

# ON RESILIENT AUTONOMOUS DRIVING

## Autonomous Systems with Humans-in-the-Loop

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# Resilient System

*The ability to plan and prepare for, absorb, recover from, and successfully adapt to adverse events.*

(U.S. National Academy of Sciences)



# Resilient System

Can withstand or recover from unexpected events, malfunctions, or environmental changes. This resilience can come from different features:

- **Robustness:** The system is built to be strong and resistant to failures in individual components.
- **Redundancy:** Critical components have backups to ensure the system can keep functioning even if one part fails.
- **Modularity:** The system is designed in separate parts that can be easily replaced or repaired.
- **Adaptability:** The system can adjust its behavior and decision-making based on new information or changing circumstances.



# Can we build resilient autonomous systems?

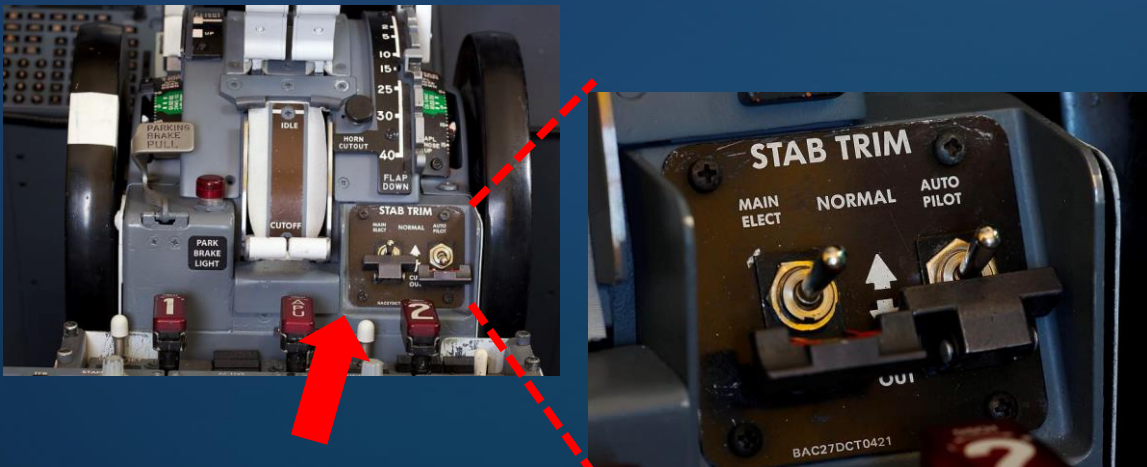
THE VERGE

On the adverse relationship between humans and autonomy

By Darryl Campbell | May 2, 2019, 8:03am EDT



- Soon after takeoff, the “stick shaker” started to vibrate
- B737 MAX’s MCAS system made the plane pitch down
- There was NO checklist for this Autonomous System behavior, neither did the system explain itself
- The First Officer searched for the right procedure for 6 minutes ... there was none!
- “What about the Runaway Stabilizer checklist?”
- They followed the Runaway Stabilizer checklist and flipped the STAB TRIM switches to CUT OUT to shut off the trimming of the stabilizers ... saved the plane!
- Next morning, PK-LQP took off again ... this time the pilots did not think about the Runaway Stabilizer checklist
- PK-LQP crashed at a speed of 600 mph!!
- Cause: single sensor failure (amongst many others)



# Can we build resilient autonomous systems?

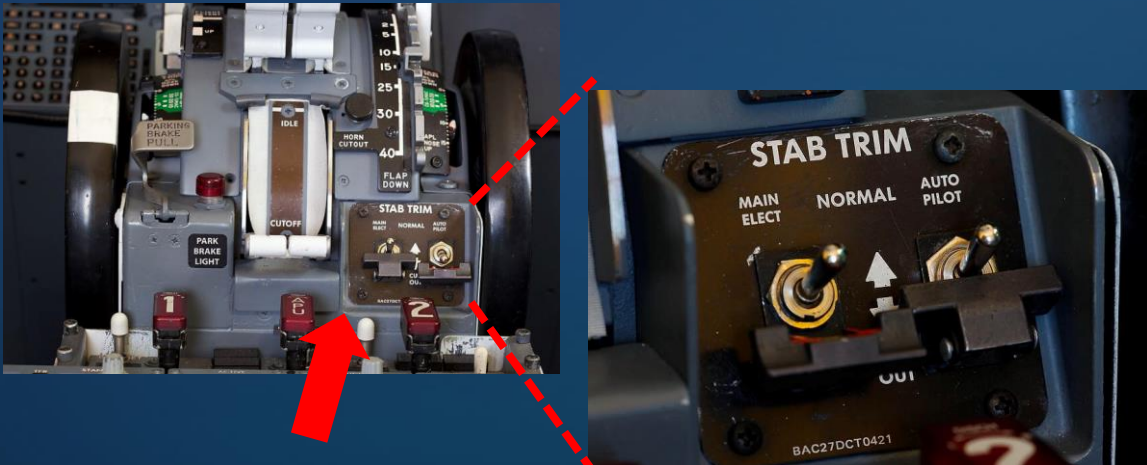
THE VERGE

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- Fatal accidents after 40 years of autopilots
- Single point of failure in the MCAS system
- No explanation for the pilots
- No pilot training
- No checklist for the problem at hand
- Many other design flaws, organizational issues and business pressures



## Driver hits woman in S.F., then Cruise driverless car runs her over; photo shows victim trapped

By [Jordan Parker](#), [Nora Mishanec](#)

Updated Oct 3, 2023 3:52 p.m.



