Comments given verbally, March 27, 2019, by Paul W. King, PhD, California Public Utilities Commission, and previously Acting Chair of TRACS. Comments referring to:

What criteria should be considered when evaluating new technology?

Considerable research cites a tendency to envision new technologies for “how they can work,” to the neglect of “how they can fail.” Human factors are generally and seriously neglected. Many problems have been identified in accidents and research. I sent out a document to TRACS that reviews the research literature. The document is the CPUC’s comments to the FRA’s request for information on of autonomous vehicle safety in the railroad industry. I’m resubmitting it with these comments.

Problems and errors include:

Errors of omission, where operators become complacent, overly trusting the technology, failing to be vigilant, and failing to intervene when needed, such as in the Uber self-driving car accident in Arizona where the driver wasn’t paying attention; the system didn’t recognize the pedestrian, and the car struck and killed her.

Errors of commission, where the operator follows the directives or allows the automation to continue even though there’s visual evidence indicating danger requiring operator intervention.

Automation errors and design flaws have caused accidents, such as is likely being revealed in the Boeing 737 Max 8 tragedies.

The need for more training when automation takes over tasks, while somewhat counter-intuitive, is critical. Operators not only need to know how to operate the vehicle, but need to understand the technology, when to trust it, when to mistrust it, when to intervene, and how to intervene safely.

There’s the conundrum where the more reliable the technology, the more complacent an operator may be and not intervene when needed; and the less reliable the technology, the more likely the operator will disengage it even when it can significantly assist with a critical task.

Automation and technology may diminish operator skill development, leaving operators unprepared to intervene when needed, especially in an emergency situation when responses need to have been firmly ingrained.

Automation tends to leave the operator passive and less aware of the real-time operational characteristics and context, and less prepared to intervene, with a difficult transition from a passive to an active control state.

Employee and public acceptance is essential. For example, I recall as a brakeman in the 70’s that locomotive engineers occasionally used a “packing hook” (metal bar) to lock down the “deadman pedal,” which is designed to engage the train’s brakes when the engineer lifts feet off of it due to fatigue-induced sleepiness or other incapacitation.

There’s a critical process issue in evaluating technology through accident investigations: root-cause analysis must be performed to avoid blaming employees for not handling the situation. In one of TRACS previous reports, we presented “The Arrow,” which is a graphic representing different levels of responsibility for causation or preventing an accident. At the “arrow’s sharp end” is the employee most proximal to the event, who appears in the position to be able to prevent the occurrence. But responsibility for prevention runs up the “arrow” to supervisors, managers, trainers, policies such as rest opportunities, to regulators, legislators, and finally the public. I mentioned the developing details of the Boeing 737 Max 8 tragedies partly being attributed to very high levels in the organization where competition with Airbus prompted a rush to deliver, and possible lax regulatory oversight.

Roadway Worker Protection: Agencies' experiences must be considered, including the tendency to want to replace a human-provided protection with a technology, thus without the redundancy that technology should provide. For example, agencies may wish to replace flaggers with early-warning technology too generally and when the technology hasn't been sufficiently tested in all possible contexts.

Technology has enhanced ability to produce data, but how is it then used? The human is still in the loop, and failure may just shift to a different and less stimulating task. For example, the FRA is examining autonomous track inspection technology, which will provide considerable data. Being vigilant while sifting through a lot of data may be considerably more difficult than being vigilant while attending to real-world infrastructure where all sensory input is real, not virtual or condensed into reams of numbers.

Regarding the notion of not performing original research: national experience provides an economy of scale, and tests generalizability to a diversity of situations. TRACS is well-suited to examine a diversity of experience.

And finally, technology must be evaluated in a socio-technical context. For example, technology to stop trains in time to avoid crossing collisions with highway vehicles may not work well on trains, since cars often move into the track space at the last minute, long after any train has the needed stopping distance. In this case, reaching out to the larger societal transportation network, i.e,. highway vehicles, for vehicle-stopping technology may be effective where train applications can't be. I'm aware of the NTSB reaching out to Google, Apple, and other vehicle navigation providers to provide warnings of the proximity of railroad tracks. Given the automatic braking systems now being implemented in cars, it may be that these systems could stop cars at crossings at critical times. Many other socio-technical interactions are likely to exist and must be evaluated.

