HUMAN FACTORS

IN SAFETY CRITICAL AND HIGHLY AUTOMATED SOCIO-TECHNICAL SYSTEMS

PAOLA LANZI
Head of Automated and Multimodal Transport

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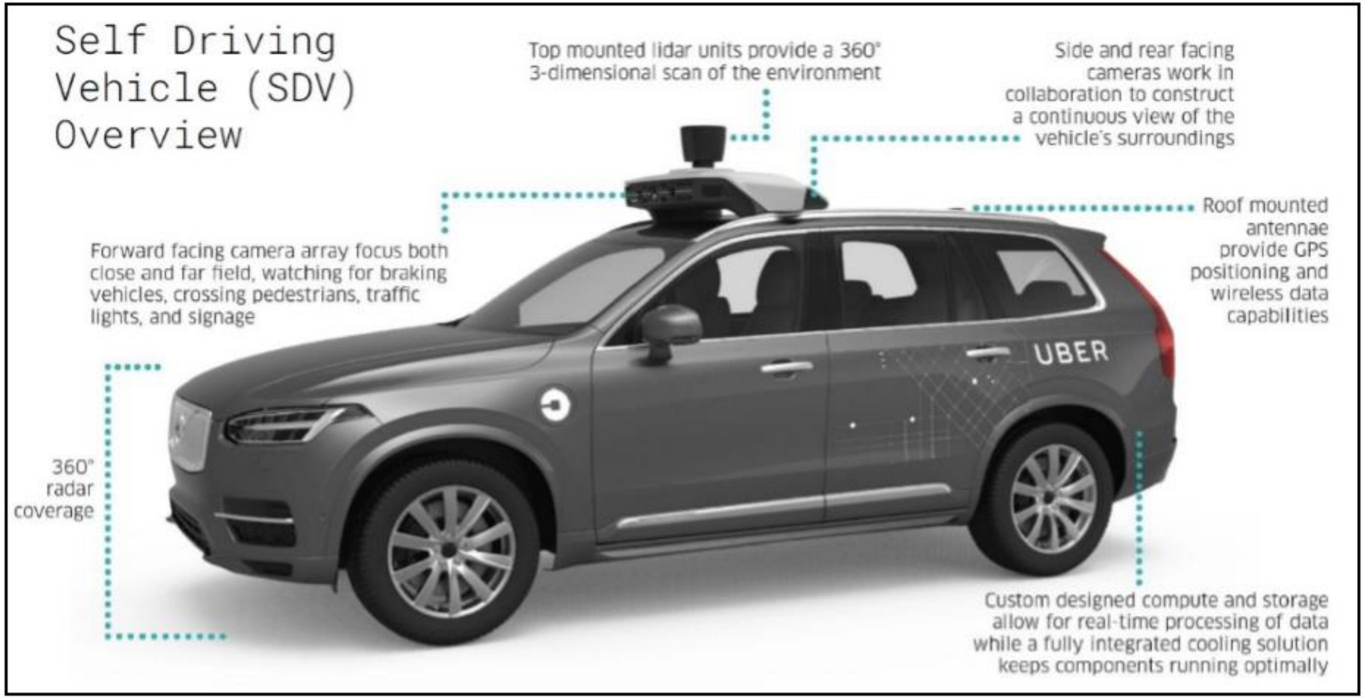
TEMPE, ARIZONA

