THE LINUX FOUNDATION
OPEN SOURCE SUMMIT
EUROPE

U-Boot in the Fast Lane: Developing a Safety Test Framework for Automotive Applications

Neha Malcom Francis

August 27th, 2025

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- ✔ Decades of contribution and collaboration
- ✔ Focus on long term, sustainable and quality products
- ✔ Upstream & opensource ecosystem in device architecture
- ✔ Ingrained culture to give back to the community

Speaker Introduction

```
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    Texas-Instruments;
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    hobbies = “dancing”, “travelling”, “painting”;
};
```
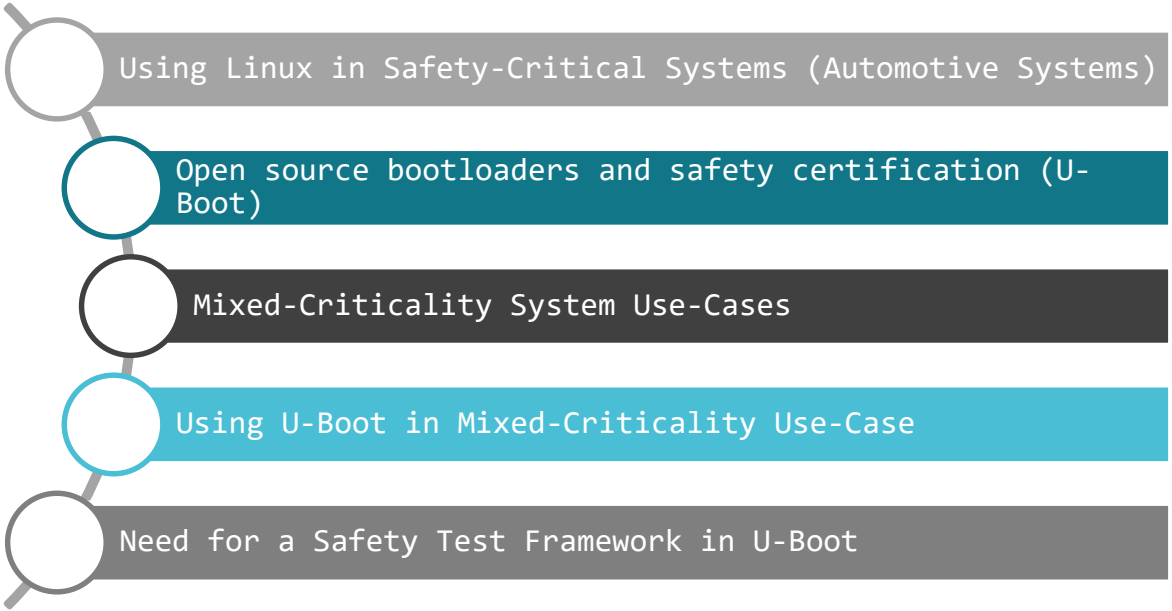

Disclaimers

- This is a technology presentation, not product-readiness or roadmap commitment
- Opinions presented here are that of the speakers and may not reflect that of Texas Instruments Inc.

