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Tesla's Self-Driving Tech: Legal Battles, Regulatory Scrutiny, and Technical Insights

Recent Legal Cases Involving Tesla's "Full Self-Driving" Claims

Consumer Class Actions & False Advertising: Tesla has faced lawsuits alleging it misled customers about Autopilot and "Full Self-Driving" (FSD) capabilities. Notably, a 2022 consumer class action in California (Matsko v. Tesla) claimed Tesla deceived buyers by overstating that its cars were on the cusp of full autonomy. In October 2023, a federal judge ruled that these claims must go to **individual arbitration** rather than proceed as a class-action in court [1] [2]. The plaintiffs had argued Tesla charged thousands for an **"unreliable" driver-assist tech** that was advertised as nearly autonomous [3], but Tesla enforced its sales agreement's arbitration clause [4] [5]. This effectively paused the class lawsuit, illustrating how Tesla's contracts shield it from courtroom scrutiny over FSD marketing.

Securities Fraud Allegations: In a separate case, Tesla investors filed a **securities fraud class action** (Lamontagne v. Tesla) claiming Elon Musk and Tesla misled them about the progress and safety of its self-driving tech. In a September 2024 order, a judge summarized that the plaintiffs identified *29 separate false or misleading statements* about Tesla's autonomy timeline, safety, and capabilities [6] [7]. For example, during the alleged class period (2019–2023), Tesla repeatedly touted being *"very close"* to **Level 4–5 autonomy** (full self-driving without human supervision) and even promised a network of Tesla "**robotaxis**" generating income for owners [8] [9]. Yet evidence showed Tesla's FSD Beta remained **unsafe without human oversight**, and *"far more" crashes had occurred than previously reported* [10]. The complaint cited serious FSD defects (ignoring Do Not Enter signs, speeding in school zones, swerving into oncoming traffic) and noted **U.S. safety investigators (NTSB)** had criticized Tesla's marketing for lulling drivers into inattention [10]. Strikingly, the investors pointed out Tesla's **lack of transparency** on safety metrics: unlike rivals, Tesla did *not* report "disengagements" (instances where a human must intervene) to regulators [11]. Instead, using crowdsourced data, they estimated Tesla's FSD required driver intervention roughly **once every 16 miles** – a frequency about **1,000× worse than Waymo's** autonomous cars and **5,800× worse than GM's Cruise** [12]. (Waymo and Cruise, which report disengagements to California's DMV, routinely logged tens of thousands of miles between interventions, versus mere dozens for Tesla [13].) This case underscores how Tesla's optimistic public statements about autonomy contrast with its actual performance data [12].

Product Liability Trials: Tesla is also facing and defending wrongful-death and injury lawsuits from Autopilot-related crashes. One high-profile example is a California suit by the family of **Walter Huang** (an Apple engineer who died in a 2018 Autopilot crash). In that case, internal documents revealed Tesla never studied how quickly a driver can retake control from Autopilot in an emergency [14] [15]. A **2017 safety analysis** warned Autopilot might make sudden *"unexpected steering"* movements requiring an alert driver [14] – essentially predicting the scenario that killed Huang – yet Tesla only added driver-monitoring cameras years later (in 2021) [16]. In deposition, Tesla's corporate representative admitted being unaware of any research on drivers' ability to intervene in time [17]. Such evidence bolsters plaintiffs' claims that Tesla knew Autopilot could **lull drivers into complacency** and failed to mitigate that risk [15]. This theme – that *"Autopilot is safe if used properly, so crashes are the driver's fault"* – is being tested in court. Similarly, in a **2019**

crash in California (Maldonado v. Tesla) where a Tesla on Autopilot tragically rear-ended another car at high speed, killing a 15-year-old, the victim's family alleges Tesla's *"deceptive marketing"* created false trust in a Level-2 system incapable of true self-driving [18] [19]. Their complaint cites Tesla's own engineers: years prior, Tesla developers objected to naming the system "Autopilot," calling it misleading and suggesting "Co-Pilot" instead – but Tesla's executives overrode them [18]. By **branding its driver-assistance as "Autopilot" and "Full Self-Driving Capability,"** Tesla, in their view, implied it was closer to SAE Level 3–4 autonomy (hands-off driving) even though it was only Level 2 (hands *on*, full driver supervision required) [20]. These cases underscore the legal risk Tesla faces for **overstating the autonomy** of its tech.

Regulatory Actions: Beyond private lawsuits, regulators have taken note. In July 2022, the California DMV filed a complaint accusing Tesla of **false advertising** – essentially, saying terms like *"Full Self-Driving"* are misleading since no Tesla is actually self-driving. That case remains pending (as an administrative proceeding) [21] [22]. At the federal level, the U.S. Department of Justice opened a **criminal fraud probe** into whether Tesla's FSD claims have deceived consumers or investors [23]. And in October 2023, a jury in Florida *did* find Tesla at fault (along with a driver) in a civil trial over a fatal Autopilot crash, awarding \$ **243 million in damages** [24]**. In short, Tesla's marketing of "self-driving" features has landed it in courtrooms frequently of late – with judges and regulators scrutinizing whether Tesla knowingly** oversold the capabilities** of Autopilot/FSD.

