Mission Operation Concept Analysis of the NanosatC-BR2 Using CPRIME/INPE's Satellite Simulator

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Abstract

Operation concept is a discipline addressed by system engineers very early in satellite development cycle. Mission requirements are analyzed taking into account power consumption and data rate each payload needs. Dealing with the limited power budget available in CubeSat-based missions is a challenge. In this paper we show the usage of the satellite simulator developed by Chagas [1] at INPE's Space Mission Integrated Design Center (CPRIME), in the analysis of the NanosatC-BR2 issues regarding operation concept of its payloads. NanosatC-BR2 is INPE's second scientific CubeSat, expected to be launched by early 2019. The simulator encompasses orbital propagation, power generation and consumption, equipment usage, the use of mass memory for On Board Data Handling (OBDH) tasks, and communication with ground stations for science data download. The focus of the simulations was to verify plausible mission operation concept with regards to the power and data budgets considering the operation of the three physical payloads onboard the satellite. Each simulation scenario varied the individual operations of each payload relative to the orbital period and data generation limits. The simulation results highlight scenarios in which power and data budgets are balanced in order to meet the operation requirements of each payload. These scenarios were very useful to the NanosatC-BR2 team to make the decision concerning the feasible implementation.

INPE's Mission Concept Satellite Simulator

Designed for verification of Mission Operation Concepts during studies carried out mainly in Pre-Phase A at CPRIME, it is a simulation tool focused on the dynamics of data and power usage, and data exchanged between the satellite and the ground stations.

The simulator consists of a core written in Julia language with four modules that calculate the orbit propagation along with the power generation and consumption of the satellite's equipment, and also the data generated and exchanged with the ground stations. The core then sends the results to a GUI with a window for each module to display the results to the user.

Orbit Module

This module is responsible for propagating the satellite's orbit and its position. It also computes the Sun's position and check's whether the satellite is in eclipse or not, and verifies if there is a line-of-sight and the available ground stations. The GUI windows show 2D and 3D views, which can be seen in Figure 1:

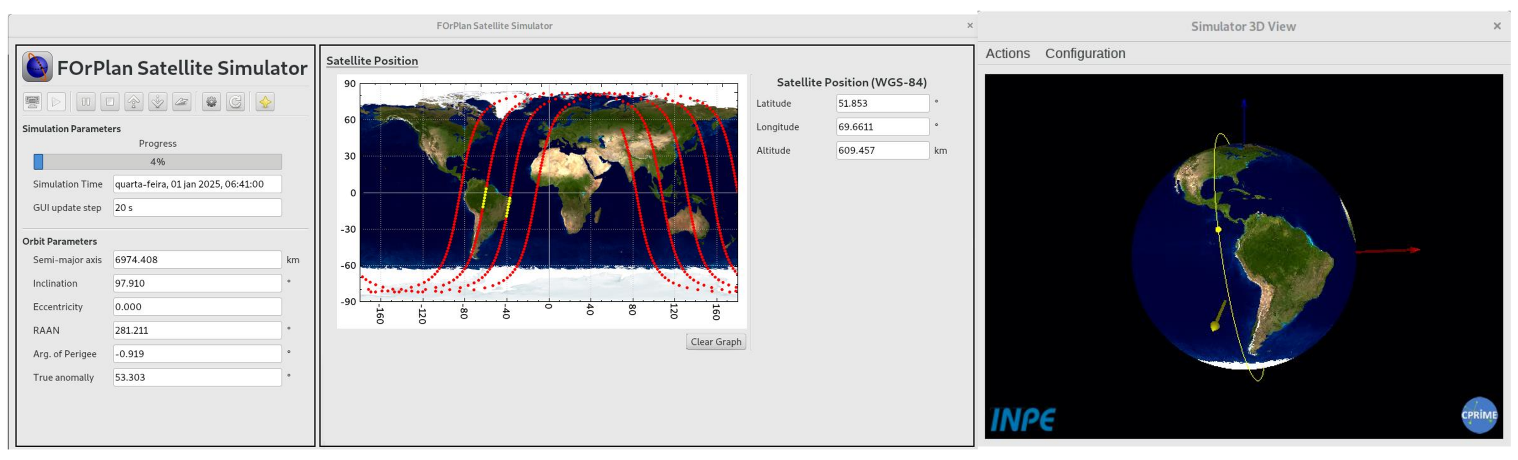

Figure 1: Orbit Module GUI

Equipment Module

The equipment module simulates the behavior of the equipment onboard the satellite with regards to power consumption and data generation. The equipment can be programmed to be turned on and off accordingly. An example of the GUI window with multiple equipment can be seen in Figure 2:

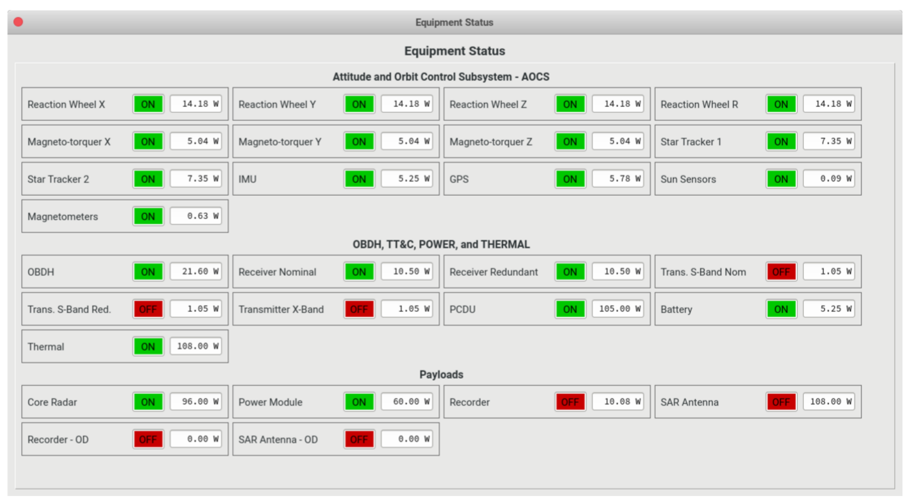

Figure 2: Equipment Module GUI [1]

Power Module

The power module computes battery capacity and charge, and solar power conversion by the solar panels. Through the GUI window it is possible to follow the power generation, power consumption, battery power drain and battery charge level. It is also possible to include a degradation factor to simulate the EOL conditions. An example of the GUI window can be seen in Figure 3:

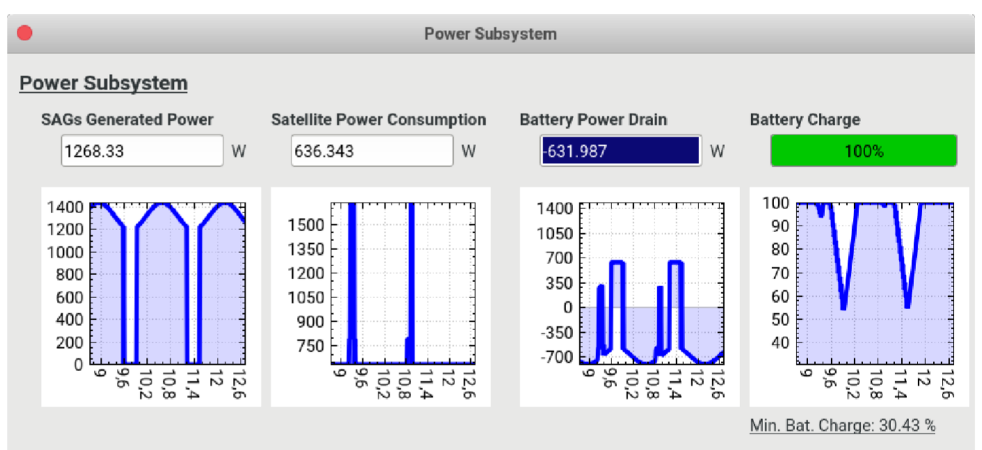

Figure 3: Power Module GUI [1]

OBDH and TT&C Module

The On-Board Data Handling and TT&C module is responsible for validating the mass memory design and data budget. Each equipment is configured to generate an amount of data accordingly and when line-of-sight is available to a possible ground station, data is downloaded according to the configured baud. In the GUI window for this module it is possible to follow the memory usage at each state, which can be seen in an example in Figure 4:

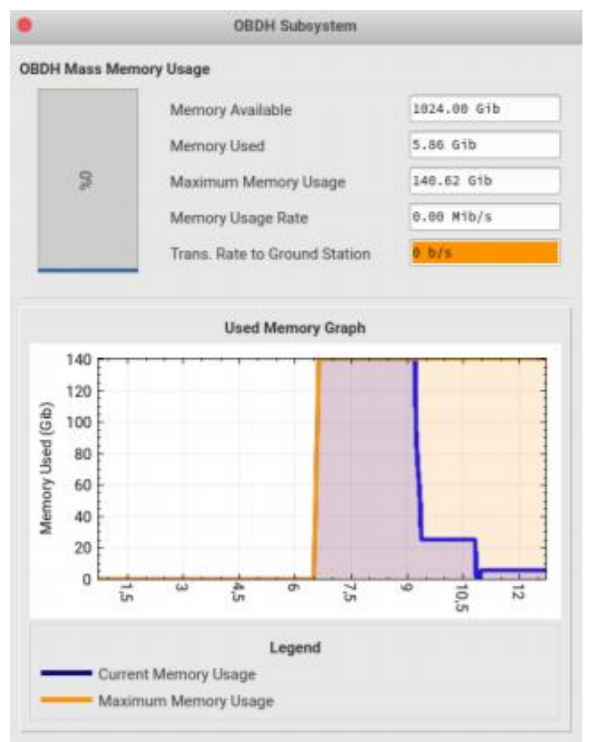

Figure 4: OBDH and TT&C Module GUI [1]

NanosatC-BR2 Simulation

Considering the low power and data budget available for the satellite, since it's power generation is strictly dependent on the solar panels covering the small surface area on each of its sides and limited baud for UHF transmission, operation of the mission payloads has to be planned to attend not only the payloads' goals but also the satellite's limitations. This is a common issue in CubeSat-based satellites that opt for the simplicity of non-deployable solar panels and typical UHF downlink channels.

