

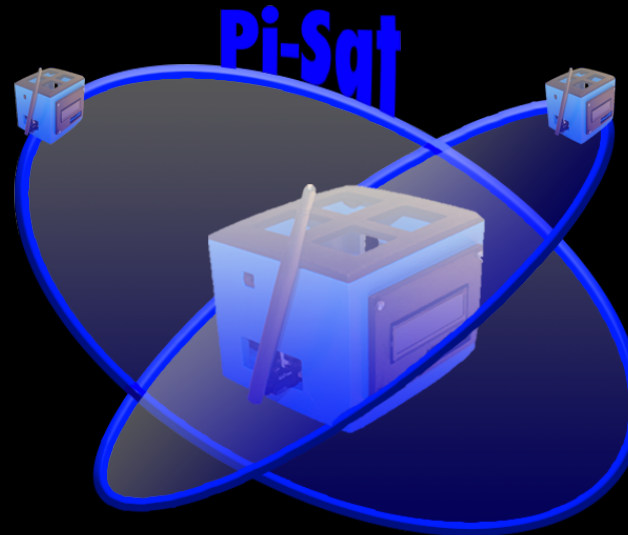
National Aeronautics and Space Administration

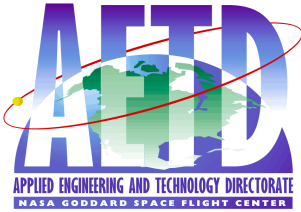


# Pi-Sat:

## A Low Cost Small Satellite and Distributed Mission Test Platform

Alan Cudmore  
Code 582





# Outline



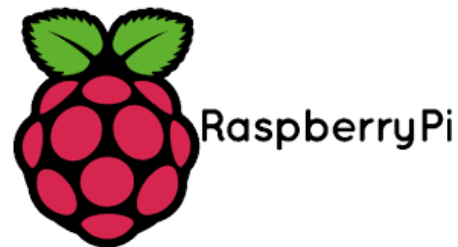
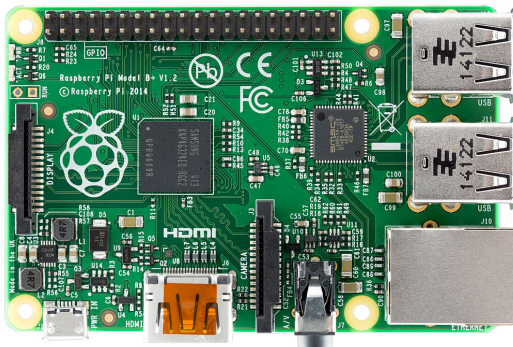
- Introduction:
  - What is the Pi-Sat?
  - Why Pi? Introduction to the Raspberry Pi
  - The sum is greater than the parts
  - Don't forget the Software.. The core Flight System
- Designs:
  - Pi-Sat Cube
  - Pi-Sat Wireless Node
  - Pumpkin Pi Card
- Applications:
  - Smallsat/Cubesat Prototype
  - Distributed Mission Ted Bed
  - Flight Software Training/Education
- Team
- Future Plans

# Introduction: What is the Pi-Sat?

- The Pi-Sat is a (**very!**) low cost platform for:
  - Prototyping Smallsat and Cubesat flight software
  - Research and development of Distributed Spacecraft Mission concepts
  - Flight software training and educational outreach
- The Pi-Sat combines:
  - A credit-card sized ARM processor (Raspberry Pi)
  - A suite of low cost sensors
  - A 3D printed enclosure and battery
  - NASA GSFCs core Flight System flight software architecture
- Funded by FY14 and FY15 IRADs

