STPA in Support of Next-Gen Automotive E/E Architecture Development

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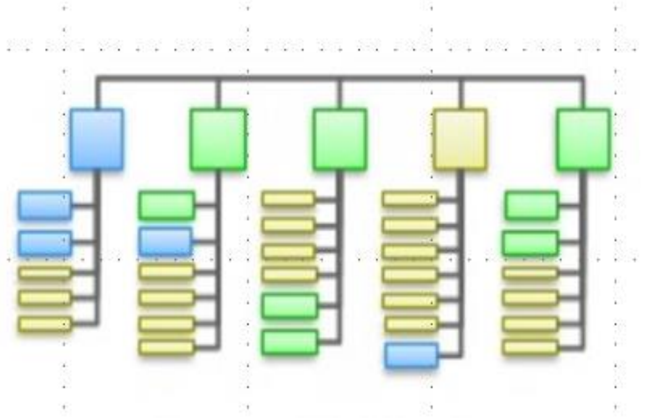
Outline

1. Motivation: Why next-gen EEA? Why STPA? What’s the challenge?
2. Approach: Findings from Highway Pilot example

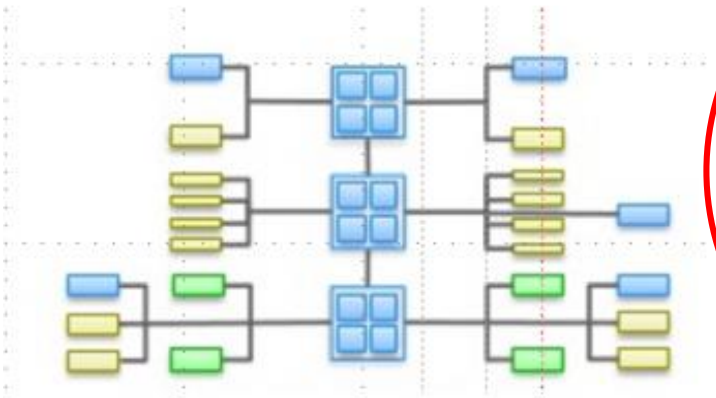
Motivation: Automotive E/E Architecture (EEA) Consolidation

ECU-based EEA



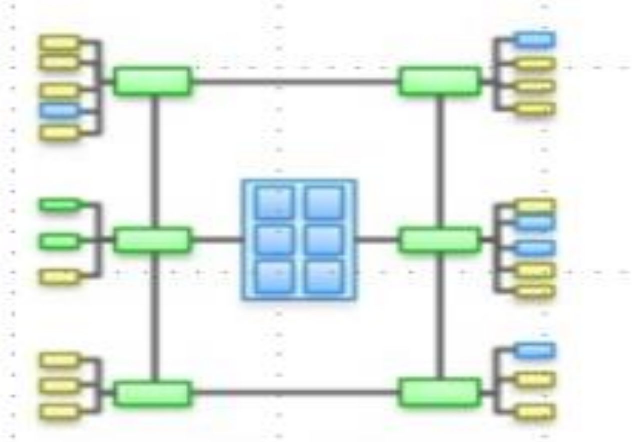
Established

Domain-based EEA



Upcoming

Software-Defined Vehicle (SDV)

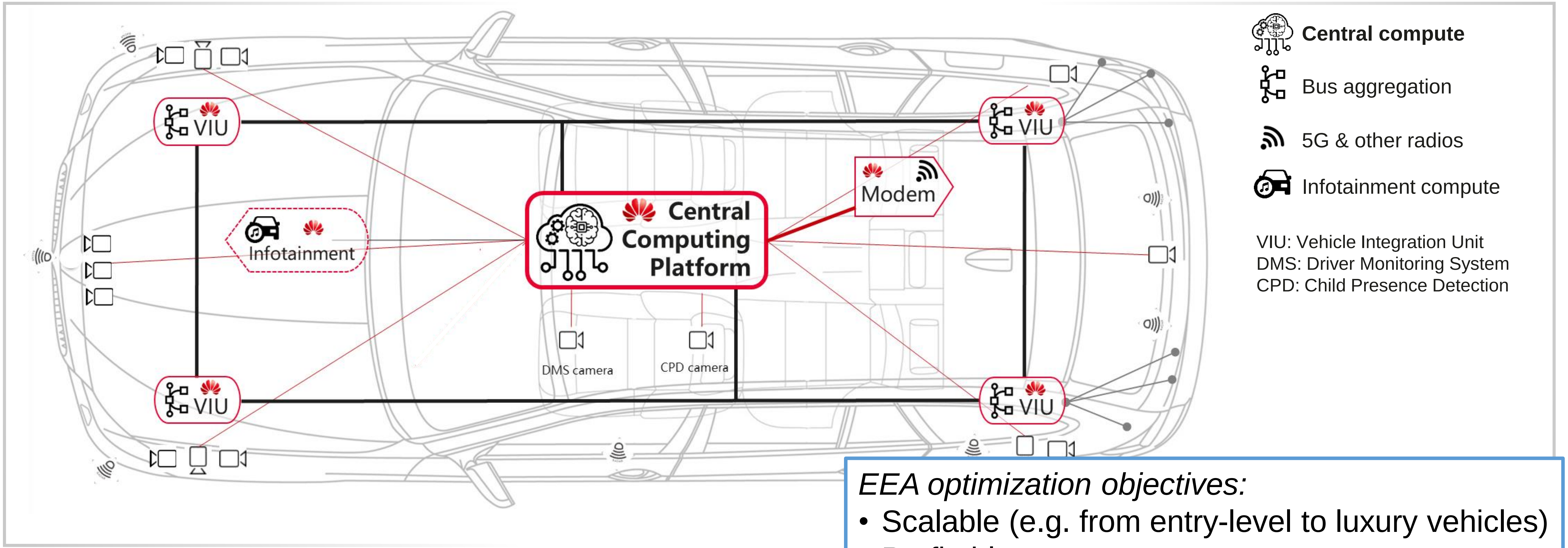


Next Generation

- Existing EEA reach a complexity limit.
- Not suited to satisfy needs of the future vehicles:
  - Frequent software updates
  - Automated driving
  - Customer individualization
  - V2X, AI, teleoperation, etc.

