EVoCS – Evolutionary Validation of Complex Systems

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Lead Partner:

Partners:

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Introduction

Systems of Systems

Validation of SoS Design

Validation of SoS Implementation

Future Work

Conclusions

EVoCS Project Overview

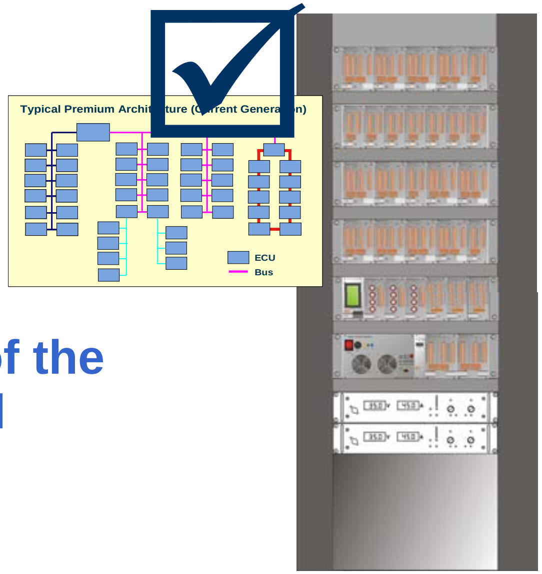
Part of UK Technology Programme

- Project size £10M Total 2006-2010

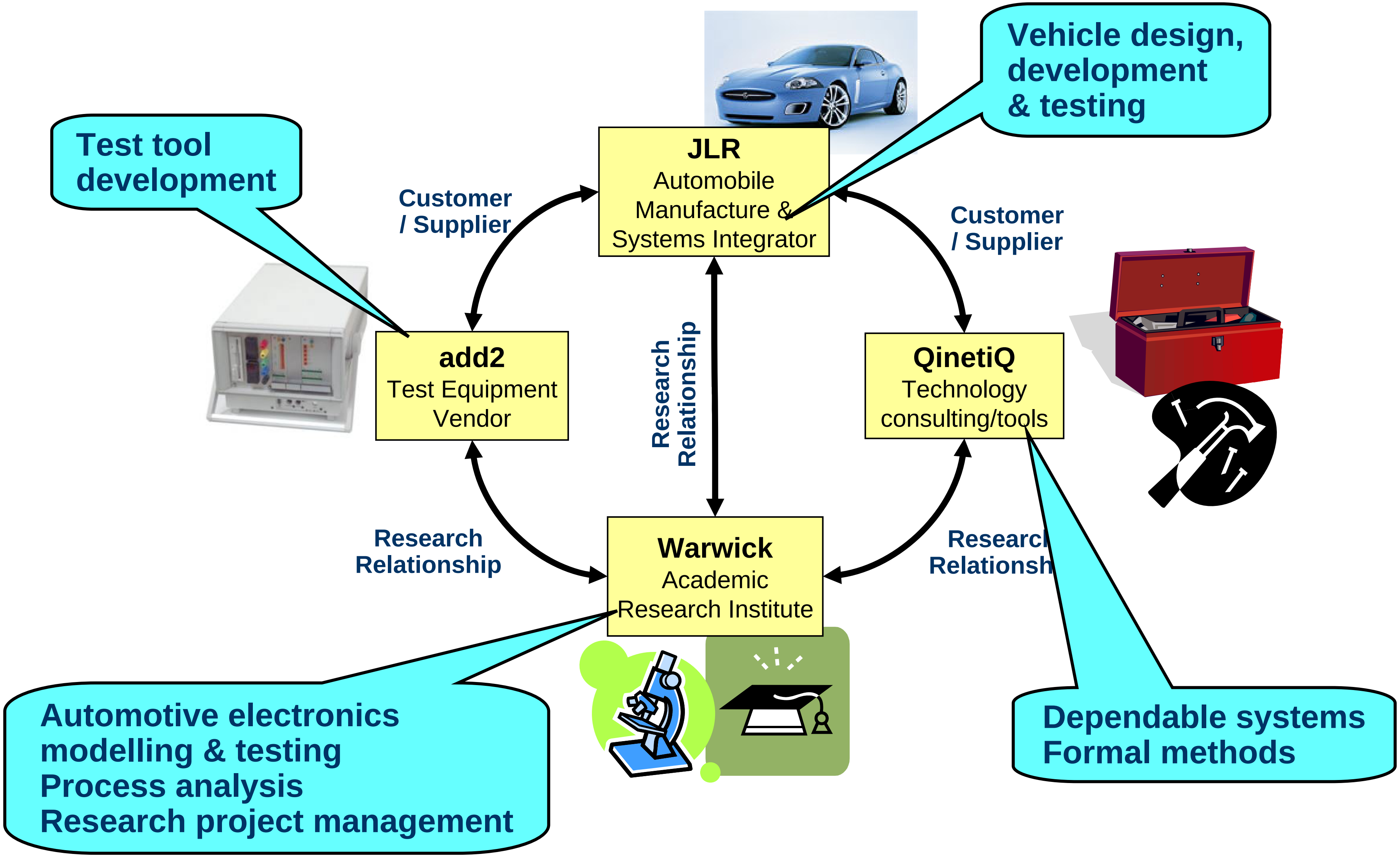
Partners: Jaguar Land-Rover, QinetiQ, add2, Warwick Univ

Objective: To maximise confidence in the design and implementation of complex automotive electrical systems through:

- Innovative techniques for the validation of the <u>design</u> at a System of Systems level
- Next Generation Platforms for the validation of the <u>implementation</u> at a Systems of Systems level