Overview

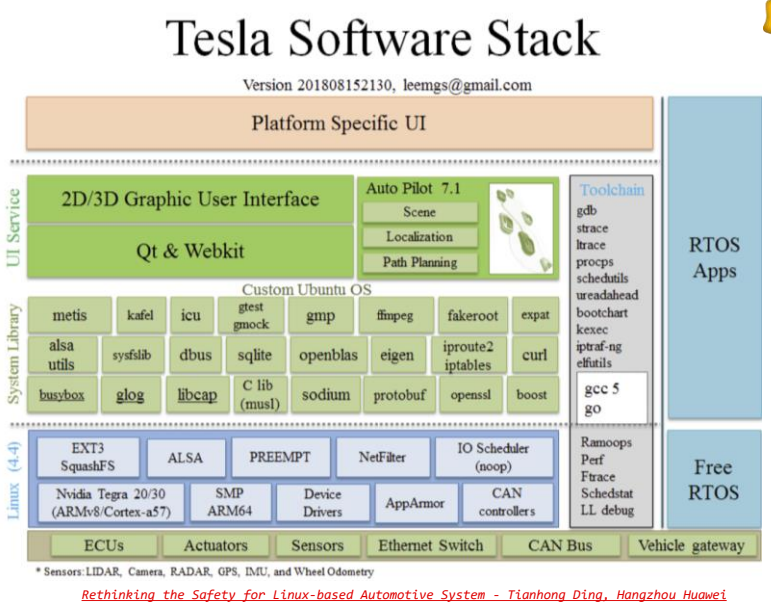


Focus of this presentation would be on **why** and **how** we need to develop a safety test framework in U-Boot, not implementation level details which may be trivial

Using Linux in Safety-Critical Systems (Automotive systems)

Linux in Automotive

- Advantages that make adoption tempting:
  - Heterogeneous computing
  - Rich HW platform support
  - Cheap development cost
  - Security capabilities
  - And everything else that comes with it being open source!



Rethinking the Safety for Linux-based Automotive System - Tianhong Ding, Hangzhou Huawei

Tesla makes use of the Linux ecosystem

Linux in Automotive

- Excuses for not picking up Linux?
  - RT
  - Monolithic
  - Insufficient testing
  - Safety-compliance

Linux in Automotive

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ZDNET

20 years later, real-time Linux makes it to the kernel - really

After 20 years, Real-Time Linux (PREEMPT_RT) is finally -- finally -- in the mainline kernel. Linus Torvalds blessed the code while he was at Open Source...

18 Sept 2024

Linux in Automotive

- Excuses for not picking up Linux?
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Xen Project Wiki
https://wiki.xenproject.org › wiki › Xen_Project_Softwar...

Xen Project Software Overview

13 Feb 2024 — **Linux distributions that are based on Linux kernels newer than Linux 3.0** are Xen Project-enabled and usually include packages that contain the ...

Linux in Automotive

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KernelCI

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KernelCI

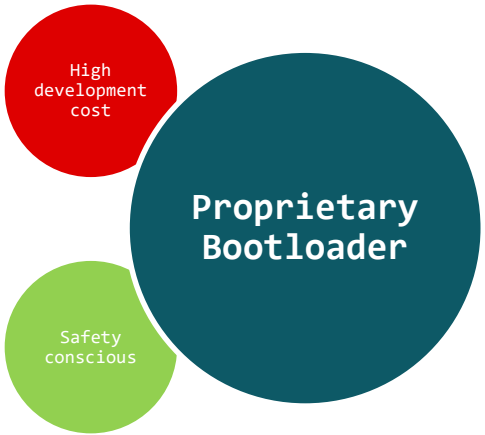
Strides in safety compliance by Linux

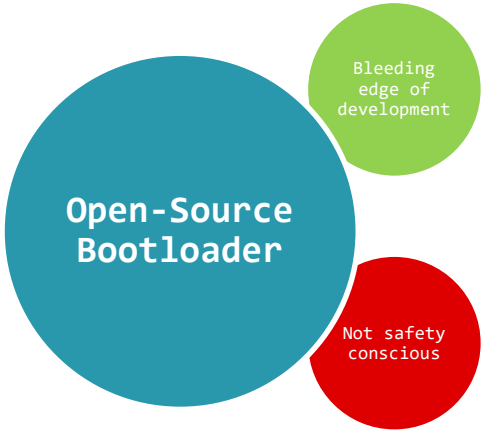
- OSADL SIL2LinuxMP Project
  - Methodology to qualify Linux on a multi-core embedded platform at SIL2
  - Open
- ELISA
  - Defining and maintaining processes that can safety certify Linux-based systems
  - Open
- Automotive Grade Linux
  - Actively developing a Linux-based, open software platform for automotive applications
  - Open
- RHIVOS
  - Targeting functional safety certification prioritizing automotive in Linux
  - AGL
  - Partially open
- OpenAMP
  - Making strides in standardizing heterogeneous communication
  - Not safety specific, but helps

Where are we with bootloaders?

