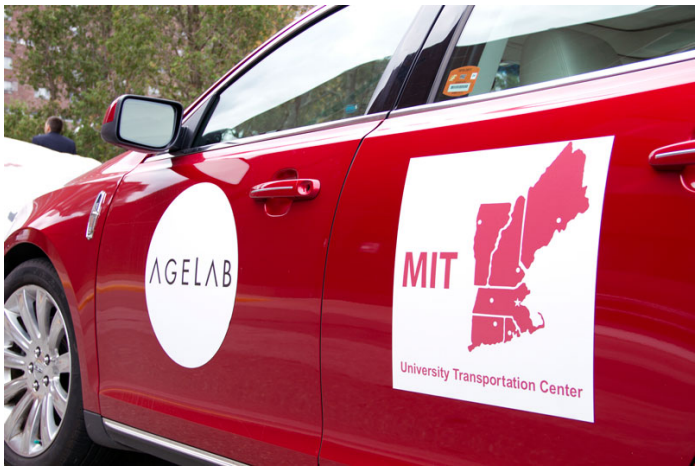
The pathway to self-driving vehicles: Disconnects between human capabilities and advanced vehicle systems?



Bryan Reimer, Ph.D.
MIT AgeLab & New England University Transportation Center

JITI Self-Driving Cars Seminar
Osaka, Japan

October 21, 2013

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The Ever Changing Vehicle

- Over the past 100 or so years, while the outward appearance of vehicles has changed, we have seen little change in how drivers interface with the vehicle.
- What do trends in advanced driver assistance systems, automation and information connectivity tell us about expectations for the next 100 years?

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Benefits of Vehicle Automation

"Autonomous cars may seem like a gimmick, he begins, but when you consider all the **time** that people won't be devoting to their rear view mirrors, and all the **efficiencies** that come from cars that could be zipping between errands rather than idling in parking lots, the world looks like a very different place. Car ownership would be unnecessary, because your car (maybe **shared** with your neighbors) will act like a taxi that's summoned when needed. The **elderly** and the **blind** could be thoroughly integrated into society. **Traffic deaths could be eradicated**. Every person could gain lost hours back for working, reading, talking, or searching the Internet."

Google co-founder Sergey Brin as reported by Brad Stone of Bloomberg Business Week – May 22, 2013

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Technological Advances

Will lead to driverless vehicles but challenges remain

- Sensor technology
- Computational power
- Algorithm development
- Connectivity

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Vehicle Automation

National Highway Traffic Safety Administration

- Level 0 – No Automation
- Level 1 – Function Specific Automation
- Level 2 – Combined Function
- Level 3 – Limited Self-Driving Automation
- Level 4 – Full Self-Driving Automation

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Levels of Control

"Partially Autonomous Driving" is the focus of todays talk

- Level 0 – No Automation
- Level 1 – Function Specific Automation
- Level 2 – Combined Function
- Level 3 – Limited Self-Driving Automation
- Level 4 – Full Self-Driving Automation

Key area of focus

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Human Centered Considerations

A partial list in no particular order of significance

- Trust in technology
- The theory of experience
- Education
- Failures in automation
- Social / political expectations
- Workload