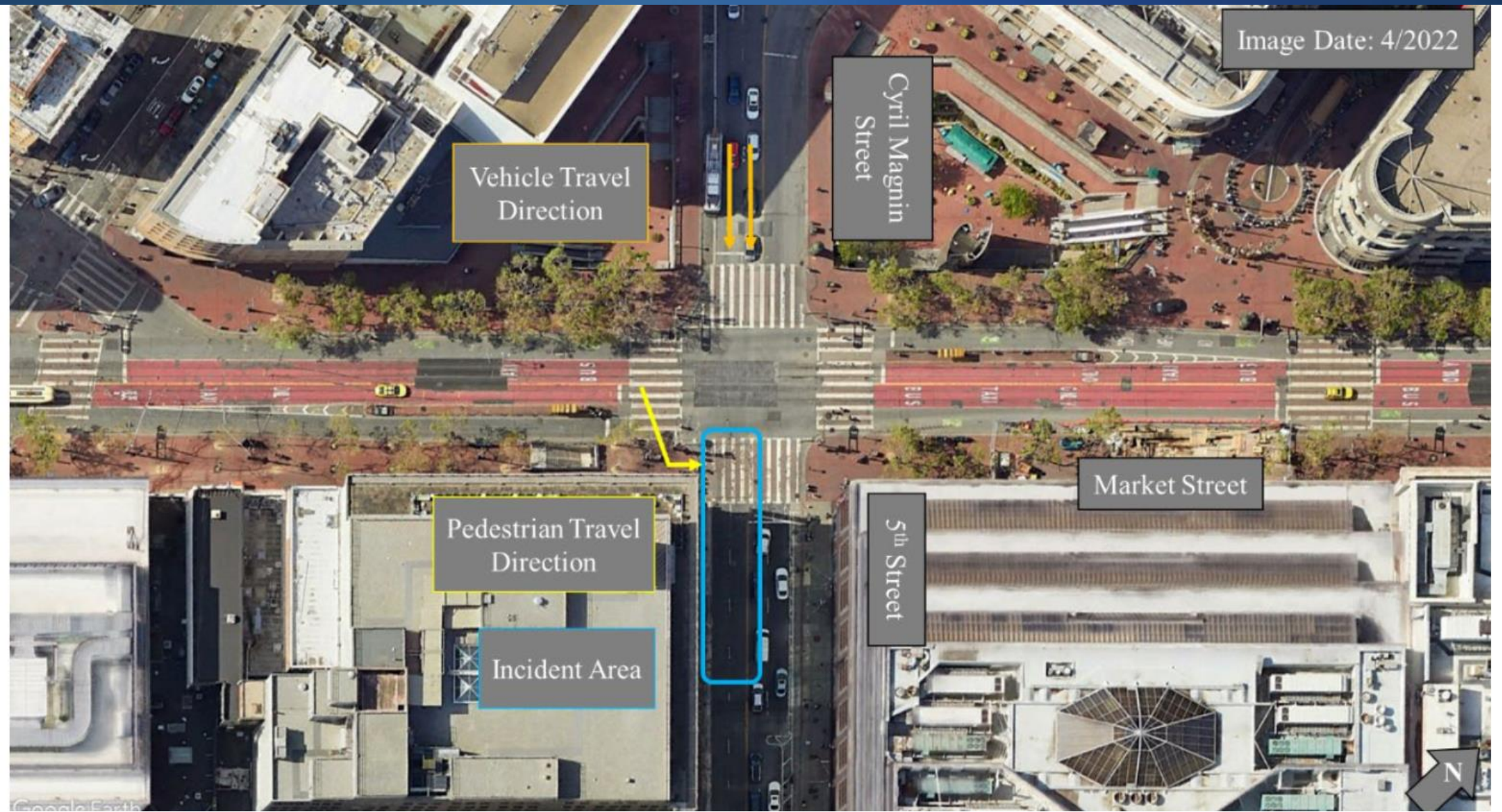


Image Date: 4/2022

Cyril Magnin Street

Vehicle Travel Direction

Market Street

Pedestrian Travel Direction

5th Street

Incident Area



FROM: APPENDIX PAGE 18: CRUISE AV SF INCIDENT—PEDESTRIAN COLLISION (EXPONENT PROJECT 2310645.000) IN REPORT TO THE BOARDS OF DIRECTORS OF CRUISE LLC, GM CRUISE HOLDINGS LLC, AND GENERAL MOTORS HOLDINGS LLC REGARDING THE OCTOBER 2, 2023 ACCIDENT IN SAN FRANCISCO BY QUIN EMANUAL TRIAL LAWYERS, JAN 24, 2024

