DAY ONE
PROJECT

Leading the Way: A National Task Force on Connected Vehicles
Jon M. Peha
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Summary
By bringing wireless communications technology to cars and trucks, we could prevent hundreds of thousands of car crashes every year, saving many lives. We could also reduce commute times, fuel consumption, air pollution and greenhouse gas emissions, and the cost of mobile Internet access. In the longer term, deployment of connected vehicle technology can lay groundwork for better autonomous (self-driving) vehicles. Nevertheless, after two decades of trying, there has been little progress on connected vehicle deployment.

Those benefits of "connected vehicles" can only be achieved through a coherent strategy, meaningful leadership, and collective action. In the U.S., too many decision-makers are pushing in opposite directions, or at best, waiting for someone else to lead. The U.S. Department of Transportation (DoT) and the Federal Communications Commission (FCC) strongly and openly disagree with each other on direction, and often appear to have different objectives. The majority of state and local transportation agencies would oppose both of these federal agencies. Major companies are on opposite sides of contentious debates. Yet, for connected vehicles to succeed, all of these public and private sector actors must work in concert, sometimes making large investments that will only pay off if others follow as expected. This is not going to happen without a new approach to advancing connected vehicle policies. While U.S. decision-makers fail to work together, and government agencies fail to lead, other nations such as China move ahead, undermining U.S. competitiveness.

In 2021, the federal government should establish a task force to develop a coherent vision through an open and inclusive process, and provide leadership to achieve that vision. This task force would work across federal agencies. It would coordinate with representatives of state and local governments, since state and local agencies are responsible for deploying much of the infrastructure. This task force would actively engage with the automobile industry, the telecommunications industry, public interest groups that are concerned with consumer safety and privacy, and experts from academia.

Using this inclusive process, the task force would identify important applications that must be supported, agree on a technical standard, launch a new proceeding at the FCC to produce spectrum rules that suit the applications and standard, encourage consistent deployment by local governments by developing a set of guidelines and best practices, and create a grants program to put the technology in vehicles for which safety is especially important, such as school busses, fire trucks, police cars and ambulances.

Challenge and Opportunity

How Connected Vehicle Systems Work
The wireless systems needed for connected vehicles are different from anything we have today. With a cell phone, we can communicate with any phone on the planet, but only if we know its phone number. With connected vehicles, a car may need to communicate with all vehicles that are approaching the same intersection at the same time, including cars that are around the corner, but not with any device that is more than a couple blocks away.

A connected vehicle system must include mobile devices installed in vehicles. Whereas communications in a traditional cellular system all pass through an expensive cell tower, a device in a connected vehicle can communicate directly with any similar device that is within a few hundred feet. Thus, vehicle-to-vehicle (V2V) communications occurs without a tower, and without an operator that runs the towers and charges for service. V2V communications works as long as all of the vehicles involved support compatible technology and applications, which may or may not occur. Car companies are now choosing from two technologies that are completely incompatible: *Dedicated Short-Range Communications* (DSRC) and *cellular vehicle-to-anything* (C-V2X). Additional technologies will emerge someday.

Many life-saving applications can operate with V2V communications alone, i.e. even without the infrastructure that is also an important part of a V2X strategy. For example, after receiving messages via V2V from all of the vehicles that are nearby, a car can determine whether it is in danger of colliding with the truck in front of it, and whether it can safely turn left at the next intersection. Still more safety applications are possible when these devices are carried by cyclists and pedestrians, in addition to motor vehicles. Researchers at Carnegie Mellon University have developed an application that would allow a blind pedestrian to safely cross a busy street, thanks to communications between the pedestrian's smartphone and a signal light.[1]

The system can do much more when roadside infrastructure is deployed, so vehicle-to-infrastructure (V2I) communications becomes possible. This infrastructure may be attached to signal lights, so vehicles can know when the light is about to turn yellow, and signal lights can adjust timing to oncoming traffic. Infrastructure may be attached to sensors such as cameras and ice detectors, so this infrastructure can inform cars that there is ice on a bridge, or pedestrians in a crosswalk. Cars can download the latest detailed maps from roadside infrastructure showing how to navigate around today's road construction.

