Before We Start…

- Everyone is muted
- ZOOM for verbal questions (use raise hand)
- SLIDO is being used for written questions & polls
- CHAT for ongoing discussion & networking
- In between each panelist presentation, the moderator will select a question to be posed to the panelist. Questions will be fielded for no more than 2-3 minutes between presentations.
- Panelist presentations are expected to be approximately 5 minutes (or less)
- General audience Q&A will be open after the last panel presentation

Image courtesy of Adobe Stock

Unlocking the Potential of Automotive PHM

13th PHM Society Conference [Virtual]
2 December 2021

Steve Holland, Panel Chair

Steve Holland Background

- Long Career with GM (retired in 2019)
  - A leading proponent of PHM in the auto industry
  - Helped launch OnStar Proactive Alerts which provides prognostics for millions of GM vehicles
  - Led deployment of large-scale machine learning prognostics applications in GM manufacturing
- Now Principal Consultant, VHM Innovations, LLC
- PHM Society Board of Directors inaugural champion for automotive industry
- Active in the SAE IVHM Standards efforts & Health-Ready Components & Systems Consortium
- Steve is a Fellow of IEEE, PHM Society & SAE

VHM Innovations, LLC

Unlocking the Potential of Automotive PHM

The automotive industry has proven to be one of the most fertile application domains for PHM technology in terms of financial impact, analytics sophistication and sheer scale. Successful examples have been implemented for both manufacturing systems and the automotive vehicles themselves. The case has been made for even greater opportunity in coming decades as the continuing electrification of vehicles takes place. Similarly, the potential impact for fleets is anticipated to be huge. This applies to conventional automotive and trucking fleets as well as for future autonomous fleets. But, the pace of PHM introduction continues to lag behind what it might be. *This panel seeks to understand the key enablers for recent industry successes as well as the barriers that have limited more rapid progress. The discussion will be centered on strategies that effectively exploit those enablers while mitigating the barriers.*

Poll Question

SAE JA6268™ on Health-Ready Components

SURFACE VEHICLE/AEROSPACE RECOMMENDED PRACTICE	JA6268™	APR2018
	Issued 2018-04	
Design & Run-Time Information Exchange for Health-Ready Components		

RATIONALE

This Surface Vehicle & Aerospace Recommended Practice was created to help reduce existing barriers to the successful implementation of Integrated Vehicle Health Management (IVHM) technology into the aerospace and automotive sectors by introducing health-ready components. Health-ready components are augmented either to monitor and report their own health or, alternatively, ones where the supplier provides the integrator sufficient information to accurately assess the component's health via a higher-level system on the vehicle. The principal motivation for health-ready components is to facilitate enhanced IVHM functionality in supplier-provided components that better meet the needs of end users and government regulators in a cost-effective manner. Underlying this motivation is the assumption that market forces will drive the need to achieve IVHM's benefits, which will in turn drive new requirements that suppliers must ultimately meet. This recommended practice has two primary objectives: (1) to encourage the introduction of a much greater degree of IVHM functionality in future vehicles at a much lower cost, and (2) to address legitimate intellectual property concerns by providing recommended IVHM design-time and run-time data specification and information exchange alternatives in an effort to help unlock the potential of IVHM.

https://www.sae.org/standards/content/ja6268_201804/

Evolution of VHM Capabilities

SAE Level	Vehicle Health Capability	Narrative Description	Participation in Repair Actions	Key Data Resources	Availability of Logged &/or Real-Time Data	Use of Supporting Models	IVHM System Characteristics
Manual Diagnosis & Repair Process performed by Technician							
0	Limited On-Vehicle Warning Indicators	Service actions for scheduled maintenance or when Operator notices problems or is alerted by indicator lights or simple gages.	**Operator/Driver & Service Tech**	On-Vehicle Measurements & Observation	N/A	Paper-based Manuals	Only Manual Diagnostic Tools & No Condition-Based Services
1	Enhanced Diagnostics Using Scan Tools	Service techs gain added diagnostic insight using automated scanners to extract vehicle operating parameters & diagnostic codes.	Operator/Driver & Service Tech	**On-Vehicle & Service Bay/ Depot Tools**	Logged Diagnostic Codes & Parameters available to Service Tech	Paper-based Manuals	On-Board Diagnostics Available
2	Telematics Providing Real-Time Data	Service techs gain real-time vehicle data via remote monitoring of vehicle to more completely capture issues.	Operator/Driver, Service Tech & Remote Support Center Advisor	On-Vehicle, Service Bay / Depot & Cloud Data	**Telematic Data Available to Service Tech with Diagnostics Info**	Paper-based Manuals	On-Board & Remote Data Available
Diagnosis & Repair Augmented by Prognosis & Predictive Analytics							
3	Component Level Proactive Alerts	Operator and service techs are provided with component health status (R/Y/G) before problem occurs . Limited condition-based maintenance.	Operator/Driver, Service Tech & Cloud-Based Services	On-Vehicle, Service Bay & Cloud Data	Telematic Data Available to Service Tech with Diagnostics Info	**Addition of Component-Level Health Models**	Component-Level Health Predictions
4	Integrated Vehicle Health Mgmt.	Operator and service techs are provided with system or vehicle level health indicators before problems occur with remaining useful life estimated. Condition-based maintenance.	Operator/Driver, Service Tech & Cloud-Based Services	On-Vehicle, Service Bay & Cloud Data	Telematic Data Available to Service Tech with Diagnostics Info	Addition of Vehicle-Level Health Models	**Vehicle-Level Health Management**
5	Self-Adaptive Health Mgmt.	Self-adaptive control and optimization to extend vehicle operation and enhance safety in presence of potential or actual failures.	Operator/Driver, Service Tech & Cloud-Based Services	On-Vehicle, Service Bay & Cloud Data	Telematic Data Available to Service Tech with Diagnostics Info	Addition of Vehicle-Level Health Models	**IVHM Capability Integrated into Vehicle Controls**

https://www.sae.org/servlets/works/committeeResources.do?resourceID=659064

New SAE-ITC HRCS Consortium Launched

➔ GOAL: Increase Impact of JA6268 to Deliver Value to Industry

Cross Industry Initiative under SAE-ITC

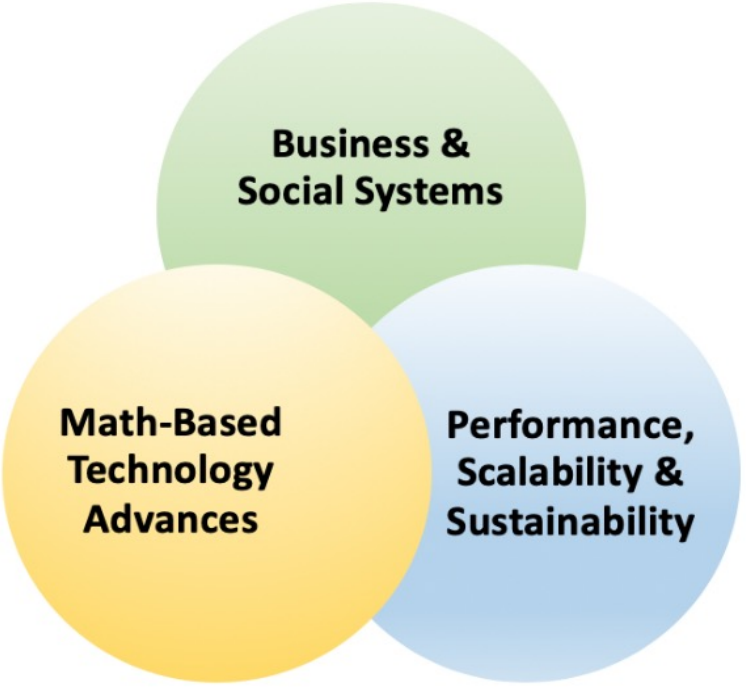
Collaboration with ATA/TMC

The American Trucking Association (ATA) represents a large number of commercial trucking fleets. Its Technology & Maintenance Council (TMC) works to improve its maintenance management processes. HRCS is collaborating with TMC on a project to improve “Design-Time and Run-Time Data For Vehicle Health and Safety” based on SAE JA6268™. It seeks to lower up-front and operating costs by increasing interoperability across different component manufacturers and system suppliers.

https://www.sae-itc.com/programs/hrcs

Barriers to Faster Progress

- The barriers to more effective VHM implementation go far beyond technology alone*
- SAE JA6268™ offers recommended practices to address some of the problems holding the technology back
- SAE's new HRCS Consortium seeks to build on JA6268 by a set of programs agreed by its member companies
  - →Component/system registry
  - →Info exchange templates
  - →Collaborative demonstrations



* **Unsettled Technology Opportunities for Vehicle Health Management and the Role for Health-Ready Components**, SAE EDGE Report: https://www.sae.org/publications/technical-papers/content/epr2020003/

Today's Expert Panel Will Address What Can and Should be Done

1. Troy Schilling
   Bosch
2. Joe Klesing
   Nexteer
3. Rex Struble
   SafeRide Technologies
4. Shiming Duan
   GM

Tim Felke – Q&A Moderator
Garrett Automotive

Our panelists are highly experienced & sophisticated VHM practitioners:

- *2 component suppliers,*
- *1 technology supplier &*
- *1 automotive OEM*

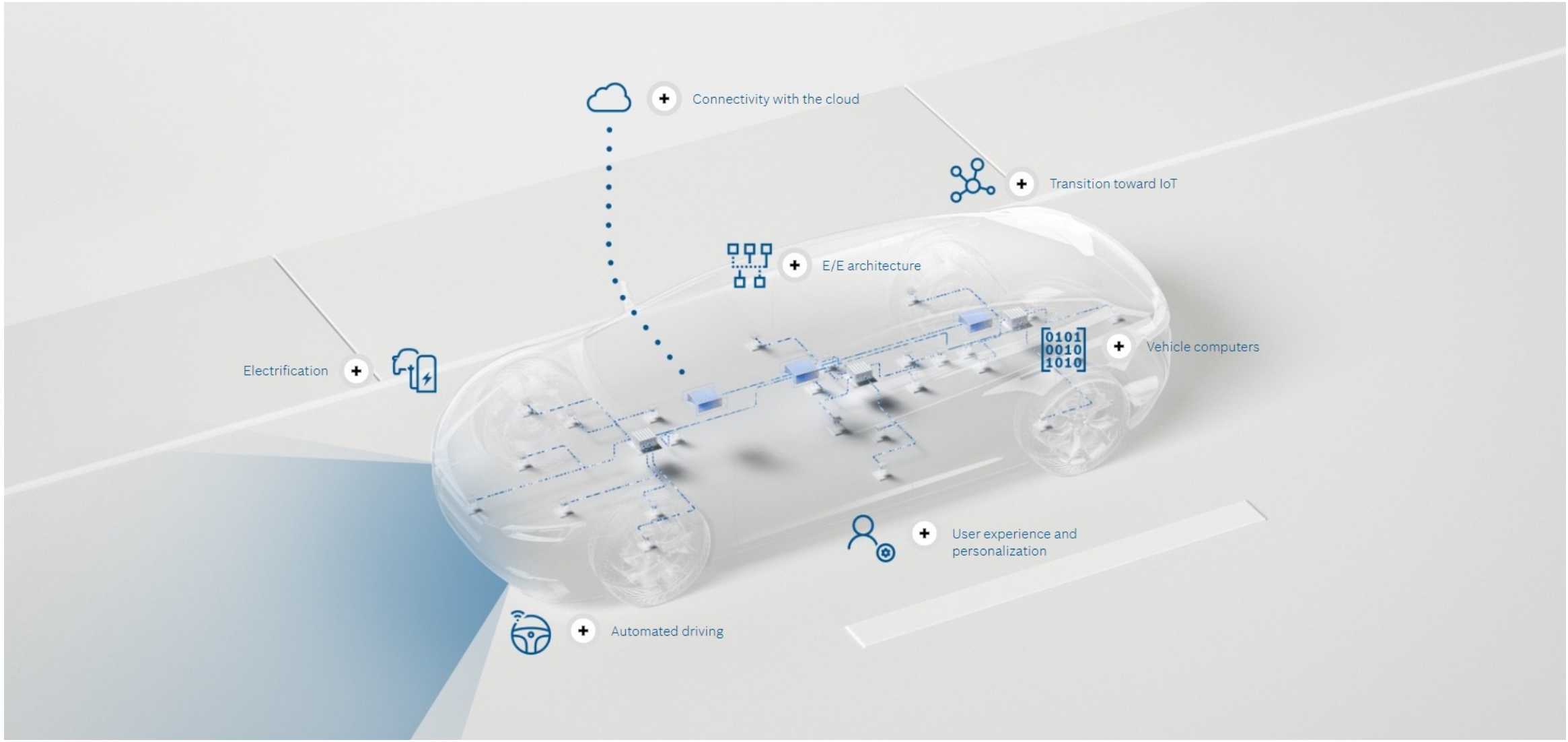
Each panelists will have only 5 minutes to quickly:

- *Introduce themselves & their company*
- *Explain their perspective*
- *Offer approaches to speed the implementation of successful VHM solutions*

Troy Schilling Background

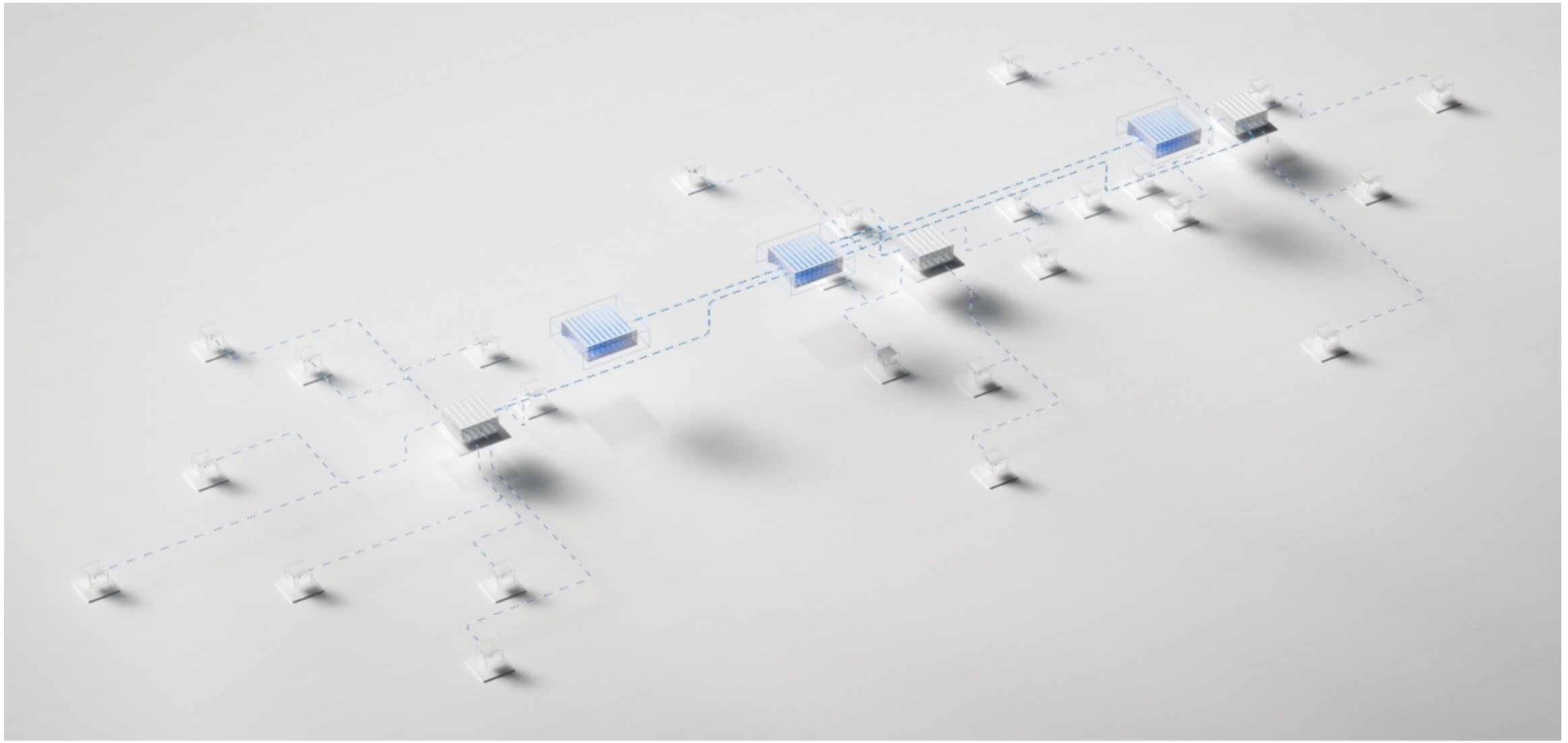
- Troy has 23 yrs+ in Automotive, 18+ with Bosch
- Part of the initial NA cross-divisional team to drive the development and deployment of the Connected Services product offerings.
- He has been a coach within Bosch's Innovation Framework and has a vast engineering / business development experience spanning the transportation, powersports, off-highway, medical and marine industries.