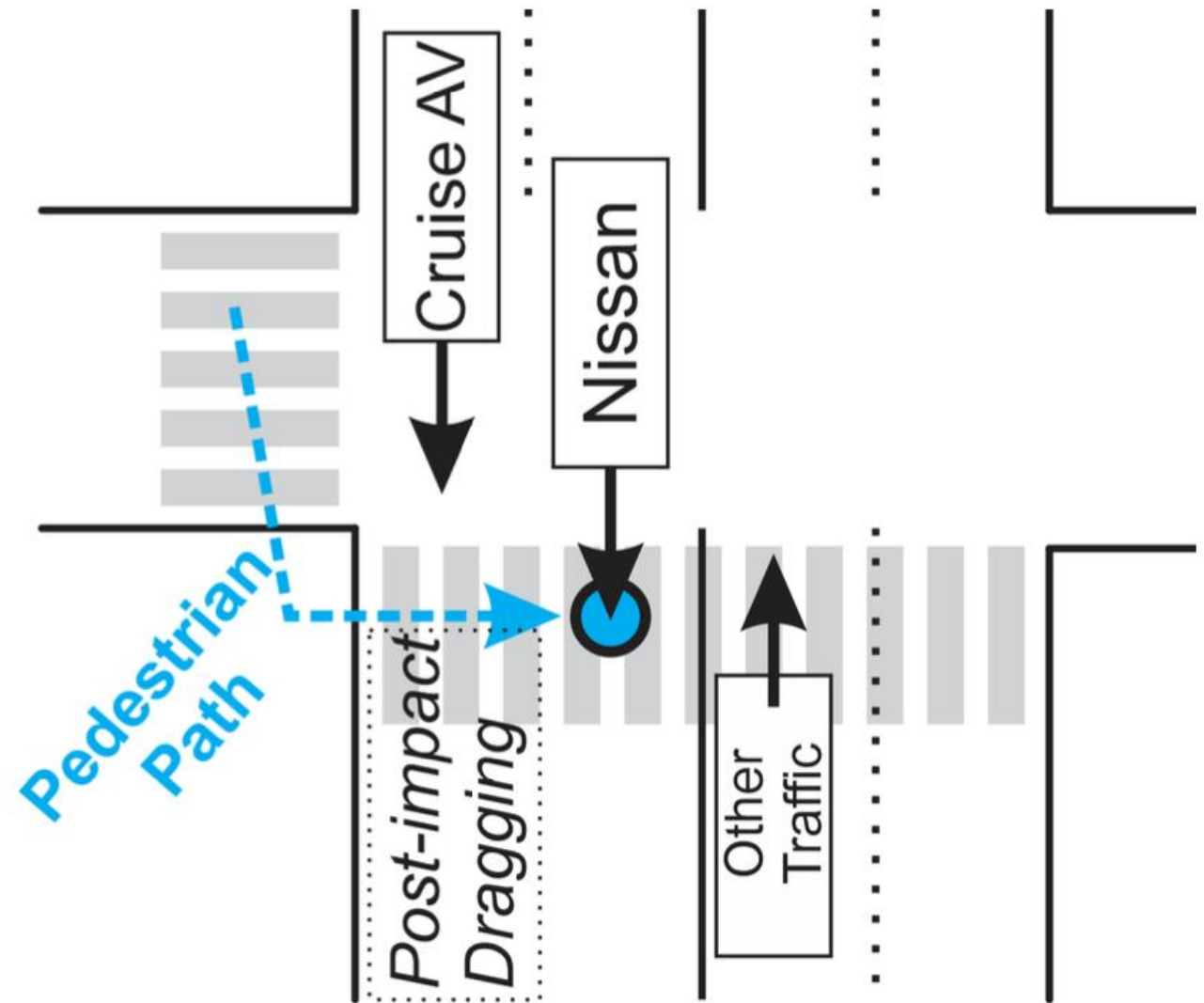


Figure 1. Simplified diagram of mishap; not to scale.



Table 6. Timeline of salient events

Event	Unix Time (s)	Relative Time (s)
Pedestrian first classified as pedestrian and 'tracked' with ID 138048784 at approximately 21:28:34 PDT	1696307313.4	-38.3
AV becomes static due to red traffic light	1696307324.8	-26.9
Traffic light changes to green	1696307341.7	-10.0
Nissan begins moving after light change	1696307342.4	-9.3
AV begins moving after light change	1696307342.4	-9.2
Pedestrian appears (visually) to enter 5th Street crosswalk	1696307343.8	-7.9
Prediction output shows pedestrian path crossing AV travel lane <sup>48</sup>	1696307344.0	-7.7
Pedestrian leaves AV's travel lane	1696307346.4	-5.3
Pedestrian stops/pauses in crosswalk	1696307347.0	-4.7
Contact between pedestrian and Nissan occurs	1696307348.8	-2.9
Pedestrian track (ID 138048784) is dropped	1696307349.7	-2.0
Pedestrian begins separating from Nissan (visually)	1696307350.49	-1.17
[REDACTED]	1696307350.85	-0.81
Pedestrian lands in AV's travel lane	1696307350.89	-0.78
An imminent collision is predicted by the 'collision checker' <sup>49</sup>	1696307351.25	-0.41
AV begins sending commands for steering & braking <sup>50</sup>	1696307351.41	-0.25
Initial contact between pedestrian and AV occurs	1696307351.66	0.00
Collision checker node outputs that a collision has occurred	1696307351.87	0.21
ABS status change	1696307351.89	0.23
AV velocity initially becomes zero post impact <sup>51</sup>	1696307353.44	1.78
AV begins sending commands to begin accelerating post impact	1696307353.49	1.83
TCS status change	1696307355.5	3.8
DS4 triggered	1696307357.5	5.8
AV reaches its final point of rest	1696307360.4	8.8



