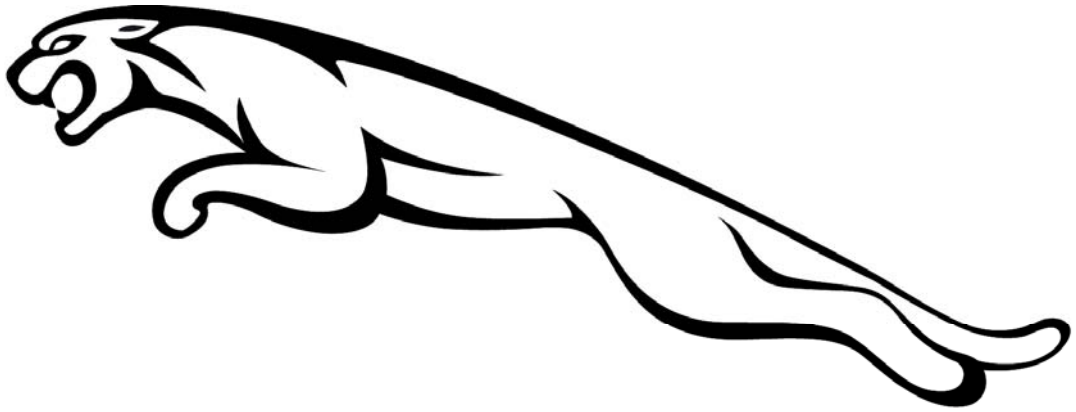

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Development and testing of complex automotive control systems using hardware-in-the-loop platform

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Automotive Control SIG Meeting
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Contents

- The challenge – complexity of embedded control software
- Overview of vehicle electrical architecture
- Traditional vehicle development process and platforms
- Concept of the VITAL
- Model-based development process for ECU development
  - Requirements capture
  - Auto-code generation
  - VITAL development – three phase process
- Model-based ECU software testing and validation process
- Concluding remarks

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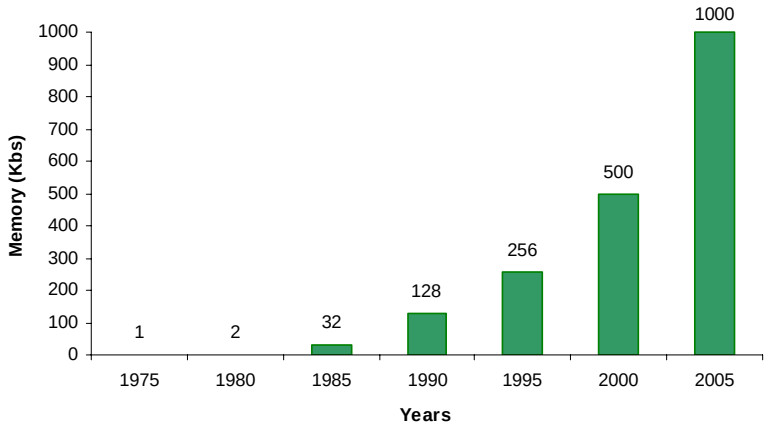
Electronic control unit (ECU) memory usage trend

- Digital controls first introduced in 70's.
- First production units consisted of about 1 Kb of memory.
- Nowadays, it is not unusual for ECU to have 1 Mb of memory.
- 1000 times increase in memory over the last 30 years



Source: Thomas, M. G. (2003). Electronics systems testing and validation for commercial vehicles. SAE Technical Paper Series, 2003-01-3383.

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What drives automotive system complexity?

- Customer demands for greater overall vehicle performance and comfort
- Reliability and quality
- Fuel economy
- Increasing restrictions on emissions levels
- Today, automobiles can contain up to 90 ECUs

Availability of more memory and microprocessor speed have provided the design engineers with greater flexibility, but also has driven greater complexity.

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Electronic body control systems - the challenge

- Complexity of embedded software for automotive ECUs in modern cars is continuously increasing
- Electronic body systems (EBS) functionality is distributed among many ECUs providing the customer with functions such as security, lighting, seat comfort and windscreen cleaning
- These functions are highly visible, with significant customer interaction and yet often they are taken for granted
  - Potential to provide real “surprise & delight” features
  - Large opportunities for customer complaints
- New approach is essential for the development and testing of complex automotive systems

