

ELEC 424/553

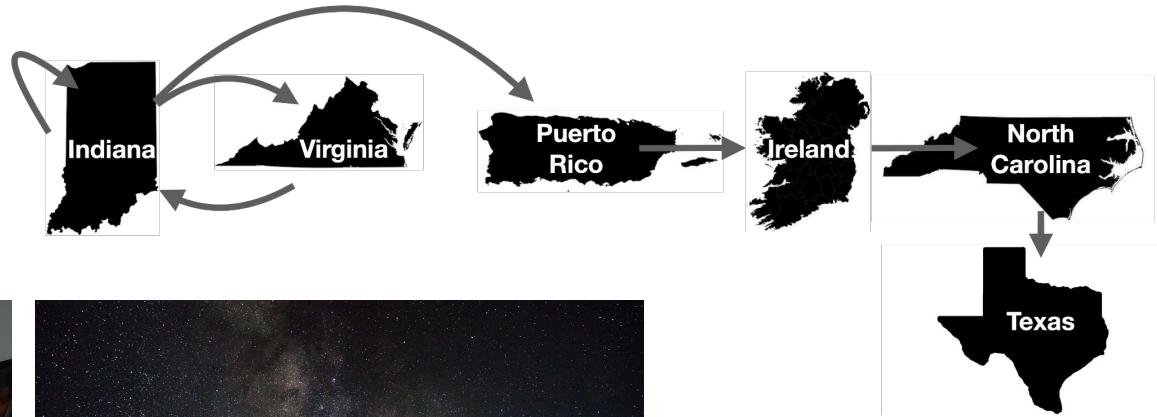
Mobile & Embedded Systems

Lecture 1 Course Introduction

A Graphical Model of My Relocations

Joe

- BSEE NC State
- PhD in ECE @ Rice
- Assistant Teaching Professor
- Director of the MECE



Ask The Class: What's an Embedded System?

“despite the fact that we engineers spend our careers building embedded systems, **no one really seems to be able to define “embedded system.”**

“Though this is surely not an important issue, it sure seems odd **we can't define what we do.** Any suggestions?””

- Jack Ganssle

<https://www.embedded.com/whats-embedded/>

The World Today - Tesla FSD Beta V10.69



openpilot: ‘The Android of Self Driving Cars’



Images from comma_ai's site:

<https://comma.ai/shop/products/three>

<https://www.comma.ai/shop/comma-3x>

CAR HARNESS IS SOLD SEPARATELY; PARTS ARE CAR SPECIFIC
MOST INCLUDE THE ABOVE HARNESS, RJ45 CABLE, AND COMMA POWER

openpilot: ‘The Android of Self Driving Cars’



Overall Ratings Results

SYSTEM NAME	SCORE	CAPAB. & PERF.	KEEPING DRIVER ENGAGED	EASE OF USE	CLEAR WHEN SAFE TO USE	UNRESPONSIVE DRIVER
Comma Two Open Pilot	78	8	9	8	6	8
Cadillac Super Cruise	69	8	7	3	8	9
Tesla Autopilot	57	9	3	7	2	6
Ford/Lincoln Co-Pilot 360	52	8	4	3	4	5
Audi Driver Assistance Plus	48	8	3	3	2	6
Mercedes-Benz Driver Assistance	46	6	4	4	2	5
Subaru Eyesight	46	7	4	3	4	5
Hyundai Smart Sense, Kia Drive Wise	46	5	4	5	4	4
BMW Active Driving Assistance Pro	44	7	3	3	2	5
Porsche Active Safe	41	4	3	6	2	5
Volvo Pilot Assist	41	6	3	3	2	5
Toyota/Lexus Safety Sense 2.0	40	5	4	2	4	5
Honda/Acura Sensing	40	6	4	2	4	4
Nissan/Infiniti ProPILOT Assist	40	5	3	3	4	7
Volkswagen Driver Assistance	39	4	3	6	2	5
Land Rover Driver Assist	38	4	3	6	2	4
Buick/Chevy Driver Confidence	36	3	3	5	2	6
Mazda i-ACTIVSENSE	27	3	2	5	2	1

It Was A Joke Until...

Consumer Reports

Active Driving Assistance Systems:

Test Results and Design Recommendations

Nov. 2020

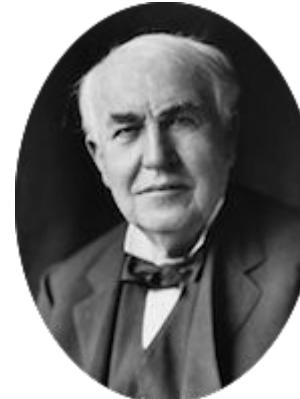
<https://data.consumerreports.org/wp-content/uploads/2020/11/consumer-reports-active-driving-assistance-systems-november-16-2020.pdf>

Any Experiences with Self-Driving Cars?

A Historical Perspective



Is it not demonstrated that a true flying machine, self-raising, self-sustaining, self-propelling, is physically impossible?
— *Joseph LeConte, November 1888*



It is apparent to me that the possibilities of the aeroplane, which two or three years ago were thought to hold the solution to the [flying machine] problem, have been exhausted, and that we must turn elsewhere.
— *Thomas Edison, November 1895*



I can state flatly that heavier than air flying machines are impossible.