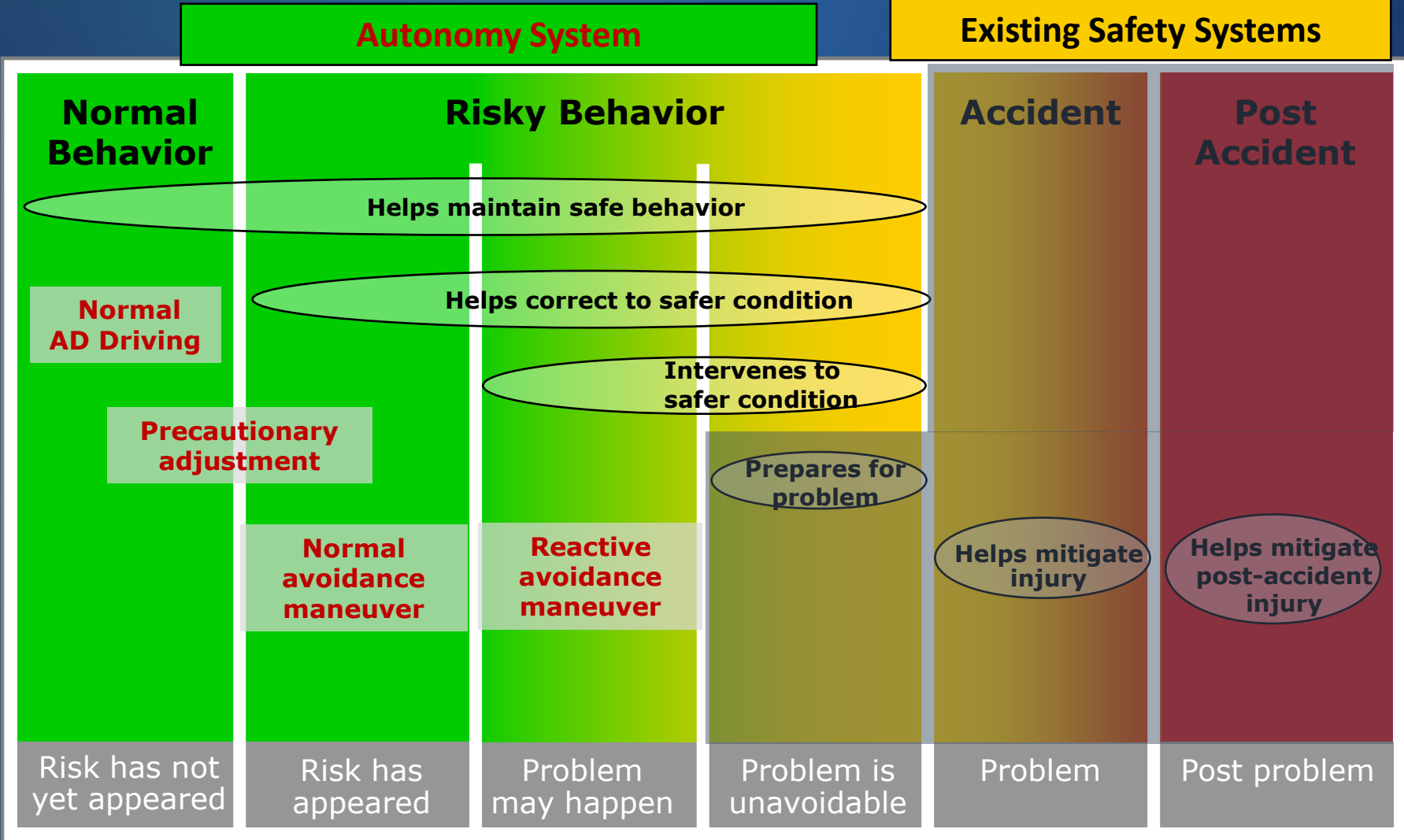
Image Date: 4/2022

**FROM: APPENDIX PAGE 44: CRUISE AV SF INCIDENT—PEDESTRIAN COLLISION (EXPONENT PROJECT 2310645.000) IN REPORT TO THE BOARDS OF DIRECTORS OF CRUISE LLC, GM CRUISE HOLDINGS LLC, AND GENERAL MOTORS HOLDINGS LLC REGARDING THE OCTOBER 2, 2023 ACCIDENT IN SAN FRANCISCO BY QUIN EMANUAL TRIAL LAWYERS, JAN 24, 2024**