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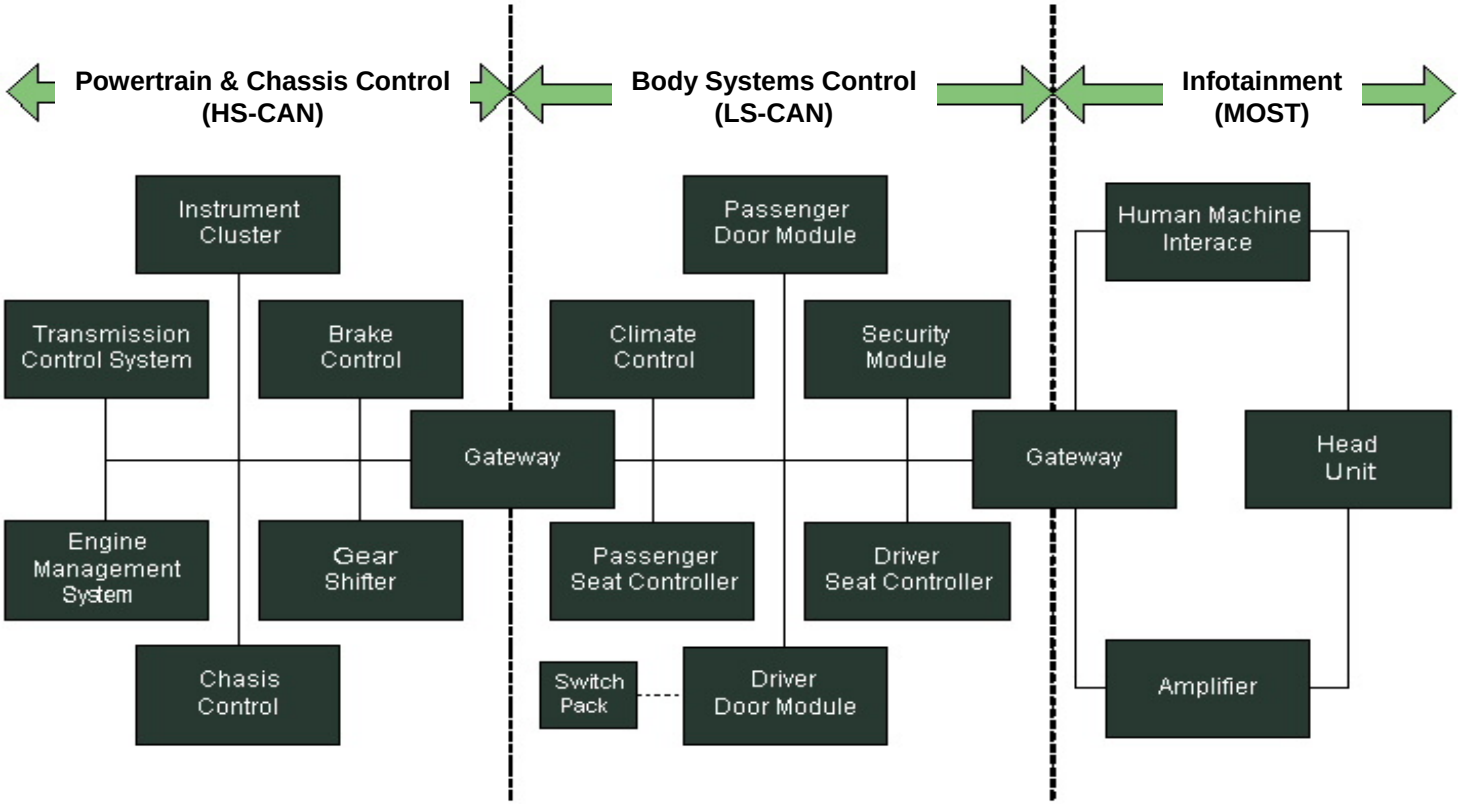
Vehicle electrical architecture



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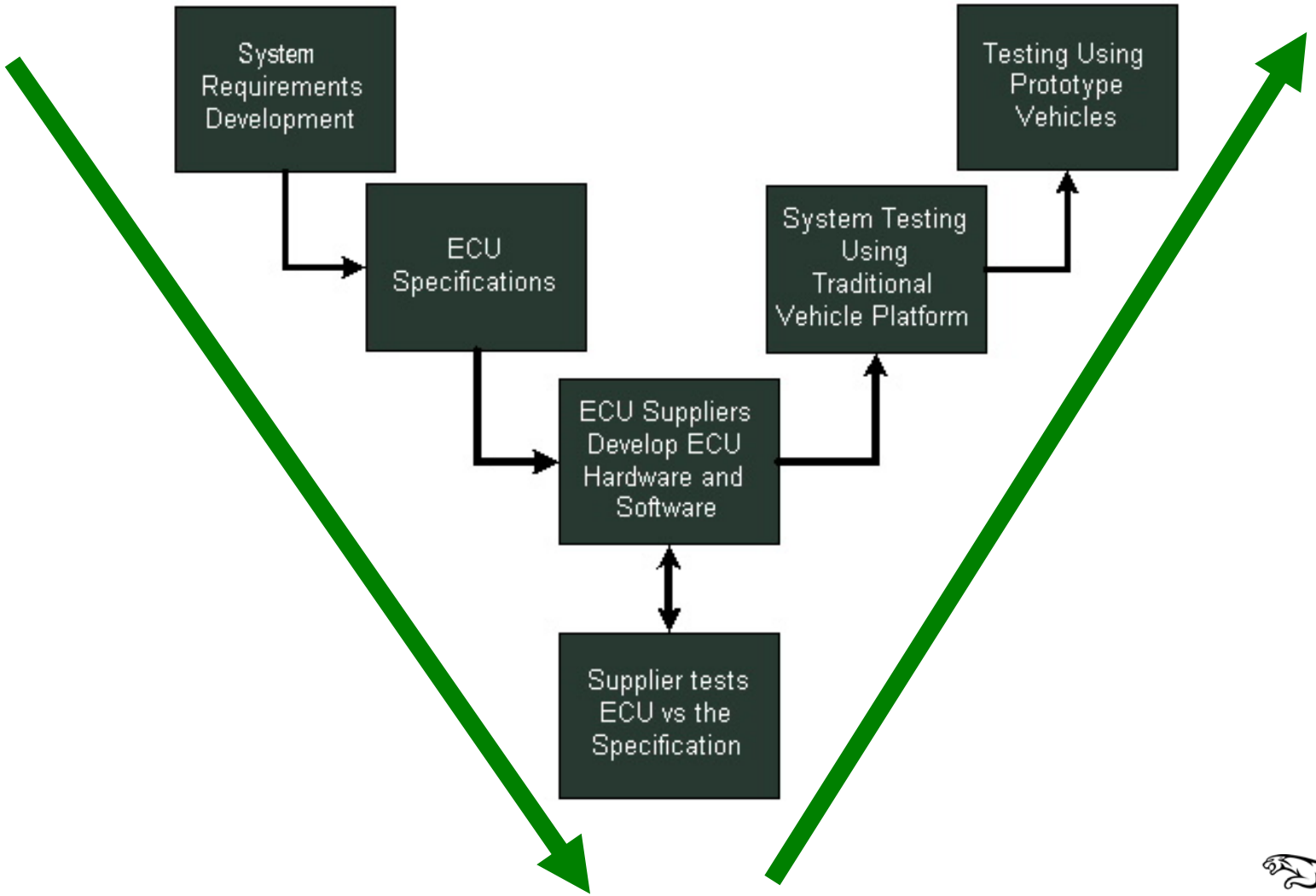
Traditional approach to ECU development