Vehicle Is Evolving Into An IoT Device



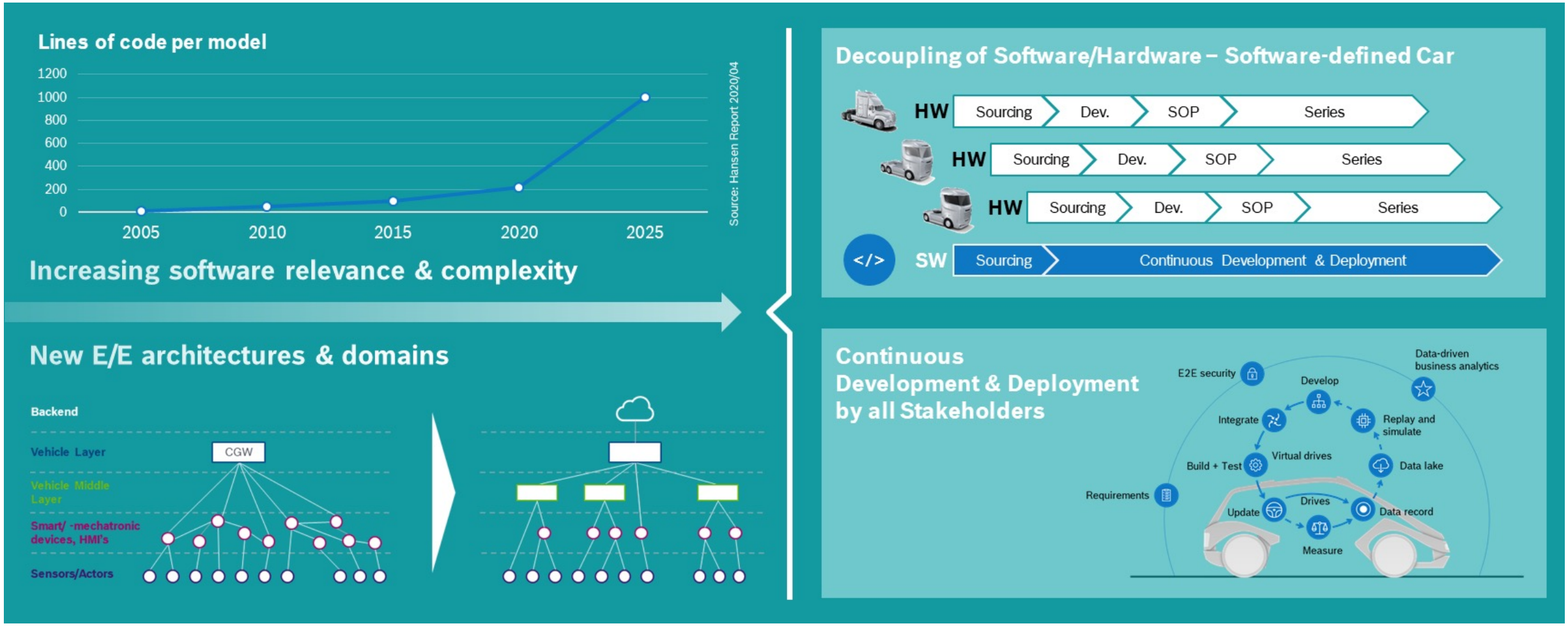
BOSCH

E/E architecture of the future



BOSCH

Transformation of Vehicle Software Development



BOSCH

Data Analytics – Generic Stepwise Approach

Insights & value

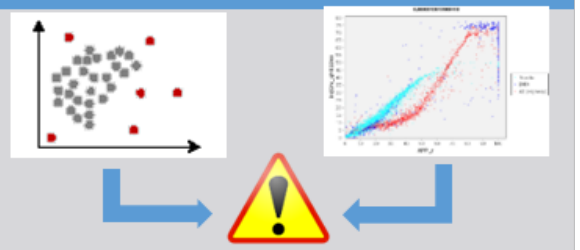
Step 1

Health Monitoring

- Data preparation
- Visual analytics & clustering
- Dashboard implementation

Step 2

Outlier Detection



- Root Cause Analysis
- Anomaly & outlier detection
- Breakdown & trend prediction
- On vehicle level

Step 3

Predictive Diagnostics

- State-based breakdown prediction with in-vehicle features and cloud data
- Small data by single vehicle
- Big data by fleet data
- Long data accumulation time

Implementation time

Remote State of Health

Motivation

- **Advanced vehicle specific Remote State of Health** with component specific **Remaining useful Life (RuL)** based on **domain knowledge**.
  - Pin pointing to suspicious components or priority list of components.
  - Seamless integration into vehicle life cycle.

Value

- **Avoid vehicle downtime** due to **precise pre-warning** with Remaining useful live information.
- **More uptime for end customers | Less quality claims in series | Less NTF (no trouble found)**

A Portfolio That Encompasses The Vehicle Life Cycle

BOSCH

Thank you

Troy Schilling

Bosch in North America

troy.schilling@us.bosch.com

www.bosch-mobility-solutions.com

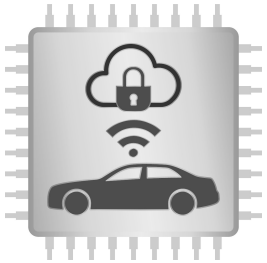
BOSCH

Joe Klesing Background

- Product Line Executive Software at Nexteer Automotive
- 30 years industry experience in Tier 1 Auto Industry in executive engineering and product management roles globally
- Currently focused on software-implemented value creation including Vehicle Health Management

This is Nexteer

Software

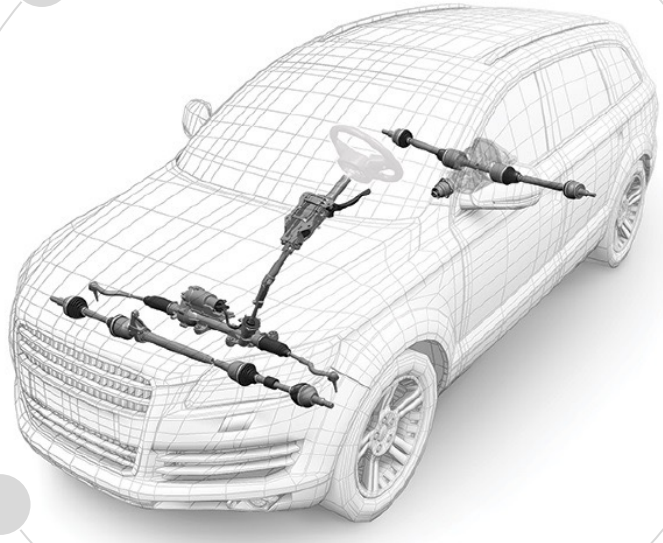


- ADAS
- Chassis Features-on-Demand
- Prognostics
- Connected Services
- Cybersecurity

ADAS & Automated Driving Enabling Technologies

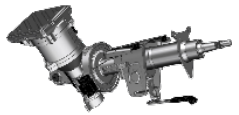
Steer-by-Wire

- Steer-by-Wire
- Quiet Wheel™ Steering
- Steering on Demand™ System
- Stowable Steering Column
- High Availability EPS



Electric Power Steering (EPS)

High Availability



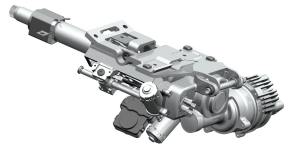
Column Assist

Dual Pinion Assist

Rack Assist

Single Pinion Assist

Steering Columns & I-Shafts



Stowable Steering Column
(Ideal with Steer-by-Wire Applications)

Steering Column

Intermediate Shaft

Driveline

Halfshaft

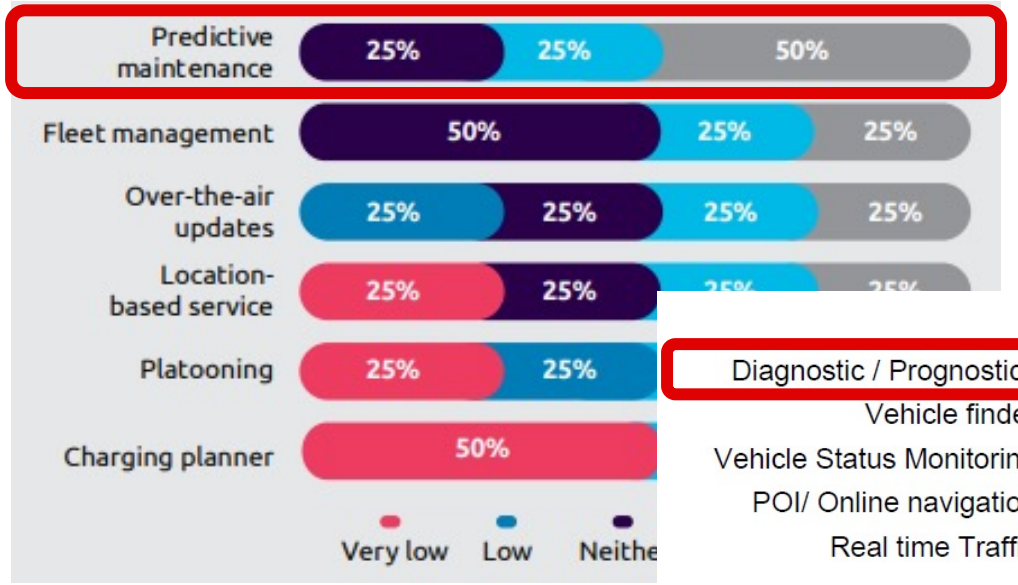
Propeller Shaft
CV Joint

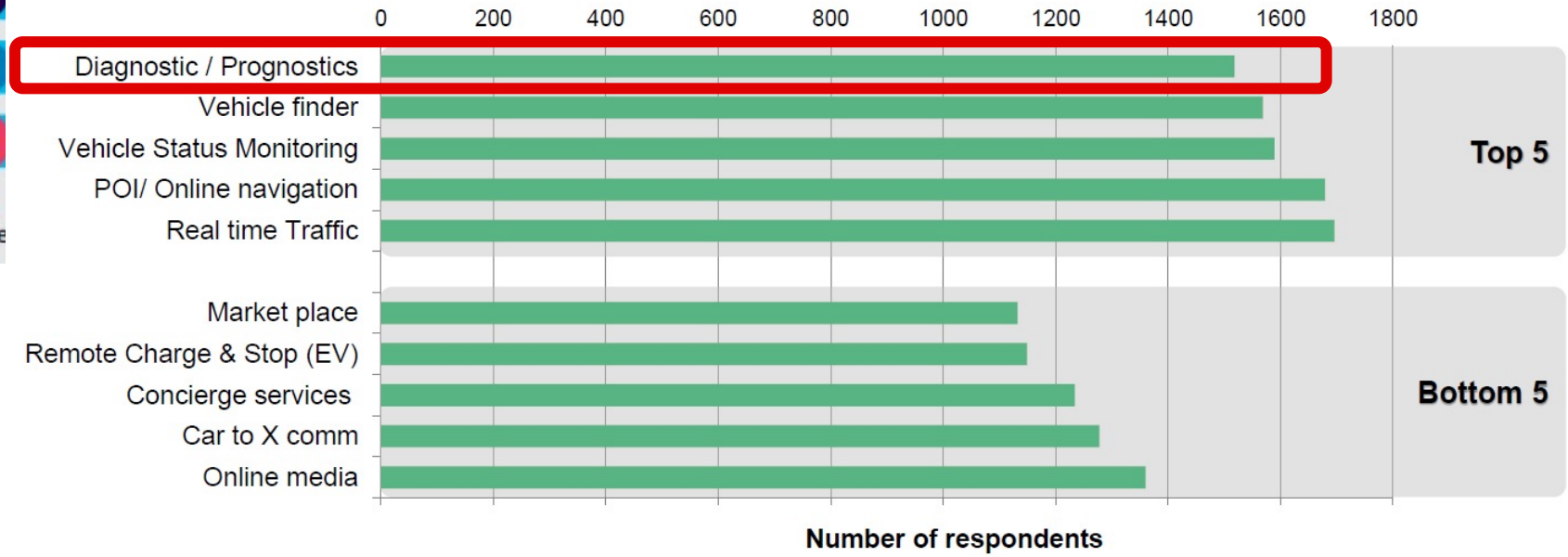
Intermediate Driveshaft

nexteer AUTOMOTIVE
a leader in intuitive motion control

Predictive Maintenance / Health Management:

Best B2B Monetization Potential & Best Value for Consumers





Sources: Connected Vehicle Trend Radar_2, Report Capgemini, 2020
Consumer Sentiment on Automotive Technology, IHS Automotive Fall Briefing 2021

Value Drivers for Vehicle Health Management

Fit-for-Use, Operational Efficiency & Customer Service Experience

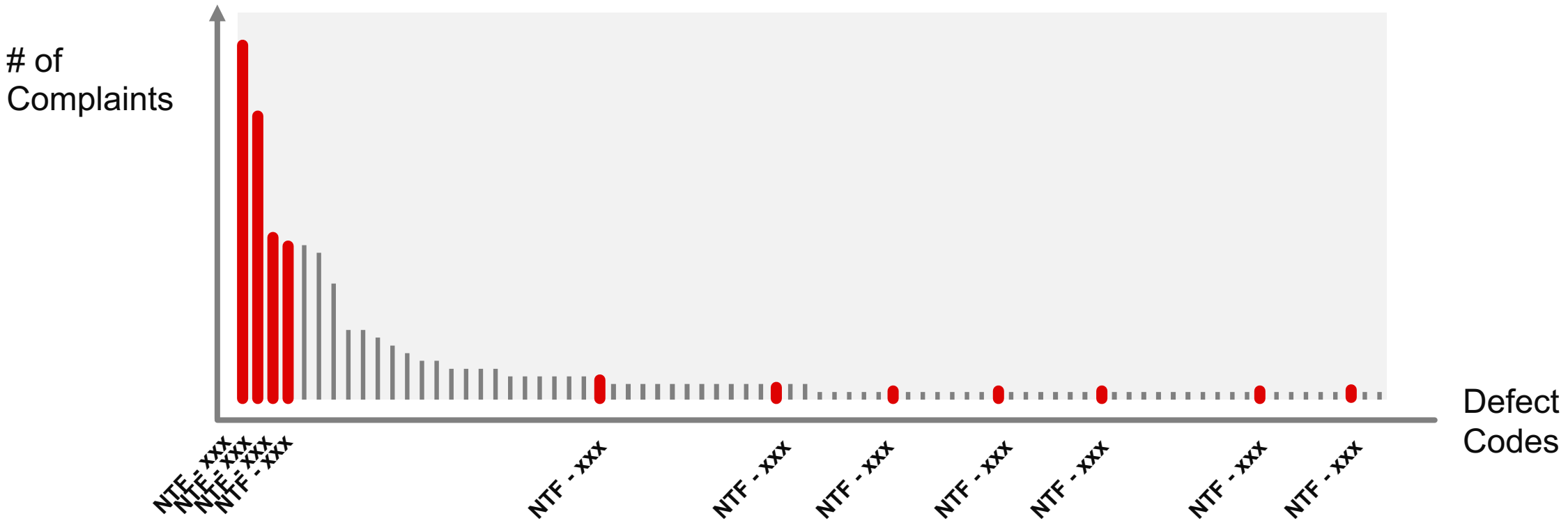
Value Drivers

Component Manufacturer	Vehicle Manufacturer	Dealership	Vehicle Owner
Detect Failures in Incipient Phase	Replacement Part Cost	Reduced Labor: Diagnosis, Repair	Avoid Disruption due to Repair
	Warranty Mitigation: No Trouble Found	Replacement Part Availability	
Feedback into New Designs	Functional Risk Reduction	Technician Training Gap for new technologies	Managed vs. Scheduled Maintenance
Services	Enhance Owner Loyalty	Product Placement Life-Limited Parts	Residual Value

Cost Avoidance
Cost Reduction
Revenue Increase

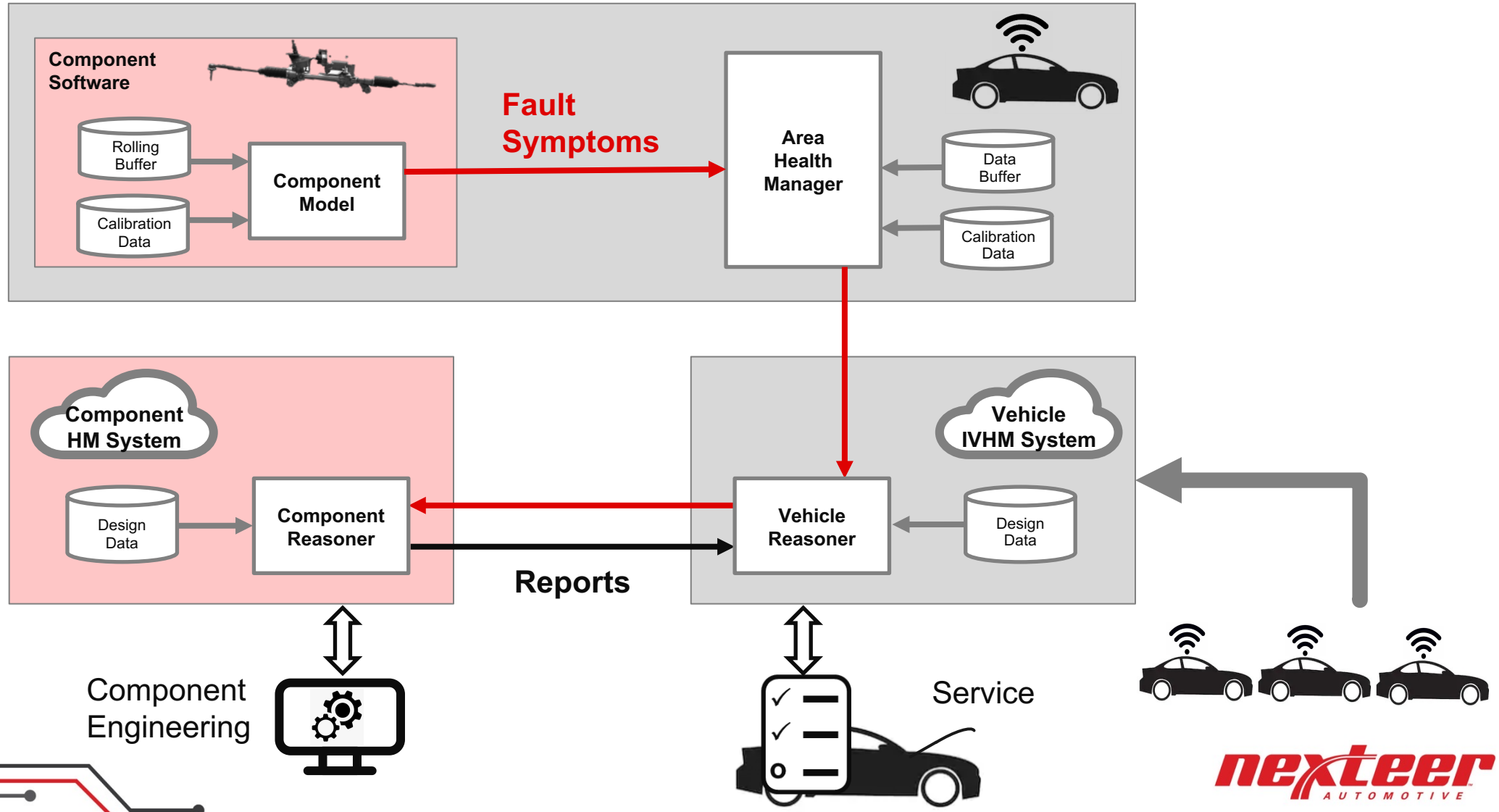
Example: Electric Power Steering Warranty

