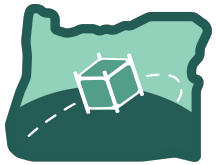


OreSat

Overview of an inexpensive, modular, and open source 1U - 3U CubeSat system

Open Source CubeSat Workshop 2021

Andrew Greenberg, and like a billion students

Portland State Aerospace Society at Portland State University
1900 SW 4th Avenue ste 160, Portland, OR 97201
503-708-7711 / adg4@pdx.edu

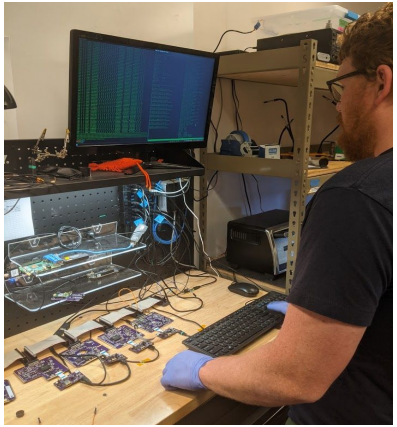
Background: PSAS

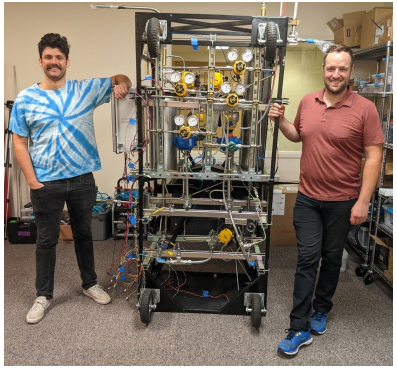
Open Source Space Hipsters from Portland

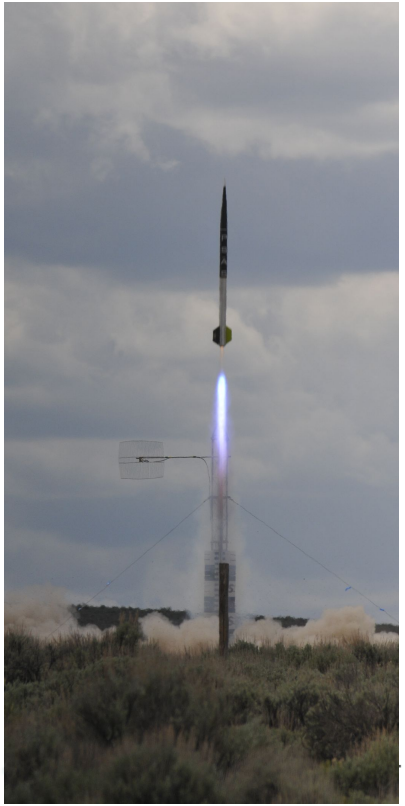
- Extracurricular interdisciplinary team-based hands-on student aerospace project
- Militantly interdisciplinary
  - “Space Program” model, not a “satellite club” model
  - Not just ME/EE/CS; also business, math, physics, marketing, psychology
- Completely open source
- No formal funding source
  - Crowdfunding
  - NASA Oregon Space Grant Consortium grants

- We have no idea what we’re doing (just delivered our first CubeSat)

Portland State Aerospace Society

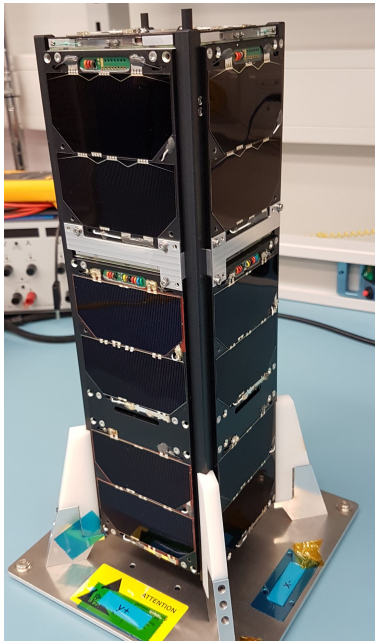






Oh hey we kinda built a nanosat

=



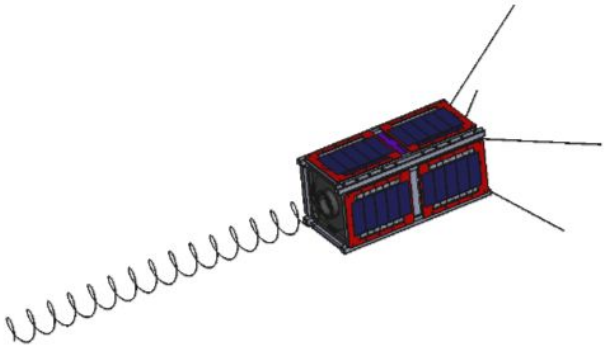
NASA CSLI Application

In Response to Solicitation NNH16ZCQ002O

For

OreSat: Oregon's First Nanosatellite

November 22, 2016



Submitted by

The Portland State Aerospace Society

Portland State University

Maseeh College of Engineering and Computer Science

1930 SW 4th Ave suite 500, Portland, Oregon, 97201

Application Contact:

Andrew Greenberg

Adjunct Faculty

Portland State University

Dept. of of Electrical and Computer Engineering

503-708-7711

adg@ece.pdx.edu

OreSat Motivation

Educational CubeSat Dilemma

- COTS CubeSat kits
  - Robust, flight proven, mostly plug and play components
  - Purchase what you can, build only what you need
  - Minimum development time (sophisticated beepsat in a month)
  - $35,000 (simple 1U beepsat) - $125,000 (3U with ADCS)
- DIY CubeSat
  - Absurdly risky
  - Build everything - you'll need teams of MEs, EEs, and CS students
  - Absurdly expensive in time and effort
  - *Still* going to cost you ≥ $10,000 for a 1U *just for the development*

What we really really want (Requirements)

- 1 - 3U scalable design
- “COTS” subsystems
  - Solar, battery, OBC, deployables, ADCS
  - Capable subsystems, not just educational toys
- Open source to understand how these things work
- Scalable subsystem reference designs (microcontrollers to Linux boxes)
- Student team friendly
  - APIs everywhere - common interfaces for software, electrical and mechanical systems
  - Boards and systems are easily swappable
  - Uses common and obtainable development tools, with existing onboarding media
  - Documentation with explanation of *why* things are this way
- Based on standards
  - Duh

