Systems Aspects for Remote Operation

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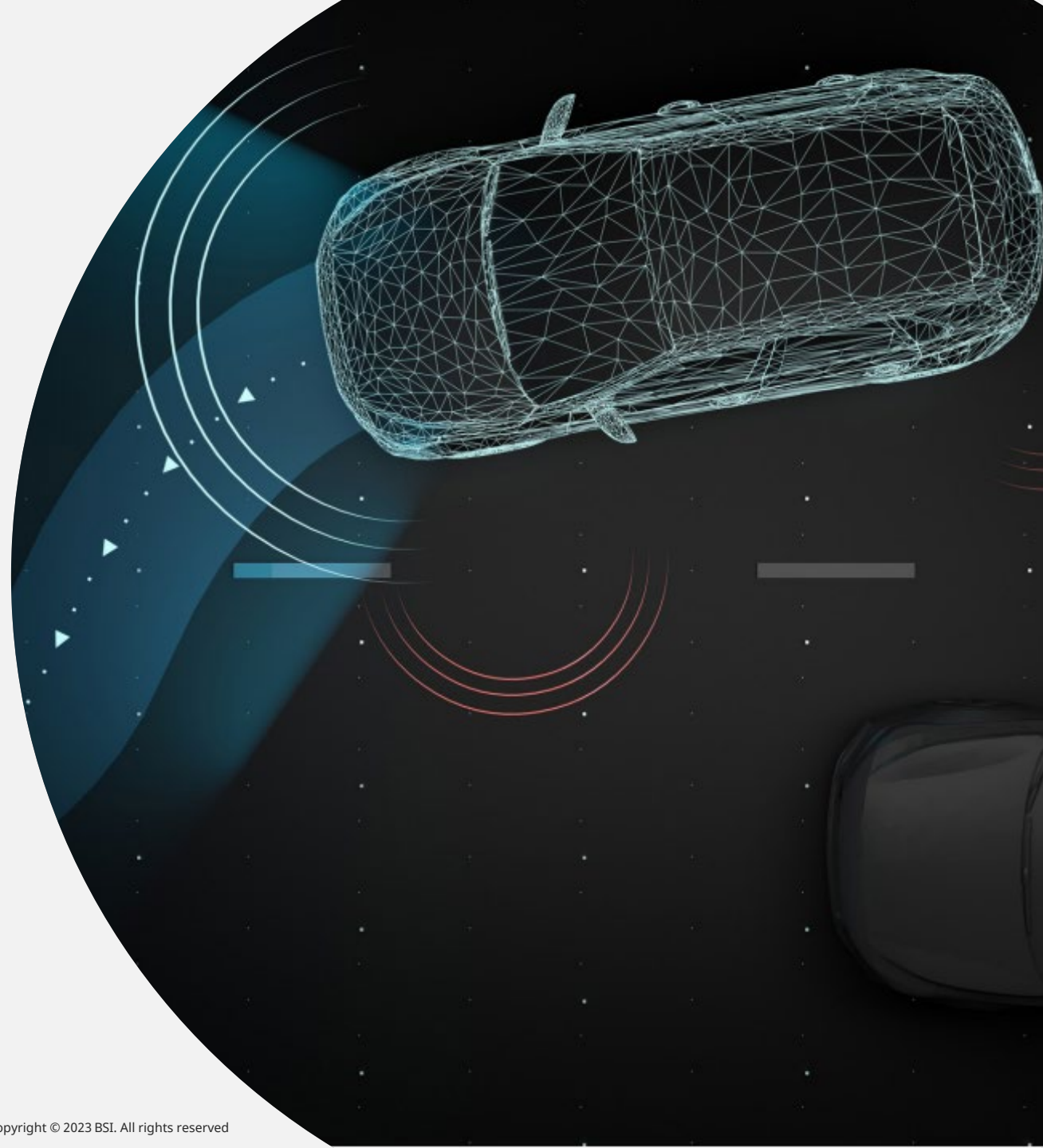


