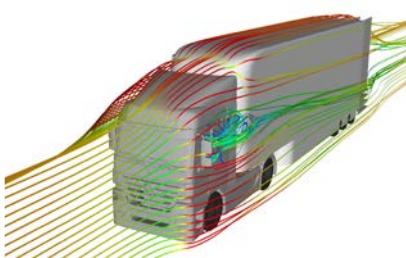
Regulatory NDT Requirements for Composites on Public Roads

Richard Whiting

April 4, 2017

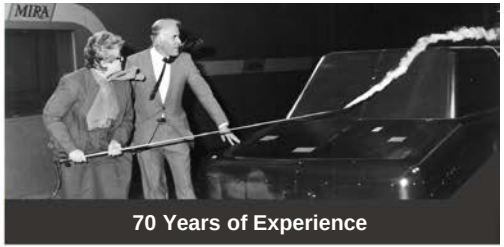


HORIBA MIRA has a Well Established Offering as an Engineering Service Provider and R&D Location

World-Class Vehicle Engineering Consultancy

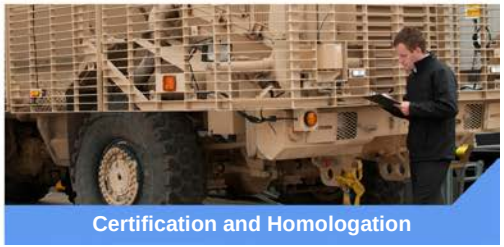
Test Engineering Services

Technology Park



70 Years of Experience

Transport Technology R&D



Certification and Homologation

HORIBA MIRA Engineering and MIRA Technology Park

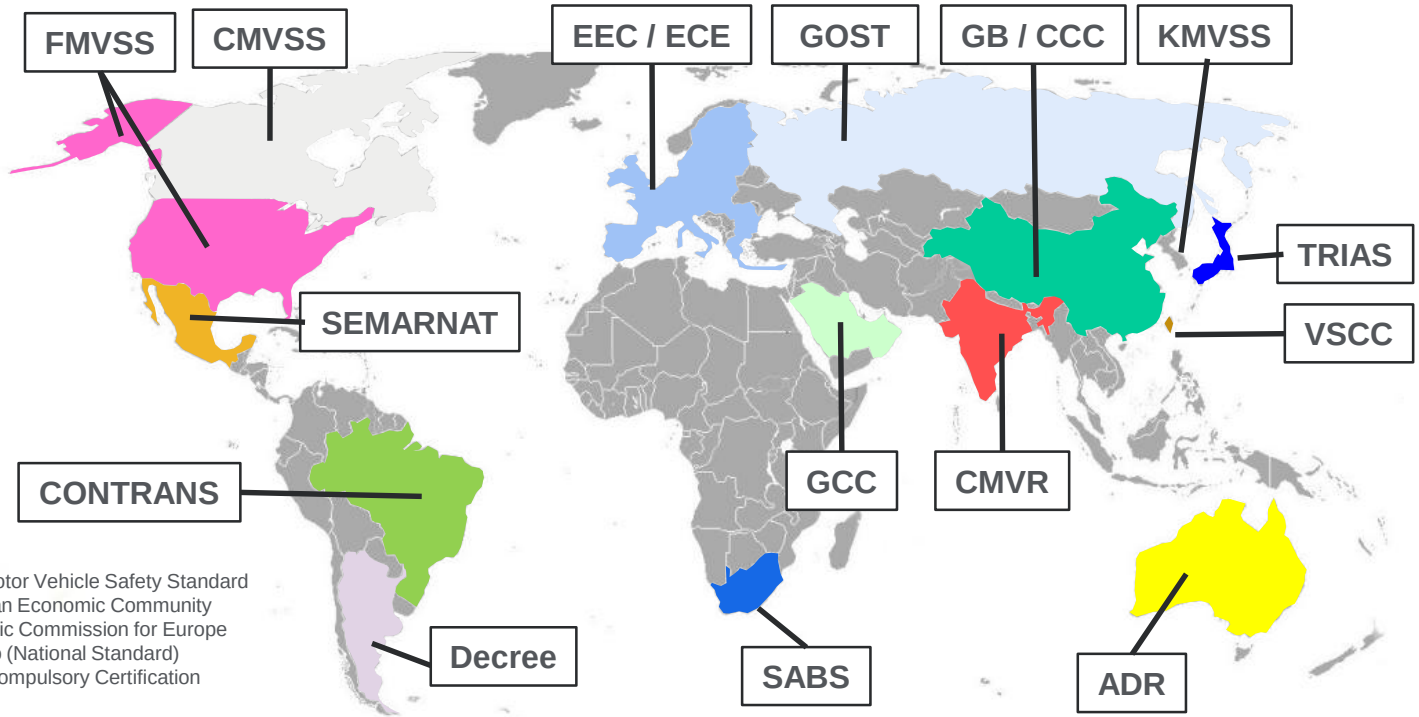
- Est. 1946 by UK Gov. & Industry
- Leading vehicle, test and systems engineering consultancy
- £46m annual turnover (2014)
- 600+ staff; 75% engineers and technicians
- 842 acre (336 ha) site
- 62 mile (100km) proving ground facility
- Over 37 major laboratory facilities
- 1.75M sq ft technology park attracting global businesses
- UK national centre of excellence in transport sector R&D
- 60% growth in last 6 yrs, 338 high tech jobs created / safeguarded

Agenda

- Background to Type Approval
- Requirements for EU Type Approval
- Key Legislation Areas for EU Type Approval
- NDT For Type Approval
- NDT for the Future

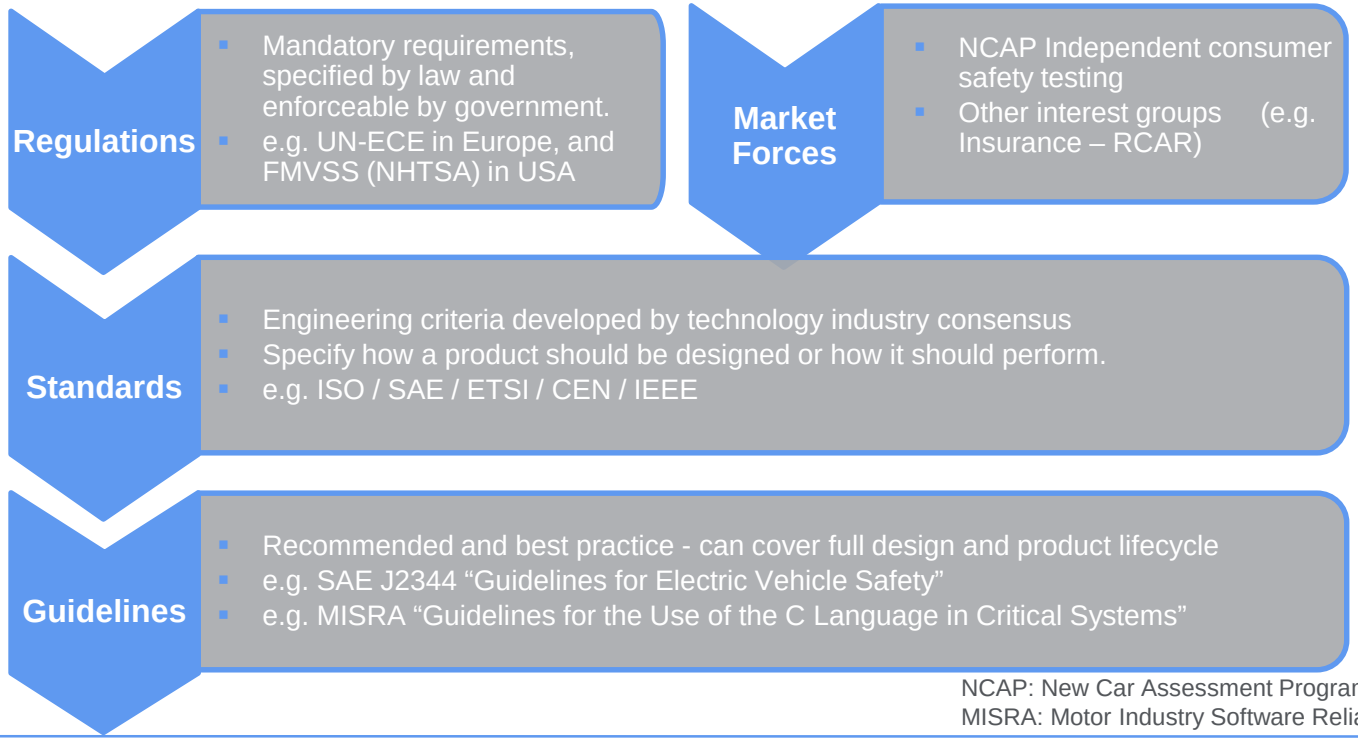
Background to Type Approval: Standards and Legislation Related to Type Approval

Global Requirements



FMVSS - Federal Motor Vehicle Safety Standard
EEC - European Economic Community
ECE - Economic Commission for Europe
GB - Guobiao (National Standard)
CCC - China Compulsory Certification

Standards and Legislative Framework



NCAP: New Car Assessment Programme
MISRA: Motor Industry Software Reliability Association

