NSF Workshop on the Effect of Automated/Autonomous Trucks on the U.S. Economy

Any opinions, findings, and conclusions or recommendations expressed during the workshop are those of the workshop participants and do not necessarily reflect the views of the National Science Foundation or the United States Government

This workshop was supported by the National Science Foundation under grant No. 1744348

Introductions

Purpose of Human-Technology Frontier

- Looking at the merging/convergence of technology and humans:
  - Understand and advance the human-technology partnership
  - Promote new technologies to augment human performance
  - Understand the risks and benefits of new technologies
  - Foster lifelong and pervasive learning with technology

What does that mean for this workshop?

- Understand, anticipate, and shape the implications of this technology for truck drivers.
  - Augmenting human performance for skill acquisition
  - Improving truck driver quality of life and employer financial metrics
  - Enhancing the economic and social well-being of the country

Goal of Workshop

- Unanswered questions as well as potential solutions related to how automated/autonomous trucks will affect the current and future truck driver workforce
  - How can automated/autonomous trucks enhance capabilities of current workforce?
  - What data are need to answer these questions, test hypotheses?
  - Will inform future NSF solicitations

Other Entities

- The Partnership for Transportation Innovation and Opportunity
  - Truck and Car OEMs
  - Find solutions that ensure Americans benefit from adoption of this technology
    - Developing a well-rounded and data-based understanding of the impact of autonomous vehicles on the future of work
    - Soliciting the expertise, concerns, and aspirations of interested parties
    - Fostering awareness of existing and near-term career opportunities for workers during the transition to an autonomous-vehicle-enabled economy

Overview of Activities

- Brief panel presentations
  - Strict time limits
  - Save questions till group discussion
- Group discussion
- Small group discussion
  - Stay with group on name tent
  - 2 thought questions
  - Audio recording
    - Not stored, deleted after workshop
    - Used to summarize discussion, no name attributions

Ground Rules for Discussion

- Civil discussion
- Many different disciplines
- All members of the group have a chance to speak
- All members of the group can hear others' ideas and feelings stated openly
- Group members can safely test out ideas that are not yet fully formed
- Group members can receive and respond to respectful but honest and constructive feedback.
- A variety of points of view are put forward and discussed
- The discussion is not dominated by any one person

Day 1 Agenda

- Session 1: Automated/Autonomous truck implementation scenarios and the role of the driver
- Session 2: Regulatory/insurance perspectives on automated/autonomous trucks
- Session 3: Industry views on use of automated/autonomous trucks in the end-to-end delivery system
- Session 4: Trucking impact on US economy/driver demand

Day 2 Agenda

- Session 5: Convergence of automated/autonomous trucks and human labor – enhancing the driver-truck interface and understanding skill requirements
- Session 6: Convergence of automated/autonomous trucks and human labor – job skills training/re-training challenges and strategies

Session 1: Automated/Autonomous truck implementation scenarios and the role of the driver

NSF Autonomous Workshop

Bill Kahn – Principal Engineer

ADVANCED DRIVER ASSIST SYSTEMS

L4
High Automation

- Improved Safety
- Improved Productivity
- Reduced Operating Cost

Improved Safety

- Forward Collision Avoidance
  - Radar
  - Lidar
  - Camera
  - DSRC
  - Tier 1 Collision Avoidance System
- Always Vigilant
- Doesn't Get Sleepy
- Never Distracted

Improved Productivity

- Increased Hours of Service (1-2 Hours)
  - Traffic Jams
  - Driver Breaks
  - Marshalling Yards
  - Drayage Pickup
- Team Driving
  - Time Critical Cargo
  - Able to Makeup Delays
- Better Asset Utilization

Reduced Operating Cost

- Fuel Efficient Driving
- Reduced Maintenance
- Platooning
- Green Lighting
- Lower Insurance Cost

L4+ System Developers





TuSimple

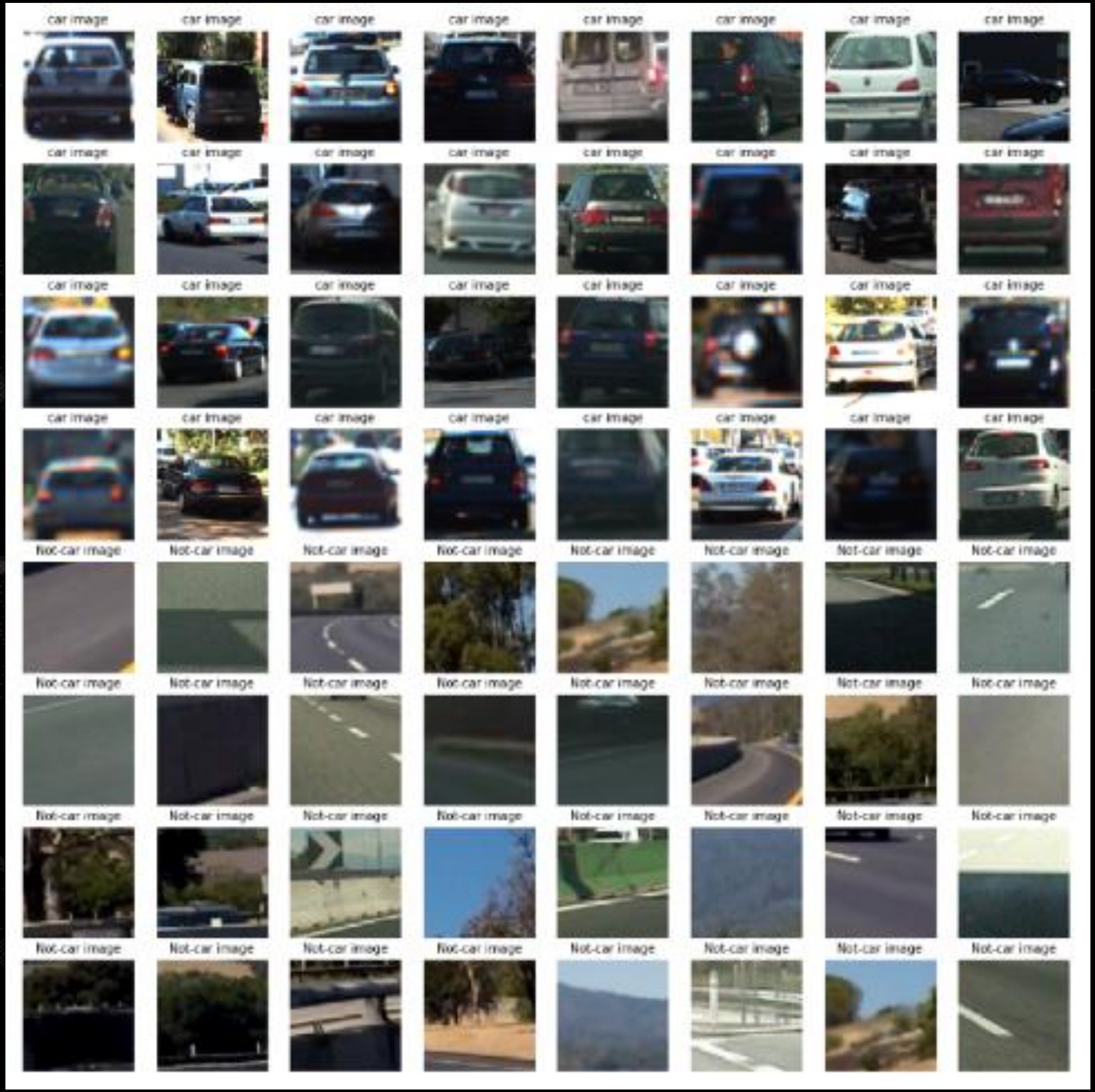
- Vision Based System
- 300M Range
- Warehouse to Warehouse
- Testing in Tucson, AZ

Embark

- Vision Based System
- 300M Range
- On Ramp to Off Ramp
- Marshalling Yards Close to Highway
- I-10 Segmented Roll Out
- Revenue Hauling Underway

Vision Based Systems

- Sense / Plan / Act
- NVidia PX-2
- 2 Million Images
- 5 Terabytes per Sec
- 5400 Amps of Vehicle Power

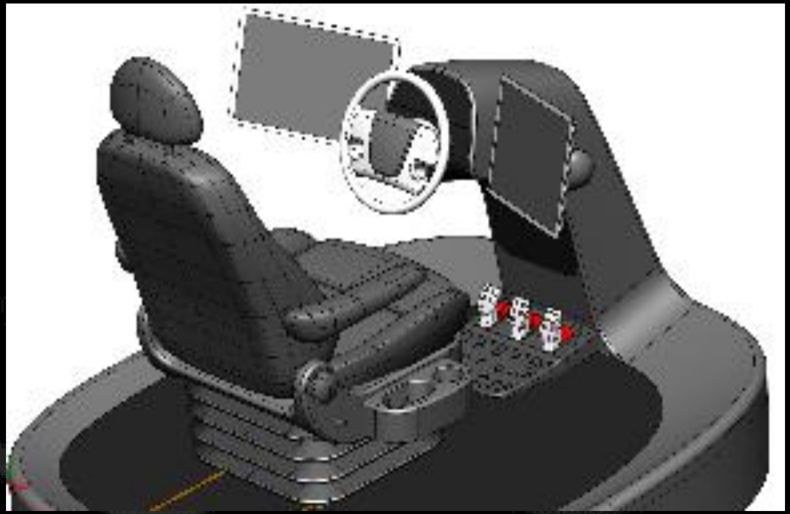


Waymo

- Sensor Based System
- 200M Range
- Warehouse to Store Capable
- Testing in Atlanta, GA

Sigma Integrale

- Project Meteor
- Remote Control Driving of Truck
- One Person Multiple Assets
- Enhanced Driver Pool



L5 Applications

- Fastest ROI
- Long Distance Destinations
- Single Lane Operation
- Mundane Routes
- Well Marked Highways
- Good Weather Locals
- Low Value Cargo
- Yard Operations

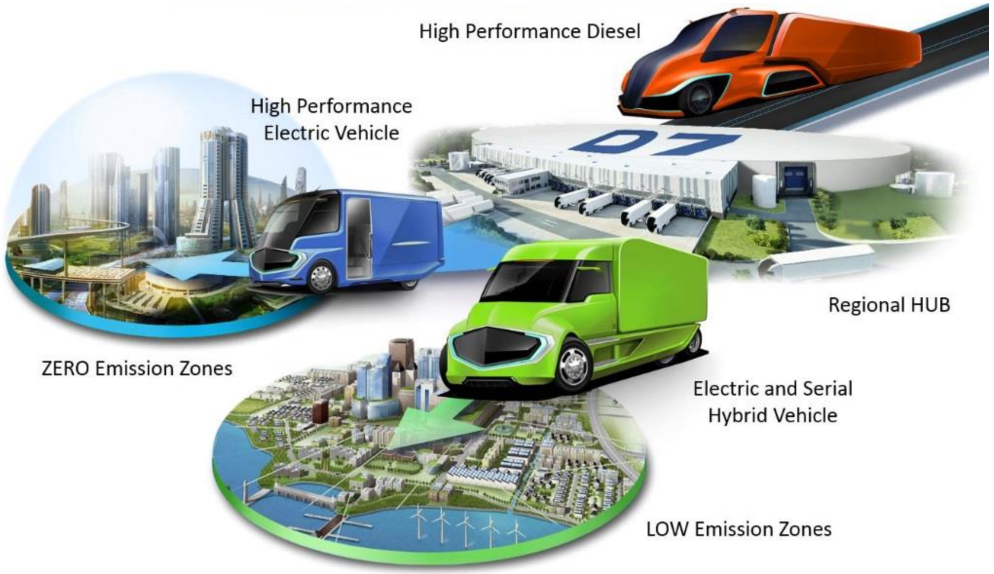
Truck of the Future

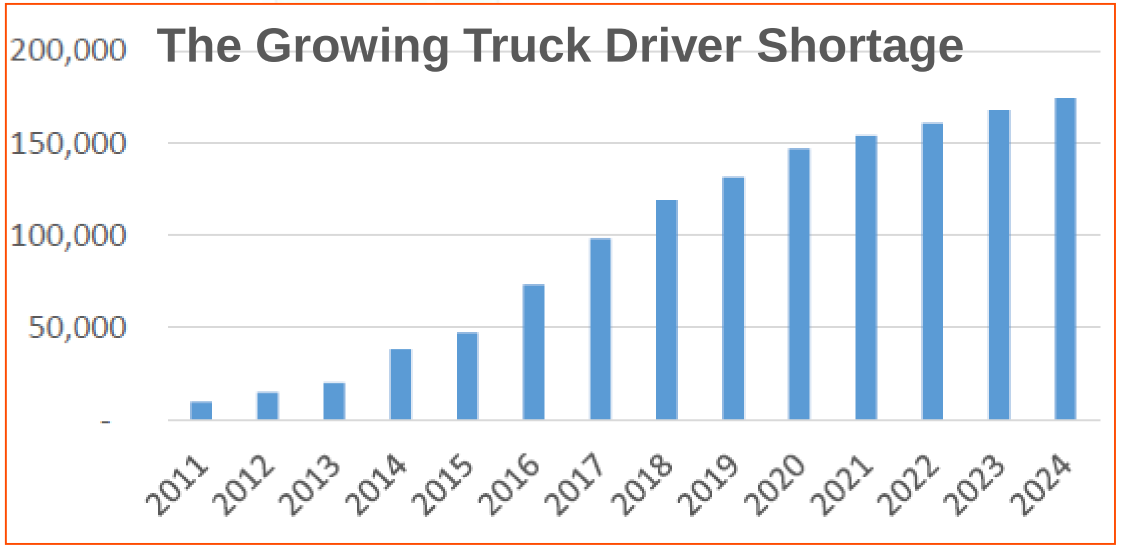
Autonomous Truck Workshop at NSFA

Jim Yan
Director, Advanced Technologies
Navistar Inc.

INTERNATIONAL IT'S UPTIME™

Achieving the Vision





Source: American Trucking Associations

INTERNATIONAL IT'S UPTIME™

Towards Safe, Interactive, and Intelligent Autonomy

Sanjit A. Seshia

Professor

EECS, UC Berkeley

NSF Workshop

June 28, 2018

“***Safety critical***” systems ***interacting*** with humans.