2022 Report: Standardizing Remote Operation of Vehicles

- **Engagement** with industry & agencies
  - UK & International
  - Supporting Automated Vehicle deployments
  - In business with Teleoperation services
- **Key factors** considered:
  - Safety of human driving through sensors
  - Connectivity from remote operator to vehicle
  - Safe remote control of vehicles
  - Remote operator performance
- Sector is rapidly **evolving**
  - Multiple approaches to a wide range of Use Cases
  - Regulatory exemptions in several geographies

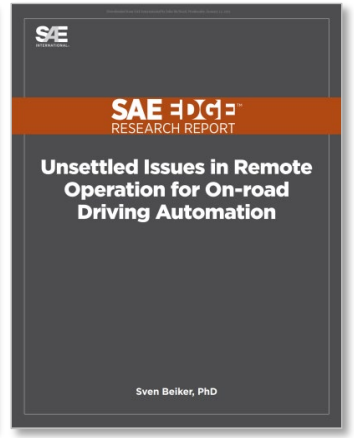
www.bsigroup.com/en-GB/CAV/cav-resources/standardizing-remote-operation-of-vehicles/

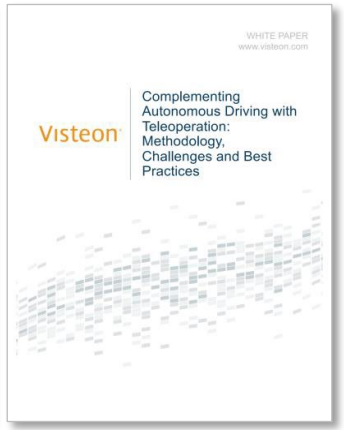
https://www.lawcom.gov.uk/project/remote-driving/

2022 Report: Organizations Interviewed / Research Sources

- Conigital
- Designated Driver US
- DVSA
- Halo Car US
- Imperium Drive
- NIST US
- Oxbotica
- Phantom Auto
- Starship
- Streetdrone
- VCA
- Waymo

- BSI PAS 1884
- SAE J3016
- ISO/SAE 22736
- SAE EPR202128
- TRL Report PPR1012
- Waymo briefing paper
- Visteon White Paper
- Law Comm 1, 2 & 3





Wide range of use cases

Use cases	Operating environment	Regulation	Speed	What is being carried?
Pavement Micro Vehicles	**Un**controlled	**(On**-road)	Very Low	Goods only
Local Deliveries	**Un**controlled	**On**-road	Road speeds	Goods only
Buildings & Factories	Controlled	**Off**-road	Low	Goods only
Yards & Warehouses	Controlled	**Off**-road	Low-Medium	Goods & Machinery
Construction & Agriculture	Controlled	**Off**-road	Low	Machinery
Rental Car Deliveries	**Un**controlled	**On**-road	Road speeds	Empty
Remote Valet Parking	**Un**/Controlled	**Off-road** / **On**-road	Low – Medium	Empty
CAV Safety Backup	**Un**controlled	**On**-road	Road speeds	Passengers
CAV Truck Safety Backup	**Un**controlled	**On**-road	Road speeds	Goods

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Classes of remote operation

Remote Monitoring

Remote Assistance

Remote Driving

Details dependent on Use Case and Implementation

Supervision but no intervention

Remote human monitors vehicle progress
Human advises or provides additional information for decision support

Support but no direct control

Remote human provides a path to avoid stationary obstacles, for example
May need to start with stationary vehicle

Direct remote control of the vehicle

Remote human is the driver, monitoring the driving environment, tactical interventions such as steering and braking.