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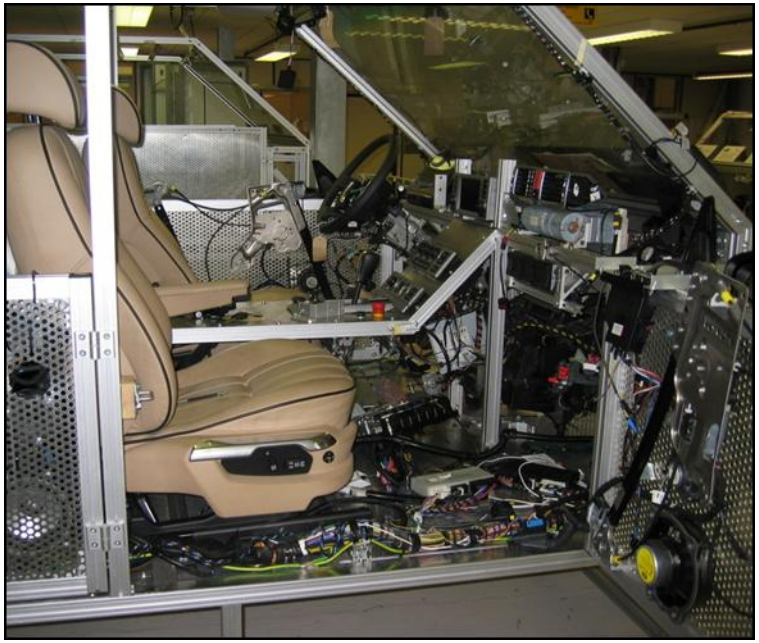
Traditional vehicle development platform



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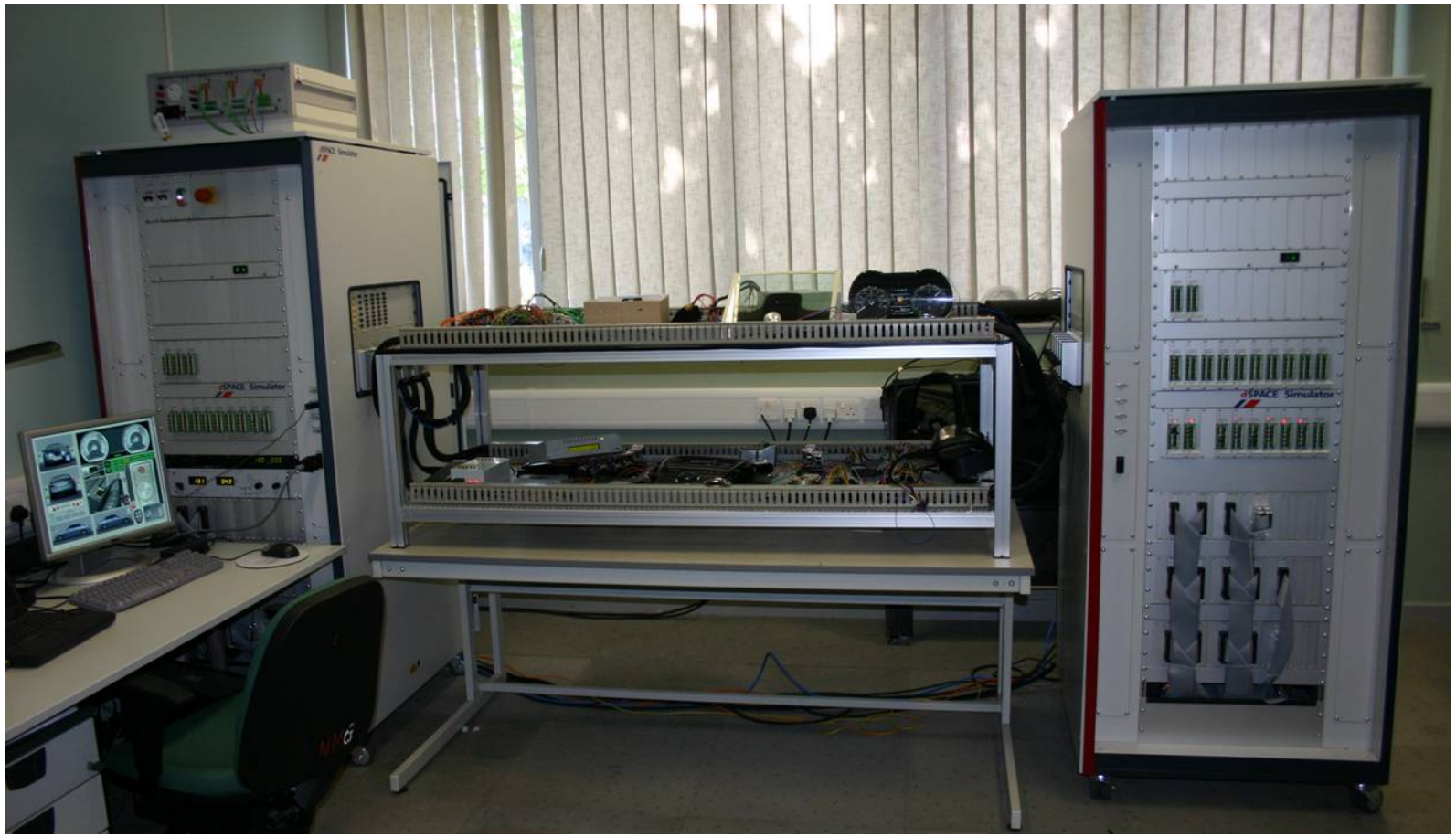
VITAL
Virtual Integration and Test Automation Laboratory



