EMBEDDED IOT SUMMIT

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THE LINUX FOUNDATION OPEN SOURCE SUMMIT JAPAN

Zephyr Project: Results from Applying Open Source Best Practices in Embedded

Kate Stewart, VP Dependable Embedded Systems

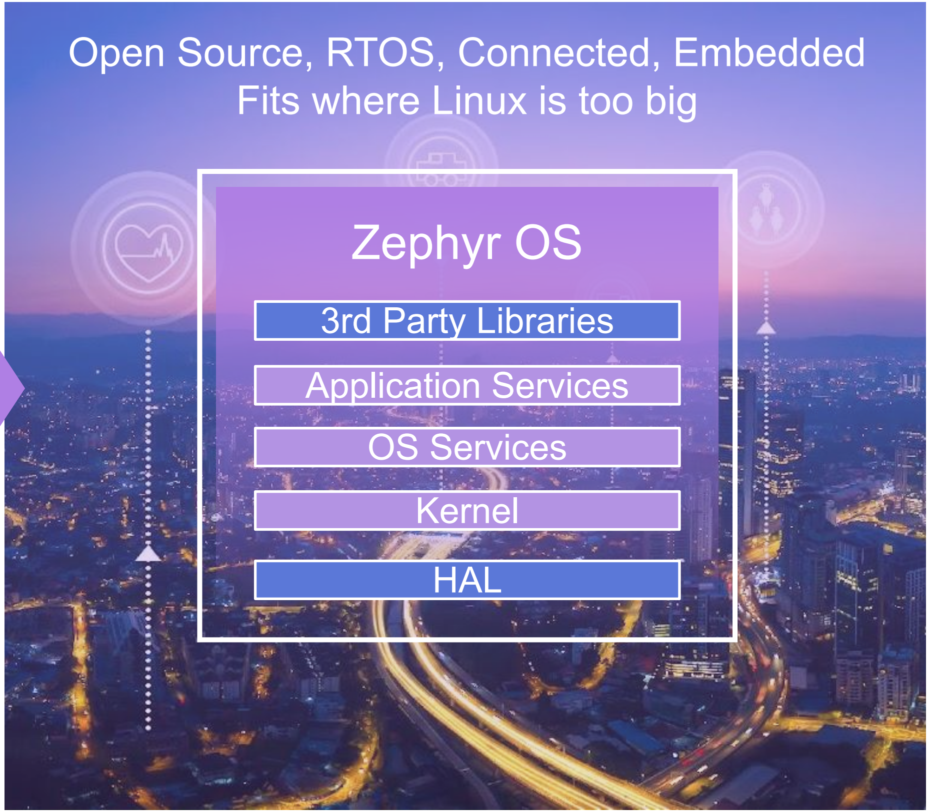
#OSSummit @_kate_stewart

THE LINUX FOUNDATION

Zephyr Project

Zephyr®

- **Open source** real time operating system
- **Developer friendly** with vibrant community participation
- Built with **safety and security** in mind
- **Broad SoC, board and sensor support**.
- **Vendor Neutral** governance
- **Permissively licensed** - Apache 2.0
- **Complete**, fully integrated, highly configurable, **modular** for **flexibility**
- **Product** development ready using LTS includes **security updates**
- **Certification** ready with Zephyr Auditable



THE LINUX FOUNDATION PROJECTS

Operating System	First Commit	Controls Commits	Declared License	Total Contributors	Contributors in last month	Total Commits	Commits in last month
Zephyr	2014/11	**community**	**Apache-2.0**	**1863**	**269**	**88,107**	**1,777**
nuttX	2007/?	community	BSD-variant → Apache-2.0	492	49	51,863	248
RT-Thread	2009/06	community	GPL-2.0 → Apache-2.0	661	30	15,524	77
RIOT	2010/09	community	LGPL-2.1	342	17	44,624	137
Tizen RT	2015/04	Samsung	BSD-variant → Apache-2.0	183	14	10,796	41
FreeRTOS	2004/07	Richard Barry	GPL-2.0 w/ FreeRTOS → MIT	146	12	3,320	38
SeL4	2014/07	community	GPLv2 AND BSD-2-Clause	100	8	4,423	27
Contiki-NG	2017/10	community	BSD-3-Clause	217	6	17,656	35
myNewt	2015/06	community	Apache-2.0	134	4	10,785	6
ThreadX	2020/05	MSFT → community	MSL → MIT	15	4	148	12
mbed OS	2013/02	ARM	Apache-2.0 or BSD-3-Clause	691	2	34,558	2

Data extracted on 2023-12-01 from github

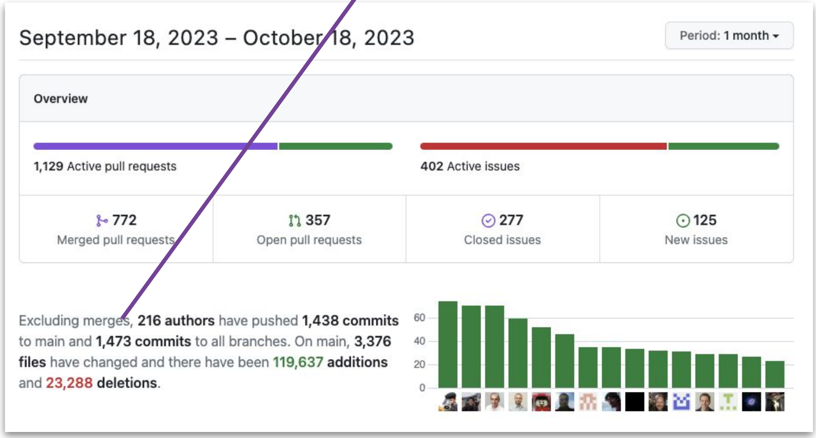
Methodology - with data extracted 2023-10-19

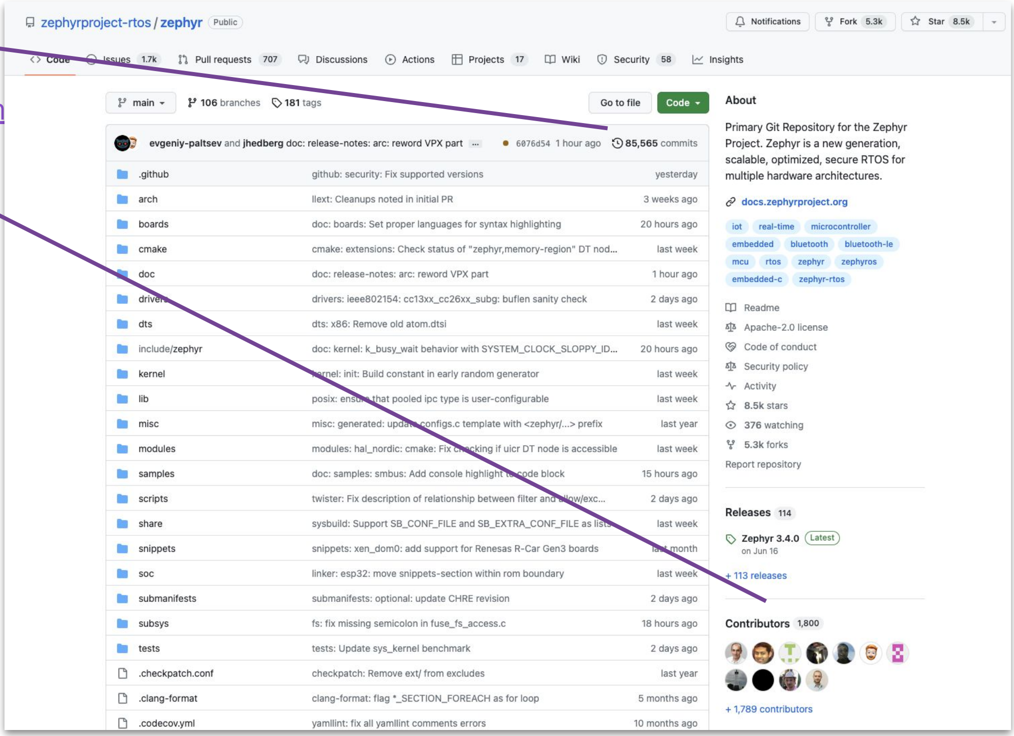
https://github.com/zephyrproject-rtos/zephyr

- Total commits: 85,565
- Total contributors: 1,800

https://github.com/zephyrproject-rtos/zephyr/pulse/month

- Monthly contributors: 216
- Monthly commits: 1,473→ 2 commits/hour





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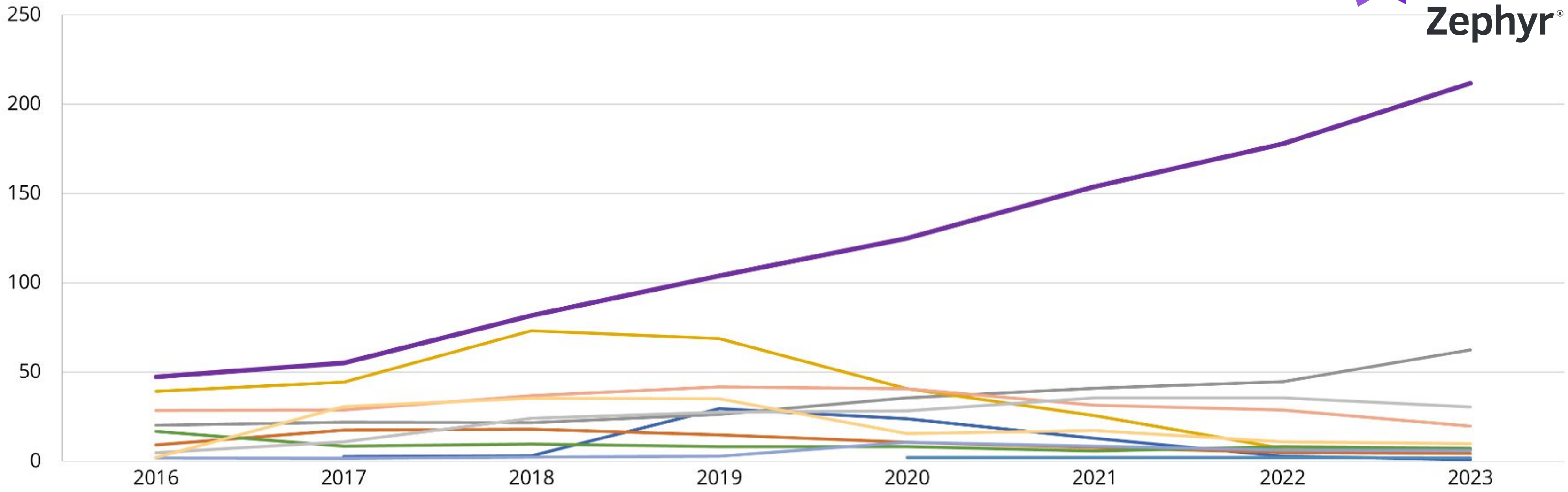
2.45 commits/hour

