Tesla Model-X Autopilot Architecture And Operational Requirements

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I. INTRODUCTION

When it comes to the automotive industry, the "Big Three" are the United States car manufacturers, German car manufacturers, and Japanese car manufacturers. The "Big Three" American automakers are Ford Motors, General Motors, and Chrysler Stellantis. Volkswagen & Audi Group, Mercedes-Benz Group, and BMW AG are the German "Big Three" automakers. Toyota, Nissan, and Honda are the "Big Three" Japanese automakers. These car manufacturers produced gasoline-powered vehicles and, for many years, focused their research and development solely on gasoline vehicles until Tesla introduced the electric vehicle (EV), which changed the face of the automotive industry as we know it today. This assignment will concentrate on describing the Tesla Model X architecture and operational requirements, as well as performing analysis on the possible causes of the same Model X crash on March 23, 2018, Highway 85, southbound US 101, Mountain View California, US. The final section includes a drawing of a fault tree resulting from the aforementioned accident.

II. TESLA

Tesla was founded in 2003 by a group of engineers who wanted to show that driving electric didn't have to be a compromise – that electric vehicle could be better, faster, and more fun to drive than gasoline cars. Tesla now manufactures not only all-electric vehicles, but also infinitely scalable clean energy generation and storage systems. Tesla believes that the faster the world transitions away from fossil fuels and toward a zero-emission future, the better. The Roadster, which debuted in 2008, showcased Tesla's cutting-edge battery technology and electric powertrain. From there, Tesla created the world's first premium all-electric sedan from the ground up, the Model S, which has gone on to become the best car in its class in every category. With the longest range of any electric vehicle, over-the-air software updates that improve it over time, and a record 0-60 mph acceleration time of 2.28 seconds as measured by Motor Trend, Model S has reset the world's expectations for the car of the twenty-first century. Tesla expanded its product line in 2015 with the Model X, the safest, quickest, and most capable sport utility vehicle in history, with 5-star safety ratings from the National Highway Traffic Safety Administration in every category [1].

III. AUTOPILOT

George De Beeson coined the term "Autopilot system" in the 1930s. A system that controls the path of an aircraft, marine craft, or spacecraft without the constant manual control of a human operator is referred to as an autopilot [2]. It is important to note that in any system with autopilot capability, the autopilot does not replace the human operator; rather, it aids in the smooth operation of the vehicle, allowing the operator to focus on other aspects such as weather monitoring, trajectory, and so on. The autopilot is quite often integrated into a system; for example, in aircraft, it is integrated into the Flight Management System. Autopilot is now used in automobiles thanks to new technologies, particularly artificial intelligence. The autopilot, like most systems, is made up of tightly controlled software and hardware, with extensive testing procedures in place. For the most part, an autopilot's hardware and software are designed with redundancy and reliability in mind for such safety-critical system.

IV. TESLA MODEL-X AUTOPILOT ARCHITECTURE

Tesla Autopilot is a suite of advanced driver-assistance system (ADAS) features that amounts to Level 2 vehicle automation provided by Tesla. Lane centering, traffic-aware cruise control, automatic lane changes, semi-autonomous navigation on limited access freeways, self-parking, and the ability to summon the car from a garage or parking spot are among its features. The driver is responsible for all of these features, and the vehicle must be constantly monitored. The features, according to the company, reduce accidents caused by driver negligence and fatigue from long-term driving. Consumer Reports ranked Tesla Autopilot as "a distant second" in driver assistance systems (behind Cadillac's Super Cruise) in October 2020, despite ranking first in the "Capabilities and Performance" and "Ease of Use" categories [3].

Full Self-Driving (FSD) : is an AI inference chips to run a FSD software, considering every small architectural and micro-architectural improvement while squeezing maximum silicon performance-per-watt. Perform floor-planning, timing and power analyses on the design. Write robust tests and scoreboards to verify functionality and performance. Implement drivers to program and communicate with the chip, focusing on performance optimization and redundancy. Finally, validate the silicon chip and bring it to mass production of vehicles.

Tesla Dojo Chips: Is an AI training chips to power the Dojo system. Implement bleeding-edge technology from the smallest training nodes to the multi-die training tiles. Design and architect for maximum performance, throughput and bandwidth at every granularity. Dictate physical methodology, floor-planning and other physical aspects of the chip. Develop pre-silicon verification and post-silicon validation methods to ensure functional correctness. Write compilers and drivers to optimize power and performance for neural networks throughout the entire Dojo system.

Dojo Systems: Tesla design and build the Dojo system, from the silicon firmware interfaces to the high-level software APIs meant to control it. Solve hard problems with state-of-the-art technology for high-power delivery and cooling, and write control loops and monitoring software that scales. Work with every aspect of system design where the limit is only your imagination, employing the full prowess of mechanical, thermal and electrical engineering teams to create the next-generation of machine learning compute for use in Tesla datacenters Figure 1. Collaborate with Tesla fleet learning to deploy

training workloads using a massive datasets, and design a public facing API that will bring Dojo to the masses.