Relevant Projects at UC Berkeley

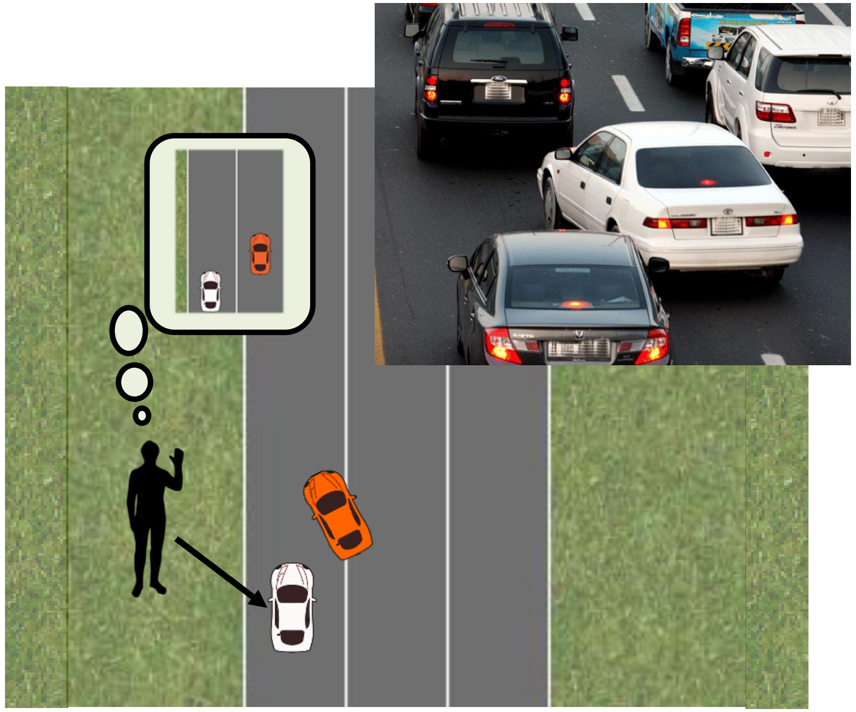
- NSF VeHICaL Project http://vehical.org
  - Verified Human Interfaces, Control, and Learning for Semi-Autonomous Systems
  - **How to co-design human machine interfaces and control to ensure safety and interactivity?**
  - Focus application areas: semi-autonomous vehicles

- Berkeley Deep Drive and DARPA Assured Autonomy
  - Focus on Machine Learning based Autonomous Systems
  - **Creating software tools to design and verify safety of learning-based systems**

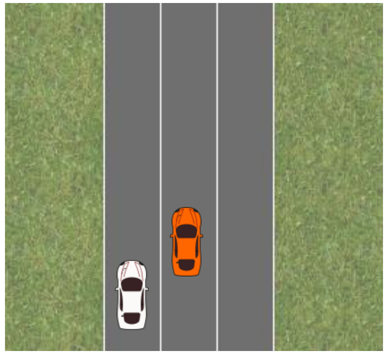
Human-Aware Control of Vehicles

How to control autonomous vehicles so as to make them interact with humans more naturally and safely?

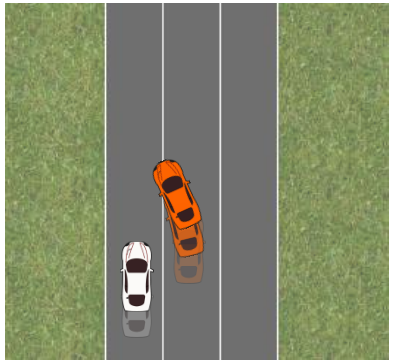
Leverage human *responses* to estimate human internal state.



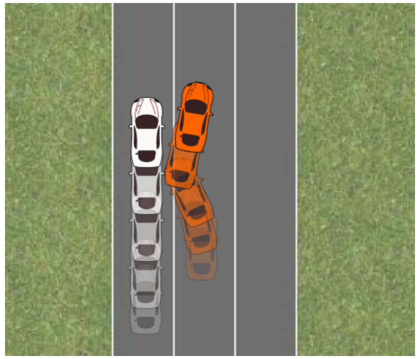
SAMPLE RESULT



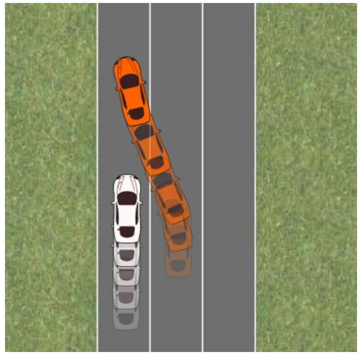
Lane Change



Nudging In



Distracted Human



Attentive Human

[Sadigh, Sastry, Seshia, Dragan; RSS, IROS '16; RSS'17]

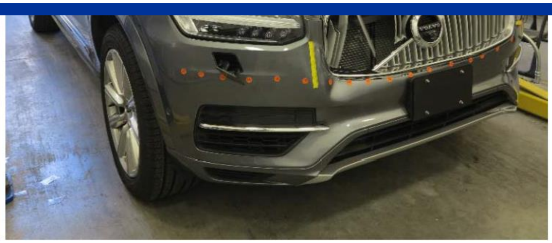
Humans Augment Autonomy

How to design semi-autonomous systems so that humans can improve the safety and performance of autonomy?

Where does autonomy fail? We are developing verification & validation tools for determining corner-case scenarios for machine learning (deep learning) based perception systems that leads to

According to data obtained from the self-driving system, the system first registered radar and LIDAR observations of the pedestrian about 6 seconds before impact, when the vehicle was traveling at 43 mph. As the vehicle and pedestrian paths converged, the self-driving system software classified the pedestrian as an unknown object, as a vehicle, and then as a bicycle with varying expectations of future travel path. At 1.3 seconds before impact, the self-driving system determined that an emergency braking maneuver was needed to mitigate a collision (see figure 2).[2] According to Uber, emergency braking maneuvers are not enabled while the vehicle is under computer control, to reduce the potential for erratic vehicle behavior. The vehicle operator is relied on to intervene and take action. The system is not designed to alert the operator.

March 2018 Uber accident in AZ Preliminary report



What are the Design Requirements for Semi-Autonomous Systems?

- Safe & Correct Autonomy
  - Autonomous mode should be verified correct
- Effective Monitoring
  - Sensors must monitor all relevant environment variables
- Prescient Switching
  - Sufficient lead time to switch between human & auto
- Minimally Intervening
  - Should *rarely* request human intervention
- Other Properties:
  - Security & Privacy
  - HMI Properties: Absence of Mode Confusion, ...
  - ...

[Li, Sadigh, Sastry, Seshia, TACAS'14]

Training and Education for Semi-Autonomous Driving

What training/education tools and material are needed?

- Training the Designers
  - Emphasize co-design of human machine interfaces and control/planning/perception systems
- Training the Drivers / Operators
  - Effective training simulators that use verification tools to cover corner-case scenarios

- CPSGrader System for Auto-Grading and Personalized Tutoring developed at UC Berkeley
  - Deployed in a MOOC on Cyber-Physical Systems on edX in 2014

CPS Grader

UC Berkeley Auto-Grader for Cyber-Physical Systems

Summary of Questions

- What are the design requirements for semi-autonomous vehicles?
- How to co-design control/planning with human-machine interfaces?
- Where can humans best augment autonomy (and vice-versa)?
- What training/education tools and material must be developed?

Goal: Design *for* Safe, Interactive & Intelligent Autonomy

Session 1: Thought Questions

- Which types of automated/autonomous truck implementation scenarios are likely to occur in the future (e.g., fully autonomous truck, limited use, etc.)?
- What types of yet to be created jobs are needed under these scenarios?

Session 2: Regulatory/insurance perspectives on automated/autonomous trucks

U.S. Department of Transportation
Federal Motor Carrier Safety Administration
Office of Analysis, Research, and Technology

Federal Motor Carrier Safety Administration

Automated Driving Systems Program Overview for the Automated Truck Workshop: Impact of Autonomous Trucks on the U.S. Economy

June 28-29, 2018



Office of Research and Information Technology

FMCSA Mission

Reduce crashes, injuries and fatalities involving large trucks and commercial buses

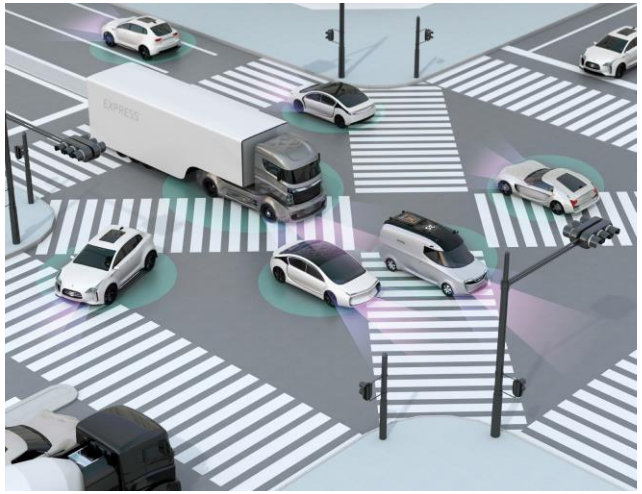
FMCSA ADS Activities

- FMCSA CMV-Automated Driving Systems (ADS) Stakeholder Meeting Jan. 2017
- ADS Listening Session – CVSA April 2017
- DOT/VOLPE completed a review of the FMCSRs and identified which regulations will be affected by ADS.
- Motor Carrier Safety Advisory Council is tasked to assist FMCSA to identify prospective guidance for developers and data needs to consider when developing framework for potential pilot program.
- Request for Comment (RFC) on FMCSRs and ADS-Equipped CMVs – Comments due May 10, 2018, docket still open
- ADS Listening Session – MCity, Ann Arbor, MI, June 2018
- ADS Listening Session – AVS 2018, San Fran., CA, July 2018

FMCSA ADS Activities Cont'd

Multi-pronged approach:

- Research/Data Sharing
- Pilot Programs/Exemptions
- Policy Guidance
- Cybersecurity
- Outreach and Communications



USDOT photo

USDOT photo

Discussion Topics: Deployment of ADS-Equipped CMVs

- Agency's goal is to enable the safe introduction of these technologies
  - Examine current FMCSRs and identify unintended or unnecessary barriers to safe ADS deployment
  - Continue active engagement with entire stakeholder community
- Follow an open and flexible policy approach to evolving technology
  - Technology neutral
  - Best practices and voluntary standards
  - 49 CFR 381--Waivers, exemptions, pilot programs to support innovation
- How Safe is Safe Enough?
  - Key for public acceptance; identify data sources for analysis
  - Developing a scientific and engineering approach to build confidence in ADS systems
  - What methods and metrics make sense to build public confidence?

Contact Info

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NATIONAL SCIENCE FOUNDATION AUTONOMOUS TRUCK WORKSHOP

ELLEN PARTRIDGE

ENVIRONMENTAL LAW & POLICY CENTER

JUNE 28-29, 2018

WHAT ARE THE AV PROBLEMS THAT WE MIGHT NEED A LAW FOR?

- Safety
- Congestion
- Land Use
- Pollution
- Access/Mobility
- Equity
- Standardization
- Liability/Insurance
- Privacy

POLICIES

- What are the policies that we want to put in place? De-carbonization? Vision Zero? Equitable access and mobility? Reduced VMT?
- What behaviors do we need to encourage – Technological innovation? Active modes of transportation? Or discourage – Privacy intrusions? Zombie vehicles?
- The policies are really about how we define the problem
  - Is it “bikes getting in the way of cars” or “cars getting in the way of bikes?”
  - Is it “the government setting unreasonable insurance requirements that keep newcomers out of the market” or is it “companies going bankrupt and leaving injured persons uncompensated?” With lots of new entrants that are making vehicles, not all will succeed.

LEGAL/REGULATORY AIMS

- Proactive
- Cautionary
- Reactive
- Educational
- Research
- Process
- Enabling/Challenging
- Prescriptive/Discretionary
- Clarifying
- Liability/Accountability
- Transparency

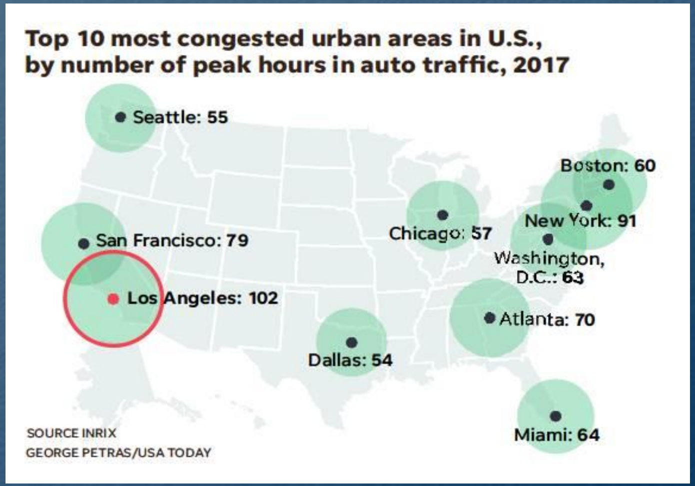
WHAT ARE THE OPPORTUNITIES?

- Radical innovation with transition to a new mode
- Patterns and expectations are not as hide bound, change is possible
- Manuals and standards as well as laws set expectations and rules
- Triggers might be set for future developments, such as % penetration in market, timeframe. E.g., Georgia insurance requirements

EXAMPLES OF STATE LAW PROPOSALS

- All AVs must be electric or renewable
- VMT tax imposed
- Lower VMT tax in off-peak hours or for multiple passengers
- Higher tax on zombie vehicles
- “No local government or state entity shall impose a tax on, or impose requirements on, an autonomous vehicle or autonomous technology.”
- Mischief-making – thwarting an AV as “reckless driving”

FEDERALISM – WHO REGULATES WHAT?



