Your systems.
Working as one.

The Evolving Architectures of Autonomous Vehicles

Performance, Safety and Security using Connext DDS

Bob Leigh, Senior Director of Market Development, Autonomous Systems

The Network is the Car

Architecture Challenges

Autonomous Systems Challenges

- Manage complex data flow and state
- Ease system integration
- Ensure reliable data availability
- Guarantee real-time response
- Allow any network
- Build in security from the start
- Make deployment flexible
- Ease safety certification
- Adapt Intelligence
- Connect Vehicle/Cloud Systems

Research to Production

- State-of-the-art isn't good enough (functional)
  - Innovation arms race
- Still can't forget the "-ilities" (non-functional):
  - Reliability, Durability, Manufacturability, Serviceability, Maintainability, Flexibility, Scalability, Extensibility, Portability, Security, Reusability, Compatibility, Interoperability, …

AUTONOMOUS SYSTEMS MUST HANDLE BOTH

Are Drivers Safe?

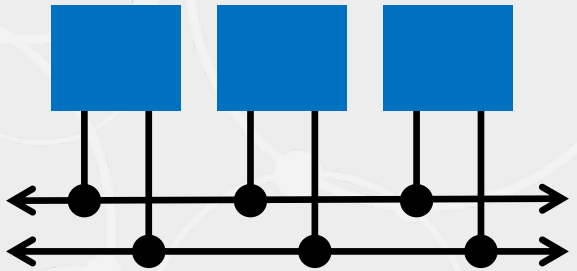
Autonomous vehicle at-fault accident rate is much less than humans

HUMAN ERROR ACCOUNTS FOR 94% OF ROAD ACCIDENTS

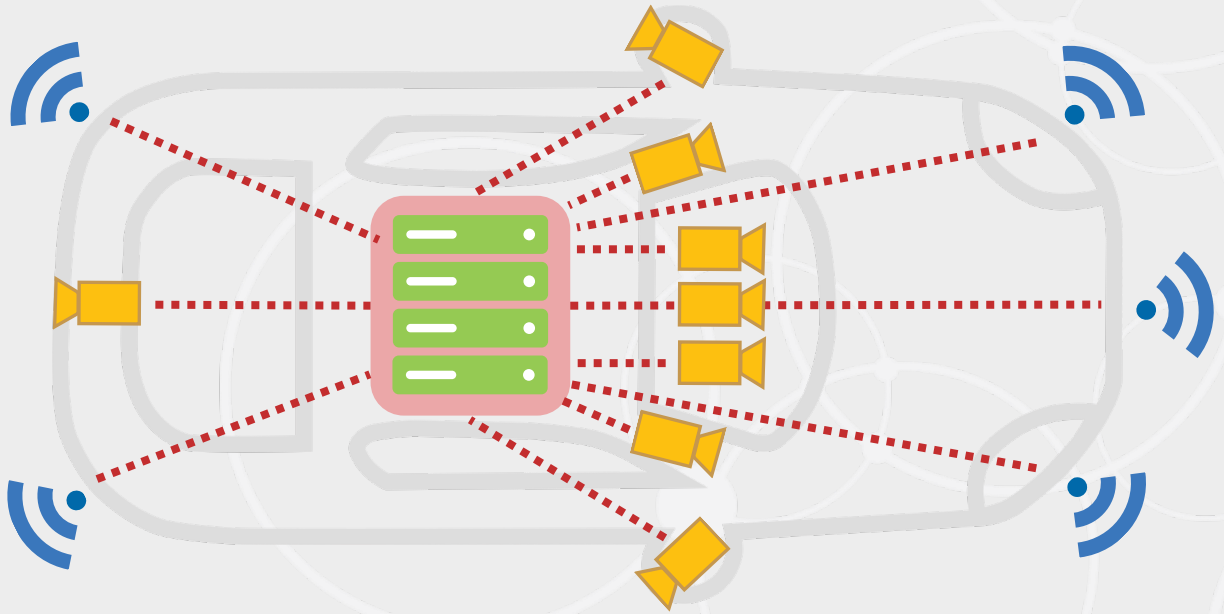
Are Carbots Safe?

Safety-Certifiable Connectivity Platform

- Provides non-stop availability
  - Decentralized architecture
  - No single point of failure
  - Support for redundant networks
  - Automatic failover between redundant publishers
  - Dynamic upgrades
    - No central server or services
    - Version-independent interoperability protocol
- Supports subsystem isolation and incremental certification
- Controls real-time Quality of Service (QoS)
- Makes missed deadlines and presence visible
- Proven in thousands of mission critical systems



Sensor Fusion



Low Latency High throughput Safety Critical

How to Deal with the Data?

Source	Type	Size	Frequency	Volume (approx.)
8 Cameras	2D high-res. video stream	8x 1-4 Mpixel/frame x 30 frames/s x 12-24bit/pixel	30 Hz	2.5-20 Gbit/s
4 Lidar sensors	3D point cloud	4x 300k-3M 3D points /s * 24bit/point	5	30-300 Mbit/s
5 Radar sensors	Object/target list	bytes to kbyt	Hz	~10 kB/s
16 Ultrasonic sensors	Object/target list	by	10 Hz	~10 kB/s
1 GPS	Data mess	A couple of bytes	20-200 Hz	~10 kB/s
Control commands	ge	A couple of bytes	50-250 Hz	~10 kB/s
Status/error handling	Data/string message	Whatever needed	Whenever needed	Whatever needed

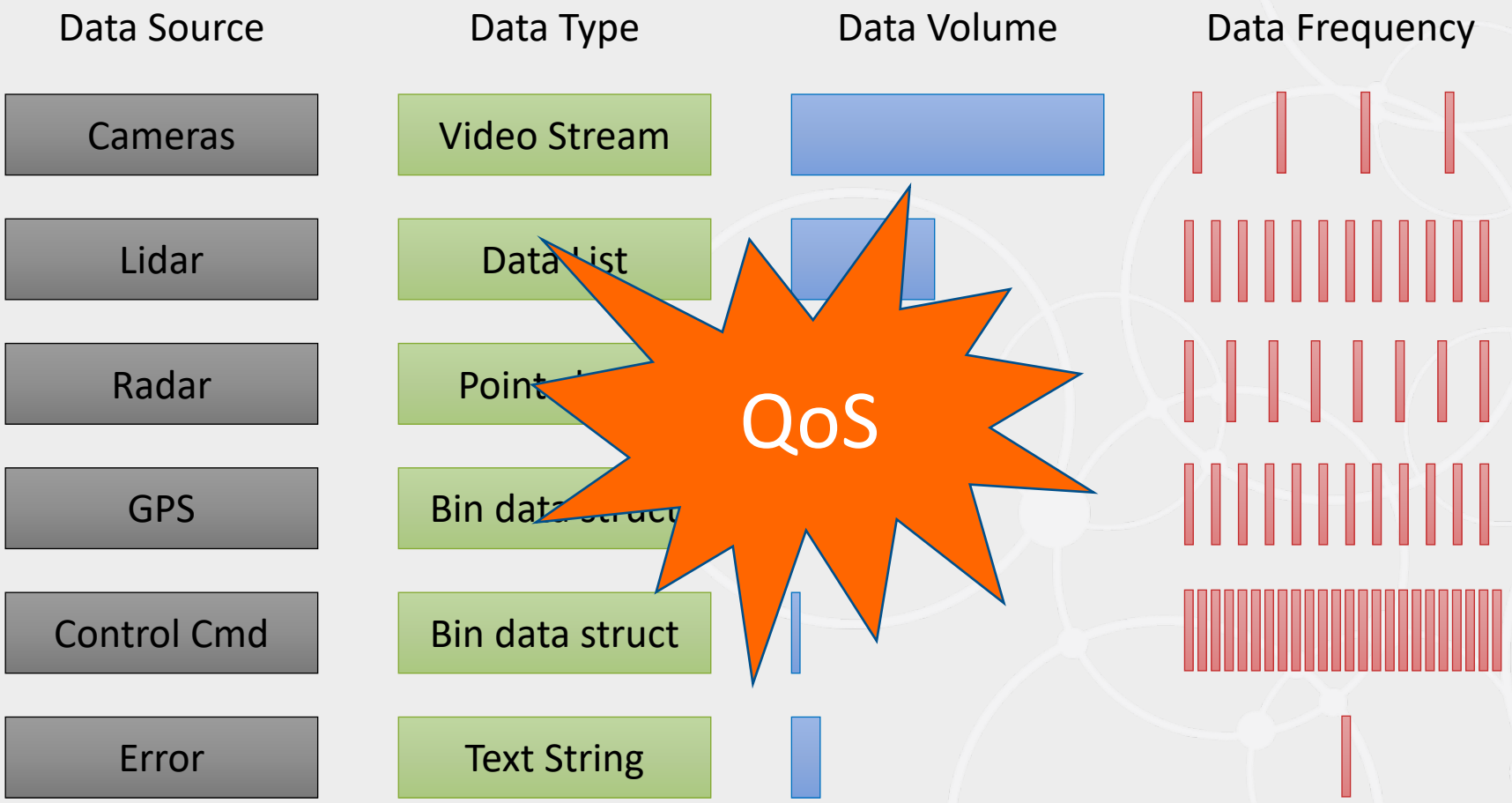
Autonomous Systems Need Massive Data Flow

12 Gb/s or 1.5 GB/s or 90 GB/min or 5 TB/h or 100 TB/d

Approximately and assuming 20h of operation per day

5G data rate: 100Mbps (cell edge) to 10Gbps (theoretical)