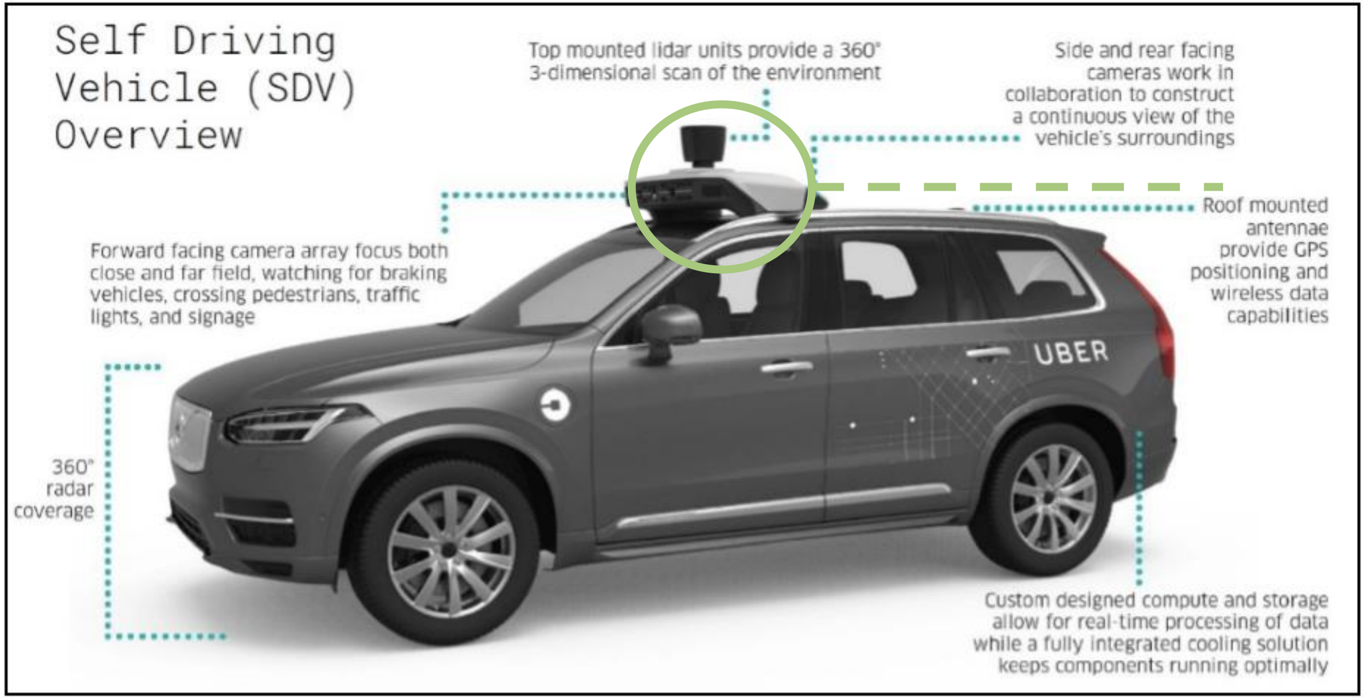
March 18, 2018 – 9:58 pm

A pedestrian was pushing a bicycle across a four-lane road in Tempe, Arizona, United States, when she was struck by a vehicle and died.

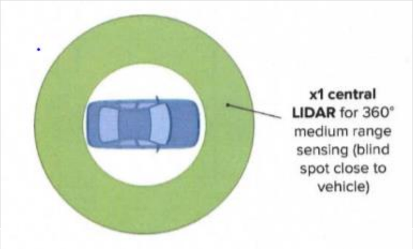

The first recorded case of a pedestrian fatality involving a self-driving car



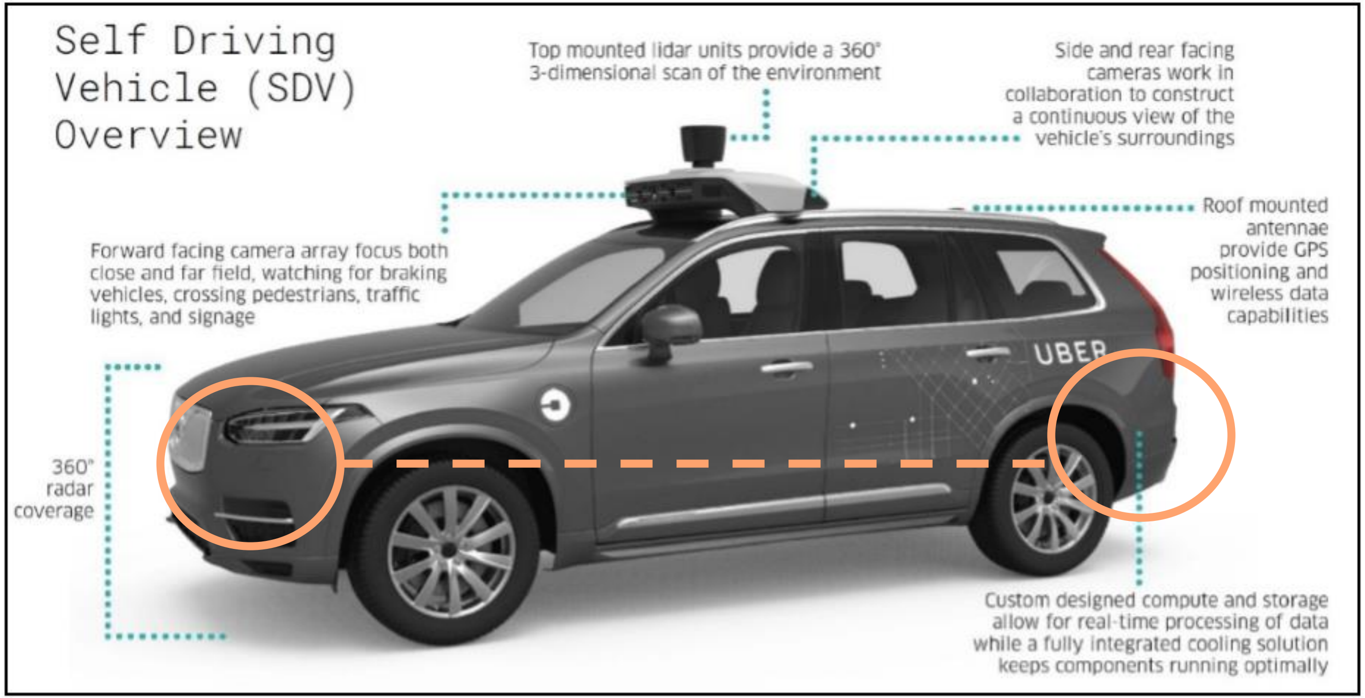
Automated Driving System designed to operate in a **fully autonomous mode on pre-mapped designated routes**.



Laser Imaging Detection and Ranging (LIDAR)
is a sensor system using laser light to detect and measure distance to objects by directing light and receiving it back upon its reflection from an object (range 100m). **Used to build a representation of the surrounding environment which is continually updated as new objects are detected**



