabilized and operational, the satellite commanded by the ground, will undergo experimental testing and calibration, transitioning to the operational phase.

4) Operational Phase: The fourth mission phase, Operations, is where the satellite is expected to spend most of its orbital lifetime, approximately one to two years. During this phase, the satellite's health is monitored, payload operations are scheduled and executed, and housekeeping tasks are performed to maintain the satellite's functionality.

5) End of Life and Post-mission Phase: The final phase begins once the team decides to conclude operations, either because the payload is no longer functioning correctly or the satellite can no longer operate. Expected to commence after about two years of operations, the satellite enters a passivation state, gradually depleting its energy until battery exhaustion or atmospheric re-entry. During this phase, the Federated Satellite Systems (FSS) may remain operational, providing services to nearby satellites thorough a federation agreements.

Satellite Operational Modes

The operational modes for the satellite and its subsystems are:

Init: This mode is directly associated with the LEOP. The LEOP phase is the most critical, as it begins when the satellite is deployed and concludes when the Communications (COMMS) antenna is deployed and contact with the ground segment is established. For the ^{Po}Cat mission, it includes the following steps in this order:

1. **Standby:** To comply with the requirements, after injection in orbit the spacecraft must wait a minimum of 30 minutes before beginning operations or deploying appendages, specifically the COMMS and payload antenna. At the same time, no radio emissions are permitted after the spacecraft has been integrated into the PocketQube deployer, and this restriction remains in effect for 45 minutes following deployment. Therefore, no beacon transmissions are allowed. This precaution is necessary to prevent interference with other satellites being deployed or with other systems on the rocket. To meet these requirements, the satellite will wait 45 minutes before commencing operations and communications.
2. **Deployment of the LoRa Antenna:** As mentioned, it is necessary to deploy the COMMS antenna to begin transmitting beacons, which will facilitate the first contact with the GS (Ground Station).
3. **First Contact with the Ground Station:** The satellite will remain in this state until it receives confirmation from the GS that everything is functioning correctly, at which point nominal operations can begin.
4. **Nominal:** If all the performance criteria and actions of the **Init** phase are successfully completed, the satellite enters into nominal mode. This mode serves as the default operating state in the best-case scenario, and the satellite remains in this mode as long as the batteries are above a certain threshold value. While in nominal mode, payload-related operations can be conducted, including the mission experiments, and the FSS.

Contingency: The satellite enters this mode when the batteries fall below a certain value. In this mode, some functionalities of the flight software are disabled, including the experiments conducted by the payload and the FSS. Also, the ADCS subsystems stop performing nadir pointing to reduce power consumption.

Sunsafe: This mode is associated with a critical condition of the satellite and is activated when the batteries drop below an even lower threshold. More restrictions are applied in this mode to further conserve energy. The Electrical Power Subsystem (EPS) and ADCS subsystems cease all activities, such as heating the batteries in the case of the EPS or dumping and detumbling in the case of the ADCS. These subsystems enter a passive

Survival: This final state is the most critical, occurring when the satellite lacks sufficient energy to perform any vital actions. It may also arise if a significant error occurs in the code, making it safer to remain in this state until operators determine the best course of action. In this state, all subsystems remain active but are only polling information from the sensors. At the same time, transmissions are ceased, and no beacons are transmitted to prolong battery life; the COMMS subsystem is only in reception mode.

The Figure 1.1 illustrates the transitions between the states. From the **Init** state, which is the first state the satellite enters after being released by the deployer or after a reboot, the satellite will transit to the Nominal state following the first contact with the ground segment. Once the satellite exits this state, it can only re-enter if a reboot event occurs.

All other states can transition up or down to the adjacent state. Transitioning to a state with more restrictions can occur automatically if the satellite does not have enough energy to remain in the current state, or it can be triggered by operators through the reception of a telecommand. Conversely, to transition to a less restrictive state, two conditions must be met: the battery level must be appropriate, and the satellite must receive a telecommand requesting the change of state.

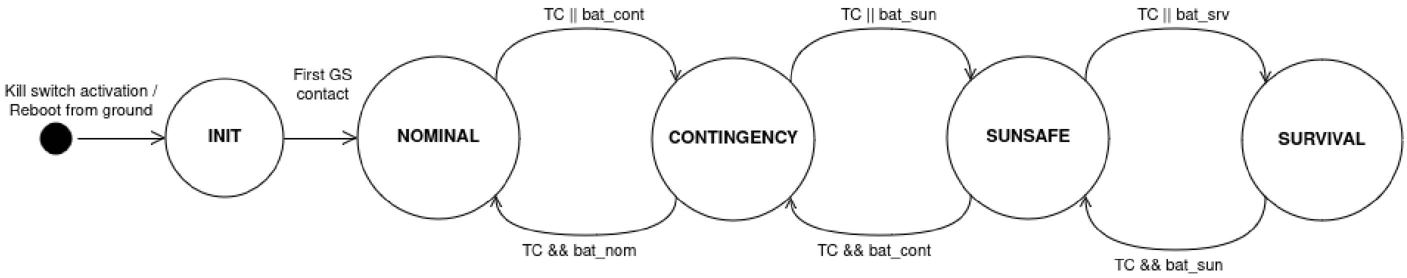

Figure 1.1: PoCat Operational Modes and Transitions