Data extracted on 2023-12-01 from github

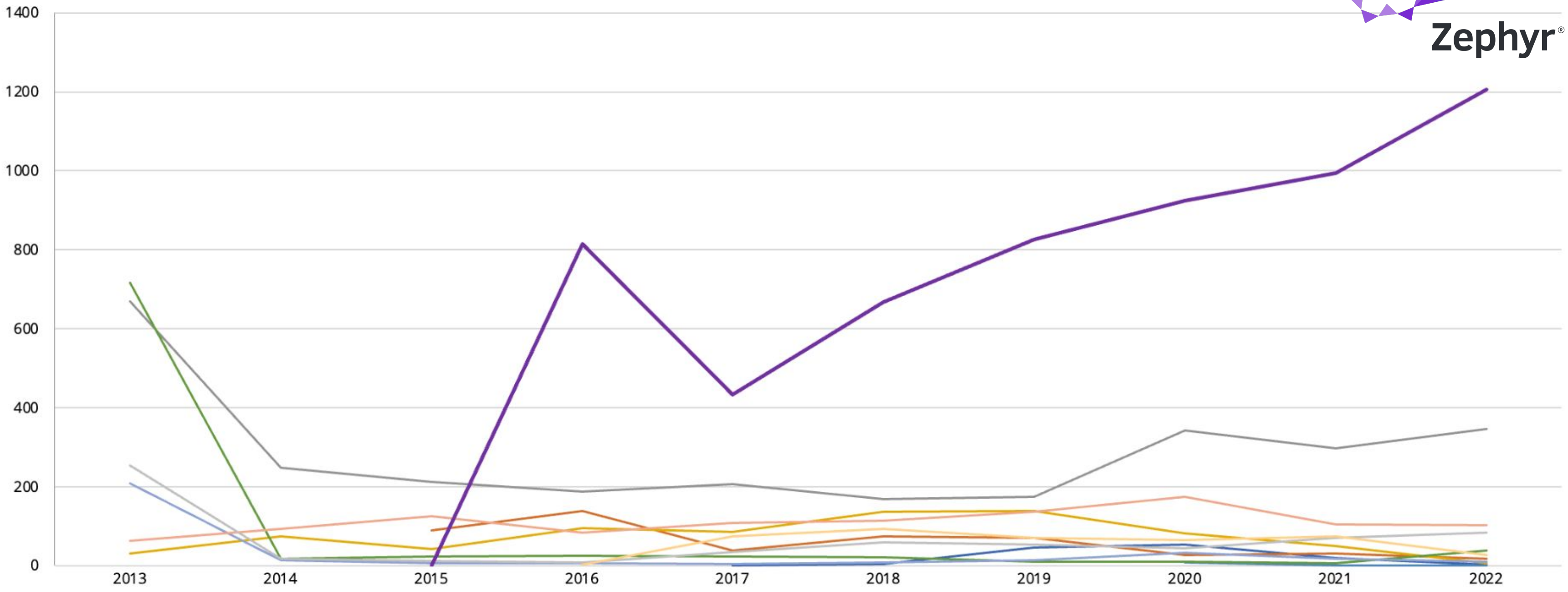
Average Number of Unique Contributors per Month

Zephyr®



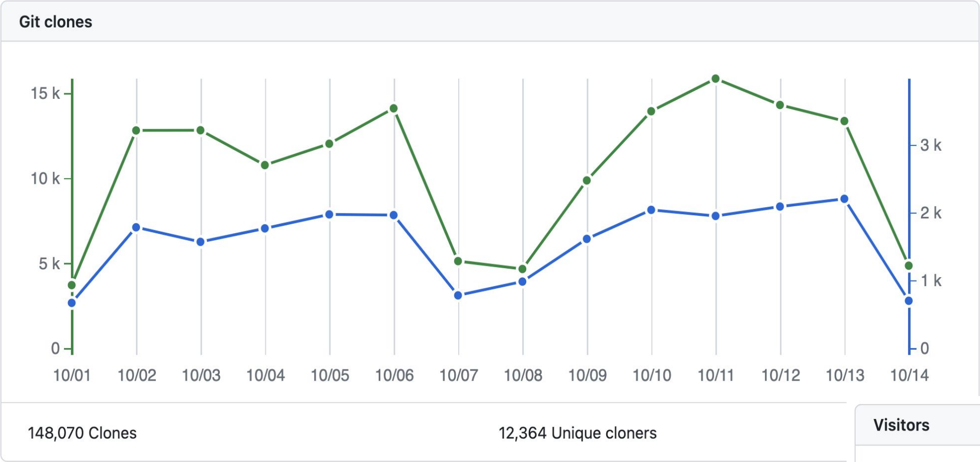
	2016	2017	2018	2019	2020	2021	2022	2023
Amazon FreeRTOS		3	3	30	24	13	3	1
Apache Mynewt	9	18	18	15	11	8	5	4
Apache NuttX	20	22	22	26	36	41	45	62
Arm Mbed OS	39	44	73	69	41	26	7	7
Azure RTOS ThreadX					2	2	2	2
Contiki-NG	17	9	10	8	8	6	8	7
FreeRTOS	2	2	2	3	11	8	6	6
RIOT OS	29	29	37	42	41	31	29	20
RT-Thread	5	11	24	28	28	36	36	30
TizenRT	2	31	35	35	16	17	11	10
Zephyr	47	55	82	104	125	154	178	212

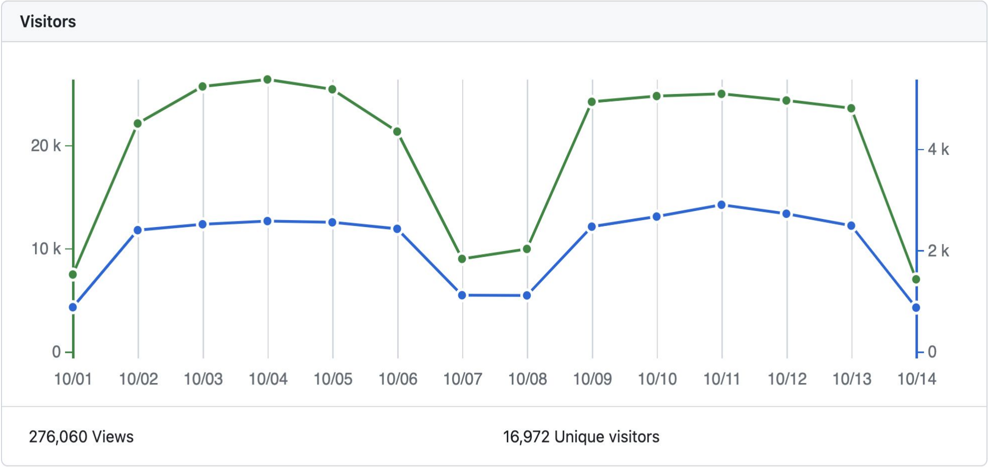
Average Number of Commits per Month



	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Amazon FreeRTOS					2	4	47	53	20	2
Apache Mynewt			90	138	38	74	70	27	31	18
Apache NuttX	670	248	212	187	206	169	174	343	297	347
Arm Mbed OS	30	74	42	95	86	136	138	82	51	6
Azure RTOS ThreadX								7	1	2
Contiki-NG	717	17	23	25	23	22	9	11	7	38
FreeRTOS	209	13	6	6	4	8	13	32	17	11
RIOT OS	63	93	126	84	108	115	136	175	105	103
RT-Thread	253	18	13	9	35	60	53	43	70	84
TizenRT				2	73	93	71	64	74	27
Zephyr			0	814	434	667	825	924	995	1206