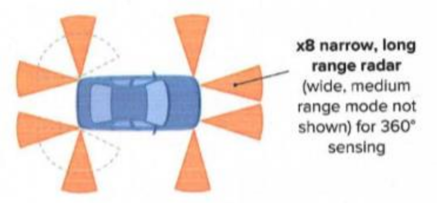
LIDAR



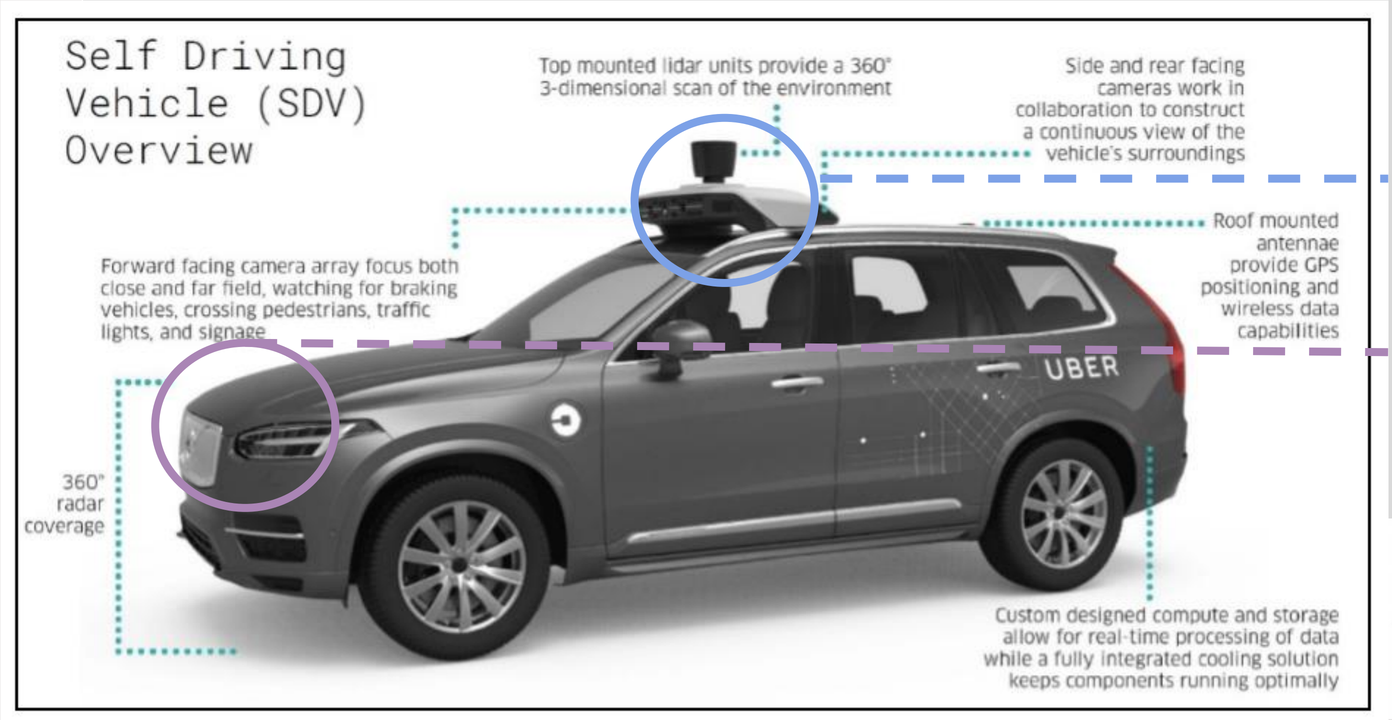
2 radars on the front end
2 radars on each side and
2 radars on the rear end

