KONGR45GPEN

DESIGN OF FAULT DETECTION, ISOLATION AND RECOVERY IN THE ACUBESAT NANOSATELLITE

DRAFT SPACEDOT

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Abstract

Space is not a welcoming environment; while the aerospace engineering community has managed to reliably operate thousands of satellites in orbit, CubeSats, the most popular class of nanosatellite, only have a 50% success rate. Low costs, lack of strict technical requirements and scarcity of publicly available documentation often drives up the risks for educational, scientific and commercial CubeSats. This thesis investigates a configurable and modular Fault Detection, Isolation and Recovery (FDIR) architecture that uses the ECSS Packet Utilisation Standard. This FDIR concept, along with the provided open-source software implementation, can be used by CubeSat missions to increase the reliability of their design and chances of mission success, by autonomously responding to on-board errors. The thesis also includes background information regarding CubeSat reliability, and explores the software and hardware used to implement the proposed FDIR design on the AcubeSAT mission, currently under design by students of the Aristotle University of Thessaloniki.

1
Reliability Engineering in CubeSat Systems

1.1 Kalispera

space is very important[1] Fault Detection, Isolation and Recovery (FDIR)

[1] **durou_hierarchical_2002**.

2
The AcubeSAT mission

2.1 CubeSat

2.2 Subsystems

The AcubeSAT nanosatellite is technically and programmatically split into **N** different subteams or **subsystems**, each responsible for a different section of the satellite, and made up out of **M** dedicated members.

In the following sections, a brief introduction on the function and design of each subsystem is presented. For more detailed information, the reader is encouraged to refer to AcubeSAT's website[1], or to the publicly available Critical Design Review (CDR) documents[2].

[1] https://acubesat.spacedot.gr/subsystems/
[2] https://gitlab.com/acubesat/documentation/cdr-public

2.2.1 Attitude Determination and Control Subsystem (ADCS)

2.2.2 Communications (COMMS)

The communications subsystem is responsible for transmitting data between the Earth and the spacecraft in orbit. The transmitted data is split into 3 different categories:

- **Telecommands (TC)**: Commands from the Earth to the satellite. They can be used to request information, or to perform specific spacecraft actions.
- **Telemetry (TM)**: Information sent from the satellite towards Earth, typically including vital information such as sensor values, system status, timestamps and events.
- **Science data**: The scientific data generated by the payload. These are the highest-volume data and represent the main scientific output of the mission.

It is important to mention that the satellite orbit only allows for a very short visibility duration every day, increasing the needs for on-board autonomy and the importance of a correctly implemented FDIR method.

The main component of the COMMS subsystems is the **SatNOGS COMMS board**,[3] an open-source RF transceiver developed by the

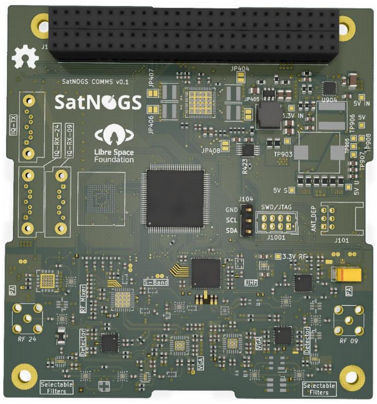

Figure 2.1: The SatNOGS COMMS board

[3] **surligas_satnogs-comms_2021**.

LibreSpace Foundation, based on CCSDS telecommunications standards.

Communication will take place using 2 frequency bands on the ISM range, namely 436.5 MHz and 2.425 GHz, supported by a deployable turnstile and a directional patch antenna respectively. The use of ISM frequencies allows easy radio-amateur access to the satellite.

The communications subsystem is also responsible for the Electromagnetic Compatibility (EMC) analysis and interference mitigation, as well as the design and construction of the satellite Ground Station. The Ground Station will be part of **SatNOGS**,[4] a global network of satellite ground stations based on open technologies and open data.

[4] **white_overview_2018**.

2.2.3 *Electrical Power Subsystem (EPS)*

The EPS is the subsystem responsible for the generation, distribution and storage of electrical power of the spacecraft. It is a critical aspect of the spacecraft due to the direct dependence of all subsystems to the high power needs of many CubeSat subsystems, and is theorised to be the most common reason for CubeSat failure..[5]

[5] **langer_reliability_2016**.

AcubeSAT has opted for a Commercial Off-The-Shelf (COTS) subsystem approach for the EPS:

- **Solar panels** are procured from EnduroSat. Four 3U panels cover the X and Y faces of the satellite, and one 1U panel covers the $-Z$ face.
- The **Power Conditioning & Distribution Unit (PCDU)** is procured from NanoAvionics and offers 10 switched channels with overcurrent protection over 4 voltage rails, as well as 4 Maximum Power Point Tracking (MPPT) converters.
- The **battery pack**, also procured from NanoAvionics, contains 4 18650 Li-Ion cells in a 2S2P[6] configuration.

[6] 2 series, 2 parallel

2.2.4 *On-Board Data Handling (OBDH)*

2.2.5 *Operations (OPS)*

2.2.6 *Structural*

2.2.7 *Systems Engineering (SYE)*

2.2.8 *Science Unit (SU)*

2.2.9 *Thermal*

2.2.10 *Trajectory*

2.3 *Tools used*

3
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4
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5
Hardware implementation of FDIR