FEDERAL

National safety standards for vehicle design and performance

Vehicle design and safety

Insurance minimums for trucks

STATE

Driver licensing CDL implementation, training and vehicle registration

Revenue development

Liability and insurance

Law enforcement

LOCAL

Localized issues: street by street congestion

Prioritizing walking, biking, transit

Discouraging VMT, e.g., zombie cars

Shifting freight to off-peak hours, designated roads

ACCIDENTS INVOLVING BIG RIGS

- 4,317 people died in large truck crashes in 2016 (NHTSA)
  - 17% were truck occupants
  - 72% were occupants of cars and other passenger vehicles
  - 11% were pedestrians, bicyclists or motorcyclists.
- 4317 number of deaths in 2016 is substantially higher than the 3,147 deaths in 2009, which was the lowest since data collection of fatalities began in 1975 (NHTSA, IIHS)
- Drinking and driving rarely a factor for truck drivers (IIHS):
  - 3% of large truck drivers killed in 2016 had BAC at or above 0.08%, down from 17% in 1982
  - 29% of passenger vehicle drivers killed in 2016 had BAC at or above 0.08%, down from 51% in 1982

COST OF TRUCK ACCIDENTS

Insurance payouts (by one estimate)

- $100-$200,000 – Property damage
- $135-$850,000 – Injury
- $850,000-$1.3 million or more – Fatality

FMCSA INSURANCE REQUIREMENTS

Federal Insurance Regulations: FMCSA regulates the operation of interstate motor carriers, including insurance. Title 59, Section 387 of the United States Code of Federal Regulations, separates the insurance requirements for interstate trucks into categories based on weight and cargo. Trucks over 10,000 pounds must have insurance in these amounts:

- $750,000 for general, non hazardous commodities
- $1 million for hazardous freight except class A and class B explosives
- $5 million for class A and class B explosives

- Will there be calls to increase these amounts for AVs because of scarcity of data, concern about severity of accidents? Or calls to decrease because of increased safety of AVs?

INSURANCE REACTION TO AVs

- Robots need insurance too
- How long does it take for the insurance market to catch up to new technology and business models? Insurance companies are run by actuaries, who need data to calculate risks. Slow but steady. Limits are a key issue, to avoid high jury verdicts
- New data capabilities
- New markets
  - Cybersecurity
  - Products liability
  - Infrastructure insurance

GOVERNMENTAL RESPONSES TO AVs

- How long does it take for the government to catch up to new technology and business models?
- Congress, NHTSA, FMCSA – all play a role on federal level
- History of NHTSA regulations – sometimes requiring new technology after it is well deployed
- States – searching for competitive advantage
- Cities – retaining control of their streets
- Industry codes – regulation by those who know it best?

DISCUSSION

- How should we treat Level 5 trucks differently from human-driven trucks?
- How much safer than human drivers do AVs need to be before we allow them out on the road? Based on what evidence?
- During the transition from today's cars to AVs, is there a "tipping point" when new laws need to come into play? Can we identify triggers in advance?
- What is the right mix of federal, state and local regulation?
- How do we ensure that cities and states get data that will help plan infrastructure?
- Is this an opportunity to address issues of equity, funding for transportation, environmental restoration, infrastructure renewal….?

Thank you!

Session 2: Thought Questions

- Governmental policies play a critical role in the transition to automated/autonomous trucks without deterring technological progress. What regulatory, insurance, and/or legal perspectives will be needed as the technology matures?
- What are the research challenges in achieving and assuring safety and verification in automated/autonomous trucking?

Session 3: Industry views on use of automated/autonomous trucks in the end-to-end delivery system

ATA

AMERICAN TRUCKING ASSOCIATIONS

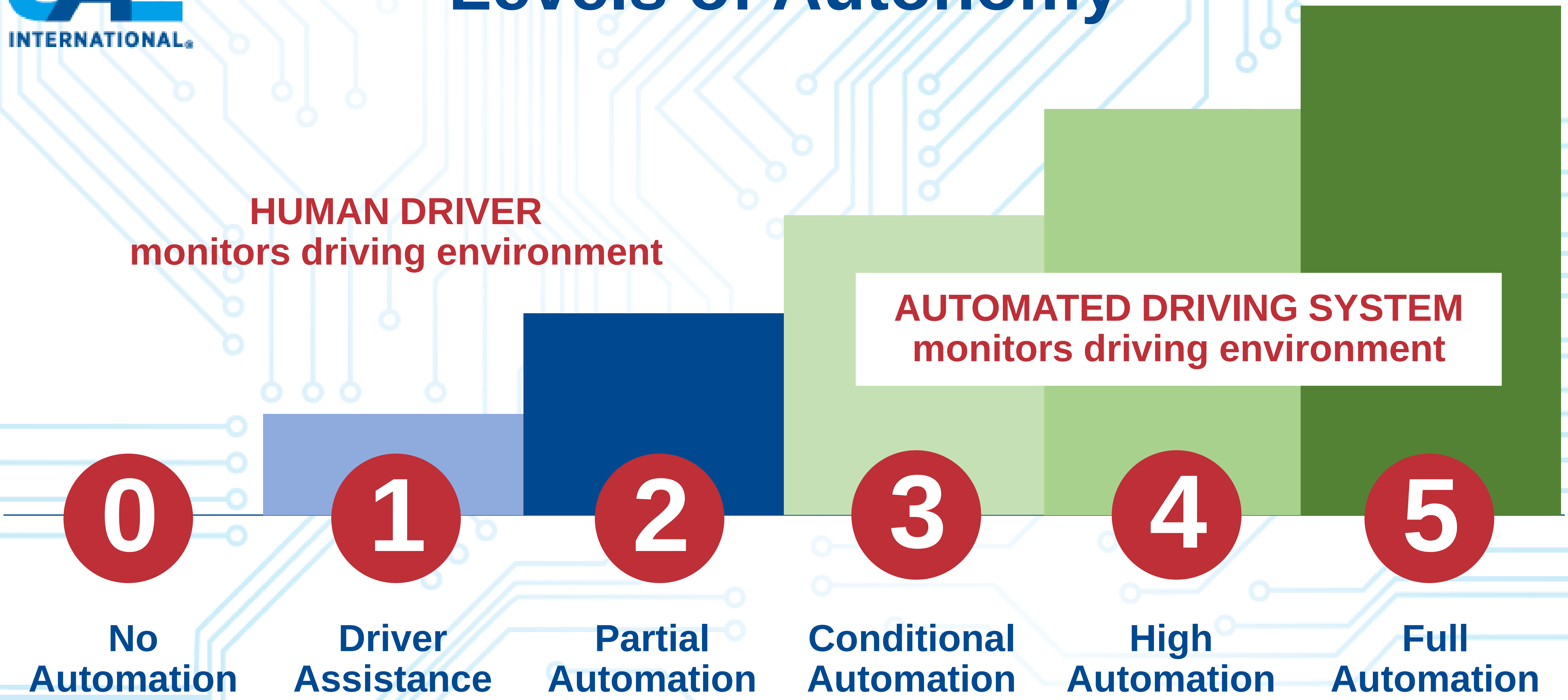
Automated Trucks: Technology and Applications

Mike Cammisa

Vice President, Safety Policy, Connectivity & Technology, American Trucking Associations

