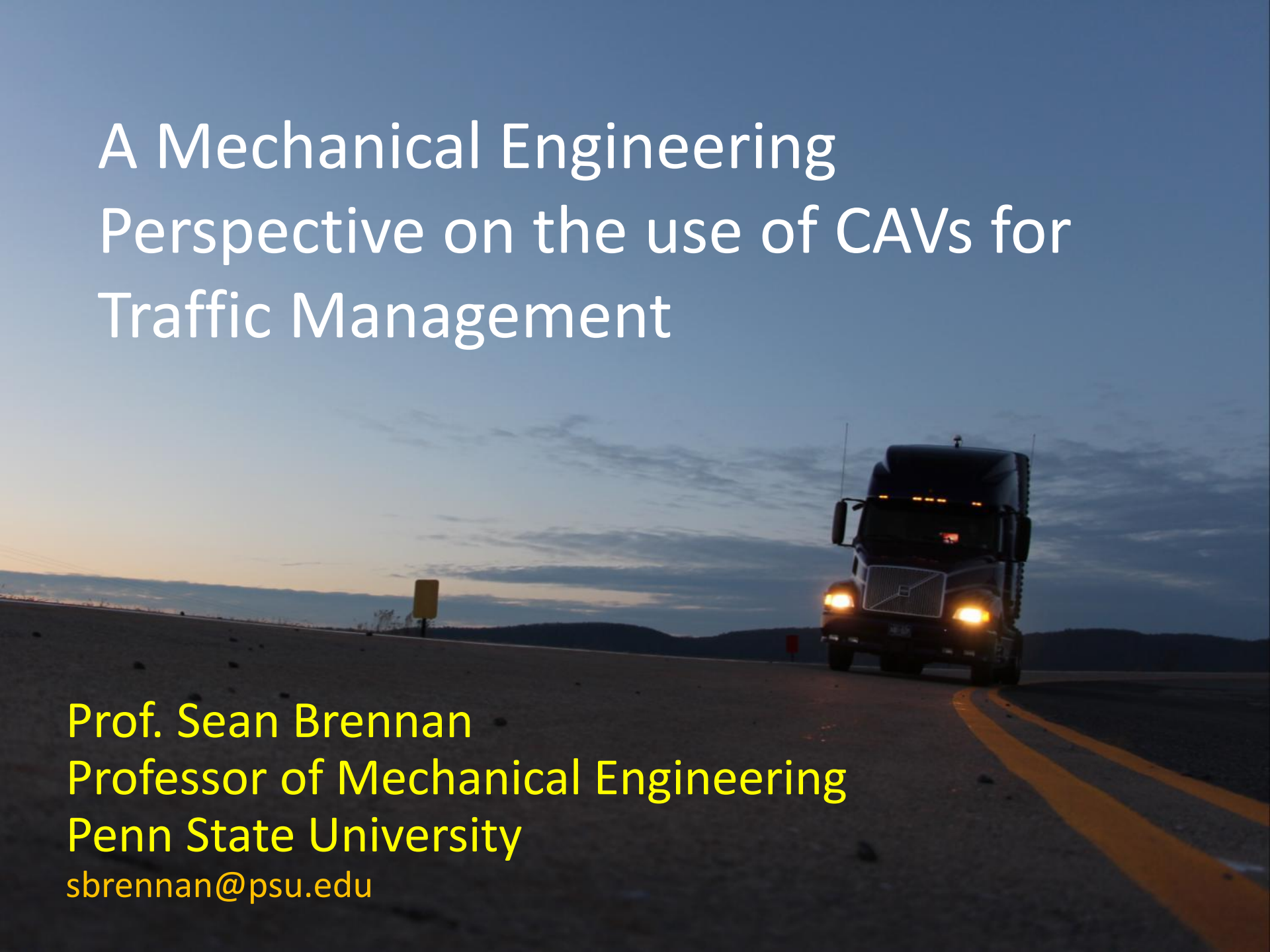
A Mechanical Engineering Perspective on the use of CAVs for Traffic Management



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There are many challenges for research on transportation automation

Congestion

Environmental Impact

Driver Distraction

Aging Drivers

Just-in-time Delivery

Changing Ownership Patterns

To lay out my cards first: I feel that automation and connectivity might not be the silver bullet

Congestion

Environmental Impact

Driver Distraction

Aging Drivers

Just-in-time Delivery

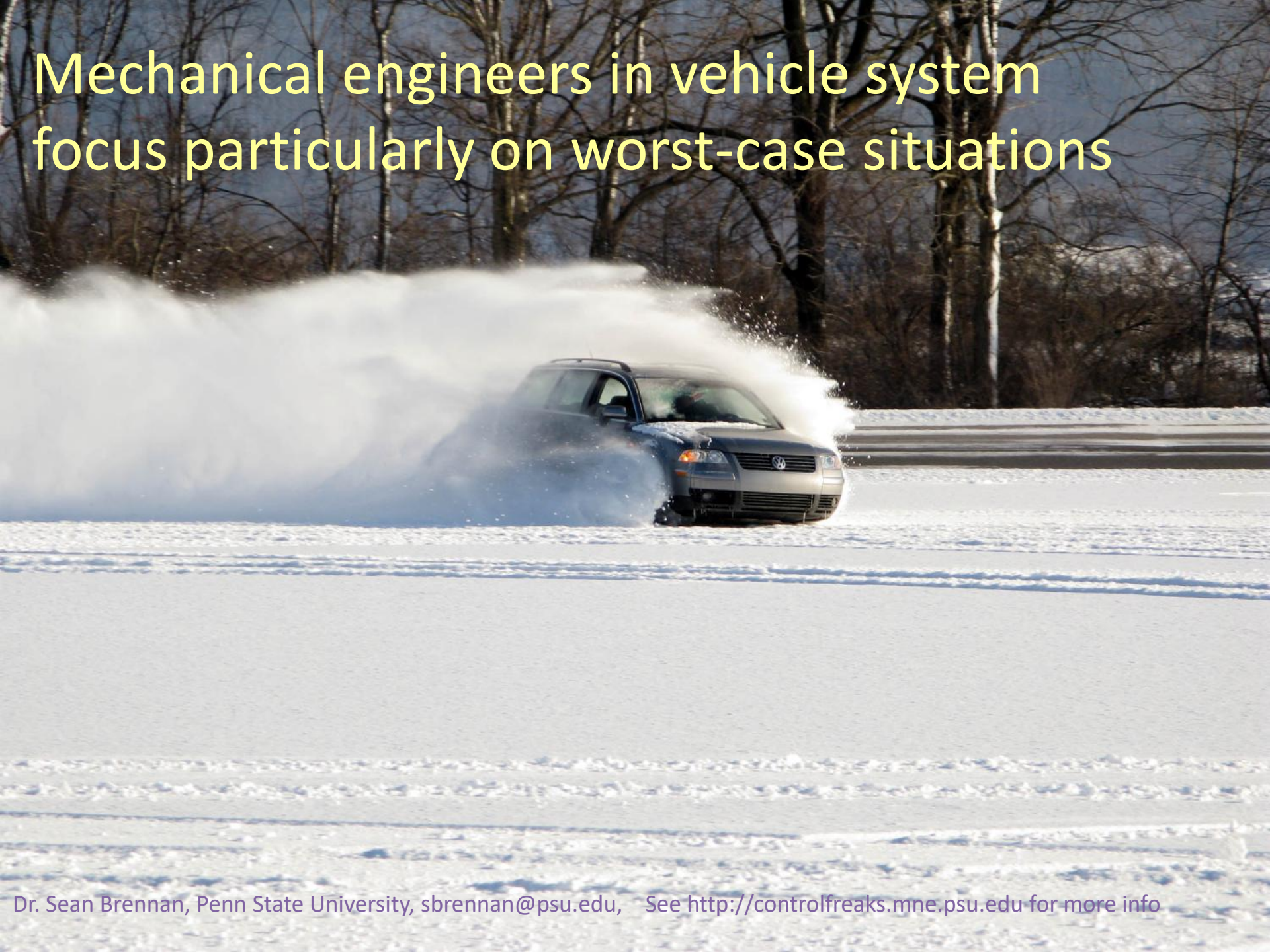
Changing Ownership Patterns

Before beginning, I want to recognize the amazing group of student colleagues who have helped with this transportation research.