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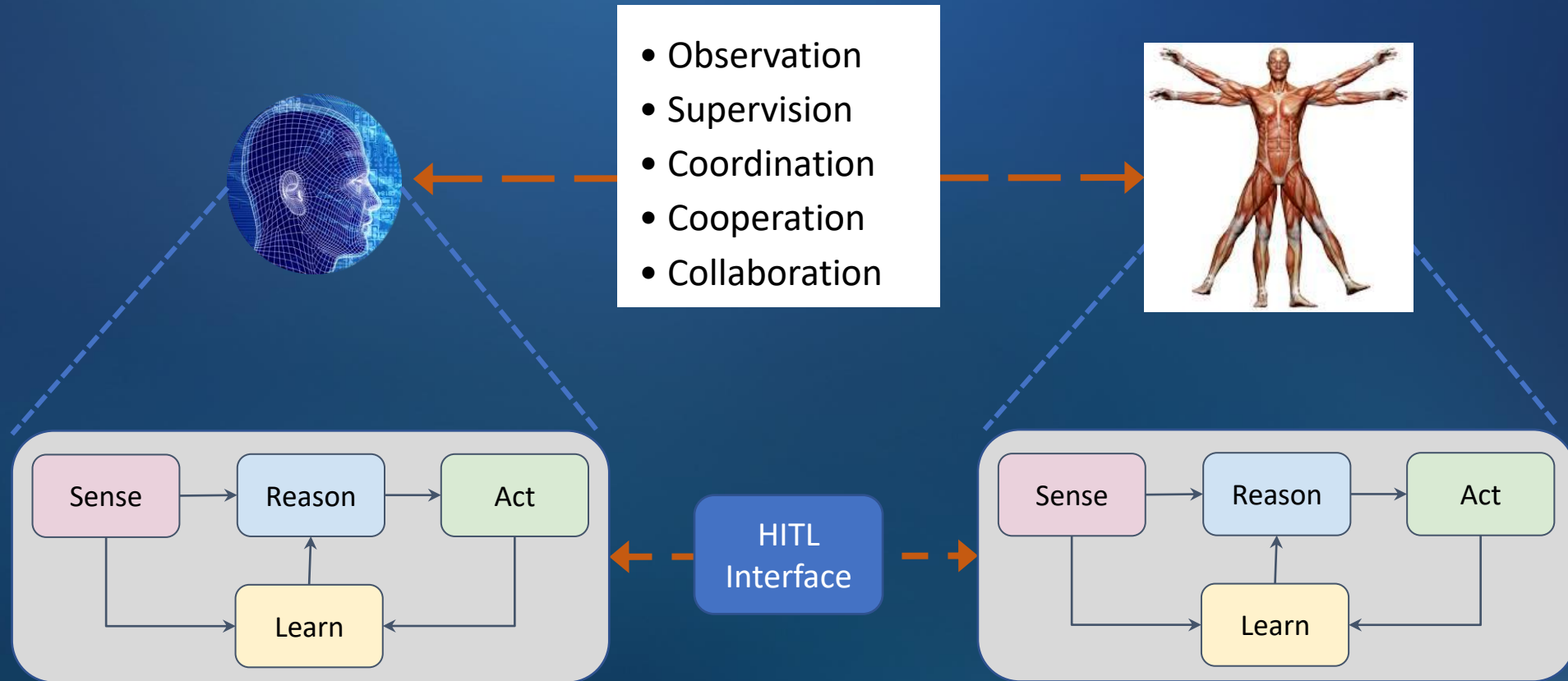


# Current Autonomous Architectures



NOT ENOUGH

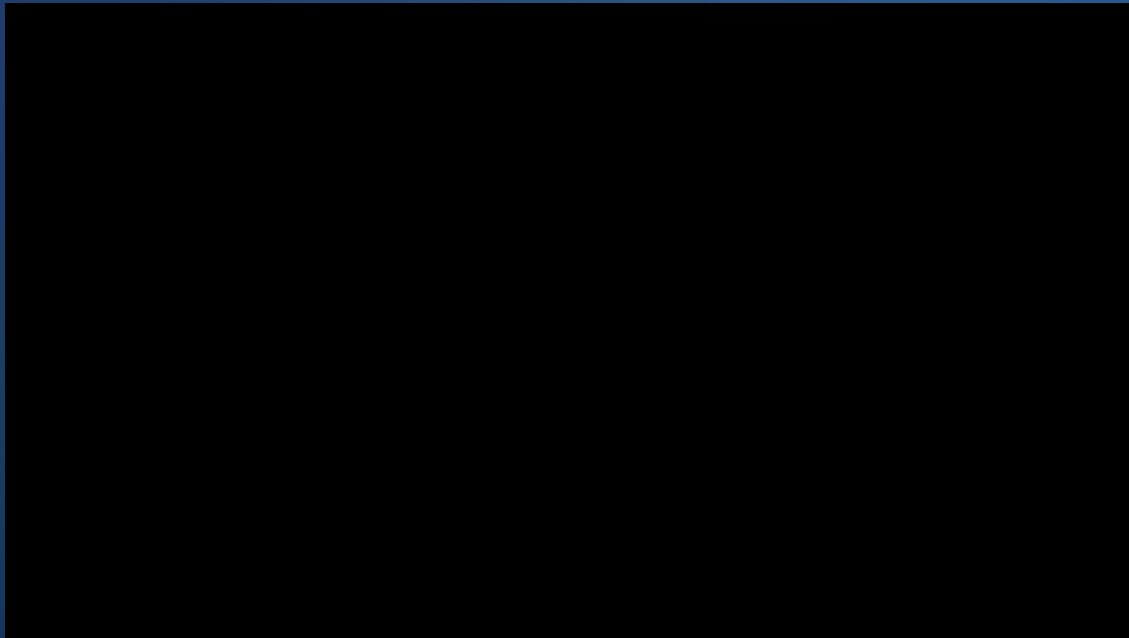
# Autonomous Systems with Humans-in-the-Loop