Automated Truck Technology

Levels of Autonomy



Building Blocks for Automation

RSC

AEBS

LKA

CMS

ACC

LDW

FCW

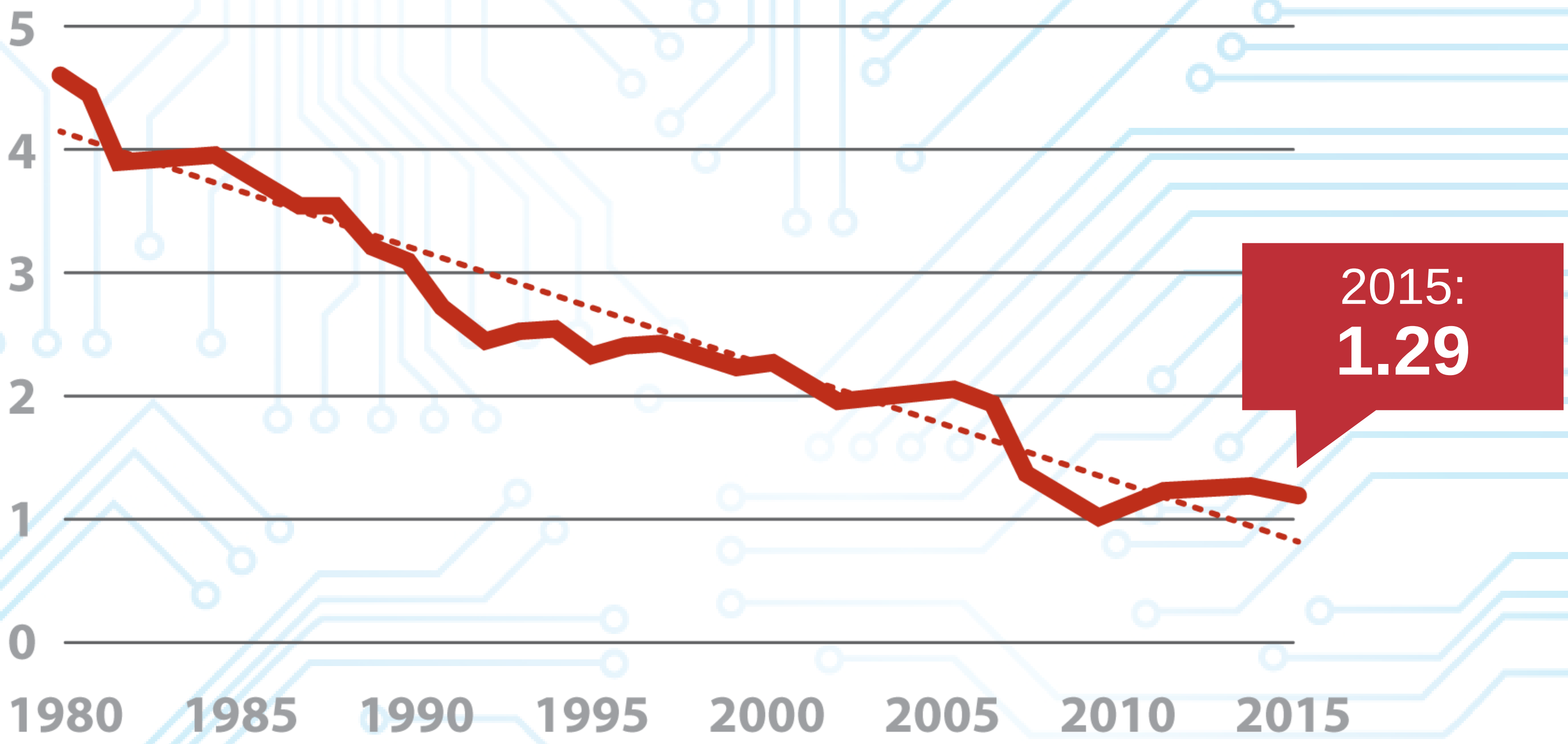
ABS

ESC

Trucking Trends

Large Trucks Fatal Crash Rate

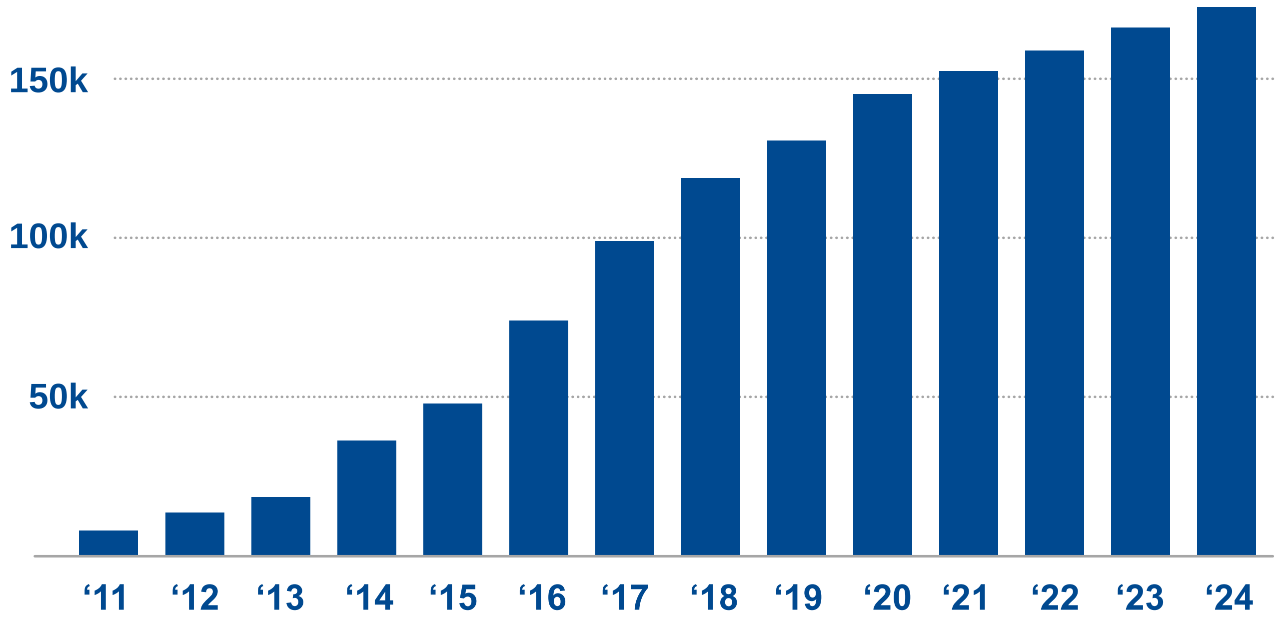
(Per 100 Million Miles) 1980 – 2015



Growing Freight Demand

Driver Shortage Estimates

2024:
175,000



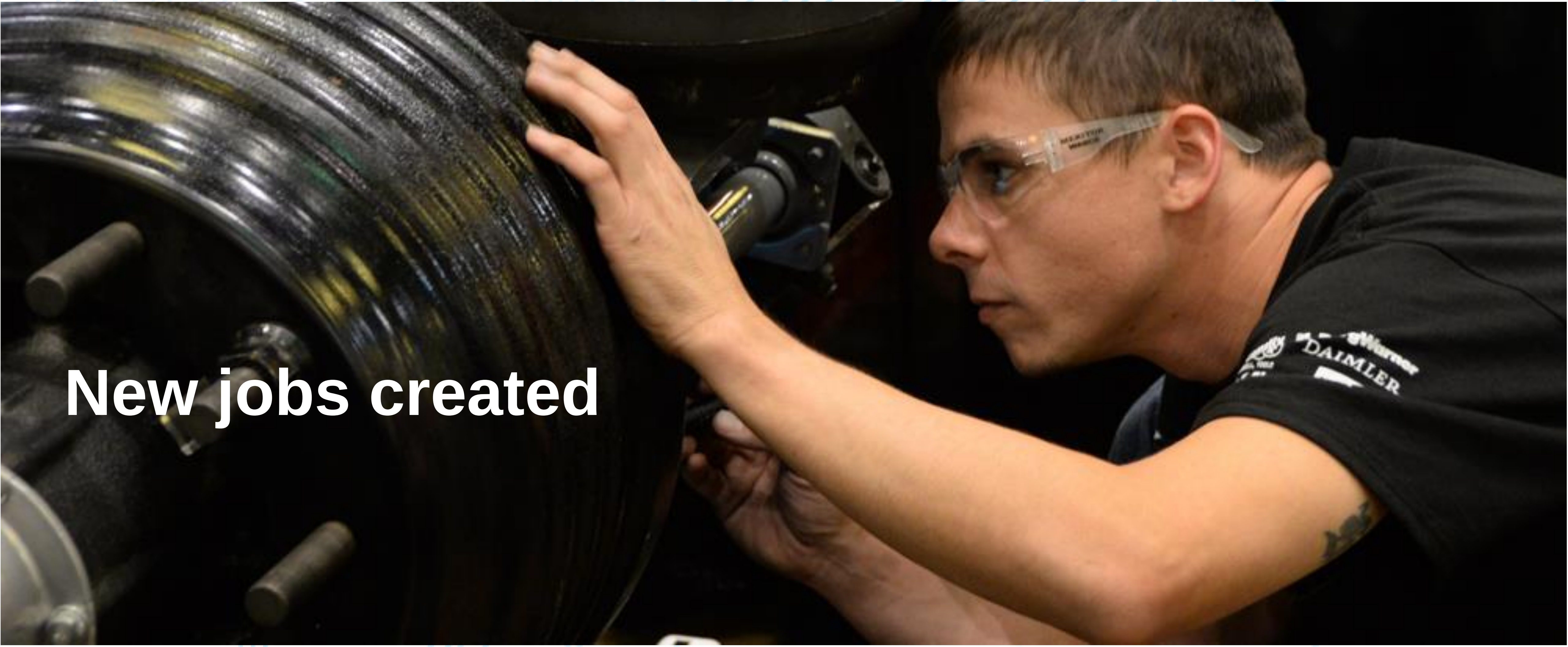
Source: ATA Truck Driver Analysis, 2015

Technology Applications

Technology choices will depend on business operations

Role of the Driver

New jobs created



Considerations for Automated Technology


2/6/2017 2:45:00 AM

Write a Letter to the Editor

States Partner for Testing, Research of Autonomous, Platooning Vehicles

Recommend 1 | Tweet | Share | Print This | E-mail This

This story appears in the Feb. 6 print edition of Transport Topics.

Three states are joining forces to work on autonomous and connected vehicles research and testing.

After more than a year of discussion, the adjoining states of Michigan, Ohio and Pennsylvania announced Jan. 17 that they have formed the Smart Belt Coalition, which is made up of the departments of transportation in the three states, the University of Michigan, the Ohio State University and Carnegie Mellon University, as well as the Ohio Turnpike and Infrastructure Commission, the Pennsylvania Turnpike Commission and Ohio's Transportation Research Center.

Meritor Wabco

Technology is developing

Flexibility for innovation

Safety & Productivity

What's the ROI?

Different business models

ATA

AMERICAN TRUCKING ASSOCIATIONS

Truck Platooning –
The Road to Life- Saving Autonomous Trucking Through Connected Vehicle Technologies

Ray A. Mundy
Jill M. Bernard Bracy
Ken Q. Bao

University of Missouri – St. Louis
Center for Transportation Studies

Economic and Societal Benefits from AT

- 4000 highway deaths annually in which large trucks are involved
- 130,000 injuries each year in which large trucks are involved
- Can the economic and societal impacts of significant reductions in deaths and injuries be calculated?
- Congressional presentation of 1918
  - The highway system will transform the U.S.
  - Economic and societal benefits will be enormous
  - But, in forty years we expect to kill at least 40 to 50 thousand people per year…
- Knowing all this, would we still build it?

Economic and Societal Benefits from AT

- Our generation of transportation researchers and motor carrier operators has made tremendous strides in reducing this carnage
- In the future, however, we have the responsibility to say to Congress that over the next forty years we can substantially decrease or even eliminate this carnage on our highways
- How?
  - Relentless pursuit of Connected Infrastructure (CI) and Autonomous Trucking through truck platooning.

AV and CV Technologies

- Autonomous Vehicle (AV) technologies can replace human drivers with a computation-based decision making process for a varying array of driving tasks.
- Connected Vehicle (CV) technologies focus on vehicle-to-vehicle (V2V) communications by synchronizing the movements of nearby vehicles.
- Truck platooning can be the bridge to AT
  - Platooning consists of at least two trucks that drive in a synchronized fashion where the lead vehicle dictates the actions of the following vehicle(s).

Truck Platooning

- Numerous exercises already in progress
  - Advances by ATA and Peloton Technology
  - FHWA's CACE Platooning
  - Ohio's setting aside highway for demonstrations
  - Caltrans is expanding research
  - Missouri had blocked platooning, now approved
- Evolutionary nature of truck platooning
  - One master truck and one slave, drivers in both trucks but controlled by lead truck driver – benefit, substantial fuel savings estimated at 15%
  - One master truck and two slaves, drivers in all trucks, fuel savings, 25%
  - One master truck and one slave, no driver in slave, cost savings, labor savings, estimate, 15% or total fuel and labor savings of 20% or more for combination of both trucks.

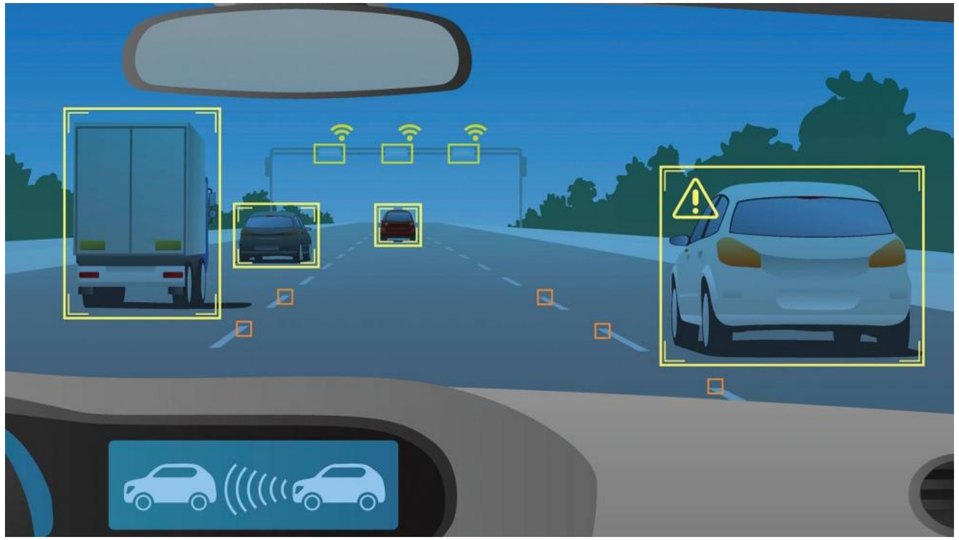
Truck Platooning

- **Level 1** - The driver’s hands or feet are not engaged when operating a vehicle.
- **Level 2** - Both hands and feet are disengaged, but the driver’s eyes are monitoring travel.
- **Level 3** - Hands, feet, and eyes are not involved, but the driver is alert and ready to take control.
- **Level 4** – There is no human driver, but the vehicle is constrained, such as operating in low speeds only or in certain stretches of highway.
- **Level 5** - Fully unconstrained and driverless

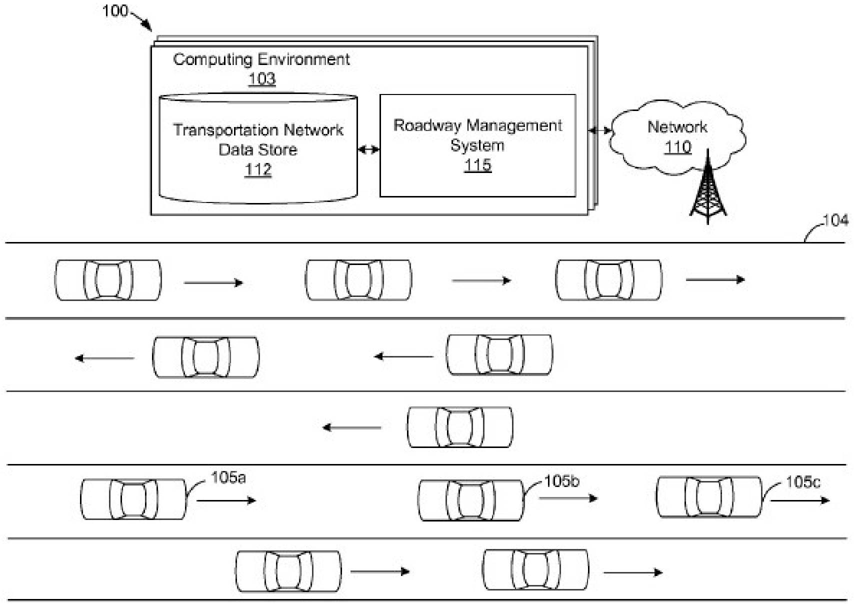
- Richard Bishop of Bishop Consulting, chairs of the Automated and Connected Trucking Technologies Task Force at the American Trucking Association.

Key Needs for AT

- Autonomously readable lane markings
- Autonomously readable traffic signals and signs
- Managed lane and infrastructure dedicated to ensure the safe entering and exiting of highways



The Drive (2018)



USPTO (2018)

UMSL Business
Center for Transportation Studies

U.S. Motor Carrier Industry

- Annual Motor Carrier Expenditures
  - Total - $700 billion dollar industry
    - Fuel ……38%
    - Driver…..34%
    - Theoretical savings from Autonomous Trucks & CI is 40% -- or $280 billion!

- Obvious Conclusion
  - The Motor Carrier Industry has both the incentive and wherewithal to build the interstate CI system as quickly as possible

UMSL Business Center for Transportation Studies

U.S. Motor Carrier Industry

Which types of trucking operations are likely to adopt platooning and eventually autonomous trucks?

- Large fleet operators have the load capacity and ability
  - Can reap immediate benefits of drafting
  - Over time, ease driver fatigue
  - Demonstrate ability to let computers do the driving

How will the organization of carrier fleets adjust to the introduction of platooning to autonomous trucking?

- Major interstate routes – very swiftly
- Will create significant cost and labor benefits to companies and drivers
- Only in Level 5, or CI mode of AT will individual operators be able to compete

Conclusions

- Autonomous trucks hold great economic and societal benefits.
- Implementation should be one of our nation’s highest concerns.
- Pathway to success is through truck platooning.
- First four stages will come relatively swiftly.
- Final stage will require massive infrastructure connectively investments.
- Motor carrier industry has ability to pay for this infrastructure and still reap enormous economic benefits.
- This can and should be a public/private partnership that would both lower our logistics costs and reap enormous societal benefits at the same time.

Questions?

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Futurism NEWS FEATURES VIDEOS

7/technology/uber-trucks-autonomous/index.html

CNN tech BUSINESS CULTURE GADGETS FUTURE STARTUPS

Uber self-driving trucks are now hauling freight

by Matt McFarland @mattmcfarland

March 7, 2018: 12:07 PM ET

Semi-autonomous & Autonomous Truck Market Worth 81.8 Thousand Units by 2030

NEWS PROVIDED BY
MarketsandMarkets →
May 25, 2018, 08:30 ET

GOOGLE \ TECH \ TRANSPORTATION

Waymo's self-driving trucks will start delivering freight in Atlanta

The Google spinoff has its chips cashed in

By Andrew J. Hawkins | @andyjayhawk | Mar 9, 2018, 12:00pm EST

SHARE

Fleet Management

Which Way to the Smart Highway?

Part 9 of the Trucking in the 21st Century Series

November 2017, TruckingInfo.com - Feature

by David Cullen, Executive Editor - Also by this author

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There's no one route to the future, yet there already are on ramps open to it.

Session 3: Thought Questions

- Given the different implementation scenarios, which types of trucking operations are likely to adopt autonomous trucks?
- How will the organization of carrier fleets adjust to the introduction of autonomous trucks?

Session 4: Trucking impact on US economy/driver demand

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Virginia Tech Transportation Institute and National Science Foundation

Impact of Autonomous Trucks on the US Economy Workshop

June 28/29, 2018

NSF Headquarters in Arlington, VA.

Prof. Michael H. Belzer

Effects on **Trucking** Industry Structure

- Adoption will be incremental
- Certain sectors will see it first
  - Predictable routes
    - Terminal to terminal and within terminals
    - Staffed with freight handlers at either end
  - Within-firm before inter-firm operations
  - Uncongested times, days, routes

Effects on **Freight** Industry Structure

- At the margin, trucks will replace trains
  - Without carbon tax or labor cost, trucking will cost less
  - Hundreds of trucks replace one train
  - Carbon footprint increases proportionately
- Highways become much more congested
  - Will cargo owners pay the cost of expanded highways?
  - Will the public accept it?

