

SIL2 Video Streaming

Functional Safety from Lens to Glass

GStreamer Conference 2026

ARTECH

Made In Austria 

A&R TECH



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Computer Engineering background

Software Engineer, Team Lead “Vision Vipers”

10 YoE @ A&R TECH

Linux Kernel & Userspace Development

Safe Software Development

V4L2, GStreamer integration

A&R TECH



~130 employees in Vienna, Austria

30 years of railway culture & experience

Engineering team of ~70 people

HW/SW/Tooling and Production in one facility

Serving the big players in the railway market

A&R TECH – HMIs

Human Machine Interface

Railway, Off-Highway

Various input, outputs, expansions

25+ safety functions

Safe Visualization

Safe PCAP Touchscreen

Various Safety Layers

Safe HotSync

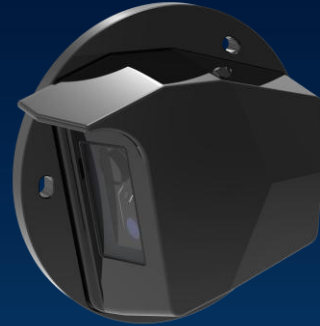


A&R TECH – Camera Systems

Rear-View Cameras (+Screens)

Cube Cams

Safe H.265 Video Streaming



Video Streaming Hazards

Artifacts (compression, noise, packet loss, ...)

Imprecise depiction of reality (colors, contrast, ...)

Latency



Video Streaming Hazards



Driver's desk in the Remote Operation Centre. Copyright: Deutsche Bahn AG / Thomas Kiewning

SIL2 H.265 Video Streaming – Safety Function



In any of the defined contextual scenarios, the image displayed on the safe streaming video sink shall **faithfully represent reality** captured by the safe video camera **in a non-hazardous way**.

SIL2 H.265 Video Streaming – Safety Function

No objects hidden/added which might have been detected by a trained operator

No significant/misleading color changes that could lead a trained operator to misinterpret reality

Safe framerate supervision

Safe latency supervision

Safety layer (no network safety constraints)

Safety (a very brief introduction)

Operational Safety – Measures for safe operation of machines or systems

Functional Safety – Predictable reaction of a system to inputs and failure

Systematic Failures (software bugs, design errors, manufacturing errors, ...)

Random Faults (temperature/voltage variations, bitflips, ...)

Software + Hardware aspects

Safety $\neq$ Security (targeted attacks)

Safety – Safety Integrity Level

SIL1 – Low Risk / Limited Harm

SIL2 – Moderate Risk / Significant Disruption

SIL3 – High Risk / Severe Injury or Fatality

SIL4 – Highest Risk / Catastrophic Consequences

Safety – Safety Integrity Level

SIL level defines required **probability of system failure on demand** (PFD)

Example:

Safety of a single sensor with PFD 1% (SIL1) is drastically increased by adding triple redundancy and 2oo3 voting (PFD 0.000298%, SIL3)

Safety - Safe Software Development

SIL levels recommend **techniques and measures required to avoid faults:**

Process (risk analysis, system life-cycle, ...)

Hardware (redundancy, component failure rate, ...)

Software (design, language features, ...)

Tests (techniques, coverage, ...)