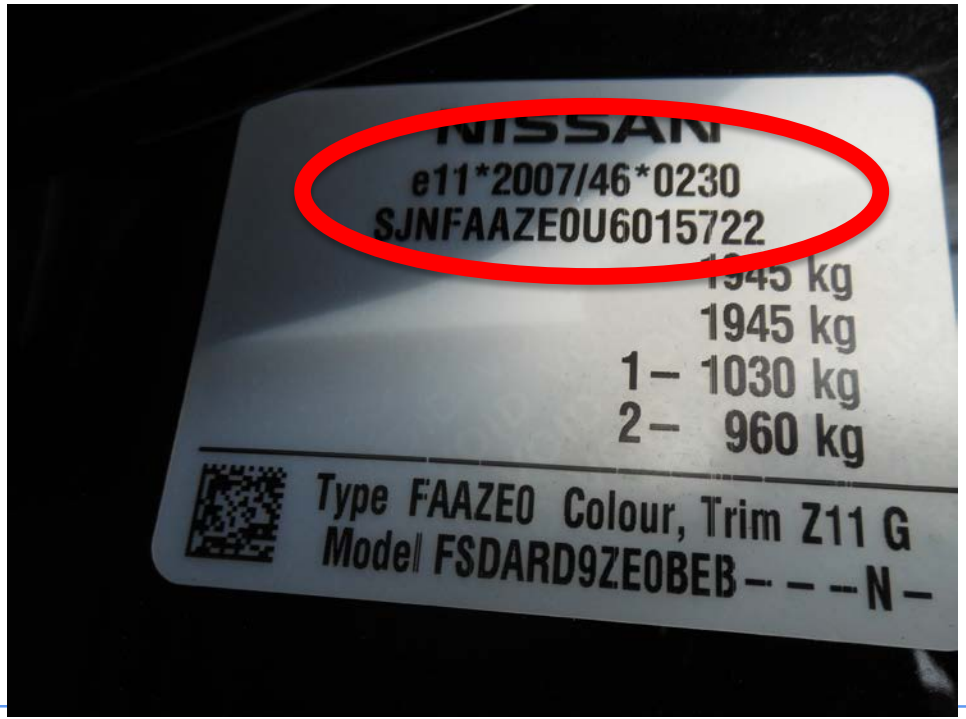
Overview – EU Vehicle Certification

- EU operates a ‘Full Witnessed Type Approval’ process.
- EC Whole Vehicle Type Approval (ECWVTA) is based around EC Directives
- It provides for the Approval of
  - whole vehicles,
  - vehicle systems
  - separate components.
- This certification is accepted throughout the EU without the need for further testing until a standard is updated or the design/production changes.

Overview – EU Vehicle Certification

- All automotive EC Directives and UN Regulations require third party Approval
- Testing, certification and production conformity assessment conducted by an independent body.
- Each member state is required to appoint an Approval authority to issue the Approvals
- Technical service is authorised by Approval authority to carry out the testing to the directives and regulations.
- An Approval issued by any member state authority will be accepted in all the member states.

Overview – EU Vehicle Certification



Awareness of Non-Legislative Tests

The Current Global Map of New Car Assessment Programmes

EU Type Approval

Overview – EU Vehicle Certification

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EU Type Approval:

European Whole Vehicle Type Approval

- Directive 2007/46/EEC for passenger cars(M), buses (M), vans (N), trucks (N) and trailers (O).
- EU Regulation 168/2013 for 2 and 3 wheeled vehicles and quad bikes (L).
- Directive 2003/37/EC for agricultural tractors.

‘M’ Category Vehicles

PASSENGER VEHICLES

Kind of vehicle		Description	Weight range
M_1		No more than 8 seats in addition to driver’s seat	Not applicable
M_2		More than 8 seats in addition to driver’s seat	5t or less
M_3		More than 8 seats in addition to driver’s seat	Over 5t
M_1	Special purpose 	Motor caravans, ambulances, hearses, armoured cars, wheelchair-accessible vehicles	Not applicable

EU Type Approval:

European Type Approval Country Codes

1	Germany	12	Austria	27	Slovakia
2	France	13	Luxembourg	29	Estonia
3	Italy	17	Finland	32	Latvia
4	Netherlands	18	Denmark	34	Bulgaria
5	Sweden	19	Romania	36	Lithuania
6	Belgium	20	Poland	49	Cyprus
7	Hungary	21	Portugal	50	Malta
8	Czech Republic	23	Greece		
9	Spain	24	Ireland		
11	United Kingdom	26	Slovenia		

European Type Approval Country Codes

Marking for EEC Directive Compliance

e9 e11 e4 e1

provides for the approval of whole vehicles, vehicle systems, and separate components

Marking for UNECE Regulation Compliance

provides for approval of vehicle systems and separate components, but not whole vehicles

EU Type Approval:

Routes to Approval

- For Europe, three routes exist

  - European whole vehicle Type Approval for Mass Market Vehicles
  - European small series for small volume vehicles
  - Individual vehicle Approval for single of very low volume vehicles

European Whole Vehicle Type Approval

European Whole Vehicle Type Approval: Aimed at Mass Market Manufacturer

- Advantages
  - One example of Type tested
  - No further certification cost for unaltered Types
  - No limit to build numbers
  - Entitles trade across Europe
- Disadvantages
  - High initial cost
  - Regular conformity of production audits
  - Full documentation required
  - Full test requirements must be met

European Small Series Type Approval

European Small Series Type Approval: Aimed at Niche Vehicle Market Manufacturer

- Advantages
  - Flexible CoP requirements
  - Technical requirements reduced
  - Inspections carried out at manufacturer's premises
  - One inspected vehicle Type covers future build
- Disadvantages
  - High initial cost
  - Annual conformity of production audits albeit relaxed
  - Limited numbers (1000)

EU Type Approval:

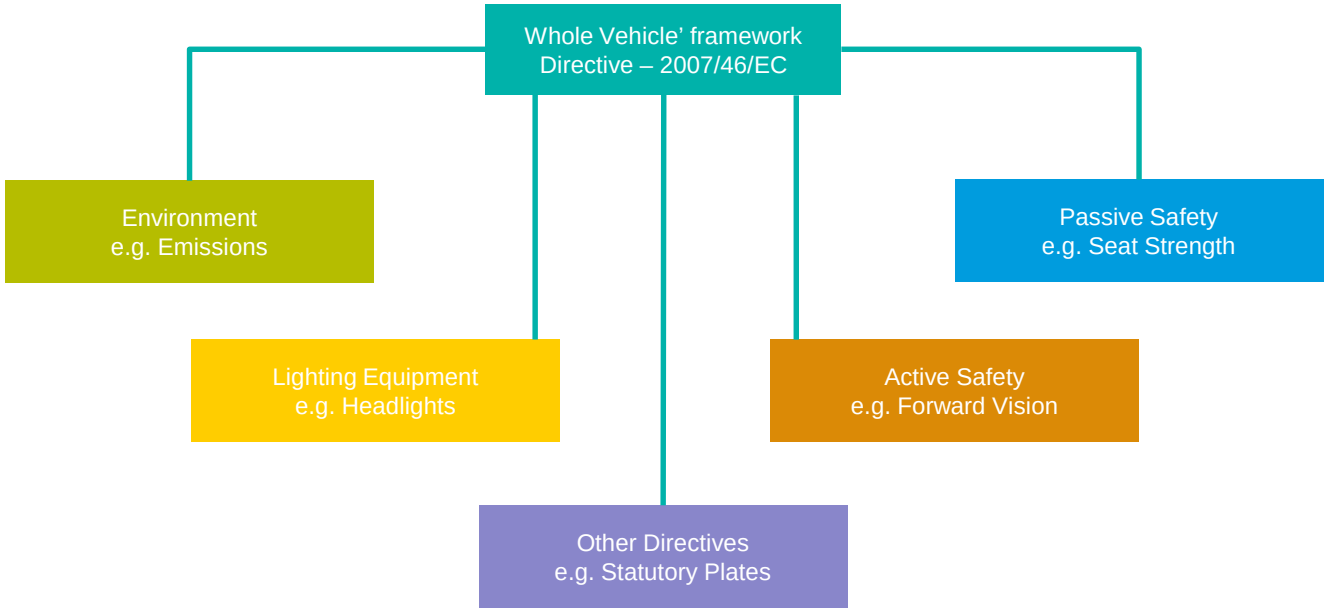
Individual Vehicle Approval

Individual Vehicle Approval: Aimed at Single or Very Low Volume Vehicle Build

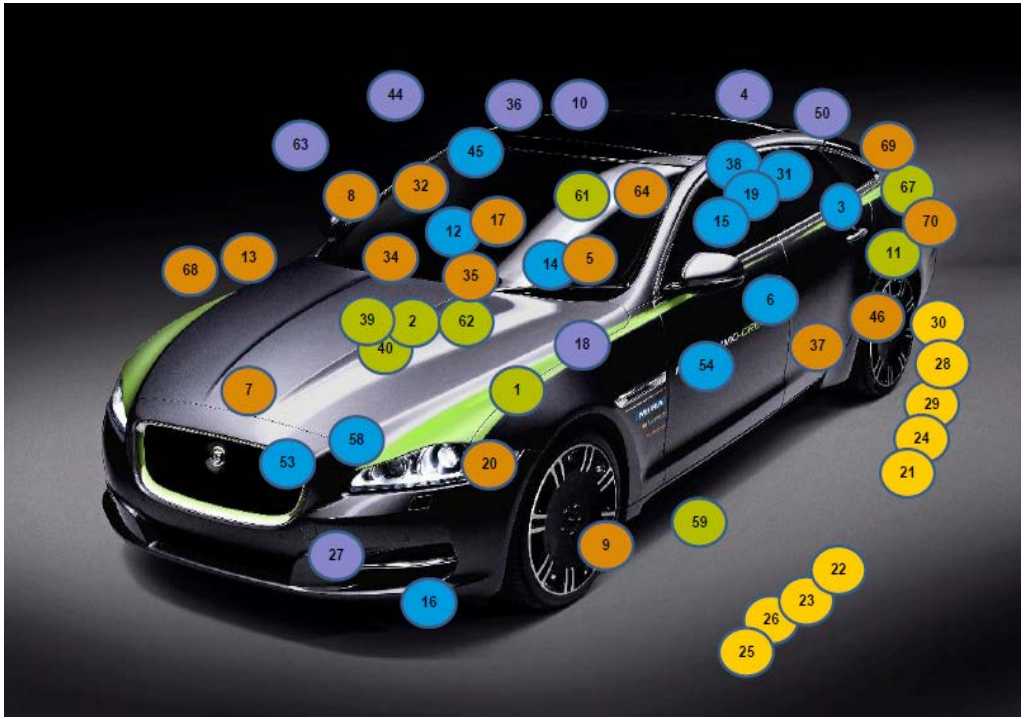
- Advantages
  - No CoP requirements
  - Inspection assessment
  - No formal link with original vehicle manufacturer
  - Suits one off or bespoke vehicles
- Disadvantages
  - Every individual vehicle has to be inspected and at an approved site
  - High cost per vehicle
  - Sales in Issuing Country only