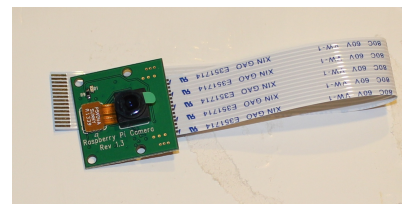
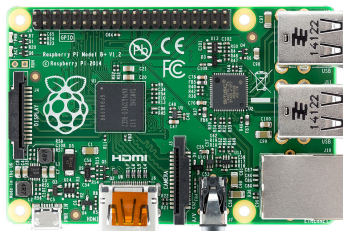
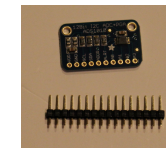
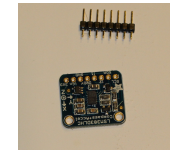
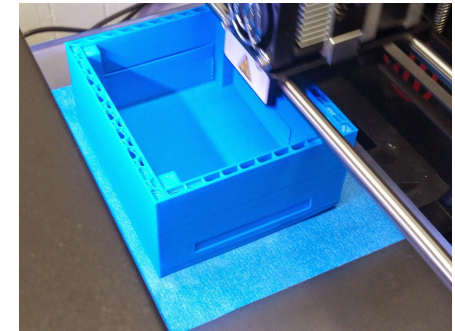
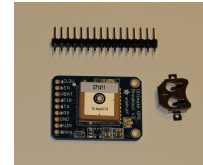


- The Pi-Sat is based on the \$35 **Raspberry Pi** single board computer
- Created by the Raspberry Pi Foundation in the UK
- Over 5 million have been sold to educators and hobbyists throughout the world
- Fits in with the “Maker” ecosystem of low cost, easy to use electronics
- The Raspberry Pi runs the Linux operating system, so it can run a wide variety of software, including GSFC Code 582s Core Flight System flight software architecture

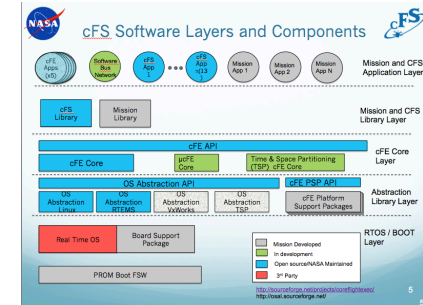


# Introduction: The sum is greater than the parts

- The Pi-Sat is completed with:
  - A 3D Printed Enclosure – Designed and built by interns
  - An array of inexpensive sensors
    - GPS
    - Magnetometer-Compass/Accelerometer
    - High Definition Camera
    - A-to-D converter
    - Real Time clock
  - An SD card for program and data storage
  - Wi-Fi for network communication
  - Xbee Wireless for Peer-to-Peer mesh networking
  - An LCD or Touch Screen display
  - Custom Pi-Sat software
- **All for around \$325**

