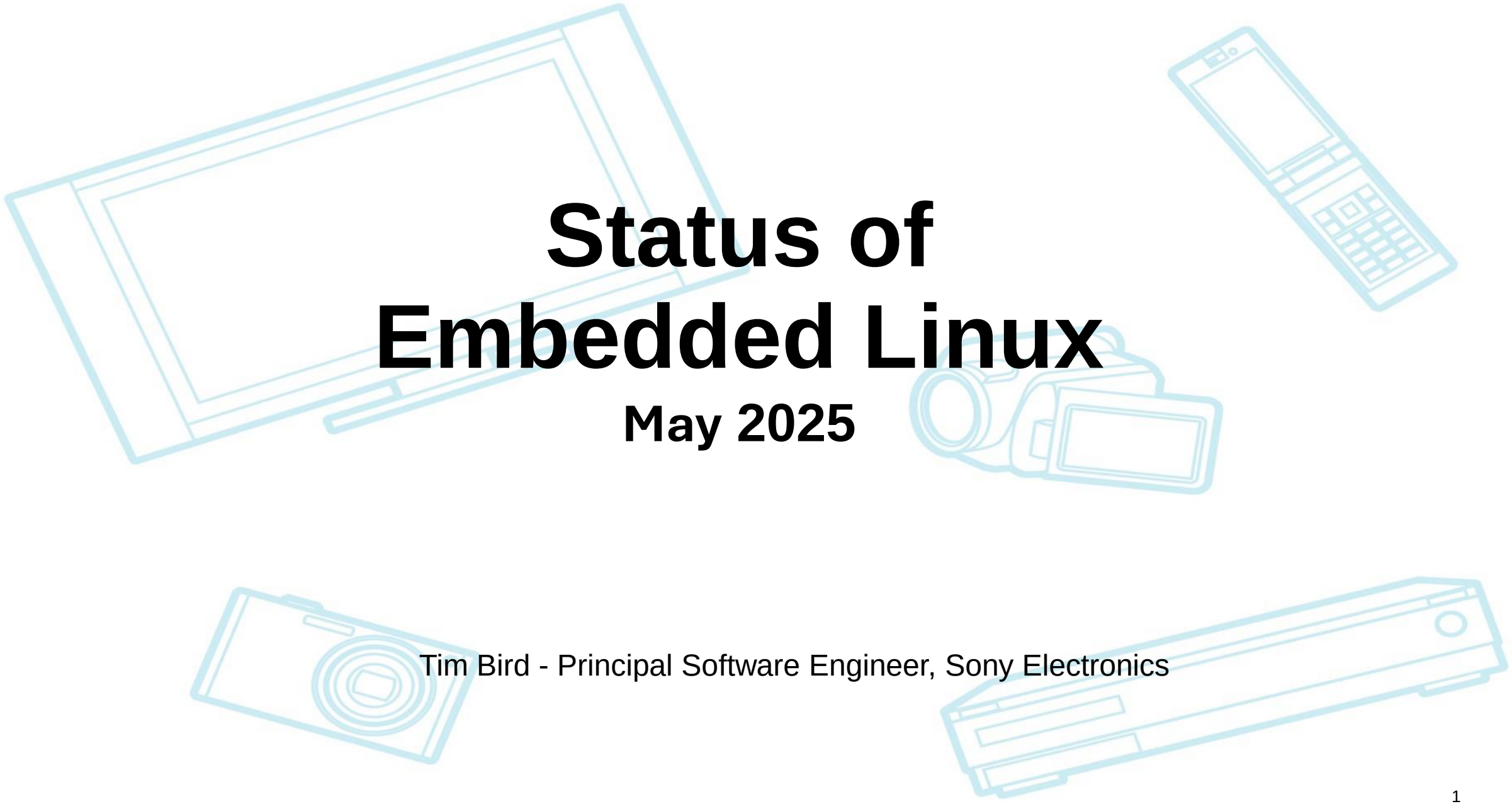

Status of Embedded Linux

May 2025

Tim Bird - Principal Software Engineer, Sony Electronics

Nature of this talk…

- Periodically take a look at the status of embedded Linux
  - Not comprehensive – just a few things I saw
- No way to cover everything
  - Sorry if I missed something you're interested in
- 2 parts:
  - The firehose/shotgun part
  - The "themes" part

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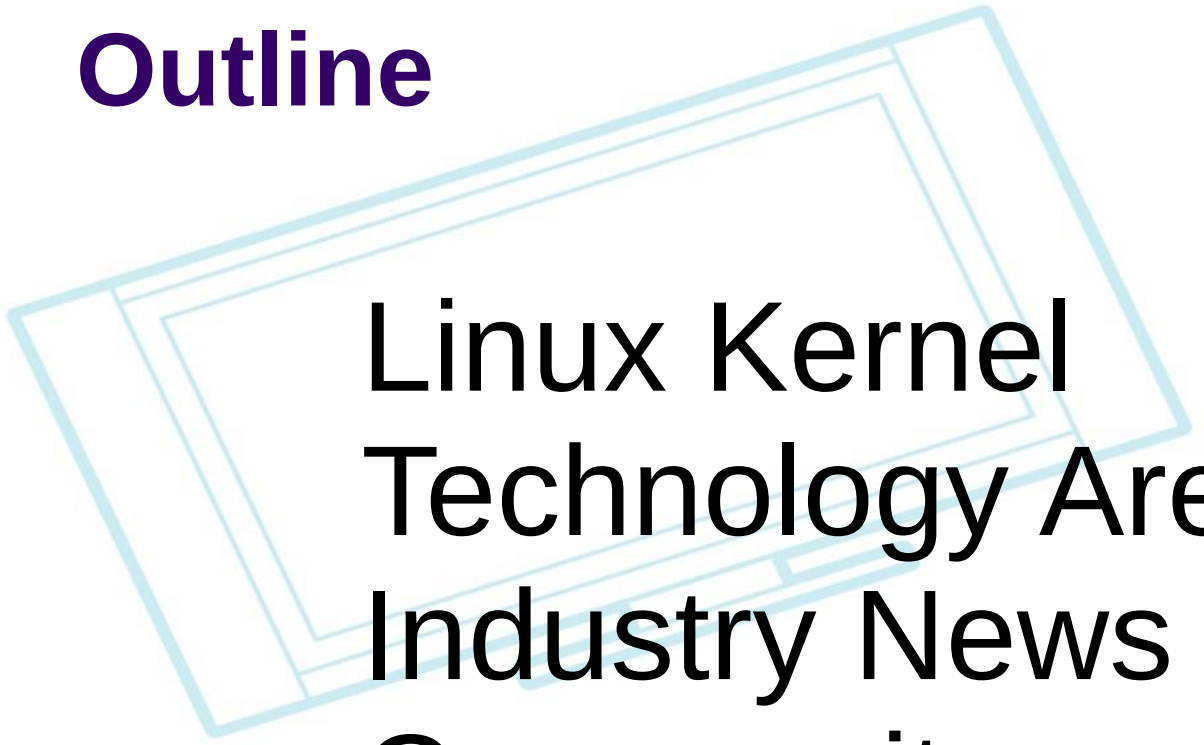
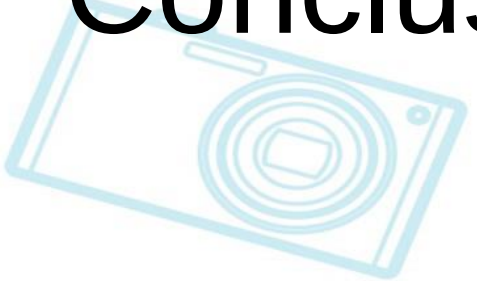
Outline

Linux Kernel
Technology Areas
Industry News
Community
Conclusions





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Kernel Versions

- Linux v6.10 – 14 July 2024 – 63 days
- Linux v6.11 – 15 Sep 2024 – 63 days
- Linux v6.12 – 17 Nov 2024 – 63 days
- Linux v6.13 – 19 Jan 2025 – 63 days
- Linux v6.14 – 24 Mar 2025 – 64 days (… on a Monday!! (gasp))
- Linux v6.15-rc6 …
  - When to expect 6.15?

Memorial Day release possibility

- Normally would expect v6.15 on 25 May 2025 (62 days!!)
  - But this is Memorial Day weekend in the U.S. (a big holiday)
- According to AI:
  - There is no documented evidence that the Linux kernel has been released on Memorial Day weekend in its 30-year history.
- I couldn't find any major releases, but these minor ones were close:
  - Saturday, May 29, 1999 (Kernel 2.2.9):
    - Notes: Stable release, Saturday weekend before Memorial Day on May 31, 1999
  - Tuesday, May 29, 2018 (Kernel 4.1.52):
    - Notes: Long-Term Support stable release, one day after Memorial Day on May 28, 2018
- IMHO: Linus should take more vacations

Linux v6.10 (July 2024)

- Continued improvements in Rust support
- Encrypted interaction with TPM
  - See Documentation/security/tpm/tpm-security.rst
- crypto stats removed
  - Apparently no one was using them
  - It imposed runtime (and maintenance) overhead
  - https://git.kernel.org/pub/scm/linux/kernel/git/torvalds/linux.git/commit/?id=29ce50e078b8
- Removal of early Alpha CPUs (EV5 and earlier)

Linux v6.10 (July 2024) (cont.)

- Memory-allocation profiling
  - Tracks all memory allocations in kernel, and what code did the allocation
    - Very useful for debugging memory usage
  - Relies on code_tagging, which was also added to 6.10
  - Now that it's upstream, work will proceed to tune the overhead of the profiling to make it as unobtrusive as possible
  - See https://lwn.net/Articles/974380/
  - Also, see Documentation/mm/allocation-profiling.rst

Linux v6.11 (Sep 2024)

- New power-sequencing subsystem
  - Can bring system devices up in the right order
  - Documented in 6.12 – see https://docs.kernel.org/next/driver-api/pwrseq.html
- "Sloppy logic analyzer"
  - Allows using GPIO lines as a poor-man's logic analyzer
  - See https://git.kernel.org/pub/scm/linux/kernel/git/torvalds/linux.git/commit/?id=7828b7bbbf20
- New RUNTIME_CONST() macro
  - Optimizes use of values that are determined at boot time and never changed
  - Converts variables into hardcoded instructions, which is faster
  - Only used in one place for now (dentry cache)

Linux v6.11 (Sept. 2024) (cont.)

- New vDSO implementation of getrandom()
  - Should speed up random number generation
  - See https://lwn.net/Articles/980447/ and https://lwn.net/Articles/983186/
  - Side effect is that mmap() now supports MAP_DROPPABLE flag
- Extensible Scheduler class (sched_ext) was NOT merged this release

Linux v6.12 (Nov 2024)

- PREEMPT_RT enablement!! (more on this later)
  - printk improvements
- Security module subsystem now uses static calls
  - Replaces indirect function calls
  - Has better performance and security
  - See https://lwn.net/Articles/979683/
- Tracing ring buffer that persists across a reboot
- Integrity Policy Enforcement security module

Linux v6.12 - Sched_ext

- Extensible Scheduler class (sched_ext)
  - Supports pluggable schedulers, using BPF
  - Linus had said he would merge it in 6.11
    - But there was a lot of debate, and a request for a 3-month delay
      - See https://lwn.net/ml/all/87bk3wpnzv.ffs@tglx/
  - See https://lwn.net/Articles/978007/ and https://lwn.net/Articles/922405/
  - Sample BPF schedulers at: https://github.com/sched-ext/scx

Linux v6.12 (Nov 2024) – more news

- Selected by Civil Infrastructure Platform for its next SLTS release
  - 4.4, 4.19, 5.10, 6.1 and 6.12 will be supported for 10 years
  - Note: 6.12 is not listed on CIP wiki yet.
- See:
  - https://www.cip-project.org/blog/2025/01/13/kernel-6-12-will-have-10-years-support-via-cip-are-all-your-maintenance-problems-solved

Linux v6.13 (Jan 2025)

- Arm64 can run Linux in virtual machines under the ARM Confidential Compute Architecture
- Arm64 support for user-space shadow stacks
  - See https://www.kernel.org/doc/html/next/arch/arm64/gcs.html
- The lazy preemption patches have been merged
- New thermal thresholds system was added
  - User space can get (netlink) notifications when a device temperature crosses a threshold
- Enough Rust support for VFS data structures and Interfaces for the Rust implementation of binder
  - See https://lwn.net/Articles/953116/ (about the Rust binder)

Lazy Preemption

- New set of patches to do preemption better with a combination of throughput-oriented and realtime workloads
- Previously had PREEMPT_NONE, PREEMPT_VOLUNTARY, PREEMPT_FULL, and PREEMPT_RT modes
  - cond_resched() calls are sprinkled around the kernel in places where long-running operations might interfere with realtime (essentially becoming voluntary preemption points)
  - Those are inaccurate and hard to maintain
- New flag TIF_NEED_RESCHED_LAZY added to augment TIF_NEED_RESCHED
  - Indicates a preempt is desired, but is not needed right away
- New PREEMPT_LAZY mode replaces PREEMPT_NONE and PREEMPT_VOLUNTARY
  - Most cond_resched() calls can be removed (estimate is 95% could be removed)
- See https://lwn.net/Articles/994322/

