PACTS
Parliamentary Advisory Council for Transport Safety

ACUTE AND CHRONIC EFFECTS OF LONG-TERM EXPOSURE TO AUTOMATED CONTROL SYSTEMS IN ROAD VEHICLES

BRIEFING PAPER

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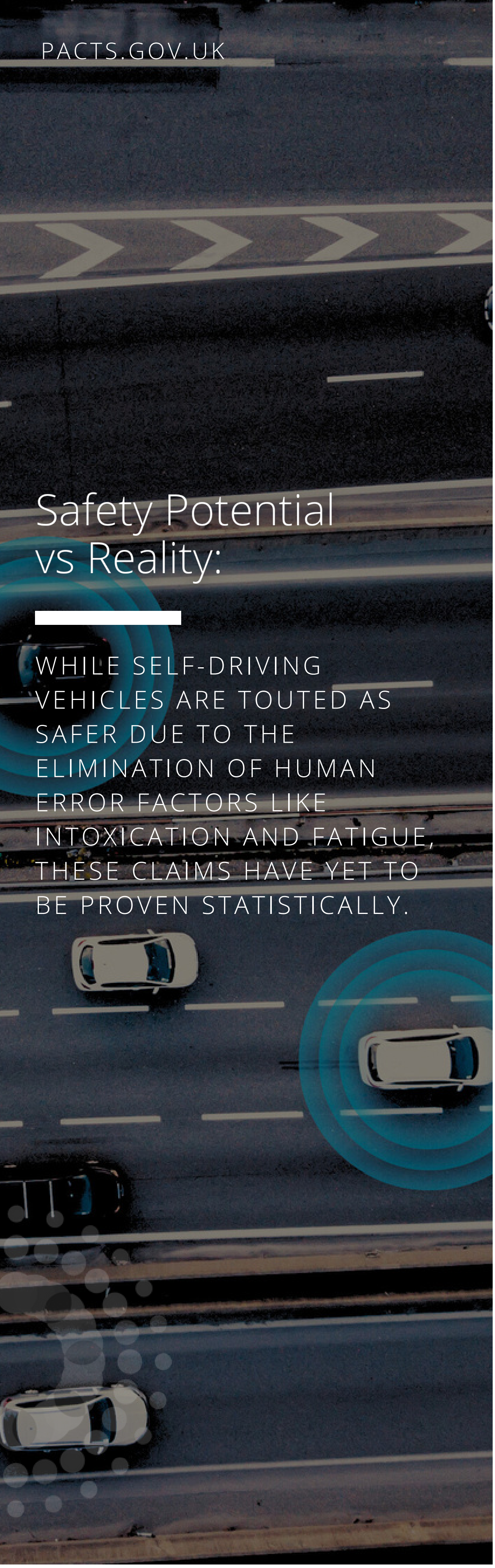


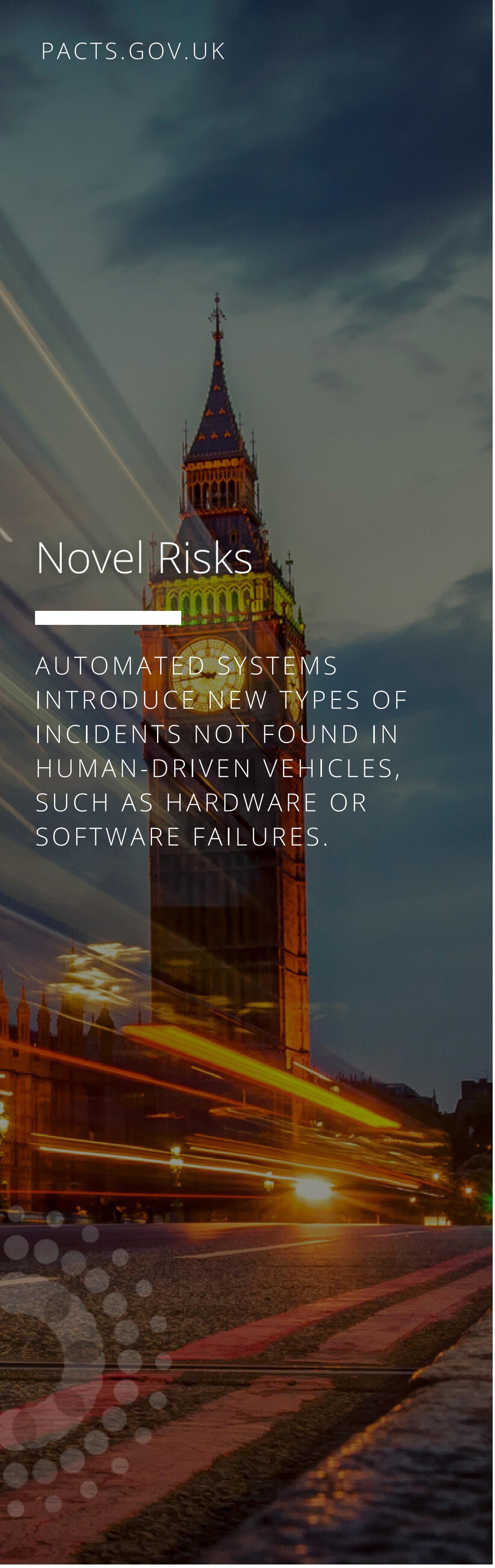
Safety Potential vs Reality:

WHILE SELF-DRIVING VEHICLES ARE TOUTED AS SAFER DUE TO THE ELIMINATION OF HUMAN ERROR FACTORS LIKE INTOXICATION AND FATIGUE, THESE CLAIMS HAVE YET TO BE PROVEN STATISTICALLY.

ACUTE AND CHRONIC IMPACTS OF VEHICLE AUTOMATION

A common claim for proponents of self-driving road vehicles is their potential to improve safety. Data from police assessments of contributory factors in more serious crashes (STATS19), suggests that the majority of crashes involve some form of human error. Self-driving vehicles are not subject to common contributory factors such as intoxication, fatigue or distraction so the theory goes that the number and severity of crashes will be greatly reduced. Whilst this logic has an intuitive appeal it has yet to be proven statistically, and other factors may reduce the anticipated safety benefit. These include novel incident types involving self-driving vehicles that do not occur with human-driven vehicles and incidents caused by hardware or software failures.

One such potential cause of increased risk in self-driving vehicles is the effect of long-term exposure of drivers to automated control systems. The hazard that emerges can be considered over two timescales. The first is what might be described as an 'acute' effect of exposure - the risk associated with the resumption of control by a human driver after an extended period of automated operation within a single journey. An example would be where a self-driving car is capable of automated operation without human oversight for highway driving, but a human must drive the vehicle from the trip origin to the highway and must drive the vehicle from the highway to the trip destination. This feature is anticipated to be one of the earliest forms of self-driving capability made available to consumers.

