ORCASat

Optical Reference Calibration Satellite

2024-02-14

Afzal Suleman

Canada Research Chair and Professor

UVic Center for Aerospace Research

Department of Mechanical Engineering
http://www.uvic.ca/engineering/mechanical/

Center for Aerospace Research
http://aero-cfar.uvic.ca/

TC approved Flight Test Range
http://aero-cfar.uvic.ca/

University of Victoria

Engineering Student Clubs [Aerospace]


BRITISH COLUMBIA
2022
ORCA SAT
University of Victoria
Centre for Aerospace Research

The ORCASAT Team

Faculty

Prof. Afzal Suleman
UVic, Mechanical Engineering

Principal Investigator

Prof. Justin Albert
UVic, Physics and Astronomy

Co-Principal Investigator

Team Leads

Levente Buzas
UVic, M. App. Sci

TT&C Lead

Andrada Zoltan
UBC, B. Eng

C&DH Co-Lead

Richard Arthurs
SFU, BASc

C&DH Co-Lead

Team Leads

Alexander Doknjas
UVic, B. Eng

Project Manager/ Technical Lead/ EPS Lead

Evan Moore
UVic, B. Eng

Payload Lead

Tristan Tarnowski
UVic, B. Eng

Mechanical & Thermals Lead / Systems

Core Students and Collaborators

Co-op Students
- Andres Martinez
- Ben Kellman
- Benjamin Mazzerole
- Colton Broughton
- Ethan Clarke
- Evan Maier
- Gregory Perry
- Josh Fernandes
- Michael Huynh
- Peter Ogilvie
- Sean McAuliffe
- Stefan Bichlmaier
- Tanner Oleksiuk
- Timothy Wriglesworth
- Ty Ellison

MSc Students
- Beatriz Alves
- Bernardo Lobo-Fernandes
- Bernardo Sabino
- Diogo Ferreira
- Ines Bernardino
- João Duarte
- Luis Romeiro
- Zeno Pavanello

Volunteers
- Alireza Alidousti
- Bryce Edwards
- Cristiano Fernandes
- Duncan MacDonald
- Jeremy Guido
- Jose Guerrero

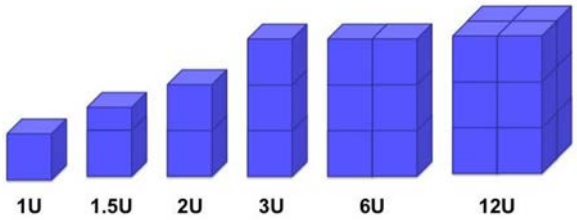
Volunteers
- Josh Gage
- Josiah Macleod
- Julie Belleville
- Mahum Azeem
- Matt Saliken
- Matthew Wegener
- Melvin Mathews
- Nic Richardson
- Richard Arthurs
- Sam Wheating
- Steven Huang
- Steven Richter
- Stewart Lusk
- Svetlana Borkovkina
- Victor Leon
- Vince Parker

Advisers
- Prof. Peter F. Driessen
- Prof. Jens Bornemann
- Maarten Meerman
  - SSL
- Viresh Wickramasinghe
  - NRC
- Alireza Seyfollahi
  - NRC

Overview

- 2U CubeSat.

- Designed and built by **students** under supervision of faculty
  - Led by the University of Victoria Centre for Aerospace Research
  - Student volunteers from engineering clubs across BC
    - UVic Satellite Design, UBC Orbit, SFU Sat
  - >100 full-time/part-time students over 4 years of development



- British Columbia's submission to the Canadian CubeSat Project (CCP)
  - First student-built satellite from BC launched into space.

- ORCASat Mission Objectives:
  - Train Highly Qualified Personnel (HQP) in space science and technology by providing a unique, hands-on learning experience for undergraduate and graduate students.
  - Demonstrate new technologies for calibrating Earth-based telescopes by providing a reference light source in orbit.

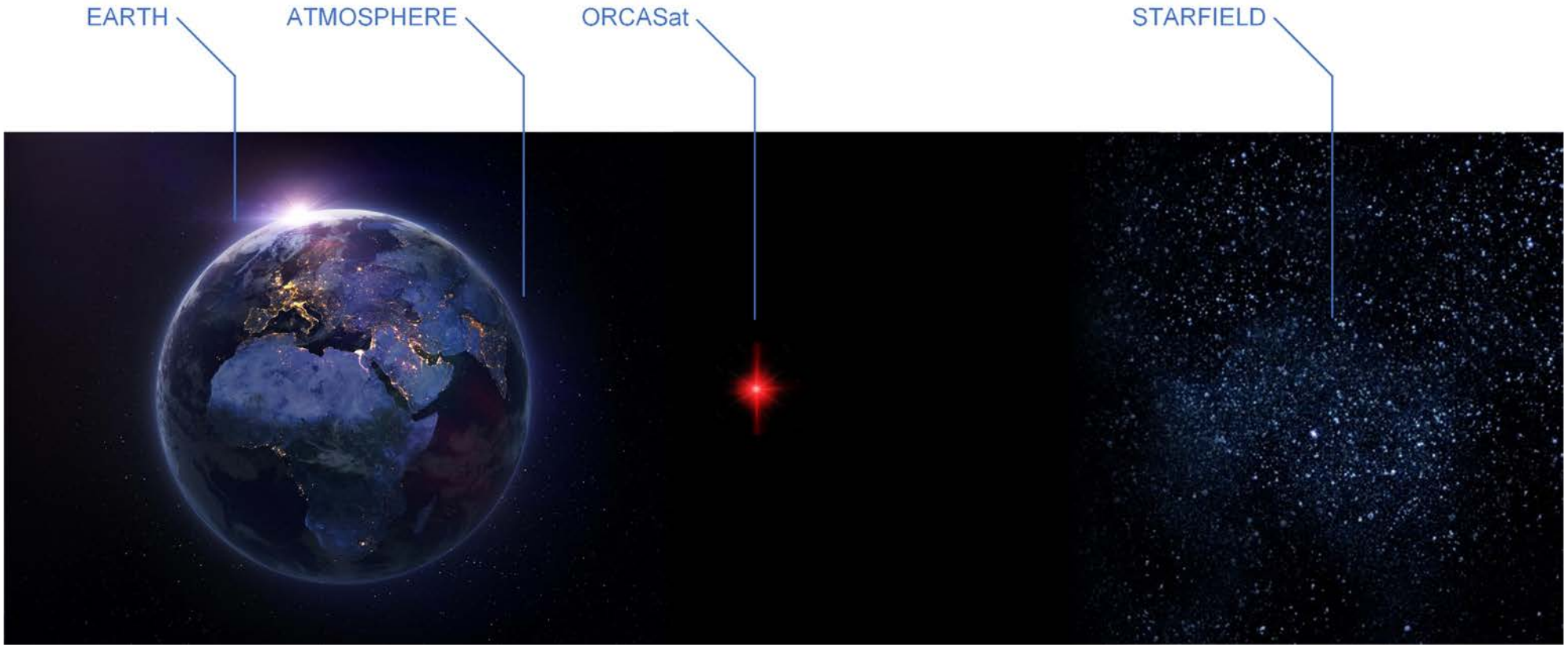
Mission

ORCASat is an orbiting light source that can be viewed by ground-based telescopes.

1. Ground-based telescopes measure how bright ORCASat *appears*.
2. ORCASat measures how bright its light source *is*.
3. Difference between how bright ORCASat is and how bright it appears
    a. Is the amount of light attenuated in the atmosphere and telescope optics.
    b. Corrected for altitude and attitude
4. Telescope is now calibrated for absolute brightness
    a. Take more accurate measurements of astronomical objects.

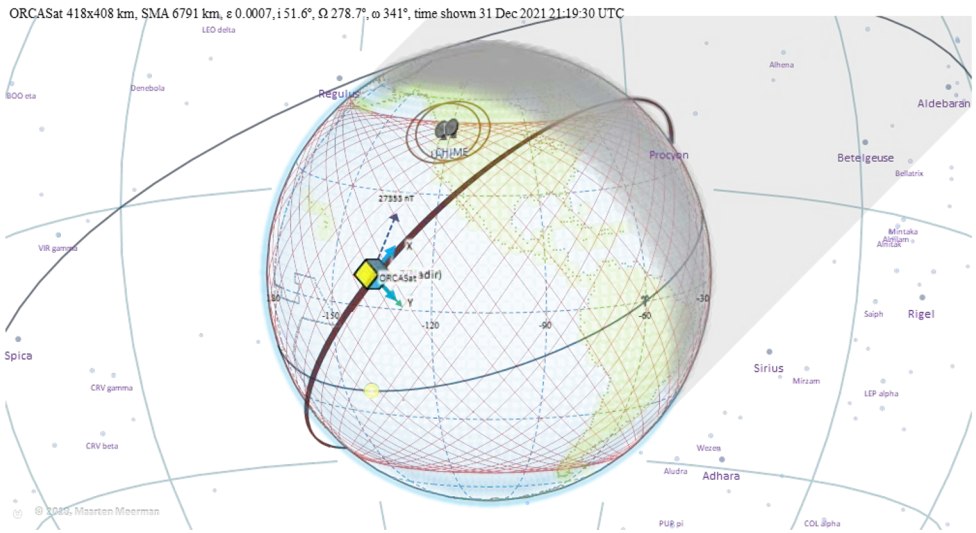
ORCASat is an artificial star

Mission Concept



Orbit

- Launch provided through NanoRacks.
  - Launch on SpaceX CRS-26 (Nov. 26, 2022)
- Deployed from the International Space Station into Low Earth Orbit
  - Inclination 51.64°.
  - Perigee: ~420 km.
- Orbit period: 93 minutes
  - 60 minutes in sunlight.
  - 30 minutes in eclipse.
- Expected life time of <1 year before natural re-entry



ORCASat Specs

2-Unit CubeSat Bus:

- 1U of internal payload volume
- Nanoracks NRCSD compatible
- 1.5 W average bus consumption

Payload average power: 240 mW

- Up to 5 W peak power

Solar array: Body-mounted panels

- Solar panels on ±X, ±Y, and -Z faces.
- 7 W peak power.