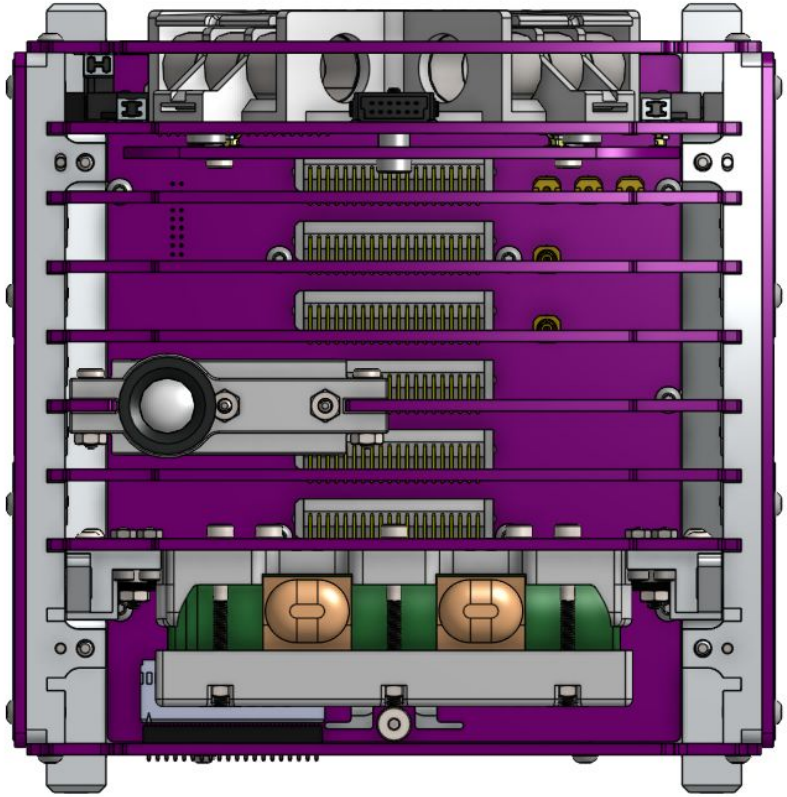
Challenge Accepted

This is a terrible idea

- Takes years (thank you CSLI for being patient)
- Hugely expensive
  - Spent ~ $75,000 on board revs and integration testing
- Hugely inefficient
  - “Generations” of student labor with hand-offs and ramp-ups and onboarding and ...
- Not enough experience
  - Need *experienced* students in RF, thermal, mechanical, power, control, software, firmware, web infrastructure, not to mention management and fundraising

