CE Workgroup

Embedded Linux Community Update

March 2021

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Principal Software Engineer, Sony Electronics

Nature of this talk…

- Quick overview of lots of embedded topics
- A springboard for further research
  - If you see something interesting, you have a link or something to search for
- Some overlap with material given previously
  - I may go quickly over some older slides
- Not comprehensive!
  - Just stuff that I saw

Outline

Linux Kernel
Technology Areas
Conferences
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Resources

Outline

Linux Kernel

Technology Areas

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Kernel Versions

- Linux v5.6 – 29 Mar 2020 – 63 days
- Linux v5.7 – 31 May 2020 – 63 days
- Linux v5.8 – 2 Aug 2020 – 63 days
- Linux v5.9 – 11 Oct 2020 – 70 days
- Linux v5.10 – 13 Dec 2020 – 63 days
- Linux v5.11 – 14 Feb 2021 – 63 days
- Linux v5.12-rc2 = current kernel this week
  - Expect 5.12 on April 18, 2021

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  - Expect 5.12 on April 18, 2021
  - v5.12 merge window delayed a few days due to power outages related to a winter storm in Oregon

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  - Expect 5.12 on April 18, 2021
- ***Note: There's no discernable impact from COVID-19***

Linux v5.6 (March 2020)

- WireGuard VPN feature added to kernel
- Work on 2038 issues for ALSA
  - New 64-bit structure for some operations
- Mechanism to disable SELinux at module load time (system runtime) is deprecated
  - Plan is to add a painful delay (increasing with each kernel release) in order to discourage future use
- Bootconfig tool to add super-long command-lines arguments to kernel
- F2FS gained support for compression

Linux v5.7 (May 2020)

- Pointer authentication and return-address signing added for ARM64
- Thermal events can effect scheduling
  - scheduler takes into account thermal status and tries to reduce load on hot CPUs
  - https://lwn.net/Articles/788380/
- exFAT fs module in staging was removed
  - Replaced with a new version better integrated into existing filesystem subsystem
    - New version contributed by Samsung
- Kunit results can now be output on debugfs

Linux v5.7 (cont.)

- BPF and PREEMP_RT can now coexist
- LLVM support integrated into kernel build system
  - Can use LLVM=1 on make command line
    - May also need LLVM_IAS=1 as well to use LLVM assembler

Linux v5.8 (Aug 2020)

- Inline encryption for filesystems (more later)
- kgdb can now work with the boot console
  - Allows debugging earlier in the boot process
- A new generic kernel event notification system was added (more on this later)

Linux v5.9 (Oct 2020)

- new debugfs= command line option allows disabling debugfs (using ‘off’)
  - To avoid disclosing sensitive data
  - Or, it can be left enabled but not mountable with (‘no-mount’)
    - Data can still be read with a debugger
- Removed uninitialized_var() macro
- initrd is deprecated (in favor of initramfs, which everyone calls initrd)
- close_range() – new syscall to close a group of file descriptors

Linux v5.10 (Dec 2020)

- static calls patches finally merged
  - Allows for indirect call that can be updated at runtime (via static_call_update())
    - Good for tracing, and maybe other stuff
  - See https://lwn.net/Articles/774743/#static
- printk has a new lockless ring buffer
  - Part of a long-term overhaul of printk
  - See https://lwn.net/Articles/800946/
- ext4 filesystem has a new “fast commits” mode (more on this later)

Linux v5.11 (Feb 2021)

- New system-call interception mechanism based on prctl()
  - Used for emulating Windows system calls
  - See https://lwn.net/Articles/826313/
- epoll_pwait2() – new syscall that supports nanosecond timeouts
- Ability to disable process migration between CPUs (more on this later)

Linux v5.12 (Apr 2021?)

- Support for oprofile removed
  - superceded by perf events
- “PREEMPT_DYNAMIC” allows selecting preemption mode at boot or run time
- Dynamic thermal power management
  - Allow power usage of groups of devices to be capped to meet thermal constraints
- Support for Playstation DualSense game controllers *(yeah Sony!)*

Linux v5.12 (cont.)