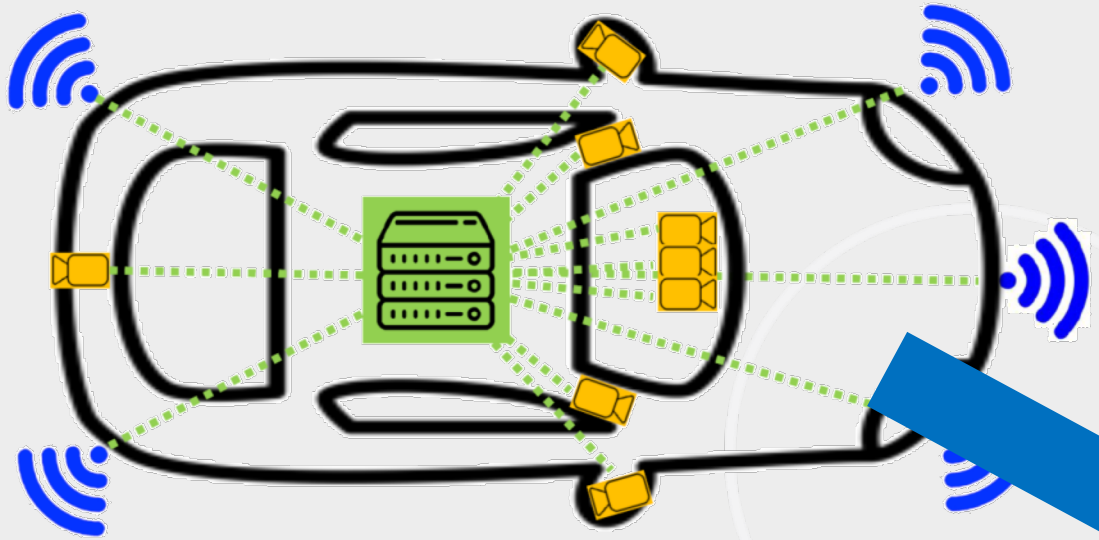
Carbot Dataflow Challenge



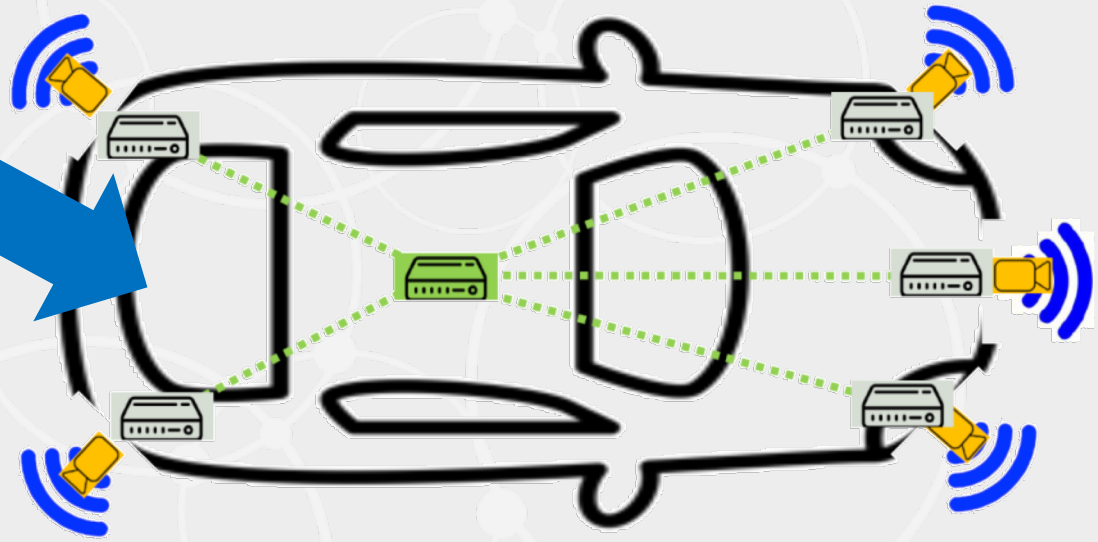
- Carbots need many different dataflows
  - Volume
  - Frequency
  - Latency
  - Reliability
  - Destination
- A single databus that can handle all greatly simplifies the system

Distributed Architectures for Higher Autonomy

Central Fusion or “Late” Fusion

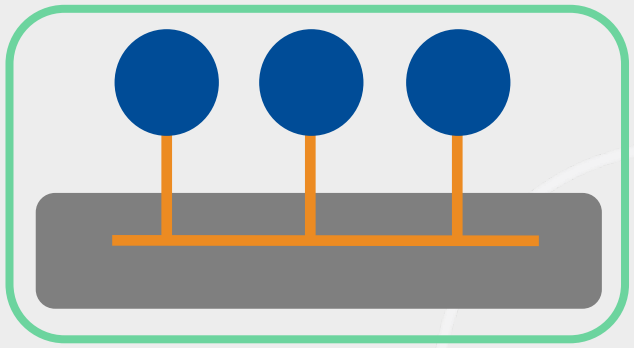


Hybrid Fusion



Data Centricity thus enables *new architectures* that are fast, distributed, and reliable.

Connected & Secure



Traditional Method

- Secure the System
- Secure the Host
- Secure the Network

Security does not need to be black and white

Secure the Data, Not the Pipe

Topic

Line	Flight	Dest	Arv
UA	5		7:32
AA	4		9:15

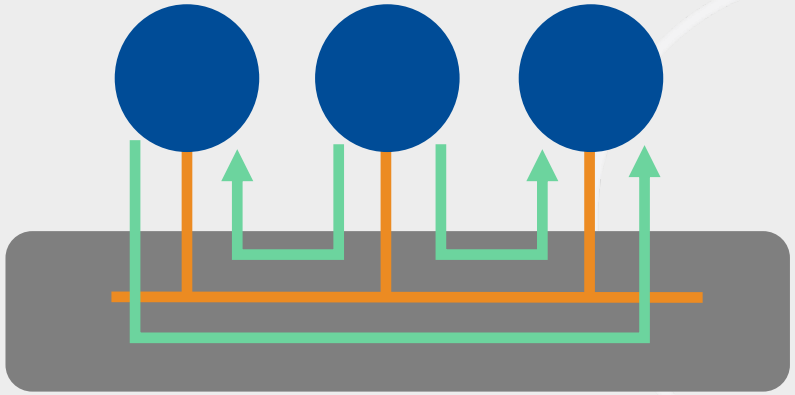
Squawk	Line	Flight
1234	A	567
7654	A	432

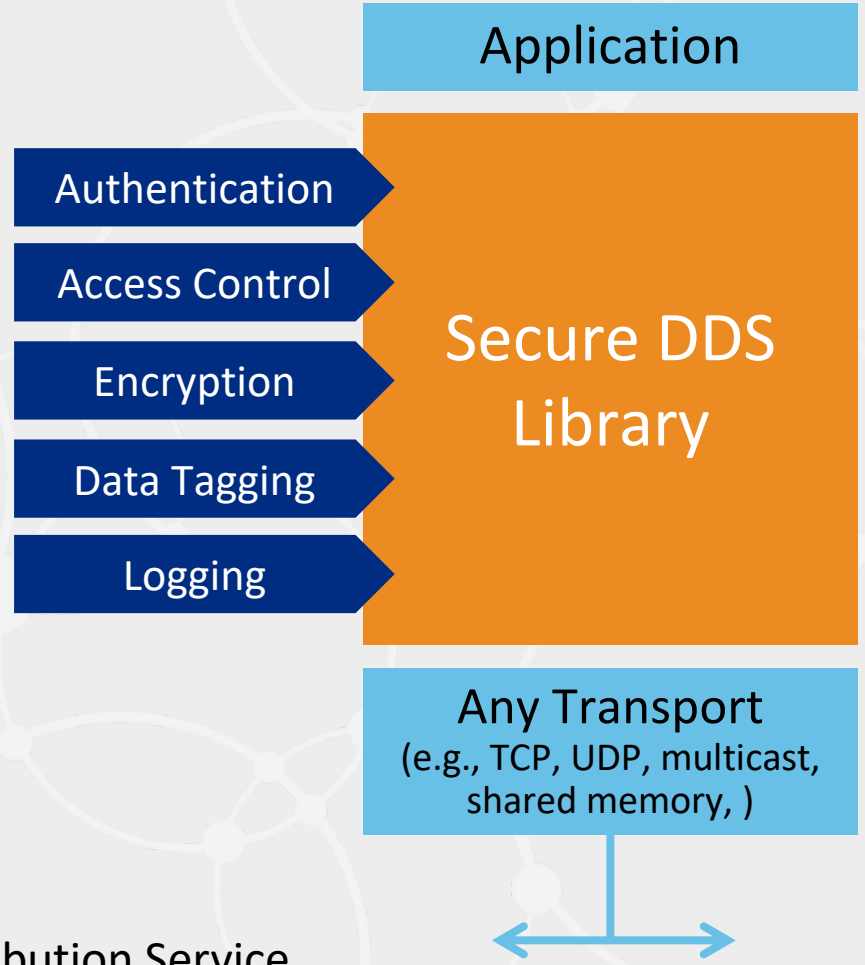
Squawk	Long	Lat	Alt
1234		2.0	500.0
7654		.0	250.0