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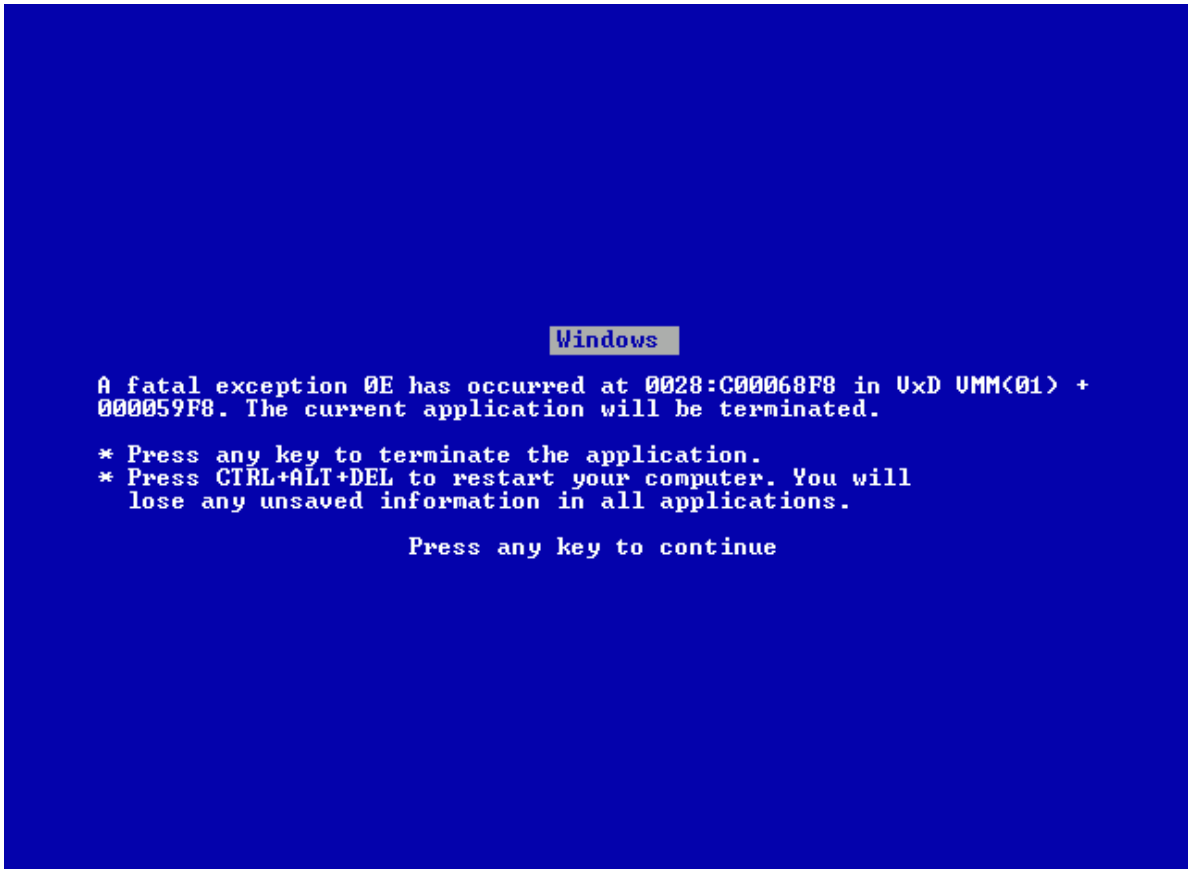
My Trust in Technology



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Automation and the Big Red Button

To Trust or Not?

- In many situations automation will outperform human operation, but will the driver trust it?
- How will one choose when to or when not to provide / accept autopilot control?
- Experiential learning does not yet exist.

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Experience

Vehicle Miles Traveled (VMT)

Vehicle Miles Driven (VMD)

Today	Tomorrow?
VMT = VMD	VMT ≠ VMD

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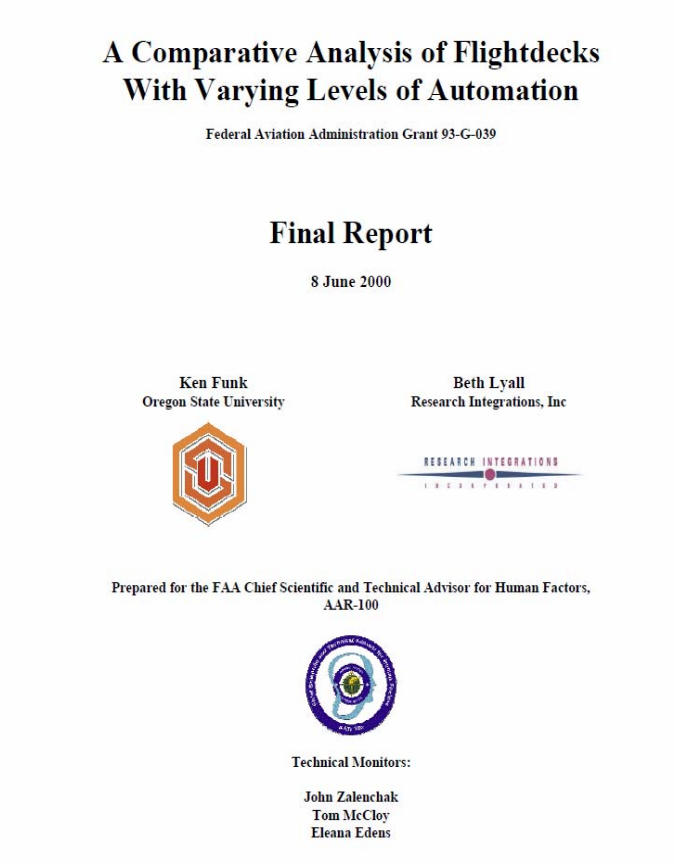
A Case Study: The FAA