- Build system can use Clang's link-time optimization (LTO) features on ARM64 and x86 architectures
- kfence memory debugging tool has been added
- Some new perf-events features:
  - Can report on instruction latency
  - Daemon mode for long-running sessions
  - See https://git.kernel.org/pub/scm/linux/kernel/git/torvalds/linux.git/commit/?id=3a36281a1719

Drama in the 5.12 merge window

- Linus marked rc1 as “don’t use”, because it had a bug that could corrupt your filesystem
  - Had to do with a bad offset in a swapfile
    - swap partitions were OK, which is what most people use (but Phoronix and Intel saw it in test systems)
    - It’s bad to mess up people’s filesystems, even for a release-candidate kernel
  - Don’t use Linux version “v5.12-rc1-dontuse”
- Problem was quickly fixed
  - https://lwn.net/Articles/848431/
    - “Occasionally, though, something goes wrong, giving early testers reason to reconsider their life choices”

Interesting Maintainer stats

- What companies are employing maintainers?
  - The top 5 employers supporting maintainers
    - That is, developers with non-author commit signoffs

Employer	Non-author sign-offs	Percent
Red Hat	2560	19.3%
Linaro	1377	10.4%
Intel	986	7.4%
Linux Foundation	878	6.6%
Google	787	5.9%

- Almost half of all patches go through gatekeepers at just 5 companies

- Table data: https://lwn.net/Articles/821813/

Active Contributors

- For 5.11 kernel, top contributors seem to be trending towards hardware companies:
  - Top 13 = Intel, Linaro, Red Hat, AMD, Huawei, Google, SUSE, IBM, NVIDIA, Facebook, ARM, Samsung, NXP
    - Side note: *MediaTek had 19K lines of changes in 5.11*
- Top individual contributors by sub-system in last year:
  - kernel: Paul McKenney, Peter Zijlstra, Christoph Hellwig
  - mm: Christoph Hellwig, Matthew Wilcox, David Hildenbrand, Wei Yang
  - fs: Pavel Begunkox, Christoph Hellwig, Jex Axboe, Darrick Wong
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- See https://lwn.net/Articles/845831/ for details

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Linux Foundation OSS Contributor Survey

LF Contributor survey

- Survey conducted by 2 organizations:
  - Open Source Security Foundation
    - More on them later
  - Laboratory for Innovation Science at Harvard
- Produced report in December, 2020
  - Can access report at:
    - https://www.linuxfoundation.org/blog/2020/12/download-the-report-on-the-2020-foss-contributor-survey
- 1866 responses, some only partial
  - Analysis come from answers from 1196 respondents

Contributor survey (cont.)

- Key findings:
  - Employment status:
    - 75% contributors are employed full time
    - 52% are paid specifically to develop FOSS
  - Top contributor motivations are non-monetary
    - Needed the feature or fix
    - Enjoyment of learning
    - Desire for creative or enjoyable work

Contributor survey (cont.)

- Key findings (cont.)
  - Only 2.27% of time is spent on security issues
  - 48% are paid by employer to contribute
    - But what happens if employer interest wanes?
  - 45% of respondents state they are free to contribute to FOSS without asking permission
    - Up from 35% 10 years go
  - 17% say their companies have unclear contribution policies
  - 6% are unaware what company polices are (if any)

Outline

Linux Kernel

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Technology Areas

- Audio
- Core Kernel
- Development
- Filesystems
- Graphics
- Networking
- Security
- Testing
- Toolchains
- Tools

Audio

- ASOC (ALSA System on Chip)
  - Kernel subsystem to provide better ALSA support fo SoC and portable audio codecs
- Good talk at ELC with overview of ASOC, hardware, protocols and issues:
  - https://elinux.org/images/a/a7/Belloni-alsa-asoc-2020.pdf