Selection of TRACS tasks:

Regarding close-call reporting systems (CCRS) / Employee Reporting Systems (ERS), TRACS member Brian Sherlock and I are on the Volpe ERS project stakeholder panel to develop a CCRS/ERS application for transit. The benefit of doing it on a national scale is the economy of scale for a resource to provide third-party confidentiality, which is likely the most difficult resource issue.

Regarding the concern about instances of CCRS or ERS not working, that in itself is a measure of safety culture (e.g., mistrust), and the root causes must be addressed. For example, at San Francisco Muni, when the voters took away pay benefits for Muni employees, it was clear that the mood was not amenable to a CCRS/ERS roll-out.

Regarding trespasser suicide issues, I'll see if it's appropriate to provide a paper that one of the CPUC's analysts drafted a while ago regarding suicides on rail lines.

BEFORE THE
FEDERAL RAILROAD ADMINISTRATION OF THE UNITED STATES
DEPARTMENT OF TRANSPORTATION

[Docket No. FRA-2018-0027]

Request for Information: Automation in the Railroad Industry

Comments of the California Public Utilities Commission

The California Public Utilities Commission ("CPUC") hereby files its comments with the United States Department of Transportation, Federal Railroad Administration's ("FRA's") Request for Information ("*RFI*") "Automation in the Railroad Industry" issued March 29, 2018, at 83 Fed. Reg. 13583. The CPUC submitted brief opening comments on May 7, 2018. The CPUC submits these full comments to the RFI as the state agency with exclusive jurisdiction over highway-railroad crossings and as the FRA's safety oversight partner under the State Safety Participation Program (49 CFR §§ 212.1 et seq.). These comments do not respond to the submissions of the railroads, stakeholders, and other state agencies on May 7, 2018 but, instead, respond only to the *RFI* of March 29, 2018. The CPUC intends to respond to the responses submitted on May 7, 2018 by the railroads, stakeholders, and other state agencies within the time prescribed by the FRA.

I. INTRODUCTION

Automation of the railroad industry has been ongoing since the inception of the industry. It is a critical and essential part of railroad transportation both freight and passenger. The development of Positive Train Control ("PTC") is one example of this evolutionary and necessary automation in the railroad industry. The delayed implementation of PTC by the nation's Class I railroads demonstrates the complexity and difficulty in developing safe and sound automation in the industry. The next evolutionary stage in the railroad industry's automation must carefully build on PTC to ensure that all developments in automation are safely implemented and compliant with all safety requirements. In that light, the CPUC recommends that the FRA ensure that any advancements in the railroad industry's automation not be confused with the development of autonomous motor vehicles, but that the industry learn from experiences with the different levels of automation in the other transportation modes where relevant. The CPUC cautions that the state of automation in the U.S. railroad industry is not at a stage that would safely permit consideration of plans for the operation of autonomous trains over the nation's general railroad system of transportation.

II. SAFE AUTOMATION IN THE RAILROAD INDUSTRY

Safety is paramount in the railroad industry and any improvements in automation must demonstrate compliance with all applicable and appropriate safety and reliability concerns. PTC provides revolutionary, as well as evolutionary, improvements to railroad safety. It will provide similar benefits and improvements to more efficient railroad operations.

Use of PTC-Acquired Data and Experience to Develop Railroad Automation

The CPUC asserts that for the foreseeable future, the bulk of automation in the railroad industry will be the result of the large amounts of data produced by the implementation and development of PTC.[1] The benefits of Global Positioning System ("GPS") data will provide a basis for substantial improvements in:

- velocity,
- routing,
- line capacity,
- service reliability,
- more efficient use of cars and locomotives,
- safer and more efficient windows for track maintenance, and
- fuel savings[2]