DDS Domain

Fine-Grained, DDS Security

Data Flow Security, by Topic

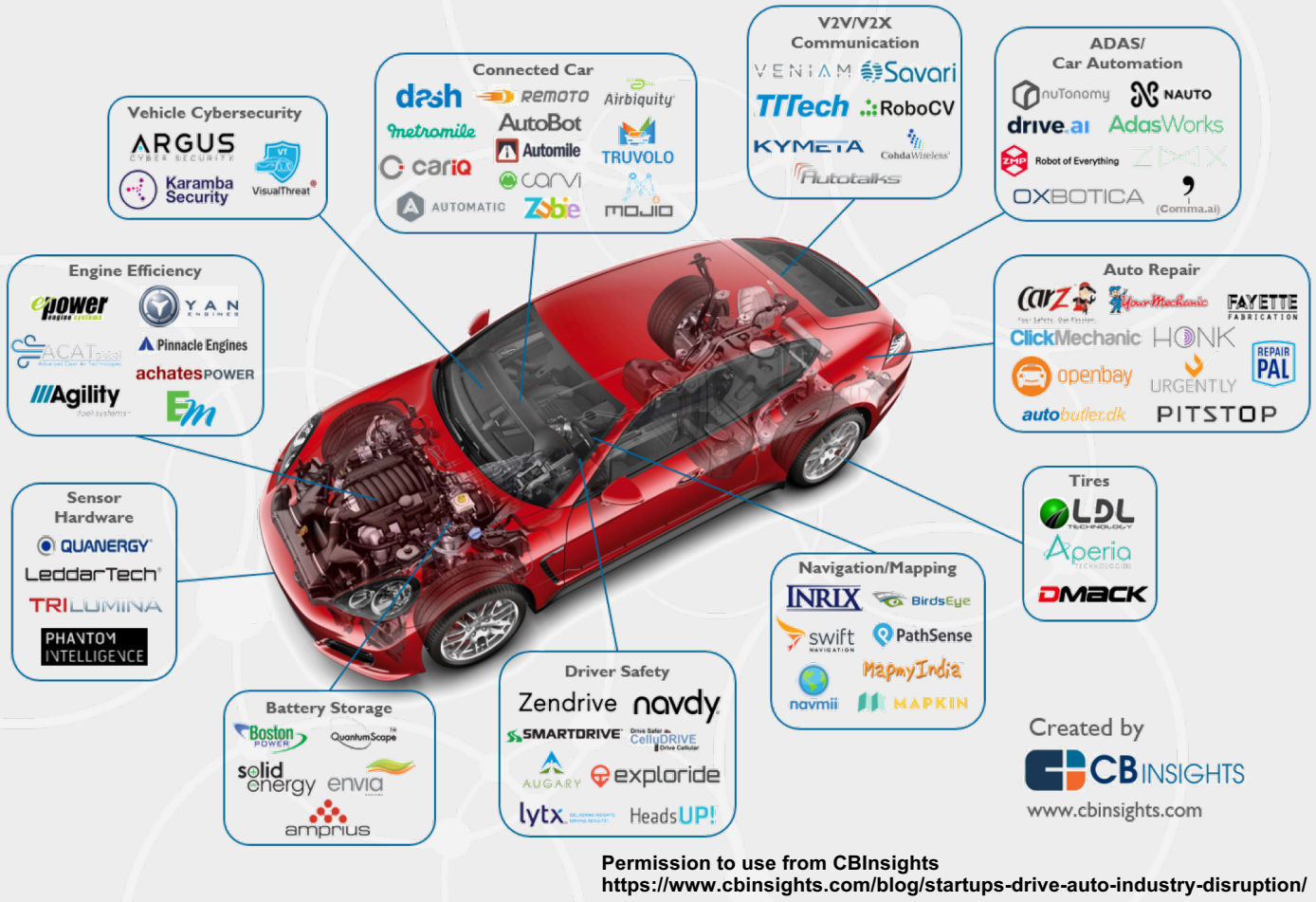




DDS = Data Distribution Service

Reusing IP

- The old way:
  - Maintain code branches for each car platform
  - Arxml to ensure vendor Interoperability
  - But it doesn't scale
- The new way?
  - Software ecosystem
  - Support across models and years
  - Interoperability is standards based
  - Supports innovation



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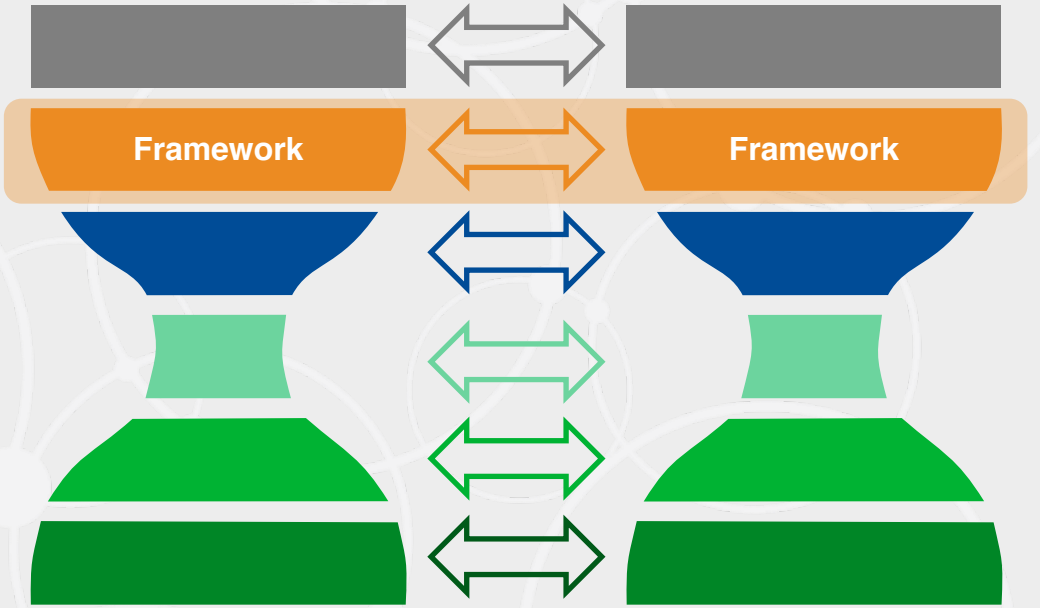
https://www.cbinsights.com/blog/startups-drive-auto-industry-disruption/

