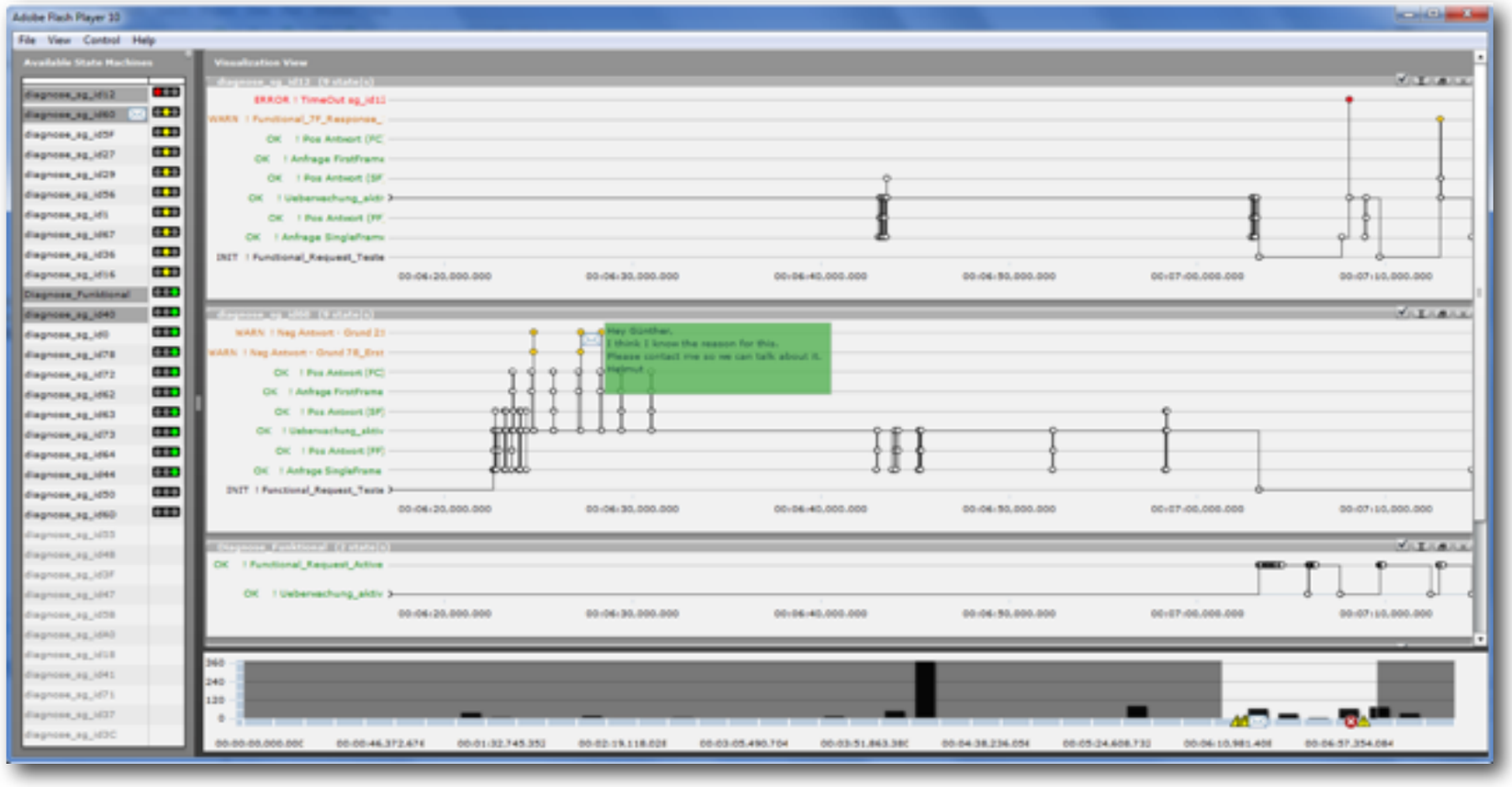
Michael Sedlmair
msedl@cs.ubc.ca

10-05-2011

Cardiogram: Visual Analytics for Automotive Engineers

Sedlmair, Isenberg, Baur, Mauerer, Pigorsch, Butz



Design Studies

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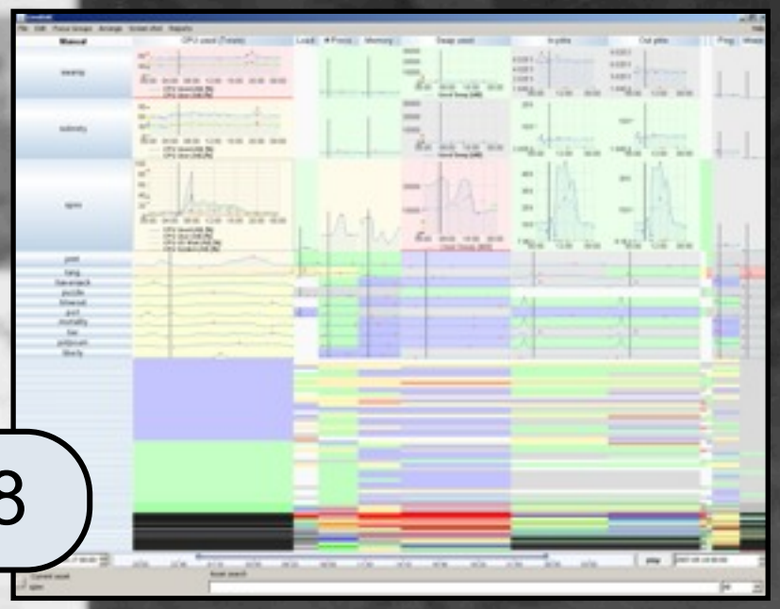
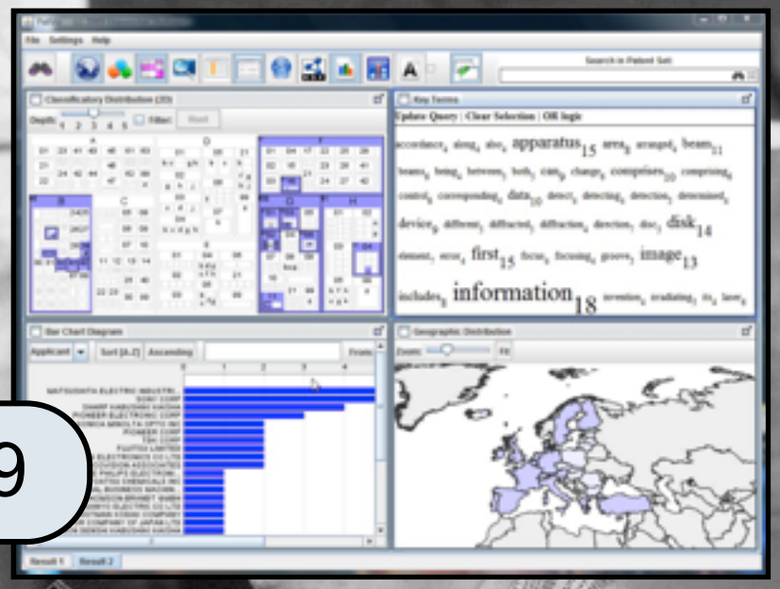
Design Studies

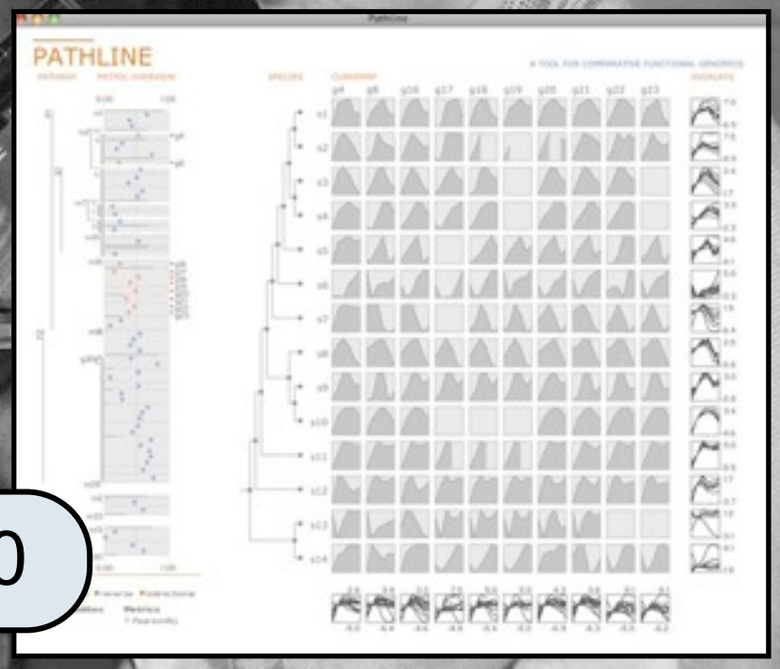
McLachlan et al., CHI 2008



Koch et al., VAST 2009



Meyer et al., InfoVis 2010



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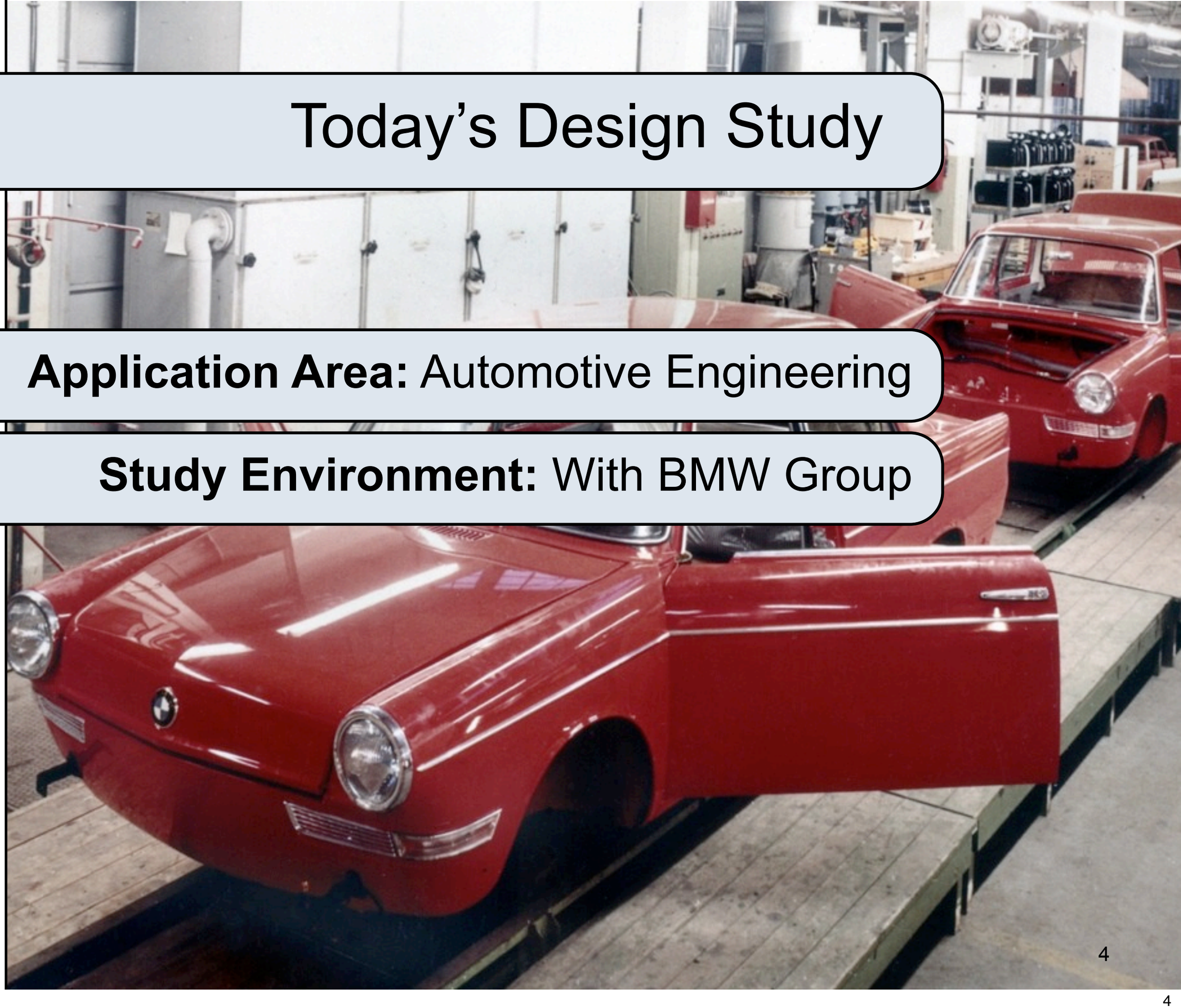
Today’s Design Study