Linux v6.13 - continued

- VFS multigrain timestamps
  - Supports a mixture of low-resolution and high-res timestamps for files
  - Supports a way to only use high-res timestamps only when they are being actively queried
    - Otherwise the overhead of high-res timestamps is too much
- New madvise() operation to install guard pages in an indicated address range
  - access to a guard page results in a SIGSEGV signal
- Reiserfs filesystem was removed from the kernel
- F2FS supports "device aliasing" to allow a portion of the block device to be temporarily used by another filesystem

AutoFDO and Propeller

- Support for AutoFDO and Propeller added to build system for 6.13 kernel
- AutoFDO allows perf and MPU information to be fed back into compiler for Feedback Directed Optimization (FDO)
  - Can handle slight variations between the code profiled and the new source code
  - Helps with function inlining, putting hot blocks together for better cache utilization, increasing branch fall-through, better register utilization, etc.
- Propeller analyzes binary and does intermediate representation transformations, using profile information
  - BOLT does something similar, without going all the way back through the compiler and linker
- See https://lwn.net/Articles/995397/
  - See also Documentation/dev-tools/autofdo.rst and propeller.rst

Linux v6.14 (Mar 2025)

- New AT_EXECVE_CHECK flag added to execveat(2)
  - Program can ask kernel to give info an executability of a file
  - Allows security checks for scripts
  - See https://docs.kernel.org/userspace-api/check_exec.html
  - And https://lwn.net/Articles/982085/
- New dmem control-group controller can be used to regulate access to device memory
- FUSE filesystems can use io_uring for performance gains
  - For background, see https://lwn.net/Articles/932079/

Linux v6.15 (May/June? 2025)

- New kernel command-line option 'traceoff_after_boot' disables tracing once the init process start
  - Helps prevent boot trace data from being overwritten
- FUSE now supports handling timeouts
  - Allows recovery when user-space server hangs
  - See https://git.kernel.org/linus/9b17cb59a7db

Kernel releases (as of May 2025)

The Linux Kernel Archives

About Contact us FAQ Releases Signatures Site news

Protocol	Location
HTTP	https://www.kernel.org/pub/
GIT	https://git.kernel.org/
RSYNC	rsync://rsync.kernel.org/pub/

Latest Release
6.14.6

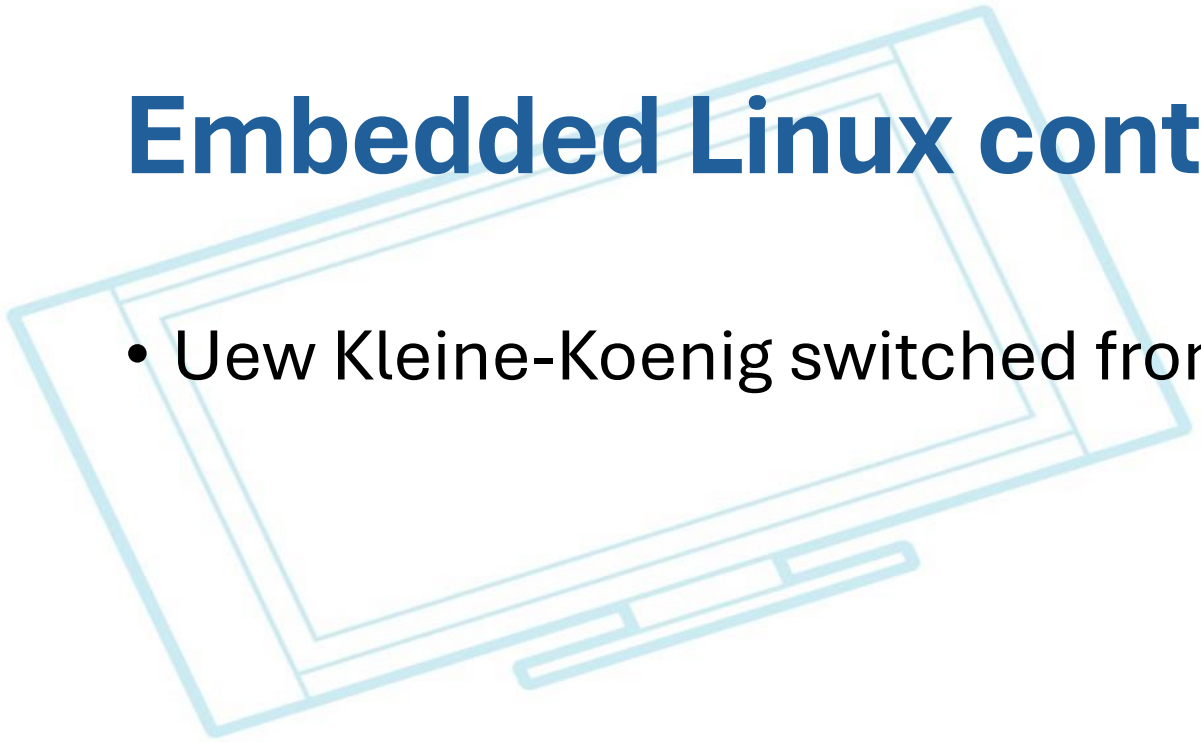
mainline:	6.15-rc6	2025-05-11	[tarball]		[patch]	[inc. patch]	[view diff]	[browse]
stable:	6.14.6	2025-05-09	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
stable:	6.13.12 [EOL]	2025-04-20	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
longterm:	6.12.28	2025-05-09	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
longterm:	6.6.90	2025-05-09	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
longterm:	6.1.138	2025-05-09	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
longterm:	5.15.182	2025-05-09	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
longterm:	5.10.237	2025-05-02	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
longterm:	5.4.293	2025-05-02	[tarball]	[pgp]	[patch]	[inc. patch]	[view diff]	[browse] [changelog]
linux-next:	next-20250513	2025-05-13						[browse]

Contributions by embedded Linux companies

Company	Commits since May 15 2024	Top contributor	Work area(s) (of top contributor)
Baylibre	703	Uwe Kleine-Koenig	pwm stuff, iio subsystem, adc drivers, fix calls to platform_driver::remove
Bootlin	635	Herve Codina	Qualcomm processor support, DRM, PMC ADC
Collabora	496	AngeloGioacchino Del Regno	mediatek processor support
Ideas On Board	229	Umang Jain	Raspberry Pi GPU (in staging)
Igalia	292	Tvrtko Ursulin	AMD drm GPU driver
Linaro	2455	Krzysztof Kozlowski	qcom fixups, device tree, lots of driver fixups and refactoring
Linutronix	804	Thomas Gleixner	ntp, timers, debugobjects, x86, preempt_rt
Pengutronix	333	Oleksij Rempel	network fixups, phy, usb
Toradex	107	Francesco Dolcini	drm bridge fixes, freescale SoC support
Wind River	23	Lizhi Xu	bugfixes in ocfs2, tracing, ntfs3, hibernate

Embedded Linux contributors notes

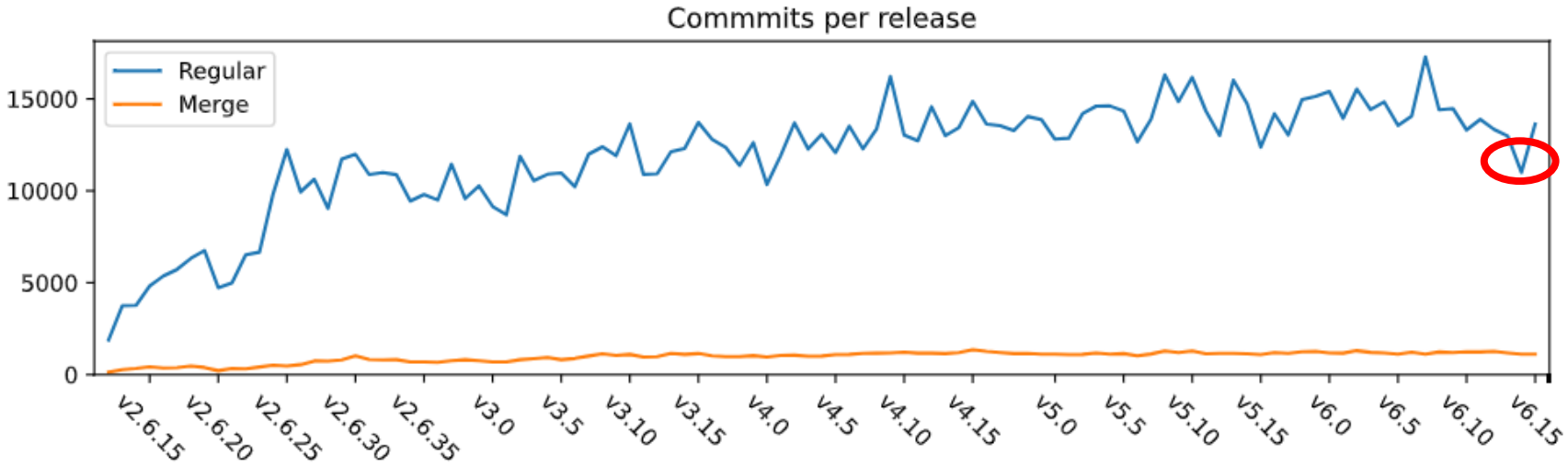
- Uew Kleine-Koenig switched from Pengutronix to Baylibre

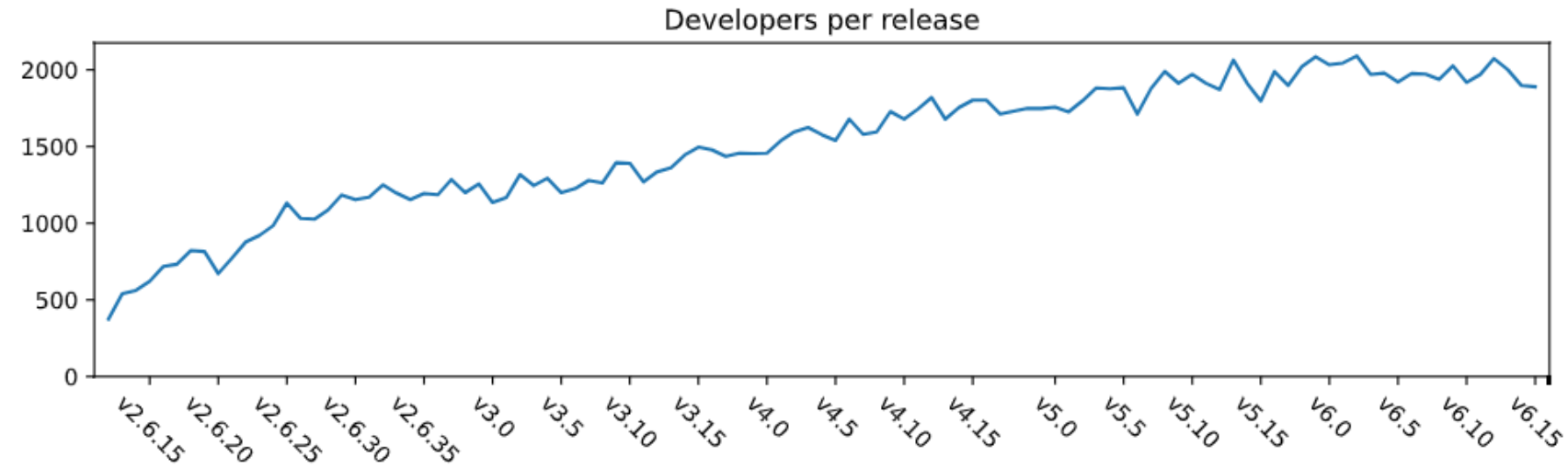



Resource - Kernel Source DataBase (KSDB)

- Service managed by lwn.net to analyze commits, contributors and employers for each kernel release
- See https://lwn.net/ksdb/
  - You can search for a specific developer, to see their contributions
  - Some nice charts of # of commits and # of developers per kernel release are available at:
    - https://lwn.net/ksdb/releases/
- Is available for subscribers only
- v6.13 stats: 1964 developers, 12812 non-merge commits

KSDB status charts





Linus likes imperative commit messages

- Linus recently complained about the use of passive voice in commit messages
- Please use:
  - 'This fixes a NULL pointer dereference in Xyzzy error handling'"
  - instead of:
  - 'In this pull request, the Xyzzy driver error handling was fixed to avoid a NULL pointer dereference.'
- Linus was quite polite about it
  - "I would love to see..."
- See https://www.theregister.com/2024/10/08/linus_torvalds_grammar_complaint/

Nobody likes deceitful modules

GPL issues with modules (2 patch sets in flight that fight this)

- 1) Ability to limit symbols access to specific Linux loadable modules
  - Kernel already supports putting exported symbols into separate namespaces
  - New patch supports exporting symbols in a namespace that is only accessible to a specific kernel loadable module
  - Intended to prevent symbols from being used arbitrarily (and incorrectly)
- 2) Set of patches to block a specific company's modules from using GPL symbols
  - Tuxedo Computers has modules with GPLv3 licenses, listed only as "GPL" in their license declaration.
  - Proposed patches target modules with incorrect or misleading license declarations (by module name)

- See https://lwn.net/Articles/998221/

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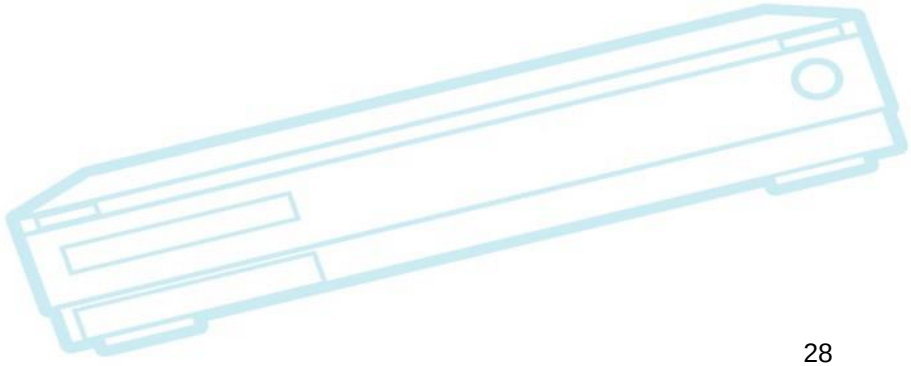


Event Slides and videos resources

- For sessions from ELC Europe 2024 (September)
  - Use https://elinux.org/ELC_Europe_2024_Presentations to find the slides and video links
    - Search by title and/or presenter name
- Talks from Linux Plumbers Conference 2024 can be found here: https://lpc.events/event/18/timetable/?view=lpc
  - Slides are available on individual session pages

Boot time Special Interest Group (SIG)

- New initiative to coordinate boot-time reduction activities
  - See https://elinux.org/Boot_Time
    - wiki pages needs a cleanup and to be updated for current work
- Planning a new "boot time tools and tricks" guide
- Using linux-embedded@vger.kernel.org for discussions
- Have a monthly conference call
  - Next one is May 27 (at 9:00 am Mountain time)
- Have set up a boot-time data repository
  - See https://birdcloud.org/boot-time/Front_Page
  - Holds data collected by tests, for different systems
    - Does data analysis on different boot problem areas and solutions
  - Would really appreciate more data sets submitted to site
- There is lots of work to do...