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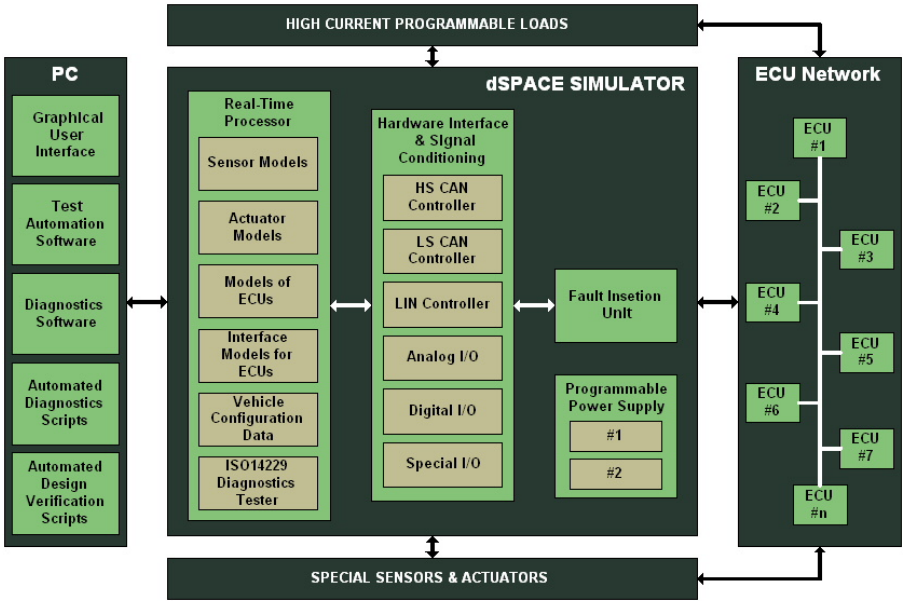
VITAL concept

- Main features
  - Simulated or real ECUs (LS-CAN)
  - Simulated sensors and actuators
  - Simulated HS-CAN ECUs
  - Simple wiring harness
- Additional features
  - CAN gateway emulation
  - Controlled ECU power up sequence
  - Full fault insertion on all I/O (all 6 fault modes)
  - Signal conditioning for all digital and analogue I/O
  - Quiescent current measurement



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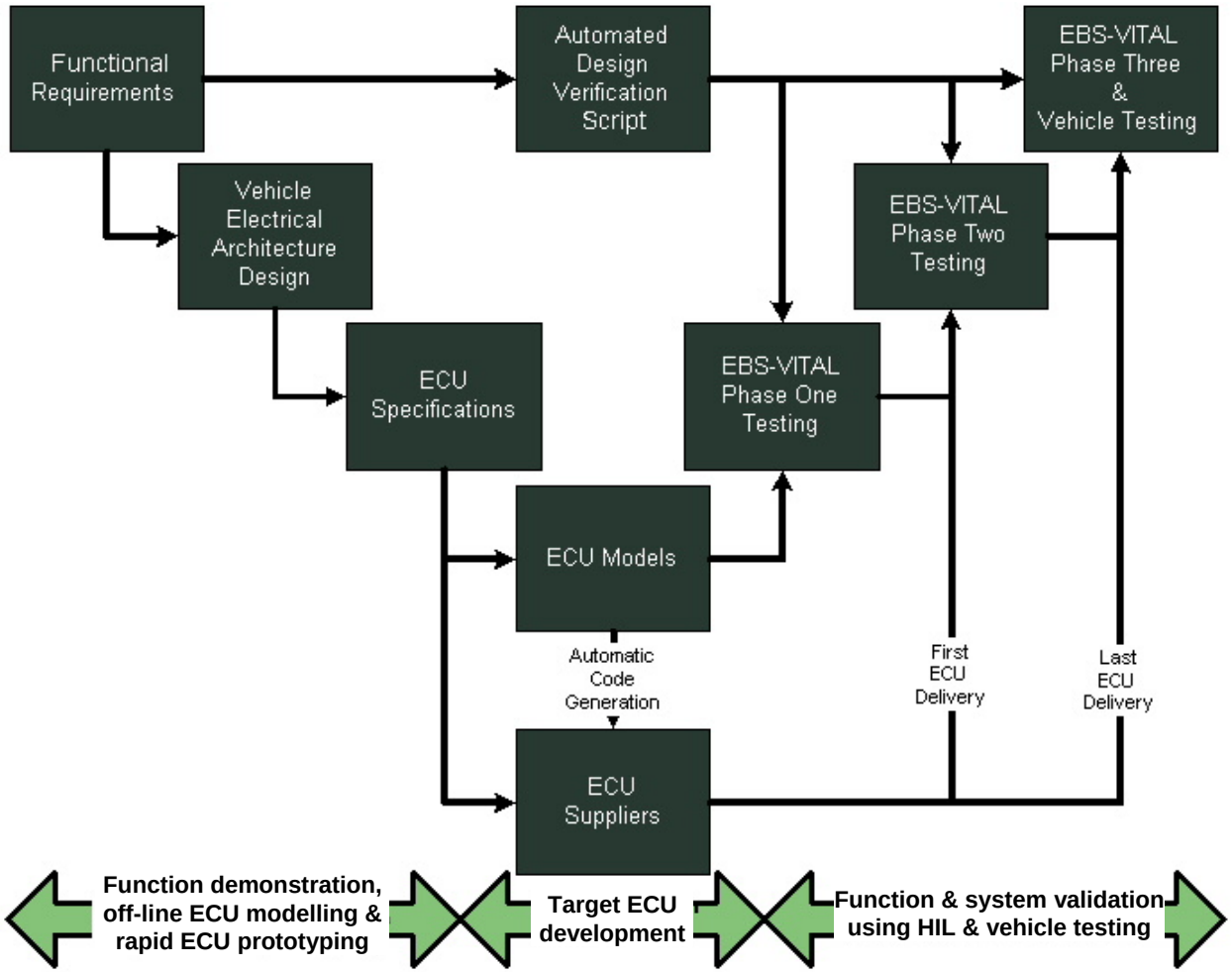
Model-based development process for body control systems