Dr. Sean Brennan, Penn State University, sbrennan@psu.edu, See http://controlfreaks.mne.psu.edu for more info

Good model fits require good experiments, so we use a test track…

Mechanical engineers in vehicle system focus particularly on worst-case situations



Dr. Sean Brennan, Penn State University, sbrennan@psu.edu, See http://controlfreaks.mne.psu.edu for more info

Most instabilities studied in my field are treated as single-vehicle events

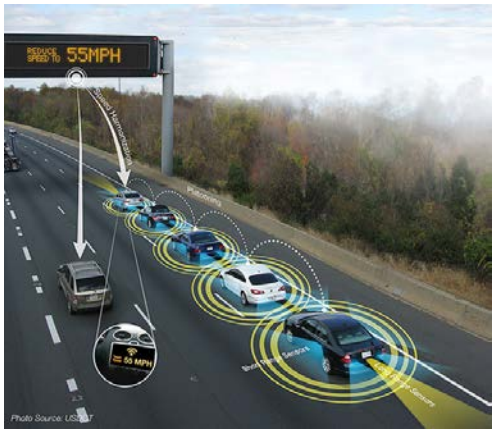
(but… no rollovers will be discussed in this talk. Sorry!)

S. Lapapong, A Brown, K. Swanson and S. Brennan "Zero-Moment Point Determination of Worst Case Maneuvers Leading to Vehicle Wheel Lift," International Journal of Vehicle System Dynamics. Vol. 50, p. 191-214. 2012.

This talk seeks to present the problem, potential solutions, and current research challenges in the area of CAV-mediated traffic

Problem

Solutions



Open Challenges

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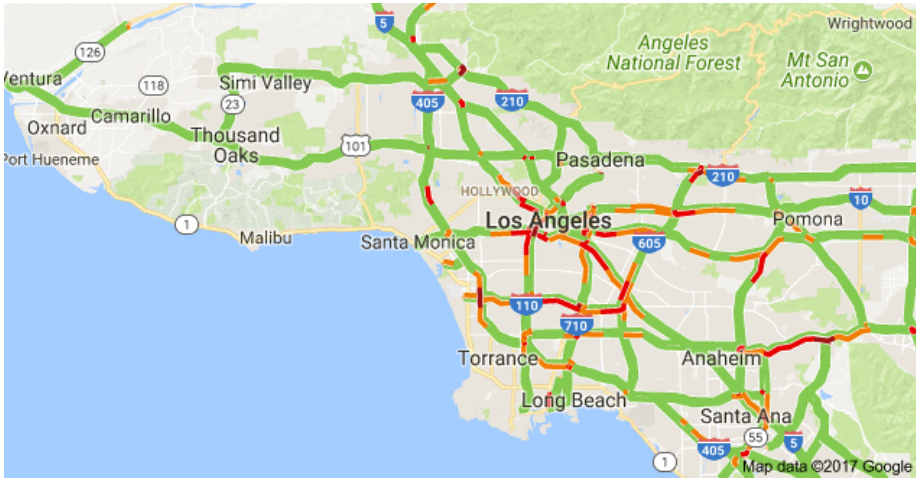
A large motivation for CAVs is that lane-miles are difficult to impossible to add in dense city environments

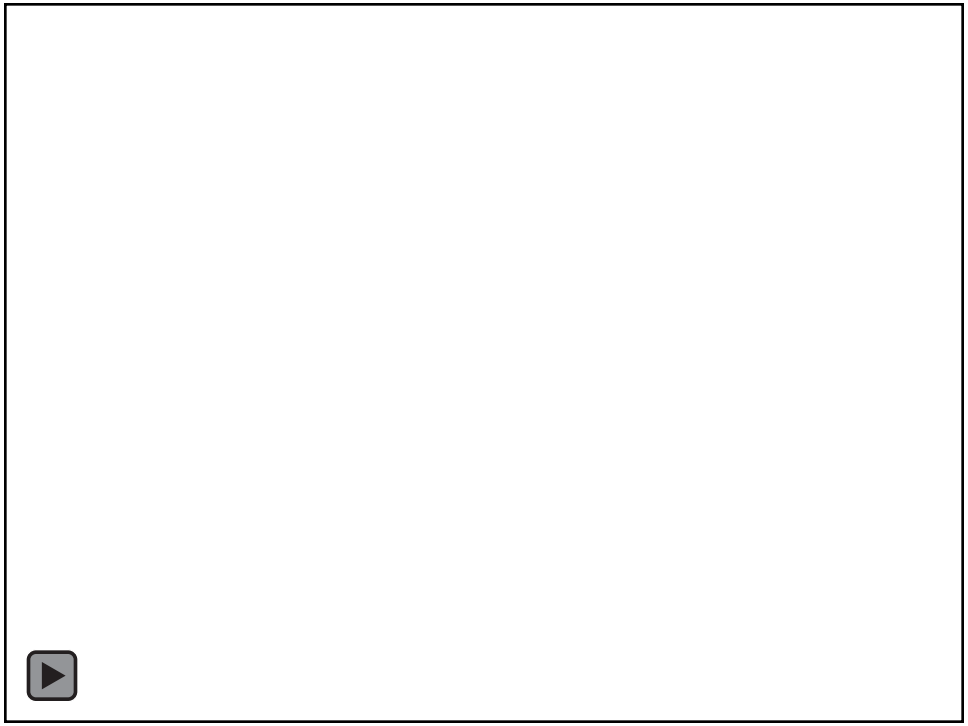
Typical estimates are that each lane-mile requires $2M to $10M.

I've been told that, for very dense environs, this can be $1B/lane mile

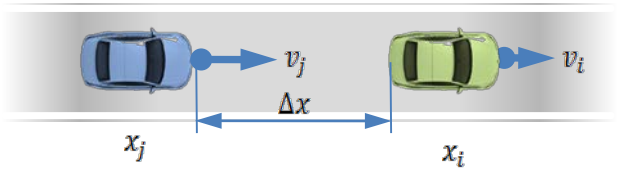


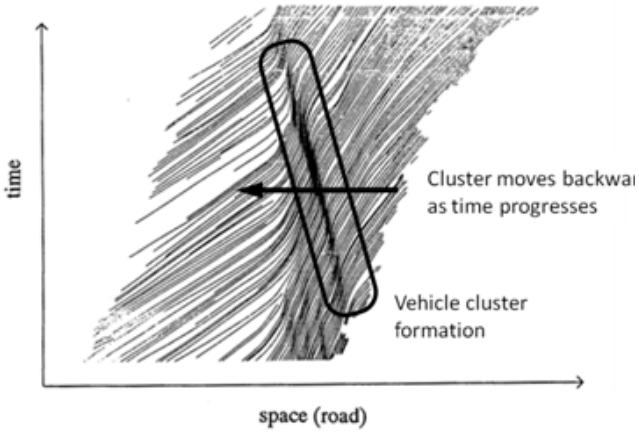
https://mobility.tamu.edu/mip/strategies-pdfs/added-capacity/technical-summary/adding-new-lanes-or-roads-4-pg.pdf