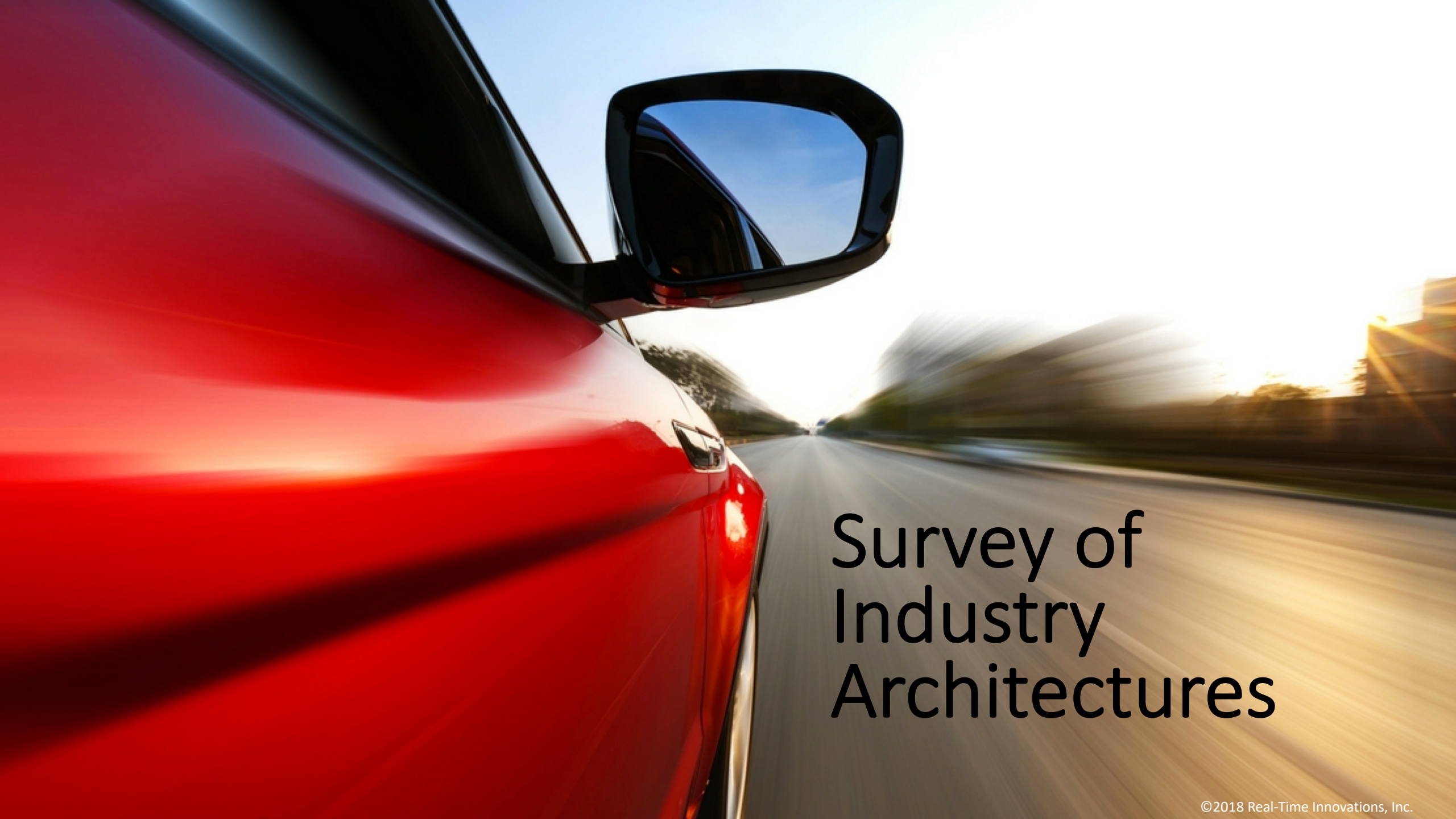
Why a Common Framework

Modern Software: *Either build for a platform, or build the platform.*

- Scalability
- Plug-n-play function
- Lower costs
- Future-proof

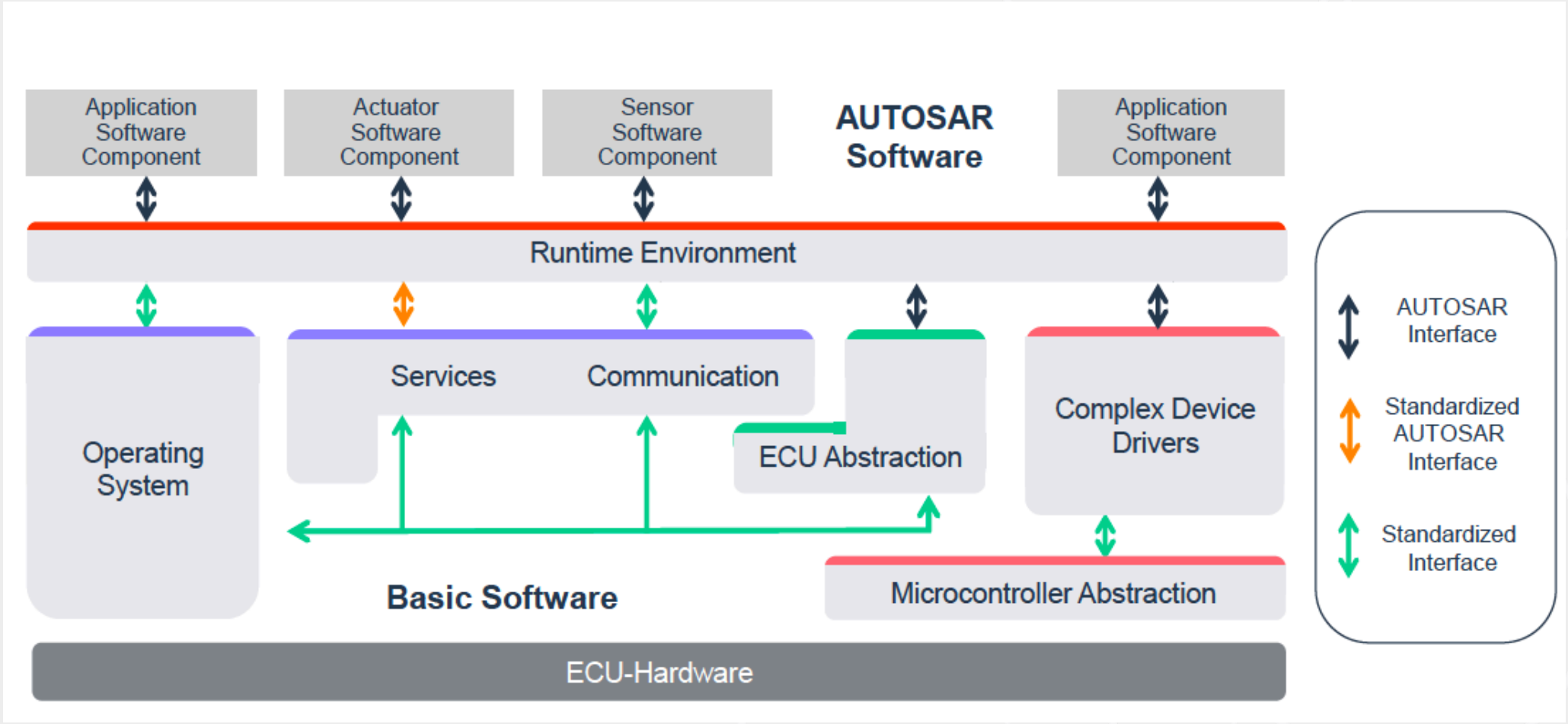


Systems Work as One



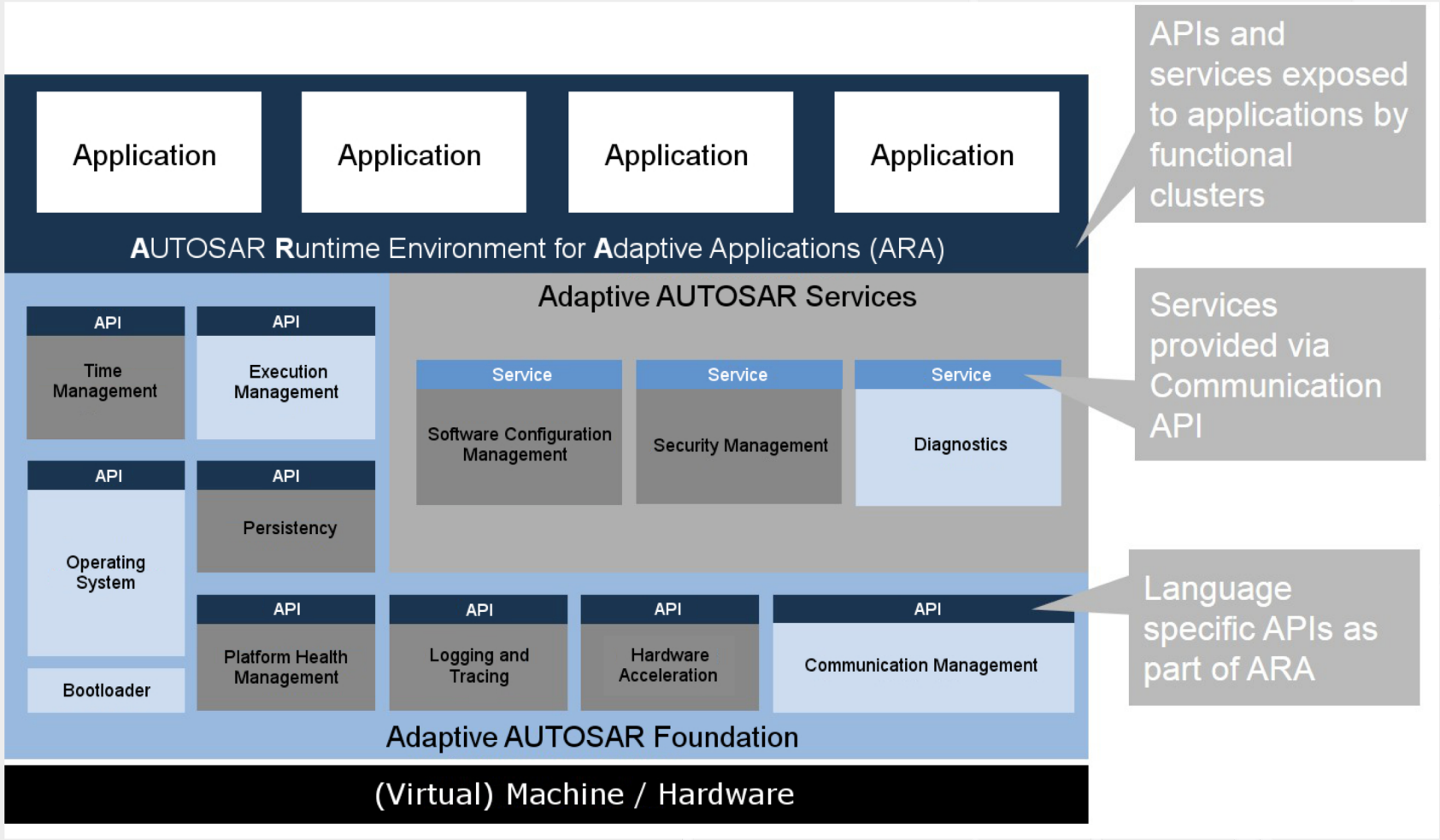
Survey of Industry Architectures

AUTOSAR Classic



from AUTOSAR.org

AUTOSAR Adaptive



from SAE.org

Service Model

AUTOSAR

rti Your systems. Working as one.

RTI News Releases

RTI Named AUTOSAR Development Partner

The IIoT Company Joins Core Partners BMW, Bosch, D[illegible]mler, Ford and more to Define an Automotive Open System Architecture Standard

SUNNYVALE, Calif.— October 26, 2017— Real-Time Innovations (RTI), the Industrial Inter[illegible] Things (IoT) connectivity company, today announced it has joined the AUTomotive Open Systems ARchitecture (AUTOSAR) development group as a d[illegible]t partner. It was nominated by an AUTOSAR core partner and was approved by the group's steering committee. RTI will contribute to the develo[illegible]ent of the AUTOSAR standard, sharing the company's expertise in industrial systems and specifically, autonomous vehicles.

AUTOSAR and Autonomous Vehicles

AUTOSAR is a worldwide development partnership of car manufac[illegible]rs, su[illegible]ers and other leading companies in the electronics, semiconductor and software industries, and is the driving organization behind the worl[illegible]est standardized automotive architecture. Earlier this year, AUTOSAR released the first version of Adaptive Platform, a completely new and standardized soft[illegible] designed to meet the increase in technology demand in the automotive industry.

Autonomous vehicles are complex systems that combin[illegible]dar, LIDAR, proximity, sensors, GPS, mapping, navigation, planning and control. Additionally, these components must combine into a reliable, s[illegible]re system that c[illegible] analyze complex environments in real-time and respond to chaotic environments, such as operating in rush hour traffic. As a result, auto[illegible]y is an extreme technical challenge. With the growth of autonomous driving, the automotive industry now requires technical capabilities, such as high-p[illegible]nce [illegible]mputing, in-vehicle communications, cloud-based applications and advanced data processing, while still meeting the highest safety and security [illegible]quire[illegible]. [illegible]work with the AUTOSAR group to advance the software platform and help ensure it meets the complex requirements for autonomous ve[illegible].

"We have been worki[illegible]with so[illegible]of the co[illegible]e partners of AUTOSAR for two years now to develop a recommended architecture for autonomous vehicles and are thrilled to officially jo[illegible]he group [illegible] development partner," said Bob Leigh, director of market development for autonomous vehicles at RTI. "With the rise of autonomous v[illegible]es, [illegible]re see[illegible] a shift in the automotive industry where software is now being prioritized over hardware. As a result, we are working with our automotive custo[illegible]s to d[illegible]tically reduce the development, certification and lifecycle maintenance costs of their systems. We are dedicated to accelerating the design [illegible]of autonomous systems, and look forward to working with the AUTOSAR partnership group to advance this effort."

The Secure [illegible]nectivity Solution for Autonomous Vehicles

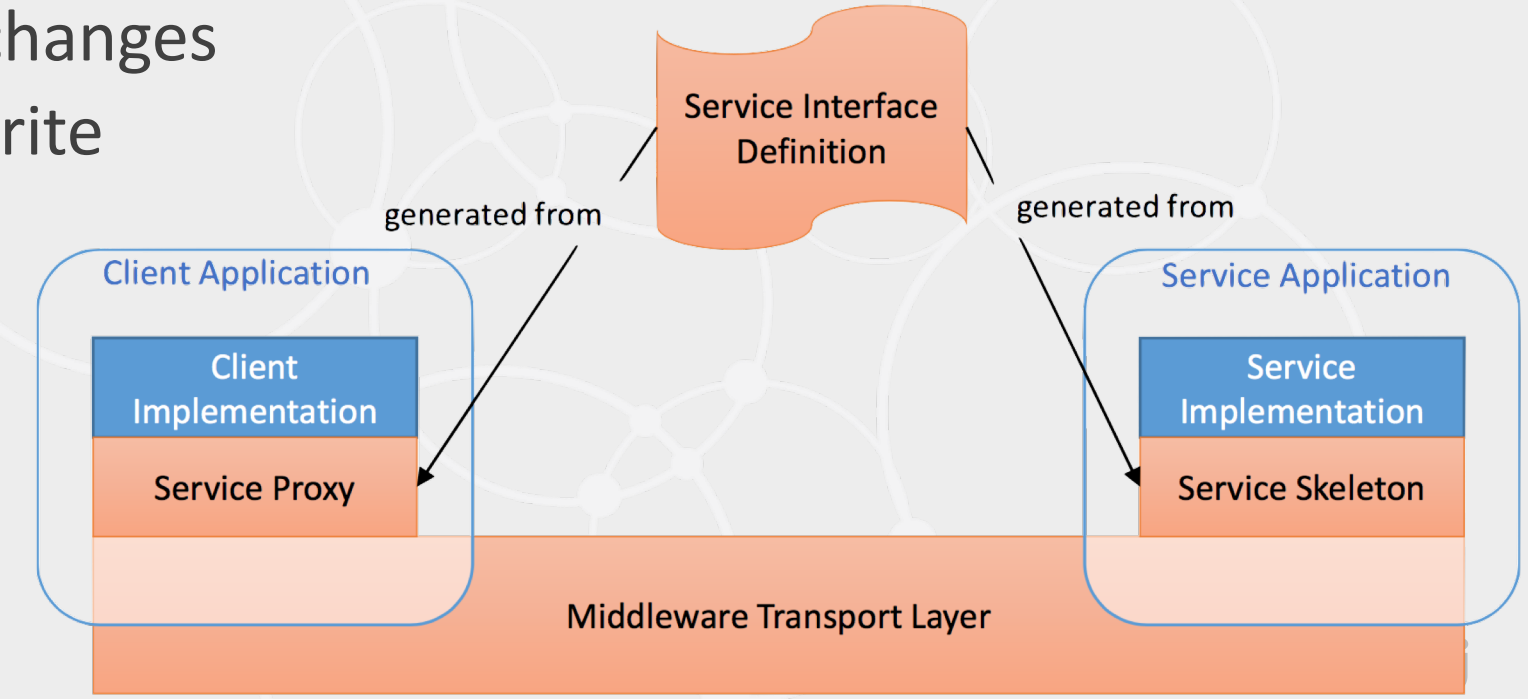
A fully autonomous car is essentially a self-driving robot with some of the most demanding performance and safety requirements in any industry. RTI's data-centric connectivity software was designed for complex applications and has a rich history in autonomous systems including planes, aviation drones, space robots and submarines.