III. SPECIAL CONSIDERATIONS IN THE IMPLEMENTATION OF AUTOMATION IN THE RAILROAD INDUSTRY

The concerns described and documented below are intended to introduce safety issues that must be taken seriously and adequately addressed in any design, build-out, operation, maintenance, and retirement of any automated system. While people are familiar with software glitches and crashes on their computers, regarding automation for cars, one researcher makes the point, "A critical concern is that software failures in cars, on roads, in live traffic, can be more catastrophic than software failures on a personal computer on a desk."[3] The CPUC's concern is that train accidents can be far more catastrophic than car accidents, given the large numbers of passengers and volumes of hazardous materials trains carry. While all the risks that have been identified in aviation, highway vehicles, and other

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[1] *TRAIN*, April 10, 2018, "BNSF Railway Executive Chairman Matt Rose says Tuesday his company hopes to extract efficiencies out of positive train control implementation, but added that he is not about eliminating crews from cabs." http://trn.trains.com/not-found.aspx?item=%2fnews%2fnews-wire%2f2018%2f04%2f10-rose-says-battery-&user=extranet%5cAnonymous&site=website

[2] See: *Positive Train Control (PTC): Calculating Benefits and Costs of a New Railroad Control Technology*, July 30, 2004, ZETA-TECH Associates.

[3] Noy, I., Shinar, D., and Horrey, W. (2018). Automated driving: Safety blind spots. *Safety Science*, Vol. 102, at p. 70.

automation-aided/control applications may not completely generalize to train operations, many certainly will, especially the all-important human-automation interaction.[4]

The CPUC's concern, expressed by many experts and researchers in the field of emerging automation is that the focus has been on *how things can work*, with insufficient attention to *how things can fail*. A strong safety culture has a strong focus on attending, even "preoccupation," to possible failure.[5] However, a recent comprehensive review of driving automation has concluded, "[w]ith rare exception, the projected benefits are accepted uncritically on the basis of industry claims."[6] Considerable research in aviation and motor vehicle transportation modes has identified critical safety issues. The following address the FRA RFI nos. 2, 4, 9, 11, 12, 13, and 20.

- **Benefits** Automation-aids and autonomous systems have the potential to reduce dependency on human fallibility. Systems like positive train control as a back-up to human performance are well on their way to addressing human error. However, as automation increasingly takes over human functions, new problems arise, including the many topics discussed below. For example, researchers have identified the following challenges:

  "The amount of training needed by the humans goes up, not down, when automation is introduced, and the design of the automation interfaces becomes more challenging and important. Also, and maybe more critically, automation usually does not replace the human; rather it changes the nature of the human's work."[7]

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[4] Noy, et al., *op cit*.

[5] Weick, K., and Sutcliffe, K. (2015). *Managing the unexpected: Sustained performance in a complex world*. Hoboken, NJ: Wiley.

[6] Noy, op cit. at p. 69.

[7] Shively, R., Lachter, J., Brandt, S. Matessa, M., Battiste, V., & Johnson, W. (2017). Why human-autonomy teaming? *Advances in Neuroergonomics and Cognitive Engineering*, pp. 3-11.

- **Security** This topic is of considerable concern and must be addressed before passengers, and populations near hazmat routes, are exposed to more autonomous train operations. The primary tenet of system safety is that of fail-safe, where if and when something in the system fails and thus presents a danger, the system reverts to a safe state, as in stopping or shutting down appropriately. The challenge for security is that, for example, reverting to a safe state under a cyber-attack is a new problem with few mitigating strategies for all the many ways an attack could take control, and thus not trigger any failure status and any built-in responses to establish a safe condition.

- **Designed-in error ("Design error or flaw")** Recent experience with Google and Tesla cars' automated assistance has revealed errors that were design-induced errors.[8] A February 2016 Google accident was deemed caused by a false assumption that was designed into the autonomous system. A May 2016 Tesla accident was deemed caused by in autopilot's failure to recognize the white side of a large truck's trailer as being an obstacle. More recent accidents may also reveal design-induced errors in self-driving cars.[9]

- **Levels of automation and the different problems of each level** The March 28, 2018 *RFI* seeks comment on taxonomies of automation, one by the Society for Automotive Engineers ("SAE"), the other by the International Association of Public Transportation (UTIP), and requests recommendations for other taxonomy categorizations. We believe such categories are critical to flesh out the different kinds of failures that each level of automation could be vulnerable to. For example, SAE Levels 2 and 3, the vehicle operator may or must take over control in some situations:[10]

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[8] Tesla has publicly stated that its autopilot system is not designed to relieve the driver of monitoring and control (ABC7news (2018), http://abc7news.com/automotive/tesla-ceo-elon-musk-speaks-on-deadly-mountain-view-crash-for-first-time/3339246/), but these instances nonetheless illustrate design-induced errors.