Project Consortium Relationships & Skills



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Systems of Systems

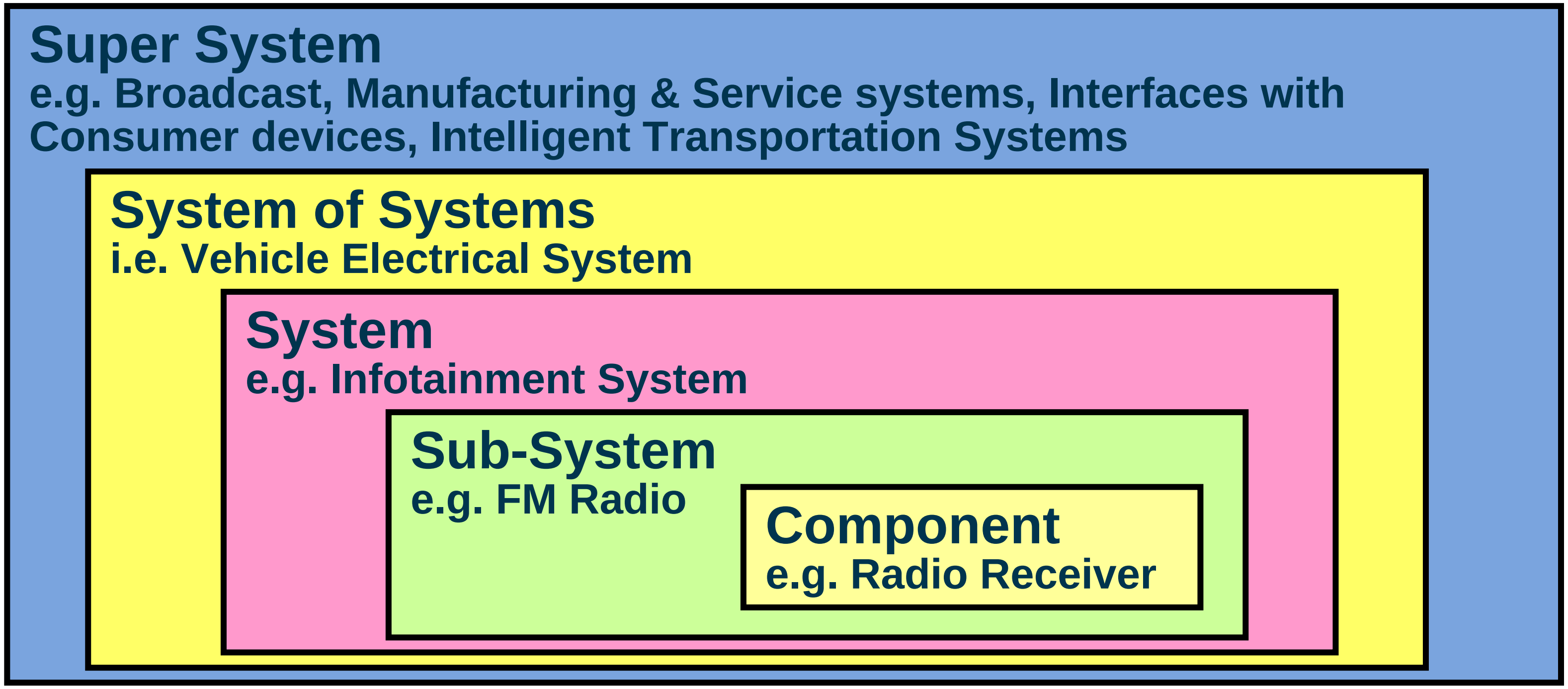
Systems of Systems are a specific type of Complex System affecting many fields including biology, sociology, engineering and military

New systems are composed of a number of individual systems with their own levels of autonomy.

Significant properties are:

- Autonomy of elements
- Evolutionary development
- Heterogeneous elements
- Sharing of resources
- Geographic distribution
- Emergent behaviour

Automotive Electronics SoS View



As systems become more complex it becomes harder:

- to predict behaviour (Emergent properties)
- to verify complete system (state space explosion) or sub-parts in isolation

New Methods are required for Validation and Verification at System of Systems Level throughout development

Validation of Systems of Systems - Issues

Late availability of vehicle level platforms

Large Scale

- Effort to model
- Understanding of interactions
- Scaling issues with formal methods

Non-homogeneous nature of individual systems

- Different levels of detail
- Different modelling techniques
- Different failure modes

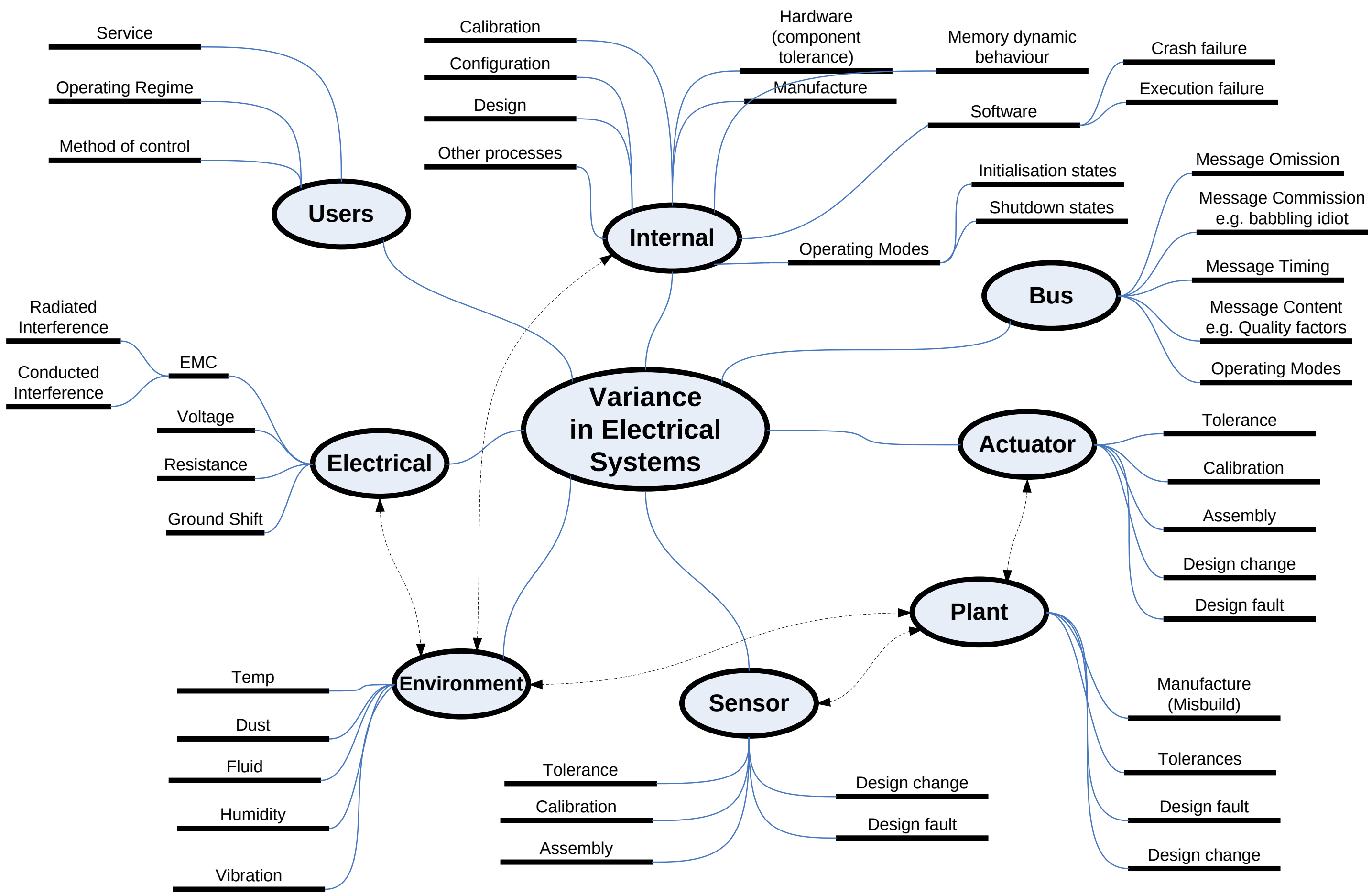
Extent of re-validation when a change occurs in one system