The OreSat CubeSat System

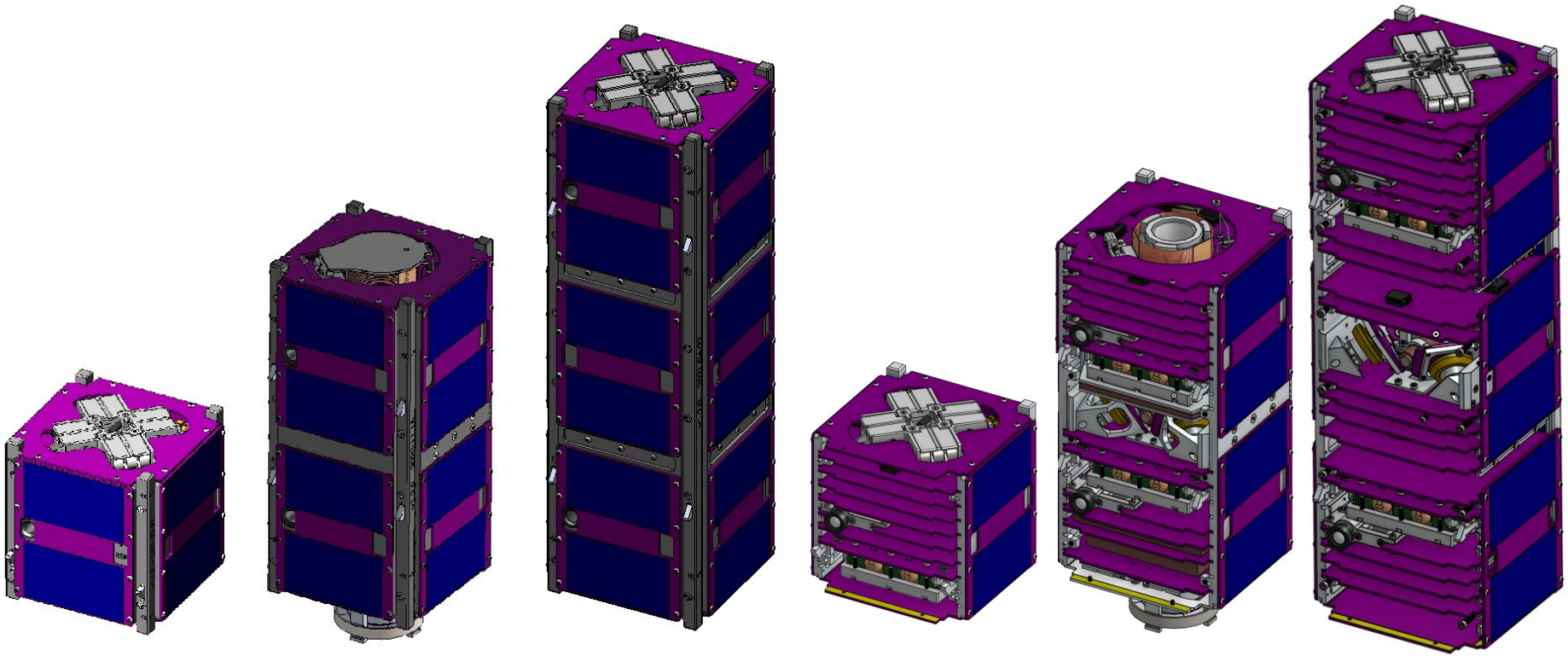
Card Cage



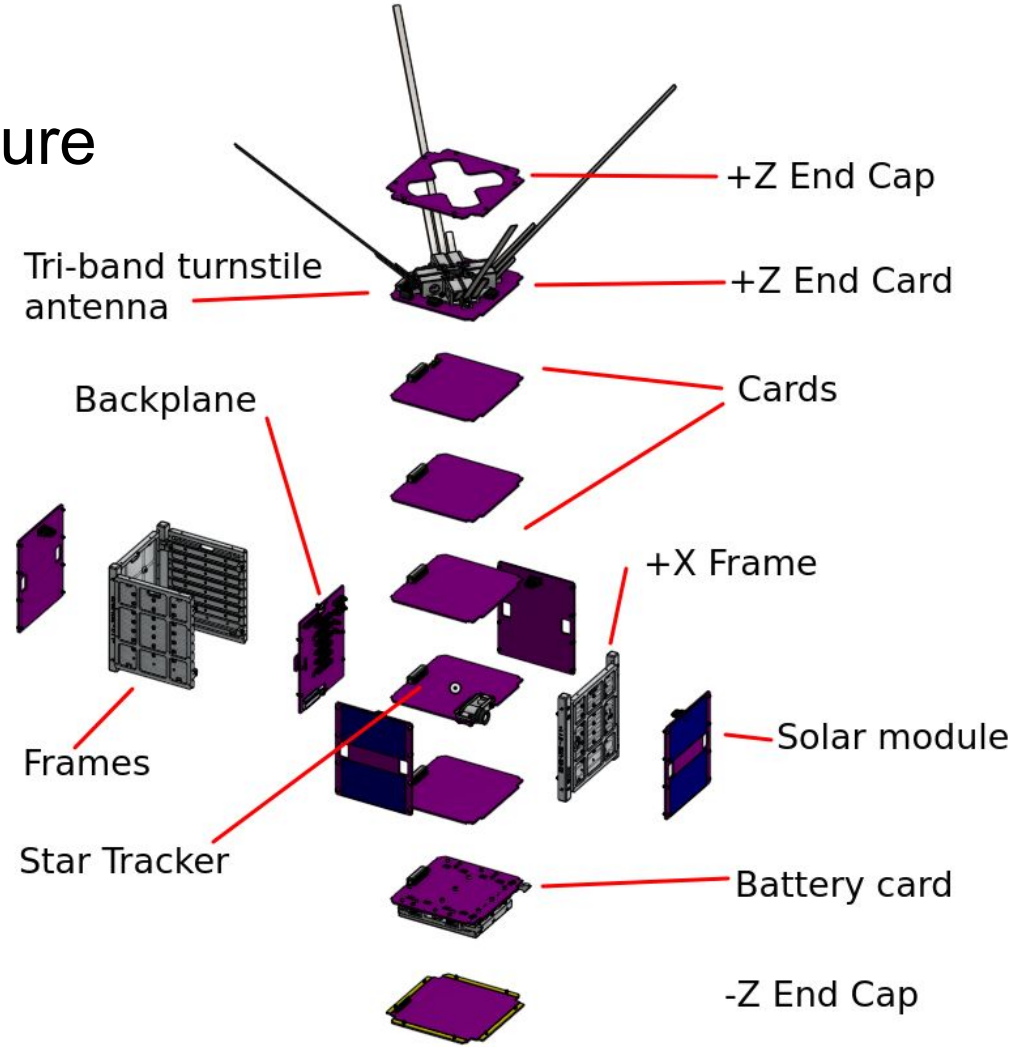
Not just for the 1970s

- Pros
  - Excellent for education teams: each subsystem is one or more cards
  - Common mechanical and electrical interfaces
  - Cards can be as simple (microcontroller) or as complex (Linux box) as necessary
  - Easily replaceable (hot swappable!)
  - ~ 40% more available board area than a PC104 stack
  - Roughly 8 card slots per U
- Cons
  - Strongly discourages systems that cut through the Z axis
  - Still not terribly space efficient compared to custom stack ups

