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Smart Features Integrated for Prognostics Health Management Assure the Functional Safety of the Electronics Systems at the High Level Required in Fully Automated Vehicles

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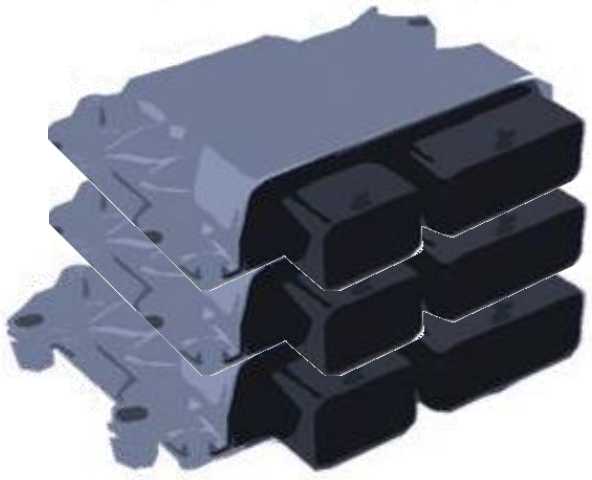
Introduction

- Automated Cars: Number & Complexity of ECUs ↑, Driver → Passenger

  ⇒ Functional safety requirement exceeds today's automotive spec

- SoA approach: System-level redundancy → Will soon be unaffordable



- New approach in AE: Active Prognostic Health Management (PHM)

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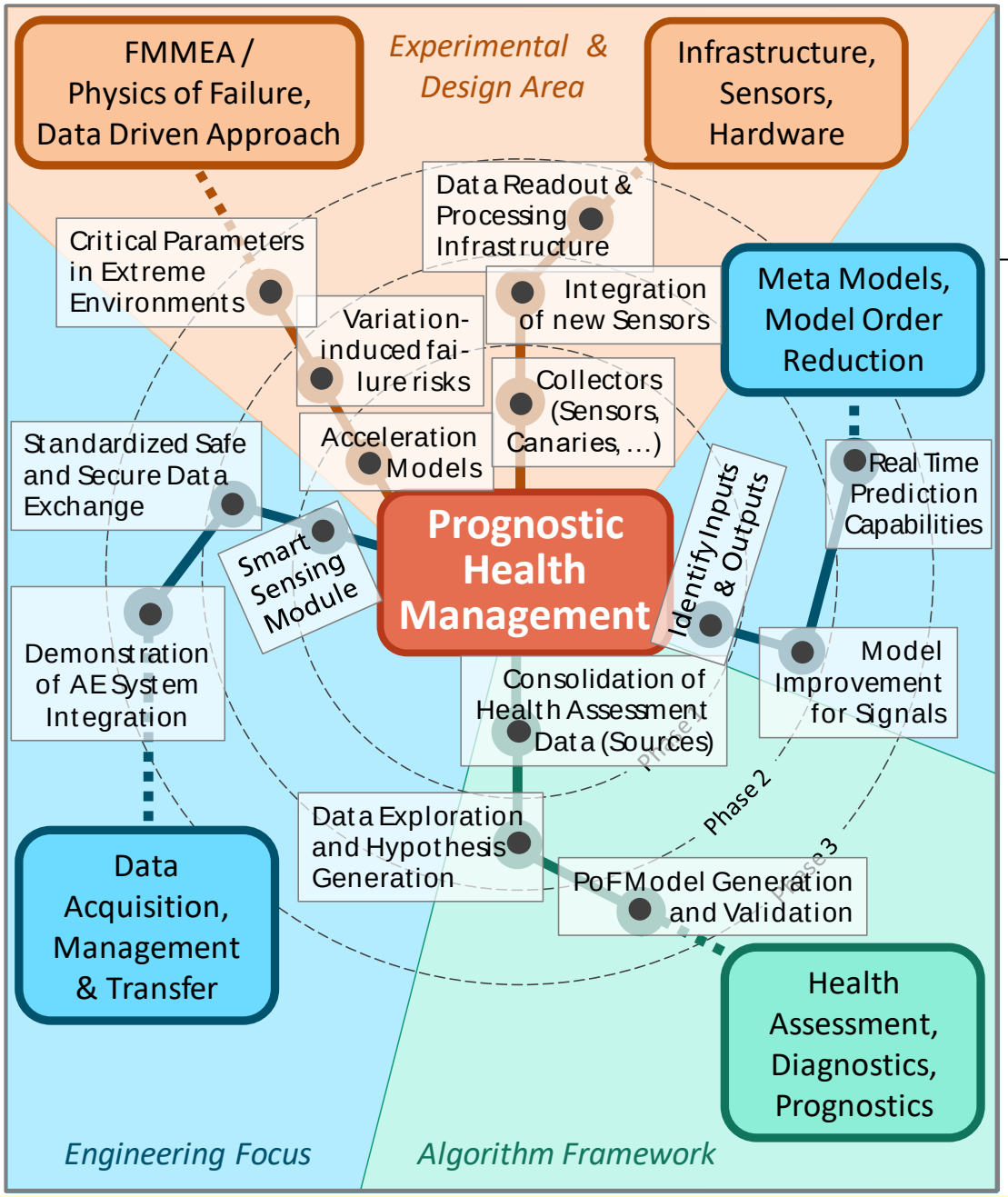


