Flight Plan, Contingency Operation and Redundancy Provision for The Communication System of a 3U CubeSat with Hyperspectral Imaging Payload

Mr. Nishant Gupta[1]*, Mr. Mohit Vyas*[2]*, Mr. Rutwik Jain*[2]*, Mr. Umang Garg*[2]*, Ms. Varsha Singhania*[2]*, Ms. Sakshi Agarwal*[2]

[1] Birla Institute of Technology and Science, Pilani, Rajasthan, India - 333031
[2] Birla Institute of Technology and Science, Pilani, Rajasthan, India- 333031

This paper details the modes of operation and various contingency provisions of the onboard communication system during the flight of a 3U CubeSat featuring a hyperspectral camera as its payload.

The satellite follows a combination of centralized and distributed architecture, with the On-Board Computing (OBC) system responsible for the execution of flight plan and payload operations, while other tasks are off-loaded to dedicated microcontrollers of the Electrical Power System (EPS) and Telemetry, Tracking and Command system (TTC). The OBC controls the sequence of operations, called modes, and communicates relevant sets of parameters to the EPS and TTC over SPI interface, whereas the individual microcontrollers perform specific operations in these modes. Control over the communication architecture, particularly downlink, is carried out by the TTC microcontroller. A hyperspectral imaging payload introduces unique constraints on power, on throughput as well as in terms of pointing. Hyperspectral cameras and associated image compression require very high amounts of power. This, coupled with the limited power generation capabilities of a CubeSat (due to their small size) presents a two-fold problem for the communication system - limited power availability, and at the same time, significant amounts of data to be downlinked. In addition to this, the communication system has to operate in limited amateur radio frequency bands due to regulations which further reduce the downlink speed and errors in downlink data increases.

Another problem is raised due to harsh space environment which presents a major challenge to the system, and the conceptualization of the system must therefore ensure reliability and robustness. These requirements significantly influence design decisions, not only for the hardware of the communication system, but also the software implementation of the modes and contingency operation for the telemetry subsystem. The satellite implements a full-duplex UHF-VHF architecture using Gaussian Minimum Shift Keying (GMSK) modulation scheme for data downlink and uplink, while a Morse coded, simplex, On-Off Keying (OOK) scheme for transmitting the beacon. The uplink is done via a monopole, while a turnstile is used for downlink.

While the OBC runs different processes in different modes, the TTC microcontroller also carries out mode-specific operations. The presentation elaborates the flight plan of communication system operations and how the TTC microcontroller switches between the modes therein. Entry conditions to and exit conditions from each mode are also described. The modes have to be designed to ensure that the system works even in case of emergencies, such as antenna deployment or system faults. Hence, interrupt-based emergency modes are included as part of the flight plan and elucidated subsequently. It also elaborates the following provisions to minimize emergencies and tackle system failures:

1. An initialization mode for the Telemetry system that determines antenna configuration full/semi-duplex settings dynamically in-flight on the basis of antenna deployment feedback and functional transceivers in circuit.
2. Sharing of beacon control between the TTC and the Electrical Power System, so that the beacon starts transmission as soon as antennas are deployed, regardless of a functioning TTC system.
3. Variable control over downlink/uplink among the TTC and OBC processing elements - The TTC microcontroller is programmed to control downlink (where uplink is handled by OBC) or both uplink and downlink (in case the initialization mode is semi-duplex)
4. Hardware duplication of critical-path resources to ensure a nominally functional system.
5. Study on configuring downlink turnstile as two independently operable dipoles in order to reduce the dependence of telemetry on the success of antenna deployment

Introducing contingency operations for hardware as well as software is crucial to achieve reliability and to ensure mission success in spite of component failure. The emergency modes have an operating communication system that is fueled by the redundancies proposed herein. In the end, a review is presented for various events of exigency, what input conditions trigger an entry into corresponding contingency modes and what processes are executed by the microcontroller.