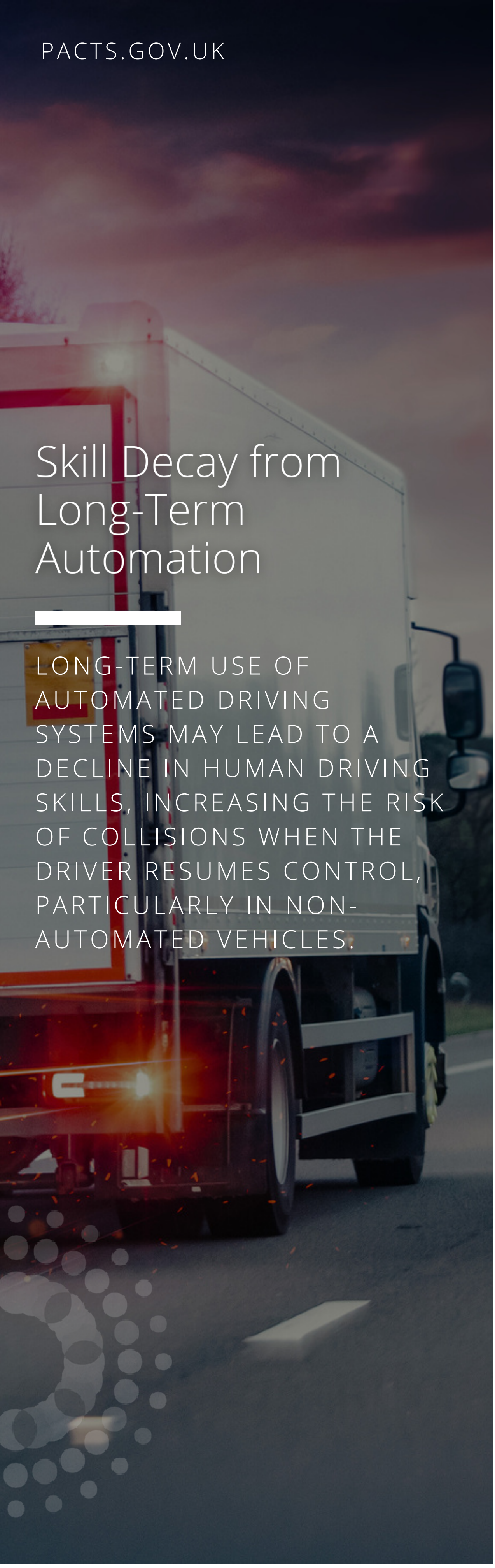


Novel Risks

AUTOMATED SYSTEMS INTRODUCE NEW TYPES OF INCIDENTS NOT FOUND IN HUMAN-DRIVEN VEHICLES, SUCH AS HARDWARE OR SOFTWARE FAILURES.

The danger here is that a driver prompted to resume control at the end of a period of automated driving may not be sufficiently alert or aware of the driving situation to be able to take over responsibility for the safe operation of the vehicle. This risk can be mitigated in two ways. Firstly, the vehicle should be designed such that the human-machine interface is intuitive, providing unambiguous information to the driver about the automation state of the vehicle, the distribution of responsibilities between the driver and the system and supporting smooth transitions from human to automated control and back again. This may use multiple sensory modalities (e.g. visual, auditory, tactile cues) and should support the driver in having the information necessary to control the vehicle safely. Secondly, the vehicle should use driver monitoring sensors (which could include cameras, heart rate monitors, breathing monitors etc.) to monitor the alertness state of the person at the controls of the vehicle. These should be used to derive an estimate of the driver's readiness to resume control when required. If the driver is unready, unable or unwilling to take control of the vehicle when the self-driving systems are unable to continue, the vehicle should trigger a minimal risk manoeuvre, seeking to achieve a minimal risk condition.

The phrases **Minimal Risk Manoeuvre** (MRM) and **Minimal Risk Condition** (MRC) are terms used in the self-driving vehicle sector used to describe risk mitigation actions taken by a vehicle when it is unable to complete a trip in automated mode.
For example, if a self-driving vehicle were unable to continue in automated mode due to a sensor failure when driving on a motorway and no occupant were able to take control, the MRM could be to slow gradually and shift the vehicle across to the hard shoulder before coming to a stop with the hazard warning lights - at which point, the MRC would have been achieved (noting that this not a zero risk conditions and any vehicle occupants should exit the vehicle on the nearside and take a position behind roadside barriers, notifying the highway authority of the situation).