- ➢ Vehicle-centralized
- ➢ Most business logic in central compute
- ➢ Scalable, open, flexible
- ➢ More resource efficient

SDV In-Vehicle Platform

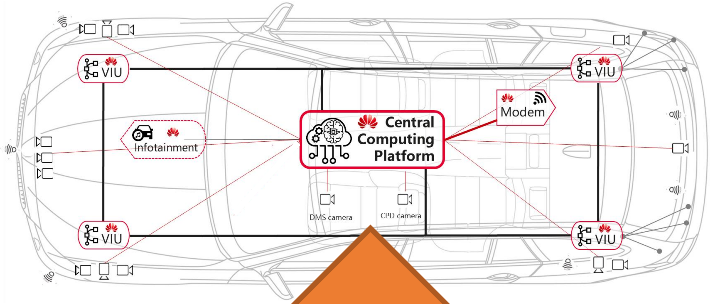


EEA optimization objectives:

- Scalable (e.g. from entry-level to luxury vehicles)
- Profitable
- **Safe!**
- Etc.

Idea: Use STPA to identify potential safety-critical weaknesses of the EEA early in the development.

Challenges when using STPA for EEA Design

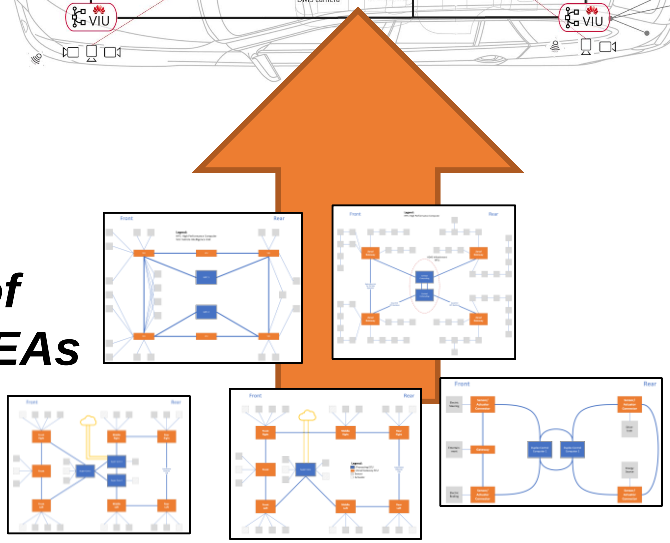


- Typical EEA development has a strong focus on **concrete technologies**.

versus

- **Typical application of STPA follows top-down paradigm**, starting from a high-level, technology-agnostic perspective.

Multitude of possible EEAs



Variables:
- Architectural patterns (ring, star, etc.)
- Communication technologies (Ethernet, PCIe, LIN, CAN, etc.)
- Number of gateways?
- Which communication links need to be redundant?
- Which components require safety integrity (ASIL)?
- Etc.

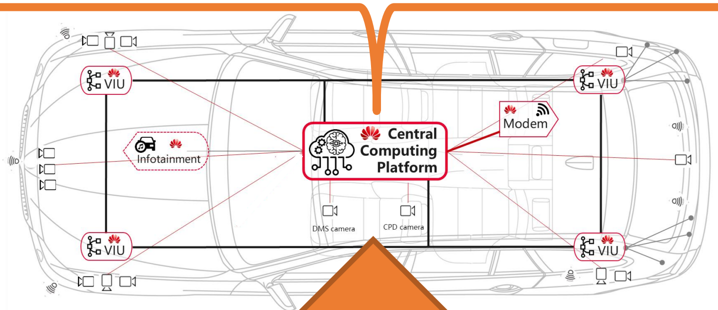
How can a technology provider such as Huawei leverage STPA to develop the next-gen EEA?

Challenges when using STPA for EEA Design

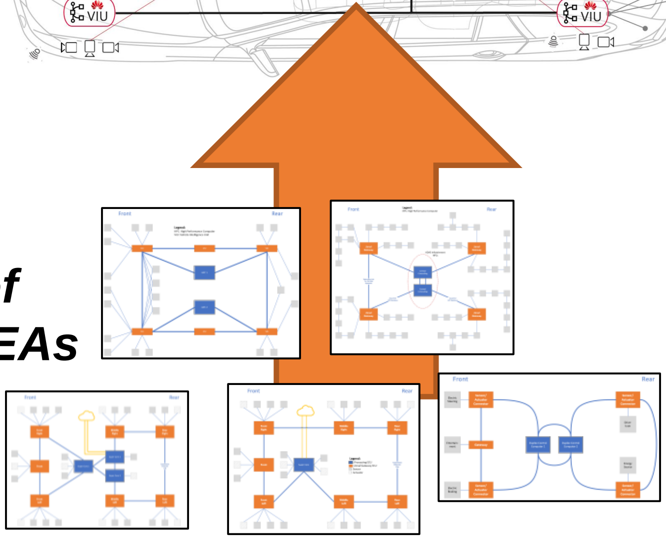
EEA needs to be applicable for various features and functions

Netflix Night Vision Driver Monitoring Adaptive Cruise Control Highway Pilot Urban Pilot

Augmented Reality Child Presence Detection Lane-Keep Assist Valet Parking



Multitude of possible EEAs



- Ideally, architecture is developed **out of context** (function-independent).
- Then applied to an OEM (specific system designs and sets of features and functions of mixed criticality)