CAVs offer huge opportunities for traffic management in urban environments, particularly with smart intersections

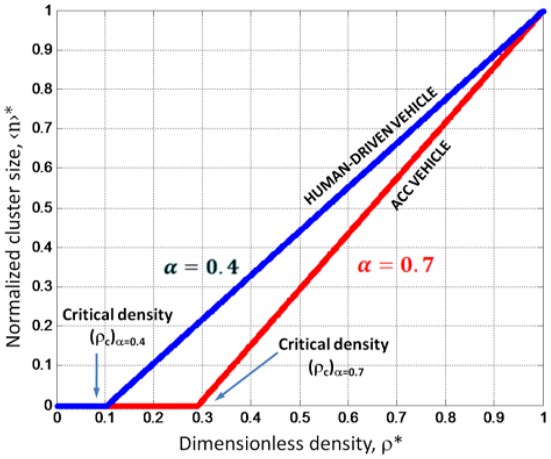


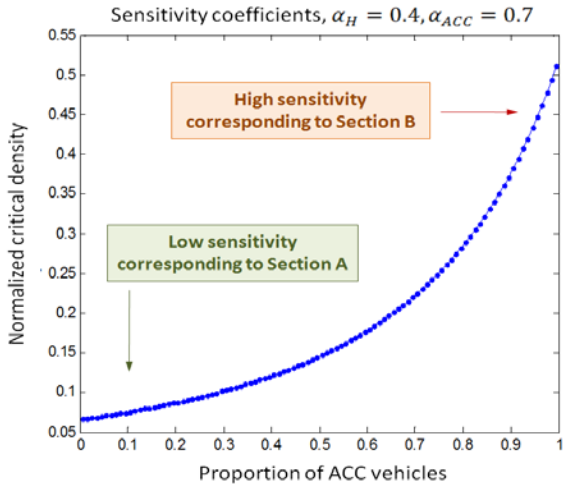
Another option is to attempt to increase density by closing inter-vehicle spacing, but this is limited by emergent dynamics such as traffic jams

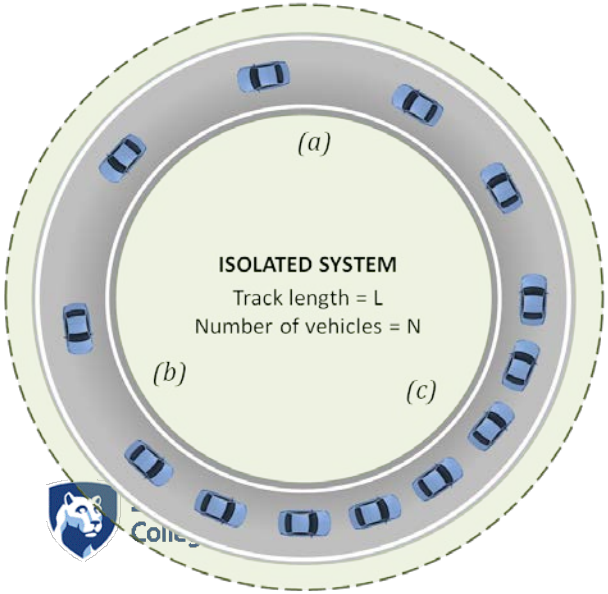




It is known that CAVs can smooth traffic flow, both in theory and in experiement

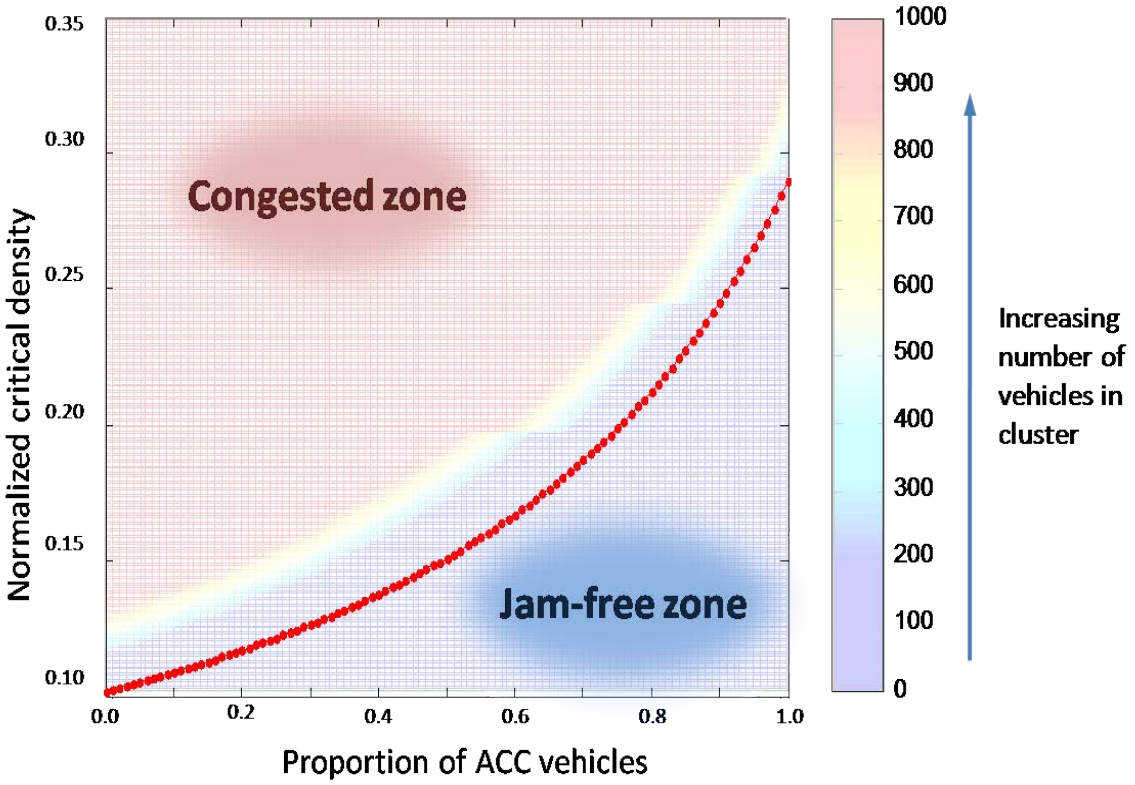




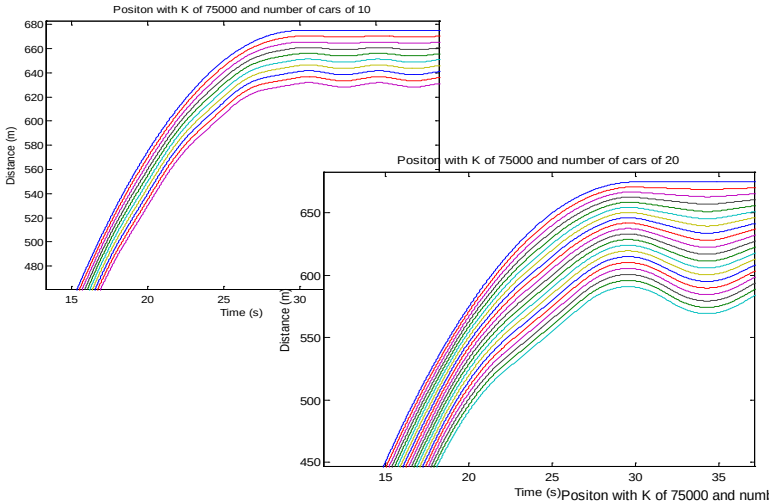


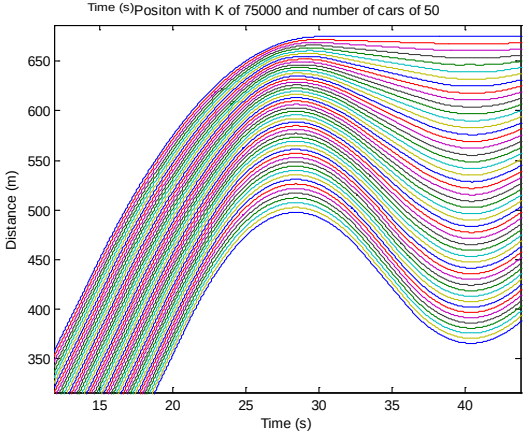
Recent work at UIUC

Automation gives 3X throughput, but with 10X the sensitivity to bad drivers



Another way to mitigate traffic is to move vehicles in platoons, but other emergent behavior arises – the “slinky” instability.