Whereas all of the communications above are between devices that are within around 500 feet, there will also be occasions when vehicles wish to communicate with information sources that are far away. This can be done in one of two ways. The roadside infrastructure described above can serve as a communications gateway between vehicles and a closed network that provides transportation-related services, or the entire public Internet. Alternatively, the vehicle might use a commercial cellular network for this purpose. Thus, commercial cellular operators are useful, but not essential, which makes them part of the strategy discussion.

Potential Benefits
Connected vehicle technology offers many benefits to today's drivers and passengers, starting with safety. DoT estimated that when fully deployed, one possible plan for connected vehicle technology would prevent over *half a million crashes* per year, sparing the nation from the pain of over four hundred thousand injuries and a thousand deaths every year.[2]

Beyond safety, connected vehicle technology combined with "smart" signal lights can benefit drivers and passengers by making traffic flow more efficiently. This would reduce the time we waste traveling in cars, the gasoline we consume, the air pollution we produce, and the greenhouse gasses we contribute to climate change. For example, in a deployment of smart signal lights in Pittsburgh, commute times decreased by 25%.[3] Such systems could be even more effective if all vehicles had connected vehicle technology.

The benefits of connected vehicles will grow as more autonomous vehicles are deployed on our streets. Autonomous vehicles can operate without connected vehicle technology, but this technology will allow them to

[1] Smith, Stephen F., Zachary B. Rubinstein, Bernardine Dias, Raj Kishore Kamalanathsharma, Jim Marousek, Sara Sarkhili, and Sina Bahram. *Connecting Pedestrians with Disabilities to Adaptive Signal Control for Safe Intersection Crossing and Enhanced Mobility: System Requirements [Year 2]*. No. FHWA-JPO-19-751. United States. Joint Program Office for Intelligent Transportation Systems, 2019.
[2] National Highway Traffic Safety Administration. *Department of Transportation (DOT)," Federal Motor Vehicle Safety Standards; V2V Communications", Notice of Proposed Rulemaking (NPRM)*. NHTSA-2016-0126, IN 2127-AL55, 2016.
[3] Snow, Jackie, "This AI traffic system in Pittsburgh has reduced travel time by 25%." *Smart Cities Dive*, (2017).

operate more safety and efficiently. For example, someday we will see platoons of trucks moving in sync along major highways.   When autonomous trucks can communicate, they can safely travel even closer together, which yields bigger platoons, greater fuel efficiency, and lower transport costs.

A less obvious but important potential benefit of connected vehicles is cheaper Internet access. The standards have long allowed V2X communications and commercial Internet services to operate side by side.[4] If government departments of transportation and providers of wireless telecommunications services coordinate on infrastructure as well, they can share infrastructure, and send installation crews out just once. This could substantially reduce costs for both, potentially reducing the price of mobile Internet access for everyone. Our analysis of one connected vehicle strategy showed that savings from cooperation would equal almost a fourth of the cost of deploying connected vehicle infrastructure nationwide.

Challenges for Policymakers
Connected vehicles have been discussed for two decades, so why has there been so little progress? Primarily because progress requires broad consensus on a multifaceted vision, along with leadership to advance that vision, and that has been lacking. Indeed, it is not within the mission of any government agency or company to even consider all aspects of a shared vision.

Success requires many different actors in both the public and private sectors to take actions that reinforce each other. Car companies must include connected vehicle technology and safety applications in their designs. The FCC must craft spectrum policy that fits the wireless technology and the applications. There must be infrastructure on signal lights and elsewhere, which requires action from many thousands of local governments. Cellular operators may play an important role for some kinds of connected vehicle infrastructure. Vehicular safety regulations matter, and this responsibility falls to the federal Department of Transportation. If all of these entities do not act in concert, then V2V communications may not be possible between General Motors cars and Ford cars, or a car's connected vehicle technology may work perfectly in Pittsburgh but fail in Philadelphia, or interference may put lives at risk unnecessarily because the spectrum regulations were not designed for the applications that will be deployed in autonomous vehicles. To make progress, federal, state and local government agencies, along with the telecommunications and automotive industries, must all act under a unified vision.

