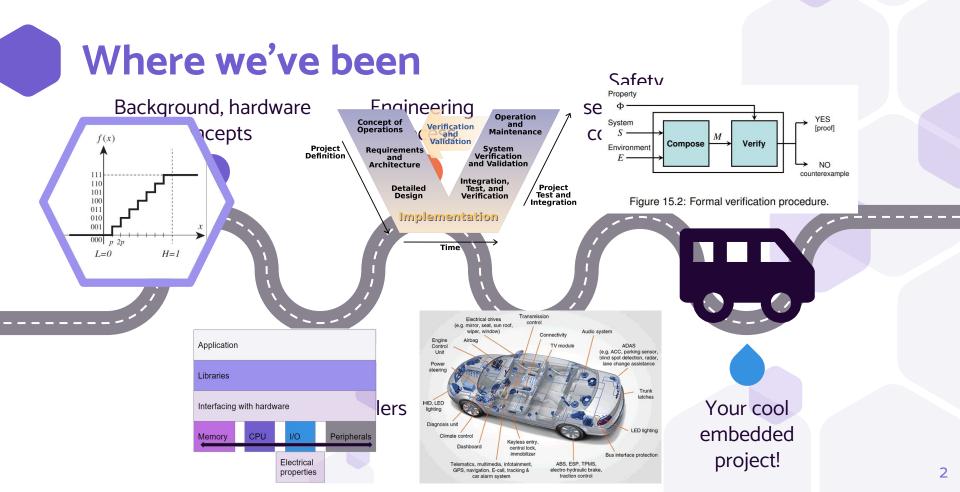
Big picture: human factors, economics, AV technology



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 (<u>Chapter 14</u>; Brown login required)
- ISO 9241: Ergonomics of HCI
- <u>NUREG-0700</u>: 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

Non-recurring expenses (NRE) – software licenses^{*}, engineering time, up-front equipment cost

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

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

Cost of messing up

Toyota has agreed to a \$1.2 billion fineto settle a U.S. government criminal case over unexpectedacceleration in Toyota and Lexus vehicles that resulted in injuries and deaths. A jury in Oklahoma foundthat, in one case at least
about the case at EELiveThe 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
cost the company staggePrinciples 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

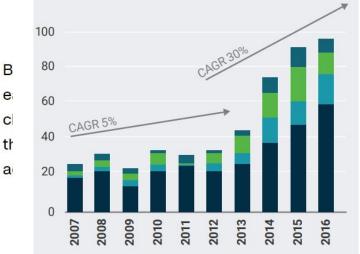
Let's be pessimistic and assume the very best avionics costs twice that of typical commercial firmware. My data pegs the latter at \$20 to \$40 per line of code, from initial specification to shipping. Doubling the high end puts the cost at \$80/LOC, or 15 times cheaper than Toyota's most recent payout. 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

New York (CNN Business) - Hyundai will recall 82,000 electric cars globally to replace their batteries after 15 reports

FIGURE 2: SINCE 2013, ELECTRONICS-RELATED RECALLS HAVE GROWN SIX TIMES FASTER THAN IN PRIOR YEARS ively small number of cars involved, Hyundai's recall is one of the ic car defects could create hefty costs for automakers — at least in



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

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

Integrated Electrical Components
 Software remedy
 Software defect
 Software integration
 CAGR-compound annual growth rate
 Source: National Highway Safety Administration recall data

Modern embedded technology: Autonomous Vehicles (AVs)

- Various levels of autonomy
- Safety considerations
- Hardware considerations



SAE **J3016[™]** LEVELS OF DRIVING AUTOMATION[™]

Learn more here: sae.org/standards/content/j3016_202104

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	SAE LEVEL O™	SAE LEVEL 1 ™	SAE LEVEL 2 [™]	SAE LEVEL 3 ™	SAE LEVEL 4™	SAE LEVEL 5™
What does the human in the driver's seat have to do?	You <u>are</u> driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You <u>are not</u> driving when these automated driving features are engaged – even if you are seated in "the driver's seat"		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	

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	These are driver support features				These are automated driving features		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/ acceleration support to the driver	These features provide steering AND brake/ acceleration support to the driver	under limited conditions and will can drive the not operate unless all required vehicle unde		This feature can drive the vehicle under all conditions	
Example Features	 automatic emergency braking blind spot warning lane departure warning 	 lane centering OR adaptive cruise control 	 lane centering AND adaptive cruise control at the same time 	• traffic jam chauffeur	 local driverless taxi pedals/ steering wheel may or may not be installed 	• same as level 4, but feature can drive everywhere in all conditions	

Note: **not** a safety standard Source: https://www.sae.org/blog/sae-j3016update

SAE J3016

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 <u>mulling a sale</u> to Apple or Microsoft. The company <u>went public</u> 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/auton omous-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

crunchbase

source:

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



What implication do market forces have on AV safety?

-robocar-sensors-in-2018/ The hardware IMAGING DEVICES Visible cameras 0 Blind-spot, side-view (mirrorless cars), **3D** cameras accident recorder, rear park assist Stereo cameras: direction & distance for-Gesture recognitions Long-range radar LDWS & traffic sign recpgnition presence detection, Adaptive Cruise Control driver monitoring Night vision camera Pedestrian / animal detection Short-range radar Front & rear parking LIDAR 3D mapping of surroundings Ultrasound Dead reckoning sensors Parking, SR pedestrian & obstacle detection Odometry

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

source:

https://www.cnet.com/roadshow/news/argoself-driving-car-hardware-upgrade/

The hardware



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

The computer





source:

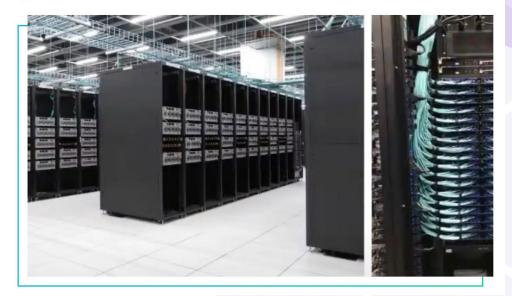
https://www.nvidia.com/en-us/autonomousmachines/embedded-systems/product-deve lopment/

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



Tesla unveils its new supercomputer (5th most powerful in the world) to train selfdriving Al

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



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