NOW WITH DDS!!!

- RTI joined fall 2017
- Working in FT-CM
- Adaptive Platform Release 18.03
  - DDS added as alternative network binding under ara::com
  - SWS Communication Management
  - TPS Manifest

ara::com model

- Based on Services
- Proxy/Skeleton pattern
- Services have:
  - Events -> Notify of changes
  - Fields -> Can read/write
  - Methods -> RPC

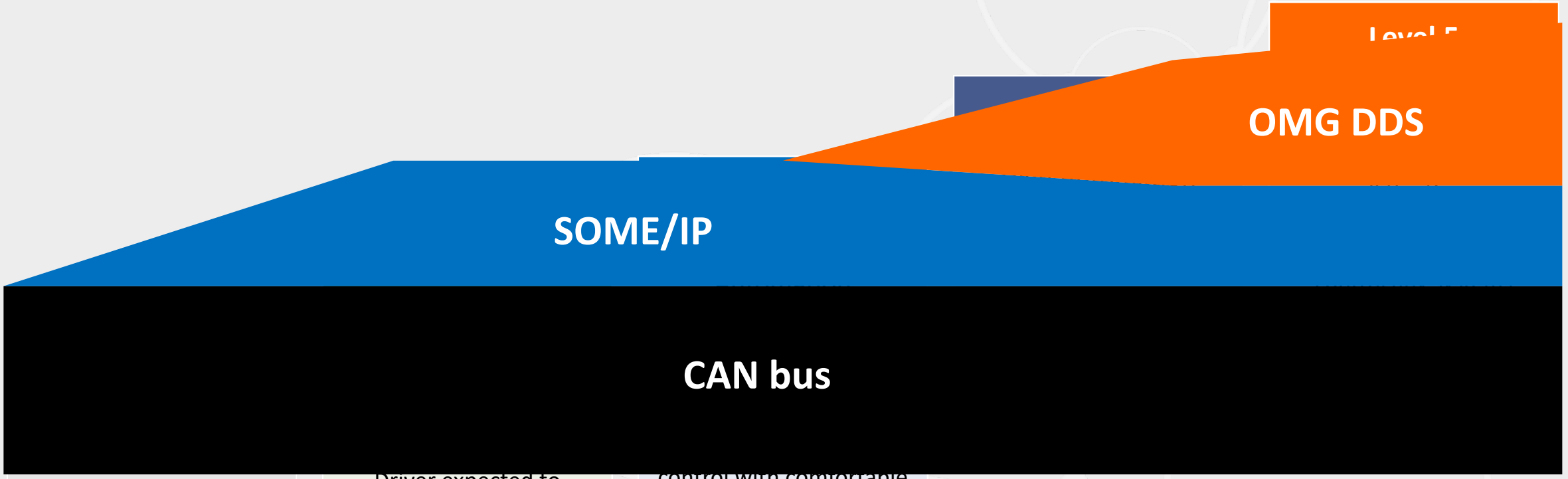


DDS NOW available in AUTOSAR

ara::com over DDS features in Release (18.03)

- Data Types ➔ IDL 4 / DDS-XTYPES
- Services ➔ DDS Entities
  - Shared DomainParticipant, Writers, Readers
  - Automatically assignment of DDS Keys
  - Configure using XML QosProfiles
- Service discovery ➔ DDS discovery
  - Send ara::com ServiceId in USER_DATA Qos
  - Map all service discovery operations
- Events ➔ DDS pub/sub
  - Automatic data-types and Topic names

Connectivity at Different Levels



Single control functions such as speed selection, braking or lane keeping are automated

