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.

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- 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.

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- 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.

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Linux Ecosystem

- Many pre-packaged distributions
 - Debian, Ubuntu, Fedora, Arch Linux, PetaLinux, KubOS, etc...

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- 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...

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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.

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Pumpkin SUPERNOVA Core, KubOS, Bright Ascension flight software.

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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.

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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 I²C bus.
 - Simple SCPI-based command interface.
- Benefits to Mission development
 - Reduces software development effort for hardware.

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- Reuse of code for the SupMCU modules.
- Reduces processing load on C&DH.





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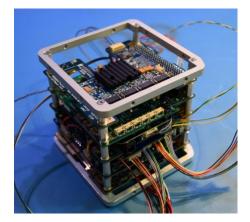
Pumpkin MBM2 and Watchdog Timer

- 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.



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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.



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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.

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Great community support and driver support for hardware used.



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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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Q&A Session



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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.

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