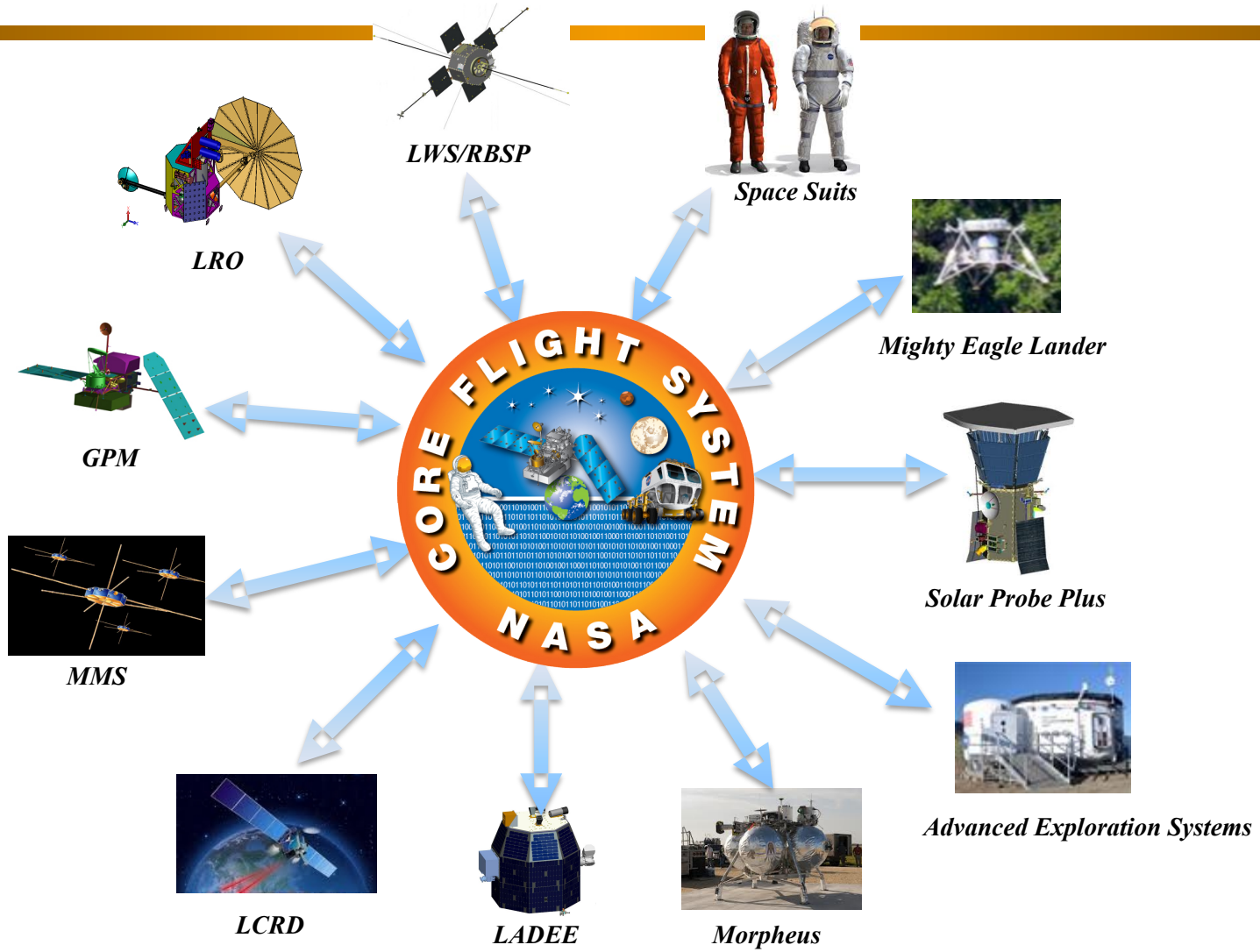


## Introduction: Don't forget the Software.. The core Flight System



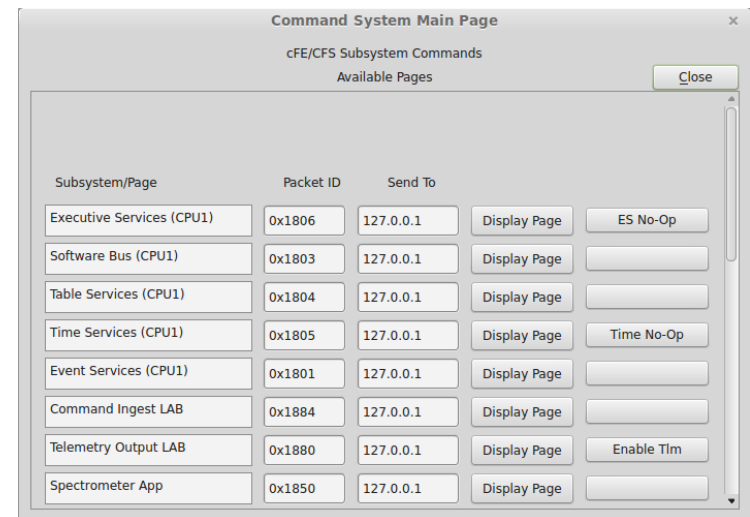
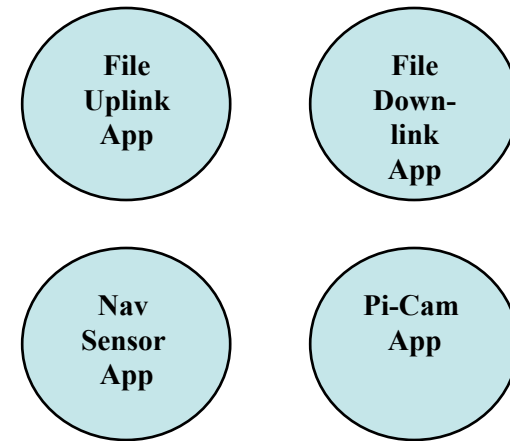
- The Pi-Sat Flight Software is NASA GSFCs **core Flight System** or **cFS**.
  - The cFS is a re-usable spacecraft flight software architecture and software suite that is both platform and project independent
  - The cFS is used on a number of missions throughout NASA (GPM, MMS, etc)
  - Although usually deployed on a real time operating system (RTOS) such as vxWorks, the cFS runs on Linux, and very well on the Pi.
  - The Pi is powerful enough to not only run the cFS, but it can serve as a development system and mini ground system!
  - More info: <http://cfs.gsfc.nasa.gov>
- The core Flight System is Open Source, so it is available to anyone to use on a Raspberry Pi based system