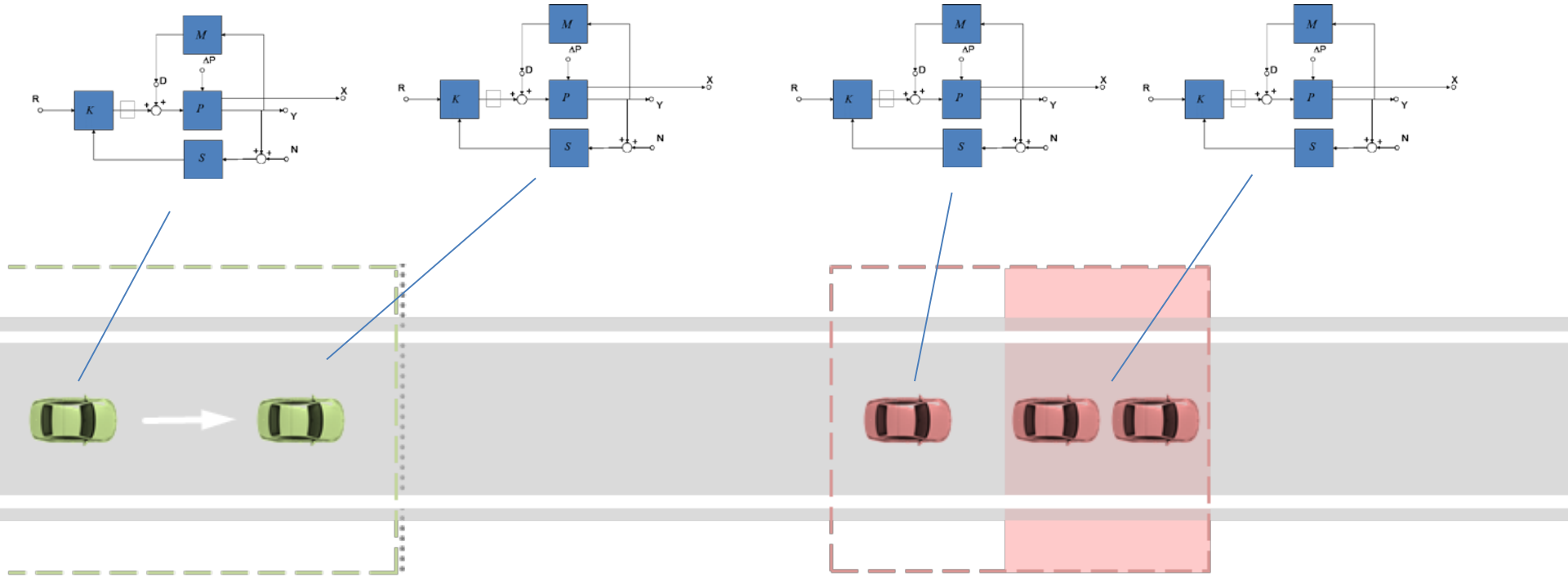


As the platoon gets large, get growing oscillations and overshoot. Vehicle trajectories in the back can cause discomfort and even “negative spacing distances”.

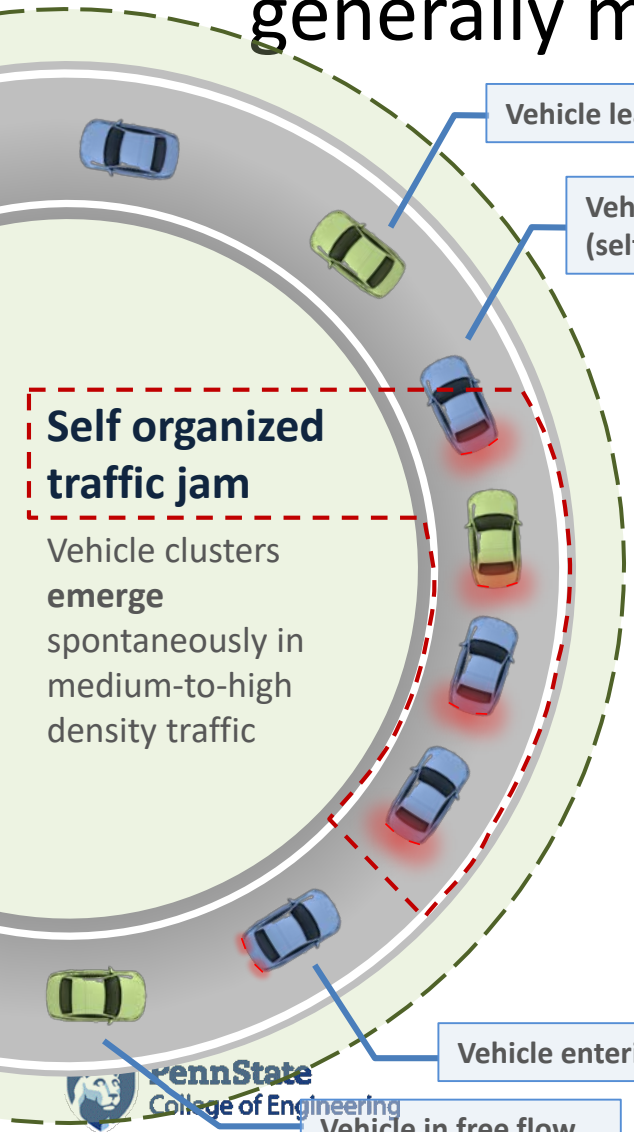
A challenge with tightly spaced vehicle convoys is that they can make choke-points worse