Documentation

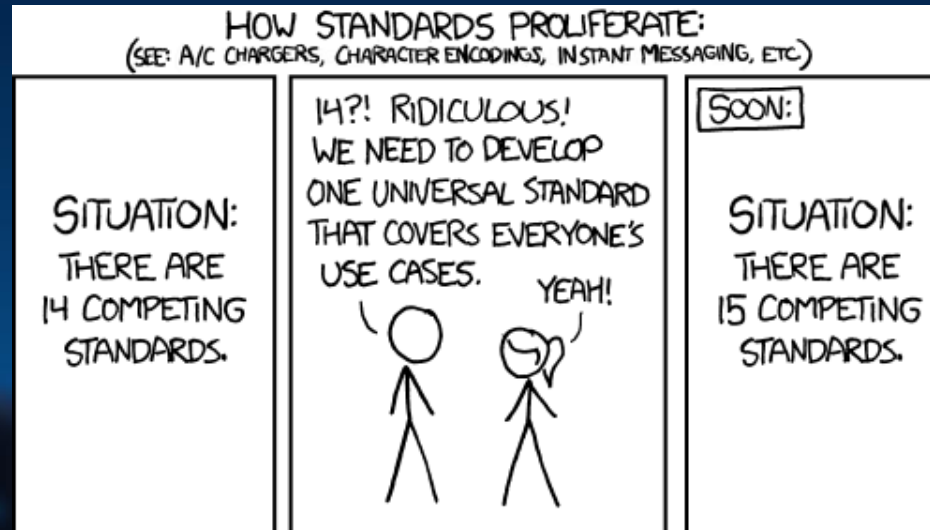
Safety - Safe Software Development

Depending on the SIL level, the recommended techniques for software development span from low-impact measures such as **defensive programming** to severe restrictions like **limited use of pointers** and **no dynamic memory allocation**.

Safety

Plethora of standards for different domains (electronics, process industry, **railway**, ...)

IEC 61508, IEC 61511, EN 50129, EN 50716, ...



xkcd.com/927/

Assessment (e.g. by TÜV) evaluates adequacy of measures for claimed safety level

SIL2 H.265 Video Streaming



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SIL2 H.265 Video Streaming - Hardware

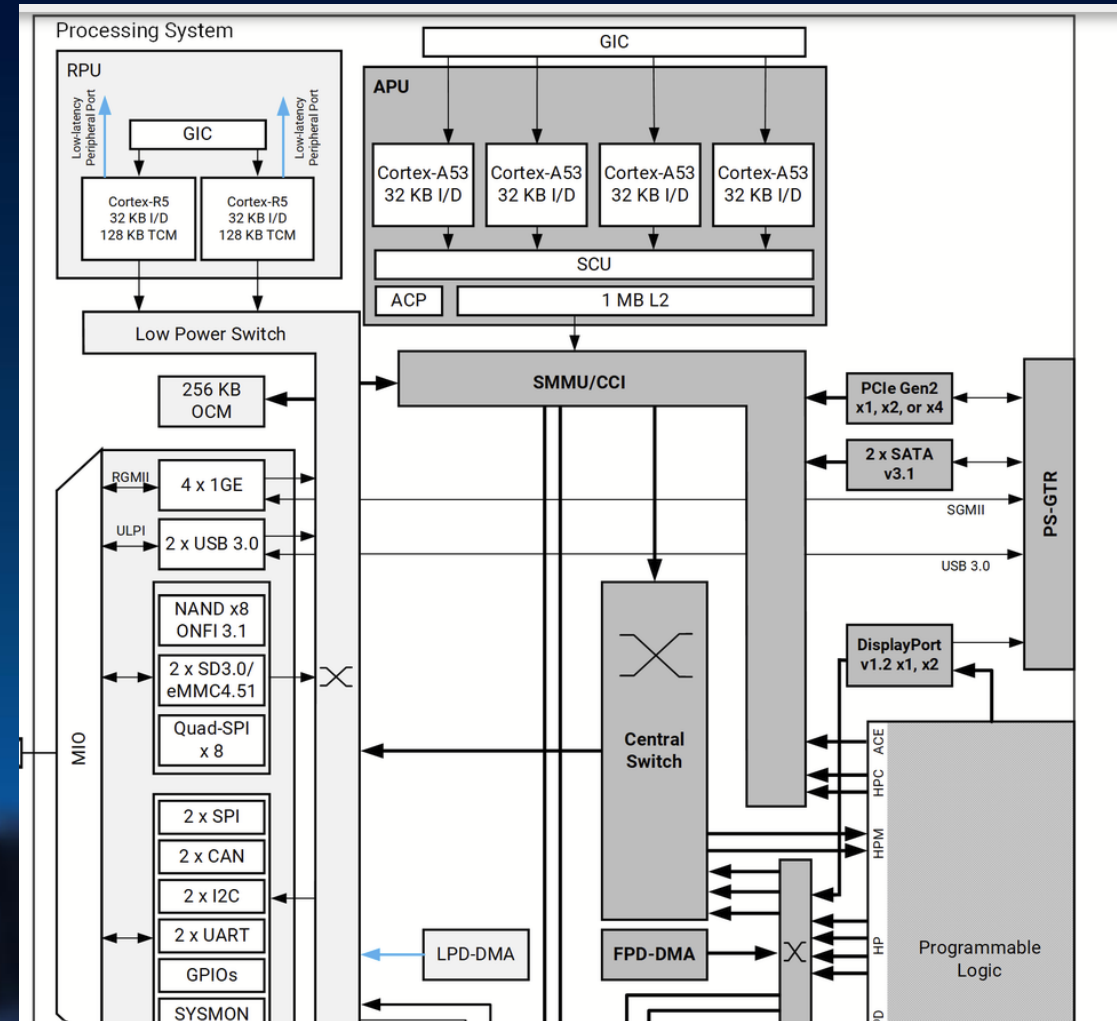
AMD ZynqMP UltraScale+ platform

Cortex-R5 RPU (up to SIL3 / ASIL-D)