Core Kernel

- New event notification system (watch_queue?)
  - Is fairly simple
    - Uses a regular Unix Pipe
    - Described by one developer as “a breath of fresh air”
  - Avoids polling by clients
  - Avoids dependency on networking code
    - Avoids netlink (“Friends don’t let friends use netlink”)
  - May replace other notification systems in future
    - For now, only used for keyring notifications
  - See https://lwn.net/Articles/760714
  - See Documentation/watch_queue.rst (in 5.8 kernel) for latest API details

Development

- New tools are being used for upstream kernel work (especially ‘b4’):
  - e-mail workflow of Linux kernel often has issues
    - Some e-mail clients and servers mangle the data
  - b4 supports doing patch management outside of e-mail
    - Acquire a patch series from lore.kernel.org, and use git to apply it
  - See “Kernel Email Tools” talk by Frank Rowands at ELCE 2020
    - https://elinux.org/images/9/93/Kernel_email_tools_elce_2020.pdf

Filesystems

- F2FS gets more compression options
  - LZ4 “high compression” mode is supported (v5.12)
  - compress_mode= option for whether kernel or user-space controls compression
    - New ioctl to give user-space control over which files are stored in compressed form
- io_uring continues to mature
  - As a reminder: see https://lwn.net/Articles/810414/
  - Supports tee() system call (v5.8)
  - Asynchronous buffered reads without using kernel threads (v5.9)
  - Integrated with memory control groups for better accounting and regulation (v5.12)

Filesystems (cont.)

- Ext4 fast commits (v5.10)
  - Introduces a 2nd “fast commit” journal
    - Holds changes since the “standard commits” journal was updated
  - Fast commit journal has file-level data
    - Omits block data and data that can be recreated from other sources
      - Reduces the amount of data that needs to be saved
  - Fast commits cannot be performed for all ops
    - Falls back to a “standard commit” in this case
  - During recovery, standard commits are replayed by journaling layer, then fast commits are replayed by the filesystem
  - Big performance improvement! (20%-200%)
  - See https://lwn.net/Articles/842385/

Graphics

- Good talk on using Flutter in Embedded Systems
  - Flutter + Wayland is better for embedded products
    - Wayland is now supported on many SoCs
      - Lighter weight than X11
  - Flutter supports cross-platform development, but with native code (generated from DART language)
  - Fewer library dependencies (only need OpenGL/EGL)
  - Easy license (BSD-3)
  - See https://elinux.org/images/6/61/Oct_27_Graphical_User_Interface_Using_Flutter_in_Embedded_Systems_Hidenori_Matsubayashi.pdf
  - *Watch the presentation later in this jamboree*

Networking

- Precision Time Protocol and packet timestamping in the Linux kernel
  - PTP is used for synchronizing clocks between machines
  - Requires accurate timestamps, applied as closely to packet transmission as possible
  - Can use “ethtool –T” to turn on kernel-level timestamping in the network stack
    - Can use a high-precision hardware clock (PHC), or something in software, for timestamps
  - Can use ‘ptp4l’ and ‘phc2sys’ user-space commands to manage clocks
  - See talk by Antoine Ténart at ELCE 2020
    - https://elinux.org/images/7/70/Tenart-timestamping-and-ptp-in-linux.pdf

Real-Time

- Can disable process migration between CPUs (v5.11)
  - Good for keeping an real-time process pinned on a particular CPU
  - Turns out to be hard (who knew?)
  - See https://lwn.net/Articles/836503/
- PREEMPT_DYNAMIC allows selecting preemption mode at boot time or run time (v5.12)
  - Can be “none”, “voluntary”, or “full”
  - There’s an option under debugfs for controlling the mode at run time

Security

- Wireguard VPN
- Inline encryption for filesystems

WireGuard VPN tunnel

- Faster and simpler than Ipsec and OpenVPN
  - Added in kernel v5.6
- Aim is to be as easy to use as SSH
  - Simple generation of public/private key pairs
  - Similar mode of distribution for public keys
- Uses Linux ip commands to set up tunnel
- Allows roaming by both sides of tunnel
- Uses state-of-the-art cryptography
  - High-speed cryptography, suitable for embedded
- Amenable to security audits
  - Due to much simpler code base