— *Lord Kelvin, 1895*

A Current Perspective



Also The World Today!

Tesla Bot



WORLD BUILT BY HUMANS,
FOR HUMANS

FRIENDLY

ELIMINATES DANGEROUS,
REPETITIVE, BORING TASKS

HEIGHT 5'8"	CARRY CAPACITY 45 LBS
WEIGHT 125 LBS	DEADLIFT 150 LBS
SPEED 5 MPH	ARM EXTEND LIFT 10 LBS



TESLA LIVE

Also The World Today



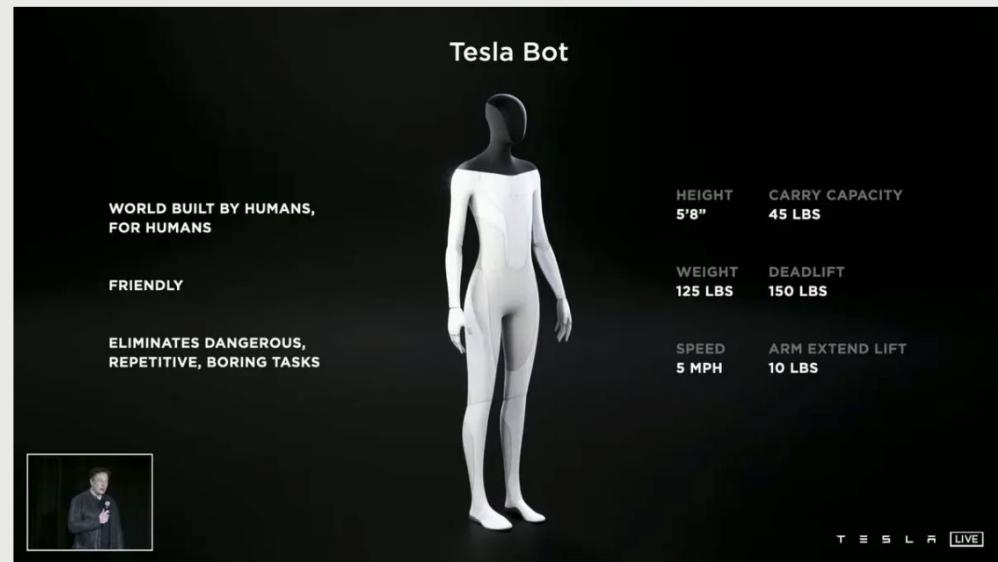
<https://www.youtube.com/watch?v=CZtF2UljwFc&t=420s>

OPINION | ROBOTICS

Elon Musk Has No Idea What He's Doing With Tesla Bot

› Humanoid robots are way harder than Musk seems to think

BY EVAN ACKERMAN | 20 AUG 2021 | 7 MIN READ |



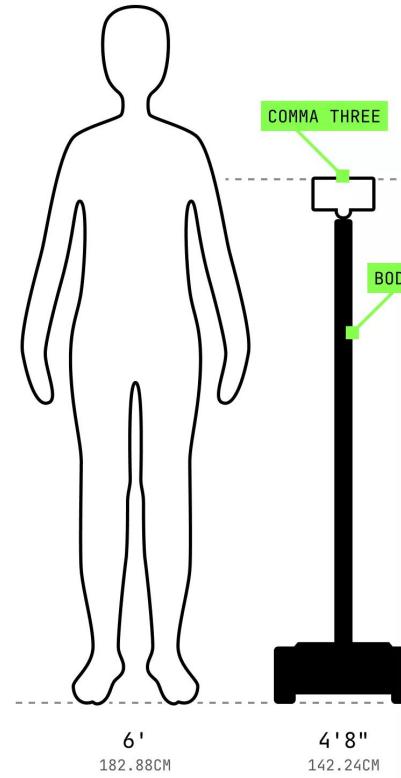
The image shows a white humanoid robot standing upright against a black background. The robot has a simple, rounded head and a white body with black arm and leg joints. Above the robot, the text "Tesla Bot" is displayed. To the left of the robot, there is descriptive text: "WORLD BUILT BY HUMANS, FOR HUMANS", "FRIENDLY", and "ELIMINATES DANGEROUS, REPETITIVE, BORING TASKS". To the right of the robot, there are technical specifications: HEIGHT 5'8", CARRY CAPACITY 45 LBS; WEIGHT 125 LBS, DEADLIFT 150 LBS; SPEED 5 MPH, ARM EXTEND LIFT 10 LBS. In the bottom left corner of the main image area, there is a small video thumbnail showing Elon Musk speaking.

<https://spectrum.ieee.org/elon-musk-robot>

Also Also The World Today



<https://spectrum.ieee.org/elon-musk-robot>



<https://blog.comma.ai/commabody/>

Also Also The World Today



Also Also Also The World Today

POD: A Smartphone That Flies

Guojun Chen

guojun.chen@yale.edu
Yale University

Noah Weiner

noah.weiner@yale.edu
Yale University

Lin Zhong

lin.zhong@yale.edu
Yale University

ABSTRACT

We present POD, a smartphone that flies, as a new way to achieve hands-free, eyes-up mobile computing. Unlike existing drone-carried user interfaces, POD features a smartphone-sized display and the computing and sensing power of a modern smartphone. We share our experience in prototyping POD, discuss the technical challenges facing it, and describe early results toward addressing them.