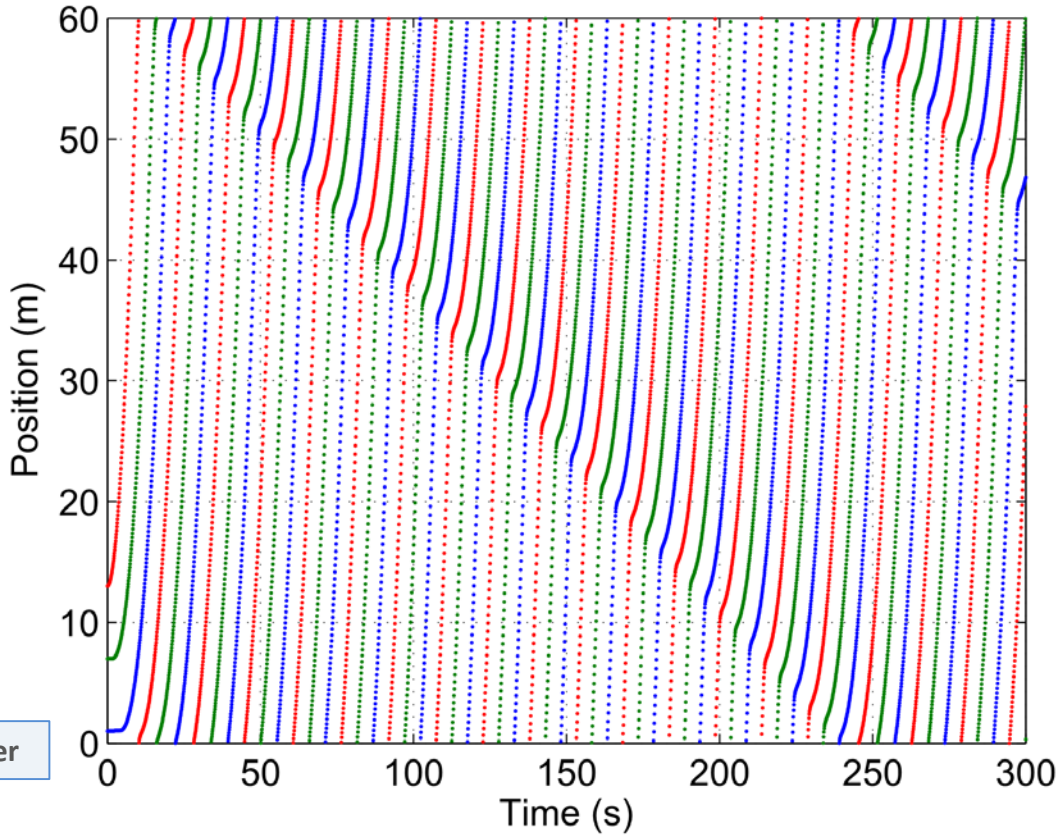
Platoons of vehicles have to be carefully managed around interchanges of roads, and around crashes. This will require infrastructure-scale coordination (V2I), and not just V2V

A challenge with managing flow of CAVs is that the most difficult behaviors to model are the ones we want to control: the transition from free-flow to congested flow



Self-organized traffic jams occur as a result of nonlinear driver behavior, and are generally modeled independent of location





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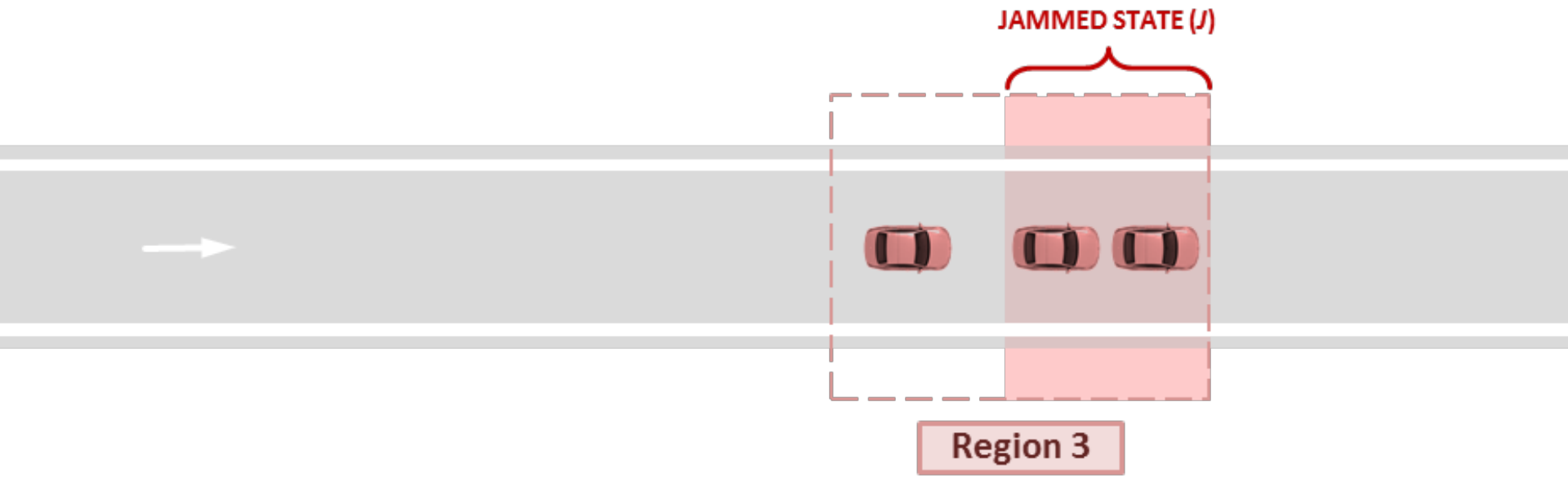
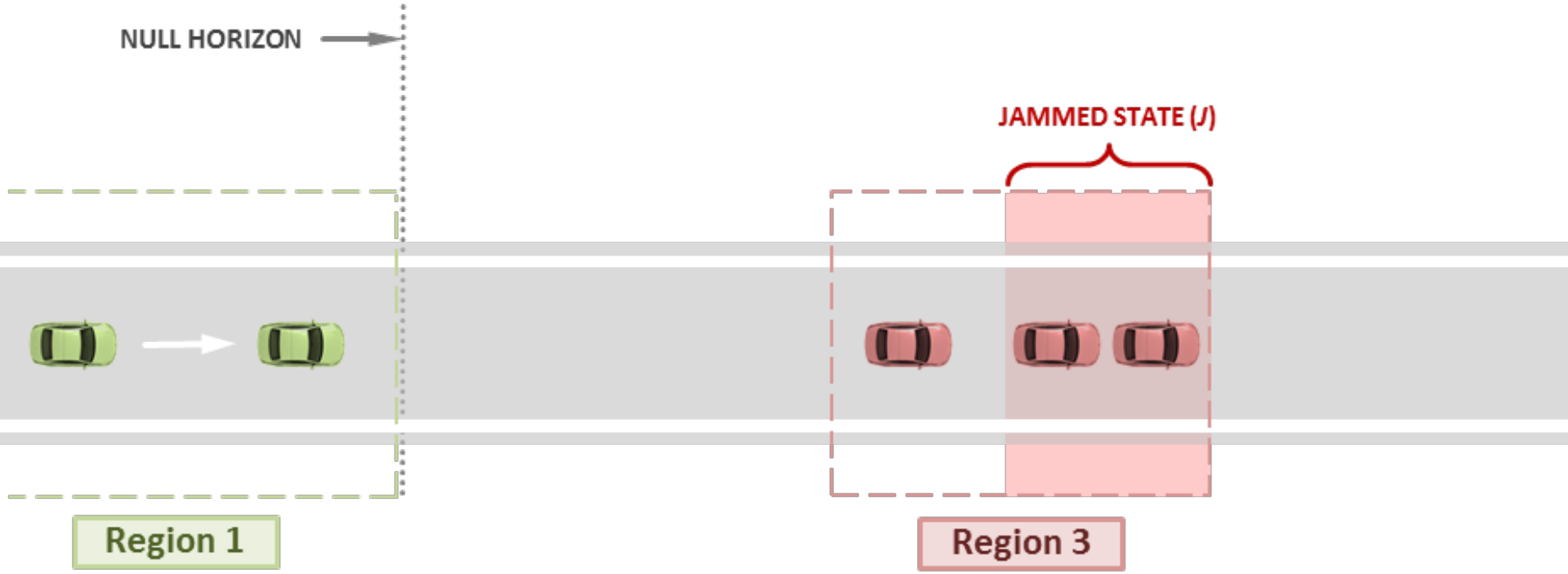
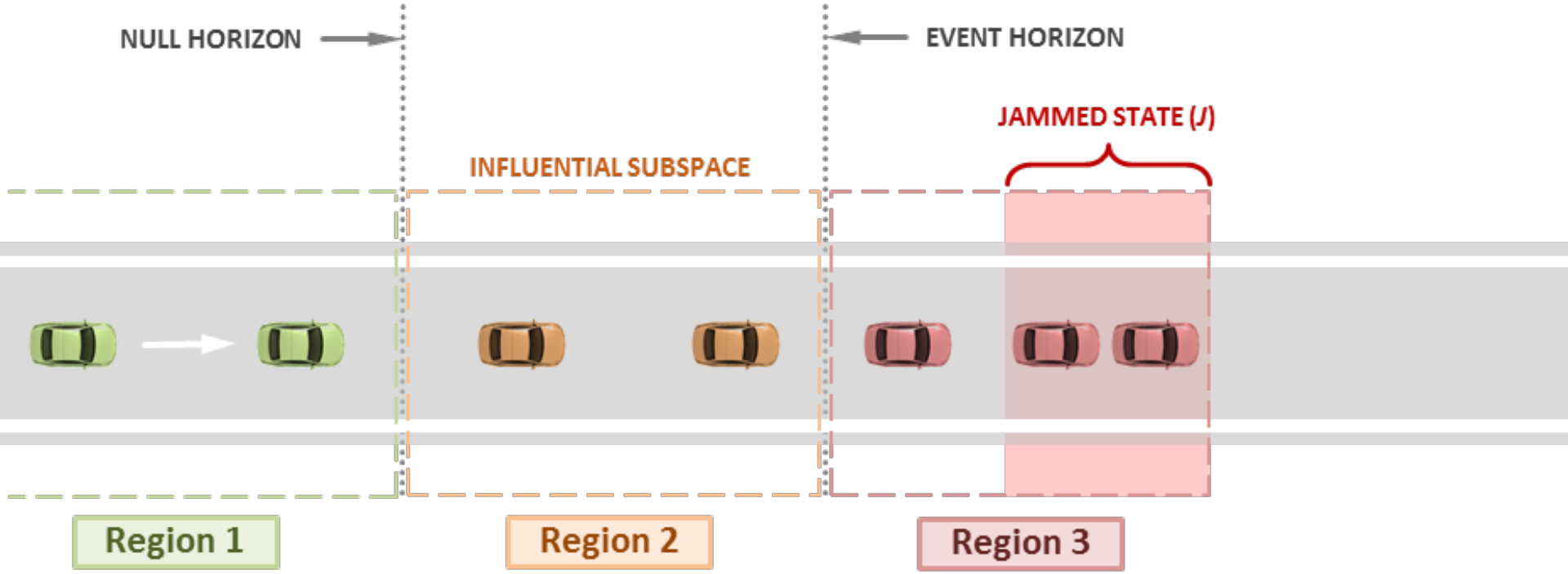
Research is showing that global behavior can be influenced by individual drivers, but only **in certain locations**



