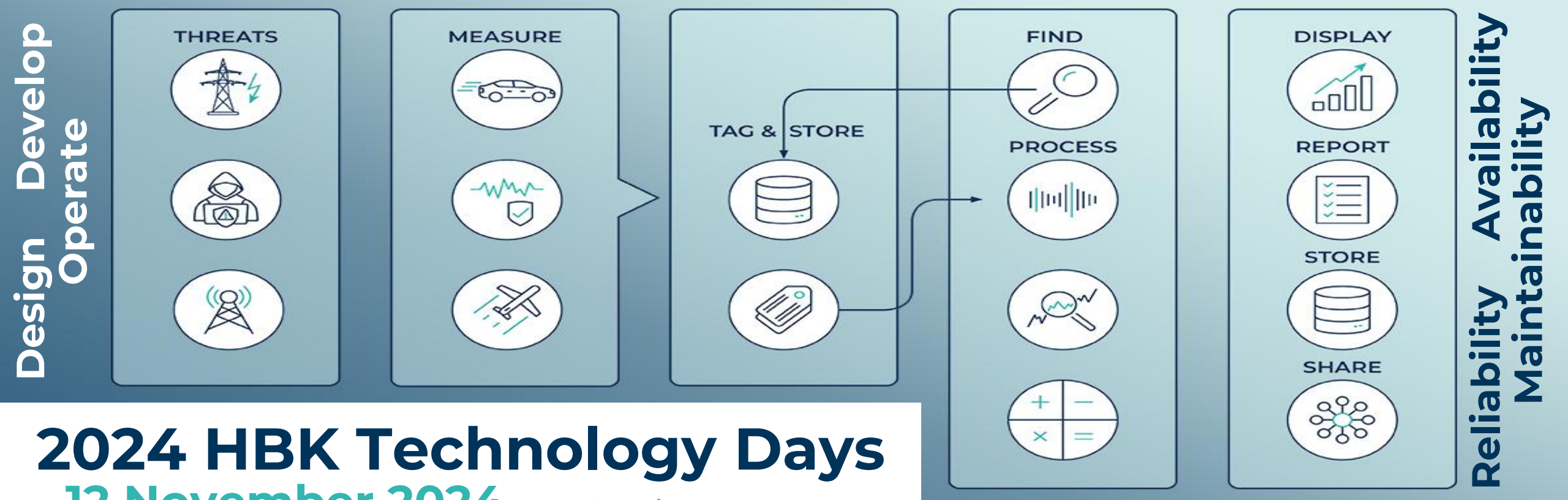
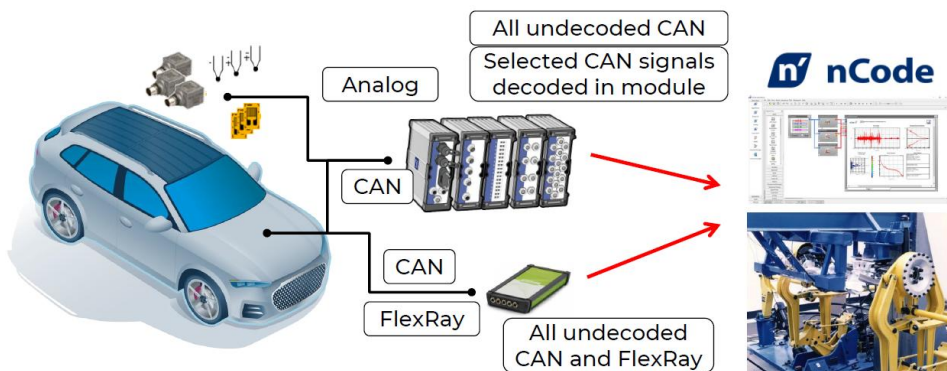




2024 HBK Technology Days

12 November 2024

Session 3: Vehicle Network Measurements



- Integrating and synchronising CAN and FlexRay bus measurements with high fidelity analogue sensor measurements

Bilel Njeh, Test and Measurement - Custom Solutions, HBK

Rob Plaskitt, Application Engineer – Durability, HBK

Integrating and synchronising CAN and FlexRay bus with high fidelity analogue sensor measurements

Abstract

- Complex control systems manage how modern vehicles behave driving on-road and off-road. These systems make their own real time decisions to control body and suspension motion based on calculations from on-board sensors. Traditional measurements of wheel forces, displacements, and accelerations describe the vehicle response but not the internal state of these systems. Whereas previous vehicle generation control systems required a small number of internal state signals, modern vehicles have increasingly complex control systems requiring many more internal state signals to be synchronously measured.
- This leads to an increasing requirement to capture many more vehicle bus signals together with traditional measurements and maintain their synchronicity through signal processing workflows for provision to their respective vehicle development groups. This presentation describes integration and synchronisation of HBK SomatXR and STAR Electronics FlexDevice measurements, and nCode GlyphWorks developments for post-processing workflows.

Integrating and synchronising CAN and FlexRay bus with high fidelity analogue sensor measurements

▲ About the presenters

▲ Bilel Njeh, Test and Measurement - Custom Solutions, HBK

- Bilel is a Project Engineer at HBK, specializing in custom key systems to meet the diverse needs of HBK clients. He earned his degree in Electro-Mechanical Engineering from Sfax, Tunisia, followed by a Master's in Mechanics and Mechatronics from Friedberg, Hessen, Germany. With experience in implementation, delivery and project management, Bilel has made significant contributions across various industries, including medical, automotive, and aerospace. His expertise lies in developing automated production machines and test benches, where he excels in providing innovative test solutions.
- For this work, Bilel led the initiative to find and qualify a partner with a suitable solution to log FlexRay bus messages synchronized with Precision Time Protocol (PTP).

Integrating and synchronising CAN and FlexRay bus with high fidelity analogue sensor measurements

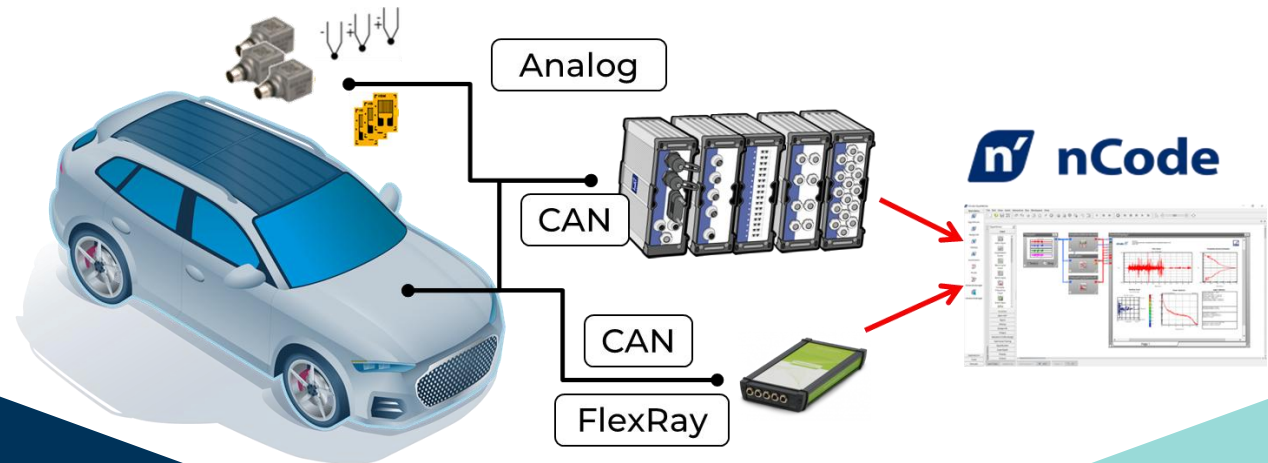
▲ About the presenters

▲ Rob Plaskitt, Application Engineer – Durability, HBK

- Rob Plaskitt is an application engineer supporting nCode durability software for HBK with a degree in Mechanical Engineering (Loughborough) and a master's in Structural Integrity (Sheffield). He has over 30 years of experience working as an engineer at HBK (formerly nCode) in areas of automotive, aerospace, defence and power generation. He has applied nCode software and technology in these industries from CAE concept design through full-scale testing, fleet monitoring, structural durability and vibration qualification.
- Rob led the nCode GlyphWorks developments implemented to increase speed and flexibility of post processing workflows for CAN messages to support and demonstrate this synchronisation.

Integrating and synchronising CAN and FlexRay bus measurements with high fidelity analogue sensor measurements

2024 HBK TECHNOLOGY DAYS – 12 NOVEMBER

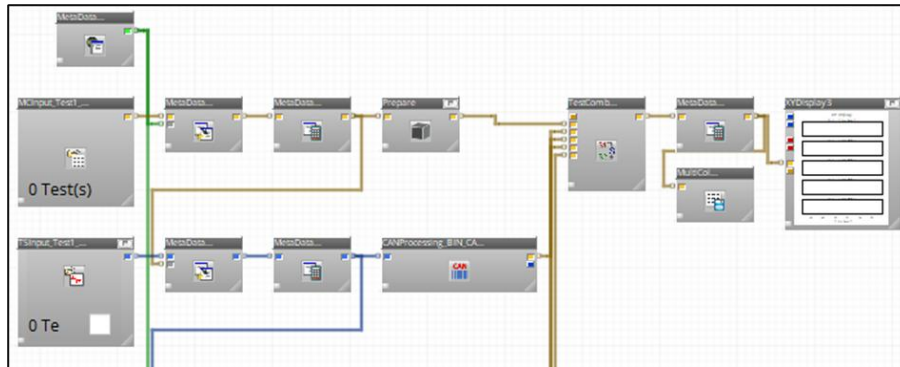


Rob Plaskitt
Bilel Njeh

Rob Plaskitt



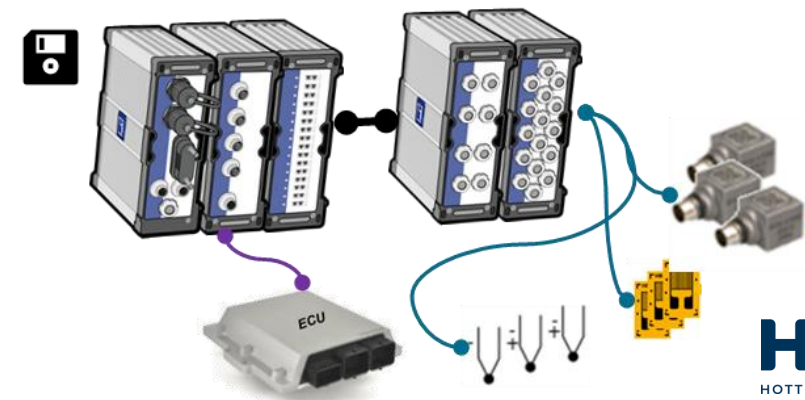
- ▲ Application engineer for nCode software.
- ▲ 35 years originally with nCode and now HBK.
- ▲ Experienced in digital signal processing, vibration, fatigue, and durability analyses.
- ▲ Experienced in automotive, off-highway, aircraft and helicopter applications.



Bilel Njeh



- ▲ Bilel Njeh, Project Engineer
 - Degree in Electro-Mechanical Engineering Sfax, Tunisia (2014)
 - Master in Mechanics and Mechatronics Friedberg (Hessen), Germany (2019)
- ▲ Experience
 - Automotive, precision instruments, medical
 - Test bench and automation



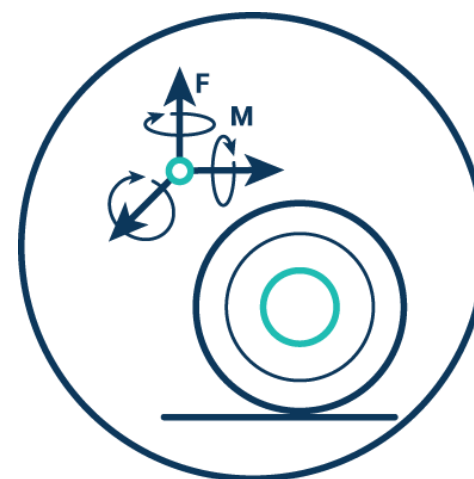
Agenda

1. Introduction and Requirements
2. Bench Testing - Development
3. Bench Testing - Post Processing
4. Vehicle Trials
5. Summary

Automotive Road Load Data Challenge

– Complex Vehicle Technologies

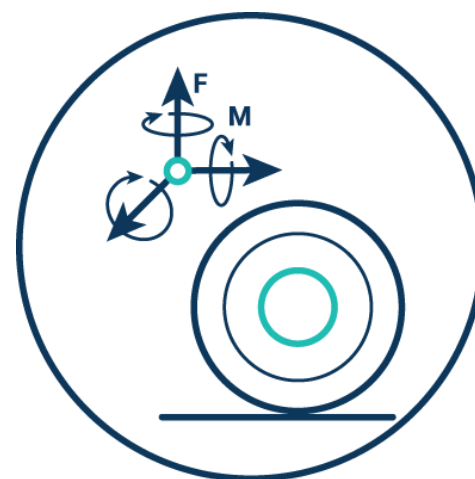
- Complex control systems manage how modern vehicles behave driving on-road and off-road.
- These control systems use electronic control units (ECUs) to make their own decisions to control body and suspension motion based on lots of internal calculations.
- Traditional measurements (wheel forces, displacements, accelerations) describe the system response but not the internal state of these systems.



