Reliability Aspects of Connected and Autonomous Vehicles

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Why Transportation Needs to Evolve

In this rapidly changing world, cities are growing fast. With urban centers dealing with record levels of traffic and pollution, the United Nations has identified increasing urbanization as one of the defining trends of the 21st century.

This growth is also causing a shift from individual vehicle ownership to the use of shared mobility options such as ride-hailing services. Most of our infrastructure was built to meet the needs of individually used vehicles. However, most of those vehicles sit idle about 95% of the time. As a result of this, as much as 30% of the real estate in city centers is devoted to parking.[1]

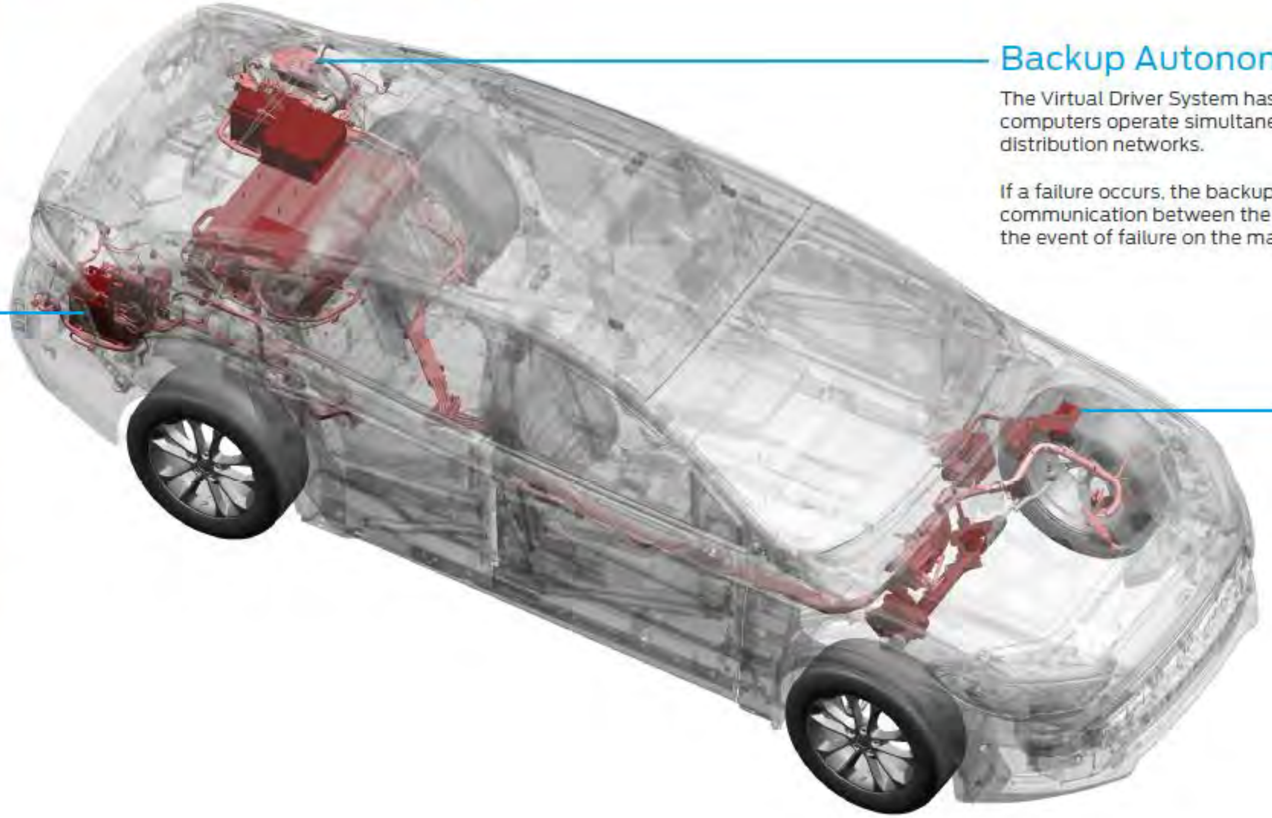
At Ford, we see this as an opportunity to design smart vehicles for a smart world. If applied correctly, new technologies can enable solutions to help city transportation systems improve the quality of life for everyone. That's why we're approaching these opportunities in a holistic way. We recognize that just injecting new mobility technologies and services into a city or neighborhood won't solve their existing challenges and may even make them worse.

Therefore, we created a City Solutions team dedicated to working closely with cities and communities to address these challenges. We're learning how each city works, what its needs are and how our technology can adapt and support each city's unique transportation system. We're developing a portfolio of solutions that can help a city improve its transportation system through better orchestration of traffic, transit and the ever-growing mobility options emerging every day.

Self-driving vehicles are one of the solutions to help enable this future. Ford is designing them to operate as a productive, safe and valuable part of a city transportation system to help make people's lives better.

[1]Keeping the Nation Moving: Facts on Parking. RAC Foundation. 2012. www.racfoundation.org/wp-content/uploads/2017/11/parking_fact_sheet.pdf

Ensuring Reliability through Redundancy



Diagnostics and Vehicle Health Monitoring

A sophisticated vehicle health monitoring strategy employs diagnostics integrated across multiple systems within the vehicle to determine vehicle health and perform fallback maneuvers when needed.

In addition to diagnostics, we also monitor the vehicle to determine its readiness, such as if all doors are closed.

Electrical Power Systems

While main power to the vehicle is provided from the high voltage battery, there are backup electrical power sources and distribution to several critical components. In the case of a power failure, the backup powernets are able to provide low voltage power to the computers, sensors, braking and steering systems to bring the vehicle to a controlled stop.

Backup Autonomous Driving System

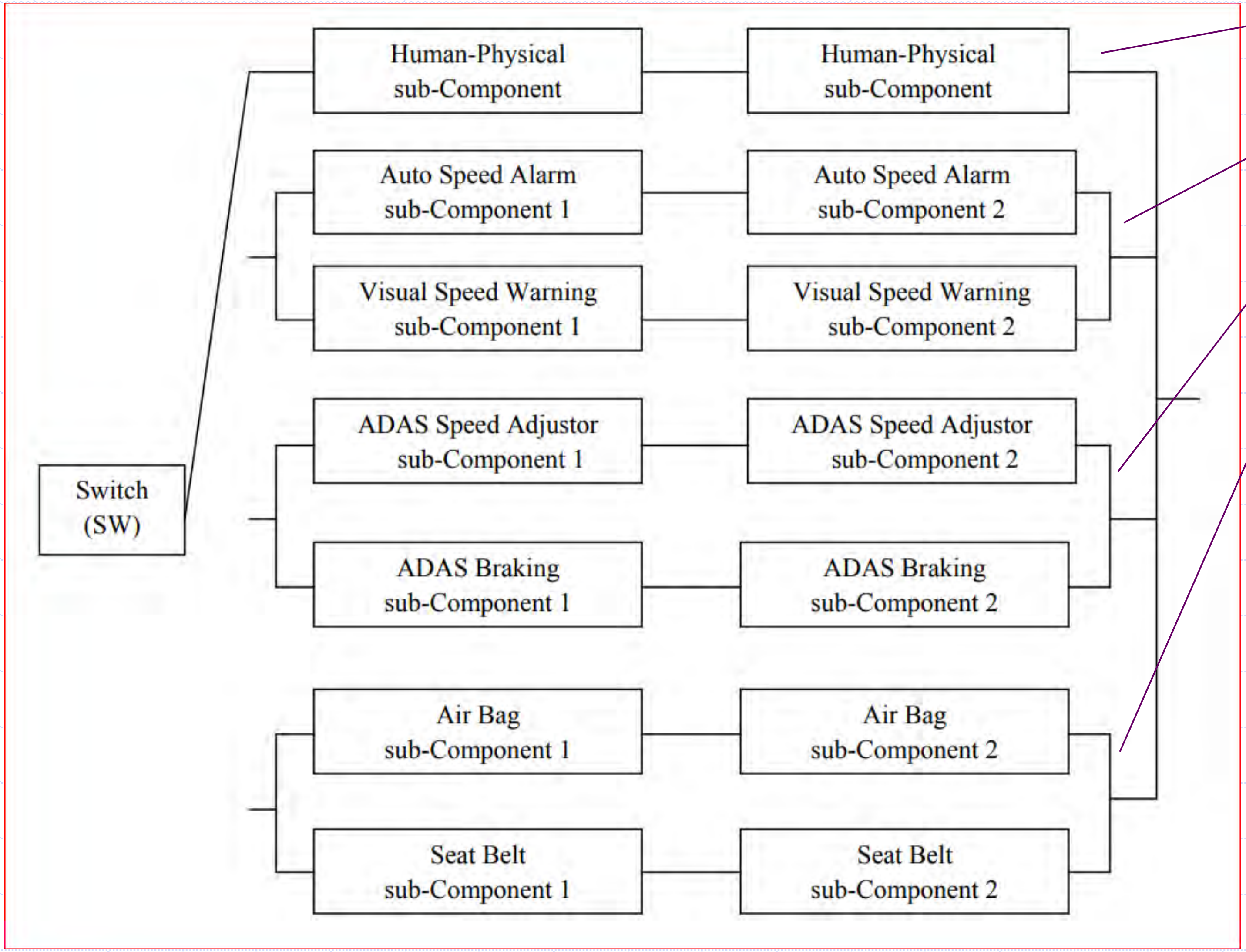
The Virtual Driver System has both main and backup computing systems. These two computers operate simultaneously while sharing information yet are on separate power distribution networks.

If a failure occurs, the backup system will bring the vehicle to a controlled stop. In addition, communication between the sensors, computers, and actuators have an alternate path in the event of failure on the main system.

Redundant Braking and Steering Systems

Backup braking and steering systems exist on separate power distribution networks. This redundancy allows the system to bring the vehicle to a controlled stop if a system fails.

ADAS Redundancy Modelling | Classical RBD Representation



- Human Component (A)
- ADAS Warning Systems (B)
- ADAS Crash Avoidance (C)
- Passive Safety Systems (D)

System Reliability Model:

$$
\begin{aligned}
R_S(t) &= R_{SWA\to B} R_A(t) \\
&+ \int_0^t f_A(x_A) R_{SWA\to B} R_B(t-x_A)\, dx_A \\
&+ \int_0^t f_A(x_A) \int_{x_A}^t \begin{matrix} f_B(x_B) R_{SWB\to C} \\ R_B(t-x_A-x_B)\, dx_B \end{matrix}\, dx_A \\
&+ \int_0^t f_A(x_A) f_B(x_B) \int_{x_B}^t \begin{matrix} f_C(x_C) R_{SWC\to D} \\ R_D(t-x_A-x_B-x_B)\, dx_C\, dx_B \end{matrix}\, dx_A
\end{aligned}
$$

Reference: K Hojjati-Emami, BS Dhillon , K Jenab (2012) “Reliability prediction for the vehicles equipped with advanced driver assistance systems and passive safety systems” Int. J of Industrial Eng Computations s 3 (2012) 731–742.

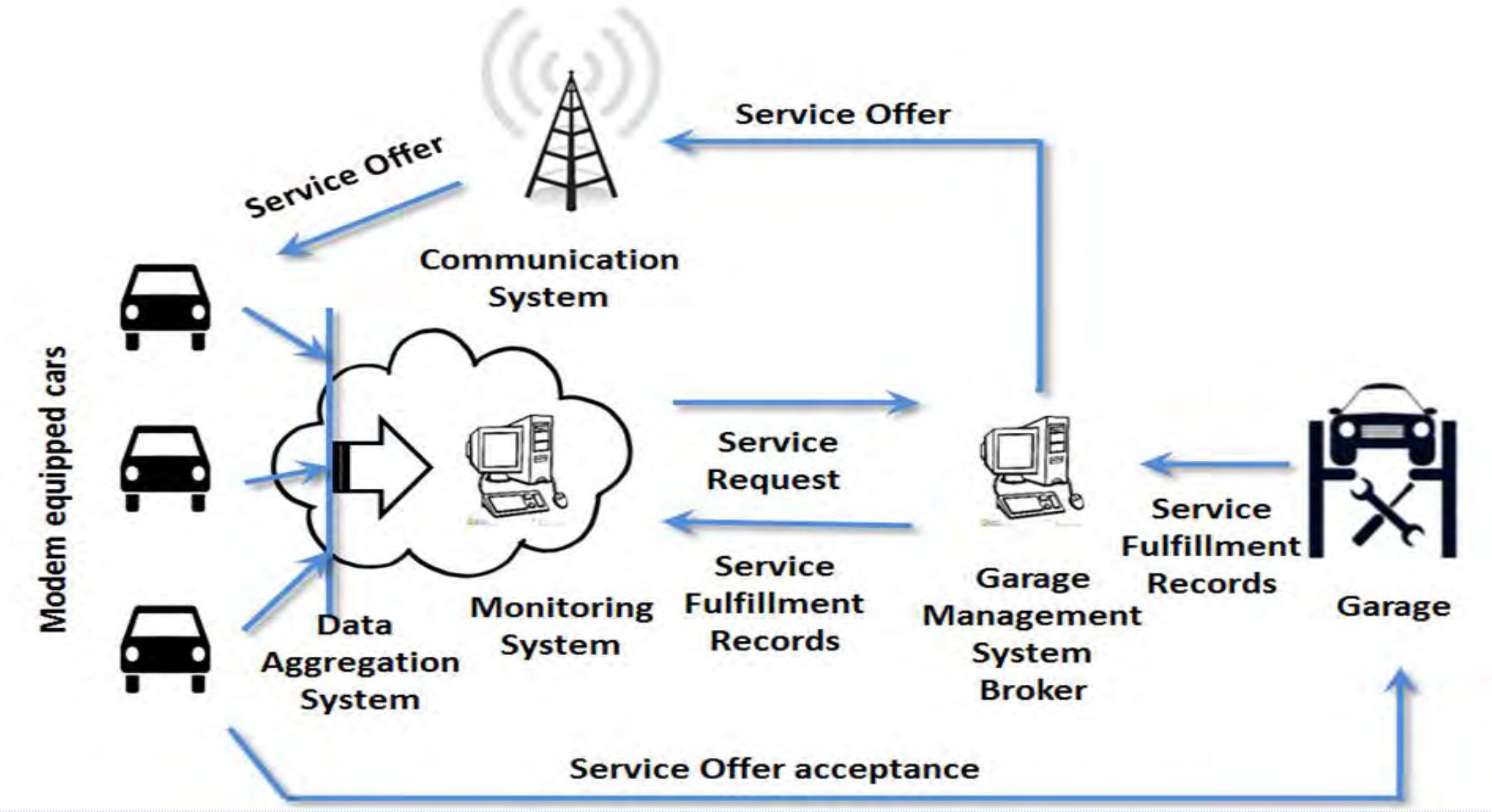
Design Life Implications

- Usage rate of average conventional passenger cars is 5%
- This translates into 72 mins in 24 hrs
- In a mixed, primarily urban duty cycle, with 30 MPH average speed, this further translates into ~13,140 miles/year
- Current design life target: 10YIS|150K (90th percentile)

- Usage rate of ride sharing and autonomous cars is expected to be (at least) 75%
- This translates into 1,080 mins in 24 hrs
- In a mixed, primarily urban duty cycle, with 30 MPH average speed, this further translates into 197,100 miles/year
- What should be design life target then?