European Approval Flow Chart

Whole vehicle framework directive for road vehicles contains five Approval topics:



Key Legislative Areas



Environment

Passive Safety

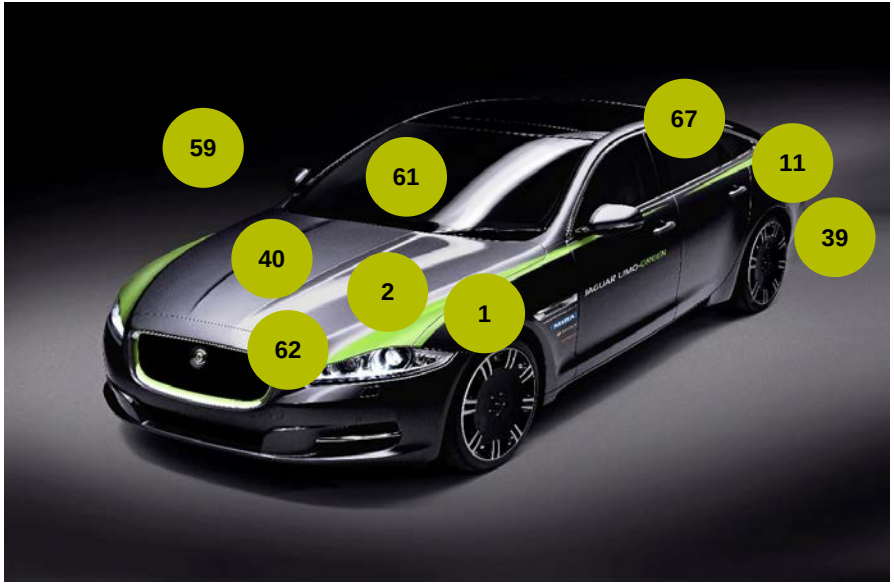
Active Safety

Lighting Equipment

Miscellaneous

EU Type Approval:

Key Legislative Areas

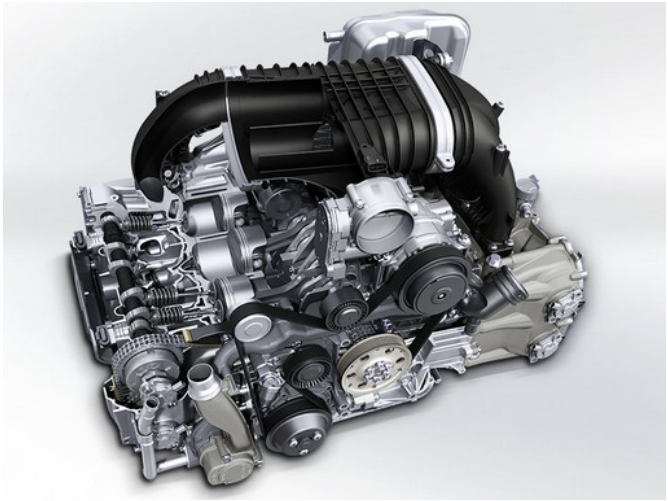


Environment

- 1 Sound Levels 70/157/EEC
- 2 Emissions EU V/VI EC 715/2007
- 11 Diesel Smoke 72/306/EEC
- 39 CO2 emissions/Fuel Consumption 80/1268/EEC
- 40 Engine Power 80/1269/EEC
- 59 Recyclability 2005/64/EC
- 61 Air Conditioning Systems 2006/40/EC
- 62 Hydrogen System EC 79/2009
- 67 LPG EC 661/2009

EU Type Approval:

Key Legislative Areas

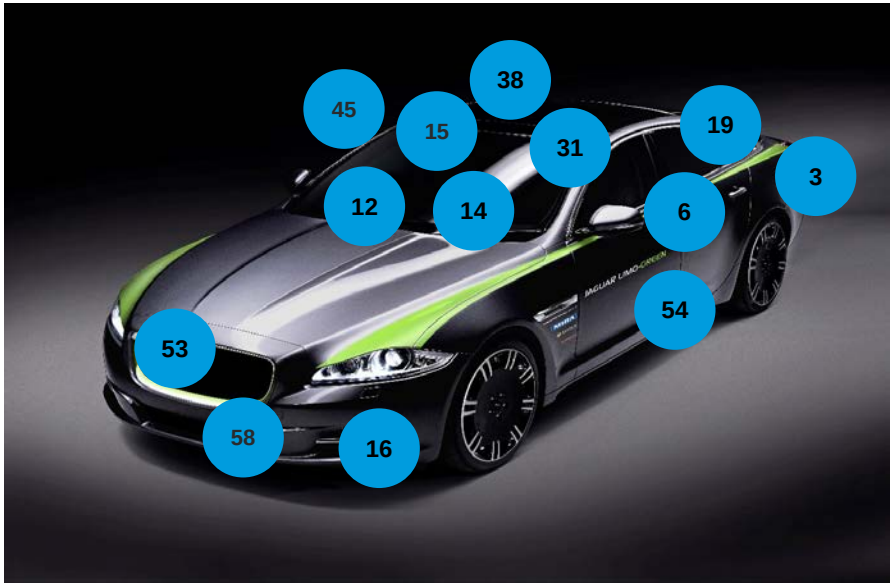


Environment

- 2 Emissions EU V/VI EC 715/2007
- 39 CO2 emissions/Fuel Consumption 80/1268/EEC
- 40 Engine Power 80/1269/EEC

EU Type Approval:

Key Legislative Areas

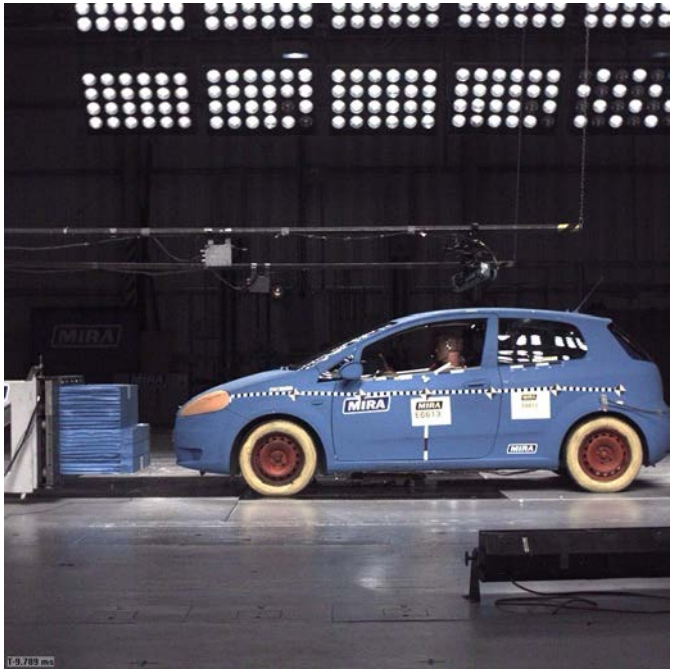


Passive Safety

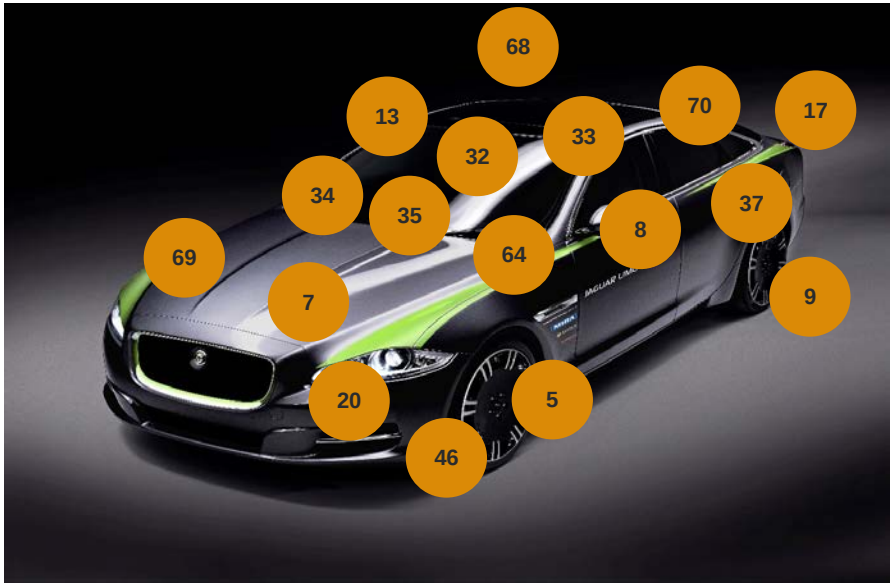
- 3 Fuel Tank UNECE R34
- 6 Door Latches & hinges UNECE R11
- 12 Interior Fittings UNECE R21
- 14 Protective Steering UNECE R12
- 15 Seat Strength UNECE R17
- 16 Exterior Projection UNECE R26
- 19 Safety Belt Anchorage UNECE R14
- 31 Safety Belts UNECE R16
- 38 Head Restraints UNECE R25
- 45 Safety glazing UNECE R43
- 53 Frontal Impact UNECE R94
- 54 Side impact UNECE R95
- 58 Pedestrian Protection EC 78/2009

EU Type Approval:

Key Legislative Areas- Passive Safety



Key Legislative Areas



Active Safety

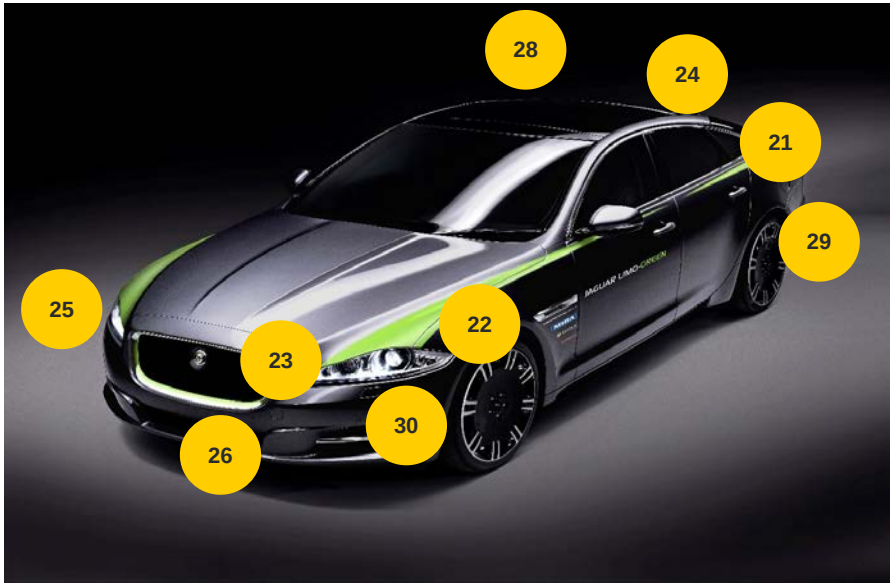
- 5 Steering Equipment UNECE R79
- 7 Audible Warning UNECE R28
- 8 Devices for Indirect Vision UNECE R46
- 9 Braking UNECE R13H
- 13 Antitheft UNECE R18/R116
- 17 Speedometer and Reverse Gear UNECE R39
- 20 Lighting Installation UNECE R48
- 32 Forward Vision UNECE R125
- 33 ID of Controls UNECE R121
- 34 Defrost / Demist EU 672/2010
- 35 Wash / Wipe EU 1008/2010
- 37 Wheel Guards EU 1009/2010
- 46 Tyres UNECE R30/117 & 64 (spare +TPMS)
- 64 Gear Shift Indicators EU 65/2012
- 68 Vehicle Alarm Systems VAS UNECE R97
- 69 Electric safety Regulation UNECE R100
- 70 Specific components for CNG UNECE R110

Key Legislative Areas

Active Safety

7 Audible Warning 70/388/EEC {UNECE R28}

Key Legislative Areas



Lighting Equipment

21 Retro Reflectors UNECE R3

22 Side, Rear, Stop & Daytime running lamps UNECE R7, 87, 91

23 Direction indicator lamps UNECE R6

24 Rear registration plate lamp UNECE R4

25 Headlamps (including bulbs) UNECE R31, 37, 99, 112, 123

26 Front fog lamps UNECE R19

28 Rear fog lamps UNECE R38

29 Reversing Lamps UNECE R23

30 Parking Lamps UNECE R77

Example of lighting equipment

1st - Component Approval

e.g – front headlamp comprising of:

- Main Beam (R112),
- Passing Beam (R98),
- Indicator (R6),
- Daytime running lamps (R87)

2nd - Lighting installation (R48)

Each of the subjects will either be to a Directive or Regulation.
Depending upon the standard, this will dictate the Approval mark:

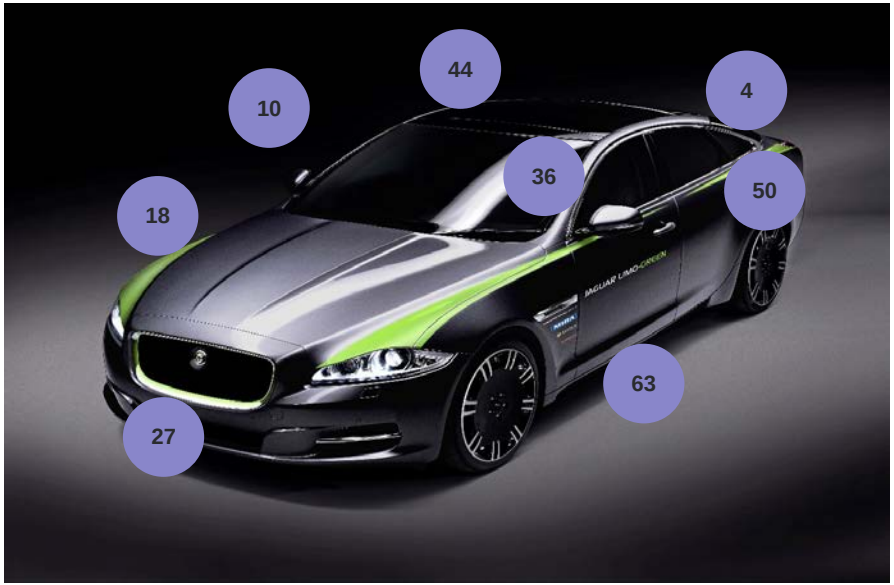
"e" marked against EC directives

and/or

"E" marked against UN ECE regulations.

EU Type Approval:

Key Legislative Areas



Miscellaneous

- 4 Rear Registration Plate EU1003/2010
- 10 Radio Interference Suppression UNECE R10
- 18 Statutory Plates EU 19/2011
- 27 Towing Hooks EU 1005/2010
- 36 Heating systems UNECE R122
- 44 Masses and Dimensions EU1230/2012
- 50 Mechanical Couplings UNECE R55
- 63 General Safety Regulation EC 661/2009

Key Legislative Areas

Miscellaneous

10 Radio Interference Suppression
72/245/EEC
{UNECE R10}

Key Legislative Areas for EU Type Approval

Frontal Impact Crash Tests

ECE R12

Basic level of crash test: only captures steering column intrusion

ECE R94

50th % HIII

Advance level of crash test: captures significantly more injury criteria

Key Legislation Areas for EU Type Approval:

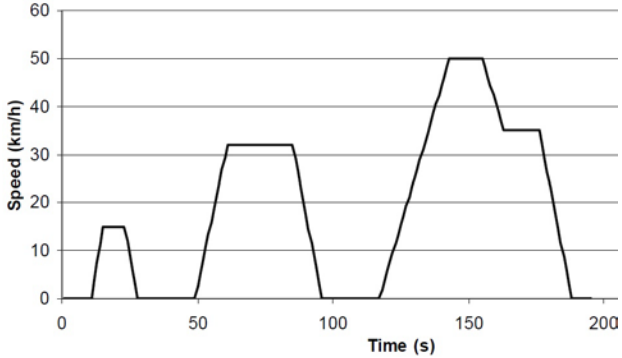
Frontal Impact Crash Tests

Emissions Tests

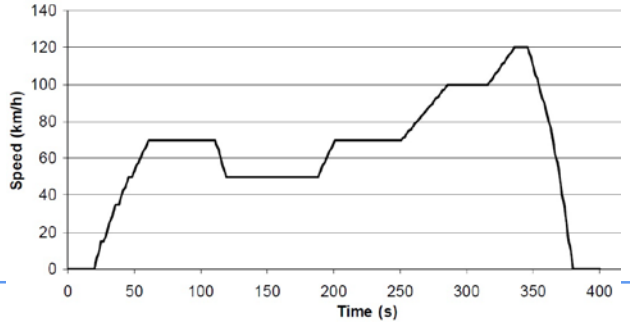
- Emission standards for light-duty vehicles are applicable to all vehicles of category M1, M2, N1 and N2 with a reference mass not exceeding 2610 kg (EU V/VI).
- EU regulations introduce different emission limits for compression ignition (diesel) and positive ignition (gasoline, NG, LPG, ethanol,...) vehicles.
- Diesels have more stringent CO standards but are allowed higher NOx.
- Positive ignition vehicles with DI engines have PM mass emission standards (EU V/VI), equal to those for diesels.
- Reference fuel is used and specific standards are required for available fuels

Emissions and the New European Drive Cycle

ECE 15 Drive Cycle



Extra Urban Drive Cycle



Characteristics	Unit	ECE 15	EUDC	NEDC†
Distance	km	0.9941	6.9549	10.9314
Total time	s	195	400	1180
Idle (standing) time	s	57	39	267
Average speed (incl. stops)	km/h	18.35	62.59	33.35
Average driving speed (excl. stops)	km/h	25.93	69.36	43.10
Maximum speed	km/h	50	120	120
Average acceleration[1]	m/s^2	0.599	0.354	0.506
Maximum acceleration[1]	m/s^2	1.042	0.833	1.042

† Four repetitions of ECE 15 followed by one EUDC
[1] Calculated using central difference method

Emissions Tests

- Type I Test
  - The urban driving cycle, ECE 15.
- Type II Test
  - Type II test is a warmed-up idle tailpipe CO test.
- Type III Test
  - Type III test is a two-mode procedure for crankcase emission determination.
- Type IV Test
  - Type IV test is a evaporative emission determination procedure.
- Type V Test
  - Type V test is a ageing test durability.
- Type VI Test
  - Cold Start emissions
- OBD Test

Real Driving Emissions

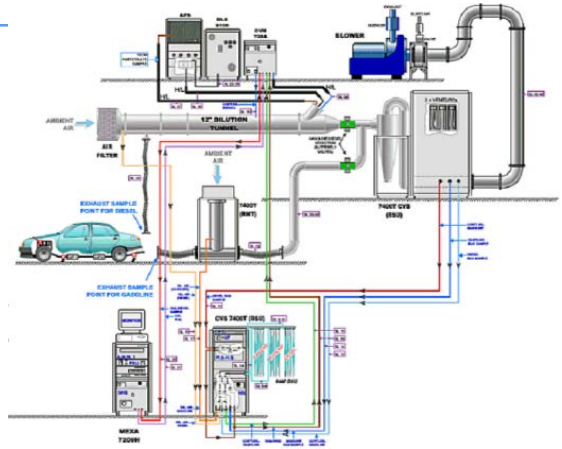
- Real Driving Emissions (RDE) introduces an additional type approval requirement in the 2016-2020 timeframe.
- RDE legislation is adding ***the road*** as a new *test environment* for emissions development and certification.
- This will pose significant new challenges on the design and calibration of new engines.
  - Until now, emissions laboratories have been selected and optimised for perfect cycle-to-cycle reproducibility.
  - Driving a vehicle on the road, with all the randomness of 'real life' means that two test runs will never be directly comparable.
- Scope: Diesel & Gasoline (ALL fuel & injection types are now in scope).
  - This was NOT the case initially, as the original driving force behind the legislation was to tackle Diesel NOx.

