
PROVES Electronics

Unlocking Space with
Modularity and Affordability

*Amanda Ewing and Nicole
Maggard*

*Senior Engineering Students in
Bronco Space at Cal Poly
Pomona*



Agenda



- PROVES
- Challenges
- Background
- Yearling
- Xmera (Chimera)
- Subsystems
- Impact

PROVES:

Pleades

Rapid

Orbital

Verification

Experimental

System

Rapid

Verification

Experimental

Challenges

- Space is really hard
 - We failed twice before success
- Space is expensive
 - Intention is to get it right the first time
 - BroncoSat-1 cost about \$48k in just components
- Stop reinventing the wheel
 - Offer up a standard
- Difficult to scale designs up
 - Make design expandable

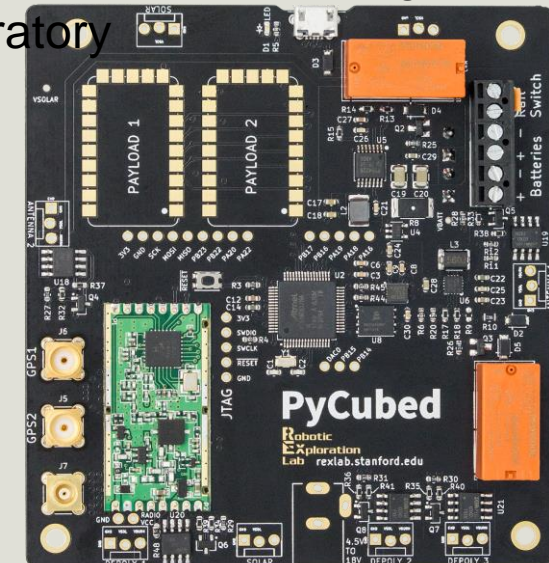


Background

- Two architecture paths
 - PC/104 mounting hole pattern
 - Artemis CubeSat Kit
 - PyCubed
 - Backplane
- Which one to use?
 - Yearling satellites used PC/104
 - Xmera satellite will use backplane