Long-range scan: up to 180 meters, 20-degree field of view

Medium-range scan: up to 65 meters, 90-degree field of view

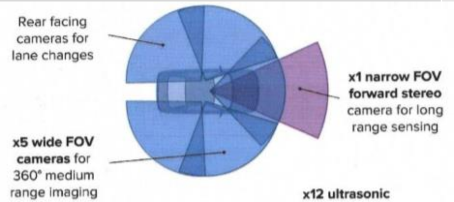


8 RADARS

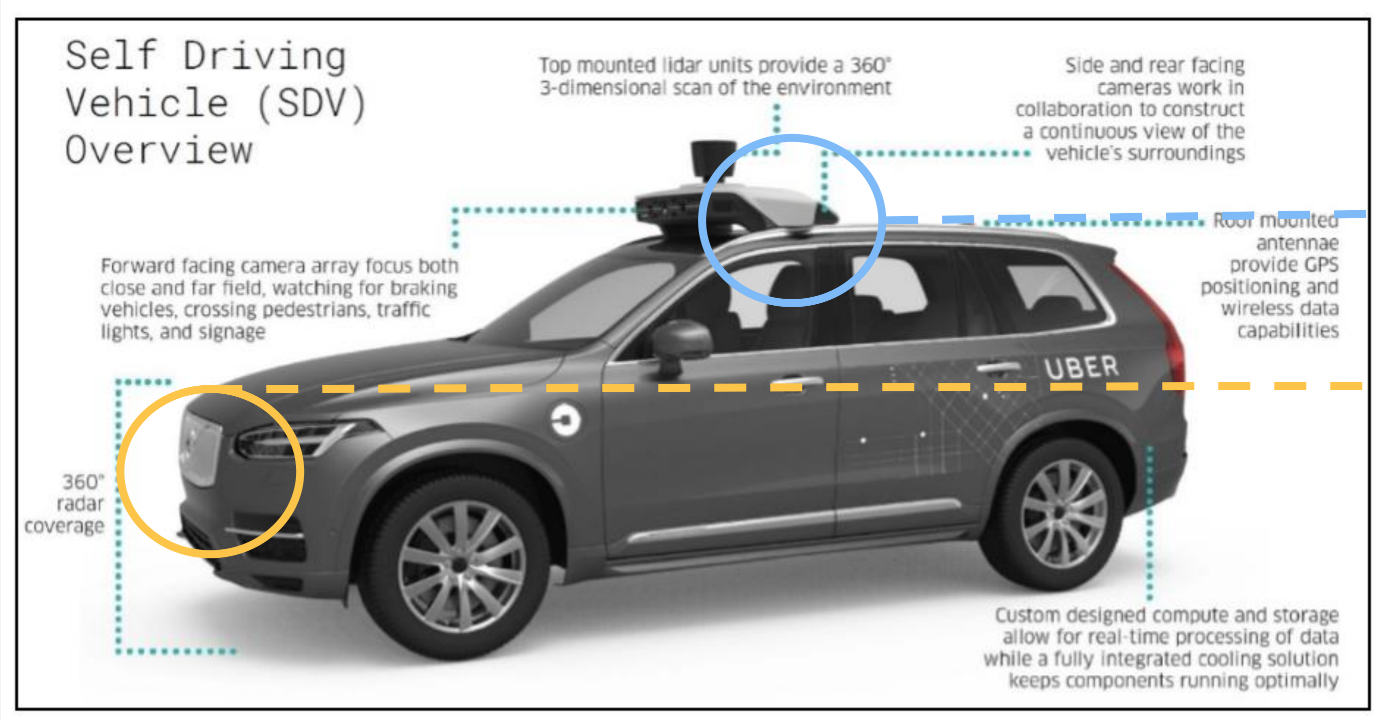


10 cameras positioned around the vehicle to provide a 360degree view of the surrounding environment.

The forward camera provides data for the detection of vehicles and pedestrians, and for reading of traffic lights

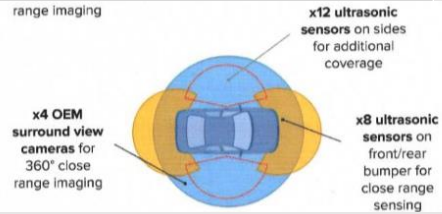


10 CAMERAS



GPS and Inertia Measurement Unit for determining the vehicle's position

20 ultrasonic sensors with a range of 5m used to detect other vehicles during lane changes, pedestrians, curbs and other obstacles when parking and collecting passengers.



GPS

THE ACCIDENT

About 9:58 p.m., on Sunday, March 18, 2018, an Uber Technologies, Inc. test vehicle, based on a modified 2017 Volvo XC90 and operating with a self-driving system in computer control mode, struck a pedestrian on northbound Mill Avenue, in Tempe, Maricopa County, Arizona.

- **VICTIM** - The crash occurred as the pedestrian, a 49-year-old female, walked a bicycle east across Mill Avenue, while jaywalking.
- **VEHICLE OPERATOR** - The Uber test vehicle was occupied by one vehicle operator, a 44-year-old female. No passengers were in the vehicle.
  - On the night of the crash, the operator departed Uber's garage with the vehicle at 9:14 p.m. to run an established test route.
  - At the time of the crash, the vehicle was traveling on its second loop of the test route and had been in computer control since 9:39 p.m. (i.e., for the preceding 19 minutes).

Everything clear so far?

NTSB Preliminary report (May 2018)

Surprisingly the preliminary report of the National Transport Safety Bureau pointed out

- **NO FAULTS**
  - All aspects of the self-driving system were operating normally at the time of the crash, and there were no faults or diagnostic messages

- **THE (IN)ATTENTIVE OPERATOR**
  - According to Uber, the developmental self-driving system relies on an attentive operator to intervene if the system fails to perform appropriately during testing.
  - In addition, the operator is responsible for monitoring diagnostic messages that appear on an interface in the center stack of the vehicle dash and tagging events of interest for subsequent review

Yavapai County Attorney
255 East Gurley Street
Prescott, AZ 86301
ycao@yavapai.us

SHEILA POLK
Yavapai County Attorney

March 4, 2019

Hon. Bill Montgomery
Maricopa County Attorney
301 W. Jefferson Street
Phoenix, AZ 85003

Re: Rafael Vasquez / Uber Corporation, Tempe Police Department #2018-32694

Dear Mr. Montgomery:

This Office accepted this matter on a conflict basis due to a prior working relationship between the Maricopa County Attorney's Office (MCAO) and Uber. We agreed to accept the case and review the matter for a charging decision only.

After a very thorough review of all the evidence presented, this Office has determined that there is no basis for criminal liability for the Uber corporation arising from this matter. Because this determination eliminates the basis for the MCAO conflict, we are returning the matter to MCAO for further review for criminal charges.

Based on the entire investigation, this Office has concluded that the collision video, as it displays, likely does not accurately depict the events that occurred. We therefore recommend that the matter be furthered to the Tempe Police Department to obtain additional evidence. Specifically, we believe that an expert analysis of the video is needed. The purpose of the expert analysis is to closely match what (and when) the person sitting in the driver's seat of the vehicle would or should have seen that night given the vehicle's speed, lighting conditions, and other relevant factors.

This will end this Office's official involvement in this matter. It has been our pleasure to be of assistance in this matter and to work with the outstanding professionals at the Tempe Police Department. If you or your staff need any additional questions answered, please do not hesitate to contact us.