Reference: JW Wasiloff (2018) "How Ride Sharing and Autonomous Vehicles impact Customer Usage and Reliability", Automotive Excellence, No. 1-2018, 4-7.

Advanced Diagnostics & Vehicle Health Monitoring



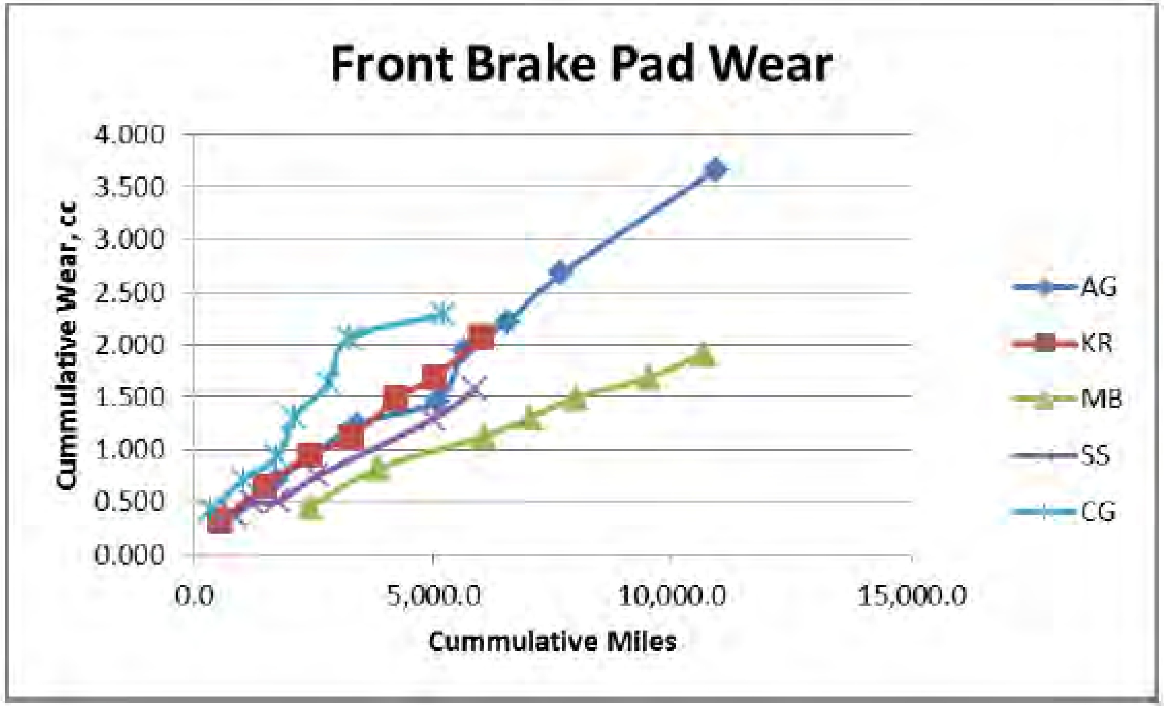
A Virtual Sensor for Brake Pad Thickness

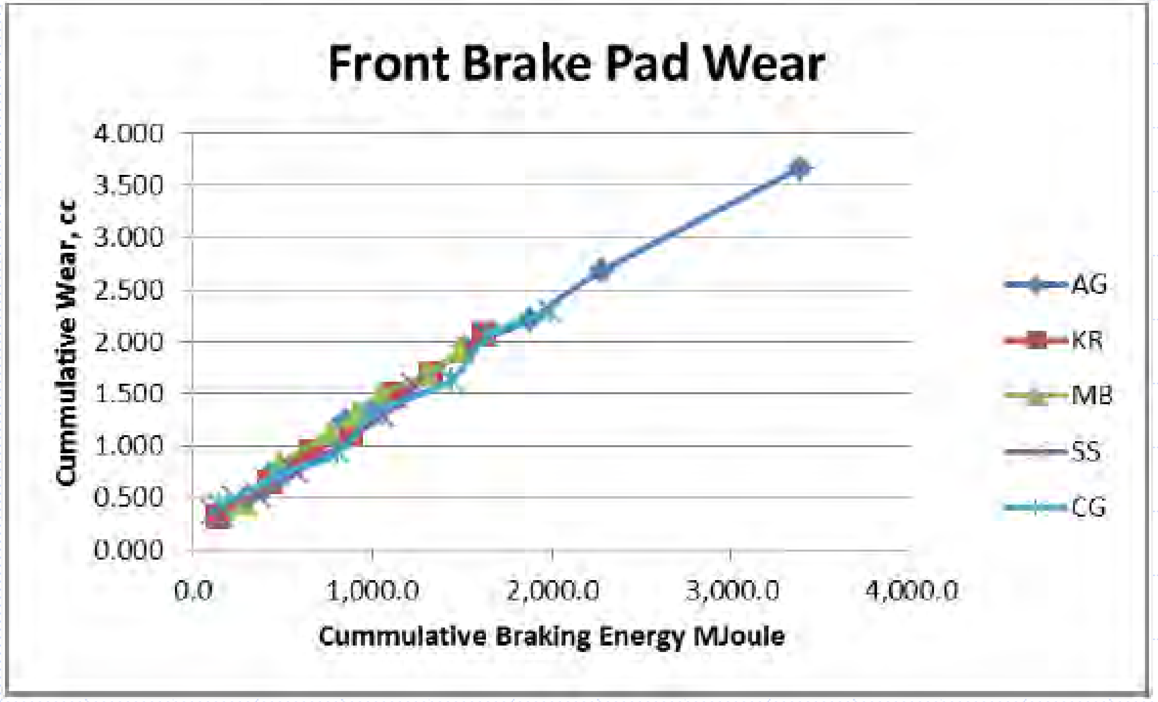
U.S. Patent (Ford) 2014
US20160163130A1

Brake pad wear is proportional to the consumed kinetic energy during a breaking event

$$\Delta W \propto \frac{m\left(V_1^2 - V_2^2\right)}{2}$$

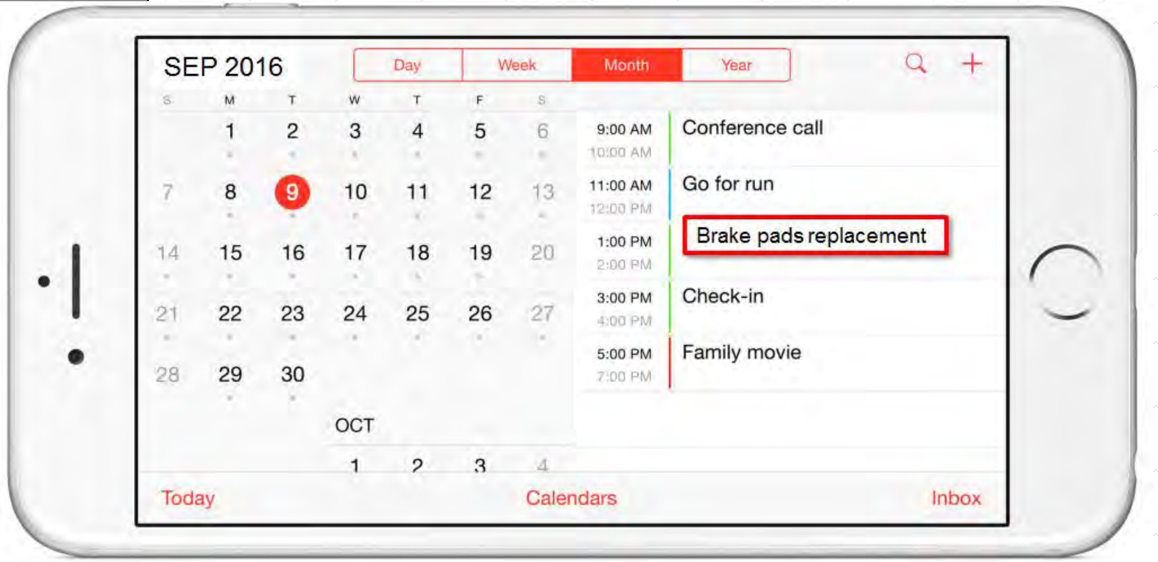
m = vehicle mass
V_1, V_2 = vehicle speed before and after breaking, respectively





Incremental Mileage to Critical Wear (6.5mm) by VIN @ 95% Confidence Probability: $Pr(w \geq 6.5 | \Delta m \leq m_0) = 0.95$

VIN	Current Energy, kJ	Current Mileage	Increm. Mileage to Critcal Wear (6.5 mm)	VIN	Energy, kJ	Current Mileage	Increm. Mileage to Critcal Wear (6.5 mm)	VIN	Energy, kJ	Current Mileage	Increm. Mileage to Critcal Wear (6.5 mm)
1	85,174	33,162	12,214	34	101,005	40,669	4,707	67	107,086	42,005	3,371
2	93,523	36,649	8,726	35	149,004	57,592	0	68	106,369	41,474	3,901
3	96,627	38,286	7,090	36	101,604	39,803	5,573	69	107,696	41,806	3,570
4	97,509	39,065	6,310	37	102,978	40,608	4,768	70	108,764	42,294	3,082
5	98,826	39,213	6,163	38	102,140	40,439	4,937	71	115,706	44,957	419
6	96,917	37,642	7,734	39	104,759	41,305	4,071	72	111,724	44,018	1,358
7	98,816	39,946	5,430	40	101,328	39,452	5,924	73	108,249	42,858	2,517
8	93,715	36,288	9,088	41	106,389	42,408	2,968	74	120,261	47,015	0
9	97,493	37,879	7,496	42	116,492	45,363	13	75	128,423	49,802	0
10	96,873	37,304	8,072	43	108,667	42,544	2,832	76	112,112	43,779	1,597
11	97,752	38,765	6,611	44	102,123	41,323	4,053	77	114,569	44,233	1,142
12	98,156	39,531	5,844	45	119,629	47,037	0	78	114,942	44,742	634
13	96,802	37,958	7,418	46	102,464	40,039	5,337	79	110,311	44,059	1,317
14	97,841	38,346	7,030	47	106,181	41,198	4,177	80	111,238	44,925	451
15	97,841	39,110	6,265	48	117,006	45,465	0	81	111,895	43,735	[illegible]
16	110,082	43,630	1,746	49	104,887	41,384	3,992	82	111,732	44,485	[illegible]
17	97,309	37,509	7,867	50	106,952	43,003	2,373	83	111,799	43,081	[illegible]
18	100,972	39,358	6,018	51	106,018	41,339	4,037	84	119,269	46,853	[illegible]
19	100,681	41,443	3,933	52	103,950	41,523	3,853	85	114,238	45,269	[illegible]
20	98,497	38,833	6,542	53	103,724	40,733	4,643	86	113,638	43,731	[illegible]
21	99,796	39,355	6,021	54	128,458	49,944	0	87	115,484	46,213	[illegible]
22	115,142	45,044	332	55	105,463	41,404	3,972	88	116,146	44,769	[illegible]
23	103,395	39,811	5,565	56	106,118	41,408	3,968	89	116,649	45,354	[illegible]
24	98,935	39,165	6,211	57	105,911	40,853	4,522	90	118,022	45,573	[illegible]
25	97,952	39,052	6,324	58	111,092	43,458	1,917	91	118,839	46,533	[illegible]
26	97,664	38,710	6,665	59	110,512	42,765	2,611	92	124,132	48,493	[illegible]
27	101,899	39,926	5,449	60	105,160	41,735	3,641	93	119,340	46,787	[illegible]
28	114,682	46,115	0	61	114,311	44,674	702	94	121,323	48,970	[illegible]
29	102,820	40,045	5,331	62	108,987	42,629	2,747	95	125,575	48,371	[illegible]
30	118,054	47,012	0	63	108,928	42,140	3,235	96	123,799	47,641	[illegible]
31	100,019	39,489	5,887	64	123,365	47,805	0	97	121,673	47,319	[illegible]
32	103,405	39,998	5,378	65	116,424	44,903	473	98	130,634	52,227	0
33	101,783	39,914	5,462	66	112,773	45,043	333	99	126,404	49,546	0
								100	143,458	55,378	0



Autonomous Vehicles (AVs) Safety, Reliability and Security (SRS) Assessment Techniques; Are We Ready?