Automotive Road Load Data Challenge

– Complex Vehicle Technologies

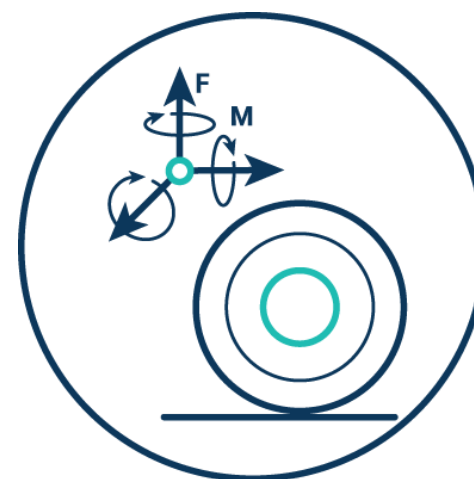
- Internal vehicle system messages describe the state of these control systems.
- The more complex these systems the more important their interactions become when testing vehicle performance.
- Time synchronised loads and vehicle system state are critical for structural durability testing and simulation of **Active Systems**:
 - active suspension
 - dynamic steering
 - traction control
 - off-road control



Automotive Road Load Data Challenge

– Structural Durability

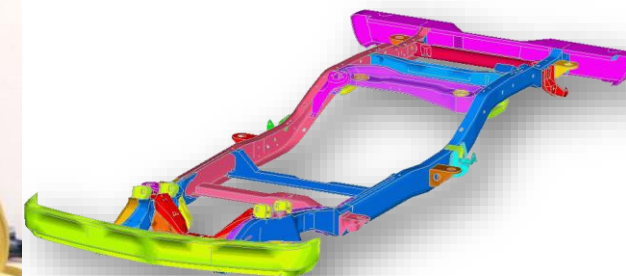
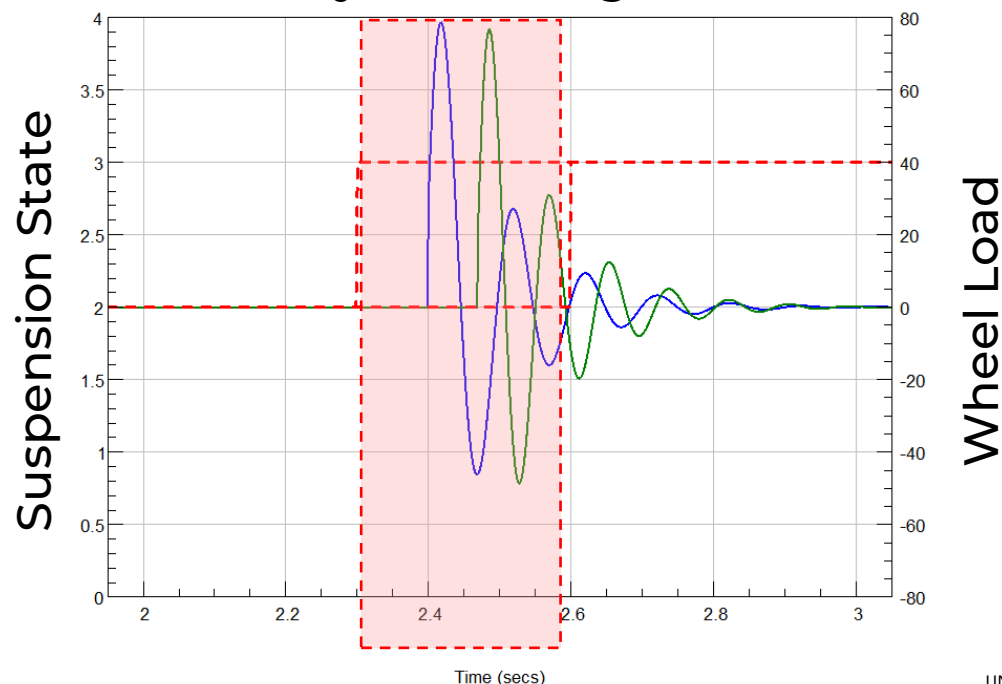
- ▲ Laboratory and virtual test campaigns need to replicate the vehicle system state in the real-world and from accelerated test procedures.
- ▲ Vital to have the data to describe the vehicle system states to feed into the control loops (closed or open simulations) along with the physical road input and responses.
- ▲ Required for testing sub-systems through to whole vehicle test solutions.



Automotive Road Load Data Challenge

– Structural Durability

- Time synchronised loads and vehicle state are critical for structural durability.
 - Kerb strikes, pot-holes, off-road terrain
- Time uncertainty between load and vehicle suspension state:
 - will invalidate computer simulation
 - could write-off your test vehicle
 - could break your test rig



Automotive Road Load Data Challenge

– Structural Durability – Analog

- Traditional vehicle road load data acquisition with analog sensors and a constant sample rate is channel limited.
 - By physical size and/or weight in vehicle.
 - By DAQ module and/or sensor availability. (wheel force transducers)
 - Bespoke instrumentation and calibration.
 - Resource intensive and time consuming.
- Today's vehicles have 1000's of internal signals that are available "for free" from sensors to-and-from control system ECUs in vehicle networks.
 - CAN, LIN, FlexRay, Automotive Ethernet
- Required to acquire these internal vehicle network signals.



Automotive Road Load Data Challenge

– Structural Durability – CAN

- ▲ Requirement to acquire vehicle network signals alongside analog sensors with constant sample rate.
- ▲ CAN capability with HBK SomatXR DAQ.
- ▲ Acceleration, strain, displacement, wheel force, speed, temperature, pressure, etc.
 - Resource and space limited to about 250 analogue sensors maximum per vehicle.
- ▲ CAN and CAN FD
 - 4 CAN channels, all messages, undecoded.
 - Real-time decoding (max 128 per module) of selected CAN signals to time synchronous constant sample rate.



Automotive Road Load Data Challenge

– Structural Durability – FlexRay

- ▲ Requirement to acquire FlexRay and Automotive Ethernet.
 - Not available with HBK SomatXR DAQ.
- ▲ Need a 3rd party device to acquire FlexRay and Automotive Ethernet with capability to integrate into a SomatXR DAQ system.
- ▲ STAR COOPERATION : FL3X Device-L (Flex Device)
 - multiple bus connectors, multiple interfaces
 - Up to 10 CAN-FD or 15 CAN-HS
 - Up to 8 FlexRay
 - Automotive Ethernet 1000 & 100 BASE-T1
 - and external time synchronisation control

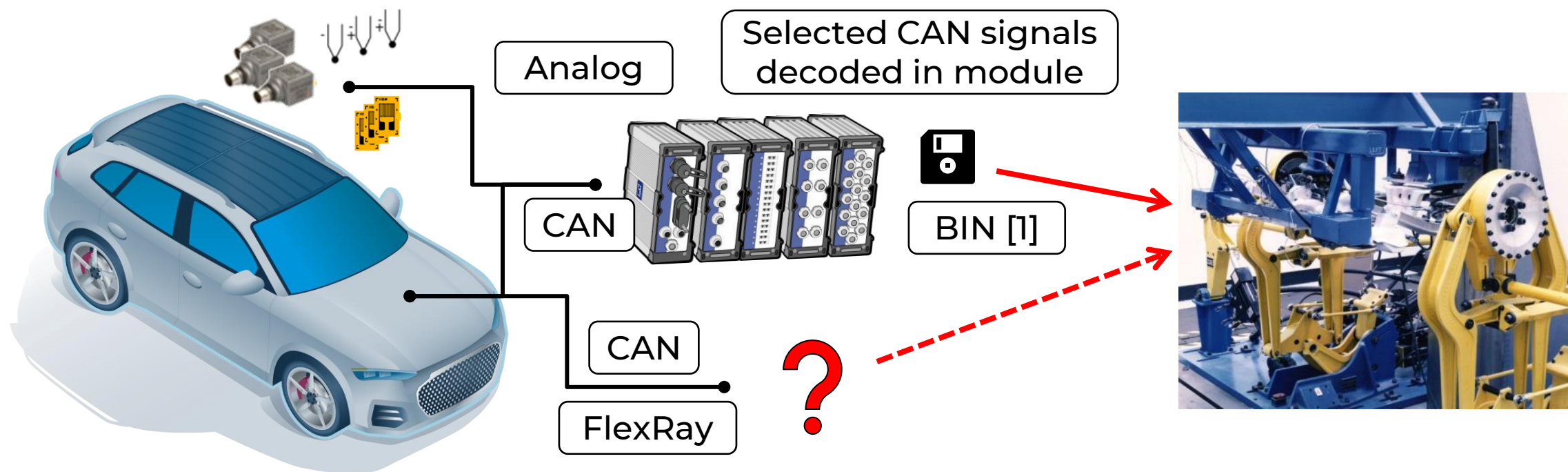


Automotive Road Load Data Challenge

– Structural Durability – FlexRay

- Requirement to acquire all CAN and FlexRay messages.

- What is missing – what signals are available in CAN and FlexRay that are needed for rig test.



Can only capture **predefined** messages currently. Most messages not captured. Issue arises if a critical message for running active systems on rig test is missed.

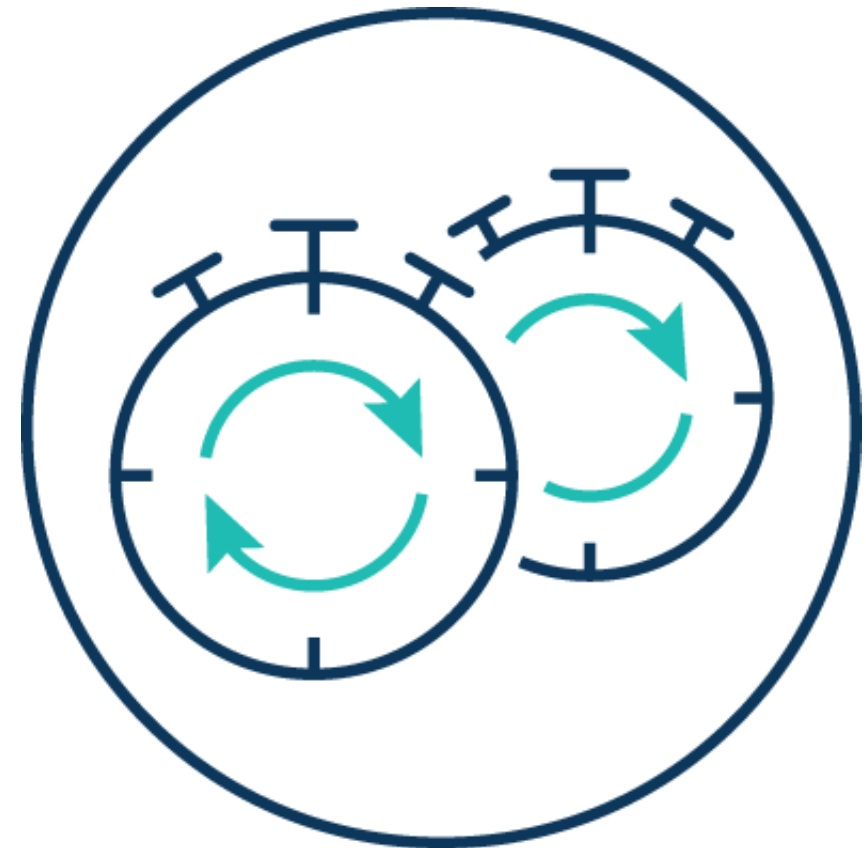
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Time Protocols

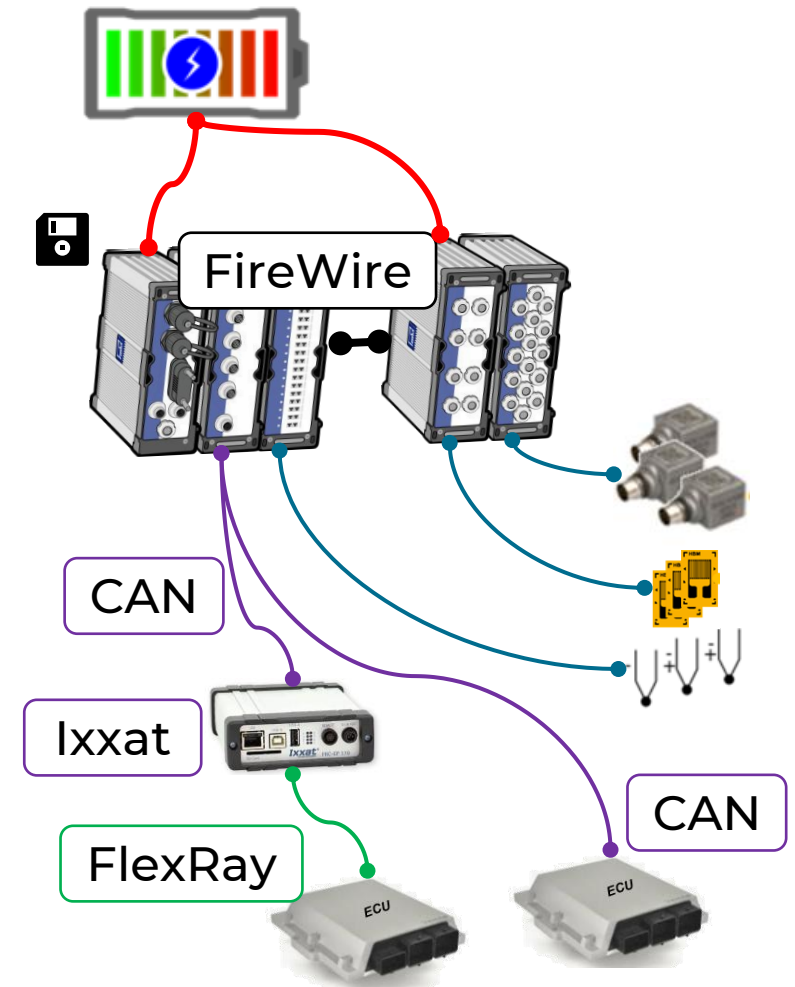
- ▲ Precision Time Protocol (PTP) IEEE 1588v2
 - For clock synchronization throughout a computer network with high precision and high accuracy.
- ▲ Grand Master Clock (GMC)
 - A precise master clock to provide timing signals to synchronise follower clocks as part of a clock network.
- ▲ Best Master Clock Algorithm (BMCA)
 - The BMCA specifies how each clock on the network determines the best master clock of all the clocks it can see, including itself.
 - The BMCA runs continuously on the network and quickly adapts to changes in the network configuration.