Inline encryption for filesystems

- Allows kernel to offload encryption and decryption to the storage device
- Normally, encrypted filesystem has lots of overhead
  - On main CPU or in crypto hardware and busses as data is copied multiple times
- This is faster
  - Kernel manages setup, then storage device handles cryptography
- Kernel can also validate that encryption worked as expected
- See https://lwn.net/Articles/797309/
  - Added in v5.8

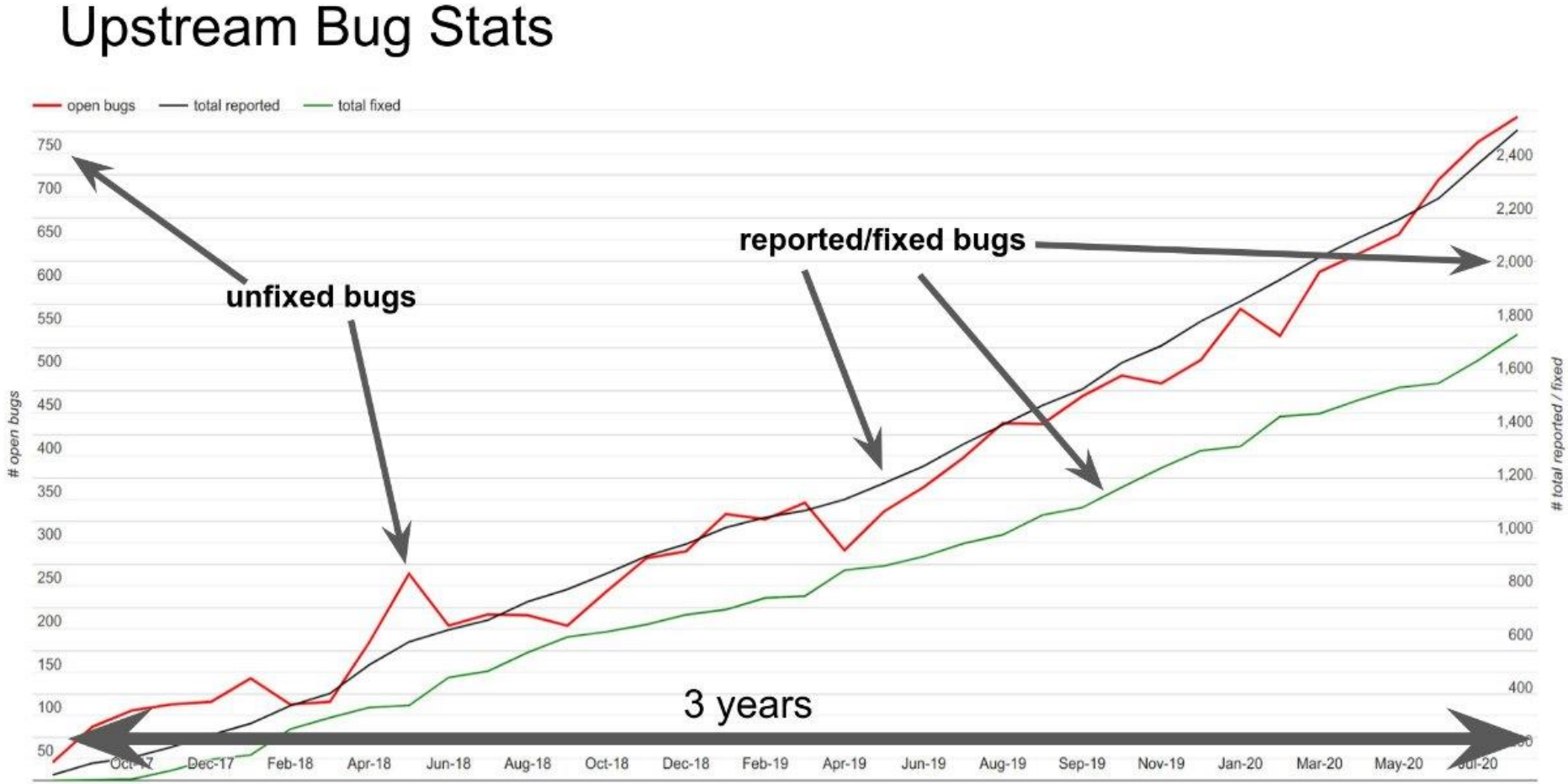
Tracing

- New Bootconfig system
  - Extra boot configuration
  - Allows passing a large set of options to the kernel during boot
    - Was not a good fit for device tree
  - Passes a tree-structured key-value list
  - Data is loaded with initrd
  - Used primarily to pass kernel command line items for ftrace and early tracing
  - Mainlined in 5.6
  - See https://lwn.net/Articles/806002/

Testing

- Syzbot fuzzer continues to find an alarming number of bugs
  - Number of unfixed bugs climbs every release
    - Over 2400 open bug reports (just from syzbot)
    - Some were reported years ago
    - Need to be fixing more bugs than we find
  - See https://github.com/ossf/wg-securing-critical-projects/blob/main/presentations/The_state_of_the_Linux_kernel_security.pdf

Syzbot Upstream Bug Chart



Testing (cont.)

- Board Farm REST API
  - TimeSys and Sony introduce API concept for hardware testing at ELCE 2020
  - Use a web-based (REST) API to manage endpoint for a test (where endpoint is not on the device under test)
    - e.g. serial line, USB endpoint, CAN bus, audio, video (anything not on the DUT)
  - Demonstrated simple gpio test at ELCE
  - See talk by Tim Bird and Harish Bansal
    - See https://elinux.org/images/3/3e/ELC-Board-Farm-API-Sony-Timesys-2020-10-27.pdf

Toolchains

- Now possible to build full embedded Linux system with Clang (LLVM v10)
  - Can build Linux kernel with Clang (for a while now)
  - Harder to build the distribution
  - There's a 'meta-clang' layer available to do builds in Yocto Project
    - Some individual packages will have problems