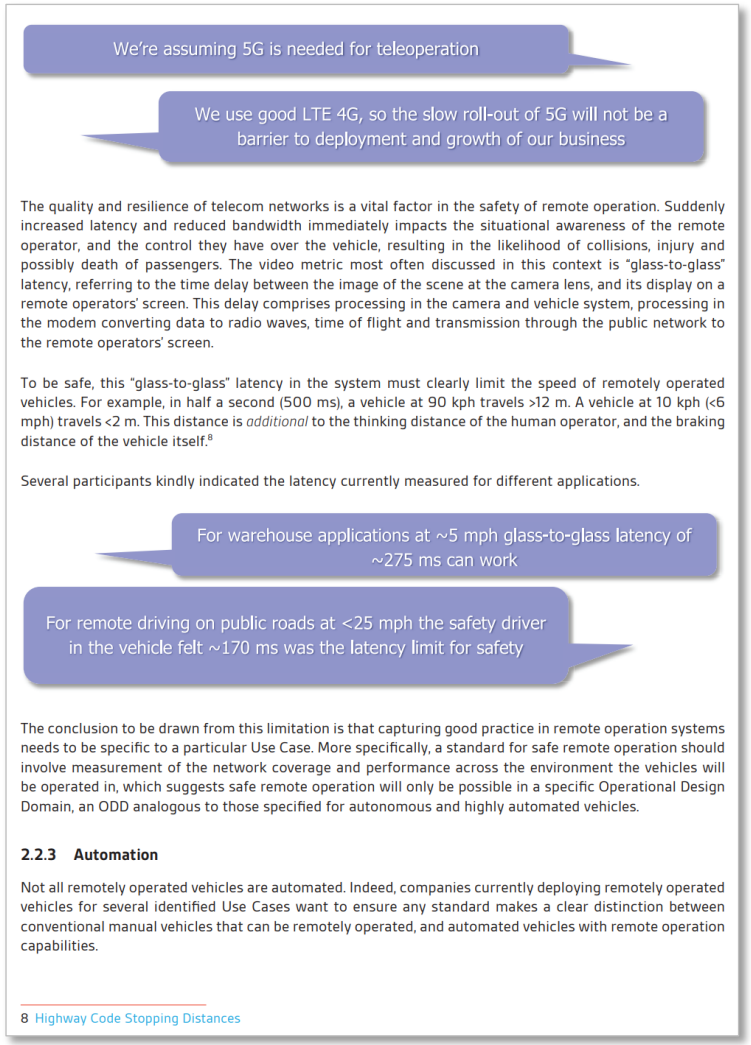
2022 Report: Selected Inputs from Industry

Across a wide range of..

- Systems
  - Field of View
  - Vehicle functionality
- Connectivity:
  - Ubiquity & Latency
  - 4G LTE or 5G
- Operations:
  - Remote Operators
  - Remote Workstations

.. often in conflict!

- Different Use Cases
  - Public – Private
  - Speed
- Different Perspectives:
  - Industry – Authorities
  - Automated Vehicles – Teleoperation



We're assuming 5G is needed for teleoperation

We use good LTE 4G, so the slow roll-out of 5G will not be a barrier to deployment and growth of our business

The quality and resilience of telecom networks is a vital factor in the safety of remote operation. Suddenly increased latency and reduced bandwidth immediately impacts the situational awareness of the remote operator, and the control they have over the vehicle, resulting in the likelihood of collisions, injury and possibly death of passengers. The video metric most often discussed in this context is "glass-to-glass" latency, referring to the time delay between the image of the scene at the camera lens, and its display on a remote operators' screen. This delay comprises processing in the camera and vehicle system, processing in the modem converting data to radio waves, time of flight and transmission through the public network to the remote operators' screen.

To be safe, this "glass-to-glass" latency in the system must clearly limit the speed of remotely operated vehicles. For example, in half a second (500 ms), a vehicle at 90 kph travels >12 m. A vehicle at 10 kph (<6 mph) travels <2 m. This distance is *additional* to the thinking distance of the human operator, and the braking distance of the vehicle itself.[8]

Several participants kindly indicated the latency currently measured for different applications.