And the location is not nearby congestion (event horizon), nor far away (null horizon)

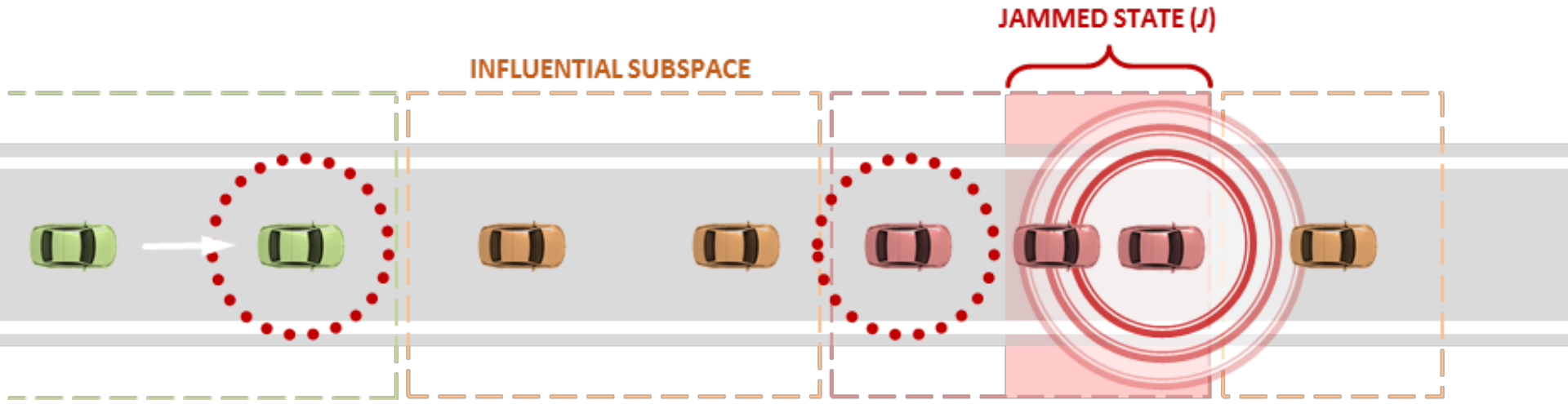


For emergent behavior in highway traffic, the influential subspace appears to occur several miles away from congestion

