HORIBA MIRA has a Well Established Offering as an Engineering Service Provider and R&D Location
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
Regulatory NDT Requirements for Composites on Public Roads:

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
Background 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

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Background to Type Approval:

Standards and Legislative Framework

**Regulations**
- Mandatory requirements, specified by law and enforceable by government.  
  - e.g. UN-ECE in Europe, and FMVSS (NHTSA) in USA

**Standards**
- Engineering criteria developed by technology industry consensus  
  - Specify how a product should be designed or how it should perform.  
  - e.g. ISO / SAE / ETSI / CEN / IEEE

**Guidelines**
- Recommended and best practice - can cover full design and product lifecycle  
  - e.g. SAE J2344 “Guidelines for Electric Vehicle Safety”  
  - e.g. MISRA “Guidelines for the Use of the C Language in Critical Systems”

**Market Forces**
- NCAP Independent consumer safety testing  
- Other interest groups (e.g. Insurance – RCAR)

NCAP: New Car Assessment Programme  
MISRA: Motor Industry Software Reliability Association
Background to Type Approval:

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.
Background to Type Approval:

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.
Background to Type Approval:
Overview – EU Vehicle Certification

![EU Vehicle Certification Label](image-url)
Background to Type Approval:

**Awareness of Non-Legislative Tests**

The Current Global Map of New Car Assessment Programmes

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EU Type Approval
EU Type Approval:

Overview – EU Vehicle Certification

- EU operates a ‘Full Witnessed Type Approval’ process
- EC Whole Vehicle Type Approval (ECWVTA) is based around EC Directives / UN Regulations
- 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
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).

### EU Type Approval:

#### ‘M’ Category Vehicles

<table>
<thead>
<tr>
<th>Kind of vehicle</th>
<th>Description</th>
<th>Weight range</th>
</tr>
</thead>
<tbody>
<tr>
<td>M₁</td>
<td>No more than 8 seats in addition to driver’s seat</td>
<td>Not applicable</td>
</tr>
<tr>
<td>M₂</td>
<td>More than 8 seats in addition to driver’s seat</td>
<td>5t or less</td>
</tr>
<tr>
<td>M₃</td>
<td>More than 8 seats in addition to driver’s seat</td>
<td>Over 5t</td>
</tr>
<tr>
<td>M₄ (Special purpose)</td>
<td>Motor caravans, ambulances, hearses, armoured cars, wheelchair-accessible vehicles</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
## EU Type Approval:
### European Type Approval Country Codes

<table>
<thead>
<tr>
<th></th>
<th>Country</th>
<th></th>
<th>Country</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Germany</td>
<td>12</td>
<td>Austria</td>
<td>27</td>
</tr>
<tr>
<td>2</td>
<td>France</td>
<td>13</td>
<td>Luxembourg</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
<td>Italy</td>
<td>17</td>
<td>Finland</td>
<td>32</td>
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<tr>
<td>4</td>
<td>Netherlands</td>
<td>18</td>
<td>Denmark</td>
<td>34</td>
</tr>
<tr>
<td>5</td>
<td>Sweden</td>
<td>19</td>
<td>Romania</td>
<td>36</td>
</tr>
<tr>
<td>6</td>
<td>Belgium</td>
<td>20</td>
<td>Poland</td>
<td>49</td>
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<tr>
<td>7</td>
<td>Hungary</td>
<td>21</td>
<td>Portugal</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>Czech Republic</td>
<td>23</td>
<td>Greece</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Spain</td>
<td>24</td>
<td>Ireland</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>United Kingdom</td>
<td>26</td>
<td>Slovenia</td>
<td></td>
</tr>
</tbody>
</table>

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April 4, 2017
EU Type Approval:

European Type Approval Country Codes

Marking for EEC Directive Compliance

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
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
EU Type Approval:

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
EU Type Approval:

European Small Series Type Approval

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
Whole vehicle framework directive for road vehicles contains five Approval topics:
EU Type Approval:
Key Legislative Areas

Environment

1. Sound Levels 70/157/EEC
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
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

- Fuel Tank UNECE R34
- Door Latches & hinges UNECE R11
- Interior Fittings UNECE R21
- Protective Steering UNECE R12
- Seat Strength UNECE R17
- Exterior Projection UNECE R26
- Safety Belt Anchorage UNECE R14
- Safety Belts UNECE R16
- Head Restraints UNECE R25
- Safety glazing UNECE R43
- Frontal Impact UNECE R94
- Side Impact UNECE R95
- Pedestrian Protection EC 78/2009
EU Type Approval:
Key Legislative Areas - Passive Safety
EU Type Approval:
Key Legislative Areas

Active Safety

- Steering Equipment UNECE R79
- Audible Warning UNECE R28
- Devices for Indirect Vision UNECE R46
- Braking UNECE R13H
- Antitheft UNECE R18/R116
- Speedometer and Reverse Gear UNECE R39
- Forward Vision UNECE R125
- ID of Controls UNECE R121
- Defrost / Demist EU 672/2010
- Wash / Wipe EU 1008/2010
- Wheel Guards EU 1009/2010
- Tyres UNECE R30/117 & 64 (spares + TPMS)
- Gear Shift Indicators EU 65/2012
- Vehicle Alarm Systems VAS UNECE R97
- Electric safety Regulation UNECE R100
- Specific components for CNG UNECE R110
Key Legislative Areas

Active Safety

Audible Warning 70/388/EEC (UNECE R28)
EU Type Approval:

Key Legislative Areas

Lighting Equipment

21 Retro Reflector 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
EU Type Approval:
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