Open Source Bootloaders

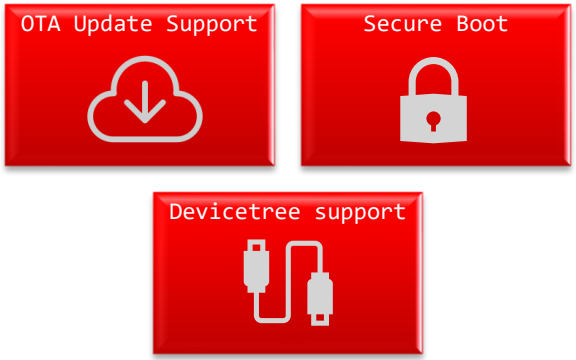
- Not much advancement in safety certification
- Onus on the SoC vendor to safety certify their proprietary bootloaders
- Usually the flow picked is: Proprietary bootloader → Linux





U-Boot in Automotive

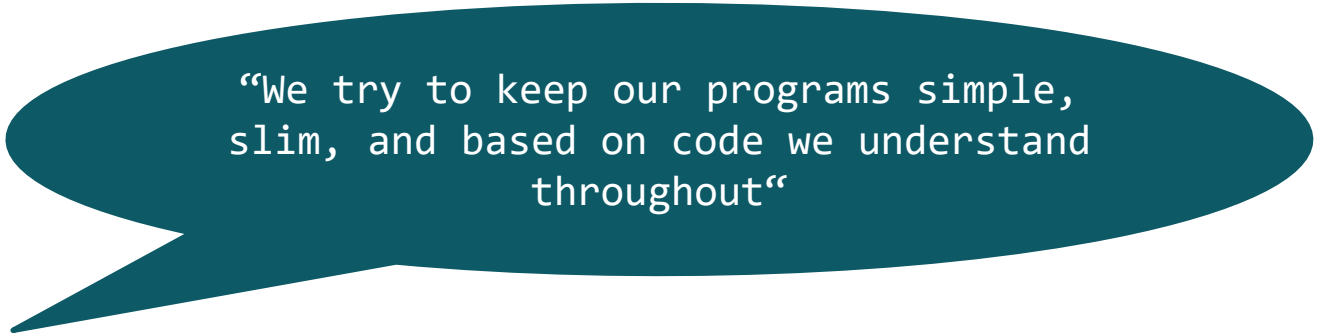
- U-Boot is quite rich
  - Peripheral drivers and stacks
  - Integration with the Linux kernel
  - Multiple arch support: ARM, x86, RISC-v etc.
- Opportunities within automotive for using U-Boot



It’s not like U-Boot hasn’t been leveraged anywhere …

- In fact, it’s more than we think

Project	Bootloader Used
EB Corbos	
RHIVOS	
SpaceX’s Falcon 9	
AGL Images	



Dietrick - SpaceX

Writing simpler, robust code is the underlying principle of U-Boot and all open-source software; and this inherently eases the safety risk

Proprietary bootloaders

- For valid reason, proprietary bootloaders do pretty well for automotive use-cases

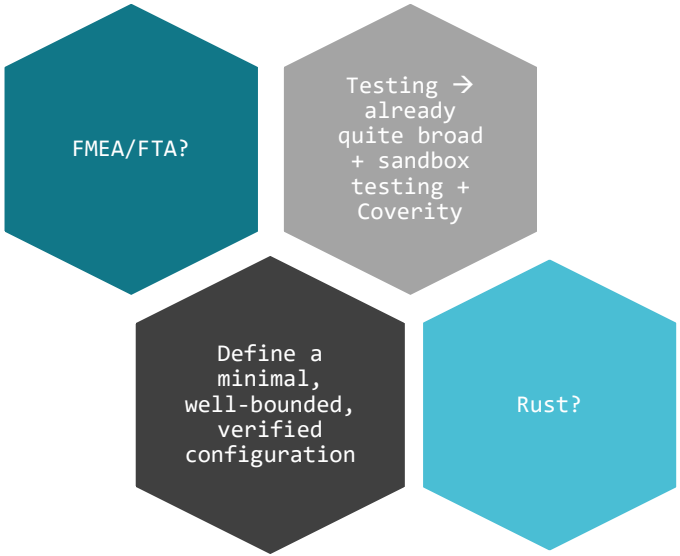
Project	Bootloader Used
Embidetel	Proprietary Flash Bootloader
Vector Informatik	Proprietary Flash Bootloader
Elektrobit	Proprietary ACO Bootloader
ALTEN	Proprietary Auto Bootloader
Texas Instruments	Proprietary SBL

And more …

Safety certifying U-Boot

Is safety certifying U-Boot possible?