Application Area: Automotive Engineering

Study Environment: With BMW Group



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Outline

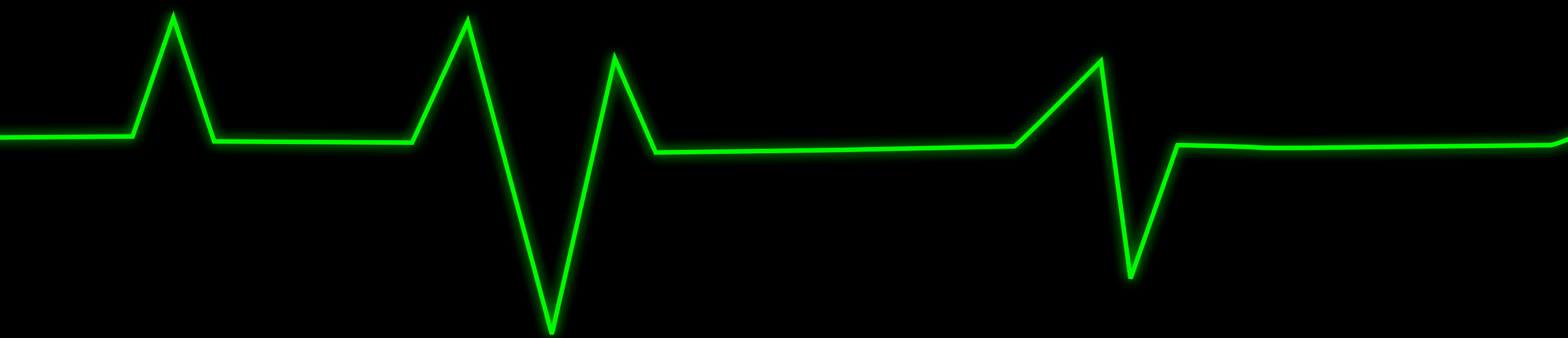
Problem and Requirement Analysis

Design of **Cardiogram**

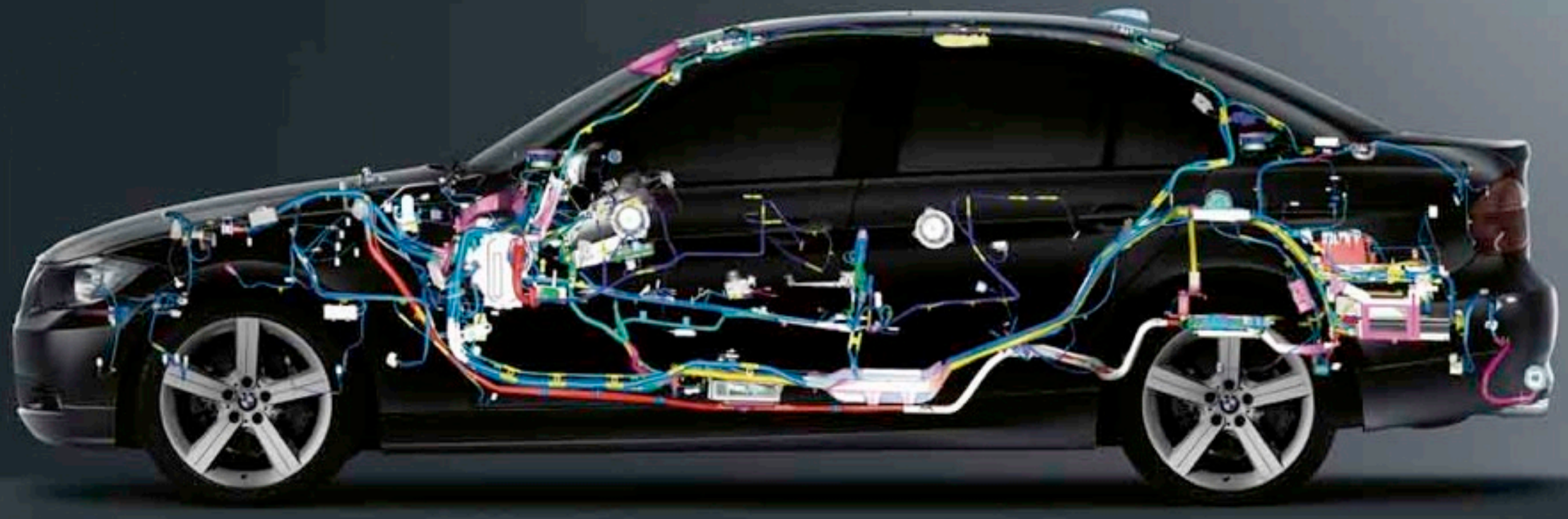
Evaluation of **Cardiogram**

5

Problem
&
Requirements

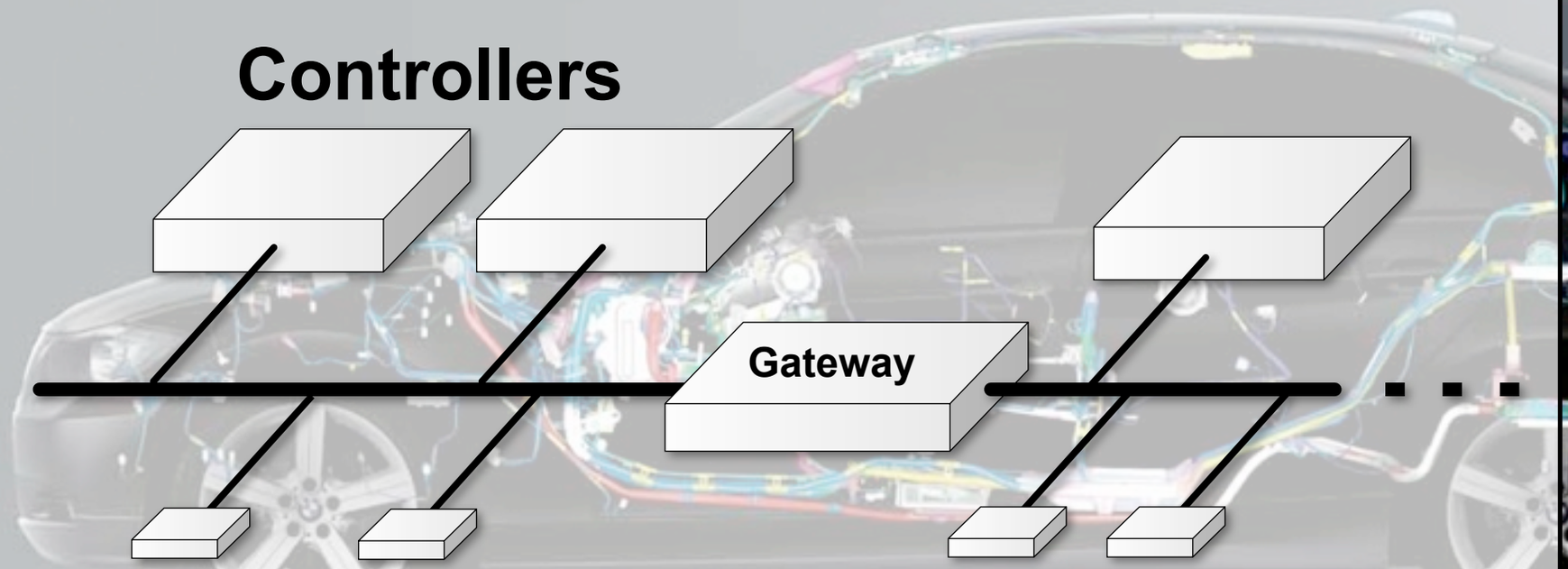


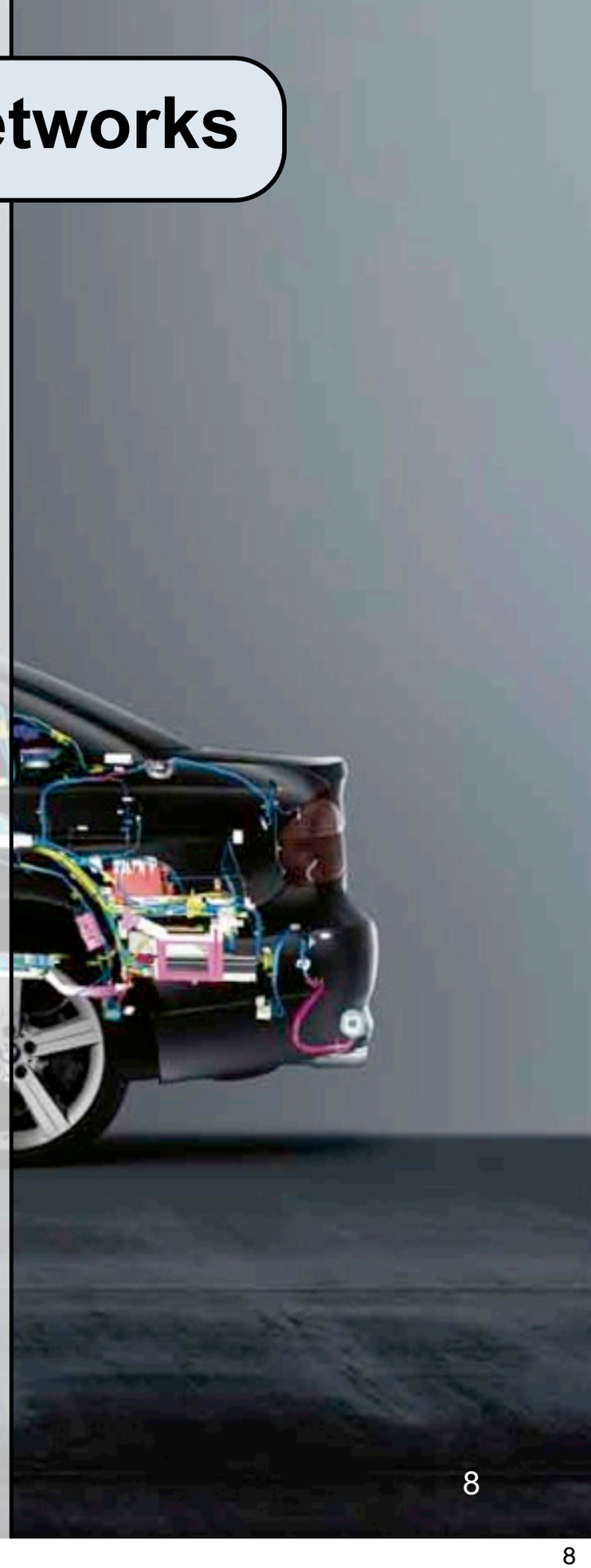
General Motivation: More and more electronics...



7

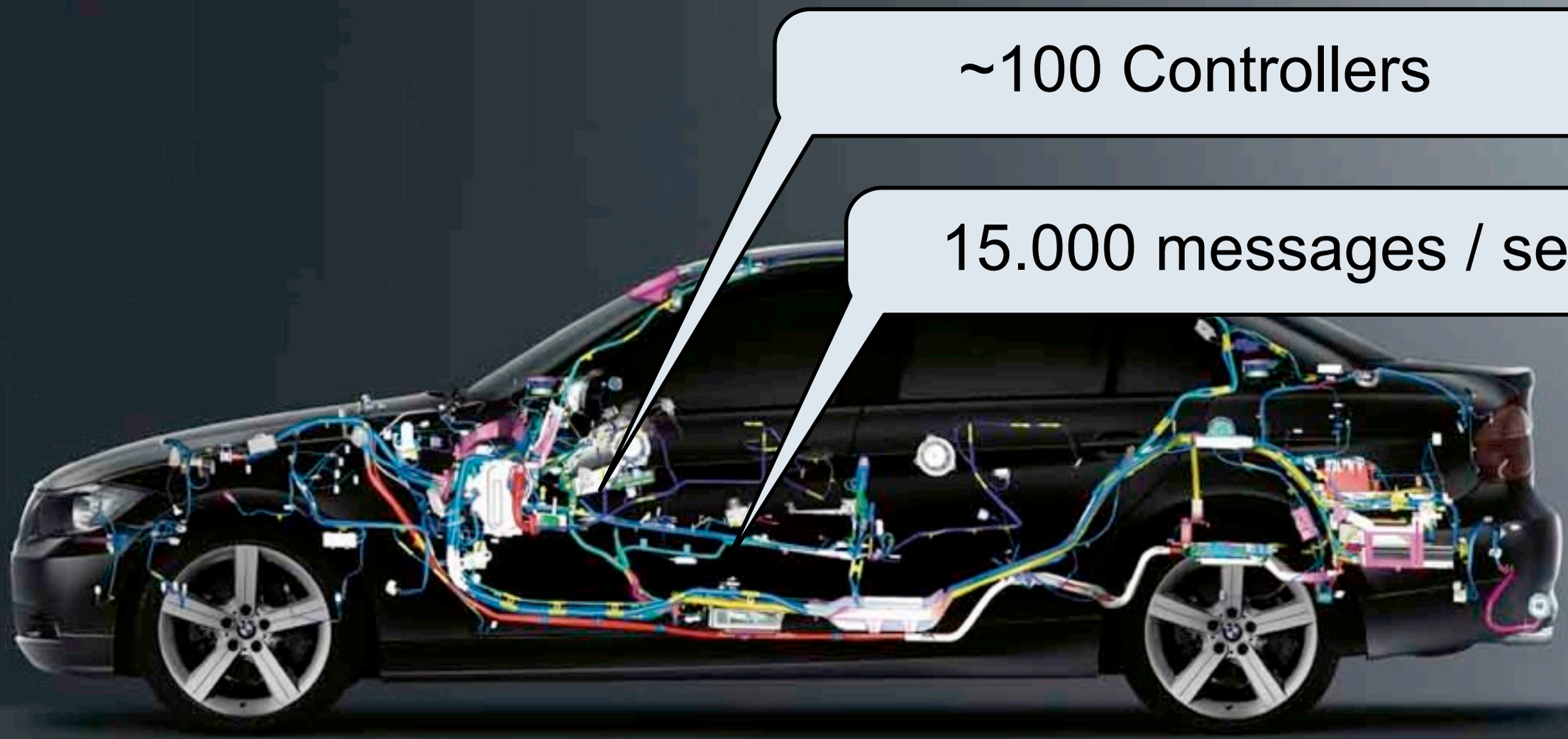
... Enabled by In-car Communication Networks





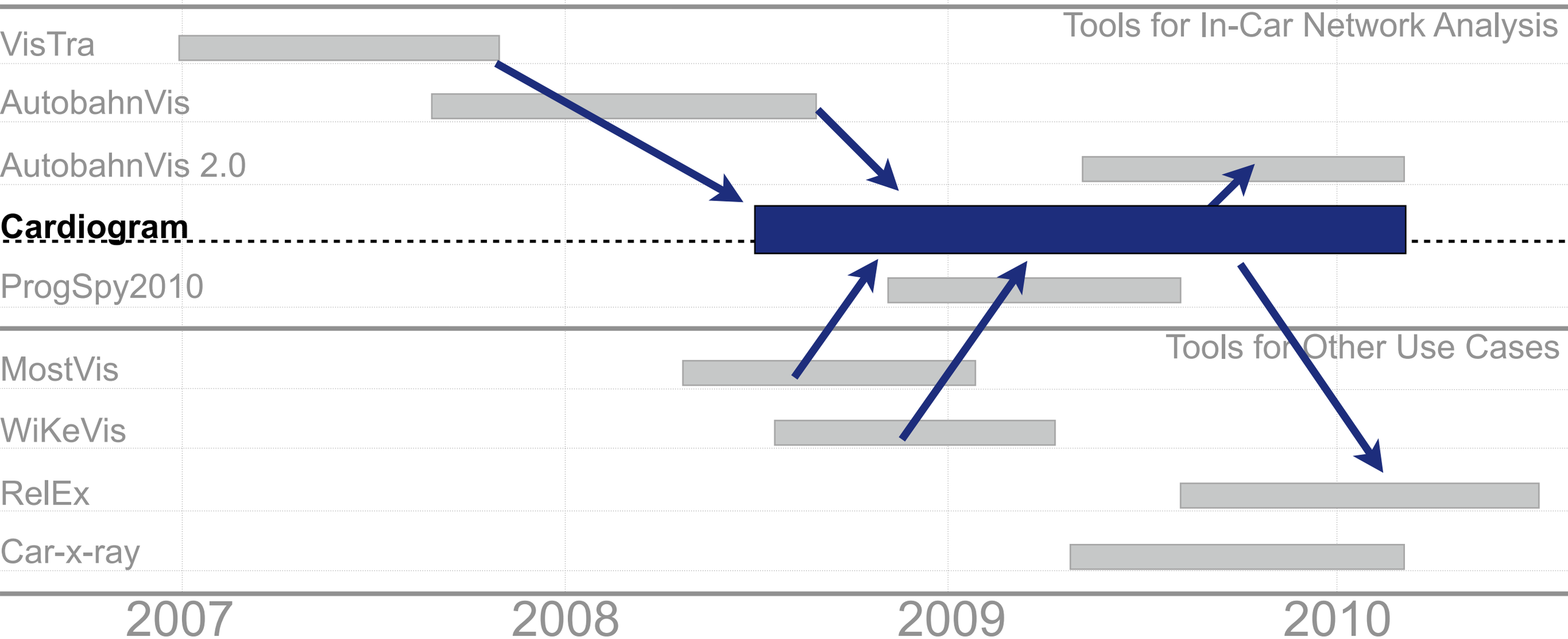
8

General Problem: It got complex...



General Challenge: Understand Network Data

9



Methodology

Studies with and without tools

~150 Engineers / 3.5 years

Grounded Theory

Our Focus Today

Target Users: In-car Network Analysts

Task: Find errors in in-car communication networks

Procedure: Test drives and data analysis

Data: Recorded Traces (List of network messages)

A usual trace (15 minutes): ~10 million msg.