Driver expected to available for control at all times and on short notice

control with comfortable transition times

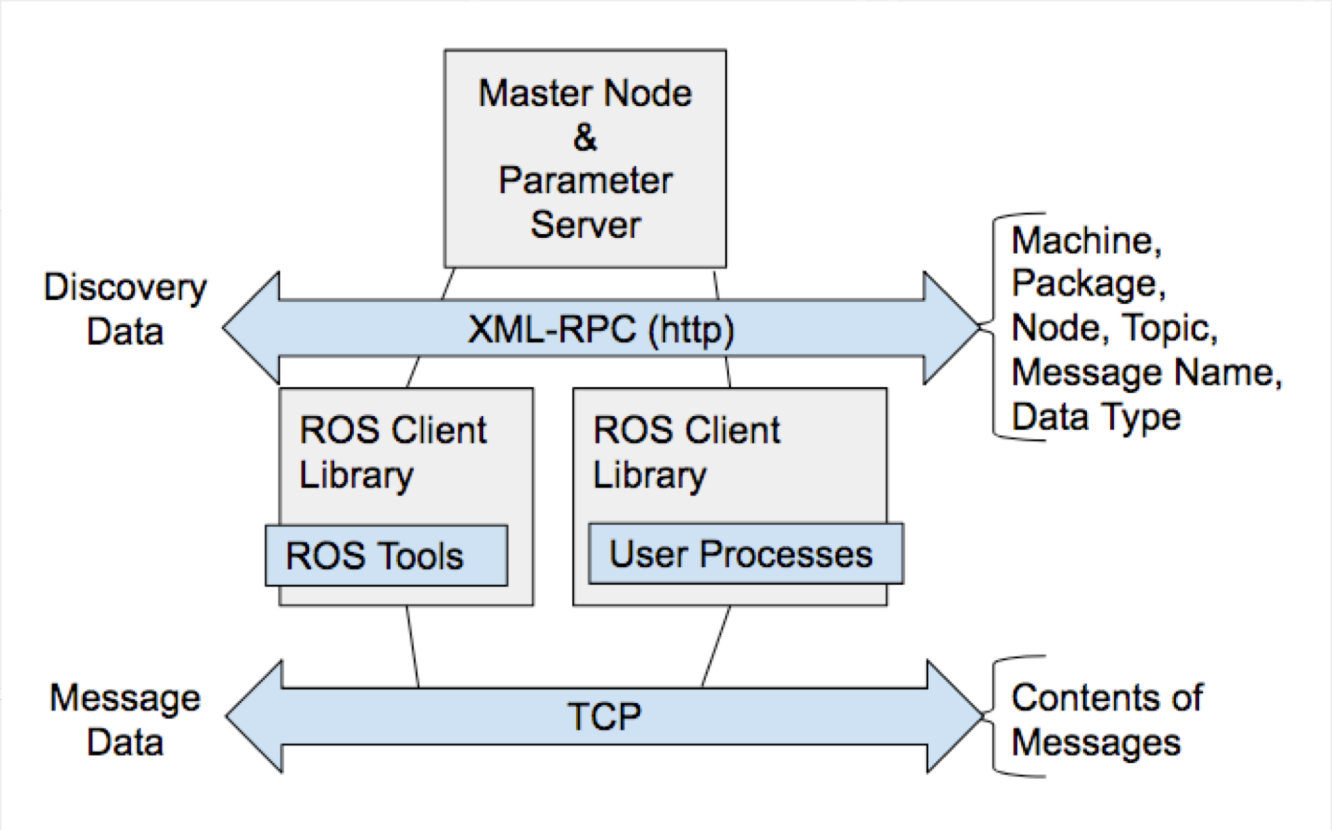
Robotic Operating System

ROS 2

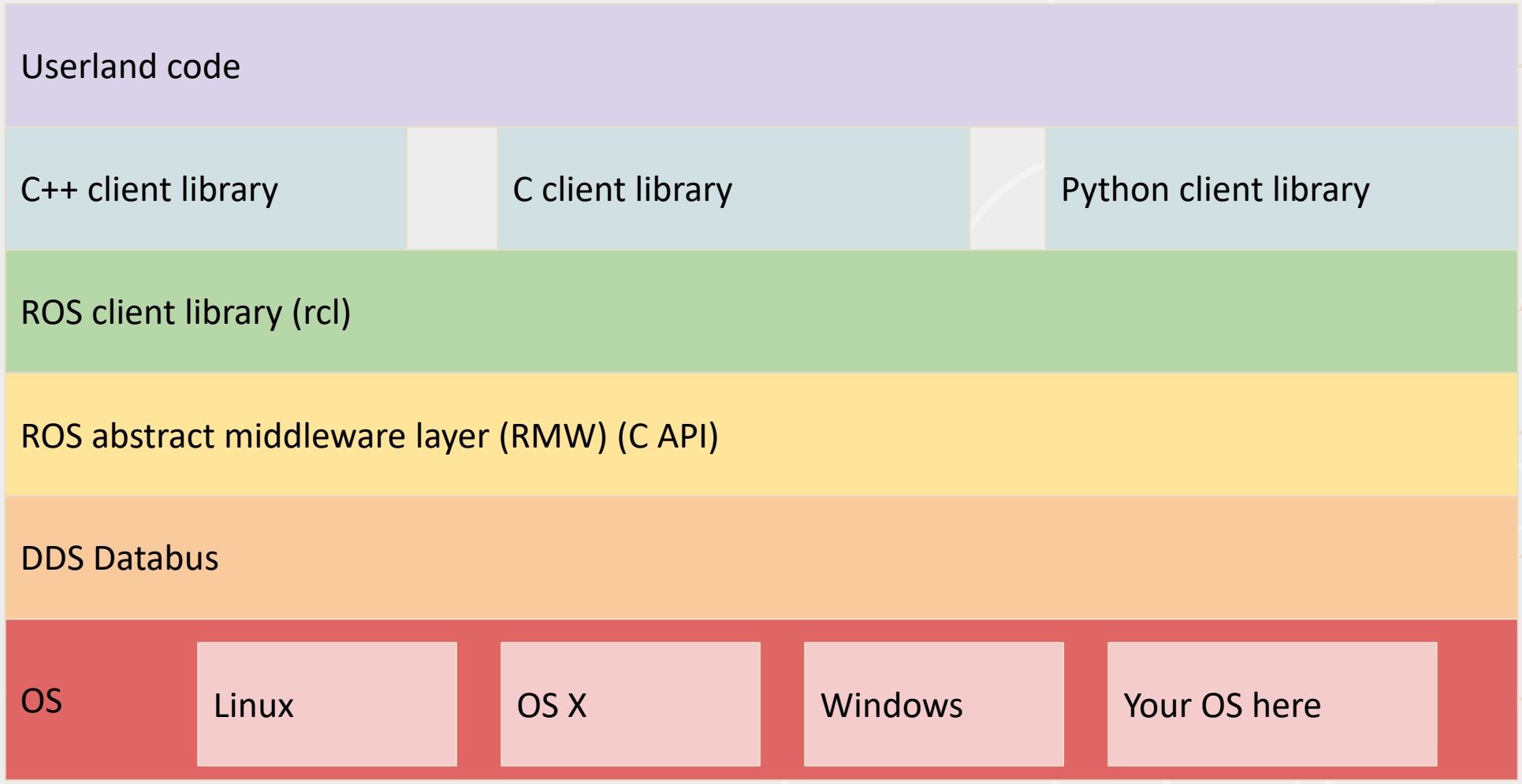
Component Model

Original ROS

- Includes:
  - Tools
  - Communication Infrastructure
  - Robot-Specific Features
- Master Node is Single Point of Failure
- Designed for research (not for the “-ilities”)



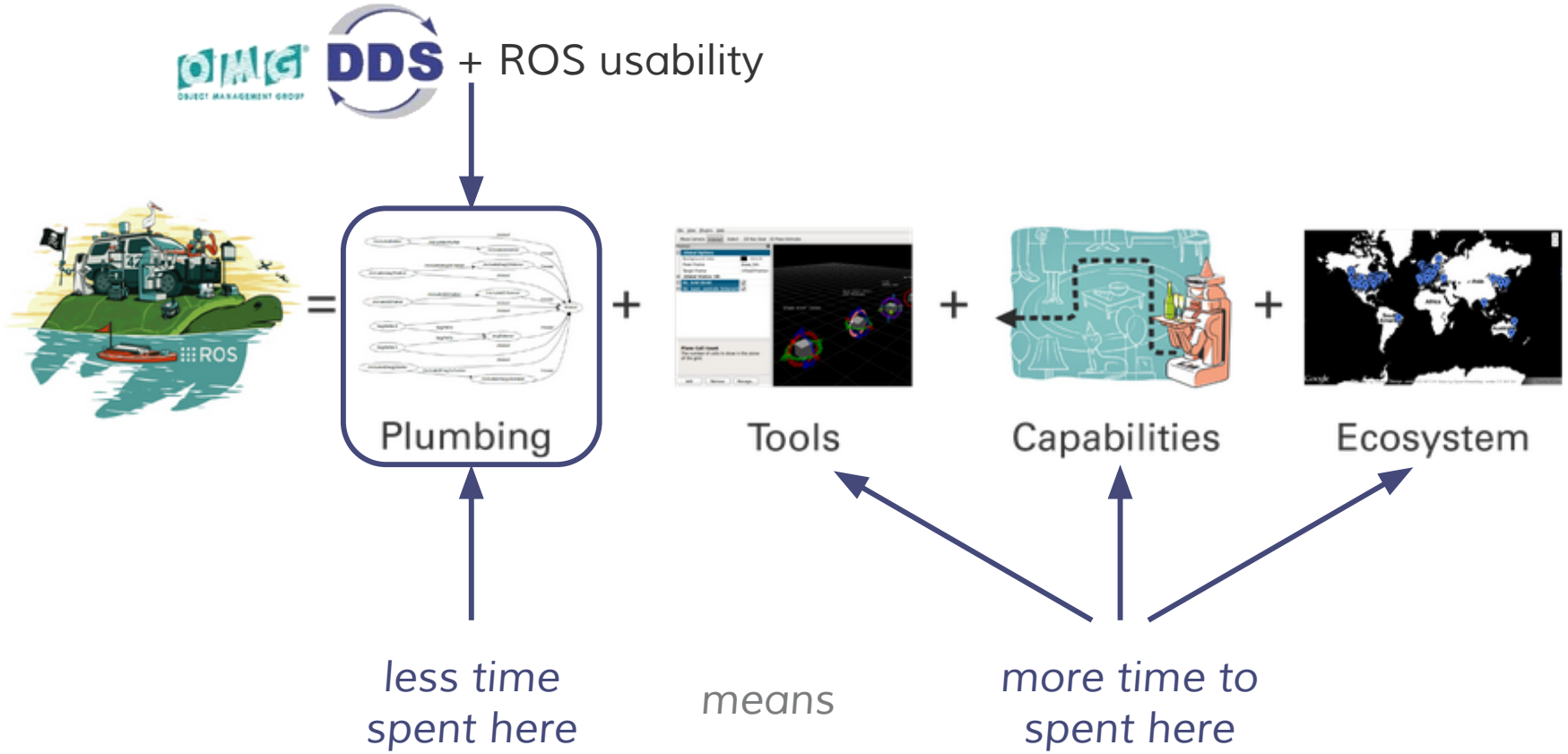
Underlie ROS2 Software Stack



ROS Variants

- ROS-Agriculture (rosagriculture.org)
- ROS-Industrial
- ROS-Aerial
- ROS-Military (SwRI effort)
- ROS-DOE (SwRI effort)
- ROS-Logistics (Amazon)
- And More!!

Why build ROS 2 on DDS

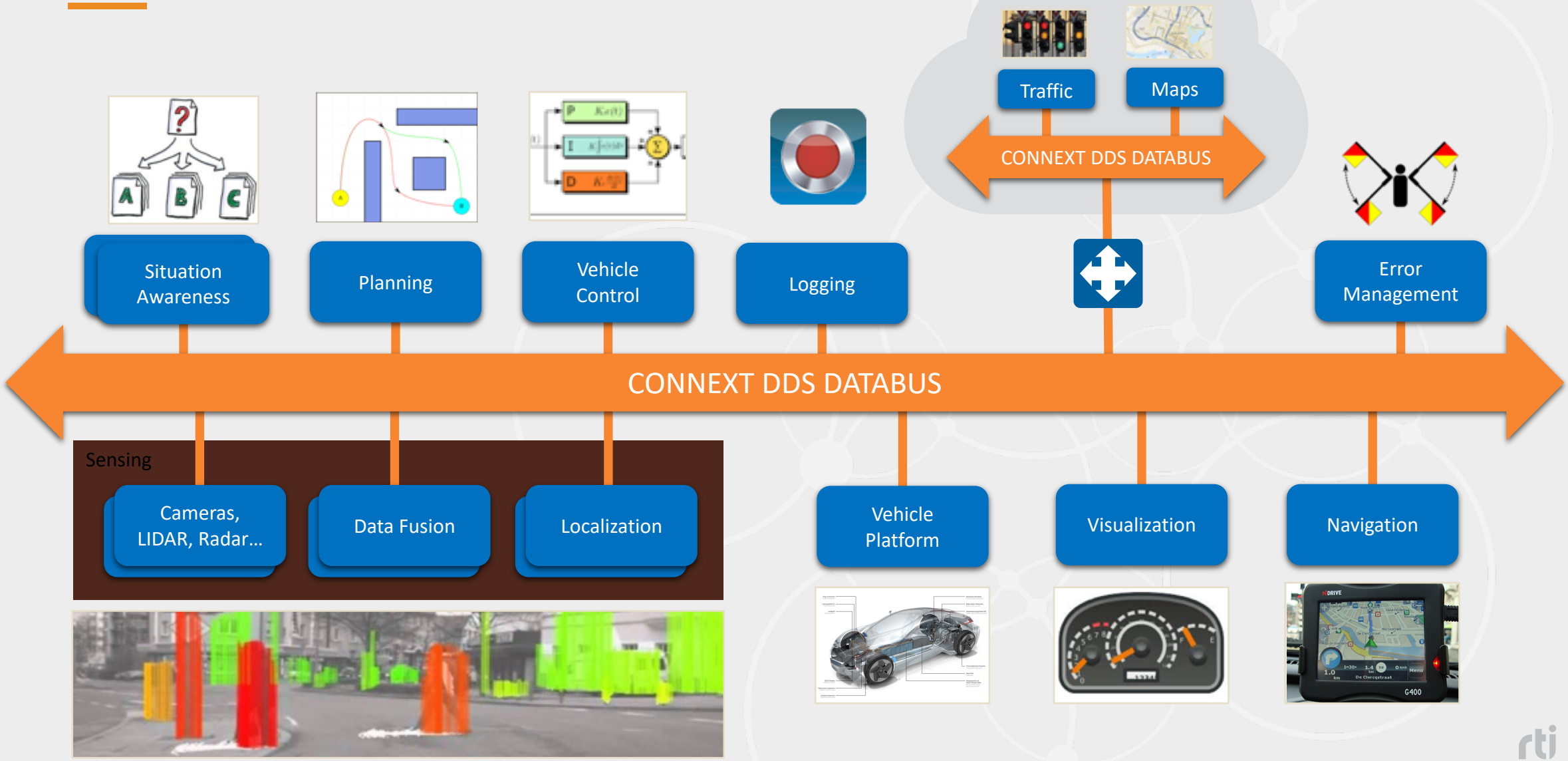


Open Source Robotics Foundation

Proprietary and Hardware Specific

- Quick Start, platform vendor enforces interoperability
- Homogeneous or limited HW support
- Leverage hardware capacities
- Single source & locked-In