Boot time – current work

- TI working on:
  - Streamlining firmware startup in multi-core, secure environments
  - Handoff of pre-initialized hardware to the kernel (to prevent duplicate initializations)
  - Unified Boot Log – covering firmware, kernel and user-space
- RedHat working on:
  - initramfs reductions, use of RCU expedited mode, deferred memory init, reducing udev rules, high-priority boot sequencing
- Sony (Tim) working on:
  - common boot markers and boot-time regression testing
  - high-priority boot sequencing, deferred initcalls, boot time tuning tool
- Qualcomm working on deferred memory initialization

Core kernel

- Capability analysis using source annotations
  - Can check mutex ownership and lock semantics at build time, using annotations (that map to directives provided by Clang)
  - Compiler can detect thread safety violations, and warn developers of issues
  - Requires annotating mutex and lock usage
  - Uses an opt-in design
  - 2 patch sets recently proposed
    - Developers working on integrating them
  - See https://lwn.net/Articles/1012990/

Core kernel - RUST

- Rust support in kernel continues to improve
  - Can now implement serious sub-systems (Binder driver) (6.13)
- From Jon Corbet's talk at OSSJ: (see https://sched.co/1jKBj)
  - RUST in kernel is viable, but
  - Lots of issues remain:
    - language is not stable
    - RUST compiler doesn't support all architectures that kernel supports
    - Can't backport RUST features from newer to older kernels
    - Still needs lots of infrastructure (lots of interface code between Rust and C)
  - What will be merged first:
    - Binder
    - Apple GPU driver
    - NOVA (Nvidia GPU driver)
- Greg KH at the Linux Members Summit (November)
  - "Linus says the future of Linux is RUST"

Filesystems

- Linus doesn't like case-insensitive filesystems
  - Discussion came up in the context of bcachefs fixes for case-insensitive directory lookups
  - Linus is most often diplomatic - he had strong feelings on this one
  - See https://lore.kernel.org/lkml/CAHk-=wjajMJyoTv2KZdpVRoPn0LFZ94Loci37WLVXmMxDbLOjg@mail.gmail.com/#r
  - Read the whole thread for an interesting discussion, and the pitfalls of developing mature systems that need strong backwards-compatibility

Filesystems and I/O

- Talk "Maximizing SD Card Life, Performance, and Monitoring with KrillKounter" (ELC 2024)
  - By Andrew Murray, The Good Penguin
  - Great overview of SDCard / NAND flash hardware and software issues
    - Write amplification, how to measure it and avoid it
    - Need to measure at block layer and optimize
    - https://github.com/The-Good-Penguin/tgp-krill-kounter

Graphics – GPU work

- "Raspberry Pi 5: Challenges and Solutions in Bringing up an OpenGL/Vulkan Driver for a new GPU" (ELC 2024)
  - by Alejandro Pineiro Iglesias, Igalia
  - Good overview of Raspberry Pi upstream driver work
  - Rpi 5 required substantial rework
    - Worked was done with a simulator, before hardware became available
    - Vulkan 1.2 and OpenGL ES 3.0 conformant

Graphics – Information about Mesa 3D

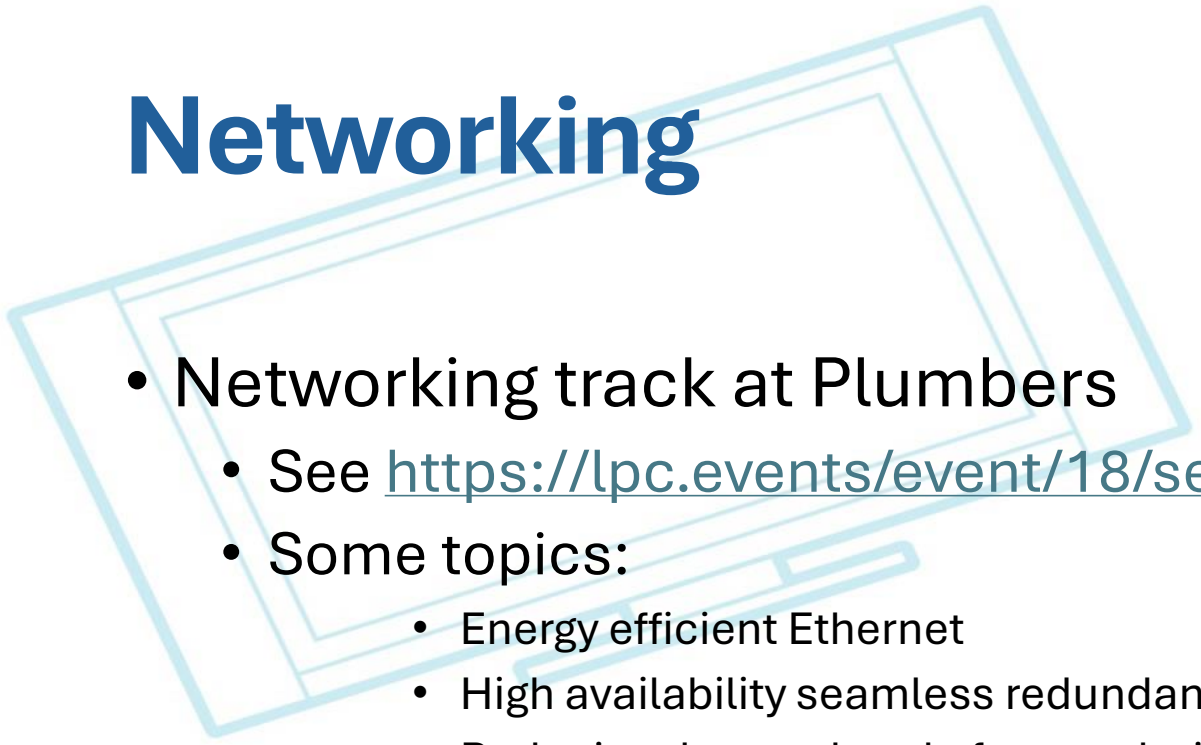
- "Mesa3D Unveiled: From glDrawArrays(...) to GPU Magic"
  - By Christian Gmeiner (at ELCE 2024)
  - Good introduction to Mesa3D (which is an OSS implementation of OpenGL AI)
    - Covers core API, mesa core, state tracker, dispatcher, and shader compilation
  - See https://osseu2024.sched.com/event/1jtFi/mesa3d-unveiled-from-gldrawarrays-to-gpu-magic-christian-gmeiner-igalia

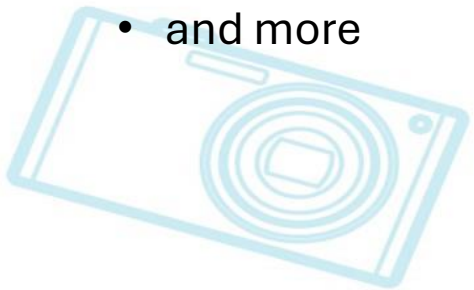
Networking

- "In the kernel Trenches: Mastering Ethernet Drivers on Linux" (ELC 2024)
  - By Maxime Chevallier, Bootlin
  - Excellent overview of structures and issues for a kernel driver
- "Bluetooth on Embedded Linux Systems Deep Dive" (ELC 2024)
  - by Marcel Ziswiler, Toradex
  - Good overview of Bluetooth development issues
    - Overview of hardware, Linux driver code, debugging techniques, etc.

Networking

- Networking track at Plumbers
  - See https://lpc.events/event/18/sessions/179
  - Some topics:
    - Energy efficient Ethernet
    - High availability seamless redundancy (HSR)
    - Reducing the overhead of network virtualizaton
    - Reasoning about cache usage of network stacks
    - State of BufferBloat
    - and more





Power management

- "Linux Power Management Features, Their Relationships and Interactions" (ELCE 2024)
  - by Theo Lebrun
  - Good overview of PM structures in the kernel
    - device PM callbacks
  - Dealing with system-wide suspend issues
    - standby modes, hibernation, clock handling
  - Runtime PM
    - enabling/disabling runtime suspend per-device

Power management – SoC PM Driver

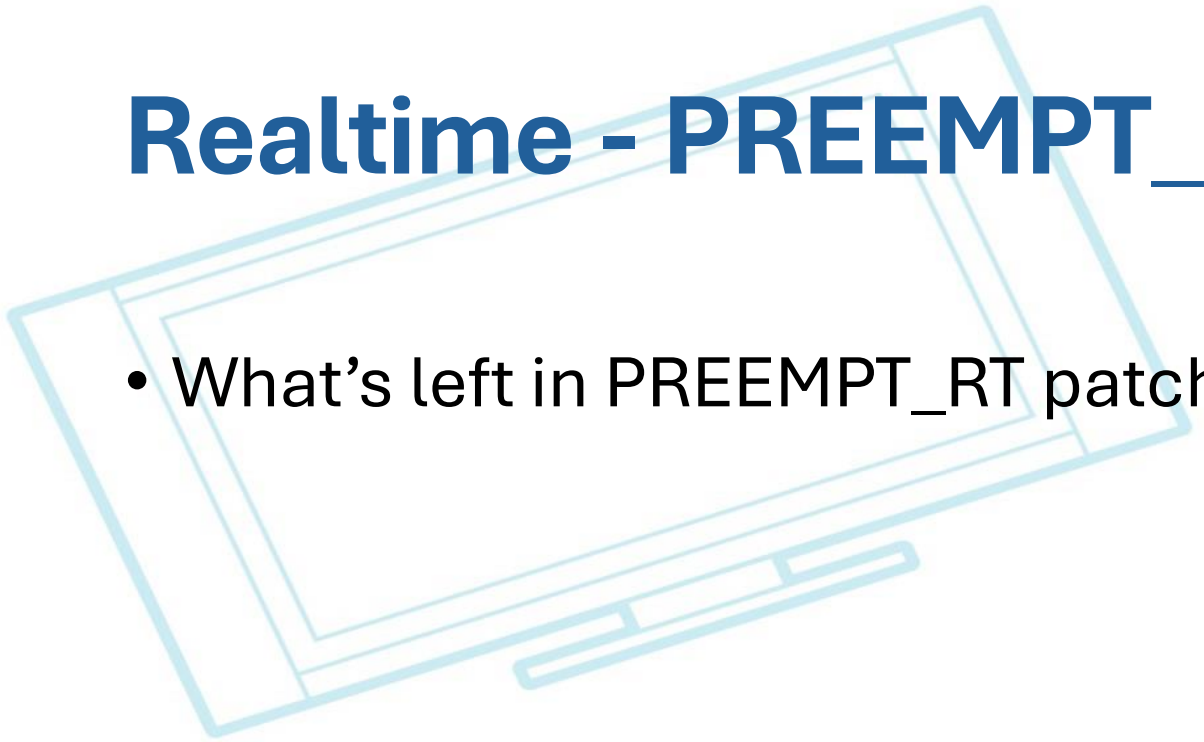
- "The case for an SoC Power Management Driver" (ELCE 2024)
  - by Stephen Boyd
  - See https://osseu2024.sched.com/event/1ej38/the-case-for-an-soc-power-management-driver-stephen-boyd-google
  - Proposes implementing an ACPI-like power management framework in Linux, but for systems using device tree
    - In device-tree systems, drivers must be firmware aware
    - SoC PM integration details are spread throughout the driver tree
    - Overall SoC power state is unknown
  - Propose a driver per-SoC that can manage PM domains on that SoC
    - See talk for implementation details

Power management - pwrseq

- pwrseq sub-system added to v6.11 kernel
  - Handles problem where resources need power before they can be detected, but bringup ordering is not controlled by device tree config
- "Introducing the power sequencing subsystem" (Plumbers 2024)
  - by Bartosz Golaszewski
  - See https://lpc.events/event/18/contributions/1908/
  - Example:
    - Must power the PCI bus before PCI devices can be detected and drivers attached to DT nodes
  - Some drivers already using pwrseq for Bluetooth and WLAN
  - Expect to refine and expand coverage (seems to be pent-up demand)