A Comparative Analysis of Flightdecks With Varying Levels of Automation

Federal Aviation Administration Grant 93-G-039

Final Report

8 June 2000

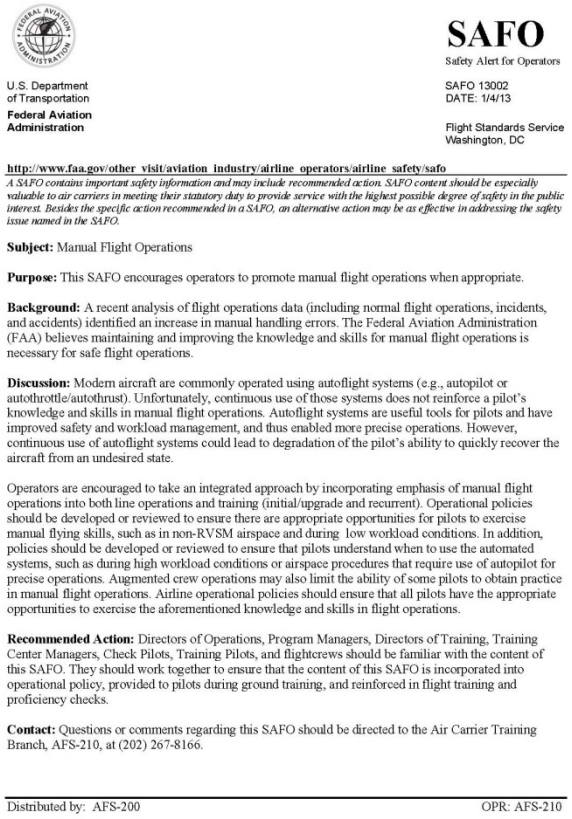
Ken Funk
Oregon State University

Beth Lyall
Research Integrations, Inc

Prepared for the FAA Chief Scientific and Technical Advisor for Human Factors, AAR-100

Technical Monitors:

John Zalenchak
Tom McCloy
Eleana Edens



U.S. Department of Transportation
Federal Aviation Administration

SAFO
Safety Alert for Operators

SAFO 13002
DATE: 1/4/13

Flight Standards Service
Washington, DC

http://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/safo

A SAFO contains important safety information and may include recommended action. SAFO content should be especially valuable to air carriers in meeting their statutory duty to provide service with the highest possible degree of safety in the public interest. Besides the specific action recommended in a SAFO, an alternative action may be as effective in addressing the safety issue named in the SAFO.

Subject: Manual Flight Operations

Purpose: This SAFO encourages operators to promote manual flight operations when appropriate.

Background: A recent analysis of flight operations data (including normal flight operations, incidents, and accidents) identified an increase in manual handling errors. The Federal Aviation Administration (FAA) believes maintaining and improving the knowledge and skills for manual flight operations is necessary for safe flight operations.

Discussion: Modern aircraft are commonly operated using autoflight systems (e.g., autopilot or autothrottle/autothrust). Unfortunately, continuous use of those systems does not reinforce a pilot's knowledge and skills in manual flight operations. Autoflight systems are useful tools for pilots and have improved safety and workload management, and thus enabled more precise operations. However, continuous use of autoflight systems could lead to degradation of the pilot's ability to quickly recover the aircraft from an undesired state.