Battery: 12 Whr LTO battery

Pointing Accuracy:

- Nadir pointing nominal
- 3-axis stabilization
- 1-axis (pitch) control
- Roll and Yaw angles: < 5° error
- Pitch angle control: < 1° error

Data Rate: 10 kB/s down/uplink

Antenna: 437 MHz UHF dipole antenna

Over-the-air Firmware Updates

Housekeeping Telemetry Collection:

- Temperature
- Voltage, current, and power
- Logs and flags

On Board Computer:

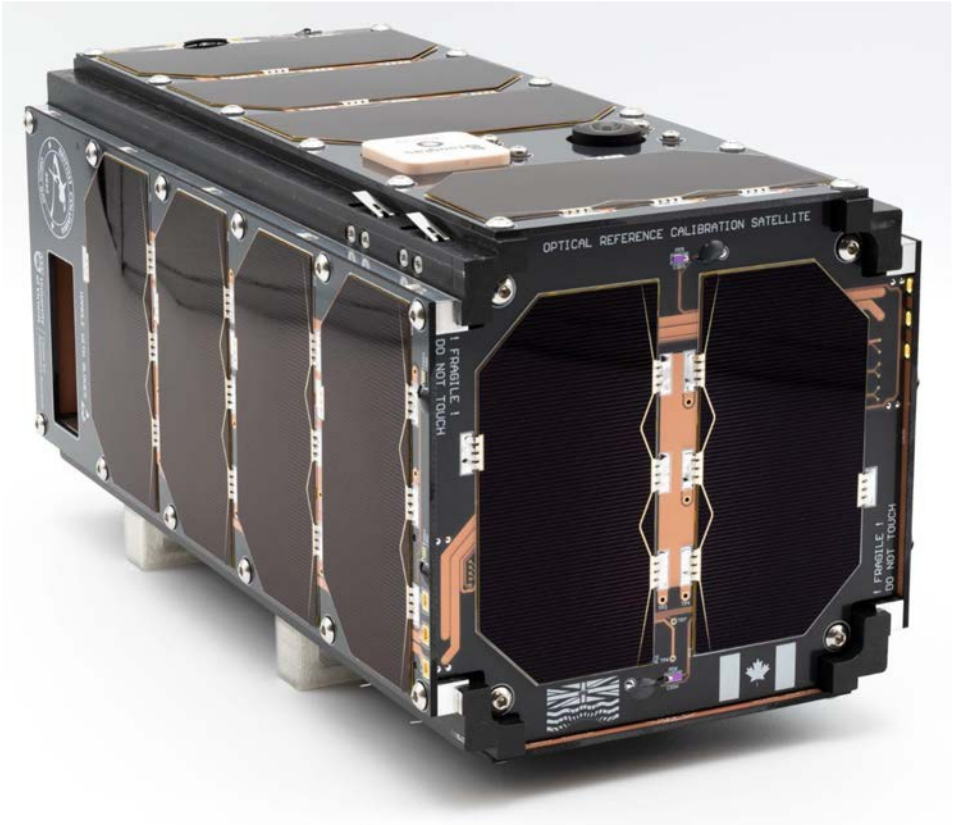
- Safety-critical Arm Cortex-R5F
- Dual-Core Lockstep CPU
- Dual-redundant Real Time Clocks
- Data storage: 128 Mb NOR Flash
- Firmware storage: 128 Mb ECC NOR Flash
- 256 Kb MRAM

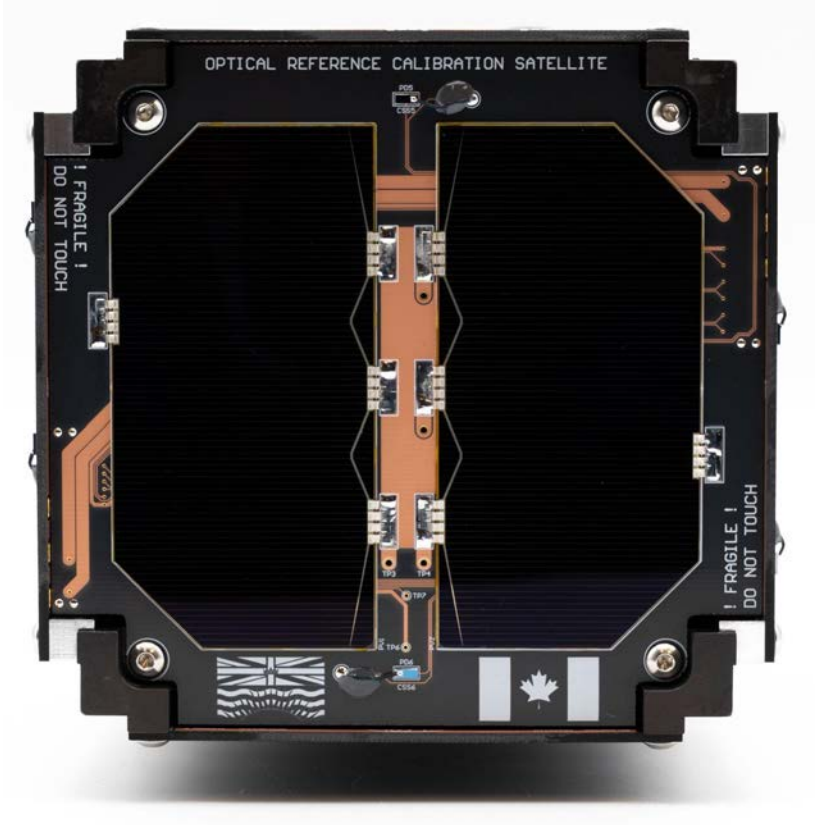
On board GNSS receiver:

- Time synchronization to UTC
- Positioning, altitude, velocity data
- Patch antenna on Zenith face