Mohammad Pourgol-Mohammad, Ph.D

Safety Engineering and Risk/Reliability Analysis (SER^{2}D) Division

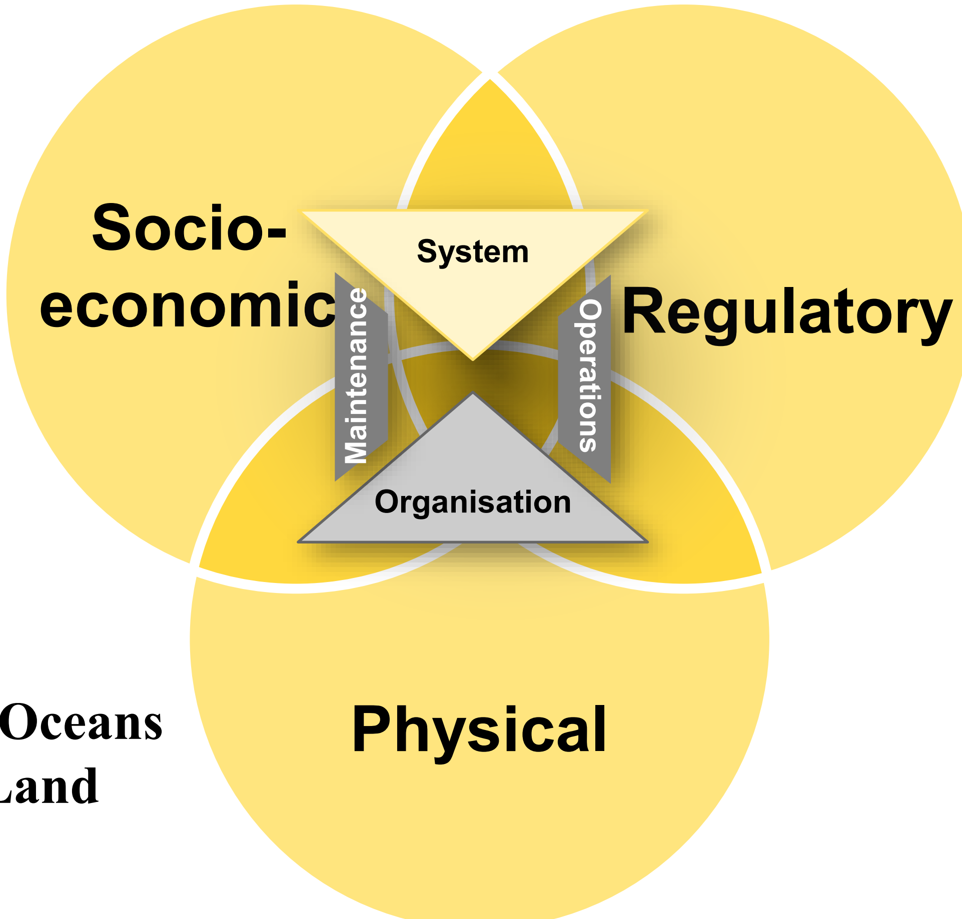
Outline

- Problem Statement
  - AV System Characterizations
  - Main Problems in SRS Assessment for AVs
- Advancements in SRS Assessment Techniques
- SRS Techniques Readiness for AV Systems Assessment and Certification
- Proposed SRS Assessment Technique Framework

Characterizing AV System Environments

Autonomous Land-based

Inspections of Physical Structures



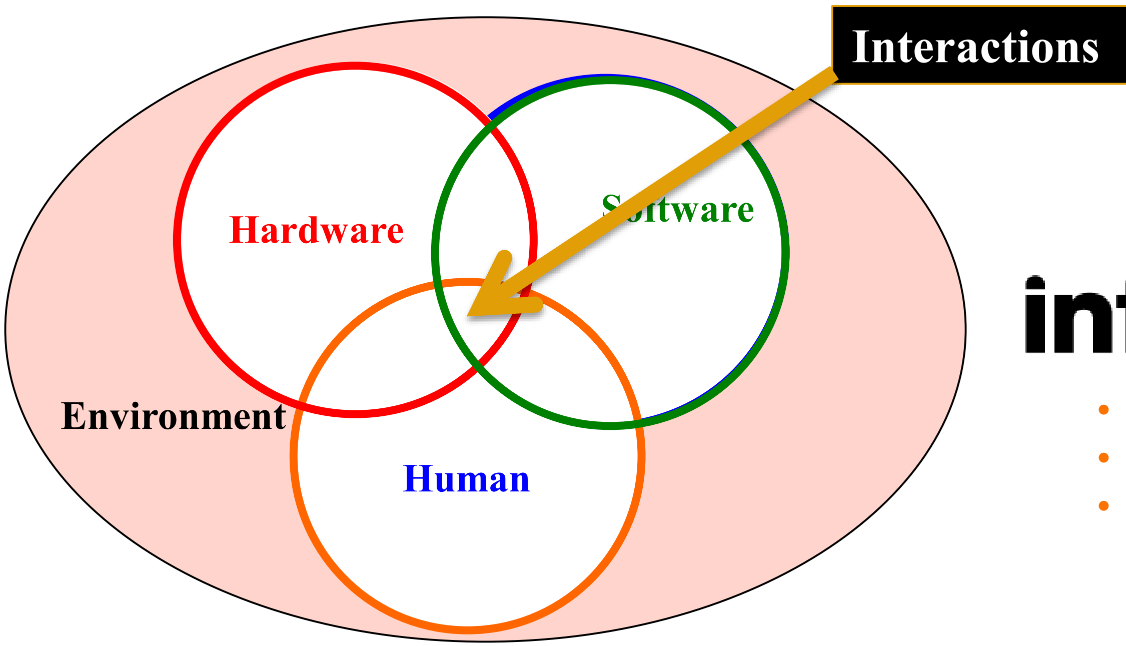
Air Transportation

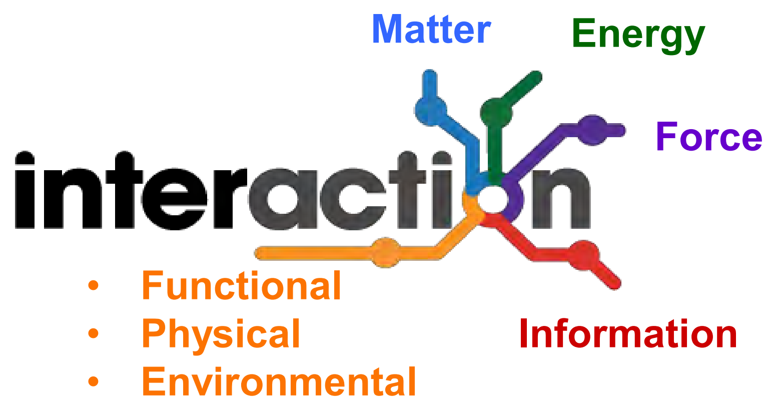
Mapping and Monitoring of Oceans and Areas on Land

Maritime

Challenges

Human in the loop – benefits and risks





Interaction Makes Big Difference in Precise SRS Assessment of AV Systems with Heavy Interactions

Levels of Autonomy

«A system's or sub-system's own ability of integrated sensing, perceiving, analyzing, communicating, planning, decision-making, and acting, to achieve its goals as assigned by its human operator(s) through designed human-machine interface (HMI)"

Level of Autonomy	Description
1	Fully manual control
2	The computer offers a complete set of decision/action alternatives.
3	The computer narrows alternatives down to a few
4	The computer suggests one alternative
5	The computer executes that suggestion if the human approves
6	The computer allows the human a restricted time to veto before automatic execution
7	The computer executes automatically, then necessarily informs the human
8	The computer informs the human only if asked
9	The computer informs the human only if it decides to
10	Fully autonomous Control

Main Questionss on SRS Assessment of AV Systems

- What is "acceptable risk" for autonomous systems and operations?
  - Do autonomous systems and operations need to be "as safe as" , or "safer than" other types of systems?
  - Should "acceptable risk" change with level of autonomy (LoA)?
- How can risk assessments and risk models of autonomous systems take " shared control " and "adaptive autonomy" sufficiently?
  - Propagation of Failure, lack of coordination of elements' behaviors, Failure Masking
- A challenge in risk analysis is to identify everything that can go wrong.
  - How can we deal with the unknown unknowns?

Advancements in SRS Assessment Techniques

SRS Community is working Hard

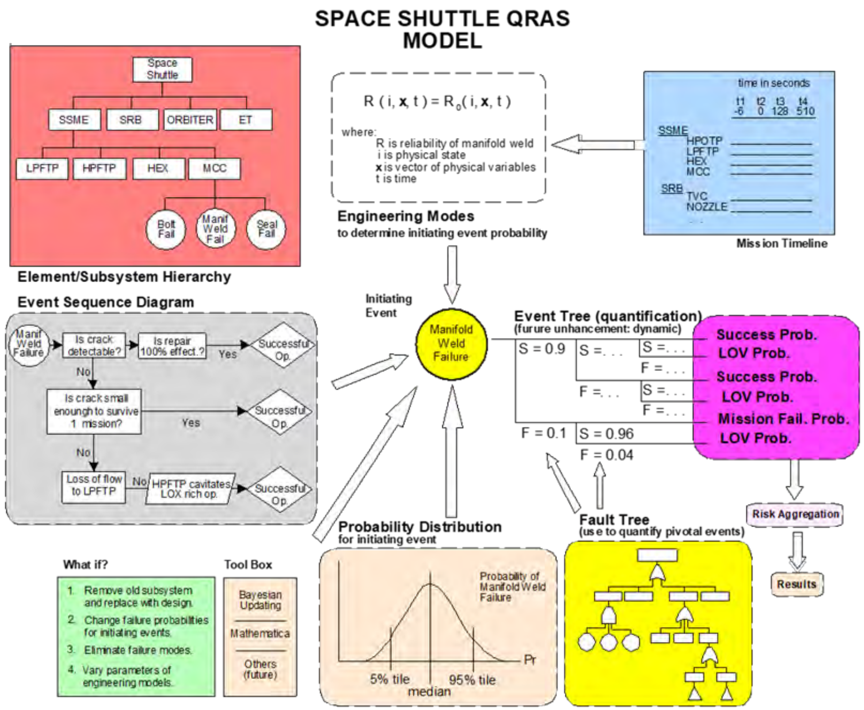
ASME Safety Engineering and Risk Analysis
70 years of Contributions for Safety Technologies

University of Maryland Center for Risk and Reliability
Almost 30 Years of Research and Education in SRS Area

UCLA Garrick Institute for Risk Science Studies

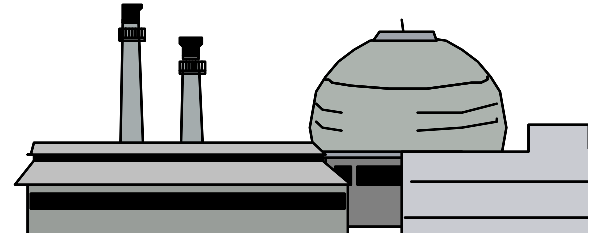
Advancements in SRS Assessment Techniques-1

Aerospace



-Significant Safety Improvement
-Over 12.5 Millions of USA Commercial Annual Flights

Nuclear Power Safety



- 1975, Reactor Safety Study, WAHS-1400
  - First comprehensive, large scale probabilistic
    risk assessment (PRA) of a complex system

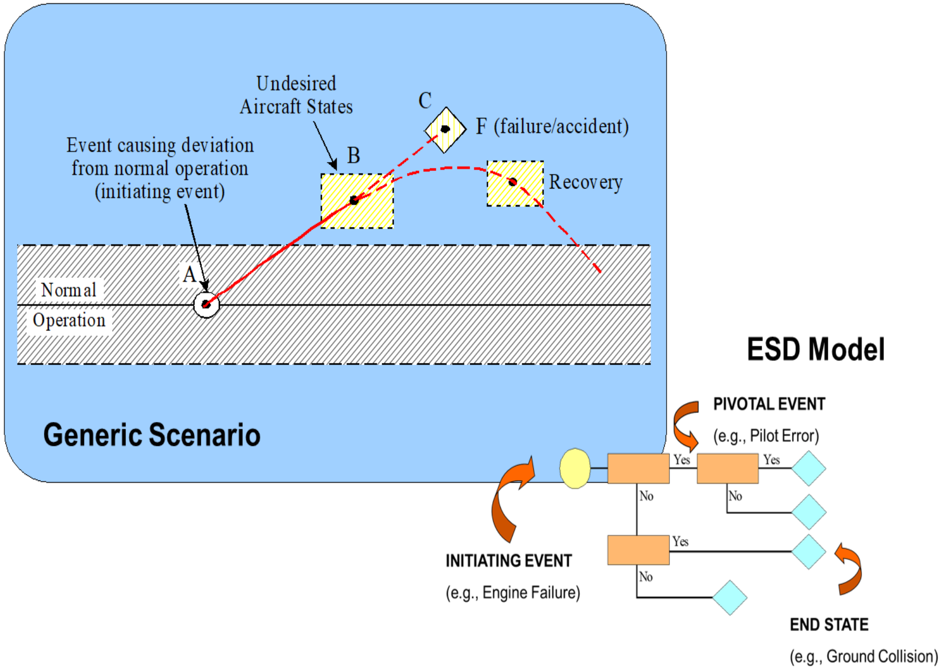
All results in Safety improvement by Order of Magnitude

- ~20000 Years of NPP Experience

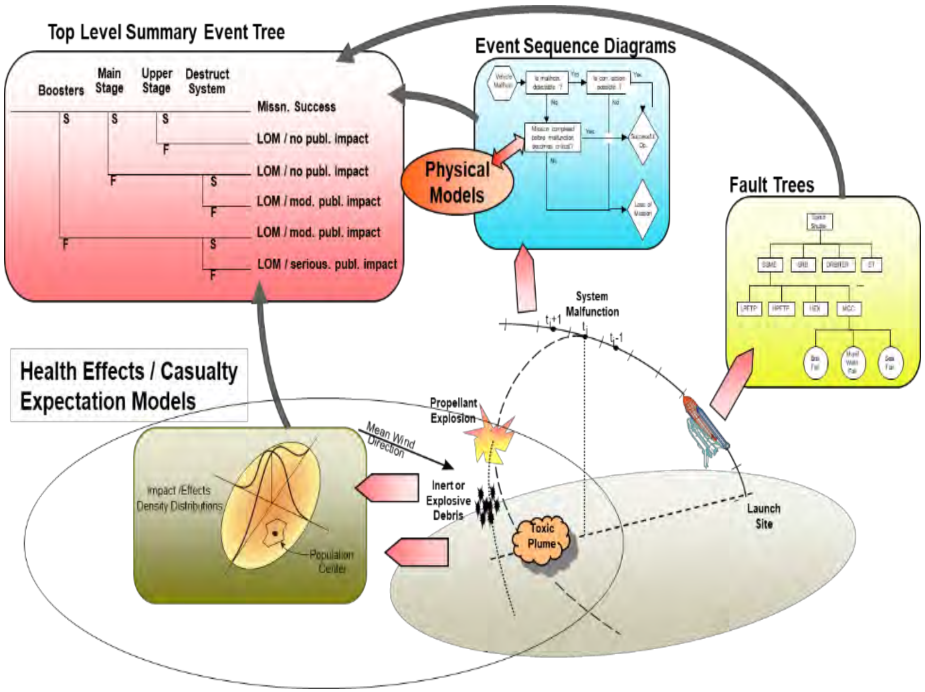
Lots of Conservatism; Making Design, Operation and maintenance Expensive