# Introduction: cFS use at NASA



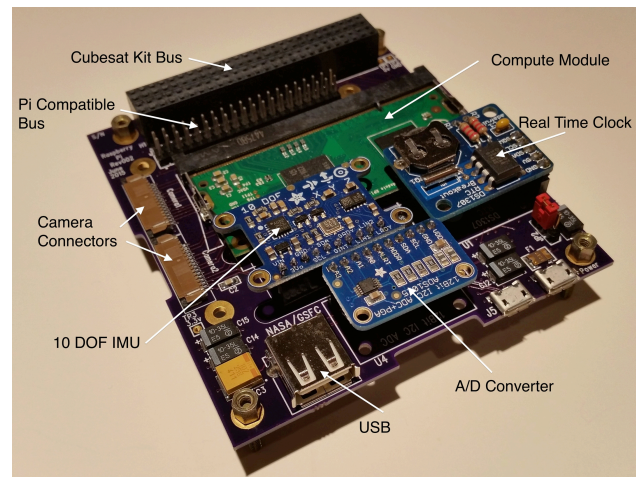
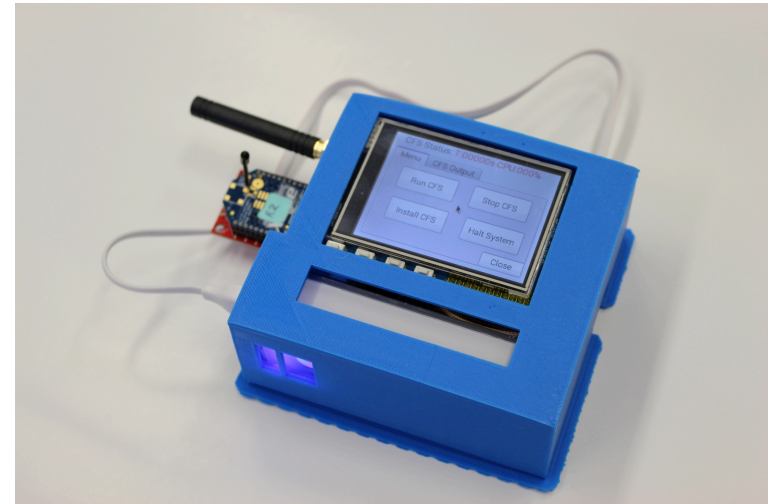
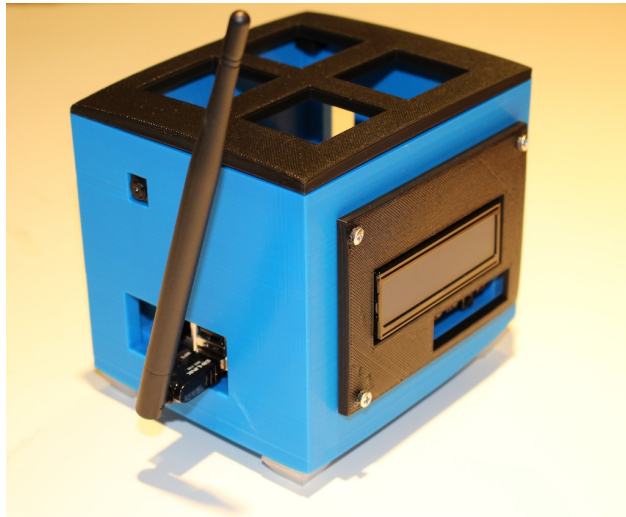
# Introduction: Don't forget the Software.. Custom Pi-Sat Software

- In addition to the cFS, the following Custom Pi-Sat software was developed
  - cFS Applications
    - File Uplink cFS App
    - File Downlink cFS App
    - Nav Sensor cFS App
    - Pi-Cam cFS App
  - Custom Pi-Sat LCD and Touchscreen Menu Systems
  - Startup/Shutdown Scripts
  - Python/QT4 and ZeroMQ based simple ground system ( Runs on the Raspberry PI )