ORCASat

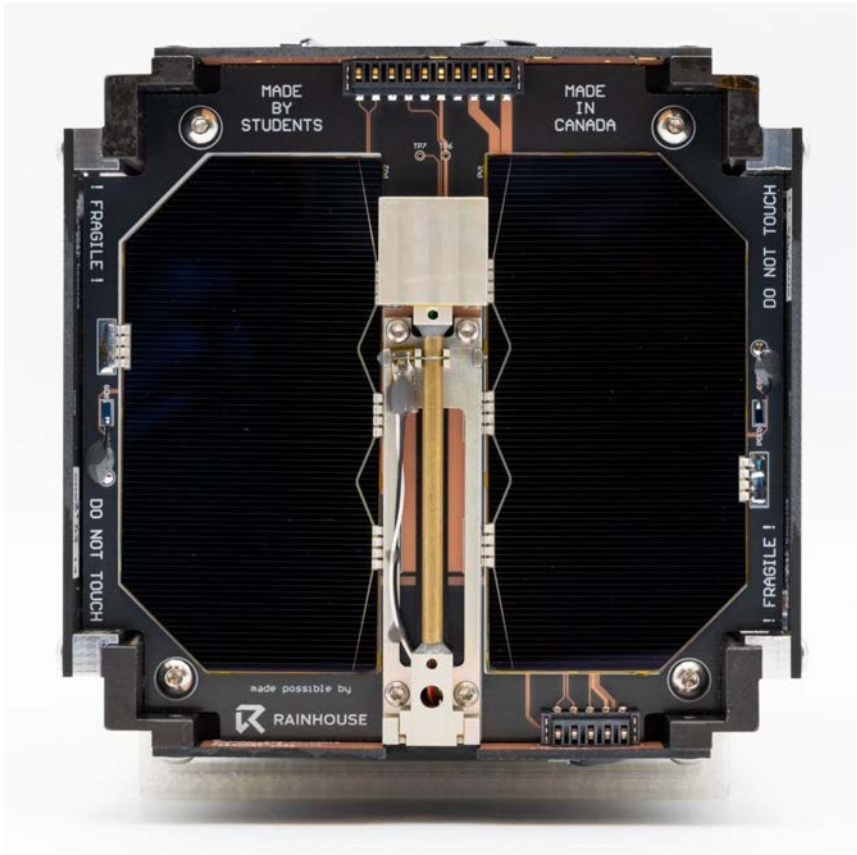
ORCASat





BRITISH COLUMBIA
2022
ORCA SAT

ORCASat



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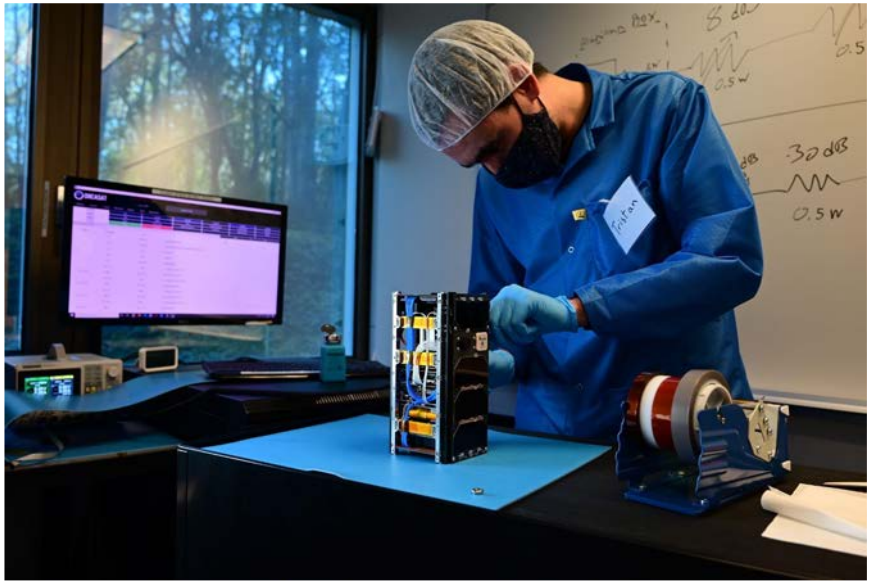
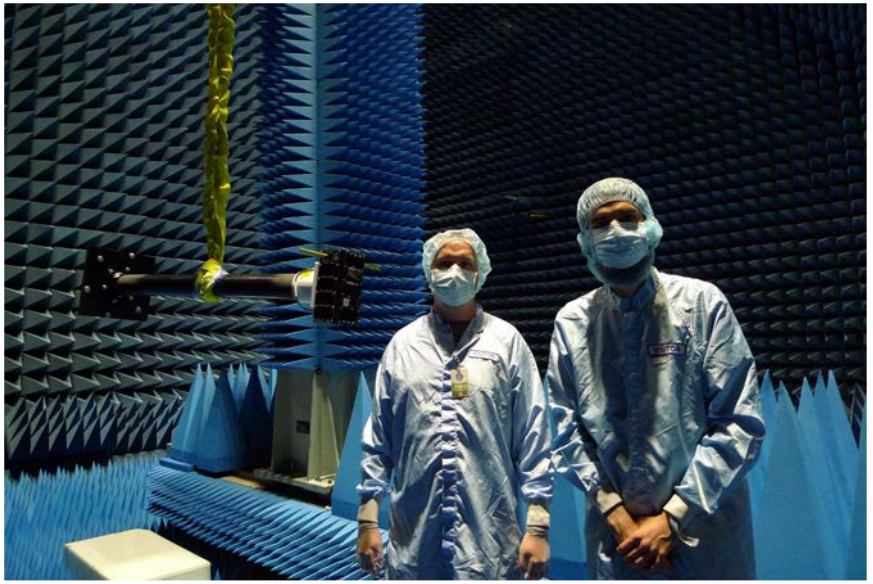
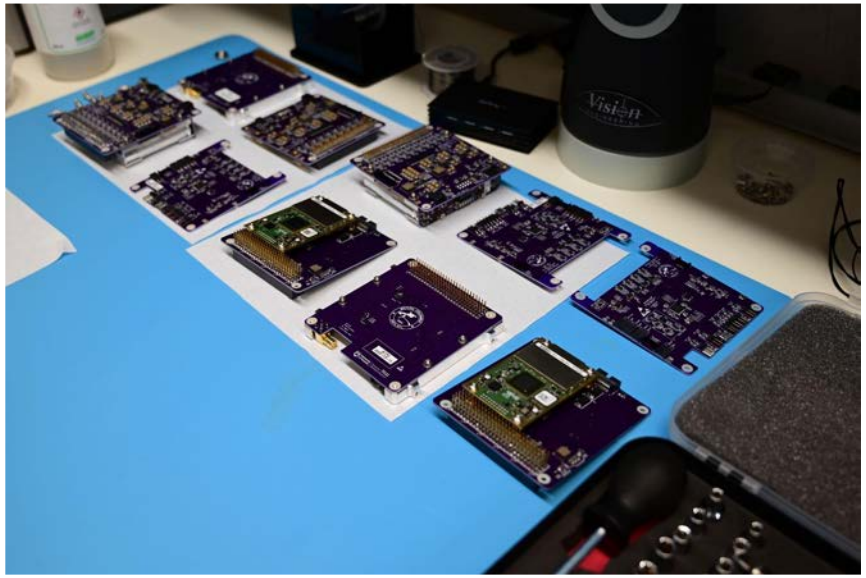
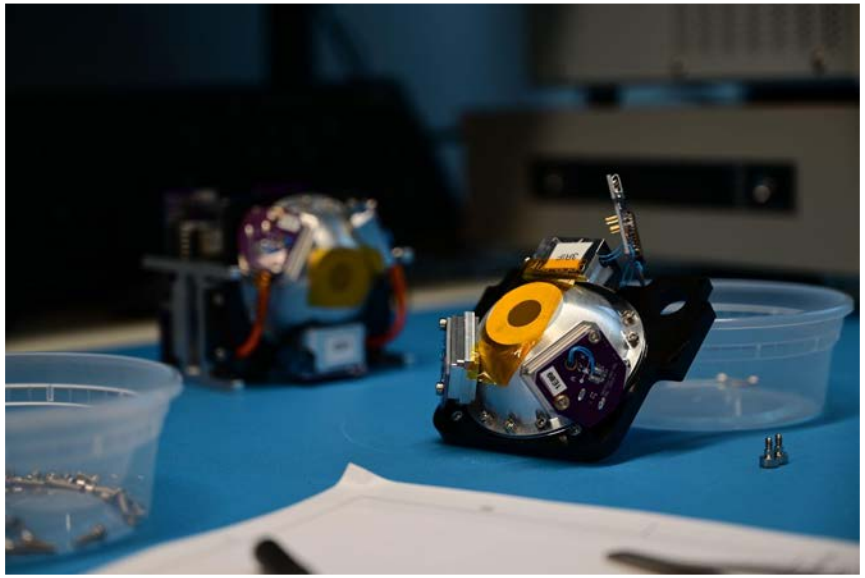
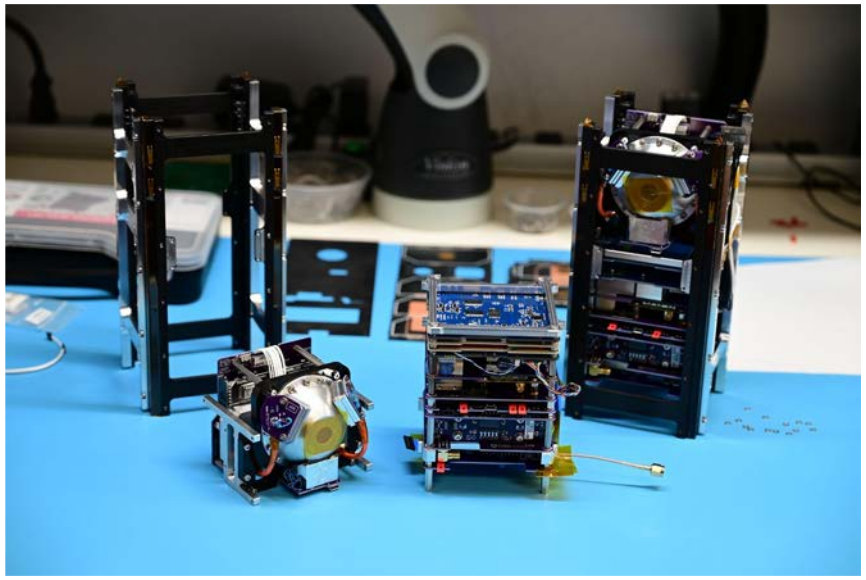
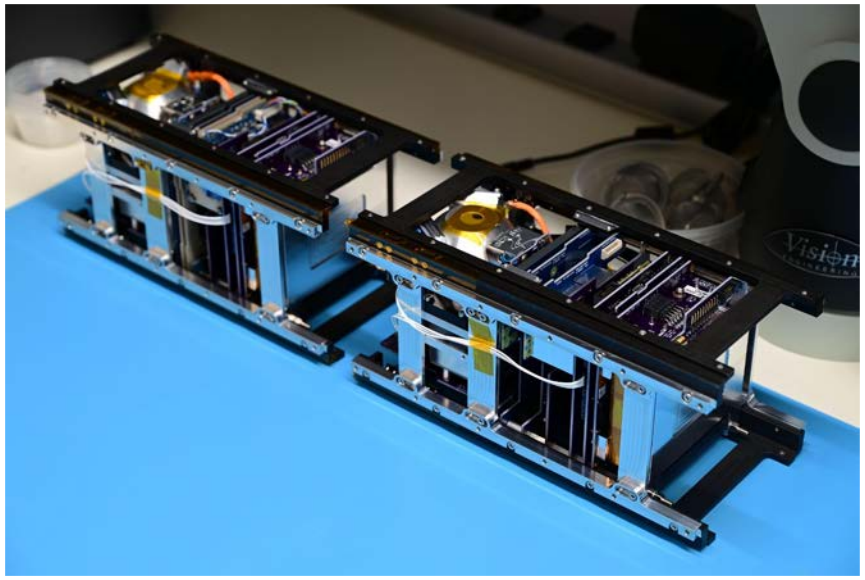

30 dB
0.5 W



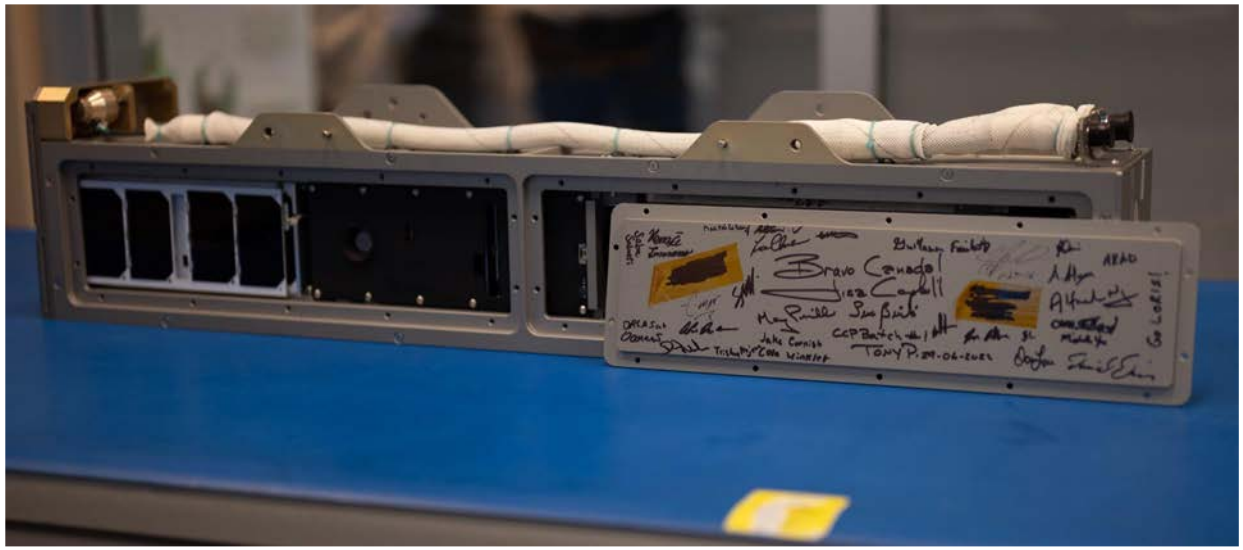









Visiteur - Visitor

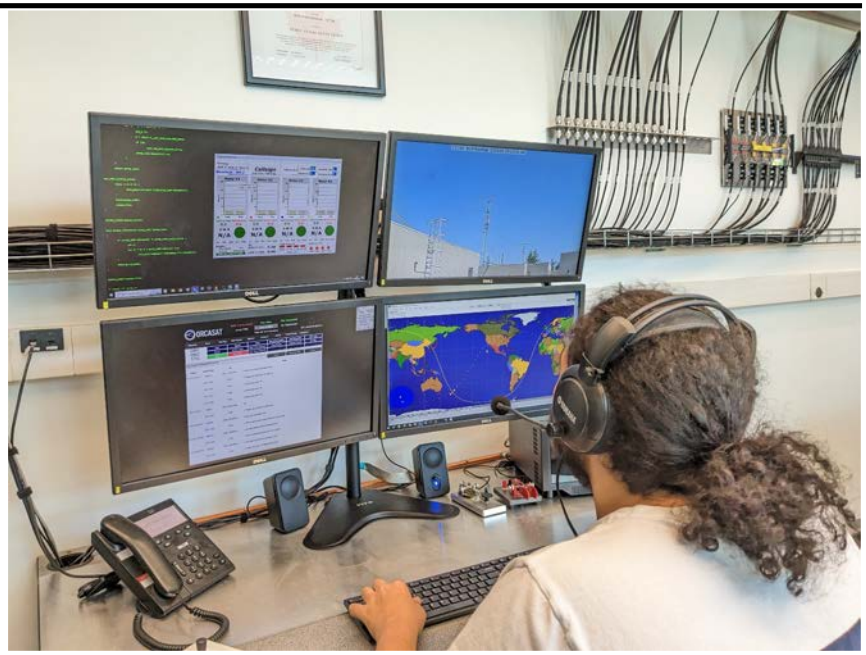

Bravo Canada!