Tesla's Approach vs. Waymo's: Transparency and Regulatory Cooperation

Working *with* Regulators vs. Against: A stark contrast exists between Tesla and rivals like Waymo when it comes to collaborating with regulators and disclosing safety data. **Waymo (Alphabet's self-driving unit)** and others have embraced transparency – for instance, Waymo regularly publishes detailed **Safety Reports** and has submitted **Voluntary Safety Self-Assessments (VSSAs)** to the U.S. National Highway Traffic Safety Administration (NHTSA) [25]. In fact, by 2021 *"more than two dozen companies"* developing autonomous vehicles (Waymo, GM Cruise, Ford, Zoox, etc.) had publicly released VSSAs or safety white papers about their technology [25]. **Tesla, by contrast, has *never* completed a voluntary safety self-assessment report** for its Autopilot or FSD [25]. This reluctance to share data has been noted by safety advocates – one industry group pointed out in 2021 that every major AV developer except Tesla was submitting such reports and engaging openly with NHTSA [25]. Likewise, **California's DMV** requires firms testing autonomous vehicles to file annual disengagement reports (documenting miles driven and human interventions). Companies like Waymo and Cruise comply, providing an *"objective, albeit limited"* glimpse of their progress [26] [27]. Tesla, however, purposely avoids this by arguing its FSD Beta is only a Level-2 **"driver assist"** feature – not an "autonomous vehicle" under DMV rules – thus exempt from reporting [28]. For several years running, Tesla's name has been absent from California's public AV test reports due to this self-classification [28]. (State officials have moved to **"close this loophole,"** given that Tesla has tens of thousands of customers effectively testing semi-autonomous tech on public roads [28].) The result is that **Waymo's performance data is public** – e.g. Waymo logged ~629,000 miles in California in 2020 with **29,944 miles between disengagements** on average [29] [30] – whereas **Tesla provides no official data** to regulators on how often FSD requires human takeover. In fact, an internal Tesla **self-report** (from owners in FSD Beta) suggested **one disengagement every ~16 miles** in 2023 [11], a rate orders of magnitude worse than Waymo's **tens of thousands of miles** per disengagement [12]. Tesla's stance has been essentially to **decline proactive oversight**, instead rolling out beta features to its customers with minimal external review [31].

NTSB's Warnings: Tesla's friction with regulators is exemplified by its interactions with the **National Transportation Safety Board (NTSB)**. After investigating multiple Autopilot-related crashes, the NTSB in 2017 issued safety recommendations urging Tesla (and other automakers) to implement better driver-monitoring (e.g. camera-based eye tracking) and to **restrict the use of driver-assistance to conditions it can handle** [32] [33]. *Five other automakers* promptly responded within NTSB's 90-day window and agreed to address these issues [34]. Tesla, however, **never officially responded** at all [34]. By 2021, the NTSB Chair was "*deeply concerned*" that Tesla's inaction had contributed to further deadly crashes [35] [36]. In a public letter to Elon Musk, NTSB Chair Jennifer Homendy scolded Tesla for ignoring the 2017 guidance and then expanding its FSD Beta program in 2021 despite *"basic safety issues"* remaining unaddressed [35] [37]. She specifically called Tesla's use of the term *"Full Self-Driving"* **"misleading and irresponsible,"** saying it has "clearly misled numerous people to misuse and abuse" the technology [37]. (Indeed, surveys show **71% of drivers** believe a car advertised as "self-driving" can actually drive itself today [38] – a misconception safety experts blame on marketing hype.) The **NTSB lacks regulatory power** – it can only recommend, not require – and Tesla's pattern has been to do the bare minimum (e.g. increasing Autopilot's "hands on wheel" alerts) while **ignoring bigger fixes** like driver monitoring or renaming the product [39] [40]. This stands in contrast to companies like **GM**, which not only responded to NTSB but also installed **driver-facing cameras** in its SuperCruise-equipped cars to ensure drivers stay attentive. Waymo and Cruise go even further: their autonomous taxis operate with no human driver at all, but only in controlled conditions (specific cities and speed limits) and under active regulatory permits. In sum, *Waymo's approach has been one of cautious, transparent deployment hand-in-hand with regulators*, whereas *Tesla's approach has often been "deploy first, fight regulation later."*

Transparency & Sensor Strategy: Another difference is sensor philosophy and external scrutiny. Waymo and others publish detailed technical reports and even invite media/officials to ride in their cars. They generally use a **"sensor fusion"** suite (lidar, radar, and cameras) to maximize safety redundancies [41]. Tesla, on the other hand, famously **removed radar and lidar**, relying only on cameras and AI – a bold approach that even some Tesla engineers internally questioned [41] [42]. Where Waymo geofences its operations and **incrementally expands** service (after millions of miles of testing in each new city), Tesla pushed a broad FSD Beta to ~400,000 customers across North America [43]. As a *Medium* op-ed wryly observed, **"Tesla is testing self-driving features on the public and making changes along the way,"** whereas the leading AV companies **"don't bring something to market until they're confident it's fully functional and safe"** [44] [31]**.** The **regulatory implication**: Waymo's cars operate under approved experimental licenses (with safety reporting to authorities), but Tesla's wide Beta was essentially unregulated, relying on users to supervise a system touted as nearly autonomous. This divergence – Tesla's maverick, consumer-beta model vs. Waymo's methodical, regulator-friendly model – has prompted federal officials to consider new rules. In fact, NHTSA (under pressure from incidents) has multiple defect investigations open into Tesla's Autopilot and FSD for safety issues like phantom braking and failure to detect obstacles [45] [46]. As NHTSA's acting head commented, **federal self-driving standards are needed** to "build public trust" – implicitly highlighting that Tesla's high-profile mishaps risk eroding confidence in autonomous tech [47].