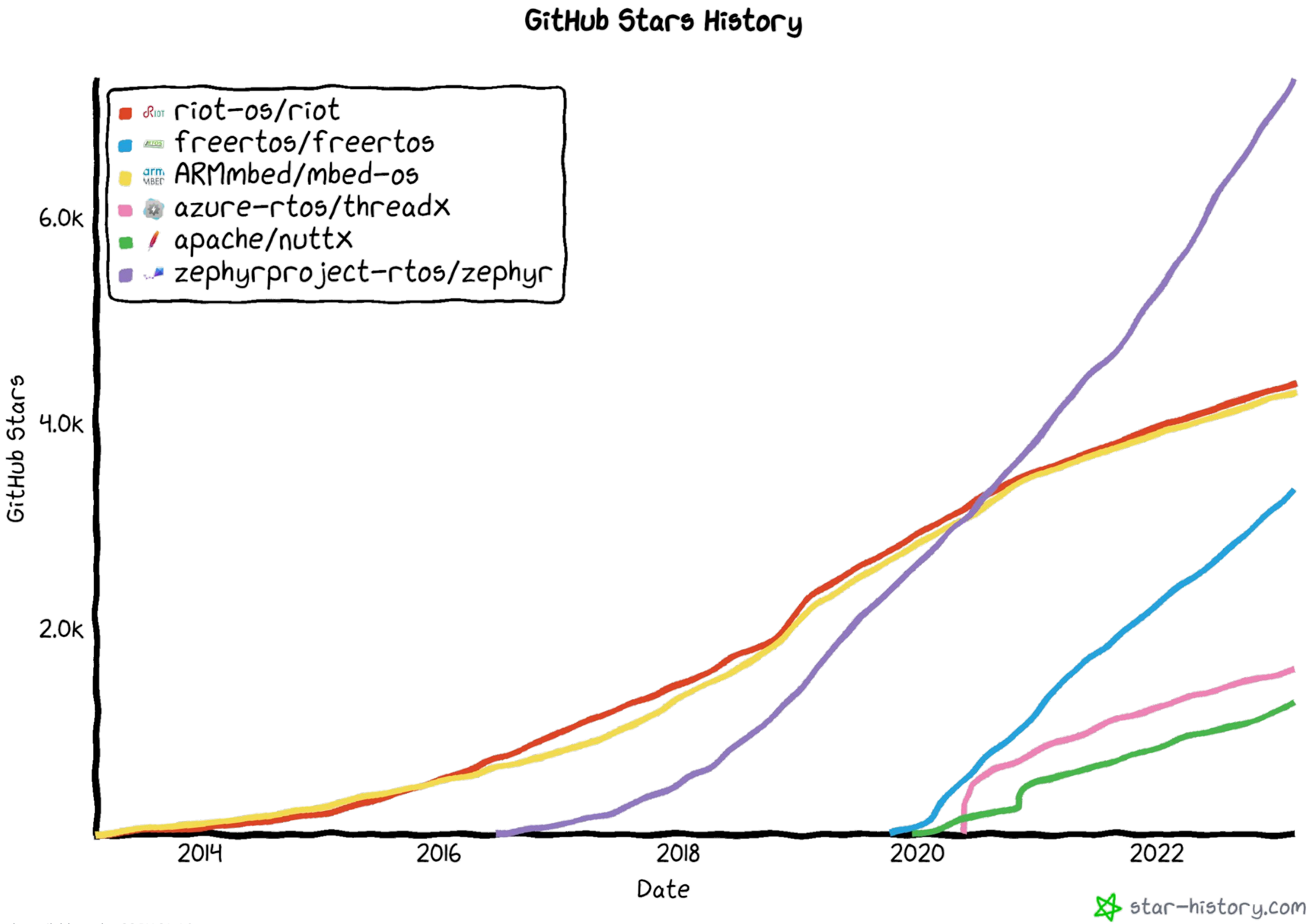
GitHub Clones & Unique Visitors



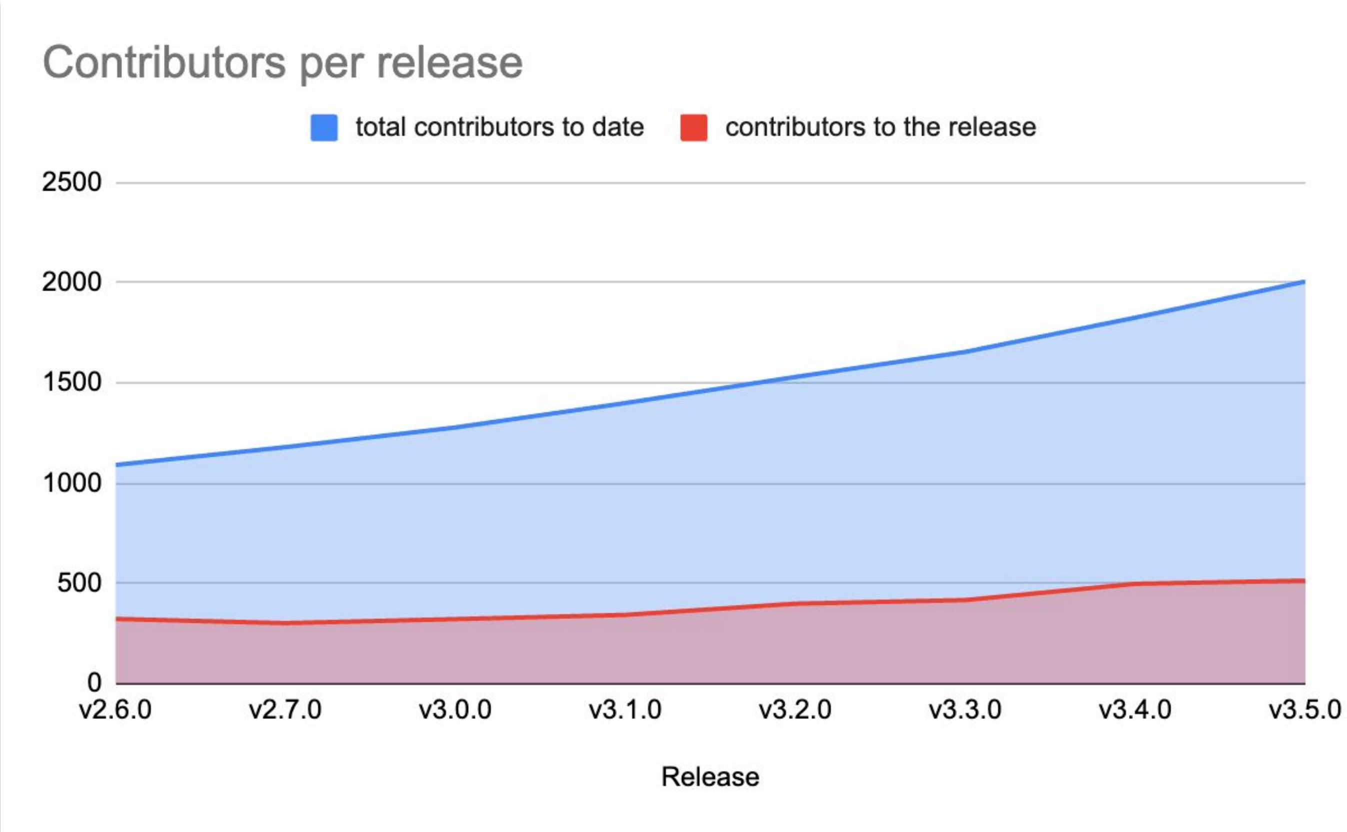


2023-10-01 → 2023-10-14

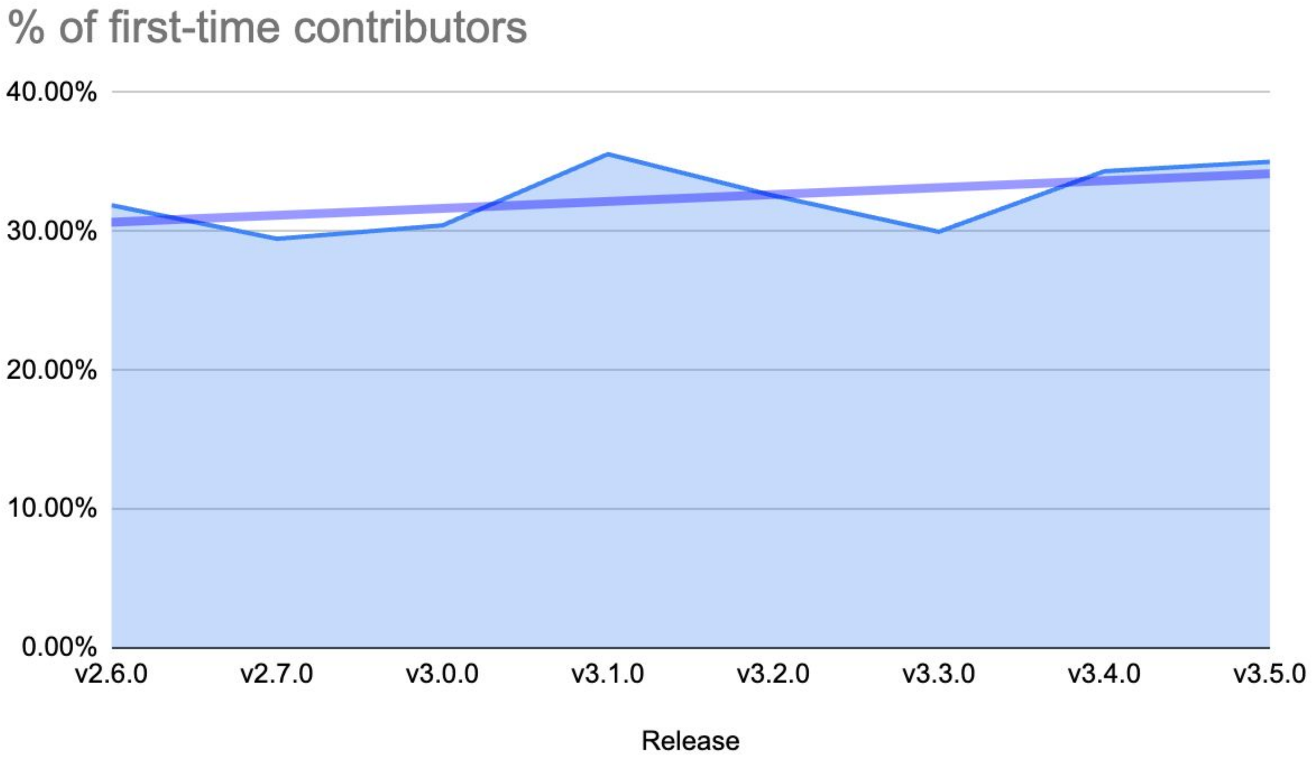
~883 unique clones per day
~1212 unique visitors per day


GitHub Stars History
riot-os/riot
freertos/freertos
ARMmbed/mbed-os
azure-rtos/threadx
apache/nuttx
zephyrproject-rtos/zephyr
6.0k
4.0k
2.0k
GitHub Stars
2014
2016
2018
2020
2022
Date
star-history.com

Contributors Growth per Release



New Contributors per Release



How does this compare to the Linux Kernel?

How does this compare to Linux?

6.5 Linux Kernel Statistics*

1,921
Contributors From
218 Organizations

7,064
Lines of Code
Added Daily

1,945
Lines of Code
Modified Daily

1,281
Lines of Code
Removed Daily

9
Changes Per
Hour

* Source: https://lwn.net/Articles/948970/   Time period for 6.5: 2023/6/26-2023/8/27=63 days
Also data from: Source: https://github.com/gregkh/kernel-history/blob/master/kernel_stats.ods

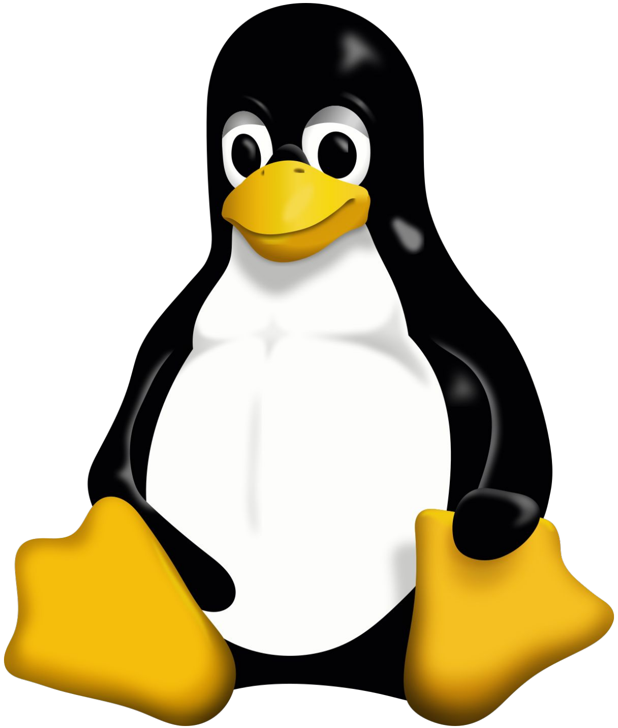
So what was it like when Linux started?

UNIX Source Available:

SVR4, MINIX 1.5, 4.3BSD

Commercial Distributions:

A/UX, IBM AIX, Dec Ultrix, HP-UX, IRIX, SunOS, MIPS RISC/os, Xenix …



What is Linux like Today?

100% Supercomputer Market

82% Smartphone Market Share

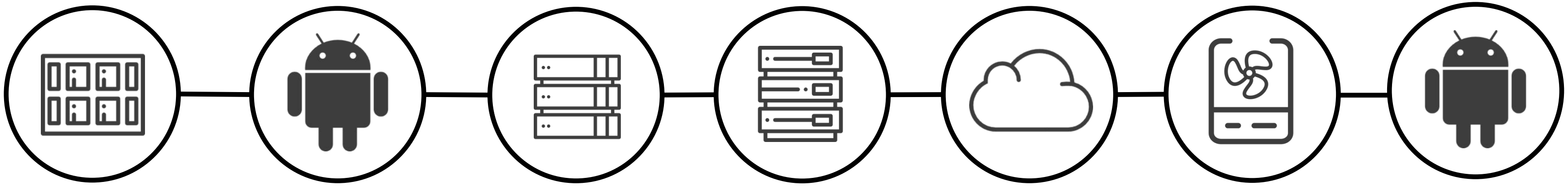
2nd To Windows in Enterprise

90% Mainframe Customers

90% Public Cloud Workload

69% Embedded Systems Market

#1 Internet Client



Every market Linux has entered it eventually dominates

Lessons Learned by Linux Community circa 2016/2017


Linux Kernel Development Report

Jonathan Corbet, *LWN.net*
Greg Kroah-Hartman, *The Linux Foundation*

Source: https://www.linuxfoundation.org/tools/state-of-linux-kernel-development-2017/

More recent stats can be found at: https://www.linuxfoundation.org/tools/linux-kernel-history-report-2020/

- Short release cycles are important.
- Process scalability requires a distributed, hierarchical development model.
- Tools matter.
- The kernel’s strongly consensus-oriented model is important.
- A related factor is the kernel’s strong “no regressions” rule.
- Corporate participation in the process is crucial.
- There should be no internal boundaries within the project

++ Lessons Learned

- **Vendor-neutral environment for technical decision making**
- Mix of companies and individuals participating – "scratching their itches"
- **Streamline upstreaming process** – DCO - "signed-off-by:"
- **Public code reviews** – "reviewed-by:"
- Consensus-oriented decision model – email, in-person summits
- Hierarchical development model (**maintainer model**) – "signed-off-by"
- No internal boundaries – developer can contribute anywhere
- **Tools matter** - git enabled distributed version control - push/pull
- Short predictable release cycles and **with fixed merge windows**
- **Stable & LTS:** stable and long term support releases support product development

KEY: Developer frustration with status quo inspires creative solutions.