~100 traces / error case

```
75836...  F...  55                          Rx    16   5a 77 f8 27 00 20 00 20 20 0f 00 0...
75851...  1     1a1   V_VEH                 Rx    5    c1 f7 00 00 8a
  V_VEH_COG                 0 km/h          [          0]
  ST_ECU_V_VEH    Sig
  QU_V_VEH_COG    Si
  DVCO_VEH        F
  CRC_V_VEH                 193             [          c1]
  ALIV_V_VEH
75851...  F...  5c
75851...  1     1c4
75851...  F...  12f                         Rx    72   00 00 00 00 00 00 ff 59 87 21 4c 0...
75851...  1     1c5                         Rx    6    02 00 04 00 ff ff
75836...  F...  1                           Rx    16   10 7d 18 28 00 20 00 20 20 0f 00 0...
75836...  F...  2                           Rx    16   ca 76 f9 27 00 20 00 20 20 0f 00 0...
75836...  F...  3                           Rx    16   6a 7d fa 27 00 20 00 20 20 0f 00 0...
75836...  F...  4                           Rx    16   a3 76 0e 28 00 20 00 20 20 0f 00 0...
75836...  F...  5                           Rx    16   2c f7 1f 00 02 20 ff 21 22 22 07 f...
75851...  F...  7                           Rx    16   6d f9 76 12 75 d2 6f f2 70 f2 01 1...
75851...  F...  12                          Rx    0
75851...  2     301   AVL_STEA_DV           Rx    7    51 15 f8 7f ff 7f 11
75851...  3     301   AVL_STEA_DV           Rx    7    51 15 f8 7f ff 7f 11
75851...  4     137                         Rx    2    fd 00
75851...  3     d9    ANG_ACPD              Rx    8    9b 99 00 c0 00 e0 7f f0
75848...  1     299                         Rx    5    9f ff ff ff ff
75851...  F...  21                          Rx    0
75851...  4     a5    TORQ_CRSH_1           Rx    8    45 f5 48 f7 7f 00 00 fc
75851...  3     a5    TORQ_CRSH_1           Rx    8    fe f9 48 f7 7f 00 00 fc
75836...  F...  23                          Rx    16   7c 10 05 05 ea f3 53 20 74 10 20 f...
75851...  F...  26                          Rx    0
```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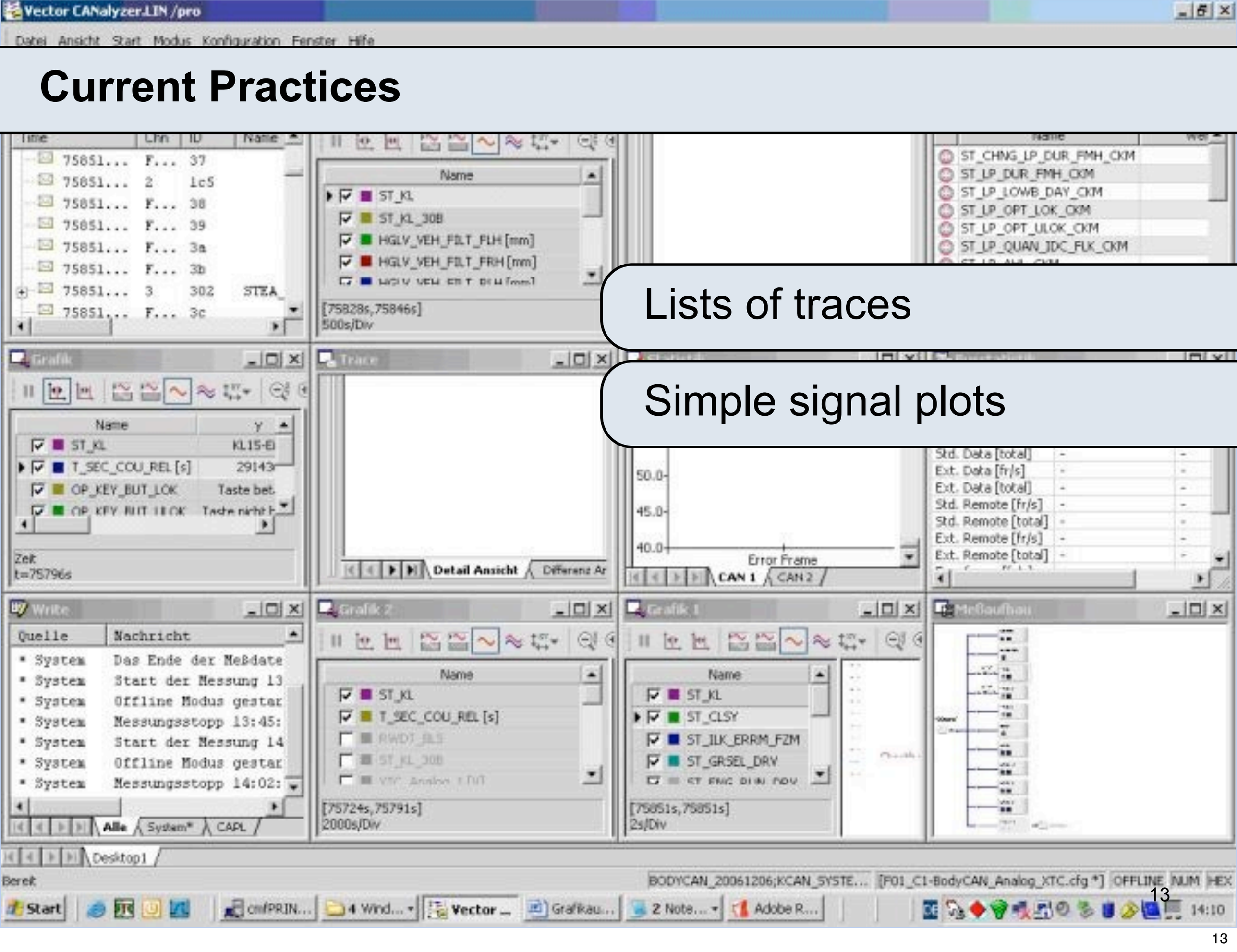
Current Practices



Lists of traces

Simple signal plots

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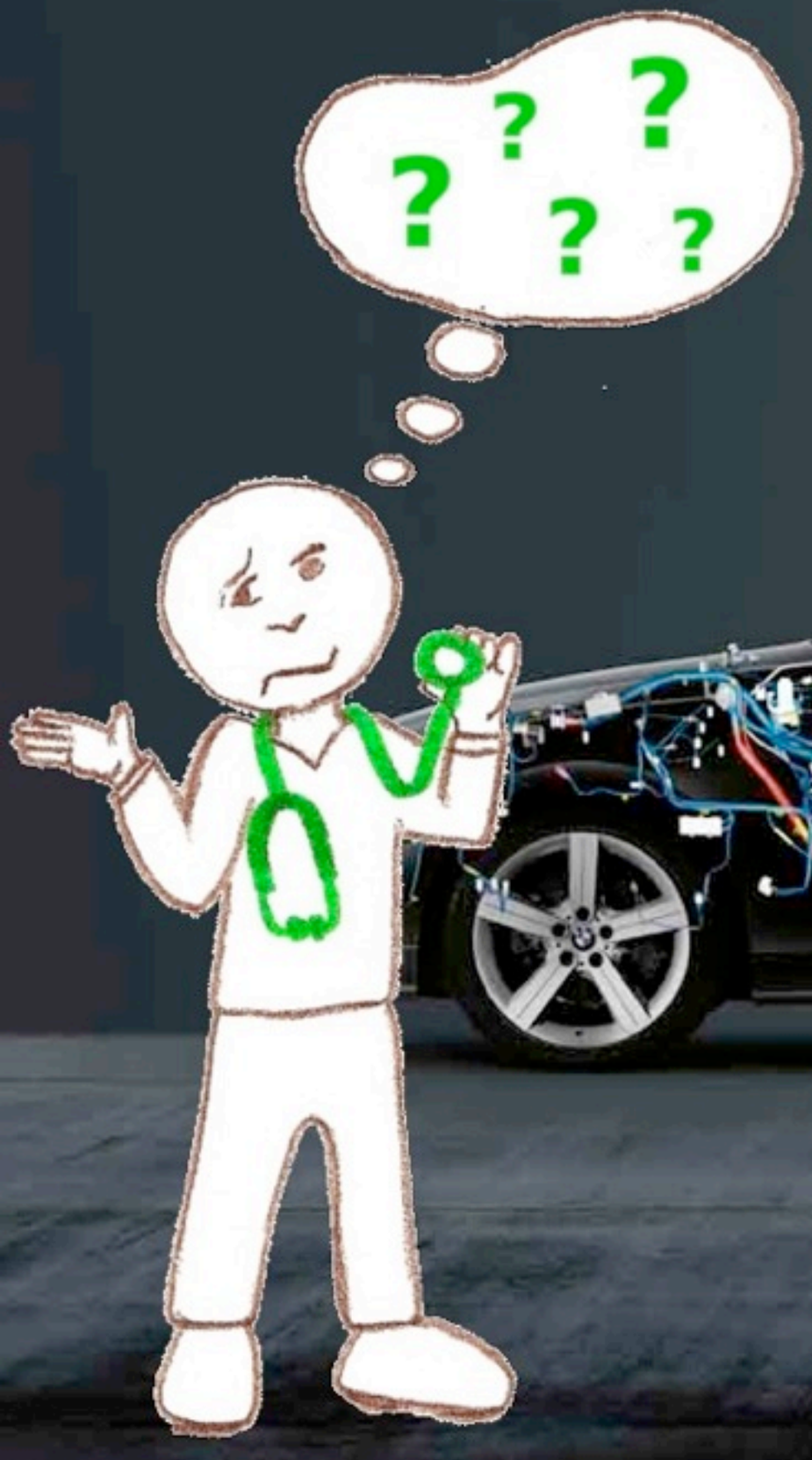
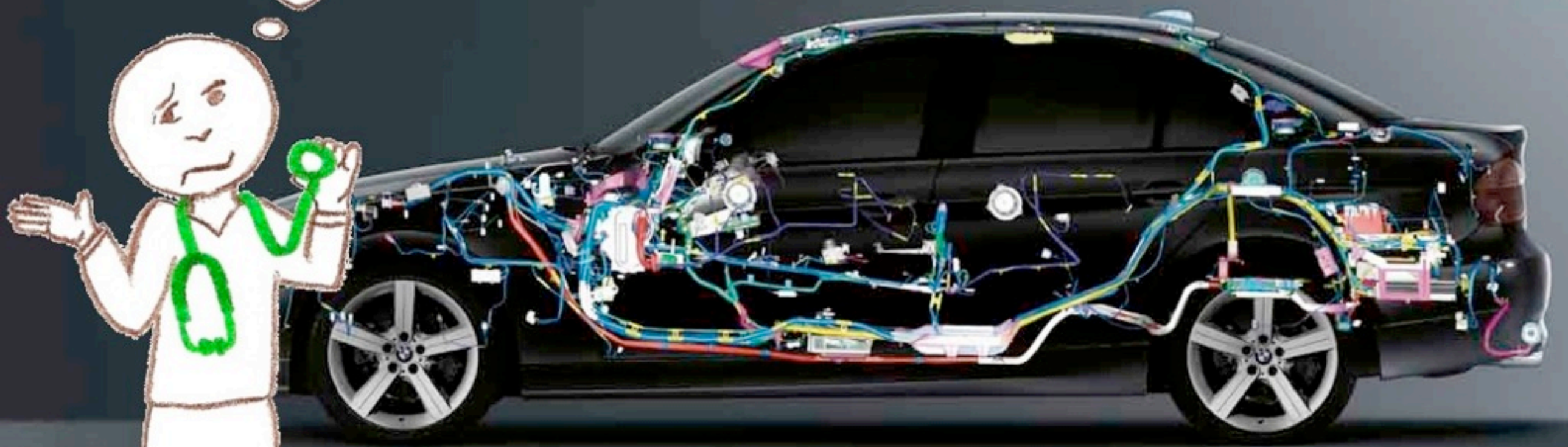
(Some) Problems





Distributed errors?

Car Behaviour vs. Trace?

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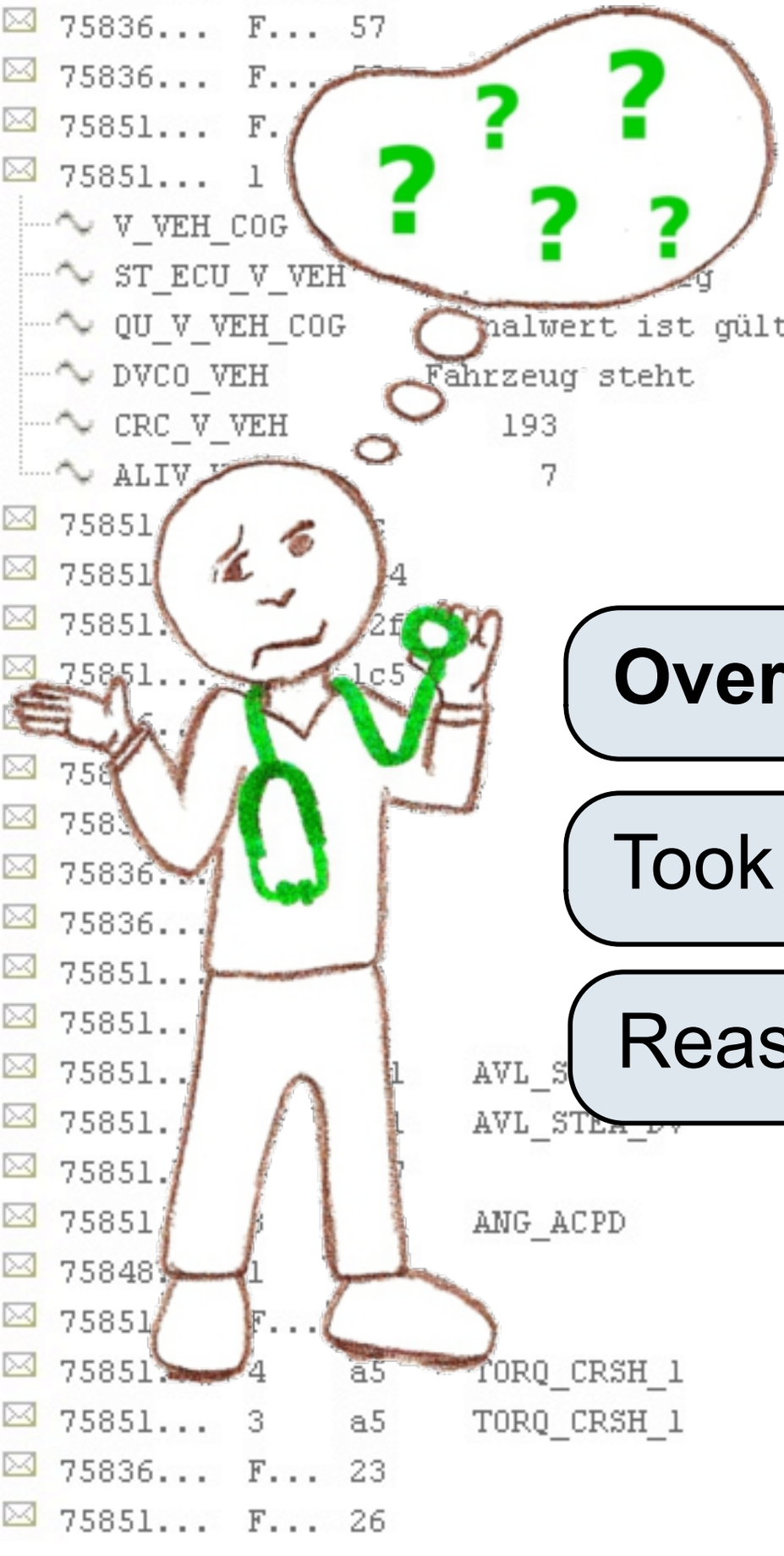
An Example Problem