      - Still need gcc for glibc (use musl C library instead)
  - Debian clang project (https://clang.Debian.net)
    - 96% of packages build
  - See talk by Khm Raj at ELCE 2020
    - https://elinux.org/images/3/3a/ELC_2020_clang.pdf

Tools

- Great talk on static analysis tools for embedded
  - There are lots of great tools available for static analysis (testing of code, without executing it)
    - gcc –fanalyzer, clang scan-build - for kernel
  - meta-sca is a yocto layer with a collection of tools (87 different tools)
  - meta-codechecker is another yocto layer
    - Can analyze a full build and generate a report using Codechecker tool (by Ericsson)
  - See talk by Jan-Simon Möller at ELCE 2020
    - https://elinux.org/images/e/ed/ELCE_FOSS_Static_Analysis_Tools_for_Embedded_Systems_and_How_to_Use_Them.pdf

Miscellaneous

- Long term support upgraded to 6 years for two LTS kernels!!
  - 4.19 and 5.4 will be supported for six years instead of two years

kernel.org/releases.html#longterm

Longterm release kernels

Version	Maintainer	Released	Projected EOL
5.4	Greg Kroah-Hartman & Sasha Levin	2019-11-24	Dec, 2025
4.19	Greg Kroah-Hartman & Sasha Levin	2018-10-22	Dec, 2024
4.14	Greg Kroah-Hartman & Sasha Levin	2017-11-12	Jan, 2024
4.9	Greg Kroah-Hartman & Sasha Levin	2016-12-11	Jan, 2023
4.4	Greg Kroah-Hartman & Sasha Levin	2016-01-10	Feb, 2022
3.16	Ben Hutchings	2014-08-03	Jun, 2020

- See https://kernel.org/releases.html#longterm

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Conferences – 2020

- Embedded Linux Conference 2020
  - Was planned for June 22-24, Austin, Texas, USA
  - Went virtual with, along with OSS Summit
- Linux Plumbers
  - Virtual in August
- ELC Europe 2020
  - Virtual in October
- Open Source Summit Japan
  - Changed to December, and went virtual

Conferences - 2021

- Embedded Linux Conference North America
  - Canceled (was August in Vancouver)
  - Open Source Summit also canceled
- Embedded Linux Conference 2021
  - September 28-October 1, Dublin, Ireland (??)
  - Venue is booked, but probably wise to wait until summer to make travel arrangement

COVID-19 issues?