Advancements in SRS Assessment Techniques-2

Phenomenological and Event Based Techniques

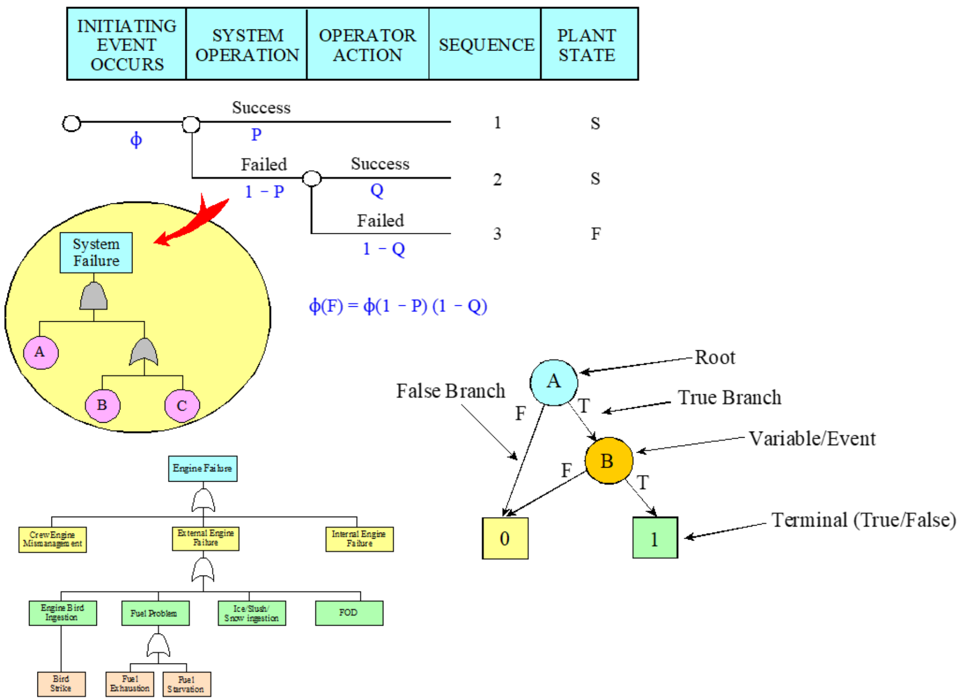


Phenomenological and Logic Based Models



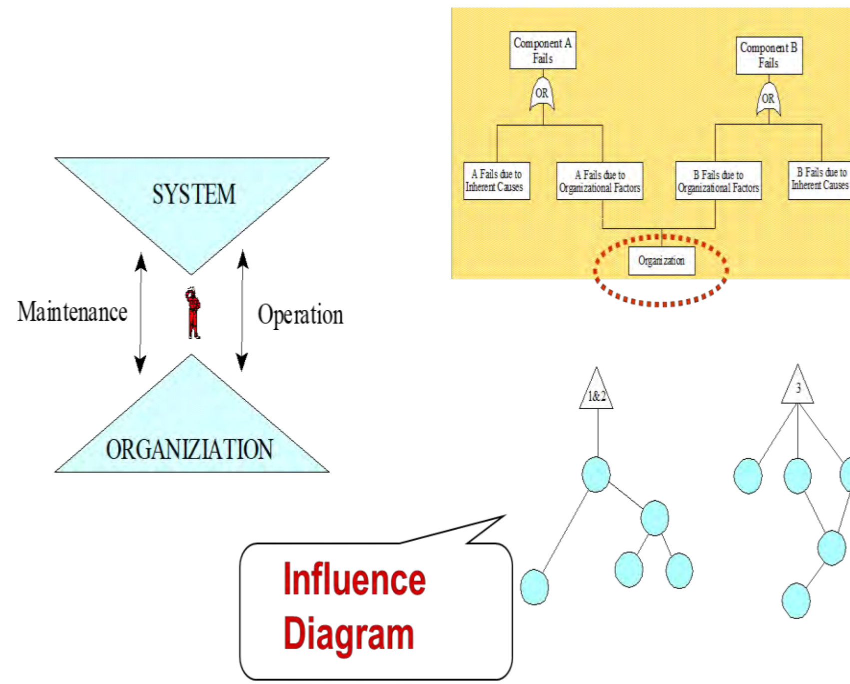
Advancements in SRS Assessment Techniques-3

Hardware Causal Relations with BDD Algorithm



Soft Causal Relations

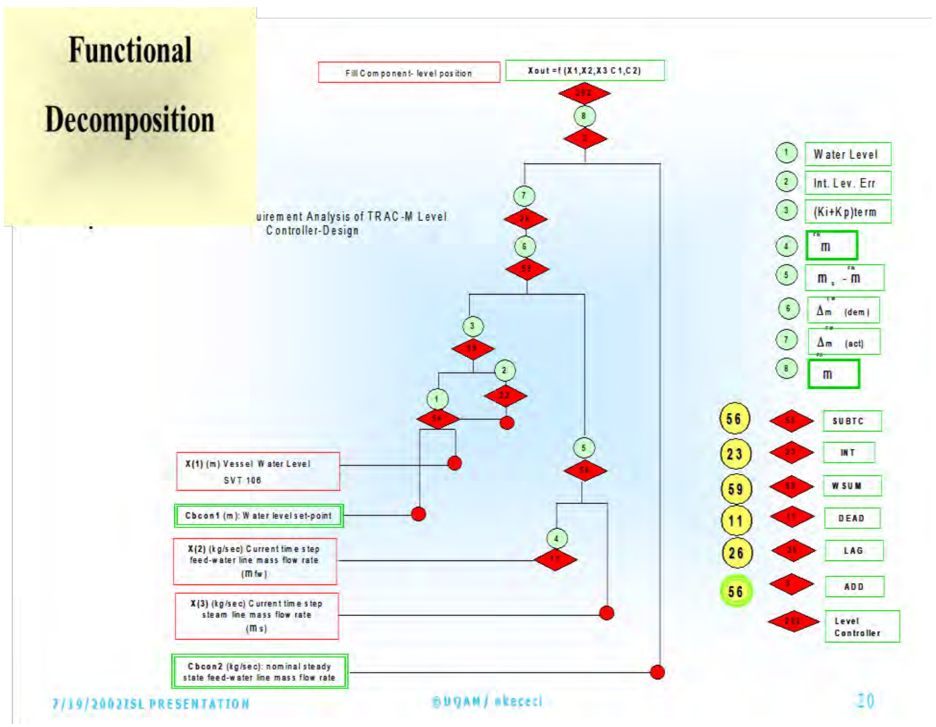
Human, Organizational, and Regulatory Environment



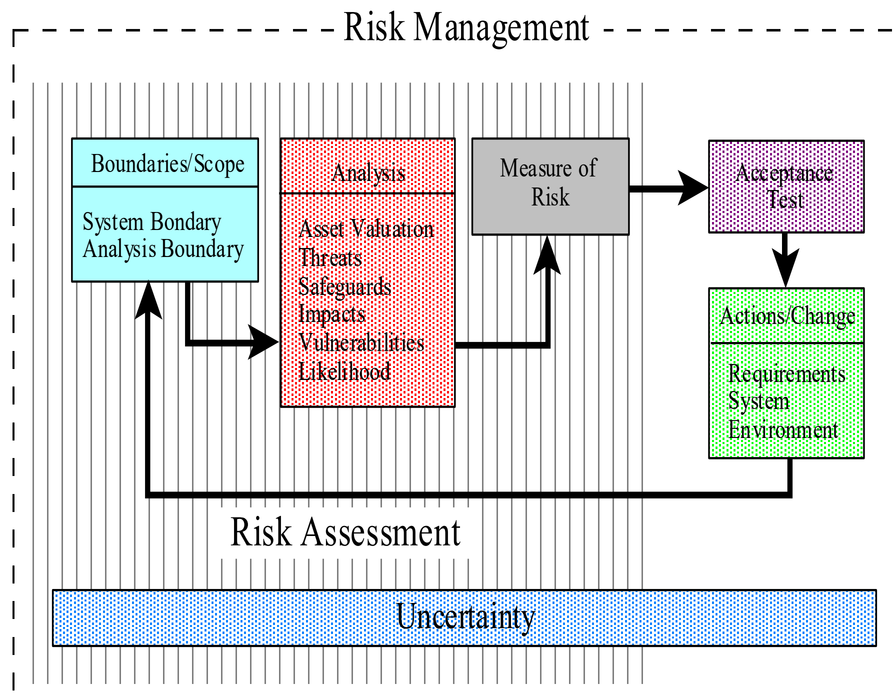
ASME
SETTING THE STANDARD

Advancements in SRS Assessment Techniques-4

Software Failure Modeling

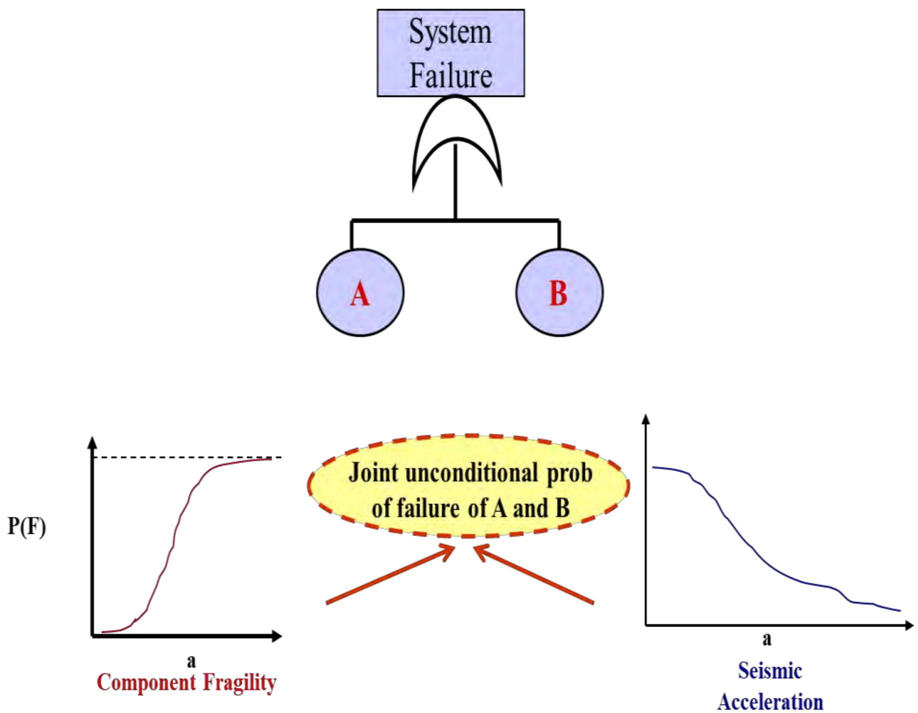


NIST IT Security Risk Management Framework

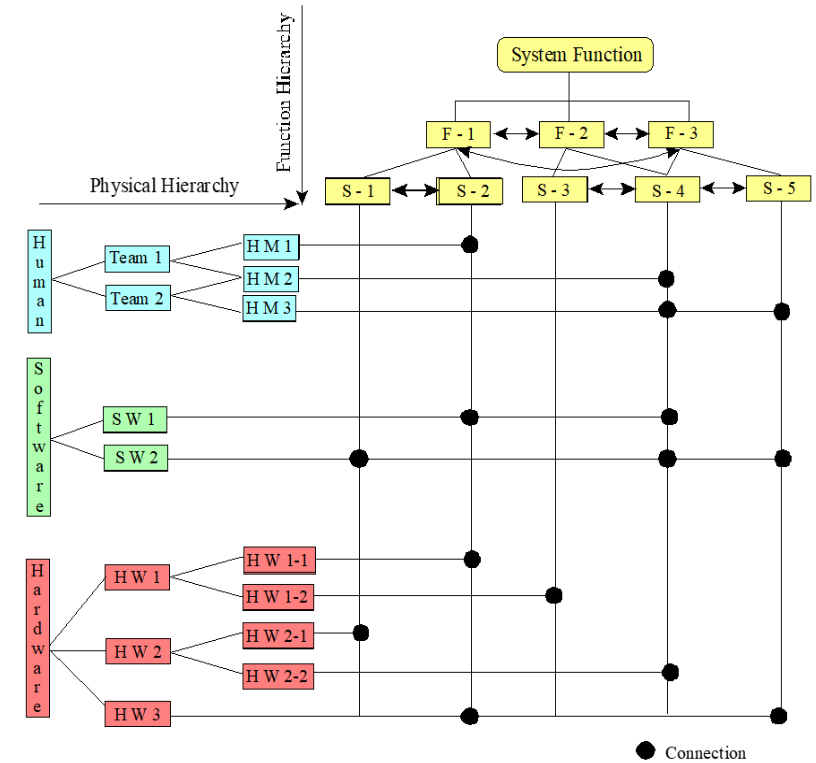


Advancements in SRS Assessment Techniques-5

External Environmental Causes



Dependencies Analysis
Functional-structural Hierarchy



Failures of X-Ware Systems

Mars Polar Lander Crash on Mars

- Functional

Informatio
n

CRH D310 rear-ended CRH D3115 in 2011, China, 35 died, 211 injured

Matter

Force

- Functional
- Environmen
  tal

Information

System Level CPH Failures

- Propagation of Failure
- Conflicts: lack of coordination of elements' behaviors
- Failure Masking: suppression of behavioral deviations

TUMBLING JUMBO

- During a flight, a China Airlines B-747 experienced a flame-out of one of the engines
- The crew failed to notice the problem, since the autopilot software was compensating for the resulting thrust imbalance
- The compensating actions kept the plane in a stable, yet abnormal state
  - The autopilot now played a critical role in the plane's stability
- The crew finally detected the problem
- They tried to take control of the plane, by switching off the autopilot
- The plane immediately became unstable, and started to tumble

Why is the number 32 768 important?

Ariane 5 rocket

first launched in 1996 by the European Space Agency (ESA)

expendable launch system (i.e. no crew)

heavy reliance on software

https://www.youtube.com/watch?v=gp_D8r-2hwk

Why is the number 32 768 important?

the Ariane 5's control software converted 64-bit floating point values to 16-bit signed integers

... the maximum value for a 16-bit signed integer is 32 768

ASME SETTING THE STANDARD

What Happened ?