[9] ABC7news (2018); http://www.businessinsider.com/uber-first-footage-fatal-self-driving-car-crash-2018-3 .

[10] March 28, 2018, *RFI*.

- At SAE Level 2, an automated system on the vehicle can actually conduct some parts of the driving task, while the driver continues to monitor the driving environment and performs the rest of the driving task.

- At SAE Level 3, an automated system can both actually conduct some parts of the driving task and monitor the driving environment in some instances, but the driver must be ready to take back control when the automated system requests.

As discussed further in these comments, many human factors variables affect the safety of the operation when and how the vehicle operator decides to either take or not take control of the vehicle from the automation. These variables are significantly affected depending on the level of automation.

Other important categorizations of levels of automation distinguish between different stages of an operation, from inputs to outputs, such as identification of critical information, to processing of that information,[11] to creation of possible courses of action, and finally to implementing the response.[12] State-of-the-art research must be included in any new automation aided applications in the rail industry. To ignore these new categorizations and taxonomies would hinder learning from past application experiences, and most importantly, from past human-automation interaction failures.

- **Automation Bias** ("Automation bias is the propensity for humans to favor suggestions from automated decision-making systems and to ignore contradictory information made without automation, even if it is correct."[13])

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[11] Wickens, C., Li, Y., Santamaria, A., Sebok, A., & Sarter, N. (2010). Stages and levels of automation: An integrated meta-analysis; *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, Vol. 54, 389-393, and Onnasch, L., Wickens, C., Li, Y., & Manzey, D. (2014); and Human performance consequences of stages and levels of automation: An integrated meta-analysis. *Human Factors*, Vol. 56(3), pp. 476-488.

[12] Sheridan, T. (1992). *Telerobotics, automation, and human supervisory control*, Campbidge: MIT Press, and Endsley, M. (1999). Level of automation effects on performance, situation awareness and workload in a dynamic control task. *Ergonomics*, Vol. 42, pp. 462-492.

[13] Wikipedia, "Automation Bias" citing Cummings, Mary (2004), "Automation Bias in Intelligent Time Critical Decision Support Systems" at: https://web.archive.org/web/20141101113133/http://web.mit.edu/aeroastro/labs/halab/papers/CummingsAIAAbias.pdf For the origin of the term "automation bias," and a comprehensive discussion of decision

> Considerable research in commercial aviation automation has demonstrated a human tendency to err when utilizing automation-assisted vehicle control systems. One of the more important research errors has been termed the "automation bias," defined as "when a human decision maker disregards or does not search for contradictory information in light of a computer-generated solution which is accepted as correct."[14] Tragic commercial aviation accidents have been attributed to automation bias.[15]
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> Operators may over rely on automation aids and neglect the usual first-hand information, e.g., visual, auditory, memory, checklists, which may indicate a contrary but correct response, and instead commit an operational error due to a bias to follow the directives of the automated decision "aid" – termed an *error of commission*.[16]
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> For example, in aviation, cases have been reported where crews erroneously relied on false alerts ("ghost" or "phantom" radar images,) rather than available disconfirming information, and committed risky incursions into conflicting airspace.[17]
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> On the other hand, operators may fail to monitor the usual first-hand information, become complacent and omit the appropriate operational response, - termed an error of omission.[18]

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biases as they relate to automation, see Mosier, K. & Skitka, L., (1996), "Human decision makers and automated decision aids: Made for each other?" in R. Parasuraman & M. Mouloua (Eds.)(1996), *Automation and Human Performance: Theory and Applications*. NJ: Erlbaum, pp. 201-220.

[14] Cummings, M.L. (2004) "Automation Bias in Intelligent Time Critical Decision Support Systems" *supra* at: *American Institute of Aeronautics and Astronautics 1st Intelligent Systems Technical Conference, p. 2*.

