Exploration of Linux with RTOS for Nanosatellites

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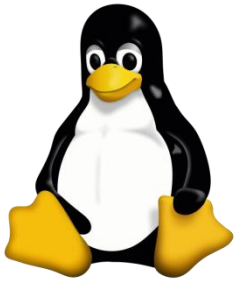
Overview

- Linux Platform & Ecosystem.
- Linux Hardware & Software Architectural considerations.
- Architectural considerations taken for Pumpkin MBM2 and Linux.
- Use cases of Pumpkin MBM2.
- Use case of Linux on Pumpkin developed payload.
- Conclusion

Linux as a Platform

- Portable
  - Runs on ARM, PowerPC, x86, and many more architectures.
- Customizable
  - Service customization through systemd/upstart/init scripts.
  - Complete custom installs can be made through Buildroot/Yocto.
- General-Purpose OS
  - Non-deterministic scheduler, however soft real-time threads may be substituted in some cases.



Linux Ecosystem

- Many pre-packaged distributions
  - Debian, Ubuntu, Fedora, Arch Linux, PetaLinux, KubOS, etc…
- Large community of support
  - Used by many industries and commercial services.
  - Many developers are familiar developing with/for Linux.
- Vast support of COTS devices
  - Image Sensors, USB-Serial devices, etc…
- Huge pool of software packages
  - rsync, systemd, gcc, rsyslog, and much more...

Hardware Considerations for Linux

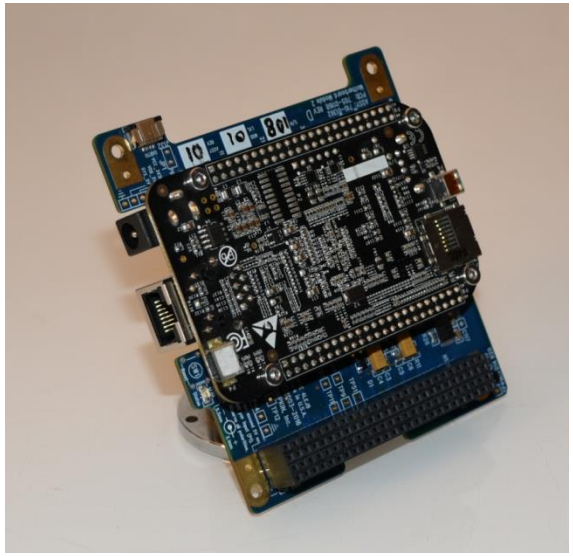
- Power consumption for Linux C&DH boards
  - ARM-based Linux SoC can consume >1W.
- Timing Requirements
  - Hardware interfaced with C&DH could require strict scheduling deadline targets to ensure safe operation of spacecraft.
- Rad-Hard Processors
  - Much more expensive than unprotected counterparts, lower processing performance, limited selection.
- Bus Watchdog
  - Pumpkin bus utilizes watchdog timer (WDT) combined with WDT gate on bus to reset in event of software latch up.

Software Considerations for Linux

- Mission software compatibility
  - Hardware and software supported by target.
- Audit system settings/packages
  - Ensure non-essential packages are removed
- Offloading hard real-time processes
  - Dedicated boards to interface with hardware requiring real-time priority.
- Recovery from failure
  - Restoring from known good image upon failure detected.
  - Secondary C&DH system to fallback on.

Pumpkin C&DH for Linux

- Pumpkin Motherboard Module 2 (MBM2) features
  - Beaglebone Black (BBB) with ARM Cortex-A8 @ 1 GHz
  - I2C, UART, Ethernet, MicroSD...
  - CSK Bus Interface.
- Supported Linux Distributions and Flight Software
  - Debian Linux and KubOS are officially supported.
  - Pumpkin SUPERNOVA Core, KubOS, Bright Ascension flight software.