- Control software was responsible for handling the ‘horizontal bias’ variable …
- … **which was left unprotected by a handler because it believed the rocket physically limited the value**.
- When the number exceeded 32768, the software reset the field to 0
- The rocket self-destructed believing it to be 90 degrees misaligned

the 1996 launch was Ariane 5’s first

Characteristics of Autonomous Systems Cyber–Physical-Human (CPH)

- Heterogeneity, complexity, openness, learning ability
  - Too many risk event scenarios
  - Complexity of software and human failures vs. hardware failures
  - – Past failures do not indicate future behavior in Software and Human
  - Potential learning capabilities of the software increase the difficulty in validating performance.
- Big data domain (lots of sensors and data collecting devices)
  - Challenge in Uncertainty of sensor data
- Functional and physical distribution, Interconnectivity of technology and social dimensions
- High levels of integration of the technical and social dimensions
- Very high pace of development and deployment
- Higher levels of diversity of supply chain

ASME SETTING THE STANDARD

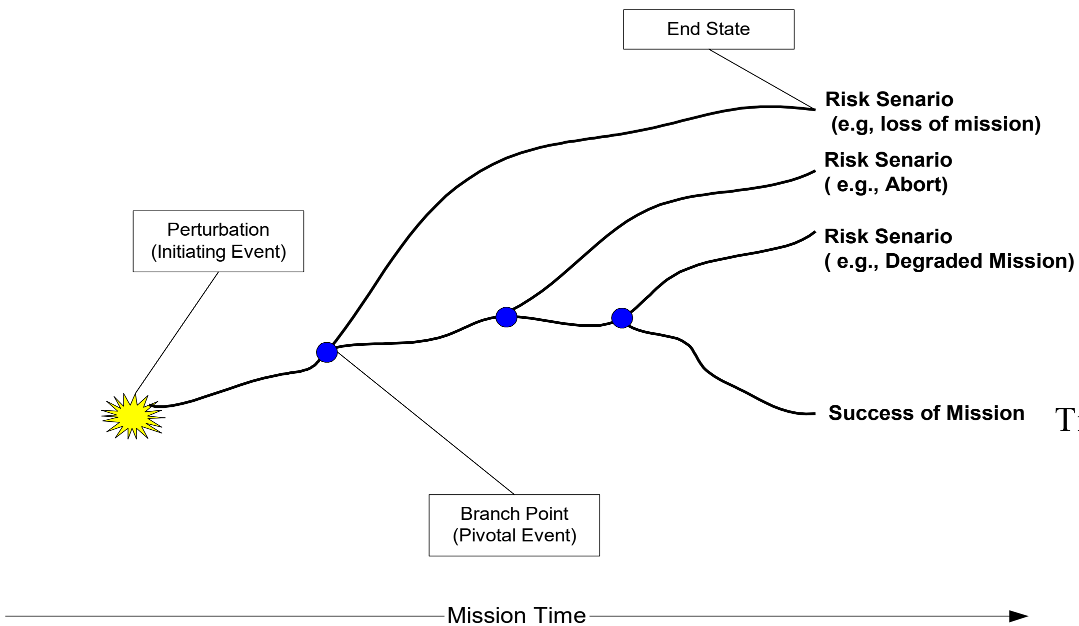
Solutions

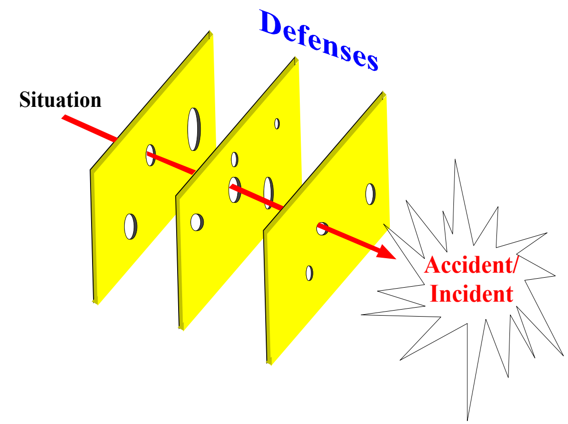
- Many of the current methods can still play a part in supporting SRS Assessment of AVs;
  - Traditional modeling and analysis methods have significant limitations
  - Data driven methods are inadequate to demonstrate safety
  - Techniques are mostly hardware driven

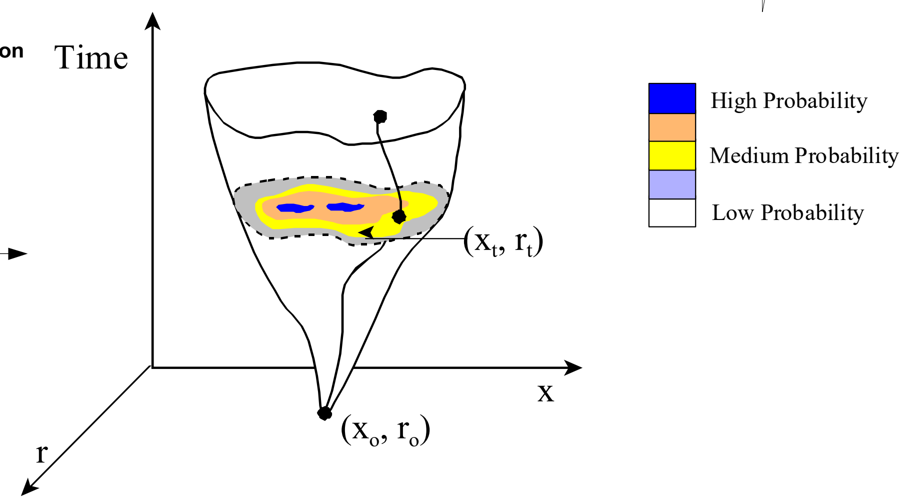
- Many areas require new modelling techniques to be developed
  - New holistically modelling techniques capturing the connectivity and interdependencies
  - Inclusion of large number of options of environment, and operation modes
  - Simulations may assist in the detailed understanding of autonomous systems behavior, identification of SRS issues, and performing system validation.
  - Inclusion of software failures and network security
  - Human plays both positive (operators) and negative (hackers); The complexity of their involvement must be included.

- Importance of quantifying SRS may increase in the future to enable real-time decision making
  - Identify when the system performance drops below the acceptable threshold during operation.

Anatomy of a Risk Scenario



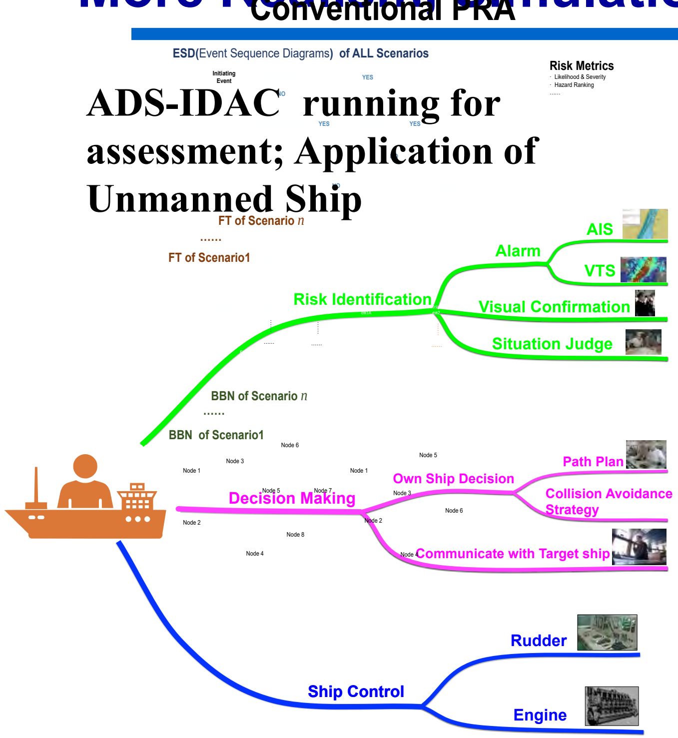


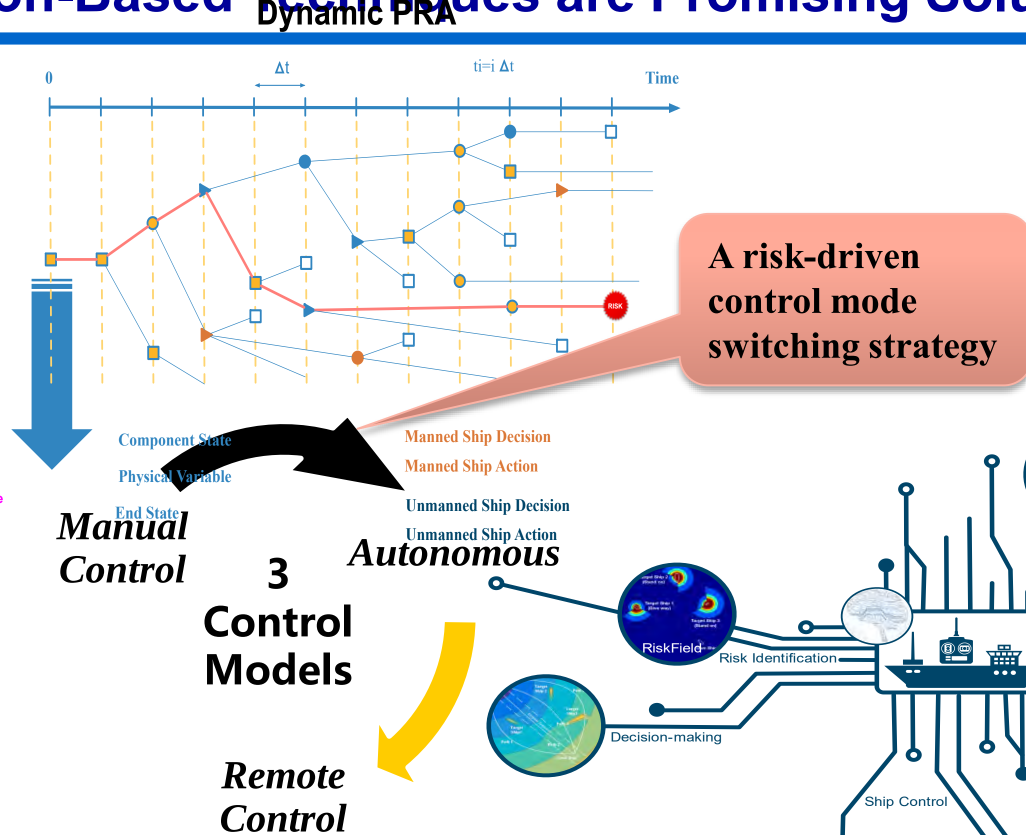


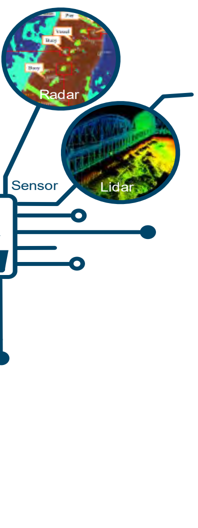
Too Many Risk Scenarios

More Realism, Simulation-Based Techniques are Promising Solutions

ADS-IDAC running for assessment; Application of Unmanned Ship







Are we in Final Stage of Development and Implementation: Answer is "NO"

UCLA ENGINEERING
B. John Garrick Institute for the Risk Sciences

Autonomous Vehicles:
Inserting Society into the Loop

Daniel Metlay
Senior Fellow
The B. John Garrick Institute for the Risk Sciences
University of California, Los Angeles

Silicon Valley pioneered self-driving cars. But some of its tech-savvy residents don't want them tested in their neighborhoods.

"[Waymo's] employees and families work and live there, said spokeswoman Alexis Georgeson, and test the vehicles, too. It's also educating the public at local events. 'Our vehicles are programmed to be safe and cautious drivers.'"

"[One resident] wants to make sure developers learn lessons from science-fiction literature: Heed the social implications of your innovations, and don't let the technology run amok. 'It's too early,' she said. 'They're too excited. They're chasing the rainbow, and I just don't want them driving down my street.'"

Washington Post, October 3, 2019

Technologies Are Not Value-Free

- Out of necessity, autonomous technologies will contain embedded values.
- By their decisions, engineers, scientists, designers, regulators, and developers all make choices that implicitly or explicitly enhance or discount certain cultural and societal values.
- Because those decisions are rarely transparent or accountable, the social acceptability of autonomous technologies depends on trust, both in the technology itself and in the organizations that implement and regulate it.

Development Currently Outpaces Governance

- Private governance operates by the choices individual firms make and via industry rules and regulations, best practices, and standards.
- Public governance is legally binding and entails liability. It regulates the behavior of people and organizations by establishing procedures and constraints.
- Trustworthy hybrid governance institutions ultimately will need to be put into place prior to widespread deployment of autonomous vehicle technologies.
- I suspect that doing so will be quite challenging.

Too Little, Too Much, Just Right

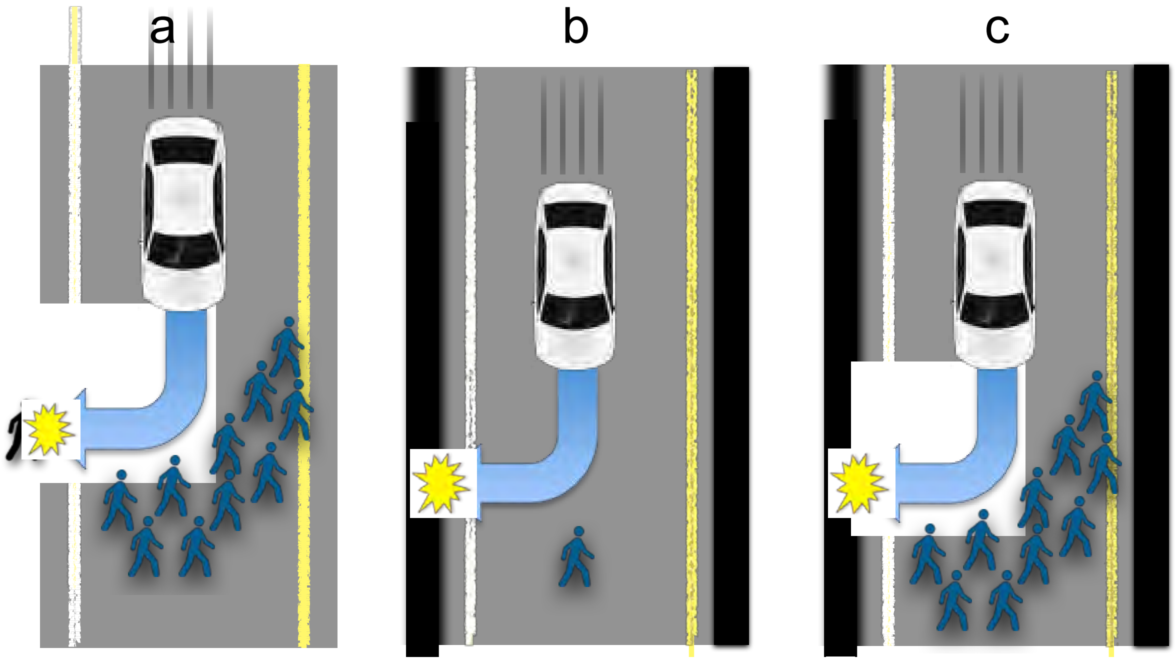
- A rush to deploy products in the market and the prioritization of industry interests may lead to accidents or failures with unacceptable societal and ethical consequences.
- Over-governance at the earliest stages of technological maturity may stifle innovation and deprive society of potentially significant benefits.
- Ideally, in a robust pluralistic society, the "right" balance emerges as a result of transparent and accountable "political" processes. In the real world, however, the processes are typically distorted in favor of the interests of one set of parties over another set.

How Safe is Safe Enough?

- ❑ Determining the "safety" of autonomous vehicles poses particular challenges.
  - They are currently in the early stage of deployment, but they need additional testing.
  - They interact with human decision-makers, ie, other drivers, in ways that may be hard to predict.
  - The competence of both the advocates and the "regulators" is just beginning to be developed.
- ❑ Answering the question "how safe is safe enough" must be an iterative and ongoing effort through the whole lifecycle of systems.