Prognostics and Health Management (PHM)

- Developing the required infrastructure, sensors, electronic HW
- Studying and characterizing the Failure Modes and Mechanisms by thorough Effect Analyses for PoF & data driven approaches
- Providing appropriate solutions to the data acquisition, management, and secure data transfer
- Performing data fusion for reaching at an integrated single health assessment, diagnostics, and prognosis score per application
- Establishing highly efficient yet precise metamodeling and model order reduction schemes that can be executed in each of the individual cars locally assisted by self-learning capabilities provided by cloud service

Dedicated stops and three methodology research phases → Strategy: PHM integrated into ECS

Development of a Comprehensive Scheme of Multi-level **Prognostics and Health Management (PHM)**

PHM features: Self-Detecting

1. Circuit-level: Event detectors added
   Wafer-level: Sensors added to the ICs
   IC component-level: Extra solder joints
2. Passive component-level: Canaries
3. Board component-level: Local warpage

PHM objects: Self-Monitoring

4. Board-level: Smart sensors provide data

Local PHM Unit: Self-Diagnosing

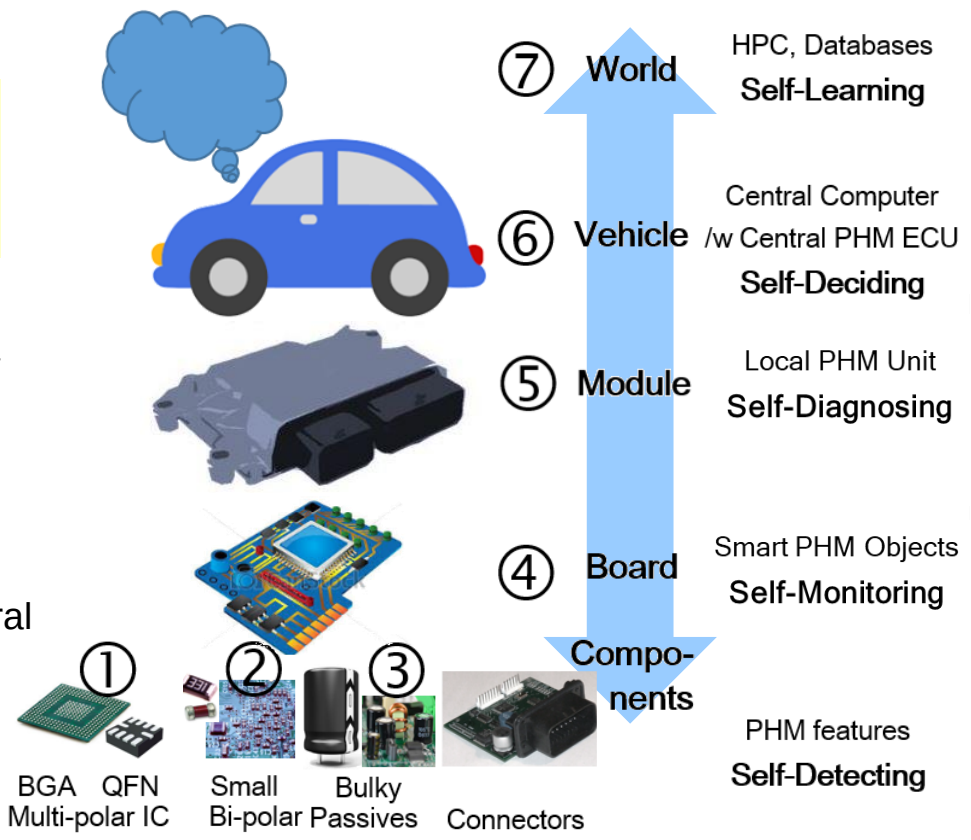
5. Module-level: One SiP collects, prepro-
   cesses & communicates the PHM data