CCS CONCEPTS

- Computer systems organization → Robotic autonomy.

KEYWORDS

Content stabilization, Smartphone, Human following

1 INTRODUCTION

Our driving vision is *hands-free, eyes-up* mobile computing. That is, mobile users are able to interact with a computer without holding a device in hand and looking down at it. The key to this vision is a user interface (both input and output) that does not require a human hand. Wearable devices, such as Google Glass, are perhaps the most

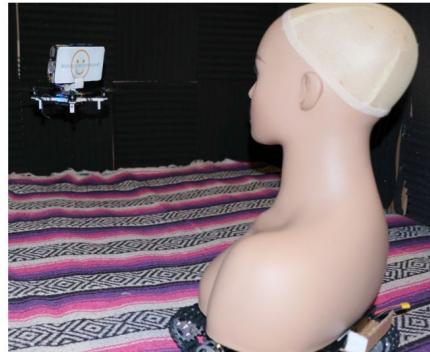


Figure 1: POD (top left corner) interacting with our test mannequin mounted on a Wi-Fi-controlled robotic chassis.

the usability of an onboard display, especially if the drone needs to maintain a safe distance of one to two feet from the user's eyes.
Second, drones are noisy. Even the quietest drone operating at one

Also Also Also The World Today



YouTube channel: Noah Weiner. URL: <https://www.youtube.com/watch?v=ZVm9seYu1o>



Going Back to the Beginning...

From Apollo to the iPhone to ?

1960s



2007



?

<https://dodlithr.blogspot.com/2016/12/dsky-interface-part-12-apollo-control.html>

<https://www.wired.com/story/iphone-history-dogfight/>

**What Do You Think Is the
Next Big Product?**



Some Possibilities

Picture of inside Tesla Model Y from Motor Authority. URL:
https://www.motorauthority.com/news/1134695_tesla-increases-price-of-full-self-driving-to-12-000-as-demand-wanes

Picture of Apple Vision Pro from Apple. URL:
<https://www.apple.com/newsroom/2023/06/introducing-apple-vision-pro/>

Picture of Neuralink from Neuralink. URL:
<https://neuralink.com>

1960s: Apollo Guidance Computer (AGC)



https://commons.wikimedia.org/wiki/File:Agc_view.jpg

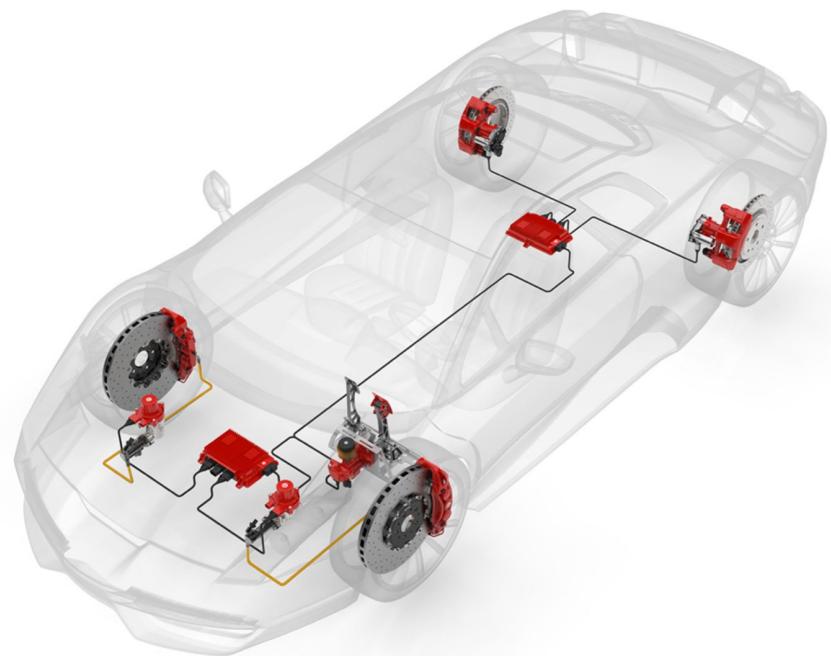
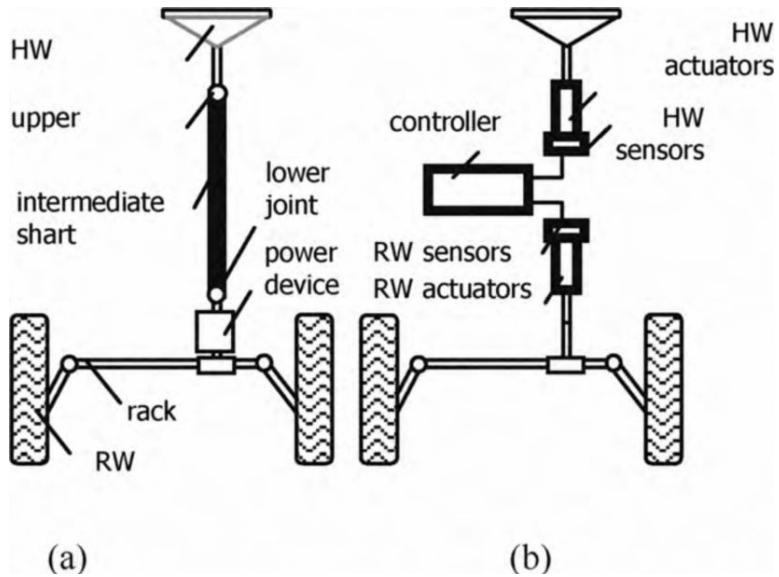
- First embedded system ever
 - <https://future-markets-magazine.com/en/innovators-en/the-apollo-guidance-computer/>
- “it was the first computer based on silicon integrated circuit (IC) chips”
 - <https://www.sothbys.com/en/buy/auction/2021/space-exploration/apollo-guidance-computer?locale=en>
- <https://forrestheller.com/Apollo-11-Computer-vs-USB-C-chargers.html>
 - 1.024 MHz clock speed
 - 4KB RAM
- <https://history.nasa.gov/computers/Ch2-5.html>
 - 24 by 12.5 by 6 inches
 - 70.1 pounds
 - 70 watts at 28 V DC