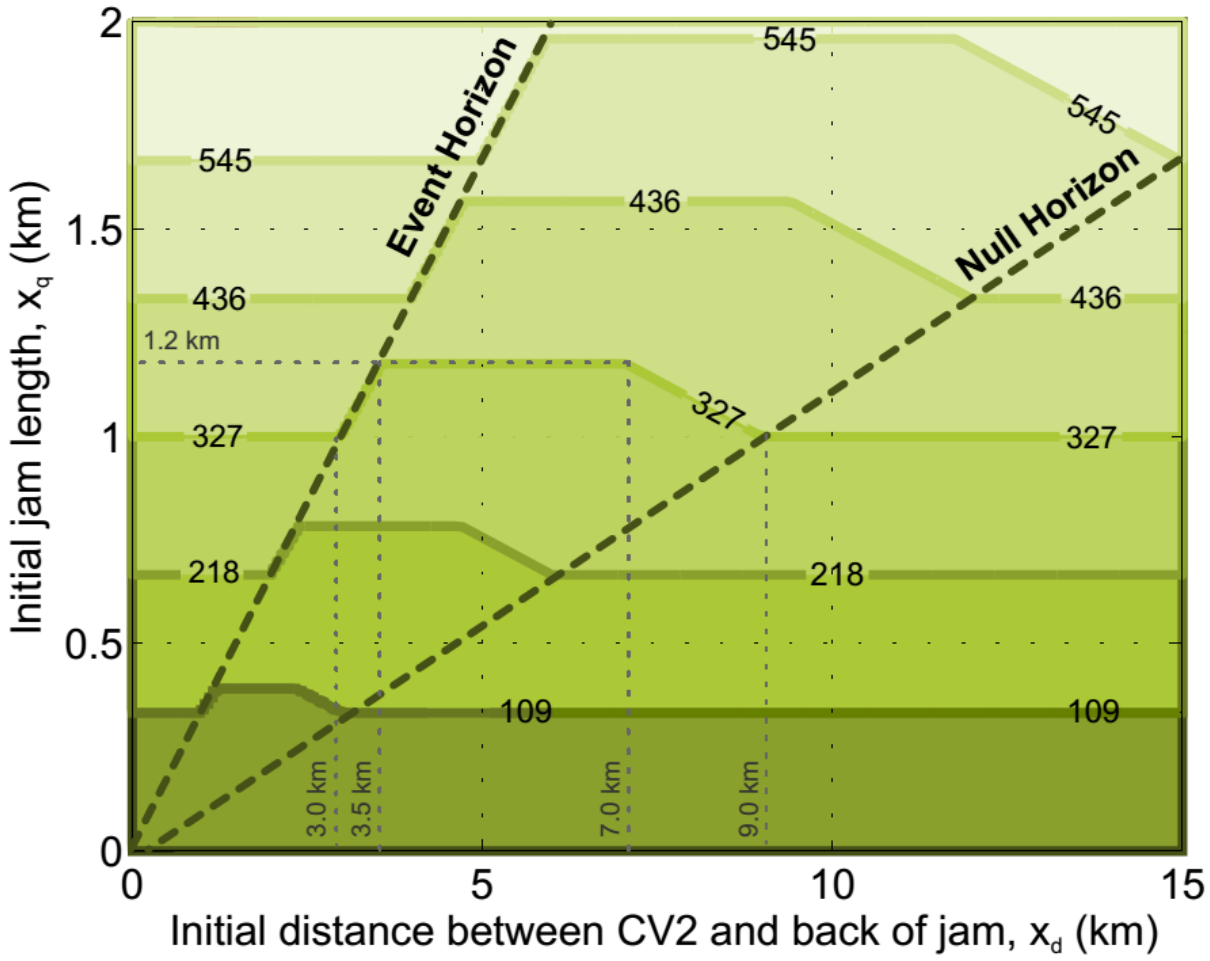


Why are influential subspaces of interest?

- Bandwidth utilization
- Route planning
- Determining locations of V2I infrastructure



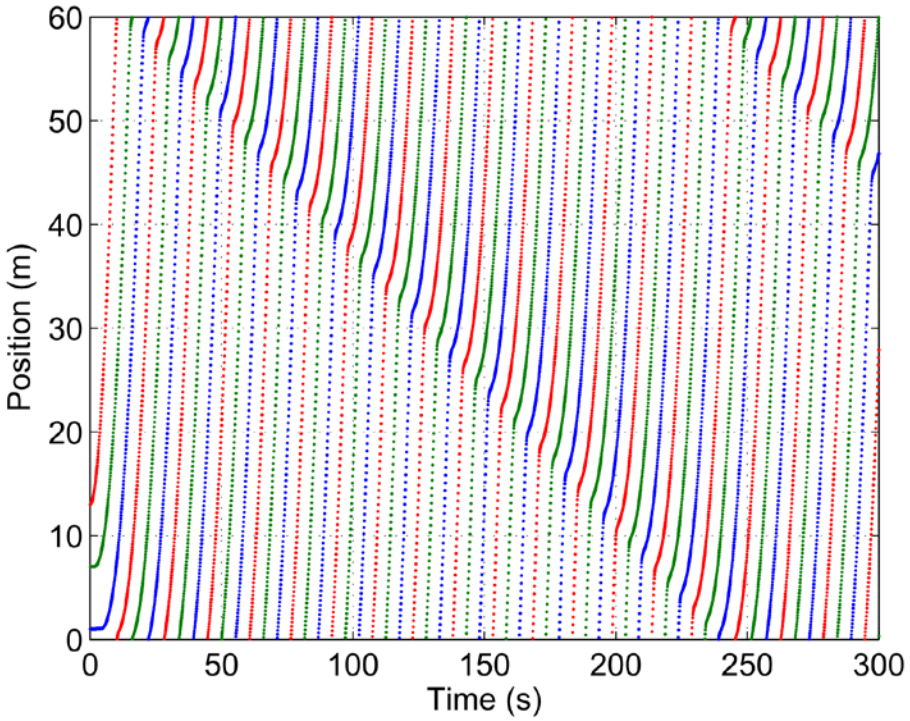
Communication between connected vehicles must occur across **several kilometers**

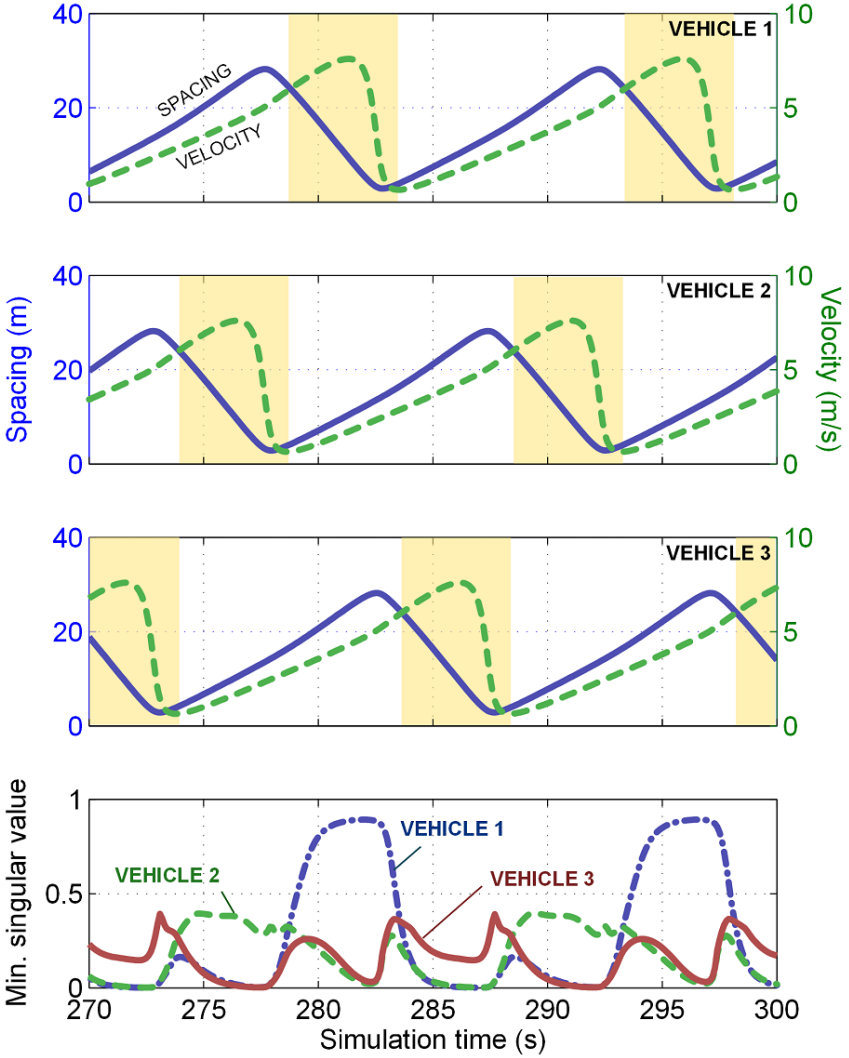


Result from unpublished work presented in

Event Horizons and Influential Subspaces of Connected Vehicles

Spatial dependence of influence can be derived from low-order model nonlinear model reductions (2015 ACC)





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But CAVs may introduce other problems