Economics

- Capital replaces labor when wages are high
  - Average trucking compensation is low
  - Lease-purchase and subcontracting further reduce labor cost, sometimes to zero or less
- Low labor cost reduces incentive to automate
  - Replacement of labor with capital should increase productivity
  - With low labor cost, this may not make economic sense

Autonomous Trucks: Impact on US Economy/Driver Demand

Workshop on Autonomous Trucks

National Science Foundation

June 27-28, 2018

Stephen Burks

Truckers & Turnover Project

University of Minnesota, Morris

Portrait of the Speaker as a Young Man

TL Steelhauler, Indianapolis, IN; 1977

LTL Road Driver, White Deer, PA; 1983

Truckers & Turnover Project, UMM: S.V.Burks Photo Collection

The Truck Driver Labor Market

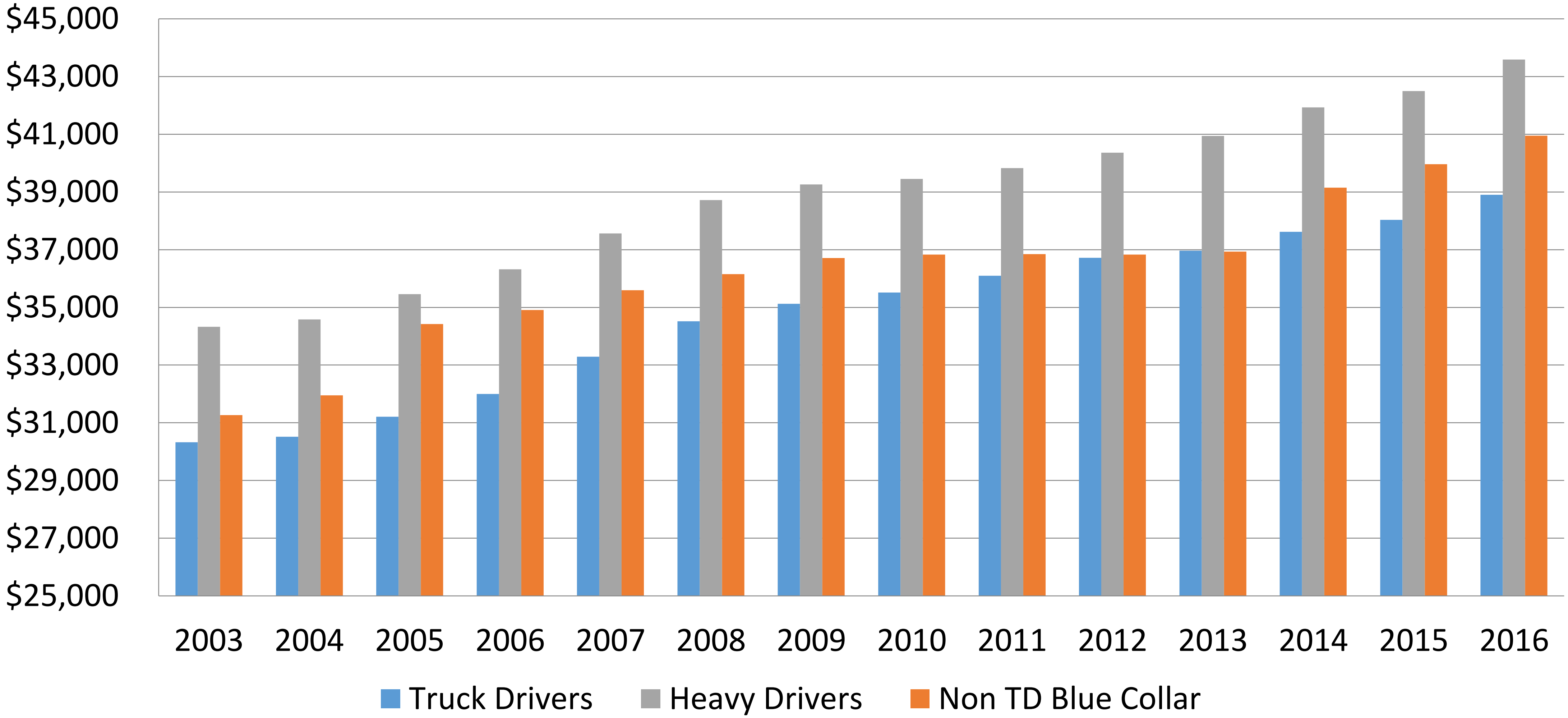
- Approximately 2.1 million heavy and tractor trailer truck drivers (2016 OES)
  - 1.87 million employee drivers (SOC 53-3032)
  - Approximately 250,000 owner operators (estimate)
- Other types of drivers add 1.4 million (2016 OES)
  - Driver/sales workers (SOC , 468,000)
  - Light and delivery truck drivers (SOC , 944,000)
- Primary focus currently on heavy and tractor trailer drivers

Overall, the Truck Driver Labor Market Works “Normally”

- OES Data
  - Mean nominal earnings of truck drivers exceed those of other blue collar workers
  - Track earnings of blue collar workers over time
- CPS Data (ORG analysis)
  - Unemployment rate of truck drivers persistently lower than other blue collar workers
  - Occupational attachment modestly higher
  - Occupational exits and entries associated with hours and earnings in the expected fashion
  - Can’t directly observe firm-specific attachment

Source: Burks, Monaco, and Kildegaard

Mean Nominal Earnings: Blue Collar Workers, All Truck Drivers, &Heavy and Tractor-Trailer Drivers



Source: Burks, Monaco, and Kildegaard

Distribution of Heavy and Tractor-Trailer Trucks by Usage Radius (2002 VIUS)

50 miles or less	51-100 miles	101-200 miles	201-500 miles	501 miles or more
49.6%	16.9%	8.5%	10.4%	14.6%

Estimates from Gittleman & Monaco, 2017.

How Big is Long-Distance TL?

- 2012 Economic Census (2017 data not available)
  - Establishments (not firms)
  - 29,800 in Long Distance TL
  - 14,600 in other Specialized Long Distance (mostly TL)
  - Total 44,400
  - Overestimates firms in that a few large firms have many establishments
  - Underestimates firms in that many owner-operators with own authority are not counted
- FMCSA MCMIS
  - Regulatory database
  - 524,000 registered carriers of all types
- Driver employment: approximately 400,000 to 500,000

High Turnover in a Key Segment of For-Hire Trucking

- Annualized turnover rates in other parts of trucking are normal
  - Less than Truckload (LTL) Linehaul, 2000-2017:
  - **Mean 12%,** high 22%, low 5%.
  - Private Carriage: typically ranges between 3% and 15%
- Annualized turnover rates in TL are higher (ATA quarterly survey)
  - Large TL firms, 1996-2017:
    - **Mean 97%**
    - High 136% (Quarter 3, 2005)
    - Low 39% (Quarter 2, 2010)
  - Small TL firms, 1996-2017:
    - **Mean 79%**
    - High 114% (Quarter 3, 2006)
    - Low 35% (Quarter 1, 2009)

Minimizing Costs in Long Distance TL

- Long distance TL is "perfectly competitive"
  - Entry barriers very low
  - Average costs similar across small and large firms
  - Cost minimization is thus a key managerial strategy
- Labor costs are about 40% of all costs (ATRI 2017)
- Three operational cost components
  - Dispatch intensity (how efficiently are costly capital goods-truck tractors-utilized: higher intensity lowers effective cost but raises turnover)
  - Turnover costs (recruiting and training new drivers: increases with turnover)
  - Wage costs (paying a compensating differential lowers turnover)
- Question: what is the least cost **combination**?

Sketch of the Model

- Objective function: minimize the total cost (the sum of capital costs, wage costs, and training costs) required to meet a fixed shipments-handled-per month target
- Constraints
  - The technology (the relation between quantity of inputs and quantity of output depending on intensity of use, and the substitutability among inputs)
  - A misery index: the driver dissatisfaction level due to time at home being increasingly limited as shipments handled per month rises
  - The quit rate as a positive function of the driver “misery index” and a negative function of the wage paid per shipment
  - A demand for trainees from the quit rate and currently employed driver stock

Source: Burks, Monaco, and Kildegaard

Key Implications

- The quit rate depends (only) on
  - the cost of capital
  - the cost of training, and
  - the technology (trucks operated per driver)
- The optimal quit rate is never zero
- Combined with evidence of 30 years of history
- Suggests that cost-minimizing mixture is
  - High dispatch intensity (use trucks efficiently)
  - Modest compensating differential for those that adapt to industry
  - High turnover
- Hunt: “exception that proved the rule” (1996 wage increase)

Source: Burks, Monaco, and Kildegaard

Implications of Cost Minimization

- Example:
  - If the attractiveness of TL jobs increases
  - Holding other elements fixed
  - After all adjustments
  - Wage rate falls
  - Dispatch intensity rises
  - Driver misery level rises
  - Quit (turnover) rate is unchanged

Source: Burks, Monaco, and Kildegaard

Turnover as a Market Shock Absorber

- Why do practitioners periodically raise more serious concerns about shortage?
- Possible explanation:
  - Positive demand shock
  - Only spot market rates can rise
  - Contract rates (>75% of TL freight) are sticky upwards
  - Firms raise wages cautiously
    - Demand may not stay high
    - Lowering nominal wages is bad news
  - Immediate response is sign-on bonuses, aggressive recruiting
  - This raises turnover rate
  - Accompanied by “unseated trucks” until freight rates adjust
  - Then wages go up more broadly
  - Amount of increase required depends on how good other job options are

Source: Burks, Monaco, and Kildegaard

Main Take-away from Model of Least Cost Production in Long Distance TL

- In this segment competition is focused on costs
- Cost minimization will determine when and which TL operations will introduce AT
  - Balance of costs and benefits
  - Additional cost of AT trucks
  - Benefits in higher tractor utilization
- The solution to the labor supply issues for individual firms does not tell us about the results when all firms follow a similar strategy
- The global effects may be different than practitioners' intuitions suggest

Source: Burks, Monaco, and Kildegaard

Session 4: Thought Questions

- Given the different implementation scenarios, what are potential impacts to drivers and other workers in the delivery process during the first decades of automated/autonomous truck implementation?
- How will autonomous trucks influence the location choices of warehouses, distribution centers, manufacturing factories, truck stops in the future?

Day 2 Overview

- Session 5: Convergence of autonomous trucks and human labor – enhancing the driver-truck interface and understanding skill
  - 8:20-8:50: Panel Presentations
  - 8:50-10:15 Discussion
    - 8:50-9:10: Group discussion with Panel
    - 9:10-10:00: Small group discussion
    - 10:00-10:05: Facilitator distill notes
    - 10:05-10:15: Facilitator Reporting
- 10:15-10:25: Break

Day 2 Overview

- Session 5: Convergence of autonomous trucks and human labor – enhancing the driver-truck interface and understanding skill
  - 10:25-10:55: Panel Presentations
  - 10:55-12:20 Discussion
    - 10:55-11:15: Group discussion with Panel
    - 11:15-12:05: Small group discussion
    - 12:05:-12:10: Facilitator Distill Notes
    - 12:10-12:20: Facilitator Reporting
- 12:20-12:25: Final Wrap and Thank You

Outputs

- Research directions
- Data needed (currently unavailable)
- Hypotheses

Session 5: Convergence of automated/autonomous trucks and human labor – enhancing the driver-truck interface and understanding skill requirements

Analyzing the impact of automated trucking on human workers

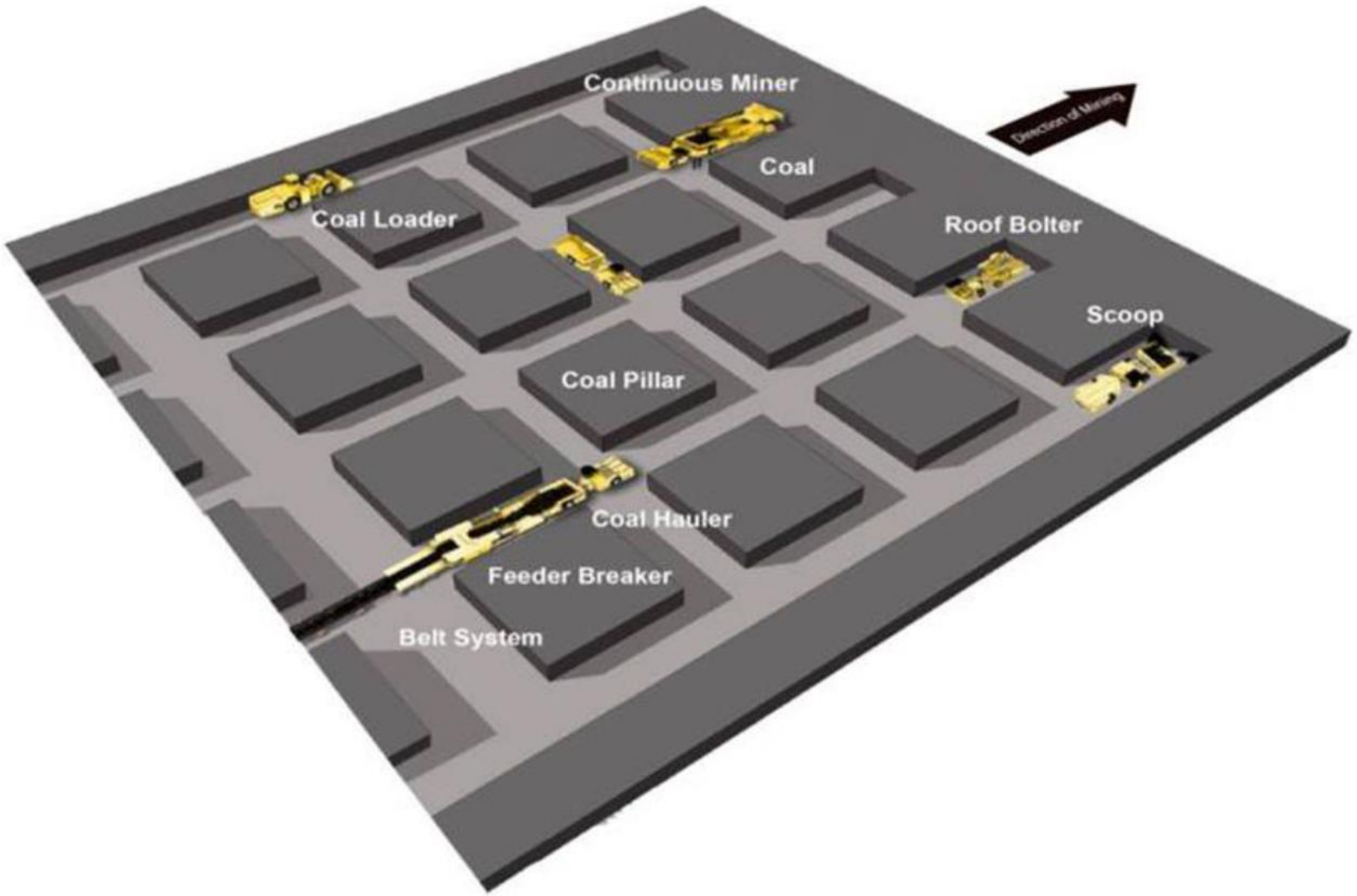
Johan Engstrom, Andrew Miller
Center for Truck and Bus Safety