What properties/attributes to validate at an SoS level?

- Those that relate most strongly to robustness

Robustness of Systems of Systems

Robustness concerns the resilience of a system to maintain an appropriate level of function during and after variations or disturbances.



Factors in Validating Robustness of SoS

Sources of variation

Continuous and state event driven based behaviours

Coverage v’s time to market

Impact of failures

Detecting latent faults outside nominal operating regions

- **Transient conditions**
- **Under fault condition in another area of SoS**
- **Under conditions of variation e.g. tolerance spread, wear out**

System Interactions expected range

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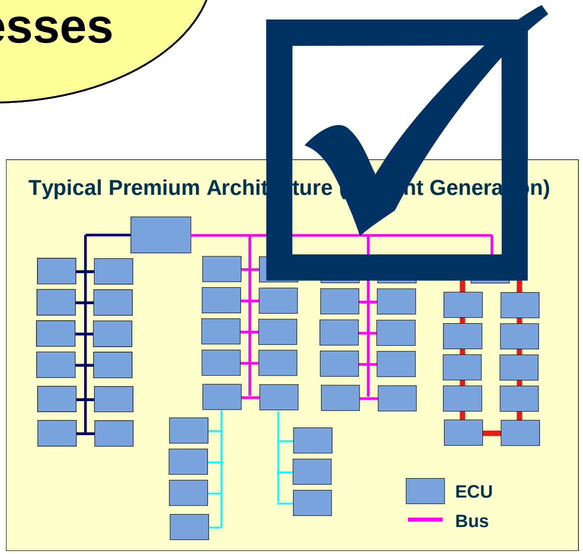
System of System Design Validation

Model Based Development Processes

Enhanced Physical Modelling

Automated Model Based Testing



Interaction Modelling

Test case generation & coverage metrics

Design for Robustness

Formal Methods for Dependability

Static Code Analysis Tools

Interactions at SoS Level

Understanding System interactions vital for design of SoS

- Information typically spread across several specifications
- Large amount of interactions

CANdb2DSM Tool Interaction Analysis

	TPMS	RSJB	RCCM	PSM	PDM	PAM	KVM	JDS	INST	ICP	ICM	HDM	FSJB	DSM	DDM	CANalyz
TPMS	0	0	0	0	0	0	0	16	9	0	0	0	0	0	0	16
RSJB	2	0	1	0	0	0	0	8	85	1	8	0	18	0	9	0
RCCM	0	4	0	0	0	0	0	8	22	0	10	0	9	0	0	0
PSM	0	0	1	0	0	0	0	8	8							
PDM	0	0	0	0	0	0	0	24	8							
PAM	0	0	0	0	0	0	0	8	0							
KVM	0	0	0	0	0	0	0	8	12							
JDS	16	8	8	8	24	8	8	0	0							
INST	1	29	36	0	0	1	0	0	0							
ICP	0	0	0	0	0	0	0	8	8							
ICM	0	0	16	0	0	0	0	8	27							
HDM	0	1	0	0	0	0	0	8	10							
FSJB	1	10	5	0	2	0	19	8	48							
DSM	0	0	1	0	0	0	0	8	13							
DDM	0	0	0	0	11	0	0	24	9							
CANalyz	8	0	0	0	0	0	0	0	0							

	DSC	ESCL	INST	ACC	ADCM	JDS	TCM	AFLS	PIE	RCM	CANaly:	GSM	ECM	EPB
DSC	0	2	29	20	7	8	21	3	2	10	0	0	28	3
ESCL	0	0	8	0	0	8	0	0	0	0	0	0	0	0
INST	21	22	0	29	20	16	21	22	18	32	0	4	81	33
ACC	8	0	8	0	0	8	0	0	0	0	0	0	7	1
ADCM	0	0	2	0	0	16	0	0	0	0	0	0	4	0
JDS	16	16	24	16	24	0	48	16	16	16	0	16	16	16
TCM	7	3	10	4	1	64	0	4	0	0	4	3	24	3
AFLS	0	0	3	0	0	8	0	0	0	0	0	0	0	0
PIE	0	0	5	0	0	8	0	0	0	0	0	0	0	0
RCM	0	0	7	0	0	8	0	0	0	0	13	0	2	0
CANalyz	0	0	0	0	0	0	0	0	0	0	0	0	16	0
GSM	1	0	2	0	0	8	3	0	0	0	0	0	2	0
ECM	13	2	67	21	9	40	21	6	2	7	44	4	0	7
EPB	2	0	15	3	0	8	2	0	0	0	1	0	3	0

Lack of analytical modelling techniques at SoS level to capture inter system interactions

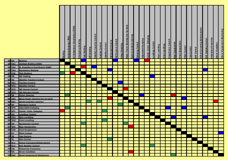
- Conflict between detail and coverage
- Differing levels of detail known by integrator across systems

Interaction & Dependability Modelling & Analysis

Modelling

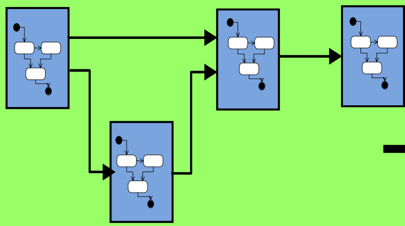
Static Interaction Model

e.g. INTERACTION MATRIX



Interactions classification:
- Generic: input, output, request/acknowledge.
- Complex

