



Space Grade Linux

An Introduction - Michael Monaghan, NASA Goddard Space Flight Center



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Why use Linux?

The Space Industry is adopting Linux, Fast!

- Free and open source
- Abundant workforce expertise
- Unparalleled software ecosystem
- Strong embedded hardware support
- Extensively reviewed and tested
- Adaptable to real-time or performance-centric workloads

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Who is using Linux?

Space

- NASA
 - Ingenuity
 - International Space Station
 - Starling
 - Various CubeSats
- SpaceX
 - Falcon 9
 - Dragon
 - Starlink (>30k Linux nodes!)

Automotive

- Tesla, Toyota...
 - Autopilot/Advanced driver assistance

Telecom

- Verizon, Qualcomm...
 - Majority of LTE and 5G chipsets. (including iPhone)
 - LTE and 5G infrastructure

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What is SGL?

Space Grade Linux is a collaborative, open-source project bringing together space agencies, industry, and academia to establish a trusted ecosystem of Linux-based, open-source software for mission critical spacecraft operations.



Spacecraft Environment Considerations



One-off Designs

Mission specific.
Not mass-produced.
Substantial investments.
Assets that require security
Require reliability guarantee.



Unreliable comms

No traditional networking.
Slow.
Periodic loss of signal (LOS).
Considerable delays.



Structured CMD/TLM

Need server-like administration without cmdline console
Operated by mission control centers, not sysadmins.



Sudden Resets

Radiation induced.
(single event upsets, etc.)
Power constraints.
NAND Bit flips.

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Purpose of SGL

Reduce cost. Reduce error.

- Stop reinventing the wheel!
- Reuse software and collaborate.
- Minimize time to launch.
- Reduce required expertise.
- Leverage collective knowledge base.
(i.e. mailing list)

Facilitate modern workloads in space

- Prepare for next-gen high performance spacecraft processors.
- Tap into unrivaled performance and software support offered by Linux
- Support nearly all AI/ML frameworks out of the box.
- Address challenges presented by spacecraft environments.

Inspire Confidence in Linux

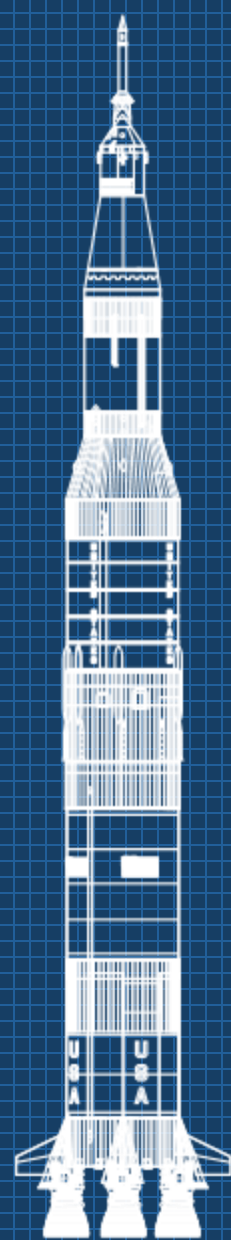
- Establish a trusted ecosystem.
- Demonstrate reliability outside terrestrial applications.
- Serve as a baseline for future certification.

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SGL Blueprint



Your Mission (Software Payload)

- *Mission Specific Flight Software (cFS Apps, FPGA design, drivers...)*

Space Grade Linux

- Userspace
 - Software Framework (e.g. cFS)
 - Linux-specific framework apps.
 - Daemons and tools (systemd, udev...)
 - Dependencies and libraries (busybox, glibc...)
 - Dependency and library config
 - Distribution policy and config
- Board Support Package
 - Kernel & Config
 - Drivers
 - Bootloader (e.g. u-boot)
 - Bootloader additions (resilient boot flow, update mechanisms)
 - Hardware Platform Support
- Baseline Certification
 - Kernel + Userspace
 - Security hardening



Focus Areas



Software

Yocto Linux Distro tailored to space.

Stop re-inventing the wheel.

Reduce time to launch.

Establish a common code base.

Support cutting edge open-source software, such as for AI/ML.



Hardware

Yocto BSP for common space processors.

Facilitate high-performance mission processing needs.

Target next-gen space processors.

Meet aggressive SWaP constraints.



Safety

High design assurance levels.

Agency certifiable for Mission Critical Ops.

Establish a track record.

System security and integrity by design.

Protection against malicious actors.

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Next Steps

- Space Grade Linux is Incubating as an ELISA Special Interest Group
 - **Join the mailing list**
<https://lists.elisa.tech/g/space-grade-linux>
- Start an argument (or two!)
 - SGL Flavors? cFS, F', Space ROS?
 - Minimal vs traditional userspace?
 - Systemd vs SystemV vs custom init system?
 - glibc vs musl? Static vs dynamic? No MMU support?
 - Containerized applications?
 - Asymmetric multi-processing (OpenAMP)?
 - Kernel Config validation?
 - Standardized and secure system updates?
 - (Android style) recovery mode? u-boot features for in-flight recovery/upgrade?
 - Custom boot flows focusing on resilience?
 - Future Open-source project governance?



Questions and Comments