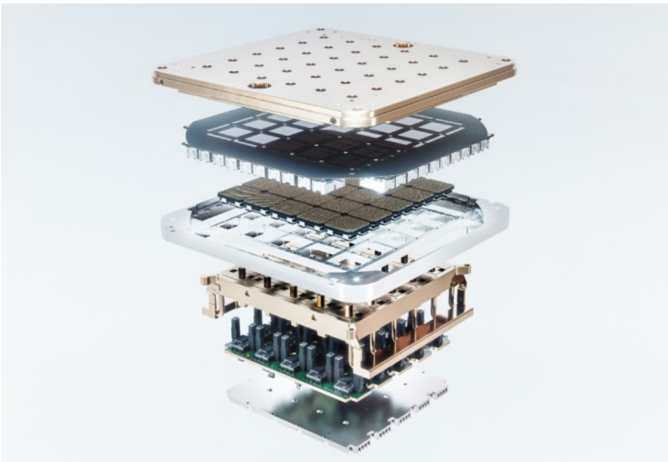


Figure 1. Tesla Dojo Technology

Neural Networks: Apply cutting-edge research to train deep neural networks on problems ranging from perception to control. A per-camera networks analyze raw images to perform semantic segmentation, object detection and monocular depth estimation. Tesla's birds-eye-view networks take video from all cameras to output the road layout, static infrastructure and 3D objects directly in the top-down view. The networks learn from the most complicated and diverse scenarios in the world, iteratively sourced from a fleet of nearly 1M vehicles in real time. A full build of Autopilot neural networks involves 48 networks that take 70,00 GPU hours to train. Together, they output 1,000 distinct tensors (predictions) at each timestep.

Autonomy Algorithms: Develop the core algorithms that drive the car by creating a high-fidelity representation of the world and planning trajectories in that space. In order to train the neural networks to predict such representations, algorithmically create accurate and large-scale ground truth data by combining information from the car's sensors across space and time. Use state-of-the-art techniques to build a robust planning and decision-making system that operates in complicated real-world situations under uncertainty. Evaluate your algorithms at the scale of the entire Tesla fleet.

Code Foundations: Throughput, latency, correctness and determinism are the main metrics we optimize the code for. Build the Autopilot software foundations up from the lowest levels of the stack, tightly integrating with a custom hardware. Implement super-reliable bootloaders with support for over-the-air updates and bring up customized Linux kernels. Write fast, memory-efficient low-level code to capture high-frequency, high-volume data from sensors, and to share it with multiple consumer processes— without impacting central memory access latency or starving critical functional code from CPU cycles. Squeeze and pipeline compute across a variety of hardware processing units, distributed across multiple system-on-chips.

Evaluation Infrastructure: is an open- and closed-loop, hardware-in-the-loop evaluation tools and infrastructure at scale, to accelerate the pace of innovation, track performance improvements and prevent regressions. Leverage anonymized characteristic clips from a fleet and integrate them into large suites of test cases. Write code simulating a real-world environment, producing highly realistic graphics and other sensor data that feed Autopilot software for live debugging or automated testing.

Tesla Bot: Tesla develop the next generation of automation, including a general purpose, bi-pedal, humanoid robot capable of performing tasks that are unsafe, repetitive or boring. We're seeking mechanical, electrical, controls and software engineers to help us leverage AI expertise beyond Tesla's vehicle fleet [4].

V. ANALYSIS OF THE TESLA MODEL-X ACCIDNET ON HIGHWAY 85, MOUNTAIN VIEW, CALIFORNIA 2018

The National Transportation Safety Board (NTSB) is an independent US. Government Investigative agency responsible for civil transportation accidents investigation, two years later the accident on February, 11, 2020 released new factual information for a Tesla accident investigation–the March 23, 2018, crash of a Tesla Model X in Mountain View, California. A 2017 Tesla Model X P100D electric-powered passenger vehicle equipped with advanced driver assistance features – a feature Tesla refers to as "autopilot" – left the southbound travel lanes of Highway 101 and collided with a previously damaged crash attenuator. The driver, the only occupant of the vehicle, was killed in the collision. The main purpose of NTSB is to determine the possible cause of accidents and investigate and issue safety recommendations aimed at preventing future accidents [5].

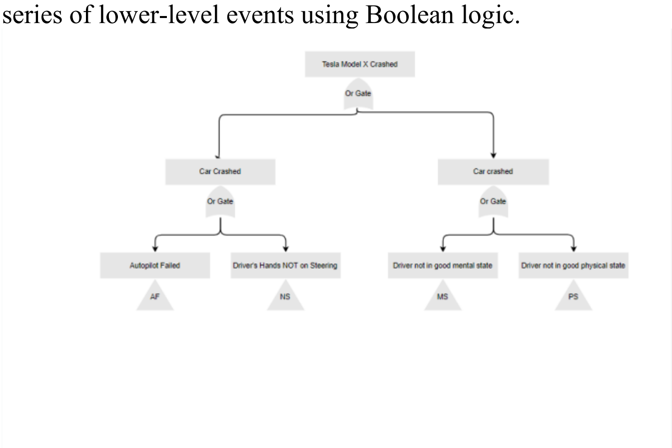
Analysis 1*:* The NTSB's investigation included two data investigations: the driver's mobile phone and the system performance data downloaded from the Model X in question. The former revealed that a game application was activated, which could mean he was playing a game while handing over cruise control to autopilot and his hands was not on the steering for six seconds, and the latter revealed that the driver was operating a specific feature of the ADAS, an adaptive cruise control or traffic-aware cruise control, and an Auto-steer system responsible for a Lane-Keeping Assist System, in other words, the driver engaged the full Autopilot system.