Overpressure Sensor Problem

Took Engineers ~4 Month

Reason: All 4 doors slammed simultaneously

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Deriving Requirements

- **Handling the masses of data**
  - *Data abstraction and automated filtering*
  - *Support for automated error detection*
  - *Avoid repetitive work and unnecessary iterations*
- **New Perspectives on Complex Errors**
  - *Beyond raw data and signal plots*
  - *Visual Overview Techniques*
  - *Multiple, modular and coordinated solutions*
- **Engineer-centered solutions**
  - *Fast access to raw data*
  - *Familiarity*
  - *Support collaboration*

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Requirements: Today's Focus

- **Handling the masses of data**
  - ***Data abstraction and automated filtering***
  - ***Support for automated error detection***
  - *Avoid repetitive work and unnecessary iterations*
- **New Perspectives on Complex Errors**
  - *Beyond raw data and signal plots*
  - *Visual Overview Techniques*
  - *Multiple, modular and coordinated solutions*
- **Engineer-centered solutions**
  - *Fast access to raw data*
  - *Familiarity*
  - *Support collaboration*

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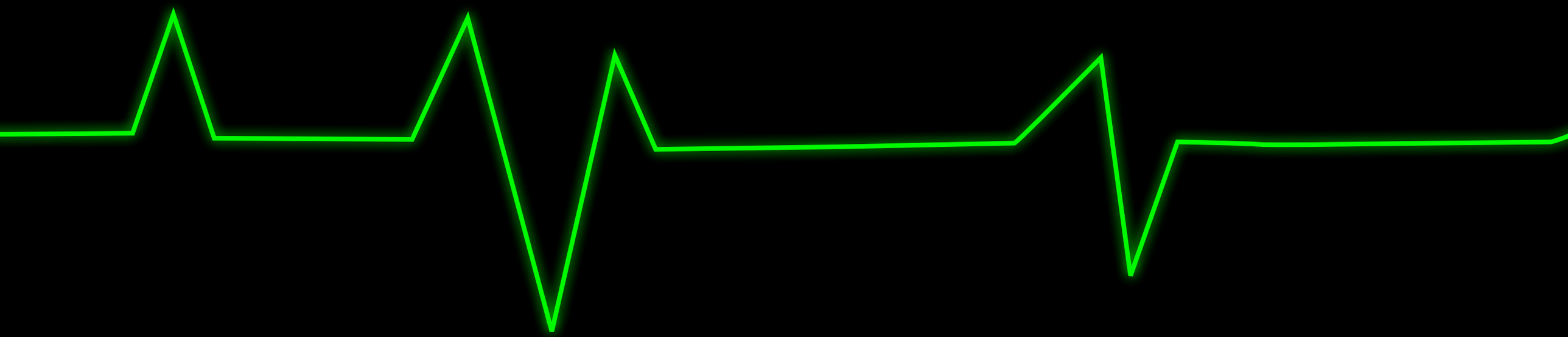
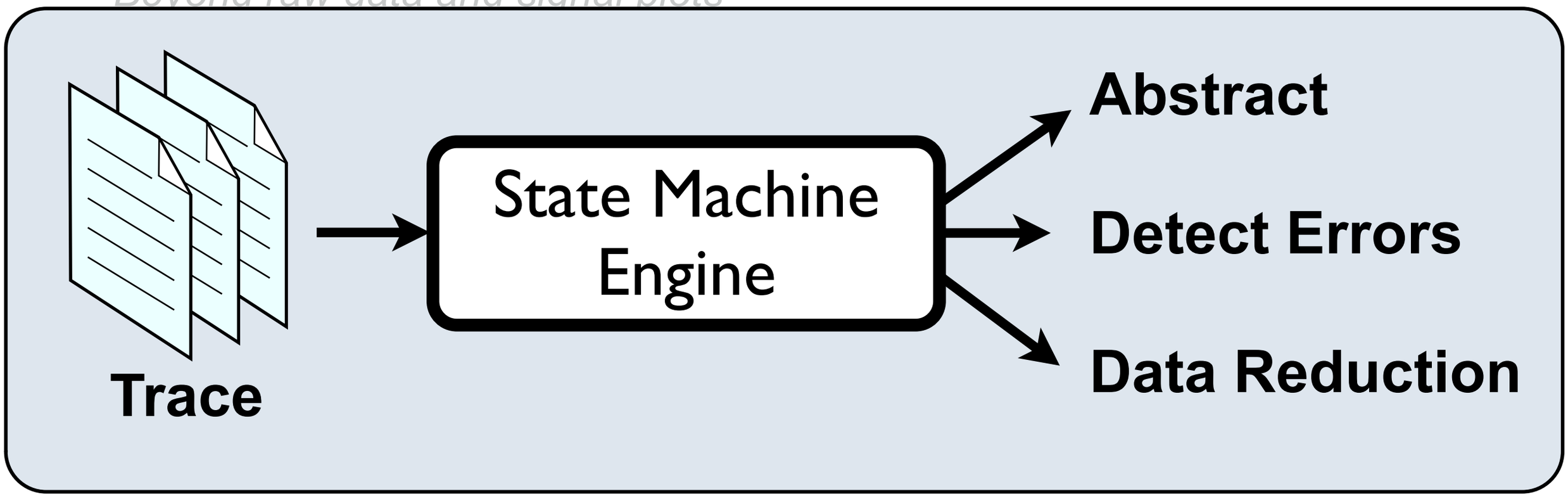
Our Solution:
Cardiogram



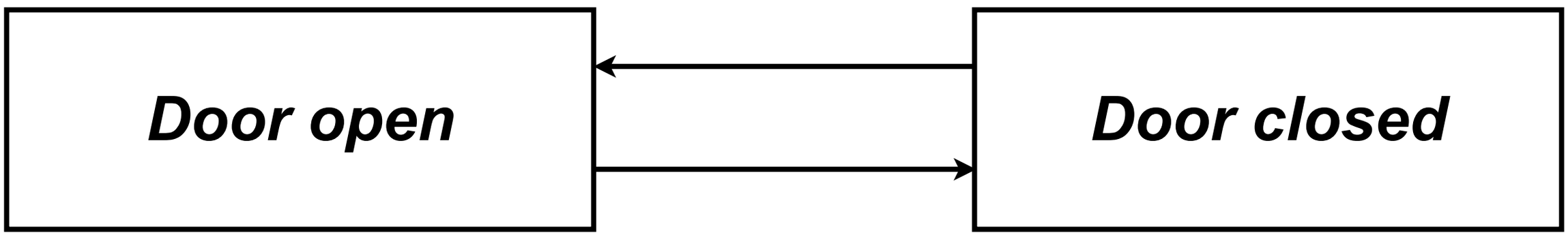
Our idea: Using State Machines

- **Handling the masses of data**
  - ***Data abstraction and automated filtering***
  - ***Support for automated error detection***
  - *Avoid repetitive work and unnecessary iterations*
- **New Perspectives on Complex Errors**
  - *Beyond raw data and signal plots*



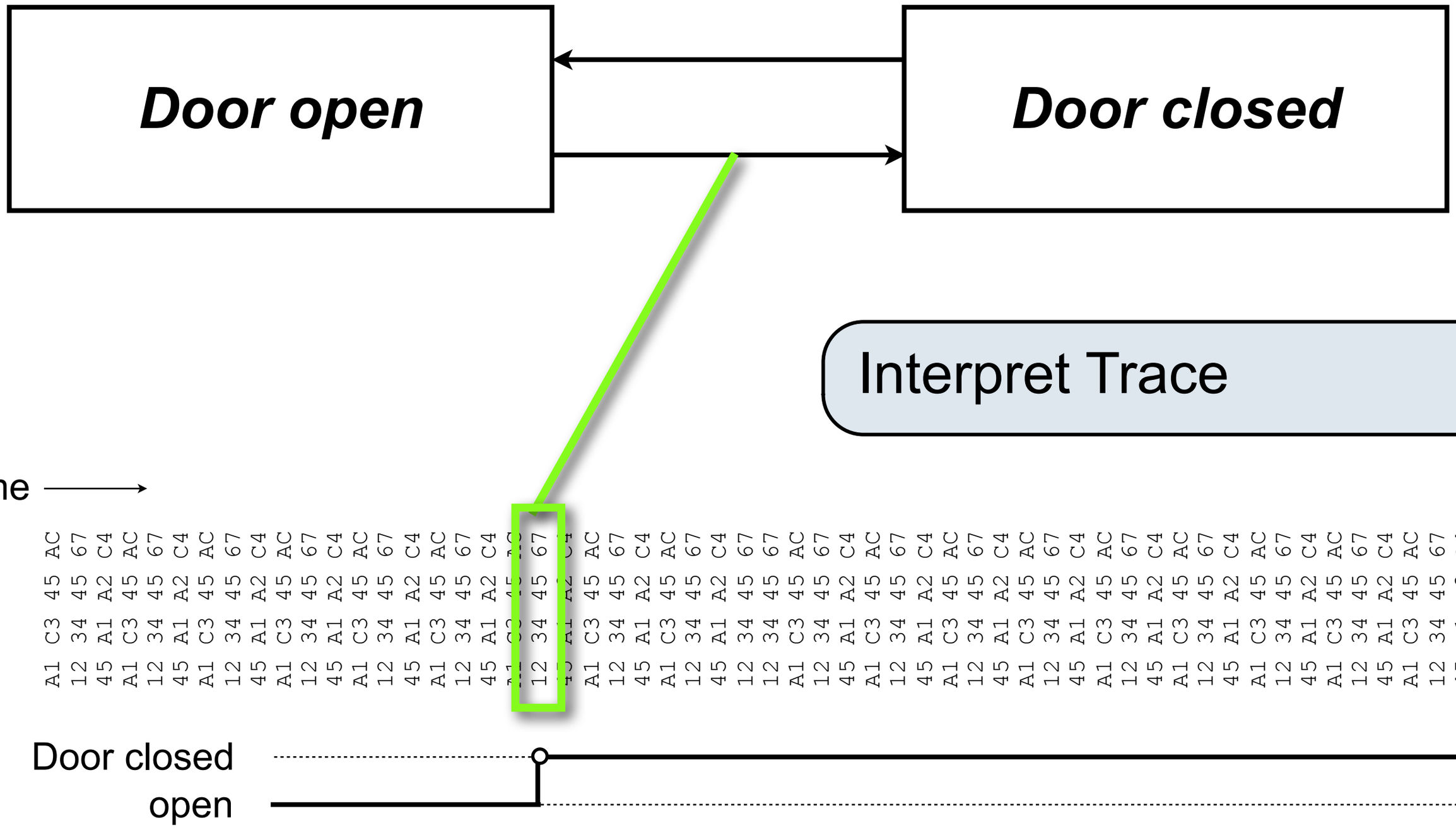
19

Abstraction: SMs to Interpret Vehicle Behavior (simplified)



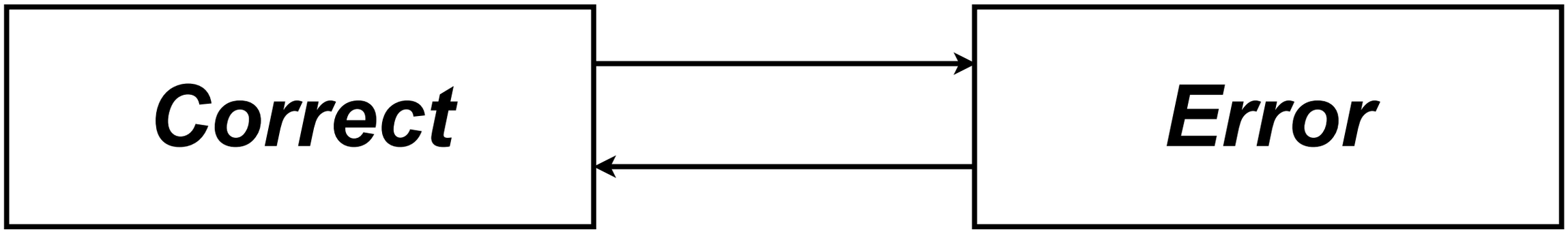
20

Abstraction: SMs to Interpret Vehicle Behavior (simplified)

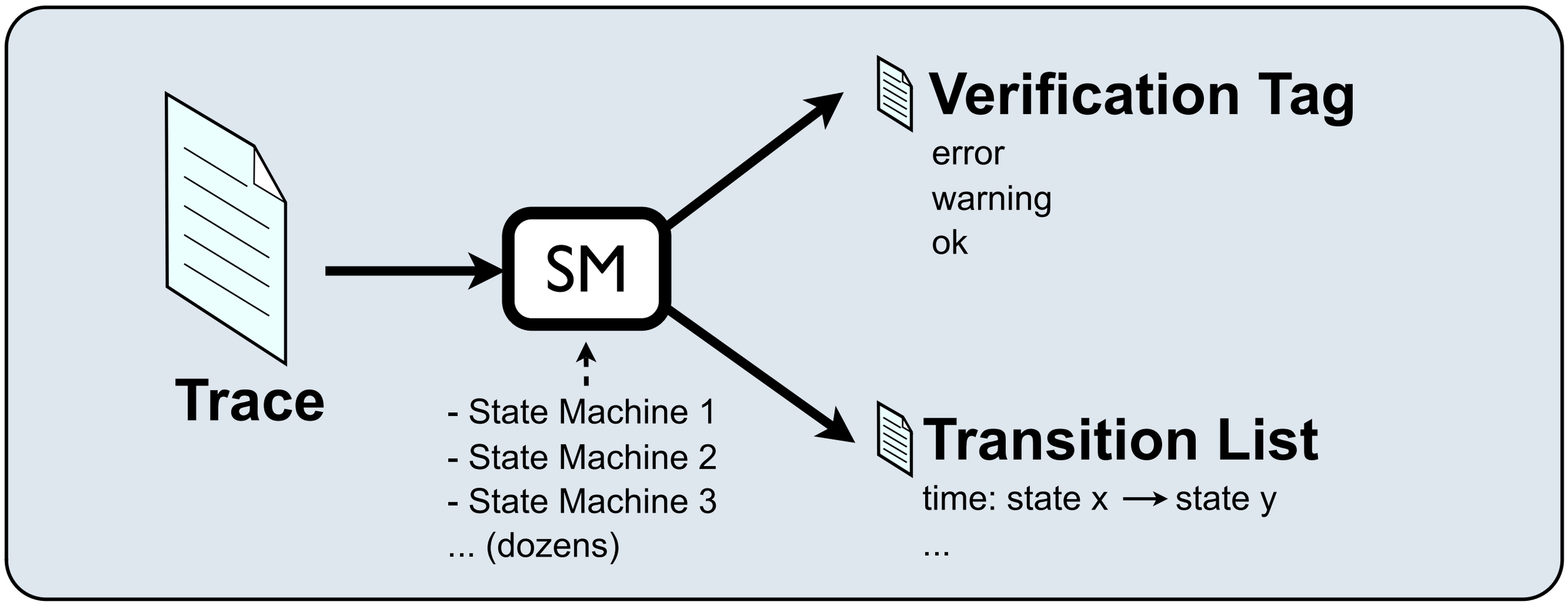


21

Aut. Error Detection: SMs to Interpret Errors (simplified)