For warehouse applications at ~5 mph glass-to-glass latency of ~275 ms can work

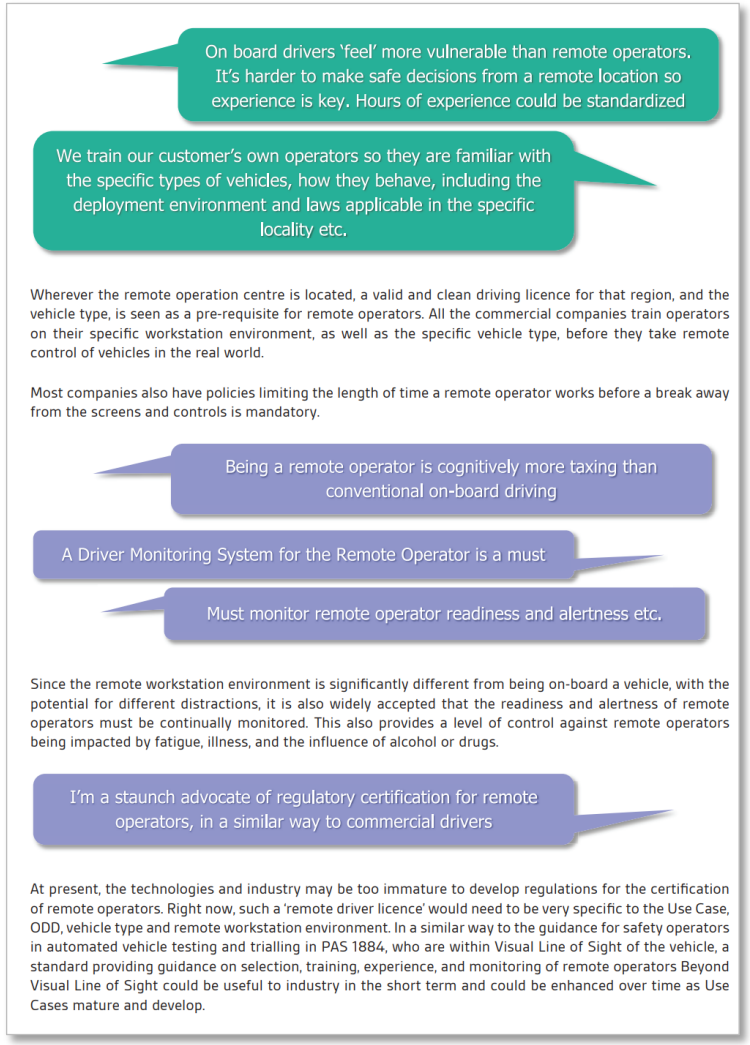
For remote driving on public roads at <25 mph the safety driver in the vehicle felt ~170 ms was the latency limit for safety

The conclusion to be drawn from this limitation is that capturing good practice in remote operation systems needs to be specific to a particular Use Case. More specifically, a standard for safe remote operation should involve measurement of the network coverage and performance across the environment the vehicles will be operated in, which suggests safe remote operation will only be possible in a specific Operational Design Domain, an ODD analogous to those specified for autonomous and highly automated vehicles.

2.2.3 Automation

Not all remotely operated vehicles are automated. Indeed, companies currently deploying remotely operated vehicles for several identified Use Cases want to ensure any standard makes a clear distinction between conventional manual vehicles that can be remotely operated, and automated vehicles with remote operation capabilities.

8 Highway Code Stopping Distances



On board drivers 'feel' more vulnerable than remote operators. It's harder to make safe decisions from a remote location so experience is key. Hours of experience could be standardized

We train our customer's own operators so they are familiar with the specific types of vehicles, how they behave, including the deployment environment and laws applicable in the specific locality etc.

Wherever the remote operation centre is located, a valid and clean driving licence for that region, and the vehicle type, is seen as a pre-requisite for remote operators. All the commercial companies train operators on their specific workstation environment, as well as the specific vehicle type, before they take remote control of vehicles in the real world.

Most companies also have policies limiting the length of time a remote operator works before a break away from the screens and controls is mandatory.

Being a remote operator is cognitively more taxing than conventional on-board driving

A Driver Monitoring System for the Remote Operator is a must

Must monitor remote operator readiness and alertness etc.

Since the remote workstation environment is significantly different from being on-board a vehicle, with the potential for different distractions, it is also widely accepted that the readiness and alertness of remote operators must be continually monitored. This also provides a level of control against remote operators being impacted by fatigue, illness, and the influence of alcohol or drugs.

I'm a staunch advocate of regulatory certification for remote operators, in a similar way to commercial drivers

At present, the technologies and industry may be too immature to develop regulations for the certification of remote operators. Right now, such a 'remote driver licence' would need to be very specific to the Use Case, ODD, vehicle type and remote workstation environment. In a similar way to the guidance for safety operators in automated vehicle testing and trialling in PAS 1884, who are within Visual Line of Sight of the vehicle, a standard providing guidance on selection, training, experience, and monitoring of remote operators Beyond Visual Line of Sight could be useful to industry in the short term and could be enhanced over time as Use Cases mature and develop.