Cortex-A53

FPGA

AMD Video Codec Unit (H.264/H.265)



AMD ZynqMP Block Diagram (from AMD UG1532)

SIL2 H.265 Video Streaming System



SIL2 H.265 Video Streaming System - Sensor



SIL2 H.265 Video Streaming System – Image Signal Processing



SIL2 H.265 Video Streaming System – Image Signal Processing

Turns raw CMOS sensor signal into digital image (NV12 frame)

Performs sequence of signal processing steps:

- Auto White Balancing

- Noise Filtering

- Debayering

- Color Correction

- Tone Mapping

- ...

... and does so safely!

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SIL2 H.265 Video Streaming System – Image Signal Processing

Human Perception Model (HPM)

Derived metrics and threshold for algorithms

Provided mathematical proofs that algorithms are in line with HPM (200+ pages)

Implemented algorithms safely

.... but are there really safety hazards?

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SIL2 H.265 Video Streaming System – Image Signal Processing

Example:

Color constancy i.e. color should look the same under varying (white) lights



SIL2 H.265 Video Streaming System – Image Signal Processing

Example:

Noise filtering (noisy sensors, crucial for bitrate)

~50 Mbps → ~10 Mbps in low-light

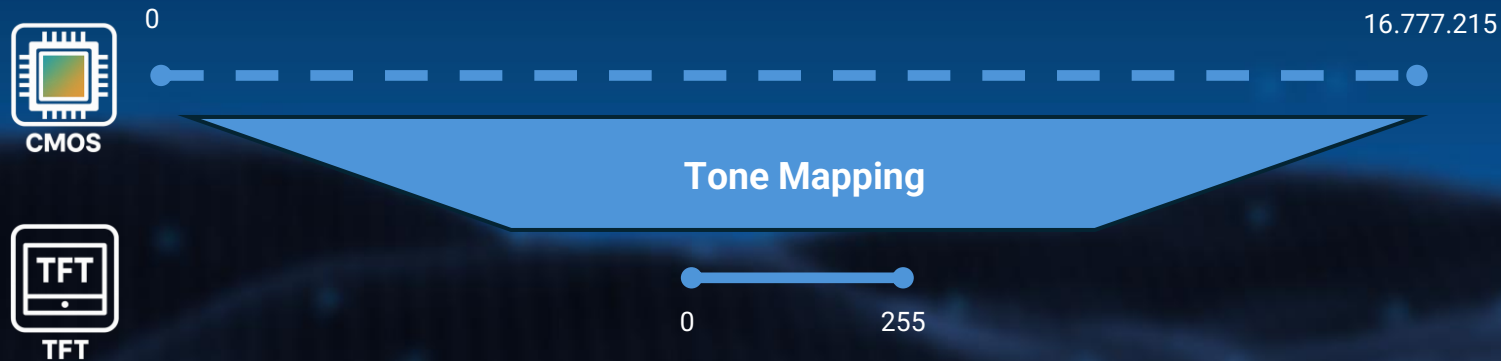


SIL2 H.265 Video Streaming System – Image Signal Processing

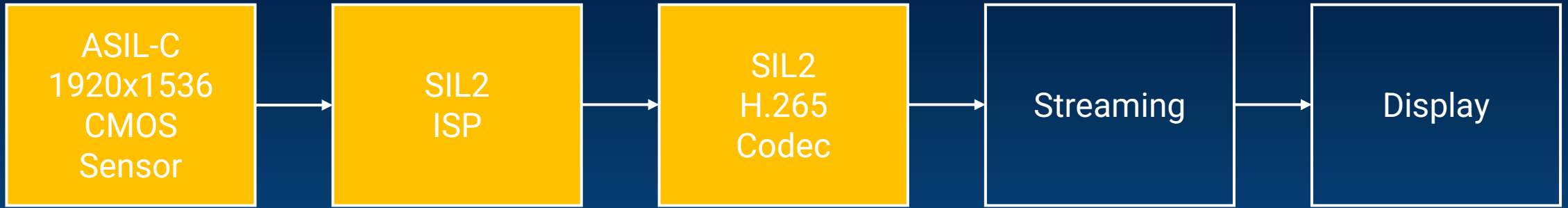
Example:

Tone Mapping (maps CMOS dynamic range to display's dynamic range)

Compresses by a factor of up to 2^{16} (!)