Dynamic Interaction Model



Modules and interactions for a function
- **Abstract state machine model of modules internal behaviour**
- **Sufficient semantics for import into Modelworks**
- **Suitable for development into full functional model / autocoding**

Detailed Component

Detailed Component

Detailed Component

Detailed Component

Detailed Component Function Model (Executable Spec)

Simulink/Stateflow

C Code

C Code

C Code

C Code

C Code

Analysis

Initial Design Analysis (DSM)

Design Structure Matrix
- **Completeness**
- **Consistency**
- **Functional Coupling & Cohesion**

Dependability Analysis (Modelworks)

CSP (Communicating Sequential Processes) Tools (QinetiQ)

Function Implementation Analysis (ClawZ)

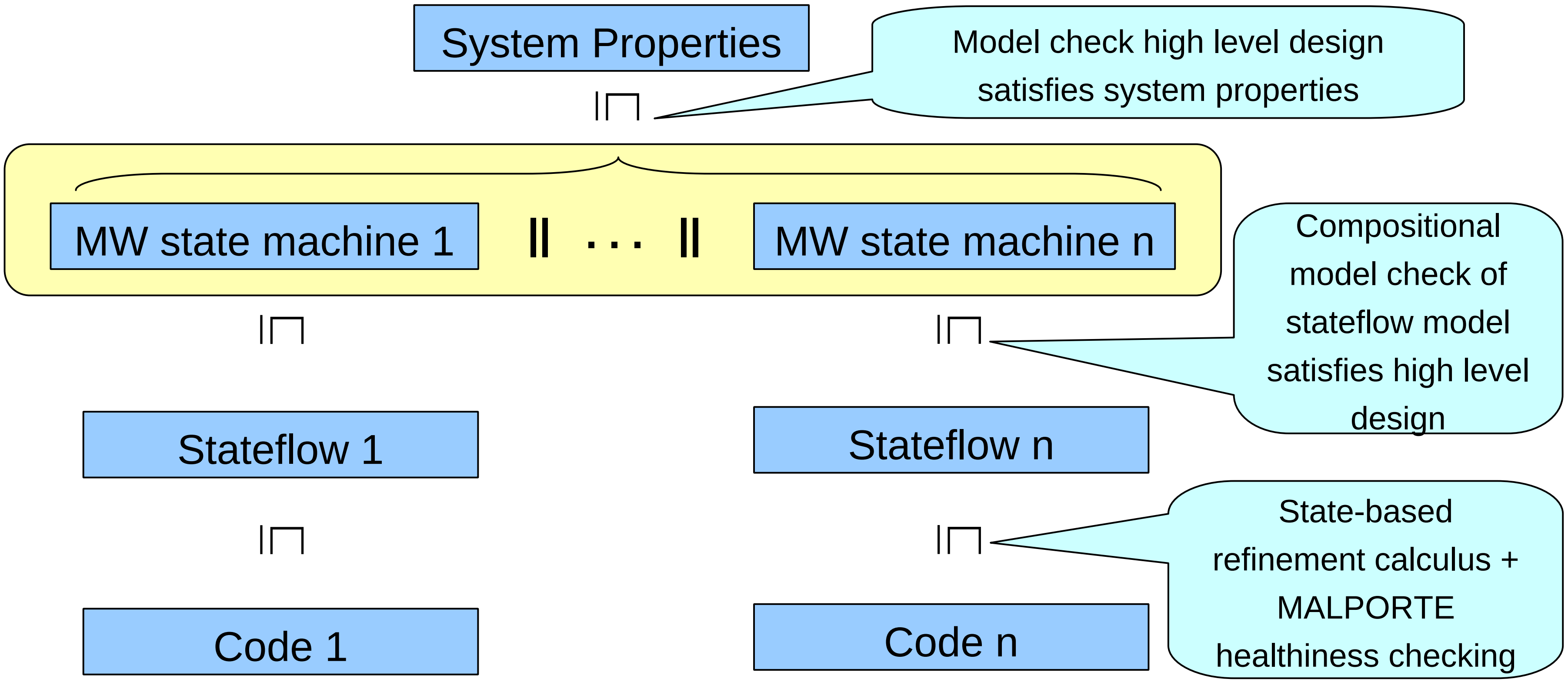
Assessment of adherence of code to model

Static Code Analysis (Malporte)

Including identification of external conditions necessary for correct execution of code

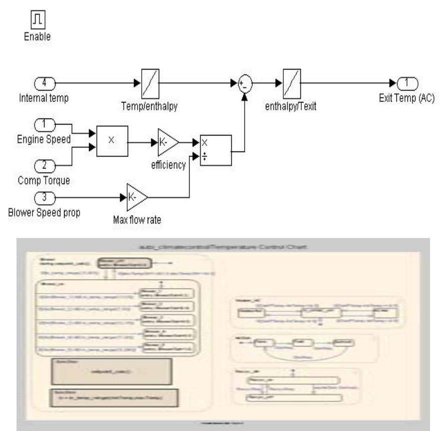
Hierarchical Approach to Design Validation

Multiple refinements to check properties of detailed system



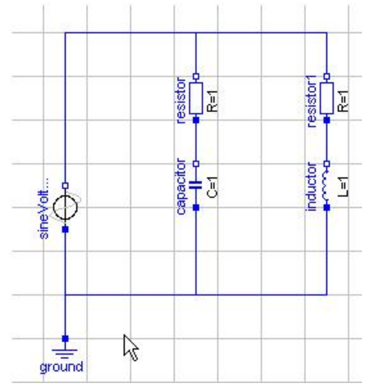
Advanced Physical Modelling

Control Algorithm

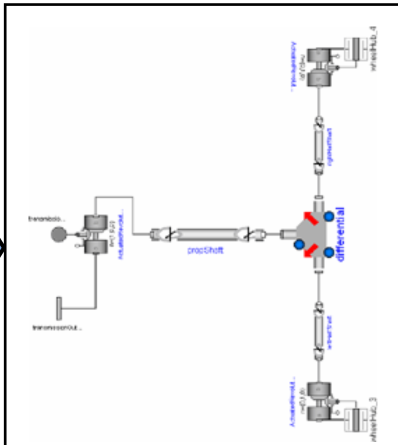


Electronic (Software)