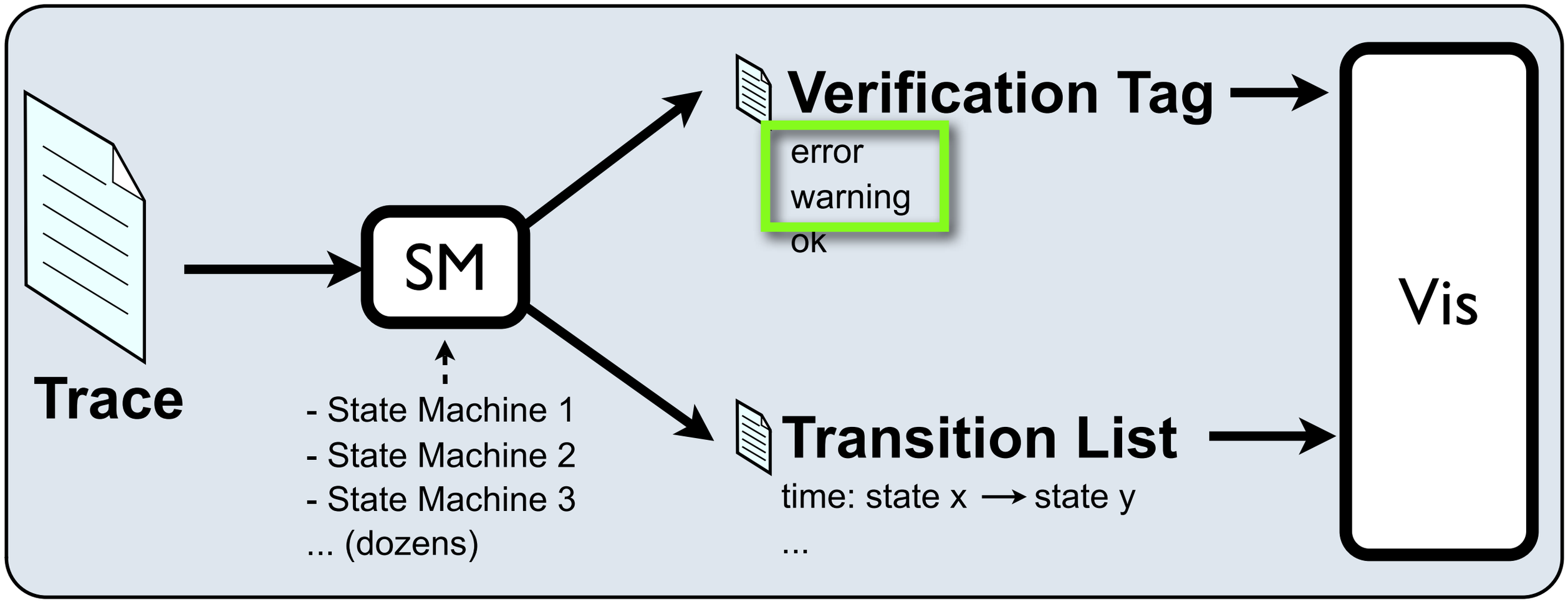
22



Data Reduction

- 1 Verification Tag per SM
- 10M messages --> 10K transitions

23



Visualization

... only when necessary

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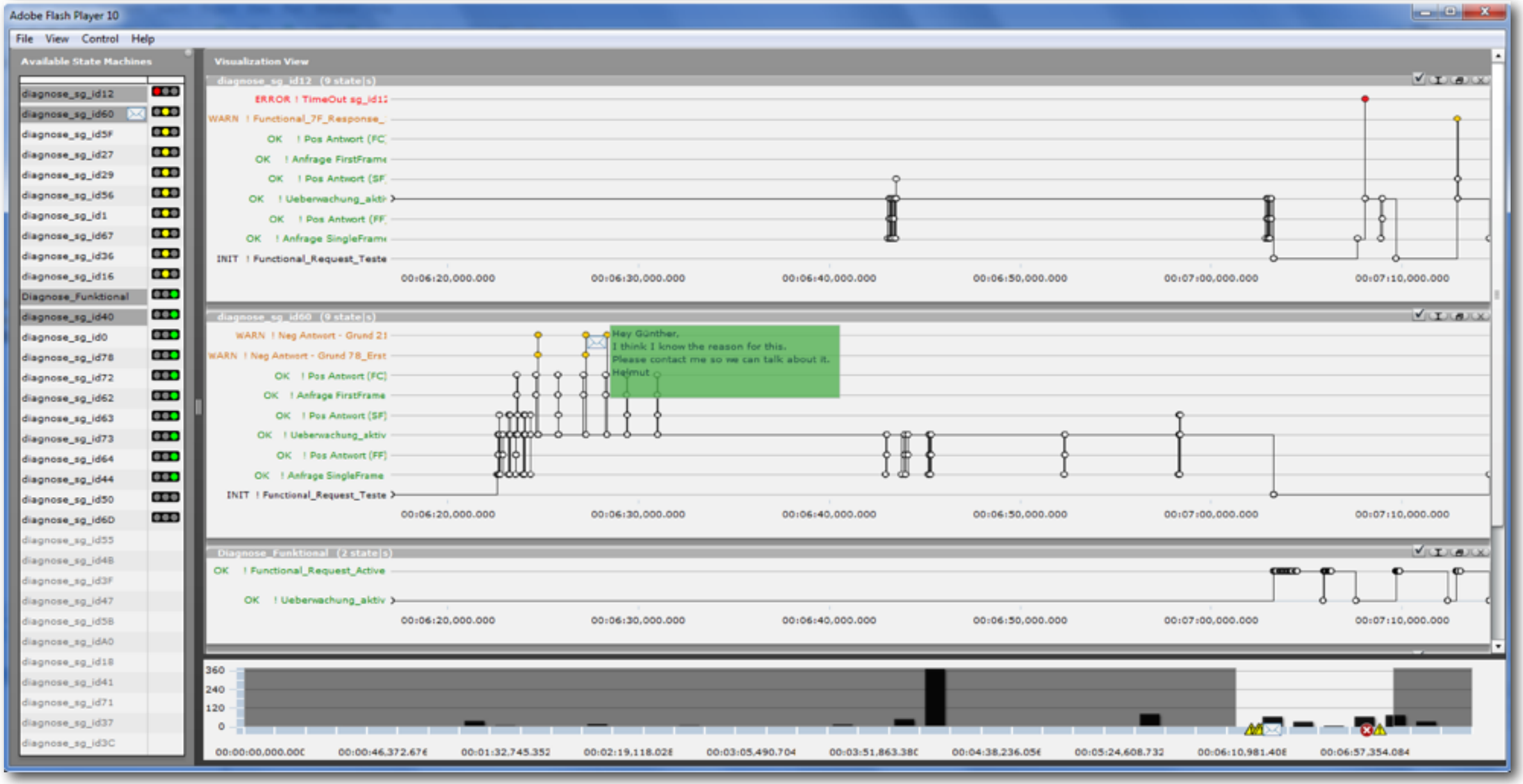

Visualization

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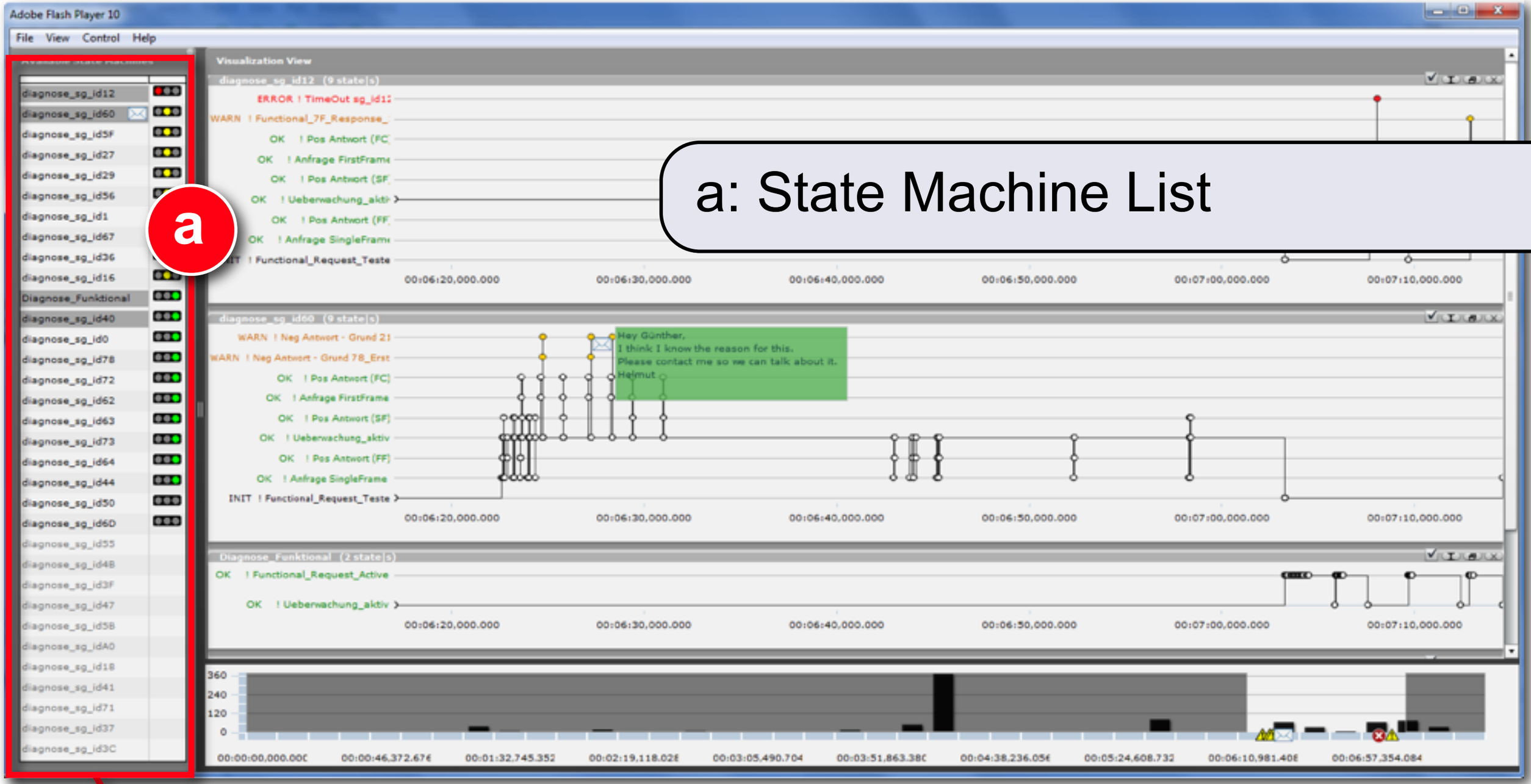
a: State Machine List



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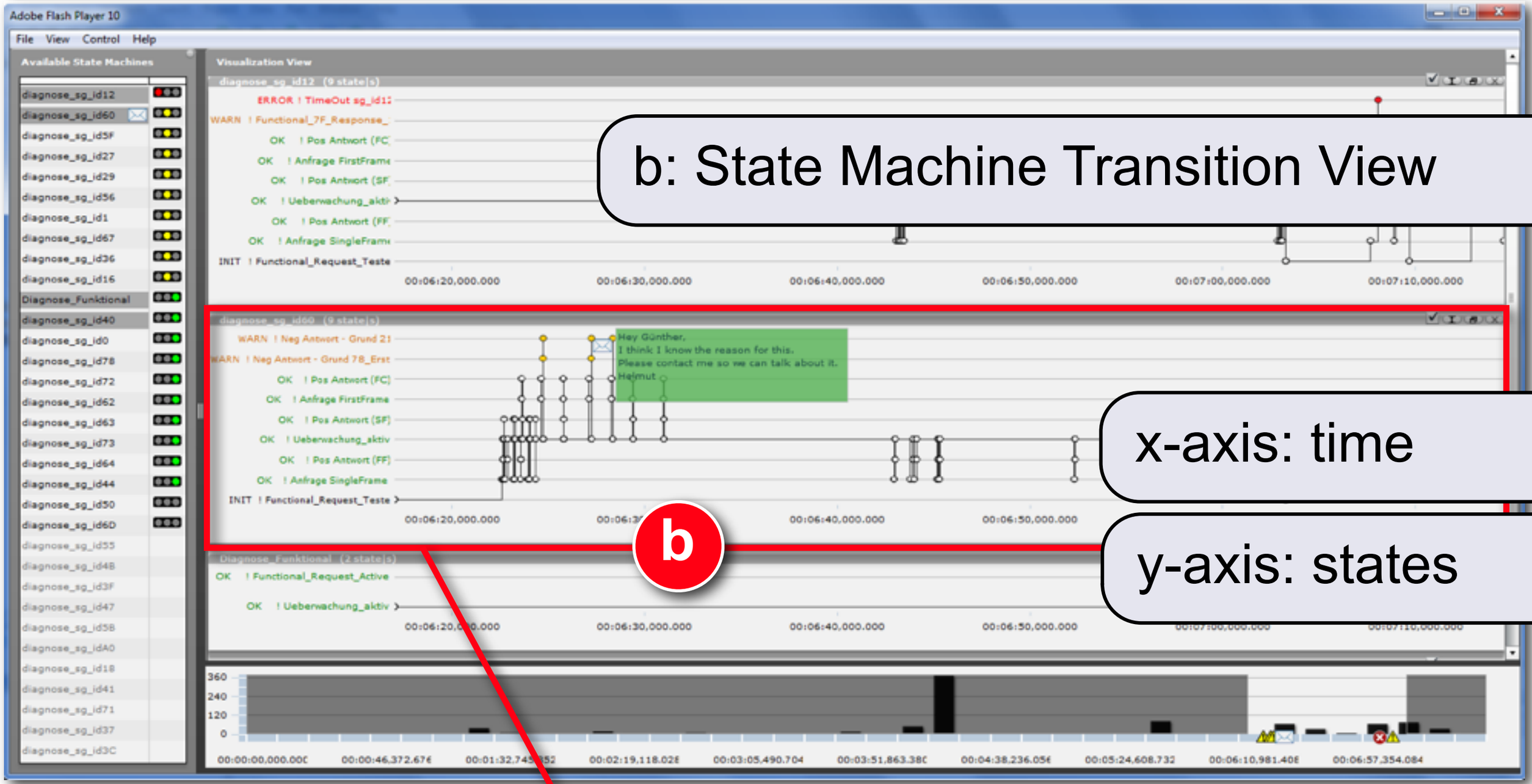
b: State Machine Transition View

