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Confidentiality	

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Summary

Despite advancements in automated driving technology, human supervision remains essential in the transport system. Remote operation can support monitoring, assisting, and driving (semi-) automated vehicles from a distance when necessary. However, passive human monitoring and occasional intervention pose challenges, as, for example, critical decision-making can be impaired by the human operator's state. Decades of traffic safety research have led to the development of Driver Monitoring Systems (DMS) and Cabin Monitoring Systems (CMS). These systems can detect risky driver states and behaviors, such as distraction, fatigue, and engagement in non-driving tasks.

This pre-study aimed to explore the potential of applying existing DMS and CMS technologies for remote operators of automated vehicles. It also sought to identify gaps in these systems and explore improvements to better support remote operators, enhancing traffic safety in future applications of remotely operated automated vehicles.

Four workshops were carried out during the pre-study. Workshop 1 reviewed DMS and CMS technologies, highlighting features like distraction and drowsiness detection, and body posture tracking. It also discussed the need for ergonomic adjustments for remote operators. Workshop 2 focused on the roles of the remote operator as well as required training and communication schemes. Workshop 3 analyzed gaps in current DMS and CMS technologies and Workshop 4 consolidated the findings from the workshops and outlined future needs for Remote operator Monitoring Systems (RMS) as well as plans for further research and development.

The pre-study concluded that DMS and CMS technologies can be adapted for remote operators of automated vehicles, detecting critical behaviors like fatigue and distraction. This adaptation could also allow real-time behavior monitoring and data collection for improved operator performance, mitigating risks from, for example fatigue and disengagement. These technologies could also provide data-driven assessments for improving the remote operator work environment and managing incident liability. However, current DMS and CMS technologies cannot distinguish between negative and positive behaviors, such as deliberate strategies to maintain focus. This limitation highlights the need for "intelligent" assessment of operator behaviors where contextual understanding is needed.

The findings from the pre-study will be disseminated within SAFER's new Remote Operations working group, with industry, academia, and research representatives. Authorities are also invited. The working group objectives are to network, share knowledge, and initiate new projects, for example a pilot study to develop a functional RMS concept and to address traffic safety challenges associated with remote operations of automated vehicles.

REMOSAFE: REMOte operator state monitoring for traffic SAFEty

1 Background

Despite technological advancements enhancing automated driving, humans are still expected to supervise the transport system. In this context, remote operation of automated vehicles can include monitoring, assisting, and driving (semi-) automated vehicles from a distance. However, monitoring and occasional intervention is known to be a challenging task for humans, where critical decision-making abilities are affected by the operator's state. In parallel, for decades, research on traffic safety has led to the development of Driver Monitoring Systems (DMS) and Cabin Monitoring Systems (CMS). These systems can detect risky driver states and behaviors such as distraction, fatigue, and engagement in non-driving tasks. A solution that combines DMS and CSM for remote operation purposes, i.e., here called, a Remote operator Monitoring System (RMS), could potentially contribute to traffic safety in remote operation settings. This pre-study, REMOSAFE, has explored how remote operation work and driver monitoring technologies could be combined (Figure 1).

2 Pre-study set up

2.1 Purpose

The purpose of the pre-study was to gain an understanding about the needs, feasibility and development of Remote Operator monitoring Systems (RMS) adapted from a state-of-the-art of driver monitoring systems. The following research questions have been guiding the pre-study:

- **RQ1**: *What are the practical needs and ethical considerations for monitoring of the human operator in remote operations of road vehicles?*
- **RQ2**: *How can DMS/CMS technology be transferred to the remote operation domain, and evolve into RMS?*

The pre-study closely ties to **traffic safety** in future transportation systems. The remote operators of future automated vehicle fleets will have a key role in foreseeing and mitigating negative impacts of automated vehicles in traffic. They will have a pivotal role in safety, managing accidents and incidents both on the level of individual vehicles and with a "birds-eye" view to minimize and coordinate traffic system disturbances in case of critical events. For remote operators to make timely and correct decisions when needed, the operators' cognitive states and situational awareness are important aspects, which could be addressed by RMS. RMS may also have an organizational impact, e.g. enable data driven understanding of how to plan working shifts and staffing requirements.