This problem is amplified by another characteristic of connected vehicles: there is little incentive to act first. A car with connected vehicle technology cannot participate in V2V communications until other vehicles in town have the technology too.   Similarly, that car cannot participate in V2I technology until roadside infrastructure has been deployed, and local governments have been reluctant to pay for costly roadside infrastructure when few of the cars on their roads have the technology. An effective strategy may require a way to seed collective action towards that shared vision.

While the U.S. lacks a shared vision and a means for collective action, other nations move forward. By the end of 2018, the Chinese government had chosen a technical standard, allocated spectrum, released guidelines for the construction of national automotive network industry standards, and set ambitious targets for infrastructure deployment. The U.S. has not come close.

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[4] Kenney, John B. "Dedicated short-range communications (DSRC) standards in the United States." *Proceedings of the IEEE* 99, no. 7 (2011): 1162-1182.

Precedents

This is not a new issue, and there are lessons to learn from the history of U.S. connected vehicle policy. Through two decisions during the Clinton and Bush Administrations,[5, 6] the FCC created the Intelligent Transportation Systems (ITS) spectrum band, allocated 75 MHz to it, and established DSRC as the connected vehicle technology. For many years, the ITS band saw little use. Local governments built little DSRC infrastructure. Car owners and car manufacturers showed little interest in paying for a communications device that would have few peers to communicate with. Apparently, merely making spectrum available was not enough to spark widespread deployment and use.

Because usage was low, in 2013 the FCC launched a formal proceeding to consider allowing unlicensed devices such as Wi-Fi to share the ITS band, thereby reducing the spectrum available for connected vehicles.[7] The FCC sought input on how best to share spectrum. Two different sharing approaches gained prominence. The FCC laboratories began the latest phase of testing for these approaches in late 2018.[8]

While the FCC addresses spectrum issues alone, the federal agency responsible for every other aspect of automotive equipment and infrastructure is the Department of Transportation (DoT). During the Obama Administration, DoT proposed an approach that built on the FCC's earlier work.[9] DoT would require all new vehicles sold in the U.S. to come equipped with DSRC devices for safety, just as it requires vehicles to come equipped with seatbelts. There would be no requirement to add the equipment to vehicles already on the road. Eventually, most vehicles would support V2V, although it would take years. DoT also recommended the deployment of extensive roadside infrastructure, including devices on up to 80% of all signalized intersections in the U.S.[10] Most of this would be the responsibility of state and local governments, since the policy came with no federal funding. Very few municipalities deployed this infrastructure. This is inevitably a risk when federal, state and local polices are not in sync.

During the Trump Administration, both DoT and the FCC have pursued policy approaches that contradicted with those of previous administrations, and contradicted even more with each other. DoT maintained its support for connected vehicles, including keeping the 75 MHz ITS band. However, it determined it would no longer mandate connected vehicle devices in all new cars, while adopting no alternative policy to advance deployment or use. DoT also stopped overtly supporting DSRC as the technology for connected vehicles, but did not support an alternative technology. In effect, DoT has merely been waiting for leadership to emerge elsewhere, and providing none.

Meanwhile, the FCC is moving in a new direction. In December of 2019, without waiting for the results of the sharing tests that it had begun a year earlier, the FCC announced that a new proceeding would begin in

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[5] Federal Communications Commission, Report and Order, in the matter of Amendment of Parts 2 and 90 of the Commission's Rules to Allocate the 5.850-5.925 GHz Band to the Mobile Service for Dedicated Short Range Communications of Intelligent Transportation Services, ET Docket No. 98-95, Oct. 1999.