30 - 45% Classified as No Trouble Found



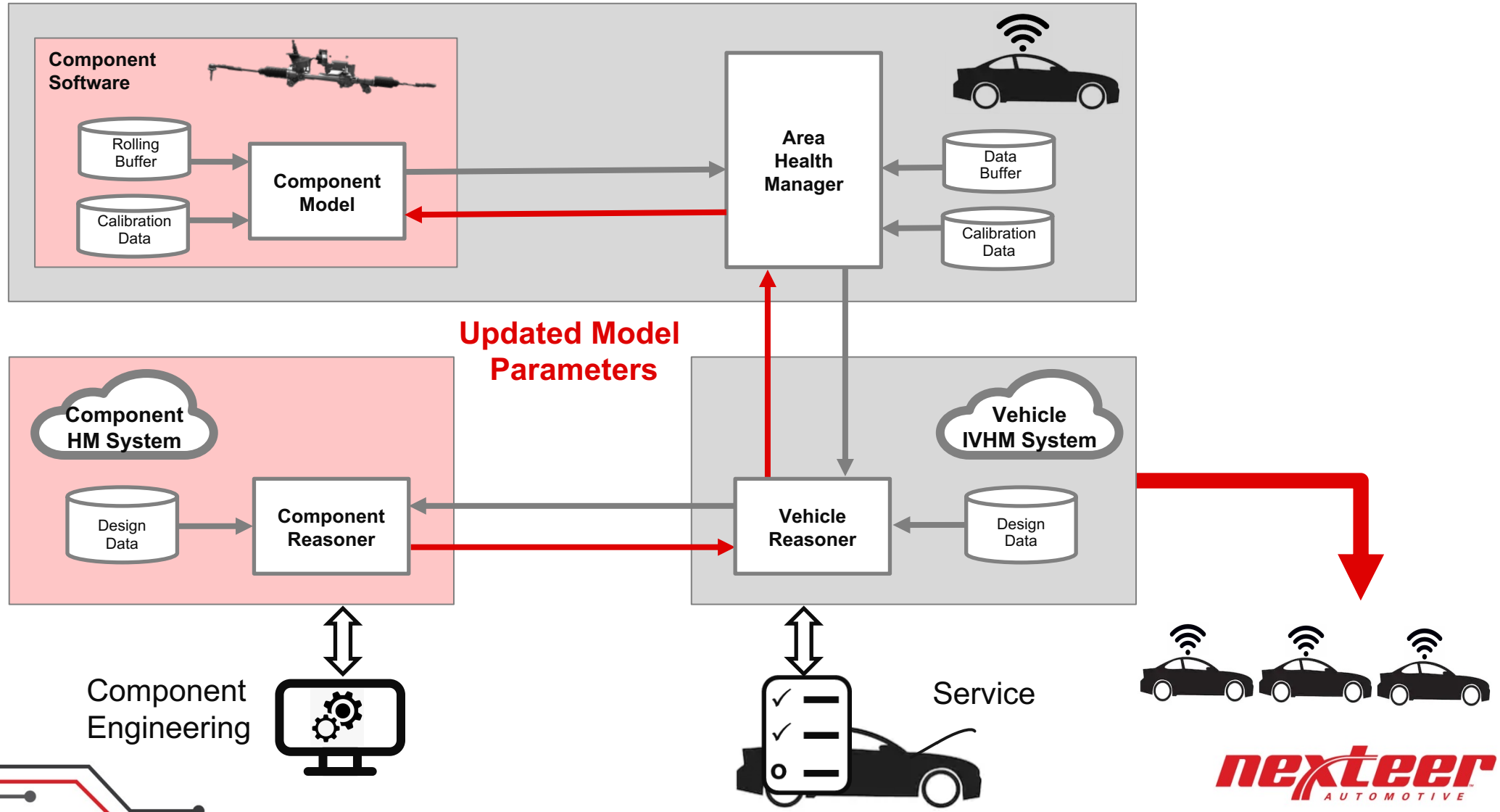
SAE JA6268 Compliant System Architecture

Indicator Computation In Component and Area Health Managers …



SAE JA6268 Compliant System Architecture

… While Any Vehicle Learns From Every Vehicle



nexteer AUTOMOTIVE

a leader in intuitive motion control

Rex Struble Background

Rex R. Struble
Head of Sales & Business Development North America
SafeRide Technologies (2 years)

SAFERIDE
Vehicle Insights. AI Driven.

- Rex has 25 years+ in Automotive engineering, sales, and business development w/ GM, TRW, and Bosch.
- Former global director of product planning for steering & suspension products at TRW; design release engineer at GM, and strategic BD for ETAS division of Bosch.
- Knowledge and experience in automotive embedded software, vehicle E/E architectures, and cybersecurity.
- Rex has also worked with automotive dev/test tools & frameworks across the product lifecycle including tools for development & calibration of diagnostic monitors.

Accelerating JA6268 level 3-4-5 with AI Technology

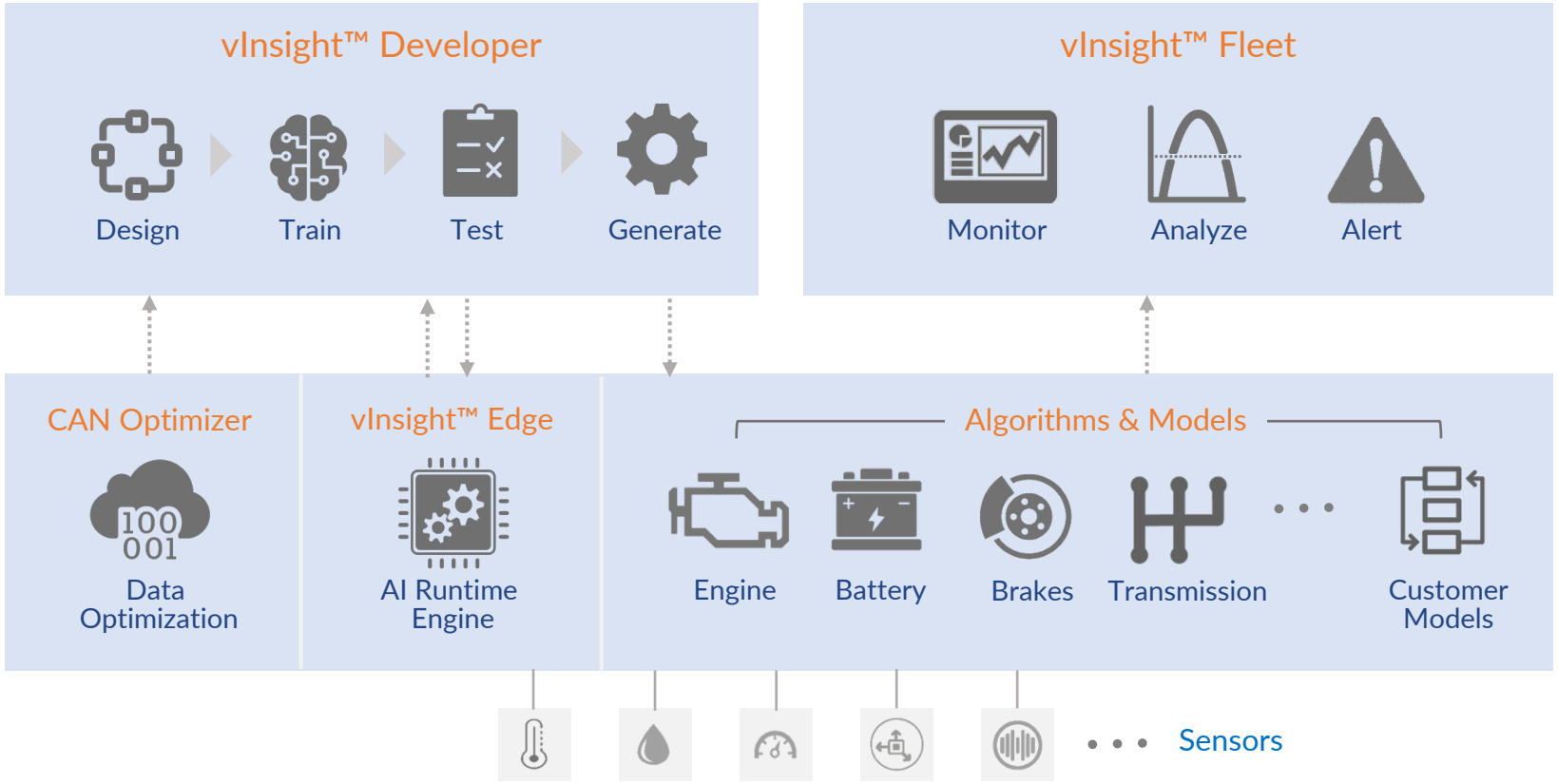
AutoML
Enables automotive engineers to build AI-based solutions quickly with little AI expertise

Hybrid
Combining AI with physics and domain expertise

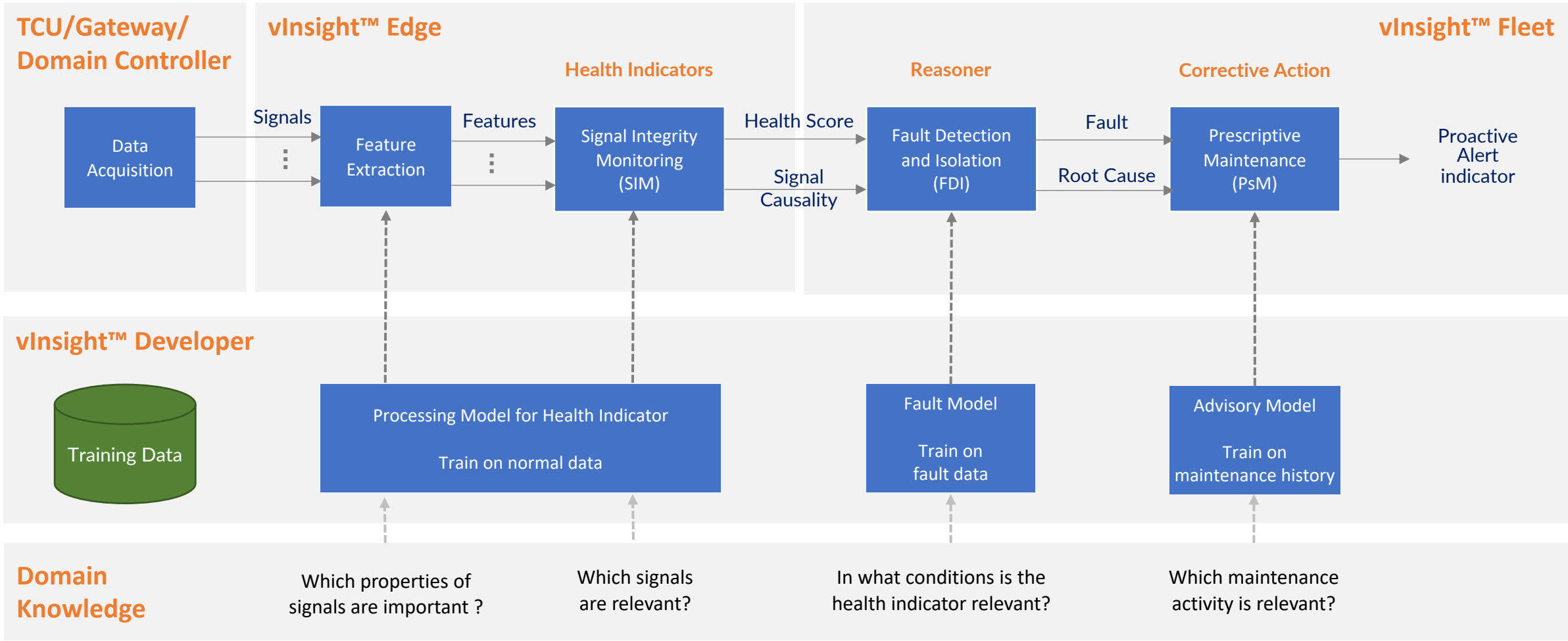
Accelerate Design
Rich library of models & algorithms. Unsupervised deep learning technology