Can Morality Be Programmed?

Not all crashes can be avoided. Even low-probability events will need to be considered if there are millions of autonomous vehicles on the road.



Bonnefon et al. 2016

For Some Additional Thoughts…..

https://www.ntnu.edu/imt/iwass

Autonomous vehicle (AV) crash rates in California: still multiples higher than humans

Dr. Roger L. McCarthy, P.E.

30 October 2019

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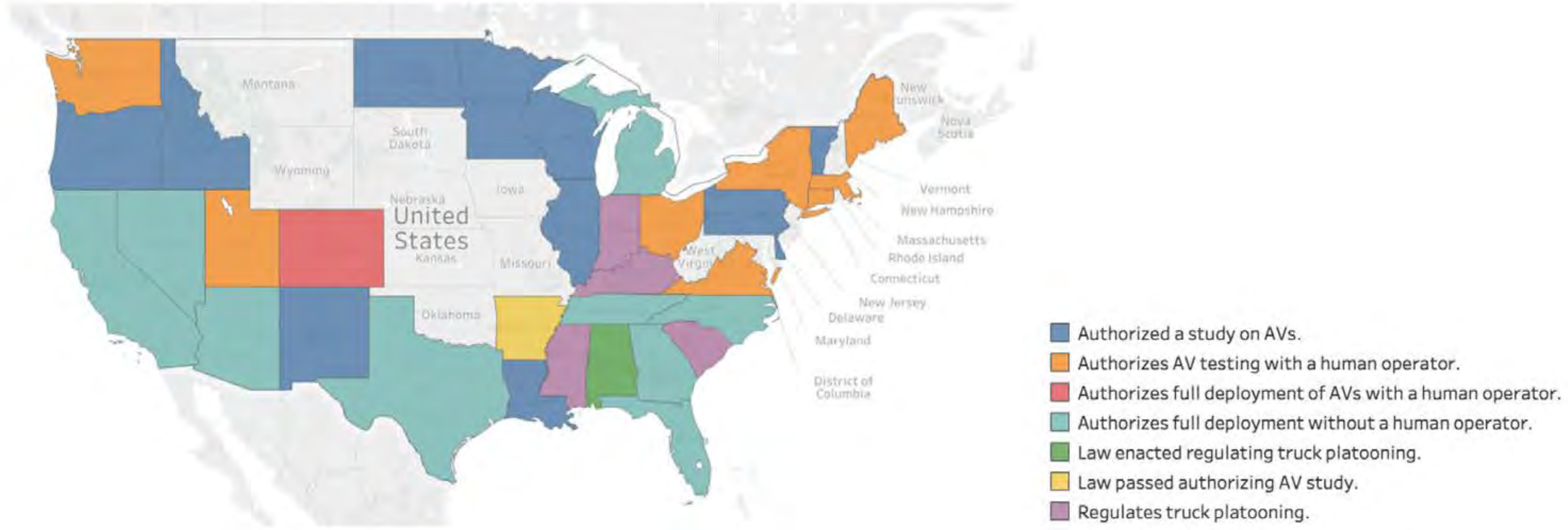
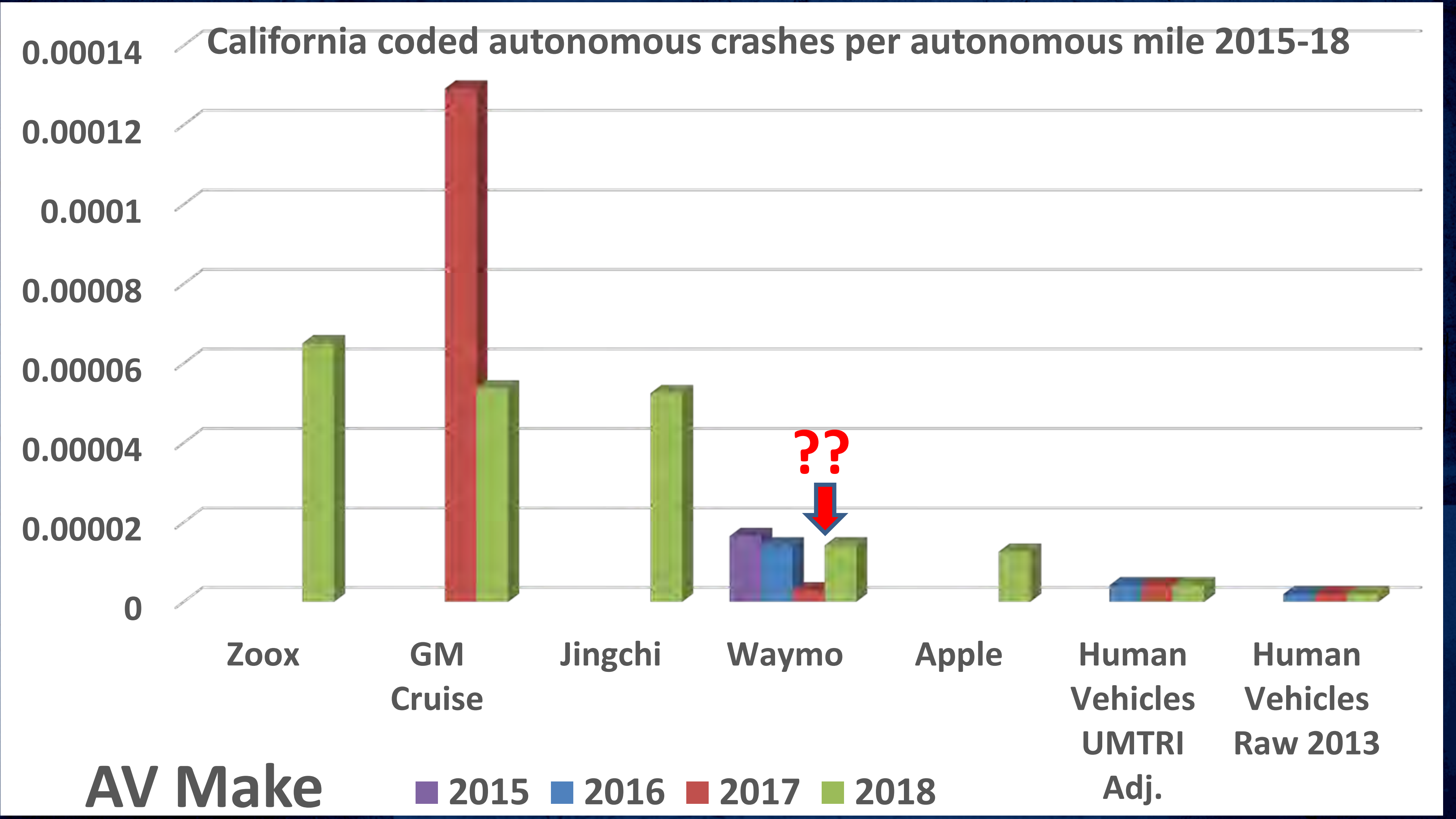
Messages today:

- California (CA) is the ONLY state requiring AV accident/risk experience be publicly reported
  - "Race to the bottom:" other states permitting AV testing with NO reporting
- One of several serious failings of the NHTSA in oversight of AV development safety
  - The NHTSA doesn't require ANY type of AV safety/data reporting
  - The NHTSA has also been far too tolerant of Tesla's "autopilot"
  - High AV crash rates show the NHTSA laissez-faire approach to AV technology development safety has not produced results
  - CA AV crash experience is far worse than human drivers
- I believe the NHTSA is looking to AV technology to remedy our nation's deteriorating relative vehicle safety record on its watch
- Unfortunately AV technology is decades away; instead the US should be adopting vehicle regulations/technologies that other nations have demonstrated work

Nationally NHTSA's lack of leadership has left AV testing an uncoordinated patchwork quilt



Source: GHSA US State Law and NCLS, 2019.


California coded autonomous crashes per autonomous mile 2015-18
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
??
Zoox
GM Cruise
Jingchi
Waymo
Apple
Human Vehicles UMTRI Adj.
Human Vehicles Raw 2013
AV Make
2015
2016
2017
2018

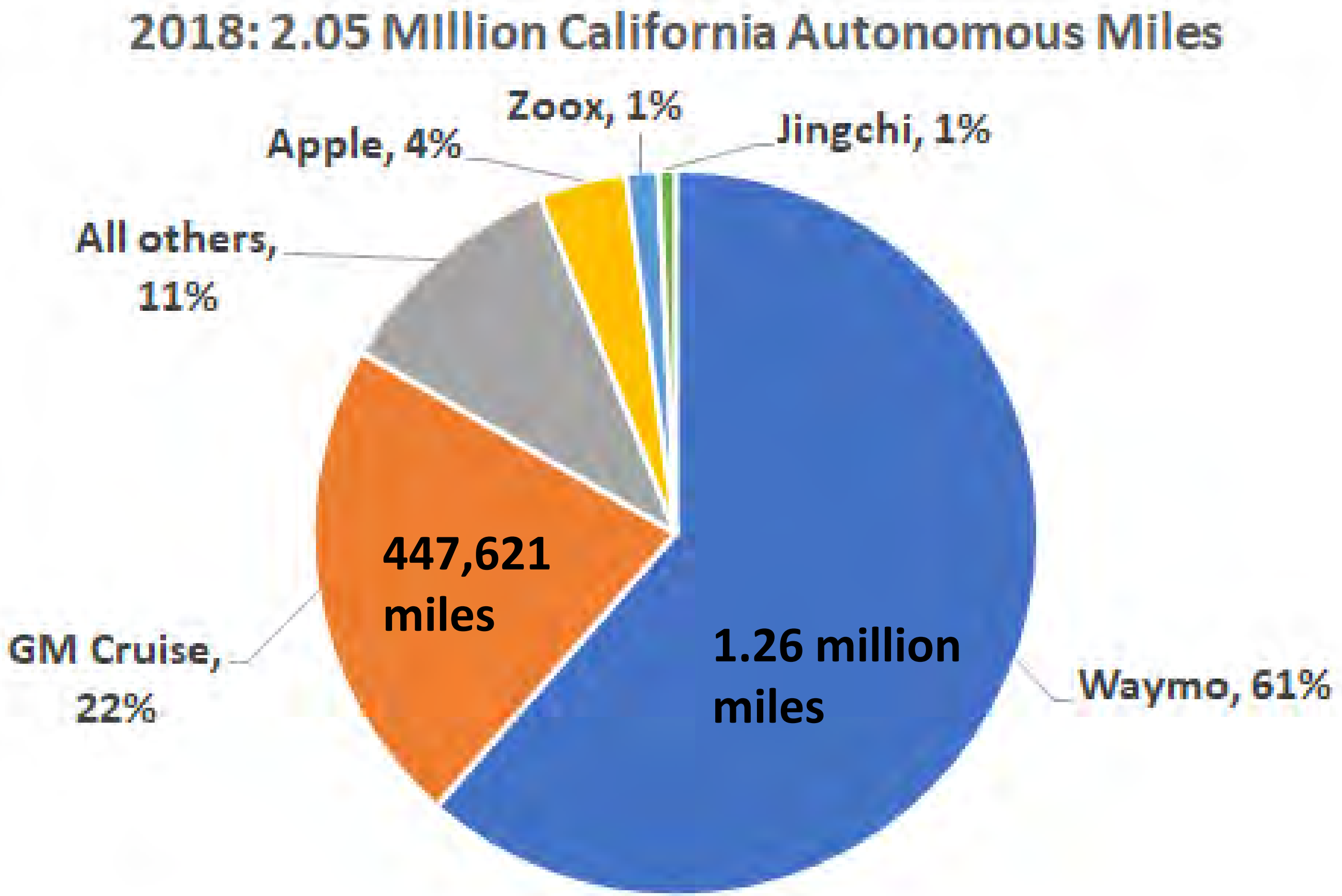
Waymo “gaming” CA AV reporting?

This was the accident narrative of one of the Waymo 2017 accidents coded in the OL316 report as occurring in the “conventional” mode