[6] Federal Communications Commission, Report and Order, in the matter of Amendment of the Commission's Rules Regarding Dedicated Short-Range Communication Services in the 5.850-5.925 GHz Band (5.9 GHz Band), WT Docket No. 01-90, Feb. 2004.

[7] Federal Communications Commission, in the matter of Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band. Notice of Proposed Rulemaking 13-22, Docket 13-49, 2013.

[8] Federal Communications Commission, Office of Engineering and Technology, Phase I Testing of Prototype U-NII-4 Devices, Report TR 17-1006, Oct. 22, 2018.

[9] National Highway Traffic Safety Administration. *Department of Transportation (DOT)," Federal Motor Vehicle Safety Standards; V2V Communications", Notice of Proposed Rulemaking (NPRM)*. NHTSA-2016-0126, IN 2127-AL55, 2016.

[10] Wright, James, J. Kyle Garrett, Christopher J. Hill, Gregory D. Krueger, Julie H. Evans, Scott Andrews, Christopher K. Wilson, Rajat Rajbhandari, and Brian Burkhard. *National connected vehicle field infrastructure footprint analysis*. No. FHWA-JPO-14-125. United States.

2020 on a very different approach.[11] Under these proposed rules, the ITS band would be reduced from 75 MHz to 30 MHz, and C-V2X would replace DSRC as the permissible technology in either two thirds or all of the ITS band. The Secretary of Transportation wrote that she has "significant concerns" about the FCC's reversal, and 38 Members of Congress connected with the House Committee on Transportation and Infrastructure went on record to concur with the Secretary, arguing that "the FCC's proposal undercuts the potential to prevent many of the 37,000 traffic fatalities each year by impeding the development and deployment of safety-critical technologies."[12] DoT has officially opposed the FCC's proposed rules.[13]

In the public meeting when this proceeding was announced, FCC commissioners emphasized how reducing the spectrum for ITS would cause this valuable resource to be used more efficiently. After all, making better use of limited spectrum is part of the FCC's mission. DoT continues to argue that the full 75 MHz is needed for connected vehicles to prevent causalities on our roads. After all, improving roadway safety is part of DoT's mission. These counterproductive conflicts occur because neither agency is responsible for a vision for the entire federal government and all of its policy goals, much less a vision that includes state and local government, the automobile industry, the telecommunications industry, and consumers.

To make matters worse, at least in the current FCC proceeding, neither the FCC nor the DoT presented serious analysis that would justify their respective positions for ITS spectrum, or that would justify any position for that matter.[14] If it is no one's responsibility to develop a broad vision, perhaps it is no one's responsibility to do rigorous analysis.

Proposed Actions

We need a broadly-shared vision on all aspects of connected vehicles, including what technology to use, who will build the infrastructure, what business models they will use, how spectrum will be managed, and how connected vehicle policy integrates with automated vehicle policy. This takes leadership and inclusiveness.

A Task Force to Lead Collective Action
The first step is to establish a task force that will push for progress across multiple fronts. The task force would be housed within a single organization within the federal government. An obvious choice is the White House's Office of Science and Technology Policy (OSTP), which is uniquely situated to speak for the president, and draw on resources from many federal agencies. The DoT and the FCC are also candidates, but only if they are commanded to address issues that extend beyond their own authority and mission. Other federal agencies involved in the task force could include the National Institute for Standards and Technology (NIST), the National Science Foundation (NSF), and the National Telecommunications and Information Administration (NTIA).

The task force must also extend beyond the federal government, using transparent consultative processes. After all, if mayors, state DoT's, car companies, and consumers don't support the vision, it will fail. The task force should establish formal and informal advisory committees, drawing members from all major stakeholder groups, as well as objective experts. It could also hold a series of public workshops to involve thought leaders from all sectors.