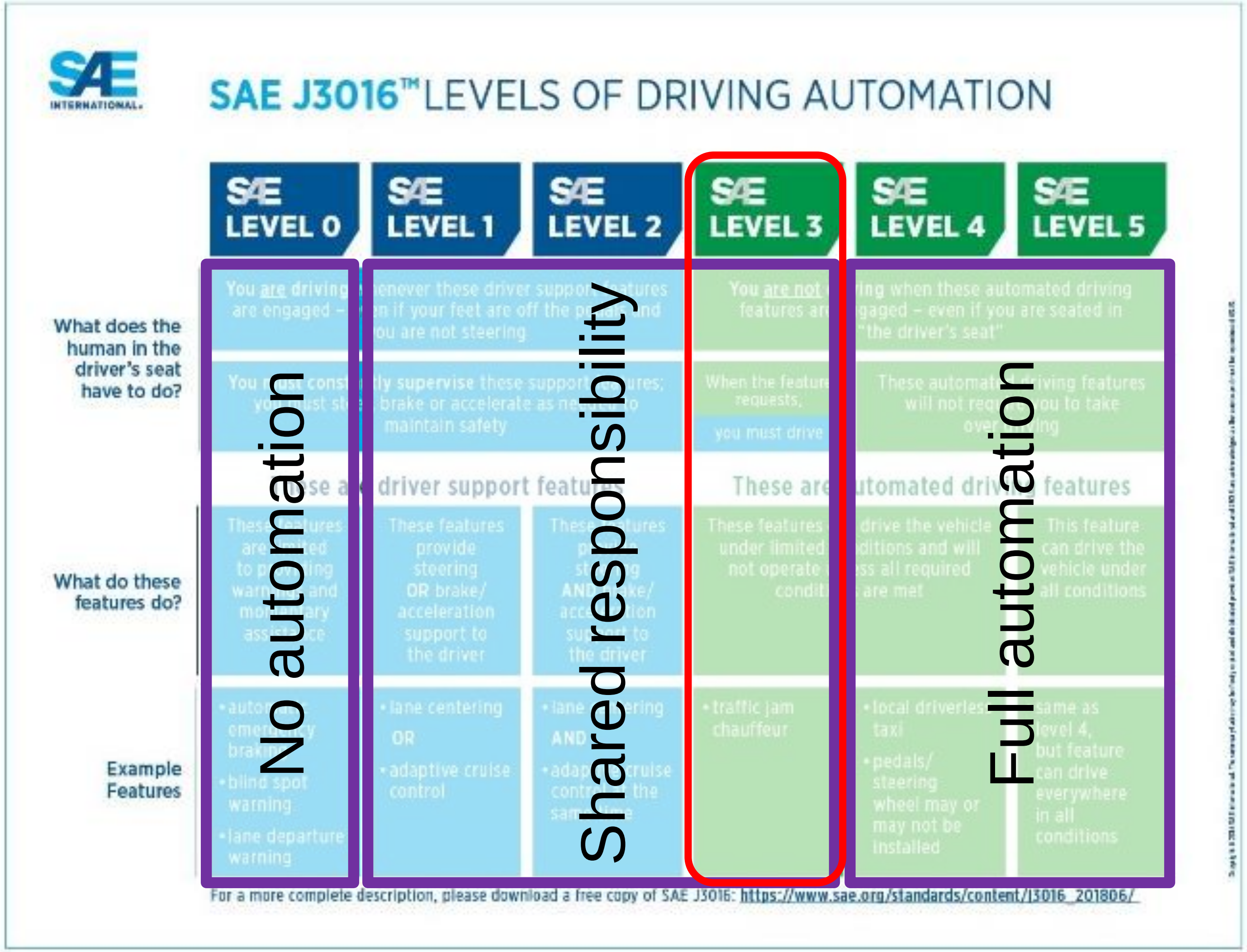
"Ensure every UCA specifies the context that makes the control action unsafe." [STPA Handbook, 2018]

How do we analyze the safety of an architecture which is developed out of context?

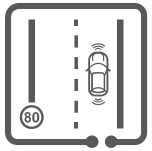
Our Approach in 4 Steps

1. Feature assumption for context
2. Perform STPA on feature
3. Map control loop onto EEA
4. Identify EEA weaknesses

Assumed Feature: Highway Pilot



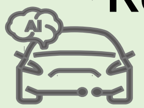
Highway Pilot (HWP) allows automated, high-speed highway driving



[Safety First for Automated Driving, 2019]

Automated Driving feature of SAE Level 3

- ➢ Shared responsibility between driver and system



Responsibility of the system:

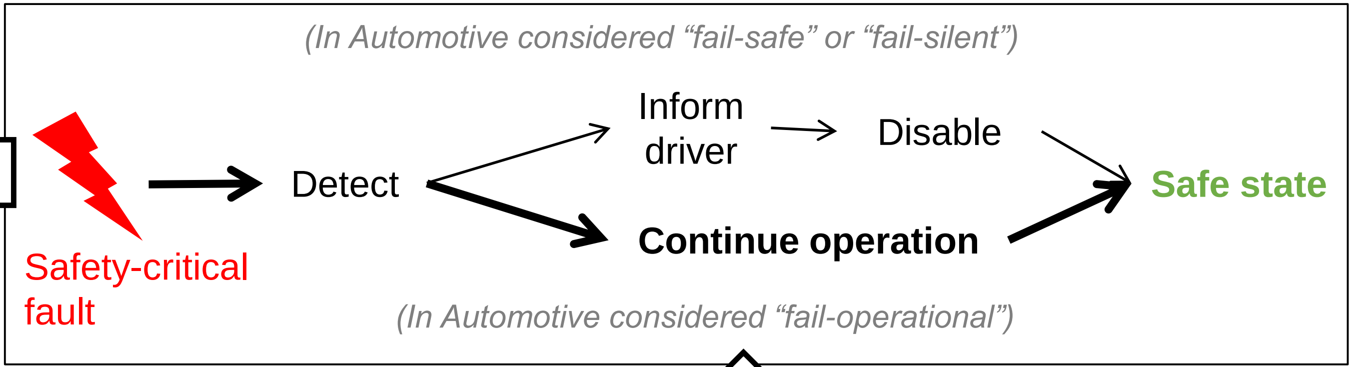
- Performs all driving tasks
- Provides driver take over request (TOR) if it cannot execute the function anymore.
- Allows ~10s for driver to respond to TOR, otherwise slows down or stops.