VIRGINIA TECH TRANSPORTATION INSTITUTE

Cognitive Work Analysis (CWA)

- Well-established human factors framework for representing the **constraints** in a work domain
- Provides a toolkit for representing relevant aspects of the work domain
- In particular: Represents domain resources and functions in terms of their **purpose**

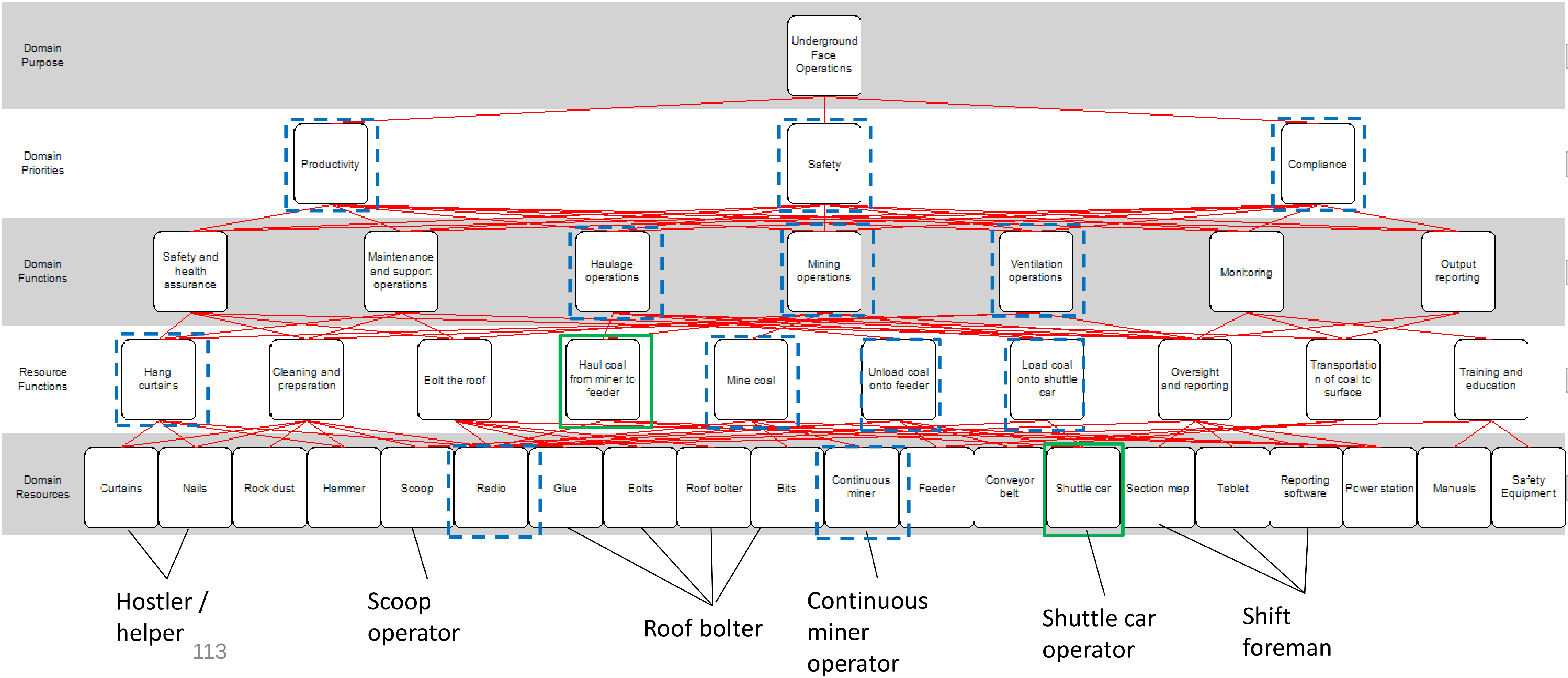
Example: Automating haulage operations in a coal mine



Shuttle car

VIRGINIA TECH TRANSPORTATION INSTITUTE

Work domain analysis: Abstraction hierarchy



Design implications for automated shuttle cars (examples)

- Introducing automated shuttle cars affects the whole work domain at the system level
- Automated shuttle car operations will need human supervision to align with other (still human-controlled) operations (e.g., mining, roof-bolting, cleaning etc.)
- New roles and procedures, new needs for training etc.
- The automated shuttle car needs to interact with other human workers (e.g., continuous miner operator, hostler) -> new safety and HMI requirements
- …

Implications for automated trucking

- Better to think about automated **operations** than automated trucks
- To understand how automated trucks will affect human workers one first needs to understand the work domain and the role/purpose of the operation(s) being automated in that domain
- Human truck drivers will not simply be replaced by automation - new roles will typically be created
- System-level effects on the work domain as a whole
- CWA offers a potential way to systematically predict and analyze these effects

Advancing Transportation Through Innovation

Name

Connected Automated Road Freight Movement

NSF Autonomous Truck Workshop
June 29, 2018
Richard Bishop

BISHOP CONSULTING

Automated Road Freight: Weak Business Cases

- Level 2 platooning: adding steering control does not increase fuel savings
- Level 3 single trucks:
  - HOS regulations unchanged: no ROI
  - HOS regulations adapt to Level 3: could become highly useful

Level 3 Traffic Jam Pilot Opportunity: Port of Palm Beach Gate Congestion

Automated Road Freight: Key Use Cases

Near Term (0-3 years)

- Level 1 Driver Assistive Truck Platooning
- Level 4 Low Speed Driverless

Longer Term (3-7 years)

- Level 4 High Speed Driverless

Automated Road Freight: Key Use Cases

Near Term (0-3 years)

- Level 1 Driver Assistive Truck Platooning
- Level 4 Low Speed Driverless

Longer Term (3-7 years)

- Level 4 High Speed Driverless

Driver-Assistive Truck Platooning Market Overview

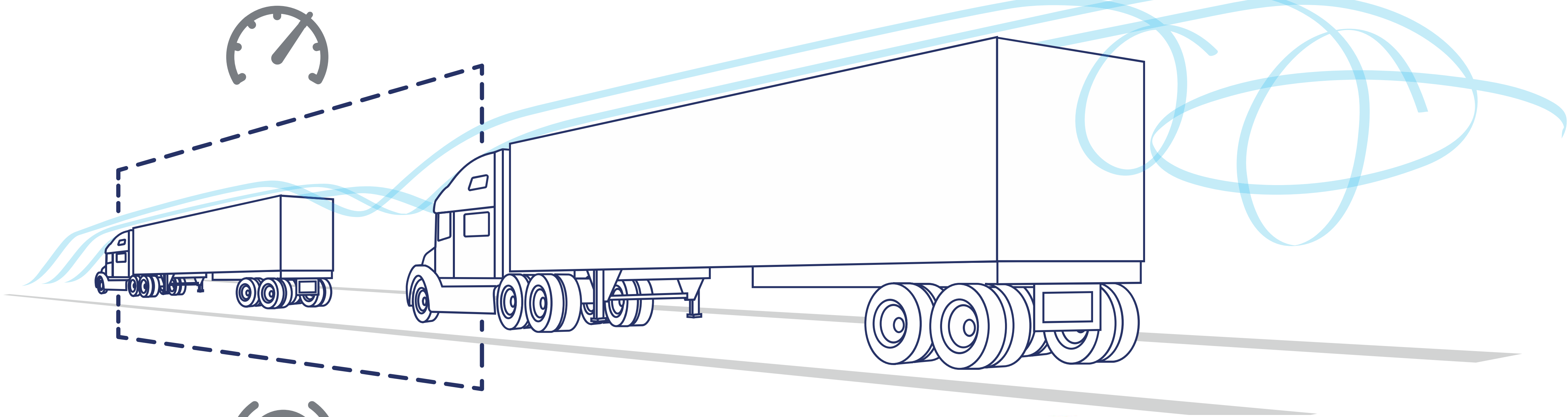
Many Companies in US, Europe, and Asia Involved with Bringing Truck Platooning to Market

Peloton
Continental
DELPHI
DAF
A PACCAR COMPANY
VOLVO
NAVISTAR
DAIMLER
SCANIA
NXP
MAN
IVECO
DENSO
HINO
Bendix™
WABCO
Peterbilt
A PACCAR COMPANY
KENWORTH
A PACCAR COMPANY
Cummins®

Solid Demand From Top Fleets

Pairs of Trucks, Both Drivers Steering At All Times

Driver Teamwork via Linked Adaptive Cruise Control



Front Driver
- **Hands on**
- Feet on+ACC
- Eyes/Mind on

Rear Driver
- **Hands on**
- Feet off
- Eyes/Mind on

Peloton PLATOONPRO

Orthagonality!

Platooning is an Operational Mode for Close Following

Levels of Automation Describe Driver/Machine Role

Platooning can occur at any level of automation in any truck. (First generation systems are Level 1.)

Automated Road Freight: Key Use Cases

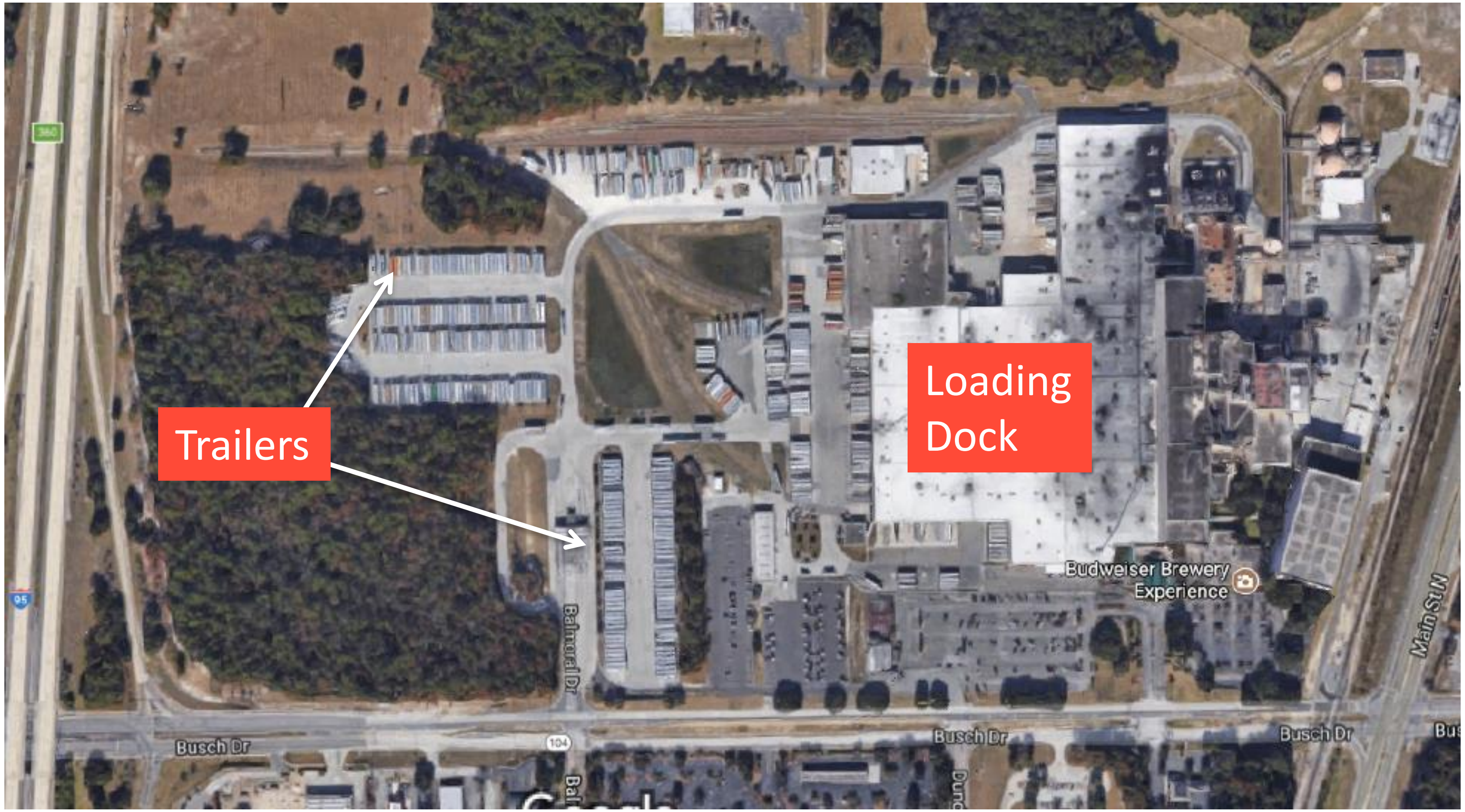
Near Term (0-3 years)

- Level 1 Driver Assistive Truck Platooning
- Level 4 Low Speed Driverless
  - private property
  - highly limited public road operations

Longer Term (3-7 years)

- Level 4 High Speed Driverless

Automated Trailer Switching: Stepping Stone to High Automation On-Road



Drayage: Jacksonville Port

Level 4 Automation Within Immediate Port Area

- very short drays between sea terminal and rail intermodal facility
- ¼ mile
- one left turn
- one stop light