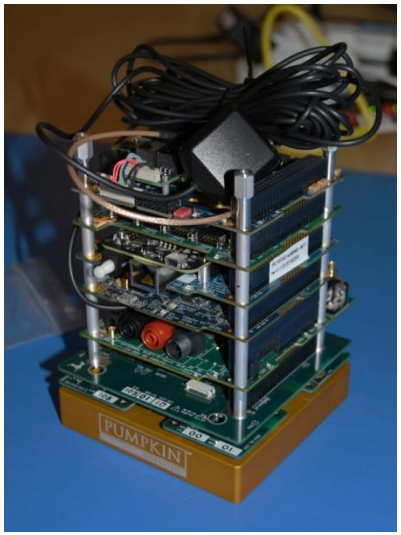


Pumpkin MBM2 and Development

- Development Pipelines
  - On Debian, GCC Linaro cross compiles SUPERNOVA Core FSW.
  - KubOS provides Valgrant image to develop missions with KubOS SDK.
- Software portability
  - Flight Software written for Linux can be ported to Pumpkin MBM2.
  - Logic to interface with SupMCU's would need to be written.

Pumpkin MBM2 and Real-time Tasks

- Pumpkin SupMCU hardware
  - Handles the real-time tasks independent of MBM2
  - Runs Pumpkin Salvo RTOS, with PIC-based MCU.
  - On-demand telemetry and commanding of hardware.
- Interface to SupMCU boards
  - Communicates as slave device on I^2C bus.
  - Simple SCPI-based command interface.
- Benefits to Mission development
  - Reduces software development effort for hardware.
  - Reuse of code for the SupMCU modules.
  - Reduces processing load on C&DH.

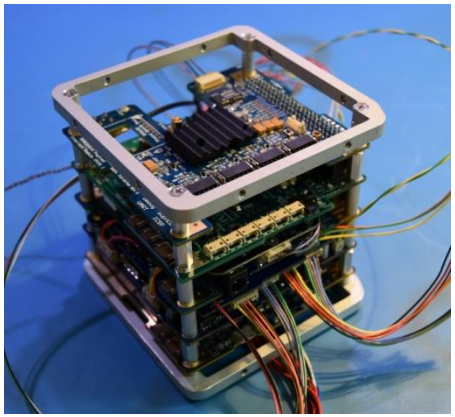


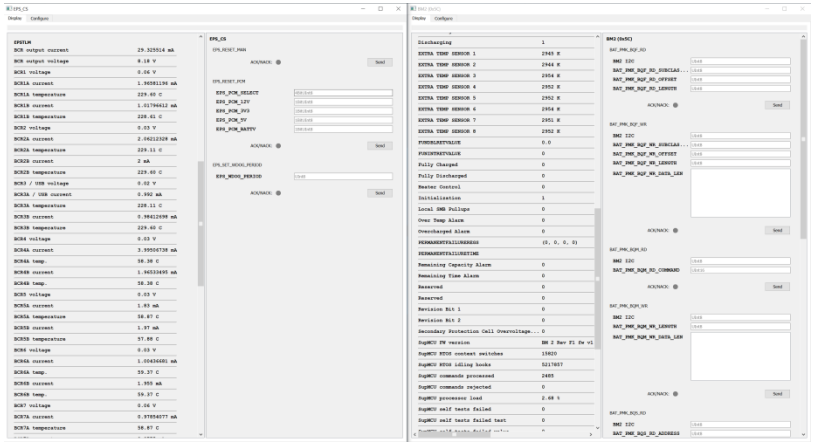
Pumpkin MBM2 and Watchdog Timer

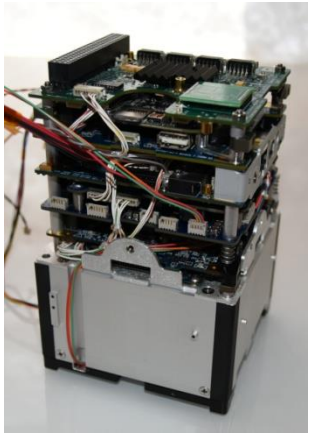
- Boot-time longer than Watchdog period
  - Pumpkin Bus WDT period is 2.5 seconds, Linux boot-time is ~30 Seconds.
  - Solution: Don’t allow WDT to reset MBM2 until booted and kicking WDT.
  - One-way gate doesn’t allow signal to propagate until opened.
  - Once gate is opened, never closes until the board is reset.