Fly-By-Wire



<https://youtu.be/B1J2RMorJXM?t=1840>

Fly-By-Wire Drive-By-Wire Brake-By-Wire



Nguyen & Ryu. 2009 IEEE International Symposium on Industrial Electronics. (2009)

<https://ieeexplore.ieee.org/document/5221999/figures#figures>

<https://www.brembo.com/en/BBW/index.html>

2007: iPhone



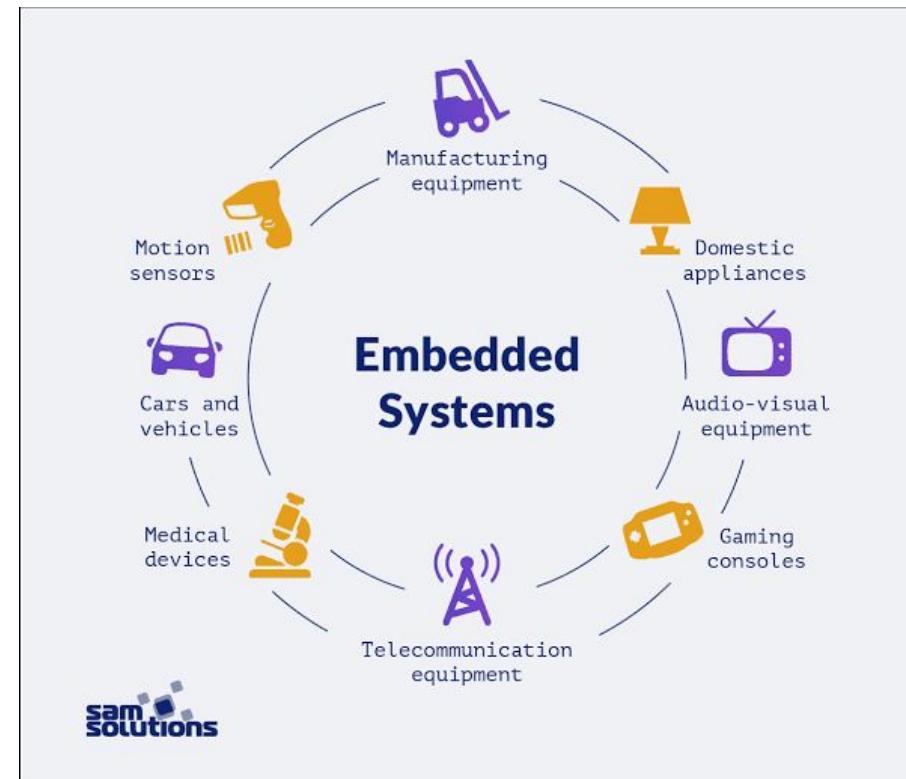
- [https://en.wikipedia.org/wiki/IPhone_\(1st generation\)](https://en.wikipedia.org/wiki/IPhone_(1st_generation))
 - Dimensions
 - 115 mm (4.5 in) H
 - 61 mm (2.4 in) W
 - 11.6 mm (0.46 in) D
 - 135 g (4.8 oz)
 - 412 MHz CPU
 - 128 MB RAM
 - Battery supports 5.18 Wh

<https://www.wired.com/story/iphone-history-dogfight/>

Defining Mobile & Embedded Systems

“An embedded system is a microprocessor- or microcontroller-based system of hardware and software designed to perform dedicated functions within a larger mechanical or electrical system.”