Automated Road Freight: Key Use Cases

Near Term (0-3 years)

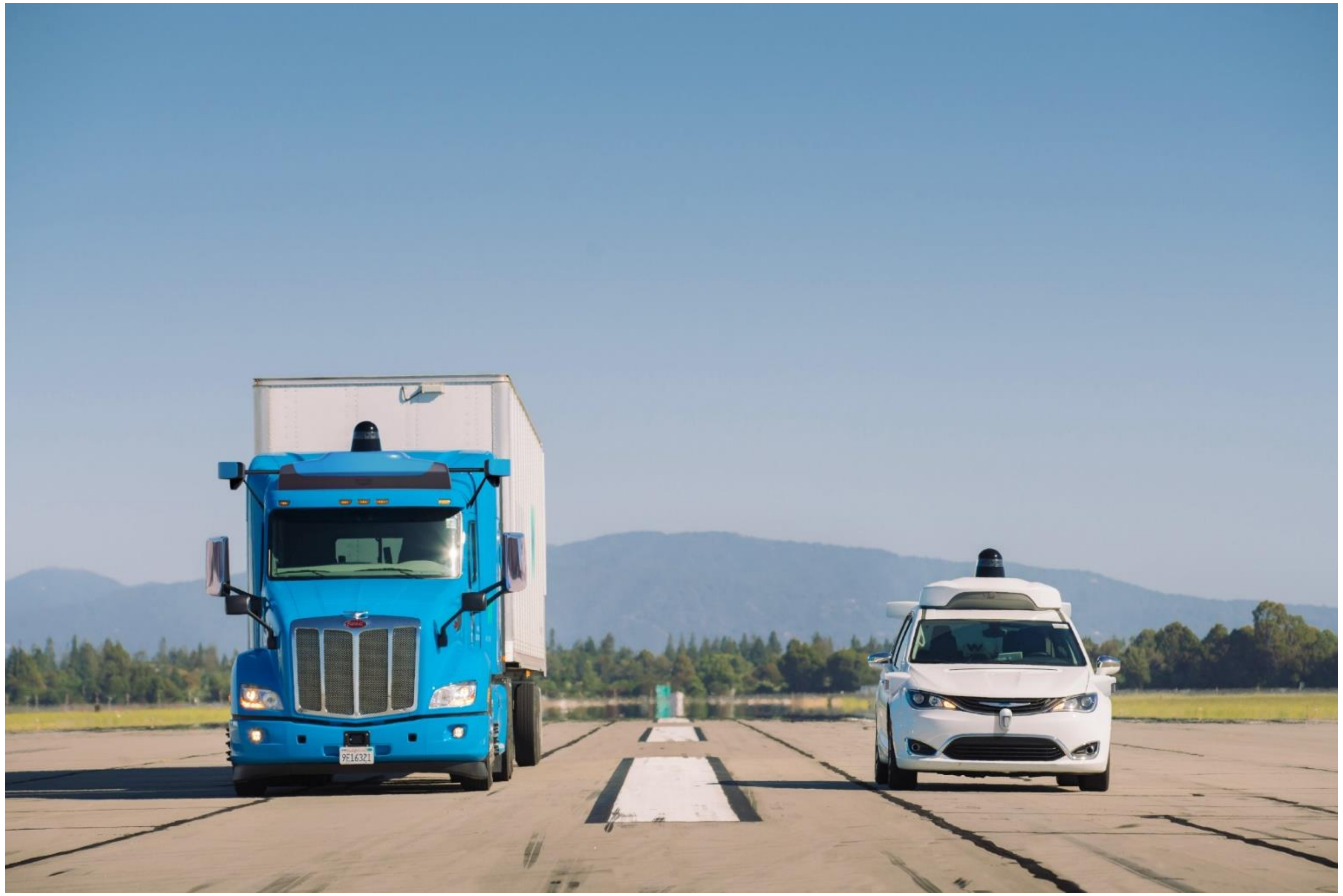
- Level 1 Driver Assistive Truck Platooning
- Level 4 Low Speed Driverless

Longer Term (3-7 years)

- Level 4 High Speed Driverless
  - substantial business value at Level 4 (forget Level 5!)

Truck Automation: High Speed Driverless

- Over-the-Road
  - tech developers:
    - Waymo
    - Uber
    - Embark
    - TU-Simple
  - "exit-to-exit" driverless, tranfer hubs at freeway interchanges
  - challenges: regulatory uncertainty in U.S.



FMCSA Request for Comments on AD Testing and Deployment

- Request for Comments Concerning Federal Motor Carrier Safety Regulations (FMCSRs) Which May Be a Barrier to the Safe Testing and Deployment of Automated Driving Systems-Equipped Commercial Motor Vehicles on Public Roads
- Docket No. FMCSA-2018-0037
- Comments closed May 10, 2018
- 82 comments submitted
  - 6 companies
  - 56 individuals
  - 20 organizations

Notable Commenters

- AV System Developers
  - Embark
  - Tesla
  - Uber
- Motor Carriers
  - Amazon
  - American Trucking Associations
  - National Motor Freight Traffic Association
  - National Tank Truck Carriers
  - The Trucking Alliance
- Driver Groups
  - AFL-CIO
  - Owner Operator Independent Drivers Association
  - Commercial Vehicle Training Association
- Insurance
  - Insurance Institute for Highway Safety
  - Property Casualty Insurers
  - Travelers
- Government / Public Safety
  - American Association of Motor Vehicle Administrators
  - Commercial Vehicle Safety Alliance
- Other
  - Competitive Enterprise Institute
  - MITRE Corporation
  - Motor and Equipment Manufacturers Association
  - Securing America's Energy Future
  - Truck and Engine Manufacturers Association

L4 Highway Driverless: Quick Fix!

- Embark, Waymo, and Uber argue that L4 Driverless can be considered legal via an interpretation of the existing regulations.
- Proposing that FMCSA issue such a clarifying interpretation.
- Would result in rapid deployment of L4 Highway Driverless.
- FMCSA considering this and other comments.

www.automatedvehiclessymposium.org

Session 5: Thought Questions

- How can the current truck driving workforce be integrated with automated/autonomous trucks? (ODD)
- What are the barriers to effective integration? (ODD)
- How can systems be designed and engineered to enhance the driver-automated/autonomous trucks interaction and interface? (EVEN)
- What are the skills needed to build these interfaces and effectively operate within these interfaces? (EVEN)

Session 6: Convergence of automated/autonomous trucks and human labor – job skills training/re-training challenges and strategies

Driverless?

Autonomous Trucks and the Future of the American Trucker

Steve Viscelli

University of Pennsylvania

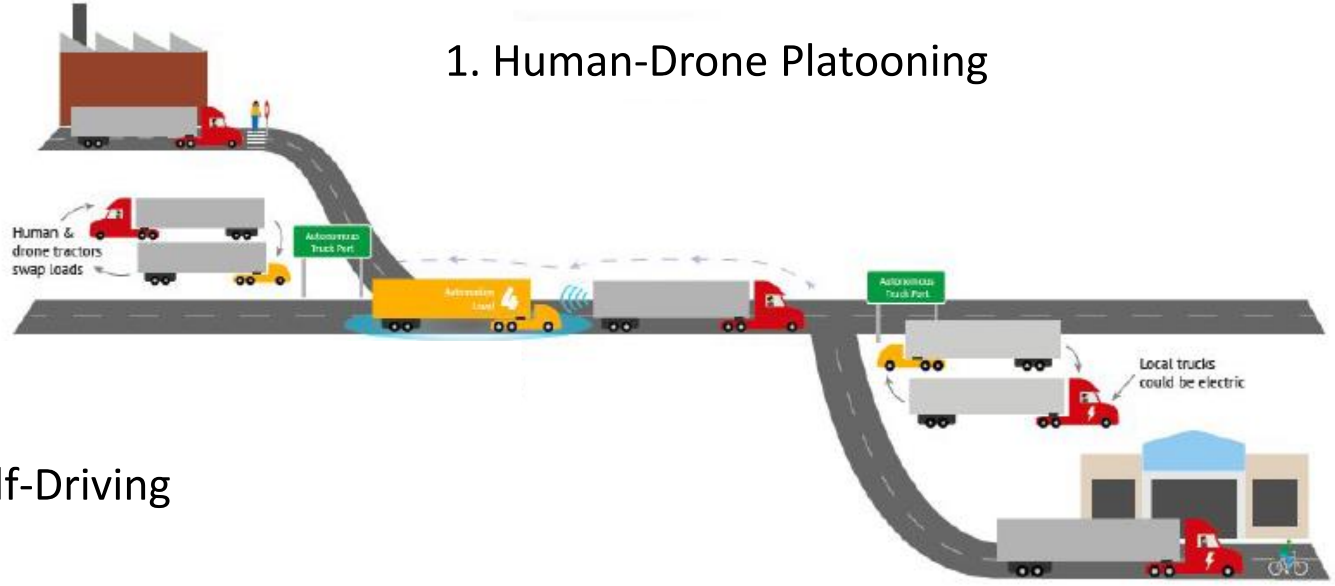
In order to know what workers might be affected and what to do for them, we need to take more seriously:

- The labor process and variations in it

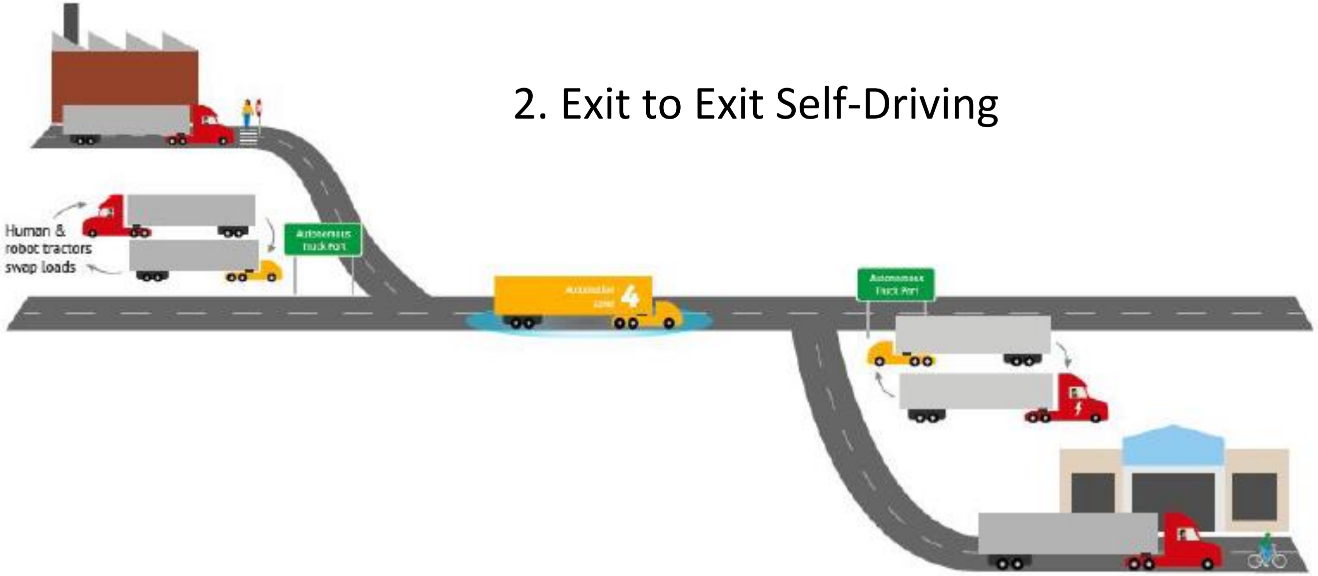
- The labor market and variations in it

Assumed Likely Tech Scenarios

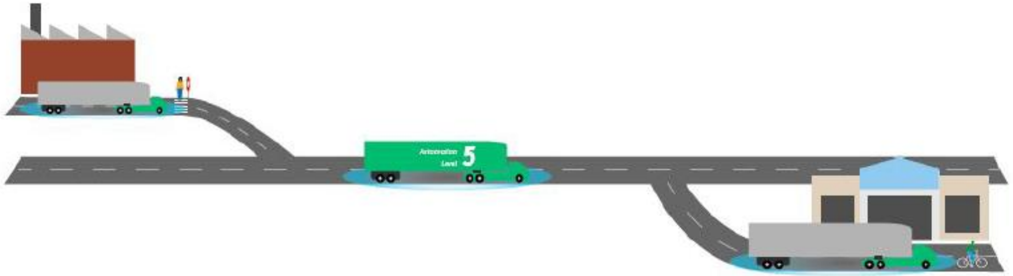
1. Human-Drone Platooning



2. Exit to Exit Self-Driving



3. Facility to Facility



Characteristics of Loads, Firms and Customers Relevant to AT Adoption by Industry Segments

	Primary Driving Environments	Uninterrupted Highway Driving	Non-driving Tasks	Primary Customer Facility Type	Route Regularity	Union Presence	Typical Carrier Size
Truckload Dry Freight	Highway	Extensive	Minimal	Warehouse	Moderate	None	Medium/ Very Large
Truckload Reefer	Highway	Extensive	Minimal	Warehouse	Moderate	None	Medium/ Large
Linehaul – LTL, Parcel, Private	Highway	Extensive	Minimal	Internal Terminal	High	High	Medium/ Very Large
Port Driving	Urban/ Highway	Minimal/ Significant	Minimal	Large Warehouse	Moderate to High	Low	Small
TL Specialized	Highway/ Complex	Significant/ Extensive	Significant/ Extensive	Varied Commercial	Varied	Low	Small/ Medium
Truckload Flatbed	Highway/ Complex	Extensive	Significant	Commercial/ Construction	Minimal	Low	Small/ Medium
Intermodal	Urban	Minimal	Minimal	Warehouse	Moderate	Varied	Small/ Medium
Local – Other	Local/Urban	Minimal	Significant/ Extensive	Varied	Varied	Varied	Small
Local Pick-up and Deliver – LTL and Parcel	Local/Urban	Minimal	Significant/ Extensive	Commercial or Residential	Varied	Varied	Very Large