Central PHM ECU: Self-Deciding

6. Vehicle-level: PHM ECU inside the central
   computer determines RUL based on mel
   models and compiles the 'health score'

PHM Cloud & Swarm: Self-Learning

7. Global Level: Database & HPC support



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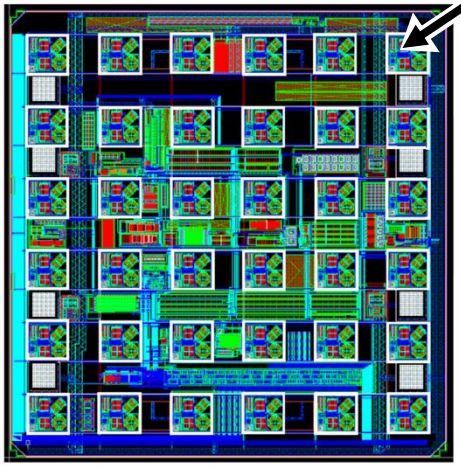
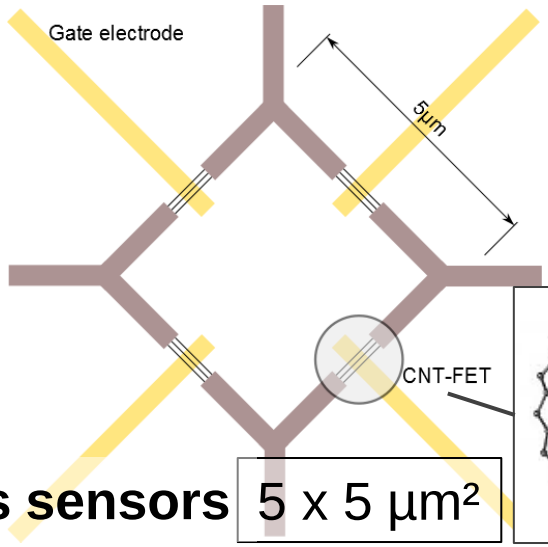
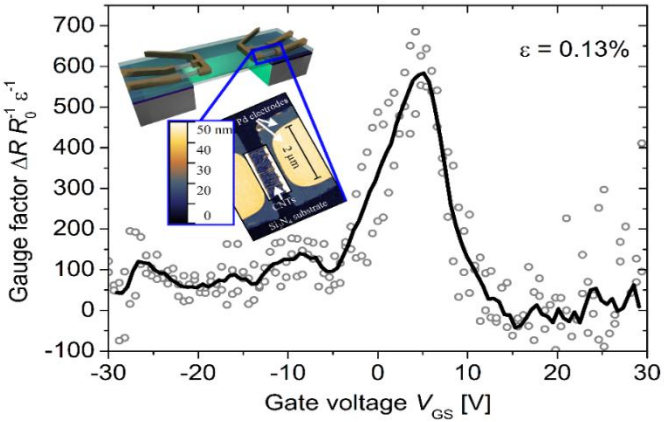
Integrated Smart Features