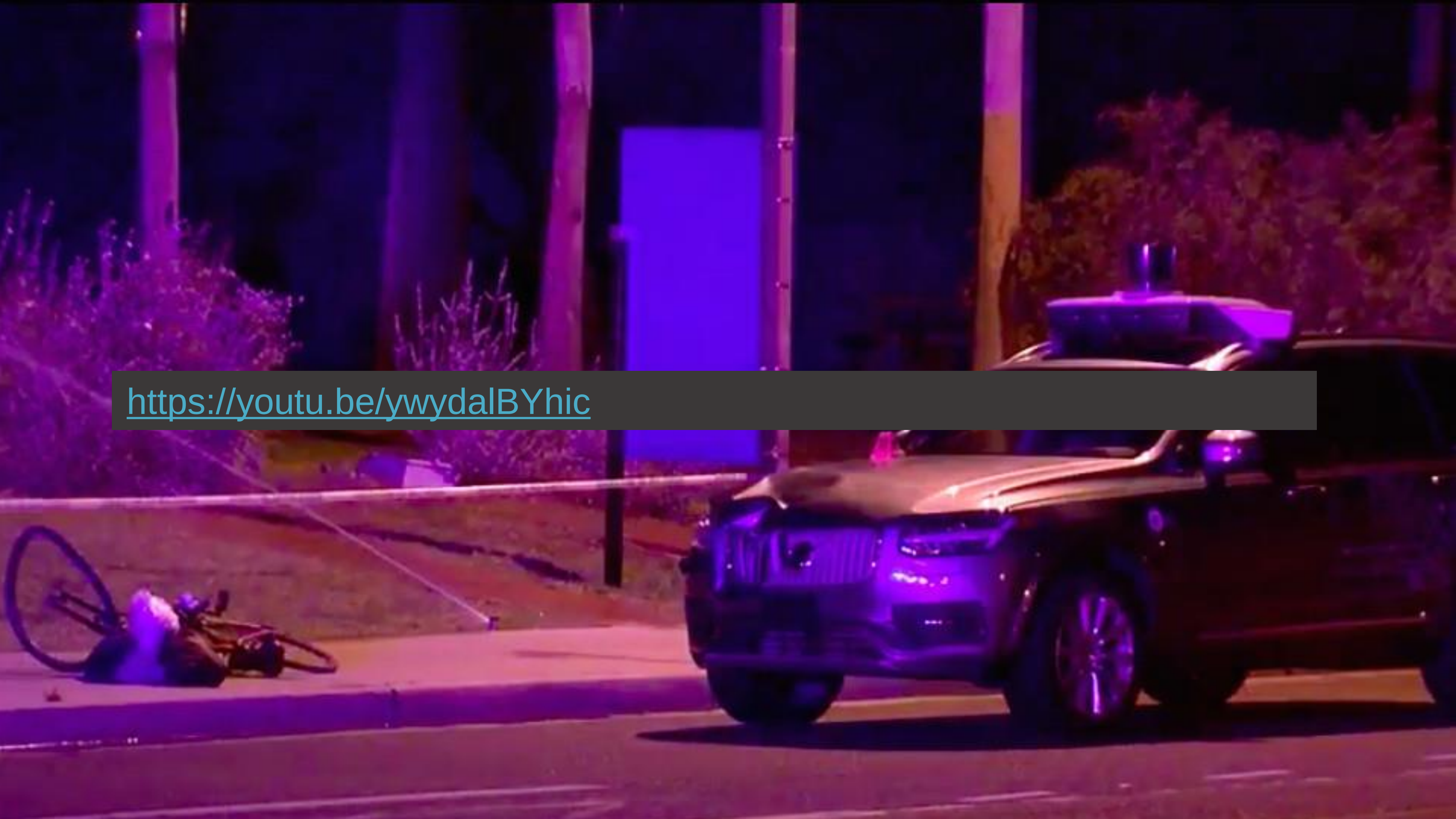
Very truly yours,

Sheila S Polk

Sheila Sullivan Polk
Yavapai County Attorney

Criminal Division	Civil Division	Bad Check Program
(928) 771-3344	(928) 771-3338	(928) 771-3490

HUMAN ERROR



https://youtu.be/ywydalBYhic

Table 1. Selected parameters recorded by the ADS.

Time (s) relative to impact	Speed (mph)	Classification and Path Prediction[a]	Other Events / Details[b]
- 9.9	35		Vehicle begins to accelerate from 35 mph due to an increased speed limit
- 5.8	44		Vehicle reaches the speed of 44 mph
- 5.6	44	Classification: *Vehicle* - by radar Path prediction: *None*; not on the path of the SUV	Radar makes the first detection of the pedestrian and estimates its speed.
- 5.2	45	Classification: *Other* - by lidar Path prediction: *Static*; not on the path of the SUV	Lidar detects an unknown object; this is the first detection of that object by lidar, the tracking history is unavailable, and its velocity cannot be determined. ADS predicts the object's path as static.
- 4.2	45	Classification: *Vehicle* - by lidar Path prediction: *Static*; not on the path of the SUV	Lidar classifies a detected object as a vehicle; this is a changed classification of an object and without a tracking history. ADS predicts the object's path as static.
-3.9		Classification: *Vehicle* - by lidar Path prediction: The left through lane (adjacent to the SUV); not on the path of the SUV	Lidar retains the classification "vehicle", and based on the tracking history and the assigned goal, ADS predicts the object's path as traveling in the left through lane.
- 3.8 ⇕ - 2.7	45	Classification: alternated several times between *vehicle* and *other* - by lidar Path prediction: alternated between *static* and left lane; neither were considered on the path of the SUV	The object's classification alternates several times between vehicle and an unknown. At each change, the object's tracking history is unavailable, and ADS predicts the object's path as static. When the detected object's classification remained the same, ADS predicts the path as traveling in the left through lane.
- 2.6	45	Classification: *Bicycle* - by lidar Path prediction: *Static*; not on the path of the SUV	Lidar classifies a detected object as a bicycle; this is a changed classification of the object, and without a tracking history. ADS predicts the bicycle's path as static.
- 2.5	45	Classification: *Bicycle* - by lidar Path prediction: The left through lane (adjacent to the SUV); not on the path of the SUV	Lidar retains the classification "bicycle" and based on the tracking history and the assigned goal, ADS predicts the bicycle's path as traveling in the left through lane.
- 1.5	44[c]	Classification: *Unknown* - by lidar Path prediction: *Static*; partially on the path of the SUV	- Lidar detects an unknown object; since this is a changed classification, and an unknown object, it lacks tracking history and is not assigned a goal. ADS predicts the object's path as static. - Although the detected object is partially in the SUV's lane of travel, the ADS generates a motion plan around the object (maneuver to the right of the object); this motion plan remains valid—avoiding the object—for the next two data points.
- 1.2	43	Classification: *Bicycle* - by lidar Path prediction: The travel lane of the SUV; fully on the path of the SUV	- Lidar detects a bicycle; although this is a changed classification and without a tracking history, it was assigned a goal. ADS predicts the bicycle to be on the path of the SUV. - The ADS motion plan—generated 300 msec earlier—for steering around the bicycle was no longer possible; as such, this situation becomes hazardous. - Action suppression begins.
- 0.2	40	Classification: *Bicycle* - by lidar Path prediction: The travel lane of the SUV; fully on the path of the SUV	- Action suppression ends 1 second after it begins. - The situation remains hazardous; as such, ADS initiates a plan for vehicle slowdown. - An auditory alert was presented to indicate that the controlled slowdown was initiating.[d]
- 0.02	39		Vehicle operator takes control of the steering wheel, disengaging the ADS.
Impact			
0.7	37		Vehicle operator brakes