x-axis: time

y-axis: states



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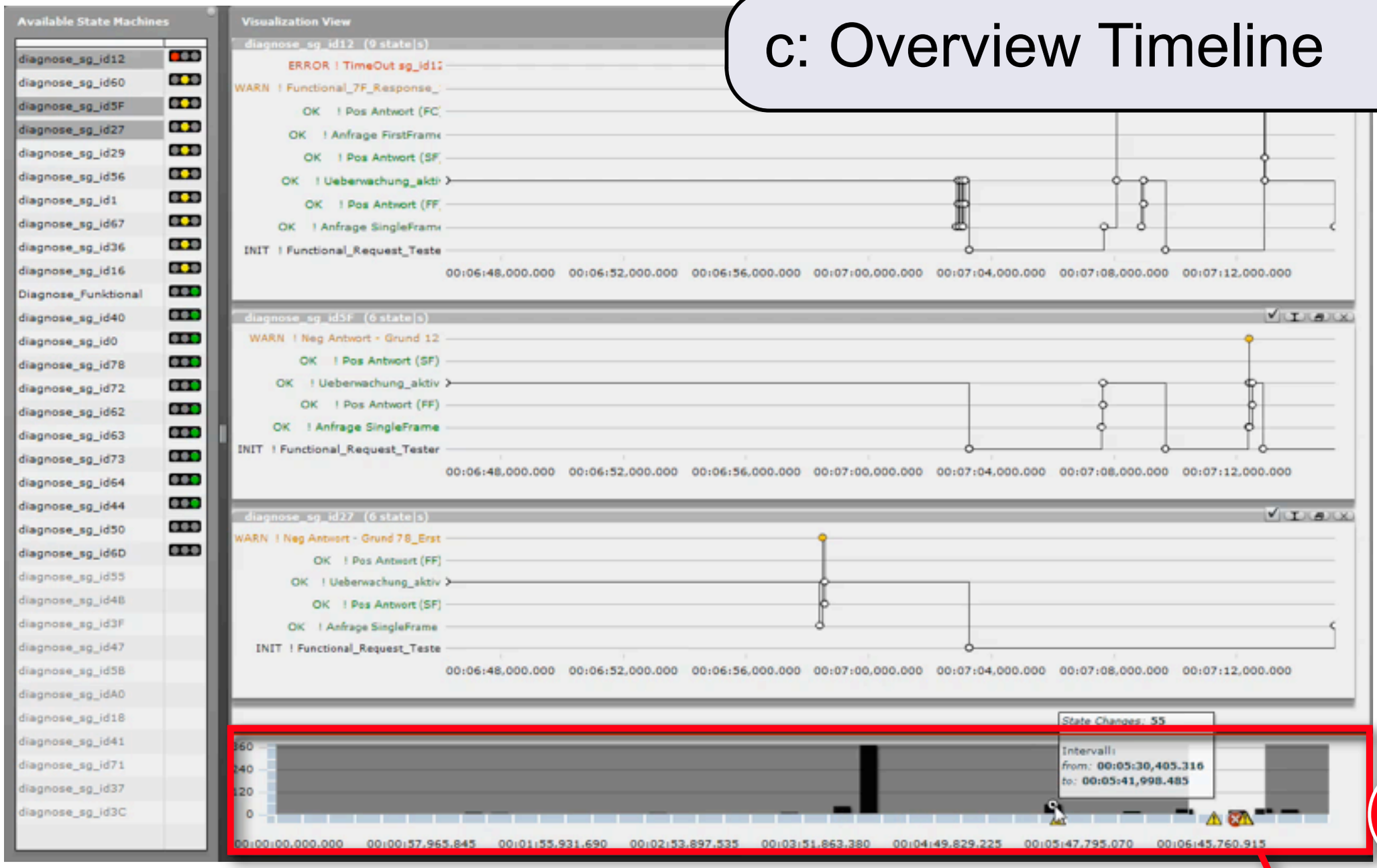
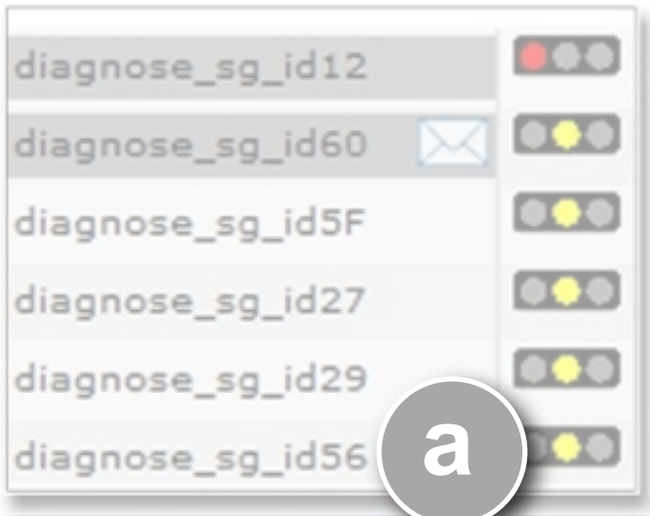
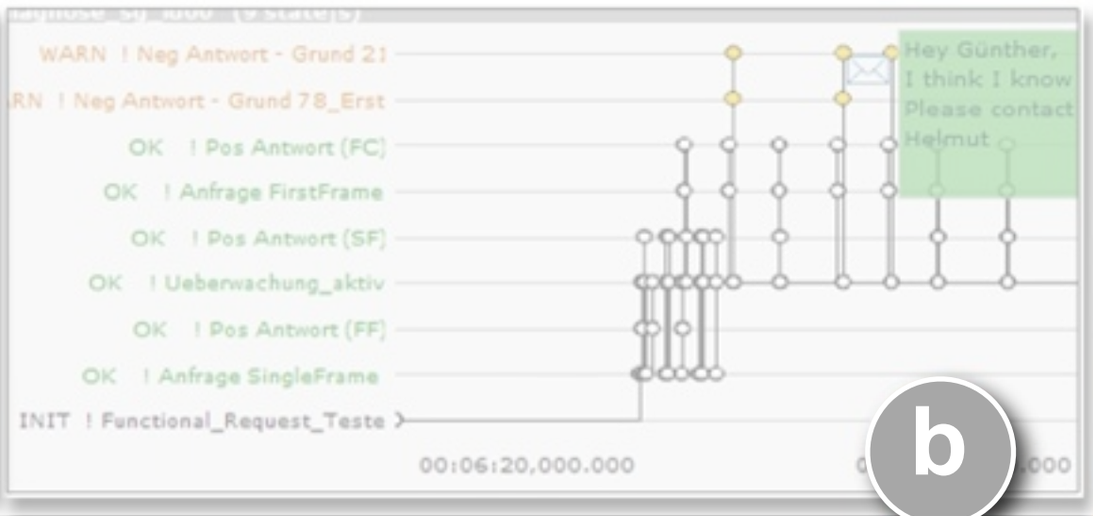
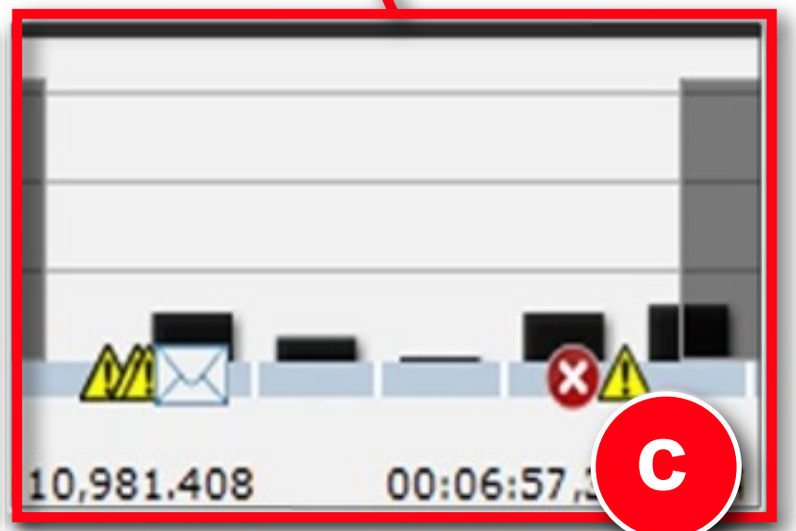
c: Overview Timeline

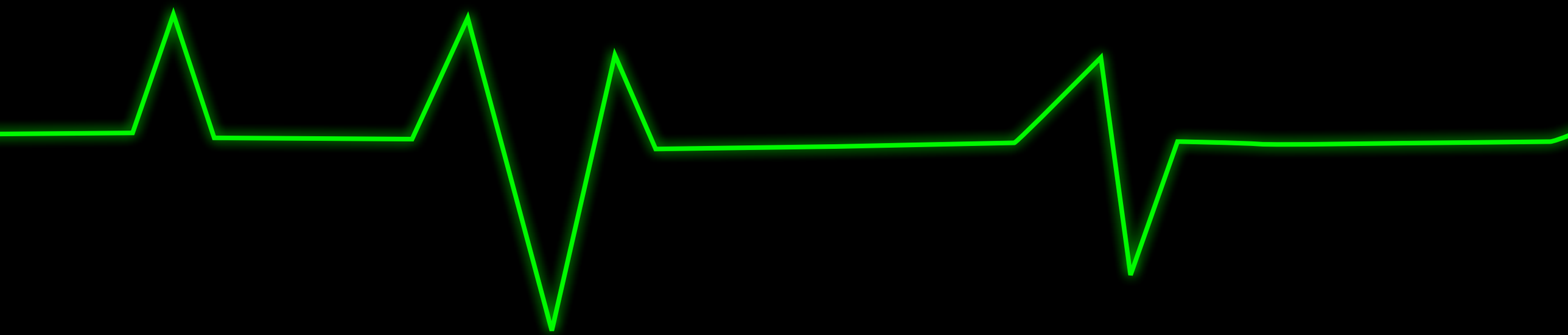








Evaluation



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Field Studies during and after deployment

2009 2010

Cardiogram Project

SM

Field study (15 engrs. / ~1 year)

Vis

Field study (2 engrs. / 8 weeks)

Think aloud study (6 engrs. / 1 hour each)

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(Some) Results: State Machine Approach

Externalization of Expert Knowledge

Additional Benefit: Supports Collaboration

Database

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(Some) Results: State Machine Approach

Complete Coverage vs. Sparse Samples

Thousands vs. Tens of Traces / Day

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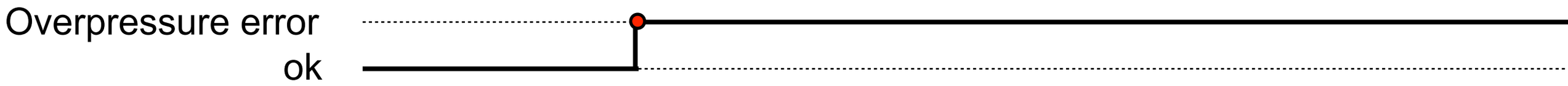
(Some) Results: Visualization

Understand Behavioral Cross-Correlations

Example: Overpressure Sensor Problem



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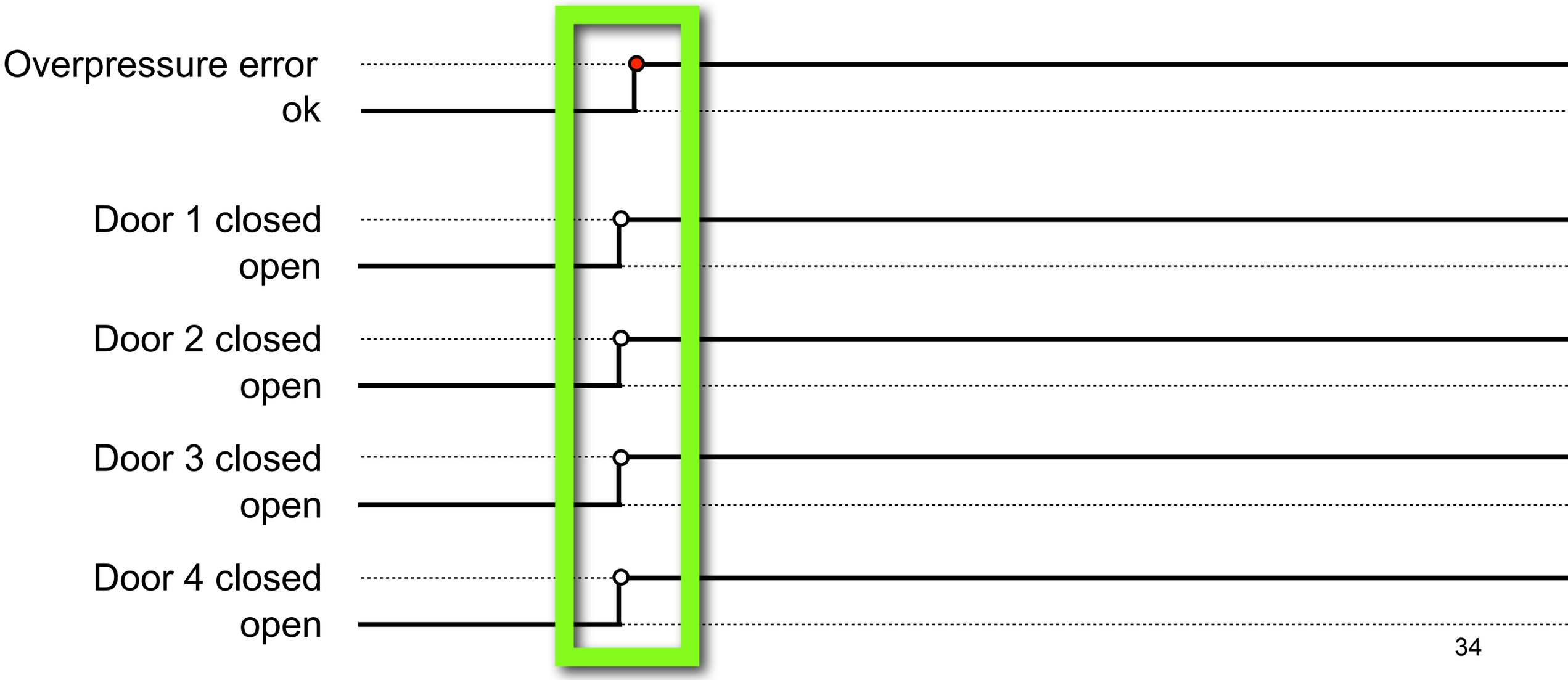
(Some) **Results:** Visualization

Understand Behavioral Cross-Correlations

Example: Overpressure Sensor Problem



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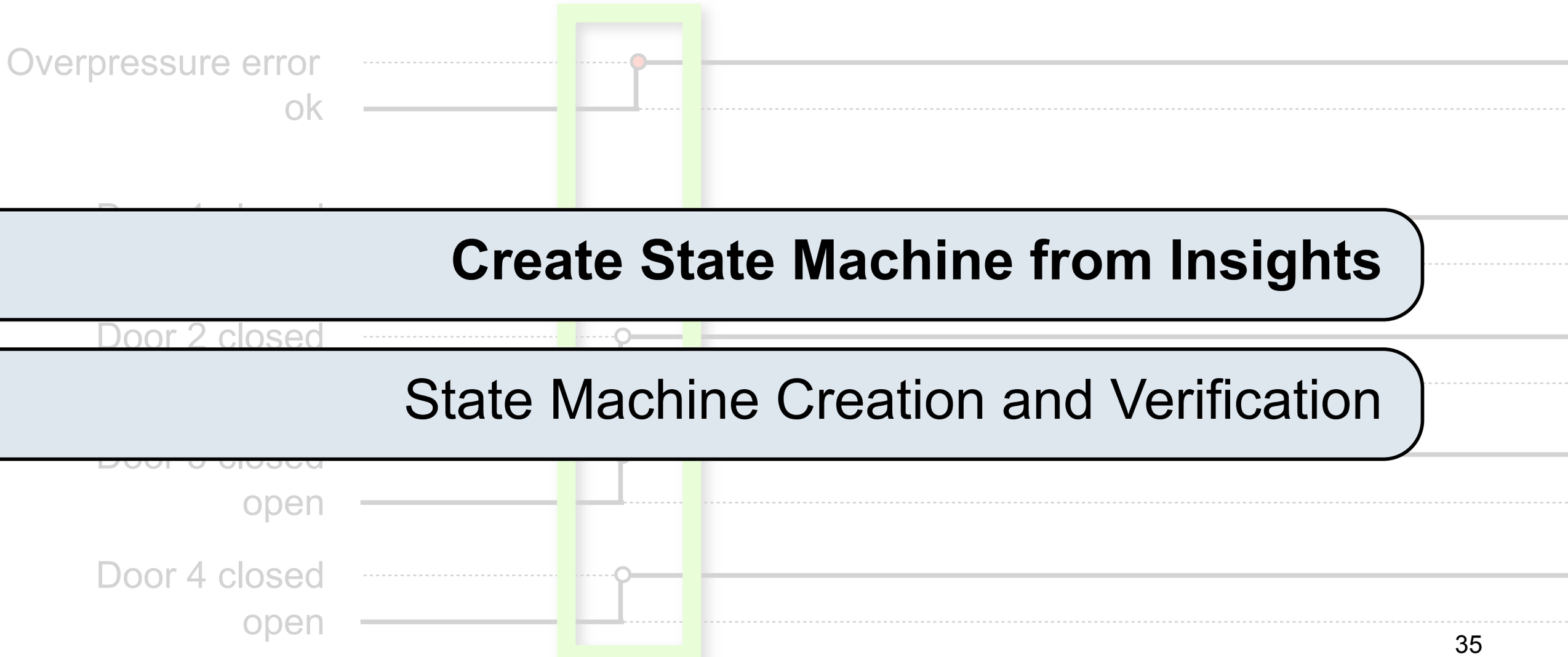
(Some) Results: Visualization