Real Driving Emissions

- VM's MUST monitor RDE from March 2016 and supply valid results to the type approval authority for new vehicle types only
  - Otherwise they will not be granted type approval, despite this being a monitoring phase
  - No pollutant limits are set for the monitoring phase (can't fail)
  - RDE Phase 2 – where legally binding "not to exceed" values for pollutants apply from Sept 2017
    - 2017 (Sept) NOx Conformity Factor = 2.1 (i.e. 168mg/Km)
    - 2020 (January) NOx Conformity Factor = 1.5 (i.e. 120mg/Km)
    - Particulates: Particle Number [PN] limits will be announced later this year
  - Driving dynamics (acceleration rates) are validated to promote 'normal driving' styles during testing, which is key for NOx production
  - There are two further 2 methods of validating the RDE test [EMROAD and CLEAR], which are based on CO2
    - For a valid RDE test the data must pass one of the two post-processing methods

Real Driving Emissions (RDE)

- RDE requires Portable Emissions Measurement Systems (PEMS)
  - Portable equipment developed to fit inside car to measure NOx, CO, CO_2 and PN (future requirement)
  - PEMS to replicate laboratory measurements, but miniaturised to allow on-road testing.
  - Exhaust Mass Flow is measured using a flow tube, mounted to the tailpipe.
  - 100% Road-based testing
    (test tracks NOT allowed for certification tests)
  - Boundary Conditions are very challenging for test validity
  - Test must be conducted on working days (7am – 7pm)



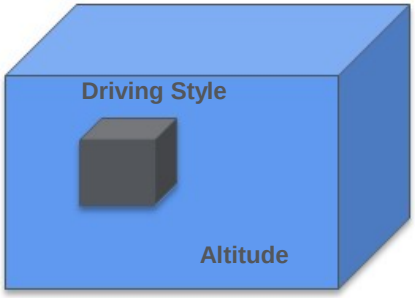
RDE Boundary Conditions

Boundary Conditions

- Altitude: ≤ 700 m altitude (up to 1300 m for ‘extended’ conditions). Start and end of test route must be within 100m altitude
- Temperature : 0°C to +30°C
- (-7°C to +35°C for ‘extended’ conditions)

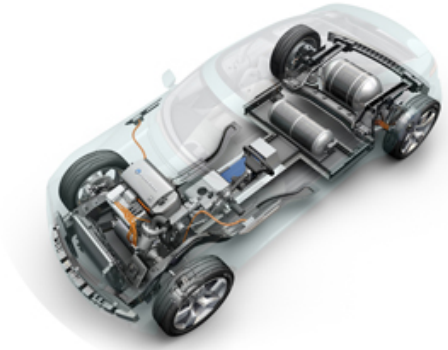
Test Conditions: Cars will need to meet standard for the entire measurement boundaries, which is best thought of as a virtual box with altitude, temp & driving style as it’s 3 axes

- It is physically impossible to cover the entire spectrum of environmental conditions in one RDE test, so test routes will be testing in a small zone (small ‘grey’ box), within the larger ‘blue’ boundaries box
- The final Type Approval test simply has to sit somewhere within the overall measurement zone (large ‘blue’ box)



Electric Safety Regulation UNECE R100

- Addresses the safety requirements specific to the electric power train of road vehicles including rechargeable battery systems.
- Revision 02 of R100 implemented significant changes in the Type Approval process applicable to motor vehicles and Rechargeable Energy Storage Systems (RESSs).
- Introduction also acknowledged changes to other regulations such as UNECE R10.



Electric Safety Regulation UNECE R100

- Revision 02 of R100 provided a separate Approval path for RESSs (most often, rechargeable battery packs)
- Introduced a number of tests exclusively applicable to RESSs
- With the introduction of these new testing requirements the responsibility for obtaining Type Approval for a rechargeable battery may also shift to the RESS manufacturer.
- New approach to Type Approval may provide manufactures with new market opportunities

Conformity of Production

- Conformity of Production (COP) is a means of evidencing the ability to produce a series of products that exactly match the specification, performance and marking requirements outlined in the Type Approval documentation.
- Before an Approval is granted, suitable COP arrangements must be made.
- Typically, the manufacturer will submit an Initial Assessment documentation pack.
- Need to demonstrate suitable quality control through a suitable QMS.
  - Examples include ISO9001 or TS16949
- Factory audits for EACH manufacturing plant are conducted annually along with reviews of the agreed control plan submitted during the Initial Assessment

Maintaining the Approval

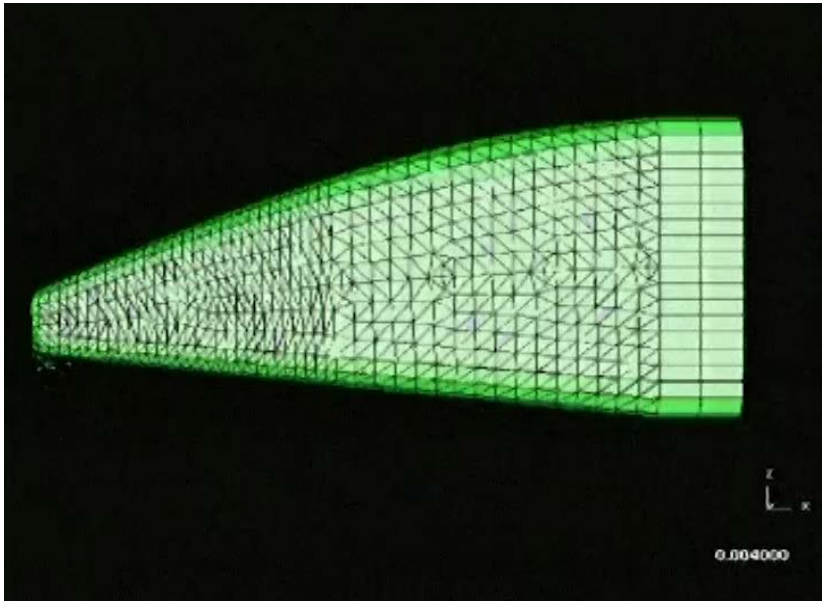
- In addition to conformity of production audits and testing, manufacturer needs to be able to demonstrate:

  - Control of production and notification in the event of recall
  - Design control/change process for informing the technical service for Type Approval extensions
  - Dealer network control
  - Registration processes

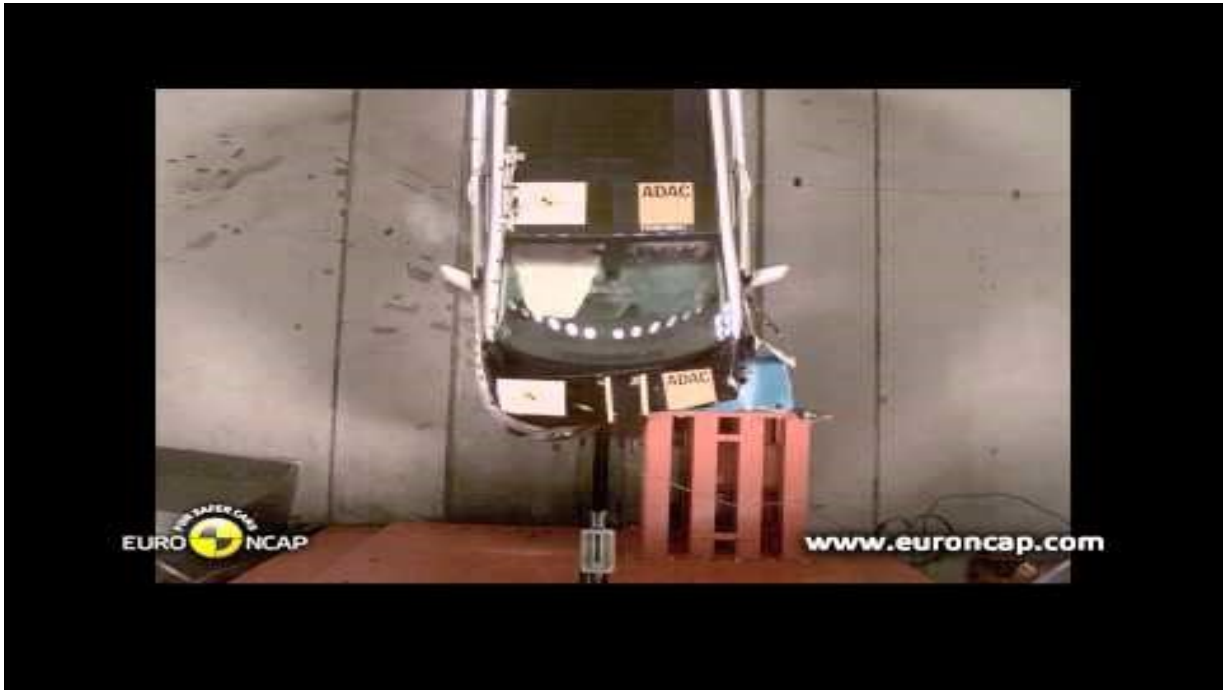
NDT for Type Approval

Composites for Road Cars

- Limited applications but growing
- Essentially safety structures developed from F1 technology
- NDT focussed on simulation testing



Composites for Road Cars



Construction of Finite Element Models

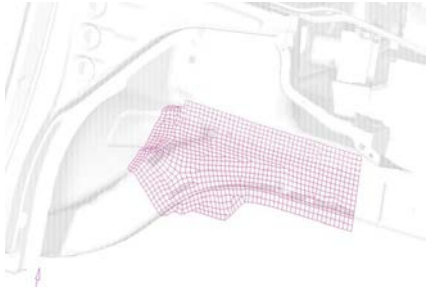
Each Structure is ‘meshed’ up as a series of elements