Time Synchronisation



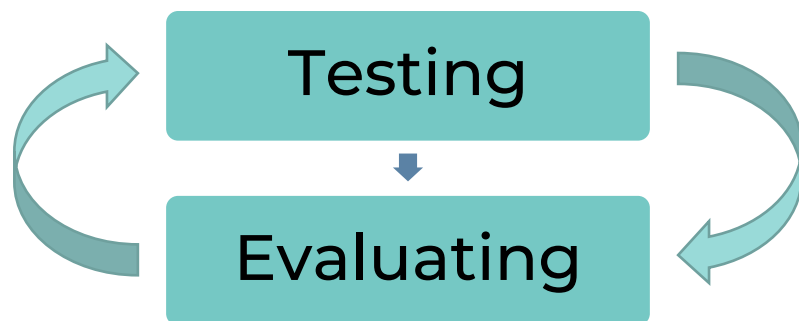
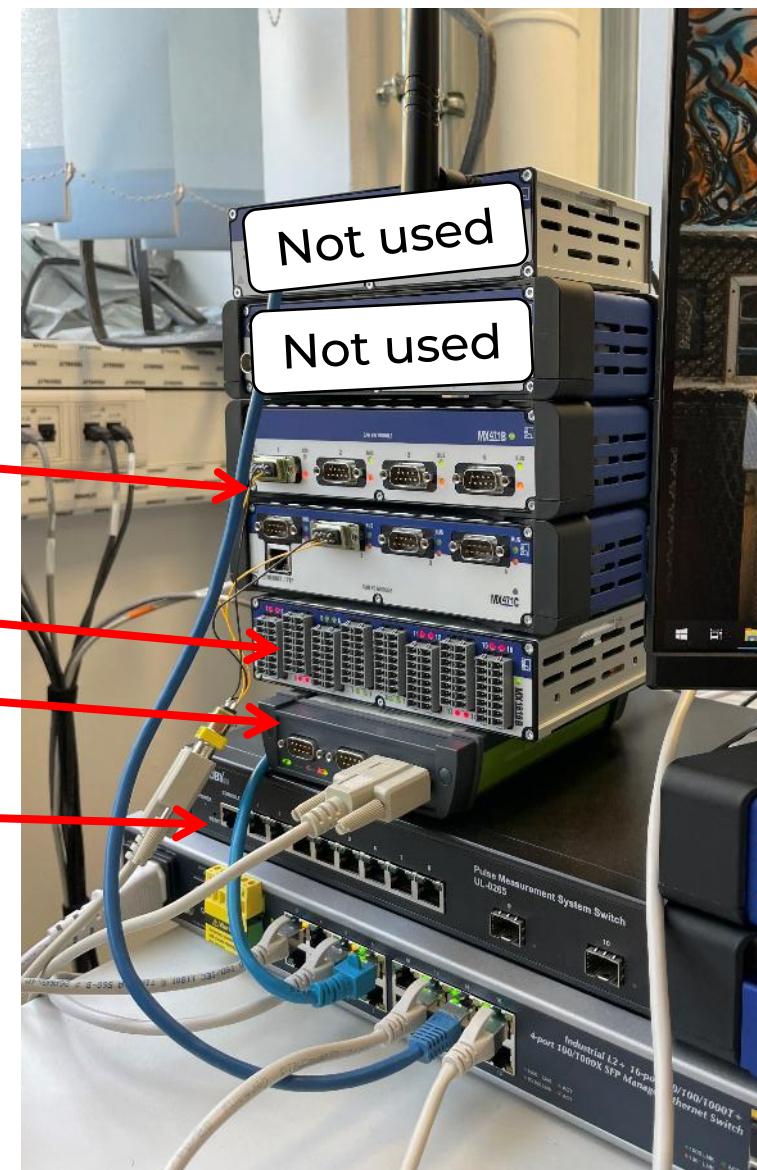
Starting DAQ System

- ▲ SomatXR analog modules are interconnected and connected to the data recorder via FireWire.
 - A module with gateway functionality is therefore not required. (MX471C or CX27C)
 - SomatXR modules control time.
- ▲ Measurement signals:
 - Analog signals.
 - CAN logging using MX471.
 - Ixxat FlexRay to CAN gateway (for up to 300 FlexRay messages)
- ▲ Measurement data stored as BIN files on the CX22B-R and processed in catmanAP and/or nCode GlyphWorks.



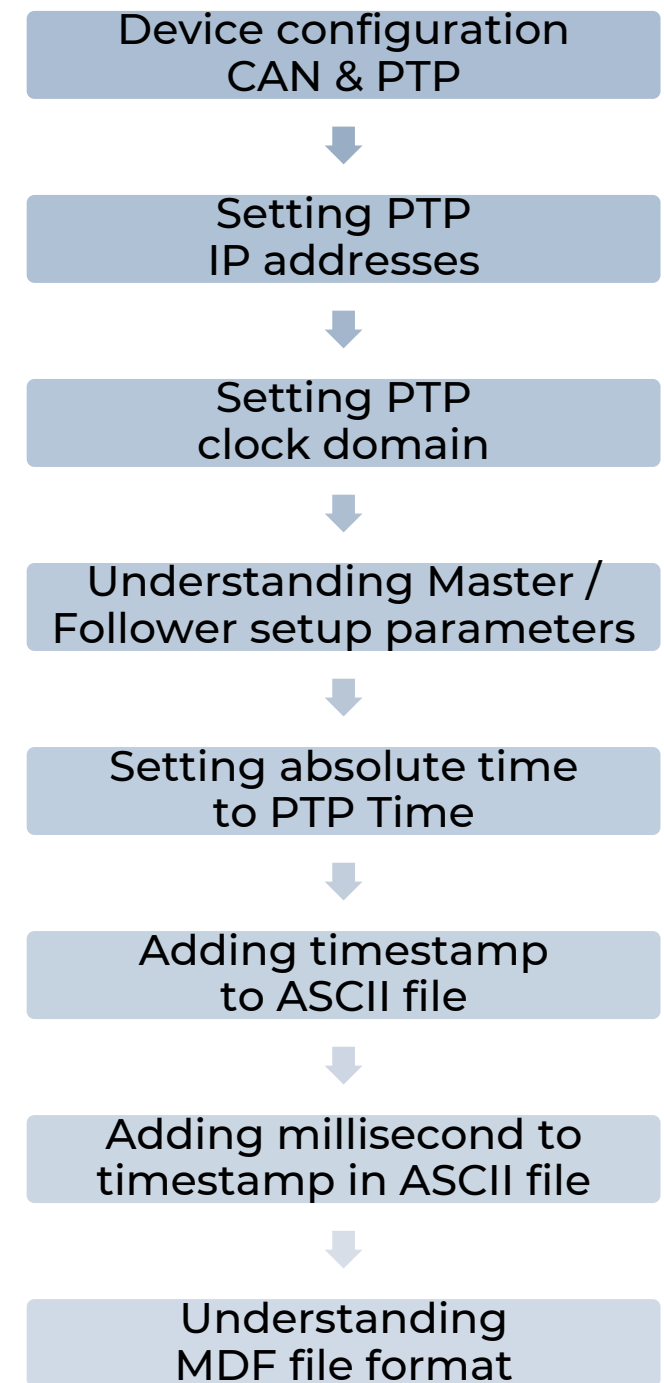
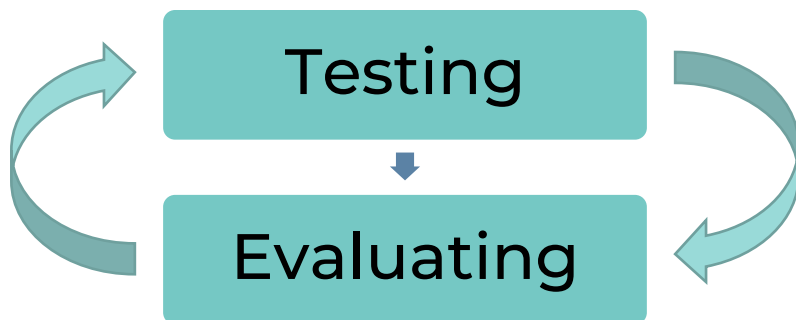
Test bench device setup

- ▲ Grand Master Clock (GMC)
 - Requires line of site to satellites
 - Included or excluded as required
- ▲ QuantumX MX471B and MX471C
 - to decouple reading & writing on CAN
- ▲ MX1616B module signal Generator
- ▲ STAR Flex Device
- ▲ PTP Switch evaluation
 - HBK (B&K) UL-0265 PTP Switch
 - Planet PTP Switch



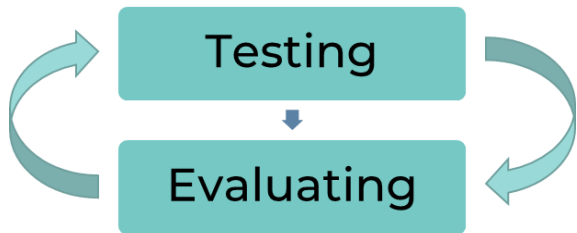
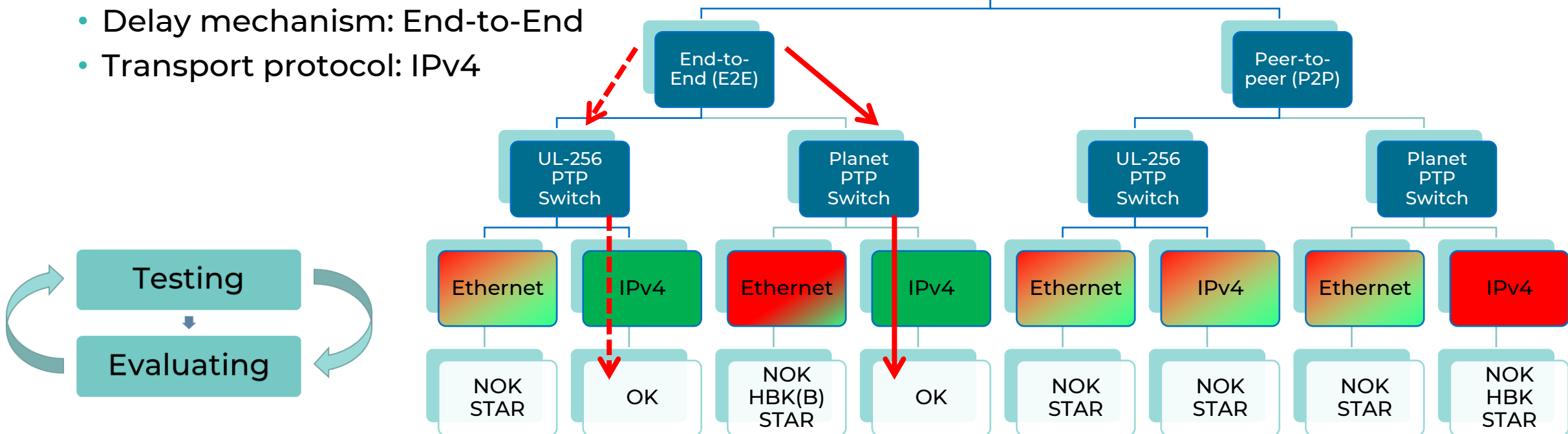
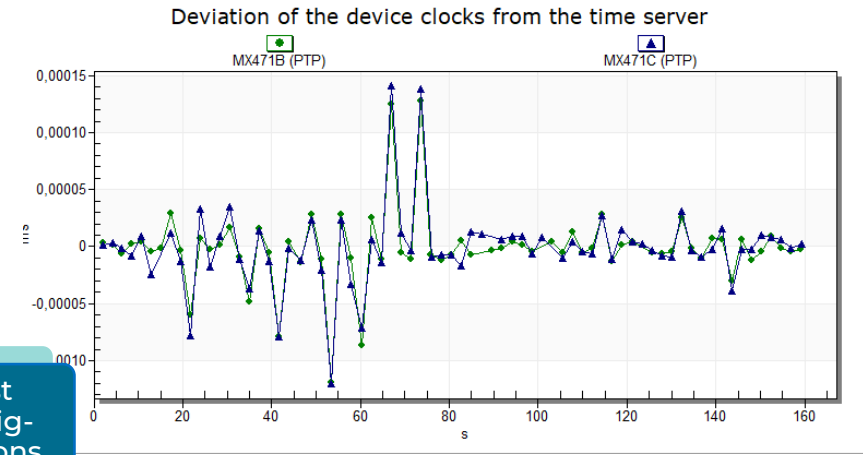
Time synchronisation – iterations with STAR

- ▲ Integrate HBK modules with Flex Device
 - QuantumX – modules for bench testing
 - SomatXR – ruggedised modules for mobile testing
- ▲ Integrate catmanAP with Flex Device API Library
 - enables catmanAP to control the Flex Device, for measurement Start and Stop
- ▲ Early bench tests use Flex Device ASCII file. Later bench tests and vehicle trials use Flex Device MDF4 file format.



