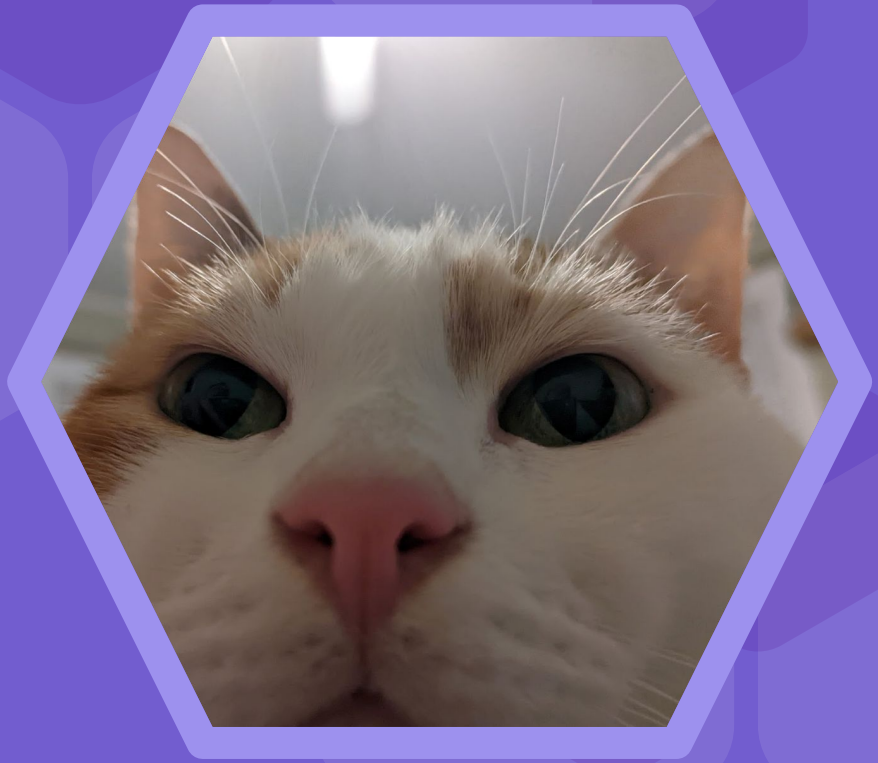
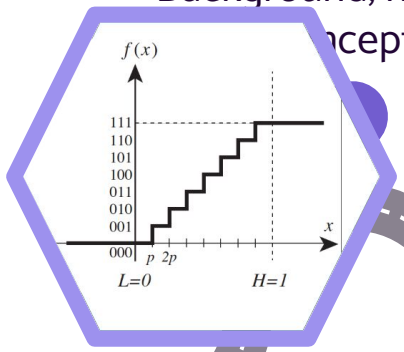
Big picture: human factors, economics, AV technology



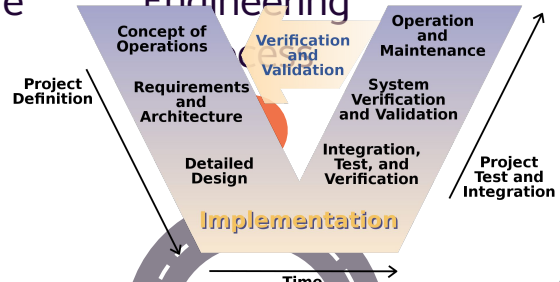
Where we've been

Background, hardware

ncepts



Engineering



Safety

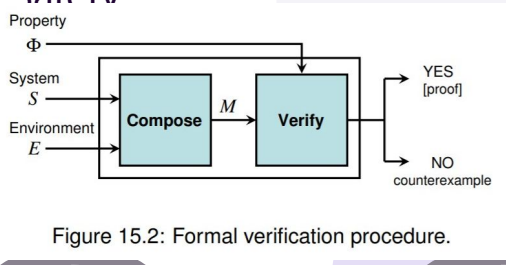
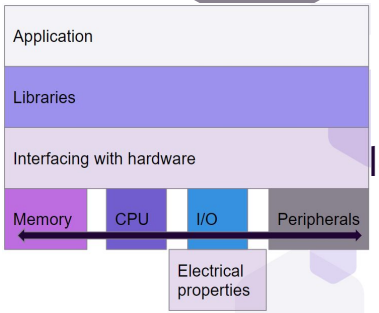
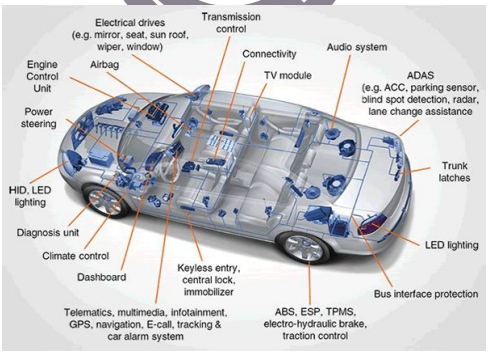


Figure 15.2: Formal verification procedure.

lers





Your cool embedded project!