- When will conferences no longer be cancelled?
  - ELCE 2021 (in late September) is first LF in-person event on schedule
    - But honestly - it's still tentative
  - Situation is changing as people get vaccinated
    - However, there are a lot of positive signs
- Events will continue with hybrid style for many months, even after in-person events start

Hybrid Events

- Events will continue supporting virtual access
  - Improvements for virtual attendees
    - e.g. live Q&A during sessions
  - Can also speak virtually, even if event is live
- On-site changes for in-person health consciousness
  - Eeduced attendance
  - Social distancing
  - Masks, extra cleaning
  - Changes to format of some event activities

Conferences – misc.

- LF continuing to push for inclusion:
  - Have programs to encourage outreach
  - Diversity training, etc.
- Tux Turns 30 this year! (September, 2021)
  - Would be nice to have some big parties, but we'll see what happens

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Industry News

- Mergers and acquisitions
- Trade associations
- Interesting cases of embedded Linux

Mergers and Acquisitions

- Nvidia buys ARM from Softbank
  - Softbank bought ARM for $32B in 2016
  - Nvidia buying it for mix of stock and cash
    - Valued at potentially $40B

Trade associations

- Linux Foundation

Linux Foundation

- Financials looking very good despite COVID
- More than 1 new member per day
- Training and mentorship has really ramped up:
  - 2M trainings and exams delivered as of Jan 2021
  - New COBOL training
- LFX tools for managing projects
  - Project insights, security, mentorship, crowdfunding, events, training, control center
  - Some tools online now
  - See https://lfx.dev/

Linux Foundation stats

We continue to scale our communities on every level by automating processes, creating innovative developer tools, and focusing on community value.

11.7M Lines of Code Added Weekly

9.4M Lines of Code Removed Weekly

208,660 Contributing Developers

12,435 Contributing Companies

16,618 Repositories

9.1M Commits

960,610 Pull Requests

1.3M Builds Monitored

859,150 Logged Issues

5.2B Container Downloads

1.6M Group Chat Messages

3.6M Group Email Messages

4,532 Scanned Repositories

282,342 Open Vulnerabilities

62,379 Recommended Fixes

36,163 Vulnerabilities Fixed

31,496 CLA Contributors

26,998 Community Meetings

THE LINUX FOUNDATION

LF Projects

- Lots of projects being announced and in the pipeline
  - 34 new projects in 1Q21
- Some big initiatives in 2020 and just announced…
  - These listed are just a few
- Public Health Initiative
  - Open source contact tracing
  - Was a big success
    - Started quickly and is already providing code used by Public Health Authorities

A few more initiatives

- Mobile Native Foundation
  - Mobile app development and deployment infrastructure for large-scale
  - Both Android and iOS
  - Testing, CI/CD for deployment at large scale
  - See http://mobilenativefoundation.org
- OpenChain project
  - OpenChain spec became an ISO 5230 standard
    - Defines standards for open source compliance process
- SPDX was also recently approved as an international standard

OpenSSF

- Open Source Security Foundation
- Comprehensive project to enhance OSS security
  - Vulnerability disclosures
  - Security tooling
  - Best practices and training
    - Already have some EdX courses
  - Securing critical projects
- Core Infrastructure Initiative (CII) work is being absorbed into OpenSSF

SigStore

- Supports signing of software, and storing records permanently in a secure, public log
- Software and free service
  - Free to use for individuals and organizations
    - See https://sigstore.dev
- Study of current practices indicated that few projects were signing their releases, and fewer were checking signatures

SigStore (cont.)