Tesla's Marketing & Public Messaging vs. Reality

"Full Self-Driving" Branding: Tesla's *marketing* of its driver-assistance features has been aggressive – and controversial. In 2016, Tesla **rebranded** its suite from a mundane "Advanced Driver Assistance System" to **"Autopilot"** (and later sold an upgrade labeled **"Full Self-Driving Capability"**) [18]. Internal emails and witness statements show Tesla's own engineers raised red flags about these names. They feared calling the system "Autopilot" **would mislead consumers** into overestimating its autonomy – one engineer suggested

"Copilot" as a safer term – but Tesla's higher-ups went ahead with the more aspirational branding [18]. Similarly, the term "Full Self-Driving" (FSD) implies no human driver needed (SAE Level 4 or 5), even though FSD Beta is still Level 2 (the *driver must monitor at all times*) [20] [48]. This gap between branding and reality has drawn legal fire. In late 2022, **California lawmakers** even passed a rule banning automakers from calling a feature "full self-driving" if it's only Level 2, specifically a response to Tesla's terminology (though enforcement is pending) [37].

Staged Demonstrations: Tesla has a history of flashy autonomy demos – sometimes stretching the truth. A **famous 2016 promotional video** bore the caption "The car is driving itself." It showed a Tesla navigating roads, stopping at lights, and parking autonomously to dramatic effect. In reality, that video was **staged and scripted**. In early 2023, Tesla's Autopilot director **Ashok Elluswamy testified** that the car's route was pre-mapped in 3D, drivers intervened multiple times during filming, and one test run even **crashed into a fence** while trying to park [49]. Internal emails revealed Elon Musk **personally oversaw the video** and even dictated the opening line touting that *"the car drives itself"* [50]. Musk urged the team that it was acceptable to **"hardcode some of it"** for the sake of an impressive demo, saying they'd later patch the real software to catch up [51]. An internal Tesla memo bluntly admitted: *"The intent of the video was not to accurately portray what was available in 2016. It was to portray what was possible…"* [52] [53]. Musk then **publicly promoted** that video, tweeting *"Tesla drives itself (no human input at all)… then finds a parking spot."* [54] Many viewers understandably believed Tesla had achieved fully autonomous driving in 2016 – which it **had not**. This staged demo is now evidence in both civil litigation and a DOJ probe, underscoring Tesla's willingness to **"fake it till you make it"** in marketing [23].

Executive Optimism and Missed Deadlines: Elon Musk's own pronouncements have consistently hyped Tesla's autonomy – and are now being scrutinized in court. Musk has repeatedly claimed full autonomy was just around the corner. *For example:* in 2016 he declared **"a Tesla can drive autonomously with greater safety than a person. Right now."** [55] ***In 2019 he promised a million Tesla "robotaxis" by 2020. In 2020–21 he set (then missed) year-end deadlines for achieving Level 5 autonomy. In 2022 he told investors Tesla would solve full self-driving*** **"this year."* None of those came true. Now, in the Huang wrongful-death case, a judge ordered Musk to sit for a** deposition **about these statements, after Tesla's lawyers tried to argue Musk's public comments might have been *"deepfakes"* – a suggestion the judge called** "deeply troubling" [55]**. The court wants Musk to confirm which promises he actually made and whether he knew they were false** [56]**. This is significant because plaintiffs argue Musk's rosy claims lulled customers (and investors) into a false sense of security about Autopilot. If under oath Musk has to walk back or contextualize his optimism, it could undermine Tesla's narrative that** drivers are always to blame** for misuse.

Leaked Data and Complaints: In 2023, a trove of **100 GB of internal Tesla data** (dubbed the "Tesla Files") was leaked to media, revealing **thousands of safety complaints** related to Autopilot and FSD [57]. According to reports, Tesla's own logs from 2015–2022 contained *~2,400 complaints* about sudden unintended acceleration and *1,500 cases* of false braking (so-called "phantom braking"), among other issues [57]. These leaks suggest that Tesla knew of widespread problems and customer reports of scary incidents, even as it continued to expand the FSD Beta. Such information bolsters claims that Tesla **"oversells and under-delivers"** on self-driving – promising an experience that in practice has been fraught with glitches.

In summary, Tesla's bold marketing – from the Autopilot name to staged videos and Musk's forecasts – has been a double-edged sword. It helped Tesla grab mindshare and billions in FSD pre-orders, but it also now serves as evidence in **fraud and false-advertising cases**. Regulators like the DMV and FTC are watching

closely, and already Tesla's **FSD marketing has been officially called out as deceptive** (e.g. by California's DMV and the NTSB) [37] [18]. This scrutiny is **forcing Tesla to temper some claims**: for instance, Tesla's website now carries disclaimers that "currently enabled features require active driver supervision and do not make the vehicle autonomous." Nonetheless, the very name "Full Self-Driving" continues to sow confusion, as intended – a recent **survey found 13% of Americans believed FSD was truly autonomous** and many more were unsure, demonstrating the public misconception Tesla's branding has created [38].