- Quite a reach, but not impossible

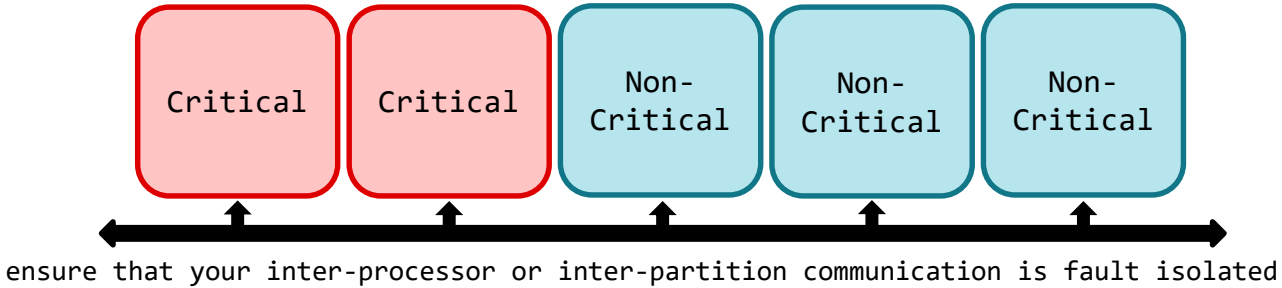


- We have a long way to go… what can we aim at now?

Mixed-Criticality Systems (MCS)

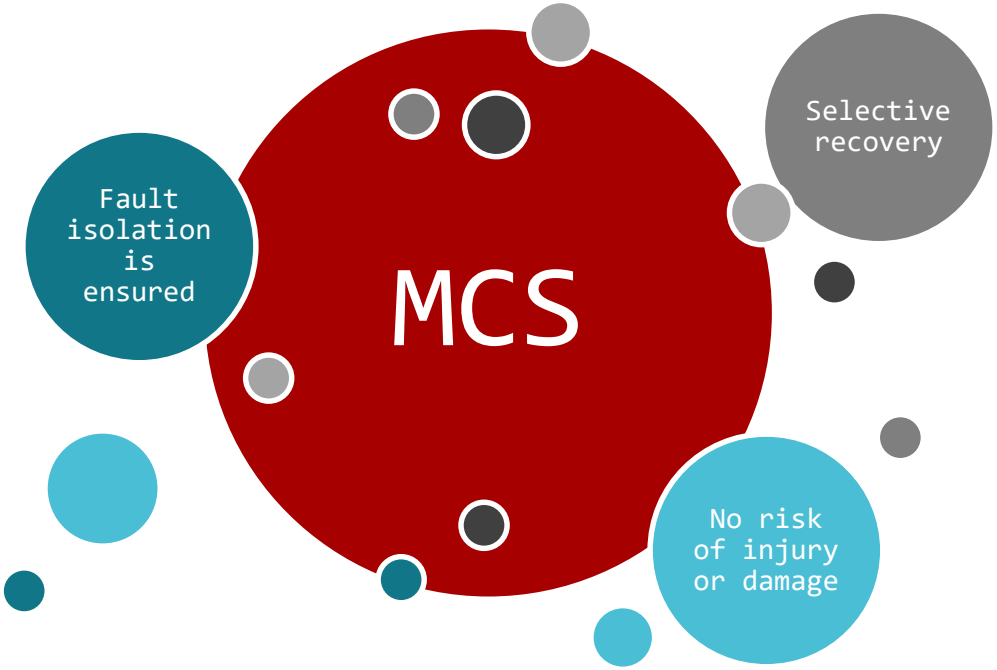
Mixed-criticality use-cases of safety

- MCS allows varying levels of safety requirements to coexist on the same hardware platform



