Pi-Sat: A Low Cost Small Satellite and Distributed Mission Test Platform

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Outline

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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
Introduction: Why Pi?

- 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 an 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!

• 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.
Applications of the Pi-Sat: Distributed Spacecraft Mission Test Bed

• 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
Applications of the Pi-Sat: Flight Software Training / Education

- 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?