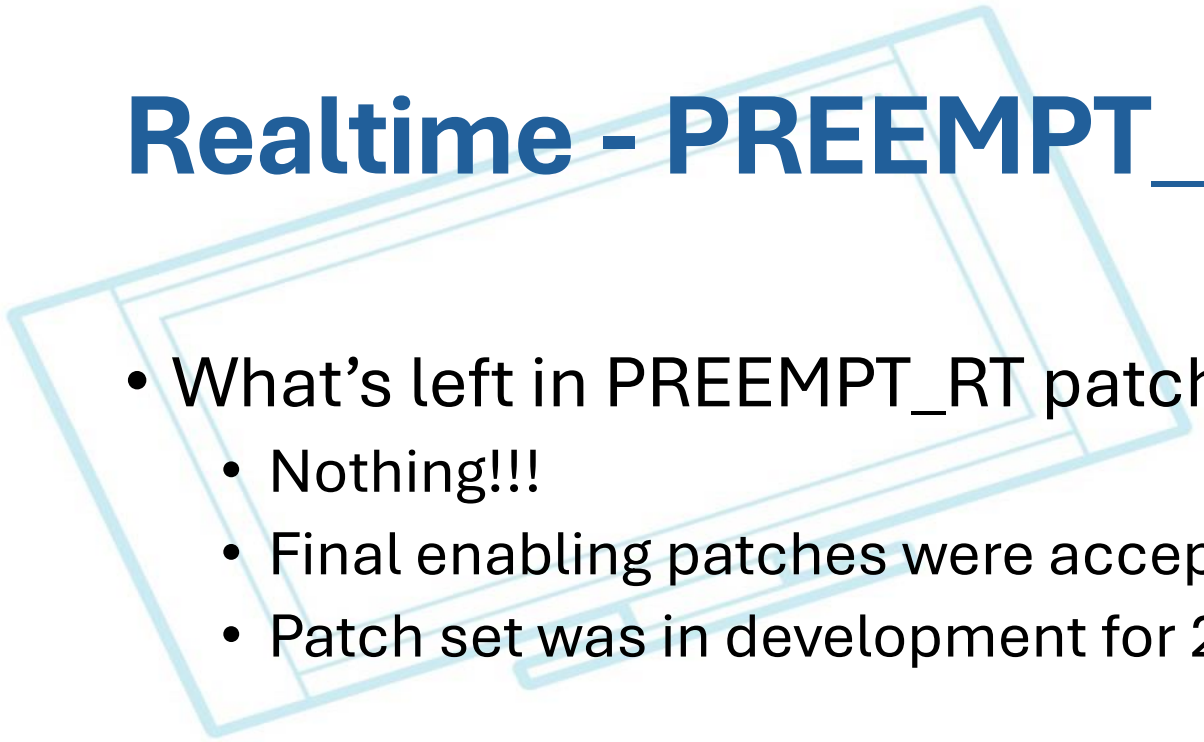
Realtime - PREEMPT_RT - What's left

- What's left in PREEMPT_RT patches out of mainline:



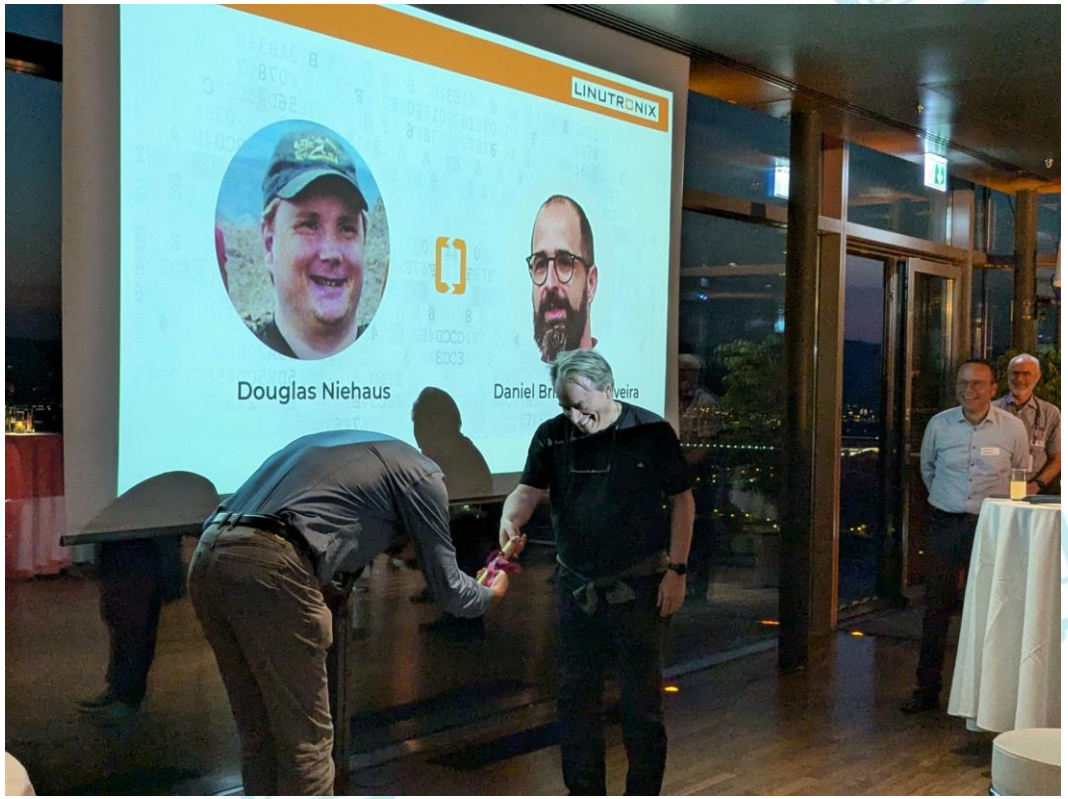

Realtime - PREEMPT_RT - What's left

- What's left in PREEMPT_RT patches out of mainline:
  - Nothing!!!
  - Final enabling patches were accepted for 6.12 (merge window)
  - Patch set was in development for 20 years!!



Realtime - PREEMPT_RT - What's left

- Thomas Gleixner handed in a printed pull request, wrapped in gold and tied with a bow to Linus, in person, in Vienna



See https://lwn.net/Articles/990985/

Realtime - PREEMPT_RT - What's left

- OK – there are still some items out-of-tree
  - About 58 patches (62 files, about 800 lines of code)
  - Module cleanup (use guard(rcu) and remove preemption guards) – 27 patches
  - Some ARM and PowerPC patches – 4 to 5 patches each
  - Some remaining DRM-i915 driver patches - 8 patches
  - serial nbcon – 2 patches
- There will always be some items under development
  - Just like any other kernel sub-system
- Work that continues
  - Finding bad lock constructs
  - Continue removal of per-CPU lock in local_bh_disable()
- Make sure to report bugs, because testing real use cases can expose bad latencies on certain code paths

Realtime - PREEMPT_RT history and status

- Great retrospectives on the history of the PREEMPT_RT patch
  - At Kernel Recipes
  - "PREEMPT_RT over the years" by Sebastian A. Siewior
    - See https://kernel-recipes.org/en/2024/schedule/preempt_rt-over-the-years/
    - History of various RT-related patches and features from 2005
    - Examples of commercial/industrial users of PREEMPT_RT
      - Including realtime potato filtering, and laser welders
  - See "Making the kernel suck less" by Steve Rostedt
    - https://kernel-recipes.org/en/2024/schedule/making-the-kernel-suck-less/

Realtime - PREEMPT_RT – what's next

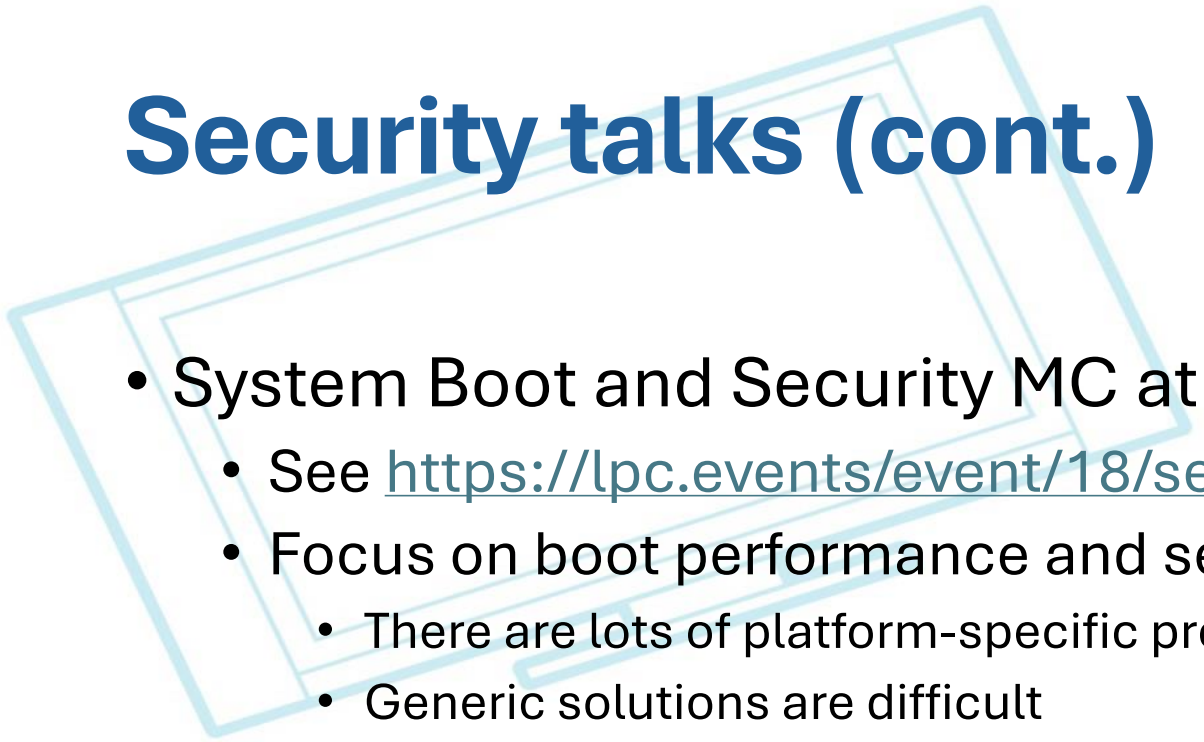
- Current research, tools and analysis of Linux Realtime
  - See the Realtime Micro-conference at Linux Plumbers 2024
  - https://lpc.events/event/18/sessions/195/#20240919
    - Note that realtime MC starts at 5hours, 30 minutes in the live stream recording
- Analyzing realtime behaviour of applications
  - with modeling
  - with new tools (rteval and others)
- Need semantic analysis of application requirements
  - e.g. calling read() system call may violate RT or not, depending on situation
  - maybe create annotation system to help app developers avoid mistakes
- More work needed on thread starvation and priority inversion avoidance

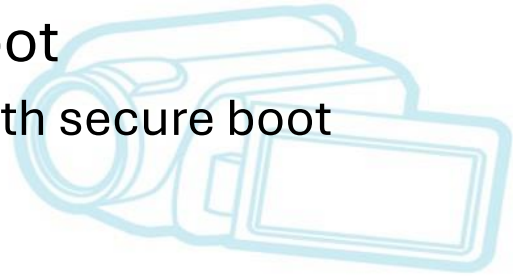
Security

- Steady stream of security-related fixes in all kernel releases
  - Any bugfix is a security fix
- Proposal to use hashing instead of signing for secure module loading
  - Uses hash list embedded in kernel, instead of crypto keys, to validate modules
  - Allows for reproducible builds (automatic signing key generation breaks reproducibility)
    - BUT, embedding the hast list requires modules to be built at same time as kernel
  - See https://lwn.net/Articles/1012946/

Security talks (cont.)

- System Boot and Security MC at Plumbers
  - See https://lpc.events/event/18/sessions/201
  - Focus on boot performance and secure boot
    - There are lots of platform-specific problems with secure boot
    - Generic solutions are difficult





Security talks (cont.)