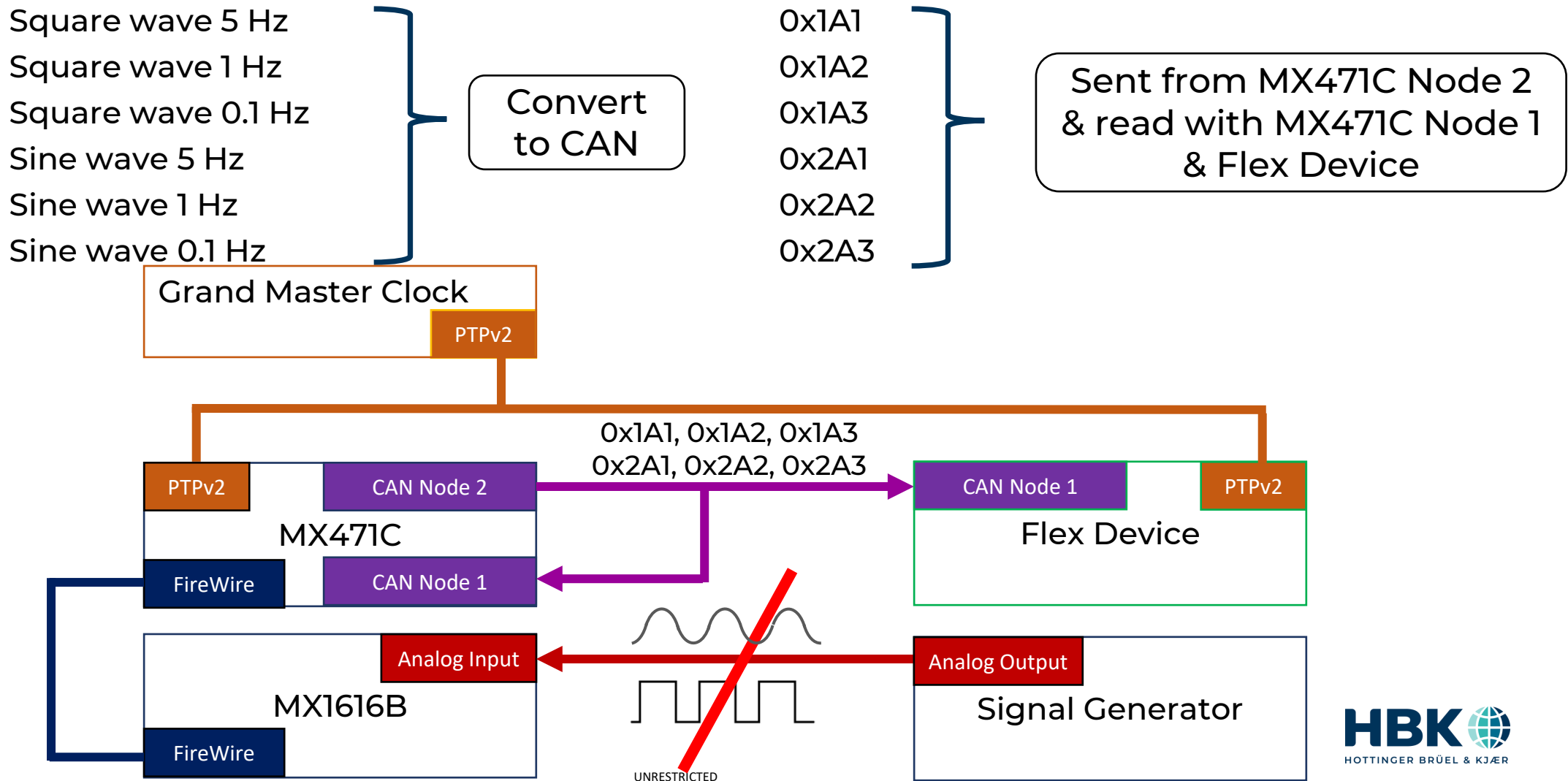
Time Synchronisation – Test Configurations

- Testing different PTP switches and configurations.
- Review deviation of the device clocks from the time leader.
- Solution:
 - Delay mechanism: End-to-End
 - Transport protocol: IPv4



Time synchronisation – Test Signals and Test Setup

▲ Test signals generated using the test signal function on the MX1616B module.



Time Synchronisation – Test Signals and Test Setup

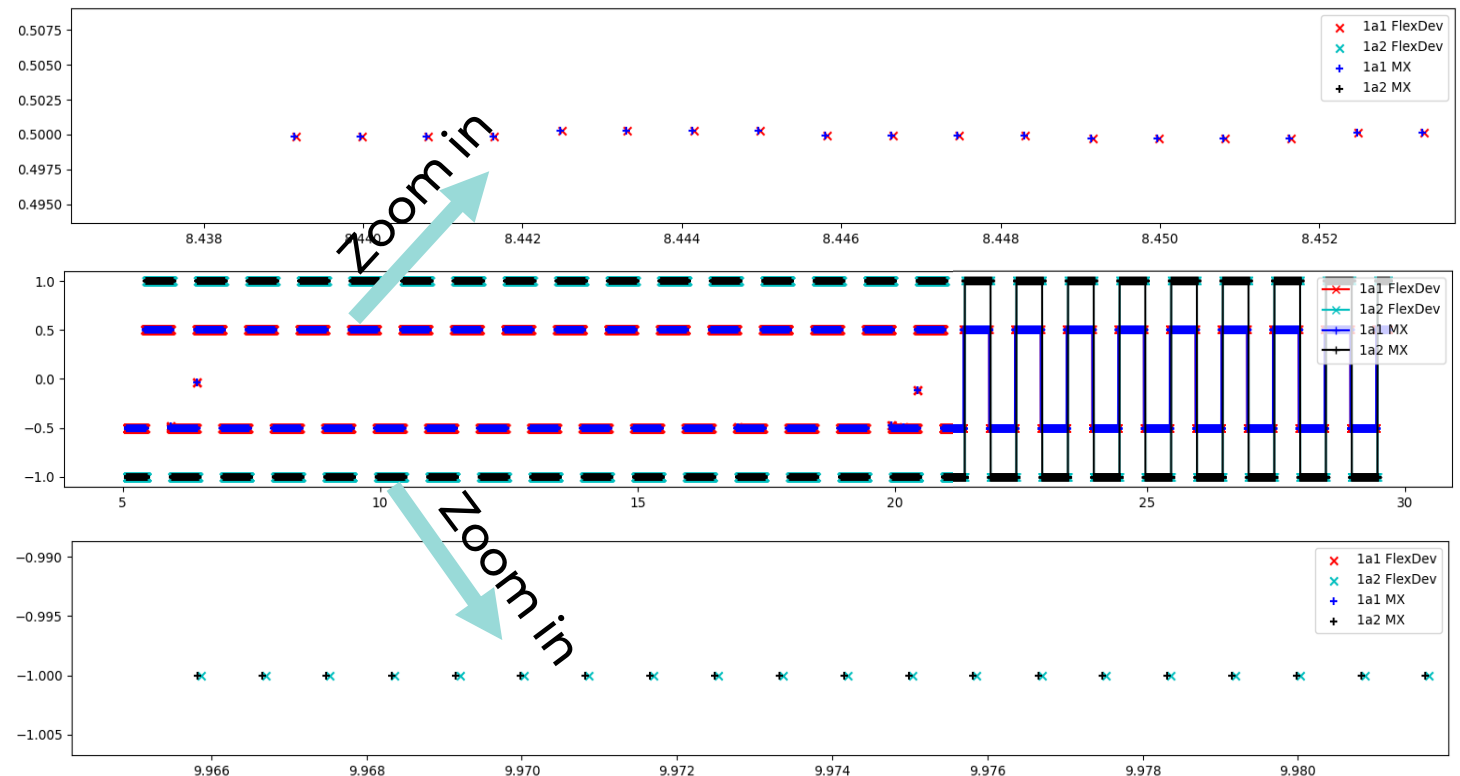
- ▲ The maximal time difference between the same message logged with MX471C and Flex Device

- 0x1A1 Delta_T max: 0.0003890s => 0.4 ms
- 0x1A2 Delta_T max: 0.0003970s => 0.4 ms

- ▲ No messages missing

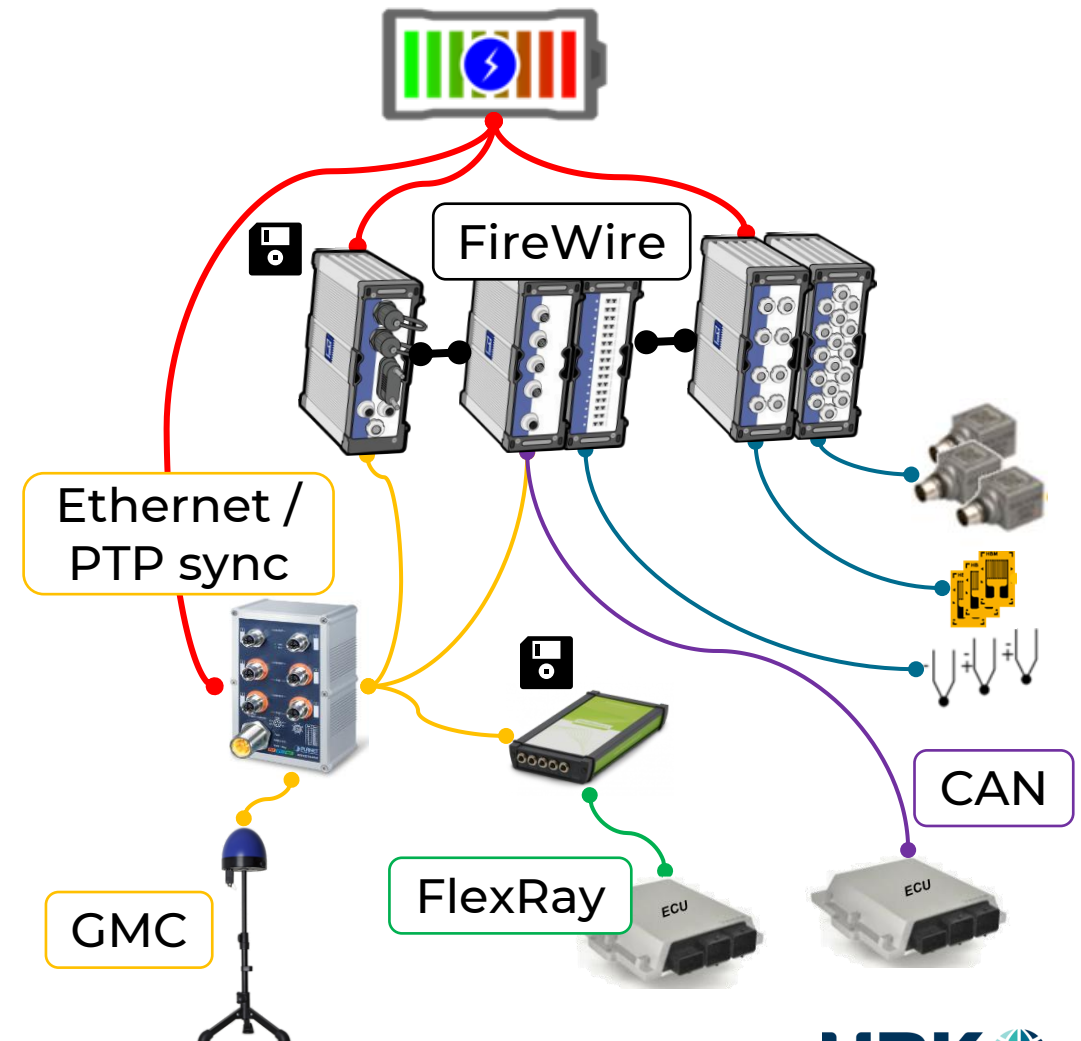
Conclusion

- ▲ After a tricky alignment, can confirm that the hardware is time synchronised and is working as expected.