Human factors in embedded systems

Development

- Does development team have a strong safety culture?
- What shortcomings do humans have when it comes to executing a project beginning to end?

Safety/ethics

- How much to spend when developing a system to make it safe?
- Who takes responsibility in the case of harm?

Design

- Who is the product designed for? Who does it leave out?
- Is the product marketing true to the capabilities of the product?

External factors

- What should be regulated by law? Left up to the market?

What other human factors/questions can you think of that apply to embedded systems?

User interface design recommended reading

- Robert Oshana: Human Factors and User Interface Design for Embedded Systems (Chapter 14; Brown login required)
- ISO 9241: Ergonomics of HCI
- NUREG-0700: Human-System Interface Design Review Guidelines

Cost of embedded systems

Software

- (Broadly) one-time cost (per release)
- **Not** free!

Hardware

- Materials that go into manufacturing device
- Can also be external to device (servers)

How might saving money on hardware cost a project?

Hardware cost

- Choice of MCU
- Memory (if external)
- External peripherals: sensors, ADC/DAC, clocks…
- Power supply/cooling/housing

Cost tradeoffs informed by: power, footprint, speed, #/variety of peripherals…

Recurring and non-recurring costs

Recurring expenses (RE) – materials, shipping, manufacturing, maintenance, utilities

Non-recurring expenses (NRE) – software licenses*, engineering time, up-front equipment cost, real estate

Cost per item = RE + (NRE / # items)

Source:
https://www.embedded.com/toyotas-expensive-software/

Cost of messing up

Toyota has agreed to a $1.2 billion fine to settle a U.S. government criminal case over unexpected acceleration in Toyota and Lexus vehicles that resulted in injuries and deaths. A jury in Oklahoma found that, in one case at least, the culprit was the firmware. (The plaintiff's lead expert, Mike Barr, is giving a talk about the case at EELive

This payout is on top of [illegible] cost the company stagge

The **NASA report** talks about a code base of "more than 280,000 lines" of code. Mike Barr tells me there were "over a million lines of C source code". For argument's sake, let's figure on a million.

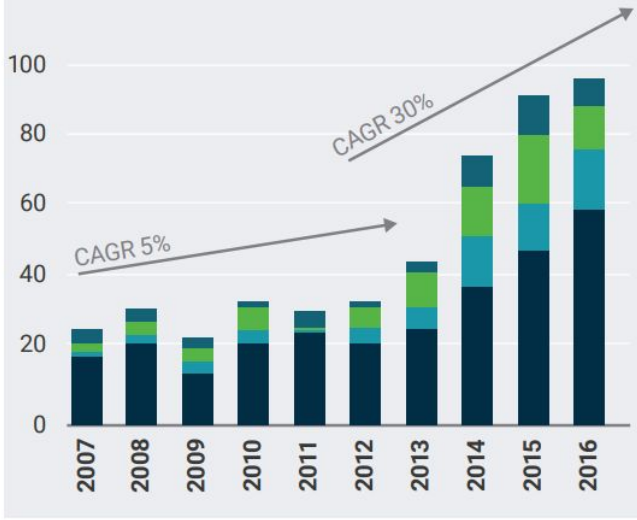
The most expensive code ever written is that of the Space Shuttle, which ran about $1000/LOC (*201 Principles of Software Development* , Alan M. Davis, 1995). With just the most recent settlement, Toyota's code cost them over $1200 per line – without accounting for any engineering effort. The difference is that the Shuttle's code is the best ever written, averaging about one bug per 400KLOC, and Toyota's has been

Let's be pessimistic and assume the very best avionics costs twice that of typical commercial firmware. My data pegs the latter at $20 to $40 per line of code, from initial specification to shipping. Doubling the high end puts the cost at $80/LOC, or 15 times cheaper than Toyota's most recent payout. Add in their other settlements, legal costs, lost sales, bad PR, and, oh, yeah, the actual firmware engineering, and that difference grows dramatically.

