Partial Automation for Truck Platooning

X. Y. Lu, C. Nowakowski, and S.E. Shladover, California PATH Program, University of California, Berkeley
D. Thompson, S. Bergquist, and A. Kailas, Volvo Group
M. Hanson, California Department of Transportation
O. Altan, Federal Highway Administration

Background

- Funded under FHWA Exploratory Advanced Research Program solicitation, Spring 2013
- Use Cooperative Adaptive Cruise Control (CACC) with DSRC for V2V communication to enable closer vehicle following than Adaptive Cruise Control (ACC) for:
  - Increased throughput while maintaining safety
  - Reductions in fuel use and emissions

CACC vs. Truck Platooning

- CACC Represents SAE / NHTSA Level 1 Automation
- Driver responsible for monitoring traffic
- Driver responsible for active steering
- Platooning Generally Represents SAE Level 2+ Automation
- Automated steering needed at short gaps because of forward visibility limitations

CACC Operational Functions

- Developed activity diagrams for CACC maneuvers
- Driver action requirements
- Driver information display requirements
- Coordination algorithm requirements
- V2V communication requirements
- Considered abnormal operating conditions
  - Loss of V2V comm. reverts to ACC & splits the string
  - Accelerator pedal override in a following truck may need to be limited & ignored by subsequent trucks for stability
  - Coordinated obstacle avoidance is an unresolved issue

CACC String Formation Maneuvers

- Lead truck can be driven manually or in ACC
- Truck order by could factor in location, destination, performance, or preference, but new trucks must always join from the rear
- Local coordination could be used to match CACC-equipped trucks and guide them, but the join procedure is still ad hoc.

CACC String Split Maneuvers

- Trucks depart a string by changing lanes
- Middle truck braking or deactivating CACC splits the string
- Cut-ins by unequipped vehicles split the string (shown below)

CACC Control System Structure

- Driver
  - Manual Driving
  - CACC Enabled
  - CACC On/Engaged
  - CACC Enabled
  - CACC MSGs
  - BSM
  - CACC Send MSG

- Follower
  - CACC On/Engaged
  - Opt. ACC Engaged
  - Opt. Safe Distance
  - Opt. Safe Speed

- Coordinator
  - Driver Confirmation
  - Vehicle / String Status
  - Vehicle Status
  - String Status
  - String Length
  - String ID
  - String Position
  - String Length

- Coordinator
  - Join Request
  - Suggested Speed
  - Suggested Distance
  - Suggested Gap
  - Suggested Lane Change

- Coordinator
  - Vehicle / String Status
  - String Status
  - String Length
  - String ID
  - String Position
  - String Length

- Coordinator
  - Requested Speed
  - Requested Distance
  - Requested Gap
  - Requested Lane Change

- Coordinator
  - Opt. ACC Engaged
  - Opt. Safe Distance
  - Opt. Safe Speed

- Coordinator
  - Opt. ACC Engaged
  - Opt. Safe Distance
  - Opt. Safe Speed

- Coordinator
  - Opt. ACC Engaged
  - Opt. Safe Distance
  - Opt. Safe Speed

Truck Dynamic Modeling and Control

- Preliminary Low Speed Test Results
  - CACC MSG (New Leader)
  - Following In Front of the String
  - String Length
  - String ID
  - String Position
  - String ID
  - String Position
  - String Length
  - String ID
  - String Position
  - String Length
  - String ID
  - String Position
  - String Length
  - String ID
  - String Position
  - String Length
  - String ID
  - String Position
  - String Length
  - String ID
  - String Position
  - String Length
  - String ID
  - String Position
  - String Length
  - String ID
  - String Position
  - String Length

Next Steps

- Extend CACC control string from 2 to 3 trucks
- Refine control strategy to ensure string stability
- Extend CACC control to highway speeds
- Design Supplementary Information Display (SID) for drivers
- Evaluate SID alternatives in driving simulator
- Test driver preferences among gap settings on highway
- Measure energy savings at preferred gap settings