CHAPTA: COLLABORATIVE HUMAN-AUTONOMOUS PLATOONED TRUCKS ALLIANCE

AN OUTLINE FOR AN INDUSTRY–SPONSORED RESEARCH CENTER

Steve Albert
Craig Shankwitz  Nic Ward

10 April 2017
What are we proposing?

- Multi-disciplinary, pre-competitive, industry-sponsored research alliance for collaborative human–autonomous platooned trucks (CHAPTA).
What is the CHAPTA goal?

- Bring together stakeholders to **cooperatively** and **quickly** bring hybrid driver – autonomous truck platoons to U.S. highways
  - Identify and address issues up front
    - Human Factors
    - Workforce Development
  - Promote U.S competitiveness
  - Ensure compatibility with existing highway traffic
### Key Objectives Include:

<table>
<thead>
<tr>
<th>Determine operating parameters &amp; conditions</th>
<th>Determine optimal driver personality type suited for platoons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determine maximum platoon size</td>
<td>Determine minimum number of humans $M$ to number of vehicles $N$</td>
</tr>
<tr>
<td>Determine V2V communication requirements</td>
<td>Determine information requirements for humans</td>
</tr>
<tr>
<td>Determine truck performance requirements</td>
<td>Determine educational needs for driving jobs displaced by technology</td>
</tr>
</tbody>
</table>

### Stakeholders Include:

<table>
<thead>
<tr>
<th>Fleet operators</th>
<th>Economists and financiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck OEMs, Tiered suppliers</td>
<td>Standards organizations</td>
</tr>
<tr>
<td>Technology providers (OTTO, Peloton)</td>
<td>FMCSA – US DOT, State DOTs</td>
</tr>
<tr>
<td>Insurance companies</td>
<td>Warehouses</td>
</tr>
<tr>
<td>Educators</td>
<td>Retailers</td>
</tr>
</tbody>
</table>
Why are we interested?

• Autonomy IS going to happen
  – Most prognosticators: within next decade

• Competitive forces from Asia and Europe
  – Technology gap – U.S. less competitive
    • Increasing issue with trade gaps / issues
    • Trucking is BIG business

• Present-day driver shortages
  – Will be worse in the future
  – Effects on U.S. Employment and U.S Economy
CHAPTA research focus

• Human Factors
  – How does the human interact with and within the platoon?

• Operations
  – How does the platoon interact with other traffic on public roads?
CHAPTA research focus

• Workforce Development
  – Driver recruitment, training, and retention

• Institutional issues
  – Perception that jobs are being “eliminated” vs. job shifts: robotics technician, first/last mile driving
CHAPTA research focus

• Important to note
  – vehicle guidance and control R&D is not the focus of the IUCRC
    • Work of other academics and private companies (OTTO, Peloton Technology)
  – CHAPTA develops pre-competitive human design insight, operational guidelines, and support for standards development
Why is this needed? Background

- Trucking is Big Business:
  - ~$117 BILLION industry moving freight 100-500 miles.
  - 65% of cost is fuel and driver salary/benefits
  - That’s $75.7B!

<table>
<thead>
<tr>
<th>Motor Carrier Costs</th>
<th>Per vehicle, per mile, 2015</th>
<th>ATRI Annual Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Costs</td>
<td>$0.45</td>
<td>$29,190,113,280.00</td>
</tr>
<tr>
<td>Truck/Trailer Lease or Purchase Payments</td>
<td>$0.27</td>
<td>$17,506,304,640.00</td>
</tr>
<tr>
<td>Repair &amp; Maintenance</td>
<td>$0.18</td>
<td>$11,321,520,000.00</td>
</tr>
<tr>
<td>Truck Insurance Premiums</td>
<td>$0.09</td>
<td>$5,770,740,480.00</td>
</tr>
<tr>
<td>Permits and Licenses</td>
<td>$0.02</td>
<td>$1,591,482,240.00</td>
</tr>
<tr>
<td>Tires</td>
<td>$0.05</td>
<td>$3,182,964,480.00</td>
</tr>
<tr>
<td>Tolls</td>
<td>$0.03</td>
<td>$1,772,626,560.00</td>
</tr>
<tr>
<td>Driver Wages</td>
<td>$0.58</td>
<td>$37,548,629,760.00</td>
</tr>
<tr>
<td>Driver Benefits</td>
<td>$0.14</td>
<td>$9,005,460,480.00</td>
</tr>
<tr>
<td>Totals</td>
<td>$1.81</td>
<td>$116,889,841,920.00</td>
</tr>
</tbody>
</table>

# Savings: Hybrid human-autonomous platoon

Number of humans in the 5-vehicle platoon.

<table>
<thead>
<tr>
<th>Cooperative Human - Truck Platooning: 5 Vehicle Platoon</th>
<th>Assumed Aerodynamic</th>
<th>Number of Humans in the Platoon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lead Truck</td>
<td>Followers</td>
</tr>
<tr>
<td>Percentage of total operating costs saved - fuel economy and labor savings</td>
<td>5%</td>
<td>10% / 20%</td>
</tr>
</tbody>
</table>
The European Truck Platooning Challenge, organized by Rijkswaterstaat this spring, involved trucks from DAF Trucks, Daimler Trucks, Iveco, MAN Truck & Bus, Scania and Volvo, in the first ever truck platooning across national borders.
Singapore to trial truck platooning with Scania and Toyota

Singapore’s Ministry of Transport (MOT) and the Port of Singapore Authority (PSA Corporation) have signed agreements with two automotive companies, Scania and Toyota Tsusho, to design, develop and testbed an autonomous truck platooning system for use on the city-state’s public roads.