Take your pick: $1200+++/LOC for crappy code, or $80– for world-class.

sources: https://www.cnn.com/2021/02/25/tech/hyundai-ev-recall/index.html
https://www.alixpartners.com/media/14438/ap_auto_industry_recall_problem_jan_2018.pdf

FIGURE 2: SINCE 2013, ELECTRONICS-RELATED RECALLS HAVE GROWN SIX TIMES FASTER THAN IN PRIOR YEARS



CAGR—compound annual growth rate

Source: National Highway Safety Administration recall data

000 electric cars globally to replace their batteries after 15 reports
y small number of cars involved, Hyundai's recall is one of the
ar defects could create hefty costs for automakers — at least in

or $900 million. On a per-vehicle basis, the average cost is
call.

Beca
easil
char
than
acco

cars on the road than EVs, the total cost of those recalls can
lyundai. For example General Motors recently took a $1.2 billion
that covered 7 million vehicles, meaning the recall cost less
ecall over the last 10 years was about $500 per vehicle,
and industrial practice at AlixPartners, a global consulting firm.

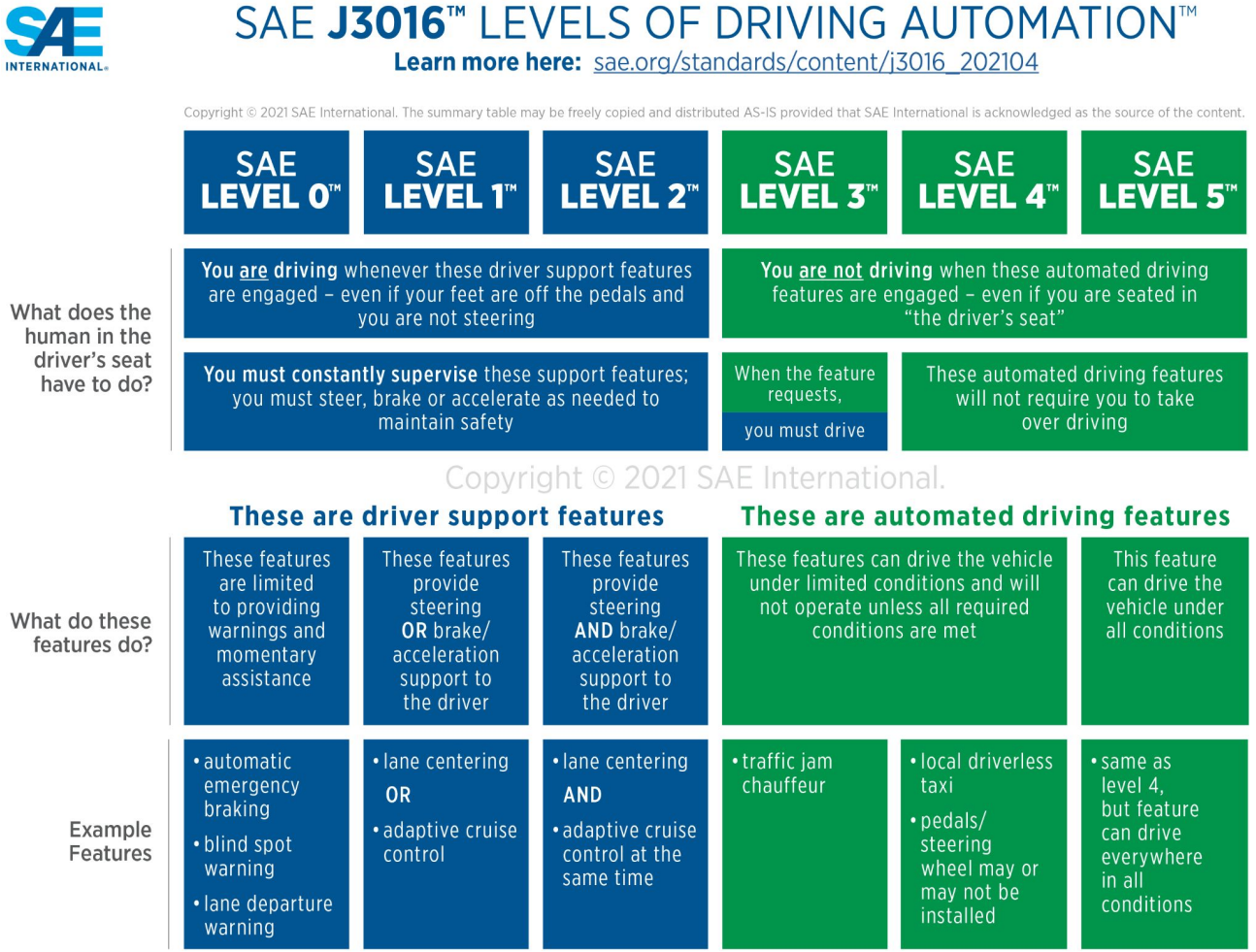
Modern embedded technology: Autonomous Vehicles (AVs)

- Various levels of autonomy
- Safety considerations
- Hardware considerations

SAE J3016

Note: **not** a safety standard
Source: https://www.sae.org/blog/sae-j3016-update

Tesla “Autopilot” is Level 2



Why does Tesla call their level 2 autonomy features “autopilot?” Is this responsible?