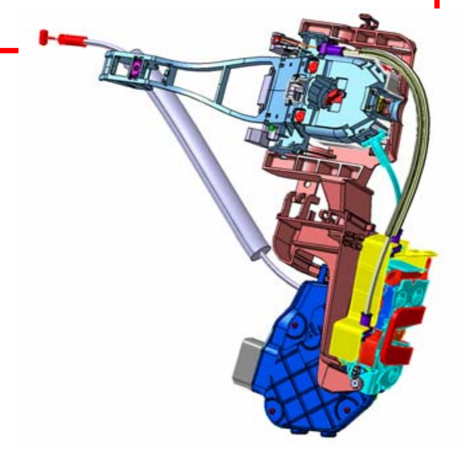
Physical Hardware



Electrical



Mechanical



Facilitates robustness testing at SIL & HIL through modelling of variability of physical parts (e.g. tolerance and wear-out)

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System of Systems Validation of Implementation

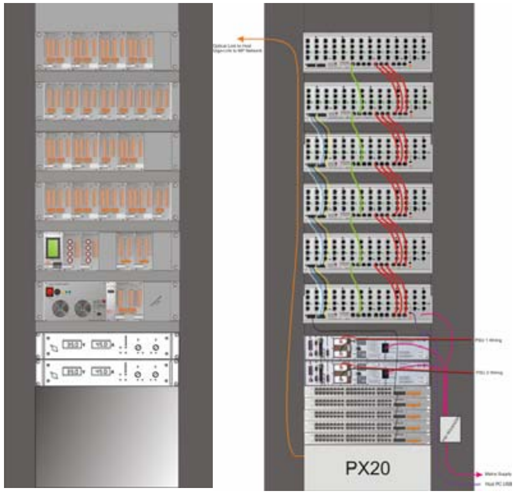
Next Generation HIL Tests

Flexible HIL Platform

Platforms for full vehicle tests

Test Automation

HMI Simulation & Testing



Machine Vision

Validation of Manufacturing Systems

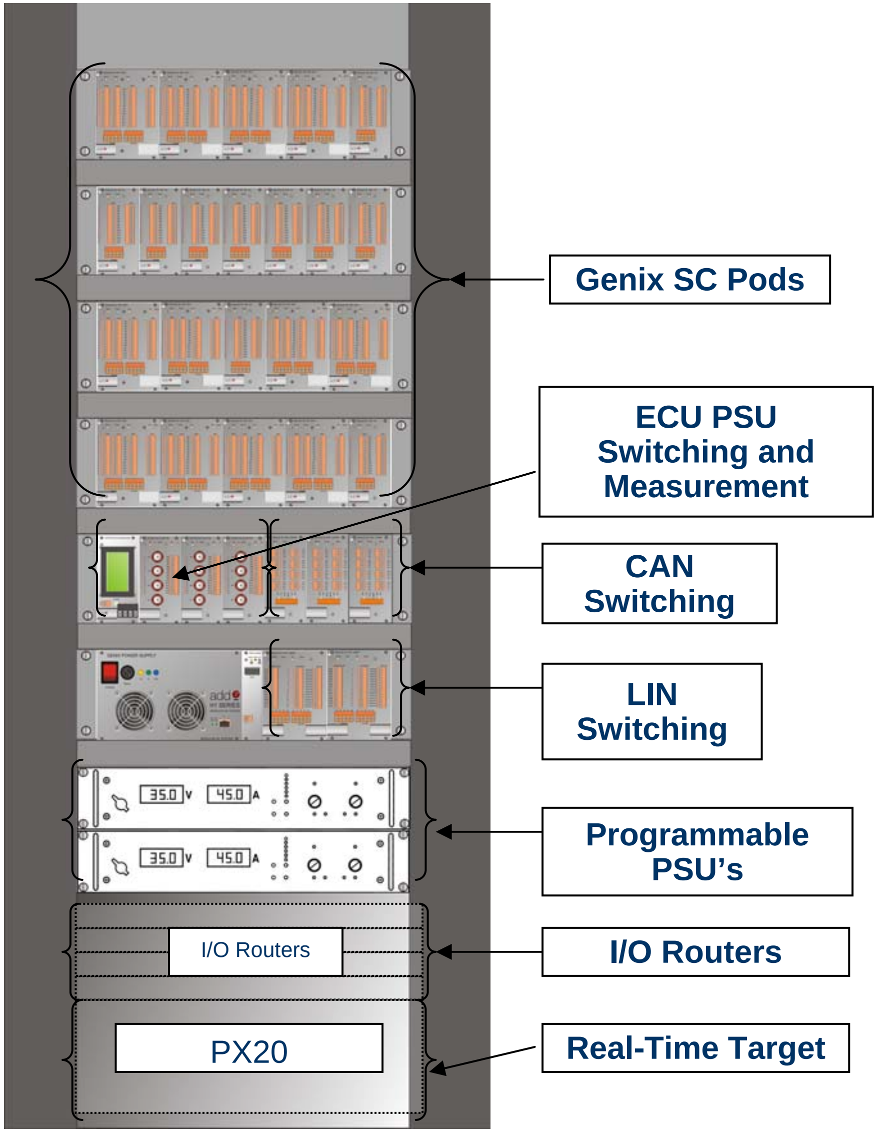
Robustness Testing

Low Voltage Testing

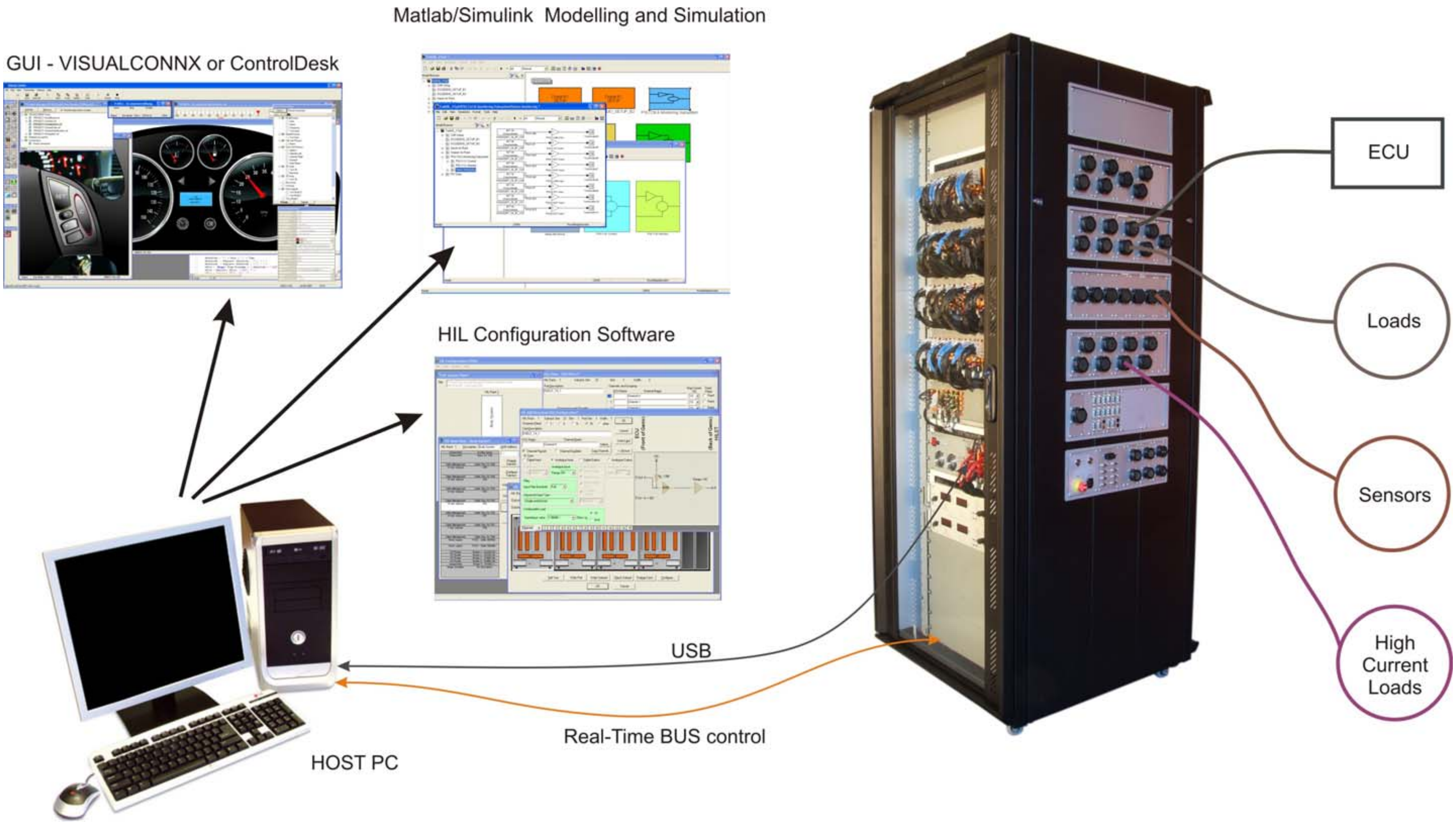
EVoCS Reconfigurable HIL Platform