<https://www.omnisci.com/technical-glossary/embedded-systems>



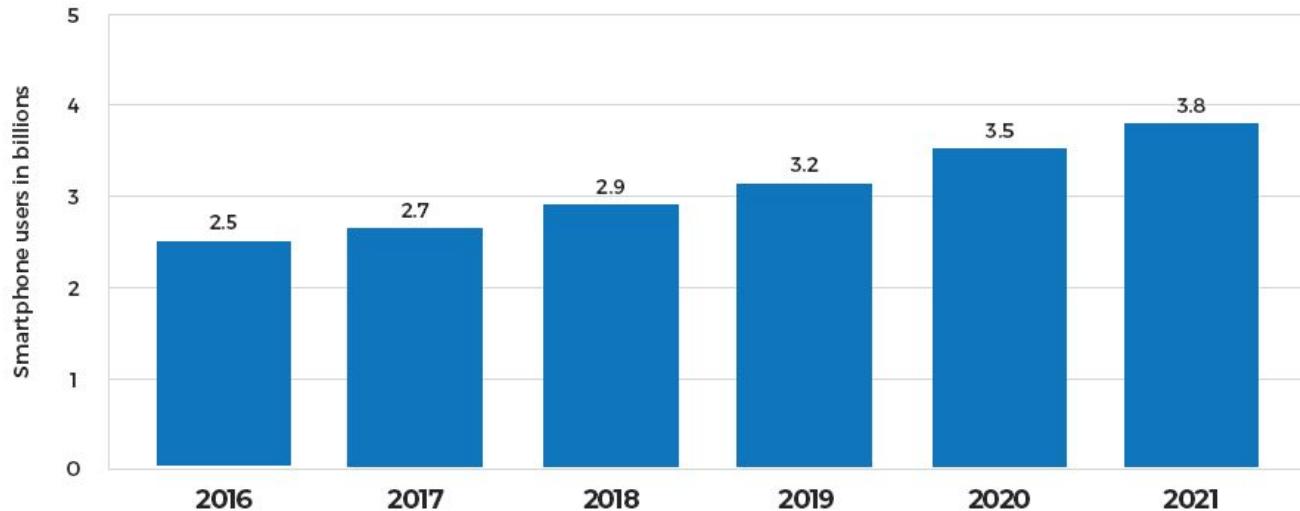
<https://www.rs-online.com/designspark/what-is-an-embedded-system>

Smartphones - A Perfect Example of a Mobile & Embedded System?

“For example, some people would state that an embedded system is one that doesn’t have a user interface, while **others would declare that a smartphone – which boasts an extremely sophisticated user interface – is the epitome of an embedded system.**”

<https://www.eejournal.com/article/what-the-faq-is-an-embedded-system/>

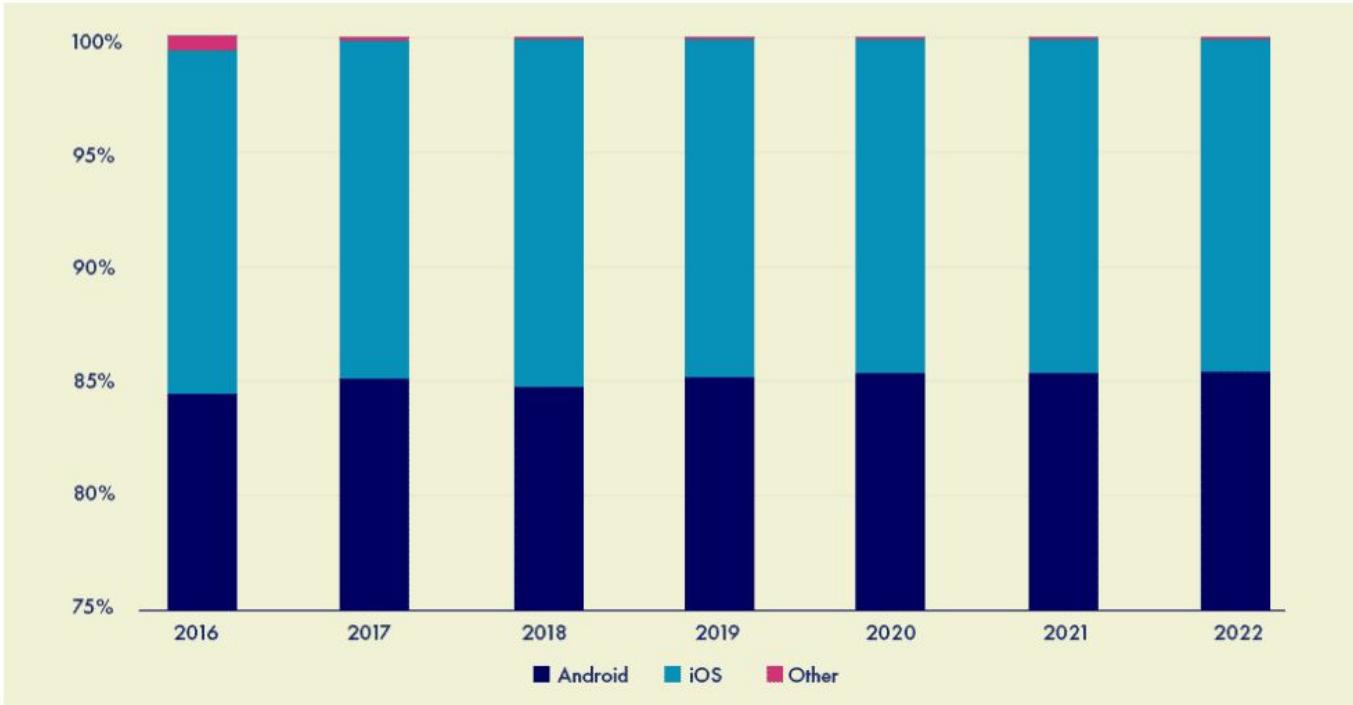
Smartphones - Is Ubiquitous Even the Right Word?