2022 Report: Recommendations

Standards are immediately useful for two aspects of remote operation:

1. System Aspects for remote operations:

- On-board vehicle systems & level of automation embodied in the vehicles
- Operating environment and speed
- Perception and connectivity
- Information the vehicle should supply to the remote operator
- How to test / approve / certify

System Aspects Flex 1886

2. Human Factors Aspects for remote operators:

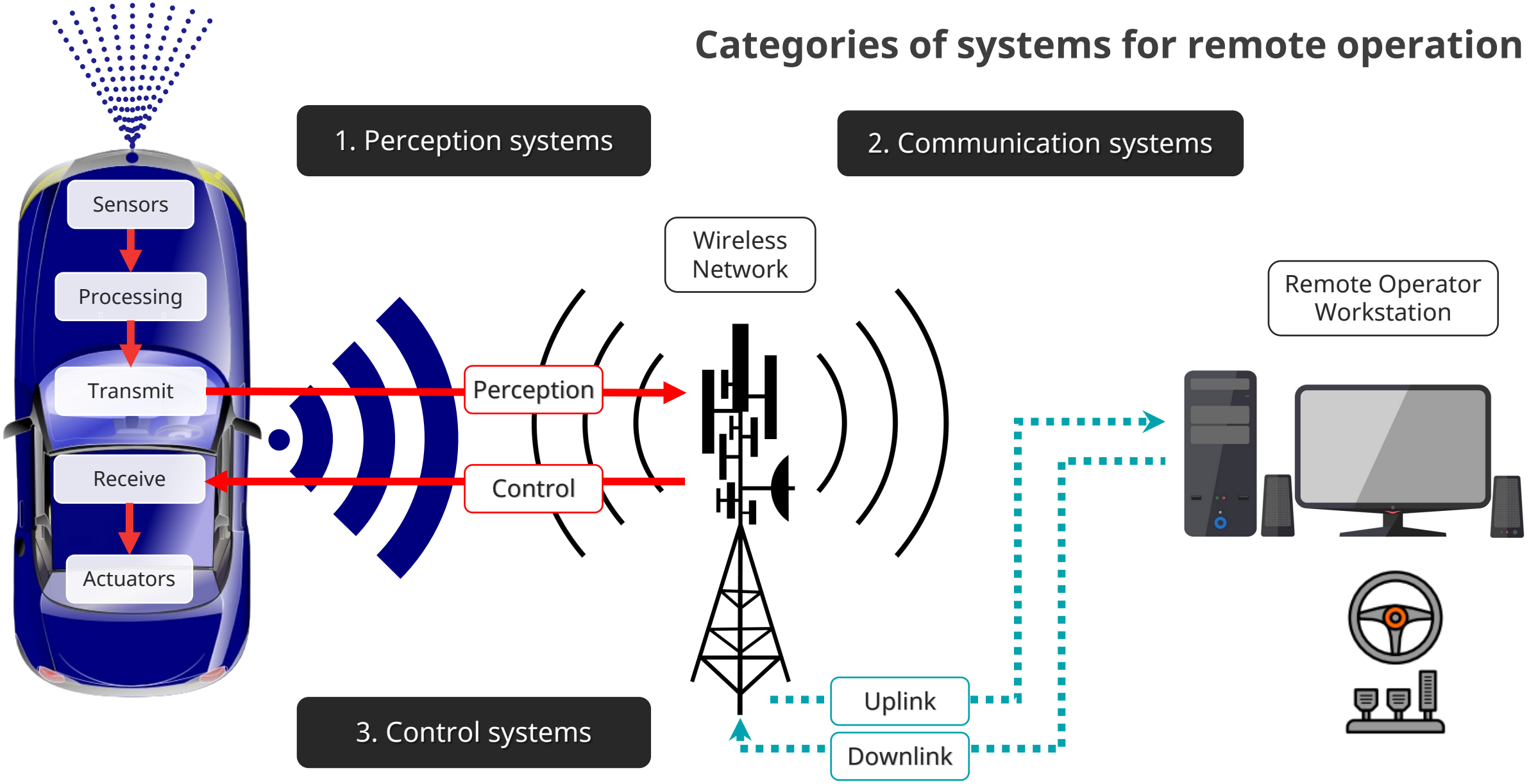
- Selection and training of remote operators
- Workstation environment & Human Machine Interface design
- Type of intervention allowed: support they provide or control they have
- How to test / approve / certify operators