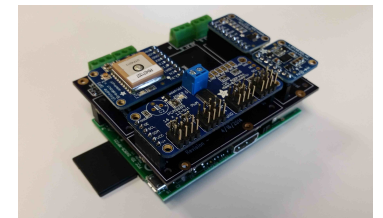
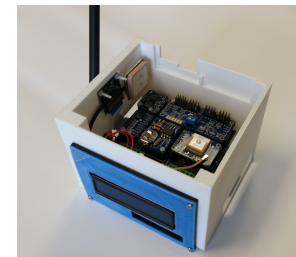
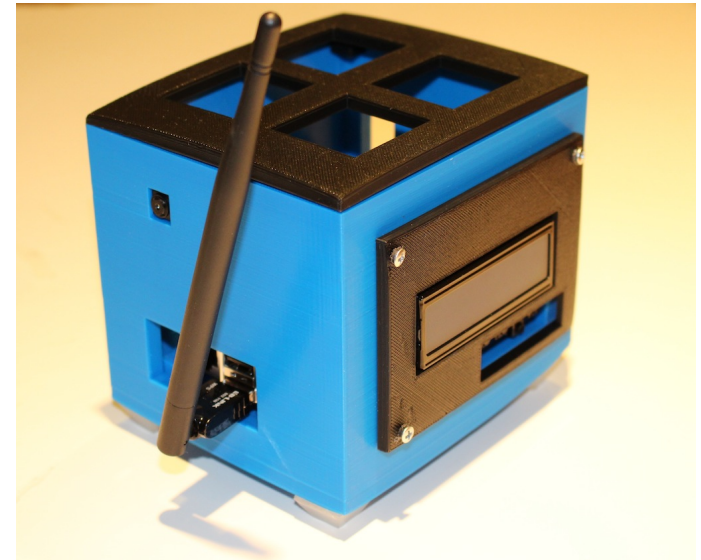


# Pi-Sat Designs



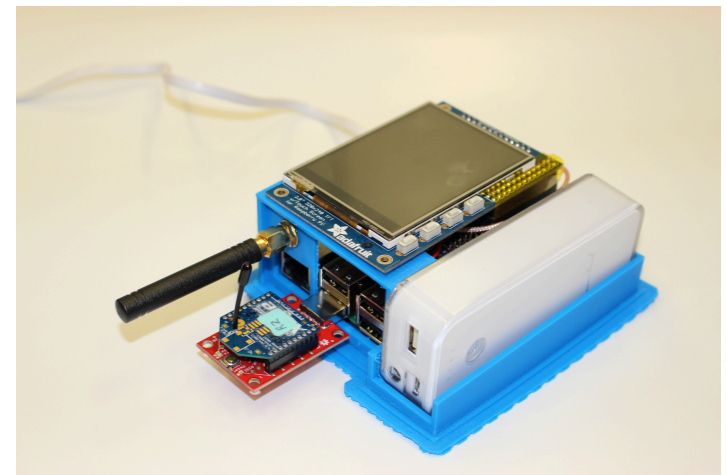
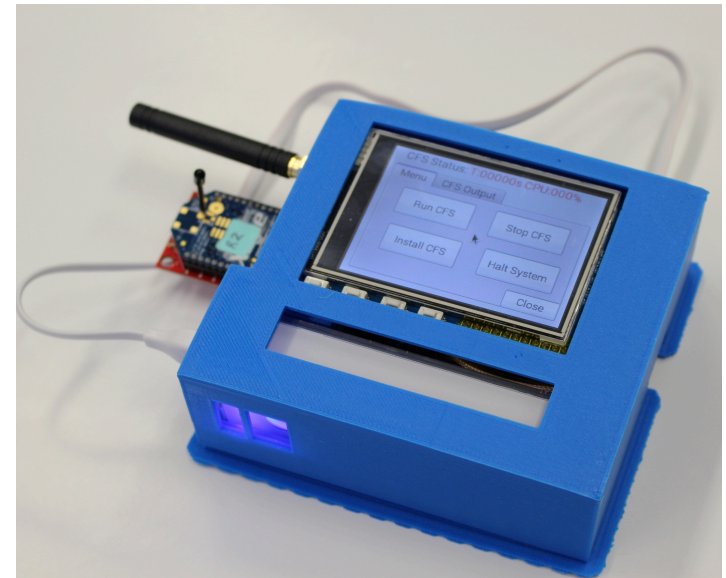
# Pi-Sat Designs: Pi-Sat Cube