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So what lessons did Zephyr apply from the Linux Kernel Community?

Zephyr’s Vision

The Zephyr Project strives to deliver the **best-in-class RTOS** for connected resource-constrained devices, built to be secure and safe.

Zephyr Developers Decide Technical Directions

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- **Configuration: kconfig & kbuild** added in 2015 prior to launch
- **Unified kernel:** nano + microkernels → **unified kernel** in 2016
- **Infrastructure:** Gerrit/JIRA → **GitHub/Issues** in 2017
- **Build system:** kbuild → **cmake** in 2018
- **Other areas:**
  - APIs & HALs - reworked
  - Modularization & Device Tree support
  - Release & LTS processes refined

Applying ++ Lessons Learned

Linux Best Practice	Zephyr Adoption
Vendor Neutral Decision Making	Yes, Project support from multiple companies.
Companies and Individuals Participate	Yes, TSC has companies & community participation.
Streamline upstreaming process	Yes, see /CONTRIBUTING.rst, DCO used
Public code reviews?	Yes, issues & pull requests reviewed on https://github.com/zephyrproject-rtos/zephyr
Consensus Oriented Decision Models	Yes, TSC votes on features & release readiness.
Hierarchical development (Maintainers)	Yes, see /MAINTAINERS.yml
No Internal Boundaries	Yes, anyone can make pull request for any area
Distributed version control	Yes, see /CONTRIBUTING.rst
Short Release Cycle (w/ Merge Window)	Yes, 10 week merge, 2-4 week stabilize
Long Term Support Releases	Yes, LTS 1 had 4 update release, LTS 2 active maintain

So what does Zephyr support today?

Supported Hardware Architectures

Cortex-M, Cortex-R & Cortex-A

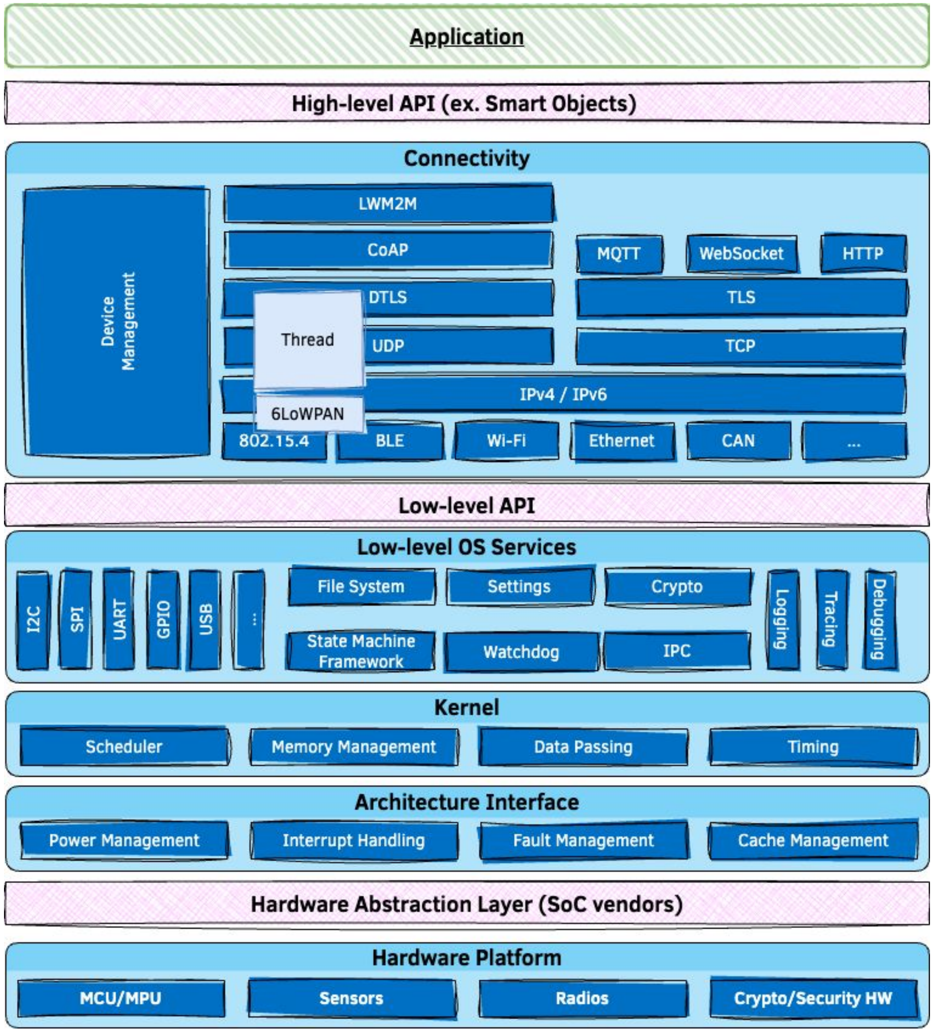
x86 & x86_64

32 & 64 bit

Xtensa

docs.zephyrproject.org/latest/hardware/index.html#hardware-support

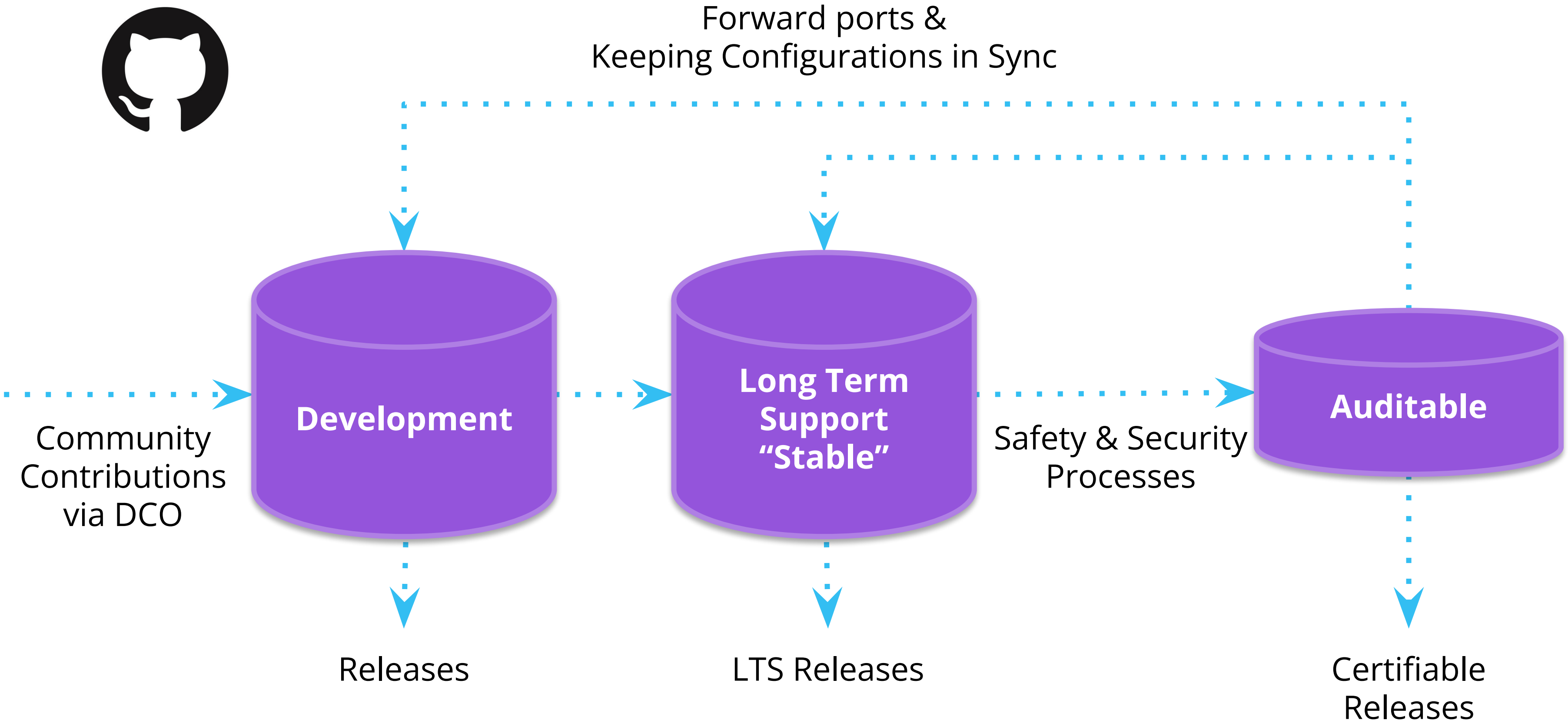
Architecture



What about Zephyr security?

Code Repositories

Zephyr®



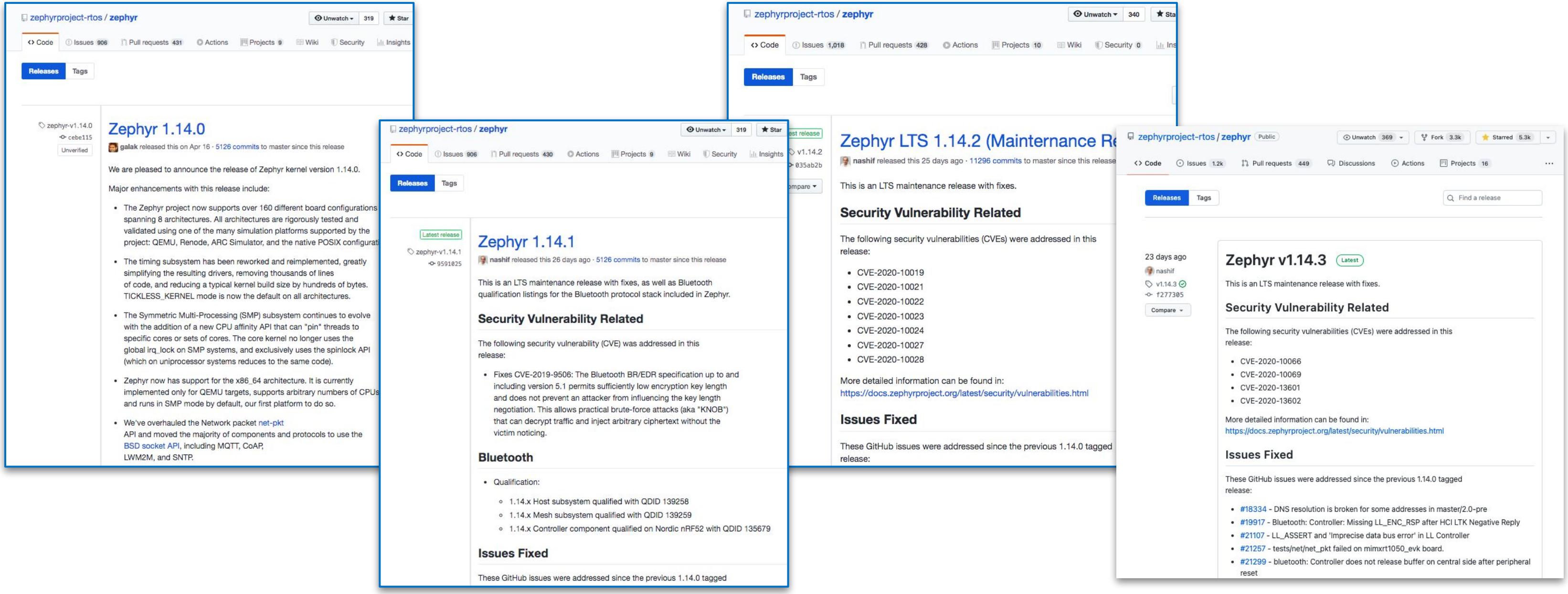
Long Term Support (Zephyr 2.7.x)

- **Product Focused**
- Current with latest **Security Updates**
- Compatible with new hardware
  - Functional support for new hardware is regularly backported
- **Tested**: Shorten the development window and extend the Beta cycle to allow for more testing and bug fixing
- **Supported for 2+ years**
- ⚠️ **Doesn't include cutting-edge functionality**

ℹ github.com/zephyrproject-rtos/zephyr/releases/tag/zephyr-v2.7.0

Long Term Support (LTS - 1.14)

Zephyr®



Delivered bug fixes and latest security updates for 2 years!