Comparing Tesla and Waymo on Autonomous Performance

Despite Tesla's market-leading **volume of driver-assist systems** (hundreds of thousands of FSD Beta users), evidence suggests **Tesla's technology trails Waymo's** in achieving safe *unsupervised* driving. The most concrete comparisons come from California's annual **autonomous vehicle disengagement reports**, which track how far cars go before a safety driver has to take over:

- **Waymo's Progress:** Waymo's self-driving cars have shown dramatic improvement over the years. In **2019**, Waymo averaged ~13,219 miles between disengagements in California testing; in **2020**, Waymo improved to ~**29,944 miles** per disengagement [29]. (Cruise, similarly, went from ~12,200 to ~28,520 miles between interventions that year [29].) These numbers indicate that by 2020 Waymo's Level-4 system could handle tens of thousands of miles in complex traffic before a human needed to take control. Waymo has since launched fully driverless robo-taxi services in Phoenix, San Francisco, and other locales – a testament to its confidence in the tech's reliability. In more challenging environments (like San Francisco's city streets), performance did dip – Waymo's 2021 report showed one disengage per ~**7,900 miles** (12,744 km) as it shifted testing from quiet suburbs to a busy urban grid [58]. But even that is orders of magnitude better than any **human-supervised** system. Importantly, Waymo and its peers achieved these results by **geofencing** operations and rigorously controlling variables. They also **report every incident** to authorities, allowing independent verification of safety performance [26] [27].

- **Tesla's Performance (Miles per Intervention):** Tesla refuses to publish comparable disengagement stats (since it claims FSD isn't a Level-3+ autonomous system). However, internal and third-party data give a rough picture. As mentioned, a Tesla investor lawsuit cited that Tesla's FSD Beta in 2023 was experiencing **an intervention every ~16 miles on average** [11]. Even if that figure is too pessimistic, there is crowdsourced data from Tesla owners suggesting that **FSD Beta's performance until recently was on the order of *hundreds* of miles between "critical" disengagements, not tens of thousands**. In late 2022 and 2023, Tesla rolled out FSD Beta v11 (a major update integrating highway and city driving stack). This led to incremental improvements; by mid-2023 some users reported a few hundred miles between takeovers in easier conditions. In early **2025**, Tesla finally launched **"FSD v12"** – a rewrite using an end-to-end AI model (more on that below). Elon Musk claimed this yielded an "exponential" improvement. However, independent tracking shows it was more modest: roughly **~200 miles between critical disengagements improved to ~400–500 miles** with FSD v12 [59] [60]. In March 2025, *Electrek* reported that after 33,000 miles of collective testing on v13 (successor to v12), the fleet averaged about **495 miles per critical intervention** [61]. While this is progress, it's still far behind the **"human level"** that Tesla itself targets – by one Tesla engineer's estimate, a human drives ~**700,000 miles** on average between collisions, so Tesla's AI needs to reach a similar order of magnitude to be truly unsupervised [62]. In Musk's own words, Tesla at ~500 miles between interventions must improve **~1,400×** to hit the 700k mile benchmark for safety [62]. This gap illustrates why Tesla's FSD remains a Level-2 driver aid while Waymo can operate at Level 4 without a

human. In practical terms, **Waymo's cars can go dozens of trips without disengagement, whereas Tesla's FSD might require driver corrections on every trip or two** in city environments. Waymo's consistency has allowed it to remove safety drivers entirely in some cities; Tesla's inconsistency means a human *must* remain ready at all times.

- **Real-World Outcomes:** The difference is also seen on the roads. **Waymo has provided tens of thousands of paid rides** to the public with no driver at the wheel, with a strong safety record (Waymo reports the few at-fault accidents it has are minor and at a rate comparable or better than human drivers). **Tesla, by contrast, has had several high-profile crashes and near-misses with FSD Beta.** In one NHTSA investigation, **FSD Beta was found to disobey traffic laws and risk crashes**, prompting a February 2023 **recall of 362,000 Teslas** to fix issues like rolling through stop signs and improper speed adjustments [63] [64]. (Tesla issued an over-the-air software update after NHTSA's finding.) This was the largest recall related to a Level-2 ADAS system to date and underscored that Tesla's approach of *"beta-testing"* on public roads can expose the public to unsafe behavior. Waymo and Cruise, meanwhile, typically address such issues in closed testing before public release, and regulators have on a few occasions suspended their permits after isolated incidents (e.g. a Cruise car dragging a pedestrian, a Pony.AI car running a red light) – swift actions that compel fixes before operations resume. Tesla's FSD Beta, not being under a special permit, hasn't faced that sort of immediate shutdown; instead, NHTSA's slower defect investigations are the remedy, which means **Tesla's shortcomings play out more publicly.**

