SOAFEE

# SDV Challenges and Cloud-native System Design Approach

## SOAFEE APAC Seminar

**Wenhung Kevin Huang**

DENSO CORPORATION

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# Who am I

Wenhung Kevin Huang (黃　文鴻)
Project Assistant Manager

Tokyo Office, DENSO CORPORATION

Interest in software verification and safety-critical systems

Love badminton, sauna, board game

# Agenda

1. About DENSO CORPORATION
2. The Future of Mobility & SDV Use Cases
3. Changes & Challenges brought by SDV
4. Solution - Cloud-native System Design Approach
5. Summary & Next Steps

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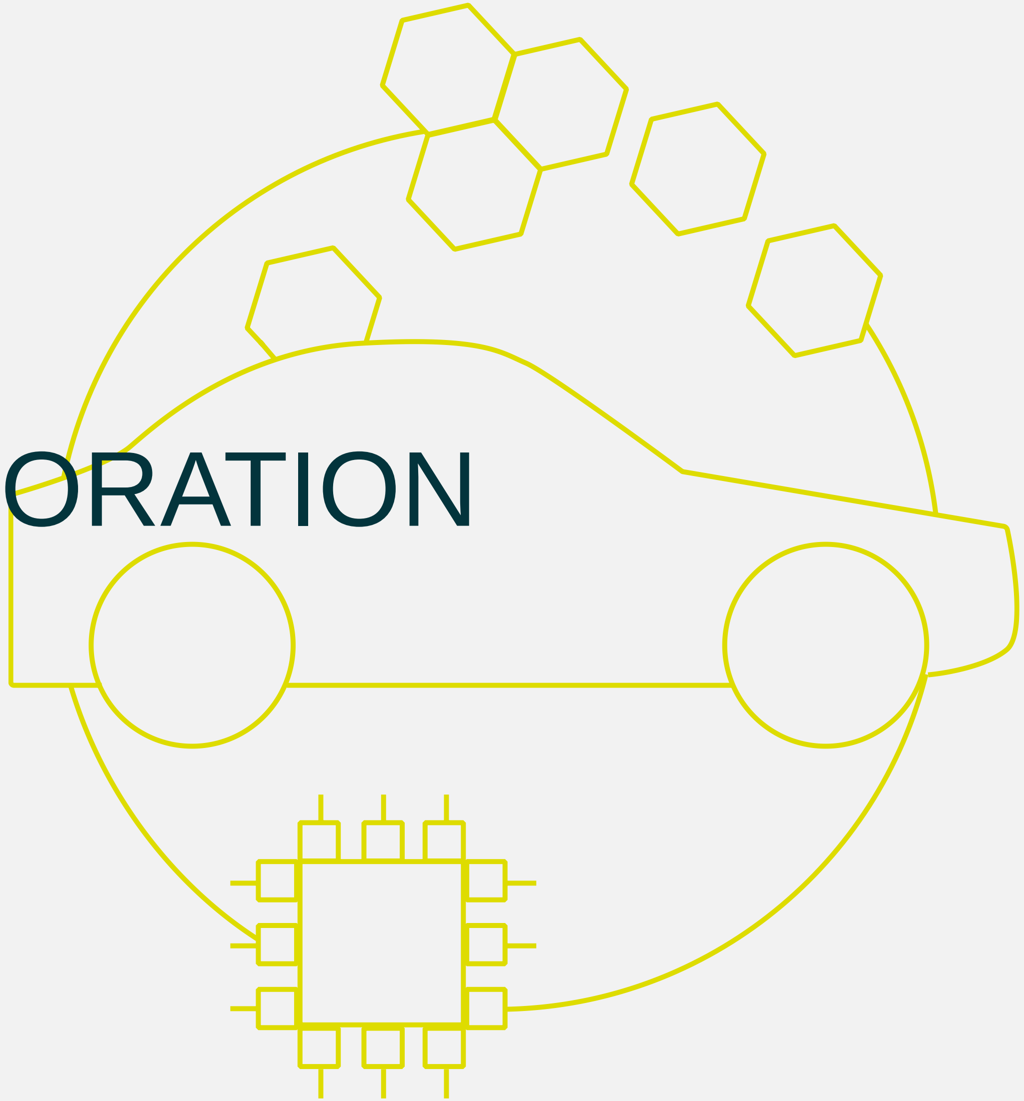
# 1. About DENSO CORPORATION



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# About DENSO CORPORATION

DENSO
Crafting the Core

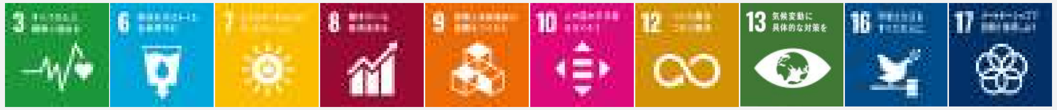
- Global Fortune 500 company
- Focus on advanced mobility
- Positively change how the world moves
- Contribute to greater well-being
- Broad product portfolio & widespread global impact

| The DENSO Group | Total number of employees | |
|---|---|---|
| 190 companies | 164,572 people | 35 countries and regions |

DENSO's Future Direction

## 4 core technologies

- Electrification
- Advanced Safety and Automated Driving
- Connected Driving
- Factory Automation /AgTech



denso.com/global/home/about-us/at-a-glance/

**Green** **Peace of mind**

Enhancing the Mobility Experience
Capturing $CO_2$
FA
HEMS
Flying Cars
Logistics
Free Movement of People with Mobility Difficulties
Medical ICT
Cyber Security for Mobility Society
Sharing
Biometrics
Telemedicine
Operation Management
Multi modal
Utilization of Drones
Automated Valet Parking
Social Solution
Utilization of Hydrogen
Renewable Energy
Food Value Chain

Contribute to happiness for everyone through "green" and "peace of mind"

Software innovation by DENSO in the era of CASE | Newsroom | News | DENSO Global Website

# Green

**CO2 ±Zero**

Aiming to become Carbon neutral by 2035

## *Monozukuri*
(Manufacturing)

Realize complete carbon neutrality at our plants

## *Mobility Products*

Realize an energy-recycling society through the development and popularization of technologies that make effective use of renewable energy

## *Energy Use*

Contribute to the electrification of cars to reduce $CO_2$ emissions to the greatest extent possible

denso_brochure_en.pdf

# Peace of mind

**Without fatalities**

Aiming to become a leading company that provides “Peace of Mind” to society

## Elimination of Fatalities from Traffic Accidents

Popularize safety products through efforts focused on “depth” and “width,” thereby realizing free mobility without fatalities from traffic accidents

## Creation of Comfortable Spaces

Enhance relevant technologies for creating peaceful, comfortable spaces

## Support for Working People

Draw on the technologies we have calculated in the mobility domain to establish a society where people are supported and their potential is nurtured

DENSO
Crafting the Core

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# Purpose of this presentation

As part of Mixed-Criticality WG, we would like to

- **Share our current understandings and progress on the foreseen challenges of mixed-criticality drawn by the SDV use cases**
- **Propose our solution ideas to such SDV's mixed-criticality challenges**