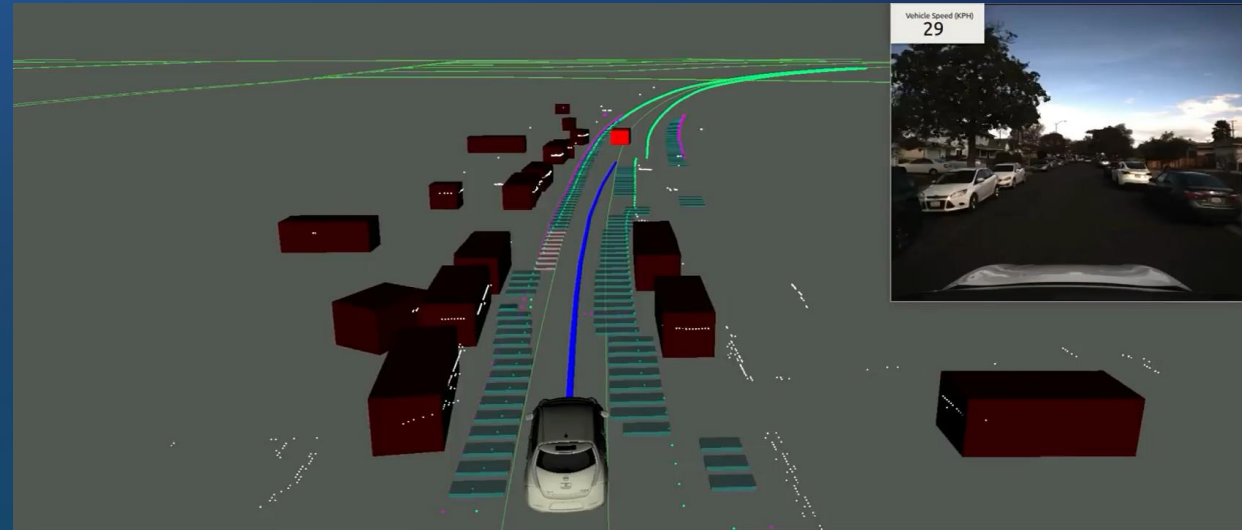
# L4 Autonomous Driving

a Human-Machine Coordination Task

“Normal” Urban Driving



Predicting “Unusual” Interactions

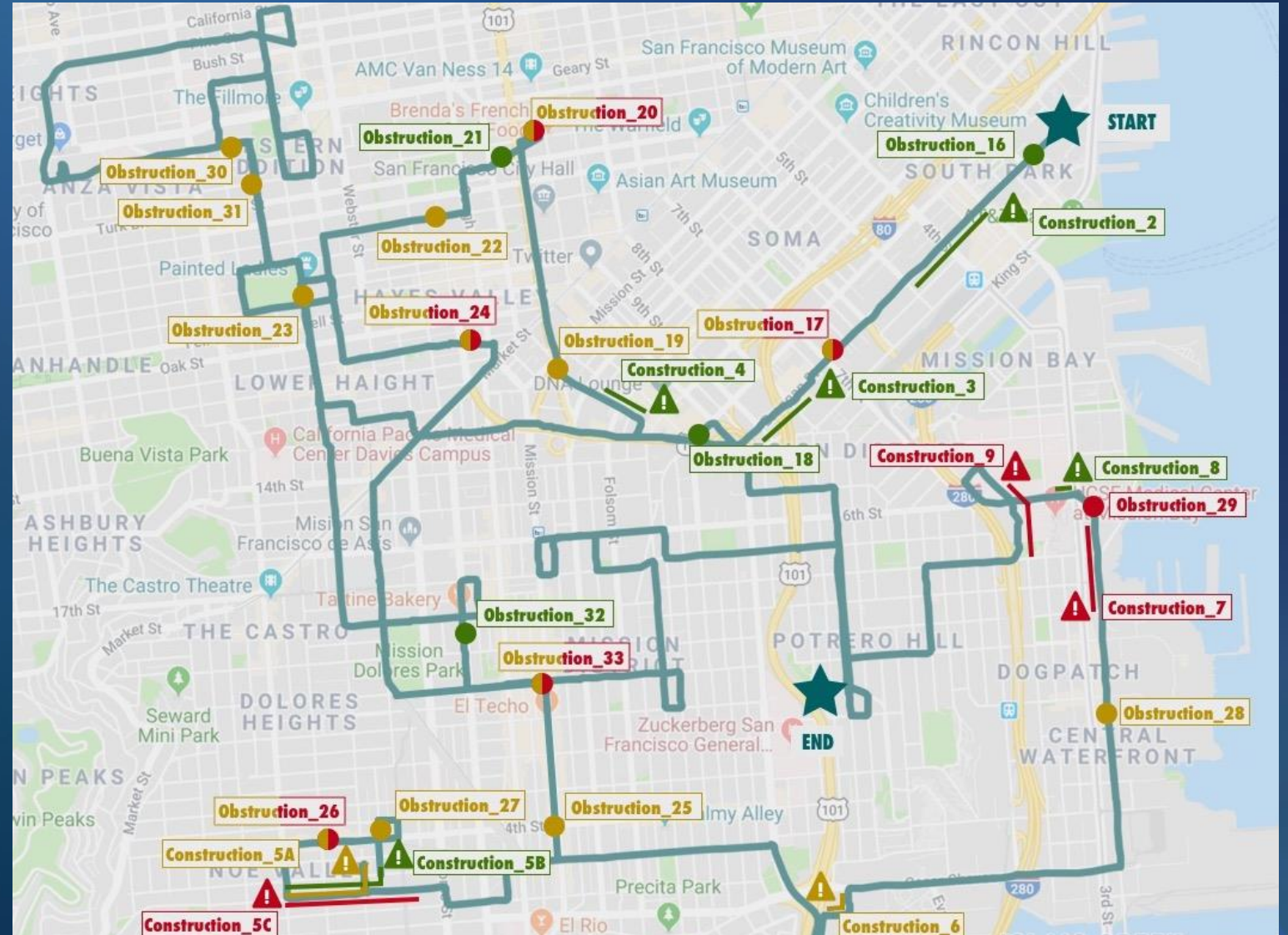


# Naturalistic research “Exceptions in the SF wild”

Frequency of Exception Situations = 10% of time

San Francisco, Nov. 2018  
Drive Time: 3:00 hrs

- temporary roadway obstruction
- ⚠ construction scene
- not an exception, regular AD handles
- is an exception, AI can handle
- is an exception, might require Mobility Manager
- is an exception, will require Mobility Manager