Figure 1. *Illustration of the combination of DMS and remote operations*

2.2 Objectives

The objectives in this pre-study were: (i) to investigate whether and how current DMS and CMS technologies can be adapted for remote operations of automated vehicles, and (ii) to identify gaps and needs that could guide the development of these systems to better support the work of remote operators and thereby contributing to improved traffic safety in future applications of remotely operated automated vehicles.

2.3 Duration and partners

The pre-study started in January 2024 and ended in September 2024. Five partners participated:

- RISE, Research Institutes of Sweden
- Astazero (Test track and certification facility)
- SmartEye AB (Development and manufacturing of driver and cabin monitoring systems)
- Einride AB (Development and manufacturing of autonomous trucks)
- CDE AB (Development and manufacturing of equipment and working environments for critical decision centers)

3 Method and activities

Four workshops were carried out, in which representatives from each partner participated.

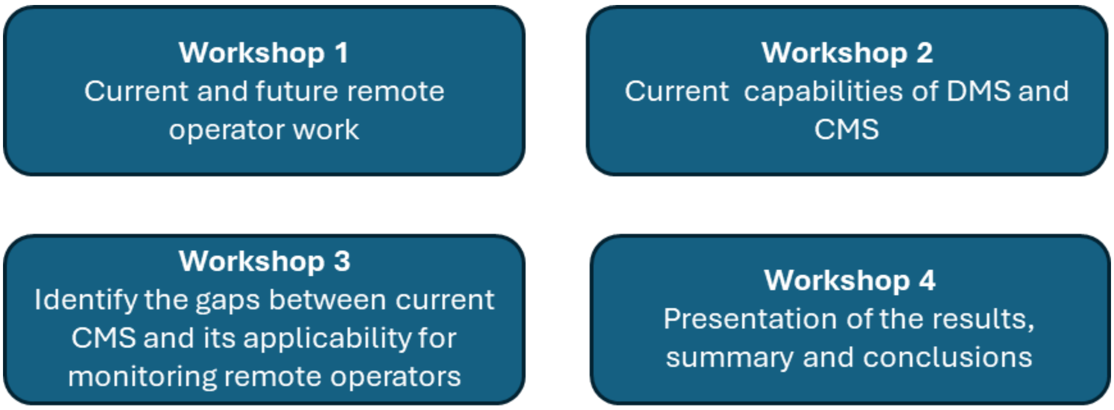

Figure 2. *The four workshops in the pre-study.*

Workshop 1 was facilitated by Smart Eye AB, which provided an overview of the features and functionalities of their DMS and CMS such as detection of distraction, drowsiness and attention as well as tracking of the driver's body postures, facial expressions and activity detection. Additionally, the workshop examined how DMS/CMS would need further development to effectively monitor remote operators in control room environments, for example ergonomic adjustments of remote operation workstations to maintain comfort and vigilance. Also, the context in a control room is different to a vehicle cab and, thus, may require adjustments of the DMS/CMS technologies to the specific tasks and responsibilities of remote operators, for example in terms of feedback and warning strategies and modalities (visual, auditory, haptic etc.).

Workshop 2, facilitated by CDE AB and Einride AB, focused on the current and future characteristics of remote operator roles, tasks, and responsibilities. The workshop also addressed challenges and needs related to training, competency requirements, communication, and collaborative work environments. The workshop emphasized the value of leveraging experience and insights from other domains involving remote operations, such as air traffic control, mining, process control and nuclear plant control rooms.

Workshop 3, facilitated by RISE, the outcomes of workshops 1 and 2 were analyzed, discussed, and evaluated to identify gaps and needs in the capabilities of existing DMS/CMS technologies for Remote Operator monitoring Systems (RMS).

Workshop 4, facilitated jointly by RISE and AstaZero, presented the results from the workshops 1-3. It also discussed the needs for future RMS and outlined a plan for further research and the possible development of next-generation RMS solutions.