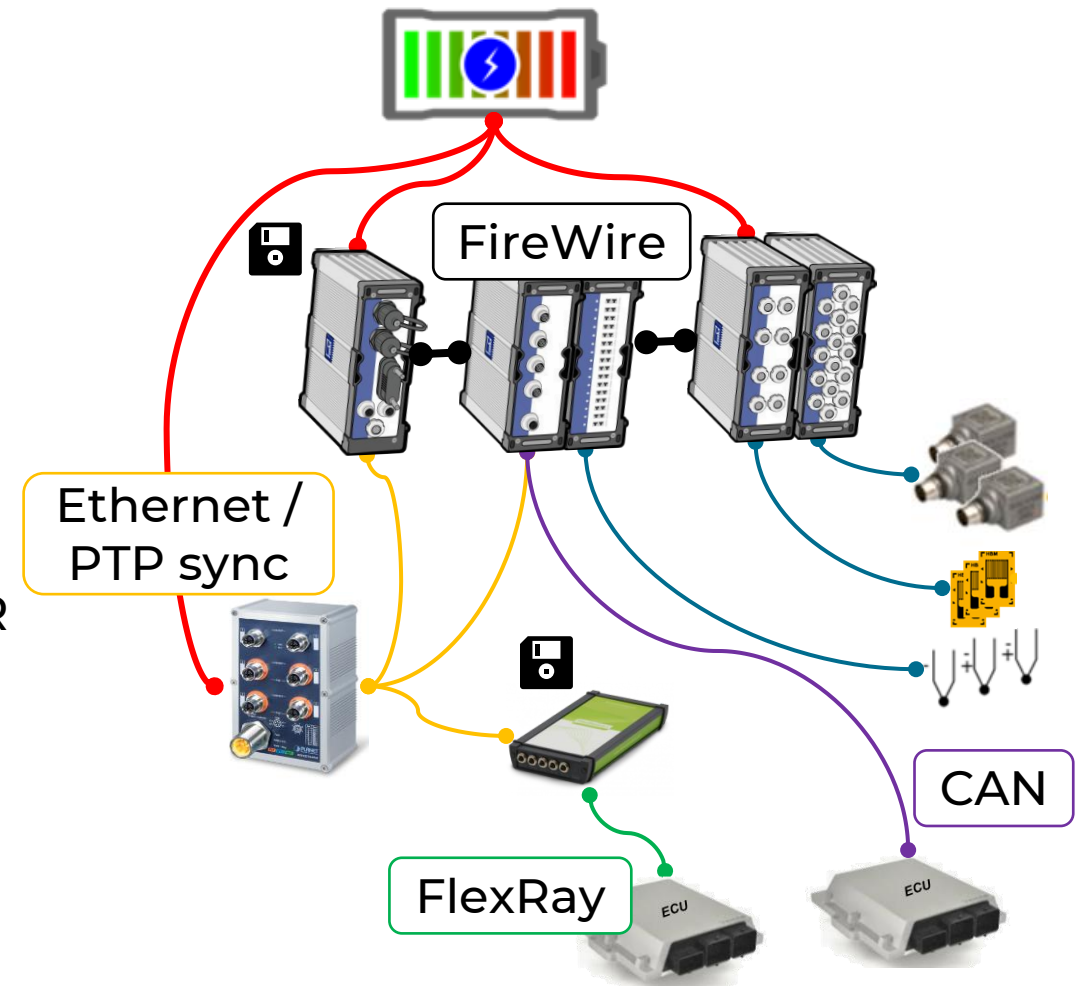
Proposed DAQ System – with GMC

- ▲ SomatXR analog modules remain.
- ▲ STAR Flex Device replaces Ixxat module.
 - FlexRay messages time synchronized via PTP with SomatXR and GMC.
- ▲ Setup one SomatXR module as the FireWire time synchronisation leader using GMC time.
- ▲ PTP Network is FlexDevice, SomatXR module, PTP Switch, PTP GMC.
- ▲ Measurement data stored as BIN files on CX22B-R-W, FlexRay data stored as MDF4 or ASCII files on Flex Device.
 - Combined and time aligned in nCode.



Proposed DAQ System – without GMC

- ▲ As previous, except with GMC removed.
- ▲ Without GMC, the SomatXR module is setup to become the PTP time leader and the FlexDevice is setup as time follower.
- ▲ With no absolute time source in the network, the SomatXR module has an absolute time in the past (e.g., 01.01.2000).
 - Solution is a script to set time on the SomatXR module to the time of the CX22B-R-W.
 - Added to the Windows autostart to run after powering up the SomatXR modules.



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Post Processing – Managing time

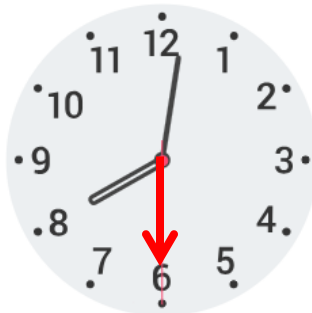
▲ Leap Seconds

- A one-second adjustment that is occasionally applied to UTC, to accommodate the difference between precise TAI and UT1 time.
- Caused by small variation in Earth rotational speed. Leap seconds are irregularly spaced and unpredictable.

▲ SomatXR uses UTC time.

▲ Flex Device uses TAI time.

UTC time



TAI time



▲ Universal Time (UT or UT1)

- UT1 is the principal form of Universal Time (UT), based on Earth rotation. Includes Leap Seconds.

▲ Coordinated Universal Time (UTC)

- Used globally to regulate time, based on UT1. Includes Leap Seconds.

▲ International Atomic Time (TAI)

- A high-precision time standard from atomic clocks. Excludes Leap Seconds.
- (*French “temps atomique international”*)

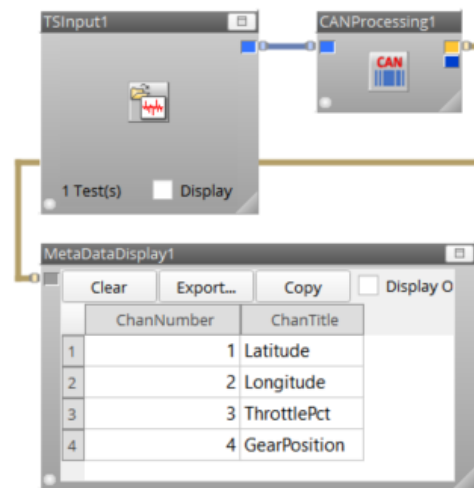
▲ In 2024: TAI – UTC = 37 seconds

- 37 leap seconds since introduced in 1972.

Post Processing – Software developments for integration

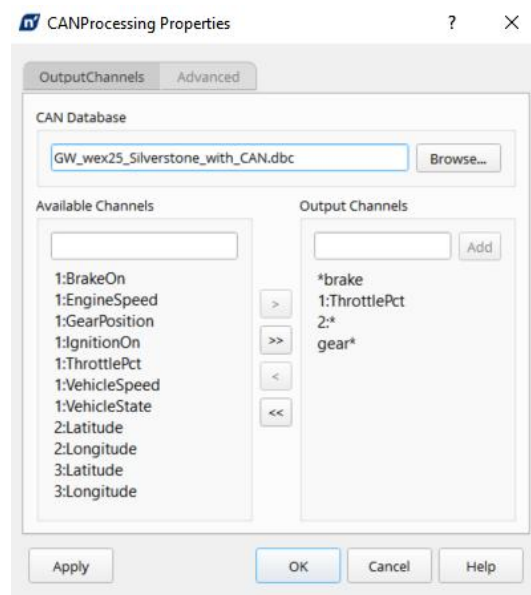
catmanAP

- *Initiates Flex Device time.*
- *Controls Flex Device start and stop.*
- Store “First Sync Time Stamp” for CAN and CAN FD for standard and triggered (Fast Stream) measurements in BIN file.



nCode

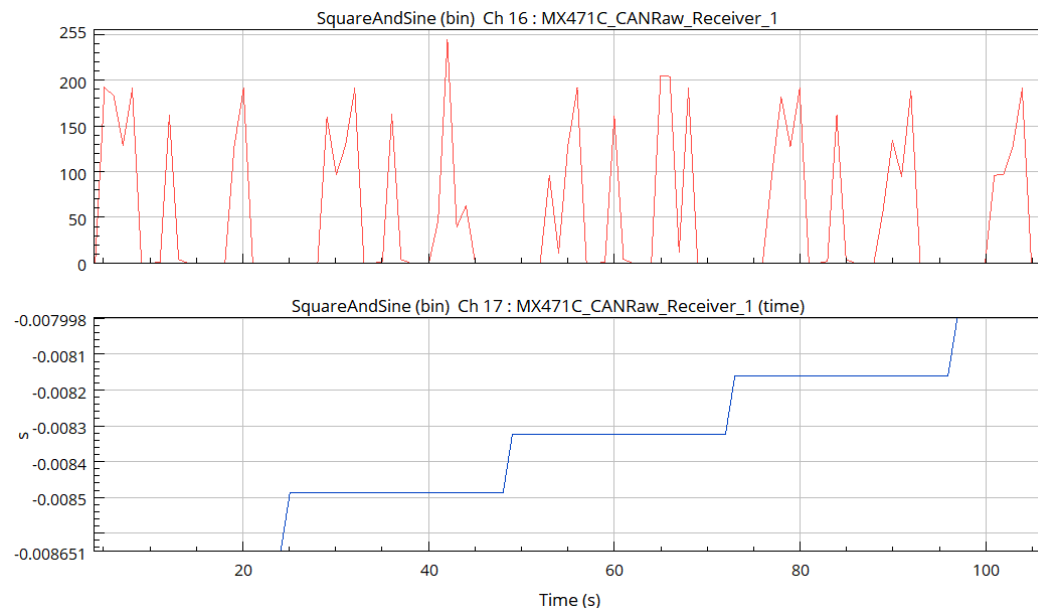
- Standard import for Flex Device CAN data from ASCII and MDF4 files.
- Enhanced import for BIN files for precise sample rate.
- CAN Raw time series format for faster import. (Minutes >> Seconds)
- **CAN Processing glyph to decode selected CAN signals.**
- TestCombination glyph with time offset for easier time alignment.
- Improved support for epoch time.
 - Requires 10 digits precision for seconds and 6 decimal places for milli-seconds. Updates to TStoMC, MCtoTS and MCFilter glyphs.
- Python import for Flex Device FlexRay data from ASCII, for decoding in CAN Processing glyph.



Post Processing – Software developments for integration

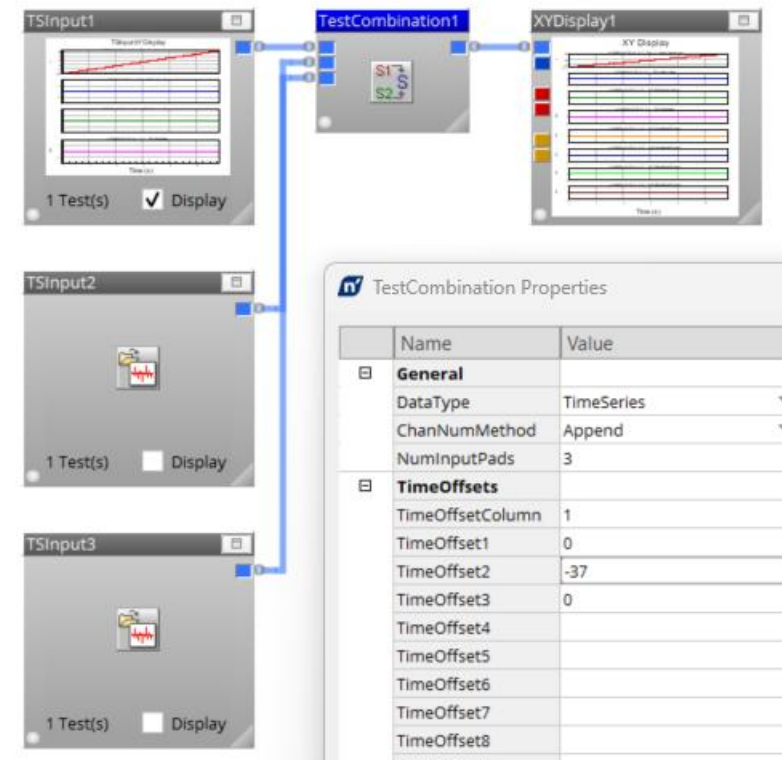
▲ nCode

- CAN Raw time series format for faster import. (Minutes >> Seconds)
- New Preference for CanChannelHandling = RawTimeSeries
- Time series of byte values 1 to 255.
- Time series of message time value.