Source: Statista

What Software Powers Smartphones?

Global Android & iPhone Market Share



What is
Android at
its core?

Linux

Is Linux Popular for Other Mobile & Embedded Systems?

It's a Linux-powered car world

It's not just Tesla with Linux under the hood. Audi, Mercedes-Benz, Hyundai, and Toyota, to name a few, all rely on Linux.



By Steven J. Vaughan-Nichols | January 4, 2019 – 16:17 GMT (08:17 PST) | Topic: Hardware



<https://www.zdnet.com/article/its-a-linux-powered-car-world/>



Find products, advice, tech news



PCMag editors select and review products independently. If you buy through affiliate links, we may earn commissions, which help support our testing. [Learn more](#).

[Home](#) > [News](#) > [Drones](#)

Linux Is Now on Mars, Thanks to NASA's Perseverance Rover

Previous NASA Mars rovers mostly used an operating system from Wind River Systems. But this time, the space agency chose Linux for Perseverance's Ingenuity helicopter drone.

By Michael Kan

February 19, 2021



<https://www.pcmag.com/news/linux-is-now-on-mars-thanks-to-nasas-perseverance-rover>

The Dominance of Linux

“Linux began life as a hobbyist operating system (OS) designed for PCs using 80386 processors. But since its introduction in 1991, it has grown into a broadly used OS, running on **PCs, servers, mainframes, and Internet of Things (IoT) devices. A majority of the top supercomputers in the world run on Linux.**”

<https://www.mouser.com/blog/linux-and-iot>

Embedded Linux

‘there is no such thing as embedded Linux! There is no special version of the Linux kernel for embedded systems; **it is just the mainline Linux kernel running on an embedded system.** That said, the term embedded Linux has broad and common use; therefore, it is used here instead of “Linux on an embedded system,” which is the more accurate phrasing.’

Molloy, Derek. *Exploring BeagleBone* (p. 72). Wiley. Kindle Edition.



GOOGLE \ TECH \ GOOGLE I/O 2021

There are over 3 billion active Android devices

That's a lot of smartphones

By Alex Cranz | May 18, 2021, 2:19pm EDT

f t SHARE

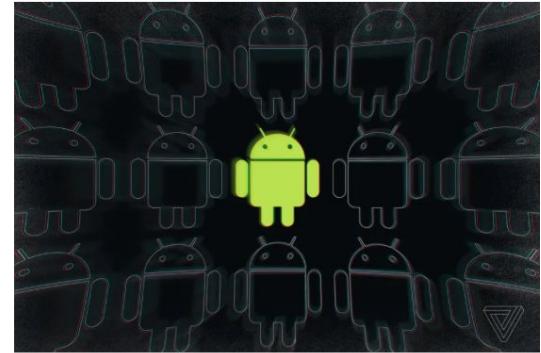
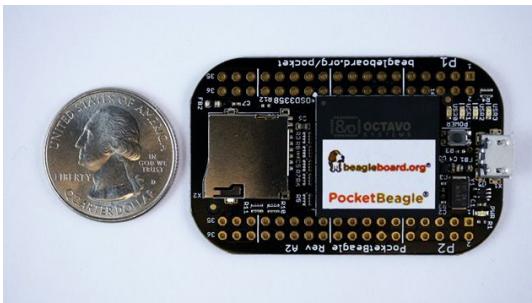
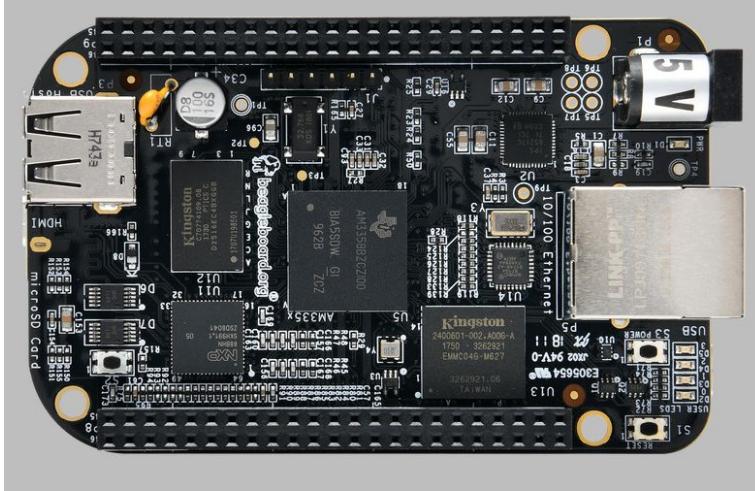


Illustration by Alex Castro / The Verge

There are over 3 billion active Android devices in the wild now.