**Agenda**

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2. The Future of Mobility & SDV Use Cases
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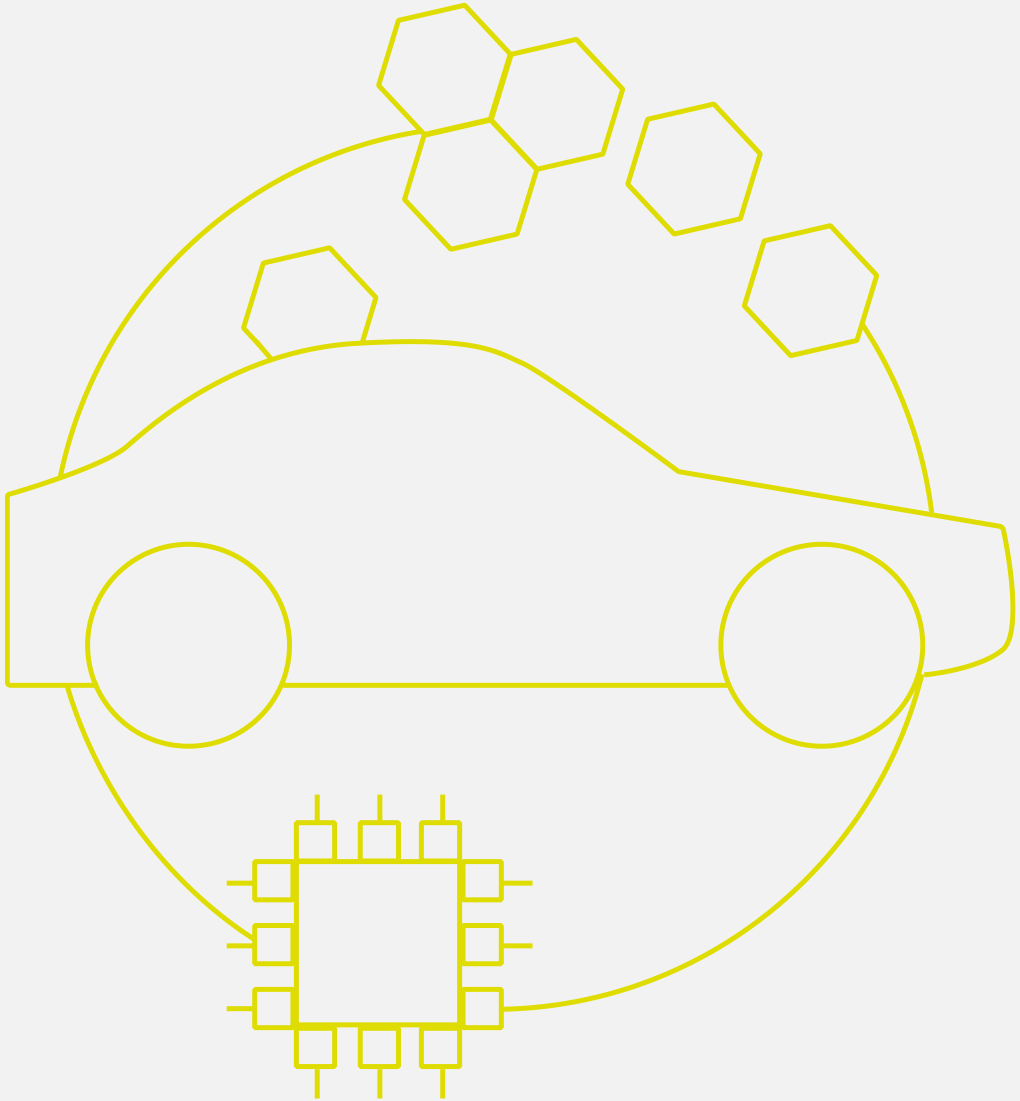
# 2. The Future of Mobility & SDV Use Cases



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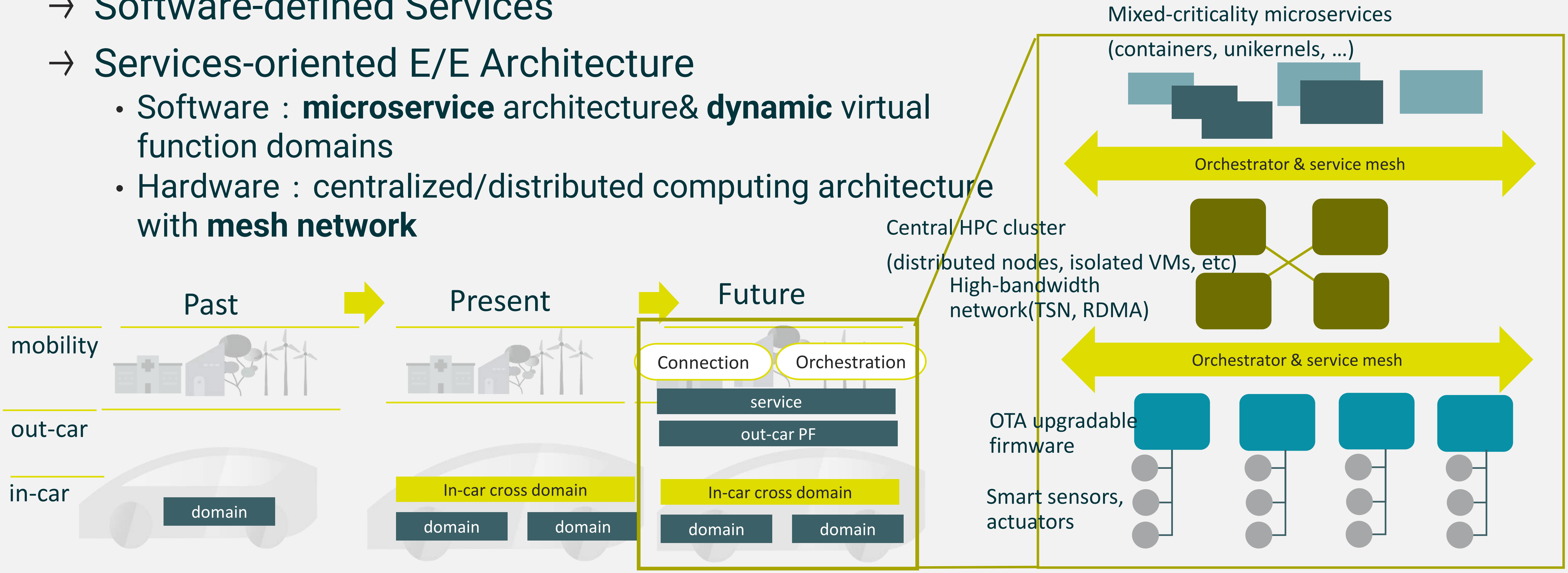
# The Future of Mobility: Software-defined Services