- e.g. IVI systems require VirtIO and PV devices
  - higher complexity + lower safety levels

Mixed-criticality use-cases of safety



Red Hat Reaches Key Milestone in Push to Functional Safety Certification for Red Hat In-Vehicle Operating System

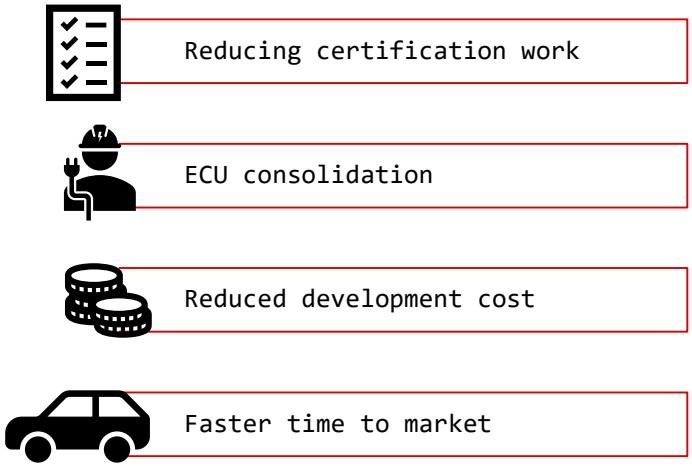
BlackBerry
Why Mixed-Criticality Is the Future of Automotive Architectures
AUTOMOTIVE & IOT / 09.14.22 / Randy Martin

wipro
Three Steps to Implementing Mixed Criticality...
Implement Mixed Criticality Systems for Automotive Safety

SYSGO
EMBEDDING INNOVATIONS
Tackling Mixed-Criticality for Automotive
Jun 14, 2021 – PikeOS, Automotive, Safety

MCS

- A lot of SDVs are adopting this already:



- Linux is a clear choice for enabling a part of such systems
- But why should U-Boot be the choice as a bootloader?

Gearing up a bootloader to work in an MCS

Gearing up a bootloader to work in an MCS

- Besides the obvious, i.e. initializing the hardware
- In an automotive system, the bootloader needs to also
  + Support OTA updates
  + Support secure boot
  + Support **diagnostic testing**

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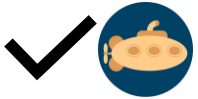
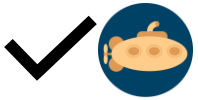
  - + Support OTA updates 
  - + Support secure boot 
  - + Support **diagnostic testing**

U-Boot in MCS

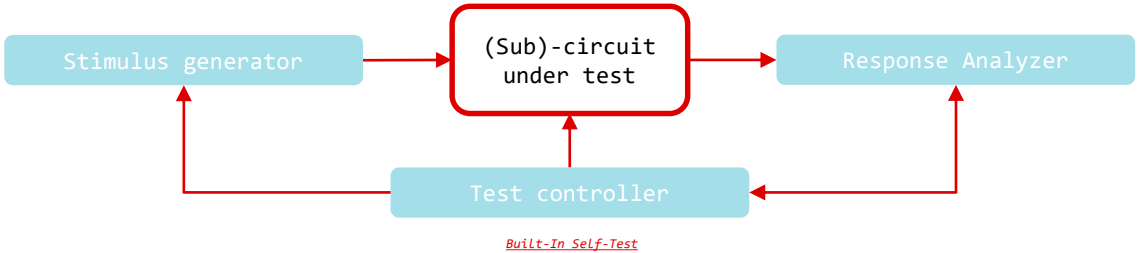
U-Boot in MCS?