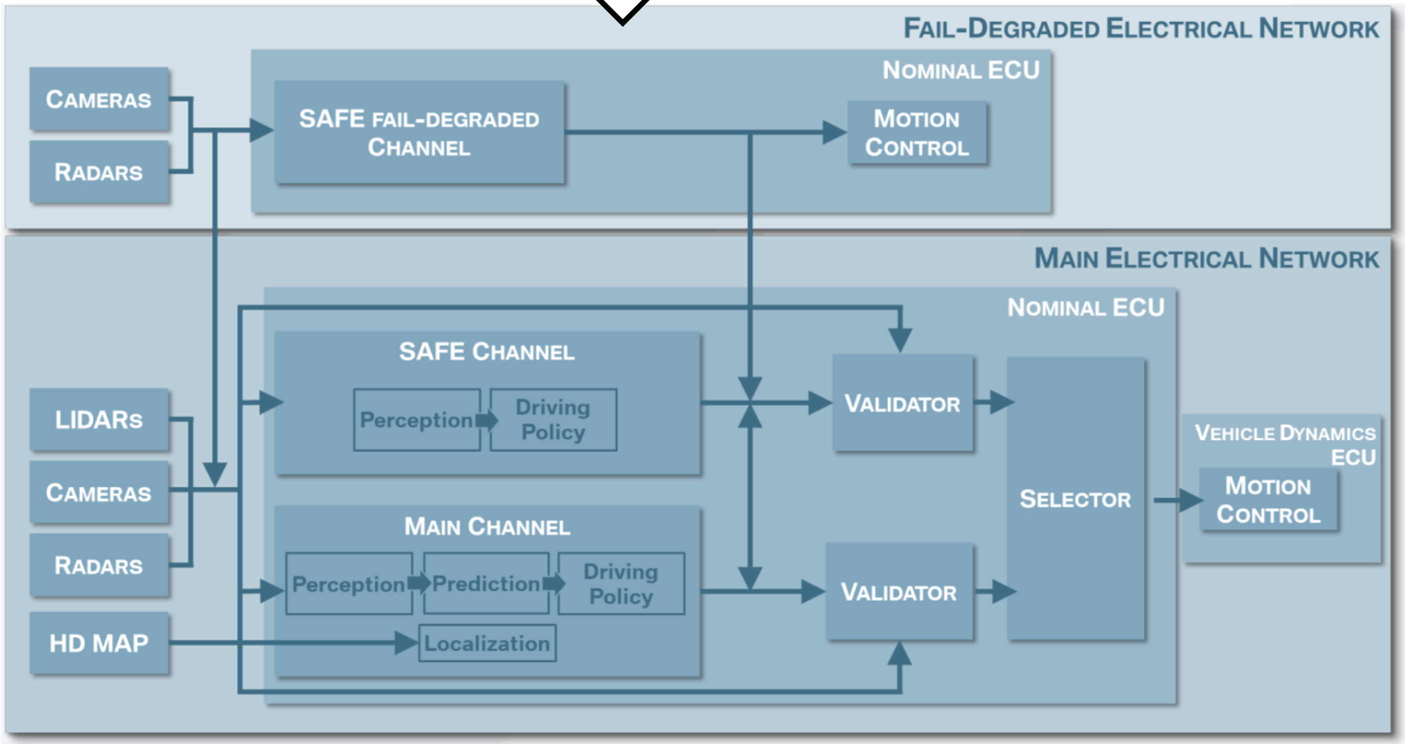
Responsibility of the driver:

- Does not have to pay constant attention.
- Needs to be ready to take over control within ~10s of TOR.

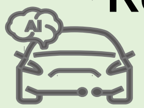
Assumed Feature: Highway Pilot

Common approach:
Dual Channel System





[BMW Safety Assessment Report, SAE Level 3 Automated Driving System, 05/2020]