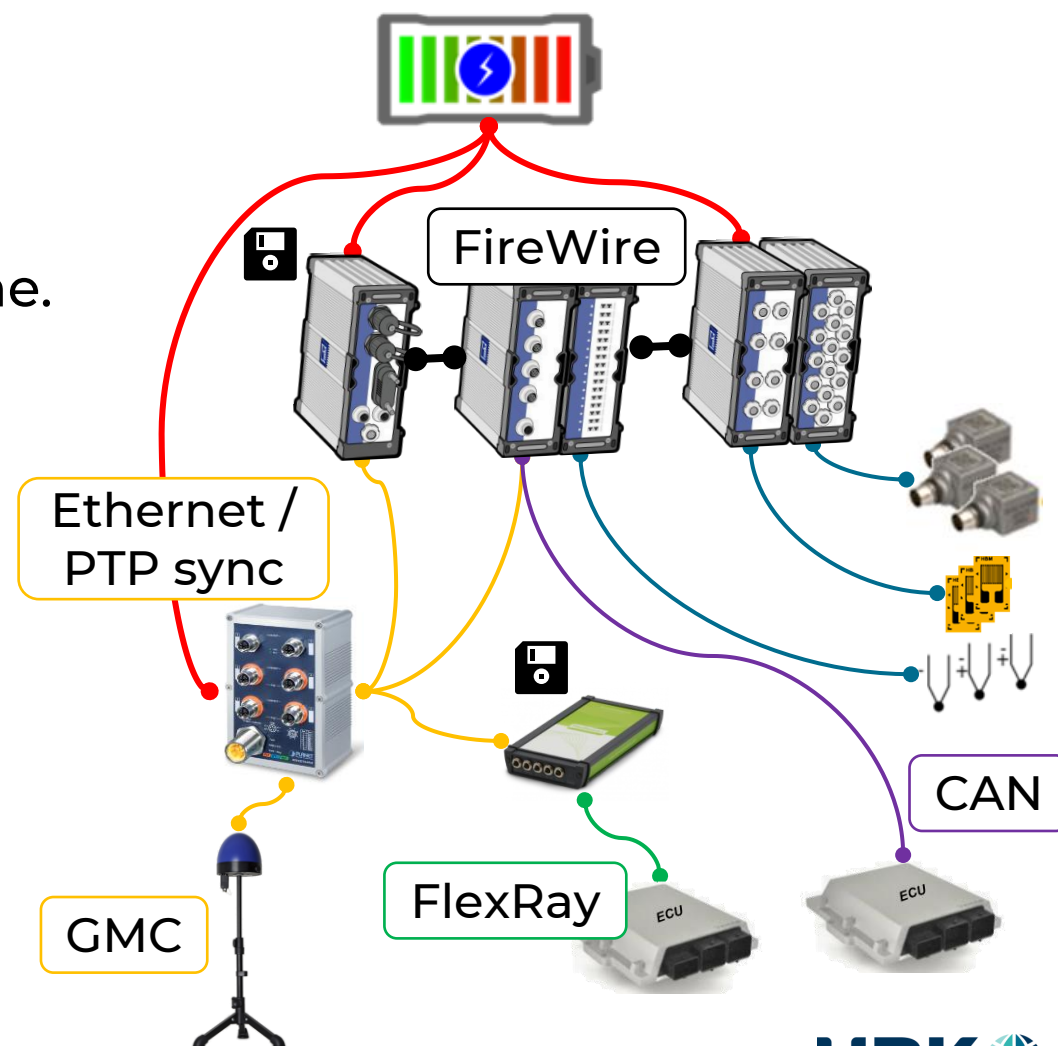
▲ nCode

- TestCombination glyph with time offset for easier time alignment.



Bench test with GMC

- ▲ GMC provides external time and regulates time during the test duration.
 - Time epoch seconds from 00:00 1-Jan-1970
- ▲ SomatXR modules uses regulated GMC time.
 - BIN file stores “First Sync Time Stamp” value.
 - A very precise number of seconds and microseconds, for example:
1.68776590799347E9
1687765907.99347 seconds
Monday 26 June 2023 : 07:51:47.99347
- ▲ STAR Flex Device receives SomatXR time.
 - ASCII & MDF store start time, from ASCII file:
date Mon Jun 26 07:52:24.808 2023



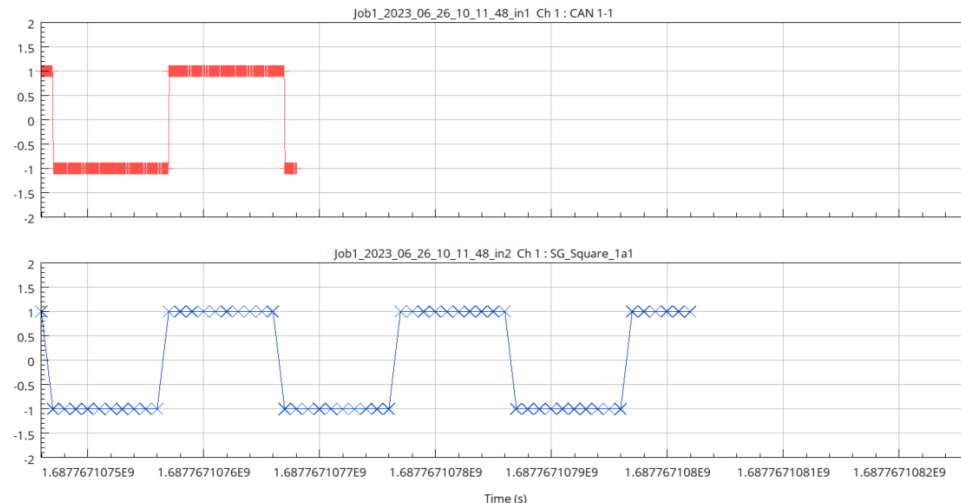
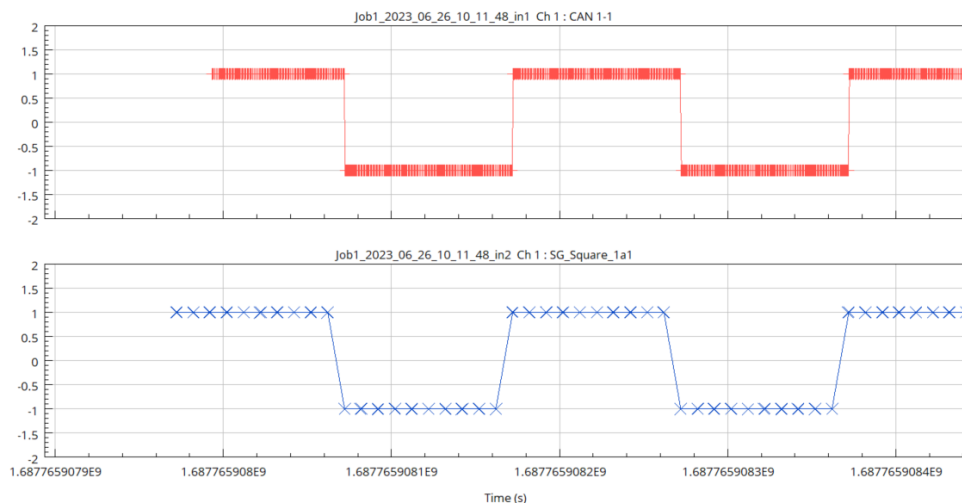
(TAI – UTC = 37 leap seconds)

Bench test with GMC

- Compare SomatXR module CAN decoded to analog (red) with SomatXR CAN Raw (blue).
 - 11997 square wave edges
 - Change in value always occurs first in CAN Raw and always observed in the following analog point.

1200Hz nominal constant sample rate the interval between data points	+0.000833 seconds
Maximum difference (delay) : CAN decoded time - CAN Raw time	+0.000483 seconds
Minimum difference (delay) : CAN decoded time - CAN Raw time	+0.000431 seconds
Range between minimum and maximum difference	+0.000052 seconds
	(less than 1 sample interval)

- Plots show alignment of first and last square wave cycles

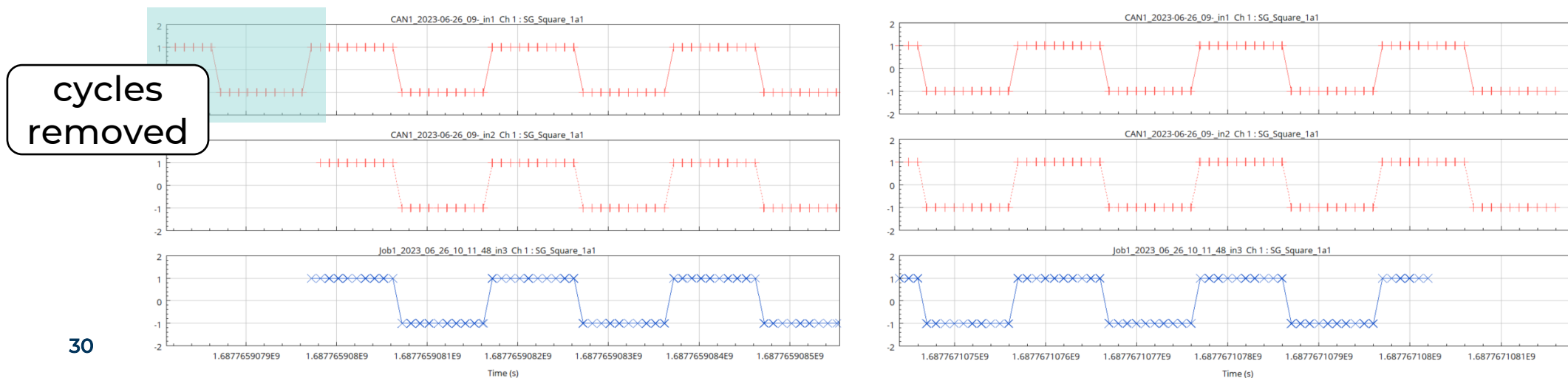


Bench test with GMC

- Compare Flex Device CAN (red) with SomatXR module CAN Raw (blue).
- 12000 square wave edges (STAR device starts earlier, so some cycles are removed for alignment)
- Change in value is first seen by either the Flex Device or the SomatXR module.

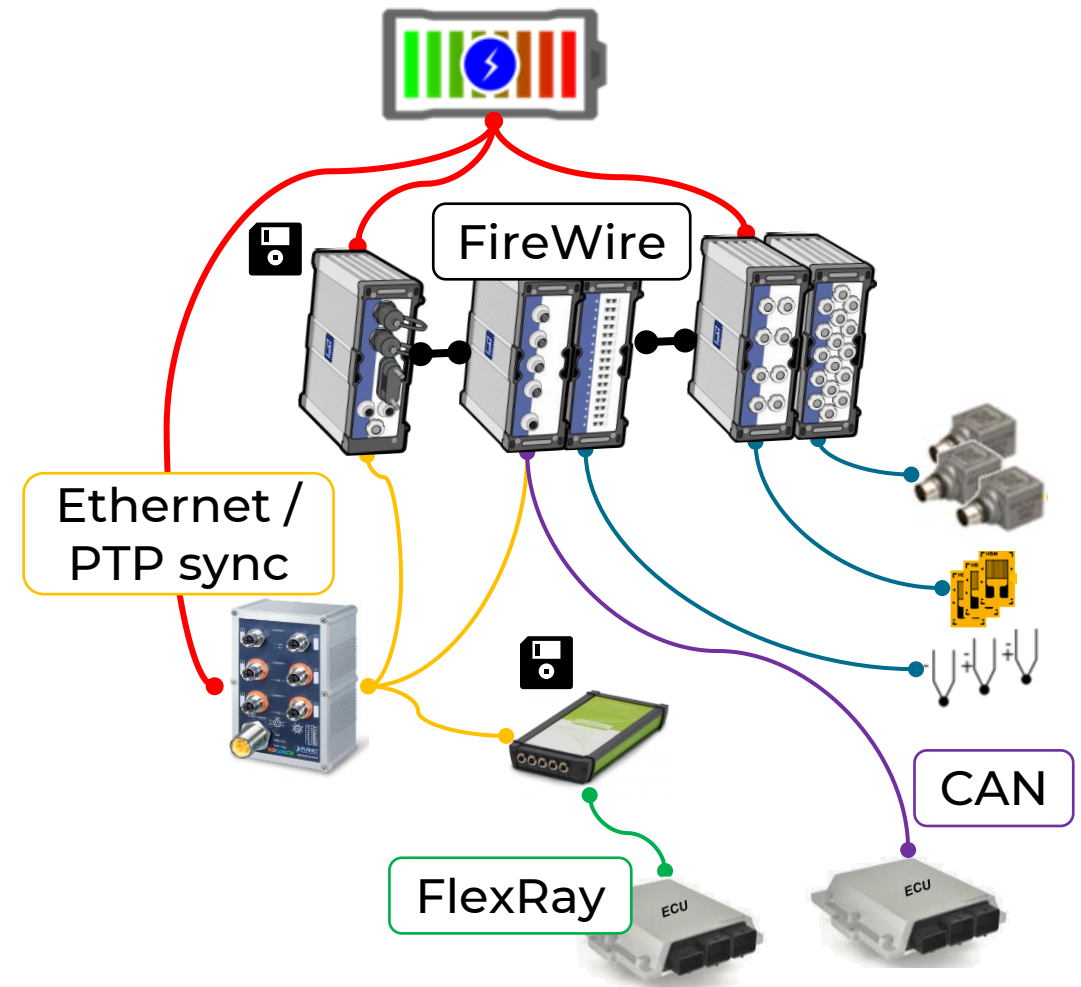
1200Hz nominal constant sample rate the interval between data points	+0.000833 seconds
Maximum difference (delay) : Flex Device time - SomatXR CAN Raw time	+0.000035 seconds
Minimum difference (delay) : Flex Device time - SomatXR CAN Raw time	-0.000098 seconds
Range between minimum and maximum difference	+0.000133 seconds
	(less than 1 sample interval)