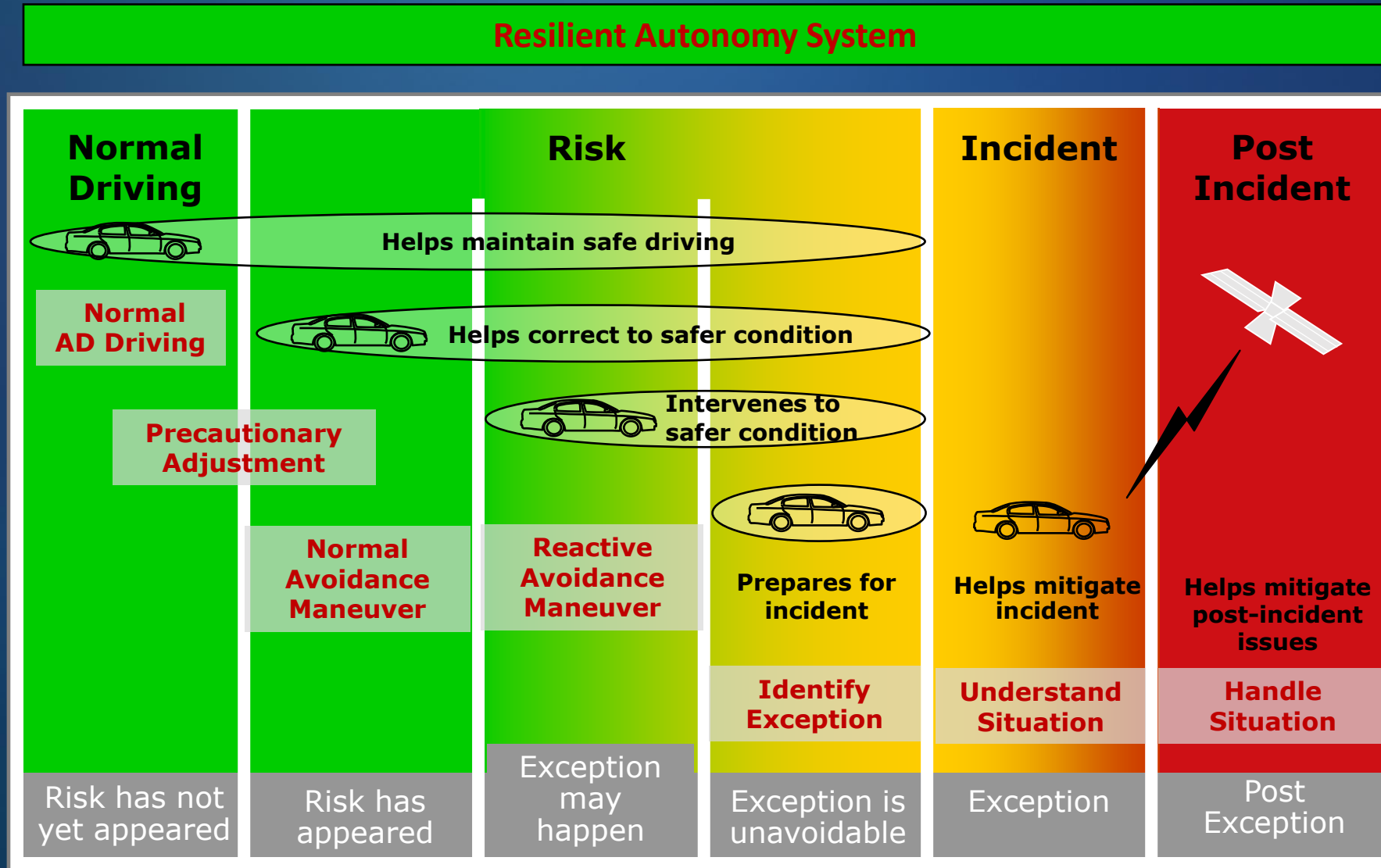
# Exceptions Other Than “Normal Driving”