- "Security Features status update" (plumbers)
  - See https://lpc.events/event/18/contributions/1920/
  - Review of features provided by toolchains for securing the Linux kernel

2024 security features review

	GCC	Clang	RustC
zero call-used registers	yes	yes	needed
structure layout randomization	plugin	yes	needed
stack protector guard location	arm64 arm32 riscv ppc	arm64 arm32 riscv ppc	N/A
forward edge CFI	CPU needed	CPU inline hash	in progress
backward edge CFI	CPU SCS:arm64 inline	CPU SCS:arm64 inline	SCS:arm64
`-fstrict-flex-arrays`	yes	yes	yes
FAM `counted_by` attribute	yes	yes	???
FAM in unions	yes	yes	N/A
unexpected integer wrapping	broken	broken	exists
`-fbounds-safety`	needed	in progress	N/A

Testing

- Linux Test Project
  - Latest release: 20250130
  - Changes in timeout and runtime handling
  - Lots of new tests, fixes, etc.
  - LTP now included in Valgrind
    - See https://www.mail-archive.com/valgrind-users@lists.sourceforge.net/msg07691.html
  - LTP devs working on reproducible test output format (easily diff'ed?)
- Revived "Automated Testing Summit"
  - For testing people to share automation and CI/CD developments and experience
  - Co-located with Open Source Summit North America (June in Denver)

Testing (talks)

- Board farm talks at ELCE 2024
- Testing MC at Plumbers 2024
  - See https://lpc.events/event/18/sessions/189/
  - Some Topics:
    - Adding benchmark results support to KTAP
    - Standardizing KTAP tooling
    - Device-tree device testing
    - Analysis of existing kernel test coverage (it's not great)
      - See "Measuring and Understanding Linux Kernel Tests"
    - Recent work in KernelCI, and how to convert CI results into actionable reports

Toolchain track at Plumbers

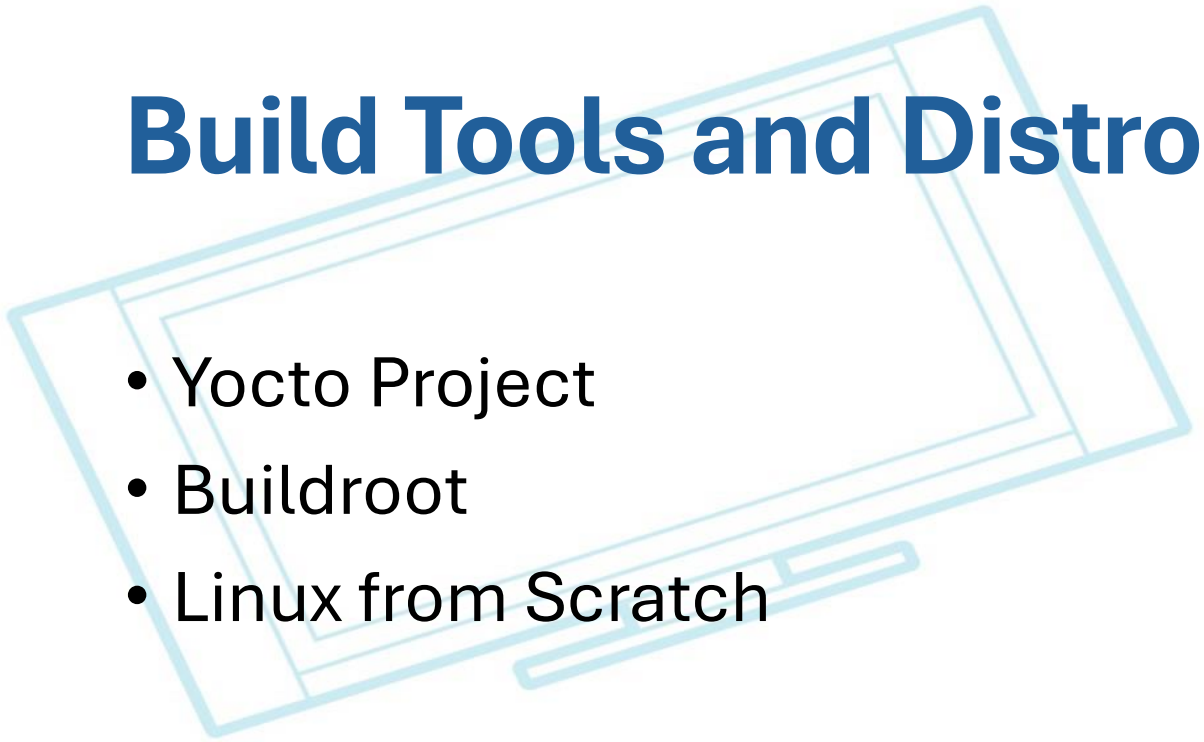
- Talks/discussions:
  - Binary optimizations: BOLT
  - FDO (feedback directed optimizations) and AutoFDO
  - Compiler support for security features
  - Tools for build environments (tuxmake, etc.)
  - Remote build services
  - and more
- See https://lpc.events/event/18/sessions/180

Tracing

- "Advanced System Profiling, Tracing and Trace Analysis with Perfetto in Android and Yocto" (ELCE 2024)
  - by Anna-Lena Marx and Stefan Lengfeld
  - Nice tool by Google to view trace data for Linux
  - Available as a layer in Yocto Project
- Persistent traces across a reboot or crash
  - Patch set by Steven Rostedt
  - Allows ftrace buffers to be placed in memory that survives a reboot
  - Can read trace data from previous instance of kernel
  - See https://lore.kernel.org/all/20240612021642.941740855@goodmis.org/
  - Looks like it went in to v6.12 (or 6.11?)

Build Tools and Distros

- Yocto Project
- Buildroot
- Linux from Scratch



Build Tools and Distros

- Yocto Project
  - Latest = 5.2 (Walnascar), released May, 2025
    - Is NOT an LTS (Long Term Support) release
    - Looks like a general bugfix release
      - Documentation and ref-manual fixes
    - See https://downloads.yoctoproject.org/releases/yocto/yocto-5.2/RELEASENOTES
  - For Scarthgap (5.0) migration guide, see
    - https://docs.yoctoproject.org/next/migration-guides/release-notes-5.0.html
  - See https://www.yoctoproject.org/community/events/ for online training
- More status later today

Yocto Project quick setup

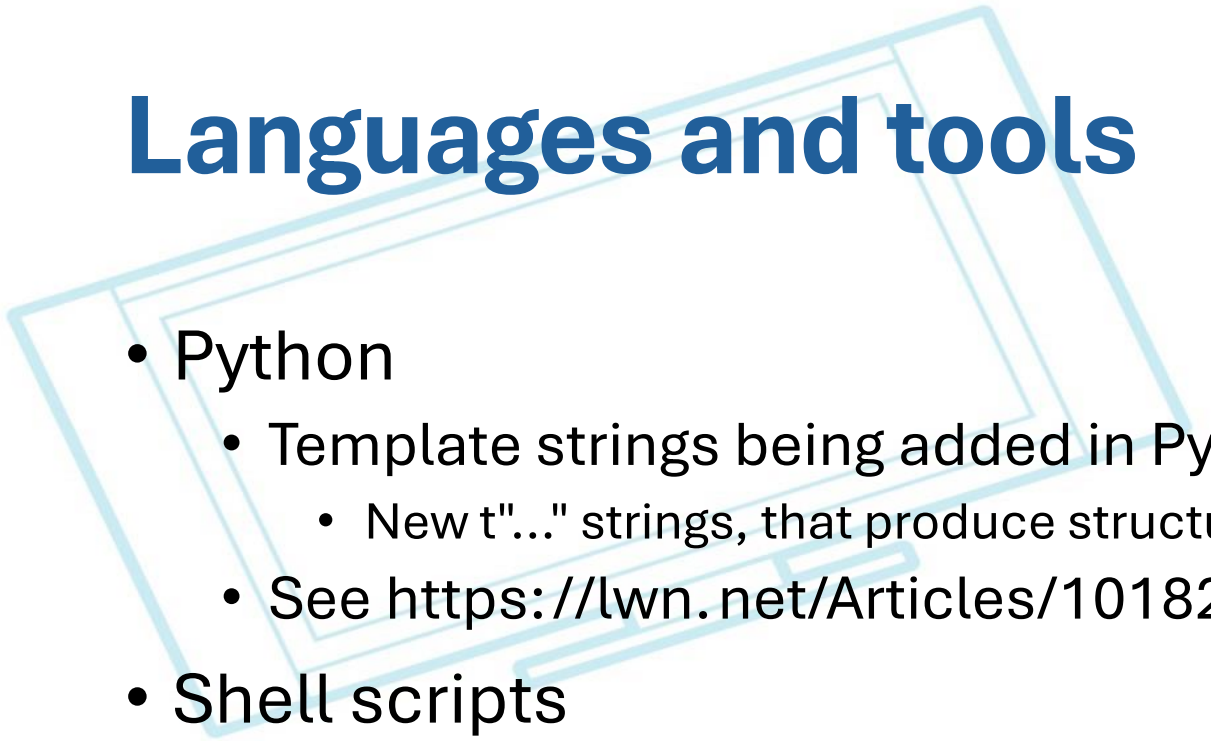
- There are three ways to do quick setup for a YP project
- KAS
  - Mature 3rd party tool to download layers and set config based on a single file
  - It's active, and there are KAS config files available (for some distros/boards)
  - See https://kas.readthedocs.io/en/latest/
- bitbake-setup
  - Similar to KAS - Allows selection from a list of existing configs
  - Status: Patches are in flight, some parts already in YP mainline
  - See https://lists.openembedded.org/g/openembedded-architecture/message/1913 for design ideas
- CROPS – Containerized instance of YP, ready to build
  - Supports multiple host environments (Windows, Linux, Mac)

Buildroot

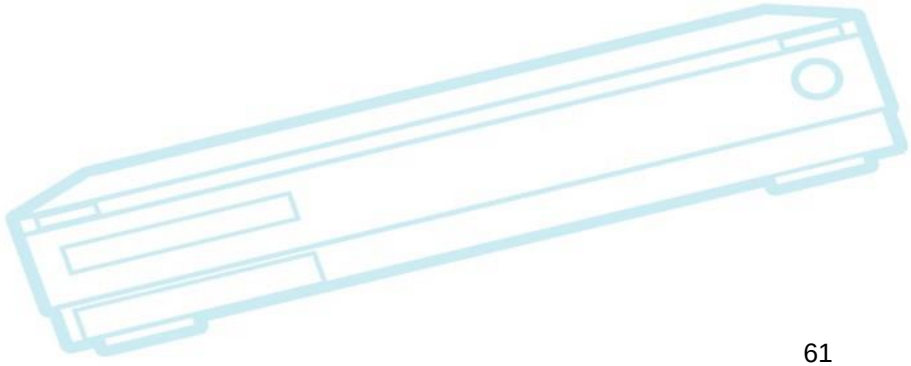
- Latest = 2025.02.01 bugfix release (April 2025)
  - Fixes some security issues from the 2025.02 release
- See https://buildroot.org/news.html

Languages and tools

- Python
  - Template strings being added in Python 3.14
    - New t"..." strings, that produce structured data, allowing custom handling logic
  - See https://lwn.net/Articles/1018297/
- Shell scripts
  - Work on static analysis to detect bugs in shell scripts before execution
  - See https://www.theregister.com/2025/04/30/shell_script_code_correctness



Outline



Linux Kernel
Technology Areas
Industry News
Community
Conclusions

Industry News

- Trade Associations
- Miscelaneous

Linux Foundation projects

- Linux Foundation
  - Automotive Grade Linux (AGL) – handles automotive vertical
  - Civil Infrastructure Platform (CIP) – handles support longevity
  - Core Embedded Linux Project – is shutting down
  - DroneCode – handles drone vertical
  - ELISA – handled issues with safety certification and standards
    - Space Grade Linux – more later
  - KernelCI – handles automated testing (for upstream)
  - OpenChain – handles issues with entities in the supply chain
  - OpenSSF – working on security throughout OSS ecosystem
  - Yocto Project – build system for embedded OSS (not just Linux)

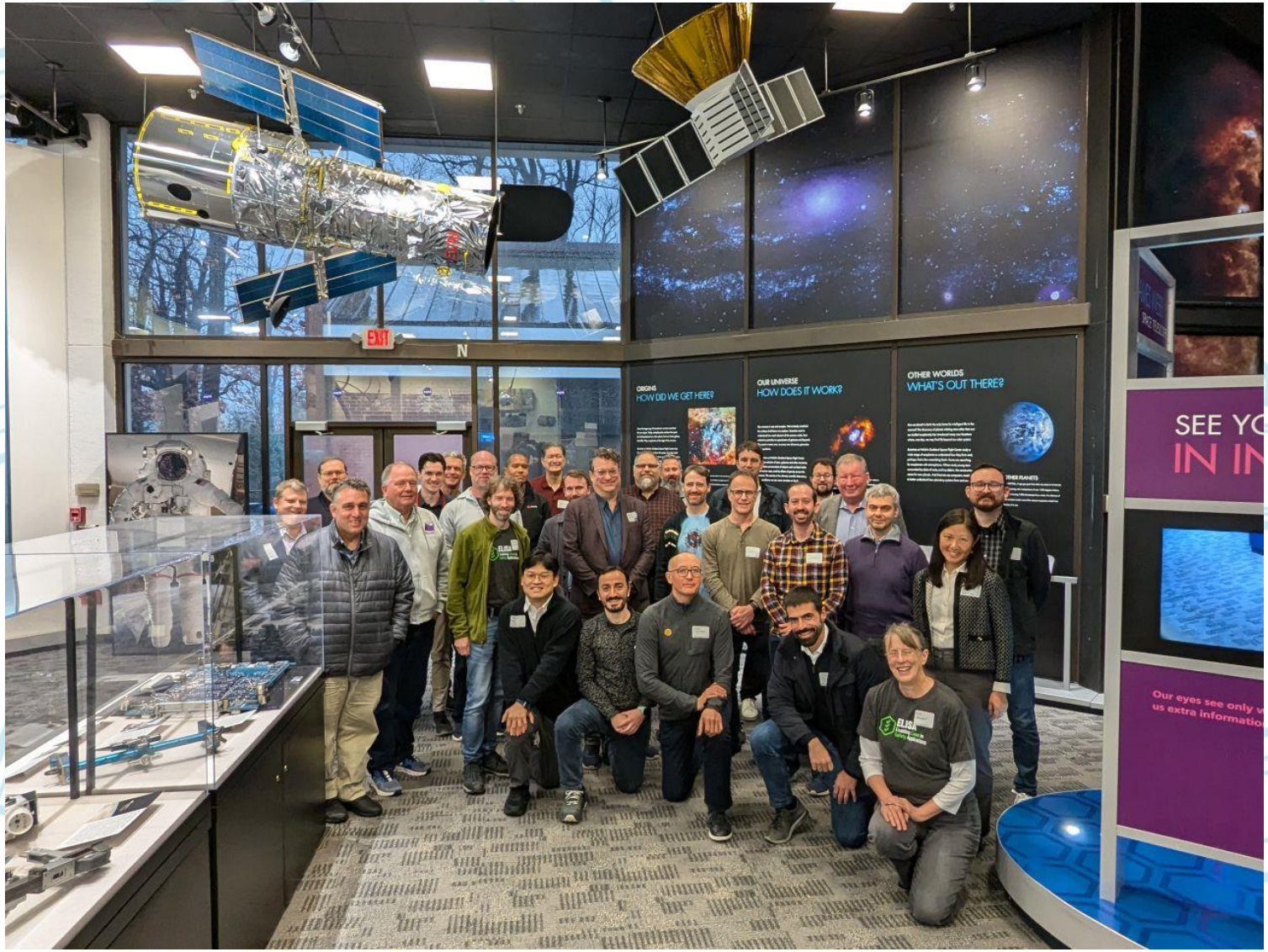
Automotive Grade Linux (AGL)