Scalable 1U - 3U

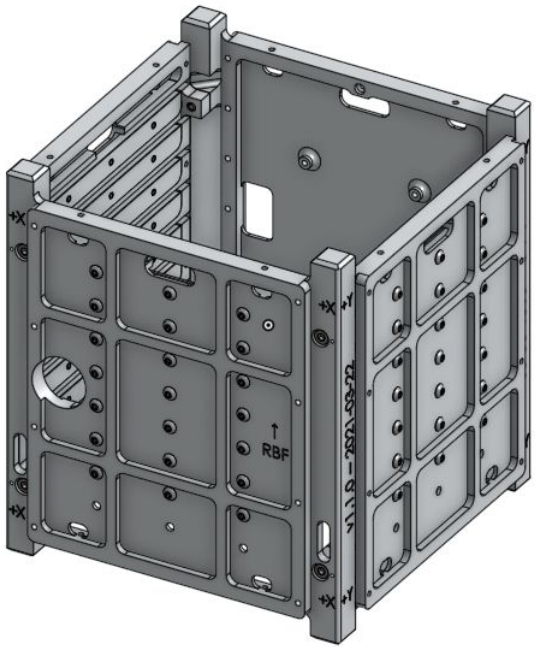


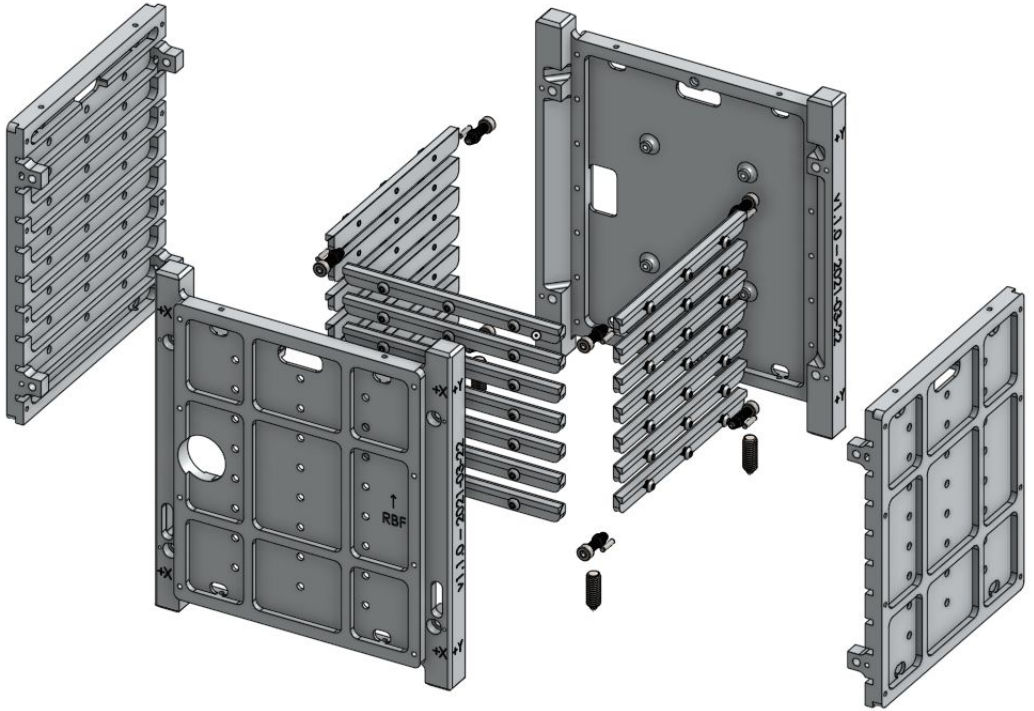
Nomenclature



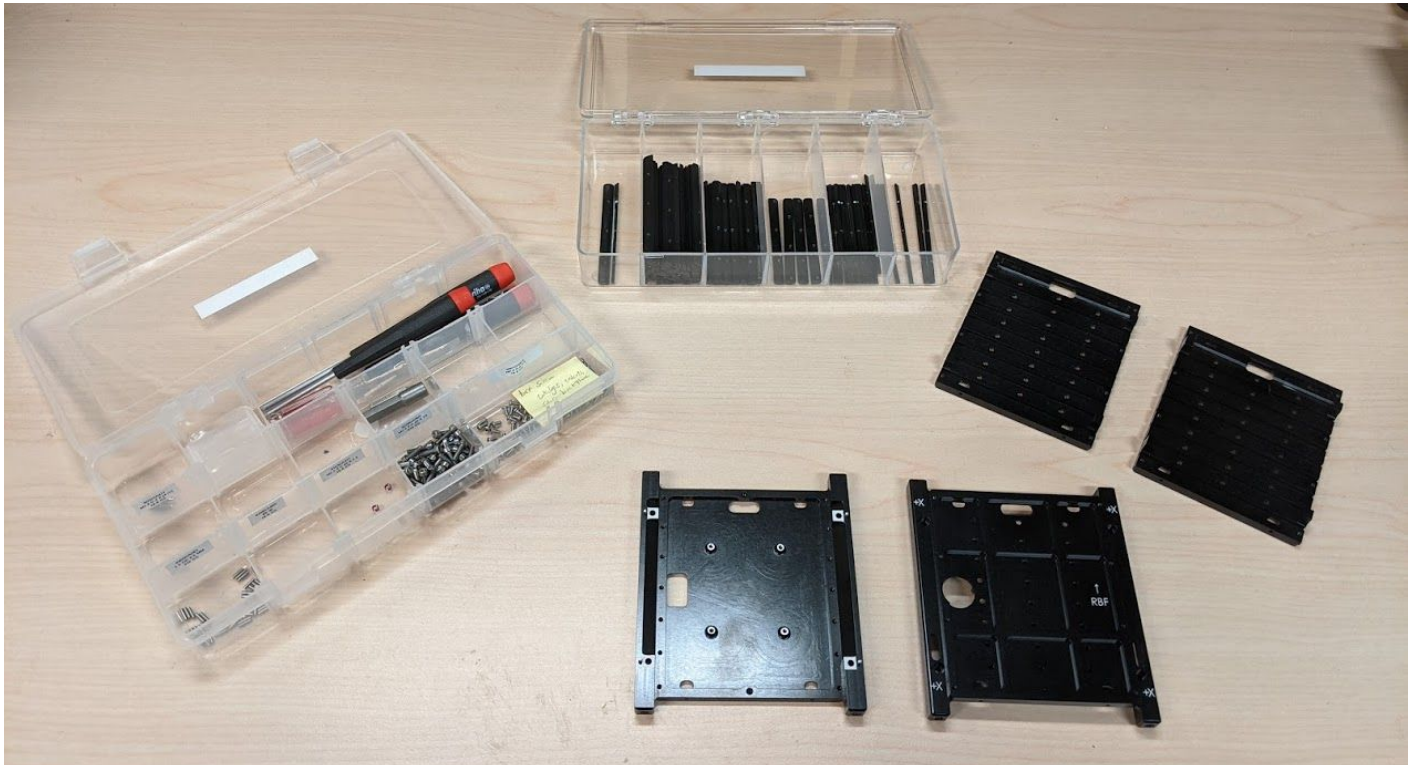
Structure

Structure (1U example)

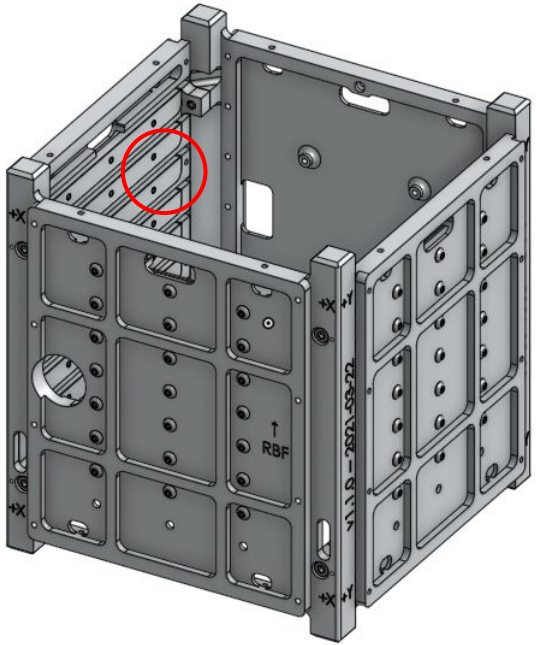


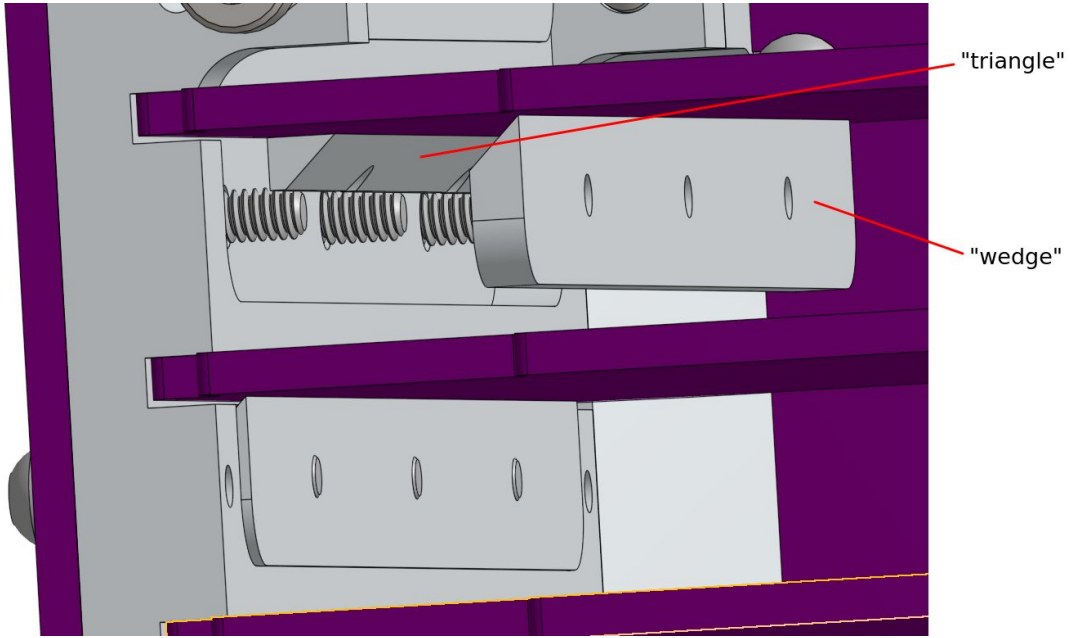


1u Structure “Kit”



Built-in Card Clamps





Frames

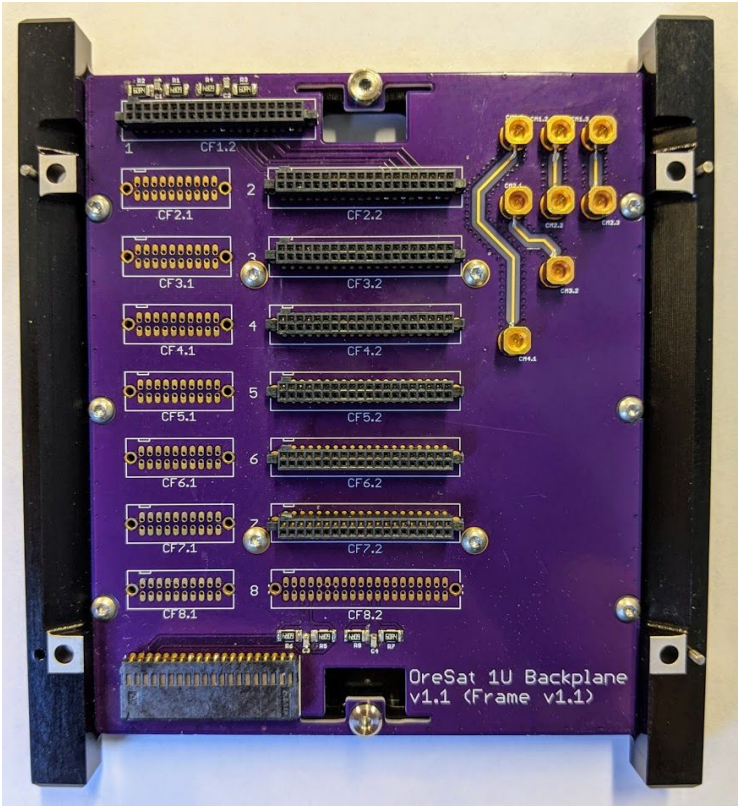
- 6061-T6 Aluminum, Type II anodized (black)
- Machinable by students on a 3 axis mill from 15 mm (½ inch) plate stock
- Decent cost if made commercially
  - 1U: $1,200/ea @ 2 down to $400/ea @ 10
- Standardized on Torx button head SS 18-8 M2 and M2.5 fasteners
- Thermal tuning
  - Type II anodization allows thermal *but not electrical contact* between cards / structure
  - Thermal properties tuned by copper ground plane under clamps
- Electrical grounding
  - Structure is grounded at backplane and frame elements are grounded together
  - Antenna cards are RF grounded to frame using anodization mask + Alodine 1201 coating at card clamp features

(MORE DETAILS IN UPCOMING OSCW TALK!)