Market forces in AV development

Zoox sold out to Amazon. Uber practically gave away its AV division for free to Aurora. Lyft sold to a subsidiary of Toyota. Cruise bought Voyage. Nuro acquired Ike. (I assure you, you're not having a stroke — these are just the quirky names of various AV startups.)

The companies that are still around are hemorrhaging money. Aurora, which absorbed Uber's discarded division, is said to be mulling a sale to Apple or Microsoft. The company went public last year by merging with a special purpose acquisition company (SPAC), and then lost about 80 percent of its value. This is the same company that was started by Chris Urmson, one of the founders of the Google self-driving car project (now Waymo), a guy once called the "Henry Ford of autonomous driving," who said he hoped his kids will never have to get driver's licenses.

source: https://www.theverge.com/2022/10/28/23427129/autonomous-vehicles-robotaxi-hype-failure-expectations

Public Market Performance Of Funded Companies Tied To Autonomous Driving And Related Technologies

Company	Valuation At IPO**	Valuation Today*	% Change
Aurora	$14,000M	$2,611M	-81%
TuSimple	$8,500M	$1,516M	-82%
Luminar	$7,000M	$2,453M	-65%
Embark Technology	$5,160M	$141M	-97%
Velodyne Lidar	$4,000M	$202M	-95%
Aeva	$2,100M	$435M	-79%
AEye	$2,000M	$178M	-91%
Ouster	$1,900M	$148M	-92%
Innoviz	$1,400M	$655M	-53%
Cepton	$1,400M	$370M	-74%
Otonomo	$1,400M	$40M	-97%
Quanergy Systems	$1,100M	$16M	-99%
Arbe	$722M	$361M	-50%
CYNGN	$198M	$32M	-84%
Total	**$50,880M**	**$9,158M**	**-81% average decline**

*Market cap as of Oct. 10, 2022 source Yahoo Finance

**Source: Crunchbase data

crunchbase

source: https://www.forbes.com/sites/johnkoetsier/2022/10/17/self-driving-startups-have-lost-40-billion-in-stock-market-valuation-in-2-years/?sh=58b844b43337

sources: https://arstechnica.com/cars/2023/06/the-death-of-self-driving-cars-is-greatly-exaggerated/
https://www.nytimes.com/2023/10/24/technology/cruise-driverless-san-francisco-suspended.html
https://www.wired.com/story/kyle-vogt-ceo-robotaxi-cruise-resigns-grisly-crash

Constantly changing market

Instead, Waymo spent several more years testing its service in a small corner of the Phoenix metro area and didn't start offering driverless rides to paying customers until 2020 the hundreds of vehicles—far fewer than 62,000.

Cruise, too, has rolled out its service more slowly than expected. Ba a driverless commercial service in 2019. In reality, the company dic and didn't start charging for the service until last year.

June 2023

So are gullible journalists like me about to be disappointed again? Waymo and Cruise are already running driverless commercial serv what's required than they did in though it's certainly possible the

The challenges they'll face in the next phase of the expansion will be different from those they faced in the past. Until now, Waymo and Cruise have been almost exclusively focusing on safety. Now they need to figure out how to turn a profit—without compromising safety in the process. That won't be easy, but it seems doable.

The New York Times

Oct 2023

Cruise's Driverless Taxi Service in San Francisco Is Suspended

California's Department of Motor Vehicles cited safety concern for the suspension, about three months after the state allowed

Kyle Vogt, CEO of Robotaxi Developer Cruise, Resigns as Questions Linger Over Grisly Crash

Nov 2023

The leader of General Motors' self-driving car unit Cruise resigned Sunday as pressure continues over an incident last month in which a pedestrian was dragged beneath a robot car.

What implication do market forces have on AV safety?

A race against the clock

While Waymo and Cruise have steadily improved their technology, the commercial rollout of that tech has been excruciatingly slow. Now both Waymo and Cruise are coming under pressure to expand more rapidly.