[a] Only changes in object classification and path prediction are reported in the table. The last reported values persist until a new one is reported.

[b] The process of predicting a path of a detected object is complex and relies on the examination of numerous factors, beyond the details described in this column.[c] The vehicle started decelerating due to the approaching intersection, where the pre-planned route includes a right turn at Curry Road. The deceleration plan was generated 3.6 seconds before impact.

[d] While the system generated a plan for the vehicle slowdown, due to a slight communication delay, the data is unclear on whether the implementation of the slowdown plan started before the operator took control prior to impact.

1

By design, the system was not able to classify jaywalking pedestrians

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2

By design, the system did not engage emergency brakes, but rather provided an auditory alert to the vehicle operator as it initiated a plan for the vehicle slowdown

Was the operator aware of it?

3

Not incapacitated, simply inattentive

The operator looked down 166 times when the vehicle was in motion, not including times she appeared to be checking gauges or mirrors.

Vasquez traveled about 3.67 miles total while looking away from the road

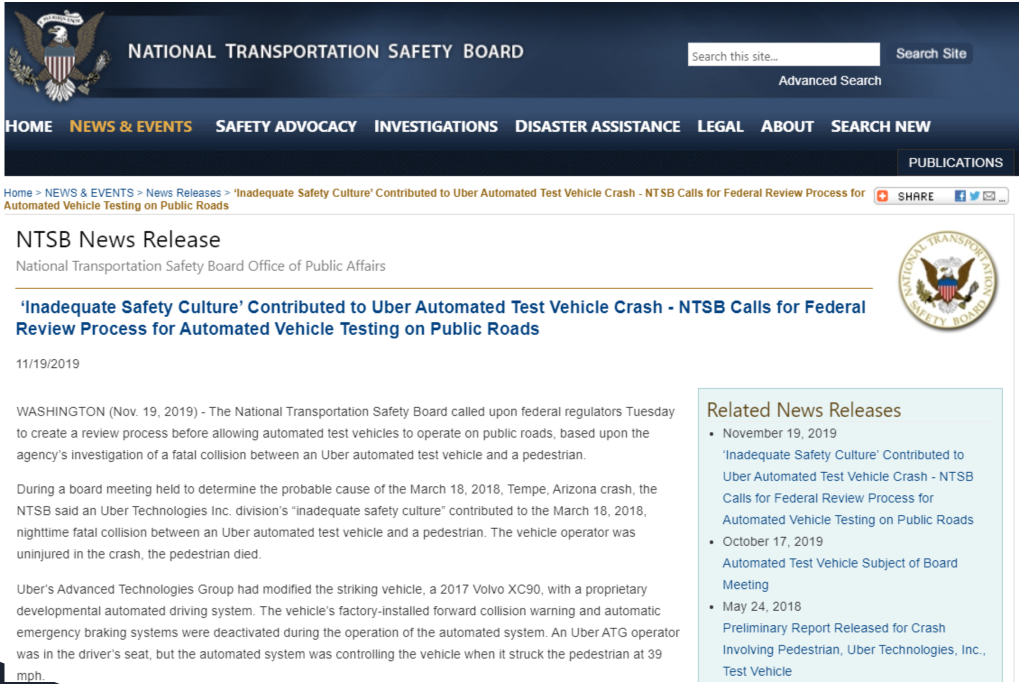
4

Not monitored

Uber had the possibility to retroactively monitor the behavior of vehicle operators, they rarely did so.

The company's ineffective oversight was exacerbated by its decision to remove a second operator from the vehicle while testing the automated driving system.