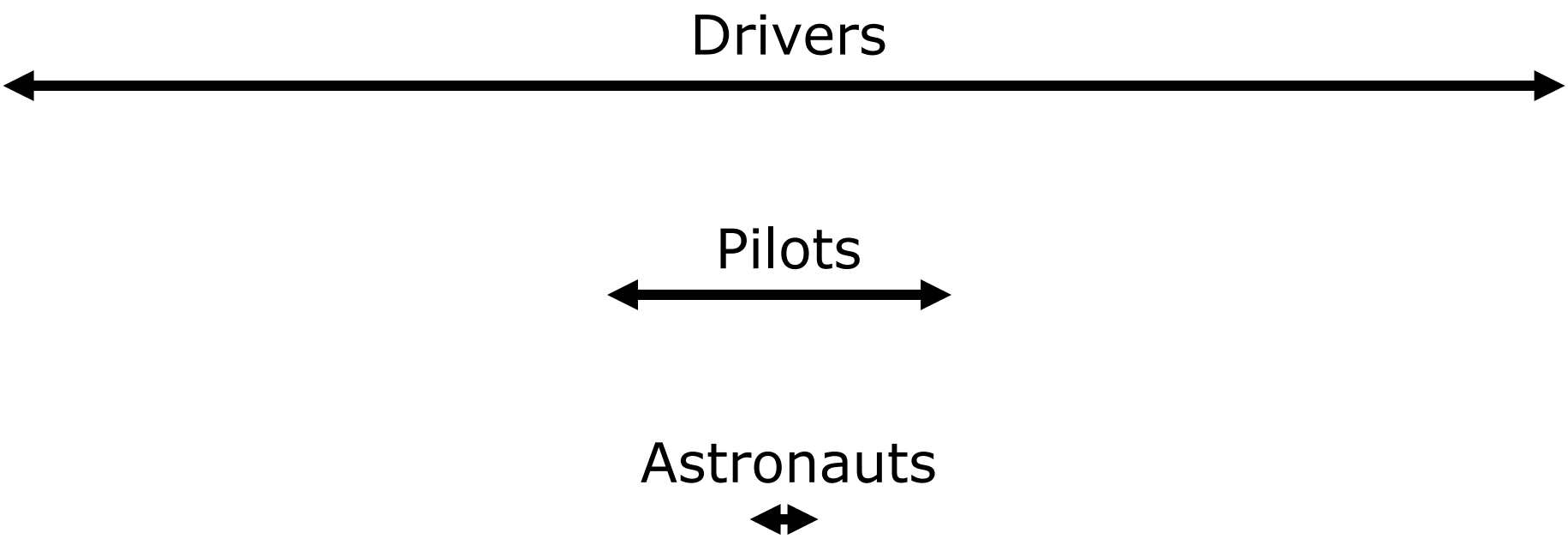
Operators are encouraged to take an integrated approach by incorporating emphasis of manual flight operations into both line operations and training (initial/upgrade and recurrent). Operational policies should be developed or reviewed to ensure there are appropriate opportunities for pilots to exercise manual flying skills, such as in non-RVSM airspace and during low workload conditions. In addition, policies should be developed or reviewed to ensure that pilots understand when to use the automated systems, such as during high workload conditions or airspace procedures that require use of autopilot for precise operations. Augmented crew operations may also limit the ability of some pilots to obtain practice in manual flight operations. Airline operational policies should ensure that all pilots have the appropriate opportunities to exercise the aforementioned knowledge and skills in flight operations.

Recommended Action: Directors of Operations, Program Managers, Directors of Training, Training Center Managers, Check Pilots, Training Pilots, and flightcrews should be familiar with the content of this SAFO. They should work together to ensure that the content of this SAFO is incorporated into operational policy, provided to pilots during ground training, and reinforced in flight training and proficiency checks.

Contact: Questions or comments regarding this SAFO should be directed to the Air Carrier Training Branch, AFS-210, at (202) 267-8166.

Distributed by: AFS-200 OPR: AFS-210

A Simple Way to Think of Operator Behavior Variability



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Motivation to Learn and Maintain Focus

Drivers

Pilots

Astronauts

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Education

"One of the myths about the impact of automation on human performance is as investment in automation increases, less investment is needed in human expertise"

(David Woods as quoted by Robert Sumwalt, 2012)

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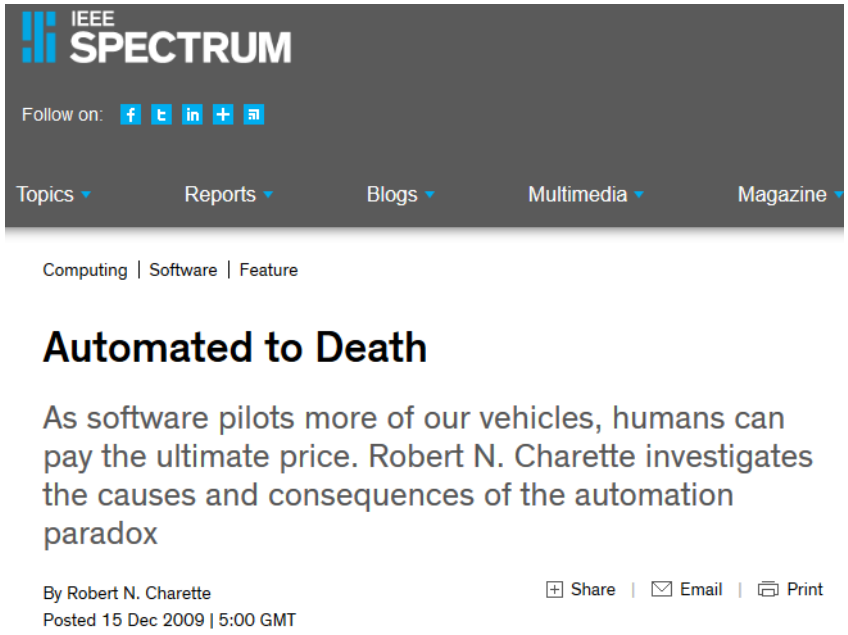
Failures in Automation

Required reading



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Automated to Death

As software pilots more of our vehicles, humans can pay the ultimate price. Robert N. Charette investigates the causes and consequences of the automation paradox

By Robert N. Charette
Posted 15 Dec 2009 | 5:00 GMT

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”There will always be a set of circumstances that was not expected, that the automation either was not designed to handle or other things that just cannot be predicted,” explains (Raja) Parasuraman. So as system reliability approaches—but doesn’t quite reach—100 percent, ”the more difficult it is to detect the error and recover from it”

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Social / Political Forces Worry Me!