- Rear Registration Plate EU1003/2010
- Radio Interference Suppression UNECE R10
- Statutory Plates EU 19/2011
- Towing Hooks EU 1005/2010
- Heating systems UNECE R122
- Masses and Dimensions EU1230/2012
- Mechanical Couplings UNECE R55
- General Safety Regulation EC 661/2009
EU Type Approval:

Key Legislative Areas

Miscellaneous

10 Radio Interference Suppression
72/245/EEC
UNECE R10
Key Legislative Areas for EU Type Approval
Key Legislation Areas for EU Type Approval:

Frontal Impact Crash Tests

ECE R12

Basic level of crash test: only captures steering column intrusion

Advance level of crash test: captures significantly more injury criteria

ECE R94

50th % HIII
Key Legislation Areas for EU Type Approval:

Frontal Impact Crash Tests
Key Legislation Areas for EU Type Approval:

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.
**Key Legislation Areas for EU Type Approval:**

**Emissions and the New European Drive Cycle**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unit</th>
<th>ECE 15</th>
<th>EUDC</th>
<th>NEDC†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance</td>
<td>km</td>
<td>0.9941</td>
<td>6.9549</td>
<td>10.9314</td>
</tr>
<tr>
<td>Total time</td>
<td>s</td>
<td>195</td>
<td>400</td>
<td>1180</td>
</tr>
<tr>
<td>Idle (standing) time</td>
<td>s</td>
<td>57</td>
<td>39</td>
<td>267</td>
</tr>
<tr>
<td>Average speed (incl. stops)</td>
<td>km/h</td>
<td>18.35</td>
<td>62.59</td>
<td>33.35</td>
</tr>
<tr>
<td>Average driving speed (excl. stops)</td>
<td>km/h</td>
<td>25.93</td>
<td>69.36</td>
<td>43.10</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>km/h</td>
<td>50</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Average acceleration&lt;sup&gt;1&lt;/sup&gt;</td>
<td>m/s²</td>
<td>0.599</td>
<td>0.354</td>
<td>0.506</td>
</tr>
<tr>
<td>Maximum acceleration&lt;sup&gt;1&lt;/sup&gt;</td>
<td>m/s²</td>
<td>1.042</td>
<td>0.833</td>
<td>1.042</td>
</tr>
</tbody>
</table>

† Four repetitions of ECE 15 followed by one EUDC

<sup>1</sup> Calculated using central difference method
### Key Legislation Areas for EU Type Approval:

#### Emissions Tests

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I Test</td>
<td>The urban driving cycle, ECE 15.</td>
</tr>
<tr>
<td>Type II Test</td>
<td>Type II test is a warmed-up idle tailpipe CO test.</td>
</tr>
<tr>
<td>Type III Test</td>
<td>Type III test is a two-mode procedure for crankcase emission determination.</td>
</tr>
<tr>
<td>Type IV Test</td>
<td>Type IV test is an evaporative emission determination procedure.</td>
</tr>
<tr>
<td>Type V Test</td>
<td>Type V test is a ageing test durability.</td>
</tr>
<tr>
<td>Type VI Test</td>
<td>Cold Start emissions</td>
</tr>
</tbody>
</table>
| 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.
Key Legislation Areas for EU Type Approval:
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
Key Legislation Areas for EU Type Approval:

Real Driving Emissions (RDE)

- RDE requires Portable Emissions Measurement Systems (PEMS)
  - Portable equipment developed to fit inside car to measure NOx, CO, CO2 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)
Key Legislation Areas for EU Type Approval:

RDE Boundary Conditions

- **Boundary Conditions**
  - Altitude: \( \leq 700 \) 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)
Key Legislation Areas for EU Type Approval:

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.
Key Legislation Areas for EU Type Approval:

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
Key Legislation Areas for EU Type Approval:

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.
Key Legislation Areas for EU Type Approval:

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
NDT for Type Approval:
Composites for Road Cars

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

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 Characteristics for different strain rates which includes the UTS
NDT for Type Approval:

Full Vehicle Finite Element Simulation of an offset deformable Crash Test
NDT for Type Approval:

Front End Structural Simulation of a 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
NDT for Type Approval:
Component Test

- Test design by MIRA
- Tests conducted by MIRA laboratory
- Boundary conditions a key part of correlation
- Excellent correlation of simulation and test
NDT for Type Approval: 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
TDT 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.
NDT for Type Approval:

Approval Test
NDT for the Future
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
Q: How do we control so many variables?
Q: How do we identify faults?
Q: How do we validate failure mode mitigation?
NDT for the Future:
Simulation

- Deployment
- Field Trials
- Prototype
- Simulation
- Component

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NDT for the Future:
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
NDT for the Future:
Prototype and Simulation: Cooperative Robots

- Realistic, portable and scalable software architecture
- Allows seamless interactions between physical and virtual vehicles
NDT for the Future:
Field trials

Deployment
Field Trials
Prototype
Simulation
Component
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

Risk Management

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
Thank you........

Any Questions?
Contact Details

Richard Whiting
MBA, BEng (Hons)
Head of Certification & Homologation
Notified Body No. 0888
Direct T: +44 (0)24 7635 5482
M: +44 (0)7767 280158
E: Richard.whiting@horiba-mira.com

HORIBA MIRA Ltd.
Watling Street,
Nuneaton, Warwickshire,
CV10 0TU, UK

T: +44 (0)24 7635 5000
F: +44 (0)24 7635 8000

www.horiba-mira.com