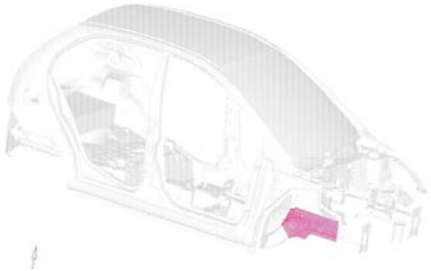
Brick elements for solid structures (castings)

Shell elements for sheet structures (pressings)

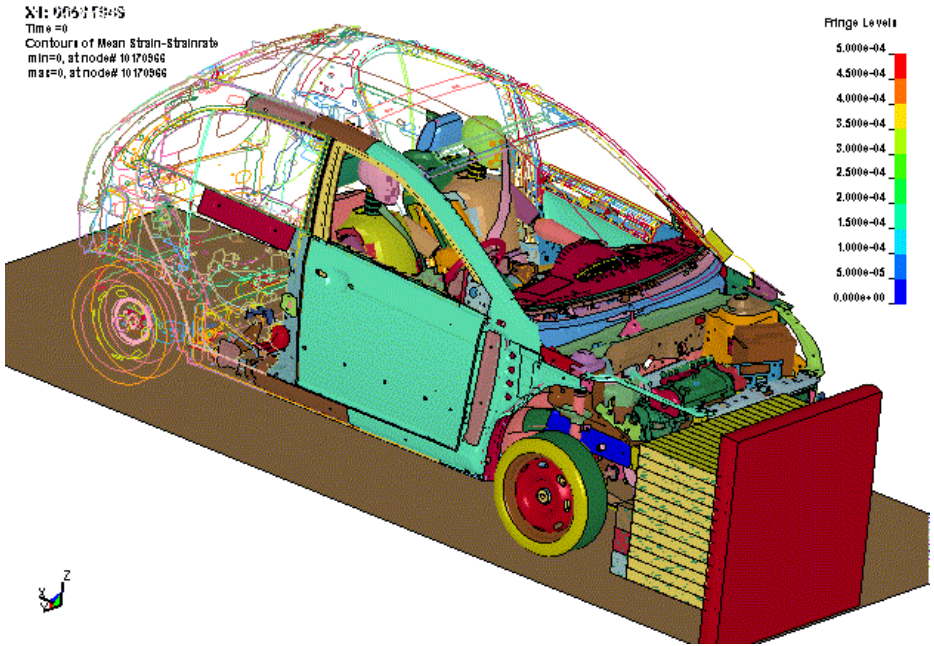
The material properties for each structure is assigned to the elements

- **Density**
- **Youngs Modulus**
- **Poissons Ratio**
- **Stress / Strain Charcteristics for different strain rates which includes the UTS**

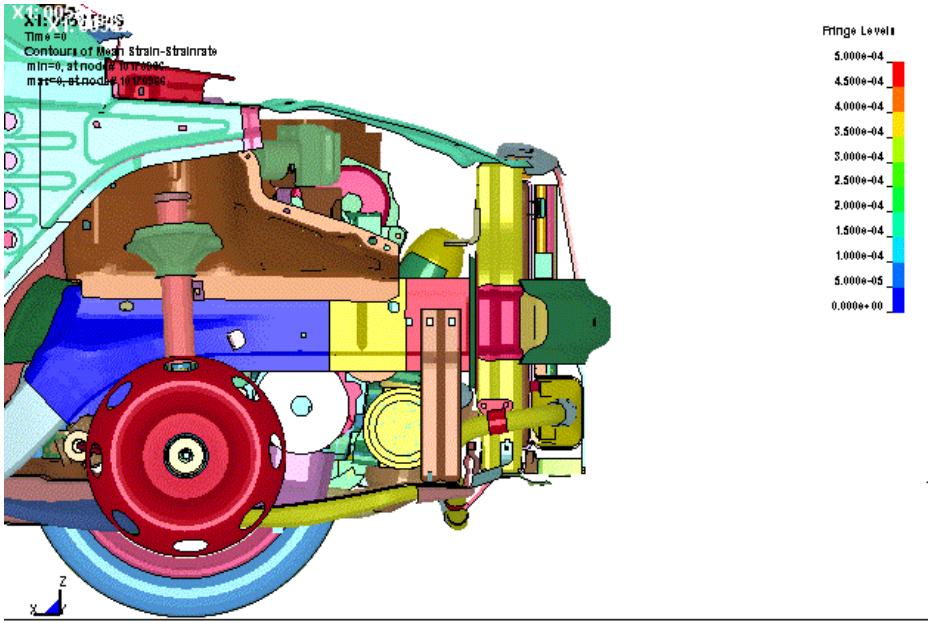




Full Vehicle Finite Element Simulation of an offset deformable Crash Test

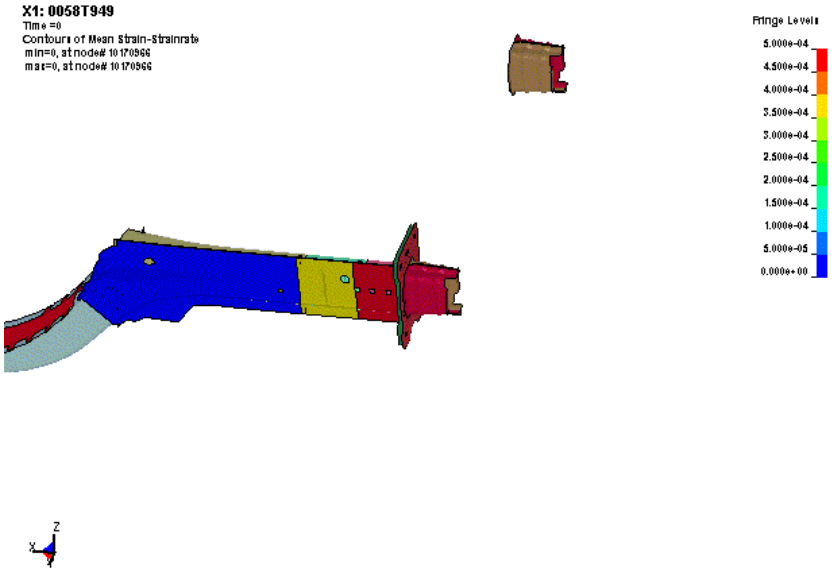


Front End Structural Simulation of a Offset Deformable Crash Test



Front Longitudinal in Full Scale Offset Deformable Crash Test

Detail of the front longitudinal from the full frontal vehicle crash test



NDT for Type Approval:

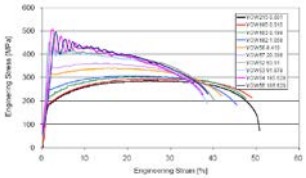
High Quality Body Simulation for Crash

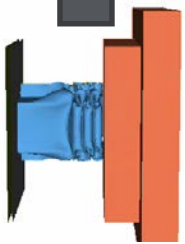
MIRA calibrated material models

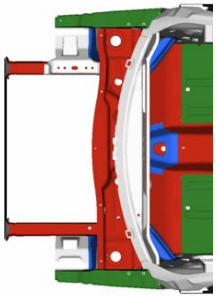
MIRA designed component test and correlated simulation

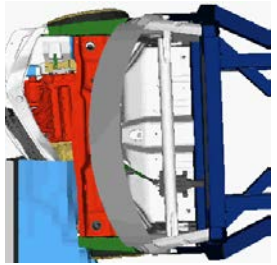
MIRA designed sub-system test and correlated simulation