→ Software-defined Services

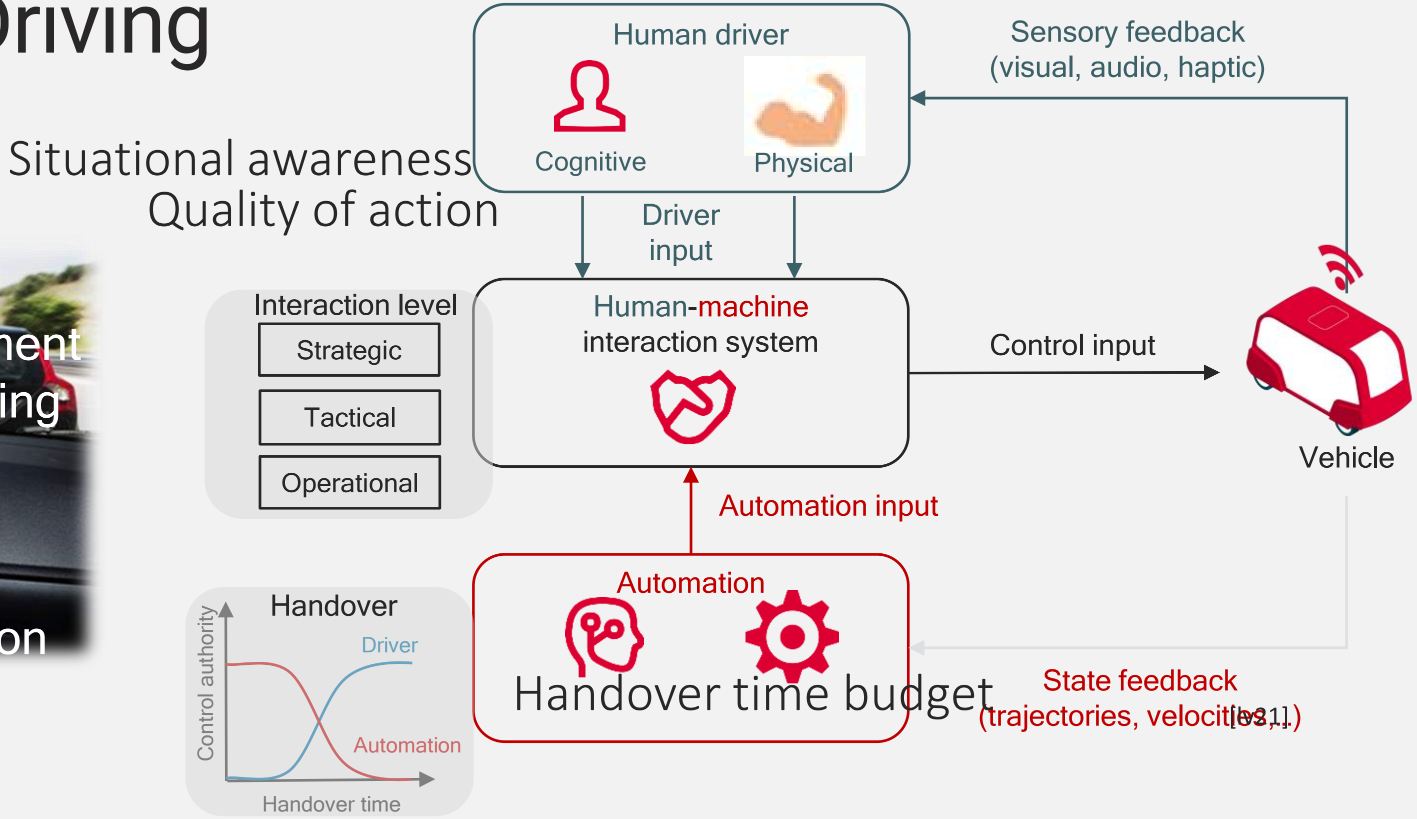
→ Services-oriented E/E Architecture

- Software：**microservice** architecture& **dynamic** virtual function domains
- Hardware：centralized/distributed computing architecture with **mesh network**



デンソーが推進するCASE時代におけるソフトウェア改革｜DRIVEN BASE（ドリブンベース）- デンソー (denso.com)

# Use Case - Autonomous Driving



→ Safe operation when a fault happens

- Fail-Safe: a system stops operations and transitions to safe state
- Fail-Degraded/Fail-Operation: a system continues operation with below/at least nominal performance

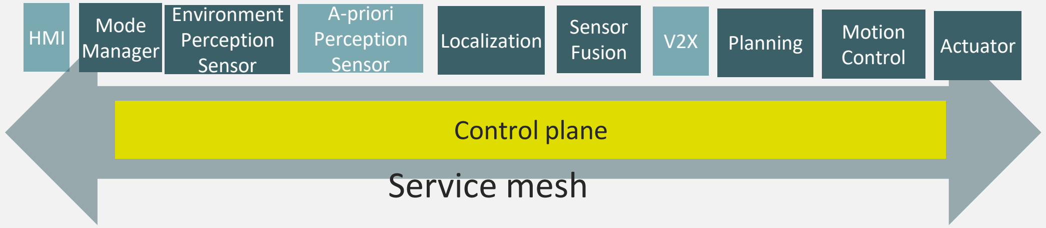
FAIL-SAFE FAIL-DEGARDED FAIL-OPERATION

SAE Level 0 1 2 3 4 5

Safety First for Automated Driving (SaFAD paper) (2019-07)

# Use Case - Autonomous Driving

Fail-Degraded/Fail-Operation

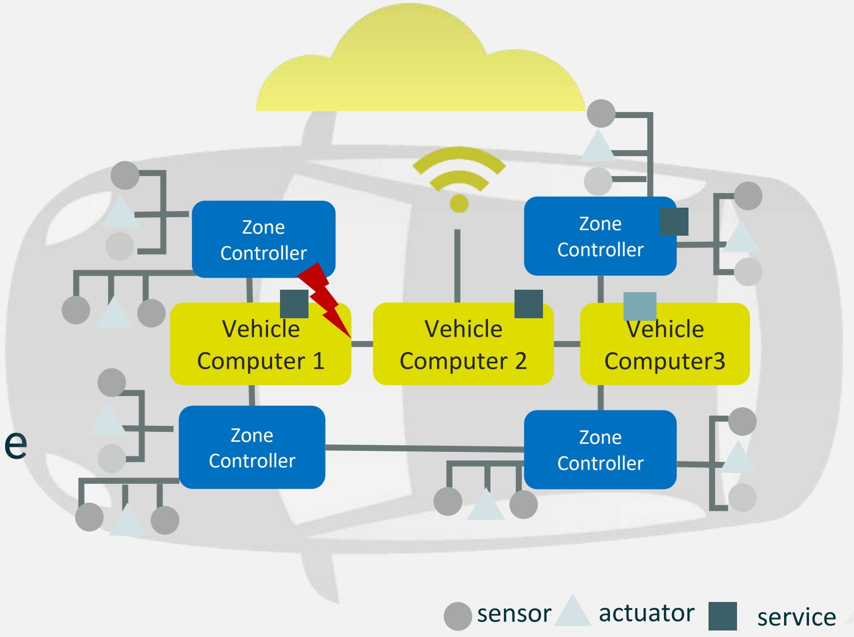


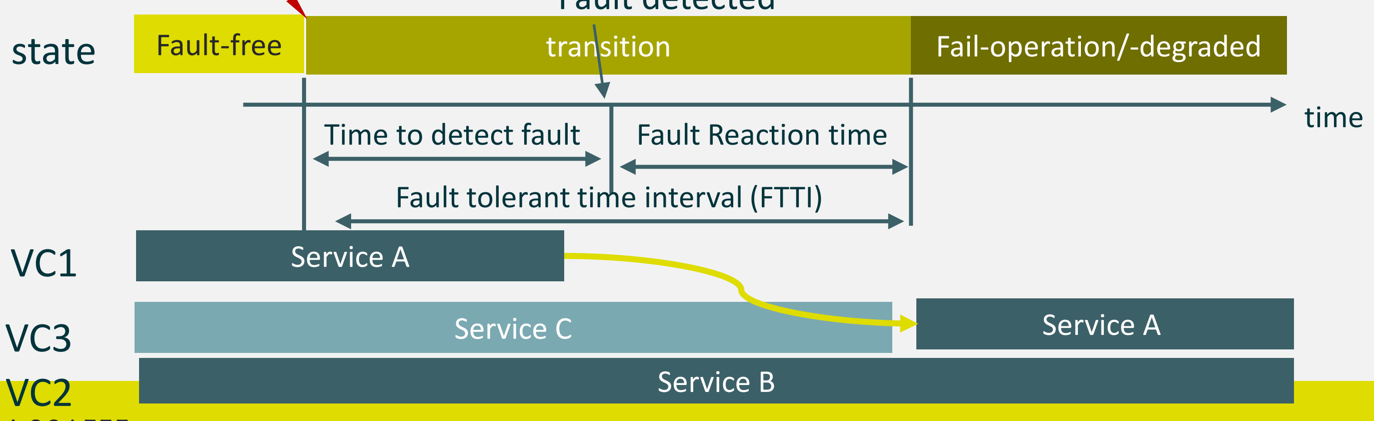
## → Safety requirement

- A system continues operation with below/at least nominal performance+ timing requirement

## → Software-defined approach

- Functions are composed by services, running by different ECUs
- Zonal ECU concept matches the demands of service-oriented architectures
- Mutual monitoring, failover, safety-aware platform
- When a fault happens, rebalancing is performed according to available resources