Milestones

- **September 2018:** ORCASat started development.
- **March 2021:** ORCASat completed its Critical Design Review.
- **June 2022:** ORCASat flight unit integrated into NanoRacks CubeSat Deployer
- **November 26, 2022:** Launched on SpaceX CRS-26 to International space station.
- **December 29, 2022:** Orbit insertion and first contact
- **July 7, 2023:** Last contact before re-entry

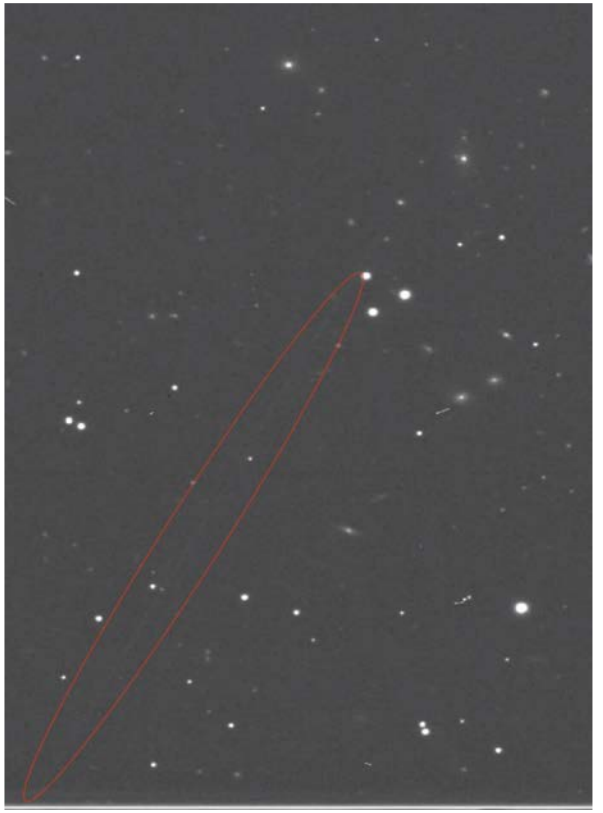
Mission Summary

- Validated new spacecraft bus
  - Consists mainly of in-house designed and manufactured subsystems
- Commissioned ground facilities
  - At University of Victoria Campus
- Gained institutional experience in LEOP
  - Developed critical practices such as ensuring complete data logging
- Unable to complete scientific mission
  - Issue with interference affected ADCS accuracy
  - Coordination issues with telescopes



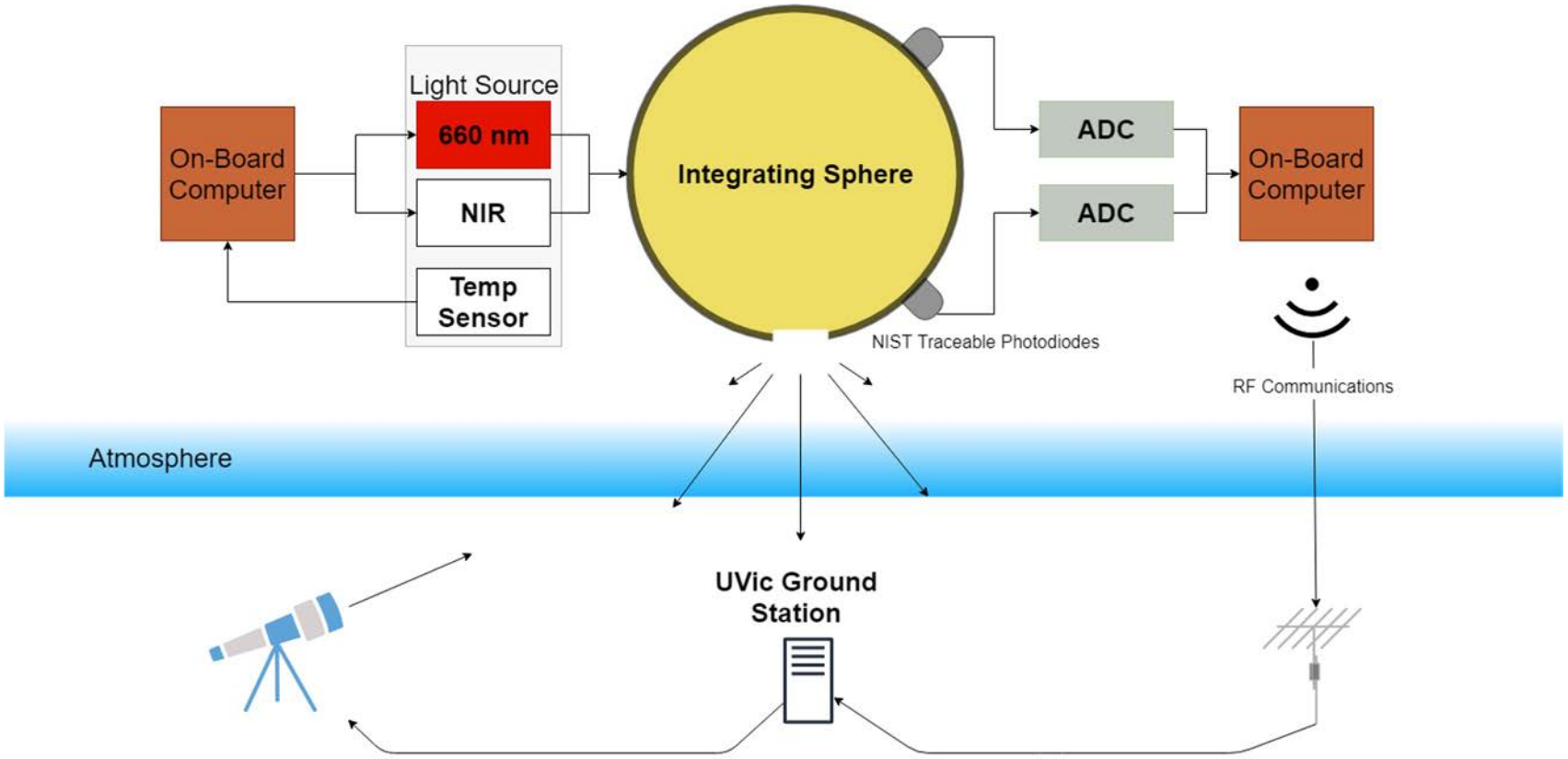
Operating the CfAR ground station during the ORCASat mission

Blanco Telescope (Chile)