SIL2 H.265 Video Streaming System – Codec



SIL2 H.265 Video Streaming System – Codec

AMD Zynq UltraScale+ MPSoC VCU (H.265)

Compression essential for rate control

Blockwise prediction of data by previous pictures and movement

Transmitting only differences (compressed, lossy) skipping blocks if too expensive

... how much loss is okay?

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SIL2 H.265 Video Streaming System – Codec

Augment AMD VCU with custom H.265 channel (FPGA)

Determine thresholds in relation to HPM, verify error post encoding

Validate integrity upon decoding (additional meta data stream)

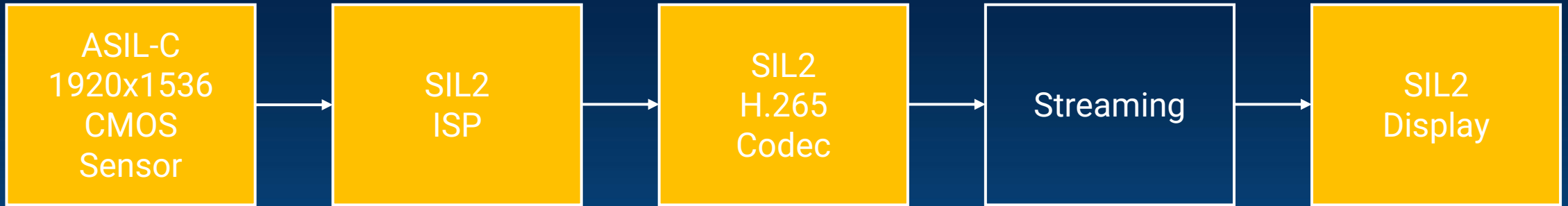
SIL2 H.265 Video Streaming System – Codec

Example:

Challenging HDR scene, QP40



SIL2 H.265 Video Streaming System – Display



SIL2 H.265 Video Streaming System – Display

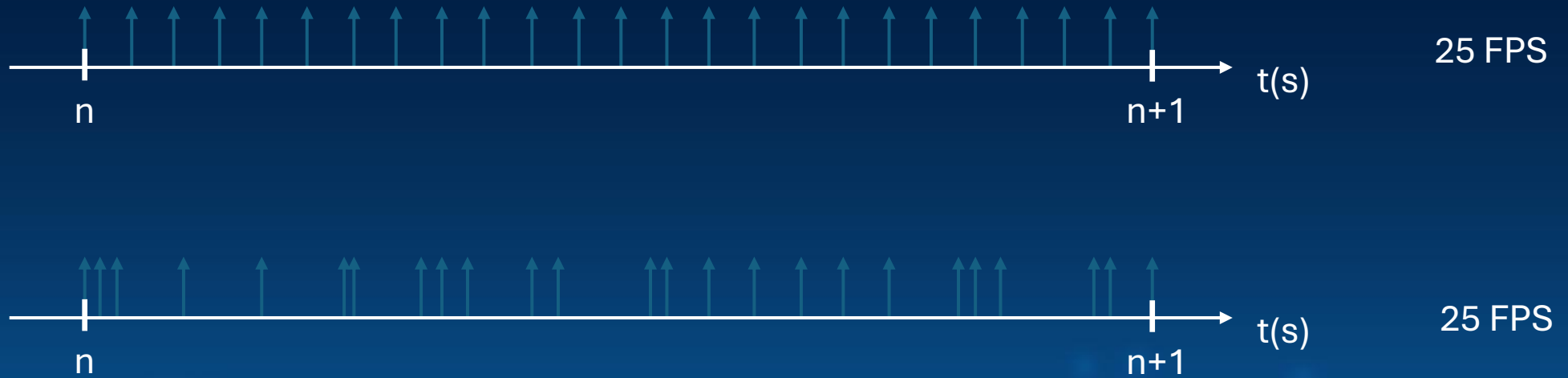
SIL2 visualization is a standard feature on our HMIs and RVMs:

- No freezing

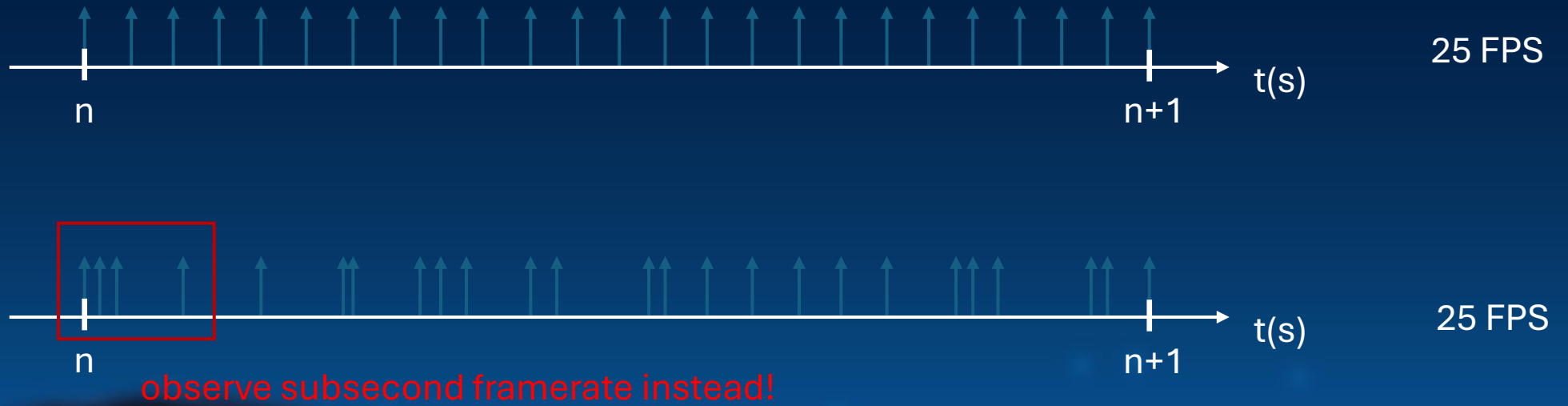
- No display of corrupt data

Safe video streams are monitored for **latency** (glass-to-glass) and **framerate**

SIL2 H.265 Video Streaming System – Display (FPS)

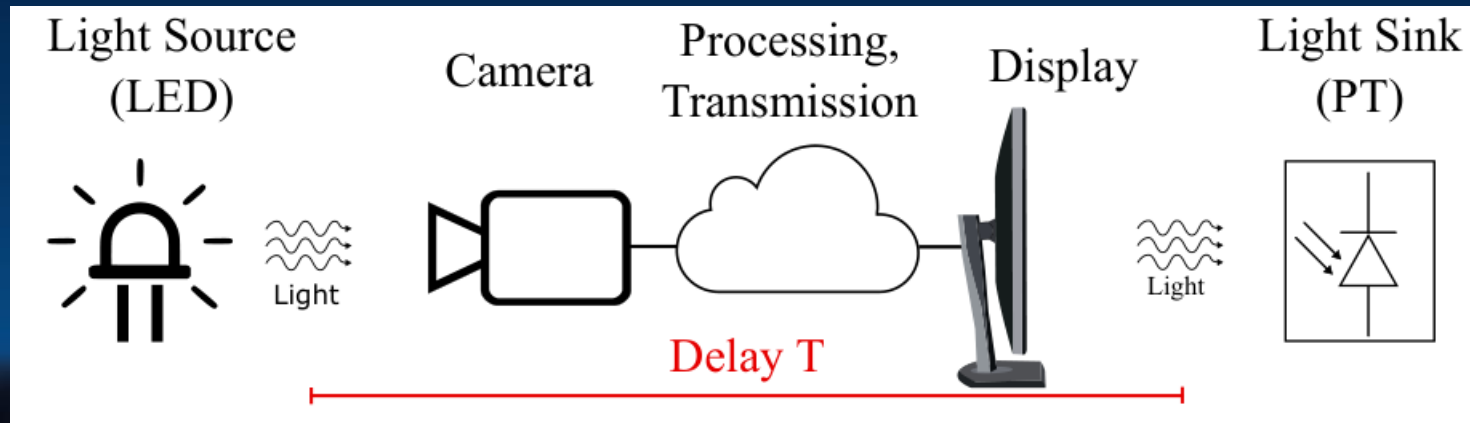


SIL2 H.265 Video Streaming System – Display (FPS)



SIL2 H.265 Video Streaming System – Display (Latency)

Glass-to-glass latency easy to measure!