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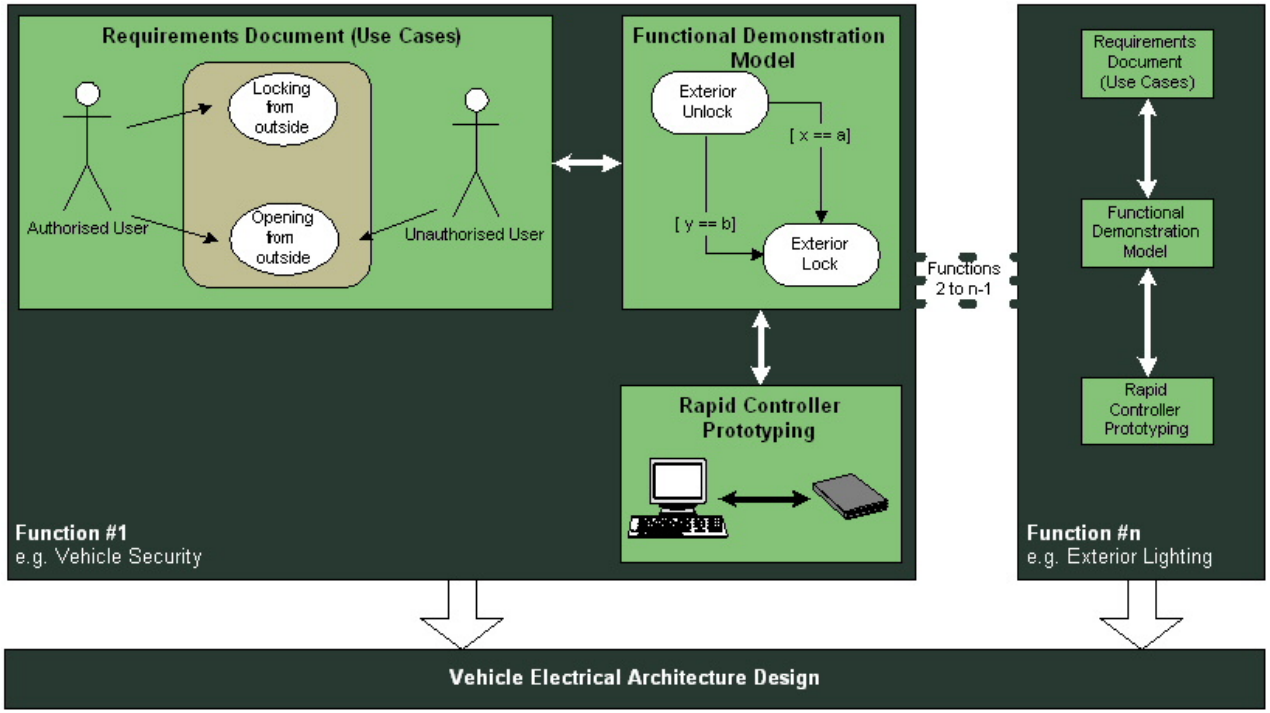
Requirements capture



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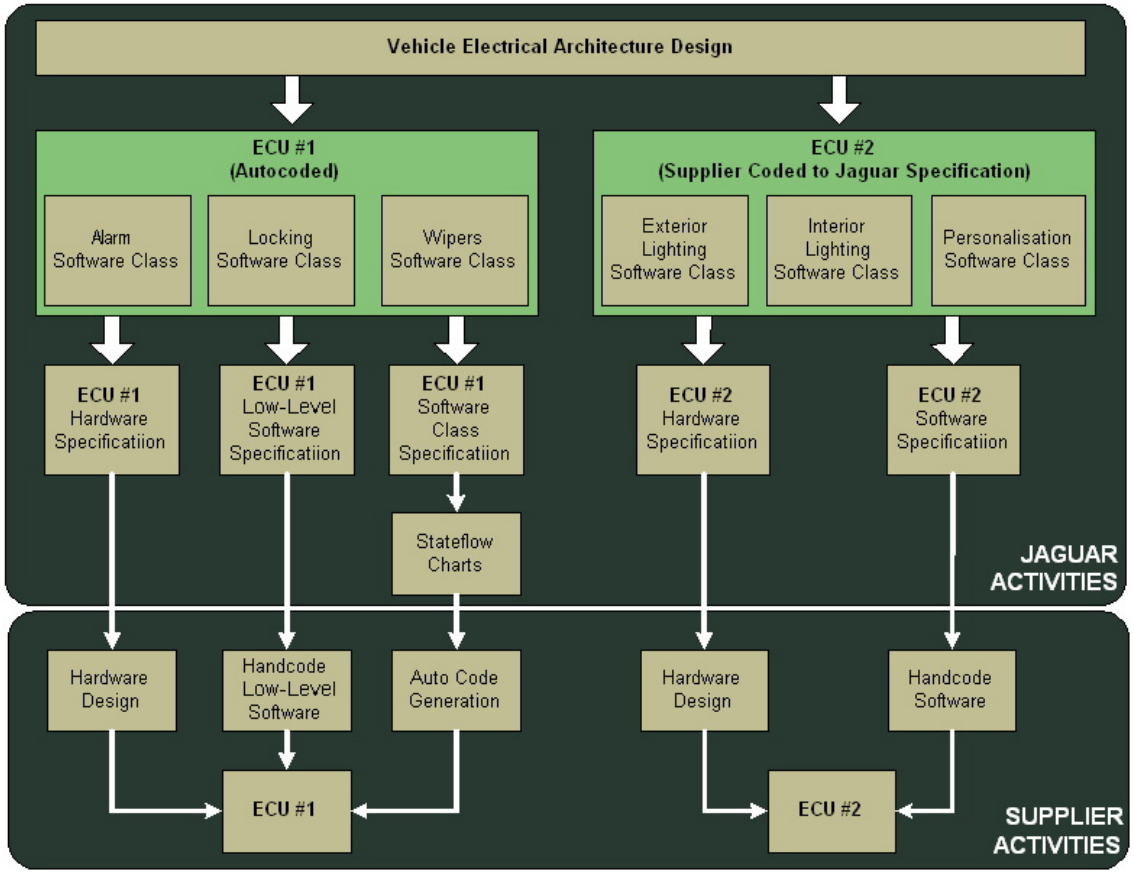
ECU development