Auditable

- An **auditable code base** will be established from a **subset of the Zephyr OS LTS**
- Code bases will be kept in sync
- More rigorous processes (necessary for certification) will be applied to the auditable code base.
- Processes to achieve selected certification to be:
    - Determined by Safety Committee and Security Committee
    - Coordinated with Technical Steering Committee

Project Security Documentation

- [Project Security Overview]
- Started with documents from other projects
- Built around Secure Development, Secure Design, and Security Certification
- Ongoing process, rather than something to just be accomplished

Software Supply Chain Support

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- Zephyr ships an **SBOM** (Software Bill of Materials) with each release
- Downstream consumers can leverage built-in tools to, in turn, generate source & build SBOMs for their deliverables

```
[...]
FileName: ./zephyr/zephyr.elf
SPDXID: SPDXRef-File-zephyr.elf
FileChecksum: SHA1: e74cebcac51dabd799957ac51e4edcd32541103d
[...]
Relationship: SPDXRef-File-zephyr.elf GENERATED_FROM SPDXRef-File-dev-handles.c
Relationship: SPDXRef-File-zephyr.elf GENERATED_FROM SPDXRef-File-isr-tables.c
Relationship: SPDXRef-File-zephyr.elf STATIC_LINK SPDXRef-File-libapp.a
Relationship: SPDXRef-File-zephyr.elf STATIC_LINK SPDXRef-File-libzephyr.a
Relationship: SPDXRef-File-zephyr.elf STATIC_LINK SPDXRef-File-libisr-tables.a
Relationship: SPDXRef-File-zephyr.elf STATIC_LINK SPDXRef-File-libkernel.a
[...]
```

CVE Numbering Authority

- Registered with MITRE in 2017
  - We issue our own CVEs
- **Zephyr Project Security Incident Response Team** (PSIRT)
  - Volunteers from the Security Subcommittee led by the Zephyr Security Architect.

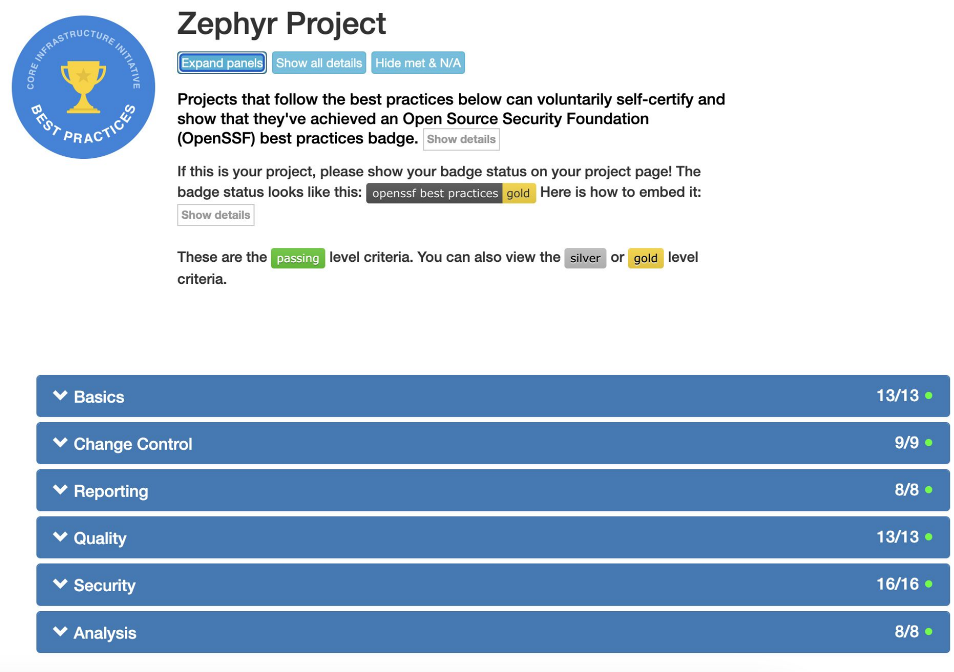
Zephyr Project

The majority of the links on this page redirect to external websites; these links will open a new window or tab depending on the web browser used.

Scope	Zephyr project components, and vulnerabilities that are not in another CNA's scope
Root	MITRE Corporation
Security Advisories	View Advisories
Program Role	CNA
Organization Type	Vendors and Projects
Country*	USA

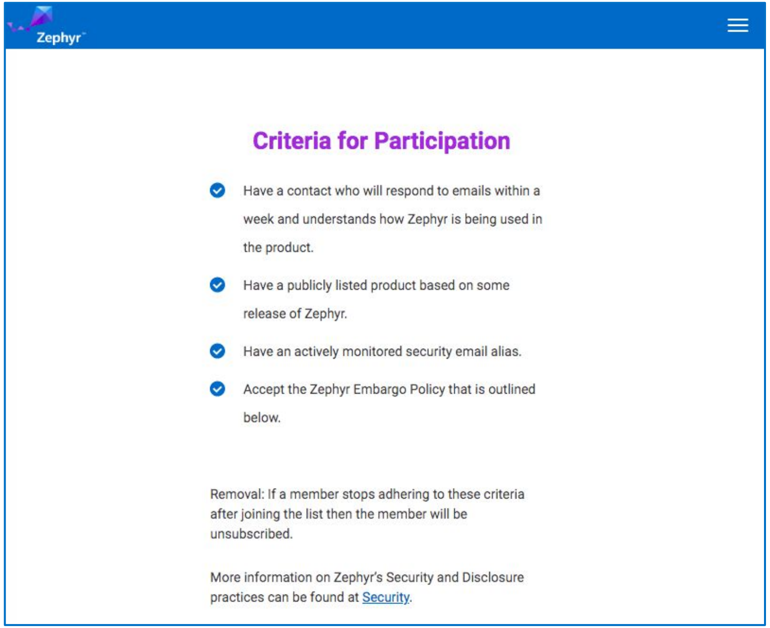
OpenSSF Gold Badge

- Core Infrastructure Initiative Best Practices Program
- Awards badges based on “project commitment to security”
- Mostly about project infrastructure: is project hosting, etc following security practices
- Gold status since Feb, 2019



Vulnerability Alert Registry

- For an **embargo** to be effective, product makers need to be **notified early** so they can **remediate**
- **<u>Goal</u>**: Zephyr to **fix issues within 30 days** to give vendors 60 days before publication of vulnerability
- Product makers can register to receive these alerts for free by signing up at Vulnerability Alert Registry



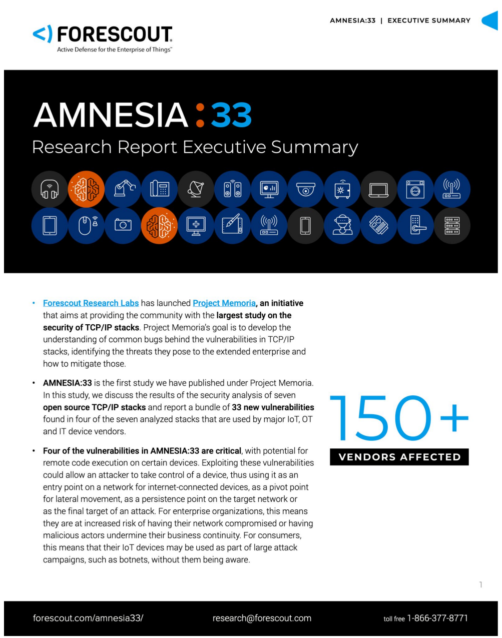
Zephyr PSIRT: Remediation and Response

Advisory Issued by project on 20201208:

- Zephyr current release (2.4) does not use Fnet or other stacks.
- The Zephyr LTS release 1.14 contains an implementation of the TCP stack from Fnet.

Of the vulnerabilities reported in Fnet, 2, CVE-2020-17468, and CVE-2020-17469, are in the IPv6 Fnet code, one, CVE-2020-17467, affects Link-local Multicast Name Resolution LLMNR), and 2, CVE-2020-24383, and CVE-2020-17470 affect DNS functionality.

None of the affected code has been used in the Zephyr project, while 1.14 does use the Fnet TCP, it does not use the affected IPv6, DNS or LLMNR code.


FORESCOUT
Active Defense for the Enterprise of Things

AMNESIA:33 | EXECUTIVE SUMMARY

AMNESIA:33
Research Report Executive Summary

- Forescout Research Labs has launched Project Memoria, **an initiative** that aims at providing the community with the **largest study on the security of TCP/IP stacks**. Project Memoria's goal is to develop the understanding of common bugs behind the vulnerabilities in TCP/IP stacks, identifying the threats they pose to the extended enterprise and how to mitigate those.
- **AMNESIA:33** is the first study we have published under Project Memoria. In this study, we discuss the results of the security analysis of seven **open source TCP/IP stacks** and report a bundle of **33 new vulnerabilities** found in four of the seven analyzed stacks that are used by major IoT, OT and IT device vendors.
- **Four of the vulnerabilities in AMNESIA:33 are critical**, with potential for remote code execution on certain devices. Exploiting these vulnerabilities could allow an attacker to take control of a device, thus using it as an entry point on a network for internet-connected devices, as a pivot point for lateral movement, as a persistence point on the target network or as the final target of an attack. For enterprise organizations, this means they are at increased risk of having their network compromised or having malicious actors undermine their business continuity. For consumers, this means that their IoT devices may be used as part of large attack campaigns, such as botnets, without them being aware.