In summary, **Tesla's self-driving tech is improving but remains far behind the true driverless capability demonstrated by Waymo.** Tesla has lots of *potential* advantages (millions of cars with the hardware, a vast dataset, a fast AI iteration cycle), and Elon Musk insists Tesla's **vision-only, generalist approach will win in the long run** [65]. However, as of 2024, **Waymo and Cruise are operating** Level 4 **ride-hail services**, something Tesla has yet to achieve. Tesla's plan to skip Level 3 and jump to Level 4 autonomy **in all conditions** is unprecedented, and current data suggests they have significant ground to cover to hit the safety reliability of those competitors. One telling metric: in California's **2022** disengagement reports, Waymo and Cruise each drove ~**500,000+ miles with only 1–2 disengagements per 10,000 miles** (99.99%+ autonomy) [29], whereas Tesla's FSD (exempt from reporting) at that time was nowhere close to that reliability. In fact, **Tesla's own safety report for Q4 2022** (which Musk often references) stated that with Autopilot engaged (mainly highway driving), Teslas crashed once every 4.85 million miles – better than human average – but note: those miles are with active driver supervision on relatively easier roads (highways) and do *not* represent FSD city driving performance [66] [67]. The true challenge is urban, unsupervised driving, where Waymo is years ahead in demonstrated capability.

Tesla's 2023–24 Statements on Achieving Driverless Tech

Earnings Call Emphasis: Tesla's leadership has made it clear that reaching **Level 4 autonomy** is a strategic priority – and a key to unlocking financial value. In Tesla's quarterly earnings calls through 2023 and the first half of 2024, Elon Musk and other execs repeatedly highlighted progress in FSD and its future potential:

- On the **Q4 2022 earnings call (Jan 2023)**, Musk announced Tesla had deployed FSD Beta to ~400,000 customers, calling it "the only way any consumer can actually test the latest AI-powered autonomy" and a *"huge milestone"* [43]. He touted that Tesla had logged over **100 million FSD miles** on city streets and implied that the data showed safety benefits [43]. (He carefully noted Tesla wouldn't have released FSD Beta if its safety stats weren't "excellent" – though regulators later disagreed with that

assessment.) Musk's tone was that Tesla's large-scale beta was something **no one else** was doing, framing it as a competitive edge in AI development.

- On the **Q3 2023 call (Oct 2023)**, Musk spoke even more directly about Level 4. He suggested that Tesla was on the cusp of turning its cars into revenue-generating robotaxis with just software updates. He emphasized Tesla's **fleet of millions of vehicles with HW3**: *"There's millions of cars where full self-driving can be sold at essentially 100% gross margin,"* he said [67]. Once FSD achieves full autonomy, Musk claimed, it would lead to *"the biggest asset value increase of anything in history"* for Tesla's fleet [67]. In plainer terms, Musk was telling investors that if Tesla makes all its existing cars Level-4 capable, it could **recognize FSD software revenue from millions of customers overnight** (since nearly all Teslas built since 2016 have the needed hardware). He described this as *"tremendous upside"*, reinforcing that Tesla views FSD software as a huge future profit center [68]. Indeed, Tesla's finance chief has noted FSD is sold as a \$12,000–\$15,000 add-on (or subscription) with high margins, and Tesla has **deferred billions in revenue** (from FSD pre-payments) that it can book once features are delivered [69]. Musk's message: cracking Level 4 autonomy isn't just a tech goal, it's pivotal to Tesla's **economic story**.

- By the **Q1 2024 call (April 2024)**, Tesla had begun rolling out its **FSD Beta v12** to employees – an end-to-end AI system Musk believed would enable true Level 4 in time. Musk called v12 *"the pure AI-based self-driving"* and told listeners it was *"profound"* with a *"rapid rate of improvement."* [70] He revealed Tesla had expanded FSD Beta access to **1.8 million cars** in North America (all owners with compatible hardware) and that about half had engaged it so far [71]. In a bold statement, Musk claimed Tesla had now accumulated over **300** billion**** FSD miles (likely a misstatement – 300* million *seems more plausible given 400k beta users – but he said* billion*) and declared:* "It's become very clear that the vision-based approach with end-to-end neural networks is the right solution for scalable autonomy… It's really how humans drive."*** [65] **He stressed that our roads are designed for human vision, so** cameras + neural nets **are the natural solution, doubling down on Tesla's strategy to eschew lidar. In essence, Musk was evangelizing Tesla's AI approach and implying that a breakthrough was imminent. He urged people to try FSD Beta v12, hinting that unsupervised driving was close (*"I strongly urge you to try it… it's profound"*)** [70] **. This optimism has been a drumbeat: Musk said in the same call that new vehicle models might come with no steering wheel or pedals by 2025 – a nod to confidence in autonomy. However, it's worth noting that Musk has given similar "this year or next" autonomy predictions for at least** six years running**, and analysts and media treat them with skepticism due to past delays. Still, these calls show Tesla** continues to treat FSD progress as a core part of its narrative to shareholders**.