Flying robots with and without missiles worry many

Aviation is safer than driving but we frequently feel less secure

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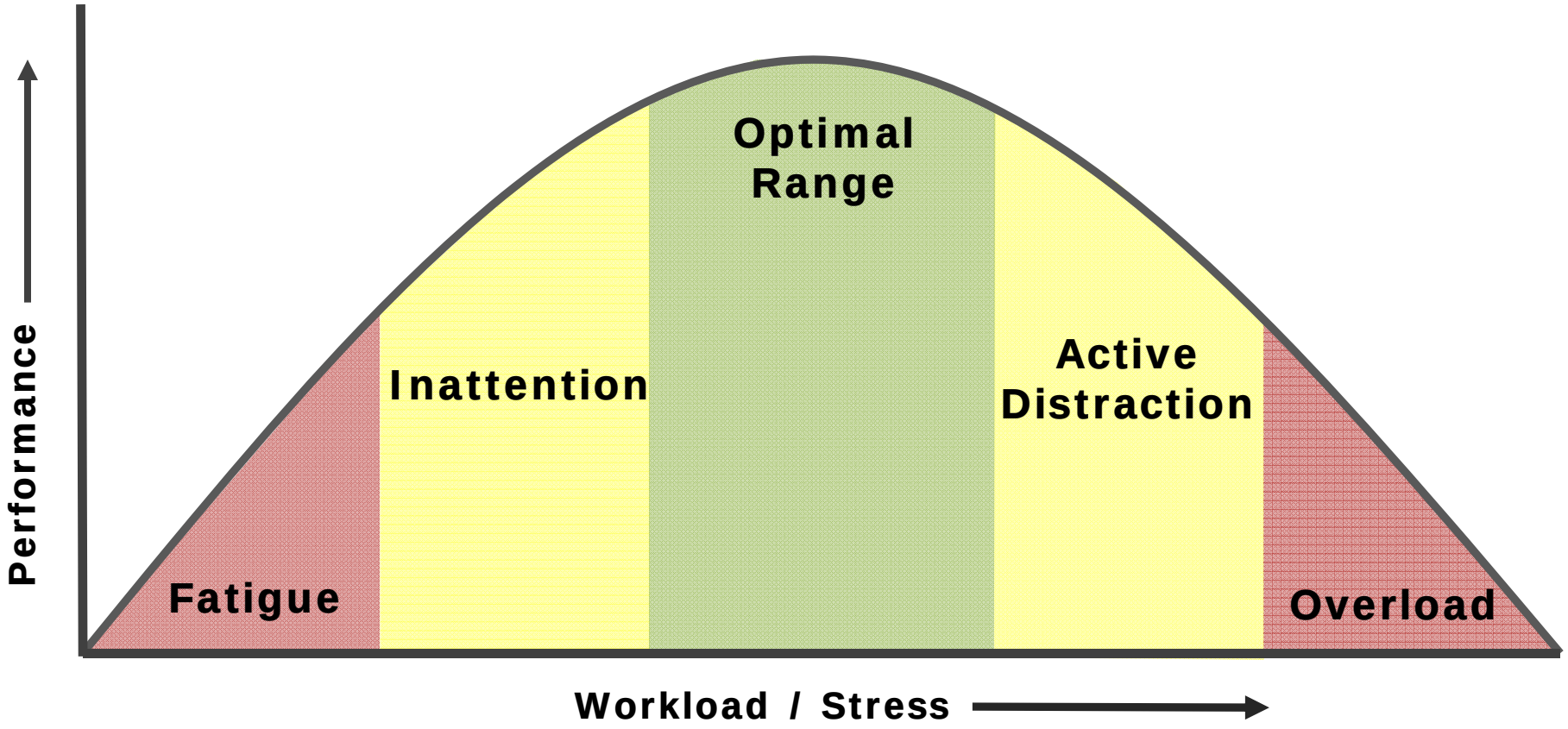
Workload & Performance