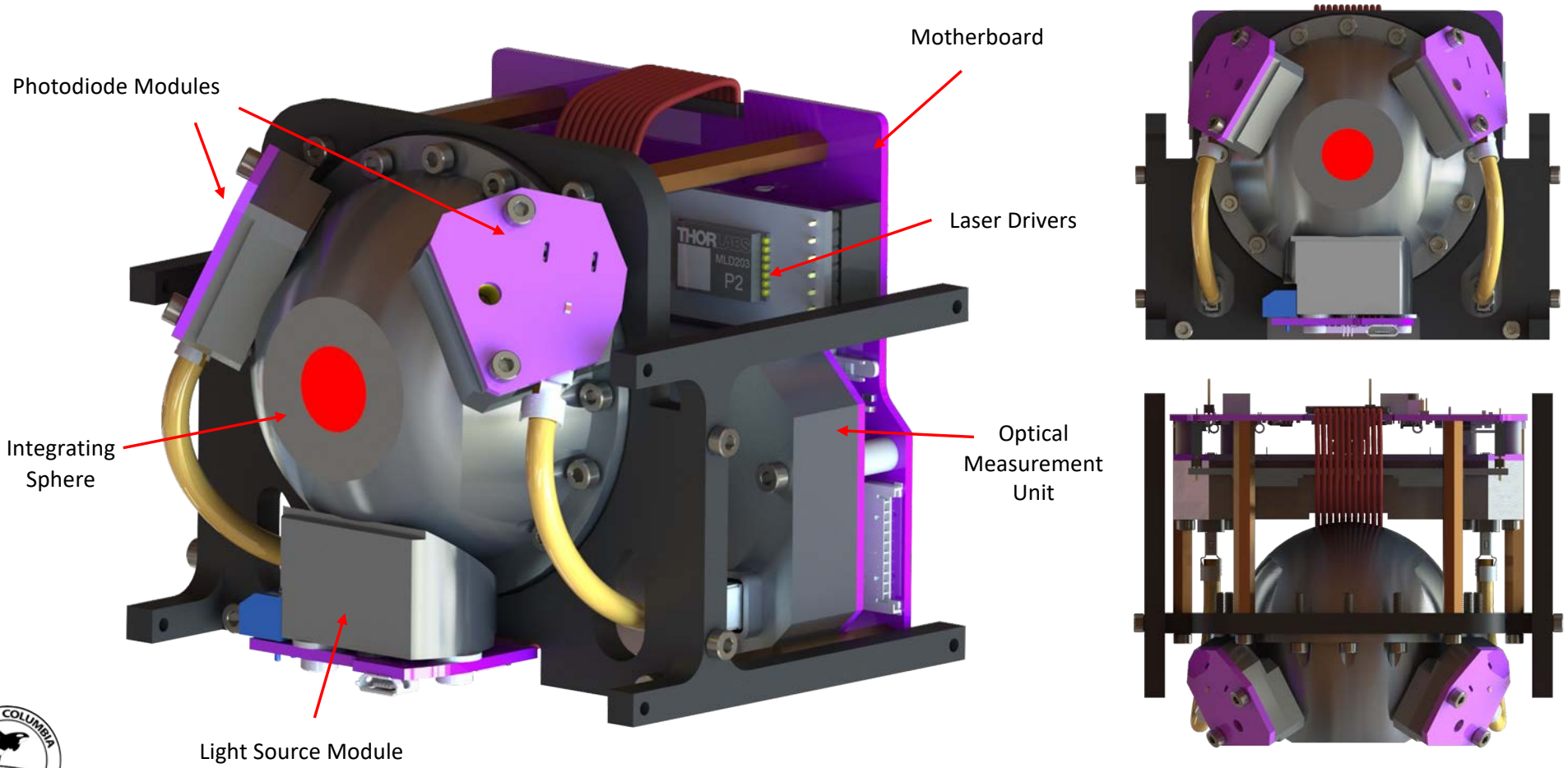


Engineering Details

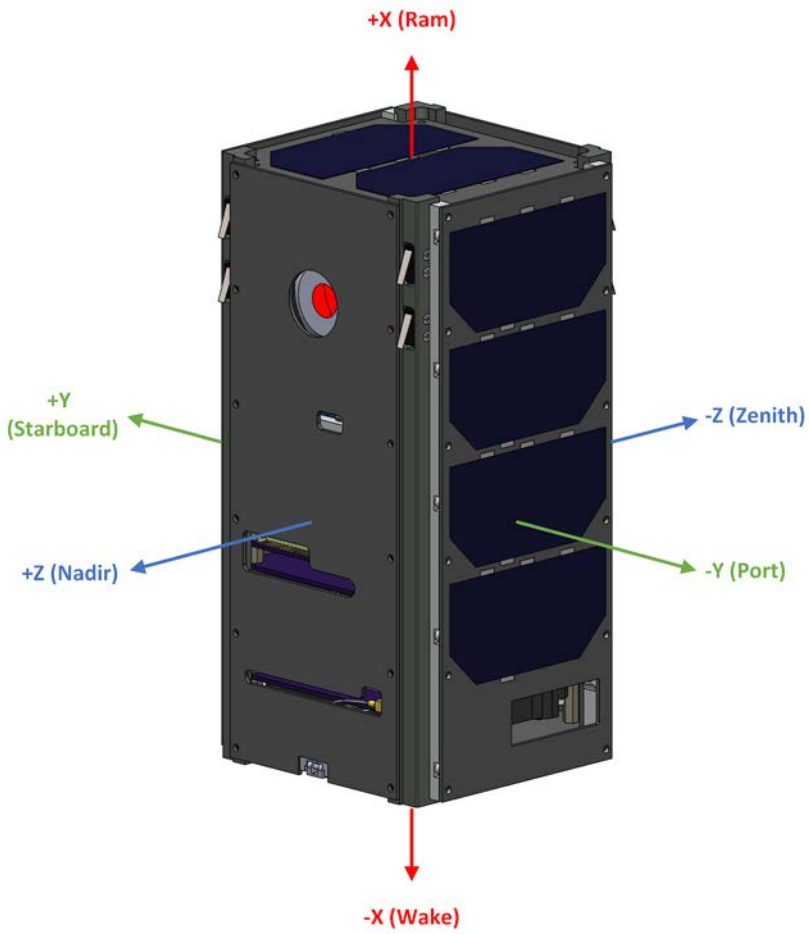
Science

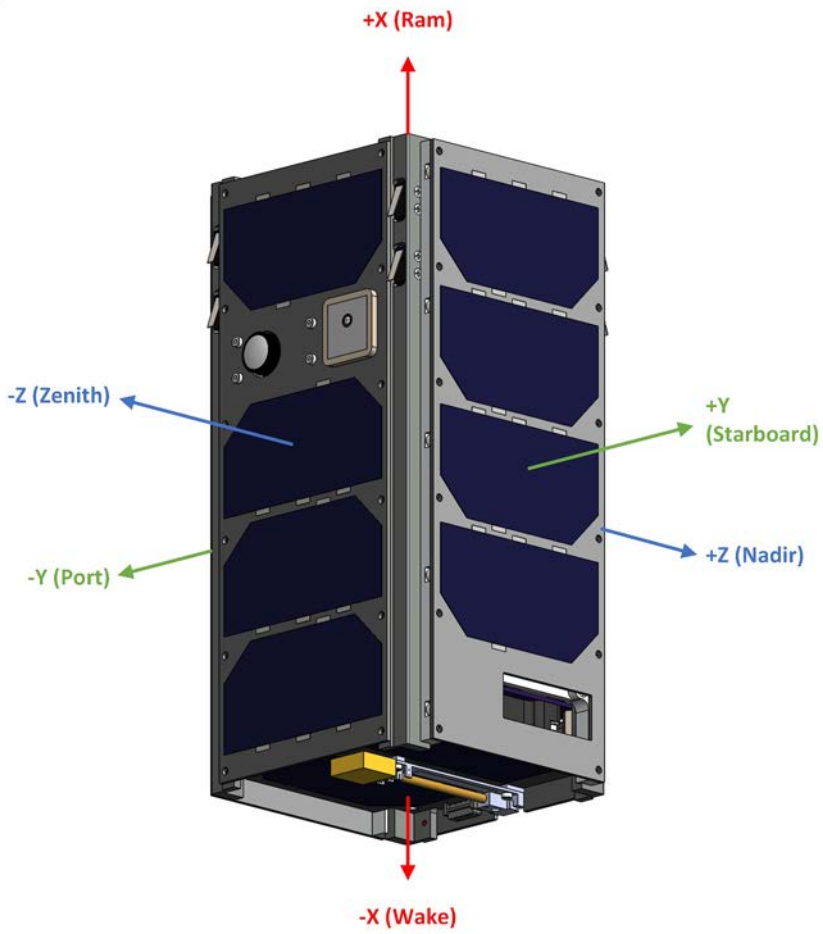

Light Source
On-Board Computer
660 nm
NIR
Temp Sensor
Integrating Sphere
ADC
ADC
On-Board Computer
NIST Traceable Photodiodes
RF Communications
Atmosphere
UVic Ground Station

