A Roadmap for Connected & Autonomous Vehicles

David Skipp
Ford Motor Company
Why does an Autonomous Vehicle need a roadmap?

Where might the roadmap take us?

What should we focus on next?
Why does an Autonomous Vehicle need a roadmap?

Industrial Strategy

Traveller Needs

City Development

... so we know where we want it to go!
Industrial Strategy

- To strengthen and promote sustainable growth of the automotive sector in the UK through enhanced dialogue and co-operation between UK government and the automotive industry
- Investment in driverless vehicles is a core part of automotive sector strategy

... the roadmap should highlight technology potential
Travellers Needs

- 2015 study identified 12 challenges to improve mobility in the UK, with potential to unlock revenue opportunities
- Innovative ‘pathways’ with extensive industry input (inc. AESIN) explored total mobility system

- Connected & Autonomous Vehicles will be part of a complex ecosystem of mobility services

... the roadmap should be relevant to travellers
City Development

Business / Education

Congestion

Air Quality

Green Space

Ride Hail

Cycling

Rapid Transit

Walking

Lifestyle

Urbanisation

Aging

Affluence

... the roadmap should respect city needs
Why does an Autonomous Vehicle need a roadmap?

Where might the roadmap take us?

What should we focus on next?
Desired Outcomes
- Desired outcomes transition from the centric to the holistic over time

Drivers
- Drivers for CAV development reflect the significant impact of future mobility;
  - on a productive national economy;
  - on efficient city and urban society;
  - on individual lifestyle
SAE 4 & SAE 5
- First introductions in high utilisation commercial applications (moving people & goods) in known and stable environments at low speeds
- Increasing geographical and environmental convergence over time
- Personal use remains niche until costs significantly reduce

SAE 2 & SAE 3
- SAE 2 Applications co-exist with full autonomy, and may dominate in some geographies for the foreseeable future
- Use of SAE 3 in limited applications only (e.g. Commercial vehicle platooning)
- Safety critical use-cases require G5-ITS, C-V2X, or 5G communications availability at scale
The Destination is Compelling and Challenging

<table>
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<tr>
<th>DRIVERS</th>
<th>Safety</th>
<th>Productivity &amp; Efficiency</th>
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<td>Short term 'live' information provision to aid personal travel choices</td>
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<tr>
<td>Smoother Drives</td>
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<td>Future travel optimisation taken at network level</td>
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<td>End to End Mobility Services</td>
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SAE LEVEL

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
<th>TECHNOLOGY</th>
<th>ENABLERS</th>
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<td>Safety</td>
<td>Sensors</td>
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<td>Assurance</td>
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<td>Efficiency</td>
<td>HMI</td>
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SAFETY

- Short term focus on ‘Driver Assistance’
- Introduction of CAVs must demonstrate a step change (ie. 1 order of magnitude) improvement in safety to earn public trust & ‘license to operate’
- Longer term expectation for significant (ie. 2 orders of magnitude) improvement in safety

CONVENIENCE, PRODUCTIVITY & EFFICIENCY

- Short term 'live' information provision to aid personal travel choices
- Transition to Real Time Predictive travel guidance optimised for network
- Productive travel supports work and entertainment as priorities
- Future travel optimisation taken at network level
Technology to translate information across the mobility system

**Note:**
- Please see Automotive Council UK Electrical Architecture roadmap for information on related technology enablers

**Sensors & Processing**
- Short term challenge to reduce costs of the sensor set (Lidar, Radar, Camera, Ultrasonic) using solid state electronics and improved local data processing
- New sensor technologies improve functionality (e.g., sensitivity; field of view; environmental robustness; size; ...) at affordable cost points
- Advanced computing architectures further optimise sensing through fusion & learning
- Future co-operative networks use 3rd party / network processed sensor intelligence
## Technology to translate information across the mobility system

### DRIVERS
- **National Needs**
- **City Needs**
- **Traveller Needs**

### SAE LEVEL
- **Industrial Strategy**
- **Industrial Leadership**
- **GDP Growth and Productivity**
- **Air Quality and CO2**
- **Less Congestion**
- **Mobility Equality**
- **Parking**
- **Smother Drives**
- **End to End Mobility Services**