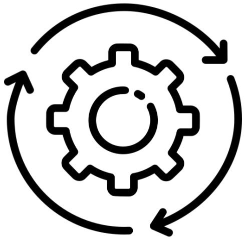
150+
VENDORS AFFECTED

1

forescout.com/amnesia33/ research@forescout.com toll free 1-866-377-8771

zephyrproject.org/zephyr-security-update-on-amnesia33

Zephyr Security Summary



Documented secure coding practices

Vulnerability response criteria publicly documented

Weekly Coverity scans

MISRA scans

SBOM generation

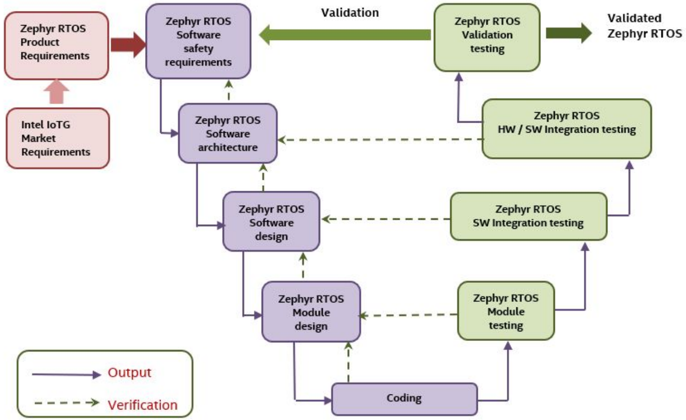
What’s all this about Zephyr safety?

Compliant Development: V-model

It is difficult to map a stereotypical open-source development to the V-model

- Specification of features
- Comprehensive documentation
- Traceability from requirements to source code
- Number of committers and information known about them

Zephyr RTOS functional safety work products mapping to IEC 61508-3 V model



⇒ Provide the evidences that open source developers can map to compliance and meet all requirements

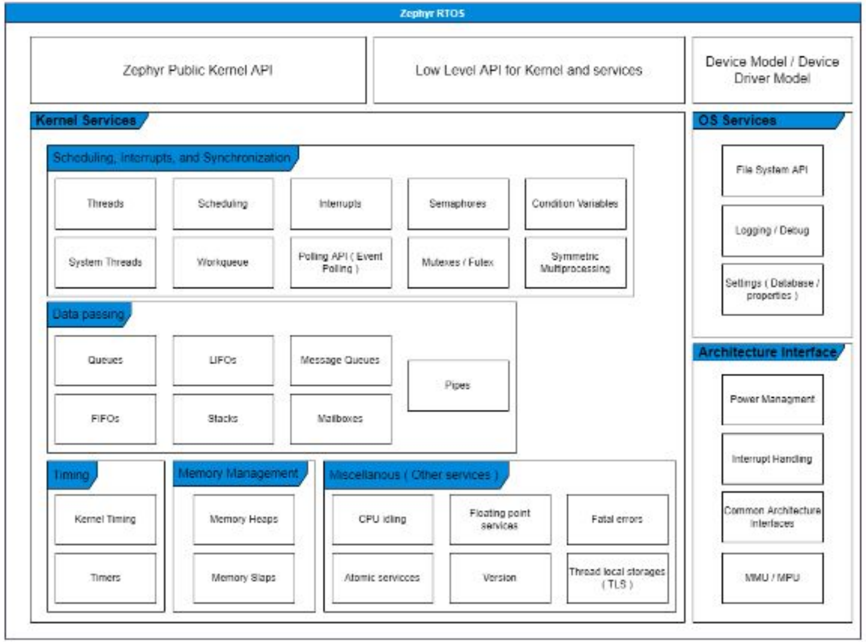
Safety Collateral Proposal

Draft (Pending Approval by Certification Authority)			
Artifacts	**Type of Doc**	**Owner**	**Work in progress Visibility**
Plans	Category		
Safety Development Plan	Plan/Process	Safety Committee	Public - Project Docs
Safety Assesment Plan	Plan/Process	FSM	Safety Committee Github
Verification / Validation / Integration Test Plan	Plan/Process	Testing WG	Public - Project Docs
Software Development Plan	Plan/Process	TSC	Public - Project Docs
Configuration and Change Management Plan	Plan/Process	TSC	Public - Project Docs
Coding Guideline	Plan/Process	TSC	Public - Project Docs
Tools Documentation	Plan/Process	TSC	Public - Project Docs
Specifications	Category		
Safety Scope Definition	Spec.	Safety Committee	Safety Committee Github
Safety Software Requirement Specification (SRS) **	Spec.	Safety Committee	Safety Committee Github
Safety Software Architecture and Interface Specification (SAIS) **	Spec.	Safety Committee	Safety Committee Github
Safety Software Component Design Specification (SMDS) **	Spec.	Safety Committee	Safety Committee Github
Safety Software Component Test Specification (SMTS) **	Spec.	Safety Committee	Safety Committee Github
Safety Software Integration Test Specification (SITS) **	Spec.	Safety Committee	Safety Committee Github
Safety Software Test Specification (STS) **	Spec.	Safety Committee	Safety Committee Github
Sources	Category		
Source Code	Source	TSC	Public
- Coding Guideline Compliance	Source	TSC	Public
Project Documentaton	Source	TSC	Public
- Software Requirement Specifications	Spec	TSC	Public
- Software Architecture and Interface Specification	Spec	TSC	Public
- Software Component Design Specification	Spec	TSC	Public
Project Testing	Source	TSC	Public
- Software Component/Unit Test Specification	Spec	TSC	Public
- Software Integration Test Specification	Spec	TSC	Public
- Software Test Specification	Spec	TSC	Public
- Tests	Source	TSC	Public
Reports	Category		
Code Review Report (pre-merge)	Report	TSC	Public
Code Change Test Report (post-merge)	Report	Testing WG	Public
Test Coverage Report	Report	Testing WG	Public
Coding Guideline Compliance Report	Report	Safety WG & Security WG	Public
Traceability Report	Report	Safety WG	Public
Tools Classification	Report	Safety Committee	Public
Tools Validation	Report	Safety Committee	TBD (based on specific tools)
Fault Injection Test Report	Report	Safety Committee	Safety Committee
Safety Traceability Report (for Safety Scope) **	Report	Safety Committee/FSM	Safety Committee
Safety Test Coverage Report (for Safety Scope) **	Report	Safety Committee/FSM	Safety Committee
Safety Analysis (e.g., FMEA)	Report	FSM	Safety Committee
Manuals	Category		
Software User Manual	Manual	TSC	Public
Safety Manual	Manual	FSM	Safety Committee
Certificates			
All safety certificates	Certificate	Safety Committee	N/A

- Requirement definition, Source Code & Test linkage are public; and developed in open using strictdoc
- The set of requirements (and associated traceability) are applicable to safety scope is managed by the safety committee.
- Other project artifacts have owners descignated.

Initial certification focus

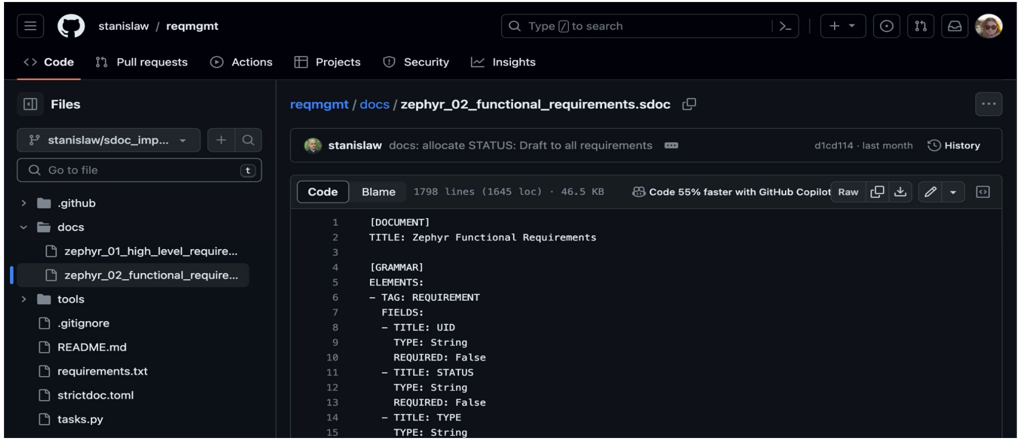
- Start with a limited scope of kernel and interfaces
- Initial target is IEC 61508 SIL 3 / SC 3 (IEC 61508-3, 7.4.2.12, Route 3s)
- Option for 26262 certification has been included in contract with certification authority should there be sufficient member interest

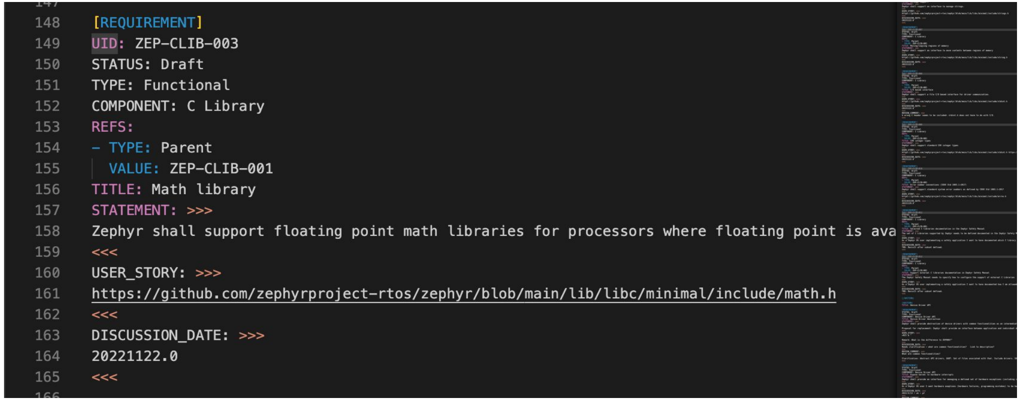


Scope can be **extended** to include **additional components** with associated **requirements** and **traceability** as determined by the safety committee

Current requirements work

- Used tooling: StrictDoc (https://github.com/strictdoc-project/strictdoc)
- Decision on UIDs for requirements (UID will be generated by StrictDoc)
- Hierarchical structure of requirements that works for the project
- Capturing the requirements in StrictDoc





What’s happening now..

Safety Committee

- Safety Certification Strategy decisions
  - Scope of certification
  - Certification standards
  - Certification timeline
- Assessment and audit specific tasks
- Owner of certification artefacts
- Participation limited to the project’s platinum members, the safety architect and the functional safety manager

Safety Working Group

- Enabling safety qualifications/ certifications in the project
- Working on creating the required documentation and evidences
  - Setting up requirements management tooling
  - creating/deriving and documenting requirements
- Open to everyone to participate, join today: https://lists.zephyrproject.org/g/safety-wg

Results of applying the best practices

Zephyr in the wild… 5.4K Forks!

Zephyr®

About

Primary Git Repository for the Zephyr Project. Zephyr is a new generation, scalable, optimized, secure RTOS for multiple hardware architectures.

docs.zephyrproject.org

iot · real-time · microcontroller · embedded · bluetooth · bluetooth-le · mcu · rtos · zephyr · zephyros · embedded-c · zephyr-rtos

- Readme
- Apache-2.0 license
- Code of conduct
- Security policy
- Activity
- 8.8k stars
- 378 watching
- 5.4k forks

Source:
https://github.com/zephyrproject-rtos/zephyr

CANINOS LOUCOS .org

HOME PROGRAM PRODUCTS PARTNERS CONTACT DEVELOPER AREA ENGLISH

THE CANINOS LOUCOS PROGRAM SUPPORTS THE MANUFACTURE OF INSPIRE PULMONARY VENTILATORS TO COMBAT COVID-19

Pulga Core V2.0

The Caninos Loucos Pulga board is a powerful microcontroller with a large number of sensors, highly secure, and ideal for IoT applications. Completely designed in Brazil.