ASIL

QM

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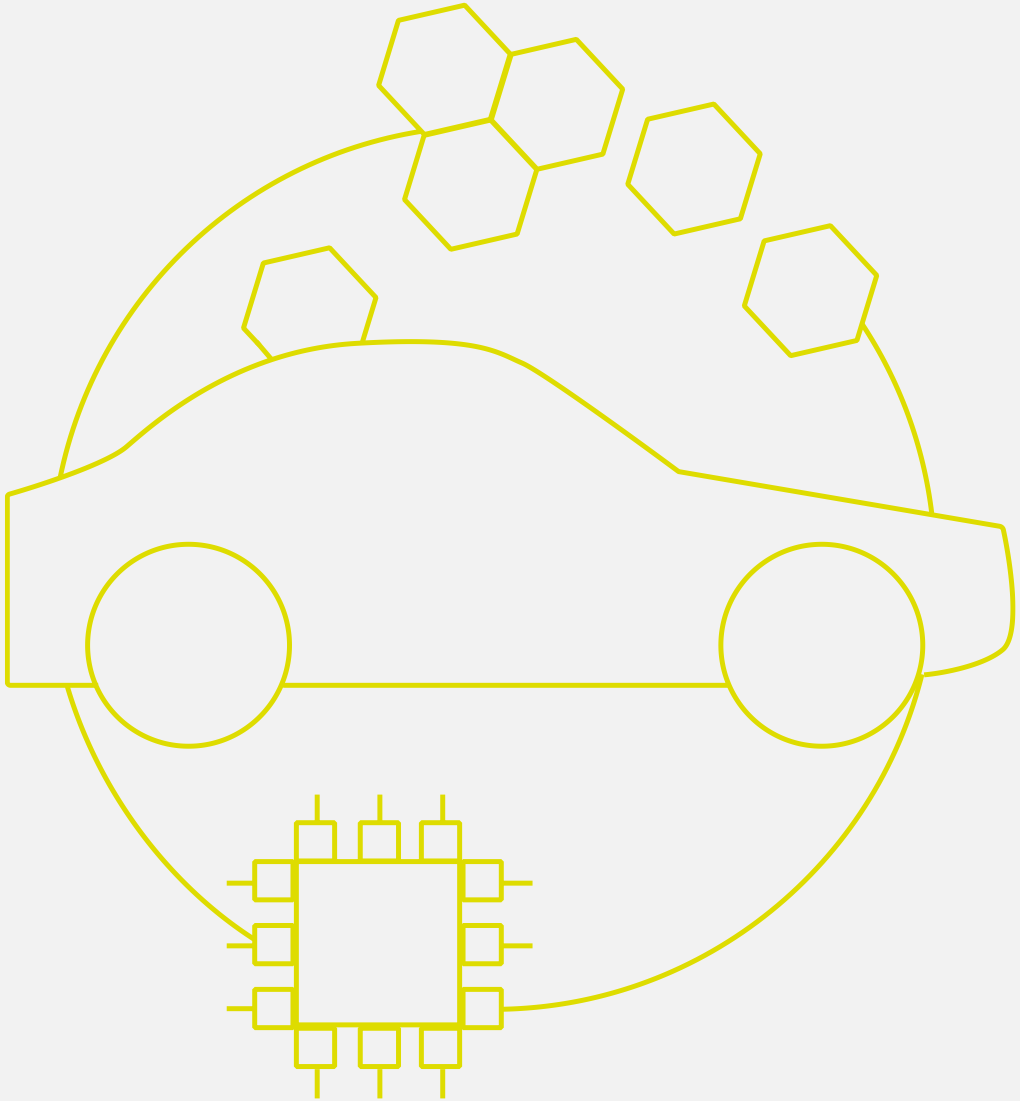
# 3. Changes & Challenges brought by SDV



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# Changes brought by SDV to the automotive industry

## Difference reduced between HW & SW development

More standardized development reduces the complexity of HW and SW integration

## HW & SW decoupling

Under the SDV concept, OTA is given more attention, promoting the decoupling of HW and SW.

## New biz models

Automotive industry is no longer just selling HW but bringing new profits to OEMs by providing services.

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# Challenges brought by SDV to the automotive industry

## Architectural design

In order to achieve rapid development and iteration, it is necessary to design a **multi-modular automotive SW architecture with low correlation between modules.**

## Functional safety

For SW upgrades, it is necessary to **test and verify functional modules with different safety requirements** to ensure safety.

## Information Security

**Information protection and control technology** are required.
For example, verification of data sources, and verification of data correctness and timeliness.

**SDV has had a significant impact on the development of automobiles, posing multiple challenges.**

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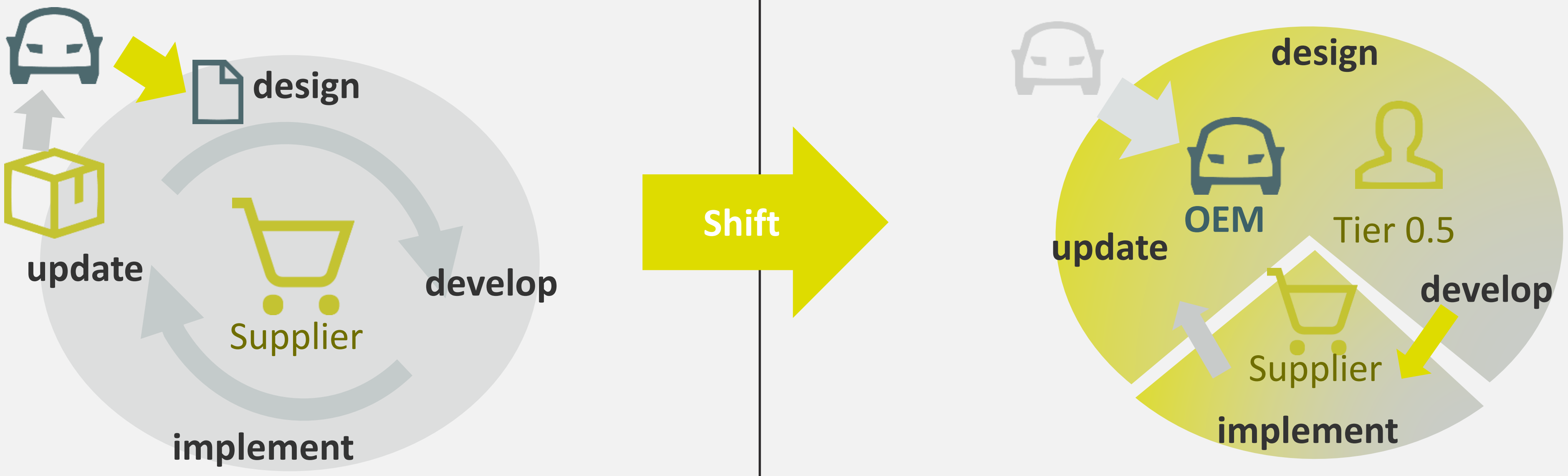
# Shift in Automotive Supply Chain

SDV pushes the automotive industry to shift towards Software Centric “Tier 0.5” approach

## Manufacturing-Centric

## Software-Centric



→ OEM: detailed specs for manufacturing

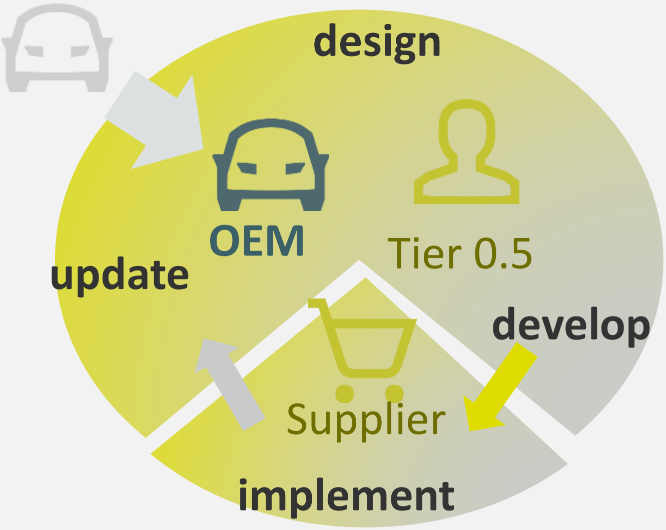
→ Tier 1: all product development and system integration