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[11] Federal Communications Commission, Notice of Proposed Rulemaking, in the matter of Amendment of Use of the 5.850-5.925 GHz Band, ET Docket No. 19-138, Dec. 2019.
[12] DeFazio, Peter A. et al, House Committee on Transportation and Infrastructure, Letter to Chairman Pai and Commissioners O'Rielly, Carr, Rosenworcel, and Starks, Jan. 22, 2020.
[13] National Telecommunications and Information Administration, Letter in the Matter of Use of the 5.850-5.925 GHz Band, Federal Communications Commission ET Docket No. 19-138, March 2020.
[14] Peha, Jon M., The Need for Analysis and a Shared Vision for Intelligent Transportation Systems, in the matter of Use of the 5.850-5.925 GHz Band, ET Docket No. 19-138, April 2020.

The FCC of 2009-2010 serves as a good model. Congress passed a law directing the FCC to produce a broad strategy for broadband deployment and use. The resulting U.S. National Broadband Plan[15] drew ideas from countless sources in the public and private sectors, and then proposed a set of strategies that went well beyond the FCC's own purview. It included concrete but non-binding recommendations for itself, for other federal agencies, for Congress, for state and local governments, and for the private sector.

Envisioning Applications
The vision should begin with a clear description of core applications that we know must be supported, while leaving room for those we cannot yet imagine. Indeed, one of the (many) problems with current federal government efforts on connected vehicles is that the FCC proposes to set technical standards and spectrum policies without trying to determine which applications those standards and policies should enable, perhaps because that is not within the FCC's traditional mission or expertise. Core applications should include many that have already been developed for the safety of vehicles driven by human drivers, such as the aforementioned application that warns drivers about the risk of forward collision. It should also include applications that we hope will emerge in the future but have thus received little attention, such as one that guides autonomous vehicles through a freeway onramp. At the same time, we should drop applications from the vision that have become obsolete over the years due to changes in technology and available services.

Unless they change course, it is likely that the FCC will make decisions about spectrum that severely limit what applications are possible without a good way of knowing which applications are considered essential. The same could occur if local governments invest in expensive infrastructure or car companies choose technical standards without a long-term vision. It may be possible to reverse such decisions, but not without wasting time and money.

Establishing Standards
The task force must then select a single technical standard that is consistent with its core applications. This will guide the actions of local governments as they deploy infrastructure, the FCC as it manages spectrum, car companies as they design next year's model, and consumers as they buy products for their cars and configure their smartphones. Today's contenders are DSRC and C-V2X, and there multiple strains of C-V2X.

There is a fierce debate over which standard is best. This paper will take no position on this complicated technical matter. However, choosing the inferior standard of the two is still better than supporting both.[16] Two devices can only communicate if they were designed in accordance with the same standard. If cars adopt different standards, then fewer fatal crashes will be prevented. For example, if half the cars adopt one standard, and half adopt another, then there is a 50% chance that the system will be useless when two cars are in danger of colliding. Similar kinds of *interoperability* failures in the communications systems used by firefighters, police and emergency medical services have led to many unnecessary deaths, and the resulting policies are instructive. For example, incompatible technology choices made it impossible for first responders from different agencies to communicate at the World Trade Center and Pentagon after the 9/11 attacks.[17] This fueled our proposal that involved coalescing around a single technical standard for public safety communications nationwide.[18, 19, 20] Moreover, DSRC and C-V2X devices cannot operate in the same spectrum band, so supporting both would mean allocating more valuable spectrum than is actually needed. Supporting

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[15] Federal Communications Commission. *Connecting America: The National Broadband Plan*, March 2010.

[16] Peha, Jon M., Standard and Spectrum Sharing for Intelligent Transportation Systems, in the matter of Use of the 5.850-5.925 GHz Band, ET Docket No. 19-138, March 2020.

[17] The 9/11 commission report: Final report of the national commission on terrorist attacks upon the United States. Government Printing Office, 2011.

[18] Peha, Jon M. "Fundamental reform in public safety communications policy." *Fed. Comm. Bar Journal* 59 (2006): 517 -546.

