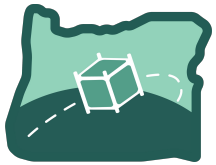


OreSat

OreSat Firmware and Software Architecture

Open Source CubeSat Workshop 2021

Andrew Greenberg, Ryan Medic, Miles Simpson, and many more!

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

Computational Architecture

3 Levels of Computing

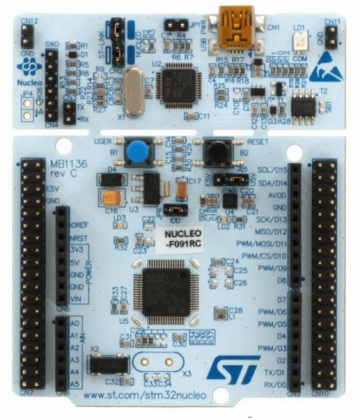
- Distributed simple computing
  - **Cortex M0** (STMicroelectronics STM32F091)
  - ChibiOS RTOS + CANopenNode
  - Subsystems: Solar modules, battery pack, etc.
- Command and control
  - **Cortex M4F** (STMicroelectronics STM32F439)
  - ChibiOS RTOS + CANopenNode
  - Subsystems: C3 on-board computer
- Mission processors
  - **Cortex A8** (Octavo OSD335x-SM)
  - Debian Linux + custom software + CANopenNode
  - Subsystems: Star tracker, SDR GPS, mission boards

So many CANs

- CAN
  - Message-based, prioritized multi-master communication 1 Mbps bus
  - Great for reliability, awkward for large messages (where large > 8 bytes)
- CANopen
  - OSI Layer 3 (Network) - Layer 7 (Application)
  - Used in industrial automation (not a *great* fit for CubeSat, but..)
  - Nodes have “datasheets” that **define** their data and messages
    - Data, parameters, etc. are stored in CANopen structures!
  - Nodes understand each other through sharing datasheets
- CANopenNode
  - Cross-platform C library for CANopen nodes
  - Used on all OreSat CAN nodes, M0 through A8

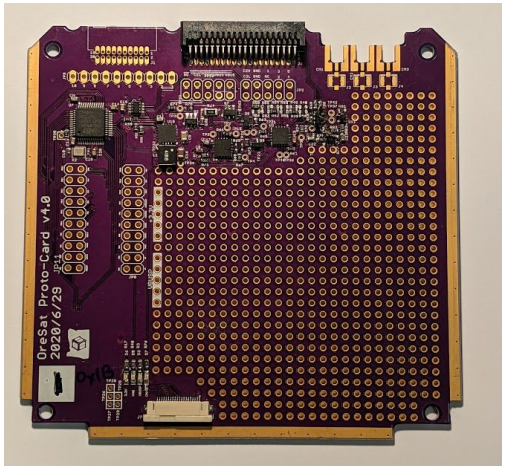
Firmware
(Code running on Cortex M0/M4F boards)

3 Levels of Firmware Development Tools



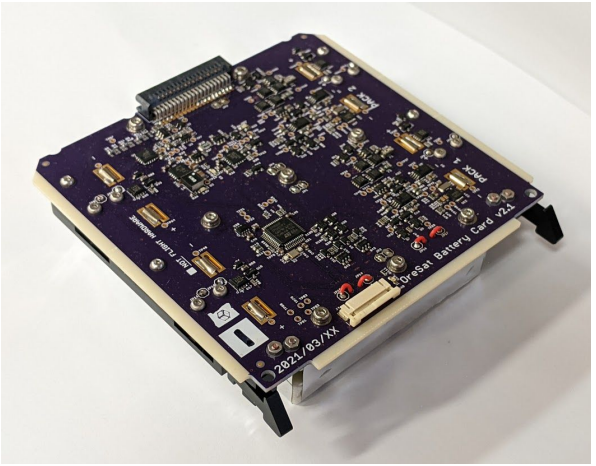
$11 COTS development board

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

The usual firmware build shenanigans

- gcc (arm-none-eabi-gcc 10.2.1) + openocd (0.11.0-rc2)
- Single OreSat firmware repo - https://github.com/oresat/oresat-firmware
  - M4F (C3 OBC) code
  - M0 (Solar, battery, etc) code
  - Shared ChibiOS drivers
  - ChibiOS/NIL RTOS submodule - https://www.chibios.org/
  - CANopenNode submodule - https://github.com/CANopenNode/
  - Littlefs - https://github.com/littlefs-project (M4F only)