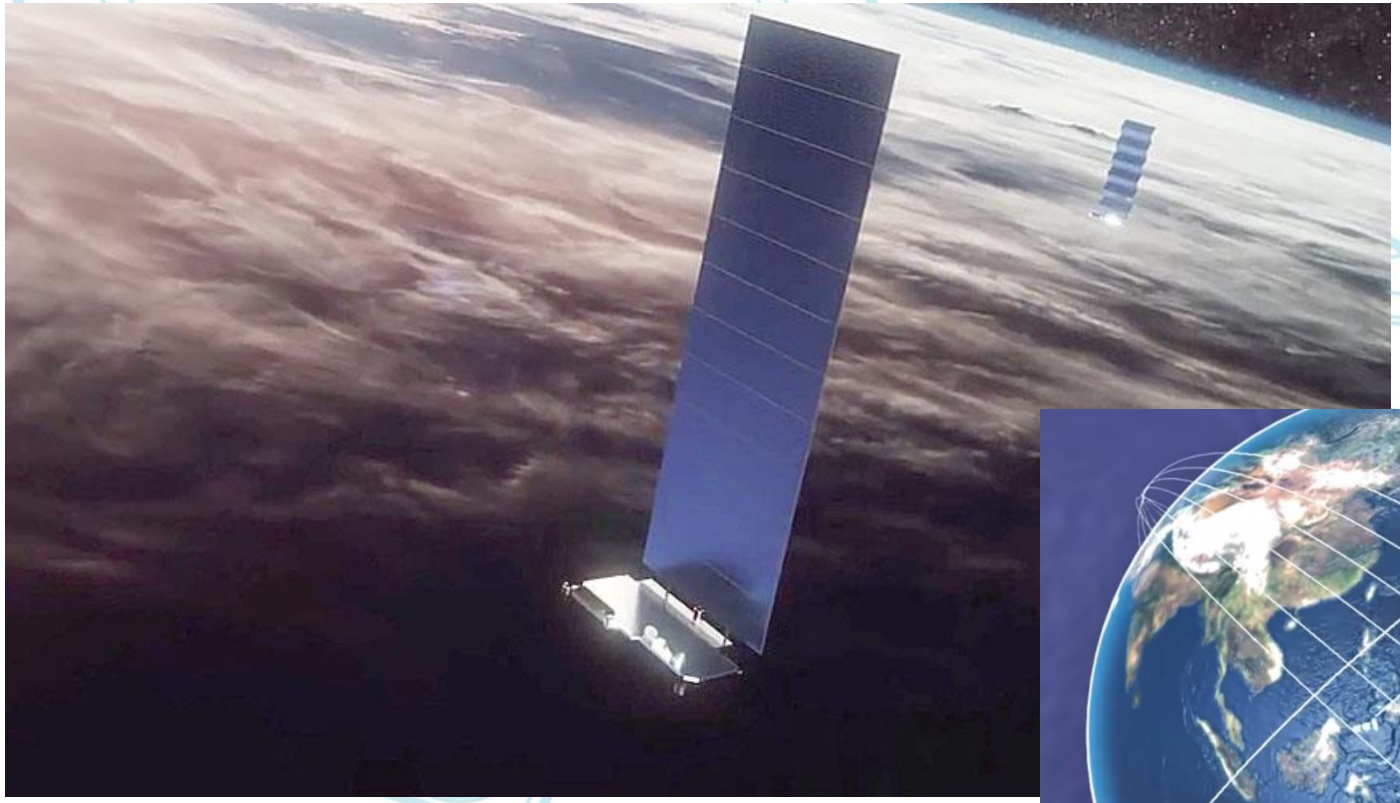
- Want to make a system that is:
  - Very easy to use
    - Specifically want to eliminate key management
  - Trustable
- Uses OpenID for authentication, and a public transparency log
- Should be fully available later this year
- Sources:
  - https://www.darkreading.com/application-security/linux-foundation-debuts-sigstore-project-for-software-signing/d/d-id/1340360