### ATTRIBUTES
- **Safety**
- **Convenience**
- **Productivity**
- **Efficiency**

### TECHNOLOGY
- **Sensors**
- **Processing**
- **Communications**
- **HMI**

### ENABLERS
- **Validation**
- **Certification**
- **Insurance**
- **Assurance**

### Communications
- Exploitation of existing 4G technology is sufficient to release Driver Assistance and Network optimisation benefits through the medium term.
- ICVs will utilise cellular /5G (when deployed for Internet Of Things), and make use of Swarm communication technologies in longer term. (case for DSRC remains uncertain)

### HMI
- Device pairing transitions to personalised cloud services across multiple interfaces
- Optimised mix of existing (eg. voice) and newer (eg. HUD, gesture) technologies to suit application and user. Promote ‘ease’ of uptake of new mobility services
- Longer term integration of mobility services into lifestyle management (work & play)
Validation & Certification

- Application of new and cross-sector (e.g., defence; gaming) modelling techniques allow simulation to address complexities of full environments and sensors
- Approach to simulating and certifying AI / ML systems is a critical challenge
- Graded structure of Licensing and Certification is likely to accommodate rapid growth in CAV capabilities and variety of applications and environments
Insurance & Assurance

- Lower Insurance premiums for Driver Assistance and Driver Monitoring technologies bridge to significantly lower insurance costs for CAVs with proven safety benefits
- Future CAV real time (RT) risk/cost based driving decisions implicitly linked to real time insurance
- Diagnostic & prognostic monitoring, combined with fail-functional designs underpin new regulatory framework for sale, ownership and operation of CAVs
- Physical security and cybersecurity robustness underpin both ‘Data Privacy’ and ‘Fail Operational’ capability
Roadmap for development of Connected and Autonomous Vehicles

**Drivers**
- National Needs
- City Needs
- Traveller Needs

**SAE Level**
- Level 2
- Level 2 and 3
- Level 2 and 3 (Safety Critical Comm's)
- Level 4
- Level 5

**Attributes**
- Safety
- Convenience
- Productivity
- Efficiency
- Safety: Safer Human Drivers
- Convenience: AV 10x Safer Than Humans
- Productivity: RT and Predicted Travel Advice
- Efficiency: Automated / Guided Travel
- Safety: Predictive Network Optimised Travel Mode, Timing and Routing

**Technology**
- Sensors
- Processing
- Communications
- HMI
- Sensors: New Sensors Inc. Edge Processing
- Processing: On-board ML -> Virtual Driver
- Communications: 3G -> 4G
- HMI: Traveller Centric Design

**Enablers**
- Validation
- Certification
- Insurance
- Assurance
- Real World and Re-Simulation
- Correlated System Modelling
- Real World Cert
- Pay As You Drive
- Privacy and Cybersecurity

**Timeline**
- 2020
- 2025
- 2030
- 2040
Why does an Autonomous Vehicle need a roadmap?

Where might the roadmap take us?

What should we focus on next?
Key breakthroughs required for the success of CAVs
– Processing (Machine Learning / Artificial Intelligence)

Critical Enablers & Opportunities → Processing
• Machine Learning / Artificial Intelligence is the essential and differentiating ingredient of an CAV bringing several challenges shared with cross-sector ML applications
• Key is the development of the tailored ML algorithms themselves, including ‘teaching’; behaviour ‘monitoring’; and sharing of learning from one vehicle across a suite of vehicles and applications

Cont …
• Also important are the opportunities to trial, apply, exploit and commercialise ML in real world use-cases that generate a route to market, a sustainable business opportunity and a customer benefit
• New value chains connecting academia, SMEs, Tier1s and OEMs are needed
Key breakthroughs required for the success of CAVs

- Communications

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Critical Enablers & Opportunities → Communications

- Without significant investment in 4G network reliability & coverage, the potential of CAVs will not be realised
- The volume of data transfer cannot be underestimated, with the advent of the connected car bringing a step change in 4G data demand

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<tr>
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<th>Shared Sensor Data</th>
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<td>Ubiquitous 4G</td>
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<td>HMI Fusion</td>
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<td>Lifestyle Integration</td>
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| ENABLERS         | Validation         | Certification                      | Insurance | Assurance |

Cont...