Optimized for Edge
Can run on cloud or onboard the vehicle

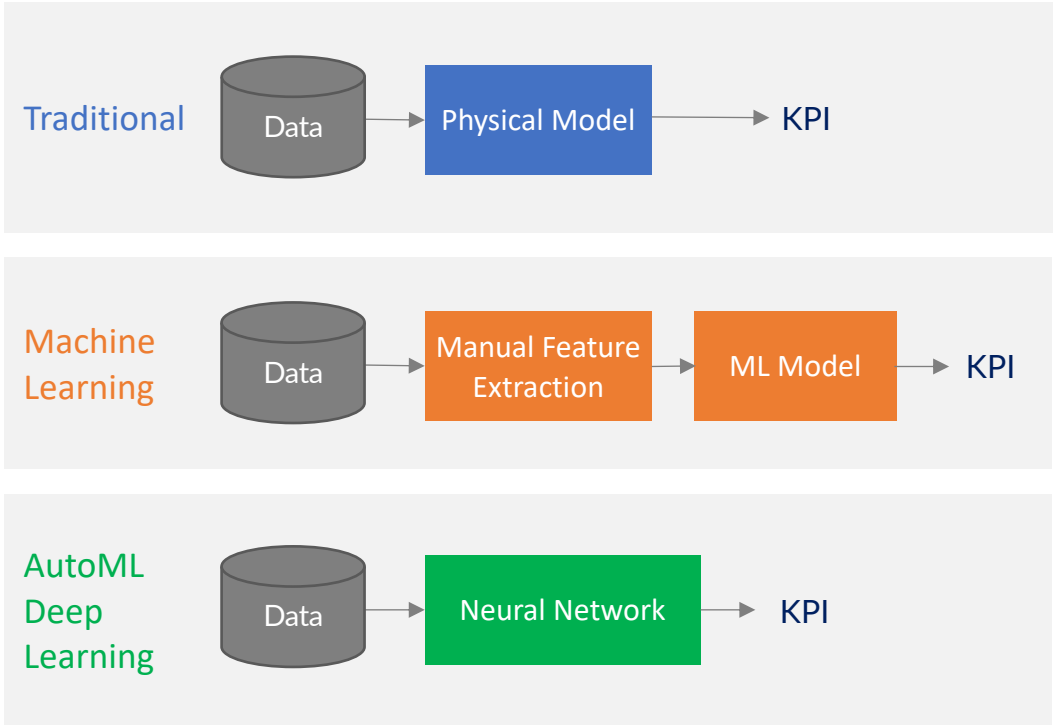
The vInsight™ Platform

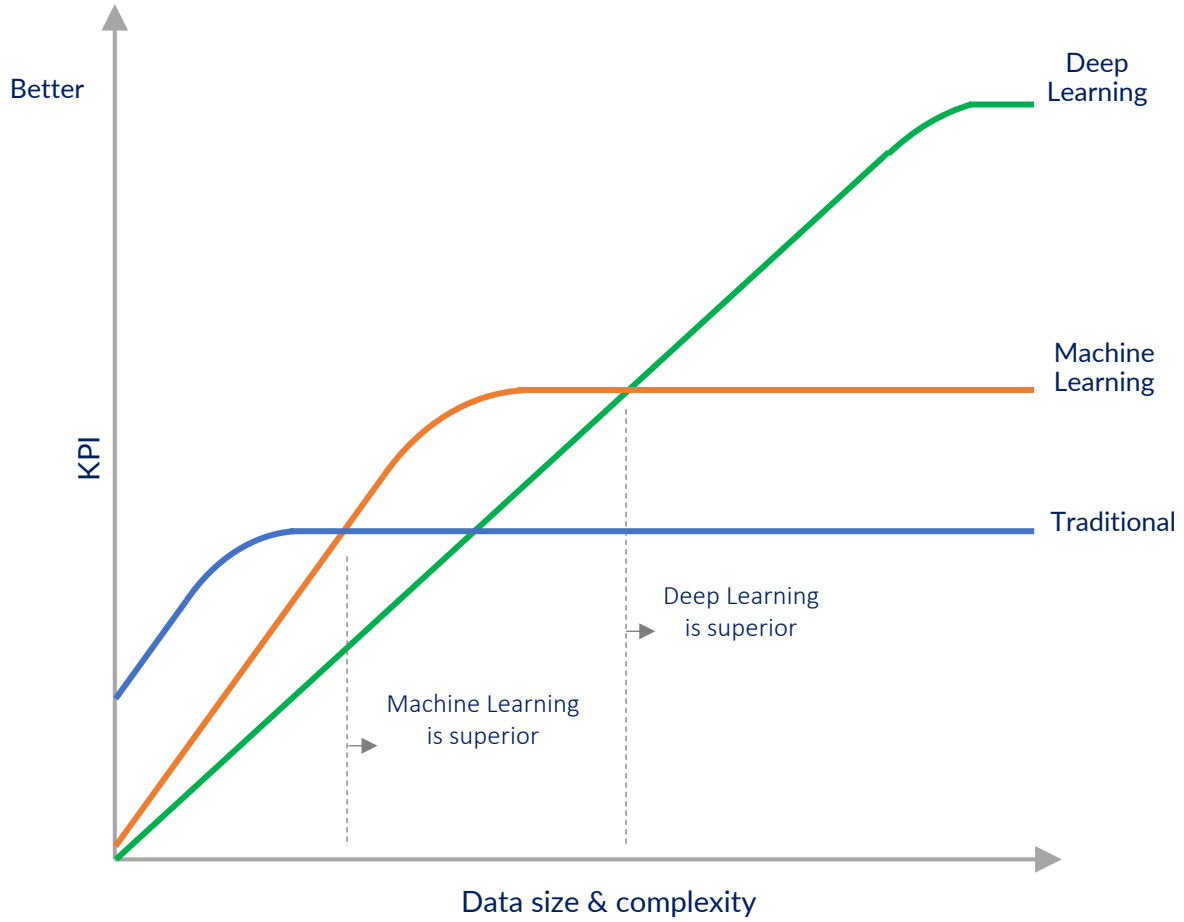


JA6268 VHM Framework Enhanced with AI

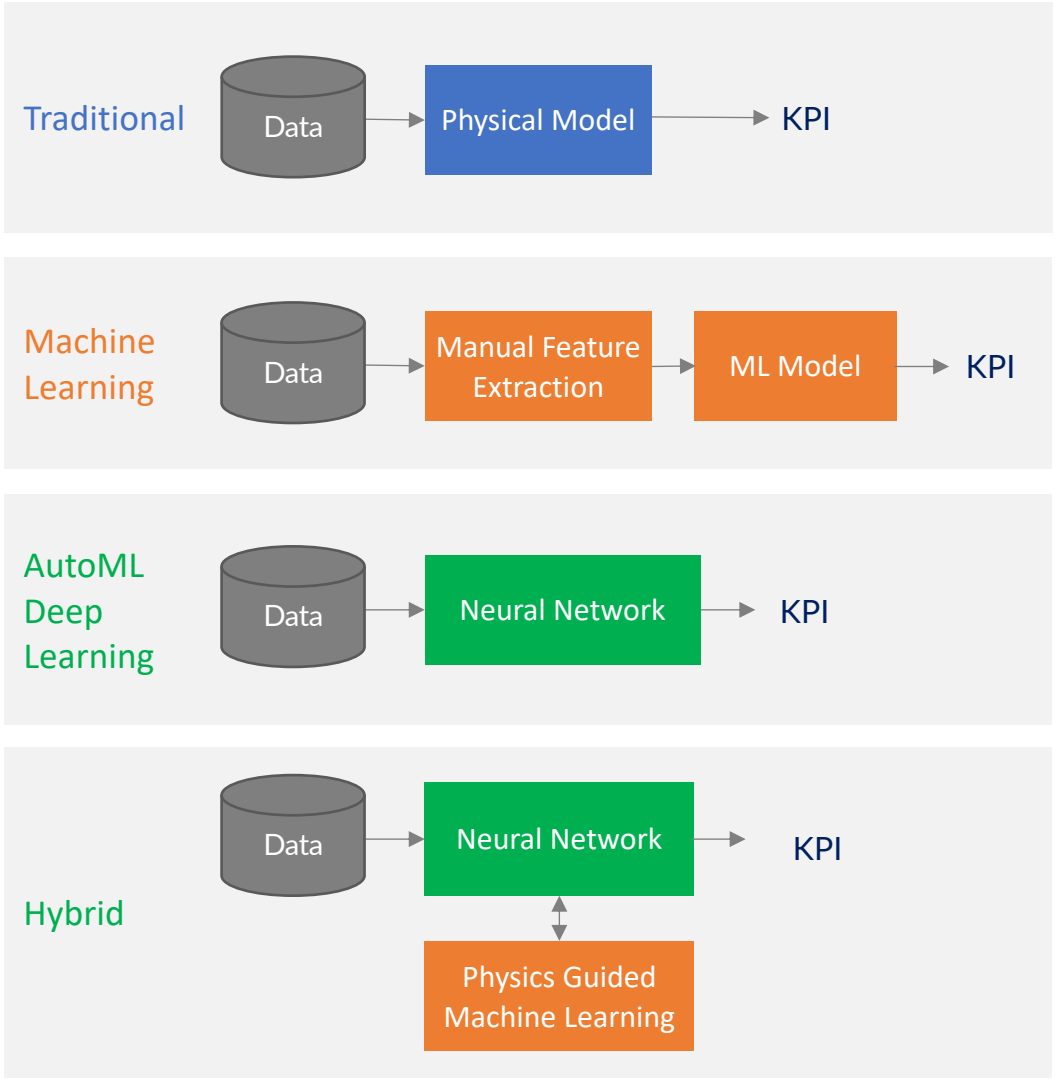


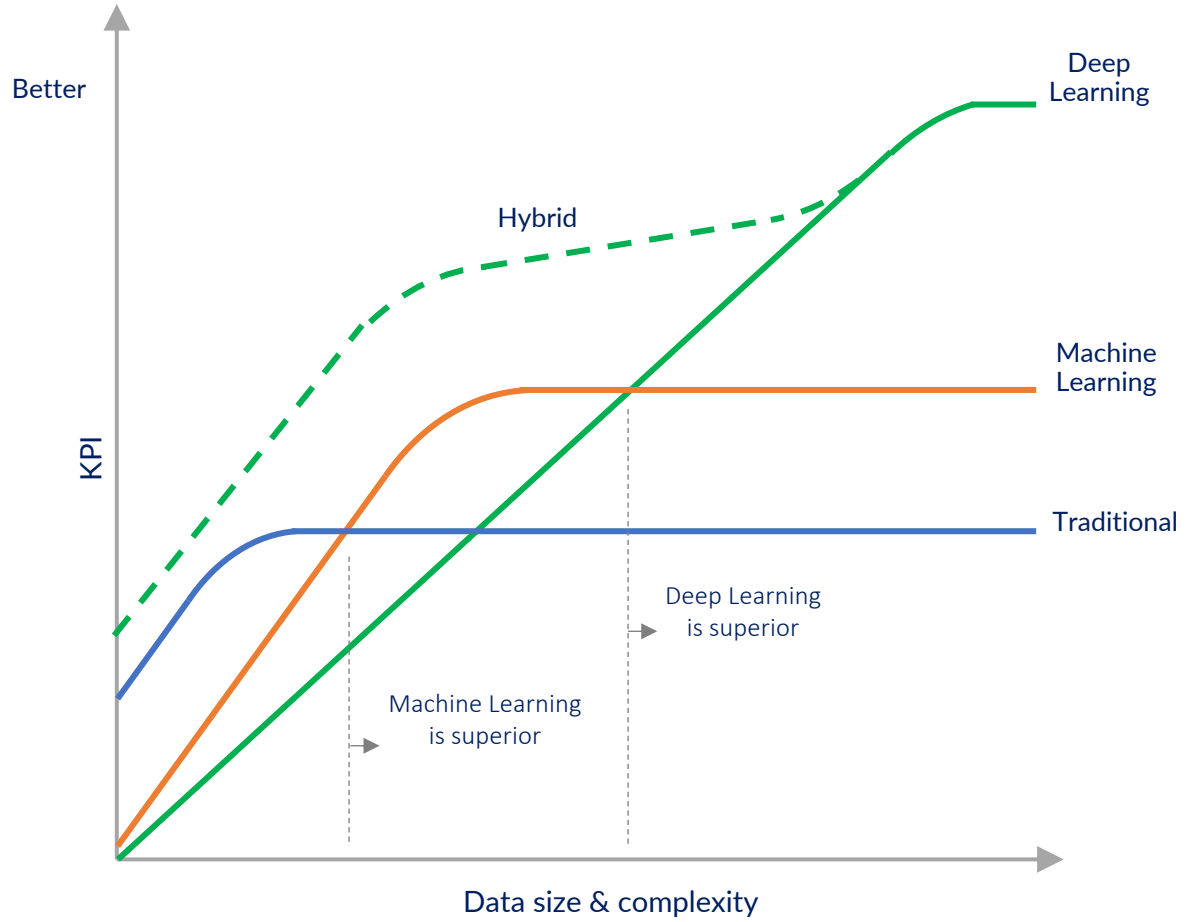
Data-Guided vs. Physics-Guided VHM





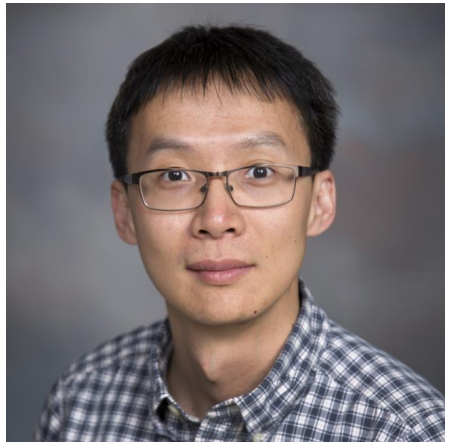
Data-Guided vs. Physics-Guided VHM