HOW IT WORKS

- Driver in first container truck leading 3 driverless trucks
- Incorporates vehicle detection, anti-collision and lateral control technologies for safety
- Coupling and de-coupling to allow other road users to cross between platoon vehicles
- Lead vehicle linked to the platoon via wireless communications

U.S. platoon programs: U Cal Berkeley

Three Trucks Equipped for CACC

- ACC + DSRC + modified vehicle following control
- Supplementary Information Display for driver

U.S. platoon programs : Auburn U.

Phase I Results

- Business case analysis
  - ATRI survey; finding platoon partners
- Vehicle and aerodynamics simulation/analysis
  - Following vehicle sees large drag reduction, even at larger distances
- Traffic modeling
  - No delays; improvement at headways <1.25 / 60% penetration

http://eng.auburn.edu/~dmbevly/FHWA_AU_TRUCK_EAR/FHWA_AuburnDATP_Phase1FinalReport

Only two trucks, both human occupied.

Phase Two (Underway; Early 2016 Complete)

- Testing
  - Track; on-road; wireless performance
- Aerodynamics
  - Model refinement based on track test results
  - Effects of lateral offset by rear truck
  - Collecting data via “coast down” testing to further refine model
- Platoon Formation
  - Taking into account different fuel economy benefits for leader vs. follower
  - Examining protocols for platoon formation based on braking ability
- Traffic Impacts
  - Addressing entry/exit factors and non-interstate highways via simulation

U.S. platoon programs : TTI

Sponsor
TxDOT through funding from FHWA

Research Team
• TTI
• Ricardo
• Texas A&M Department of Mechanical Engineering

In-Kind Partners
• Navistar
• Bendix
• ZF-TRW
• Denso International Americas
• Great Dane Trailers
• Lytx
• ARGONNE National Labs
• US Army TARDEC
Drivers

- Shortages
- Turnover
- Expense

Drivers (cont’d)

Truck driving is the most common profession in the majority of the states in the U.S.

Autonomy will have a HUGE impact on the U.S. economy, not only in freight transport costs, but jobs, job loss, education, and training.

Most common job in every U.S. state, state-by-state.

http://www.npr.org/sections/money/2015/02/05/382664837/map-the-most-common-job-in-every-state
Human factors- example research questions

• Personality suited for platoons.
  – What personalities are well-suited for platoon operations?
    • Determination of personality type.
    • How to recruit that personality?
    • How to screen?

• Cueing to promote trust.
  – How should the autonomous trucks “behave” in the platoon to make humans comfortable?
Human factors- example research questions

• Information
  – How should that information be distributed amongst the human drivers?
  – How much information can be handled by a human driver?
  – How frequently should information be provided?
  – What modalities should be used?
Operations - example research questions

• What is the minimum ratio of humans to autonomous vehicles for an operational human-robotic platoon?
  – How does this ratio change with increasing platoon size?

• Size
  – What is the maximum size of a workable platoon considering
    • Human workload
    • Economics
    • Safety
Operations – example research questions

• In what position within the platoon should the human drivers be located?
• How to arrange lower performing (braking/acceleration) vehicles in front of the platoon?
• How does the size of the platoon affect non-platooned traffic WRT efficiency and safety?
  – Size limitations on platoons
  – Specific behavior at entrance and exit ramps
Workforce development – example research questions

• Driver training and retention
  – How to (re)train existing drivers to operate/supervise a cooperative human – autonomous truck platoon?
  – How to attract and retain drivers who are well suited to operate a cooperative human – autonomous truck platoon?
Institutional issues – example research questions

• Perception that jobs are being “eliminated”
  – How to message driver shortage?
  – Future driver demand based on deployment models.

• Insurance and Liability
  – Liability limits – greater than human-driven vehicles?
  – Special considerations? Lead truck, following truck(s), last truck?
Montana State Qualifications

• Technical Expertise:
  – Nic Ward, Human Factors, Health and Safety Culture
  – Craig Shankwitz, Autonomous and Connected Vehicles

• Facilities
  – Driving simulators
    • Supports workload, information, cueing, personality studies
  – TRANSCEND test facility
    • Supports controlled testing of actual vehicles
    • *In-situ* testing on adjacent roads.
(Partial) List of Relevant Driving Simulator Studies:
— Personality evaluation
— Safe/comfortable distance to vehicle ahead
— Information Studies
  • Modality studies
  • Frequency of information
  • Content of information
  • Distribution of information amongst drivers
— Operational Studies
  • Where should humans be located in the platoon?
  • How large of a platoon can a human operator handle?
Validation studies
— Controlled Traffic Environment
  • High Speeds
  • Low Speeds
— Atmospheric conditions
  • Snow makers
  • Rain Makers
  • Mist Makers
— Pavement conditions
  • Dry
  • Wet
  • Snow covered
  • Ice covered

Operational Studies
— Size of platoon
— Platoon vehicle performance requirements
— Non-platoon vehicle interaction with the platoon
Governance

<table>
<thead>
<tr>
<th>Participant Level</th>
<th>Annual Fees</th>
<th>Number of Votes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platinum</td>
<td>$50,000</td>
<td>4</td>
</tr>
<tr>
<td>Gold</td>
<td>$40,000</td>
<td>3</td>
</tr>
<tr>
<td>Silver</td>
<td>$30,000</td>
<td>2</td>
</tr>
<tr>
<td>Bronze</td>
<td>$20,000</td>
<td>1</td>
</tr>
</tbody>
</table>
CONTACTS

Steve Albert
stevea@montana.edu
406-994-6114

Nic Ward
nward@montana.edu
406 994 7218

Craig Shankwitz
craig.shankwitz@montana.edu
406 994 6030