NTSB Final report (Nov 2019)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NTSB News Release

National Transportation Safety Board Office of Public Affairs

'Inadequate Safety Culture' Contributed to Uber Automated Test Vehicle Crash - NTSB Calls for Federal Review Process for Automated Vehicle Testing on Public Roads

11/19/2019

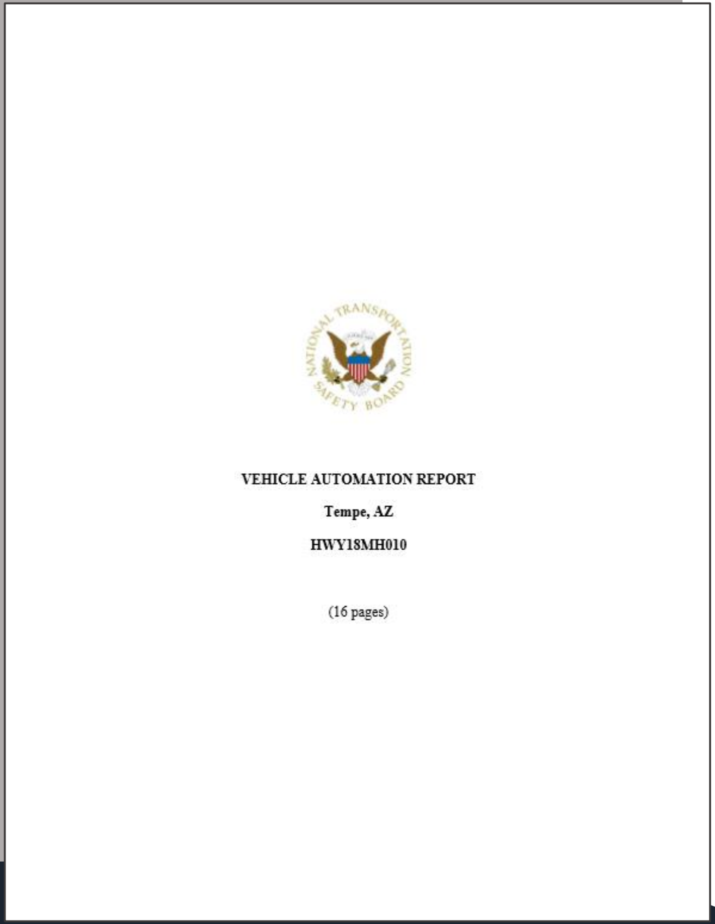
WASHINGTON (Nov. 19, 2019) - The National Transportation Safety Board called upon federal regulators Tuesday to create a review process before allowing automated test vehicles to operate on public roads, based upon the agency's investigation of a fatal collision between an Uber automated test vehicle and a pedestrian.

During a board meeting held to determine the probable cause of the March 18, 2018, Tempe, Arizona crash, the NTSB said an Uber Technologies Inc. division's "inadequate safety culture" contributed to the March 18, 2018, nighttime fatal collision between an Uber automated test vehicle and a pedestrian. The vehicle operator was uninjured in the crash, the pedestrian died.

Uber's Advanced Technologies Group had modified the striking vehicle, a 2017 Volvo XC90, with a proprietary developmental automated driving system. The vehicle's factory-installed forward collision warning and automatic emergency braking systems were deactivated during the operation of the automated system. An Uber ATG operator was in the driver's seat, but the automated system was controlling the vehicle when it struck the pedestrian at 39 mph.

Related News Releases

- November 19, 2019
  'Inadequate Safety Culture' Contributed to Uber Automated Test Vehicle Crash - NTSB Calls for Federal Review Process for Automated Vehicle Testing on Public Roads
- October 17, 2019
  Automated Test Vehicle Subject of Board Meeting
- May 24, 2018
  Preliminary Report Released for Crash Involving Pedestrian, Uber Technologies, Inc., Test Vehicle


VEHICLE AUTOMATION REPORT

Tempe, AZ

HWY18MH010

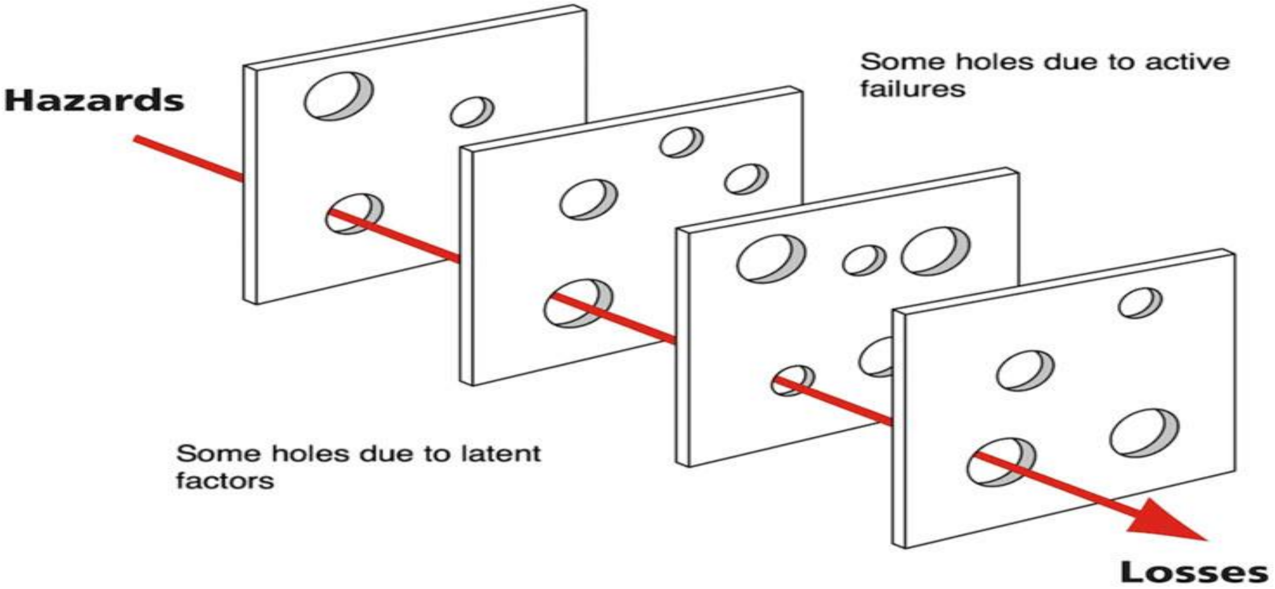
(16 pages)

WHERE IS THE HUMAN ERROR?