- **Investor Communications:** In Tesla's **2023 annual report and Master Plan presentations**, the company explicitly lists "Autonomy" as a key value driver. Tesla's 2023 Impact Report even stated that once autonomy is solved, a Tesla could provide **5x more utility** (driving itself while the owner is at work, etc.), underscoring how central robotaxi functionality is to Tesla's future plans. During 2023, Tesla also **raised FSD's price** (from \$10k to \$12k to \$15k) despite it still being Level 2 – signaling to the market that they believe a fully driverless capability (justifying those prices) is on the horizon. In multiple quarterly updates, Tesla noted it was **recognizing some deferred revenue** as FSD features were released, but also that significant revenue remains deferred until "**features achieve level 4 or 5 autonomy**" in regulators' eyes [72] [73]. This accounting nuance is important: Tesla cannot book certain FSD-related revenue until the software is considered substantially functional (which arguably

means no human supervision needed). Thus, achieving Level 4 isn't just a safety goal – it unlocks financial gains and **boosts Tesla's stock narrative** as a tech company (with high-margin software income) rather than "just" an automaker.

- **Promotional Moves:** In late Q1 2024, amid sluggish demand, Tesla made a telling promotional push: it offered a **one-month free trial of FSD Beta** to all owners who hadn't purchased it [74] [72]. Elon Musk emailed employees that *"Almost no one actually realizes how well [supervised] FSD actually works,"* instructing staff to **demo FSD to customers** and push the free trial [72]. This campaign came as Tesla's FSD **"take rate"** (the percentage of buyers paying for FSD) had plummeted – from ~**53% of new Tesla buyers in 2019 to only ~14% in 2022** [73]. In other words, many Tesla owners were no longer convinced FSD was worth the price. The free trial was seen by analysts as an attempt to **reignite interest (and gather fresh data)** [72]. It coincided with vehicle price cuts that hurt margins, so Tesla was eager to upsell software. This move implicitly shows Tesla's confidence in FSD's latest improvements – but also the need to **prove its value** to a skeptical public. Industry observers noted that Tesla's flurry of end-of-quarter tactics (price drops, FSD trials) indicated a short-term focus on hitting delivery and revenue targets [75]. The trial likely did generate a trove of driving data from new users, feeding Tesla's data engine. It also underscores Musk's view that *if people just see FSD Beta in action now, they'll be convinced how close it is to full autonomy.* Time will tell if that translates into higher FSD adoption or just one-off experimentation.

In summary, **Tesla's official communications in 2023–24 put Level 4 autonomy at center stage**: Musk portrays it as *"almost here"* and enormously valuable, and Tesla has invested heavily in that perception (from pricing strategy to investor messaging). However, until Tesla can demonstrate FSD working safely *without* a human backup, these statements remain aspirational. The company does seem to be preparing Wall Street and customers for the possibility that **2024–2025** could finally bring the long-awaited breakthrough to unsupervised driving. It's a race against not only technical challenges but also competitors like Waymo (already offering robotaxis) and emerging regulatory frameworks that could either bless or hinder Tesla's deployment of true Level 4 capability.

How Tesla's FSD Technology Works – and Why Real-World Data Is Its Lifeblood

Neural-Network Driven Approach: Unlike earlier driver-assistance systems that relied on pre-programmed rules or simple sensor fusion, Tesla's FSD is built on a **foundation of AI and machine learning** – specifically, deep neural networks that interpret camera images and make driving decisions. Tesla's philosophy (articulated by former AI director **Andrej Karpathy**) is that *"software 2.0"* – neural nets trained on vast data – can handle the complexity of driving better than hand-coded algorithms. Tesla's FSD Beta is essentially an AI **"driver"** inside the car's computer: it views 8 camera feeds, identifies vehicles, pedestrians, signs, and predicts how the scene will evolve, then plots a path and controls steering/brakes accordingly. Initially, Tesla broke this problem into subtasks (perception, planning, control). But by 2023, Tesla was pivoting to a more **"end-to-end" AI model** – meaning a single giant neural network (or set of networks) that goes directly from camera pixels to steering/braking commands. Musk confirmed in 2024 that **FSD Version 12** uses this end-to-end approach, calling it *"a pure AI-based"* solution with no high-level code for specific scenarios [70] [65]. He asserted this **vision-only neural network** approach is akin to how a human (biological neural net with eyes) drives, and thus the scalable path to full autonomy [65]. Technically, Tesla trains these networks on its powerful in-house supercomputer (codenamed Dojo), using **advanced**

architectures that output not just object detections but planning trajectories and future predictions (e.g. where other cars *will* be by the time you get there). Tesla has described using techniques like **transformer neural nets** (common in language models) adapted for video, and **occupancy networks** that densely predict space around the car in 3D. There is also a **component of reinforcement learning or simulation**: Musk hinted that Tesla uses simulations to fine-tune behavior, and some elements of decision-making can be framed as a **Markov Decision Process**, where the AI sequentially chooses actions (accelerate, brake, etc.) to maximize long-term "reward" (safe, efficient travel) [76] [77]. In fact, in the broader AV field, **Partially Observable Markov Decision Processes (POMDPs)** are the mathematical framework often used – the AI agent doesn't have full certainty (it has observations via cameras), so it must make the best decision based on probabilities and learned experience [78] [77]. The complexity of this decision-making under uncertainty is enormous, which is why **huge amounts of data** are needed to train and validate Tesla's neural networks.