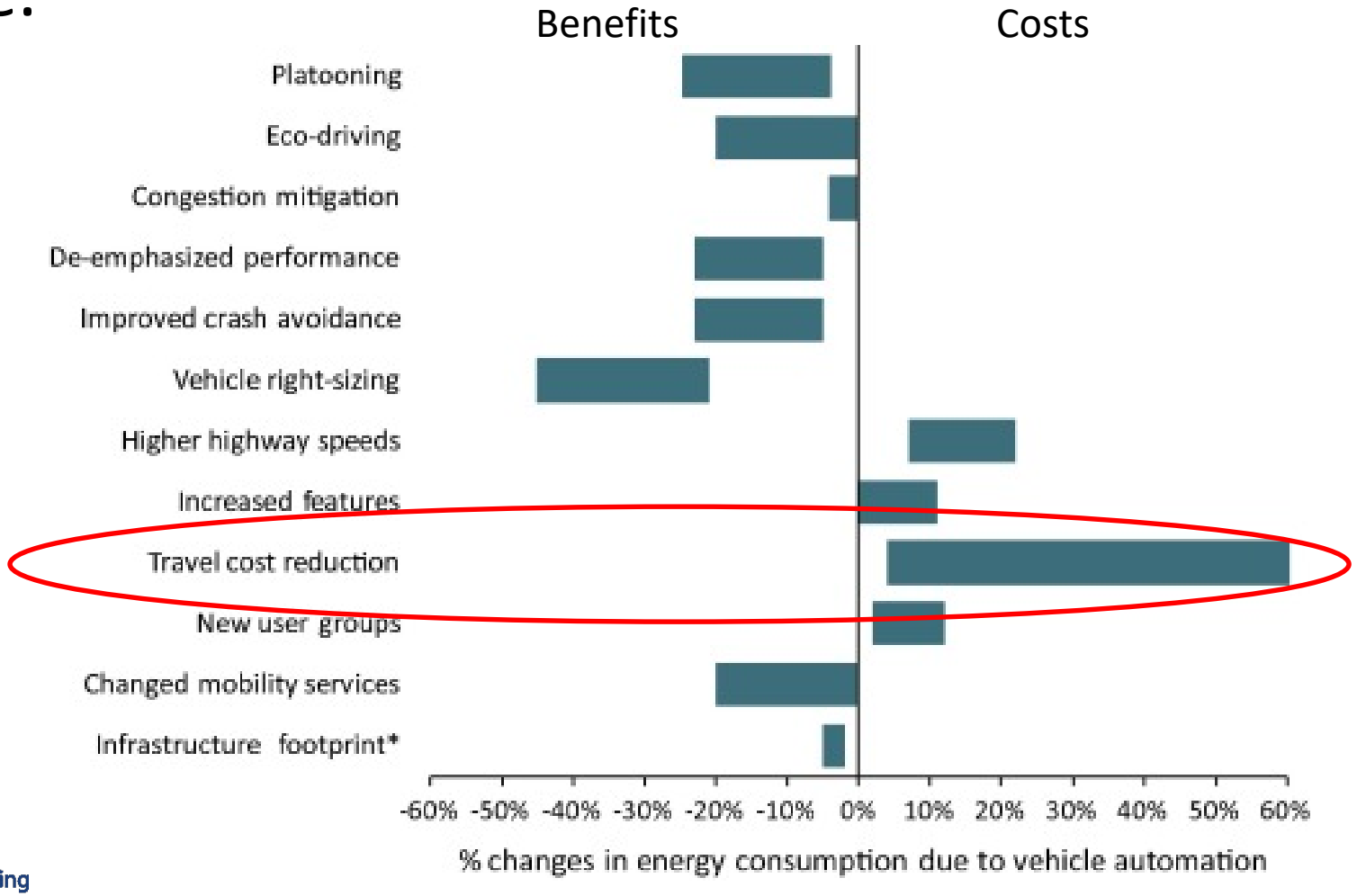
The first study to analyze the long-term carbon impact of self-driving cars predicts that automated vehicles could lead to a big increase in energy consumption and emissions, even as they become safer and more efficient.

- Zia Wadud, University of Leeds in the UK,
- Don MacKenzie, director of the Sustainable Transportation Lab at the University of Washington in Seattle, and
- Paul Leiby at the Oak Ridge National Laboratory in Tennessee



Read more: “Do Self-Driving Cars Have a Dirty Future?” By Mark Harris, 26 Feb 2016, IEEE Spectrum
http://spectrum.ieee.org/cars-that-think/transportation/self-driving/do-selfdriving-cars-have-a-dirty-future

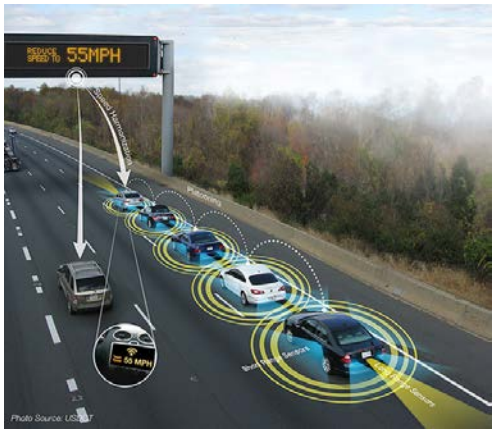
The worry is that reduced “travel costs” may significantly spur increased traffic. The increase is a guess, but reasonable estimates are a 60% increase.



Some thoughts I've shared today…

Problem

Solutions



Open Challenges

Thank you!

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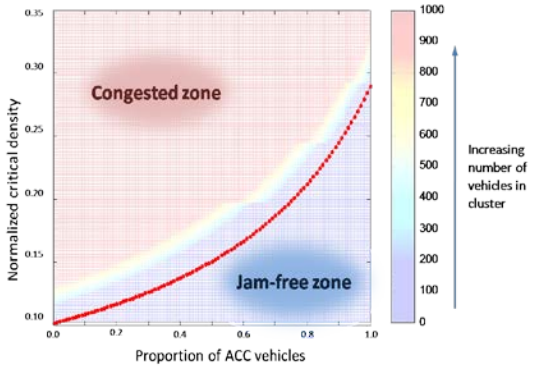

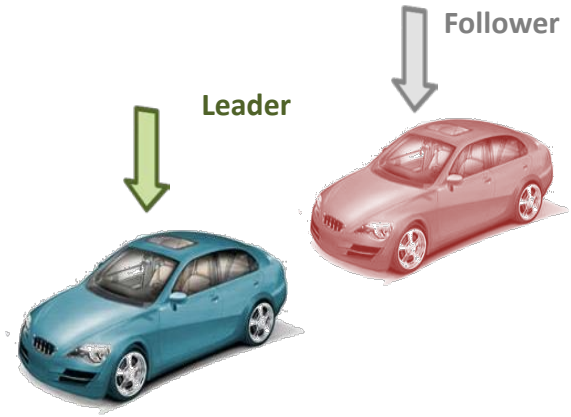

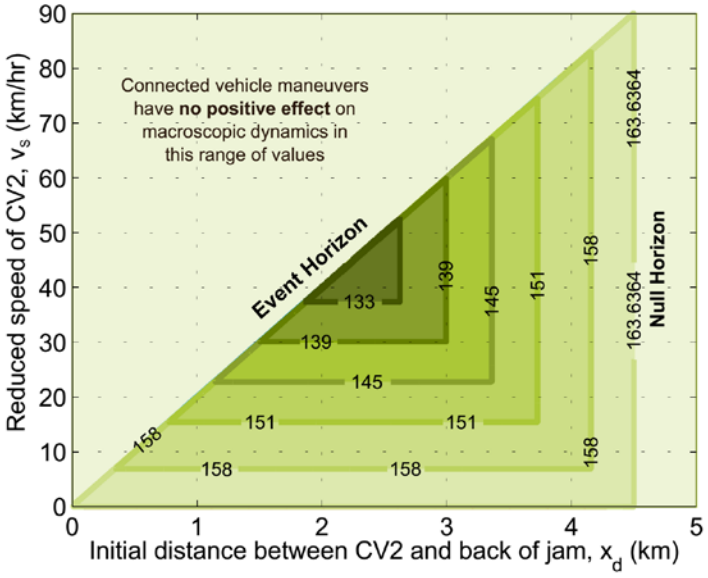

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