Department of Electrical and Computer Engineering
Capstone 2020

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University of Windsor Space & Aeronautics Team
Command, Data, and Radio Communications

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Introduction

The University of Windsor Space and Aeronautics Team's (WinSAT) objective is to design and construct a 3U Earth Observation Cube Satellite (CubeSat) for the Canadian Satellite Design Challenge (CSDC). This group was required to design, build, and test the following satellite subsystems:

- CDH – Command and Data Handling
- RF Communications
- Payload Imagery

Problem Definition

The design of the satellite must meet the following requirements and objectives as specified by CSDC guidelines [1] and [2]:

- Primary Mission: Acquire a single "Selfie-Sat" optical image (covering an area of 40x40km and 100x100km) as requested by an Amateur Radio Operator for immediate downlink.
- Secondary Mission: Acquire continuous area coverage images to be downlinked, modified, and stitched to provide local satellite imagery over countries or other large areas.
- Command: Receive and execute time-tagged or immediate commands from ground station. A subset of commands must be provided to operators for establishing connection and sending commands to the spacecraft.
- Data: Record time-tagged spacecraft telemetry at regular intervals for encrypted downlink to ground station.
- Radio: Provide 1200/9600 bps uplink/downlink, 6dB link margin at 10° elevation angle.

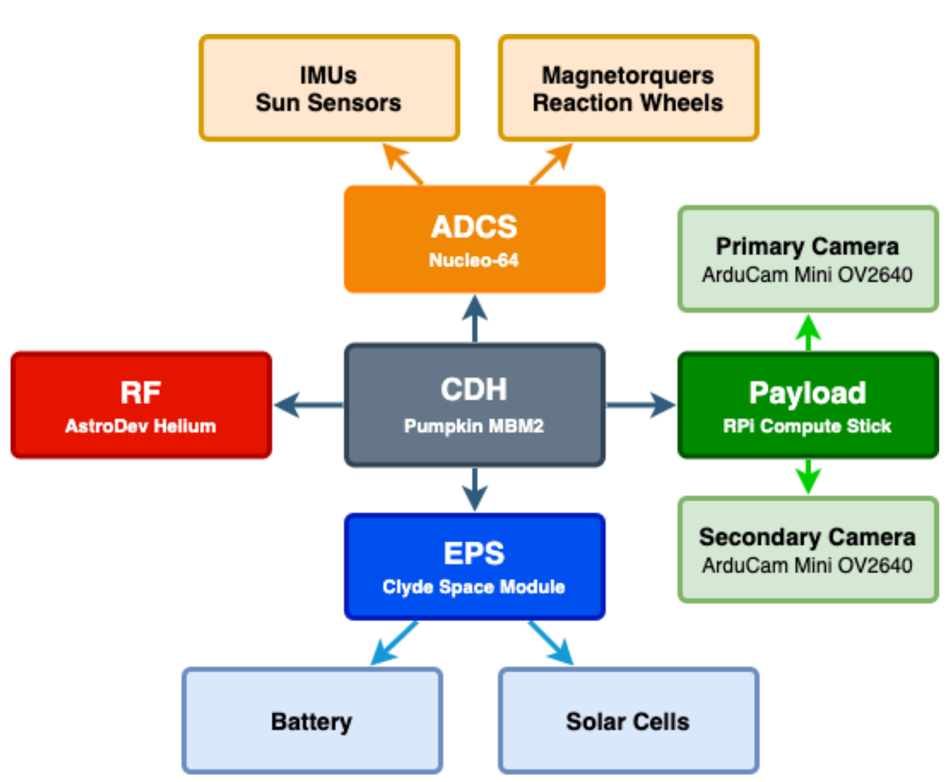

Figure 1 - Satellite Subsystem Architecture

Design Methodology

The payload design, in AGI STK, mainly involved the selection and image analysis of two optical sensors to satisfy primary and secondary mission objectives:

1. High-quality, single-point image access
2. Lower-quality area coverage

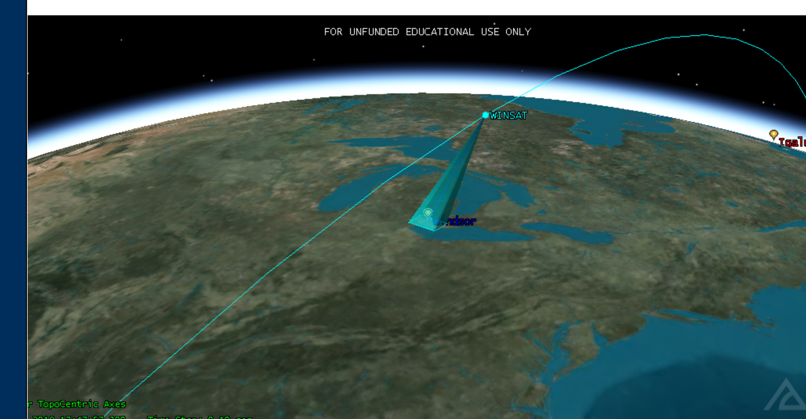

Figure 2 – Selfie-Sat Targeted Access Analysis

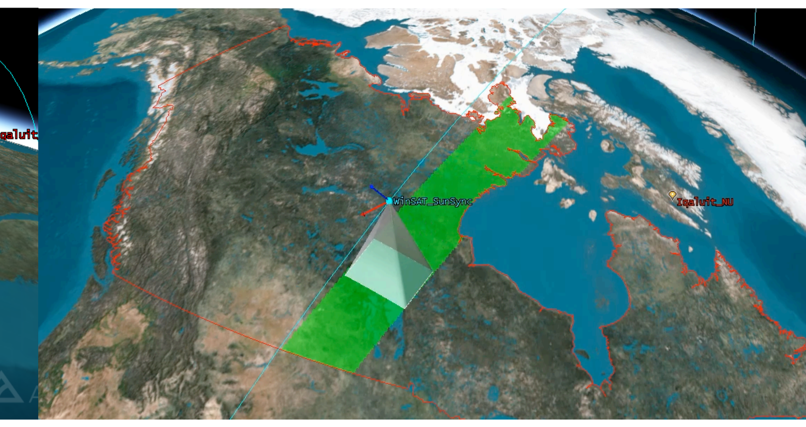

Figure 3 – Global Imaging Coverage Analysis

The team chose KubOS Linux as the onboard software architecture to prioritize modularity, robustness, and low development time in the design.

- Open-source framework that includes common satellite functionality
- Higher level development
- Linux provides large development support/tooling

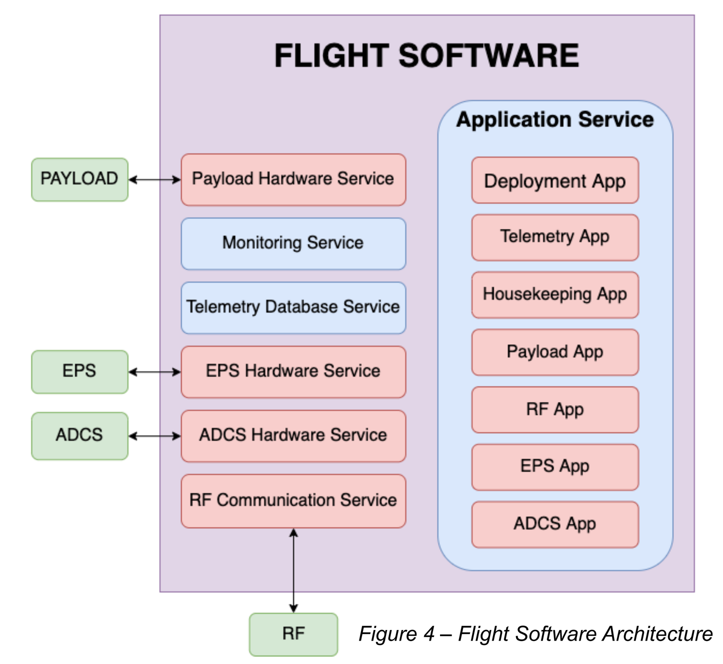

Figure 4 – Flight Software Architecture

Lower-level data interfaces:

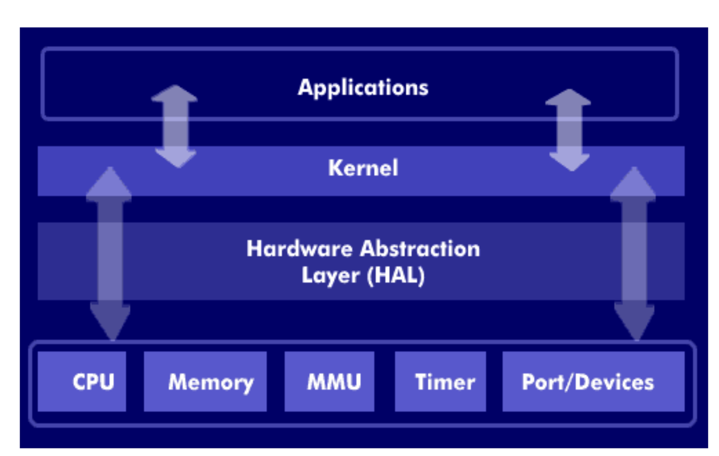

Figure 5 – Abstraction Layers [3]