- Check out keynotes by Honda and AGL at OSSJ
  - See https://events.linuxfoundation.org/open-source-summit-japan/program/schedule/
- "AGL Roadmap Update" by Walt Miner at OSSJ
  - Millions of vehicles on the road with AGL
  - YP 5.0, more Flutter, Support for Raspberry Pi 5
  - https://ossaidevjapan24.sched.com/event/1jKg0
- "Super Salmon" release in February, 2025
  - YP scarthgap support
  - Flutter update to 3.27.1, Qt updates to Qt6
  - BSP updates and new BPS for tegra and rockchip

SGL in ELISA (Enabling Linux in Safety Applications)

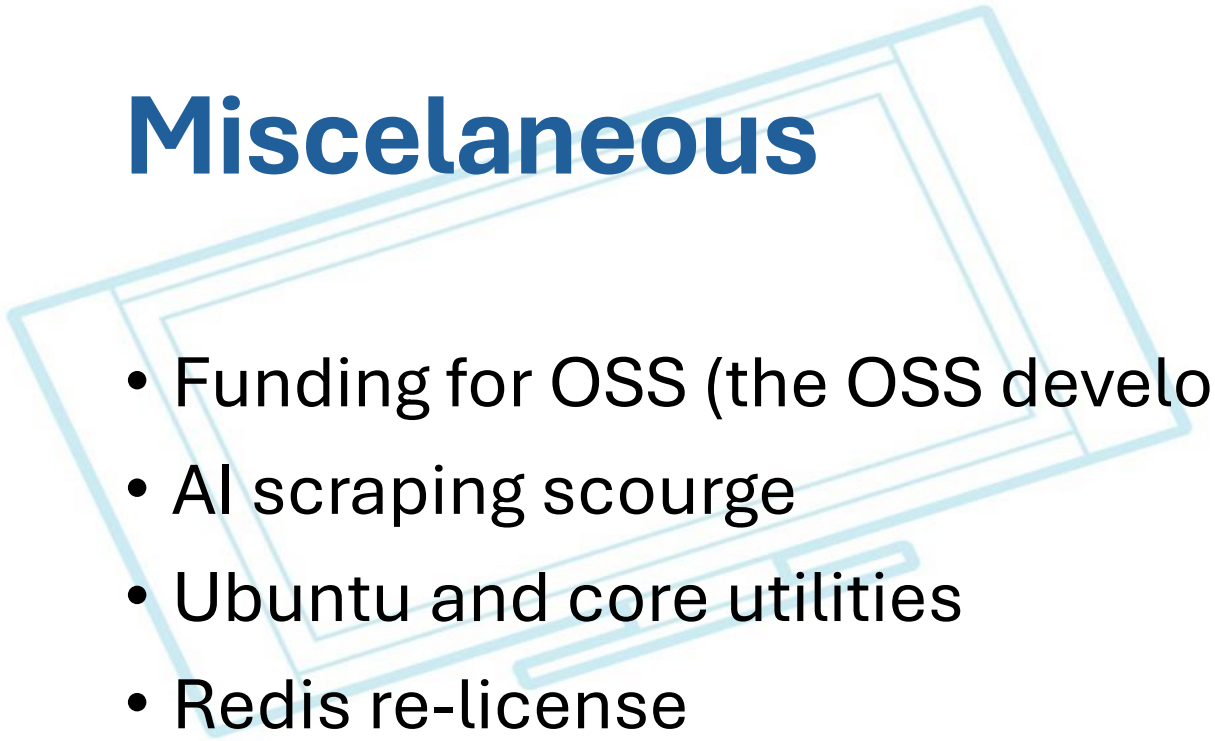
- Progress by Aerospace Workgroup
  - Workshop hosted by NASA in December
    - Expect presentations and videos soon
    - See https://elisa.tech/event/elisa-workshop-at-nasa-goddard-space-grade-linux/
  - Starting the 'meta-sgl' repository to create a Yocto distribution for space missions
    - "SGL" = Space Grade Linux

Space Grade Linux – how it started...



Miscelaneous

- Funding for OSS (the OSS developer support pledge)
- AI scraping scourge
- Ubuntu and core utilities
- Redis re-license
- Intel and Tech Stocks worries
- Nvidia Linux-based ARM/AI laptop



OSS Developer Support Pledge

- Initiative to have companies pledge money for OSS developers, based on their company size
  - Companies commit to pay $2000 per year per company engineer into a fund for OSS developers
  - See https://opensourcepledge.com/about

- Several methods are being tried to solve issue of funding OSS developers
  - Another one is a license change: Post-Open License
    - by Bruce Perens (one of the originators of OSI)

AI scraping causing OSS problems

- Too many AI systems are scraping OSS projects and public sites
  - Scraping is for training data, and the scrapers are not well-behaved
    - Change IP address, lie about their agent, don't observe 'do-not-access' standards
    - Scrape very often (every few days, when content has not changed)
    - Scrape full site (e.g. every git commit)
  - 75% of the the traffic to readthedocs.io was scrapers
    - Extra traffic costs real money: $1500 per month
- Amounts to a DDoS attack
- Some sites are blocking entire countries
- See https://arstechnica.com/ai/2025/03/devs-say-ai-crawlers-dominate-traffic-forcing-blocks-on-entire-countries/

AI problems (cont.)

- LWN.net also affected (and lore.kernel.org?)
  - Solutions like robots.txt, throttling, and tarpits have proven hard
  - It's not desirable to add gatekeeping: JavaScript, challenges, or limiting access to accounts
  - See https://lwn.net/Articles/1008897/
- lore.kernel.org has a new human-detector
- It's not just scraping, fake content is a problem:
  - curl has reported a flood of invalid AI-generated bug reports
  - stackoverflow has issues with incorrect AI-generated content

Ubuntu change in core utilities

- Ubuntu is allowing users to experiment with testing of Rust core command-line utilities for their Linux distribution
  - New tool (oxidizr) lets you test Rust-based utilities on current Ubuntu
- Changing core utilities is a big task
  - They've been around for over 20 years
- Has potential licensing ramifications
  - Rust utilities are MIT while (coreutils, findutils, and diffutils) are GPL.
- See https://lwn.net/Articles/1014002/

Redis re-license

- Redis switched to Server Side Public License (SSPL) in March 2024
- Community and industry created a fork under BSD 3-clause, called Valkey
- Redis now being offered under AGPLv3
- See https://lwn.net/Articles/1019686

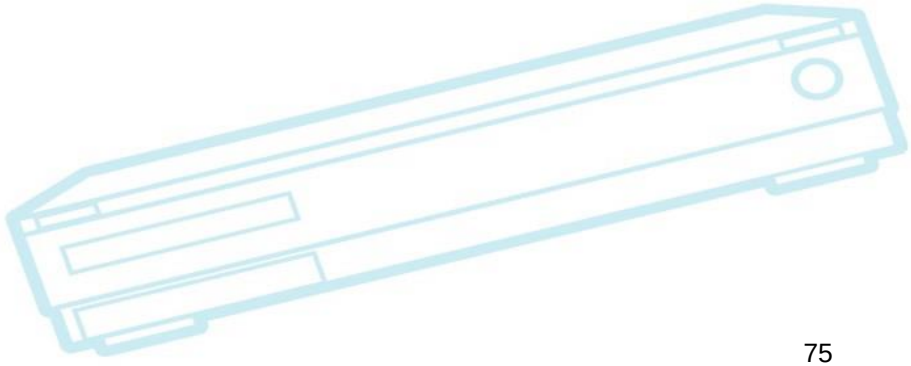
Intel and Tech Stocks worries

- Intel lost $16B in 2024 Q3
  - See https://www.tomshardware.com/pc-components/cpus/intel-lost-usd16-6-billion-in-q3-reports-usd13-3-billion-in-revenue
- Intel market cap at end of 2024 was $82B
- Meanwhile, Nvidia market cap at end of 2024 was $3.5T
- Some concerns about Tech predominance (Mag 7) on index stocks (e.g. S&P 500) in the US
  - Mag 7 = Apple, Amazon, Alphabet, Meta, Microsoft, Nvidia and Tesla
  - Mag 7 stocks make up about 31% of the value of the S&P 500 index

Nvidia Linux-based ARM/AI Desktop Computer

- At CES, Nvidia announced Project DIGITS
- $3000 device containing a GB10 Blackwell chip
  - 20-core CPU based on ARM architecture
  - 128GB of unified RAM and up to 4TB of storage
- Main purpose seems to be to allow developers to run AI models locally
  - Can handle models with up to 200B parameters
  - Can link 2 units to handle up to 405B parameters
- Runs DGX OS (a derivative of Ubuntu 22.04)
- See https://arstechnica.com/ai/2025/01/nvidias-first-desktop-pc-can-run-local-ai-models-for-3000/

Outline



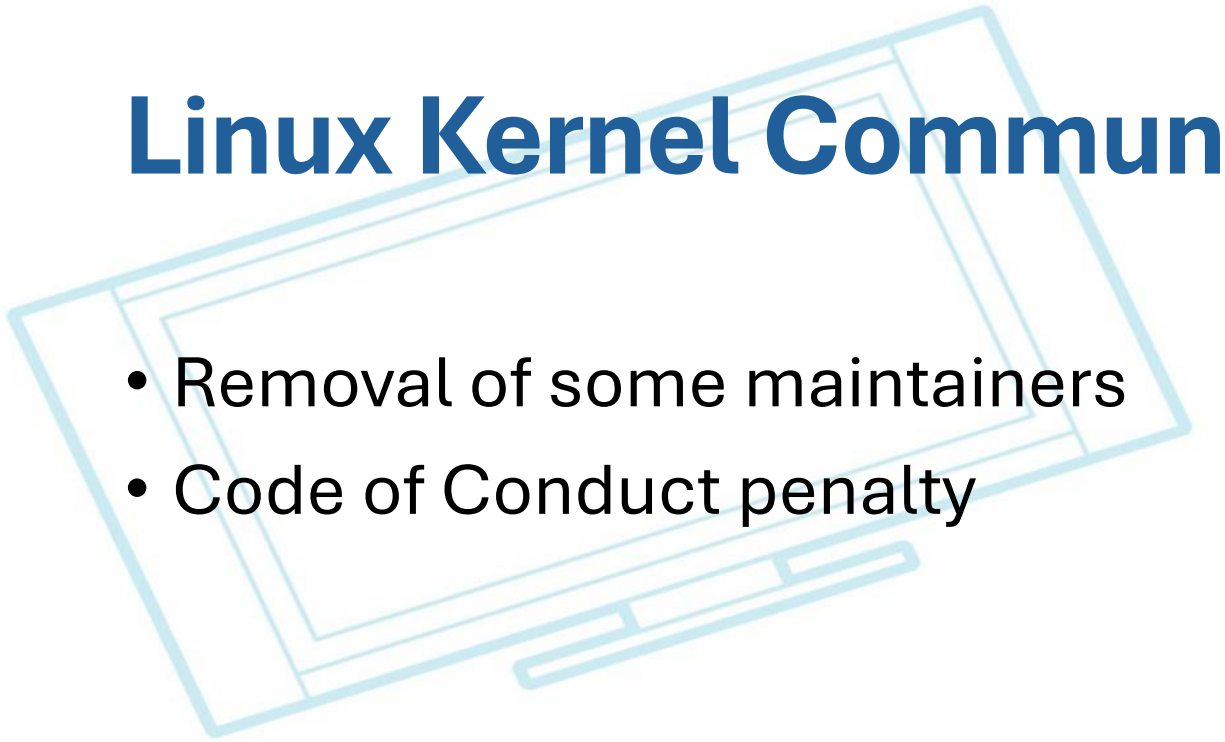
Linux Kernel
Technology Areas
Industry News
Community
Conclusions

Community

- Linux kernel community issues
- Conferences
- Elinux wiki

Linux Kernel Community Issues

- Removal of some maintainers
- Code of Conduct penalty



Removal of some maintainers

- Big kerfluffle in October about removal of "Russian" Linux maintainers from the kernel's MAINTAINERS file
  - See https://www.phoronix.com/news/Linus-Torvalds-Russian-Devs
  - See https://lwn.net/Articles/995186/
- Patch removing maintainers seemed to be delivered without much explanation
- This caused:
  - Complaints about lack of explanation
  - Speculation and mis-information about the scope of the change and reasons for it
- Was not a removal of Russian nationals, but of individual developers who worked for specific Russian companies (or their subsidiaries)
  - Not all Russian nationals were removed, and one maintainer was reinstated after showing evidence of a different employer

Removal of some maintainers – cont.