Delay Measurement Principle [1]

SIL2 H.265 Video Streaming System – Display (Latency)

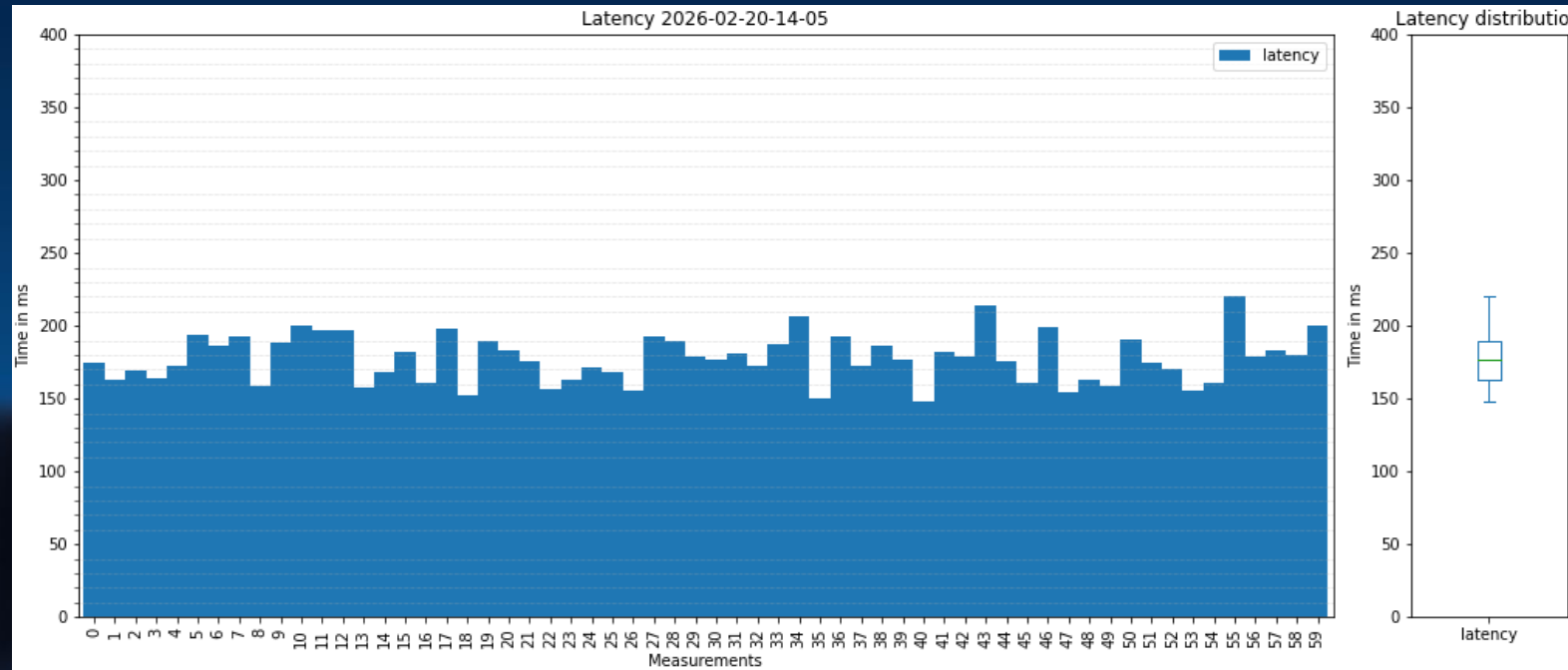
~20€ and a little soldering later:



SIL2 H.265 Video Streaming System – Display (Latency)

