How to Engage in Data-Driven Development and Testing Using MIPI Automotive Sensor Interfaces
Agenda

- Autonomous Driving: Challenges
- Data Logging
- Data Ingestion
- Data Management
- Data Labeling
- Data Replay
- Conclusion
Autonomous Driving: Challenges

Ensure safety under all conditions!

Dozens of environment sensors!

How to develop and test AI?

→ Data Driven Development
Data-Driven Development and Testing

- Record data
- Ingest data
- Analyze data
- Select data
- Label data
- Validate and homologate (closed-loop SIL/HIL simulation and software/hardware data replay tests)
- Train AI, develop software

AD SW stack
Private, public, hybrid cloud
Automotive Sensor Interfaces

Front Camera

![Front Camera Image](https://de.wikipedia.org/wiki/Spurhalteassistent#/media/Datei:Lane_Assist.jpg)  
Source: [https://de.wikipedia.org/wiki/Spurhalteassistent#/media/Datei:Lane_Assist.jpg](https://de.wikipedia.org/wiki/Spurhalteassistent#/media/Datei:Lane_Assist.jpg)  
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<table>
<thead>
<tr>
<th>Camera ECU</th>
<th>Imager</th>
<th>Processor</th>
<th>CAN/Ethernet</th>
</tr>
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</table>

Detected objects

Surround View Camera

![Surround View Camera Image](https://www.electrek.co/2019/05/29/honda-e-side-cameras/#)

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<table>
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<th>SerDes Pictures</th>
</tr>
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<tbody>
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<td>ADAS/AD ECU</td>
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Automotive Sensor Interfaces

Driver & Occupant Monitoring

- Camera sensor
- Imager
- Pictures
- ADAS/AD ECU
- Processor
- SerDes

Radar & Lidar

- Radar sensor
- Transceiver
- Radar Raw Data
- ADAS/AD ECU
- Processor
- SerDes

Data Logging
Data Logging

Record data → Ingest data → Analyze data → Select data → Label data

Validate and homologate
(closed-loop SIL/HIL simulation and software/hardware data replay tests)

AD SW stack → Train AI, develop software

Private, public, hybrid cloud
Automotive Surround View Cameras

- **Long range** sensor interfaces
  - Serializer and Deserializer
  - Today: TI FPD-Link, ADI/Maxim GMSL, Sony GVIF
  - Future: MIPI A-PHY®
Surround View Camera: Data Logging

- Camera Module
  - Lens
  - Image Sensor
  - Serializer

- SerDes Links (e.g., MIPI A-PHY)

- Deserializer
- Serializer
- FPGA
- D-PHY
- PCIe
- High-end SSD

- Processing Module
  - Image Processing Unit (SoC, GPU, FPGA, DSP)
  - μC
  - RAM Flash
  - ETH
  - CAN
  - D-PHY
  - PCIe
  - PCIe

Logging Platform
Surround View Camera: Data Logging

- Camera Module
  - Lens
  - Image Sensor
- Serializer
- SerDes Links (e.g., MIPI A-PHY)
- Deserializer
- FPGA
- Processing Module
  - Image Processing Unit (SoC, GPU, FPGA, DSP)
  - µC
  - RAM Flash
  - ETH
  - CAN
- High-end SSD
- Logging Platform
- 10G ETH
- Capture Module Protocol (CMP)
Data Logging: High Data Rates

Challenges
- High sensor data rates
- Dozens Gbit/s per car
- Hundreds TB per day per car

Solution
- Large high-throughput SSDs
- Lossless data compression
  - In real-time
  - Intelligent data selection
  - Redundancy reduction

Key takeaways
MIPI MASS℠ – Challenges

Challenges for Data Driven Development

Key takeaways

Challenges
- Advanced safety and security functions
- Encryption & authentication

Solution 1
- Disable safety/security for testing
  - “HIL/testing mode”

Solution 2
- Implement MIPI MASS℠ in logging/testing hardware
- Requires keys from OEM/Tier1 suppliers
Data Ingestion
Data Ingestion

- Record data
- Ingest data
- Analyze data
- Select data
- Label data

Validate and homologate
(closed-loop SIL/HIL simulation and software/hardware data replay tests)

AD SW stack
Private, public, hybrid cloud
Train AI, develop software
Opening the bottleneck with fast data ingestion

- Upload data from **Data Logger** directly to **storage**
  - Requires large storage
  - Requires highest-speed internet connection
- Straightforward approach for **prototyping** and **research**
  - Small data sets only
Opening the bottleneck with fast data ingestion