4 Results and Deliverables

The outcomes from the workshops related to the RQs are summarized below:

RQ1: *What are the practical needs and ethical considerations for monitoring of the human operator in remote operations of road vehicles?*

The practical needs are to detect behaviors of the remote operators and situations that negatively have impact on safety in remote operation systems. However, the better the system, the less the remote operator needs to do or attend to, and still, the remote operator must be ready to act when needed. This could lead to inactivity, boredom, lack of engagement, inattentiveness and distraction, which could jeopardize safety in critical situations.

There is an inherent paradox with automated systems that still require human supervision: The better the system, the less the remote operator needs to do or attend to. Still, the remote operator must be ready to act when needed. These kinds of inconsistencies were recognized by Bainbridge (1983)[1] when human operators are tasked with overseeing automated systems. The paradox highlights the ways in which automation can complicate human work rather than simplifying it. The paradox also shows that while automation can enhance efficiency and reduce human workload, it also shifts the nature of work. This is valid also in human-automation interaction in remote operation systems.

The ethical considerations regarding monitoring of human operators are mainly regulated by national and international regulations and laws, for example:

- GDPR (EU)
- The Law on data protection (Swe: Dataskyddslagen)
- The Law on camera surveillance (Swe: Kamerabevakningslagen)
- The Work environment act (Swe: Arbetsmiljölagen)
- The Act on privacy protection in working life (Swe: Lagen om integritetsskydd i arbetslivet)

The project budget and timeframe has not allowed for detailed analyses of the regulatory landscape concerning remote operator monitoring systems. However, the laws and regulations mentioned above needs to be carefully considered when implementing future monitoring of human work. The potential impact on personal integrity has to be balanced to safety benefits of assessing operator states.

RQ2: *How can DMS/CMS technologies be transferred to the remote operation domain, and evolve into RMS?*

[1] Bainbridge, L. (1983), Ironies of Automation*, journal Automatica,* Vol. 19, Issue 6, 1983

The current DMS/CMS technologies could be applied to detect various behavior of remote operators, for example:

- Remote Operator is not at the desk
- Remote Operator is tired
- Remote Operator is distracted and or inattentive
- Remote Operator is not responding to a message or instruction from the system
- Remote Operator is engaged in non-RO-tasks

Engagement in tasks not directly related to remote operations, as well as distraction and inattentiveness are often seen as indicators of negative states. However, these behaviors could also represent strategies employed by operators to stay vigilant and engaged, helping them balance the cognitive demands of their work and avoid both overload and underload. A key challenge for an RMS is therefore to differentiate between genuine negative states and intentional strategies used by operators to sustain attention and engagement. Another challenge is to design the work task(s) to prevent cognitive overload and underload.

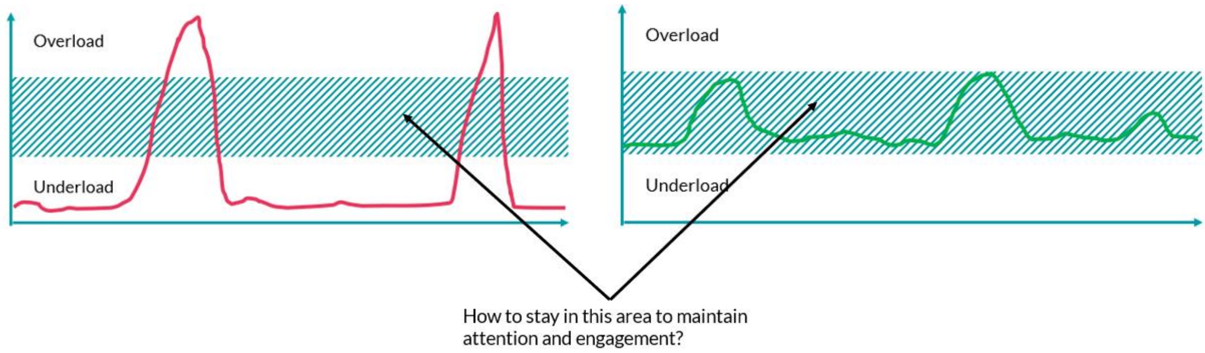

Figure 3: *To the left, an illustration of periods of cognitive overload and underload, which are unfavorable for human performance. To the right, a desired state of balanced cognitive workload which would benefit the operators' performance.*

Cognitive overload occurs when the demand of a task exceeds an individual's cognitive capacity, while cognitive underload arises when the demands are too low, leaving cognitive capacity underutilized. Both scenarios can lead to fatigue and inattention, ultimately impairing the performance of system operators (Mühlbacher-Karrer et al., 2017)[2].