“OTA” Firmware updates

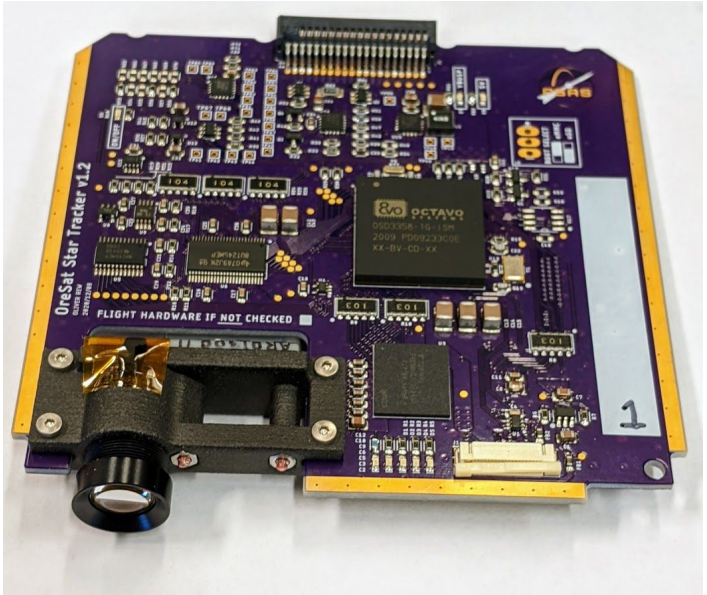
- M4F (C3 OBC)
  - Receives file over L band or UHF uplink
  - Stored on eMMC
  - Updates firmware image from file
  - Future: Dual bank allows for “backup” firmware image if new version fails
- M0
  - Software CAN bootloader in the M0s (triggers on reboot)
  - Future: M4F functionality to feed M0 the firmware update

Software
(Code running on Cortex A8 boards)

2 Levels of Software Development Tools

$35 COTS development board

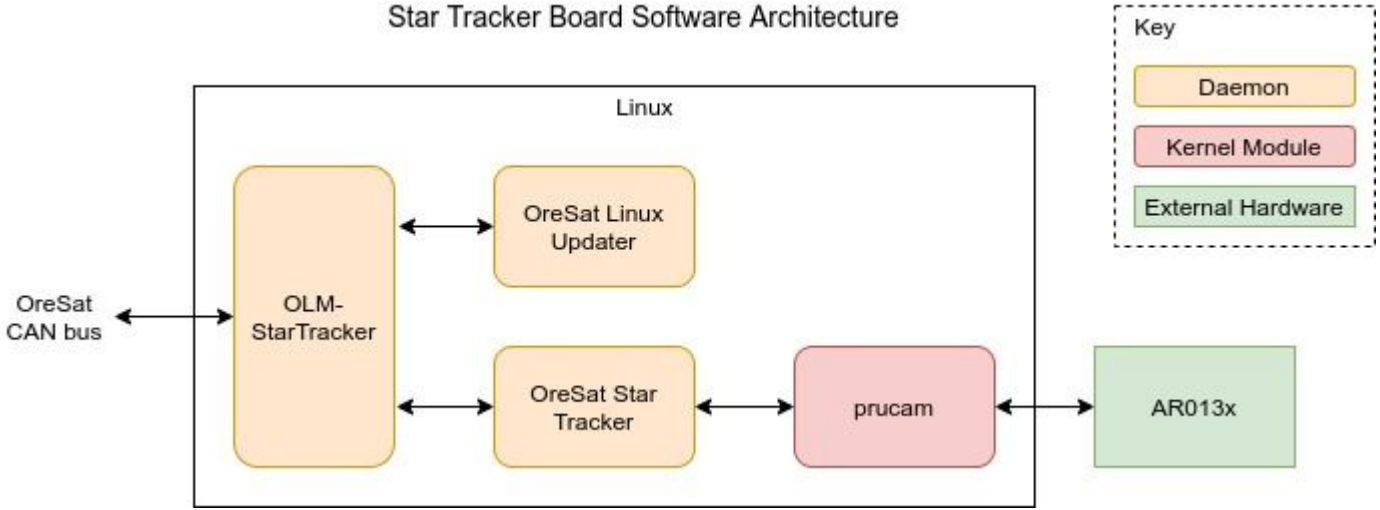
Used for software onboarding, breadboarding, tool bringup, build server