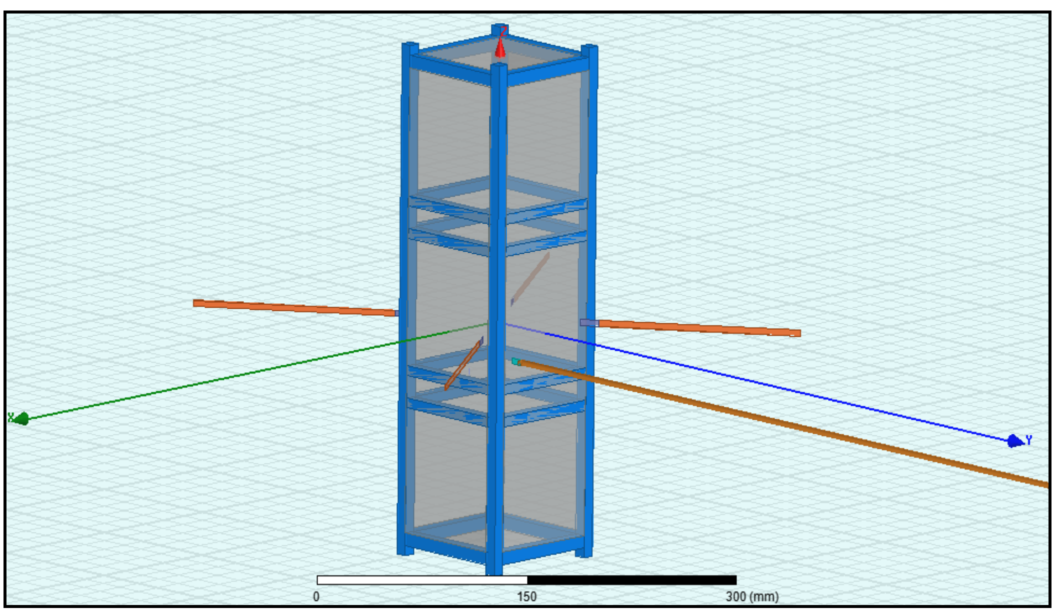

Fig. 1 Placements of Antennas (Monopole for VHF and Turnstile for UHF) with redundancy provisions

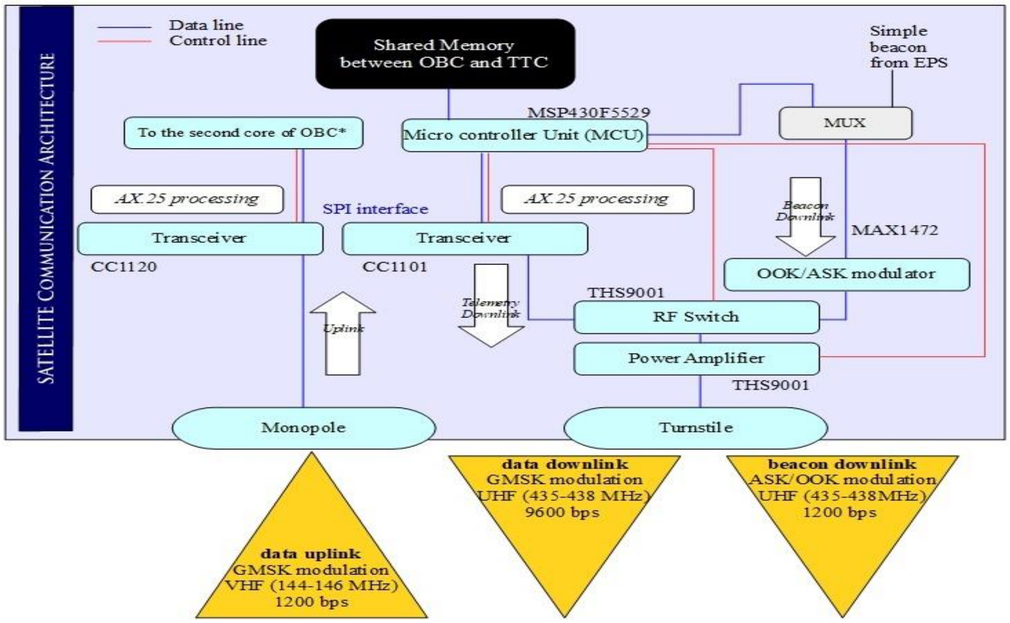

Fig. 2 Block diagram of on-board communication architecture

REFERENCES:

1. Modes of Operation for a 3U CubeSat with Hyperspectral Imaging Payload, Shubham Sharma, Rutwik Jain et. al. International Astronautical Congress (IAC) 2018, October 2, 2018, Bremen (Germany).
2. Swiss Cube,"SwissCube Mission and System Overview - Phase C," 2008.
3. Johan L. Tresvig, "Design of a Prototype Communication System for the CubeSTAR Nano-satellite", Department of Physics, University of Oslo, July 2010.

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Author for correspondence: Nishant Gupta
Birla Institute of Technology and Science, Pilani
Vidya Vihar, Pilani, Rajasthan 333031
+91-9532876832
guptanishant113@gmail.com