- Actual legal advice (policy?) was stated later, by James Bottomley:
  - "If your company is on the U.S. OFAC SDN lists, subject to an OFAC sanctions
  - program, or owned/controlled by a company on the list, our ability to collaborate
  - with you will be subject to restrictions, and you cannot be in the MAINTAINERS file."
- OFAC SDN list = Office of Foreign Assets Control Specially Designated Nationals list
  - OFAC Is part of the US Treasury department, and manages US sanctions with foreign entities
- Linus and Greg (and the Linux Foundation) don't have the option to ignore US law
- Good description of policy here:
  - https://www.phoronix.com/news/Linux-Compliance-Requirements

Code of Conduct penalty

- In November, the LF Technical Advisory Board imposed a ban on a kernel developer
  - Restriction is to "decline all pull requests" from the developer
  - The bcachfs filesystem was the affected sub-system
  - Ban was temporary, lasting 1 release (about 2.5 months)
  - Was based on an unfortunate mail exchange and failure to "publicly apologize"
- The penalty was very rare
  - Extremely uncommon for the CoC committee to recommend a penalty
  - See https://www.kernel.org/code-of-conduct.html for previous CoC committee reports
- See https://lwn.net/Articles/999197/
- Developer apologized and continued working in Linux after the penalty expired

Conferences

- Recent
  - Open Source Summit Japan
  - FOSDEM
  - Linaro Connect (this week)
  - Embedded Recipes
- Coming Soon
- Coming Later

Conferences in 2025 (coming soon)

- Embedded Linux Conference
  - With Open Source Summit North America
  - June 23-25, 2025 in Denver, Colorado, USA
- ELC Europe
  - With Open Source Summit Europe
  - August 25-27, 2025 in Amsterdam, The Netherlands
  - ELC 20th anniversary celebration is planned!
- NOTE: We tried a single CFP for both events
  - It was confusing and didn't work. We ended up splitting the CFPs.

Conferences in late 2025

- Open Source Summit Japan
  - Dec 8-10, 2025 in Tokyo, Japan
  - See https://events.linuxfoundation.org/open-source-summit-japan-2025/
- Linux Plumbers Conference
  - Dec 11-13, 2025 in Tokyo, Japan (!!)
  - Note: This is Thursday through Saturday
  - See https://lpc.events/
- Both events will be at Toronomon Hills, like last year OSSJ

About Plumbers in Japan

- Plumbers in Japan:
  - Hosting in Japan is an exception to the normal pattern of alternating between US and Europe
  - We're worried about number of attendees and sponsorships
- LPC is a weird combination of kernel developer staff meetings and contributor/user learning opportunities
- Looking for sponsors for LPC
  - Prospectus at: https://events.linuxfoundation.org/wp-content/uploads/2025/01/sponsor-plumberscon25_010625.pdf

Elinux wiki

- Site is still used for:
  - Materials for embedded Linux development boards
  - Some academics use it for coursework
  - Event materials: slides and links to videos for ELC
- Some areas of the site are out-of-date
- The site is underutilized for sharing information
- OSUOSL is low on funding
  - See https://osuosl.org/blog/osl-future/
- Have set up an LFX Crowdfunding site
  - https://crowdfunding.lfx.linuxfoundation.org/initiative/5fa1a40a-d4f0-4576-81c6-57319a591a87
  - Have $10,000 that can be spent to improve site or generate content

Outline

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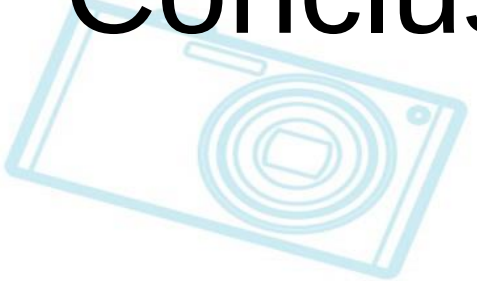
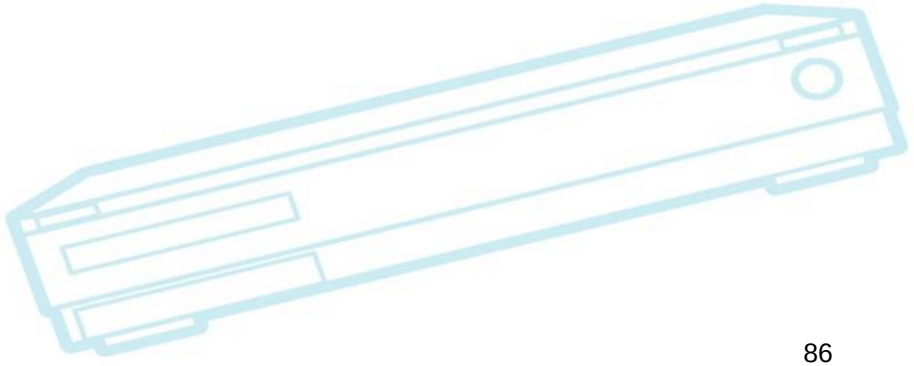
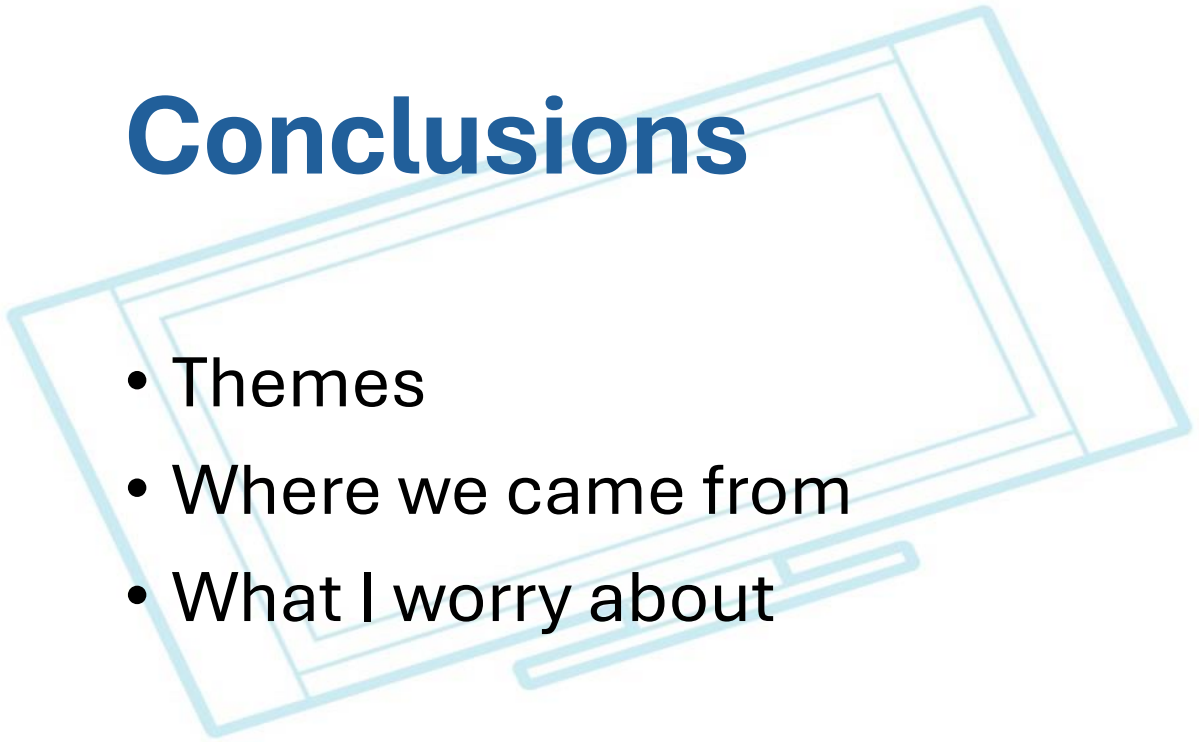



Conclusions

- Themes
- Where we came from
- What I worry about

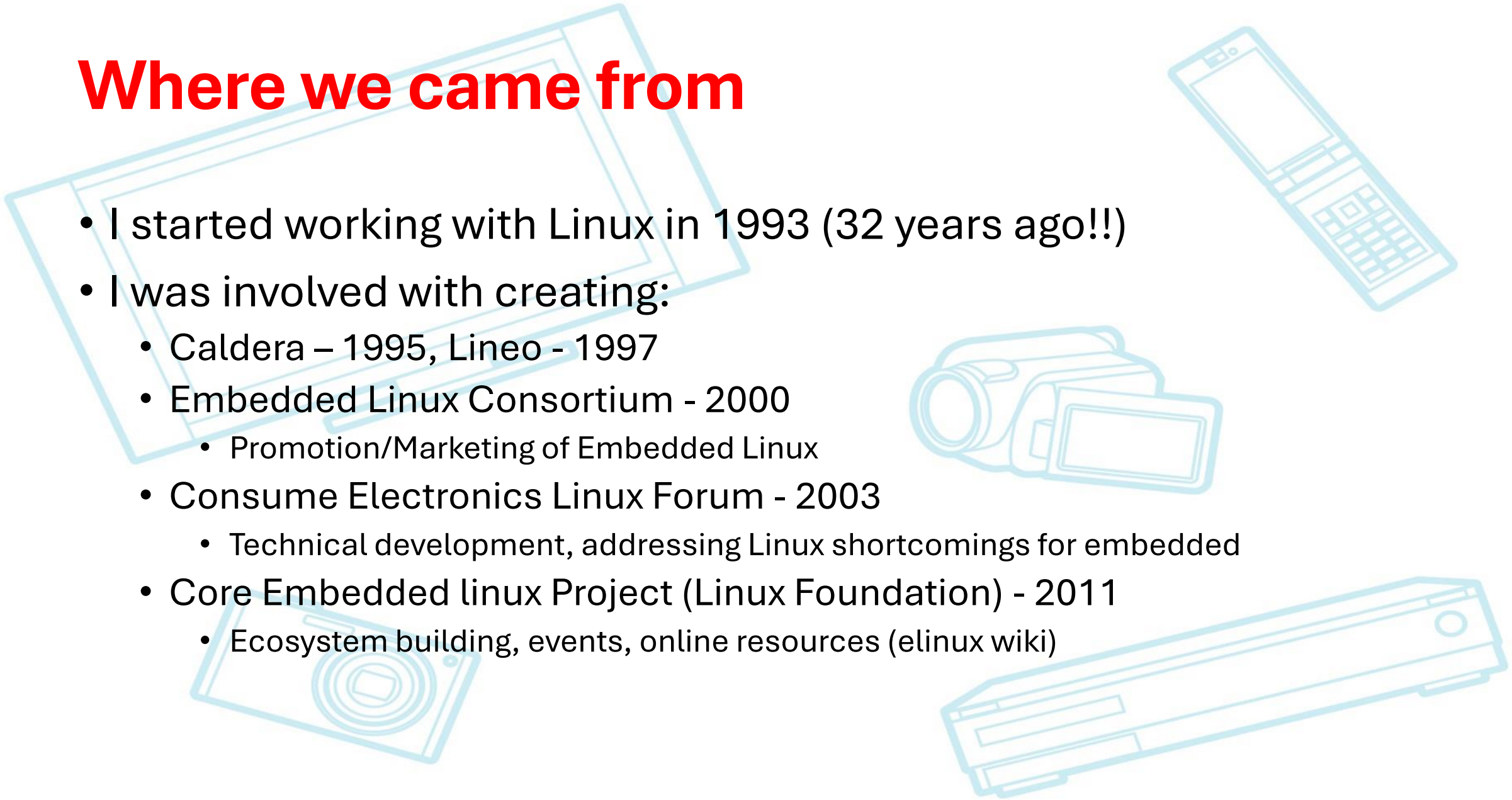


Themes

- AI is upon us
  - Was not on my bingo card for this decade
- Use of tools, compiler features, automation to address robustness and security
  - FDO, thread annotations, automated testing, the rise of RUST
- Community is more mature, professional, and friendly
  - Stuff happens in the background that we sometimes don't acknowledge or appreciate
  - Have an active code of conduct committee
  - Linux Foundation acts as Linux's: Legal, HR, IT, Marketing, Intellectual Property (IP), Payroll, and Accounting departments, …and more.
    - Fills essential roles that are missing from many other OSS projects