ORCASat Payload

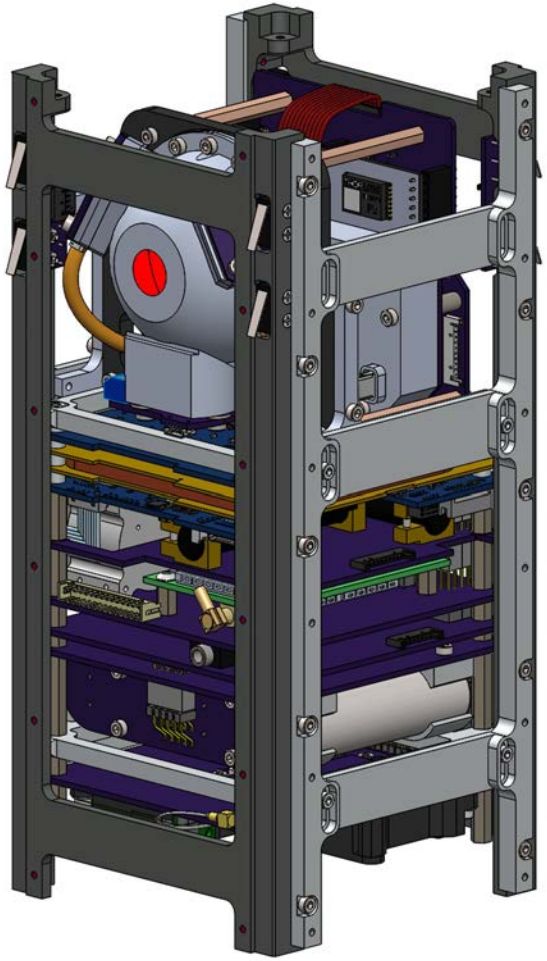


ORCASat External Features



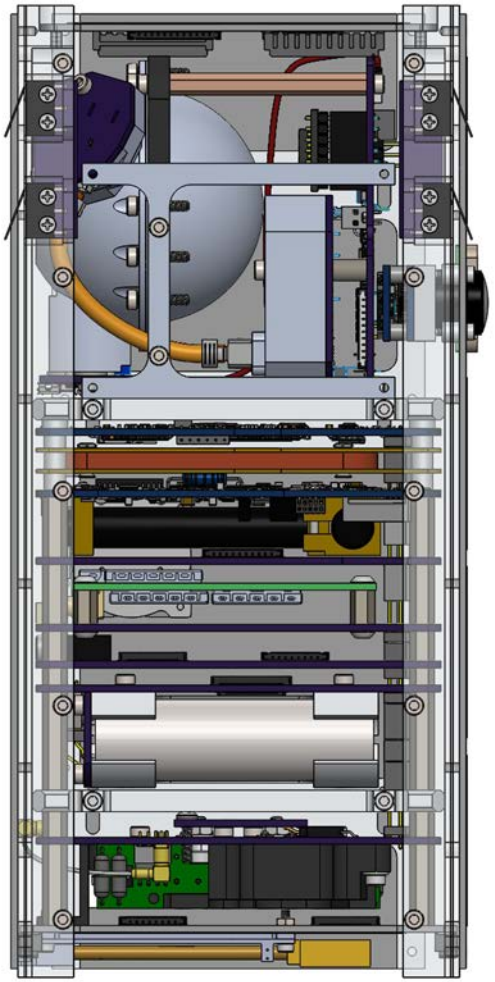


ORCASat Internal Features



Payload Module

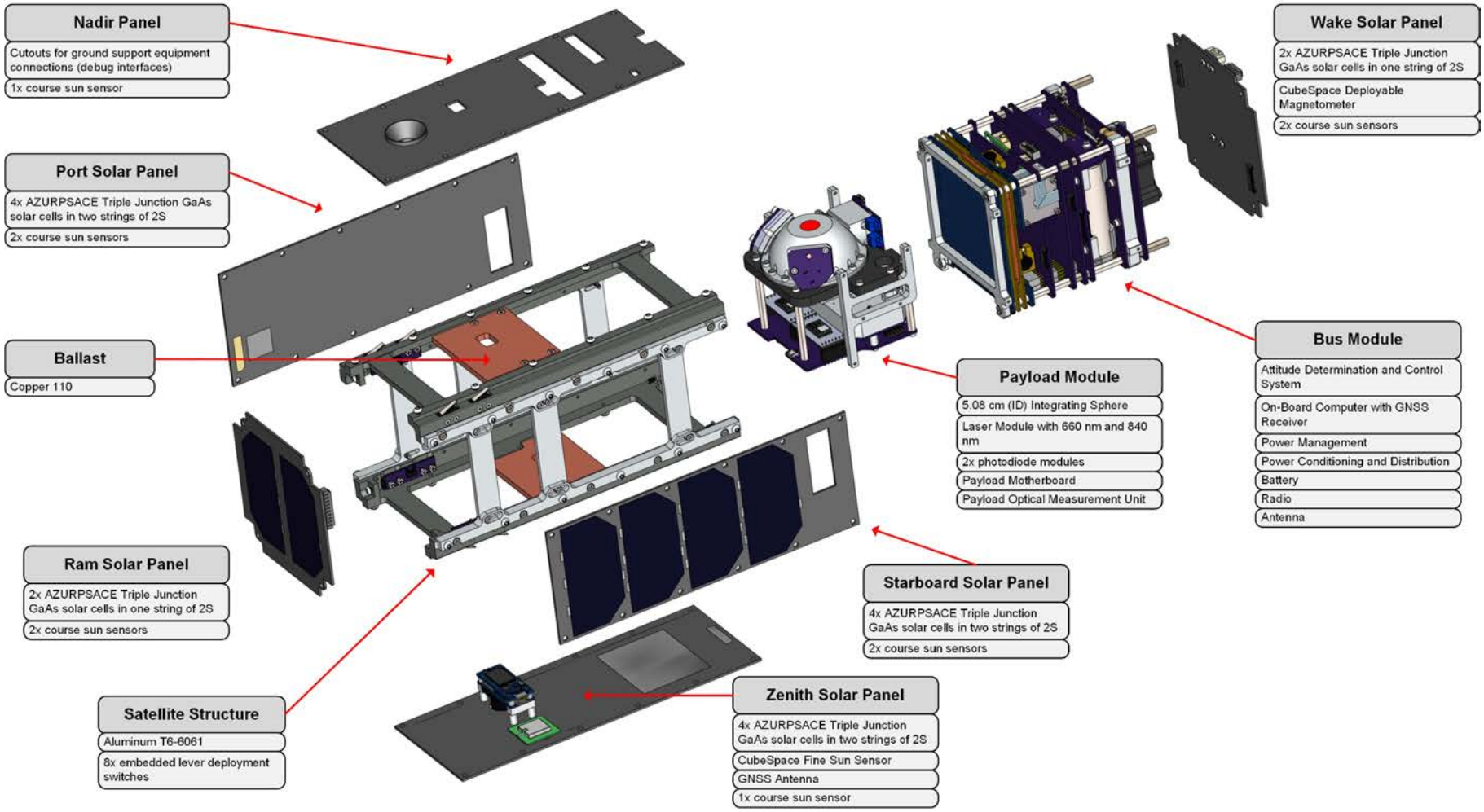
Bus Module



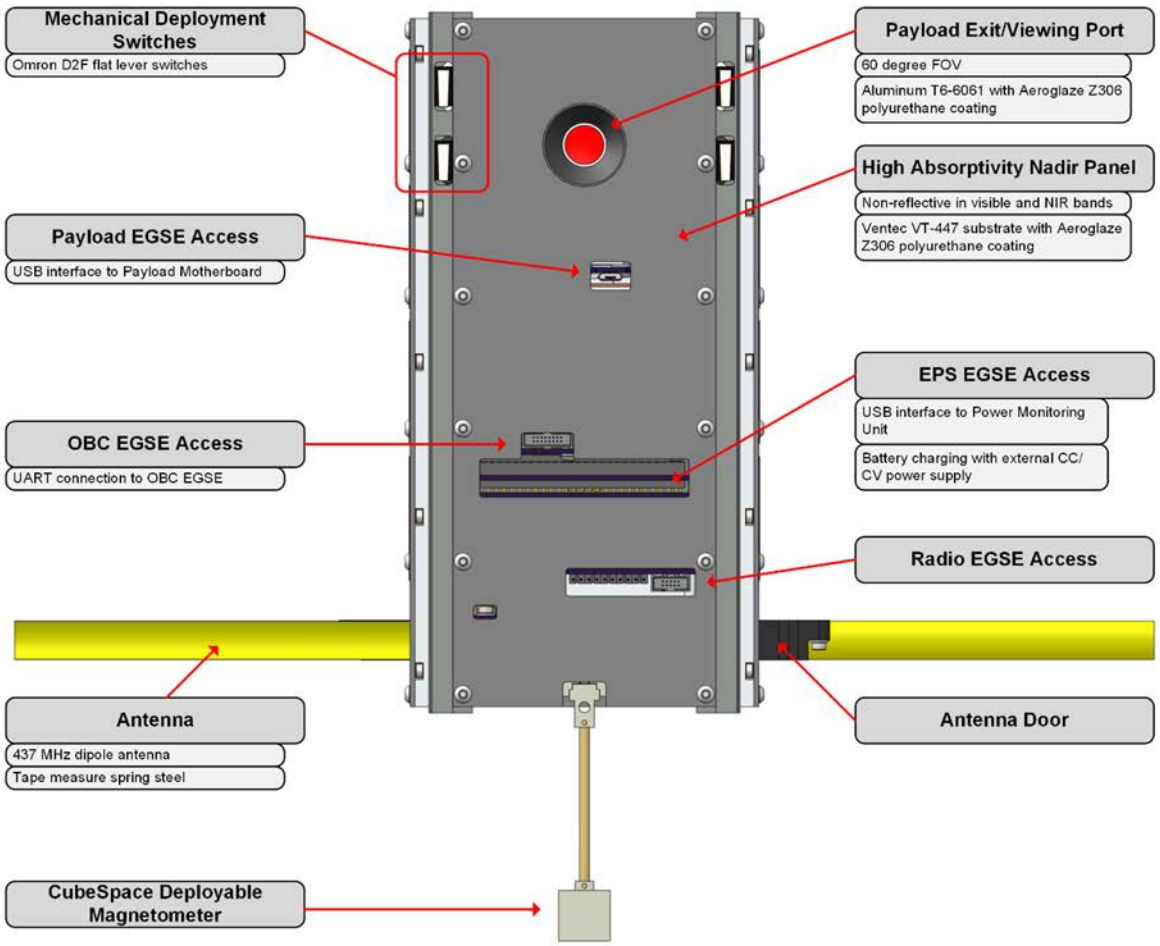
Payload Module

Bus Module

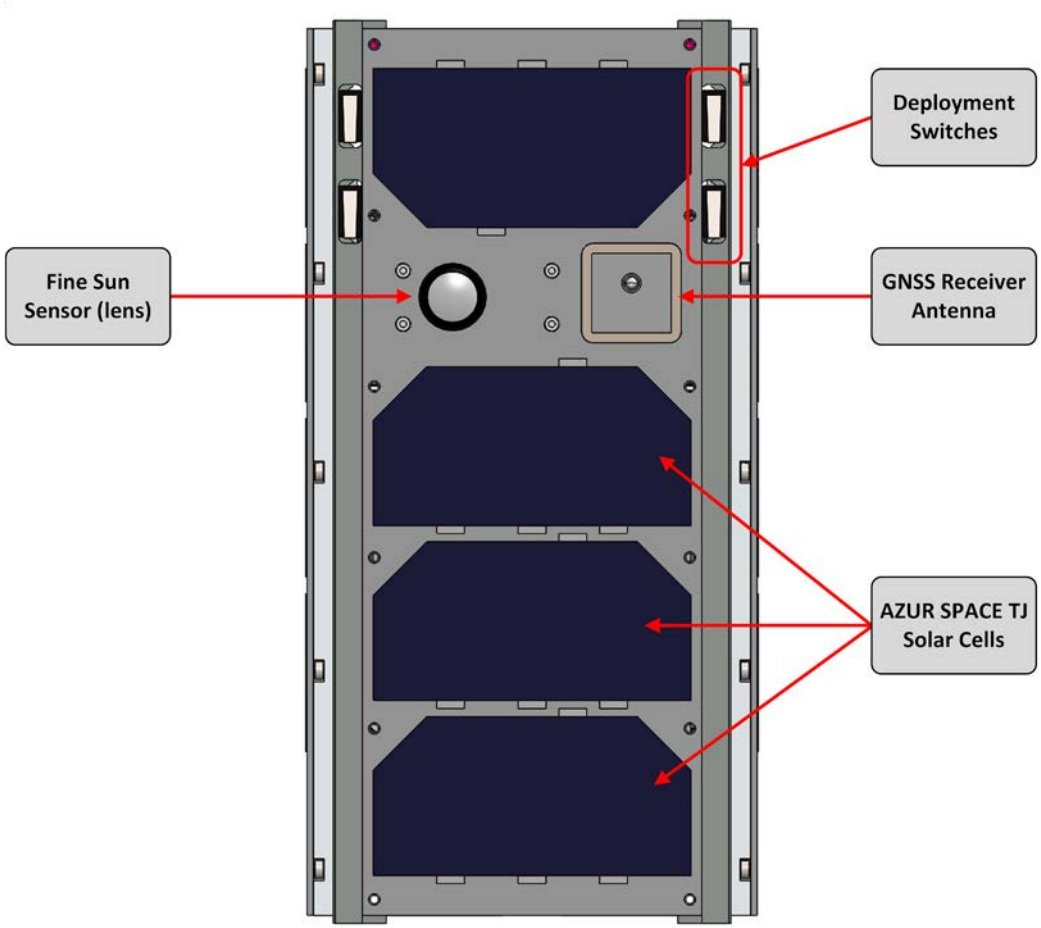
ORCASat Exploded View



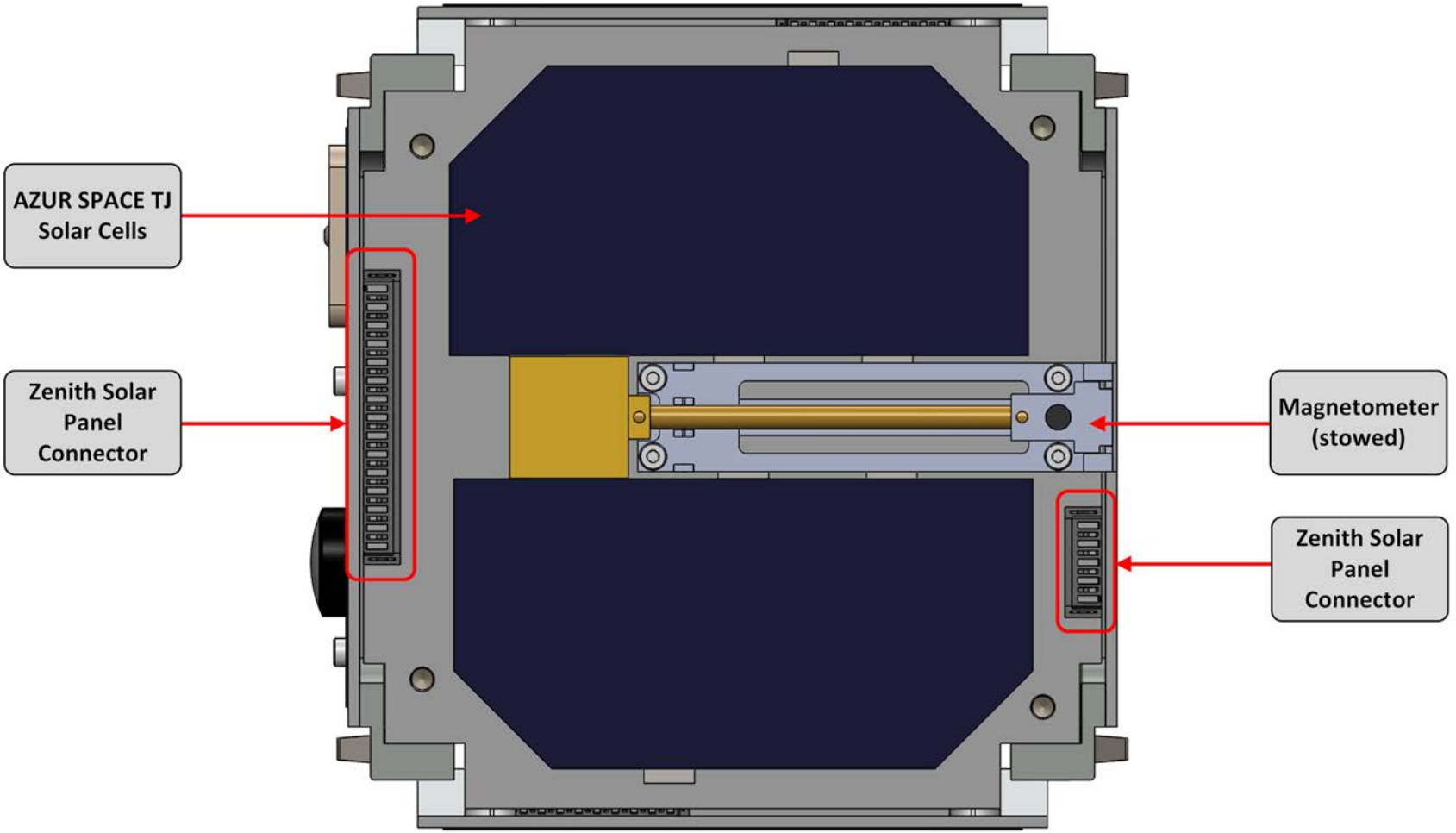
ORCASat External Features: Nadir Face



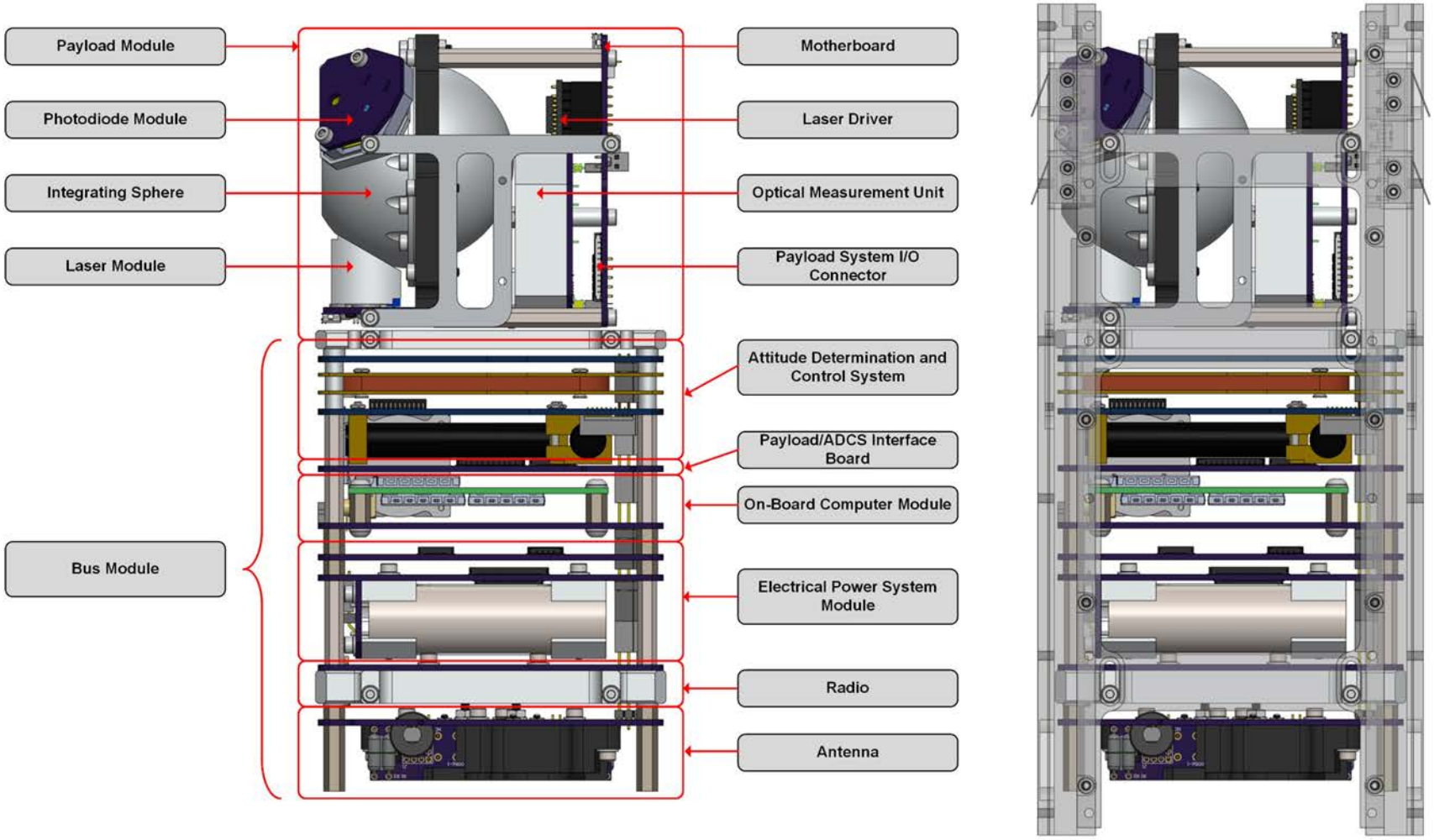
ORCASat External Features: Zenith Face



ORCASat External Features: Wake Face



ORCASat Internal Features



ORCASat Internal Features

Attitude Determination and Control System
- CubeSpace Y-Momentum ADCS