Credit: Hawaii Space Flight Laboratory



Credit: Max Holliday, REX Lab, Stanford

Yearling

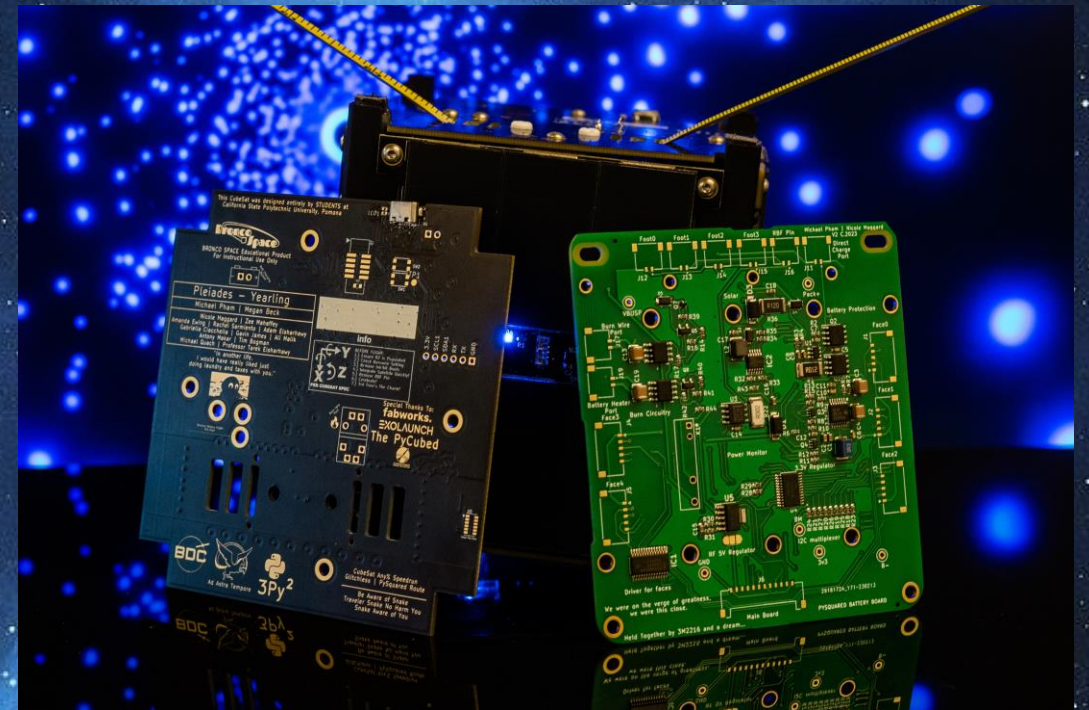
Used PC/104-mounting hole pattern

Yearling-1
used the
PyCubed

- Launched January 3rd, 2023
- Failed to deploy

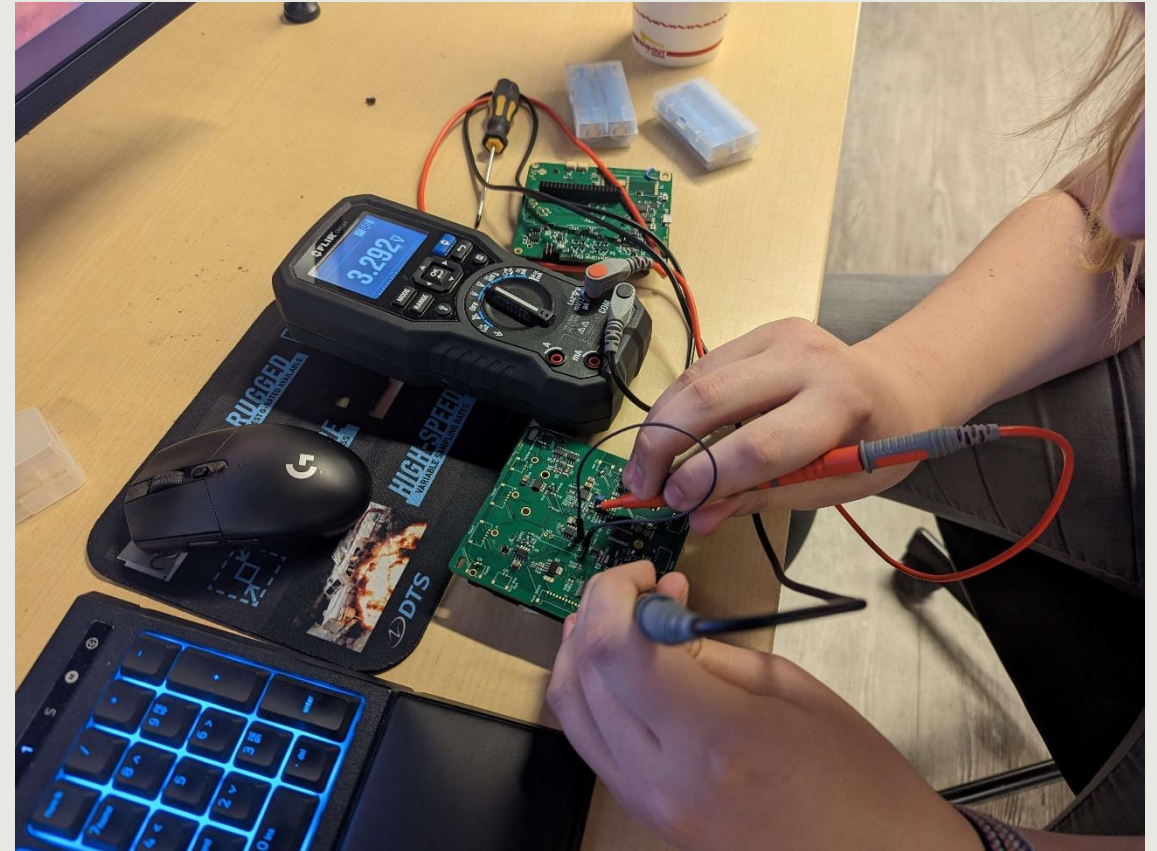
Yearling-2
used the
3PySquared

- Launched April 14th, 2023
- First received packet April 15th, 2023



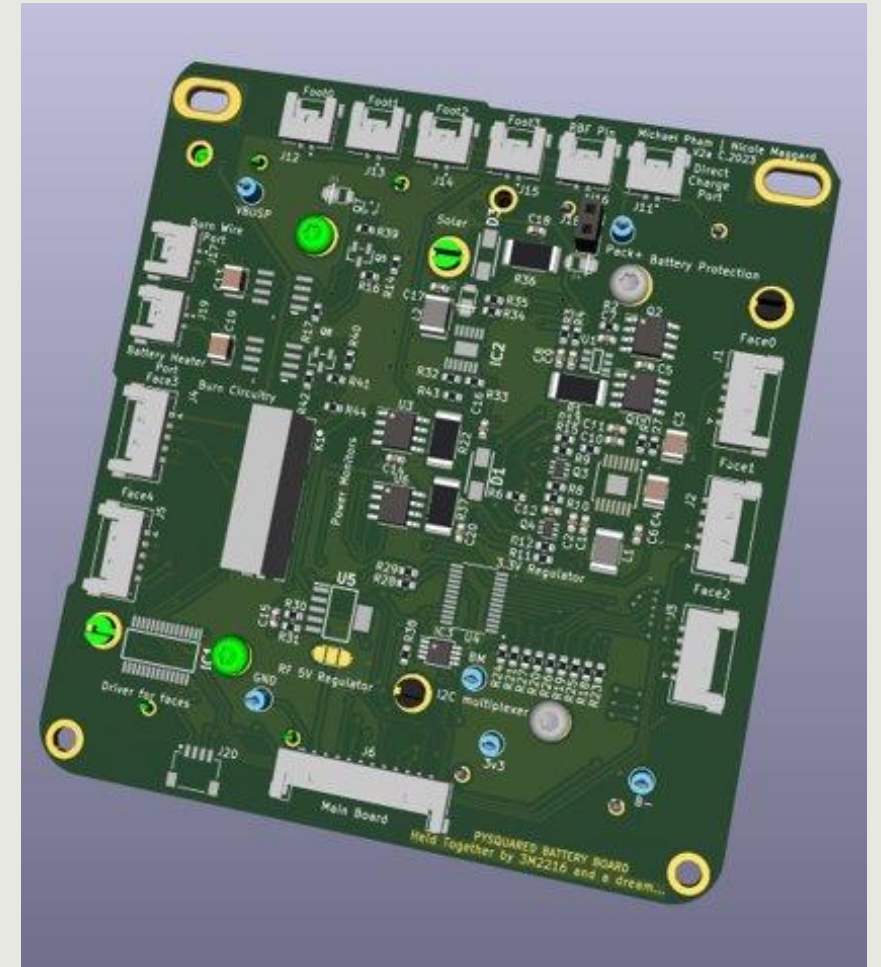
Design Drivers

- expensive
- Use of off-the-shelf components
- Increase accessibility
- Fast Design Turnaround
 - Internal organization goals
 - Readily available hardware
- Open Source
 - Access software and hardware designs
 - End user can easily adjust standards to their needs
 - Tutorials in the pipeline