Interesting embedded Linux

- Starlink satellite constellation
- Mars helicopter

SpaceX Starlink Satellite constellation

SpaceX Starlink Satellite constellation



SpaceX Starlink Satellite constellation

- Spacex uses Linux in Falcon 9 and Falcon heavy rockets, dragon space capsules, and starlink satellites
- Each Starlink satellite has over 60 processors running linux
  - Current satellites in orbit (as or Mar 4) is 1141
  - Which means there are over 70,000 instances of Linux in orbit now
  - Spacex has requested permission for 42,000 satellites (currenty have permission for 12,000)
    - This would be well over 2 million instances of Linux, eventually

Starlink software

- Uses multi-computer voting for fault tolerance
  - Instead of much more costly radiation-hardened processors
- Uses a mostly vanilla kernel, with PREEMPT_RT patch and custom drivers for their hardware
  - Careful programming to achieve deterministic performance
    - Avoid memory allocation at runtime
    - No unbounded loops
    - Avoid priority inversions

Sources

- https://www.zdnet.com/article/spacex-weve-launched-32000-linux-computers-into-space-for-starlink-internet/
- https://old.reddit.com/r/spacex/comments/gxb7j1/we_are_the_spacex_software_team_ask_us_anything/?limit=500

Mars Helicopter

Mars Helicopter

- Mars Ingenuity Helicopter landed in February on Mars (on the Perserverance rover)
- Will perform tests and demonstrations
  - Of use of COTS in space
    - BAE RAD-hardened processor on the rover is about $250,000 dollars, and runs at 200 MHz (VxWorks)
    - Helicopter has Qualcomm Snapdragon 801 processor, running at 2.6 GHz, with Linux OS
      - Same processor as used in 2014/2015 mobile phones
    - Some components were off-the-shelf:
      - e.g. LIDAR purchased from SparkFun
  - Still high development cost: Total program is about $80 million dollars, including operations

Mars Helicopter Hardware

- Hardware:
  - 2 1.2 meter counter-rotating blades
    - large, spinning 10 times faster than Earth drones
      - To compensate for thin Martian atmosphere, which is only 1% as dense as on Earth)
  - 13 megapixel camera (forward-facing) for 4K video
  - .5 megapixel camera (downward-facing) for terrain mapping and navigation
  - laser altimeter
  - tilt and other sensors
  - batteries, solar panels, carbon tube landing legs

Mars Helicopter Software

- Lots of Open Source
  - Linux operating system
  - Uses “F Prime” OSS flight software, published on github by NASA
    - https://github.com/nasa/fprime
    - Can use this flight control software in your own projects
- Guidance loops are running at 500 HZ
  - Doing feature tracking from frame to frame at 30 HZ
- Does pre-programmed flight with moderate (not high-level) autonomy

Mars Helicopter Mission

- 30-day window (budget) for flights
  - Then rover has to leave and do it's other science work
- 3 flights already planned
  - not sure when flights will be yet
  - 4th and 5th flights possible, where they may do more interesting things
- Not a lot of Mars science on this trip
  - Just a demo that it can be done at all, with COTS and Linux
  - Test hardware/software capabilities in extreme environment of another planet
    - Very thin atmosphere, very cold temperatures, less sun, less gravity, etc.

Sources for Mars helicopter

- https://thenewstack.io/how-the-first-helicopter-on-mars-uses-off-the-shelf-hardware-and-linux/
- https://www.pcmag.com/news/4-android-smartphones-with-as-much-power-as-nasas-mars-helicopter
- https://spectrum.ieee.org/automaton/aerospace/robotic-exploration/nasa-designed-perseverance-helicopter-rover-fly-autonomously-mars

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- LWN.net – https://lwn.net
  - If you are not subscribed, please do so
  - Some content is delayed by 2 weeks for non-subscribers (some links in this presentation)
- eLinux wiki – elinux.org
  - Especially the presentations from events:
    - eg. https://elinux.org/ELC_Europe_2020_Presentations
- Phoronix - https://www.phoronix.com/
- Google

Thanks!