Yerkes-Dodson Law

The relationship between performance and physiological or mental arousal



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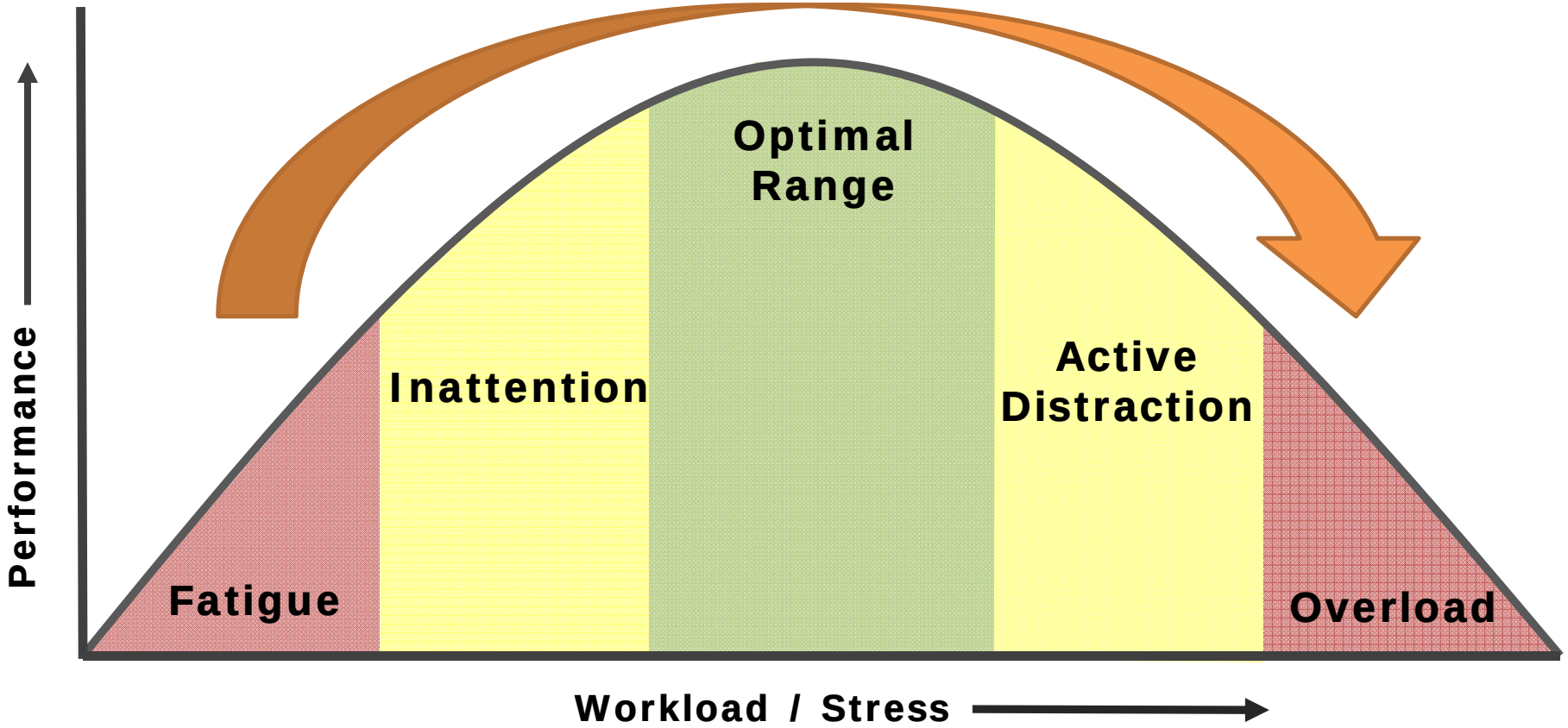
Workload & Performance