The low power board is approximately the size of a quarter dollar coin (24,26mm) and supports Bluetooth 5.0, allowing for wireless connection between multiple Pulgas.

Aspects such as modularity, via an autonomous core board and an optional base board, and energy harvesting capability, enables great exibility for hardware interfaces prototyping.

The base board allows for adding functionality for custom applications. For example, by adding long distance wireless protocols and new sensors, you can meet the demands of dierent projects.

Finally, the harvesting allows for capturing energy from dierent environmental sources, ensuring energetic autonomy to the board.

Website:: https://caninosloucos.org/en/pulgacore-v2-en/
Code: https://github.com/caninos-loucos/pulga-zephyr

Technological Integrated Systems Laboratory (LSI-TEC) with the support of the Polytechnic School of the University of São Paulo (Poli-USP)

Products Running Zephyr Today

Zephyr®

Proglove

Ruuvi Tag

PHYTEC Distancer

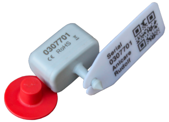
Keeb.io BDN9

Hati-ACE

Oticon More

Adhoc Smart Waste

GNARBOX 2.0 SSD



Anicare Reindeer Tracker

Safety Pod

BLiXT solid state circuit breaker

Moto Watch 100

Lildog & Lilcat pet tracker

Rigado IoT Gateway

Livestock Tracker

Laird Connectivity sensors & gateways

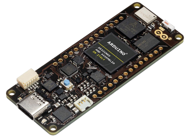
BeST pump monitoring

Vestas Wind Turbines

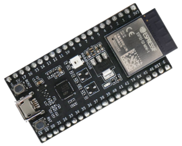
zephyrproject.org/products-running-zephyr

550+ supported boards... and growing

Zephyr®

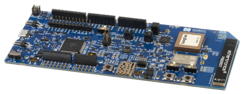


Arduino Portenta H7



ESP32

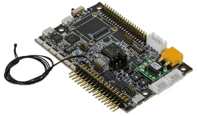
Sipeed HiFive1



nRF9160 DK

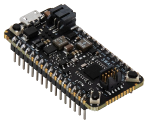
STM32F746G Disco

M5StickC PLUS

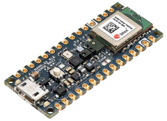


TDK RoboKit 1

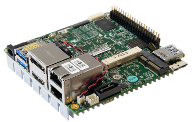
BBC micro:bit v2



Blue Wireless Swan



Arduino Nano 33 BLE

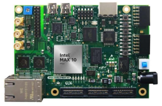


Intel UP Squared

Dragino LSN50 LoRA Sensor Node

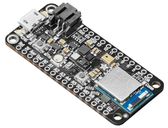
Microchip SAM E54 Xplained Pro Evaluation Kit

Raspberry Pi Pico

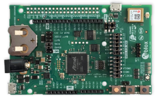


Altera MAX10

NXP i.MX8MP EVK



Adafruit Feather M0 LoRa



u-blox EVK-NINA-B3

docs.zephyrproject.org/latest/boards

170+ Sensors Already Integrated

Zephyr®

adt7420
adxl345
adxl362
adxl372
ak8975
amg88xx
ams_as5600
ams_iAQcore
apds9960
bma280
bmc150_magn
bme280
bme680
bmg160
bmi160
bmi270
bmm150
bmp388
bq274xx
ccs811

dht
dps310
ds18b20
ens210
esp32_temp
fdc2x1x
fxas21002
fxos8700
grove
grow_r502a
hmc5883l
hp206c
hts221
i3g4250d
icm42605
icm42670
icm42688
icp10125
iis2dh
iis2dlpc

iis2iclx
iis2mdc
iis3dhhc
ina219
ina23x
isl29035
ism330dhcx
ite_tach_it8xxx2
ite_vcmp_it8xxx2
lis2dh
lis2ds12
lis2dw12
lis2mdl
lis3mdl
lm75
lm77
lps22hb
lps22hh
lps25hb
lsm303dlhc_magn

lsm6ds0
lsm6dsl
lsm6dso
lsm9ds0_gyro
lsm9ds0_mfd
max17055
max17262
max30101
max31875
max44009
max6675
mchp_tach_xec
mcp9808
mcux_acmp
mhz19b
mpr
mpu6050
mpu9250
ms5607
ms5837

nrf5
nuvoton_adc_cmp_npcx
nuvoton_tach_npcx
nxp_kinetis_temp
opt3001
pcnt_esp32
pms7003
qdec_mcux
qdec_nrfx
qdec_sam
qdec_stm32
rpi_pico_temp
sbs_gauge
sgp40
sht3xd
sht4x
shtcx
si7006
si7055
si7060

si7210
sm351lt
stm32_temp
stm32_vbat
stmemsc
stts751
sx9500
th02
ti_hdc
ti_hdc20xx
tmp007
tmp108
tmp112
tmp116
vcnl4040
vl53l0x
wsen_hids
wsen_itds

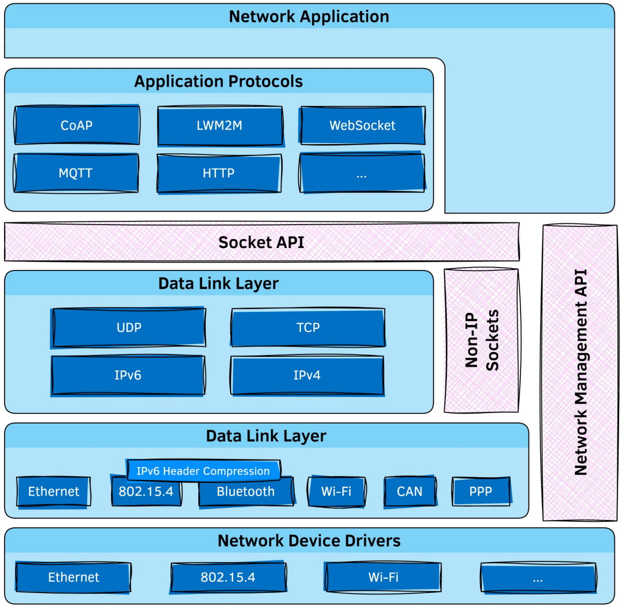
github.com/zephyrproject-rtos/zephyr/tree/main/drivers/sensor

IoT Connectivity Options

- Wide variety of **communication protocols**
  - Ethernet, 802.15.4, Thread, LoRa, Bluetooth, CAN bus, ...
- **Core network protocols** like IPv6, IPv4, UDP, TCP, ICMPv4, and ICMPv6.
- **Security** (ex. TLS, DTLS, ...)
- **Cloud integration** using MQTT, CoAP and HTTP protocols
- **Over-the-air updates**
- **Device management** using OMA LwM2M 1.1 protocol

Native IP Stack

- Built from scratch, on top of Zephyr native kernel concepts
- Dual mode **IPv4/IPv6 stack**
  - DHCP v4, IPv4 autoconf, IPv6 SLAAC, DNS, SNTP
- Multiple network interfaces support
- Time Sensitive Networking support
- **BSD Sockets**-based API
- Supports IP offloading
- **Compliance and security** tested



Bluetooth Host and Mesh

- **Bluetooth 5.3 compliant**
- Highly configurable
- Portable to all architectures supported by Zephyr
- Low Energy & experimental Bluetooth Classic
- IPSP/6LoWPAN for IPv6 connectivity over Bluetooth LE
- Multiple HCI transports

Bluetooth Low Energy Controller

- **Bluetooth 5.3 compliant** and qualified (5.1)
- Support for multiple BLE radio hardware architectures
  - Nordic nRF5x on Arm Cortex-M
  - VEGAboard on RISC-V
- Proprietary radios (downstream only)
- Unlimited role and connection count
- Concurrent multi-protocol support ready
- Multiple advertiser and scanner instances

Zephyr USB Device Stack

- **USB 2.0** & **USB-C** support
- Supports multiple MCU families (STM32, Kinetis, nRF, SAM,...)
- Supports most common devices classes: CDC, Mass Storage, HID, Bluetooth HCI over USB, DFU, USB Audio, etc.
- Tight integration with the RTOS
- Native execution support for emulated development on Linux
- WebUSB support

Power Management

- Goal: use as little power as possible
- Cross-platform (architecture / SoC agnostic)
- Tickless scheduler
- Handled by the kernel / Customizable by the user

Devicetree

Describe & **configure** the available hardware on the target system

Decouple the application from the hardware

docs.zephyrproject.org/latest/build/dts

```
&i2c1 {
    pinctrl-0 = <&i2c1_scl_pb8 &i2c1_sda_pb9>;
    pinctrl-names = "default";
    clock-frequency = <I2C_BITRATE_FAST>;
    status = "okay";

    lsm6dsl@6a {
        compatible = "st,lsm6dsl";
        reg = <0x06a >;
    };

    hts221@5f {
        compatible = "st,hts221";
        reg = <0x5f >;
    };

    // …
};
```

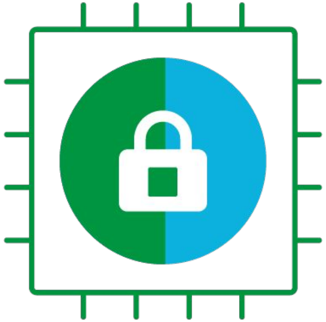
`.dts` file example

Secure boot / Device Management

- Leverage **MCUboot** as secure bootloader
- Application binary can be signed/encrypted
  - Can use hardware keys
- But also:
  - Downgrade prevention
  - Dependency checks
  - Reset and failure recovery
- Over-the-air (OTA) upgrades
  - OMA LwM2M, Eclipse hawkBit
  - Vendor offerings

Hardware security

- **Cryptography APIs**
  - Random Number Generation, ciphering, etc.
  - Supported by crypto HW, or SW implementation (TinyCrypt)
- **Trusted Firmware** integration
  - Firmware verification/encryption
  - Device attestation
  - Management of device secrets



Building on POSIX

- **Zephyr apps can run as native Linux applications**
  - Easier to debug/profile with native tools
  - Connect to real devices using TCP/IP, Bluetooth, CAN
  - Helps minimize hardware dependencies during the development phase
- **Re-use existing code & libraries by accessing Zephyr services through POSIX API**
  - Easier for non-embedded programmers
  - Implementation is optimized for constrained systems
  - Supported POSIX subsets: PSE51, PSE52, and BSD sockets

docs.zephyrproject.org/latest/guides/portability/posix.html

A real-time OS

Benchmark on Arm Cortex-M4F running at 120 MHz

Operation	Time
Thread create	2.5 µs
Thread start	3.6 µs
Thread suspend	3.3 µs
Thread resume	3.8 µs
Context switch (yield)	2.2 µs
Get semaphore	0.6 µs
Put semaphore	1.1 µs

github.com/zephyrproject-rtos/zephyr/tree/main/tests/benchmarks

Graphical User Interfaces

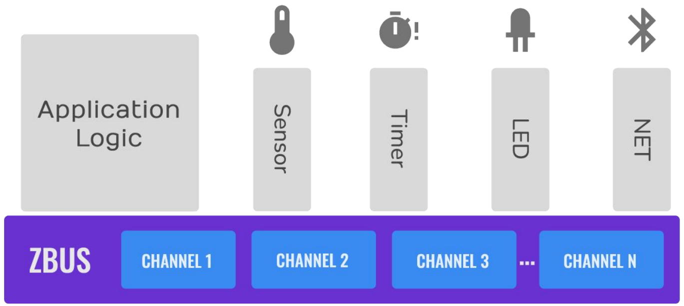
- Drivers available for various types of displays
  - LCD
  - OLED
  - Touch panel displays
  - E-ink
- LVGL integration
- Support for video capture and output