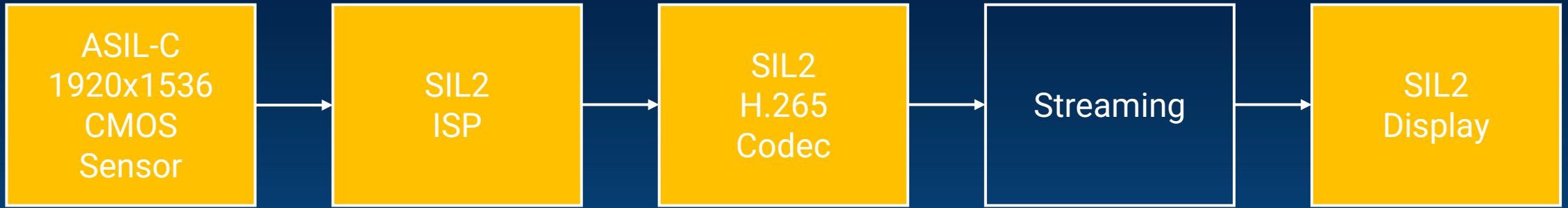
Infer live latency by timestamps (meta data) and worst-case bounds for immeasurable parts

Typical < 200ms, report violation for > 300ms

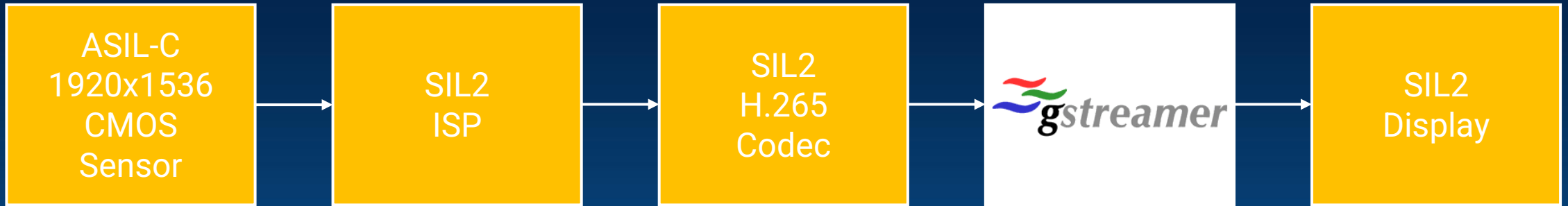


Example latency validation run

SIL2 H.265 Video Streaming System – Streaming



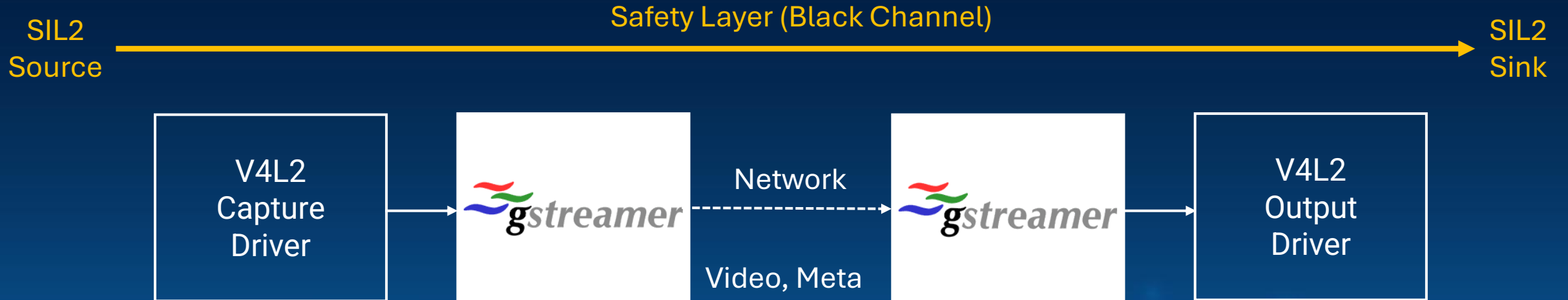
SIL2 H.265 Video Streaming System – Streaming