SECTION 5 — ACCIDENT DETAILS - DESCRIPTION

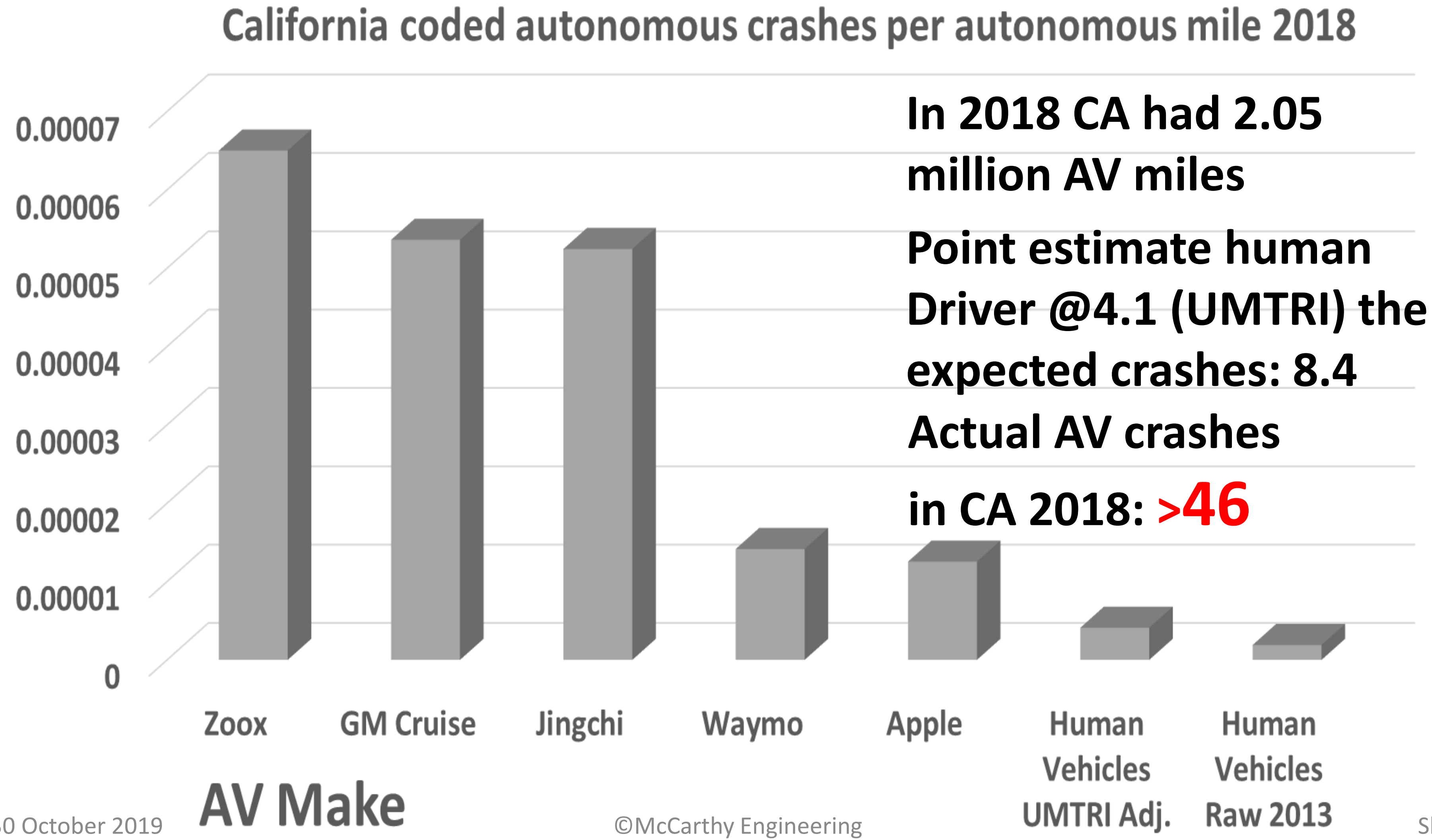
☐ Autonomous Mode ☑ Conventional Mode

A WAYMO LEXUS-MODEL AUTONOMOUS VEHICLE (“WAYMO AV”) MADE CONTACT WITH A CURB WHILE IN MANUAL MODE ON MIDDLEFIELD ROAD AT OREGON EXPRESSWAY IN PALO ALTO, CA. THE WAYMO AV WAS TRAVELING EASTBOUND IN AUTONOMOUS MODE IN THE RIGHTMOST LANE OF MIDDLEFIELD ROAD. AS THE VEHICLE CROSSED OREGON EXPRESSWAY, THE WAYMO AV AUTONOMOUS SYSTEM DETECTED THE VEHICLE IN THE LEFT ADJACENT LANE BEGIN TO DRIFT TO THE RIGHT, TOWARD THE WAYMO AV. THE WAYMO AV NUDGED TO THE RIGHTMOST SIDE OF ITS LANE. AS THE LEFT ADJACENT VEHICLE CONTINUED TO DRIFT TOWARDS THE WAYMO AV, THE WAYMO AV TEST DRIVER TOOK MANUAL CONTROL. THE WAYMO AV’S FRONT PASSENGER-SIDE TIRE THEN MADE CONTACT WITH THE RIGHT CURB, CAUSING IT TO DEFLATE. THE OTHER VEHICLE THEN STRAIGHTENED ITS TRAJECTORY IN ITS LANE AND CONTINUED ON. THERE WERE NO INJURIES REPORTED.



2018

https://www.dmv.ca.gov/portal/dmv/detail/pubs/newsrel/2019/2019_06



In 2018 CA had 2.05 million AV miles

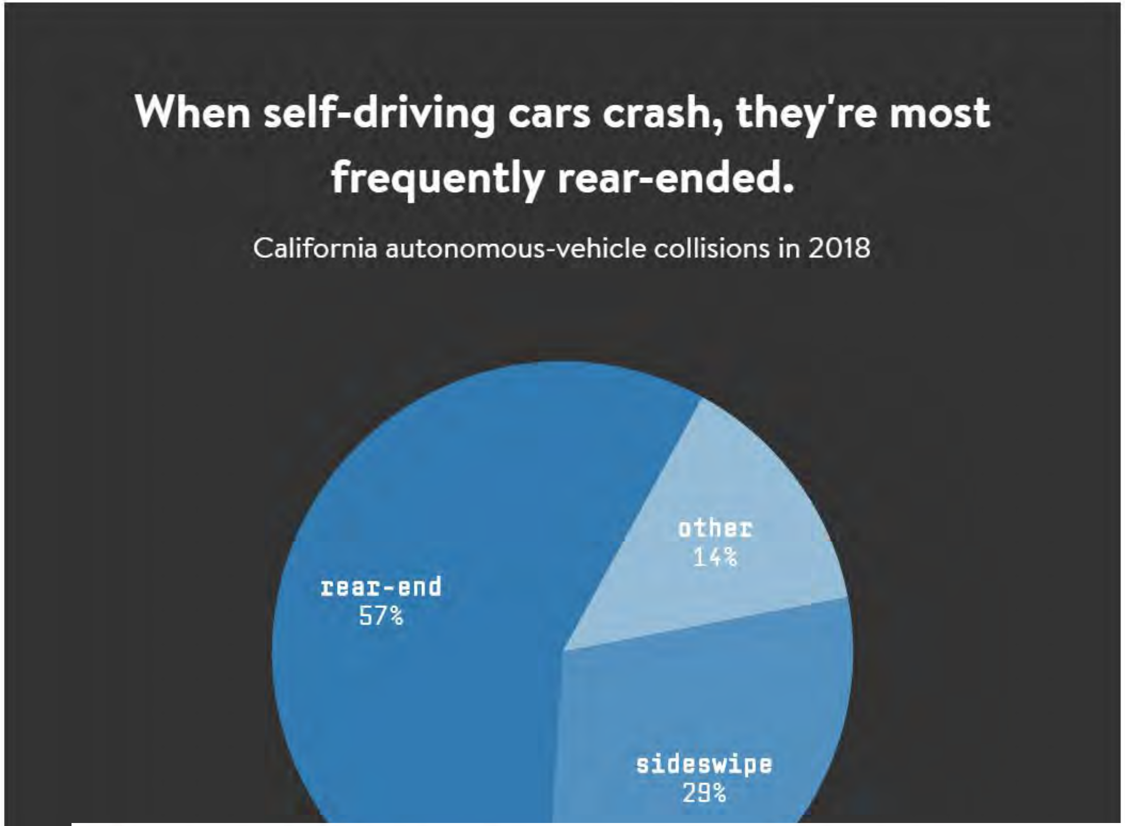
Point estimate human Driver @4.1 (UMTRI) the expected crashes: 8.4

Actual AV crashes in CA 2018: >46

Why do AVs have more crashes?

- Particularly when virtually all the crashes are the fault of the human driven vehicle involved?
- The mode of most AV accidents is the AV being struck in the rear by a following human driver
- The human driver following the AV did not anticipated the AV's sudden reaction to confusion:
- The AV just suddenly stops
- Regulators need to be prepared to see dramatically high reported crash rates in AV fleets using current techologies

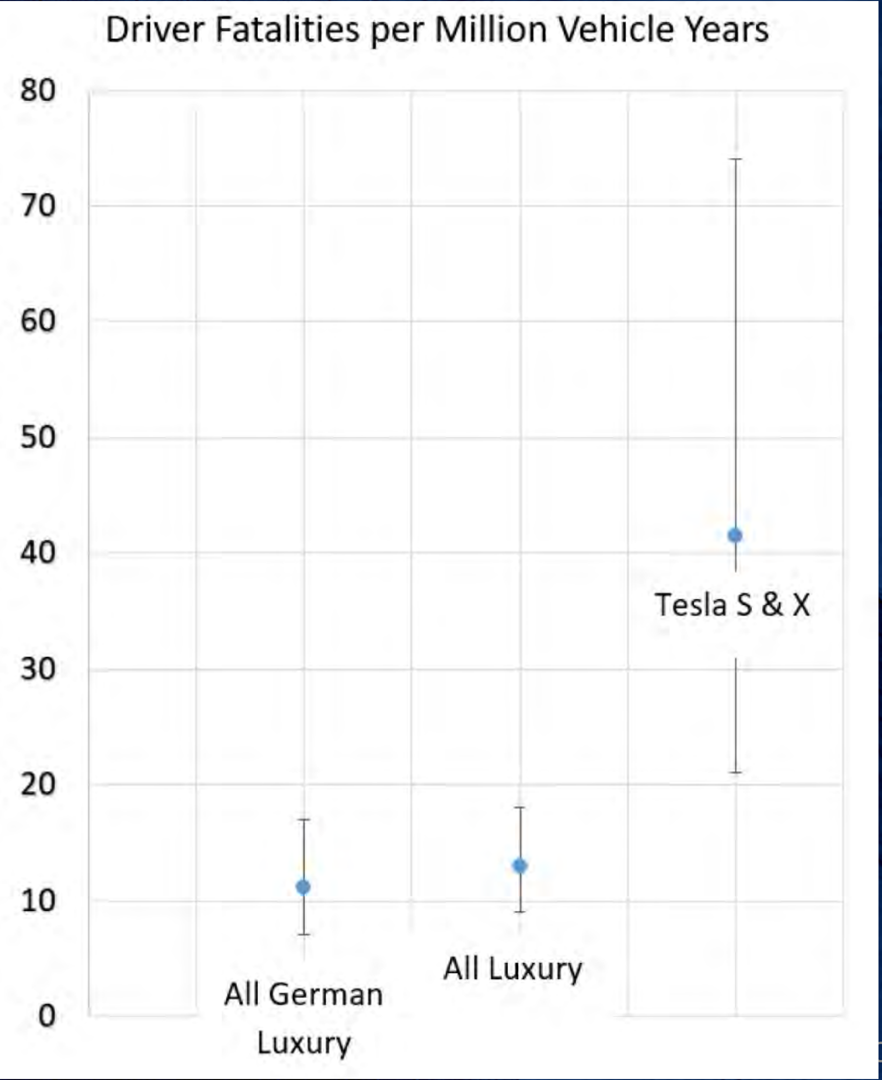
Unexpected AV behavior results in rear end collisions



However, the study suggests that humans are still the biggest problem. In fact, in three accident reports, humans were found to have attacked or climbed atop the self-driving cars.

Tesla "autopilot"

- Tesla rolled out it "autopilot" feature in 14 October 2015
- The "autopilot" mode of the current Tesla vehicles is only level 2 "self-driving"
  - not classed as an "autonomous" vehicle
  - Otherwise Telsa would have to report all data in California
- BUT - there are now probably more than 500,000 Tesla's on the road with some "auto pilot" capability and probably less than a thousand truly autonomous vehicles
- Much larger Tesla fleet might permit the detection of an incremental change in crash risk from incremental change of vehicle automation
- **UNFORTUNATELY, even though all this data is being collected on public roads, while subjecting the public to risk, the NHTSA does NOT require data from it to be publicly reported.**



In 2018: “Tesla’s Driver Fatality Rate is more than Triple that of Luxury Cars (and likely even higher)”

Result from manually correcting Tesla codes in FARS

https://medium.com/@MidwesternHedgi/teslas-driver-fatality-rate-is-more-than-triple-that-of-luxury-cars-and-likely-even-higher-433670ddde17

January 2016 Fatal Tesla "autopilot" crash in China

Tesla “autopilot”

- Tesla rolled out it “autopilot” feature in 14 October 2015
- Two months later there was fatal Tesla S crash on 20 January 2016 involving Gao Yaning in Handan, China while using the “autopilot” feature
- The Tesla S traveling at full speed exhibited no braking or evasion slammed into the back of a slow moving, large orange street sweeper partially in the high-speed left lane
- In an emailed statement, Tesla said… it had not been able to determine whether Autopilot was active at the time of the Handan accident
- “The company declined to say when it learned of the fatality in China, or whether it had reported the crash to United States safety officials”

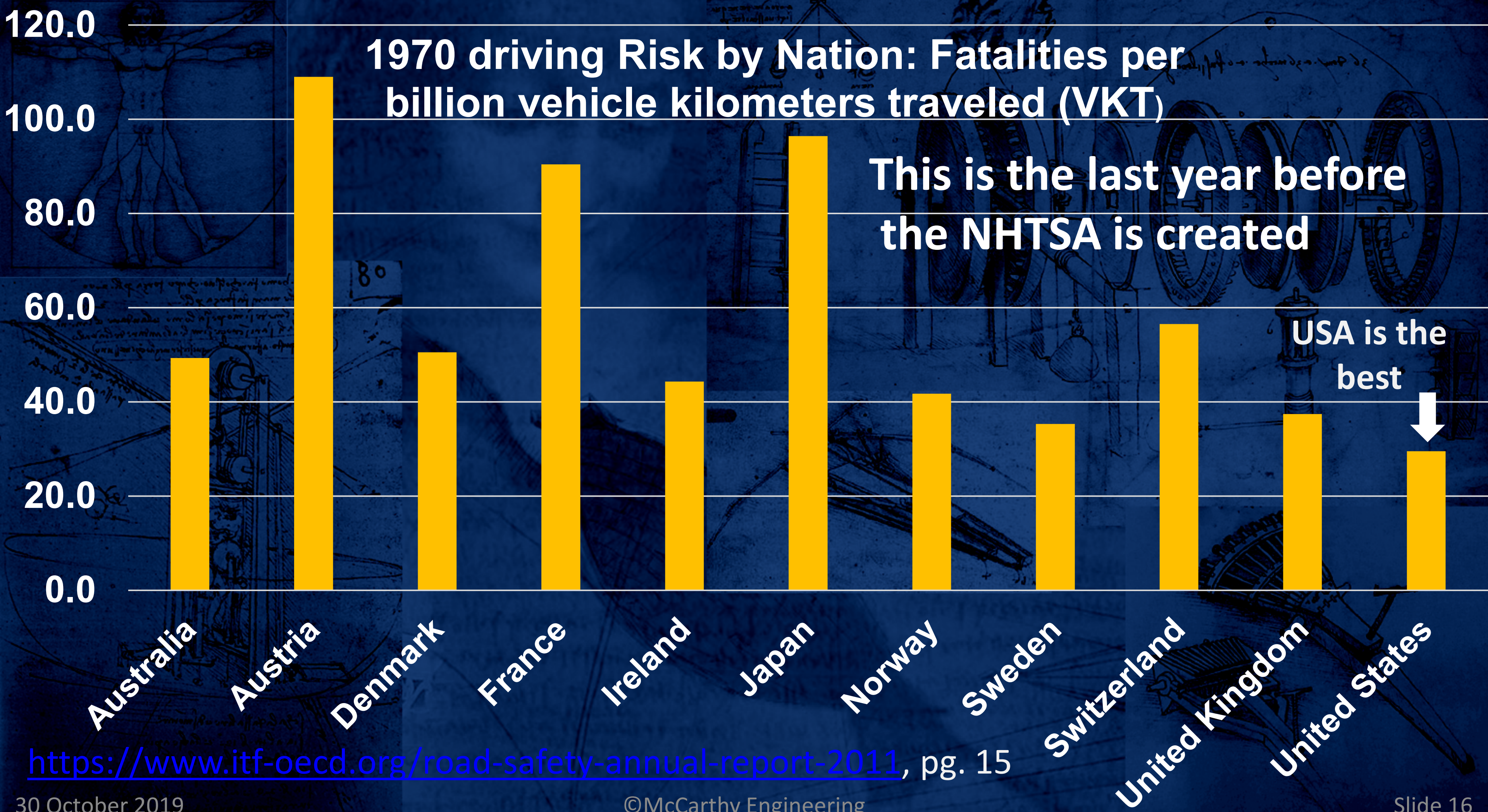
EVENTUALLY Tesla owns up

- **Tesla Admits Autopilot Feature Led to Fatal China Crash in 2016**
- (Yicai Global) Feb. 28 [2018] -- Electric carmaker Tesla Inc. has admitted that its self-driving feature was responsible for the collision that caused the death of a 23-year-old Chinese man more than two years ago