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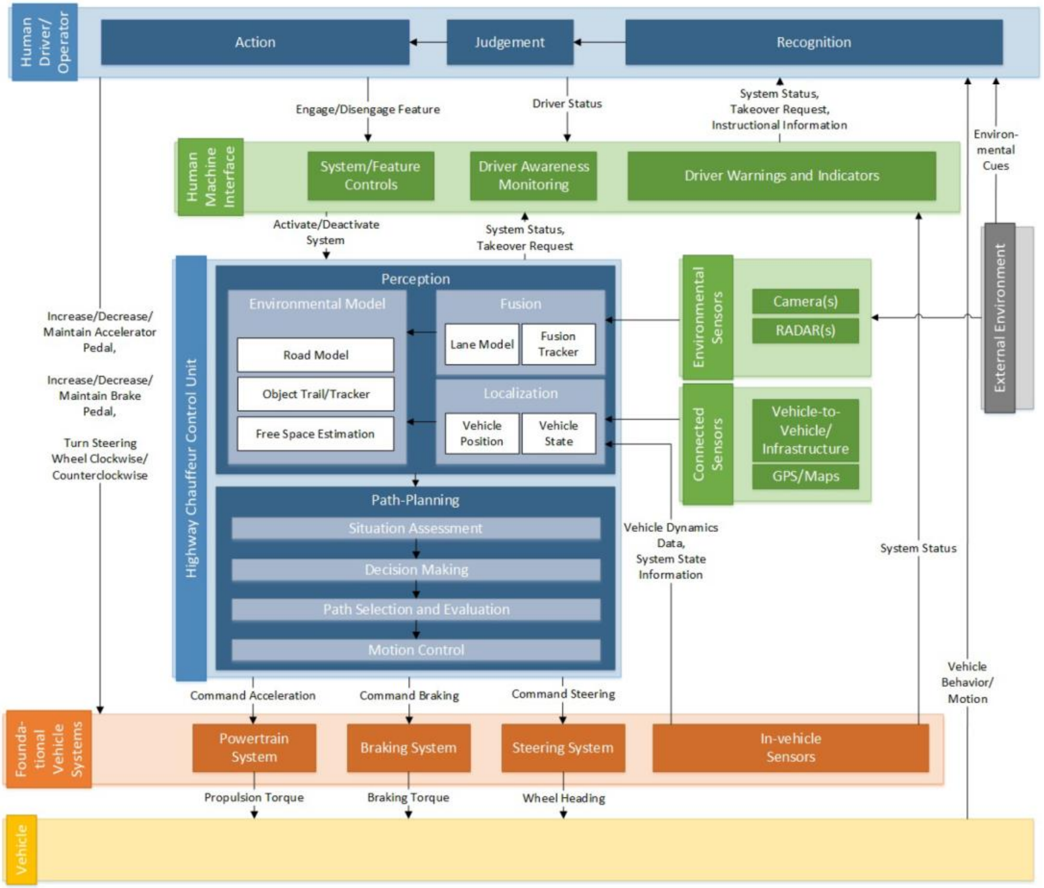
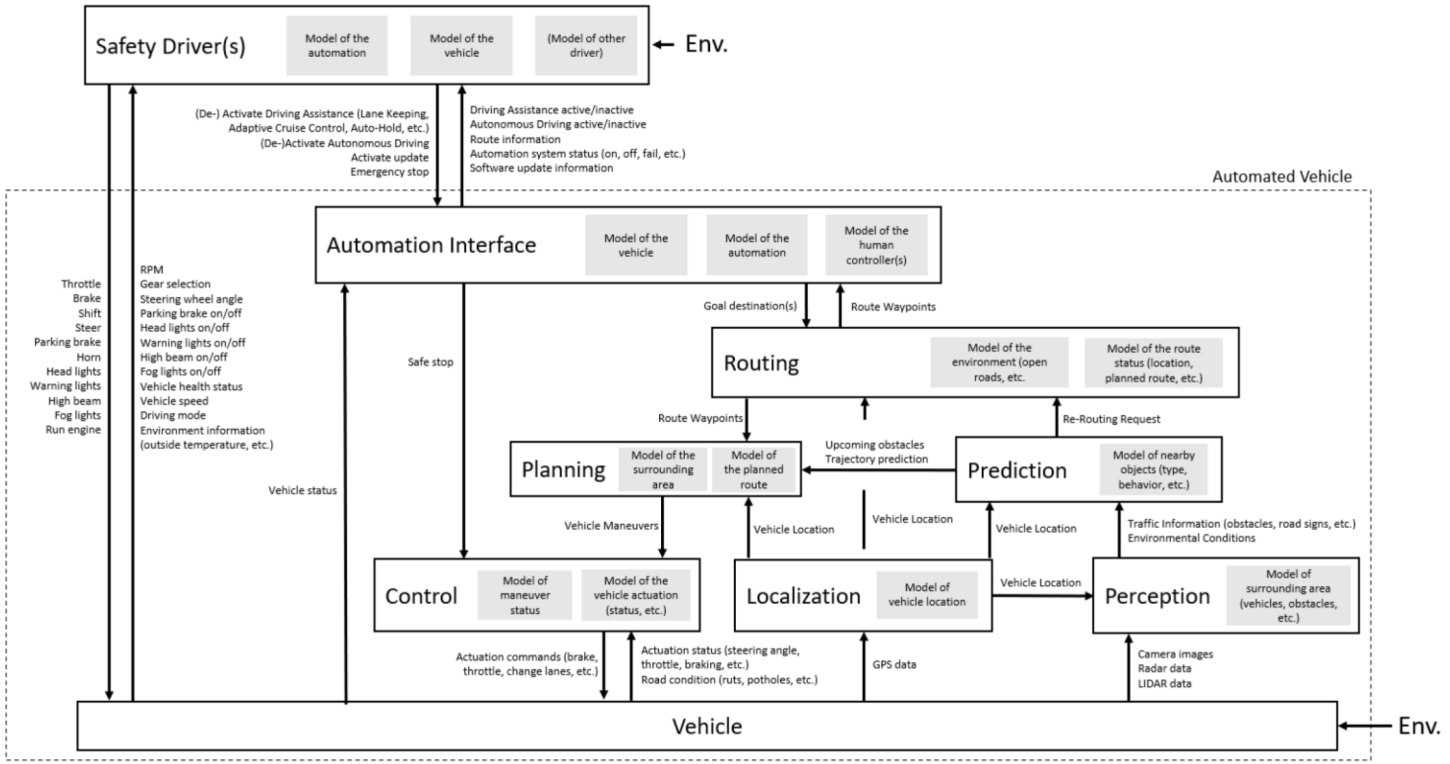
Control Structure



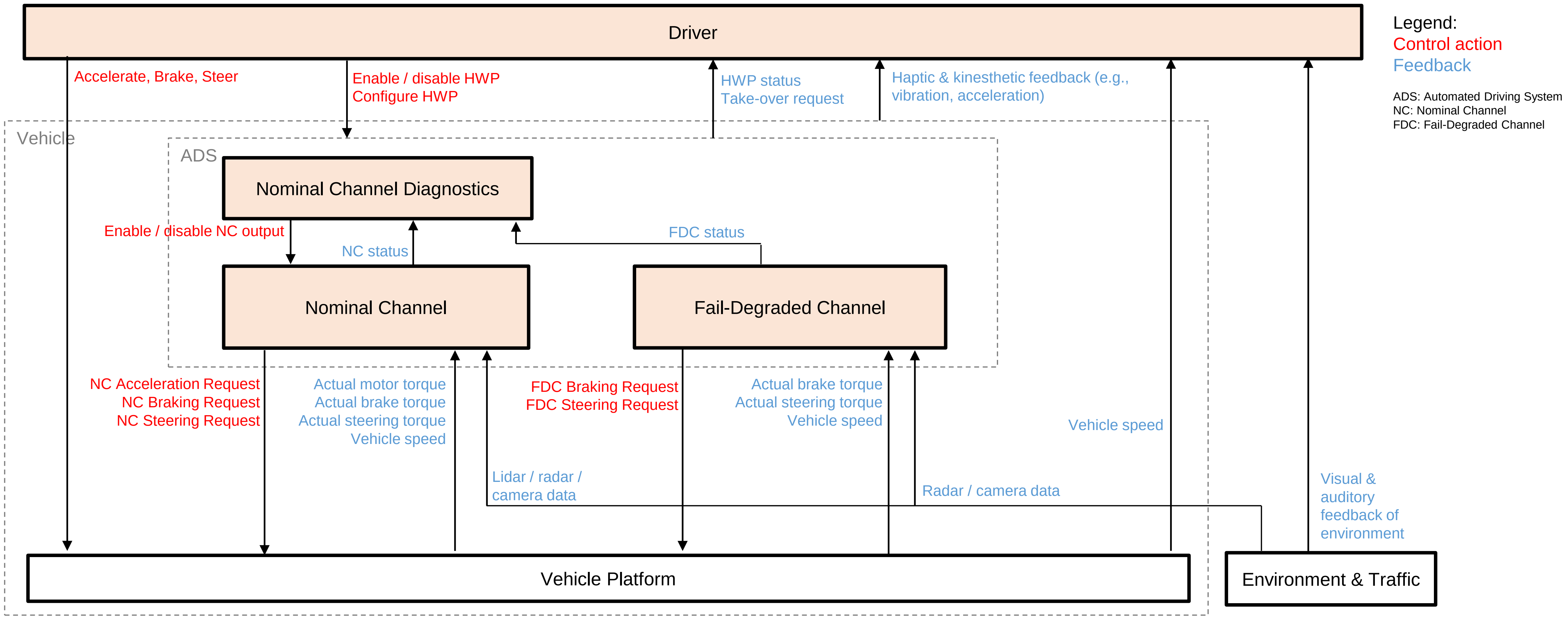
[NHTSA, SOTIF of Lane-Centering and Lane-Changing Maneuvers of Generic Level 3 Highway Chauffeur System, 11/2020]