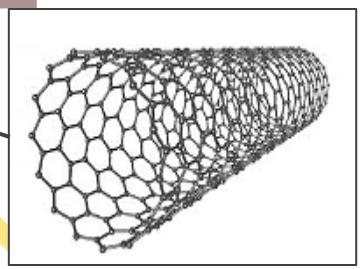
for Prognostics and Health Management

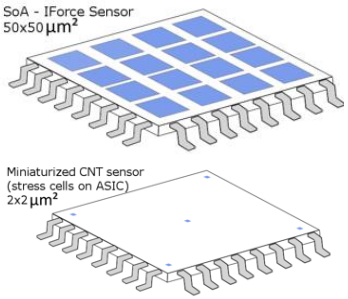
PHM Feature @ wafer-level: **Sensors added to the ICs**











CNT based stress sensors 5 x 5 µm²

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in cooperation with TU Chemnitz, ZfM

Integrated Smart Features

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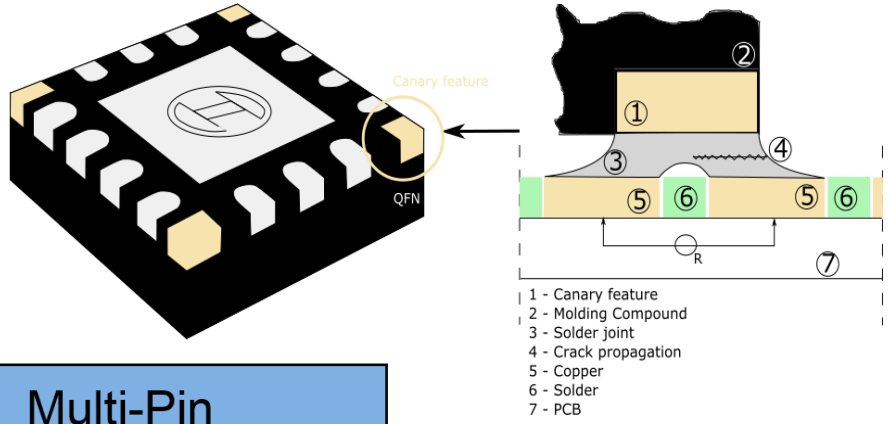
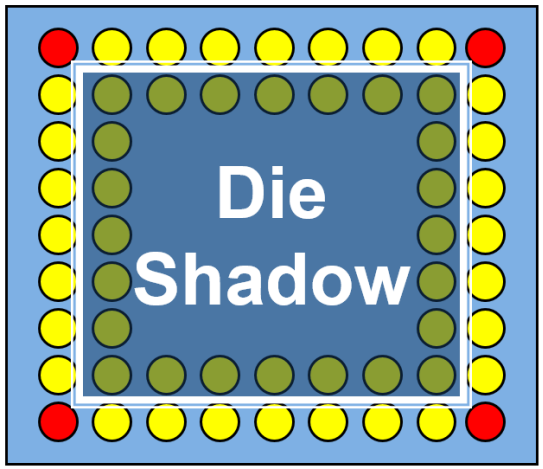
PHM Feature