- Increase the safety chapter of U-Boot → double edged sword
- In MCS, the bootloader can execute fault diagnostic tests prior to running safe applications
  - Enable ECC on memory if any

  - Check for CPU faults if any → BIST (Built In Self Test)

Using U-Boot in MCS

- Safety IP: BIST (Built-In Self Test)
  - Safety diagnostic block embedded in hardware that test memory areas and logic circuitry in an IC at boot time

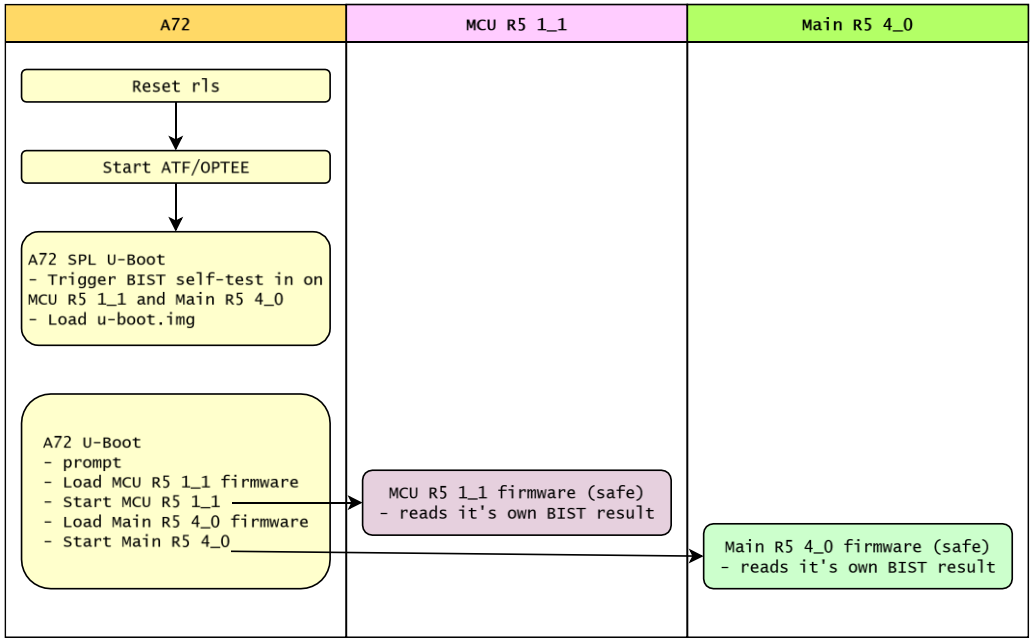


- Enhances system reliability
- Expected to be run once at boot time
- Destructive in nature, cannot be performed by applications at runtime without saving/restoring context

Using U-Boot in MCS: an example

- Customer Request: trigger BIST from non-safe U-Boot on the safety channels running safety certified firmware
- Upstreamed the BIST driver under misc/ in U-Boot
- Link to the patch series