- Points satellite at Earth at all times with a pointing error of < 10 degrees.
- 3-axis stabilization, pitch angle control

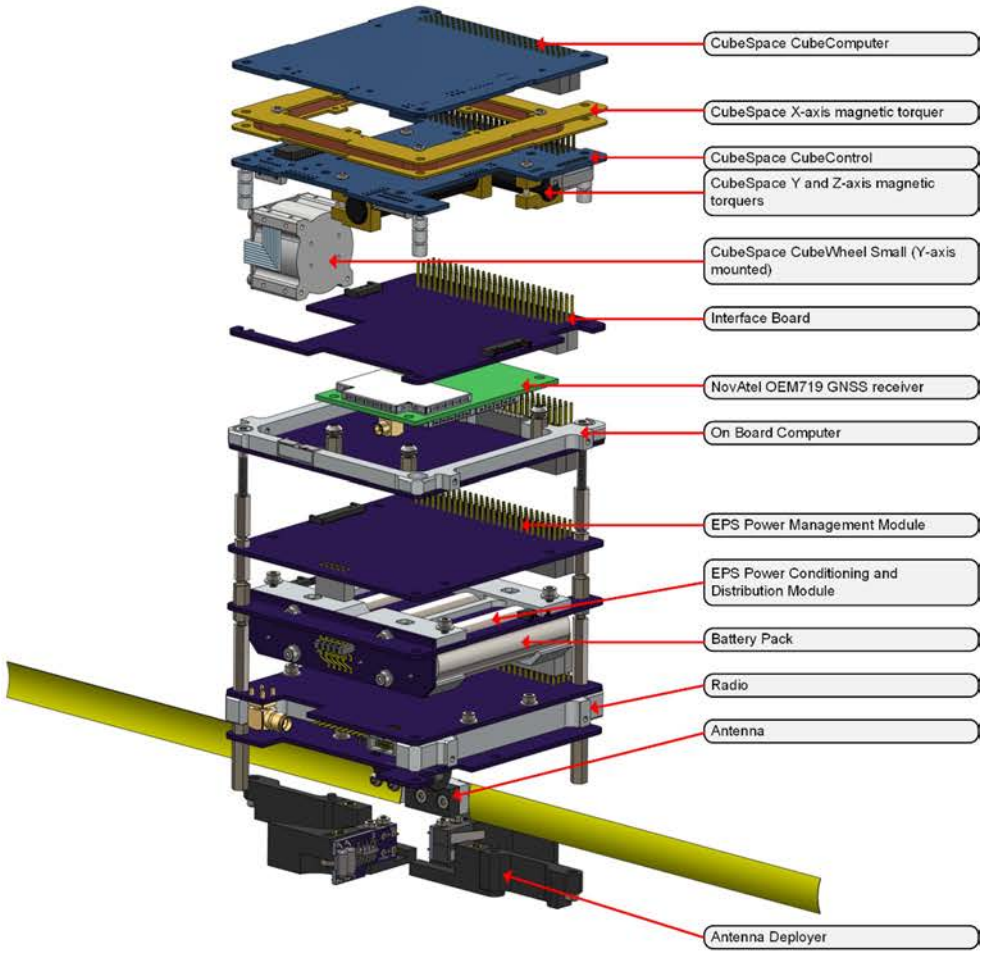
Interface Board
- Electrically connects payload electronics to bus module
- Routes out ADCS connections to be more accessible

On Board Computer
- Executes commands, collects telemetry, interfaces with all subsystems
- Includes GNSS receiver for accurate timing and positioning data

Electrical Power System Module
- Powers satellite at all times
- 12.5 Whr battery for operation during eclipse
- Reports power generation and consumption of satellite

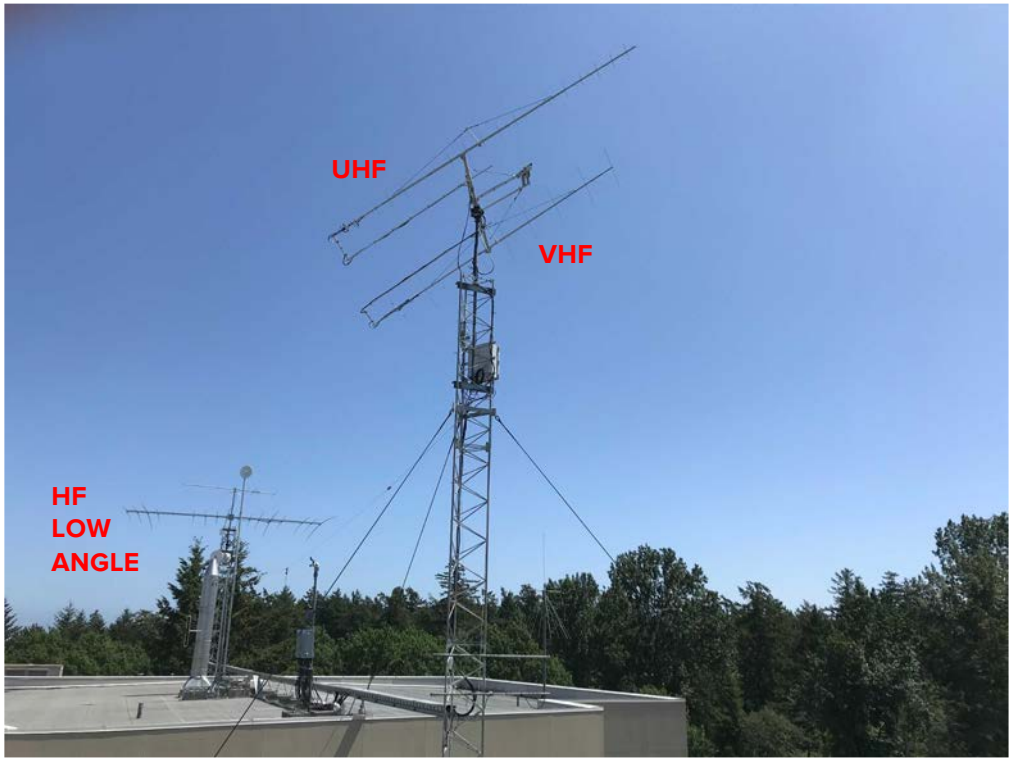
Radio
- Allows wireless communications between ground station and On Board Computer
- 10 kb/s data rate