<u>JOBS AT ANY RISK</u>

Using industry fleet numbers the number of long-haul drivers in each segment likely to adopt:

230,000 in for-hire truckload dry van and refrigerated
50,000 in linehaul within LTL operations
30,000 in linehaul for Parcel operations

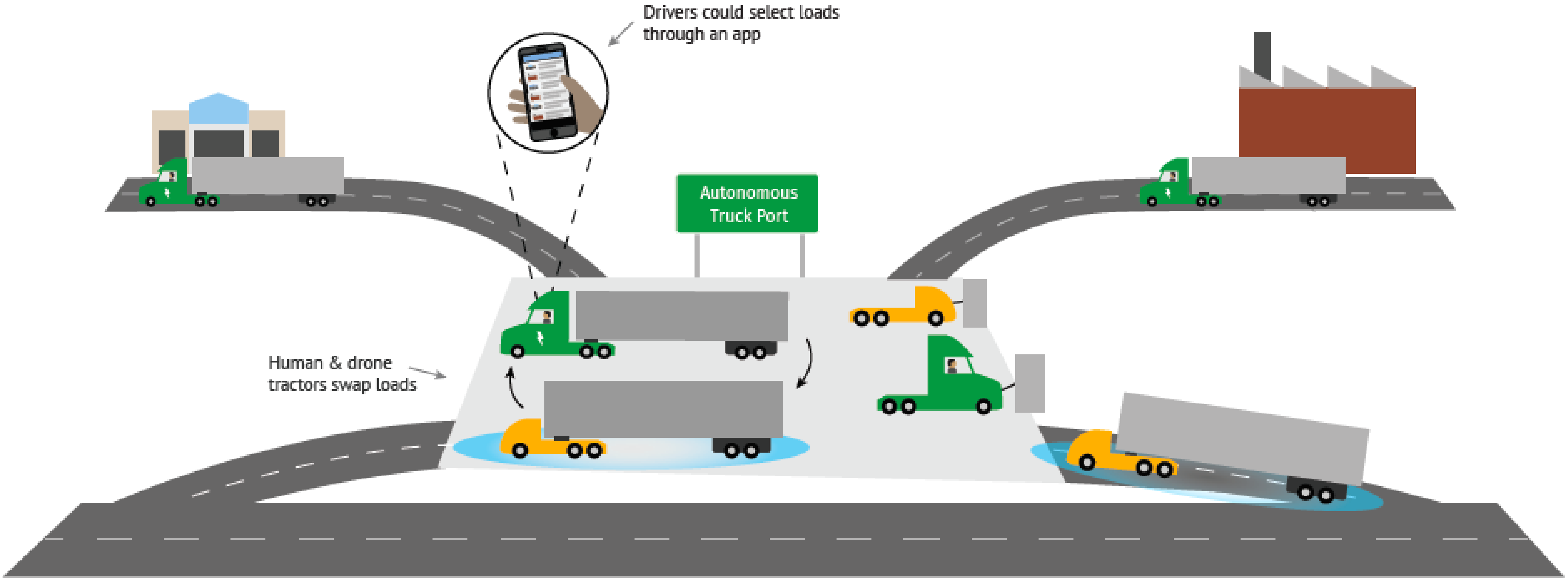
VERY ROUGH TOTAL:
310,000

<u>What would the history of trucking suggest?</u>

Decline in costs, increase in demand and demand for new kinds of services

Constellations of technologies and labor process transformation

Competition shakes-out non-adopters despite cost-cutting and cost-shifting


Drivers could select loads through an app
Autonomous Truck Port
Human & drone tractors swap loads

Photos: USA Today and
Alana Semuels

Likely Outcomes for Workers

- Net increase in jobs?
- More local driving jobs
- More deliveries as shopping time is turned into “last-mile” jobs
- More precarious and gig jobs
- Wages and working conditions will deteriorate where workers and regulation are weak (which is much of the industry)

It's Not Displaced Workers but Job Quality we need to be concerned about

- Develop apprenticeship training model instead publicly subsidized revolving door
- End the use of training contracts
- Count all hours on ELDs, including all hours on customer locations
- Institute industry-wide fees for all time spent on customer locations
- Establish a decent minimum wage as a floor for all hours worked
- Provide accurate wage and hour information to workers
- End worker misclassification

- Explore hiring hall model for drivers
- Explore driver co-ops for slip-seated operations

Autonomous Truck Workshop

Session 6, Part 2

Job Skills Training/Re-Training Challenges and Strategies

Randall W. Eberts

W.E. Upjohn Institute for Employment Research

Automation has four effects on labor markets

- Directly displace workers in the affected sector
  - E.g., autonomous trucks displacing truck drivers of same trucks
  - Rio Tinto mining company cut 200 jobs when it adopted ~100 autonomous trucks
- Create new jobs in new areas
  - Rio Tinto increased jobs in centralized control center
  - Developed a center in Brisbane with assistance of University of Queensland to analyze the multiple terabytes of data generated by Rio Tinto's processing plants
- Higher incomes (from productivity) increase demand for jobs throughout the economy
  - Hospitality and leisure sector has grown faster than overall economy
- Technology may replace specific tasks rather than entire jobs
  - Leaves room for human employment in jobs changed by worker having new tools
  - Calls for a redefining of occupations and a rearrangement of workplaces

Heavy and tractor-trailer truck drivers

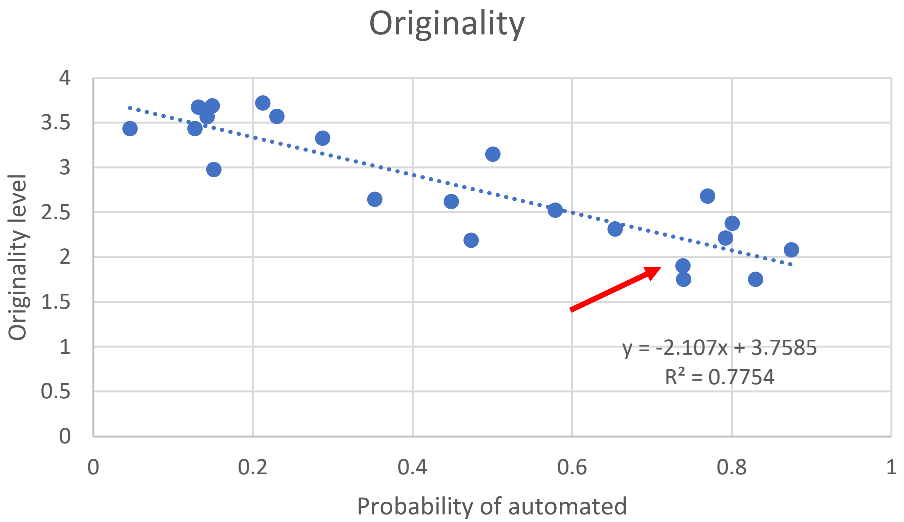
- US Department of Labor lists activities associated with each of more than 800 occupations (O*Net)
- For heavy truck drivers (SOC Code 53-3032), O*Net lists 26 distinct work activities
  - I found only half (13) of the activities are what one would typically think of as driving a truck—maintain vehicle in good working order and read maps to determine routes
  - Other less typical activities include—review documents or materials for compliance with policies and regulations and record operational or production data

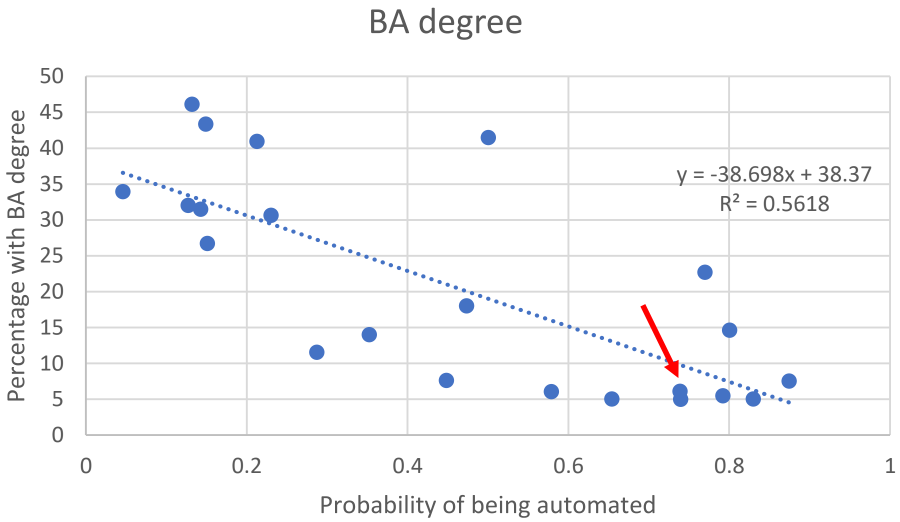
Probability of job being phased out

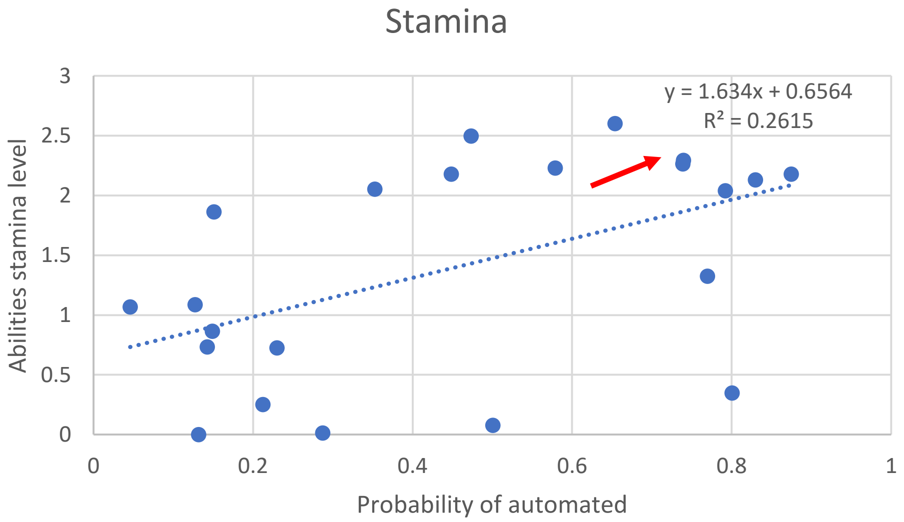
- Questions are:
  - What activities do truck drivers engage in that are not automatable?
  - What skills are possessed by truck drivers that cannot be automated (at least in near term)?
  - Can those skills be transferred to other occupations that are still in demand now and in the near term?
  - How to stay current on skills in demand?

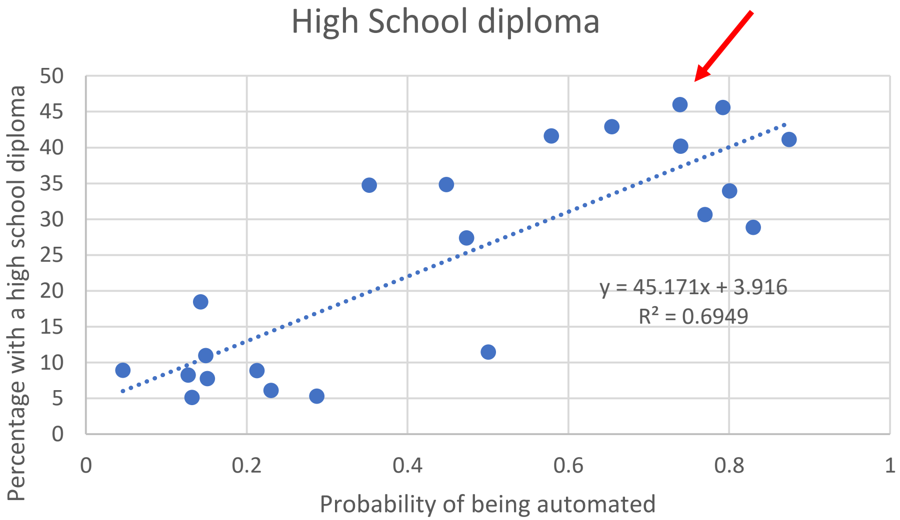
Estimating probability of job being automated

- Two British economists, using deep learning, have estimated the probability of jobs being automated for each of the USDOL occupation codes (Frey and Osborne, Oxford Martin School, September 17, 2013)
- Heavy truck drivers don’t fare that well—79 percent probability
- The average is 45 percent and the lowest is SOC Code 21—community and social service occupations (4.5%); the highest is 35—service and food preparation (87%)
  - Even within SOC Code 53, probabilities range from 2.9% to 98%
- These probabilities are related to work activities, abilities, and educational attainment









Note: Author's calculations using Frey and Osborne probabilities; arrows point to SOC Code 53.
Originality and stamina are two work abilities from O*Net.

Related Occupations

- All occupations related to truck driving, according to O*Net, are in the same broad SOC code of transportation occupations (53)
  - With an average probability of 73%
  - 42% high school grads, 11% BA degree, and a salary of $40,500
- To avoid displacement from automation, much better to be in occupations like finance, education, arts, and healthcare
  - All have average probabilities below 15%

What to do?

- Train for jobs that are not only in demand currently, but also are less likely to be automated in the near term
  - Short-term stackable modular curricula
  - Apprenticeships
  - Access to and willingness to engage in lifelong learning and training opportunities
- Adequate safety nets during periods of displacement
  - Job sharing to keep workers fully engaged in workplace
- Help businesses find ways to use their workers more effectively
  - Redefine occupations (driving from other “driving” activities) and rearrange workplace roles
  - Seek assistance from entities such as Manufacturing Extension Partnership
  - Form consortia of businesses within specific sectors, to share information

Session 6: Thought Questions

- What are the cross-disciplinary research challenges in designing new curricula for reskilling? Who can contribute to developing such modules?
- How can various groups (regulators, carriers, labor organizations, etc.) help truck drivers to reskill? Are there opportunities for public-private partnerships?

Next Steps

- ❑ Facilitator summary reports
- ❑ Review audio recordings
- ❑ Final comments to workshop attendees
- ❑ Develop report to NSF

Thank you!