The reason: Projects like Waymo and Cruise are fantastically expensive. GM said last year that it expected to spend $2 billion on Cruise in 2022. Waymo hasn't disclosed its spending, but with 2,500 employees, its annual costs are likely north of a billion dollars.

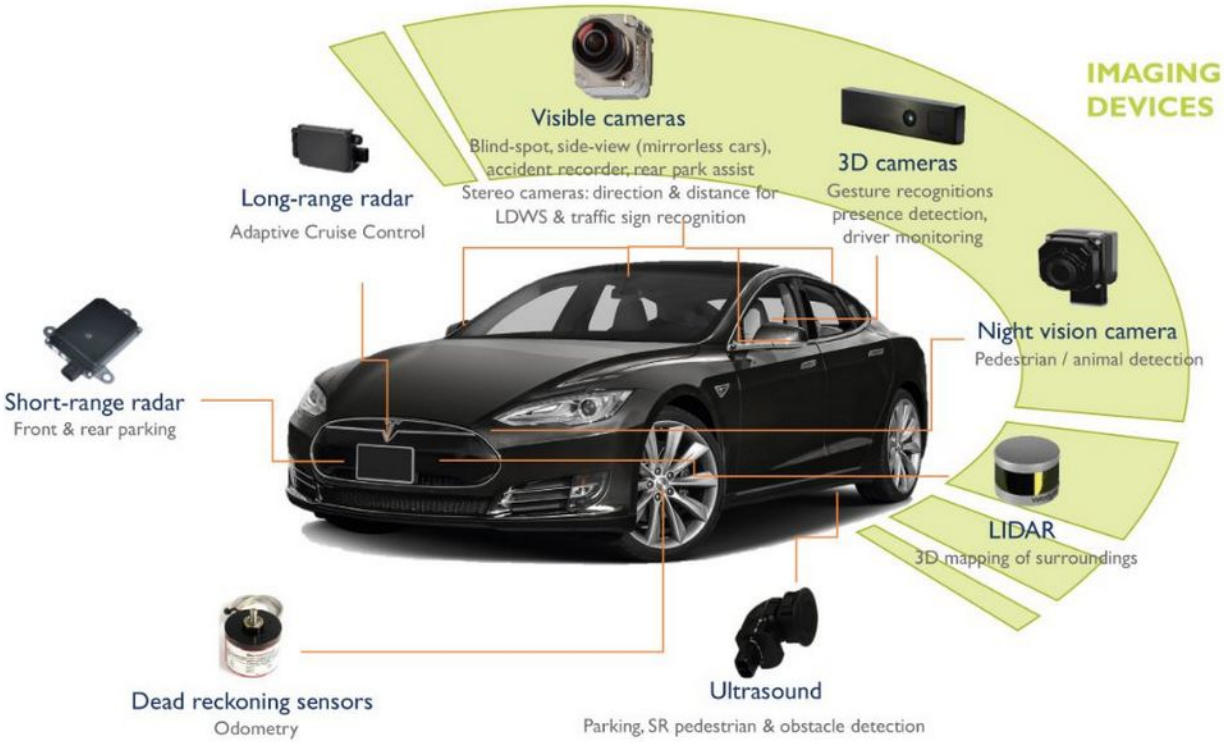
With interest rates rising, companies everywhere are looking for ways to trim costs. Last year, Ford decided that its own self-driving subsidiary, Argo, wasn't worth the cost. If I were in charge of Waymo or Cruise, I'd be worried about my corporate parent making the same decision.

So these companies need a credible path to profitability. And with an overhead exceeding $1 billion, that will require a *lot* of taxi rides.

https://arstechnica.com/cars/2023/06/the-death-of-self-driving-cars-is-greatly-exaggerated/

The hardware

source: https://www.eetimes.com/the-outlook-for-robocar-sensors-in-2018/



source: https://www.cnet.com/roadshow/news/argo-self-driving-car-hardware-upgrade/

The hardware

There are tons of improvements in this next generation of Argo hardware.

Argo

The computer

source: https://cronkitenews.azpbs.org/2016/03/02/ford-autonomous/

source: https://www.nvidia.com/en-us/autonomous-machines/embedded-systems/product-development/

Also the computer

Tesla unveils its new supercomputer (5th most powerful in the world) to train self-driving AI

Fred Lambert | Jun 21 2021 — 3:30 am PT

source: https://electrek.co/2021/06/21/tesla-unveils-new-supercomputer-train-self-driving-ai/