3 MODELS

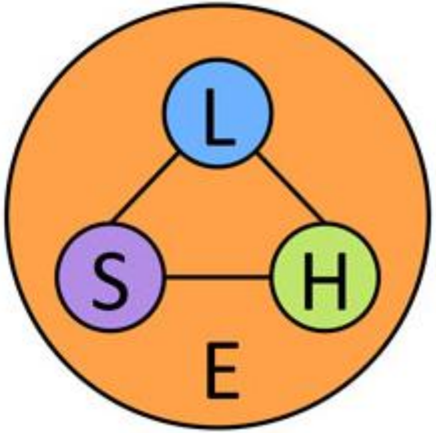
"SWISS CHEESE" ACCIDENT-CAUSATION MODEL

J.Reason, 2000



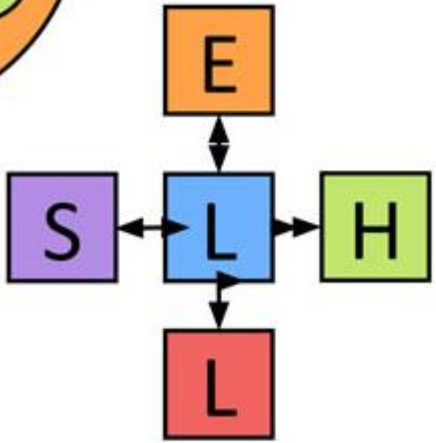
SHEL(L) MODEL OF HUMAN FACTORS

E. Edwards, 1972 – J. Hawkins, 1975



The SHELL model adopts a systems perspective that suggests the human is rarely, if ever, the sole cause of an accident.

The systems perspective considers a variety of contextual and task-related factors that interact with the human operator within the aviation system to affect operator performance



LEVEL OF AUTOMATION TAXONOMY (LOAT)

L. Save, 2014

The **LOAT** is a rather new Level of Automation Taxonomy to classify automation

Used in ATM and applicable to all domains, it offers a **framework** to guide the analysis and the design of human performance automation support.

It combines **functions** with automation levels, with the purpose of studying the implications of the automation and determine the optimal automation level in all operational contexts.

From INFORMATION to ACTION →

INCREASING AUTOMATION ↓

A INFORMATION ACQUISITION	B INFORMATION ANALYSIS	C DECISION AND ACTION SELECTION	D ACTION IMPLEMENTATION
A0 Manual information acquisition	B0 Working memory based information analysis	C0 Human decision making	D0 Manual action and control
A1 Artefact-supported information acquisition	B1 Artefact-supported information analysis	C1 Artefact-supported decision making	D1 Artefact-supported action implementation
A2 Low-level automation support of information acquisition	B2 Low-level automation support of information analysis	C2 Automated decision support	D2 Step-by-step Action Support
A3 Medium-level automation support of information acquisition	B3 Medium-level automation support of linformation analysis	C3 Rigid automated decision Support	D3 Low-level support of action sequence execution
A4 High-level automation support of information acquisition	B4 High-Level automation support of information analysis	C4 Low-level automatic decision making	D4 High-level support of action sequence execution
A5 Full automation support of information acquisition	B5 Full automation support of information analysis	C5 High-level automatic decision making	D5 Low-level automation of action sequence execution
		C6 Full automatic decision making	D6 Medium-level automation of action sequence execution
			D7 High-level automation of action sequence execution
			D8 Full automation of action sequence execution

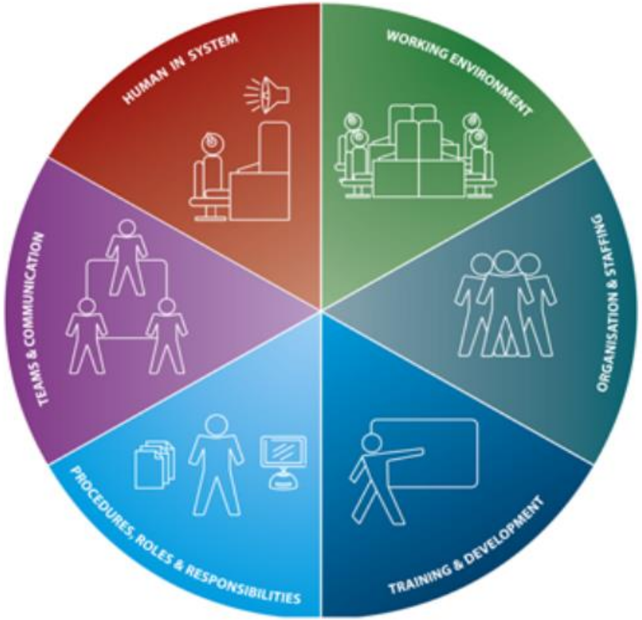
A condensed version of the LOAT matrix

SOCIO-TECHNICAL SYSTEM UNIT OF ANALYSIS

A **sociotechnical system** is the term usually given to any instantiation of socio and technical elements engaged in goal directed behaviour.

A **sociotechnical system unit of analysis** is necessary to study the implication of automation (including AI) in complex domains

The **multiple resourses** of the sociotechnical systems combine and influence each others (Edwards, 1972)



TO CONCLUDE

Automation is not all or nothing

Automation is not just substitution of a human operator

Automation provides support to human capabilities in performing tasks

The level of automation shall be designed, with a particular focus on human-system cooperation

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CONTACTS

PAOLA LANZI

Head of Automated and Multimodal Transport

paola.lanzi@dblue.it