Inter-Process Communication

- **Built-in kernel services** (see table)
- **IPC service**
  - 1-to-1 or 1-to-many communications
  - No-copy API
- **zbus** (Zephyr Message Bus)
  - 1-to-1, 1-to-many, or many-to-many channel-based communications
  - Synchronous or asynchronous

Object	Bidirectional?	Data structure
FIFO	✘	Queue
LIFO	✘	Queue
Stack	✘	Array
Message queue	✘	Ring buffer
Mailbox	✔	Queue
Pipe	✘	Ring buffer

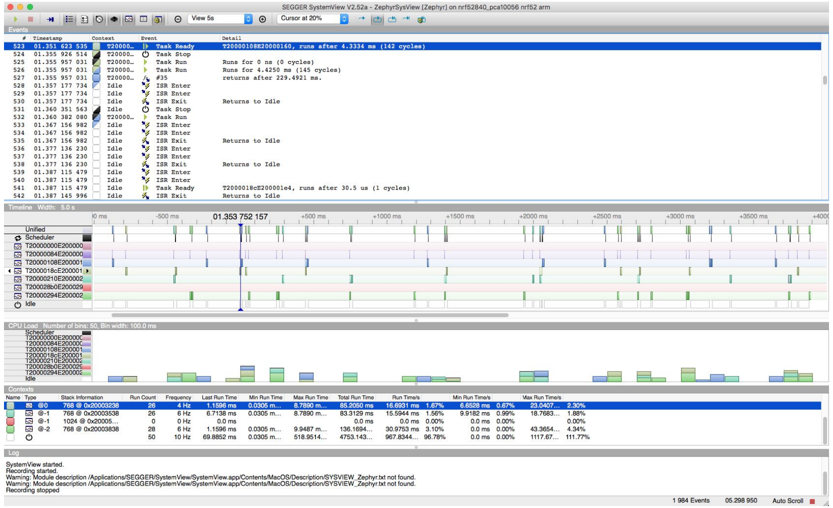
Data passing objects available in Zephyr kernel



A typical zbus application architecture

Tracing & Debugging

- Advanced **logging** framework
  - Multiple backends (UART, network, file system, ...)
  - Compile-time & runtime filtering
- **Tracing** framework
  - Visualize the inner-working of the kernel and its various subsystems
  - Object tracking (mutexes, timers, etc.)



Vibrant Ecosystem

Zephyr®

- Governing Board
- Technical Steering Committee
- Contributors

Development Tools

Applications & Middlewares

Training & Consulting

Firmwares & Libraries

Ecosystem // **Dev Tools**

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Development Tools

Training & Consulting

Firmwares & Libraries

Applications & Middlewares

IDE

eclipse

Compilers

Debuggers / Tracing Tools

LAUTERBACH DEVELOPMENT TOOLS

SEGGER

Memfault

percepio SENSING SOFTWARE

Emulation / Simulation

RENODE™

WOKWi

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antmicro

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Training & Consulting

Firmwares & Libraries

Applications & Middlewares

Security

Mbed TLS

wolfSSL

TinyML

TensorFlow Lite

EDGE IMPULSE

Language runtimes

MicroPython

Others

SOUND OPEN FIRMWARE

zscilib

Memfault

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Training & Consulting

Firmwares & Libraries

Applications & Middlewares

Remote Management

HERALD

Golioth

AVSYSTEM

Memfault

STERNUM

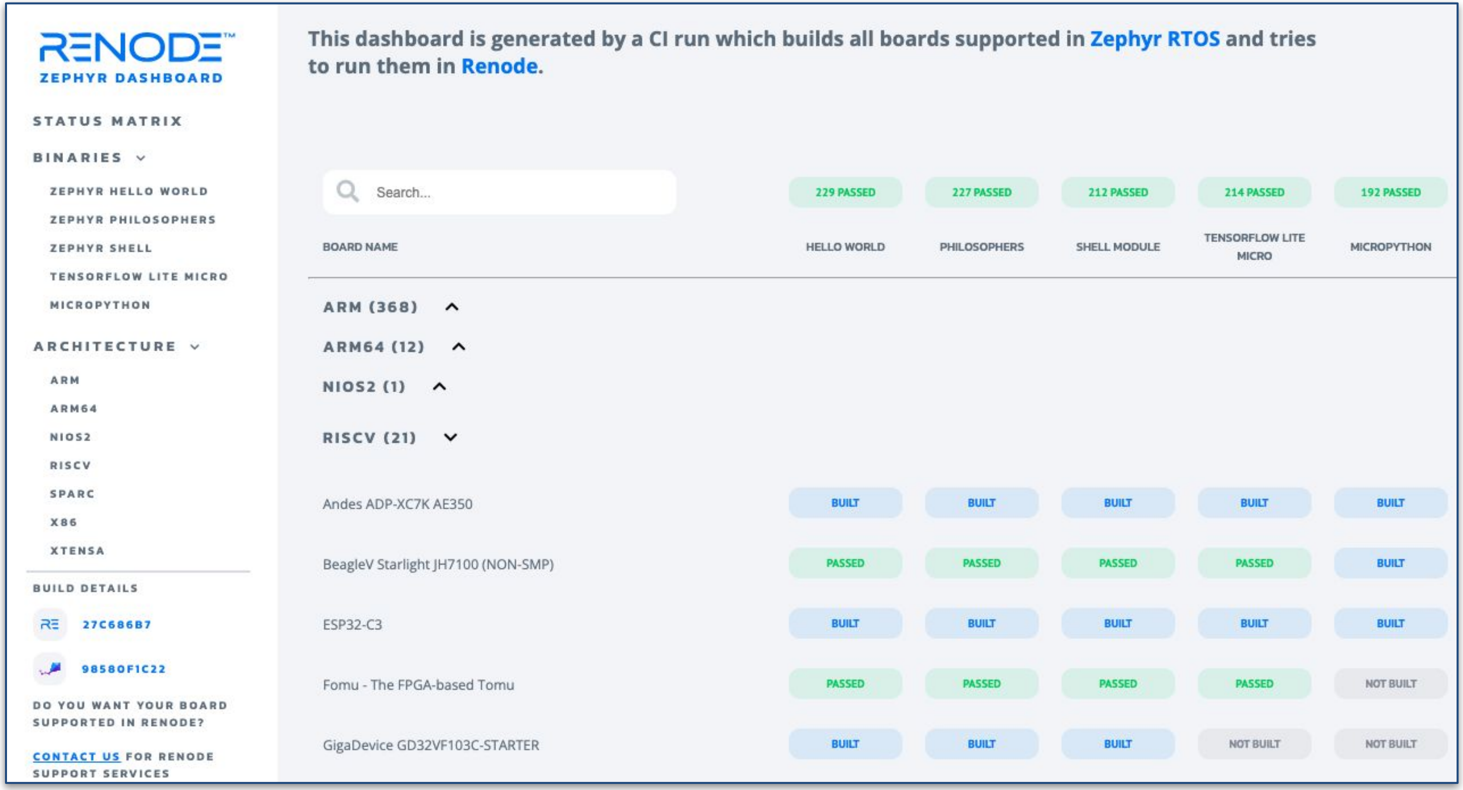
blues wireless

Robotics

µROS

SBOMs at scale - see RENODE Dashboard:
3 SBOMs Included by default on each build.

Zephyr



https://zephyr-dashboard.renode.io/

Interested to Learn More? Come Join Us!

Zephyr Community Overview:

- https://www.zephyrproject.org/community/

Code on GitHub:

- https://github.com/zephyrproject-rtos/zephyr

Mail Lists:

- https://lists.zephyrproject.org/g/main

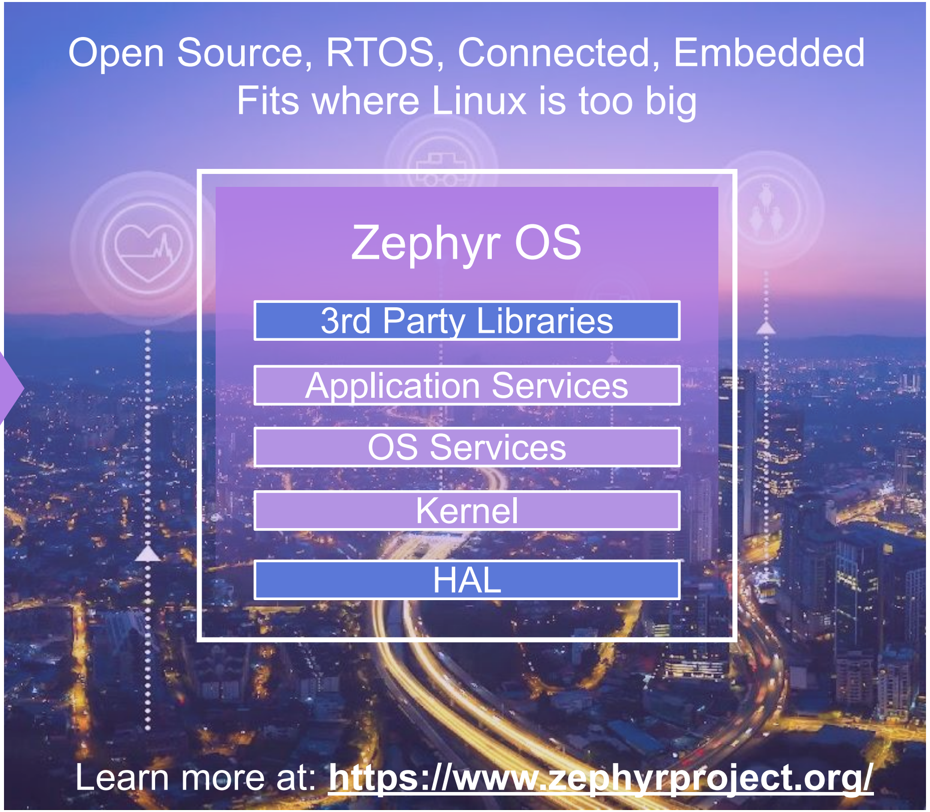
Discord (8000+ developers):

- https://chat.zephyrproject.org/ (https://discord.com/invite/Ck7jw53nU2)

Zephyr Project

Zephyr®

- **Open source** real time operating system
- **Vibrant Community** participation
- **Vendor Neutral** governance
- **Permissively** licensed - Apache 2.0
- **Cross-architecture** with broad SoC and development board support.
- **Complete**, fully integrated, highly configurable, **modular** for **flexibility**
- **Product** development ready using LTS includes security updates
- Built with **safety and security** in mind



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Questions?

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