- Send SSDs to the data center via mail
  - “Sneaker network”
  - Easy handling of SSDs required
  - SSDs must be robust
- **High bandwidth** data read and upload interface
Data Management

Record data -> Ingest data -> Analyze data -> Select data -> Label data

- Validate and homologate (closed-loop SIL/HIL simulation and software/hardware data replay tests)
- Train AI, develop software

AD SW stack
Private, public, hybrid cloud
Data Management

Collected data includes a lot of **useless data**

**Data Consumers have different needs**

- **Training Object Detection**
  - Video Duration >1 min
  - Lane Count > 2 Lanes
  - Traffic participant position relative to the Ego Vehicle [Diverse]

- **Validation of LKA**
  - Video Duration <= 1 min
  - Traffic participant position relative to the Ego Vehicle [Diverse]

- **Validation of AEB**
  - Light & weather Conditions [Diverse]
  - Traffic Participants [Diverse]
  - Traffic participant position relative to the Ego Vehicle [Diverse]

Deliver the **right data**
Data Management

Collected data includes a lot of **useless data**

Deliver the **right data**

- Light & weather Conditions [Diverse]
- Traffic Participants [Diverse]
- Traffic participant position relative to the Ego Vehicle [Diverse]

- Video Duration >1 min
- Lane Count > 2 Lanes
- Traffic participant position relative to the Ego Vehicle [Diverse]

- Video Duration <= 1 min
- Traffic participant position relative to the Ego Vehicle [Front]
Data Labeling
Data Annotation & Labeling

1. Record data
2. Ingest data
3. Analyze data
4. Select data
5. Label data

Validate and homologate (closed-loop SIL/HIL simulation and software/hardware data replay tests)

Train AI, develop software

AD SW stack

Private, public, hybrid cloud
Data Annotation & Labeling

Key takeaways

**Anonymization**
Anonymizes +99% of all identifiable faces and license plates.
Compliance to international standards

**AI-based labeling**
2D/3D bounding boxes (videos/point clouds), semantic segmentation, 2D/3D polylines...

**Manual annotations**
Huge workforce of human annotators required.

**Automated annotations**
Cuts costs with ground truth generation >90% automated.
Data Annotation & Labeling

Record data

Ingest data

Analyze data

Select data

Label data

Validate and homologate
(closed-loop SIL/HIL simulation and software/hardware data replay tests)

Train AI, develop software

Private, public, hybrid cloud

AD SW stack
Data Replay
Data Replay

1. Record data
2. Ingest data
3. Analyze data
4. Select data
5. Label data
6. Validate and homologate (closed-loop SIL/HIL simulation and software/hardware data replay tests)
7. Train AI, develop software

AD SW stack

Private, public, hybrid cloud
Data Replay

- Camera module
  - Lens
  - Image sensor (e.g., CMOS)
  - Monochrome, Bayer, or CCC filter

- Raw data (Recorded or simulated)

- Serializer

- SerDes Links (e.g., MIPI A-PHY)

- Deserializer

- Image processing unit
  - (SoC, FPGA, DSP, … e.g. EyeQ™)

- RAM/flash

- Power

- CAN

- FlexRay

- ETH

- ECU connector

- Processing module

- \( \mu \text{C} \)
Data Replay

- Camera module
  - Lens
  - Monochrome, Bayer or RGB filter
  - Image sensor (e.g., CMOS)

- Serializer

- SerDes Links (e.g., MIPI A-PHY)

- Deserializer

- Image processing unit (SoC, FPGA, DSP, ... e.g. EyeQ™)
  - RAM/flash
  - Power

- Microcontroller (μC)
  - CAN
  - FlexRay
  - ETH

- ECU connector
Data Replay

Challenges
- Various sensor interfaces used today
- Even interface chips from same supplier are not 100% compatible
- I2C register configuration
- Synchronization of all ECU interfaces

Solution Today
- Modular hardware
- Highly configurable logging and simulation

Solution Tomorrow
- Standardized sensor interfaces
  - MIPI A-PHY
  - MIPI MASS℠

Key takeaways
Conclusion
Conclusion

• Data is a key for Autonomous Driving
• Data Driven Development
THANK YOU!
ADDITIONAL RESOURCES

• MIPI MASS℠
  https://www.mipi.org/introductory-guide-to-mass

• MIPI A-PHY®
  https://www.mipi.org/specifications/a-phy

• dSPACE Data Driven Development

• dSPACE Environment Sensor Interface Unit