<https://www.theverge.com/2021/5/18/22440813/android-devices-active-number-smartphones-google-2021>

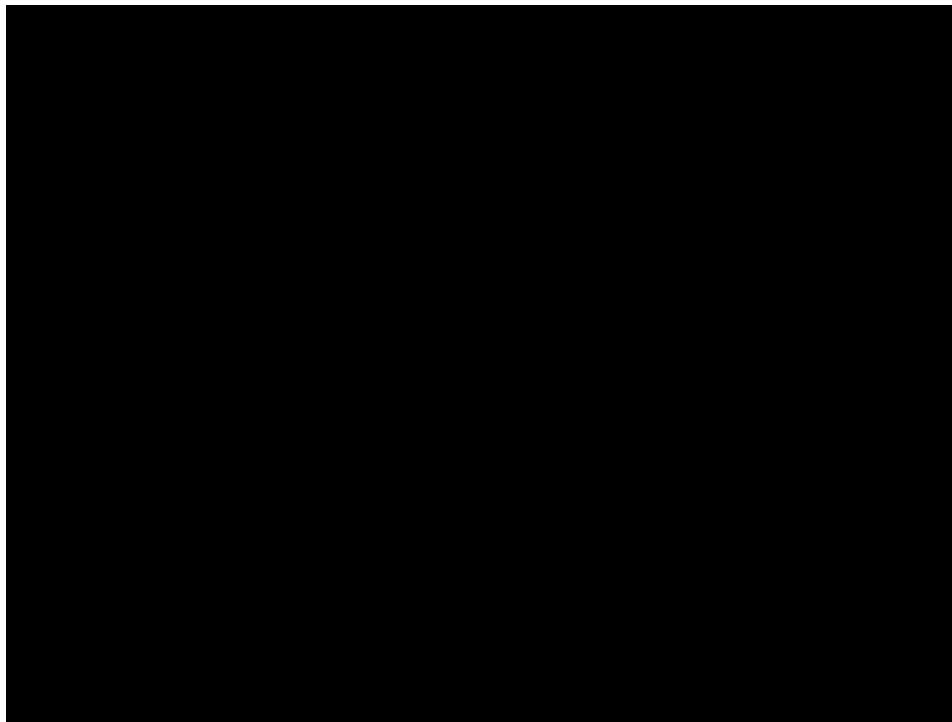
Single-Board Computers (SBCs) Can Run Linux