The workshops further concluded that behaviors such as distraction, inattentiveness, fatigue, sleeping, and engagement in non-RO tasks should be addressed from an organizational standpoint as these behaviors could reflect underlying issues related to the structure and management of remote operator work. Similar challenges are often encountered by operators in industries that rely on monitoring of automated systems, such as manufacturing and energy production, underscoring the need for systemic solutions, such as:

- Monotonous work
- Not much to do but passively monitor the system
- Little variations in the work
- Little control of the work

[2] Mühlbacher-Karrer, S et al. (2017), A Driver State Detection System-Combining a Capacitive Hand Detection Sensor With Physiological Sensors, *IEEE Transactions on instrumentation and measurement*, pp. 1-13, DOI: 10.1109/TIM.2016.2640458

- Solitary work (one station, one operator), no co-working
- Long working shifts

In addition to monitoring the states of the remote operators, an RMS can also play a role in analyzing their work methods and optimizing the organization of tasks. This could help prevent unfavorable working conditions and mitigate undesirable behaviors and thus enhancing operator performance and well-being (Figure 3).

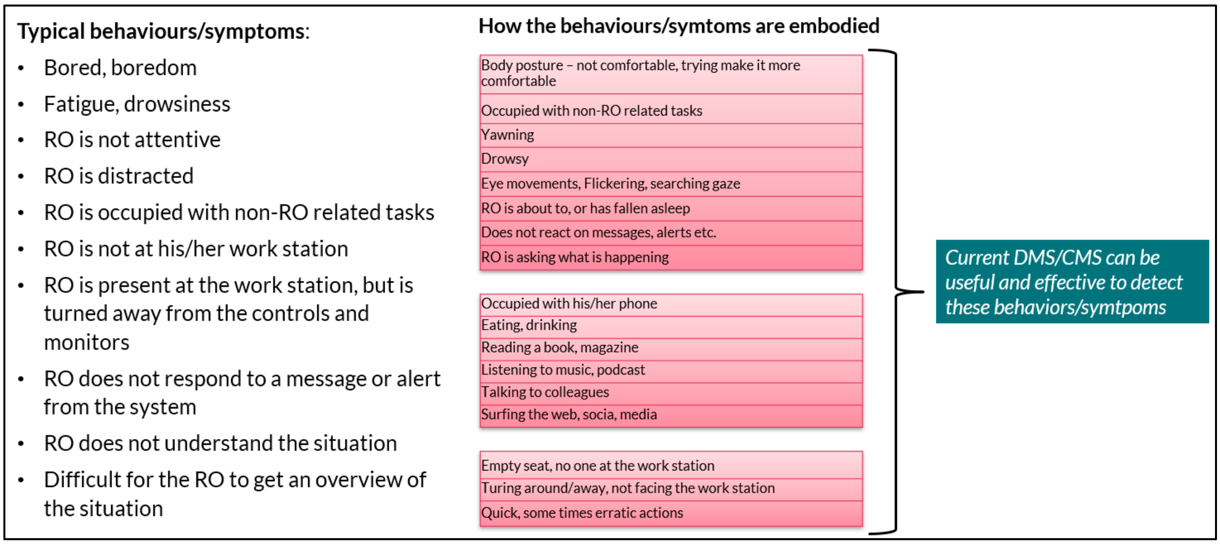

Figure 4: *Overview of behaviors and symptoms.*

With CMS/DMS technologies applied to monitoring remote operators it would be possible to:

- Detect in real-time various behaviors of remote operators
- Gather data over time for various analyses, such as:
  - Risk estimations, for example, reasonable levels that the system or the remote operator can cope with in critical situations
  - Collect data and define the FTI (Fault Time Interval), i.e. what time is required to handle a specific fault in a specific situation
  - Assessments about required activity levels in different situations
  - Discriminate positive and negative behaviors
  - Work analyzes, for example assessment of the work environment, but also work organization, tasks, procedures, training, work efficiency
  - Liability issues, e.g. logging time to respond in case of critical incidents or accidents
- Ensure that the control system can assign tasks to the appropriate operator based on the nature of the activity and the operator's current task load. This could help prevent inflicting stress on an operator who is already engaged in operator activities with high task load.

Appendix A, lists workshop results of identified Operator behavior, symptoms, DMS detection capability as well as possible causes to the behaviors and potential counter measures.

5 Conclusions, Lessons Learned and Next Steps

This pre-study has shown that CMS/DMS technologies can be adapted for monitoring remote operators of automated vehicles and to achieve real-time behavior monitoring and data collection, which could provide valuable insights for improving operator performance and safety.

Furthermore, future RMS could support operators by identifying behaviors that may negatively impact safety and efficiency. This includes mitigating risks associated with fatigue and disengagement, which are common where tasks are monotonous or require passive monitoring. RMS could also be used as a tool for addressing organizational factors, such as task structure and working conditions and to provide data-driven assessments that could guide improvements in the work environment.

However, while current CMS/DMS technologies can effectively detect *what* behaviors occur, they lack the capability to distinguish whether the behavior is positive or negative. For instance, behaviors identified as indicative of inattention or distraction (negative) might be a deliberate strategy employed by the remote operator to maintain focus and engagement (positive). In the case of true (negative) inattention, the system should notify or even warn the operator, while if the behavior is a productive (positive) coping strategy, such intervention would be unnecessary and potentially disturbing. This limitation emphasizes the need for CMS/DMS technologies to further develop the capability for the remote operation context and improve the ability to interpret operator behaviors more accurately.

The findings from the pre-study will be shared and further developed within the remote Operations working group at SAFER, which includes representatives from the automotive industry, academia, and research institutes. Authorities and regulatory bodies are also invited to participate. The objectives of the working group are to create networking opportunities, facilitate knowledge sharing, and to initiate new projects. A potential follow-up project could involve developing an RMS concept to better understand the critical factors of remote operator systems and the specific challenges related to traffic safety. This pre-study has laid a foundation and given input to needs and requirements of future RMS.

6 Dissemination and Publications

A poster was presented at the SAFER Research Day - Human, Body and Mind, 2024-09-18.

Acknowledgement

We would like to thank the partners Astazero, Smart Eye AB, Einride AB and CDE AB for their participation in this pre-study, for contributing with and sharing of their expertise, experiences and valuable insights. We would also like to thank SAFER Idea Exploration Program for the opportunity and financing.