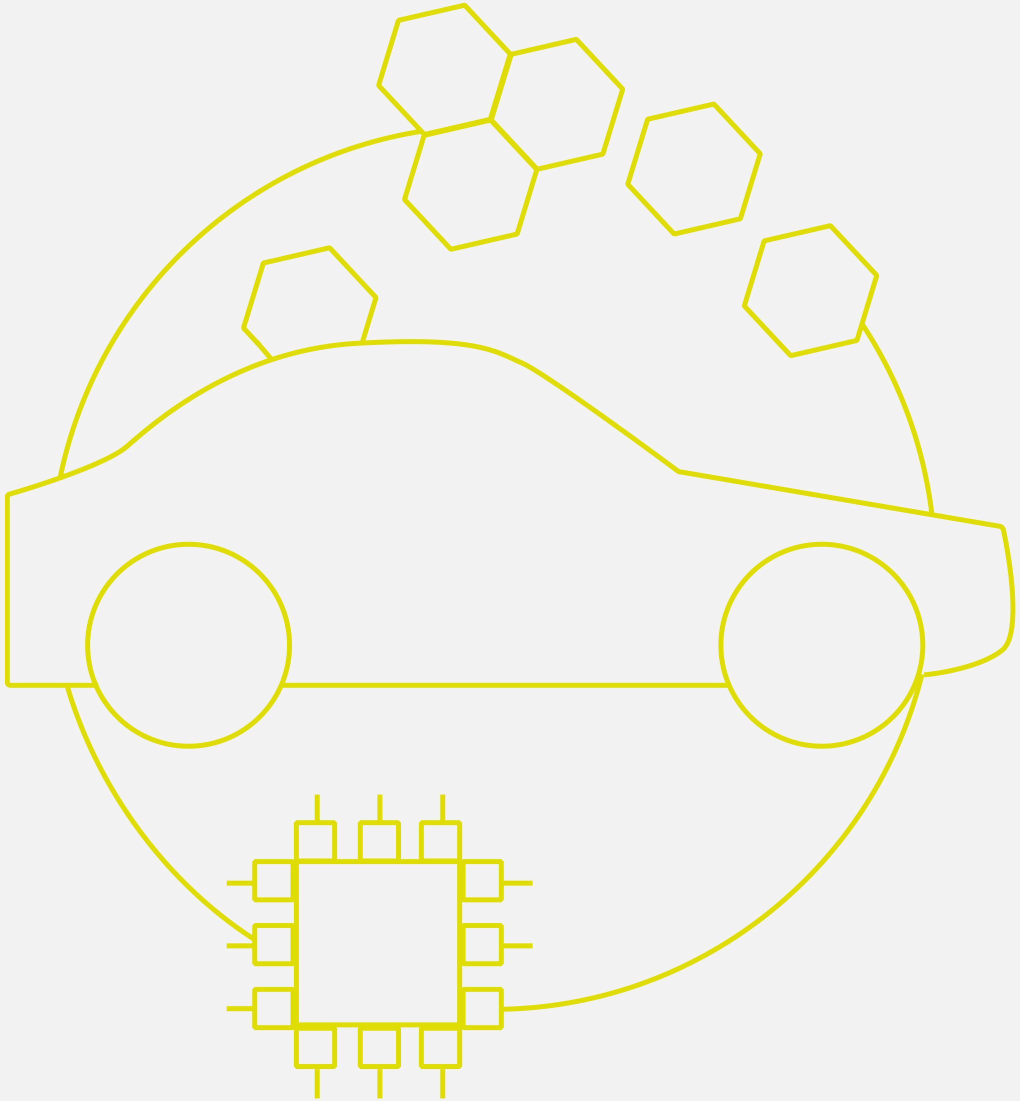
→ OEM: source “Tier 0.5” partners as domain experts for co-design & development

→ Long-term development & operational revenues

Preview - The Software-Defined Vehicle (sbdautomotive.com)

# 4. Cloud-native System Design Approach





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# Lingua Franca

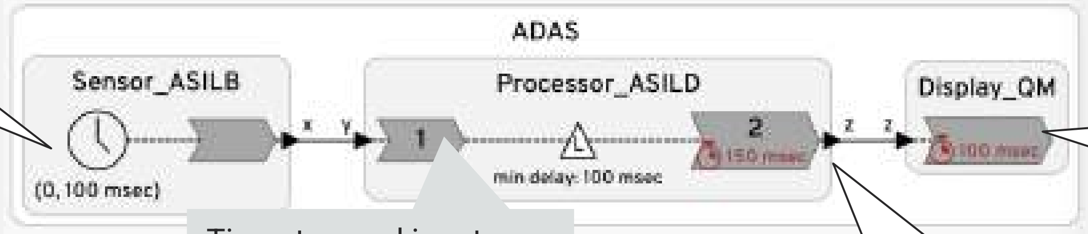
An actor-based synchronous reactive programming paradigm with a logical model of time

## → System Modeling

- Modeling software as reusable components

## → Deterministic scheduling

- Provide a runtime that enables efficient deterministic concurrency
- Support deadline-based error detection



**Periodic** sensor input

Timestamped inputs

**Factoring in** WCET of this **workload**

**Deadline handler** invoked if expected event not triggered within 100 msec

```
reactor Sensor_ASILB{
        timer t(0, 100 msec);
        output x:int;
        state count:int=0;
        reaction(t) -> x {=
                lf_set(x, self->count);
                self->count++;
        =}
}
```

Logically instantaneous outputs

Local state variables

Reaction describing time encoded event behavior

Target language code

```
main reactor {
        sensor = new Sensor_ASILB();
        processor = new Processor_ASILD();
        ivi = new Display_QM();
        sensor.x -> processor.y;
        processor.z -> ivi.z;
}
```

**Lingua Franca semantics allow us to model and develop deterministic application code**

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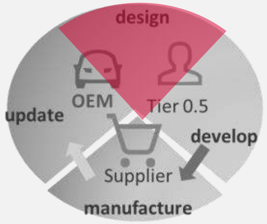
# Design: System Modeling



## - Model AS Code vs ✓ Model IS Code

Templating Language YAML/JSON/TOML - k8s,CloudFormation

→ Pros

- Easy to read for human

→ Cons

- Too complex to be used for production-grade manifests

```
application:
  name: Sensor
  asil: B
  output:
    name: x
    type: int
    targetPort: Processor.y
 --
application:
  name: Processor
  input:
   name: y
```

Programming language/DSL - CDK8s, Lingua Franca

→ Pros

- More readable and production-grade manageable

→ Cons

- learning curve is steeper

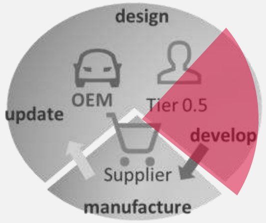
```
reactor Sensor_ASILB{
        timer t(0, 100 msec);
        output x:int;
}
```