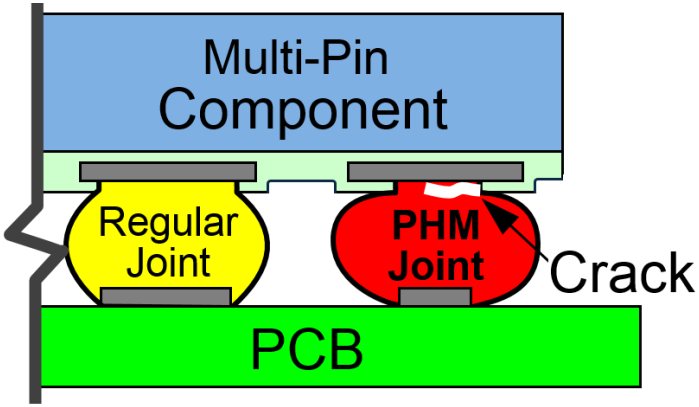
@ IC component-level:

Dedicated /

Extra solder joints







PHM joints placed at critical position and on pads that accelerate failures

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PHM Feature @ Passive component-level: **Canaries**

CHAUHAN *et al.*: INTERCONNECT FAILURE PREDICTION USING CANARIES

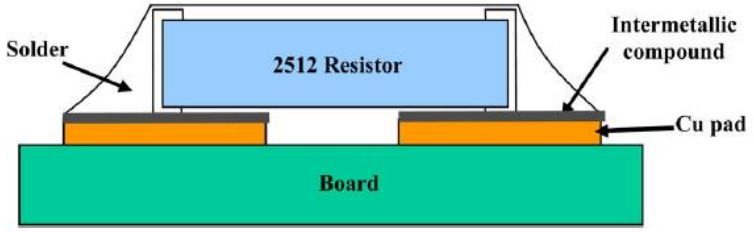


Fig. 1. Schematic of cross-sectional view of resistor assembly.

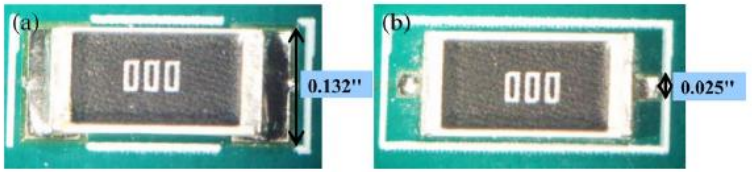
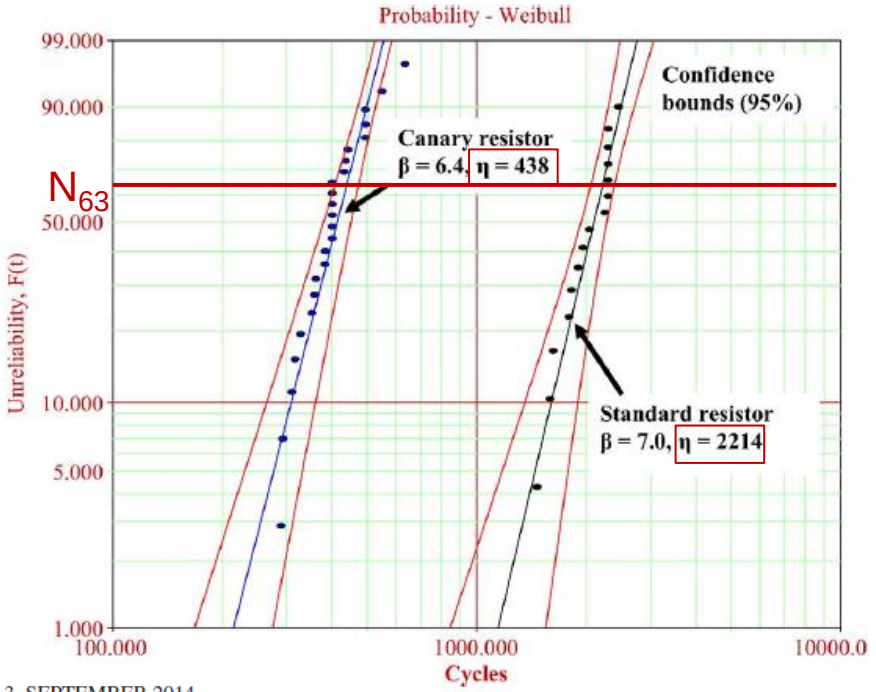


Fig. 2. (a) Standard pad resistor, and (b) Canary resistor.