Tesla's Fleet Data Engine: Tesla's single greatest asset in this AI-first approach is the **real-world driving data** collected from its **fleet of over 4 million vehicles** on the road. Every Tesla built in the last 6+ years is Internet-connected and (with customer consent) constantly uploading snippets of driving data (images and telemetry) back to Tesla. **Tesla explicitly leverages billions of miles of this real-world data to train FSD** [25] [79]. The company even advertises this: *"Tesla uses billions of miles of anonymous real-world driving data to train Full Self-Driving (Supervised)…"* [79]. This data-driven strategy is what Tesla believes sets it apart from competitors relying on limited geofenced testing.

Tesla has built a sophisticated **"Data Engine"** pipeline to make the most of fleet data [80] [81]. Here's how it works in simplified form: Each Tesla with FSD computer actually runs **two sets of FSD software in parallel** – one is the "**active**" autopilot controlling the car when engaged, and the other is a **"shadow mode"** that *silently* runs in the background at all times [82]. Shadow mode pretends to drive: it looks at the road and makes predictions, but it doesn't actually control the vehicle – the human driver does. However, whenever the human's real actions deviate from what the FSD shadow *would* have done, the system notes an **"intervention" or "disagreement."** For example, if the human brakes but the FSD neural net would not have, that's logged as an event. Likewise, if FSD is engaged and the human **force-disengages** (takes over suddenly), that's an obvious intervention. Tesla records these "inaccuracy" events and uploads them to its servers [82] [83]. Engineers then analyze them to understand *why* the AI was wrong or unsure.

Here's the clever part: If Tesla sees a pattern of similar failures, it can **data-mine its entire fleet** for more examples of that scenario [83] [84]. For instance, suppose shadow mode often misreads a construction zone merge. Tesla can search other cars' logs for "construction zone" scenarios – even from cars where FSD wasn't active – and pull those camera clips. They can then **"harvest" hundreds or thousands of similar cases** and use them to retrain the neural network to handle that situation better [84] [85]. This targeted *active learning* greatly improves the AI's capability in tricky scenarios that initially confounded it. After retraining on the new data, Tesla ships an FSD software update, and the cycle continues – now shadow mode will (hopefully) handle that case correctly, but might find other new weaknesses. In this way, Tesla's **fleet is effectively labeling edge cases and providing automatic feedback**. As an industry expert described: *"The genius of Tesla's data collection infrastructure is that it enlists real-life data examples and uses human drivers to train its machine learning models."* [86] Each intervention by a human driver is like a free annotated lesson for Tesla's AI.

Tesla's **dual-FSD computer design** (two chips running in parallel, one in shadow) enables this without compromising safety [82]. The result is a virtuous cycle: **more cars -> more data -> better AI -> FSD available in more situations -> even more data…**. It's an approach only Tesla currently enjoys at scale.

Traditional AV companies like Waymo gather detailed data but with far fewer vehicles (hundreds of cars, all under company operation). Tesla has **millions of cars with customer "test drivers"** encountering diverse environments worldwide every day. This is why many consider Tesla's *data* to be its moat.

The Value of Real-World Testing: Real-world data is crucial not just for initial training but for continuous **validation and "course-correction"** of the system. Driving involves an **open-ended long tail** of rare events – strange obstacles, erratic human behaviors, unusual weather, etc. The best simulation or closed-track testing cannot anticipate every odd scenario. Tesla's approach is essentially *massive scale crowdsourcing* of those scenarios. Every time a Tesla encounters something weird that FSD isn't confident about, Tesla eventually hears about it (either via an intervention report or a user pressing the "Autopilot snapshot" button). This is extraordinarily valuable. As one technical article noted, **"each disengagement is an opportunity to teach and refine the car"** [87]. Tesla's team explicitly says they treat **disengagements as "unit tests"**: each known failure mode becomes a test case the AI must pass after each new training run [85]. Over time, the system's competence expands. Indeed, by 2022–23 Tesla was boasting that FSD Beta can handle scenarios it *never explicitly coded for*, simply because the neural net saw enough examples in the wild (e.g. complex unprotected left turns across traffic, or narrow lanes with parked cars) – tasks that are extremely hard to write rules for, but which a neural net can master via data.

Fleet learning extends even to map data. Tesla cars contribute GPS tracks and vision data that help identify changes in road layouts, speed limits, etc. Unlike HD-map-based systems (Waymo pre-maps every road in detail), Tesla tries to do **"vision-based navigation"**, but it still benefits from a cloud database of things like where stop signs or lane splits generally are. Tesla essentially lets its cars build a constantly updating picture of the roads, based on what cameras see.

Key Technical Differentiators: A few technical points that highlight Tesla's system and why data is king:

- **Vision vs. Lidar:** Tesla famously relies on **cameras only** for sensing, using neural nets to infer depth and velocity (via stereoscopic vision and motion). This is computationally harder and initially less reliable than having a lidar give you a direct 3D point cloud. But Tesla's bet is that with enough training data, a vision system can be almost as good as lidar at perceiving the environment – and far cheaper (cameras are inexpensive and already on all cars). To make vision work, Tesla needed *billions of images* under all lighting/weather conditions to train its networks to accurately detect distances, drivable space, etc. Early on, Tesla augmented this by using radar; in 2021 it even removed radar entirely, doubling down that its vision neural net was sufficient [42]. This decision was controversial (some owners saw regressions like "phantom braking" after radar removal). But Tesla's data engine quickly gathered more instances and improved the network to compensate. Musk's rationale was that sensor **"discord"** (differences between radar and vision) was causing more issues, and that a pure vision approach – if perfected – is how humans drive and thus feasible. The jury is still out, but if Tesla succeeds, it will vindicate the power of data (since only with enormous data can a camera-based AI rival a physical sensor's precision). Notably, other companies have moved toward **simpler sensor suites** too (e.g. some dropping radar), though none have dropped lidar in true driverless systems.