- The Pi-Sat Cube is a 1U (OK.. 1.2U) sized Cubesat prototype
- CPU: Raspberry Pi Model B
- Sensors:
  - GPS
  - Mag/Compass/Accelerometer
  - Raspberry Pi Camera
  - A/D Converter
  - PWM control board
  - LCD interface
- Wi-Fi network
- Power
  - USB or 4400mAH battery



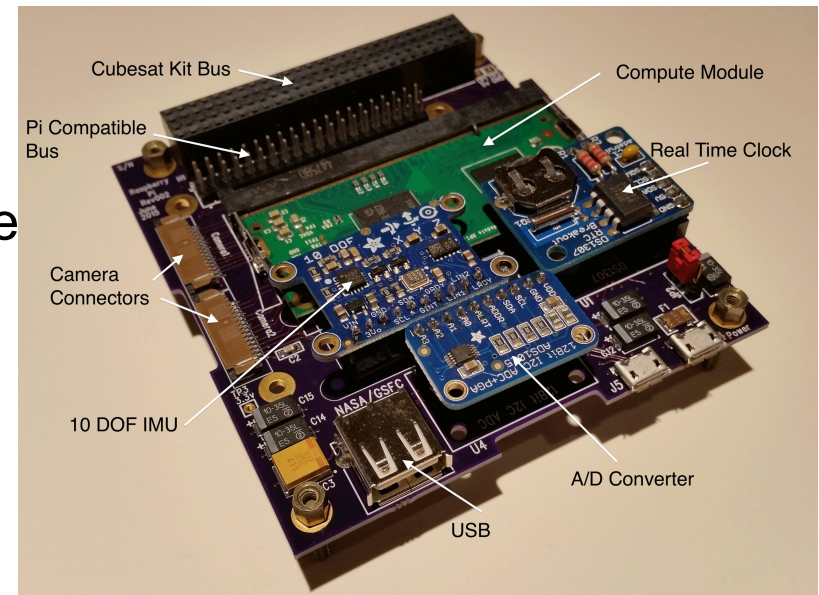
# Pi-Sat Designs: Pi-Sat Wireless Node

- The Pi-Sat Wireless node is more compact model for testing wireless mesh networks with the cFS flight software
- CPU: Raspberry Pi 2 B+ (Quad Core)
- Sensors:
  - GPS
  - Mag/Compass/Accelerometer (10 DOF IMU)
  - Touch Screen interface
- Wi-Fi network
- Xbee Mesh wireless for Peer-to-Peer comm
- Power
  - USB or 4400mAH battery



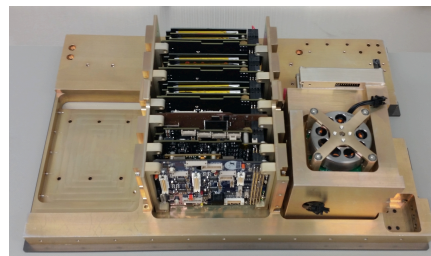
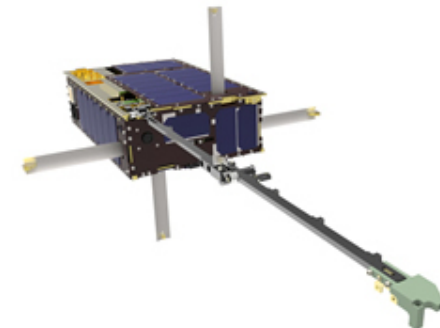
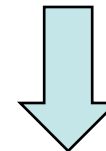
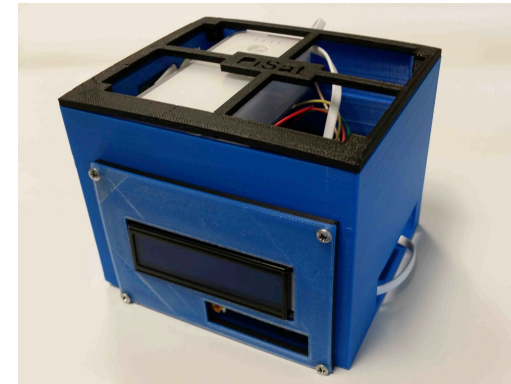
# Pi-Sat Designs: Pumpkin Pi Card