PC/104 Key Features

- Held in place by brackets or standoffs
- Can connect cards with stackable connectors or cables
- Boards can function independently of each other
- Not limited to backplane connections
 - Physical Spacing
 - Electrical interface
- Can densely stack electronics



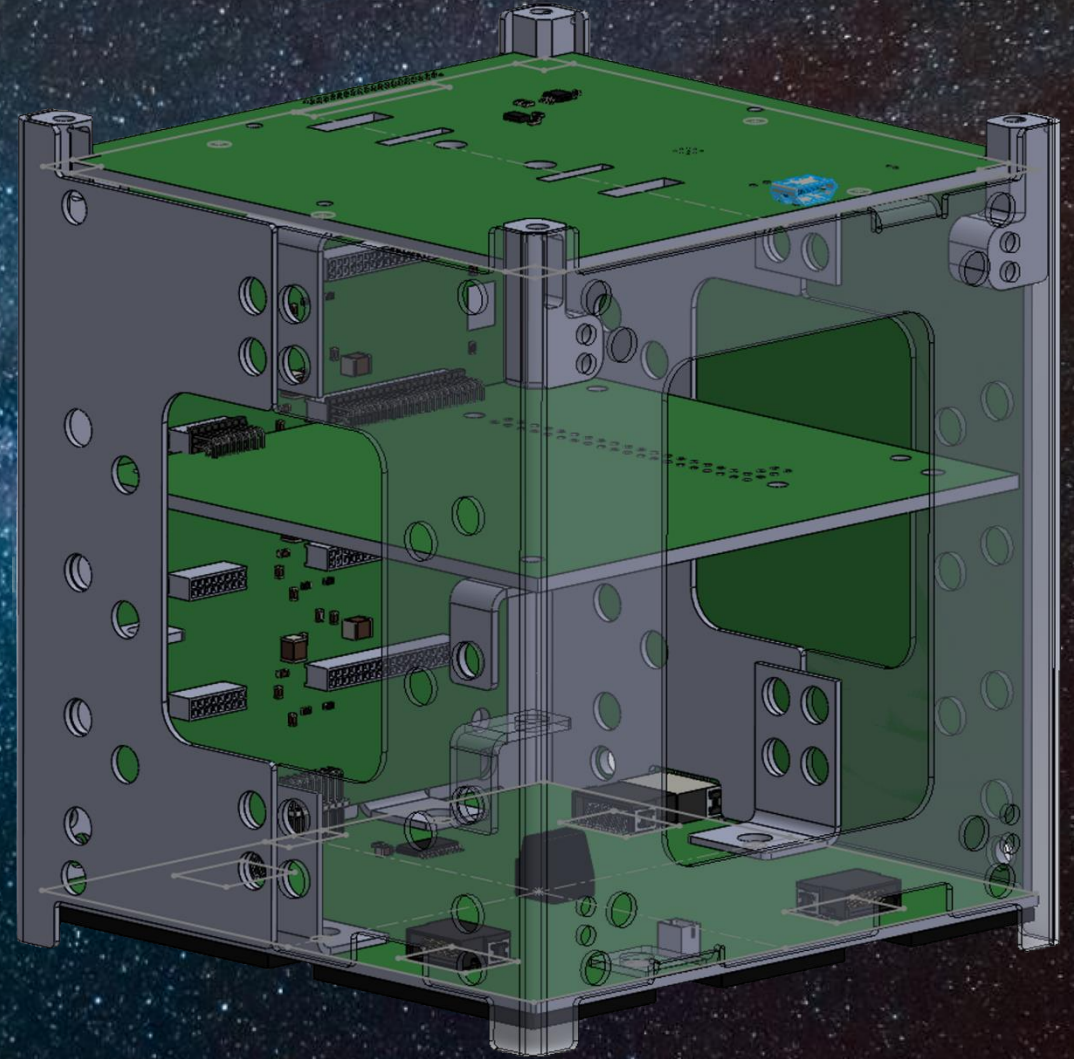
Xmera

Implements backplane architecture

Uses similar components as Yearling

Work-in-progress

Has potential to be expanded



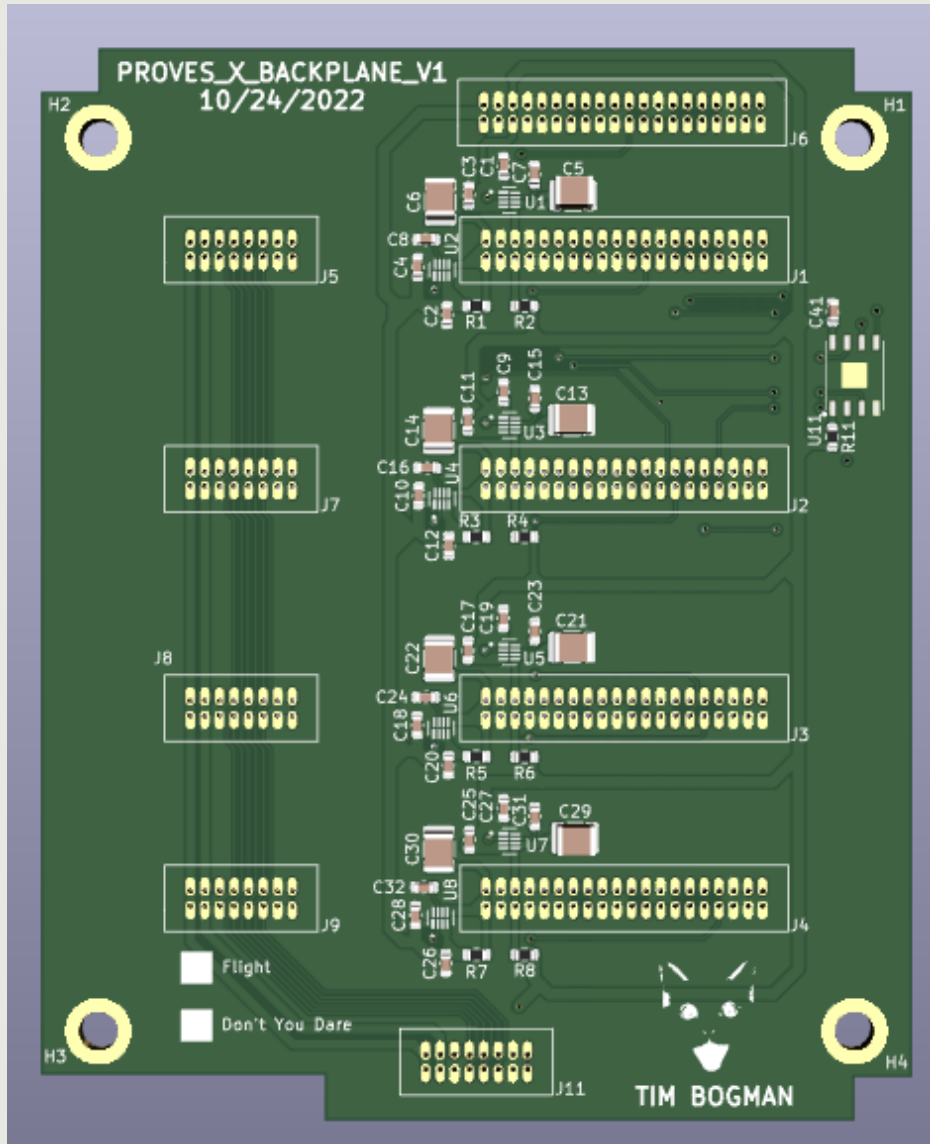
Design

Drivers

Affordable & Open-Source

- Cards slot directly with backplane
 - Minimal cabling
 - Easier access to internal cards
 - Easier to troubleshoot
 - Adds structural support
- Scalability
- Modular Subsystems
 - Easily customizable





Backplane