APPENDIX A1

WHAT	SYMPTOMS (observable)	DETECT with DMS/CMS	1= Very difficult 2= Probably not possible 3= Possibly 4= Possible, requires investigation 5= Yes, possible to detect	REASON (example)	ACTION (example)
Bored	Body language - make it more comfortable, rest	Yes	4	Monotonous job, Little variety, Can't affect work Lonely work Doesn't feel meaningful Little to do	Work rotation, varied work tasks, create forms of collaboration Shorter work shifts Adjust the work environment (lighting, work postures, temperature) Create a calm and stimulating work environment free from disturbing events and noise.
	Do other things unrelated to monitoring	Yes	4		
	Yawn	Yes	5		
	Fatigue, drowsiness	Yes	5		
	Empty eyes... unfocused		3		
	Body posture	Yes	4		
	Screw yourself	Yes	4		
	Daydreaming		3		
RO is not in his/her place	Empty chair/empty desk	Yes	5	In the restroom, Shift change, Helping a colleague, Fetching coffee	
RO does not understand the situation	Flickering, searching gaze	Emotions - face detection	5	System does not provide the right information RO does not have the right training/Operator is unsure of task, message, information, how to solve a task, etc.	With integration technology, the "right" information can be given to the operator Education, competence, training, routines Forms of cooperation, work design
	Outside normal procedure	Yes			
	Turns to ask colleague	Yes	5		
	Clenched		2		
	Fast actions	Yes	5		
	Tunnel vision	Unknown	1-2		
	Speech - asking what is happening		4		
	Measuring stress parameters - biosensors	Questionable (privacy)	3		
	Emotions	no face detection	3		
Fatigue	Sleeping	Yes	5	Understimulated Long work shift Strenuous work shift Fatigue Bored	Work rotation, varied work tasks, create forms of collaboration Shorter work shifts Adjust the work environment (lighting, work postures, temperature) Create a calm and stimulating work environment free from disturbing events and noise.
	Eyes (movements, gaze, blinks, eye closure)	Yes	5		
	Yawning	Yes	5		
	Body posture	Yes	5		
	Does not act on messages, alarms - reaction	Yes	5		
	About to fall asleep	Yes	5		
Non-Remote-Operator-Task (NROT)	Things with the phone	Yes	5	Not much to do = the AD system works well Understimulated Distracted Eating lunch at the workplace	Compare Driver-in-the-loop vs. Driver-out-of-the-loop strategies from research in self-driving vehicles SAE level 2-4
	Eating	Yes	5		
	Reading a book/magazine	Yes	5		
	Listening to podcasts	Yes	4		
	Talking to colleagues	Yes	4		
	Surf the web, social media	Yes	5		
	Write email	Yes	4		
Inattentive	See above			Bored, tired	See above
				Distracted	
				Non-Remote-Operation-Task (NROT)	

APPENDIX A2

WHAT	SYMPTOMS (observable)	DETECT with DMS/CMS	1= Very difficult 2= Probably not possible 3= Possibly 4= Doable, requires investigation 5= Yes, possible to detect	REASON (example)	ACTION (example)
Distracted	Not looking at the screen	Yes	5	Colleague comes and talks	Create a focused work environment by shielding distractions with adjustable side guards mounted on the workplace.
	Does not act on alarms, does not look	Yes	5	Other duties	Remove disturbing, distracting elements
	Do other tasks that are deemed more important	Yes	5	Information from system	
	Divergent focus compared to what the system knows and thinks...	Yes	5	Non-Remote-Operation-Task (NROT)	
	Prioritization error compared to the system's assessment	Yes	5		
Can't get an overview of the situation	Difficult to prioritize focus	Yes	5	The system does not receive the "correct" input and cannot provide correct output	Place information in the center or spread out?
	Frustration		3	RO does not have the right education/training	Collect information
				Little/no experience	
RO makes mistakes	Expression - what does it look like?		3	The system does not receive the "correct" input and cannot provide correct output	Technical obstacles from wrong actions
	Deviates from the system's prioritization	Yes	5	RO does not have the right education/training	
				Little/no experience	
RO knows what to do, is in control	Quiet	Yes	4	The system does not receive the "correct" input and cannot provide correct output	
	Concentrated, focused	Yes	4	Little/no experience	
	Satisfied	Yes	4	RO does not have the right education/training	
	Fulfills the system's priority	Yes	5		
AV performs a minimum risk maneuver (MRM)	System	System	5	RO is not in place MRM may be a symptom that the operator did not act earlier, or that a direct event caused the MRM)	Have a good alarm strategy from the start to avoid, for example, alarm floods. Integrated light alarms in the micro environment. Let sounds come from different directions for better understanding and prioritization of alarms to act on. Provide opportunities to silence subsequent alarms, when the cause is known
Messages from the system are not answered	The action/task is not carried out	No, possible via control system	5	RO doesn't know what to do RO doesn't understand the situation RO makes mistakes RO is not in place Distracted, tired	
Face away from the workplace	Can't see face	Yes	5	Engaged in other tasks or actions	
Handover between operators	Checklists cancelled/incomplete			Lack of routines, tools for checklists not appropriate	Routines, training, good tools