[15] Skitka, L., Mosier, K., and Burdick, M. (1999). Does automation bias decision-making? International Journal of Human-Computer Studies, Vol. 51, pp. 991-1006.

[16] Mosier & Skitka, *op. cit.*

[17] NASA ASRS. (1992). TCAS Incidents Reports Analysis, Quick Response Report No. 235. Mountain View, CA: NASA Aviation Safety Reporting System. Cited in Mosier & Skitka (1996).

[18] Mosier & Skitka, *op. cit.*

For example, again in aviation, an automated flight-configuration warning system failed to alert a Delta crew that the airplane’s flaps were not properly configured for takeoff. Apparently relying on the warning system, the crew did not manually verify the positions of the flaps, resulting in a crash shortly after takeoff.[19]

- **Automation-induced complacency** More recently, automation-induced errors of omission have been more commonly referred to as *automation-induced complacency*. Vehicle operators can become complacent especially when automation is usually reliable, but fail to intercede in an unusual circumstance, or intercede unprepared to react as quickly and as skilled compared to having been vigilant. Complacency in aviation has been defined as “self-satisfaction that may result in nonvigilance based on an unjustified assumption of satisfactory system state,” and the term automation complacency has been used to describe the causes of commercial aviation and other transportation industry accidents.[20]

- **Training needed for human-automation interaction** Researchers have described how the use of automation will increase the needed training. Not only will operators, whether on-board or at a central location, need to have the optimal level of trust, neither under-trusting or over-trusting, but must also maintain reasonable situation awareness in the case they must assume control over an automated function or operation. Operators now must be more than able to operate the vehicle, they must also be able to effectively manage the automation and the challenges it presents, with such phenomena as mentioned above in automation-induced bias and complacency.[21]

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[19] NTSB Report AAR-80-10, cited in Mosier & Skitka, op.cit., and Billings, C. (1991). “Human-centered aircraft automation: A concept and guidelines.” (Tech. Mem. No. 103885). Moffett Field, CA: NASA Ames Research Center.

[20] Parasuraman, R. and Manzey, D. (2010). Human Factors: The Journal of the Human Factors and Ergonomics Society, Vol. 52, p. 381-410.

[21] Noy, et al. (2018).

- **Characteristics of optimal human-automation systems** Research and experience in automation-aided and autonomous vehicle systems indicate many issues that need to be optimized for safety, as well as the efficiencies to be realized. For example, to name a few:

    - Operators must be actively engaged in the role of supervisory control when automation can diminish vigilance and increase tendencies to distraction.

    - The more reliable the automation, the more complacent the operator may be and thus not intervene when needed.

    - The less reliable the automation, the more likely the operator will disengage it even when it could provide significant assistance.

    - Automation may prevent operators from developing the skills they will need when they do need to intervene.

    - Passive monitoring of a system impedes adequate understanding of the system, in comparison to active engagement. Passive monitoring may also leave the operator ill-prepared to intervene due to not being situationally aware in real-time and having to disengage from the passive state.[22]

    - **New accident report fields** Accident investigations and reporting will need to capture the new variables presented by automation. Important information to add would, for example, include if/how automation was disengaged (automatically or manually); judgement, decision-making and other human factors problems in managing the system; system failure, either by design or deterioration; external conditions; and any other factors not categorizable in existing accident reporting categories.

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[22] Noy, et al. (2018).

- **Close call reporting.** Much of the improvement in aviation safety has been attributed to the Aviation Safety Reporting System (ASRS), which is a confidential, non-punitive, close-call/safety issue reporting system. Not only is the potential great for the benefit for automation to monitor operations, including close calls, but there also is the possibility that safety issues may not be known when they happen. Some standardization needs to be established with reporting not just accidents, but automation failures that did not result in accidents, such as conflicts between different automated systems, or disconfirmations by operators' observations. ASRS has already been helpful in identifying problems with automation in aviation, and such a tool must be utilized in any railroad application to avoid the same mistakes with the potential for tragic consequences.