[Schmid, Model-based Certification of Automated Vehicles, 05/2020]

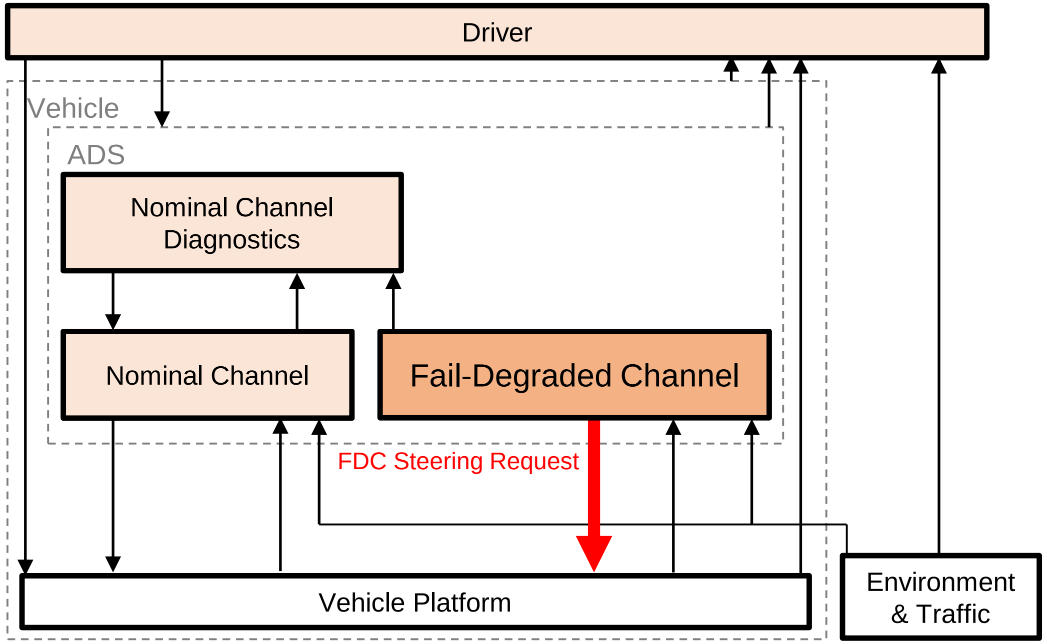
Prior work focuses on key elements of function pipeline (e.g. perception, localization, path planning, etc.).

Control Structure



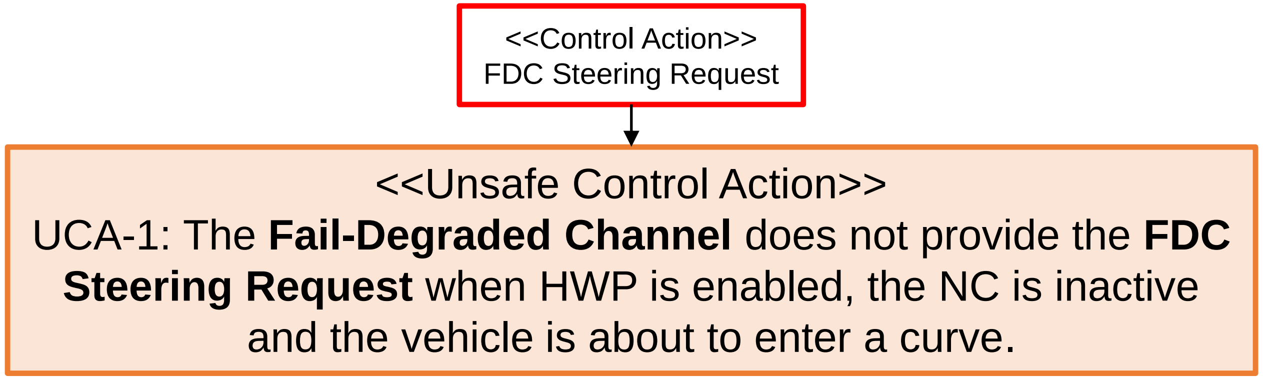
We took a complementary approach: Focus on analysis of the two channels.