While the calculated mean power generation is expected to be in the order of 2.10 W when exposed to sunlight, nominal state with all three payloads fully operational demand 3.07 W, which makes this scenario impracticable. Some scenarios were tested regarding combinations of payload operation periods with charging periods.

One of the scenarios simulated that resulted in a plausible operation was to operate each of the three payloads individually, sequentially and periodically during an orbit each, separated by a "charging orbit" of all payloads turned off between each operating orbit, following the pattern showed by Table 1, which results in a simple operation mode to be implemented:

Orbit Number	1	2	3	4	5	6
Payload	A	None	B	None	C	None

Table 1: Payload Operation Sequence

The GUI outputs for power and data can be seen in Figure 5. The max DoD in this scenario is expected to be 27.16 % and the data downlink capacity is enough for the amount generated considering the two ground stations at ITA and Santa Maria.

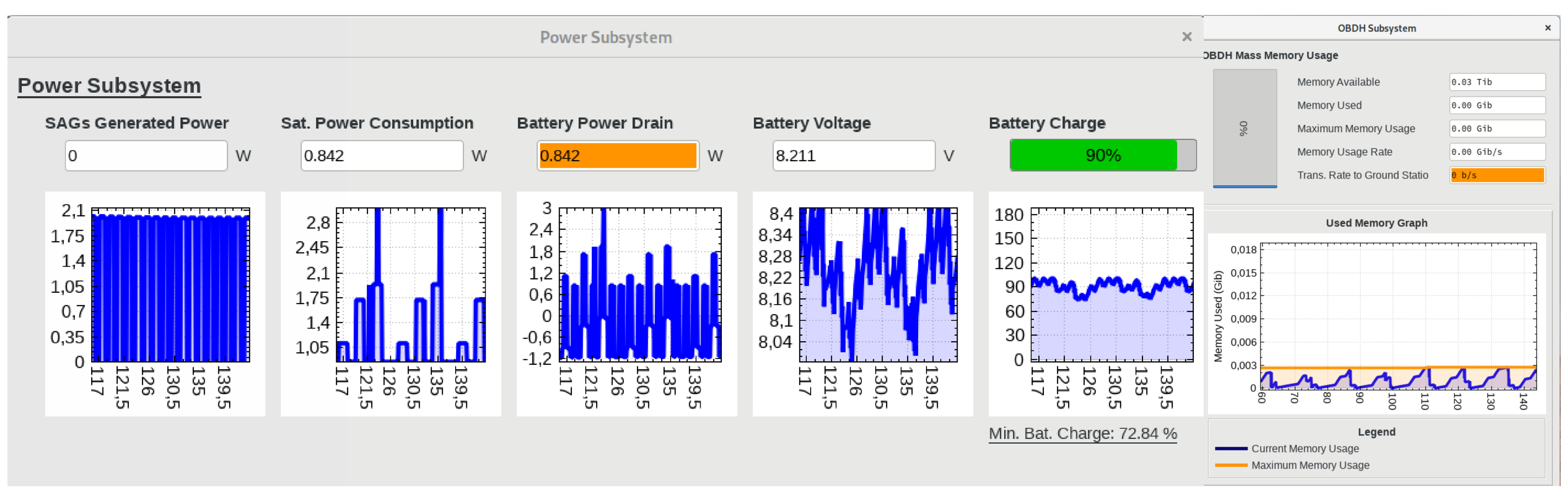

Figure 5: Power and Data GUI Results for Plausible Scenario

Results and Future Work

The simulator is an effective tool to visualize operation concepts and was helpful not only in this case but is largely used and has assisted in pre-phase A studies carried at INPE's Space Mission Integrated Design Center (CPRIME). Future works consider implementation of AOCS Dynamics, Flight plan, Model-based configurations, Satellite Constellations and Coverage Analysis, along with a more user-friendly interface.

Studies using the simulator are being carried out on operation concepts for the NanosatC-BR2 considering a payload-oriented approach dedicating more time to each payload individually.

Reference

[1] R. A. J. Chagas, A. C. Louro, F. L. de Sousa and W. G. dos Santos. Satellite Simulator for Verification of Mission Operational Concepts in Pre-Phase A Studies. 7th International Conference on Systems & Concurrent Engineering for Space Applications. October, 2016.