Antenna
- Converts radio waves into electrical signals
- 437 MHz resonant frequency
- Antenna deployment control



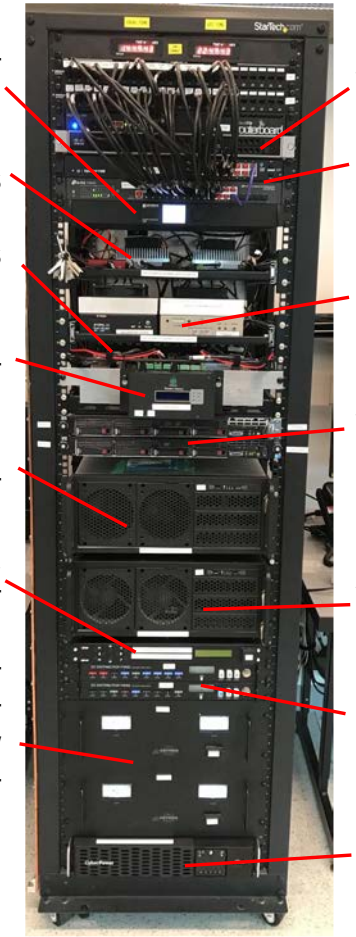
The Ground Station

UVIC RADIO ROOM
2023 SUMMER



UVIC GROUND STATION
ANTENNA FARM

The Ground Station



NTP Server

CubeSat Radios and SSPAs

RF Relays

HF Stack Azimuth Controller

Satellite Station Computer

Satellite Az./El. Rotor Controller

High Capacity Linear 13.8 and 24 Volt Power Supplies on 180 kW Diesel Generator

VPN Server

Network Switches PoE+ & Non-PoE

UHF and VHF Transverters for OSCAR

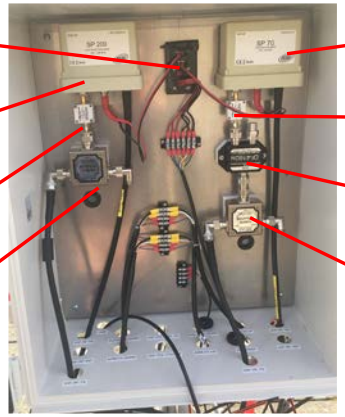
VM Host Server & NAS Server

Amateur Radio Computer

13.8 and 24 Volt Network Controlled Power Distribution

1500VA UPS on 180 kW diesel generator

RADIO RACK



Power Distribution

VHF LNA

RF Limiter

VHF Circulator

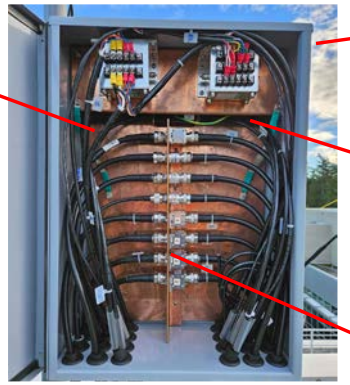
UHF LNA

RF Limiter

Mode J Desense Filter

UHF Circulator

RF FRONT END



Heavy Duty Copper Plates connected to 3/0 AWG lighting protection ground

Control Line Surge Protectors

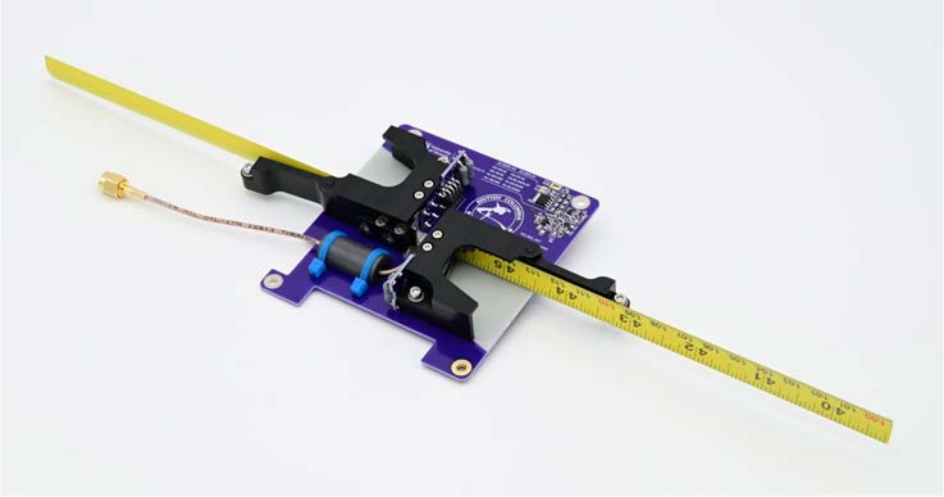
Ethernet Arrester (Under Bridge)

Coaxial Surge Protectors

SINGLE POINT GROUND ENTRY POINT

ORCASat Antenna Design Files

- The ORCASat UHF antenna is open source and available for use and/or modification by all CUBICS teams
- Altium and Solidworks design files at https://gitlab.orcasat.ca/orcasat-group/orcasat-antenna



Delivery of the Engineering Model to CSA

Lessons Learned

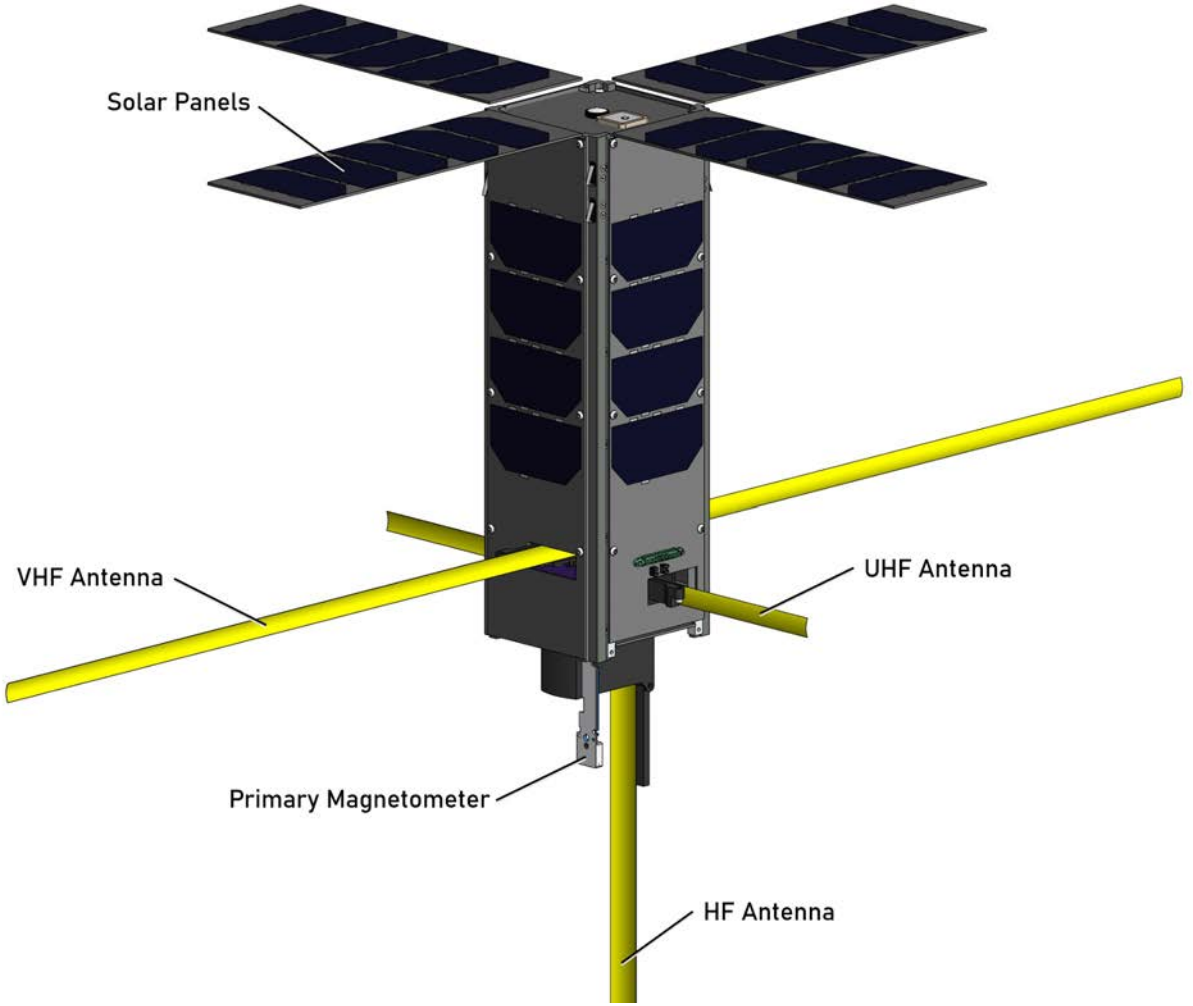
- CSA CCP program to support Canadian Universities to develop space R&D and train future space engineers has been successful
- ORCASAT enabled training of over 100 undergraduate/graduate students over a period of 5 years
- Seed funding from CSA had to be leveraged with other federal agencies and industry
- Open collaborative environment between all 15 universities across Canada was actively encouraged
- Regulatory aspects are quite onerous and require early planning
- Project allowed UVic to establish an embryonic space engineering activity and it is paying dividends
- Current CubeSat Project: SkyaanaSat – CSA CUBICS Program

SkyaanaSat

- Skyaana is UVic's submission to the 2022 offering of CUBICS
- UVic CfAR has partnered with the UVic Propagation Laboratory and UVic Satellite Design (UVSD) for the development and operation of SkyaanaSat
- Skyaana is a 3U CubeSat proposed for launch to SSO orbit in Q4 2025

- **Mission Objectives:**
  - HF radio beacon in LEO to facilitate the study of the ionosphere
  - Amateur radio experiments to facilitate training & licensing
  - SDR transceiver to service the payload with in-flight software update capabilities

External Layout - Deployed




Ad Astra!