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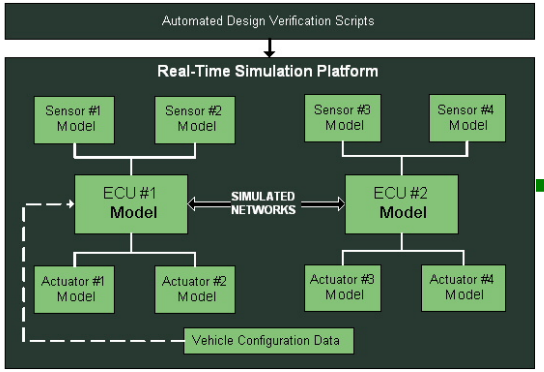
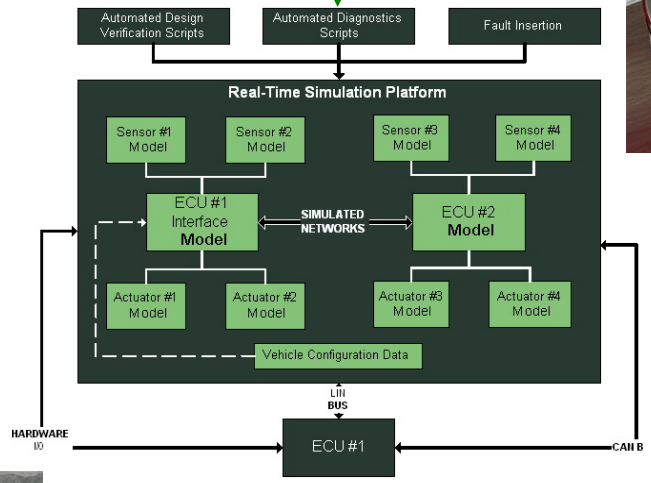
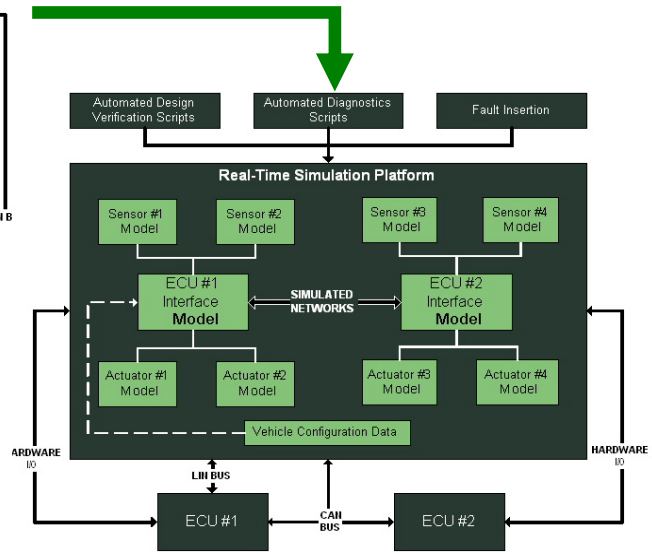
VITAL – three phase process







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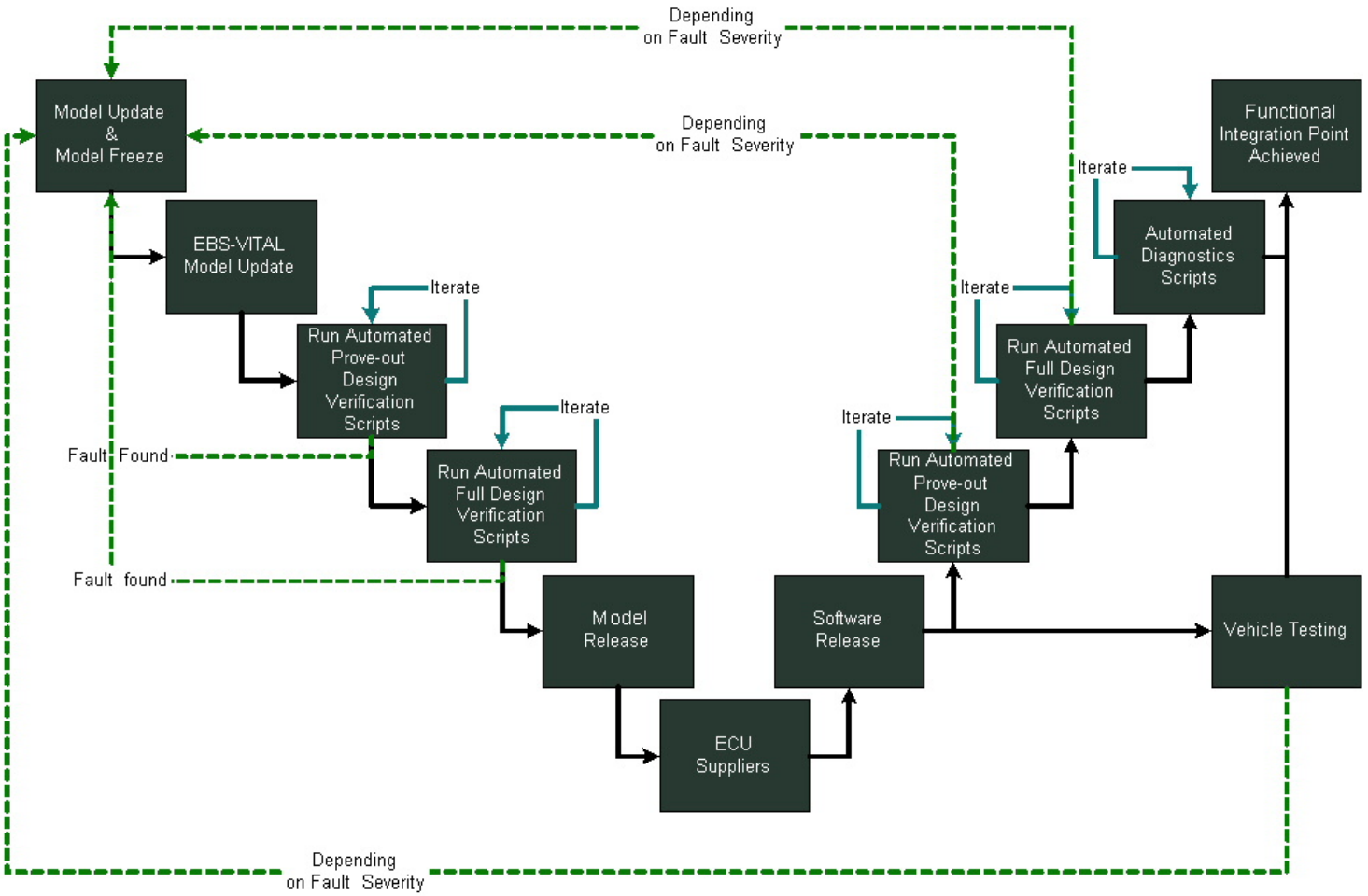
Model-based ECU software testing