Layered Databus Architecture



Benefits of RTI Connext Databus

- Who uses Layered Databus for AV?
  - NEXTDROID
  - Electric and Startup
- Why?
  - Expose RTI Connext Features
  - Maximum Performance
  - Datacentric Design

NEXTDROID

SEE PRESSS RELEASE

Shared Global Dataspace

Shared Global Dataspace

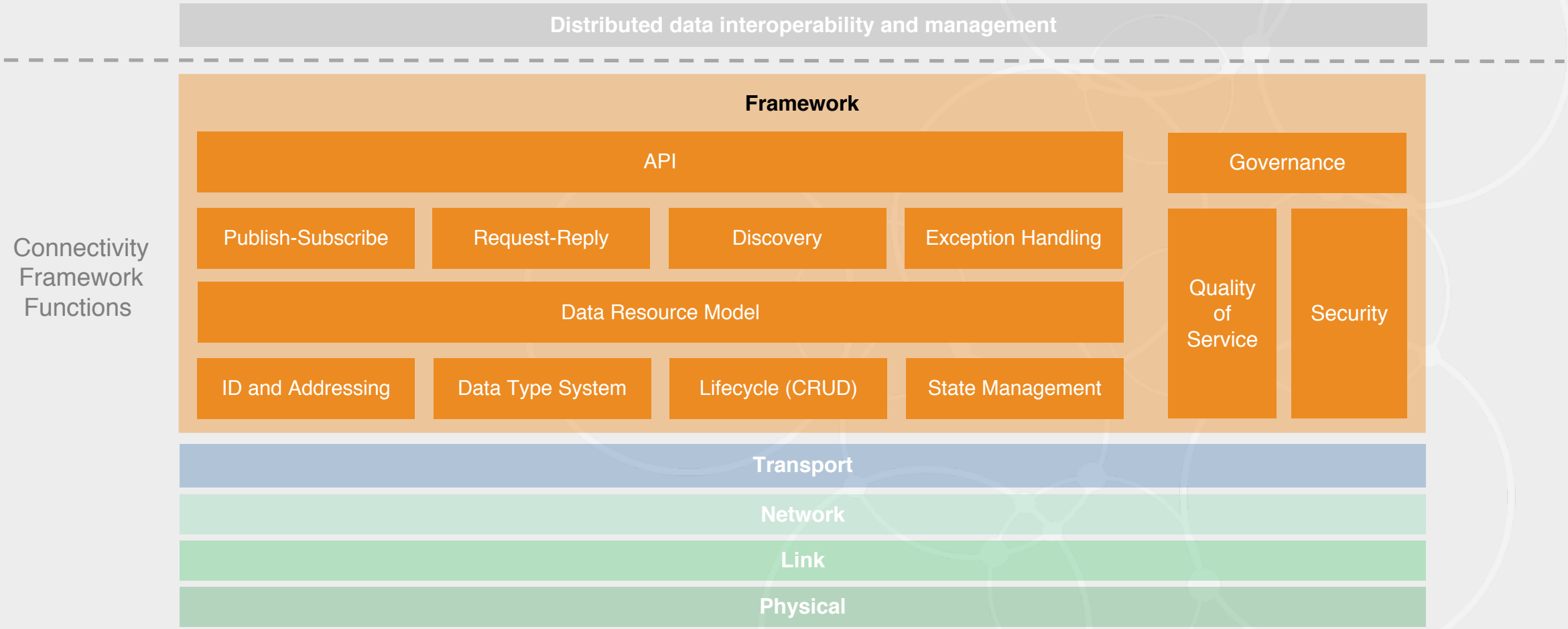
Source (Key)	Speed	Power	Phase
WPT1	37.4	122.0	-12.20
WPT2	10.7	74.0	-12.23
WPTN	50.2	150.07	-11.98