The OreSat “Bus”

Backplane

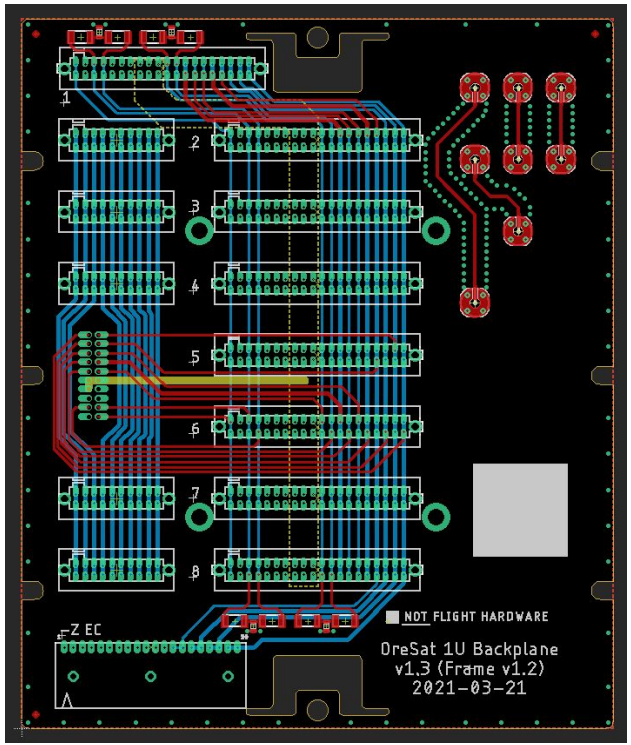
- Main Connector
  - Power: Vbus = 7.2V_{NOM} (direct battery connection)
  - Power control: “OreSat Power Domain”
  - Data: 2x 1Mbps CAN
  - Backup Coms / Bootloading: UART
  - Satellite shutdown
- RF
  - SMPM RF connectors + microstrips
- Auxiliary connector
  - Because everyone wants something different
  - Ethernet between cards, maybe
- Bespoke backplane for each mission!
  - Why not, it’s cheap!



Two kinds of Simple PCBs

- Two layer boards
  - Because: cheap
- Four layer boards
  - Because: density and RF friendly (Isola FR408-HR)

- Why Purple?!
  - **Thank you** OSHPARK Perfect Purple Prompt PCBs

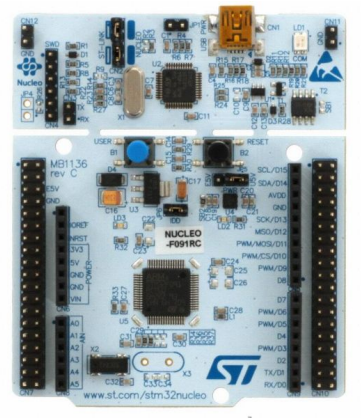


3 Levels of Computing

- Distributed simple computing
  - **Cortex M0** (STMicro STM32F091) running **ChibiOS RTOS** + CANOpen Node
  - Solar modules, battery pack, etc
- Command and control: STM32F439
  - C3 OBC
  - **Cortex M4F** (STMicro STM32F439) running **ChibiOS RTOS** + CANOpen Node
- Mission processors
  - Star tracker, SDR GPS, mission boards
  - **Cortex A8** (Octavo OSD335x-SM) running **Debian Linux**

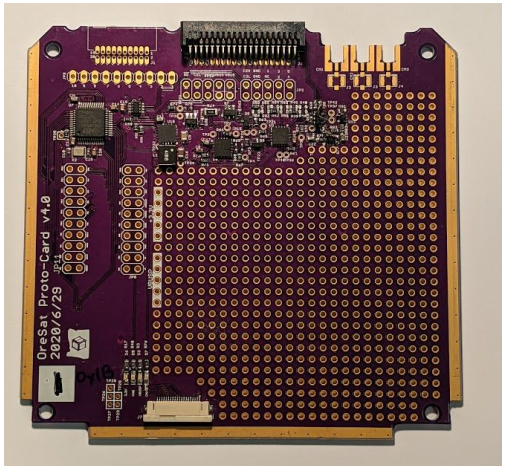
(MORE DETAILS IN UPCOMING OSCW TALK!)

3 Levels of Firmware Development Tools



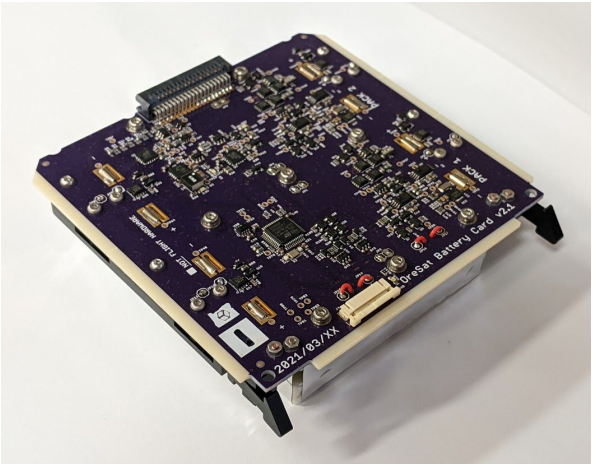
$11 COTS development board

Purchased online, used for firmware onboarding, breadboarding, tool bringup



~$75 OreSat “Protocard”