High flexibility under software control to support intersystem robustness testing

- Flexible Connectivity
- Flexible Signal Conditioning
- Flexible Signal Type
- Flexible Signal Direction
- Flexible Signal Disabling
- Flexible ground and reference selection
- Flexible Fault Insertion



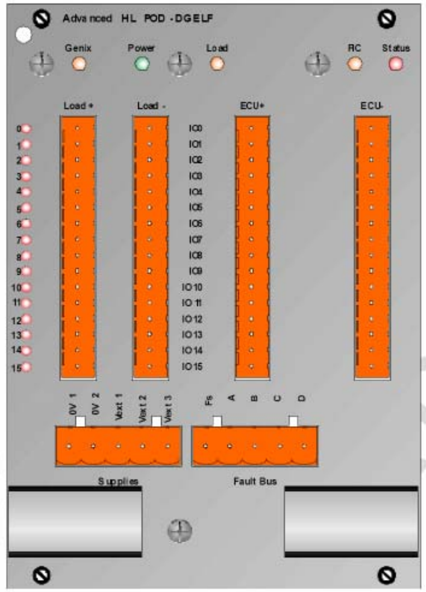
EVoCS Reconfigurable HIL Platform



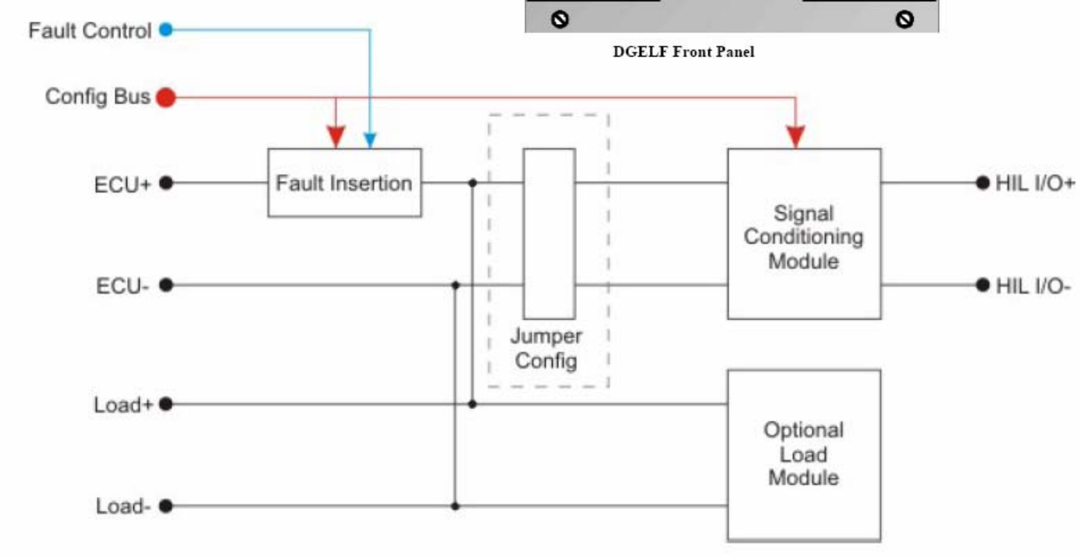
EVoCS Reconfigurable HIL Platform

Channels can be configured individually under software control

- Signal type
- Direction
- Bandwidth
- Gain
- Loading requirements
- Internal loads can be pulled up to a supply rail or pulled down to ground
- Support for external loads /sensors