- **Socio-technical context** Any future large-scale railroad automation will, or at least should be, an integral part of a socio-technical system, such as the interface with autonomous, or automation-aided motor vehicles at crossings. Crossing accidents comprise a major part of railroad-related fatalities. While it may be difficult to ever stop a train in time when a car comes on to the tracks in front of the train, even if the automation detects it and sets the train's emergency brakes, it is more likely that more automation in highway vehicles may provide some control when driver behavior ignores the hazard. Already, Google is working to augment their highway vehicle navigation device service to address rail crossings.[23]

  Integrating railroad automation into the larger socio-technical system will need to include equipment design; internet integration; physical and cyber security entities; train operator interfaces; the railroad industry; equipment suppliers; federal, state, and local crossing regulatory and funding jurisdictions; highway motor vehicle manufacturers; highway motor vehicle automation implementers (e.g., Tesla, Google, Uber); motor-vehicle codes and ordinances; and motor vehicle driver testing and training.[24]

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[23] NTSB, (2016). Train and truck crash on railroad right-of-way and subsequent fire. Report HAB1607.

[24] See Noy, *op cit*., pp. 74-77, for a discussion of these issues.

IV. CONCERNS RAISED BY PUBLIC AND PRIVATE HIGHWAY-RAIL CROSSINGS

With respect to the safety of railroad operations at highway-railroad crossings, the CPUC has the following comments regarding safety.

The *RFI's Question No. 2 in part asks: How do commenters envision the path to wide-scale development and implementation of autonomous rail operations (or operations increasingly reliant on automated train systems or technologies)?* The path to wide-scale development and implementation must research, address, and integrate the human factors, human-automation interaction, and socio-technical problems identified above. To do otherwise would negate the progress and wisdom achieved from other modes' implementation experience. Additionally, the CPUC does not profess to have addressed the complete set of issues and assert that all stakeholders should continue to identify safety issues, both from the academic literature and from experiences in other modes to-date. In general, the Railroad Safety Advisory Committee is well-suited to address and provide stakeholder guidance for this safety-critical topic.

The *RFI's Question No. 3* asks: "*Would it be helpful to develop automated rail taxonomy; a system of standards to clarify and define different levels of automation in trains, as currently exists for on-road vehicles and rail transit?*" It would be helpful to develop automated rail taxonomy; a system of standards to clarify and define different levels of automation in trains, as described earlier, but also for the different levels of automation at rail crossings and the vehicles that may use those crossings. FRA should utilize any existing and defined levels of automation in the railroad industry, academia, and other transportation modes such as aviation, highway vehicles, and/or public transit.

The *RFI's Question No. 4* asks: "*What limitations and/or risks (e.g., practical, economic, safety, or other) are already known or anticipated in implementing these types of technologies? How should the railroad industry anticipate addressing these limitations and/or risks, and what efforts are currently underway to address them?*" Freight trains require long distances to stop in comparison with any other vehicles or pedestrians. The curvature of railroad tracks, invasive vegetation, or buildings that block or obscure the engineer's line-of-sight and/or the train's ability to detect obstructions on the tracks. These limitations require additional sensors or technology in autonomous trains to detect and react, especially when nearing stations and highway-rail crossings. Autonomous and automation-aided train systems should also be able to sense when roadway users collide with the side of a train or when the train strikes a trespasser or animal on the tracks. Upon the appropriate detection, the train, in many cases, would need to stop, report the incident and wait for someone to check what the train struck. This process may hinder the efficiency of train operations.

Further, the sensors on autonomous and automation-aided trains should be able to operate in adverse weather conditions and be programmable to handle all situations. Careful design consideration must be included when creating software that may start /stop a train, or allow it to continue movement when weather conditions may hamper the sensors' ability to function properly. A human operator, and not any autonomous train system, must always have control by being "in the loop" to be able to make such decisions. Therefore, constant communication and monitoring by railroad personnel should be carefully integrated with the automation.