~ $600 OreSat Star Tracker

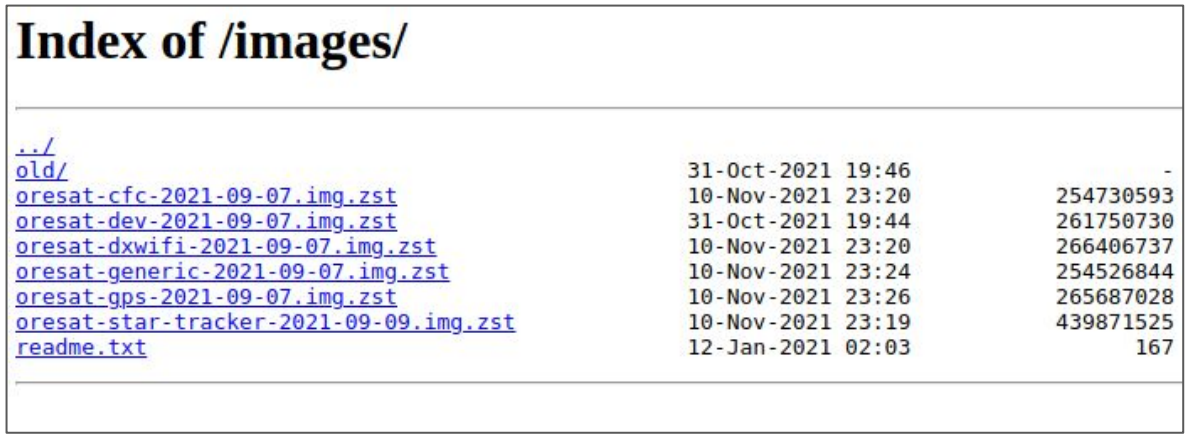
Built professionally, used for final development and integration testing

Example Linux Board: Star Tracker



OreSat Linux

- We build our own Linux images
  - BeagleBoard PocketBeagle build server running BeagleBoard's image-builder
  - https://oresat-linux.readthedocs.io/
  - https://github.com/oresat/oresat-linux
- Burned onto the Octavo's eMMC (has a back up microSD card)

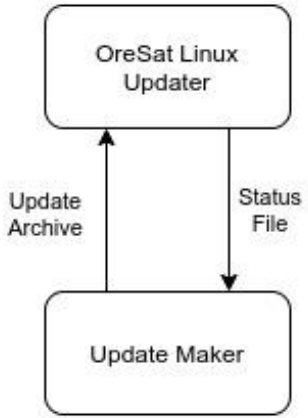


Index of /images/

../		
old/	31-Oct-2021 19:46	-
oresat-cfc-2021-09-07.img.zst	10-Nov-2021 23:20	254730593
oresat-dev-2021-09-07.img.zst	31-Oct-2021 19:44	261750730
oresat-dxwifi-2021-09-07.img.zst	10-Nov-2021 23:20	266406737
oresat-generic-2021-09-07.img.zst	10-Nov-2021 23:24	254526844
oresat-gps-2021-09-07.img.zst	10-Nov-2021 23:26	265687028
oresat-star-tracker-2021-09-09.img.zst	10-Nov-2021 23:19	439871525
readme.txt	12-Jan-2021 02:03	167