I2C Driver
Clock Stretching, SCL speed control

- OBC - KubOS
- ADCS - MBED
- Sensors

Radiation Pattern
MATLAB generated

- Model ground station and satellite antenna
- Easy to import into orbital pattern simulation tool
- Obtain access times and signal quality characteristics

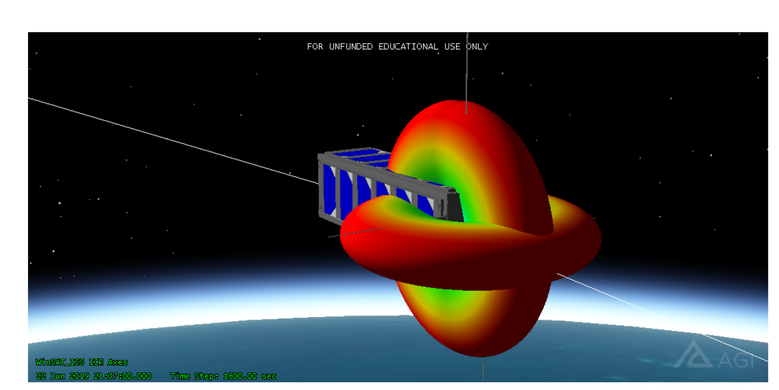

Figure 6 - Satellite Antenna Radiation Pattern

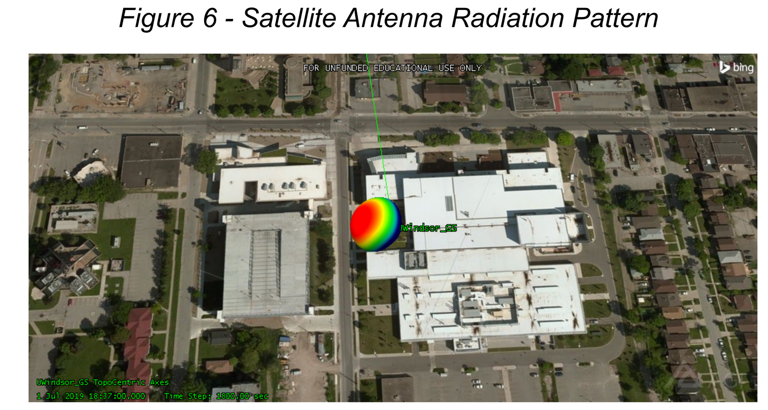

Figure 7 – Ground Station Antenna Radiation Pattern

Results and Conclusions

To test and validate the design, a "FlatSat" setup was built. This setup includes COTS replacements for all the major components that would be preset in the flight model of the satellite. This allowed for demonstration and testing of the software design on the main onboard computer and its functionality and interfacing with other subsystems.

Results:

- Successful image acquisition and downlink
- Receiving and executing of time-tagged or immediate commands
- Spacecraft telemetry collection and downlink

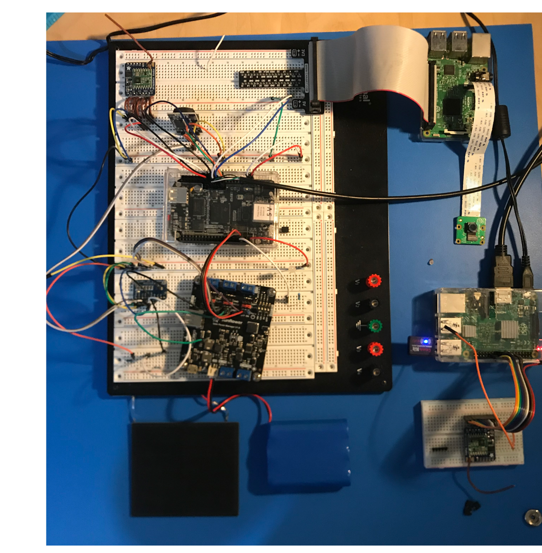

Figure 8 – "FlatSat" test model

RF Analysis Results: Link budget analysis, data transfer and access times report, satellite & ground station antenna designs