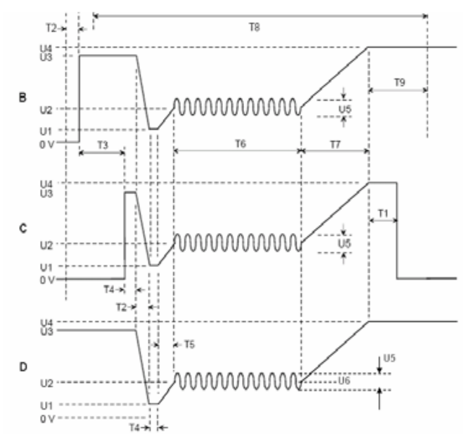
DGELF Front Panel

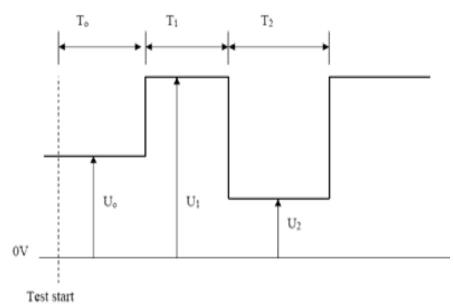


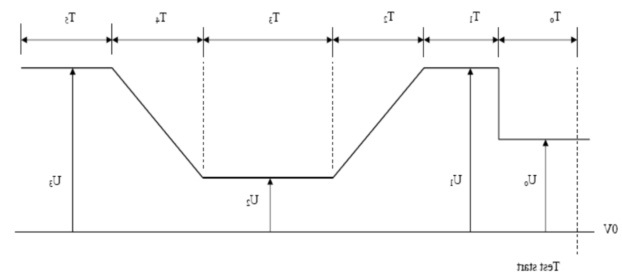
Low Voltage Robustness Testing

Low voltage a key issue for automotive SoS

- Conditions of variable system states
- Current tests insufficiently representative of real conditions
  - **Waveform variety**
  - **Duration**
  - **Coverage**



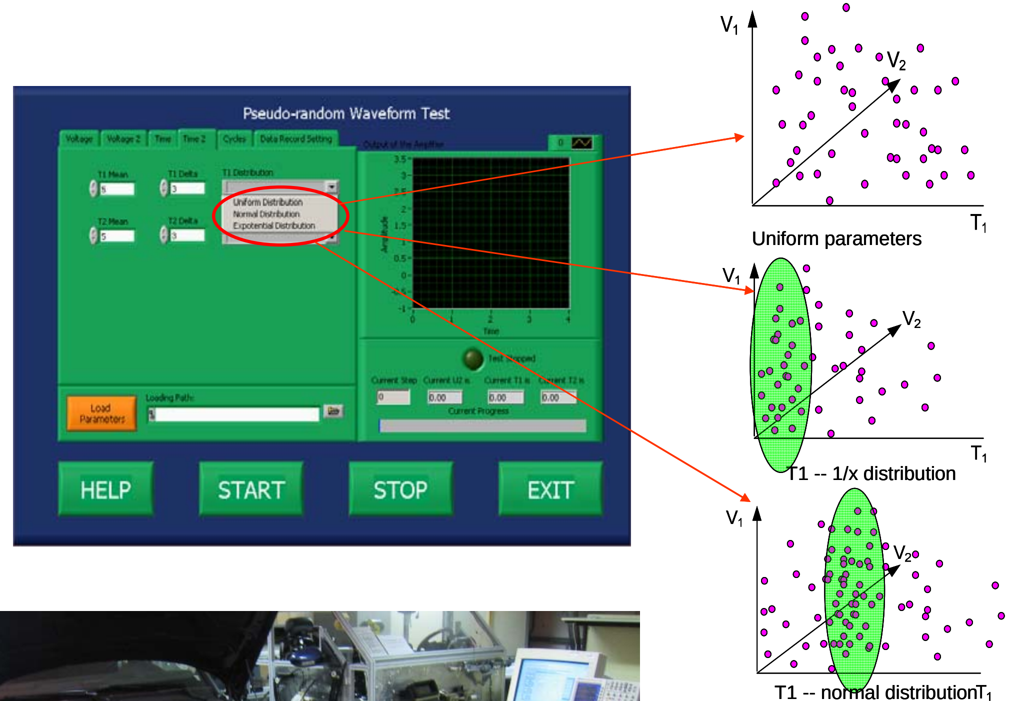


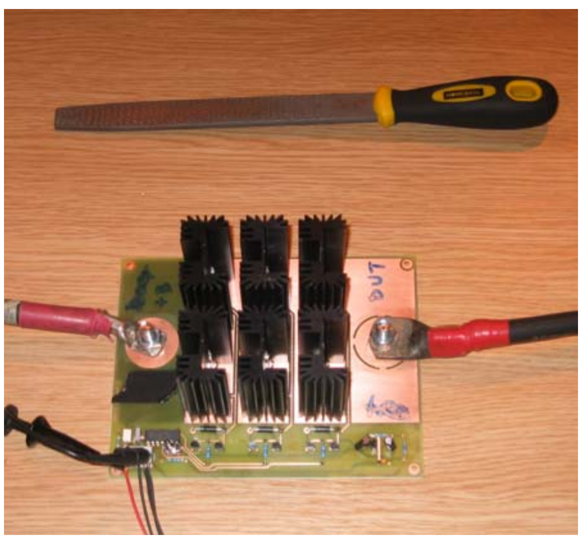


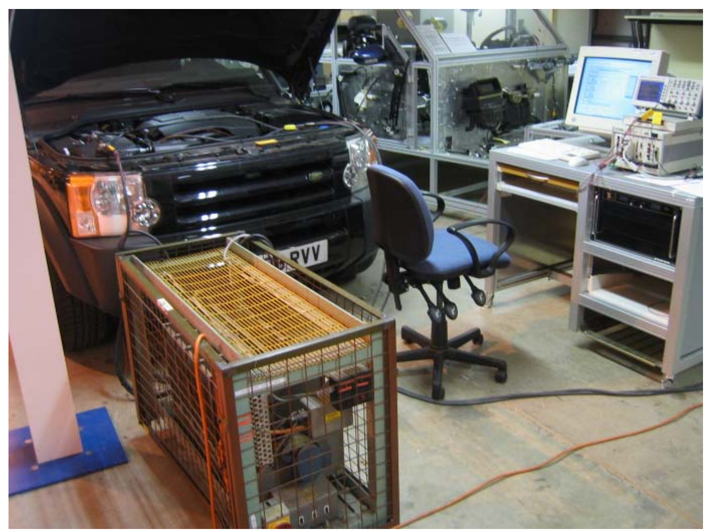
Low Voltage Robustness Testing

Low Voltage test system

- Pseudo-random automated waveform generator
- Electronic “Rusty File”
- Vehicle impedance simulator for component testing