[19] Federal Communications Commission. Public Safety, Chapter 16 of *Connecting America: The National Broadband Plan*, March 2010.

[20] Peha, Jon M. "A public-private approach to public safety communications." *Issues in Science and Technology* 29, no. 4 (2013): 37-42.

both would also increase the cost of infrastructure. If the task force chooses C-V2X, there may need to be accommodation for the DSRC systems that are already operating, but in that case this accommodation should come with a plan to phase out those systems over time.[21]

The current position of DoT is that we should let the market decide which standard is best. This makes no sense. It is the FCC and not a market that must establish spectrum rules, which necessarily determine which standards are allowed in any given frequency range. As of today, only DSRC is legal in the ITS band, and no market can change that. Even if it were possible to leave this to a market, such as by allocating two spectrum bands for each of two standards in the hope that consumers will flock to one band while the other sits idle, markets tend to work poorly when there is a need to pick a single universal winner. The FCC refused to choose a single standard for AM stereo. Since neither consumers nor radio stations wanted to waste money on a dead-end standard, no AM standard succeeded. At least failure to provide better radio didn't lead to car crashes. Letting the market pick a connected vehicle standard is as reasonable as letting the market decide whether cars should be required to drive on the right side of the street or the left. Either choice is better than no choice.

An Infrastructure Strategy
The task force must develop a vision for the deployment of connected vehicle infrastructure that has the support of all of the diverse interests involved. This includes laying out the anticipated roles for local government, federal government, commercial cellular operators, and perhaps emerging private operators of roadside units. In the most cost-effective strategies, these roles are likely to be intertwined. Where commercial operators are involved, the task force would address how they can be compensated reasonably, but not excessively.

At one extreme, it is possible that a single government agency could deploy and operate all of the connected vehicle infrastructure in a municipality, or even a state. At the other extreme, it is possible that a single commercial cellular operator could deploy and operate all of the infrastructure. Indeed, this is one of the modes of operation that was defined within the C-V2X standard, but the technical standard says nothing about how to determine which of the competing cellular operators would play this singular role, or how it would gain access to traffic lights that belong to government, or how it would be compensated. All of this must be invented. In between the government monopoly model and the cellular company monopoly model, many arrangements are worth considering in which multiple government agencies and multiple commercial companies all work in concert.

A one-size-fits-all infrastructure strategy would not be appropriate. The task force should instead develop a handful of infrastructure strategies, complete with examples of technical and business arrangements, that state and local governments can adopt if they so choose. Some of those showcased strategies may emerge from localities that have chosen to be pilots. Perhaps the task force will recommend one for big cities, and another for rural regions. However, this matter should not be left to many thousands of local governments to sort out in isolation, each attempting to reinvent solutions to difficult problems. Indeed, we also expect that there will be significant advantages to developing infrastructure strategies that cover regions with many municipalities. That kind of cooperation is much more likely if a federal task force provides a few well-developed templates to choose from.

It is important to bring local, state and federal government agencies and commercial cellular operators to the table to devise these templates, because they may all be involved in deployment. Some of the infrastructure will be attached to devices that are controlled by government agencies, such as signal lights, and signs that warn drivers that there is road construction ahead. Thus, even when it is cellular operators that are deploying infrastructure, government agencies must approve, especially (but not exclusively) local governments. In regions that are well served by commercial cellular operators, it can be helpful to use cellular service as a

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[21] Peha, Jon M., Standard and Spectrum Sharing for Intelligent Transportation Systems, in the matter of Use of the 5.850-5.925 GHz Band, ET Docket No. 19-138, March 2020.

complement to communications provided by the roadside infrastructure described above, so cellular operators also matter.

There are advantages to complex arrangements involving multiple actors. Our previous research has shown that some forms of connected vehicle public-private partnerships would be highly cost-effective.[22] Government agencies and cellular operators can reduce total costs by sharing some parts of the infrastructure, potentially saving tax-payer dollars and lowering the cost of cellular service. Moreover, government agencies can provide cellular operators access to transmitter sites that are quite valuable for other purposes, such as providing 5G cellular service, and commercial operators can provide operational capacity that government often lacks.