Unsafe Control Actions

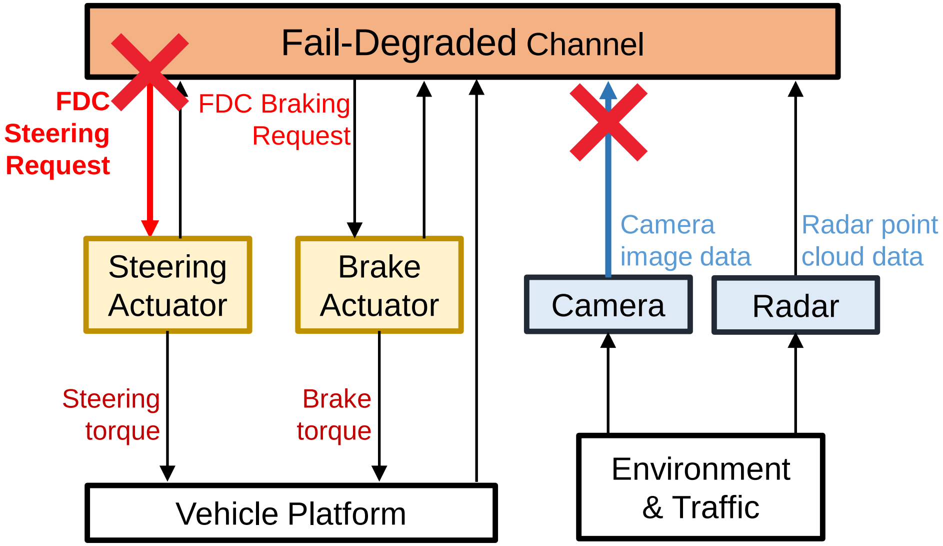


Example: Fail-Degraded Channel:

Note: Based on its responsibility, the FDC should only provide a braking and steering request if the NC is for some reason incapacitated.



Loss Scenarios



<<Unsafe Control Action>>
UCA-1: The **Fail-Degraded Channel** does not provide the **FDC Steering Request** when HWP is enabled, the NC is inactive and the vehicle is about to enter a curve.

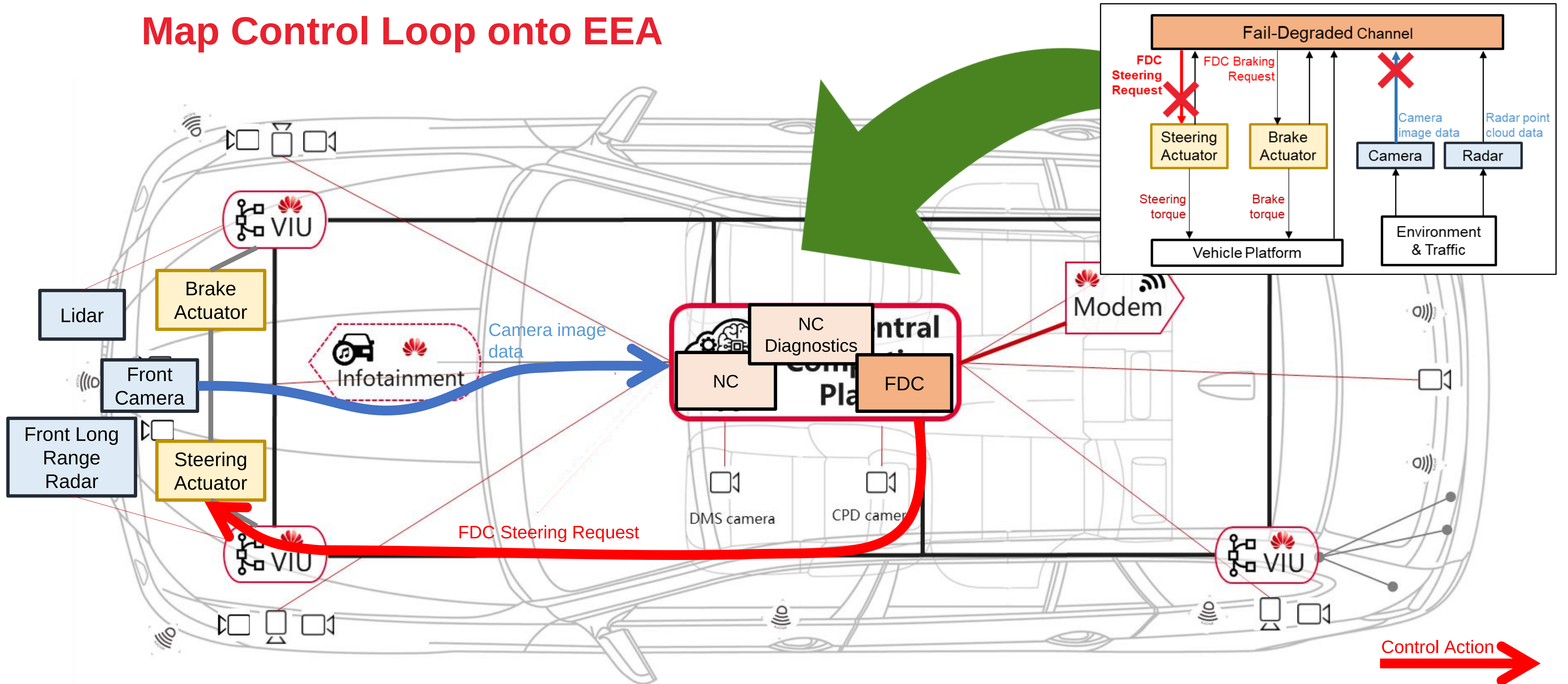
<<Loss Scenario>>
LS-1-1: HWP is enabled, the NC is inactive and the vehicle is about to enter a curve.

The FDC does not receive relevant camera image data to perceive the curve.

Therefore the FDC does not provide the FDC Steering Request.

Challenge: Need engineering judgement to focus on loss scenarios most relevant for EEA
(e.g. related to communication, power supply, computation, etc.)