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Problems with ECU model-based development process

- Significant culture shift is required
- Greater resource required earlier in the programme
- A danger of overlooking the importance of good requirements capture
- Software development skills and process required in-house
- No supplier to “kick” if errors found with functionality

Each of these issues should become less significant on each subsequent vehicle programme.

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Advantages of model-based development

- Main Advantages
  - Specification interpretation errors virtually eliminated
  - Early demonstration and testing
  - Greater software re-use between programmes
  - Encourages continuous improvement
- Additional Advantages
  - Long term reduction in development effort and cost
  - Greater flexibility with supplier selection
  - Better control of brand functionality

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Advantages of VITAL

- Main Advantages
  - Testing and validation commences much earlier, reducing late and expensive changes
    - » Testing using modelled ECUs
    - » Testing using real ECU prior to production intent harness
  - Automated testing
  - Fewer prototype vehicles required
  - Testing can cover both static and dynamic vehicle conditions
- Additional Advantages
  - Removes reliance on all suppliers supporting a single delivery point before testing can start
  - Testing of system behaviour under fault conditions is easier

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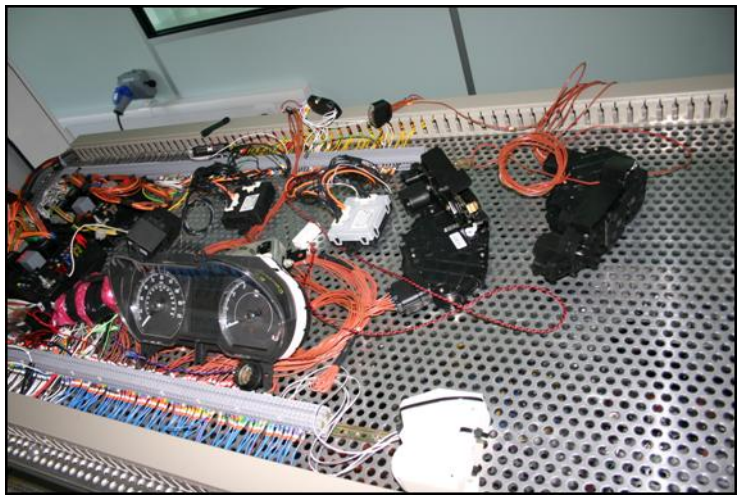
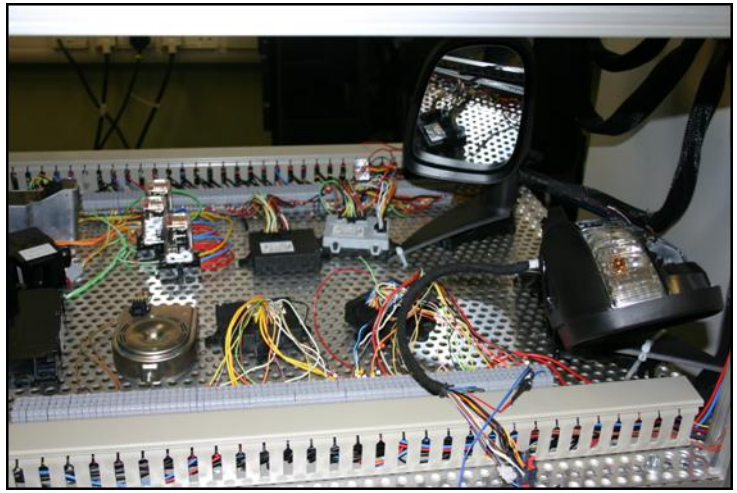
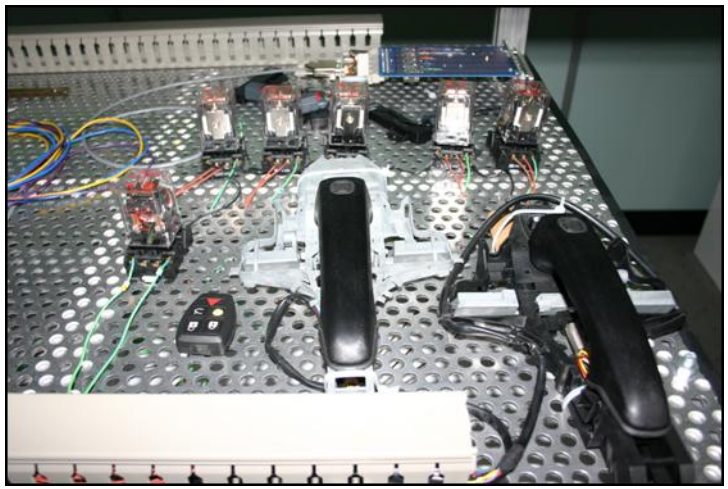
Applications – vehicle security/PEPS