Some people believe that if we choose the technical option that is preferred by the cellular industry (C-V2X), then cellular operators must run the systems, and the costs will fall entirely to cellular operators rather than tax-payers. Indeed, that is one of the arguments made by companies that have a financial interest in C-V2X. However, none of that is true. If a government agency wants to build and operate its own system, that agency can use C-V2X as easily as it can use DSRC. Conversely, even if DSRC is chosen as the standard for connected vehicles over the objections of cellular operators, which means that vehicle-to-vehicle (V2V) and vehicle to infrastructure (V2I) communications will use DSRC, this in no way limits the ability of vehicles to use a cellular service for longer-range communications. Thus, the choice of technical standard does not determine the infrastructure strategy, or who pays for what.

A Spectrum Strategy

After it knows the core applications that must be supported, the choice of technical standard, and the anticipated infrastructure strategy (or strategies), the FCC will be capable of making good decisions about ITS spectrum, whereas today it is not. The FCC should then initiate a new proceeding. In addition to addressing the most controversial issues of how much ITS spectrum to allocate, and whether spectrum should be shared with devices that are unrelated to transportation, the FCC will need to develop rules regarding how the ITS spectrum is divided into channels, and what applications and technologies can operate in each channel, albeit with enough flexibility to accommodate and encourage innovation. They should consider the needs of both vehicles driven by humans and autonomous vehicles. These are not the kind of decisions that make the headlines, but subtle changes in rules can greatly affect how the technology works, and in this case how many lives are saved on our roads. The FCC should not make such decisions with incomplete information, as it appears poised to do now.

Seeding Nationwide Deployment

Although many players must act to make connected vehicles a reality, there are simple things that the federal government can do to begin the process of nationwide deployment. Even if government provides spectrum and infrastructure, there is no guarantee that cars will have connected vehicle technology unless car companies choose to put the technology in every car. Assuming that connected vehicle technology is optional, many car owners may decide to wait until the technology is widely used, so there are other cars to communicate with. If so, someone will have to deploy first, so that others are willing to follow.

If most car companies do not make this technology standard, we propose a federal program that subsidizes the purchase of connected vehicle technology. It should begin with vehicles that contribute the most to public safety, or for which roadway safety is particularly important. Examples of the former include fire trucks, ambulances, police cars, and snowplows. Examples of the latter include busses used for schools and public transit, and even privately-owned taxis.

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[22] Ligo, Alexandre K., and Jon M. Peha. "Cost-effectiveness of sharing roadside infrastructure for Internet of Vehicles." *IEEE Transactions on Intelligent Transportation Systems* 19, no. 7 (2018): 2362-2372.

Another way that the federal government can encourage deployment is to provide significant matching funds for a few local governments that want to be leaders in the deployment of connected vehicle infrastructure. These early adopters will work out the details, and serve as models for other regions to follow.

Conclusion

The deployment of connected vehicle technology could prevent hundreds of thousands of car crashes every year, saving many lives. In the process, it can also reduce commute times, reduce fuel consumption, reduce air pollution and greenhouse gas emissions, and lower the cost of mobile Internet service. However, after two decades of trying, we have made little progress on deployment. All too often, federal, state and local government agencies, automobile companies, and telecommunications companies have worked against each other, when what we the nation needs is a shared vision that leads to collective action. We have proposed a solution.

In 2021, the federal government should establish a task force that brings together the relevant federal agencies, and representatives of state and local government, industry, public interest groups, and experts. The result would be a coherent strategy, rather than yet another set of incompatible piecemeal policies. The strategy would include recommendations about core applications, technical standards, spectrum, and infrastructure. The federal government could then encourage progress towards this shared vision by offering funding for putting connected vehicle technology in safety-critical vehicles, such as fire trucks and school busses, and funding select local governments that wish to be early adopters of the approach.