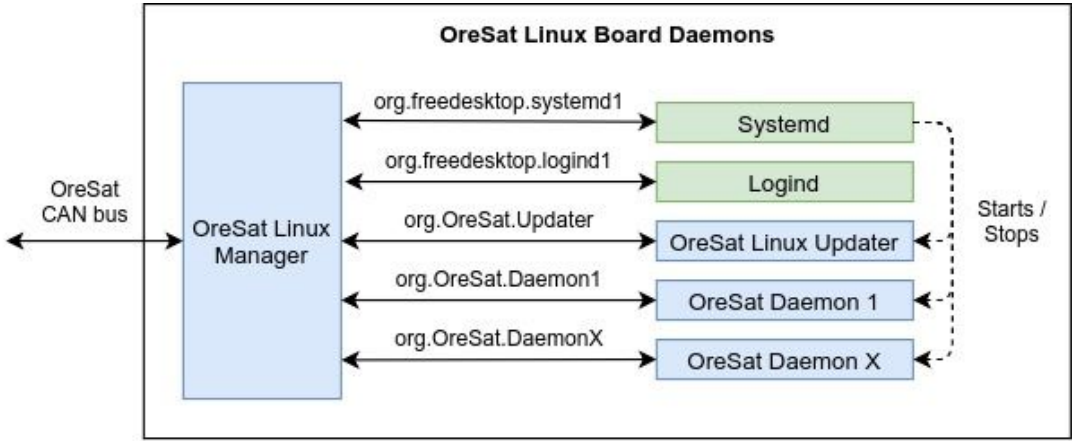
OreSat Linux Updater

- Files:
  - Update Archive: A tar file that contains .deb file and bash scripts
  - Status File: Text file with list of all installed packages and pending updates
- Update Maker (“Ground segment”)
  - Python-based CLI
  - Generates board specific update archives using status files
- OreSat Linux Updater (“Space segment”)
  - Python-based daemon
  - Updates board with update archives
  - Caches update archives until told to update
  - Generates board status files



OreSat Linux Manager

- C-based daemon
- Frontend to the board over CAN bus
- Interfaces with systemd to start/stop backend daemons
- Handles data flow between the CAN bus and backend daemons
- Collects system info: e.g. ram usage, eMMC usage, etc