1. Vehicle fires: Cars, buses, or trucks may catch fire due to mechanical failures, accidents, or other reasons, requiring emergency response and potentially causing traffic disruptions.
2. Debris on the road: Objects such as fallen tree branches, construction materials, or litter can obstruct lanes or create hazards for drivers, cyclists, and pedestrians.
3. Flooding or water main breaks: Heavy rain, flooding, or burst water mains can lead to water accumulation on roads, causing hydroplaning, traffic diversions, and potential damage to vehicles.
4. Traffic signal malfunctions: Faulty traffic lights or signals can cause confusion among drivers and pedestrians, leading to accidents or traffic congestion.
5. Animal crossings: In urban areas near parks or wooded areas, wildlife such as deer, raccoons, or stray pets may wander onto roads, posing risks to drivers and themselves.
6. Public transportation incidents: Bus breakdowns, subway delays, or tram malfunctions can disrupt traffic flow and inconvenience commuters.
7. Medical emergencies: Drivers or passengers experiencing medical emergencies such as heart attacks or seizures may need immediate assistance, potentially leading to road closures or traffic delays.
8. Terrorist threats or attacks: In rare instances, cities may face terrorist threats or attacks targeting transportation infrastructure, leading to heightened security measures, evacuations, and disruptions to normal traffic patterns.
9. Natural disasters: Earthquakes, hurricanes, or other natural disasters can damage roads, bridges, and other infrastructure, leading to closures, detours, and long-term transportation challenges.
10. Illegal street vendors or hawkers: Informal street vendors operating in roadways can obstruct traffic flow and create safety hazards for pedestrians and motorists.
11. Pedestrian collisions: Accidents involving pedestrians being struck by vehicles, often at crosswalks, intersections, or while jaywalking.
12. Bicycle accidents: Collisions involving bicycles and vehicles or pedestrians, often at intersections or on bike lanes.
13. Public transportation incidents: Accidents involving buses, trams, or other forms of public transportation, such as collisions, breakdowns, or delays.
14. Street flooding: Heavy rain or inadequate drainage systems can cause streets to flood, leading to traffic disruptions and potential hazards for drivers and pedestrians.
15. Roadwork incidents: Accidents or delays related to ongoing road construction, maintenance, or repair work, such as equipment malfunctions or worker injuries.
16. Tire blowouts: Sudden tire blowouts can cause drivers to lose control of their vehicles, leading to accidents or traffic disruptions.
17. School zone incidents: Accidents or safety concerns related to school zones, such as speeding or reckless driving near schools, playgrounds, or school bus stops.
18. Traffic violations: Speeding, running red lights, illegal parking, and other traffic violations are common on city roads and can lead to accidents or conflicts with law enforcement.
19. DUI/DWI incidents: Driving under the influence of alcohol or drugs is a serious safety hazard and can result in accidents, injuries, or fatalities.
20. Road rage incidents: Altercations between drivers, cyclists, or pedestrians due to frustration or anger can escalate into confrontations or even violence.
21. Street protests or demonstrations: Sometimes, protests or demonstrations take place on city streets, leading to road closures, traffic disruptions, and potential clashes between protesters and law enforcement.
22. Street racing: Illegal street racing can occur in some cities, posing significant risks to participants and bystanders alike.
23. Hit-and-runs: Drivers may flee the scene after being involved in accidents, leaving injured parties without assistance and complicating investigations.

.... ETCETERA



# Future Autonomous Architectures



# Resilient Autonomous Architecture



Role r1



Role rn

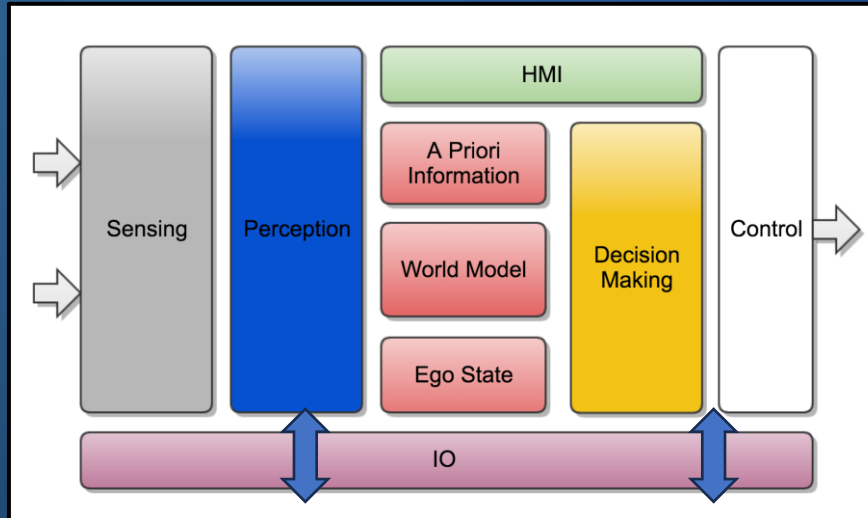
Interaction

Gestures  
Speech

App  
(Other)



## AUTONOMOUS DRIVER



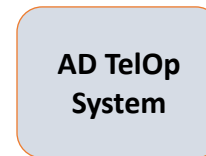
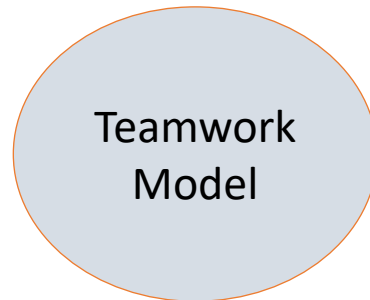
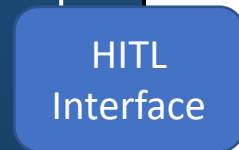
Engineer



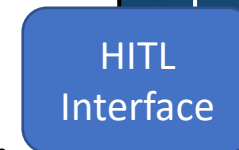
Fleet Manager



Teleoperator



- Observation
- Supervision
- Coordination
- Cooperation
- Collaboration



## HUMAN TEAMWORK AGENT