MIRA designed trolley test and correlated simulation

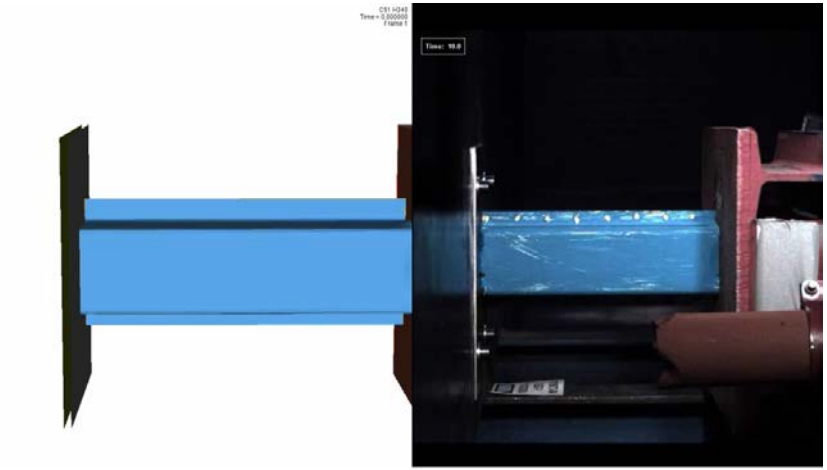


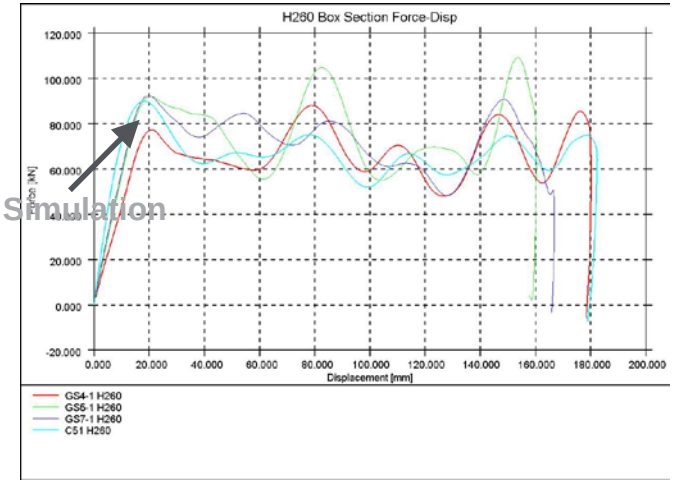






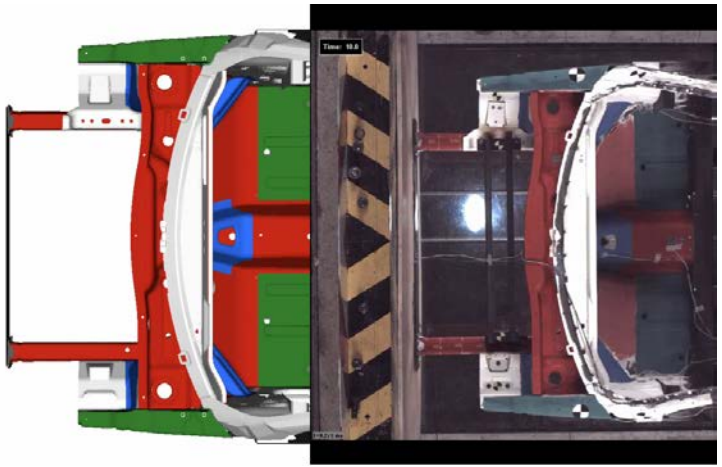
Component Test

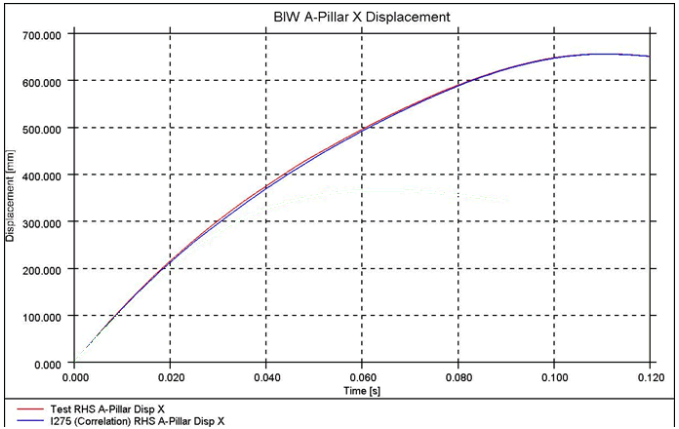




- Test design by MIRA
- Tests conducted by MIRA laboratory
- Boundary conditions a key part of correlation
- Excellent correlation of simulation and test

Sub-System Test

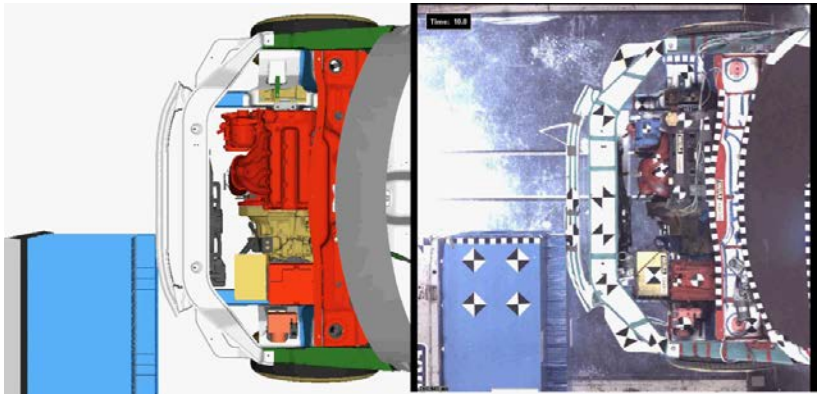


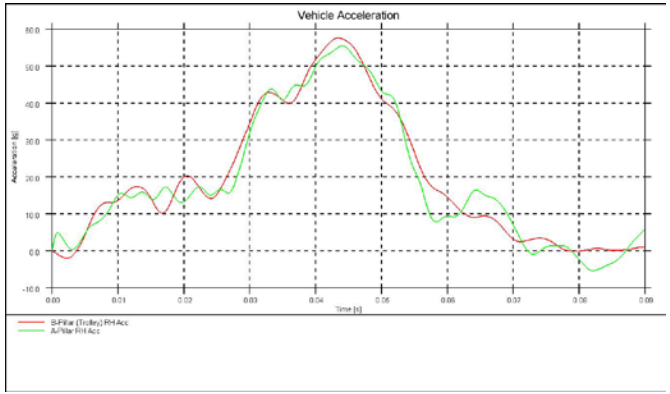


- Test design by MIRA
- Tests conducted by MIRA laboratory
- Boundary conditions, material modelling and lessons from component work a key part of correlation
- Excellent correlation of simulation and test

NDT for Type Approval:

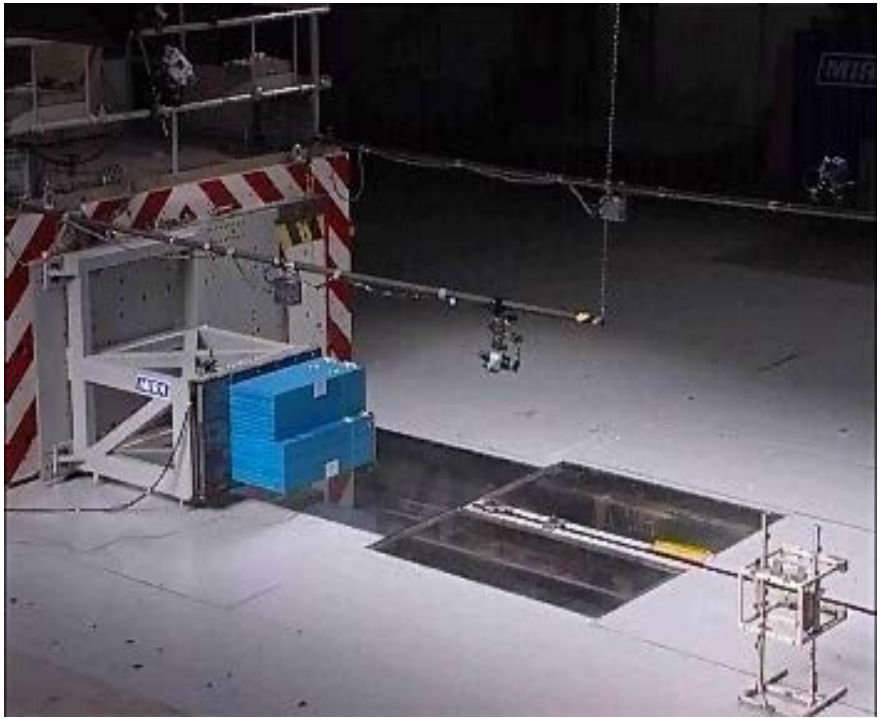
Trolley Test





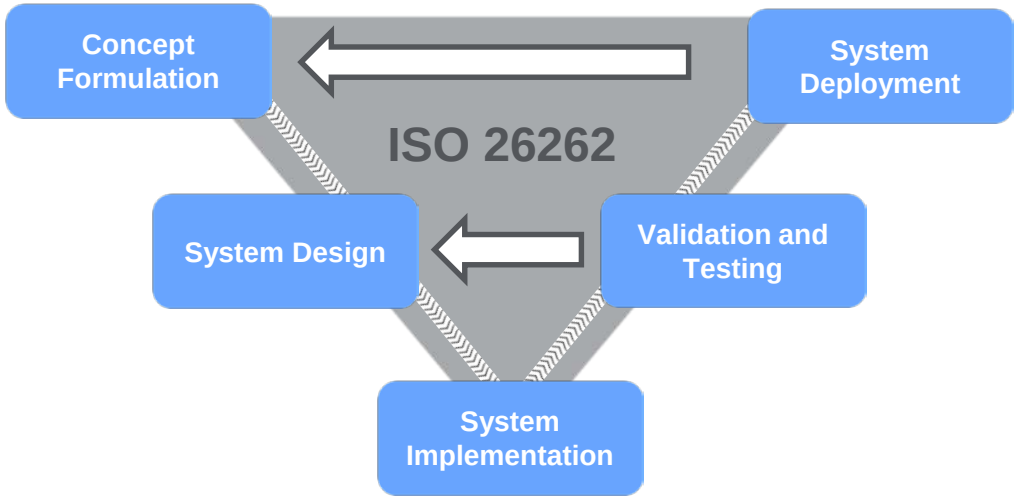
- Test design by MIRA – boundary conditions, mounting points, trolley design and inertia properties.
- Tests conducted by MIRA laboratory
- Boundary conditions, material modelling and lessons from component + sub-system work a key part of correlation
- Outstanding model correlation only achieved through clear understanding of constituent parts of trolley test device.

Approval Test



NDT for the Future

Systems engineering framework



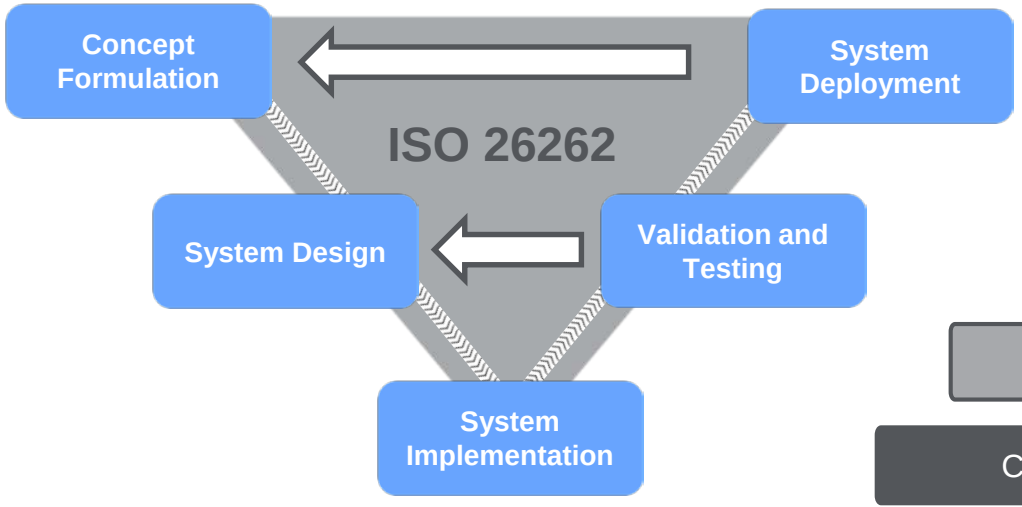
- The automated and connected car is a complex system of systems.
- In reality there are more iterations of the integration and test stages
- ISO 26262 not designed for highly automated vehicles or cyber security