IDL

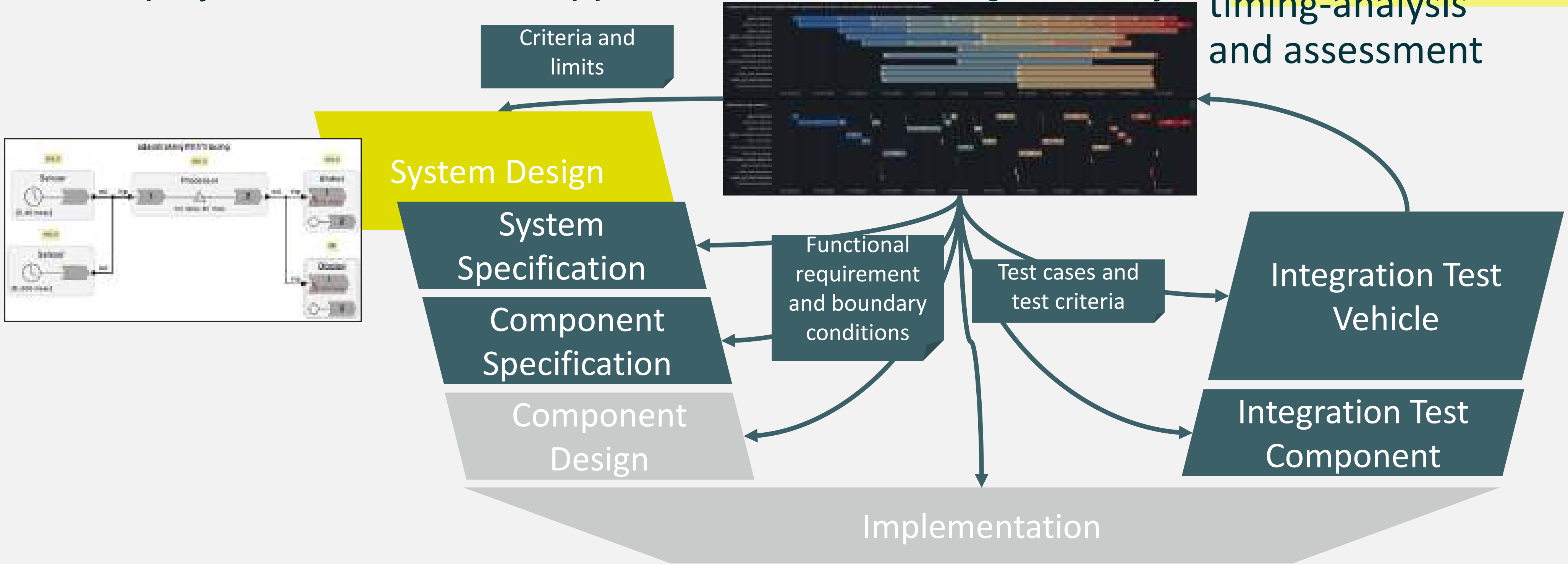
```
main reactor {
        sensor = new Sensor_ASILB();
        processor = new Processor_ASILD();
        sensor.x -> processor.y;
}
```

wiring

# Develop: System Development and Verification



- → Timing analysis in a V-model development process
- → Cloud-native design development
- → Observability
  - helps you to determine if application is functioning normally

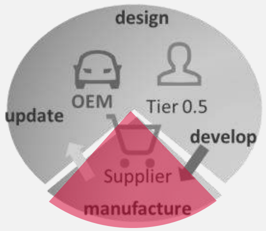


timing-analysis and assessment

Recommended Methods and Practices for Timing Analysis and Design within the AUTOSAR Development Process

# Implement: Deterministic Scheduling

A runtime with determinism and parallelism enable

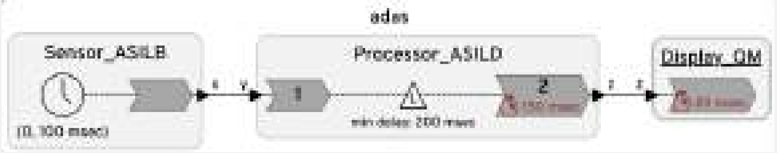


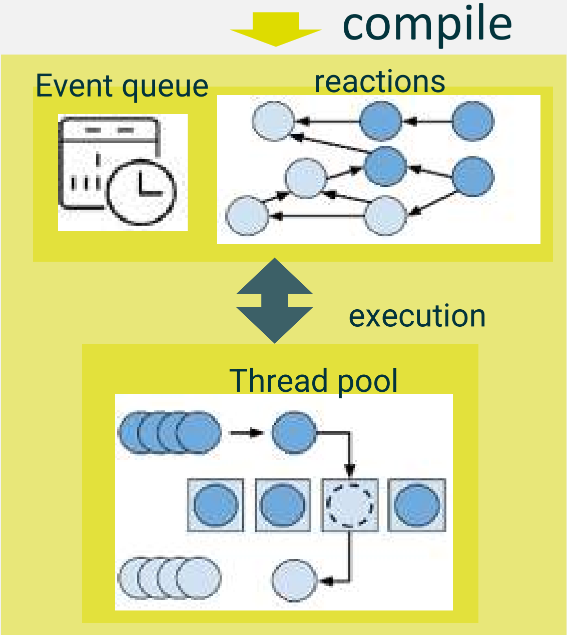
→ Determinism

- Components inform the scheduler at what logical time to trigger reactions

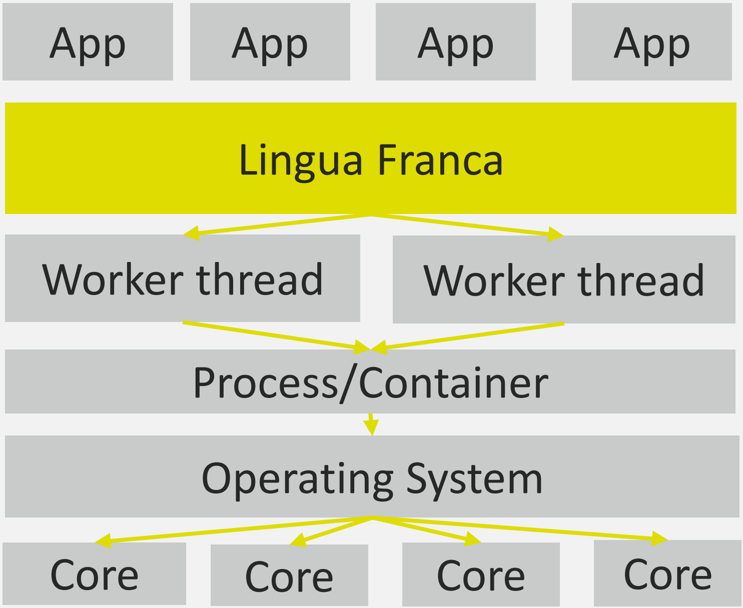
→ Parallelism

- The runtime exploits parallelism by the dependencies between reactions in the dependency graph





Control event flow through scheduling algorithms



App App App App

Lingua Franca

Worker thread | Worker thread

Process/Container

Operating System

Core Core Core Core

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# Demo of Automated Valet Parking using LF

- → Blueprint submitted to SOAFEE (to be released soon)