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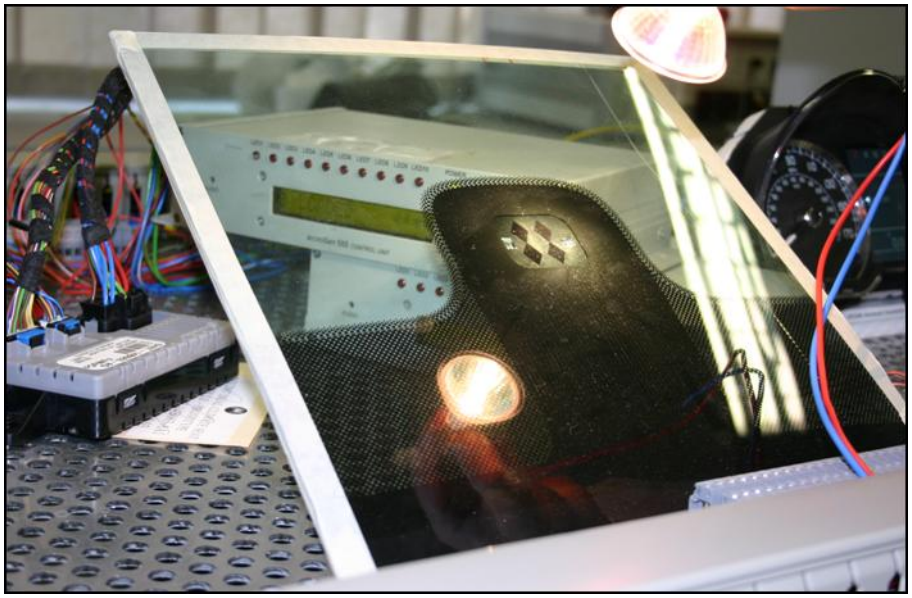
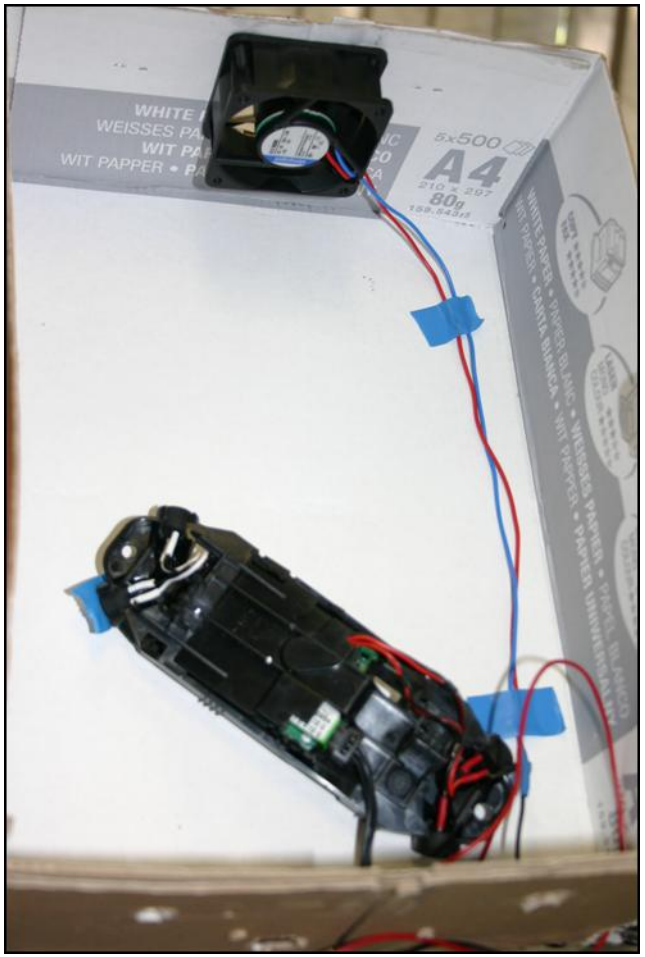
Applications – light sensor / intrusion sensor





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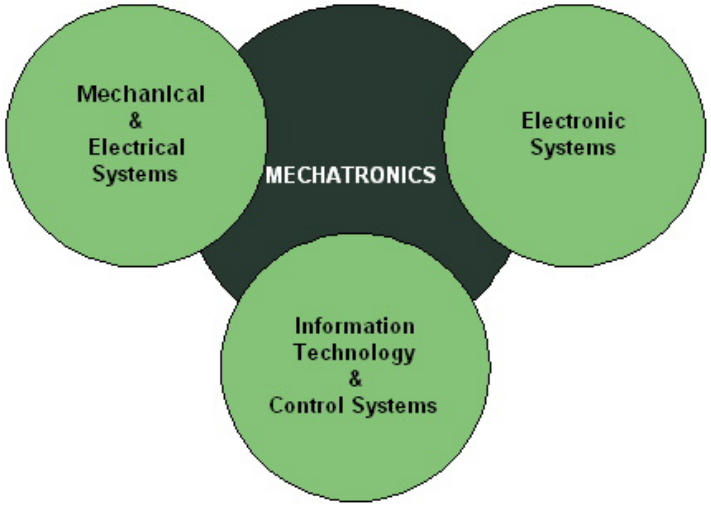
Future direction

- Electronics will continue to evolve at a very rapid pace
- The need for progress for better test techniques will continue to be very important
- Mechatronics will play an essential role as more and more mechanical components are controlled or replaced by software
- Infotainment/comfort and prognostics are the main areas to dominate future research and development activities
- Full vehicle simulator – more electrical integration testing



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Summary, concluding remarks

- Model-based development success
  - Started 2000 on current Land Rover T5 platform
  - Since used on XK sports, XJ and Range Rover
- VITAL success
  - Started 2003 on Jaguar XK sports platform
  - Since used on XF, Range Rover and XJ
- Jaguar now use model-based design in conjunction with the VITAL throughout the entire electrical body systems development process
- The main benefits to Jaguar are,
  - Higher quality validation
  - Problems can be identified earlier
- The major problems experienced have been linked to the required cultural changes

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