More Information in the Vehicle Tends to Increase Workload



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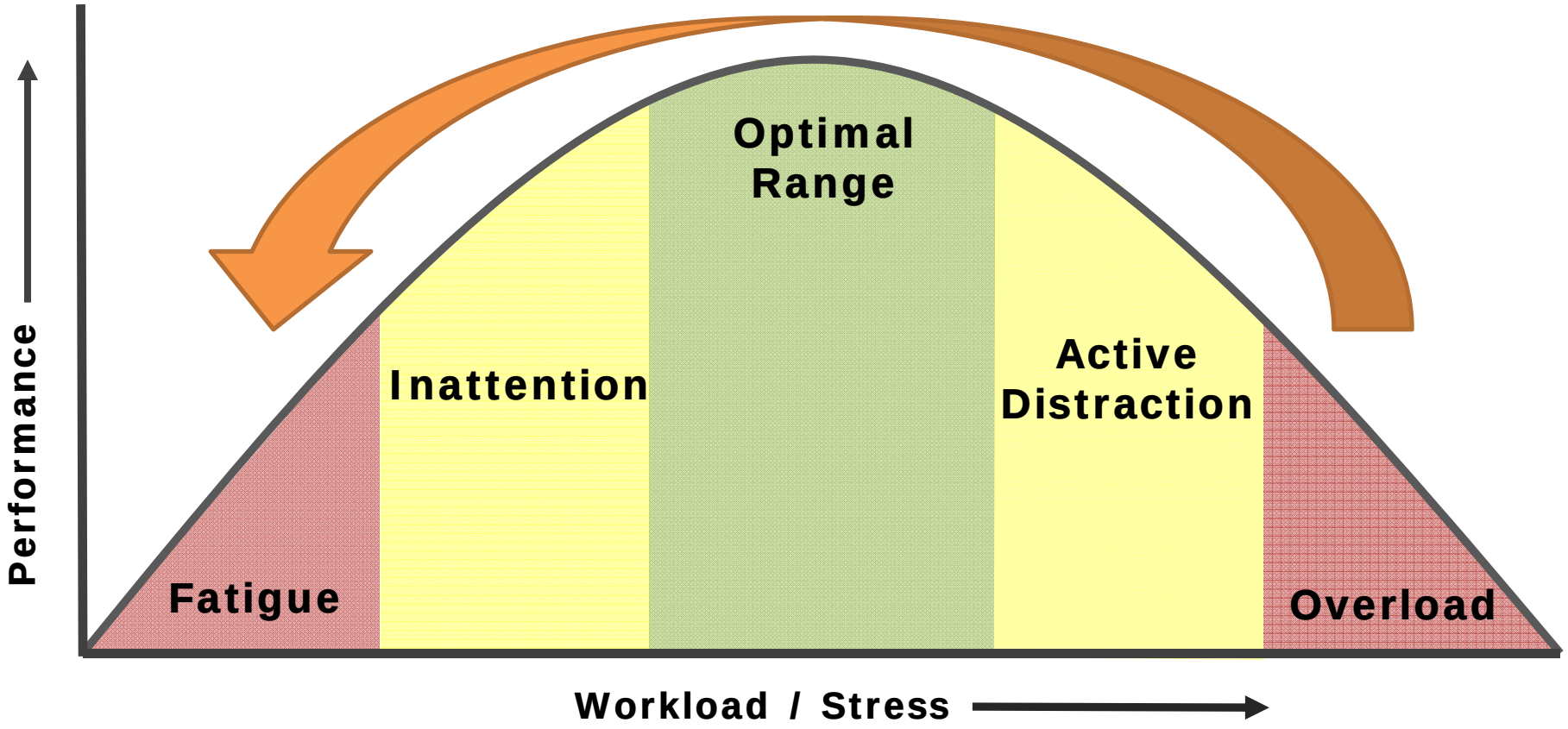
Workload & Performance

Automation Tends to Lower Workload



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Physiological Arousal
What Can We Study in the Car?

Part of a larger project evaluating various methods of detecting driver state

Measures initially considered:

- Heart Rate
- Heart Rate Variability
- Pulse height (peripheral blood flow)
- Skin Temperature
- Skin Conductance
- Skin Conductance Response
- Respiration Rate
- Pupil diameter
- Muscle Tension
- EEG (brain waves)
- Stress Hormones
- fNIRS (brain blood flow)

drawn in part from Mehler et al., 2009

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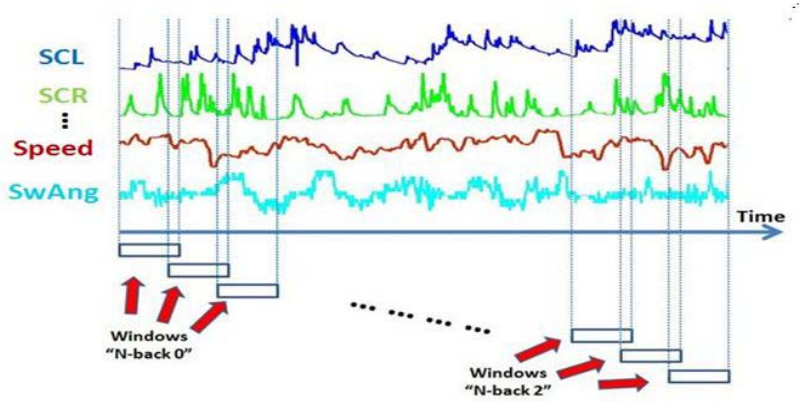
Driver State Detection