The *RFI's Question No. 5* asks: "*What benefits and efficiencies (e.g., practical, economic, safety, or other) do commenters anticipate that railroads will be able to achieve by implementing these technologies?*" Railroad trains should be able to recognize stations, highway-rail crossings and, on the railroad right-of-way, the existence of a pedestrian, vehicle, or other object and be able to stop before a collision occurs. In such cases an automation-aided or autonomous train system must be able to distinguish between normal crossing traffic and vehicles and obstructions that are not moving, such as a car stuck on the crossing or high-centered on the track. As described earlier, a fully implemented system might be one that is integrated with the automation-aided and autonomous highway vehicle systems which could automatically warn highway vehicles when trains approach and a collision is predicted.

The *RFI's Question No. 7* asks: "*What, if anything, is needed from other railroad industry participants (e.g., rail equipment and infrastructure suppliers, manufacturers, maintainers) to support railroads' automation efforts?*" Railroad automation will require additional funds from the federal, state, and local governments for grade separations. As discussed earlier, adequate testing of cyber protections against interference with automation technology is essential. The FRA's Rail Safety Advisory Committee is an ideal format for including stakeholder input and oversight.

The *RFI's Question No. 12* asks: "*How should railroads plan to ensure the integration of these technologies will not adversely affect, and will instead improve, the safety and/or security of railroad operations?*" The railroads must address not only how they envision these technologies can work, but they must address how they can fail. As expressed in a leading journal and termed "Doyle's Catch,"[25] new technology often comes with considerable risks:

> Doyle's Catch shows that… optimism is insufficient. Emerging capabilities, because they are powerful, produce new technical challenges, which if not addressed will produce negative unintended consequences. Doyle's Catch poses a new technical challenge: How can design and testing "close the gap between the

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[25] Woods, D. (2016). The risks of autonomy: Doyle's Catch, *Journal of Cognitive Engineering and Decision Making*, Vol. 10(2), pp. 131-133.

> demonstration and the real thing?" This challenge is not trivial and has not been addressed in the development of increasingly autonomous systems. Doyle's Catch contains three main technical challenges: complexity, life cycle, and testing. (p. 132)
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> Envisioning the future is a precarious enterprise that is subject to biases. As past work has shown, claims about the effects of future technology change are underspecified, ungrounded, and overconfident, whereas new risks are missed, ignored, or downplayed…. The new capabilities trigger a much wider and more complex set of reverberations, including new forms of complexity and new risks. Failure to anticipate and design for the new challenges that are certain to arise following periods of technology change leads to automation surprises when advocates are surprised by negative unintended consequences that offset apparent benefits…. (p. 131)

While these comments have identified many of these biases, both in confidence of design and in confidence in human decision-making, new technologies are bound to introduce new ones. Other authors have identified "catches" or "ironies" in the design and implementation of automation. For example, introducing a discussion of "The Ironies of Automation," researchers state the following,

> In the development of [automated driving] in which the driver has some role, it is imperative that we find solutions to what are seemingly intractable ironies of automation, some of which are listed below. These ironies are so named because rather than relieving driver workload and vigilance, they can actually place greater demands on the driver or they can lead to outcomes that manifest themselves as unintended consequences. Several papers have nicely articulated these ironies (Bainbridge, 1983; de Winter and Dodou, 2014; Fitts, 1951; Sharples, 2009). Accordingly, they present difficult challenges that must be addressed to reduce the potential for driver errors that might arise from automation. At the core of the "ironies of automation" is the semantic paradox that the more advanced the automation (excluding level 5, or full automation) the more challenging the role of the driver under critical conditions."[26]

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[26] Noy, *op. cit.* at . 72.

The researchers list several areas where the opposite of what might be expected is likely to occur, i.e., ironies, including ones in task allocation, deskilling, cognition, control, lack of trust, and liability. Constant industry and government vigilance must be maintained during the design, implementation, and lifespan of any such technology, and stakeholders must be ready to react to newly identified hazards. Safety requires any autonomous train operations to be restricted to an exclusive right-of-way at least for the foreseeable future.

Training needs will increase with automation, as experience with PTC has shown. Not only must an operator know how to operate a vehicle, but he or she must also know how to manage the automation, including how and when to trust the system, how and when to intervene, and how to stay situationally aware. This topic has been discussed widely in the research literature,[27] and underscores the need for additional training to address such problems as overreliance, underutilization, and inappropriate application of automation, not just by vehicle operators, but also by designers, managers, and regulators. This line of research should inform the design, implementation, and regulation of automation uses in the railroad industry.