Frequently Asked Questions

How important is it to improve roadway safety in the U.S.?
According to the Department of Transportation, in 2018 the U.S. saw over 6 million police-reported vehicle crashes, 37 thousand deaths, 2 million injuries, and a total economic harm exceeding $800 billion.[23] The cost of the infrastructure and spectrum needed for connected vehicles is extremely small compared to the economic harm of these crashes.

The FCC has a proceeding underway, so won't this issue be settled before the next administration begins?
No. The current FCC rulemaking does not consider most aspects of a connected vehicle vision, and does not even address all of the critical spectrum issues that fall within the FCC's authority. It remains to be seen whether the FCC will complete its current rulemaking by January 2021, despite the explicit objections of the Department of Transportation. If the FCC does make any decisions, those decisions will probably be challenged in court before any can take effect. Moreover, any such decisions are reversible. Thus, there will be plenty of work to do in 2021 and beyond.

Why can't we let industry decide how to use the spectrum, and keep government out of it?
Because the technology would fail, sometimes leading to deadly crashes. These fatal failures can occur when vehicles and roadside infrastructure use incompatible technologies, or when the vehicles on a given stretch of road are allowed to send more information than a communications channel can safety carry, or when vehicles send routine data using mechanisms that are intended for emergencies. Preventing that requires some decisions that everyone abides by, and that requires government involvement. That doesn't mean government must invent the communications technology or control its operation, any more than government needs to design cars or drive citizens around town.   But someone has to establish rules of the road, and get it paved, so that industry and citizens can prosper.

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[23] National Telecommunications and Information Administration, Letter in the Matter of Use of the 5.850-5.925 GHz Band, Federal Communications Commission ET Docket No. 19-138, March 2020.

Local governments typically make decisions about signal lights, traffic signs, and other local infrastructure. Why should the federal government be involved?
Because cars can easily drive from one community to another, and we'd like the technology to work wherever they go. There are thousands of local governments in the U.S. They should adopt approaches that are tailored to local needs, but consistent with each other and with a national vision, which means someone must define that national vision. Every local government is free to choose where to place signal lights, but no municipality should select green as the color that tells drivers to stop.

The idea of connected vehicles has been around for many years. If the technology hasn't become widespread yet, shouldn't we abandon it?
No. What we should learn from the many years of slow progress is that a strategy of hope without vision or leadership is insufficient. Car companies are already investing in V2X technology. Cellular companies are already investing in V2X technology. Local governments will invest in V2X technology when they see benefit for their citizens, which means when the technology is installed in cars. That is why other countries are moving ahead. If we had leadership from the federal government, the U.S could move ahead as well.

Do we need to succeed with connected vehicles if we are ever to have autonomous vehicles?
Autonomous vehicles should operate even when no communications are possible, but V2X is likely to be a significant advantage. V2X provides another way for autonomous vehicles to learn about the roads and obstacles that must be traversed, including obstacles that are out of sensor range. V2X allows vehicles to inform each other in advance about intentions, or coordinate, perhaps by requesting permission to change lanes. V2X provides a way for vehicles to obtain urgent software updates, or verify security credentials. The U.S. has long been a leader when it comes to investing autonomous vehicle technology. Building out connected vehicle infrastructure is a good way to help the U.S. lead in capitalizing on this emerging technology.

About the Author

Jon Peha is a Professor at Carnegie Mellon University, where he leads a research program on technology policy. He has served at the Federal Communications Commission (FCC) as Chief Technologist, in the White House as Assistant Director of the Office of Science and Technology Policy, in industry as Chief Technical Officer of three high-tech start-ups, in the House Energy & Commerce Committee, and at USAID where he ran the *Telecommunications Leadership* Program.   He has been a member of the State Department's Advisory Committee on International Communications and Information Policy, and the American Library Association's Board of Advisors. Dr. Peha is an *IEEE Fellow* and an *AAAS Fellow*. For more, see www.ece.cmu.edu/~peha/bio.html

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