Pumpkin MBM2 Use Cases

- Pumpkin MBM2 running Pumpkin SUPERNOVA Core
  - Pumpkin MBM2 running Debian Linux.
  - Pumpkin SUPERNOVA Core runs as systemd service unit.
  - Mission services interface via SUPERNOVA Apps Python library.
  - Integration tests ran through Pumpkin Command and Control software (PuCC).
- Pumpkin MBM2 running Bright Ascension FSW
  - Mission for commercial IoT sector.
  - Pumpkin MBM2 running custom build of KubOS Linux.
  - Bright Ascension FSW runs as a single service and started upon boot.

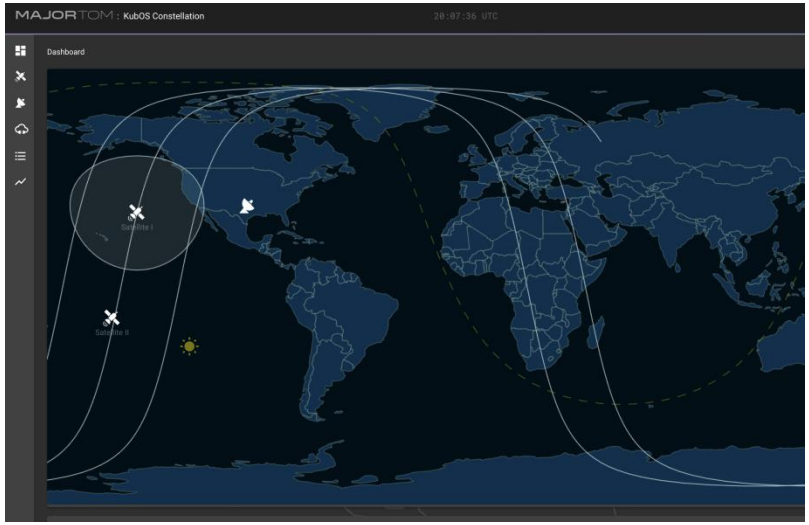






Pumpkin MBM2 Use Cases (cont.)

- Pumpkin MBM2 running KubOS FSW
  - Pumpkin MBM2 running KubOS.
  - KubOS provides system services to interface with bus hardware.
  - Pumpkin SupMCU Test Modules (STM) provided KubOS facility to test multiple Pumpkin SupMCU boards during development.
  - Remote access provided KubOS ability to test mission software on flight hardware.



Pumpkin HABSat-2 Use Case

- Goal of Mission
  - Provide HSI imagery to study and detect harmful algal blooms.
  - Test viability of low-cost HSI camera hardware on orbit.
- Jetson TX2 Platform
  - Processing and image acquisition hardware for HSI cameras.
  - Powerful processing platform offering up to 1.5 TFLOPS.
  - Power efficient for processing performance offered.
  - Great community support and driver support for hardware used.

Pumpkin HABSat-2 Use Case (cont.)

- Service based architecture
  - Payload software broken out into multiple systemd service units.
  - Each service follows principle of single responsibility.
- Software/Hardware used.
  - All services written in Python.
  - Pumpkin SUPERNOVA Apps used to interface with PuCC for operation of system.
  - COTS Hyper spectral cameras used to take HSI photography.
- Experience with HABSat-2
  - Driver support for hardware is superb.
  - TX2 is able to compress and write frame data up to 340 FPS.
  - Pumpkin SUPERNOVA Apps permits reuse of PuCC software.
  - Python allowed rapid prototyping on local development machine before deployment to target.

Conclusion

- Linux is well supported
  - Specific distributions for space.
  - Great community support.
  - Wide variety of great tools and packages.
  - “Run your laptop in space.”
- Many development benefits
  - Run and test code on multiple platforms.
  - Quickly prototype systems.
  - Familiar with many other software developers.

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SPACE SYSTEMS

Q&A Session

Appendix

- **SUPERNOVA, MISC 3 & CubeSat Kit information**
  - More information on Pumpkin's SUPERNOVA can be found at http://www.pumpkinspace.com/. Patented and Patents pending.
- **Copyright**