- The Pumpkin Pi Card is a 1U Cubesat processor card (prototype) based on the Pumpkin Cubesat kit bus
- CPU: Raspberry Pi Compute Module, upgradeable to the Raspberry Pi 2 Compute Module when released
- Sensors:
  - 10 DOF IMU unit
  - Real Time Clock
  - A/D Converter
  - Raspberry Pi Camera Connectors
- Network interface through USB port
- Power through mini-USB or Cubesat Bus Connector

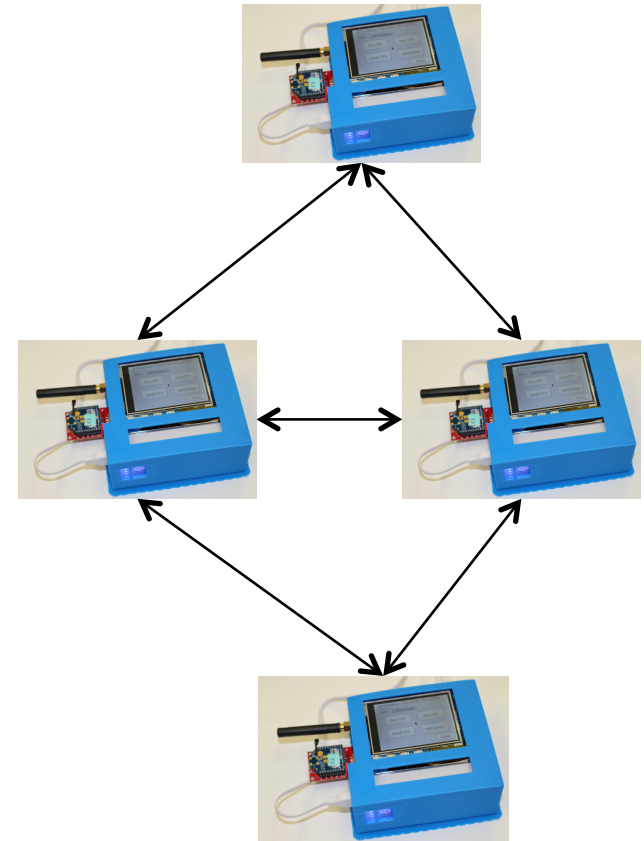


# Applications of the Pi-Sat: Smallsat/Cubesat Prototype

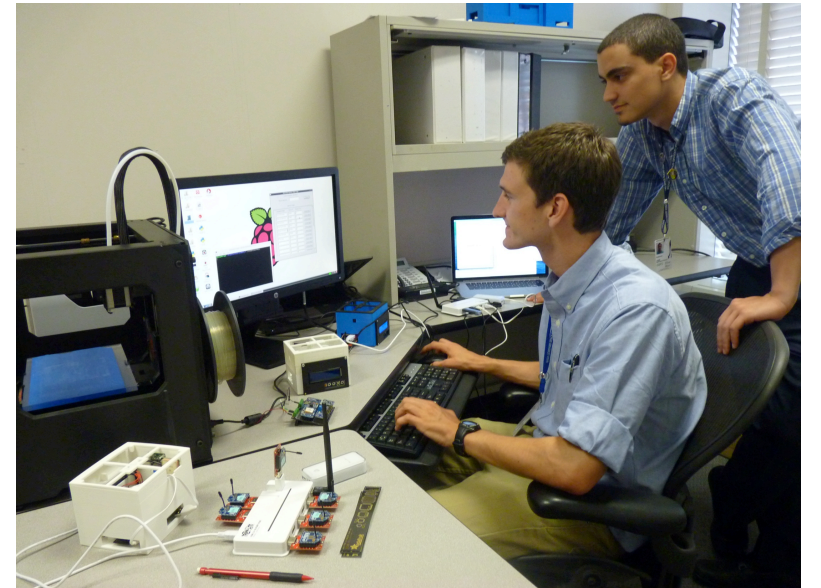
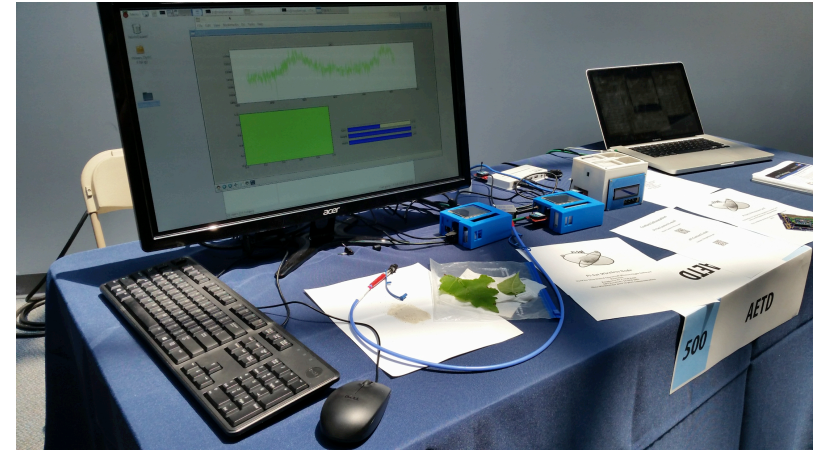
- The Pi-Sat platform can be used to rapidly prototype cFS flight software for Cubesat Missions.
- Realistic sensors for Navigation and Control
- I2C, SPI, GPIO, Ethernet, and USB for instrument interfaces
- “Out of the Box” cFS flight software with a simple ready to use ground system for initial setup
- Pumpkin Pi model is more realistic and gets closer to integrating into a real Cubesat stack.