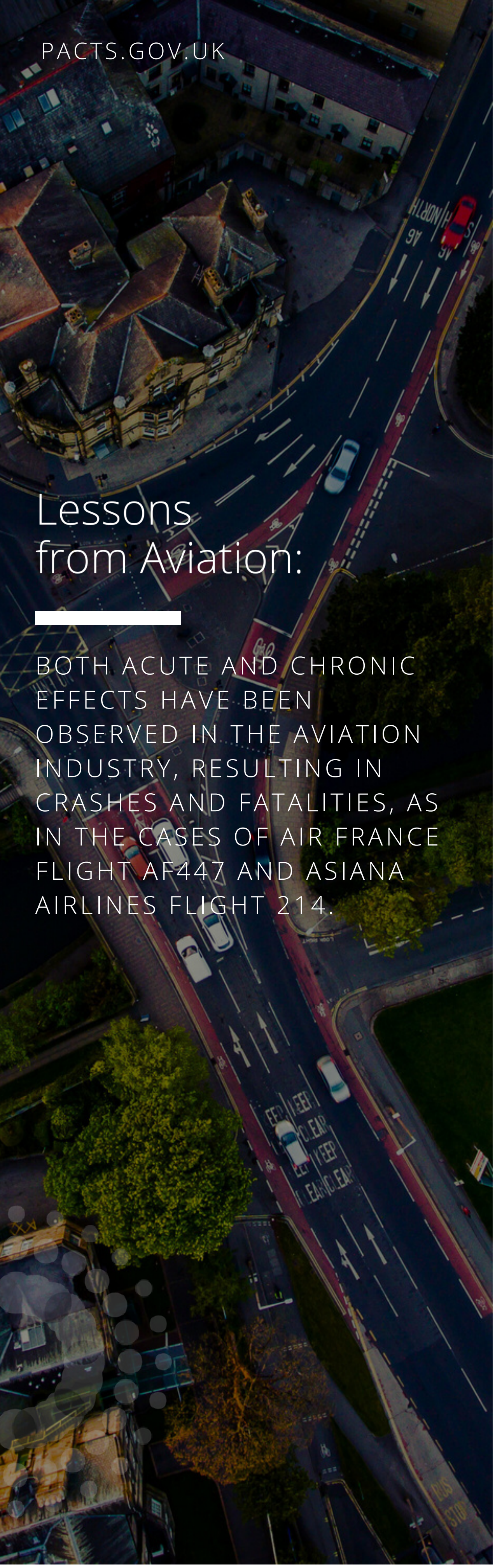


Skill Decay from Long-Term Automation

LONG-TERM USE OF AUTOMATED DRIVING SYSTEMS MAY LEAD TO A DECLINE IN HUMAN DRIVING SKILLS, INCREASING THE RISK OF COLLISIONS WHEN THE DRIVER RESUMES CONTROL, PARTICULARLY IN NON-AUTOMATED VEHICLES.

The second risk associated with long-term exposure to automated control systems might be considered a 'chronic' effect of exposure. This is the suggestion that repeated use of a self-driving system causes a gradual change in the skills and expectations of the human driver using the automated driving technology and is similar to concerns over drivers' ability to self-orient or understand maps due to long-term reliance on sat-nav devices. If a self-driving system is frequently used by a human driver and the system is therefore continually taking responsibility for observation of the driving environment, detecting (and predicting) the presence and motion of potential hazards and making appropriate responses, a human driver's abilities in these tasks may diminish over time. This skill degradation might involve fine control of the vehicle, detection of and response to hazards, manoeuvre selection, visual scanning patterns or any number of sub-tasks associated with safe driving. When such a human driver is subsequently called to operate the vehicle (for example, due to a system fault or when driving a different vehicle unequipped with self-driving features), they may fail to detect hazards, fail to respond or make poorer quality responses. As a result, collisions may become more likely due to a decline in skill of the human operator in non-automated vehicles.

The 'acute' and 'chronic' effects of automation in road vehicles are phenomena that have been observed in aviation. For example, in 2009, Air France Flight AF447 (an Airbus A330) crashed into the Atlantic Ocean with the loss of all passengers and crew (228 people). The cause of the crash has been attributed in part to errors made by the pilots in resuming control when the autopilot functionality was disrupted due to inconsistent speed airspeed measurements. Furthermore, some investigators



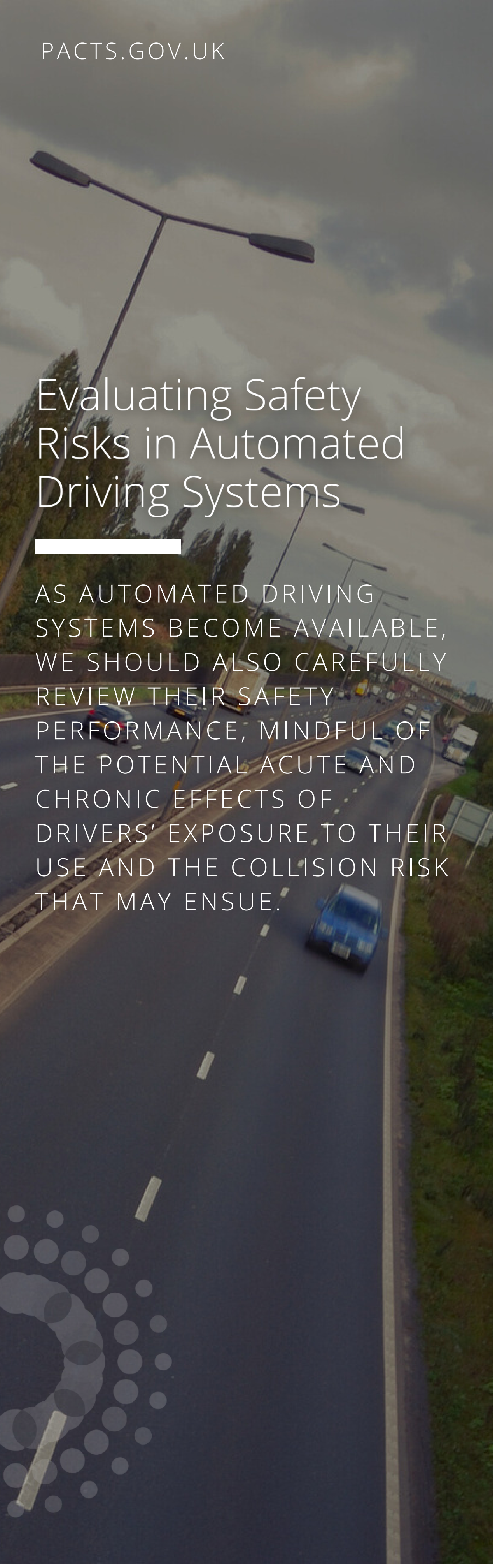
Lessons from Aviation:

BOTH ACUTE AND CHRONIC EFFECTS HAVE BEEN OBSERVED IN THE AVIATION INDUSTRY, RESULTING IN CRASHES AND FATALITIES, AS IN THE CASES OF AIR FRANCE FLIGHT AF447 AND ASIANA AIRLINES FLIGHT 214.

criticised the cockpit instrumentation, suggesting that the pilots did not have ready access to all the information needed to gain safe control of the aircraft following the requirement to resume its supervision.

An example of the ‘chronic’ effects of automation can be seen in the 2013 crash landing of Asiana Airlines Flight 214 (a Boeing 777) at San Francisco International Airport, which resulted in three deaths and 87 injuries. Maintenance at the airport meant the instrument landing system (ILS) was not available to support automated approach guidance for aircraft, and pilots were therefore required to land manually. The pilots of Flight 214 caused the aircraft to fly too low and too slow such that its tail and landing gear struck a sea wall at the eastern boundary of the airport, causing the tail section to separate from the fuselage and the aircraft to cartwheel to a stop on the runway. The investigation by the U.S. National Transportation Safety Board (NTSB) indicated that the pilots had a poor understanding of the automation functions of the aircraft when the ILS was not available. The approach trajectory resulted in an increase in pilot workload, which consequently restricted the pilots’ abilities to monitor the external environment. Furthermore, the airline adopted a policy that encouraged pilots to use automated rather than manual control. Reflecting on the cause of the crash, the NTSB acting chair, Christopher Hart, said. "In this instance, the flight crew over-relied on automated systems that they did not fully understand.”

In a critique of the effects of autopilot, Bainbridge (1983) suggested that automation acts to lower pilots’ workload for flight phases in which workload was already low and increase the workload for phases in which it was already high.



Evaluating Safety Risks in Automated Driving Systems

AS AUTOMATED DRIVING SYSTEMS BECOME AVAILABLE, WE SHOULD ALSO CAREFULLY REVIEW THEIR SAFETY PERFORMANCE, MINDFUL OF THE POTENTIAL ACUTE AND CHRONIC EFFECTS OF DRIVERS' EXPOSURE TO THEIR USE AND THE COLLISION RISK THAT MAY ENSUE.

This has been termed the 'irony of automation'. Although commercial aircrews are trained and regulated far more extensively than drivers of road vehicles, it is vital that we build on the experience gained in the aviation sector to monitor and mitigate the risks that the long-term deployment of automated control systems may present.

It is therefore recommended that longitudinal studies are conducted to observe the acute and chronic effects of long-term exposure to automated control systems in road vehicles, building on the evidence base observed in aviation. As automated driving systems become available, we should also carefully review their safety performance, mindful of the potential acute and chronic effects of drivers' exposure to their use and the collision risk that may ensue.

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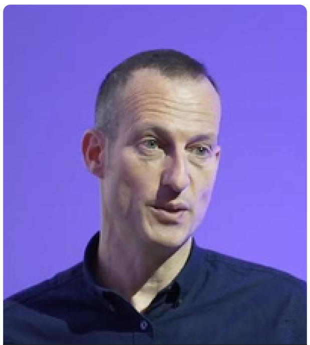
The information and conclusions in this paper are the responsibility of the author.



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