DATABUS

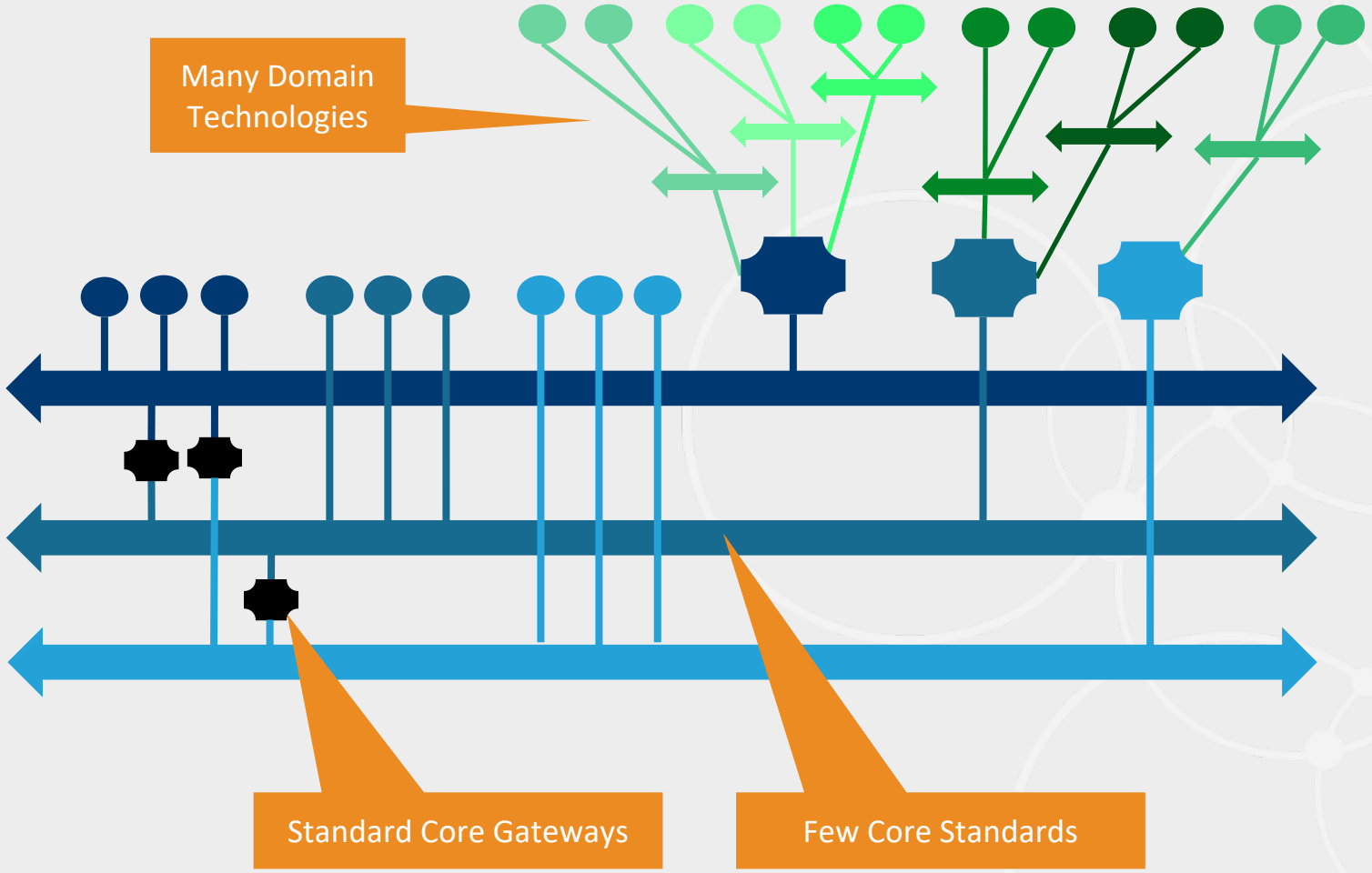
Persistence Service

Recording Service

IIC Guidance - Connectivity Framework Layer

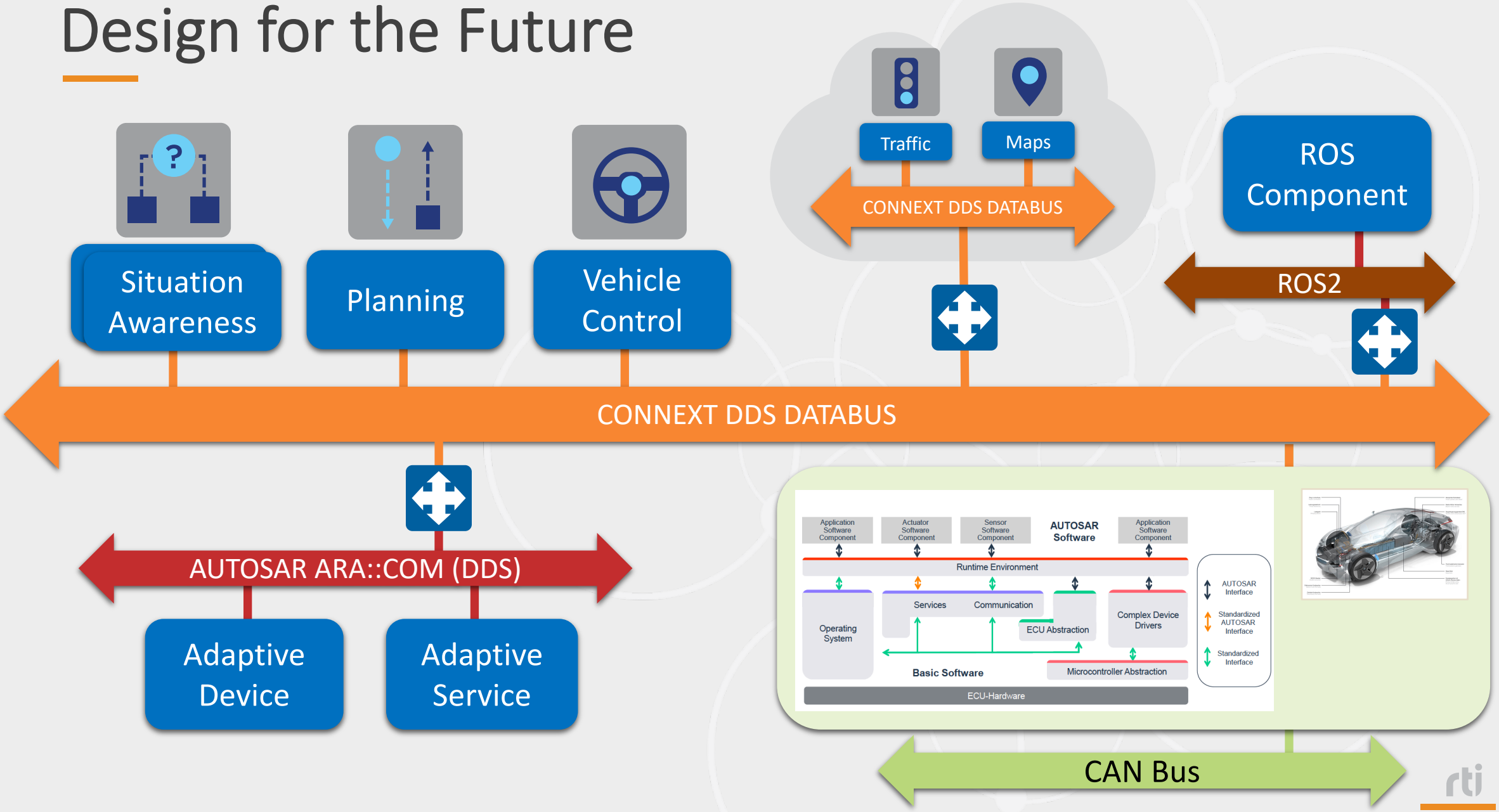


Choosing a Framework
Connectivity Core Standards Architecture



- Connectivity Core Standards
  - Provide syntactic interoperability
  - Stable, deployed, open standard
  - Standard *Core Gateways* to all other CCS
- Domain-Specific Connectivity Technologies
  - Connect via non-standard gateway to any connectivity core standard

Design for the Future



Layered Databus

- End-User Applications
- Connect with RESTful/Web Sockets

Public Internet

- Traffic Management
  - Traffic Light Control
  - Congestion Management
- Road Management
  - Environmental & Road Conditions

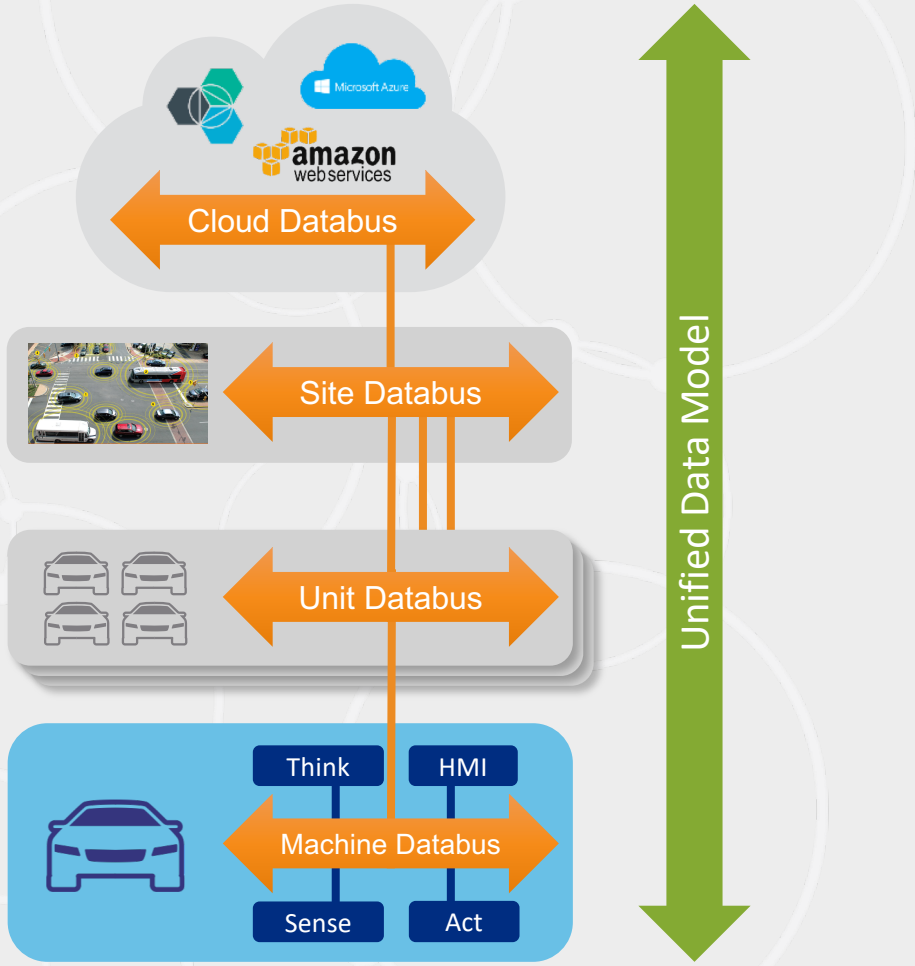
Fleet Management

- Probe Data Collection (Sensors)
- Environmental Weather
- Dynamic Vehicle Location

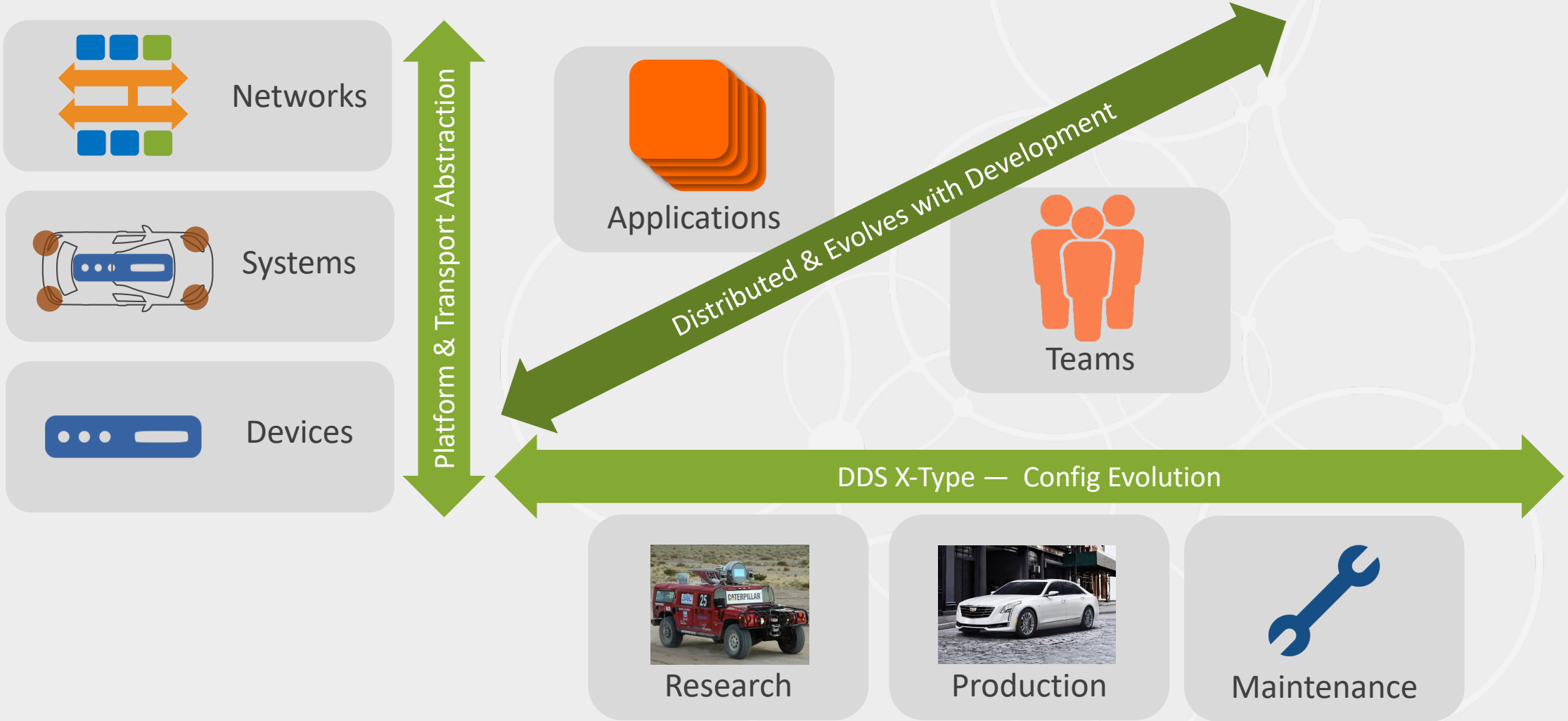
V2V & V2X

- Collision Avoidance
- Navigation
- Safety Certified

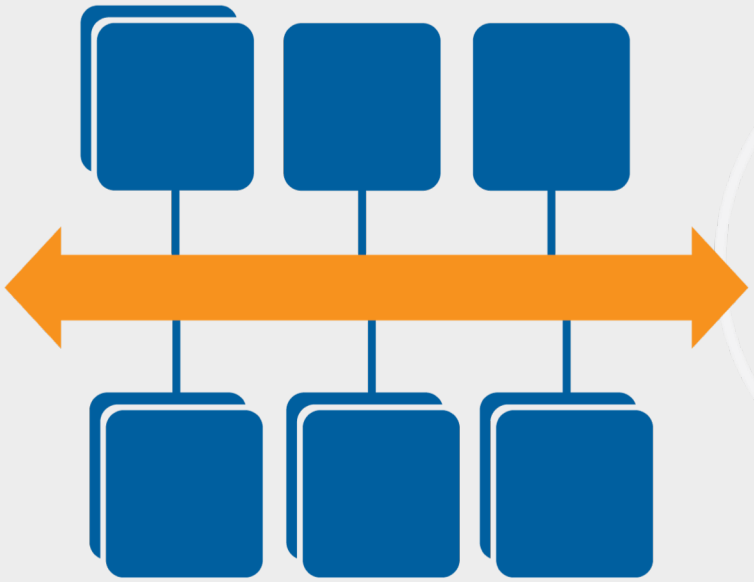
In-Car Platform



Scale in Time and Space



In Summary



- Many architectures under development
- Consolidation is inevitable
- How to choose?
- DDS is used in many architecture
- Using IIC Guidance, DDS is a core architecture
  - Bridge to other standards
- DDS meets functional and non-functional requirements

Thank you

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RTI
www.rti.com

Examples, forum, papers
community.rti.com

IIC
www.iiconsortium.org

DDS portal
portals.omg.org/dds/