Human Factors Aspects Flex 1887

BSI Flex 1886 Systems for remote operation

- ❑ Compares & Contrasts
  - Systems for Remote Operation vs Automated Driving Systems
- ❑ Highlights Safety and Security
  - On-vehicle, Communications links, Operator workstation and facilities
- ❑ Perception Systems
  - Video cameras, LIDAR and Radar, Ultrasonic, Audio, Haptic
- ❑ Communication Systems
  - Coverage, Bandwidth, Latency, Connectivity Loss, Availability, Quality of Service
- ❑ Control Systems
  - Steering, Braking, Acceleration, Speed, On-vehicle networks
- ❑ Information for Remote Operators
  - Situation and Vehicle Awareness for Monitoring, Driving, Assistance

Categories of systems for remote operation



BSI Flex 1886 Systems for remote operation

1. Perception systems

- General
- Video cameras
  - Field of View
  - Resolution and Latency
  - Contrast and Colour
  - Effects of weather and Dirt
- Light sensitivity & low light performance
- LIDAR and Radar
- Ultrasonic
- External Audio
- Internal Audio
- Haptic Systems

2. Communication systems

- General
- Coverage
- Bandwidth
- Latency
- Loss of connectivity
- Availability / Quality of service
- System Update & Security
  - General
  - Comms Link Security
  - Remote operator Security
  - Incident Response

3. Vehicle Control systems

- General
- Steering Control (Reg 79)
- Braking Control (Reg 13)
  - Operational Status
  - Deceleration
  - Component Wear
  - Redundancy
  - Brake Force Distribution
- Acceleration (Reg 89)
- Control Communications
  - Reg 155
  - Reg 156

Remote Operation Needs…

1. **Operational Design Domain (PAS 1883 / BS ISO 34503)**
   - Safety Case should include in-situ measurements of :
     - coverage, bandwidth, latency etc. in all circumstances (e.g. weather)
     - steering & braking & acceleration control in all circumstances (e.g. weather)
   - Systems should notify the remote operator *before* the vehicle is about to leave the ODD
2. **Capability for fully-featured MRMs**
   - Monitoring and prediction of comms link performance on route to trigger a safe MRM
   - Straight in-line slow to a stop is not acceptable for road-going applications
3. **Detection of Anomalies *in operation***
   - Reporting to Remote Operator in advance of failure
4. **Information for the remote operator**
   - Vehicle status in addition to situational awareness but HMI must avoid distraction, confusion, cognitive load

Flex 1886 is free to download and open for consultation until October 6th

Log your comments here:
https://standardsdevelopment.bsigroup.com/projects/9023-09084#/section

Consultation inputs will lead to version 2 of Flex 1886 (publication Q1 2024)

BSI's CAM Standard Programme has already:

- Developed **8 new standards (188X series)**
- Published an **interactive roadmap** for navigating the international standard landscape
- More than 5000 downloads in 55 countries
- Over **75 trialling organizations** involved on Steering Groups
- Shaped global practice – **PAS 1883 basis of new ISO 34503**

Programme supported by:

Centre for Connected & Autonomous Vehicles

What’s next ?

BSI Flex 1887 - Human factors for remote operations is under development, looking at:

- Selection and training of remote operators
- Workstation environment & Human Machine Interface design
- Type of intervention allowed: support provided or control they have
- How to test / approve operators

The next potential areas of standard development will be:

- Assurance of Machine Learning
- Minimal Risk Manoeuvres and Minimal Risk Conditions
- Classification of Vulnerable Road Users for ODD taxonomy

Thank you!

If you would like to get involved, or have any questions/comments get in touch at:

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