Finally, the railroads must work with Federal, State, and local regulatory and funding entities especially for the need to grade-separate any crossings for autonomous train operations.

The *RFI's Question No. 13* asks: "*What are the safety and security issues raised by automation in railroad operations at public and private at- grade highway-rail crossings? To what extent should DOT coordinate with state or local governmental entities on certain safety or security issues? How might automation improve the safety of the general public at highway-rail grade crossings or along the railroad rights-of way?*" The *2018 California State Rail Plan*[28]

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[27] Parasuraman, R., & Riley, V. (1997). Humans, and automation: Use, misuse, disuse, abuse. *Human Factors*, Vol. 39, pp. 230-253.

[28] http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0ahUKEwiGtLzJj4bbAh

acknowledges the development of driverless vehicles (automobiles, buses, and trucks) but does not touch on automated trains. The plan includes a vision for rail service in 2040 for an integrated system. The ability of automation-aided and autonomous trains to recognize approaching or stopped trains is just now being implemented with PTC. Automation must also be able to recognize the existence and functioning of highway-rail crossing warning devices (active and passive) and be able to react safely. Modally integrated automation-aided and autonomous systems should be able to safely react to a highway-vehicle blocked crossing. Autonomous rail operations should be able to detect obstructions on the tracks, provide warning and acknowledge signal preemption and warning device failures.

Coordination between state and local governmental agencies concerning the safety of railroad operations at public and private at-grade highway-rail crossings is imperative. The CPUC is concerned that autonomous trains will not be capable of adequately detecting crossing obstacles such as trespassers, vehicles, objects, etc. Autonomous trains require sensors to recognize and inform motorists, bicyclists, and pedestrians that a train is approaching. This must include the confirmation of the activation of warning devices. If the automated train cannot confirm warning device activation when approaching a crossing, the automated train should revert to manual fail-safe mode so that it is able to stop in advance of the crossing. Finally, the CPUC is hopeful that the use of automation-aided and autonomous trains may help eliminate certain human errors such as those involving fatigue, complacency, outside distractions, etc. At the same time, the CPUC is concerned that train personnel may not be properly attentive because of over-dependence on automated systems when approaching a dangerous condition at a public

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or private crossing. Train personnel must always be aware of situations that may require special alertness. They must always be able to react quickly to dangerous circumstances.

V. CONCLUSION

The railroad industry is currently in the process of implementing an important initial level of automation – Positive Train Control. However, using the SAE levels taxonomy, the current level is equivalent to Level 0, “the driver does everything,” except with the significant back-up function of stopping the train if certain operator errors occur. As the railroads choose to develop and implement higher levels of automated operations, they will necessarily move through several stages of automated assistance, with every stage being dependent on safe and effective interaction between the human operators and the automation as we have described in these comments. Even if and when the industry were to get to Level 5, where “the automated system can perform all driving tasks under all conditions that a driver could perform them,” there will still be a human somewhere “in the loop,” and thus all the human factors issues we and others identify must be sufficiently addressed to ensure safety even at this level.

The demands to ensure safety will be considerable and all available taxonomies should be utilized to anticipate necessary design, testing, training, operation, and maintenance, as we have introduced here. This will be an important endeavor, and needs to be done well not only to protect employees, passengers, and the public from the risks of accidents and hazardous materials exposure, but to instill regulatory and public confidence that the automation is being implemented not just for efficiency and profit, but for the safe and reliable transportation of people and commodities by rail. The research literature in other transportation modes is well-developed, and must be foremost in the minds, plans, and actions of all stakeholders as this field progresses.

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Respectfully submitted,

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CERTFICATE OF SERVICE

I hereby certify that I have this day submitted the **COMMENTS OF THE CALIFORNIA PUBLIC UTILITIES COMMISSION** by submitting a copy thereof to the *Federal Rulemaking portal* at http://www.regulations.gov and following the instructions for submitting comments at that website as directed by the Federal Transit Agency in Docket No. FRA-2018-0027.

Executed at San Francisco, California, this 31st day of May, 2018.

/s/ REBECCA ROJO
Rebecca Rojo