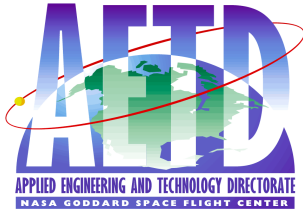


- The Pi-Sat platform can also be used for a Distributed Spacecraft Mission (DSM) Test Bed
- Xbee Mesh Network cFS extension allows the cFS “Software Bus” to communicate among multiple spacecraft units
- Low cost platform to develop Peer-to-peer cFS communication protocols and ground system concepts for constellations



- The Pi-Sat platform has been an excellent opportunity for hands-on flight software training for 582 Interns and Pathways students.
- Most of the 3D design, custom cFS Applications, and Ground System software has been developed by the Interns/Pathways students.
  - Keegan Moore integrated an ocean spectrometer instrument into Pi-Sat/ cFS software
- Working with real hardware gives students a sense of what Flight Software (and hardware) development is about.





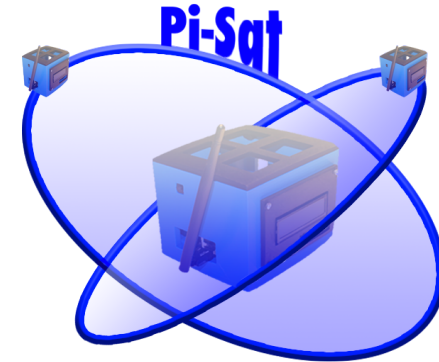
# Pi-Sat Team



- **Michael Lin / 561**
  - Pi-Sat Cube Sensor Card Design and Pumpkin Pi Card Design
- **Jose Martinez Pedraza / 582 / Pathways**
  - cFS App development
  - Ground System Development
  - 3D Enclosure Design
  - Hardware/Software Integration
- **Keegan Moore / 582 – Capitol Tech / Summer Intern**
  - cFS App development
  - 3D Enclosure Design
  - Hardware/Software Integration
- **Alan Cudmore / 582**
  - IRAD PI and Pi-Sat lead (Pi-PI?)
  - (Michael Cudmore – Pi-Sat logo design)



# What's Next?



- FY15 IRAD Wrap up
  - Delivery of Wireless Nodes
  - Documentation and Design wrap up
- FY16 Collaboration with Planetary Systems Lab
  - Continue Collaboration with ocean spectrometer instruments and Cubesat / cFS prototypes
- Consolidation of hardware designs
  - Sensor Pi-HAT card that plugs into Raspberry Pi or Pumpkin Pi
  - Unified flight software
- Education opportunities?
  - Collaboration with Capitol Technology University?
  - Kit for educators?