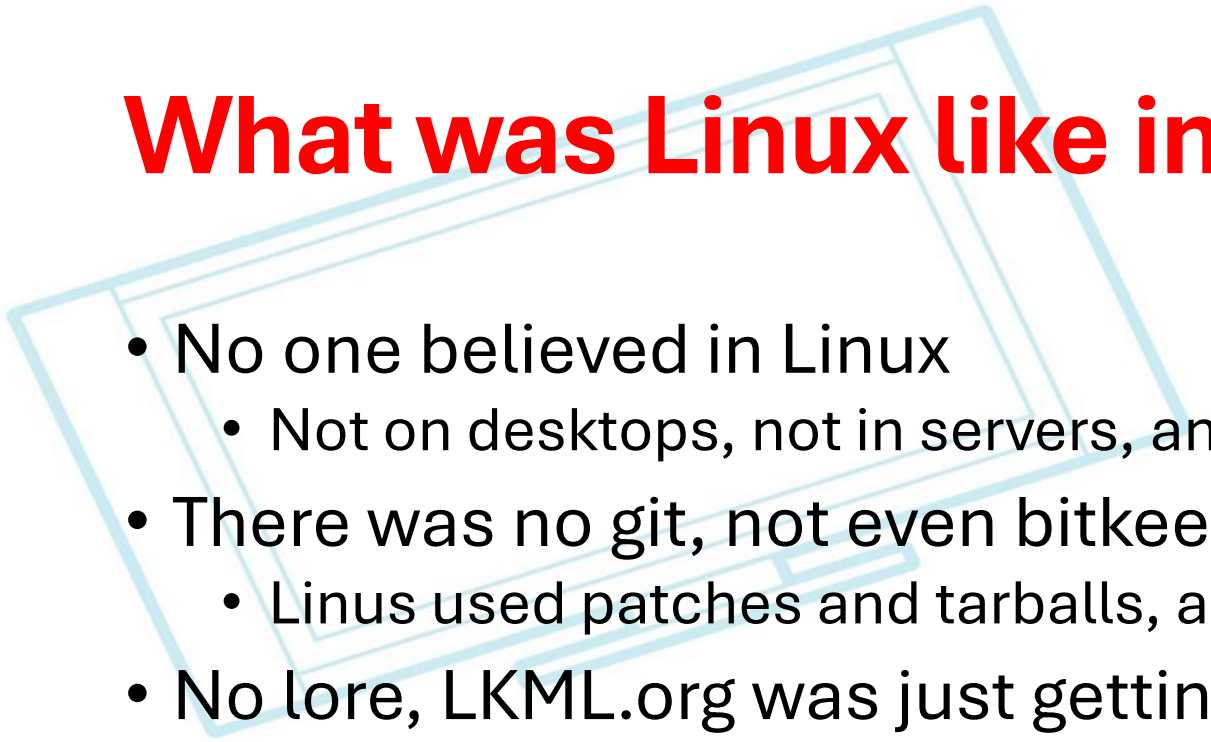
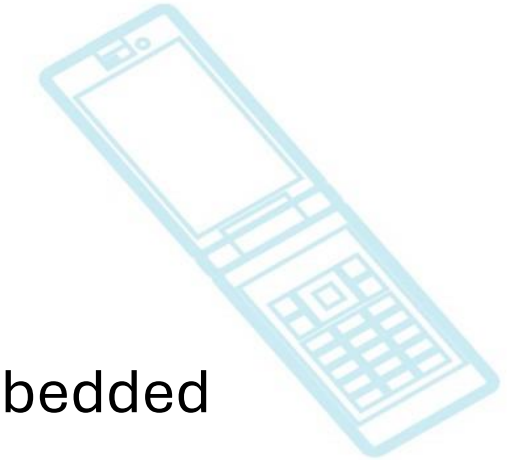
Where we came from

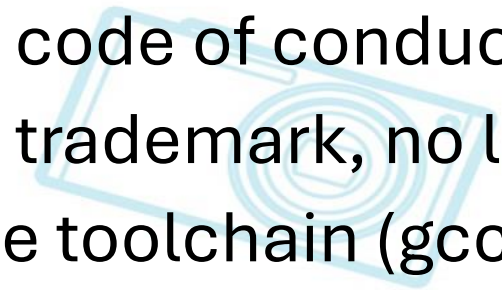
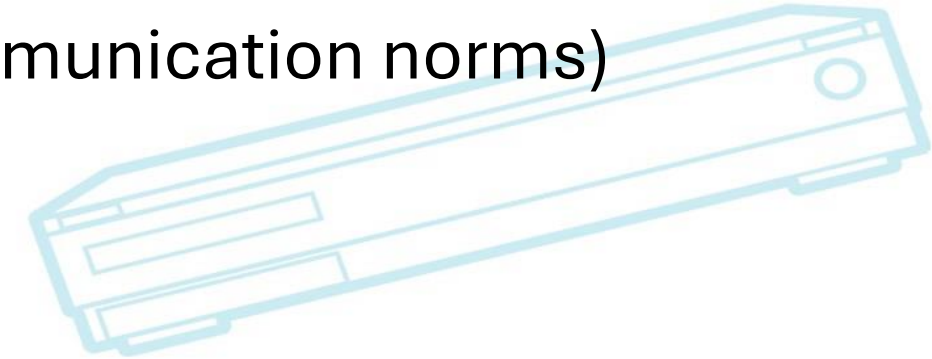
- I started working with Linux in 1993 (32 years ago!!)
- I was involved with creating:
  - Caldera – 1995, Lineo - 1997
  - Embedded Linux Consortium - 2000
    - Promotion/Marketing of Embedded Linux
  - Consume Electronics Linux Forum - 2003
    - Technical development, addressing Linux shortcomings for embedded
  - Core Embedded linux Project (Linux Foundation) - 2011
    - Ecosystem building, events, online resources (elinux wiki)



What was Linux like in the 90's?

- No one believed in Linux
  - Not on desktops, not in servers, and especially not in embedded
- There was no git, not even bitkeeper yet
  - Linus used patches and tarballs, and e-mail only
- No lore, LKML.org was just getting started (no Google)
- No methodical release process
  - Ad hoc releases
- No code of conduct (but there were communication norms)
- No trademark, no legal protection
- One toolchain (gcc)

What I worry about

- AI – will it help or hinder?
  - AI is putting stress on open source ecosystems
  - AI is introducing a new tragedy of the commons
  - So far, AI is good at copying and not good at creating new technology
- Maintainers
  - Will we have enough as the old guard ages out?
    - Recently seen more new, young maintainers – that's great
- Will tools break the network effects?, or improve test coverage?
  - Automated changes are a two-edged sword. After FDO, the kernel being run can be quite different than what the the other 2.5 billion Linux machines are running.
  - This might break network effects
- Some things still take too much effort

Conclusions

- Overall – we're doing very well
  - Embedded Linux is widely deployed and functional (billions of devices)
- Core kernel systems are in place to support embedded
  - But new hardware keeps being made
  - Some areas (like space) still have barriers to Linux adoption
- I can't believe we're not done yet

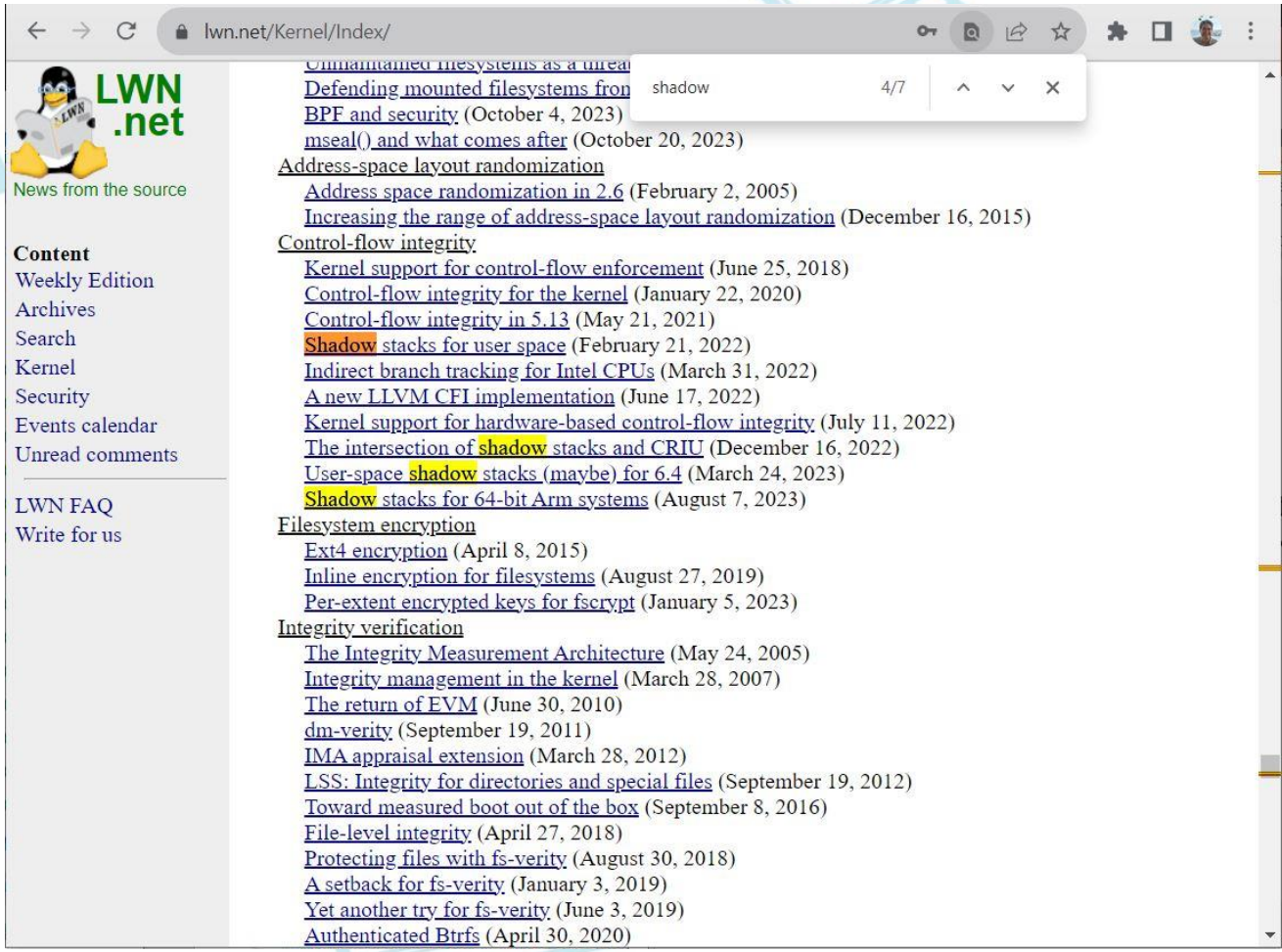
- What's left to do? (besides hardware enablement?)

Resources

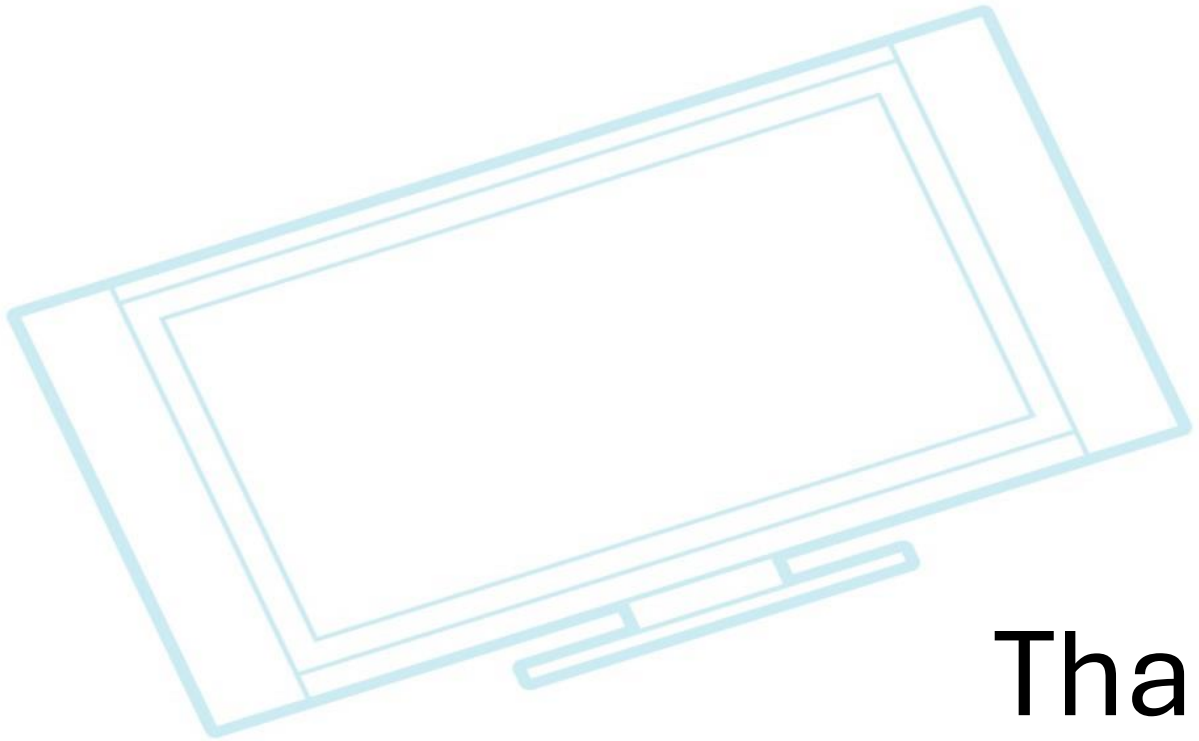
- Lwn.net
  - https://lwn.net
- Phoronix
  - https:/phoronix.com
- Kernel Newbies
  - e.g. https://kernelnewbies.org/Linux_6.9
- Elinux wiki:
  - https://elinux.org
  - Especially the event pages: https://elinux.org/ELC_Presentations
- Linux Foundation Newsletters
- Kernel Mailing lists
- Google
- Check: https://embeddedlinuxconference.com/ for event info

LWN.net Resource for Kernel Information

- LWN.net Kernel Index
  - Has many years of articles
  - Sorted by kernel subsystem and topic
- https://lwn.net/Kernel/Index/



- While we're talking about LWN.net
  - Funding could use a boost
  - Please pay for a subscription
  - See https://lwn.net/Articles/1019217



Thanks!