- **End-to-End Machine Learning:** With FSD v12, Tesla moved to effectively train the neural net to *directly output* the car's control commands (steering angle, acceleration) given raw video input [65]. Previously, parts of the stack were hand-engineered (like trajectory optimization). End-to-end learning is data-hungry – the network has to learn to internalize all the driving rules and nuances

just from examples. Tesla leveraged its massive dataset to train this end-to-end model on virtually **every scenario the fleet has encountered**. Musk said by late 2023 that Tesla was automating the **labeling** of millions of video clips to feed the training. They use **auto-labeling algorithms and neural nets to label clips in retrospect**, turning the fleet's experiences into training examples without requiring humans to manually label each one. This is critical because manually labeling petabytes of video is impossible – Tesla built an automated system using tracking and other cues to label lane lines, objects, etc. across frames [88] [89]. Again, data is vital: the more miles they have, the easier it is for Tesla to find *rare* cases and include them in training. The shift to end-to-end also means Tesla's AI can optimize holistically for driving outcomes (e.g. smooth, safe rides) rather than optimizing individual modules separately.

- **Human Feedback Loop:** Interestingly, Tesla's approach implicitly uses **its customers as a feedback loop**. When Tesla offered the one-month FSD trial in 2024, analysts noted Tesla might be seeking an influx of fresh **corner-case data** from new users who drive in ways early adopters might not [72] [75]. Indeed, some speculate Tesla's data engine could identify that *"drivers in city X keep disengaging on a certain weird highway merge"* – something that might not surface in the existing beta test base – and Tesla can then improve that. In effect, every new user broadens the data. This does raise ethical questions (customers are doing unpaid R&D test driving), but many owners are happy to participate, reporting bugs via the in-car snapshot button and on forums. It's a symbiotic relationship: Tesla gets data, users get early access to new features.

Why Real-World Data Is Invaluable: In academic terms, the problem of self-driving is **open-world and long-tailed** – you cannot enumerate all possible situations. The only way to ensure safety is to train on and test against *massive real-world distributions* of events. Tesla's data of **billions of miles** gives it a chance to see things that a smaller fleet might encounter only after commercial launch. A telling example: Tesla learned of an edge case where **traffic cones** on the road caused Autopilot to misbehave; they fixed it after noticing patterns in fleet data. Another example: **deer crossing the road** at night – Tesla's fleet in rural areas contributes those clips, whereas a geo-limited city AV program might seldom encounter deer. Over time, Tesla's AI should become **robust in diverse geographies and conditions** thanks to this breadth of data. (Critics note that lots of data isn't *sufficient* if not good quality – but Tesla's methods of focusing on interventions help ensure they mine the *most important* data).

Finally, consider **regulatory/competitive value**: Tesla's mountain of driving data could be leveraged to **prove safety** to regulators once they approach Level 4. For example, they could statistically show *"our system drives X million miles per fatality, better than human Y million baseline"*. Musk has alluded to using fleet data to demonstrate FSD's safety superiority (he's already claimed Tesla with Autopilot is safer than average driving based on Tesla's own quarterly safety reports). Having a deep well of real-world evidence will be key to convincing authorities to allow Tesla to deploy true driverless capability in private cars. Waymo had to accumulate over **20 million test miles plus billions in simulation** to satisfy California for a permit; Tesla will likely need to present comparable real-world validation. Fortunately for Tesla, it likely already has **orders of magnitude more miles logged** than all other AV projects combined – just mostly with human oversight. Converting that into an approval for *no* human oversight will be the trick.

In summary, Tesla's Full Self-Driving system is fundamentally a **machine-learning powerhouse**: neural networks trained on **fleet data** attempt to predict and react like a human driver would. Tesla's competitive strategy hinges on the idea that **"data is the new fuel"** for autonomy – and Tesla is guzzling it by the terabyte. The company's **"shadow mode" fleet learning** [82] [83] means every Tesla on the road is both a

product and a data-collector, continuously improving the mothership AI. This gives Tesla an ever-growing proprietary dataset that rivals can't easily match without millions of cars of their own. It's *patently obvious* from a technical perspective that **the value of Tesla's system comes from real-world test results and driver interactions – they are essential to validate the AI's performance and to iterate on its shortcomings**. Tesla's own engineers openly credit the fleet: as one put it, *"we use each of these [driver] disengages to teach and refine our car"* [90]. This data-centric approach is why many investors place such high value on Tesla's user base – it's not just car sales, it's a crowdsourced **AI training army**. As long as Tesla can continue to leverage this feedback loop, it stands a chance to eventually catch up to or surpass competitors in autonomous capability. On the flip side, **if** regulators or courts were ever to severely restrict Tesla's on-road testing (due to safety concerns), it would significantly hamper that data engine. Thus far, Tesla has managed to keep its beta going – and every mile driven is one step (and thousands of data points) closer to the Level 4 autonomy it promises.

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