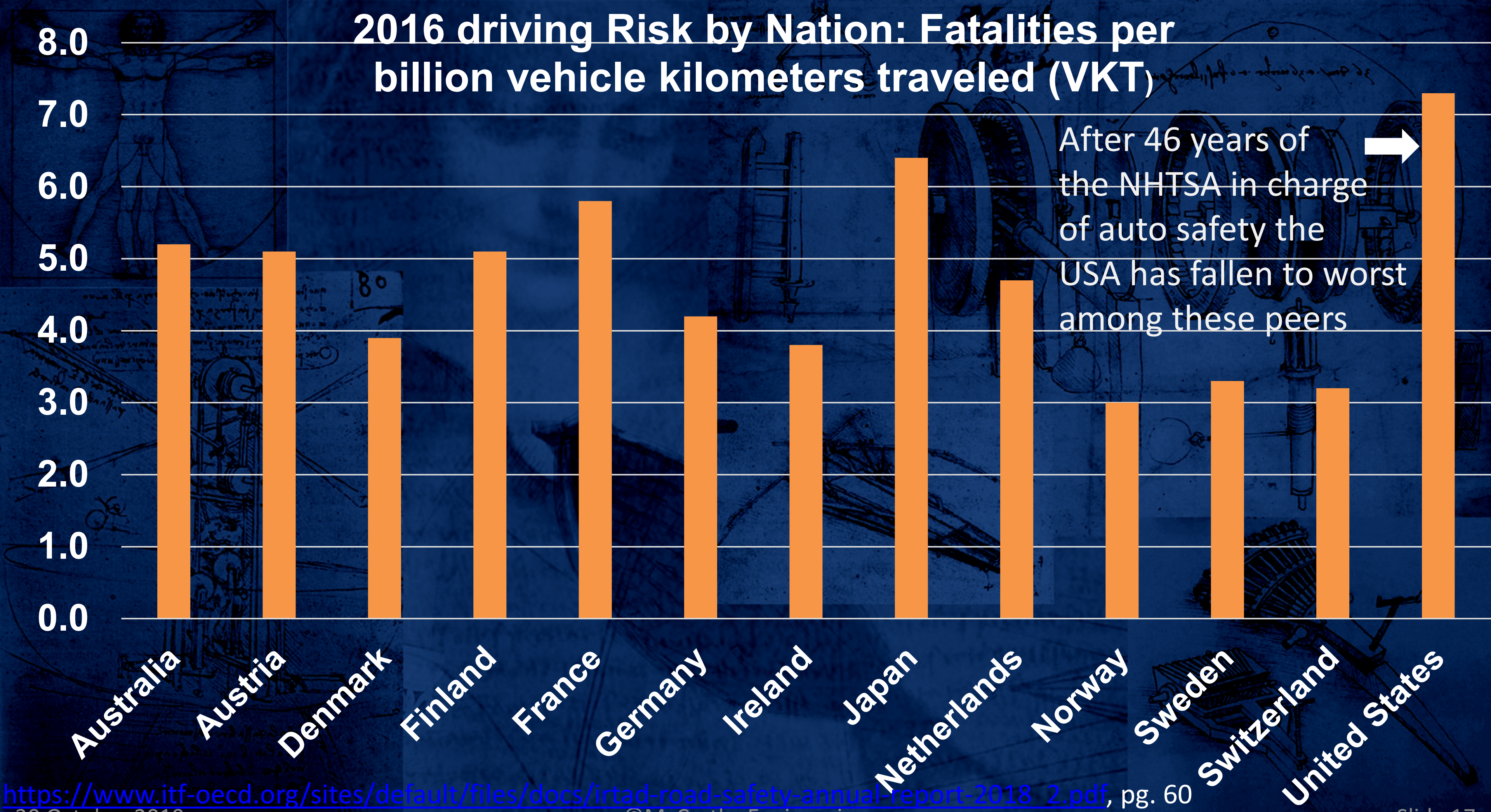
https://yicaiglobal.com/news/tesla-admits-autopilot-feature-led-to-fatal-china-crash-in-2016

Subsequently even the US NHTSA finally comes to its senses about Tesla safety

- "Tesla's Autopilot system does NOT make driving safer and may even increase the risk of crashes, new report suggests - upending the findings of 2017 safety investigation"
  - "According to Quality Control Systems Corporation, which conducted the new analysis, the NHTSA misinterpreted the data it was provided; instead of reducing crashes, the findings suggest autosteer may have made accidents more common."
  - Daily Mail, 5 March 2019
- "Federal safety regulators scolded Musk over 'misleading statements' on Tesla safety"
  - Washington Post, 7 Aug 2019

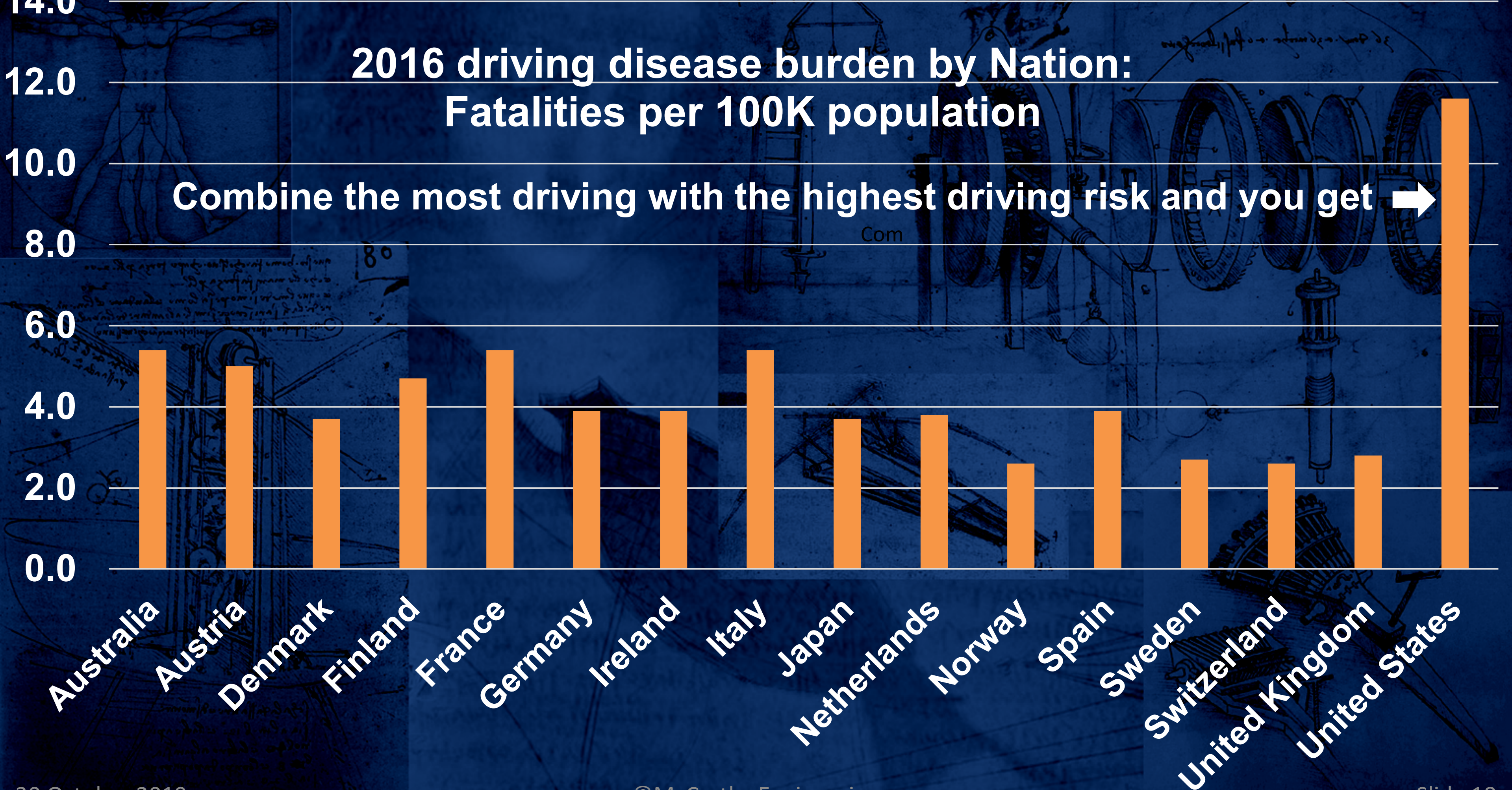


https://www.itf-oecd.org/road-safety-annual-report-2011, pg. 15



https://www.itf-oecd.org/sites/default/files/docs/irtad-road-safety-annual-report-2018_2.pdf, pg. 60

https://www.itf-oecd.org/sites/default/files/docs/irtad-road-safety-annual-report-2018_2.pdf, pg. 60



Why is the US so bad?

- The US combines the most driving with, now, the highest risk of driving
  - 47 years ago the US had the lowest risk of driving among peers
- The US NHTSA has been obsessed with vehicle safety rather than driver behavior
  - I believe this to be an unfortunate legacy of its creation
  - Dr. Leonard Evans (NAE) has suggested we rename the agency the:

    "National Vehicle Safety Administration"
- Driver behaviors are far more important to safety than vehicle safety
  - For example, the US permissible blood alcohol of .08% is a disgrace
  - "A .05% BAC legal limit is the most common and found in … Argentina, Australia, Austria, Belgium, Finland, France, Germany, Greece, Hong Kong, Israel, Italy, South Africa, Spain, Switzerland, Thailand, Taiwan, Turkey, and others" https://www.bactrack.com/blogs/expert-center/35043525-typical-bac-limits-around-the-world

As bad as this is for the US; it is about to get worse

https://www.theweek.co.uk/93687/eu-lists-11-car-safety-systems-to-become-mandatory-from-2021

"EU lists 11 car safety systems to become mandatory from 2021"

- Advanced emergency braking
- Alcohol interlock installation facilitation
- Drowsiness and attention detection
- Event (accident) data recorder
- Emergency stop signal
- Full-width frontal occupant protection crash test and improved seatbelts
- Head impact zone enlargement for pedestrians and cyclists, as well as safety glass
- Intelligent speed assistance
- Lane keeping assist
- Pole side impact occupant protection
- Reversing camera or detection system

The future

- "The notion that they [AVs] are today safer than humans is pure myth," said Steve Shladover at California PATH, a transportation research arm of UC Berkeley. "They're not even close to the capabilities of human drivers."
- Regardless of the NHTSA hopes, AVs will NOT be salvation
- A higher crash rate is currently observed in every mode of automated driving
  - And we have visited Tesla's fatal crash rate
- Instead of AVs, the biggest safety impact could be made by developing the driver "assistance" technologies as a gradual path to full AV
- AND bringing the US insane driving regulations in conformance with the rest of the world.

Questions?

Summary of the April 26, 2019 Workshop on Safety and Risks of Autonomous Vehicles

Panel on Advancing Safety Technologies for Autonomous Vehicles

United States Congress

October 30, 2019

2044 Rayburn House Office Building

Mohammad Modarres

Center for Risk and Reliability (CRR)

Department of Mechanical Engineering

University of Maryland, College Park

Autonomous Vehicles: Features & Issues

- Remarkable and trendiest technology
- Obsolete car ownership
- Industry hope of "zero crashes"
- Leaders include Waymo and Tesla, Ford Motor Company, General Motors, Mercedes-Benz
- Traffic and pollution in urban centers
- Shared mobility options
- Slow advances on safety, risk and reliability
- Poor average distance driven to an incident

Workshop Objectives

Examine views from Academia, Government, and Industry:

- Safety, risk, security, and reliability of AVs
- Adequacy of road infrastructures
- Legal, ethical and regulatory considerations
- More safety research and technology needs

Big Picture for Self-Driving Safety

- True self-driving long time away
- Aspiration: Self-driving safer than conventional technologies
- Driver assistance offers a low hanging fruit
- More independent safety transparency and collaboration
- Need minimum performance standards
- Better autonomy software safety standards

From: Philip Koopman Presentation: The Big Picture for Self-Driving Car Safety

Maryland MDOT Initiatives

- Strategic Plan for Connected and Automated Vehicles (CAV Plan)
- Develop robust CAV, including:
  - CAV sensor collects data on bridges, roads, pavements
  - Use of predictive analytics
  - Integrated communications controllers and networks
  - Planning a Security Credential Management for secure management

MDOT Administrator: Gregory Slater: Maryland Cybersecurity Initiatives in a Connected and Autonomous World

NHTSA Considerations for Automated Driving

- Evaluating emerging safety issues and technologies
- Building knowledge of new technologies
- Developing technology-neutral procedures
- Modernizing requirements and performance criteria
- Develop best practices guidance

From Dee Williams: NHTSA's FMVSS Considerations for Vehicles with Automated Driving Systems

Measuring AV Safety

- Need a better and transparent evaluation of unsafe events
- Develop a protocol for information sharing
- Common safety design taxonomy
- Establish designated demonstration period for safety benchmarking
- More research on AV safety and collaboration between regulators, academics and industry

From Marjory Blumenthal: Measuring Automated Vehicle Safety: Building Better Outcomes and Policy

More Academic Perspectives on AV Safety and Risk

- Learn from other high-risk industries: nuclear power, pharma, etc.
- Risk-informed performance-based assessment
- Insufficient collaborations between stakeholders
- Match human cognitive adaptability and on-the-fly reasoning
- Need a gradual path to full AV
- Developers appear over-enthusiastic and confident
- Regulators and policy-makers are slow

More Academic Perspectives on AV Safety and Risk

- Safety analysts highly skeptical
- Major ethical issues
- Risk modeling, safety assessment Path planning
- How machine learning techniques adapt themselves to unforeseen conditions?
- Is the policy that China views: Re-engineer entire road infrastructure better?
- Dedicated roads or lanes to AVs?
- Consensus: full autonomy principle is possible, surely not imminent

Thank You

Center for Risk and Reliability