Hand-built in-house, used for firmware bringup, CAN communication, FlatSat



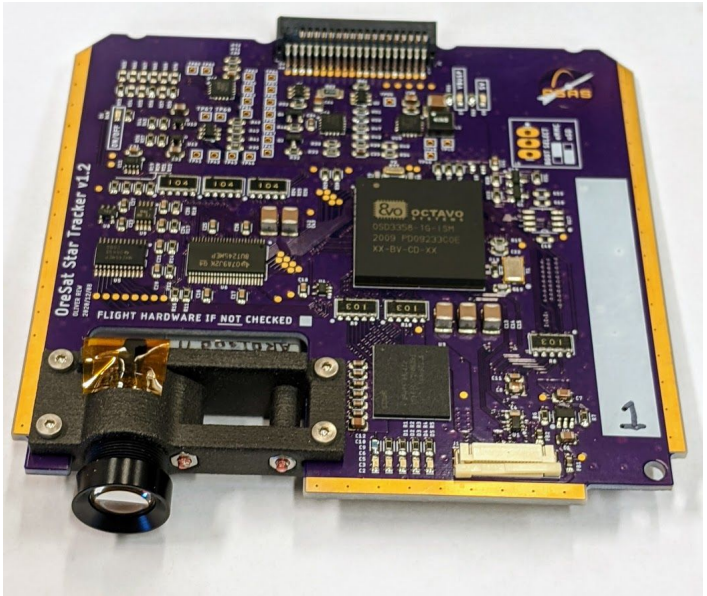
~$350 OreSat Battery Card

Built professionally, used for final development and integration testing

2 Levels of Software Development Tools

$35 COTS development board

Purchased online, used for software onboarding, breadboarding, tool bringup

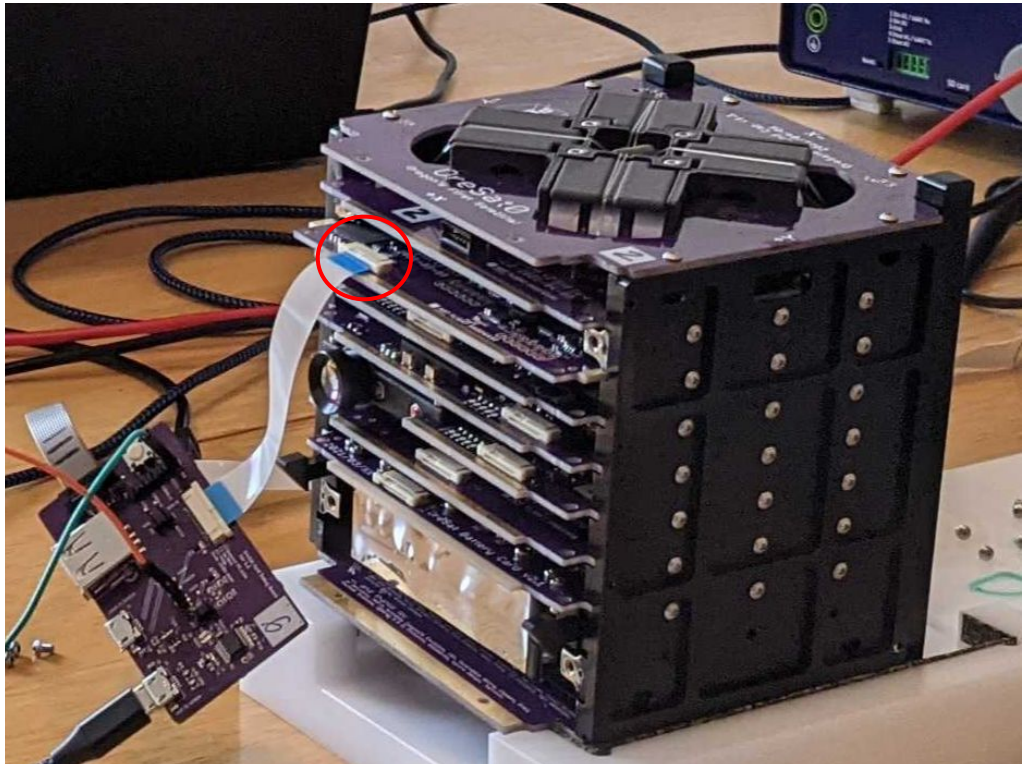


~ $600 OreSat Star Tracker

Built professionally, used for final development and integration testing

Common debugging tools for all processors

- Common FFC debug port
  - JTAG / SWD for programming
  - Serial port
  - Host/Device USB (Octavo only)
- Common debug board
  - Onboard USB to serial adapter
  - USB connectors
- Shared between all cards



1U FlatSat

Battery IMU Star tracker Mission SDR GPS OBC

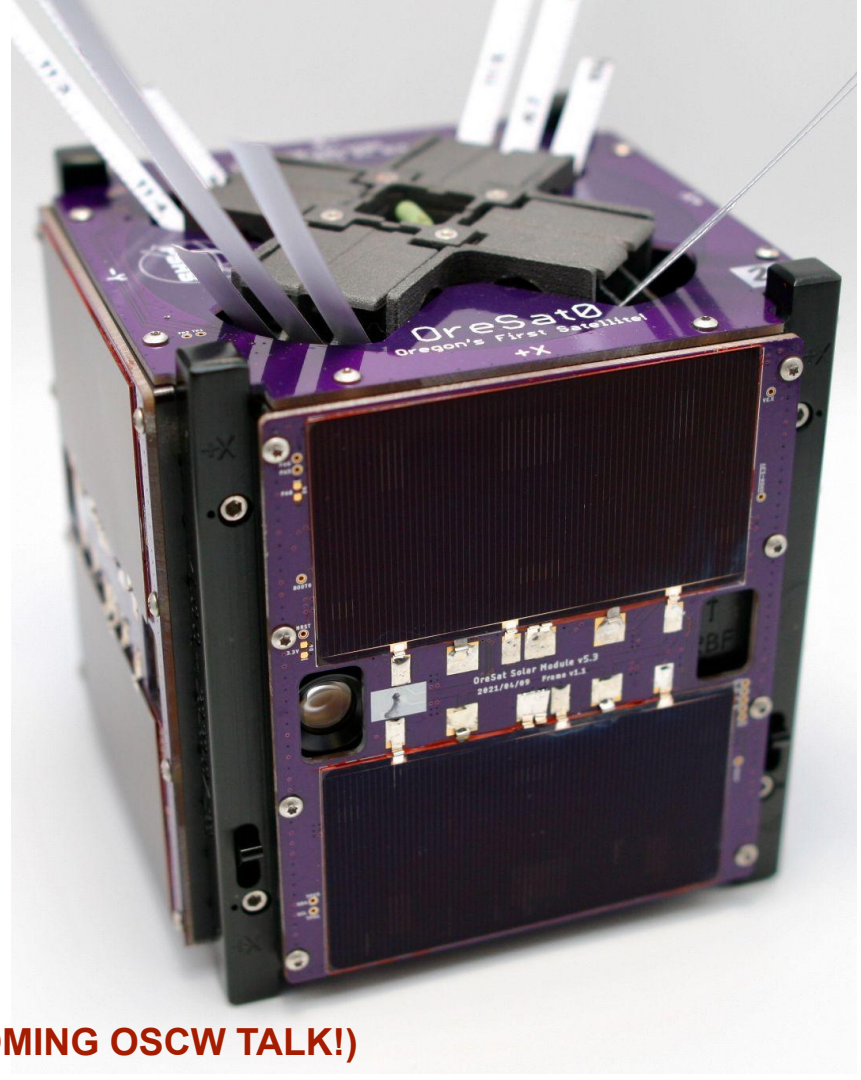
CANopen-based Card Communication

- CANopen implementation
- Each card has CANopenNode + data object descriptions
- Each card subscribes to the data objects it’s interested in

Subsystems

Solar modules

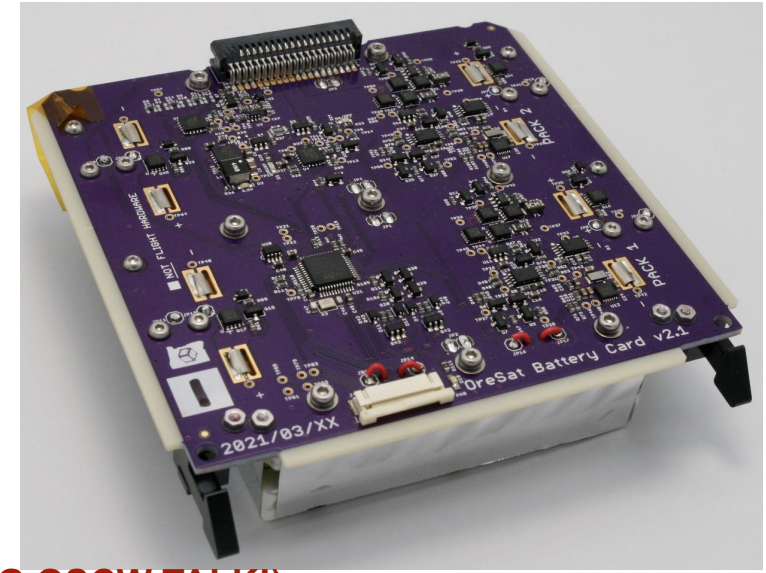
- 1 per X,Y side (4 per U)
- 2 Spectrolab XTE-SF cells
  - 2.34 W_{pk} / module
- True independent MPPT on each module
- Directly thermally connected to the frame



(MORE DETAILS IN UPCOMING OSCW TALK!)