Key Features

- Cards held in place by brackets and electrical interface
- Standardized spacing
 - Larger cards skip slots
- Mix and Match cards for mission needs
 - Ex: Multiple EPS cards can be easily stacked for additional power budget
 - Ex: Extra flight computer for redundancy
- Backplane expandable for larger satellites
- No wiring
- Possible standardized interface connector

Subsystems

Command and Data Handling (C&DH)

Attitude Determination Control System (ADCS)

Electrical Power System (EPS)

Solar

Software

Payload

Command and Data Handling

Similarities:

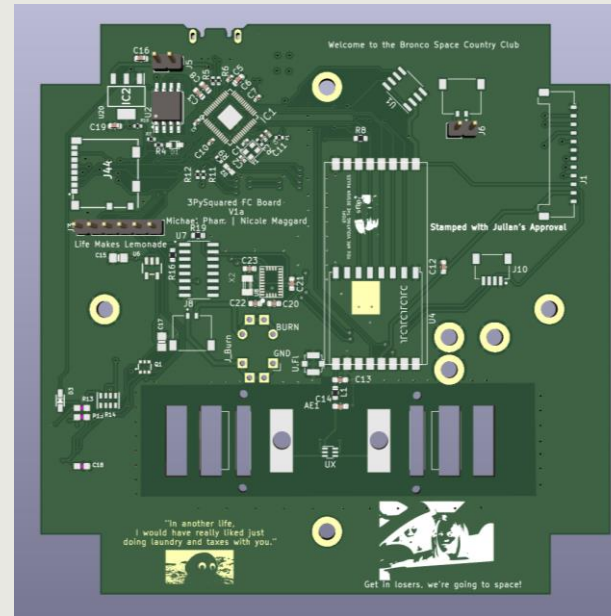
- Utilizes a HopeRF RFM9x module
 - LoRa modulation
 - 430MHz range
- Utilizes an RP2040
 - Flight heritage
 - Extremely inexpensive