- 5G roll-out will enable fully networked transport system solutions with huge potential for CAV applications and growth
- The UK has the chance to lead in 5G communications and benefit from the transport applications, productivity & growth that will result
Key breakthroughs required for the success of CAVs – Validation

- Critical Enablers & Opportunities → Validation
  - The inherent variability of the real world, and the complexity of virtual driving behaviour (incorporating machine learning capability), mean that validating complex CAV use cases using traditional methods is not possible.
  - There is broad consensus in a conceptual solution - A simulated environment that can account for the full statistical variabilities of environmental and CAV factors.
  - Achieving this concept is a huge technical, organisational and political challenge.
  - A coalition of UK sector capabilities could act as a catalyst for the development of a new world leading AV validation capability (inc. Gaming & Media simulation, Fintech analytics; Automotive MIL/SIL).
### Key breakthroughs required for the success of CAVs – Certification

**Critical Enablers & Opportunities → Certification**

- Early application of Level 4 technologies are dependant on updated Type Approval and Certification processes – lack of clear process could cause delay
- Simulation techniques offer a practical route to assess real world variability
- Building on extensive Automotive & Traffic Engineering skill base to develop robust certification and licensing for CAVs is an opportunity area for the UK; both to accelerate it’s own adoption of CAV technology; and to provide a service to other nations
## Key breakthroughs required for the success of CAVs – Assurance

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<td>• Trust and confidence in CAVs on the part of owners, operators, travellers and authorities is essential to scale adoption</td>
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<td>• Assuring privacy, safety and security for CAV users and operators throughout operating lifetime will require new technology, regulatory and recourse measures</td>
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<td>• The UK has long played a leading role in developing international standards and guidelines</td>
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<td>• The UK has the right cross-sector skills to lead in this area of CAV Assurance – particularly skills in Cybersecurity; Fail operational design (Automotive, Aerospace, Defence) and legal advice and settlement</td>
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Critical Roadmap Elements for Success

**Drivers**
- National Needs
- City Needs
- Traveller Needs

**SAE Level**
- Level 2
- Level 2 and 3
- Level 2 and 3 (Safety Critical Comm's)
- Level 4
- Level 5

**Attributes**
- Safety
- AV 10x Safer Than Humans
- AV >10x Safer
- Informed Travel Choice
- RT and Predicted Travel Advice
- Automated / Guided Travel
- Device Based
- Reliable Mobile Working
- Mobile Services
- E'thing/ E'where
- Personalised Routing
- Real Time Network Optimisation
- Predictive Network Optimised Travel Mode Timing and Routing

**Technology**
- Sensors
- New Sensors (Inc. Edge Processing)
- Shared Sensor Data
- Processing
- On-board ML → Virtual Driver
- Centralised ML
- Co-operative ML
- 3G → 4G
- Ubiquitous 4G
- 5G / Non-Cellular
- Swarm
- Device Syncing
- Traveller Centric Design
- HMI Fusion
- Lifestyle Integration

**Enablers**
- Validation
- Real World and Re-Simulation
- Correlated System Modelling
- Partial Simulation (Inc. ML, Sys)
- Full Environment, Vehicle and Sensor Simulation
- Certification
- Real World Cert.
- Part Simulated Cert.
- Simulation Based Certification
- Code of Practice
- Real World
- Part Simulated
t- Insurance
- AV Insurance (Cheaper vs Human)
- Real Time Risk Insurance
- Assurance
- Pay How You Drive
- AV Insurance (Cheaper vs Human)
- Real Time Risk Insurance
- Privacy and Cybersecurity
- Fail-Operational
- Interim Regulation
- New Reg. Framework
Thank you