Battery Pack

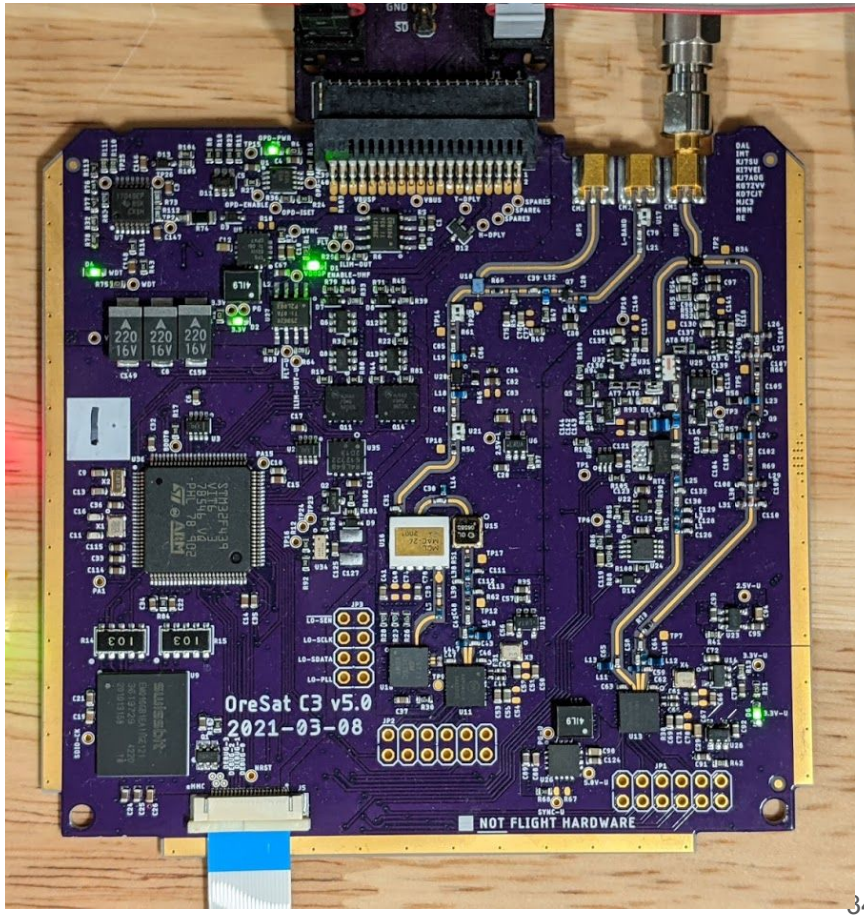
- Two 2S1P Li ion 18650 cell packs on one card (7.2 V @ 5.2 Ah)
- Hardware overcharge, overdischarge, and overcurrent circuits
- Fuel-gage with cell balancing
- Firmware charge / discharge controls
- Inhibit switches (in ±X axis rail face)



(MORE DETAILS IN UPCOMING OSCW TALK!)

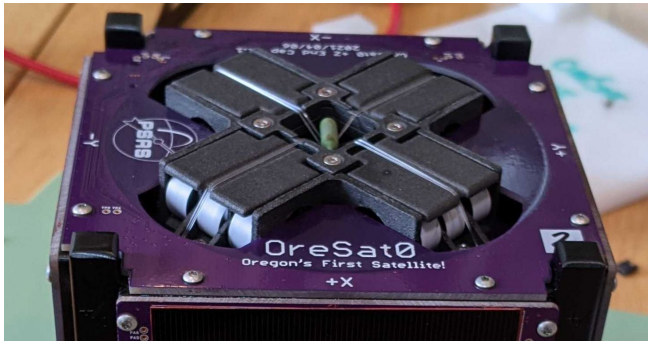
“C3” Onboard Computer

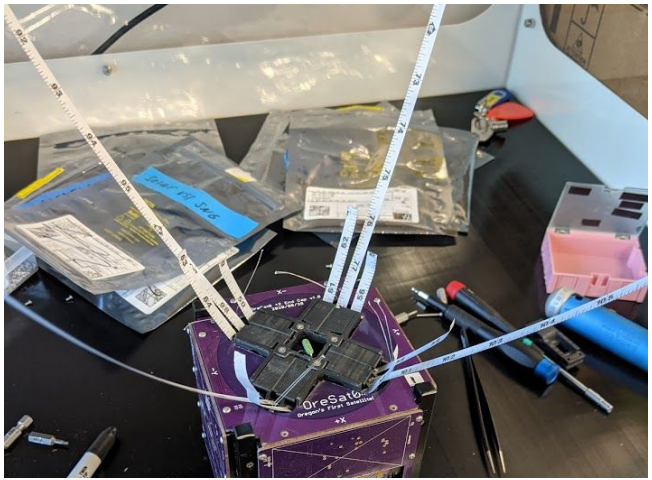
- L band receiver (1.26 GHz)
- UHF transceiver (436 MHz)
- Radiation tolerant watchdog circuit
  Tied to satellite shutdown
- FRAM + RTC state storage
- 16 GB of onboard data storage



Deployable Tri-band 4 Element Turnstile Antenna

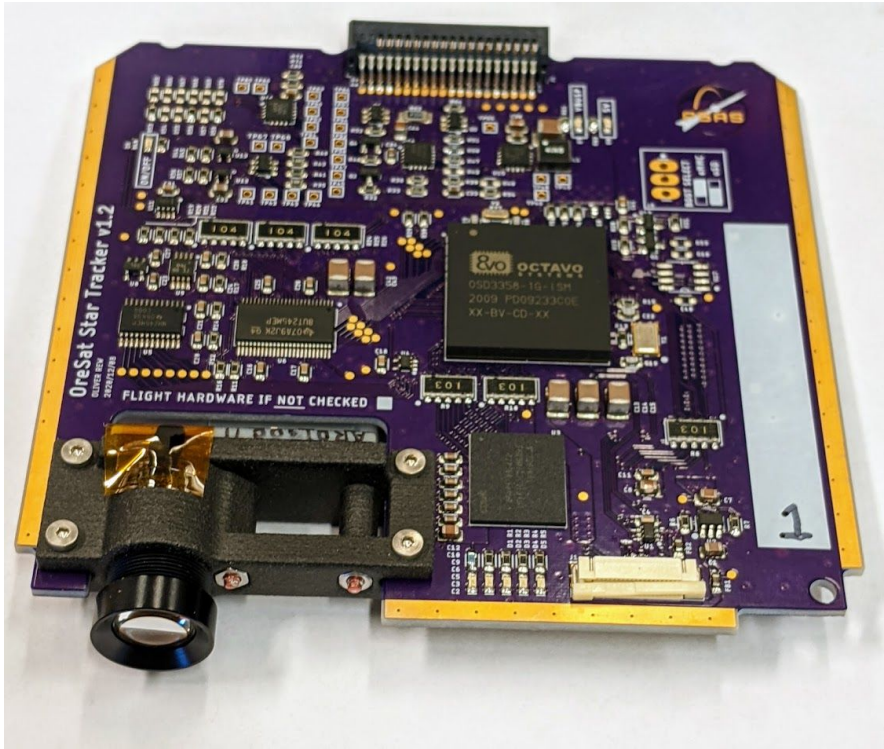
- UHF (436 MHz)
- L band (1.265 GHz)
- L1 band (1.575 GHz)
- Omnidirectional