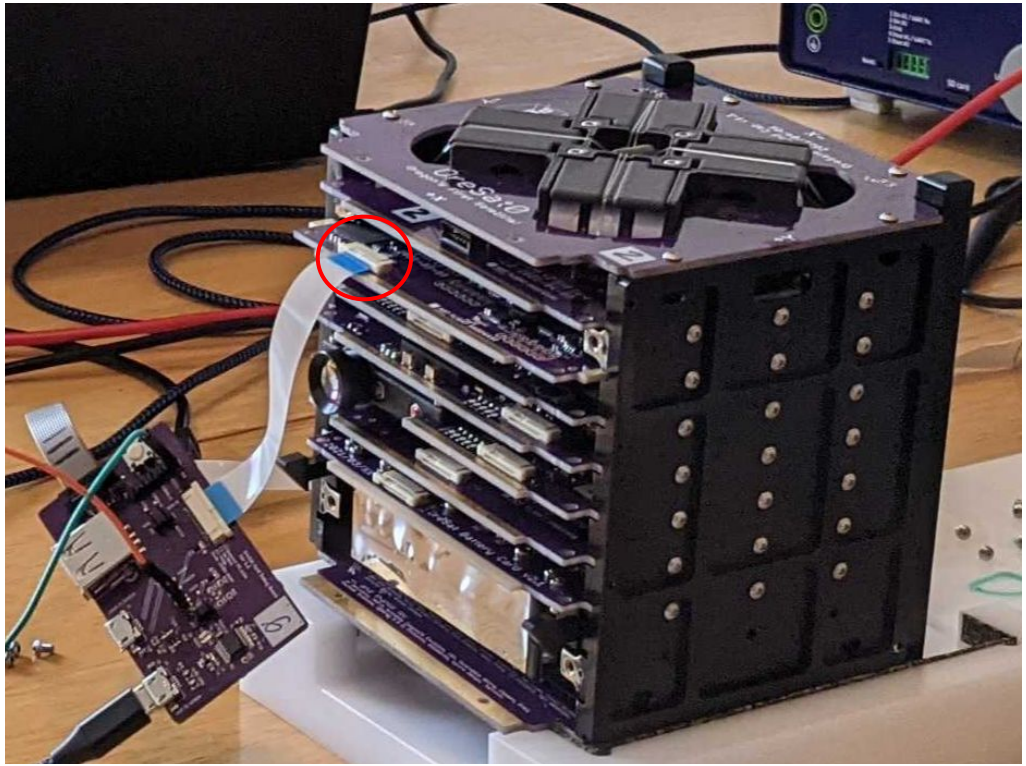
“PRUcam” Kernel Driver

- “Programmable real-time unit”
  - 200 MHz, single instruction per clock, deterministic execution peripheral
  - Two built into the Octavo’s TI AM335x Cortex A8 processor
- Used to interface to:
  - On semi AR0134 camera’s 14 bit sensor bus
  - Princeton IR’s PIRT1280A1-12 SWIR camera “CameraLink” interface
  - Maxim MAX2771 GPS SDR in 4 bit parallel interface

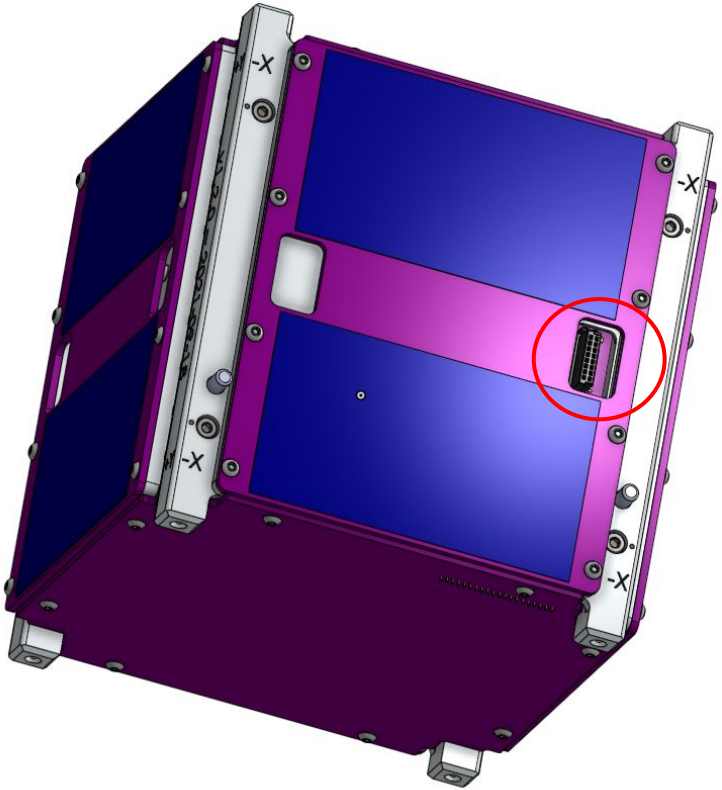
Development, Integration and Testing

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



External Debug Port



- C3 (OBC) serial port
- CAN
- Vbus
- Shutdown

1U FlatSat

Battery IMU Star tracker Mission SDR GPS OBC

CANopen-monitor

- Simple ncurses-based display of CANopen messages
  - NMT
  - PDOs
  - SDOs
- Decodes message contents in real-time based on
  - CANopen Electronic Data Sheet (EDS)
  - CANopen Device configuration file (DCF)
- https://github.com/oresat/CANopen-monitor

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!