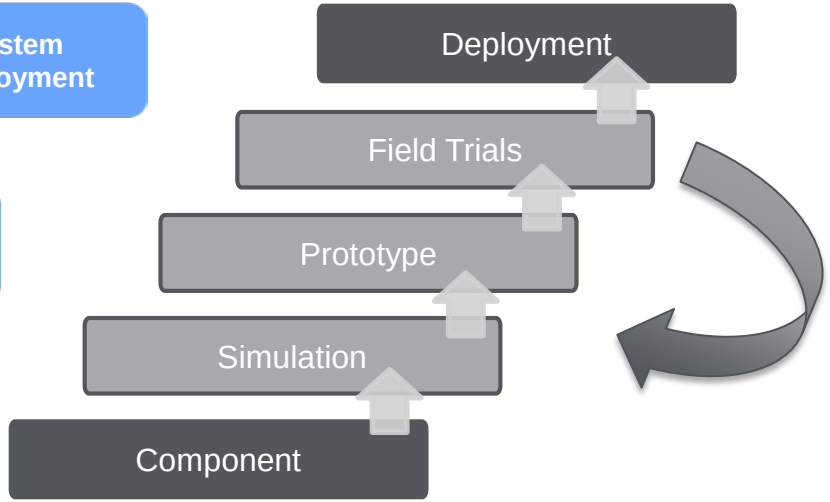
Cyber security management

- Achieving zero security risk is impracticable
  - Cost would be excessive
  - Nature of the threats is constantly changing

- A more pragmatic “risk management” approach should be adopted
  - Security must be considered from the outset;
  - Where evaluated risks are considered unacceptable, measures must be employed to reduce these risks to a level that is considered to be “broadly acceptable”;
  - Security analysis must be an on-going process throughout the product lifecycle.
- Automotive functional safety (ISO 26262) provides a model for this approach
  - Unified security and safety analysis is desirable as security threats may have safety implications

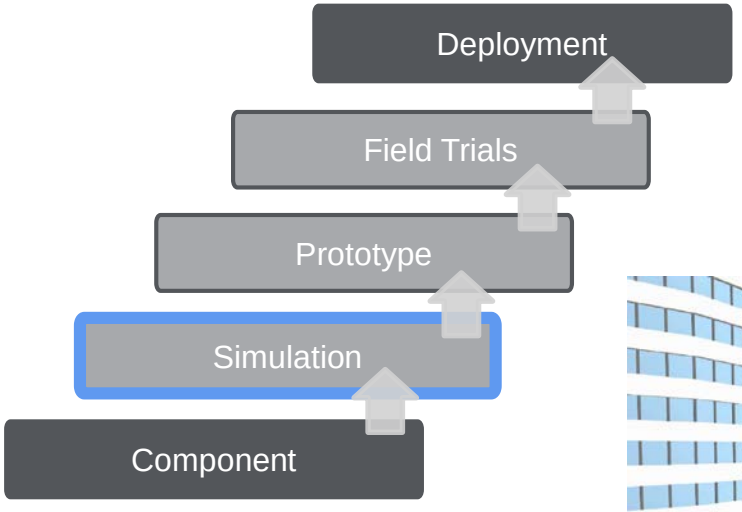
Systems engineering framework

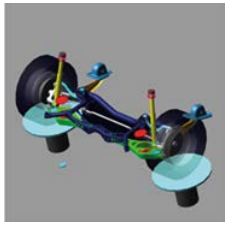


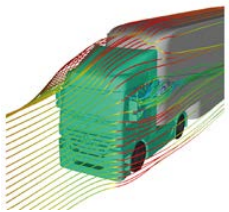


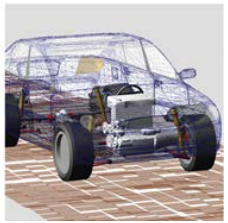
- Q: How do we control so many variables?
- Q: How do we identify faults?
- Q: How do we validate failure mode mitigation?

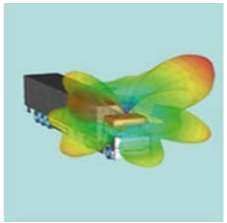
Simulation

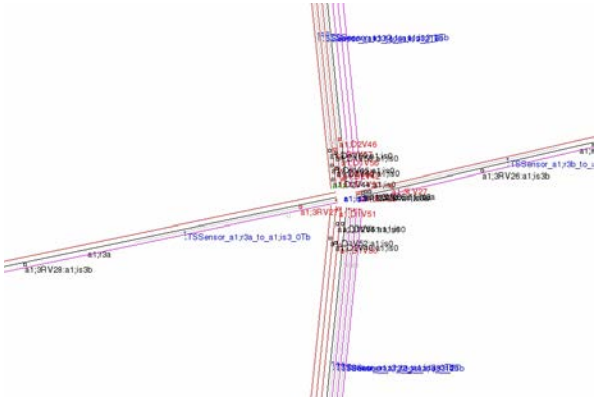




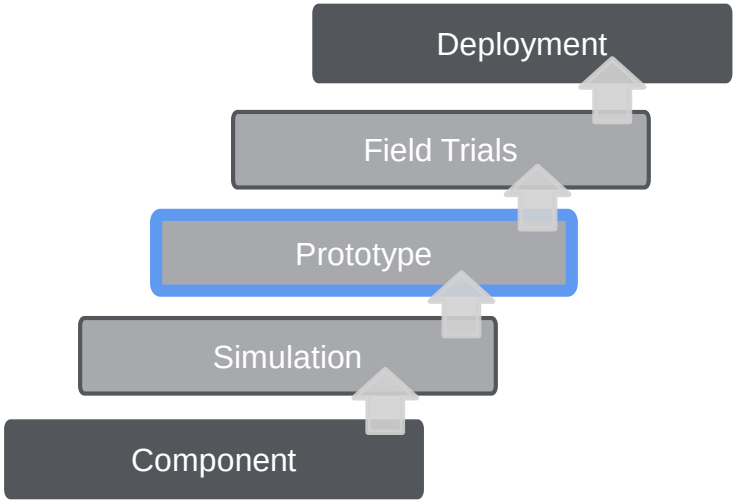






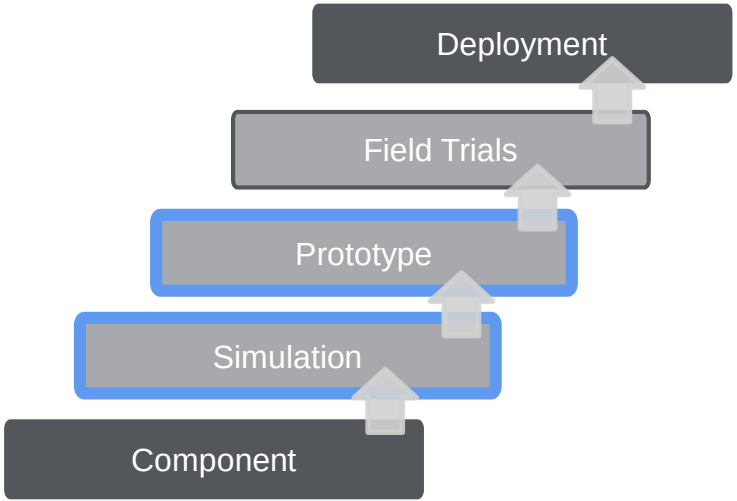


Prototype: Test environment



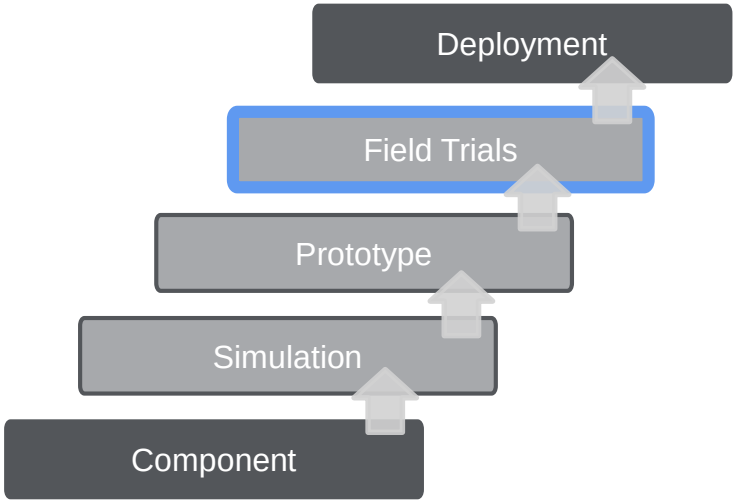
- Mixture of controlled Proving Ground trials and mileage accumulation on public roads
- MIRA City Circuit is a unique immersive urban driving environment with controlled communications

Prototype and Simulation: Cooperative Robots



- Realistic, portable and scalable software architecture
- Allows seamless interactions between physical and virtual vehicles

Field trials



UKAutodrive VENTURER GATEway

Automated vehicle design and test challenges

- Increased dependency on electronics and software
- Systems gain greater authority over the driver
- Design process must account for the inherent increase in complexity
- **Increases in the severity of a failed or compromised system**

Higher Degree of System Authority

Varied Cyber-Security Threats

- Increased use of in-vehicle networks and distributed systems
- More wireless and external connectivity
- Must be secured against unintended and malicious use
- **More attack surfaces increases the probability of interference or attack**

- **Fail-safe** (removing functionality) transitions to fail-operational (maintain critical functionality)
- **Fail-operational** behavior relies on self-healing and reconfiguration. This requires fault prediction and forecasting

Risk Management

Thank you……..

Any Questions?

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