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Blueprint –
Lingua Franca

Deterministic application middleware

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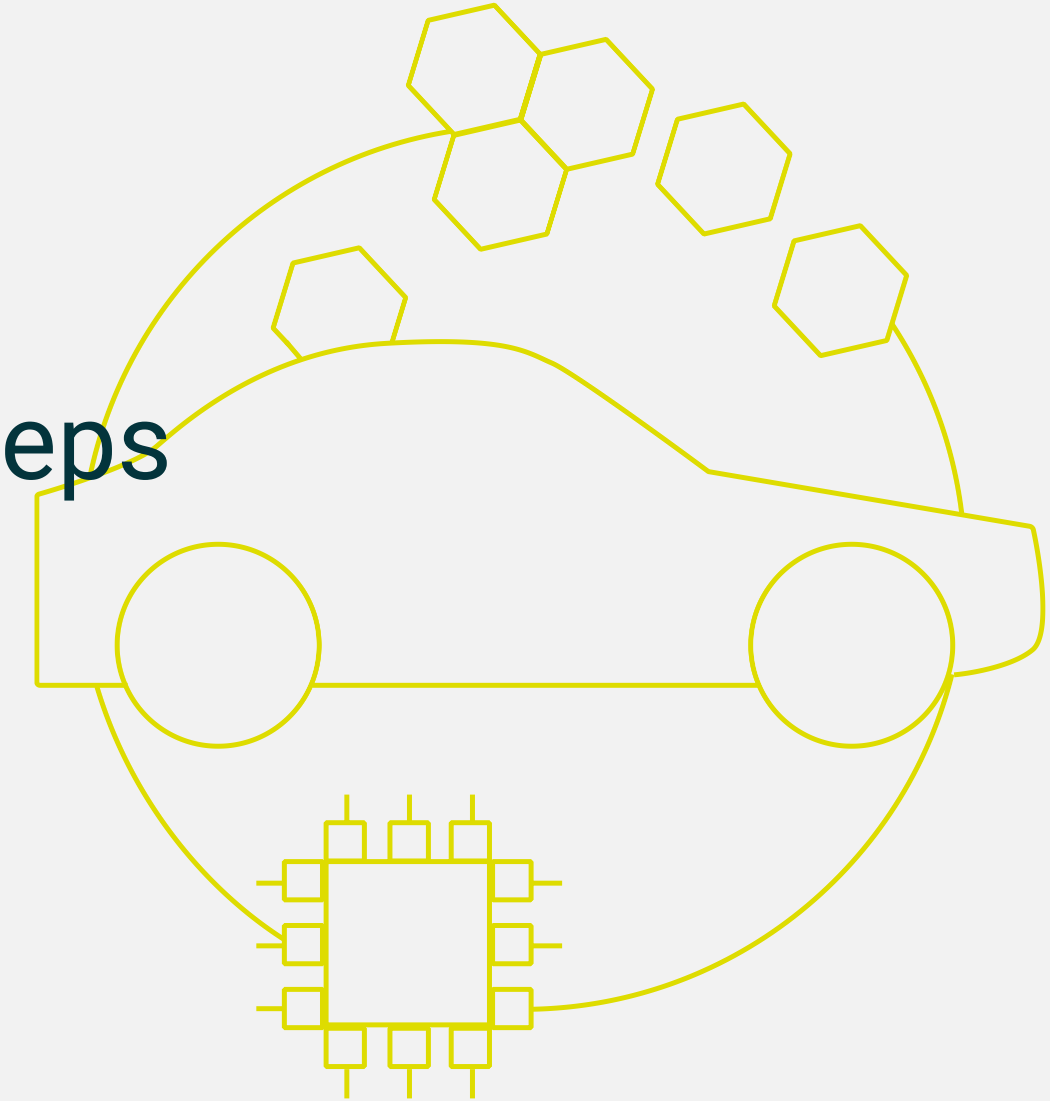
# 4. Summary and Next Steps



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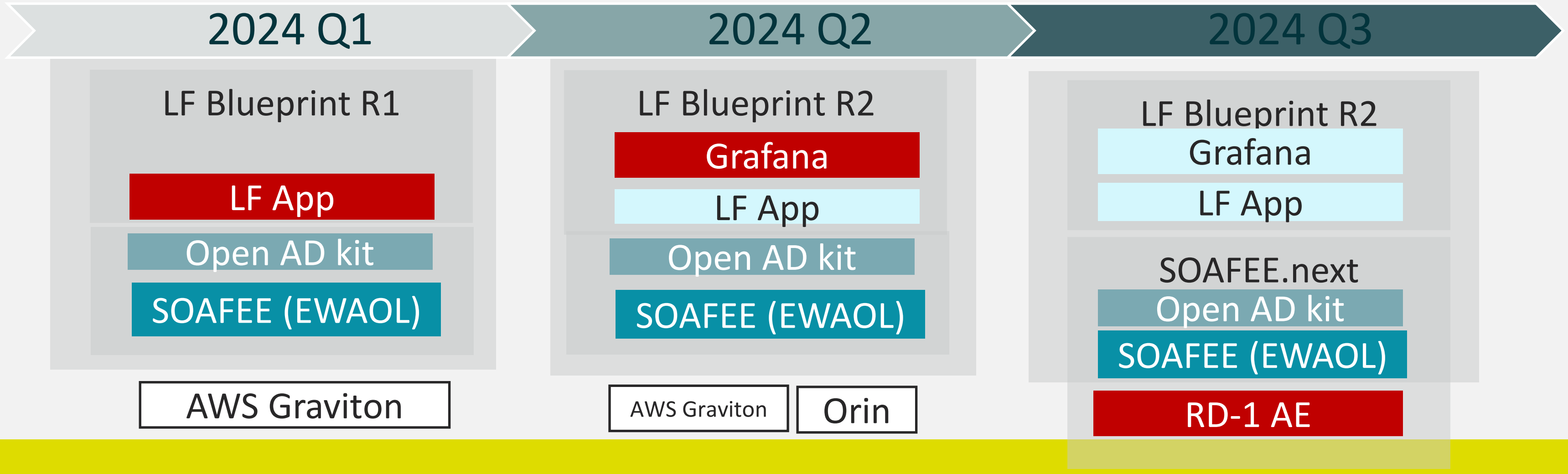
# Conclusions and Future Works

- Summary
  - Software-oriented E/E Architecture enables the future of mobility
  - We demonstrated LF as a mixed critical orchestrator solution on SOAFEE reference architecture using AVP
- Next steps
  - Proposal to MCO requirement
  - Integration of LF blueprint with SOAFEE.next



New

SOAFEE

Thank You
Danke
Gracias
Grazie
谢谢
ありがとう
Asante
Merci
감사합니다
धन्यवाद
Kiitos
شكرًا
ধন্যবাদ
תודה

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# Automated Valet Parking: Problems and Approach

## Automated Valet Parking

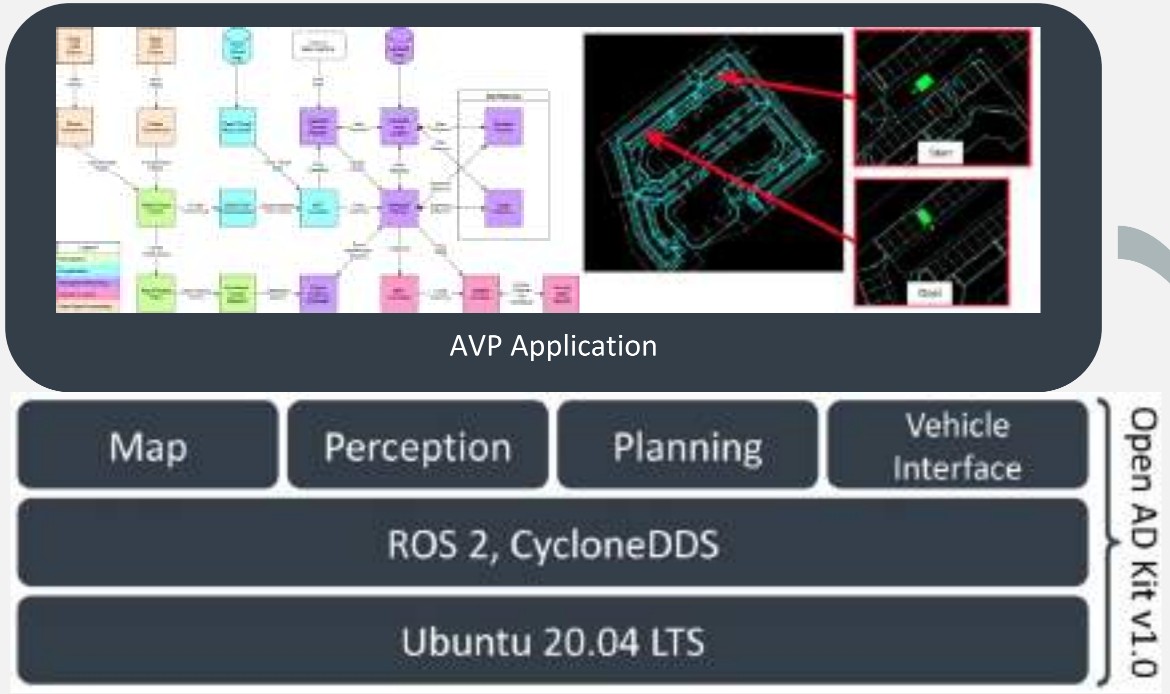
- AD application to autonomously park and return to a pick-up/drop-off area in a parking lot
- Autoware Foundation provided blueprint to show how such a service can be integrated with SOAFEE SDV reference architecture