Analysis 2: If the accident was caused by ADAS failure, there are several possible areas to investigate in terms of hardware and software. The Tesla code-foundation would be investigated because it contains the autopilot software, Autopilot Neural Network, and other components, however, Tesla in collaboration with NTSB released its own investigation and showed that the moments before the collision [6];

1. **Autopilot was engaged** with the adaptive cruise control follow-distance set to minimum.
2. The driver had received several **visual** and one **audible hands-on warning** earlier in the drive and the driver's **hands were not detected on the wheel for six seconds** prior to the collision.
3. The driver had about **five seconds** and 150 meters of unobstructed view of the concrete divider with the crushed crash attenuator, but the vehicle logs show that **no action was taken.**

VI. FAULT AND EVENT TREES ANALYSIS FOR TESLA MODEL-X POSSIBLE CUASE OF ACCIDENT

Figure 2, is a fault tree described the fault tree analysis which is a top-down, deductive failure analysis in which an undesirable state of a system is analyzed by combining a series of lower-level events using Boolean logic.



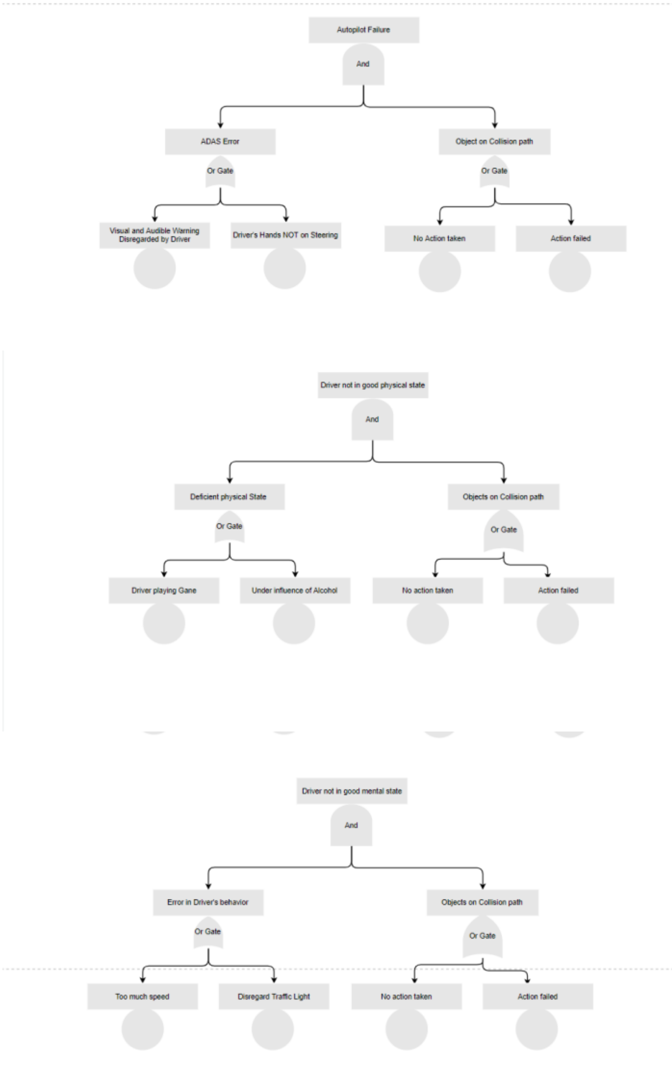


Figure 2a. Fault tree for Tesla Model-X

This analysis method is primarily used in safety engineering and reliability engineering to understand how systems fail, identify the best ways to reduce risk, and determine (or get a sense of) the event rates of a safety accident or a specific system level (functional) failure [7].

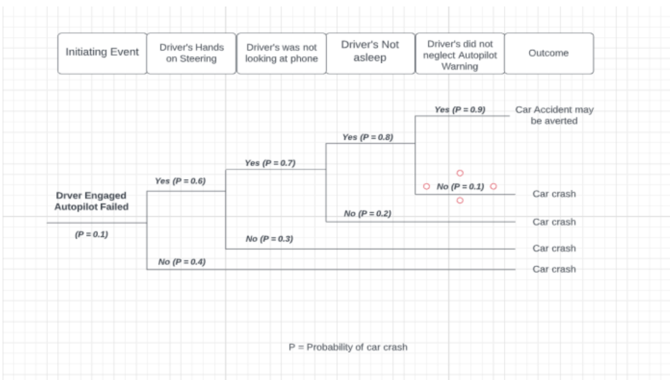


Figure 2b. Event tree for Tesla Model-X

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