Understand Behavioral Cross-Correlations

Example: Overpressure Sensor Problem



Create State Machine from Insights

State Machine Creation and Verification

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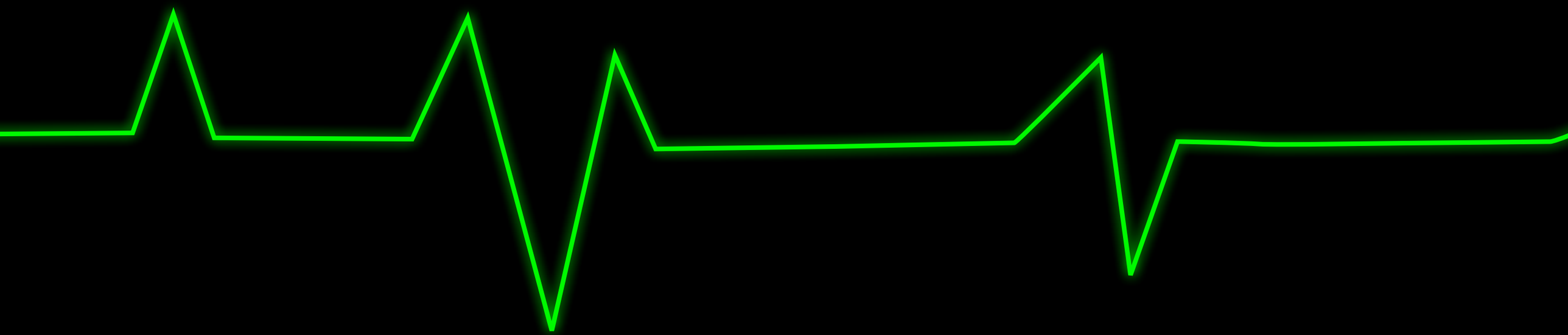
Summary



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Cardiogram / Contributions

Based on in-depth domain analysis

A: State Machine Approach

B: Visualization Component

Cardiogram adopted by engineers

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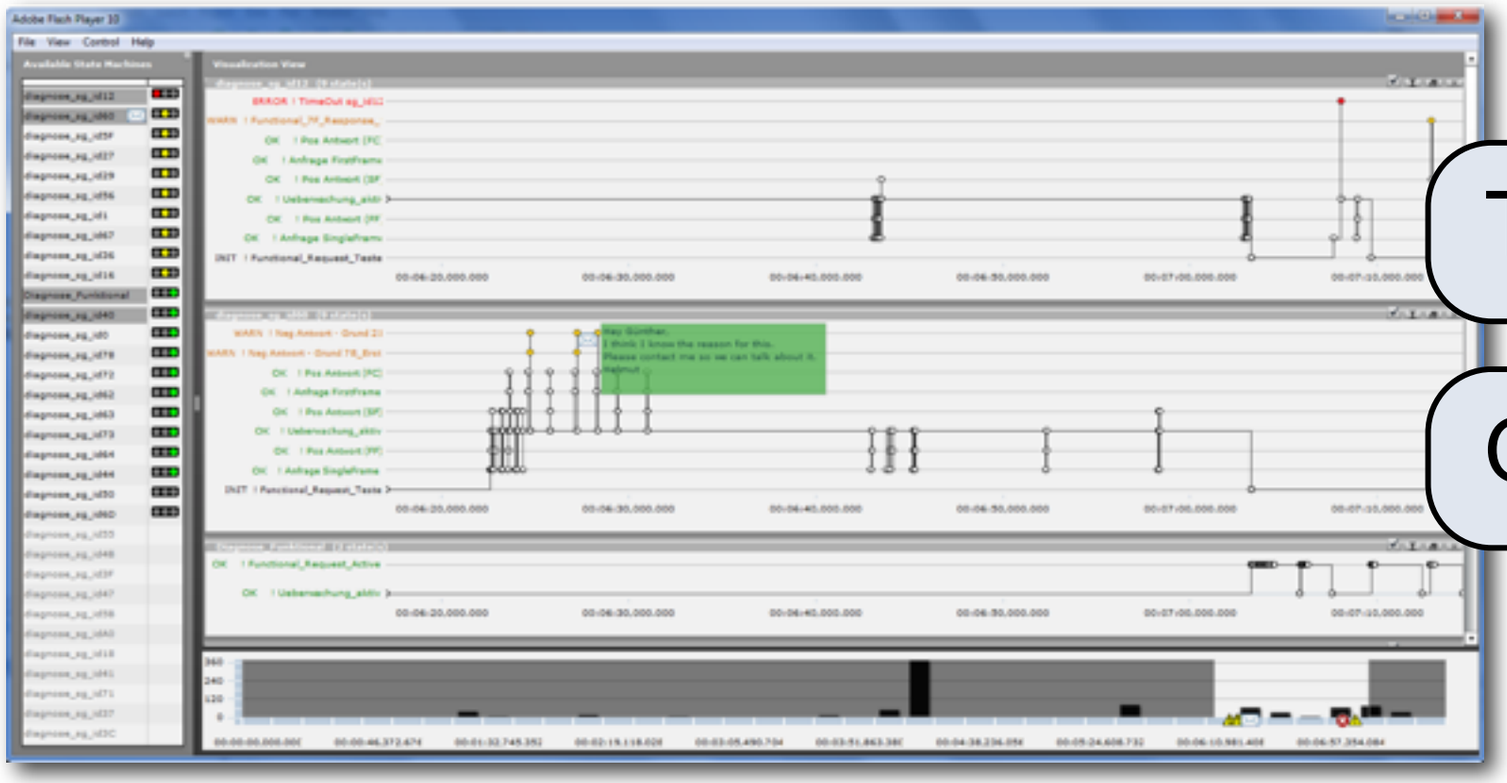
10-05-2011

Cardiogram: Visual Analytics for Automotive Engineers

Sedlmair, Isenberg, Baur, Mauerer, Pigorsch, Butz



Thank you!

Questions?

Slides: www.cs.ubc.ca/~msedl/talks/sedlmair2011chi.pdf

Back Up

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Editor.

State Machine Application

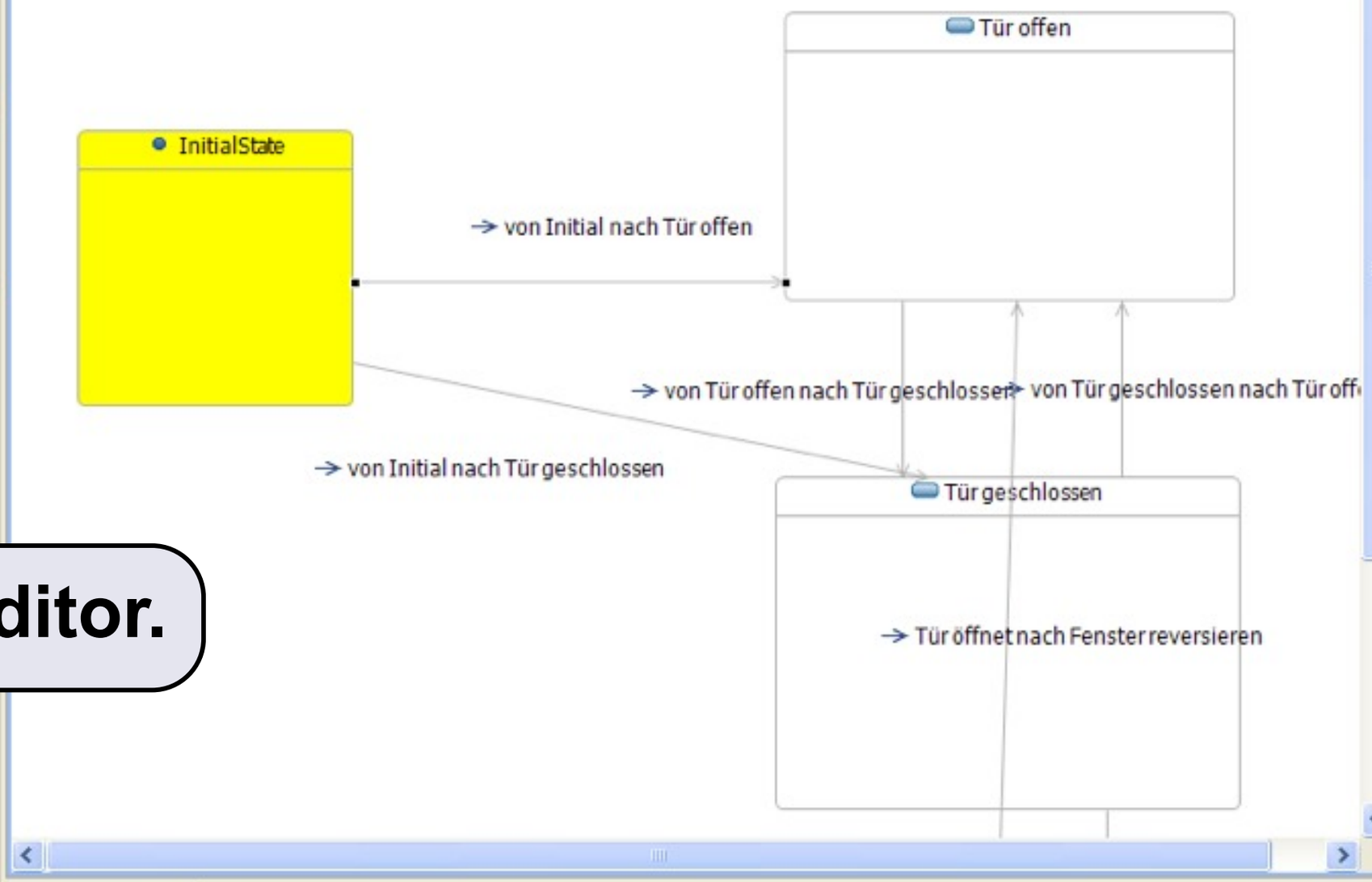
File Edit Diagram Window Help

Tahoma 9 100%

Project Explorer

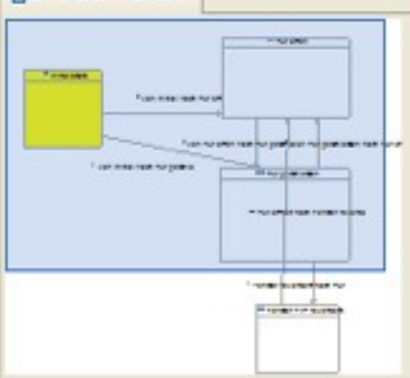
- IT-Messe
- Türzuschlag
  - Conditions
    - tuerzuschlag.conditions
    - tuerzuschlag.conditions_diagran
  - DBC
    - PL4_SYG_3_2_0.DBC
  - StateMachines
    - tuerzuschlag.statemachine
    - tuerzuschlag.statemachine_diag
      - Türzuschlag
  - default.statemachine_set

default.statemachine_set | tuerzuschlag.conditions_diag... | *tuerzuschlag.statemachine... | tuerzuschlag.statemachine



Palette
- Select
- Zoom
- Note
- State
- Transition
- ActionEntry

Outline



Properties

→ Transition Type von Initial nach Tür offen

Core | Appearance

Property	Value
Counter Max	0
Counter Min	0
Description	
Name	von Initial nach Tür offen
Source	Initial State Type InitialState
Target	State Type Tür offen

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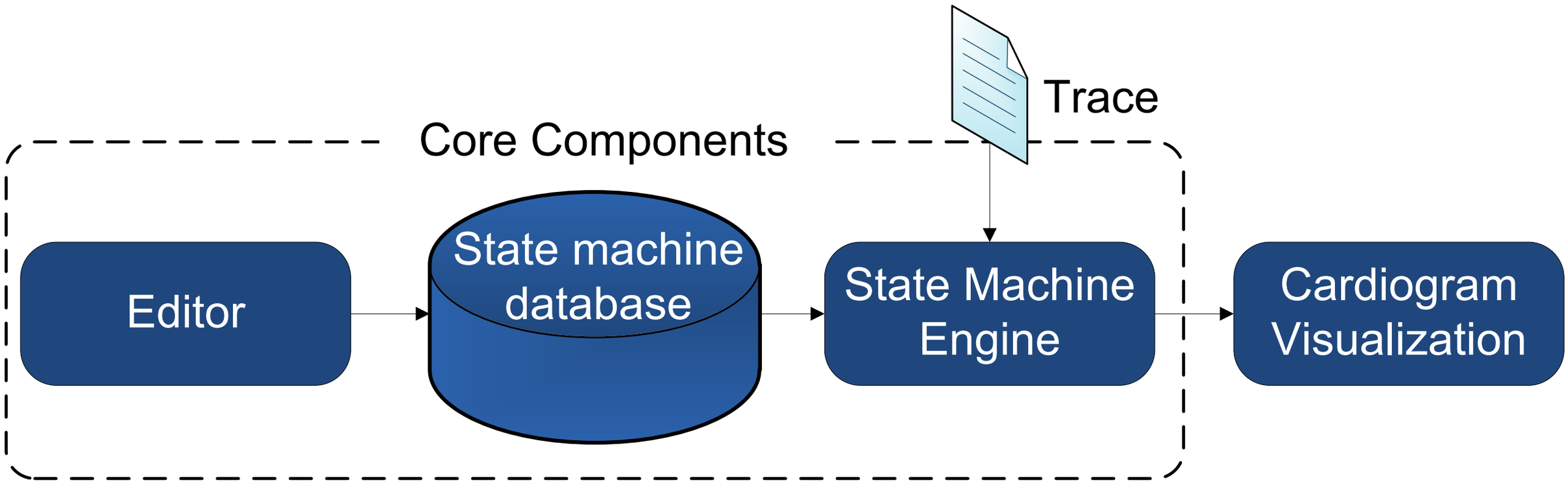
Cardiogram: 4 Steps