## Problems

- Non-deterministic behavior (Eg: unresponsiveness, jitteriness, etc.) on SDV platform

## Approach

- LF enforced deterministic scheduling to suppress observed issues in original demo



AVP Application

Map

Perception

Planning

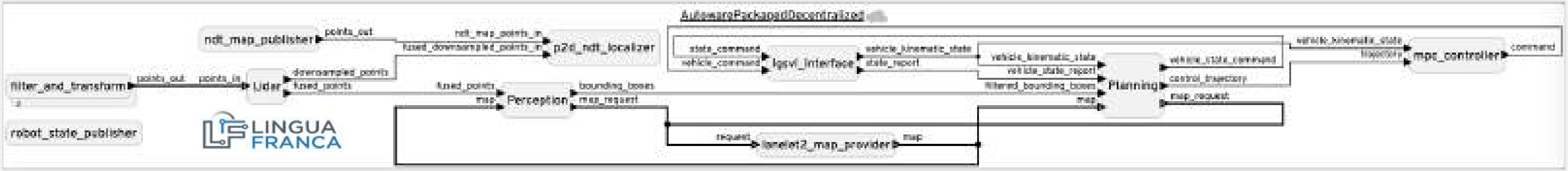
Vehicle Interface

ROS 2, CycloneDDS

Ubuntu 20.04 LTS

Open AD Kit v1.0

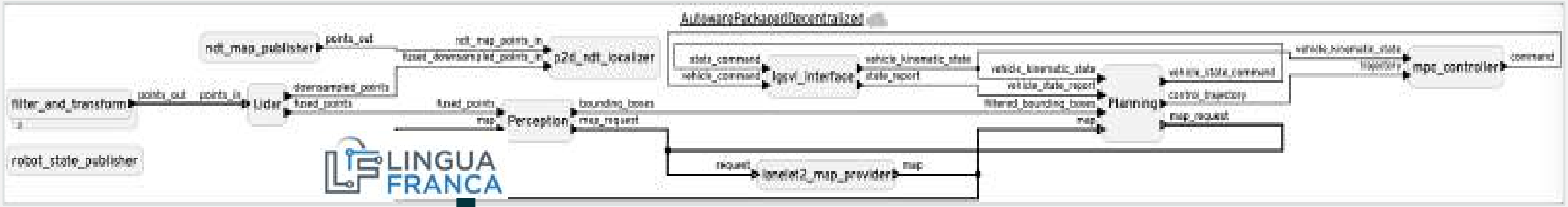
LF system modeling of AVP application

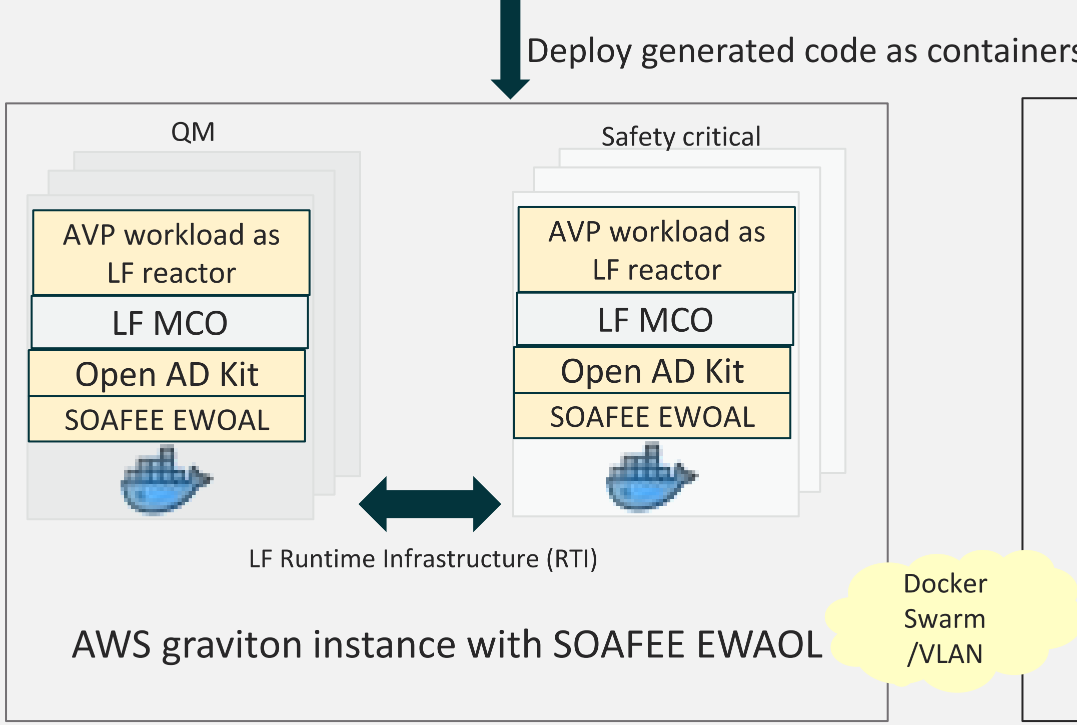


# Integrated LF and Open AD Kit application on SDV

Demonstrate LF as a mixed critical orchestrator solution on SOAFEE reference architecture using AVP

- LF Mixed Critical Orchestrator (MCO) manages the scheduling across containerized workloads
- Porting ROS2 nodes to LF
- In current configuration, safety critical and QM containers run on virtual High Performance Compute (HPC)
- The default Autoware simulator LGSVL is used




Deploy generated code as containers on cloud

QM

AVP workload as LF reactor

LF MCO

Open AD Kit

SOAFEE EWOAL

Safety critical

AVP workload as LF reactor

LF MCO

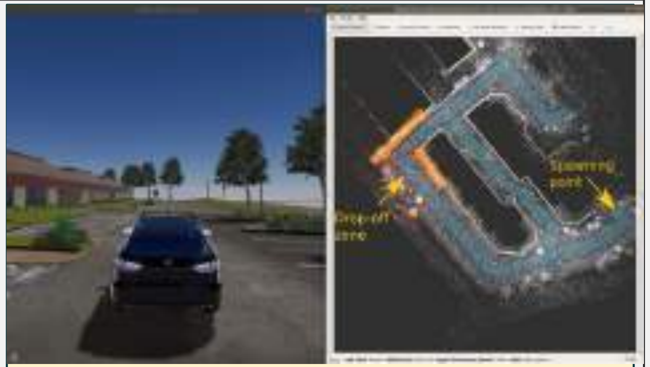
Open AD Kit

SOAFEE EWOAL

LF Runtime Infrastructure (RTI)

AWS graviton instance with SOAFEE EWAOL

Docker Swarm /VLAN



Autoware.Auto Simulator (ScenarioSim/RViz LGSVL+rosbridge)

x86_64 + gpu instance

*Evaluation on mixed criticality hardware setup is the next step.
Testbed: NVIDIA Orin (as HPC) + (R-car S4 as Safety Island)