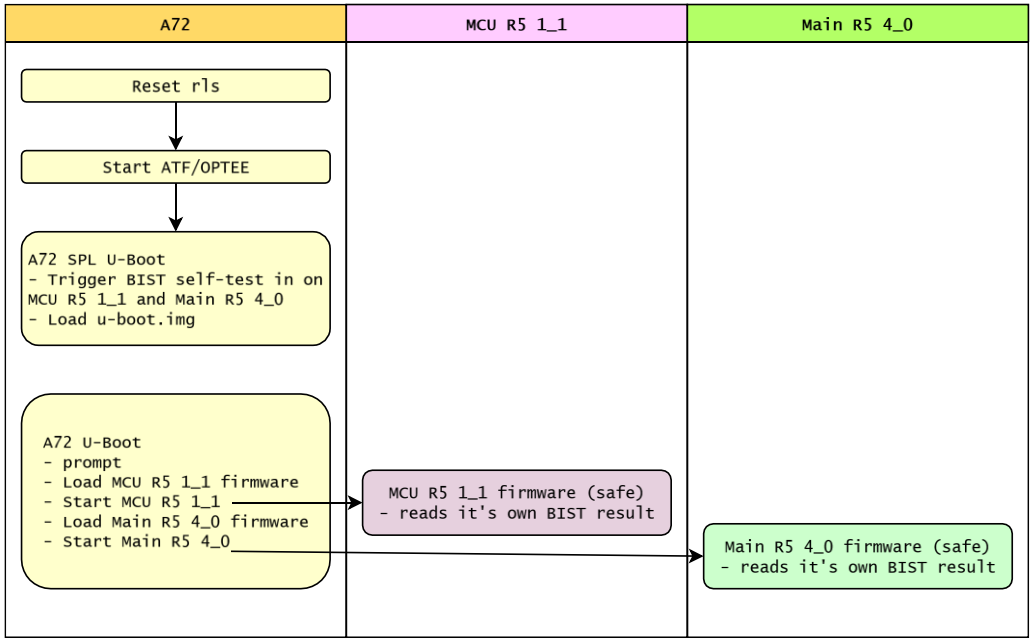
Using U-Boot in MCS: an example



Flow adopted by customer with System Level CAT3 certification using the BIST driver for a mixed-criticality safety use-case

Using U-Boot in MCS: an example

```
bist_main14: bist@33c0000 {
        compatible = "ti,j784s4-bist”;
        reg = <0x00 0x033c0000 0x00 0x400>,
              <0x00 0x0010c1a0 0x00 0x01c>;
        reg-names = "cfg", "ctrl_mmr";
        clocks = <&k3_clks 237 7>;
        power-domains = <&k3_pds 237 TI_SCI_PD_EXCLUSIVE>;
        bootph-pre-ram;
        ti,sci-dev-id = <234>;
};
```



Flow adopted by customer with System Level CAT3 certification using the BIST driver for a mixed-criticality safety use-case

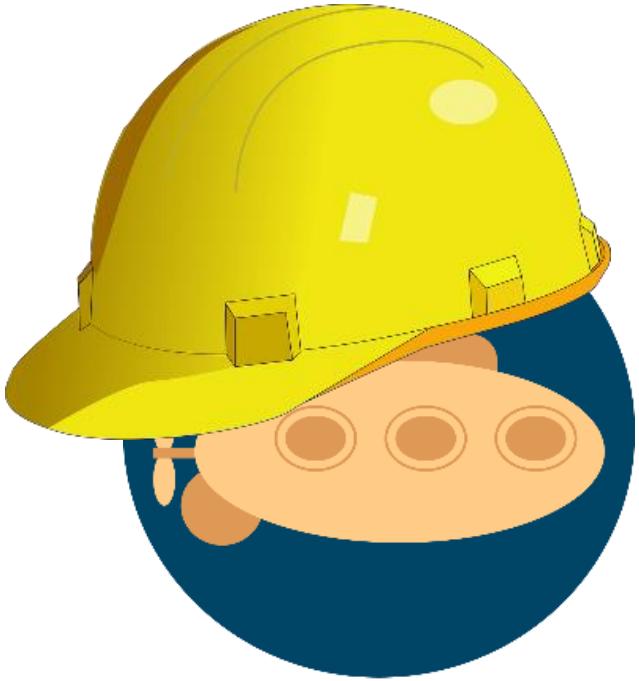
Safety IPs in U-Boot

- misc/ good enough place to house BIST driver?
- However possibilities of other safety IPs; such as JTAG, SDL, STL etc. can come up
  - JTAG: not just for debug/programmability → boundary scan tests
  - SDL/STL: ARM libraries
    - Runtime (non-destructive)
    - Boot time (includes destructive)
- Move from misc/ → safety-test/ or safety/

Conclusion

- Large scope for introducing safety IPs within U-Boot → safety-test framework
- The BIST driver in what is hopefully a series of more such drivers that can increase the use of U-Boot in mixed-criticality automotive use-cases

All part of an effort to ensure U-Boot remains the bootloader of choice in Automotive Systems!



References

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- From Space to Scrum – 3back
- TI Processor SDK Linux J784S4 - PBIST Guide
- TI Processor SDK Linux J784S4 - LBIST Guide

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- Beleswar Padhi, Texas Instruments Inc.
- SDL Team, Texas Instruments Inc.
- U-Boot community

Q&A

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  #linux-ti

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