Shiming Duan Background

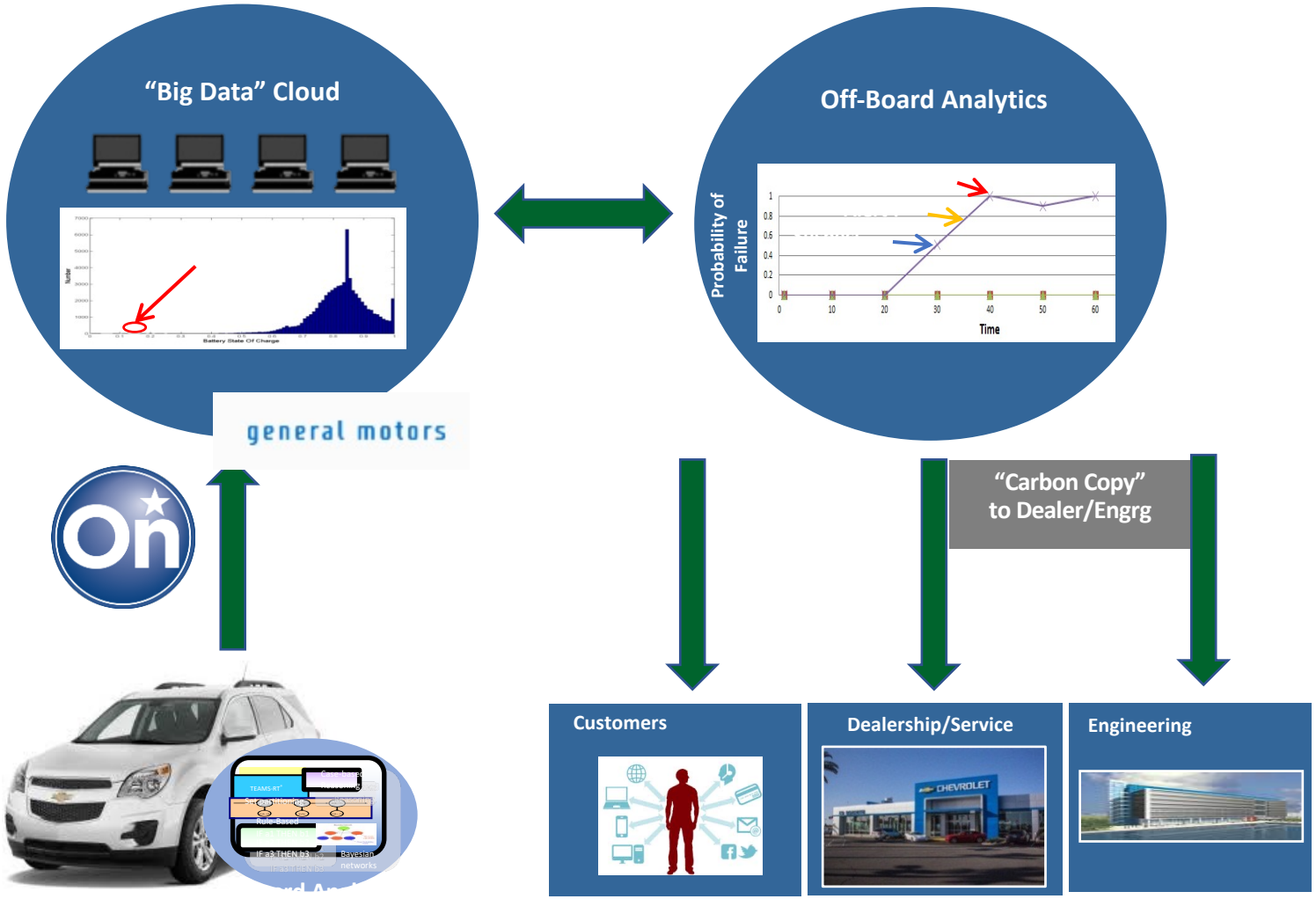
- MS and PhD from Univ. of Michigan, Ann Arbor
- Currently researcher at GM global R&D, Vehicle Health Management
- 10+ years industrial experience in the field of diagnostics and prognostic, adaptive control, machine learning, big data, etc.
- 10+ publications, 30+ patents
- Associate Editor, Journal of Intelligent & Fuzzy Systems