PC/104:

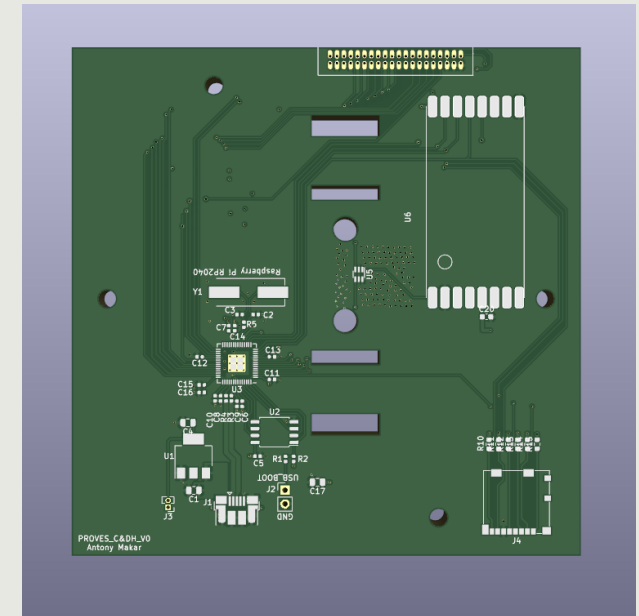
- Integrated attitude control

Backplane:

- Designed as top cap but could be slotted internally



From Yearling-2
(PC/104)



From Xmera (BP)

Attitude Determination Control System

Similarities:

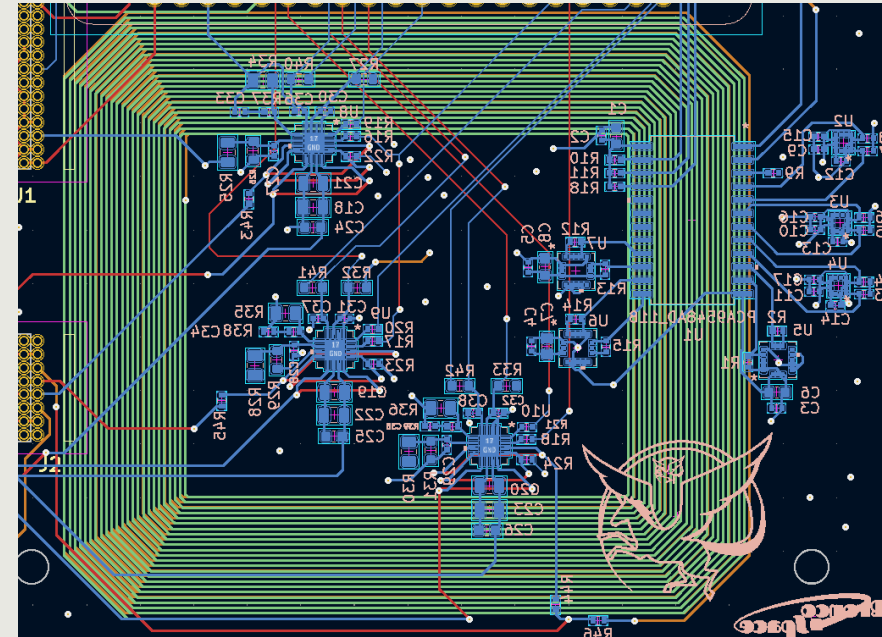
- Contains accelerometers, gyroscopes, and magnetometers

PC/104:

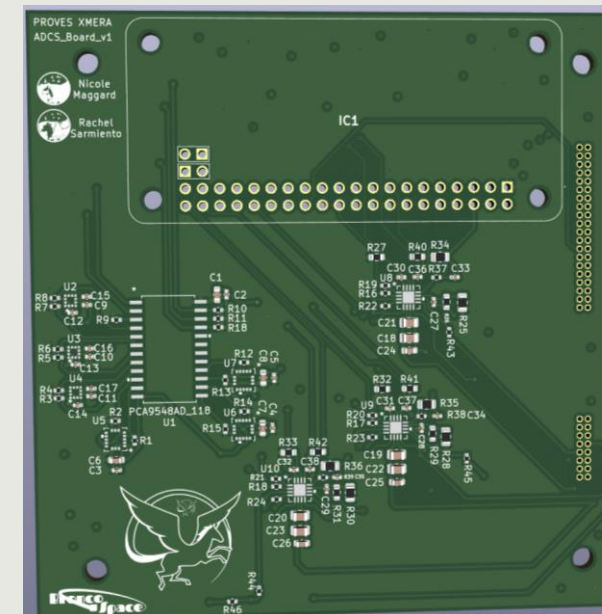
- Integrated on Command and Data Handling board

Backplane:

- 40 pin breakout
 - Could interface with Raspberry Pi zero
 - Could interface with custom compute module
- Embedded magnetorquer coil
- Contains motor drivers
 - Interfaces with magnetorquer coils, reaction wheels, or other attitude control device through the Backplane



Both From Xmera (BP)



Electrical Power System

Similarities:

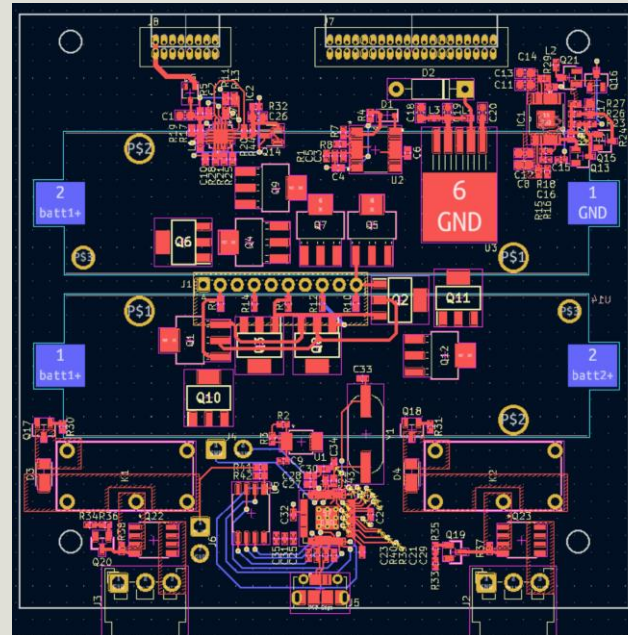
- Utilizes LT3652 to charge batteries from solar power
- Maintains all controls for battery heater
- Contains inputs for inhibit switches

PC/104:

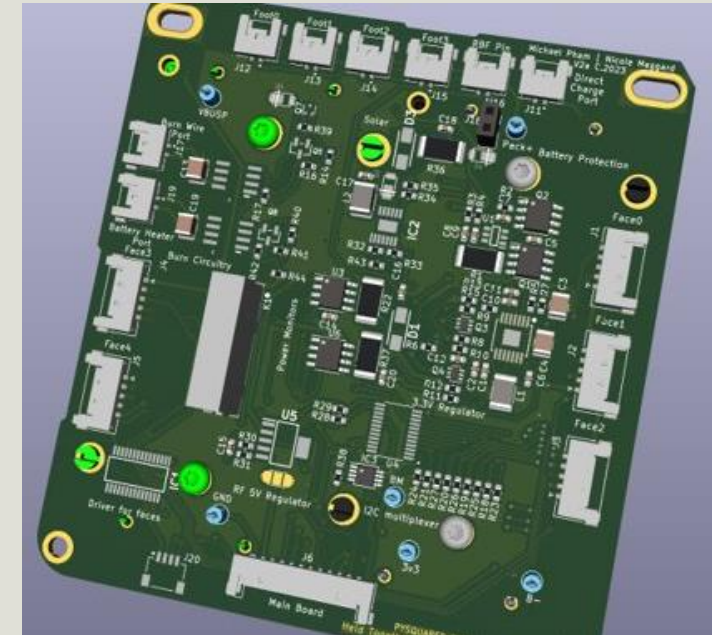
- Cabled directly to C&DH board, solar boards and switches individually

Backplane:

- Utilize an RP2040 to track power consumption, and make power-based decisions for the satellite



From Xmera (BP)



From Yearling-2
(PC/104)

Solar

Similarities:

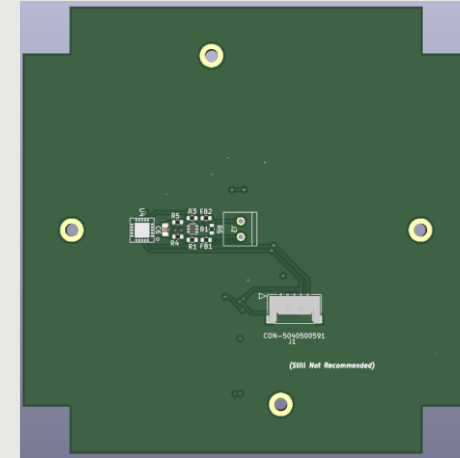
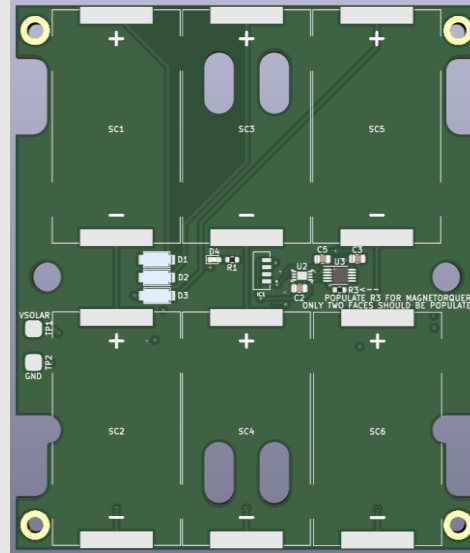
- Off-the-shelf components and sensors
- Embedded magnetorquer coil

PC/104:

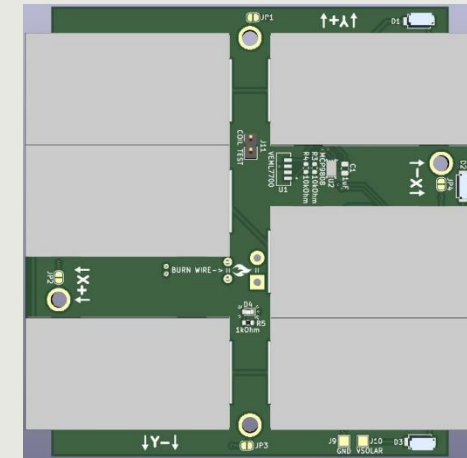
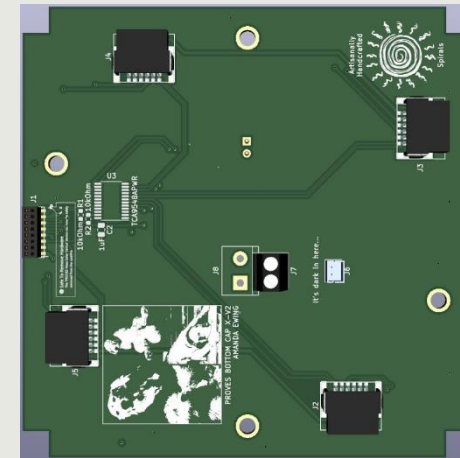
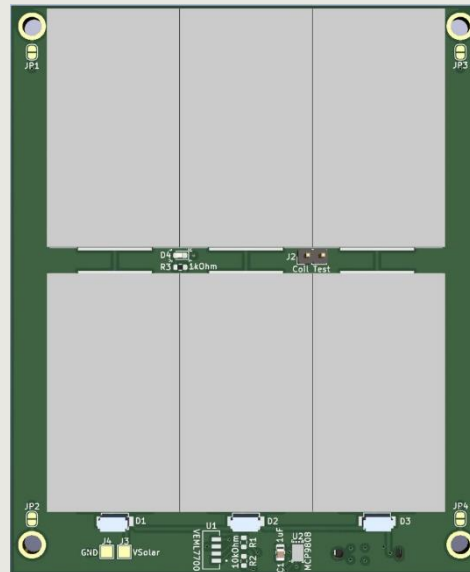
- Each face cabled to Battery Board
- Integrated motor drivers

Backplane:

- Fully modular subsystem with single backplane interface



From Yearling-2
(PC/104)



From Xmera (BP)