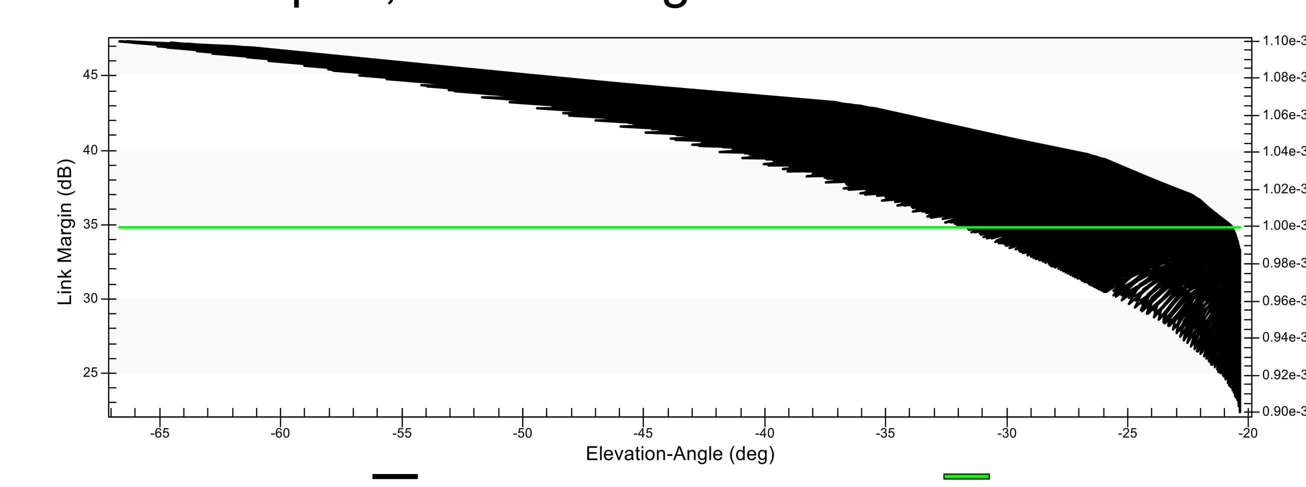

Figure 9 – Eb/No & BER vs Elevation Angle

Future Work

Future teams will use the simulations and chosen components to begin assembling and testing. They will also consider the balun and trace simulations to design the final RF PCB outlay.

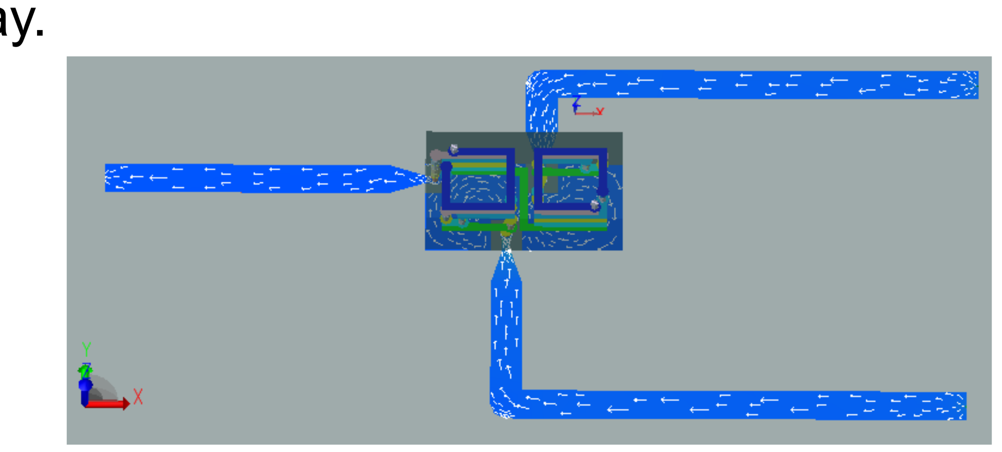

Figure 10 – EMPro Current flow Simulation

Acknowledgements and References

We would like to thank Dr. Rashidzadeh for his time and advice with this project.
[1] "*The Canadian Satellite Design Challenge: 'Selfie-Sat' Mission,"* Issue 5a, 2018.
[2] "*The Canadian Satellite Design Challenge: 'General Rules & Requirements,"* issue 3a, 2014.
[3] Editor, "*Hardware Abstraction Layer (HAL)*," *Network Encyclopedia*, 29-Aug-2019.