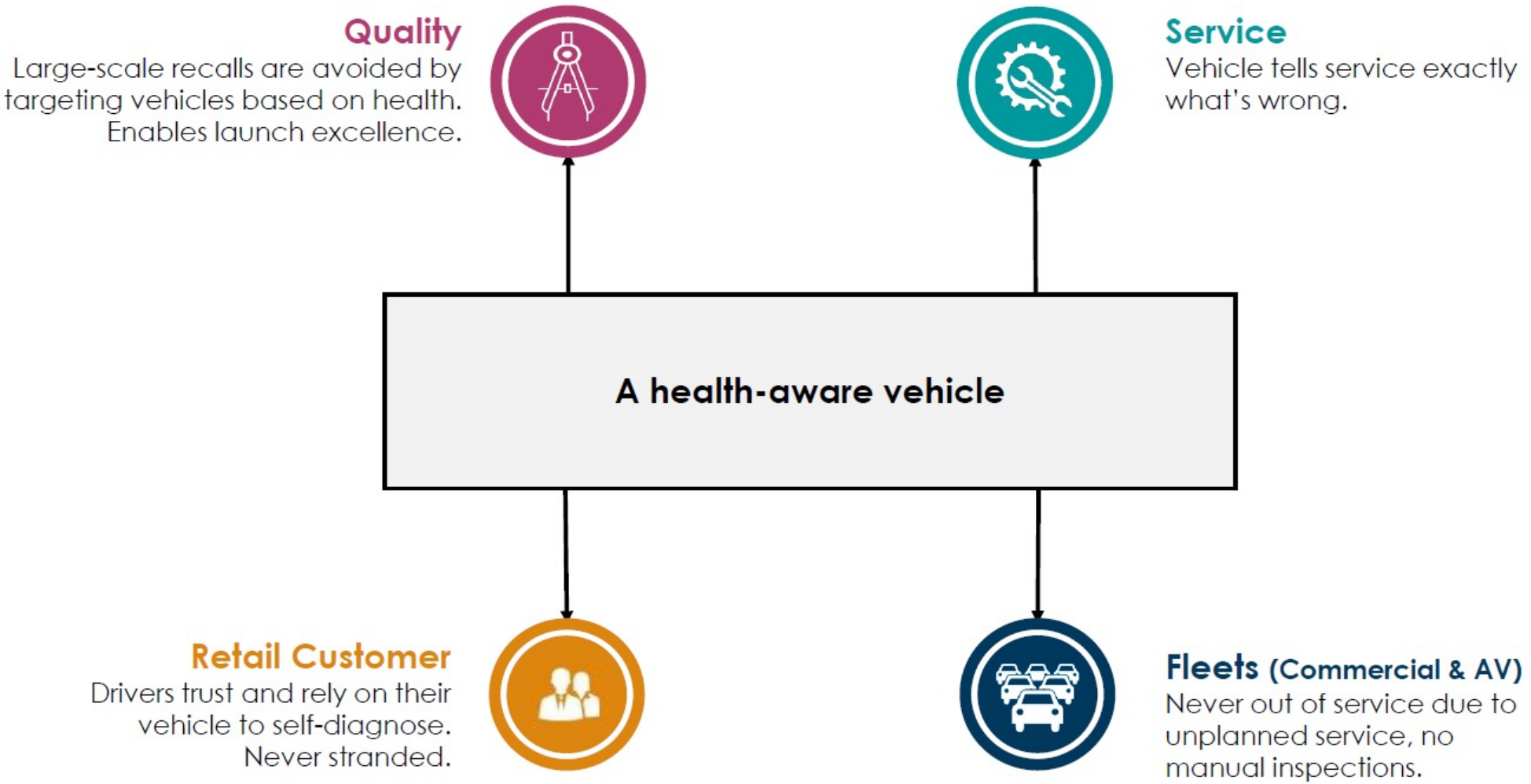
RESEARCH & DEVELOPMENT

VHM at GM

- Started in 2005
- Use telemetric data to monitor fleet health
- Proactive Alert launched for MY16+ customer vehicles for 12V battery and starting systems

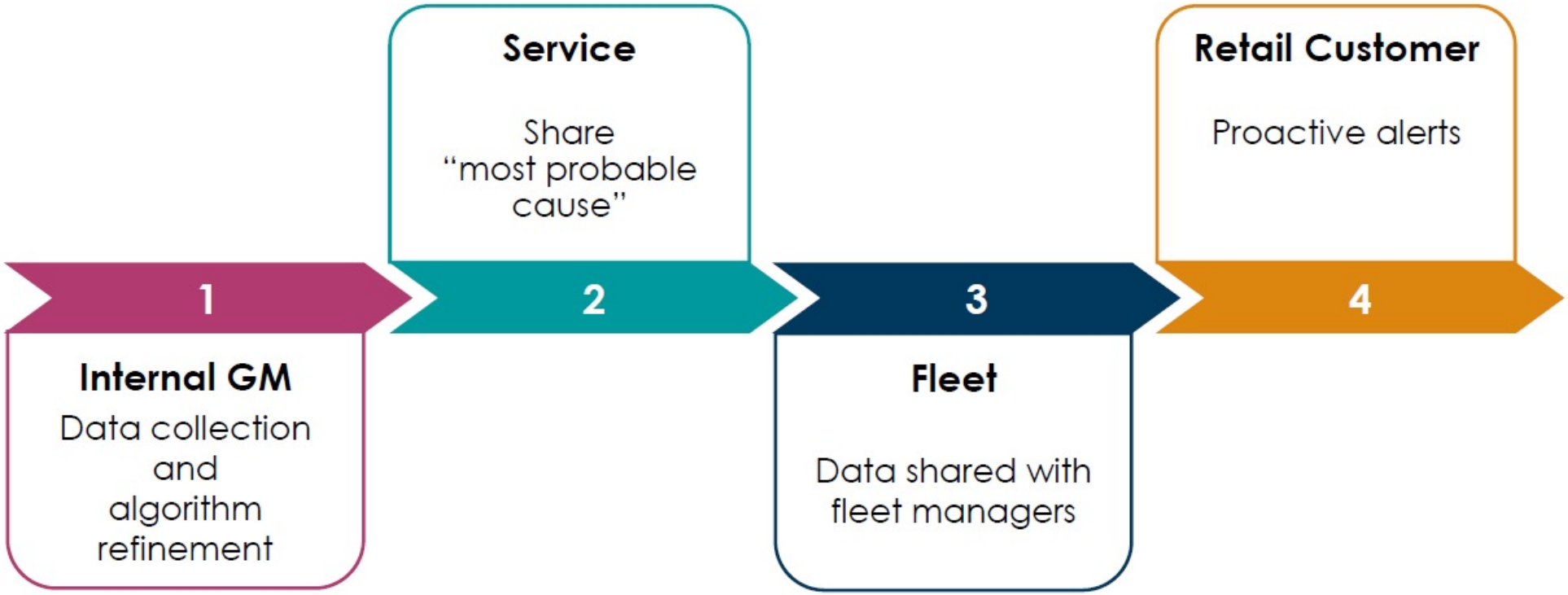


Benefits to GM



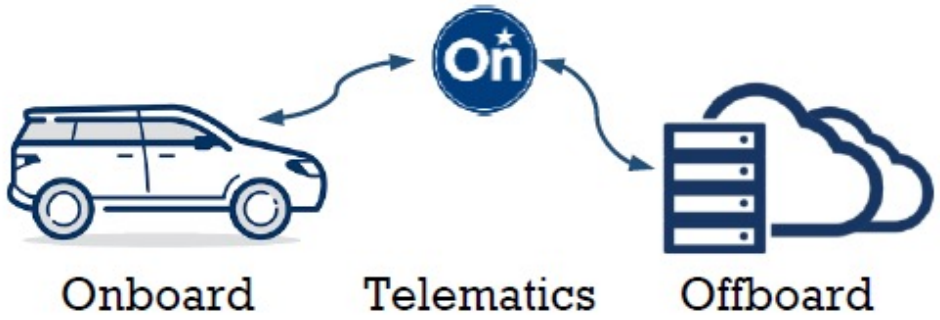
RESEARCH & DEVELOPMENT

Progression of Applications

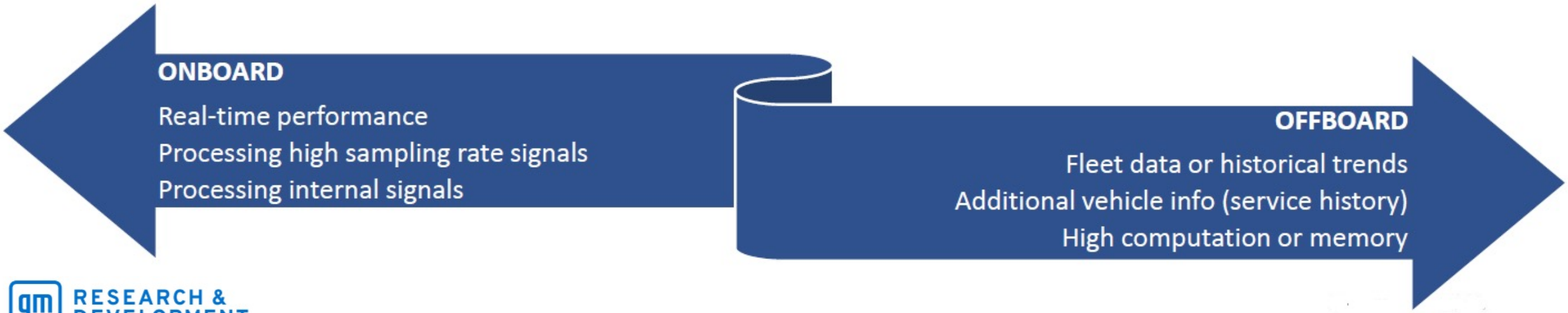


RESEARCH & DEVELOPMENT

Challenges in Data Collection & Transmission



- Design proper partition between onboard and off-board to reduce data volume for practical applications



Challenges in Data Modeling

Imbalanced data and labels

- Mostly from health conditions
- Lack of failure mode data and ground truth labels

Novelties and adaptation

- Impossible to comprehend all failure mode scenarios during initial design
- Maintain model fidelity adapting to new information

Robustness and scalability

- Scalable in multiple dimensions including different programs, # of vehicles, various operating conditions, etc.

Unlocking the Potential of Automotive PHM

Time for Q&A now, moderated by Tim Felke…

🤔

Thank you! 🤗

Thank you to all of you who attended today's panel on **Unlocking the Potential of Automotive PHM**. And thanks to our panelists for their time and perspective.

If you would like to continue these discussions and network with the other conference attendees, please use conference **Chat**

Enjoy the rest of the conference!