- Plots show alignment of first and last square wave cycles



Proposed DAQ System – without GMC

- ▲ GMC not present, SomatXR provides external time.
 - Time epoch seconds from 00:00 1-Jan-1970
- ▲ SomatXR modules uses external time.
 - BIN file stores “First Sync Time Stamp” value.
 - A very precise number of seconds and microseconds, for example:
1.68776953864195E9
1687769538.64195 seconds
Monday 26 June 2023 : 08:52:18.64195
- ▲ STAR Flex Device receives SomatXR time.
 - ASCII & MDF store start time, from ASCII file:
 - date Mon Jun 26 08:52:55.518 2023



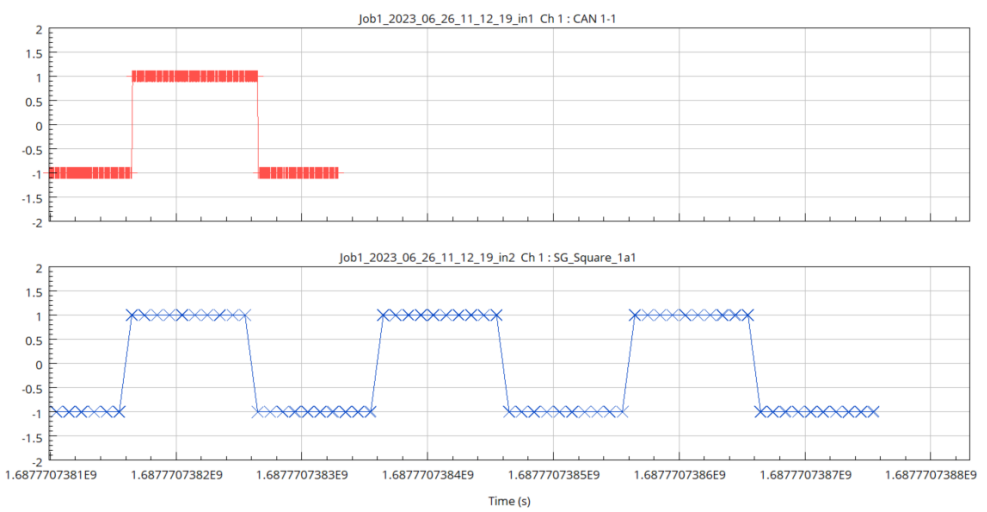
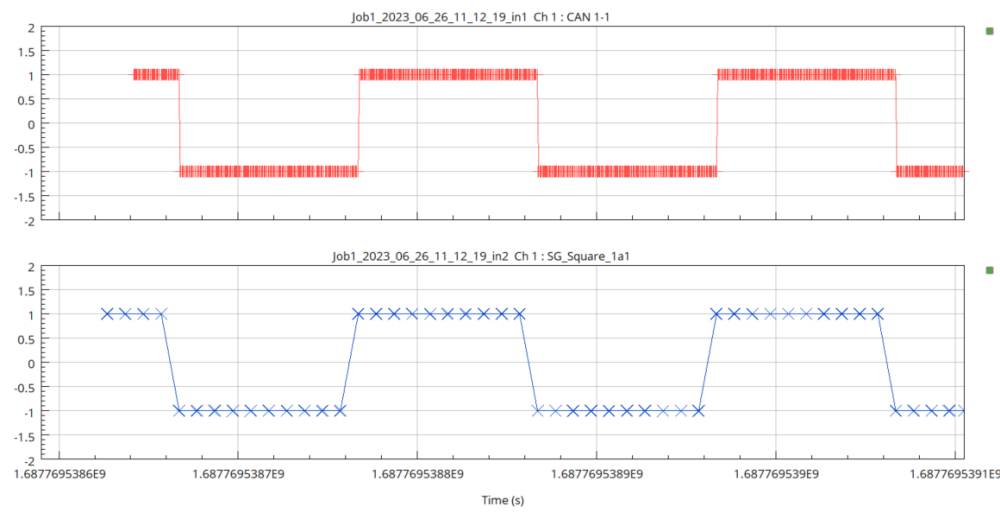
(TAI – UTC = 37 leap seconds)

Bench test without GMC

- Compare SomatXR module CAN decoded to analog (red) with SomatXR CAN Raw (blue).
- 11997 square wave edges
- Change in value always occurs first in CAN Raw and always observed in the following analog point.

1200Hz nominal constant sample rate the interval between data points	+0.000833 seconds
Maximum difference (delay) : CAN decoded time - CAN Raw time	+0.000714 seconds
Minimum difference (delay) : CAN decoded time - CAN Raw time	+0.000677 seconds
Range between minimum and maximum difference	+0.000037 seconds
	(less than 1 sample interval)

Plots show alignment of first and last square wave cycles

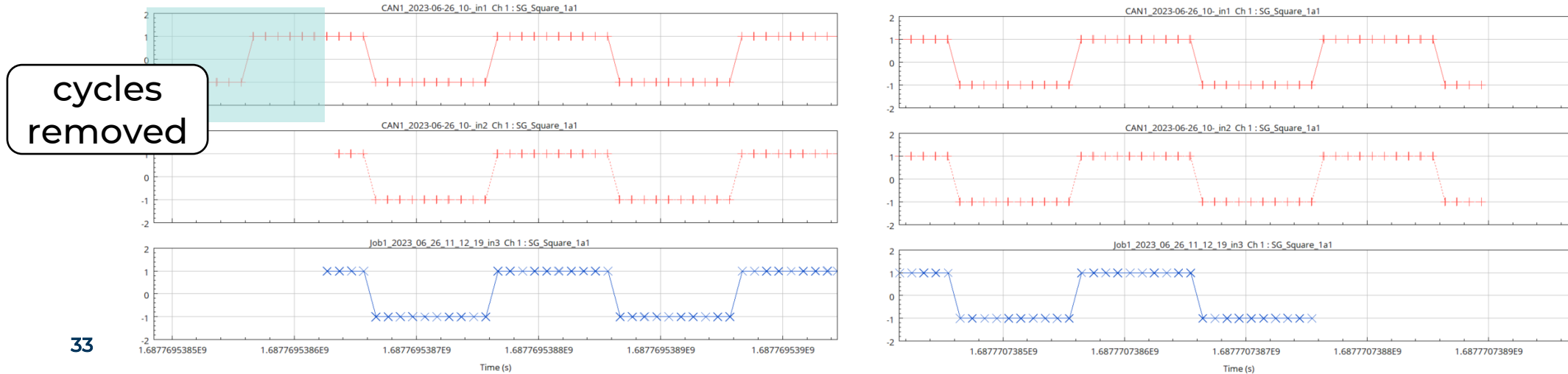


Bench test without GMC

- Compare Flex Device CAN (red) with SomatXR module CAN Raw (blue).
- 12001 square wave edges (STAR device starts earlier, so some cycles are removed for alignment)
- Change in value always occurs first in Flex Device and then the SomatXR CAN Raw.

1200Hz nominal constant sample rate the interval between data points	+0.000833 seconds
Maximum difference (delay) : Flex Device time - SomatXR CAN Raw time	-0.000282 seconds
Minimum difference (delay) : Flex Device time - SomatXR CAN Raw time	-0.000414 seconds
Range between minimum and maximum difference	+0.000132 seconds
	(less than 1 sample interval)

- Plots show alignment of first and last square wave cycles



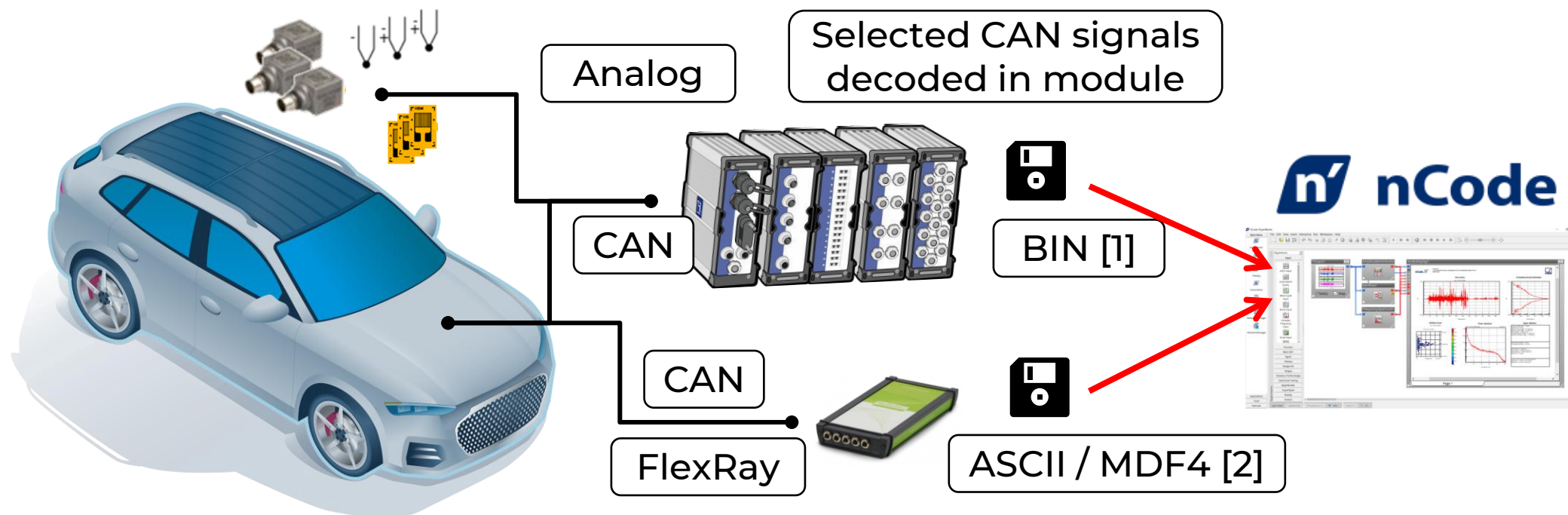
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Vehicle Trials

▲ Demonstrate integrated DAQ solution.

▲ Demonstrate review of Analog, CAN and FlexRay signals in nCode.



[1] catmanAP BIN binary file, analog, CAN decoded and all CAN RAW messages

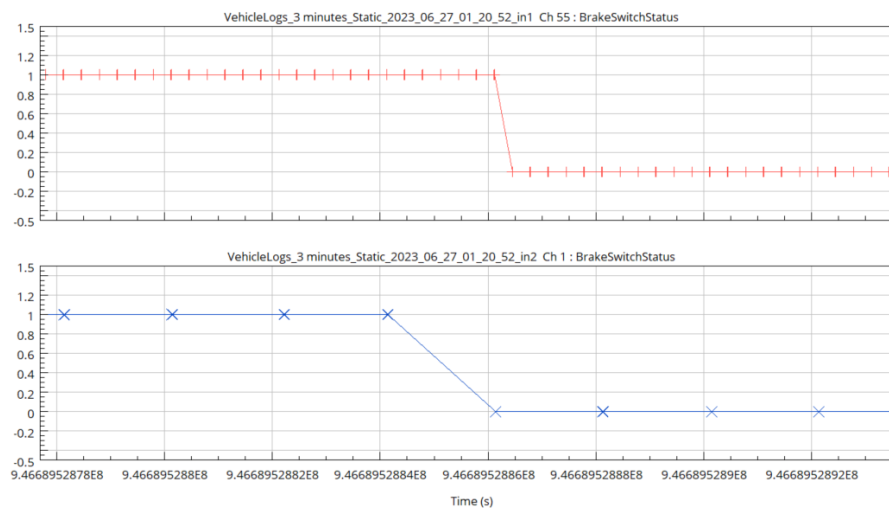
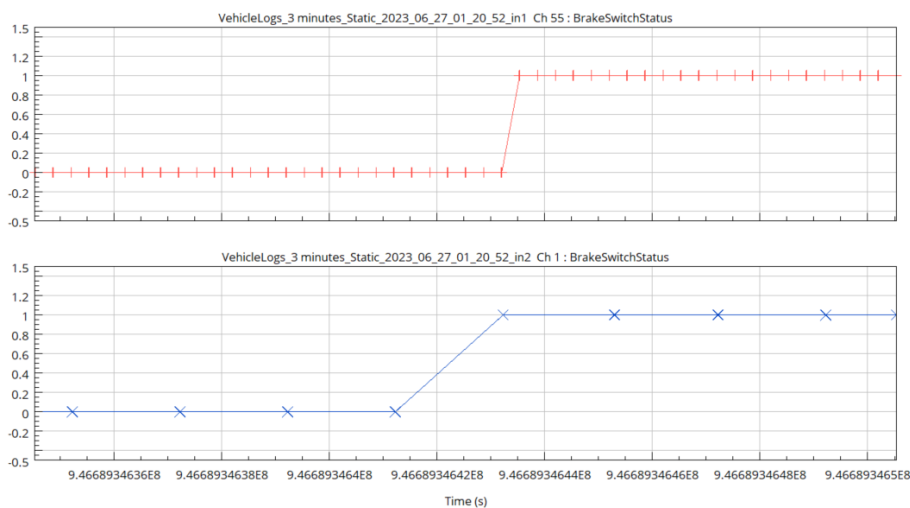
[2] ASCII or MDF4 files, all FlexRay & CAN RAW messages

Vehicle Trials – Garage Test – without GMC

- Compare SomatXR module CAN decoded to analog (red) with SomatXR CAN Raw (blue).
- 70 discrete input square wave edges
- Change in value always occurs first in CAN Raw and always observed in the following analog point.