Classification of Driver Workload / Arousal

- At the **group level,** changes in demand are clearly evident across several features
- Can machine learning be used for detection at the **individual level**?
  - › Apply sliding window to generate a feature set
  - › Use classic approaches such as support vector machines (SVN), neural networks or nearest neighbor to classify state



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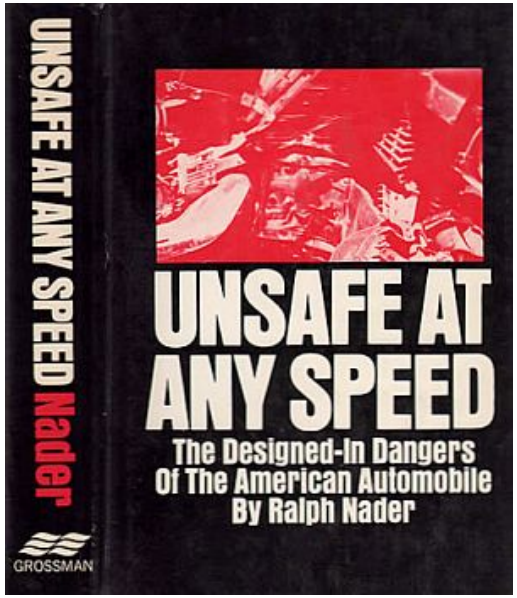
Unanticipated Consequences

Failure is not an option

1. Driverless car accident that results in loss of life
2. Major media coverage
3. Public outcry and fear of automation limits use of active safety (level 1) systems
4. Push for expedited regulation that may result in inefficient standards
5. Setbacks in auto safety could last for years
6. Benefits of Level 4 autonomy delayed



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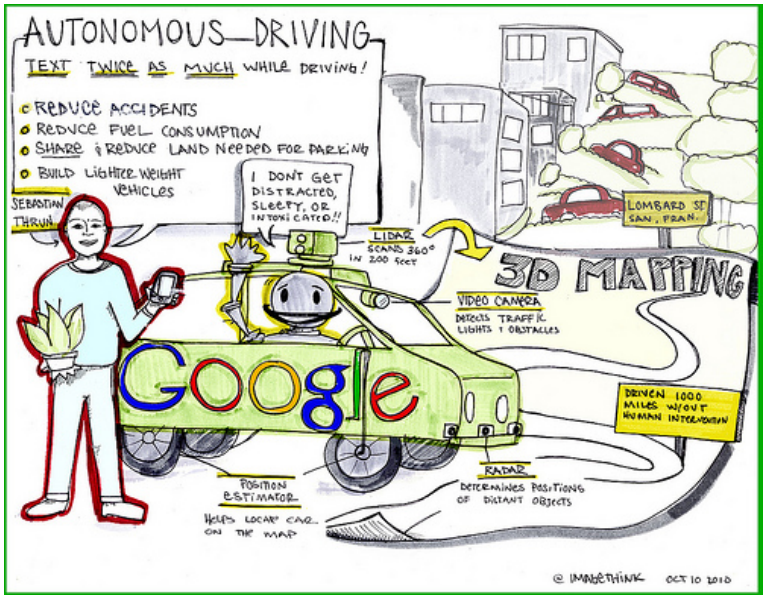
In Summary, I Believe We Need To:

- Continue exploring technologies for autonomous vehicles
- Make parallel investments in developing our understanding of how to optimize the human's connection with autonomous systems
- Clarify the benefits and consequences of system use and misuse
- Learn from complementary domains
- Stop assuming that autonomy alone will solve our nation's transportation problems



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Contact

Bryan Reimer, Ph.D.

Bryan Reimer, Ph.D., is a Research Engineer in the Massachusetts Institute of Technology AgeLab and the Associate Director of the New England University Transportation Center. His research seeks to develop new models and methodologies to measure and understand human behavior in dynamic environments utilizing physiological signals, visual behavior monitoring, and overall performance measures. Dr. Reimer leads a multidisciplinary team of researchers and students focused on understanding how drivers respond to the increasing complexity of the operating environment and on finding solutions to the next generation of human factors challenges associated with distracted driving, automation and other in-vehicle technologies. He directs work focused on how drivers across the lifespan are affected by in-vehicle interfaces, safety systems, portable technologies, different types and levels of cognitive load. This research also assesses the impact of medical impairments such as diabetes, cardiovascular disease, ADHD and autism. Dr. Reimer is an author on over 80 peer reviewed journal and conference papers in transportation. Dr. Reimer is a graduate of the University of Rhode Island with a Ph.D. in Industrial and Manufacturing Engineering.

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