IEEE TRANSACTIONS ON DEVICE AND MATERIALS RELIABILITY, VOL. 14, NO. 3, SEPTEMBER 2014

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PHM Feature @ Board component-level: **Local warpage**

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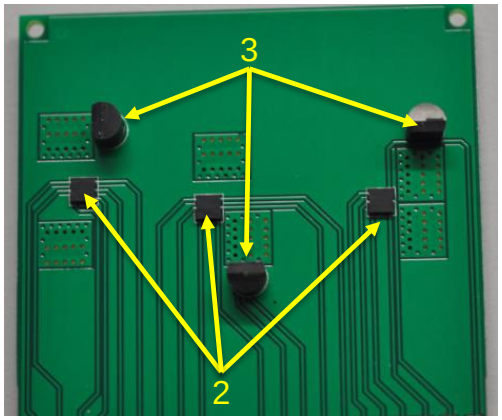
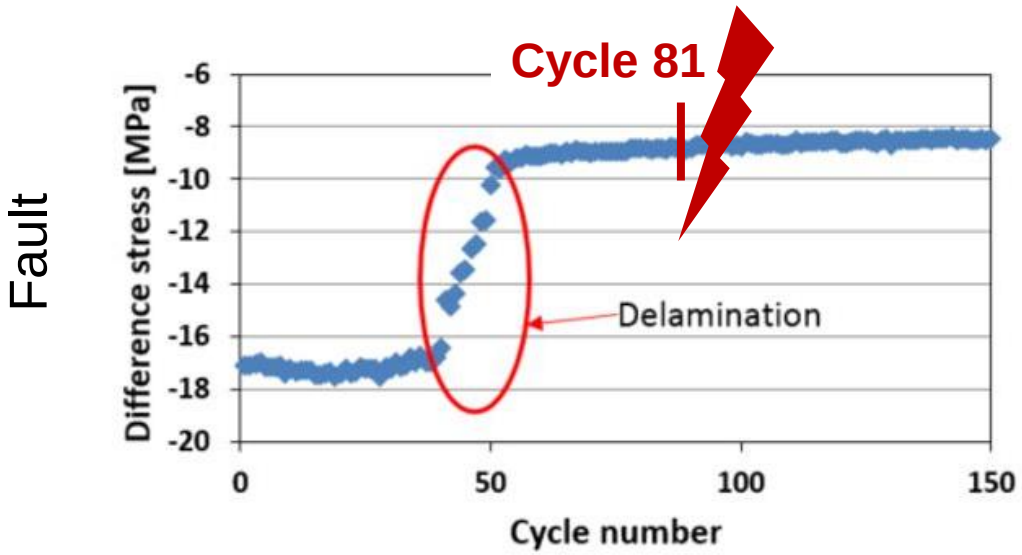
PHM Feature @ Board component-level: **Local warpage**



2 – Stress Sensor

3 – Temperature Sensor



Stress evolution underneath the device

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Development of a Comprehensive Scheme of Multi-level **Prognostics and Health Management (PHM)**

Further challenges requiring advances in Reliability Methodology:

Assessment of the **Field Data**: Handle the Data Flood / Correlate to Tests

Identify Key Failure Indicators (**KFI**) for Triggering Maintenance / Repair

Determine Remaining Useful Life (RUL) by Exp. & Sim. ⇒ **RUL-Models**

Metamodeling: Determine most effective Input & Output Parameters

Health Score: Fuse all PHM Data into a Single Quantity → Maintenance

Self-Learning: Load case & damage parameter systematics ← Databases

Self-Learning: **Automated** Load Case Assessments by Simulation ← HPC

Applicable PHM strategies - Ready for implementation by RIA

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