300Hz nominal constant sample rate the interval between data points	+0.003333 seconds
Maximum difference (delay) : CAN decoded time - CAN Raw time	+0.003168 seconds
Minimum difference (delay) : CAN decoded time - CAN Raw time	+0.000587 seconds
Range between minimum and maximum difference	+0.002581 seconds
	(less than 1 sample interval)

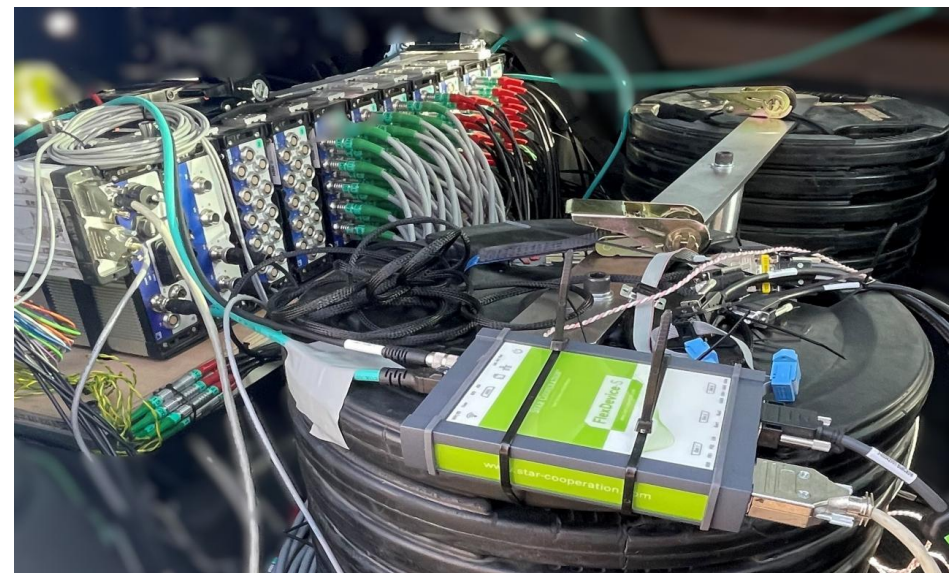
- Plots show alignment of first and last square wave cycles



UNRESTRICTED

Vehicle Trials – Continuing

- Record data from Analog, CAN and FlexRay vehicle networks.
- Record data with a PTP-derived time stamp in the data files.
- Post-process to combine and time align SomatXR and Flex Device data.



	Short Duration	Long Duration
Workshop	Fast Processing Controlled Inputs	Check Time Drift / Synchronisation
Proving Ground	Fast Processing	Check Rugged, Mobile, Robust



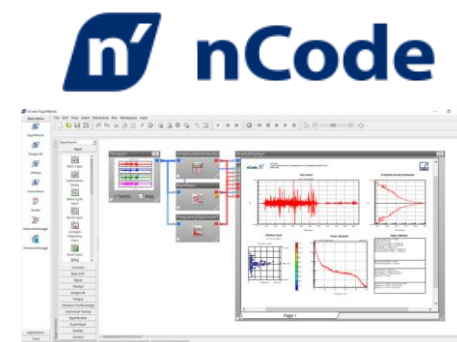
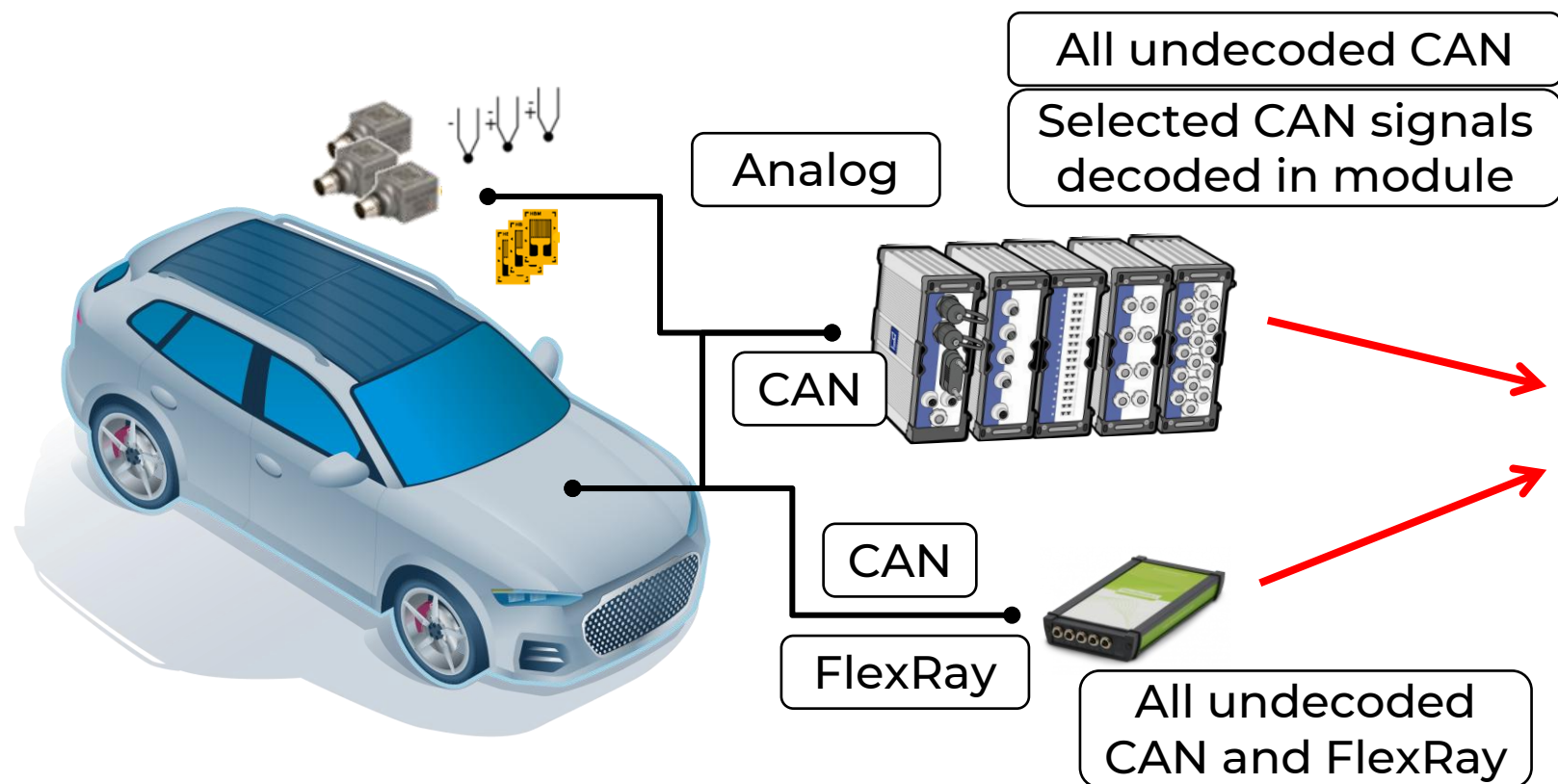
Agenda

1. Introduction and Requirements
2. Bench Testing - Development
3. Bench Testing - Post Processing
4. Vehicle Trials
5. Summary

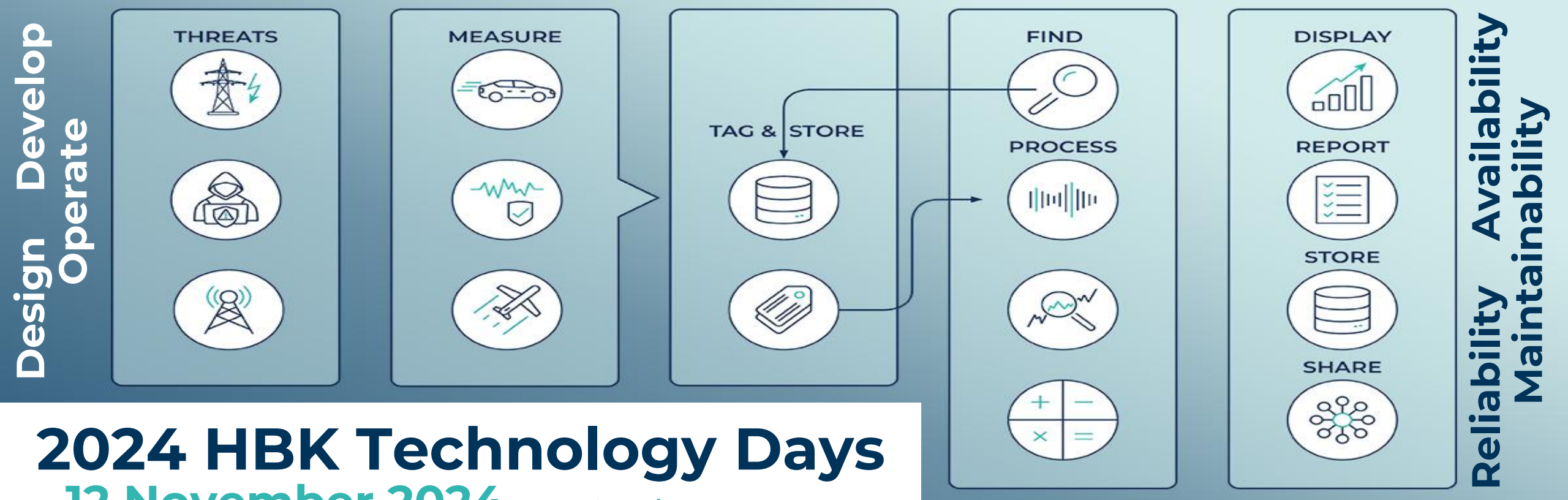
Summary

- Successful integration of STAR Flex Device with QuantumX & SomatXR DAQ solution.

- nCode enhancements to decode CAN data and time alignment of multiple measurement sources.



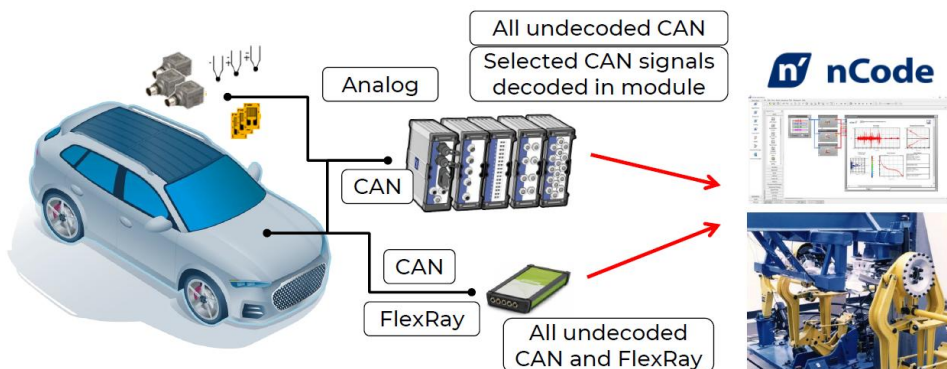
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2024 HBK Technology Days

12 November 2024

Session 3: Vehicle Network Measurements



- Integrating and synchronising CAN and FlexRay bus measurements with high fidelity analogue sensor measurements

Bilel Njeh, Test and Measurement - Custom Solutions, HBK

Rob Plaskitt, Application Engineer – Durability, HBK