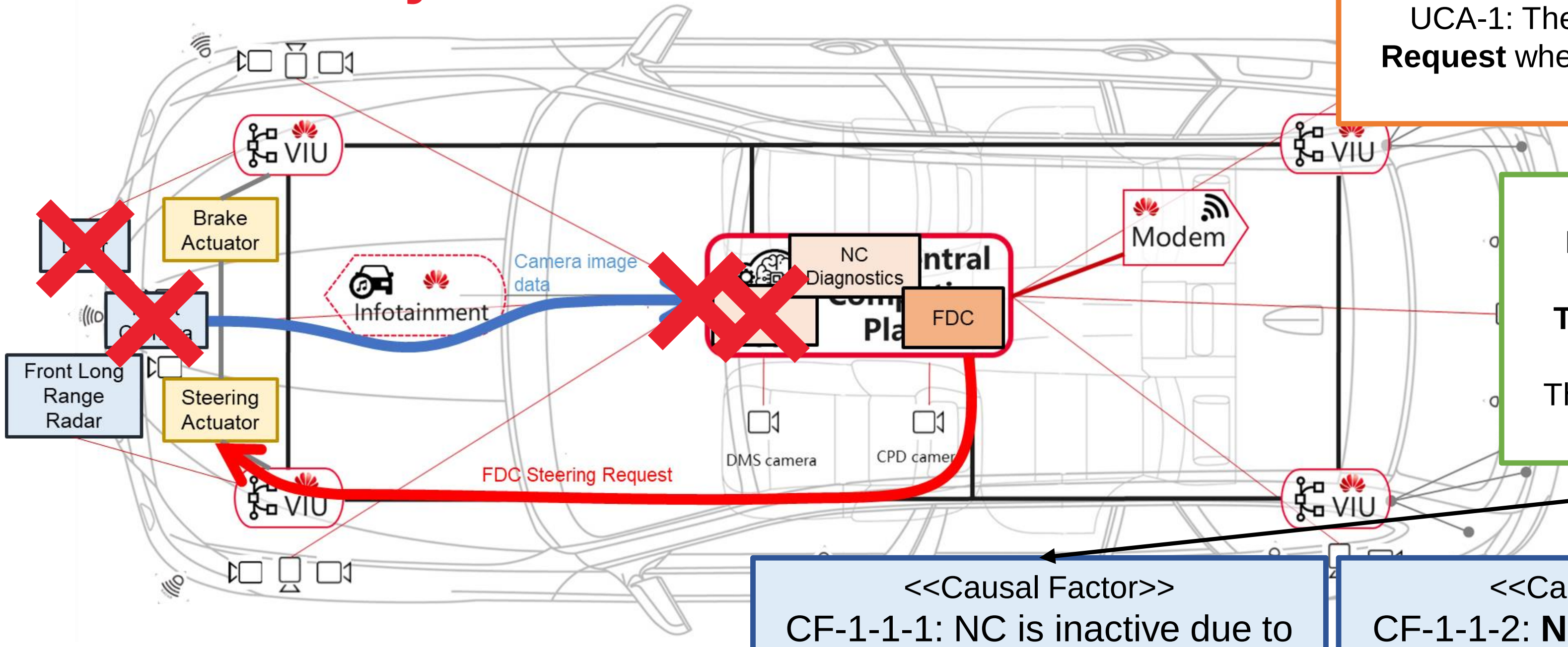
Map Control Loop onto EEA



Map control loop related to Loss Scenario onto the EEA.
→ Analysis re-usable for many EEAs.

Disclaimer: This slide depicts only an illustration of the EEA mapping, not the full-detail version.

Identify EEA Weaknesses



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UCA-1: The **Fail-Degraded Channel** does not provide the **FDC Steering Request** when HWP is enabled, the NC is inactive and the vehicle is about to enter a curve.

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LS-1-1: HWP is enabled, the NC is inactive and the vehicle is about to enter a curve.
The FDC does not receive relevant camera image data to perceive the curve.
Therefore the FDC does not provide the FDC Steering Request.

<<Causal Factor>>
CF-1-1-1: NC is inactive due to a power supply failure. **Front camera uses same power supply as NC.** Camera is therefore also inactive and does not provide camera data.

<<Requirement>>
The EEA shall provide independent power supplies for the front camera and the NC.

<<Causal Factor>>
CF-1-1-2: **NC loses access to lidar data** and becomes inactive.
Due to the same reason, FDC also loses access to front camera data.

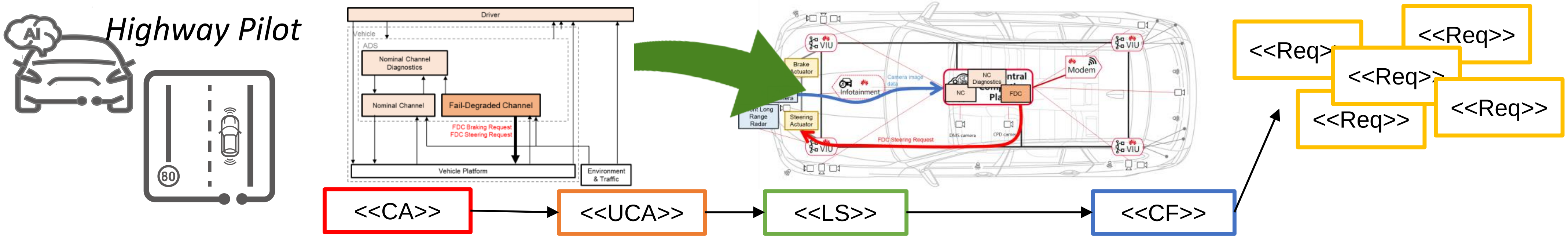
<<Requirement>>
The EEA shall provide FDC access to front camera data independent of NC access to lidar data.

<<Causal Factor>>
CF-1-1-3: **Front camera data reaches Central Compute Platform but needs to pass through inactive NC to reach FDC.** Therefore FDC does not receive required front camera data.

<<Requirement>>
The EEA shall provide a connection from front camera to FDC independent of NC.

Summary

Feature assumption for context → Perform STPA on feature → Map control loop onto EEA → Identify EEA weaknesses



- Successfully applied STPA on assumed HWP to systematically derive safety requirements for SDV Next-Gen EEA.

- Requirements only based on a single feature.
  - ➢ To derive comprehensive set of requirements need to expand to large set of features incl. their combinations.

Thank you!

- *Have you already solved a similar problem (maybe outside of automotive)?*
- *Do you have feedback regarding our approach?*
- *Do you know of a smart and scalable tooling solution for STPA?*

Are you interested in collaborating with us? Contact us!

Sandro Nüesch, sandro.nueesch@huawei.com

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