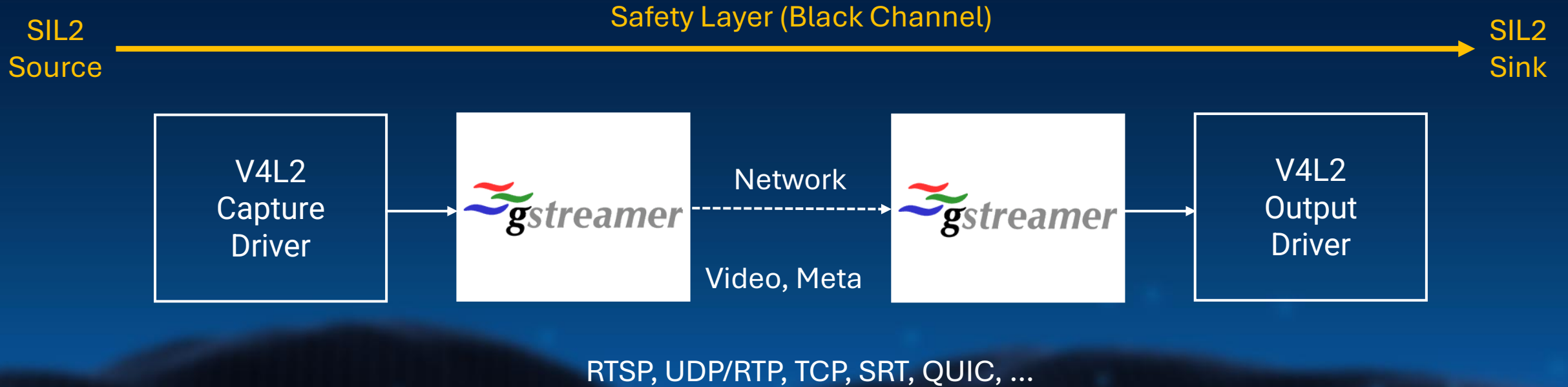
SIL2 H.265 Video Streaming System – Streaming



SIL2 H.265 Video Streaming System – Streaming



SIL2 H.265 Video Streaming System – Streaming



SIL2 H.265 Video Streaming System – Streaming

Safety layer also provides **safe pairing**

Black channel principle allows us to use full GStreamer feature set

Allows us to focus on optimizing reliability, availability and performance

Demo (SIL2 Zoom)



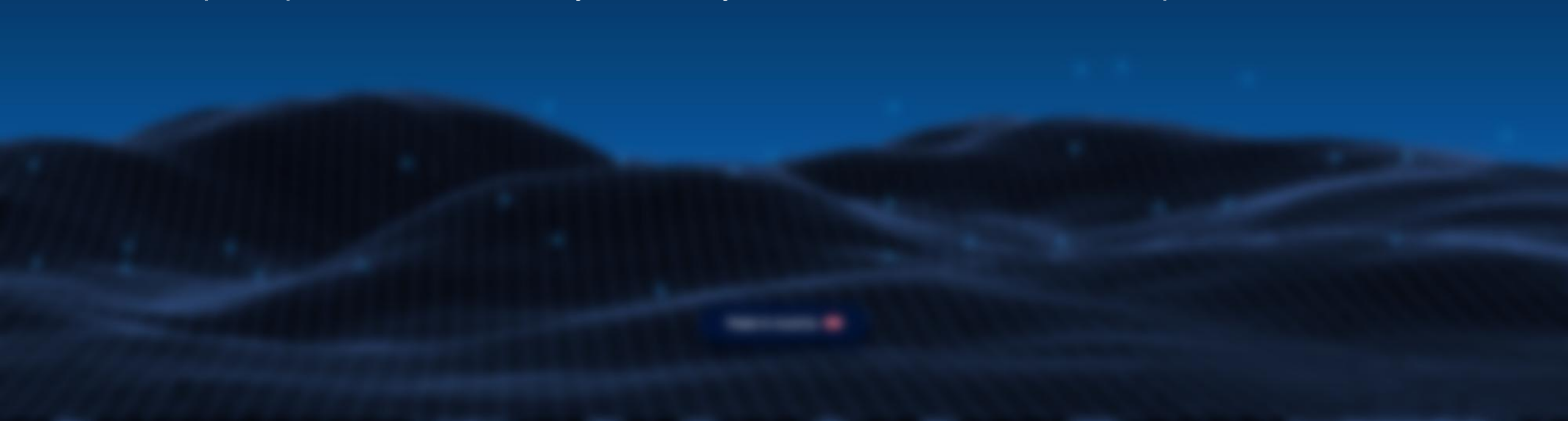
Summary

SIL2 H.265 Video Streaming provides functional safety from lens to glass (display)

Tackles **real** hazards of existing camera systems

Already in use in the field (including SIL2 Zoom)

Provides perception for novel safety-critical systems such as remote train operation



Questions?

A&RTECH

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