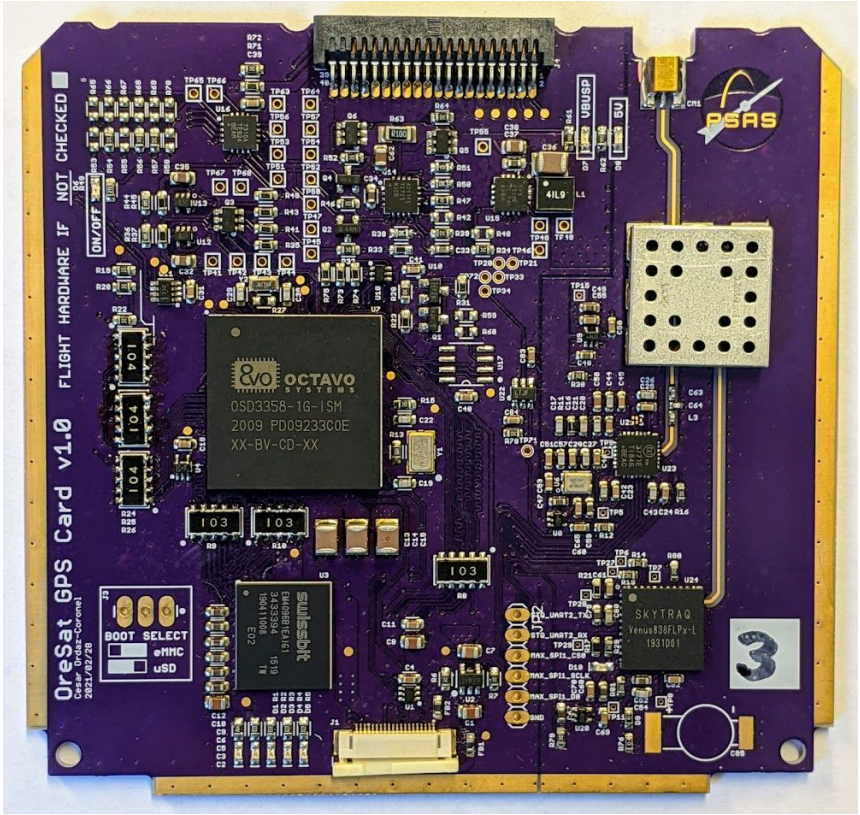
Star Tracker

- Hardware
  - On Semi AR0134 1.2 Mp CMOS sensor
  - Octavo OSD335x-SM (Cortex A8)
- Software
  - Openstartracker - http://openstartracker.org/
  - PRUCAM kernel driver
  - CANOpenNode + Python
  - Debian Bullseye



GPS

- Hardware
  - Skytraq Venus838FLPx COTS receiver
  - Maxim MAX2771 SDR GPS receiver
  - Octavo OSD335x-SM (Cortex A8)
- Software
  - GNSS-SDR - https://gnss-sdr.org/
  - CANOpenNode + Python glue
  - Debian Bullseye



Also need: Ground Station!

University Class Open Ground Station (UniClOGS)

- Worst Name Ever.
- Expensive ($10k each)
- Fully SDR based on the Lime SDR
- Transmission enabled
- 2 m, 70 cm, L- and S-band
- Eventually compatible with SatNOGS?
    - Regulatory concerns, of course!

(MORE DETAILS IN UPCOMING OSCW TALK!)

Missions

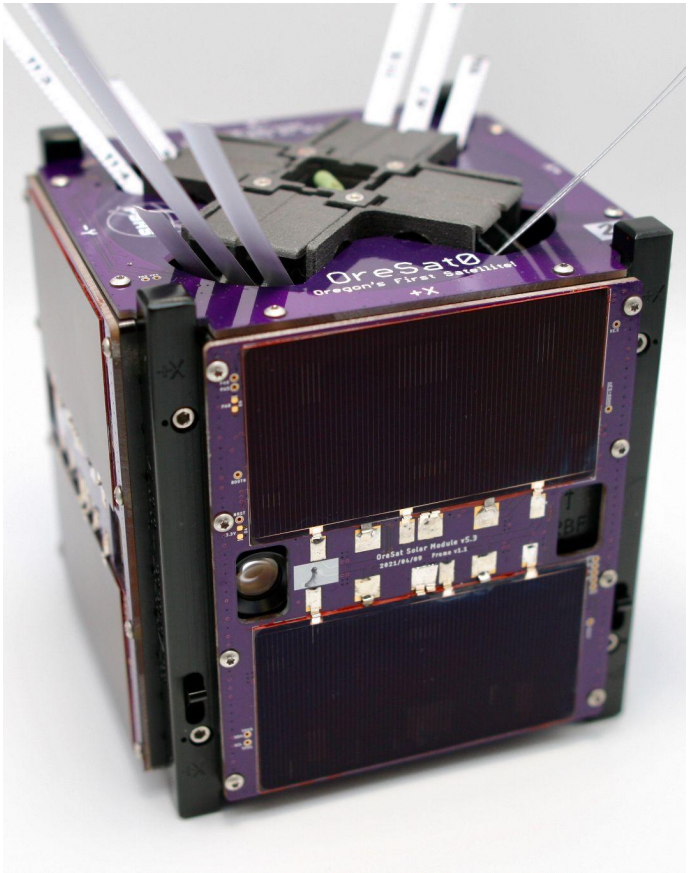
OreSat0, Oregon's first satellite

- Handed off!
- Launch NET January 10th, 2021 on SpaceX Transporter-3

- ***THANK YOU***

SPACEFLIGHT

FOR THE RIDE!

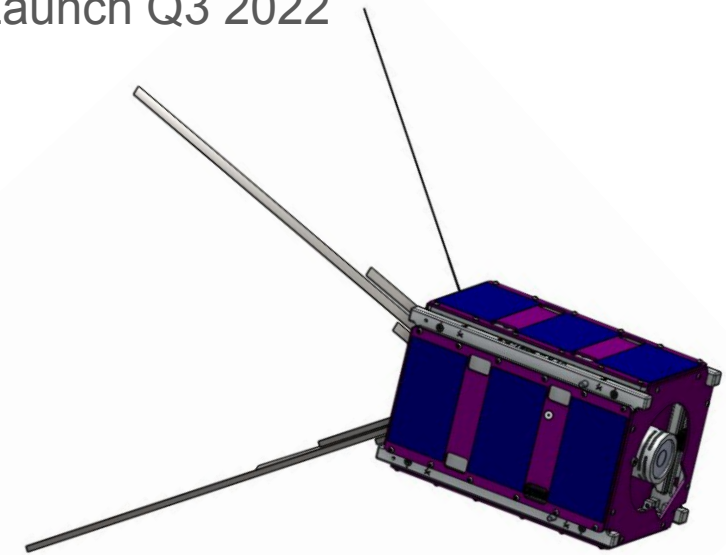


OreSat0 on Spaceflight Sherpa-LTC1 OTV

OreSat0 goes here (ISI deployer)

OreSat0.5

- 1.5U OreSat bus
- Test of the OreSat Attitude Determination and Control System (ADCS)
- Handoff Q2 2022 / Launch Q3 2022



OreSat1 (just “OreSat”)

- 2U OreSat bus
- **2017 NASA CubeSat Launch Initiative (CSLI) program**
- Handoff Q4 2022
- Deploy off International Space Station (ISS) Q1 2023

More Information/Contact

More Information

- A good place to start: https://www.oresat.org/
- Full source at: https://github.com/oresat
- More open source aerospace: https://www.pdxaerospace.org/
- Contact us at aerospace@pdx.edu

Thank you!