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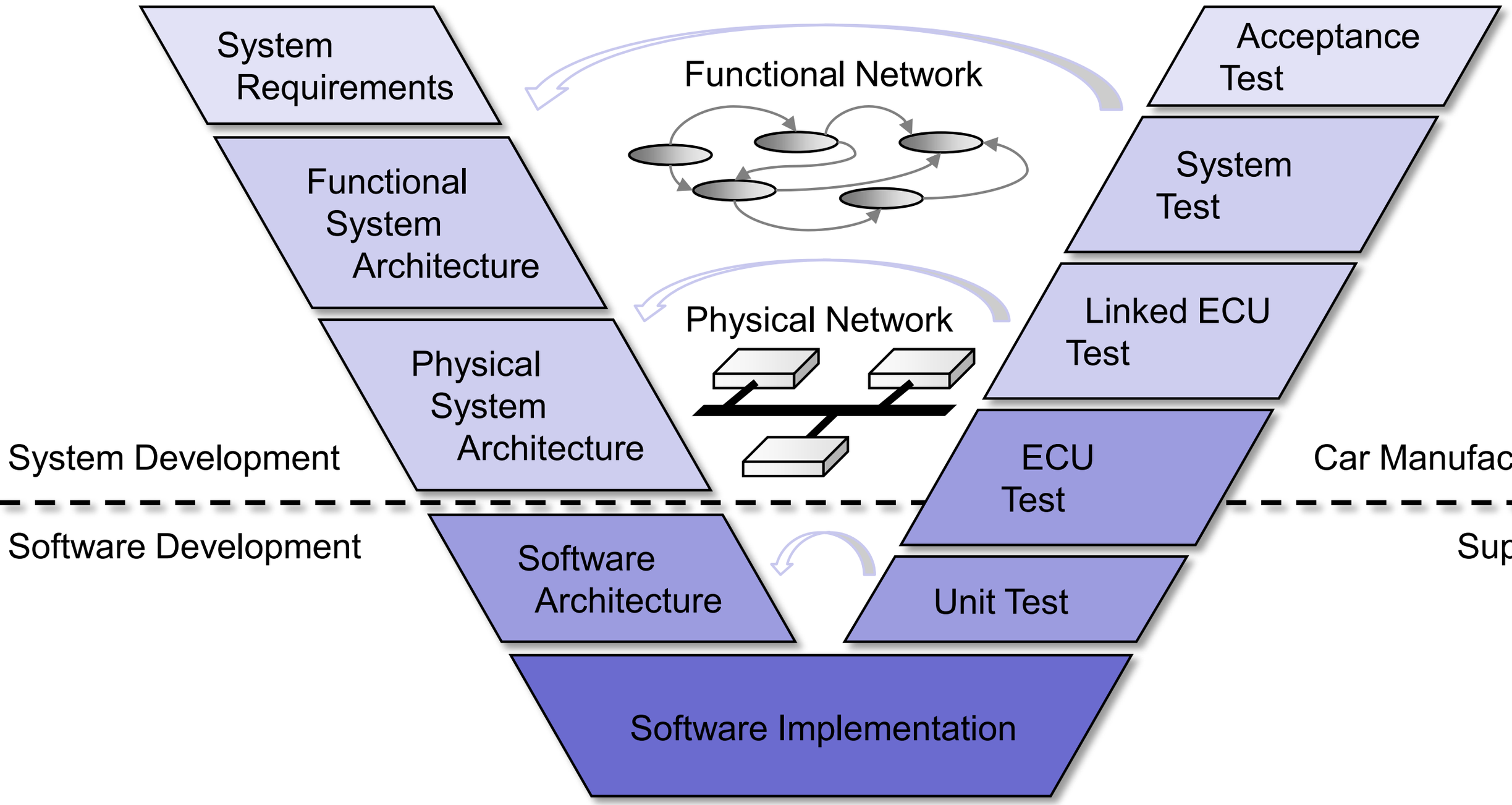
System Requirements
Functional System Architecture
Physical System Architecture
Functional Network
Physical Network
Acceptance Test
System Test
Linked ECU Test
ECU Test
Unit Test
System Development
Car Manufacturer
Software Development
Supplier
Software Architecture
Software Implementation

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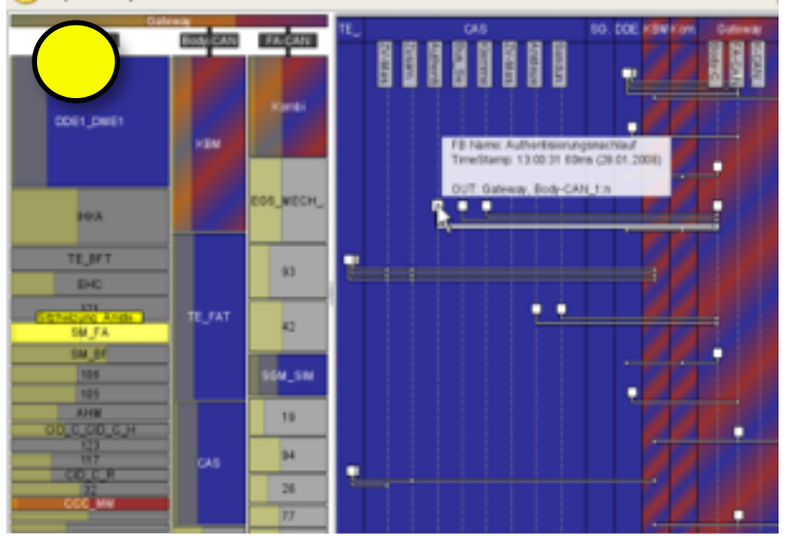
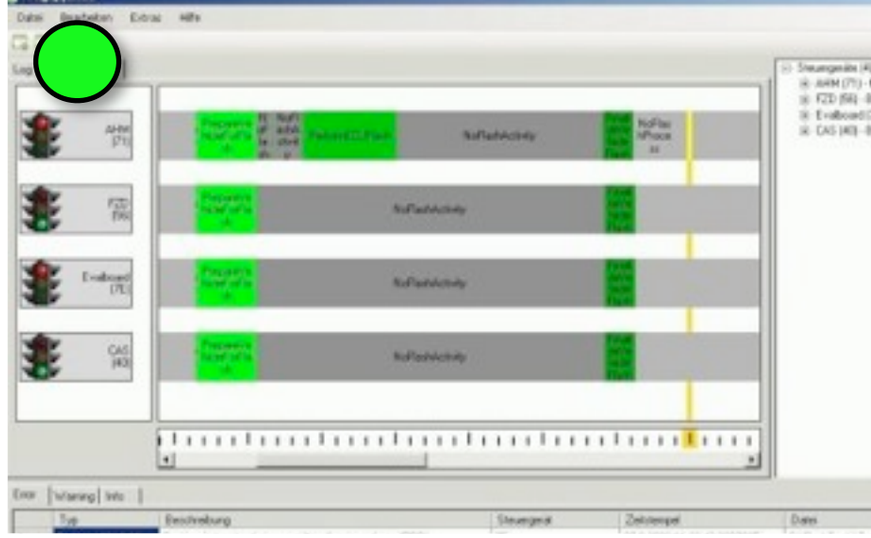
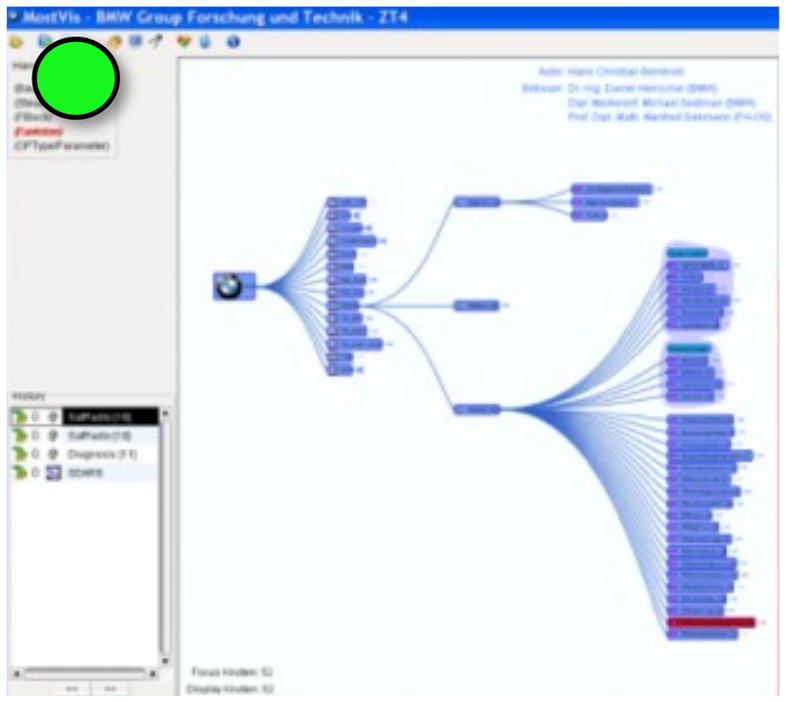
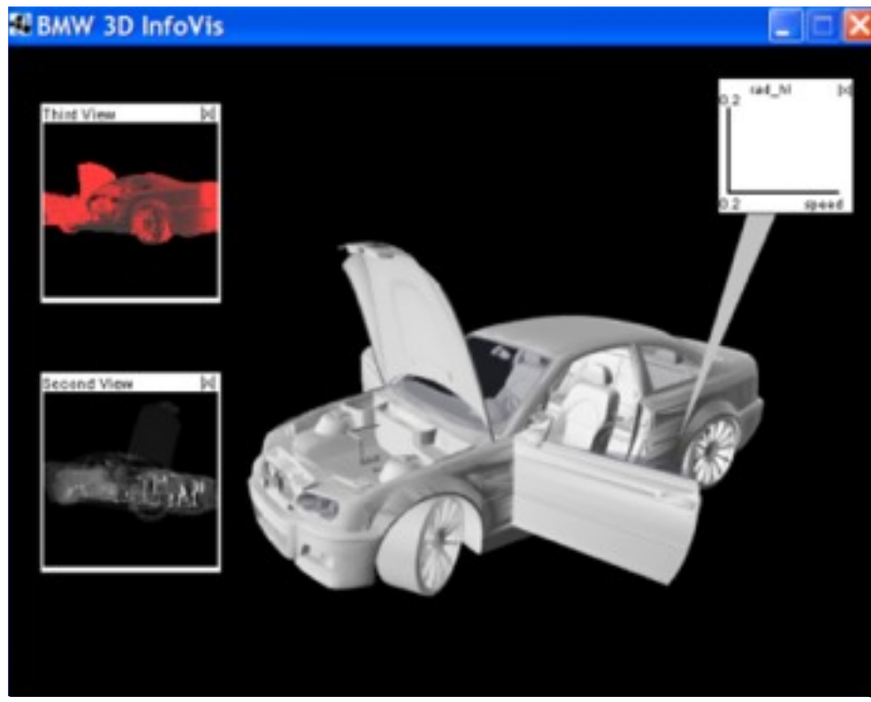
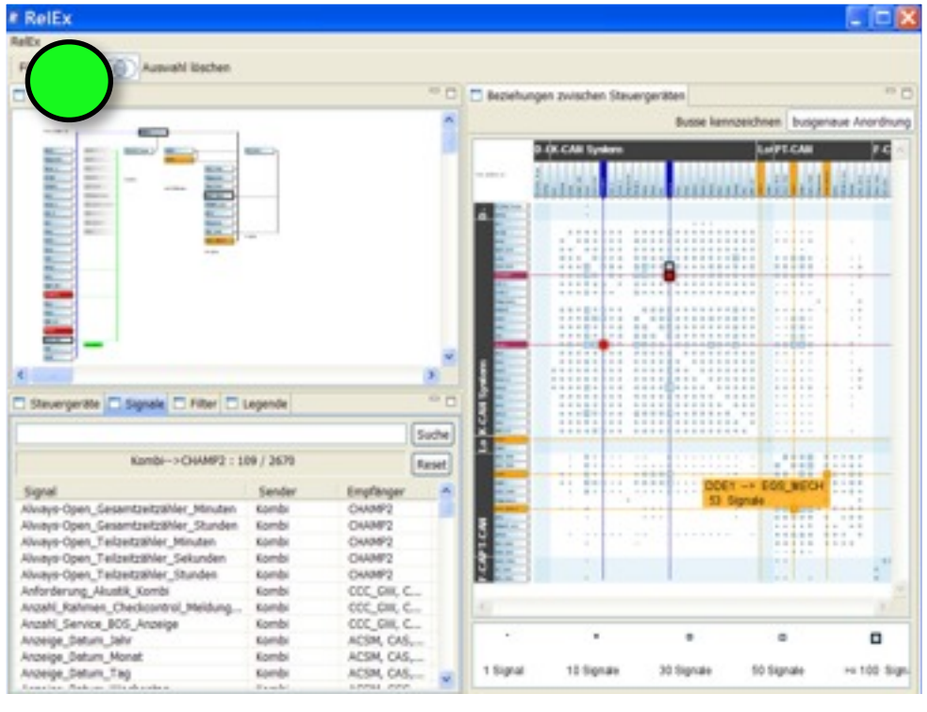


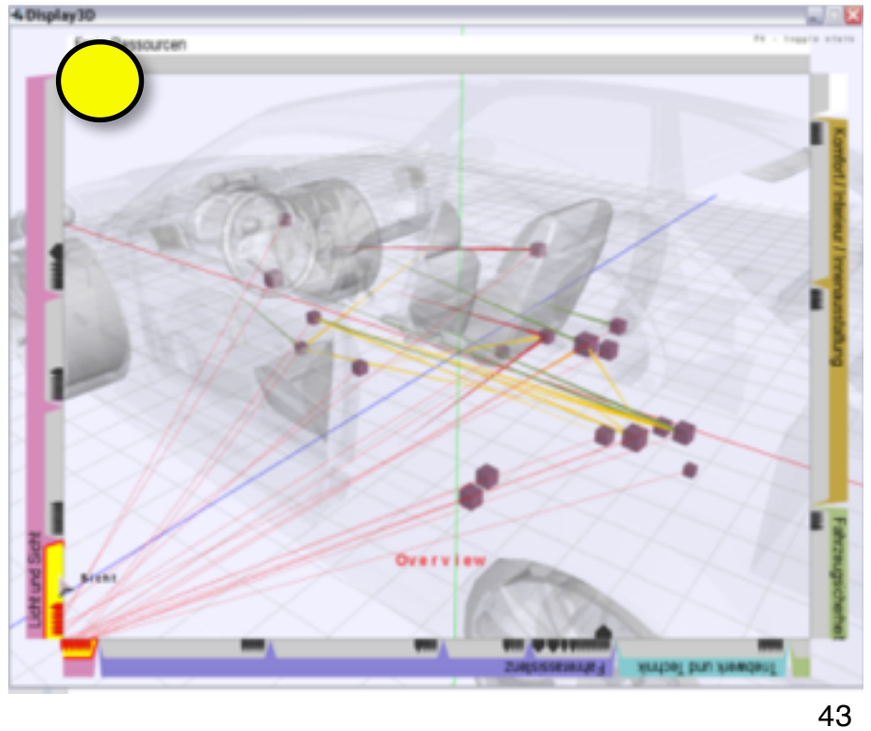



MostVis - BMW Group Forschung und Technik - ZT4


BMW 3D InfoVis
Third View
Second View


RelEx
Auswahl löschen
Beziehungen zwischen Steuergeräten
Busse kennzeichnen
busgenaue Anordnung
Steuergeräte
Signale
Filter
Legende
Suche
Reset
Kombi-->CHAMP2 : 109 / 2670
Signal
Sender
Empfänger


Welt.xml


4 Display3D
Overview