Flight Software



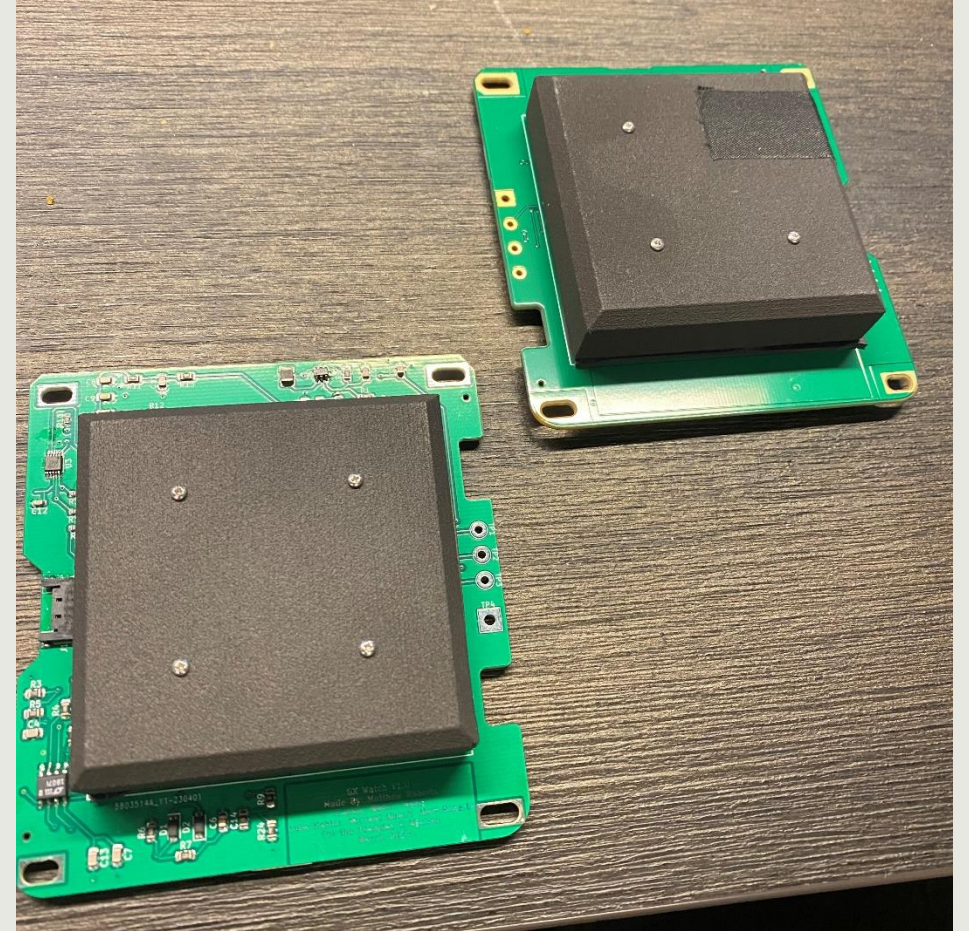
- Utilizes CircuitPython
- Beginner Friendly
- Maintained by Adafruit
- Teaches Object Oriented Programming
- Easy to debug

```
[MAIN]Looking to send face data...
[Functions]Sending Face Data
[Field]Sending face 1/6: [20.875, 45.9648]
[Field]Sending packet 1/006:
[Field]Listening for transmissions, 10
[Field]packet received
[Field]msg: True, RSSI: -6
[Field]Sending face 2/6: [21.3125, 49.248]
[Field]Sending packet 2/006:
[Field]Listening for transmissions, 10
[Field]packet received
[Field]msg: True, RSSI: 3
[Field]Sending face 3/6: [21.25, 28.512]
[Field]Sending packet 3/006:
[Field]Listening for transmissions, 10
[Field]packet received
[Field]msg: True, RSSI: 4
[Field]Sending face 4/6: [21.1875, 97.1712]
[Field]Sending packet 4/006:
[Field]Listening for transmissions, 10
[Field]packet received
[Field]msg: True, RSSI: 4
[Field]Sending face 5/6: [20.875, 81.504, (21.25, 0.0, 0.0)]
[Field]Sending packet 5/006:
[Field]Listening for transmissions, 10
[Field]packet received
[Field]msg: True, RSSI: 3
[Field]Started to manage battery
[Field]BATTERY Temp: 30 C
[Field]MICROCONTROLLER Temp: 19.1801 C
[Field]Turning heatpad on
[Field]draw current: 4.81798mA, and battery voltage: 7.19382V
[Field]system voltage: 6.99405V
[TA]Creating Face Objects...
[TA]Done!
[TA][ACTIVE][Temperature Sensor]
```

```
[CDH]Getting Battery Data...
[MAIN]normal
[BIG_DATA]Creating Face Objects...
[BIG_DATA]Done!
[BIG_DATA][ERROR][Face0 Initialization]function takes 2 positional arguments but 3 were given
[BIG_DATA][ERROR][Face1 Initialization]function takes 2 positional arguments but 3 were given
[BIG_DATA][ERROR][Face2 Initialization]function takes 2 positional arguments but 3 were given
[BIG_DATA][ERROR][Face3 Initialization]function takes 2 positional arguments but 3 were given
[BIG_DATA][ERROR][Face4 Initialization]function takes 2 positional arguments but 3 were given
[BIG_DATA][ERROR][Face5 Initialization]function takes 2 positional arguments but 3 were given
[BIG_DATA]Faces Initialized
[BIG_DATA]Creating Face List
[BIG_DATA]All Face test error:function takes 2 positional arguments but 3 were given
[FUNCTIONS]['Face4': False, 'Face5': False, 'MDT': False, 'Neopixel': True, 'Face0': False, 'Face1':
lse]
[FUNCTIONS]['PM:normal', 'VB:0.0', 'IC:0.0', 'TB:20', 'MT:31.3517']
[CDH]Getting Battery Data...
[MAIN]normal
[MAIN]Looking to send face data...
[CDH]Getting Battery Data...
[MAIN]normal
[MAIN]Getting face data...
[BIG_DATA]Creating Face Objects...
[BIG_DATA]Done!
[BIG_DATA][ERROR][Face0 Initialization]function takes 2 positional arguments but 3 were given
[BIG_DATA][ERROR][Face1 Initialization]function takes 2 positional arguments but 3 were given
[BIG_DATA][ERROR][Face2 Initialization]function takes 2 positional arguments but 3 were given
[BIG_DATA][ERROR][Face3 Initialization]function takes 2 positional arguments but 3 were given
[BIG_DATA][ERROR][Face4 Initialization]function takes 2 positional arguments but 3 were given
[BIG_DATA][ERROR][Face5 Initialization]function takes 2 positional arguments but 3 were given
[BIG_DATA]Faces Initialized
[BIG_DATA]Creating Face List
[BIG_DATA]All Face test error:function takes 2 positional arguments but 3 were given
[MAIN][
```

Payload

- Unlimited Variations
- Unlimited Expansion
- Unlimited Extrapolation
- Limited only by Creativity



Cosmic Watch

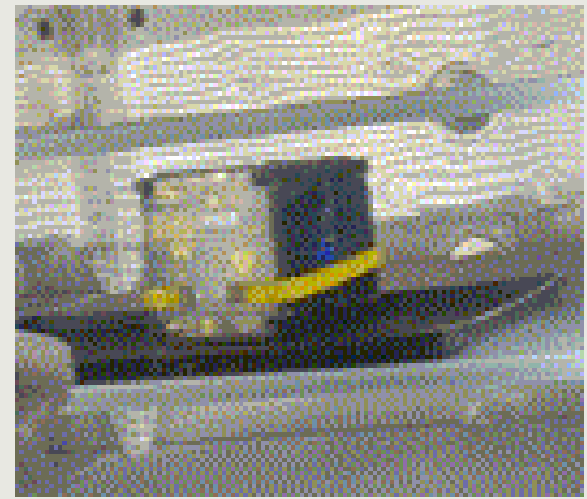
Impact

- Great educational tool
- Opportunity for industry progress
- Space for All
 - Be inspired
 - Take the leap
 - Do cool science



Bronco Space and Stanford Student Space Initiative Teams together after AOS

```
012345678
....KN6NA
Q Hello I
  am Yearl
ing! I am
  in: maxi
mum power
  mode. V_
Batt = 8.
02806V. I
HBPFJASTM
NE! KN6NA
Q
```



Thank You For Listening!
Any Questions?



Nicole Maggard: crmaggard@cpp.edu

Amanda Ewing: anewing@cpp.edu