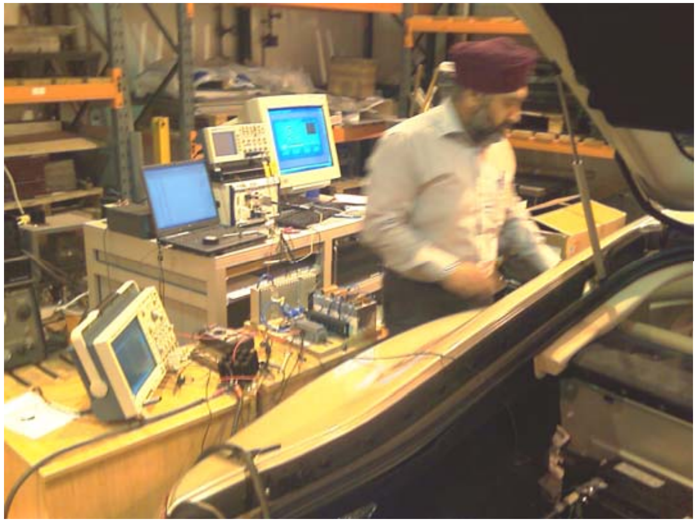




Low Voltage Robustness Testing

Work in progress

- Standardisation for release to suppliers
- Compact test equipment development by add2
- Automated analysis of DTC’s & CAN buses



Automated Infotainment Testing

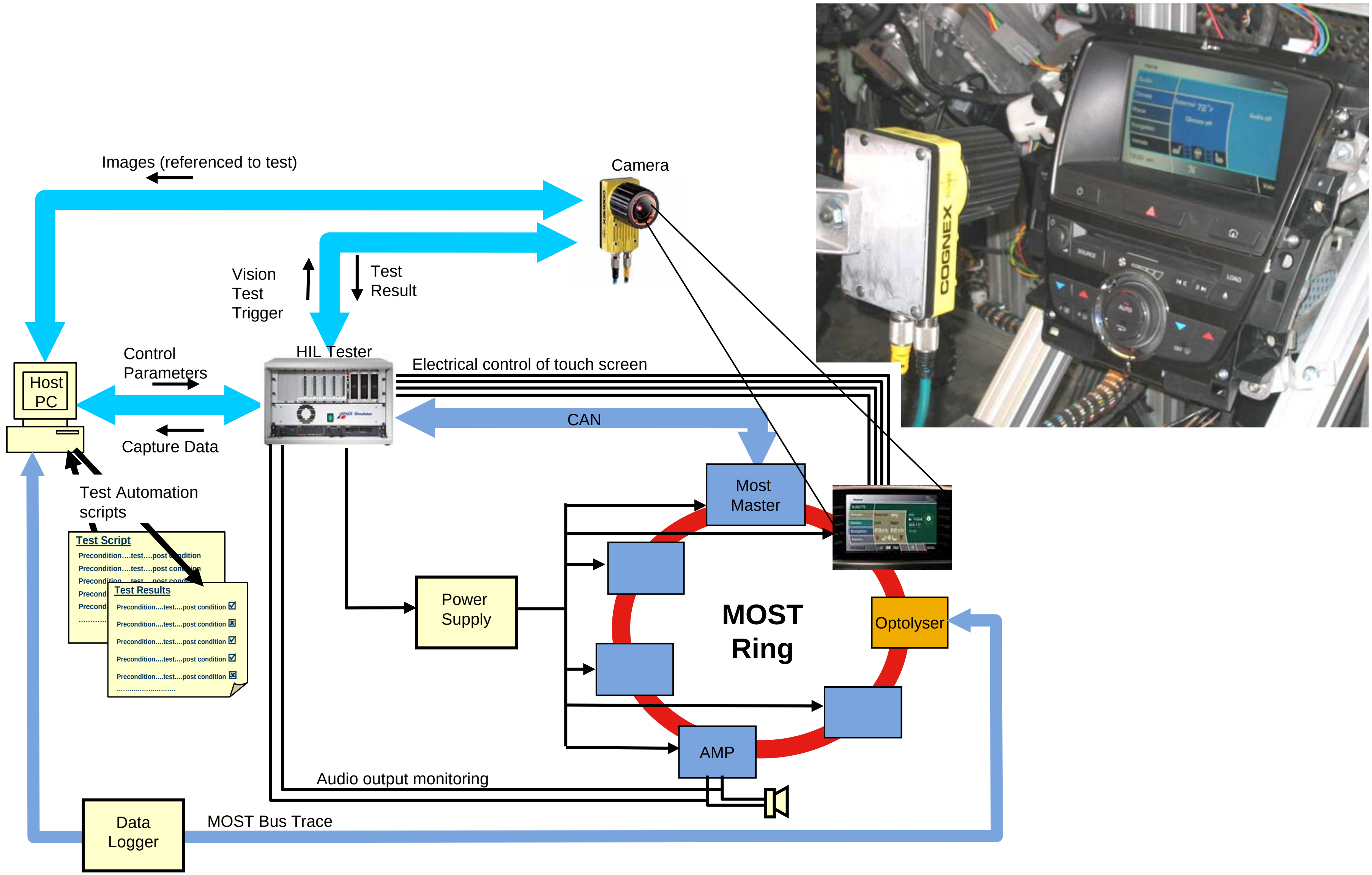
Fully automated robustness testing of Infotainment system initialisation

- Emulate expert functional testing to confirm that system (of systems) appears to be operating correctly

Key elements

- Pseudo random initialisation
- Stimulation of inputs: via electrical stimulation of touch screen and remote controls
- Monitoring and analysis of video and audio outputs
- Test Automation of manual test procedures
- Automated logging of diagnostics and MOST bus

Automated Infotainment Testing



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Design of multi-parameter robustness tests

- Large scale optimisation approach
- Incorporating domain knowledge from design stage

Modular dependability cases

Overall framework for design for robustness at SoS level

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Automotive Electrical System is in fact a system of systems with accompanying issues

Key characteristic of System of Systems is robustness to deal with disturbances or unexpected interactions

New validation tools and techniques required to deal with scale of system and fully explore robustness

EVoCS – Evolutionary Validation of Complex Systems

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END

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