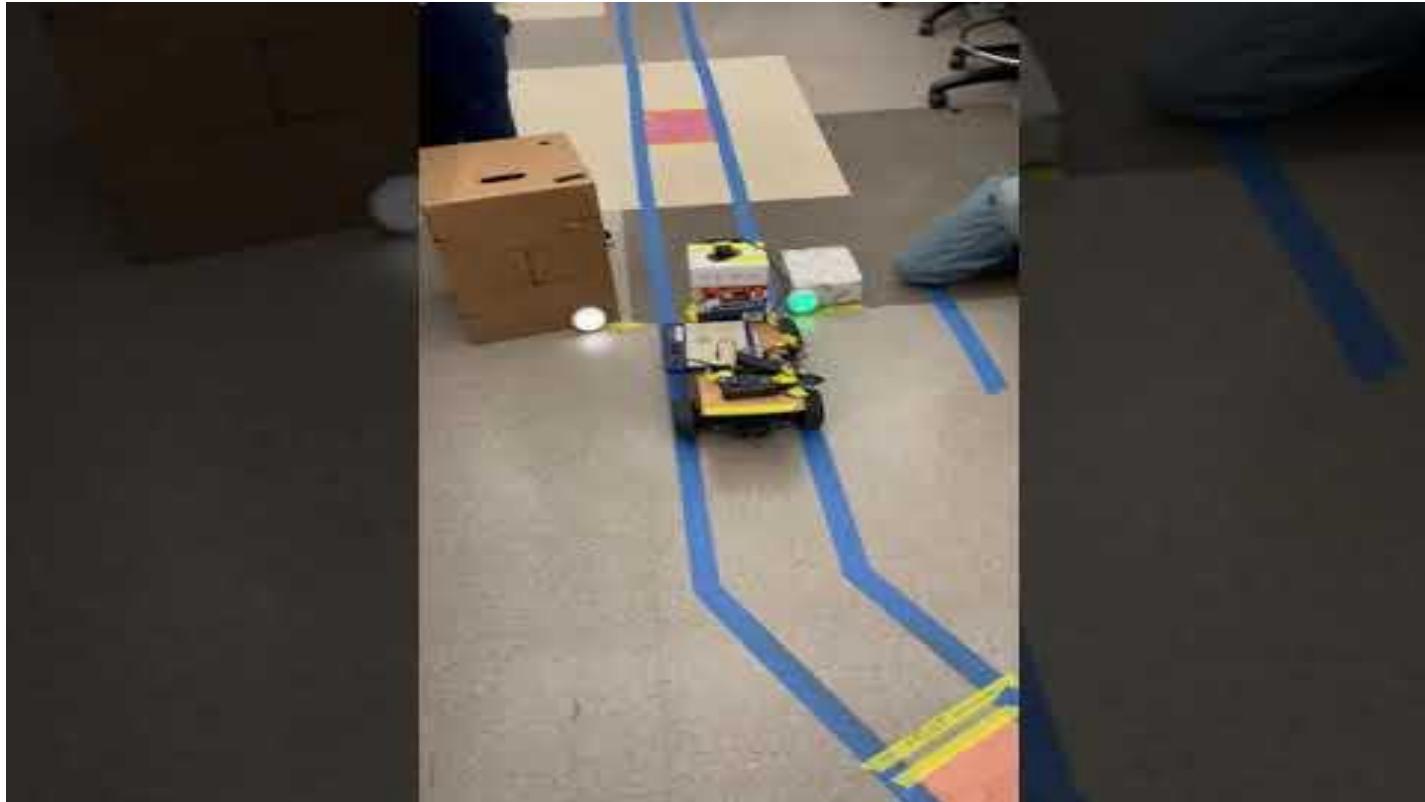
<https://beagleboard.org>

<https://www.theverge.com/2017/7/13/15966094/30-rock-buscemi-how-do-you-do-fellow-kids-meme-kill-it-please>

If a Microcontroller Running Basic C Can Do This...



What Can You Do With an SBC Running Linux?



What Will You Be Able to Do After This Class?

- Perform kernel hacking
- Write a device driver
- Work with:
 - Linux
 - Raspberry Pi Zero W
 - BeagleBone AI-64
 - OpenCV
 - CAN bus
- Create your own mobile & embedded system
 - Build a somewhat capable autonomous system

WARNING: You will encounter frustrating hardware and software bugs and unreliability

- But this should thought in the context of how **exciting** it is that we are working with a real, living system rather than pure theory or pure equations
- Computing systems are from exact or reliable
 - Story on friend's encounter with compiler
 - Space can flip bits (radhard)
- You will break things in ways I haven't seen before, so I don't always immediately have an answer
 - That does not mean an extension will be immediately given, as it is your responsibility to start the assignment before the last day

Grading Weights

- Projects 45%
- Assignments 30%
- Exam(s) 15%
- In-Class Exercises 10%

Always, Always, Always Bring a Laptop

Bring a:

Laptop

Laptop

Laptop

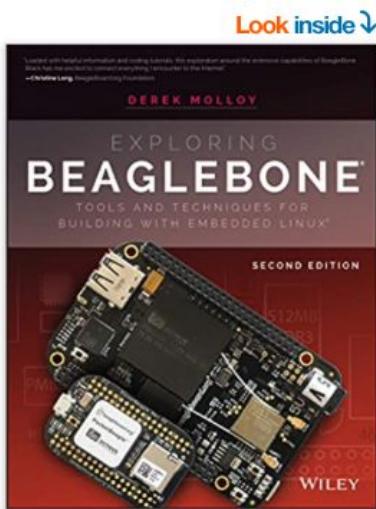


Found on The Atlantic, originally from Twitter. URL:

<https://www.theatlantic.com/technology/archive/2012/01/imacs-in-inappropriate-places-starbucks-edition/251738/>

Recommended Book(s) & Resources

Exploring BeagleBone: Tools and Techniques for Building with Embedded Linux 2nd Edition



ISBN-13: 978-1119533160
ISBN-10: 1119533163

Kindle \$24.00

Paperback \$20.44 - \$28.65

Buy used:

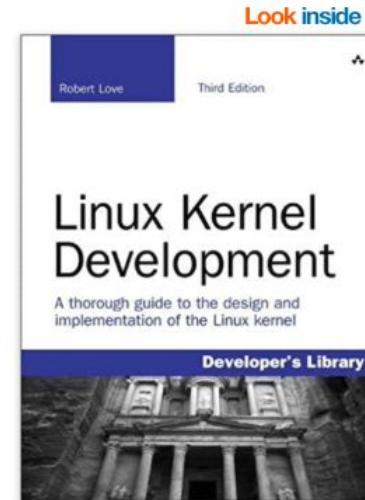
Buy new:

In stock.
Usually ships within 2 to 3 days.
Ships from and sold by [indoobestsellers](#).

Not eligible for Amazon Prime. Available on [Amazon](#).

https://www.amazon.com/Exploring-BeagleBone-Techniques-Building-Embedded/dp/1119533163/ref=sr_1_1?dchild=1&keywords=Derek+molloy&qid=1628095713&sr=8-1

Linux Kernel Development 3rd Edition



ISBN-13: 978-0672329463
ISBN-10: 0672329468

Kindle \$29.92

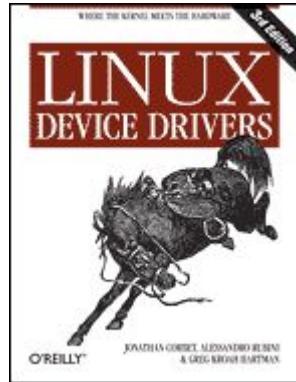
Paperback \$42.98 - \$44.99

Buy new:
In Stock.
Ships from and sold by Amazon.com.
May be available at a lower price from [other sellers](#).

https://www.amazon.com/Linux-Kernel-Development-Robert-Love/dp/0672329468/ref=sr_1_6?dchild=1&keywords=linux+kernel&qid=1628095870&sr=8-6

Recommended Book(s) & Resources

Linux Device Drivers, Third Edition



Available online for free!

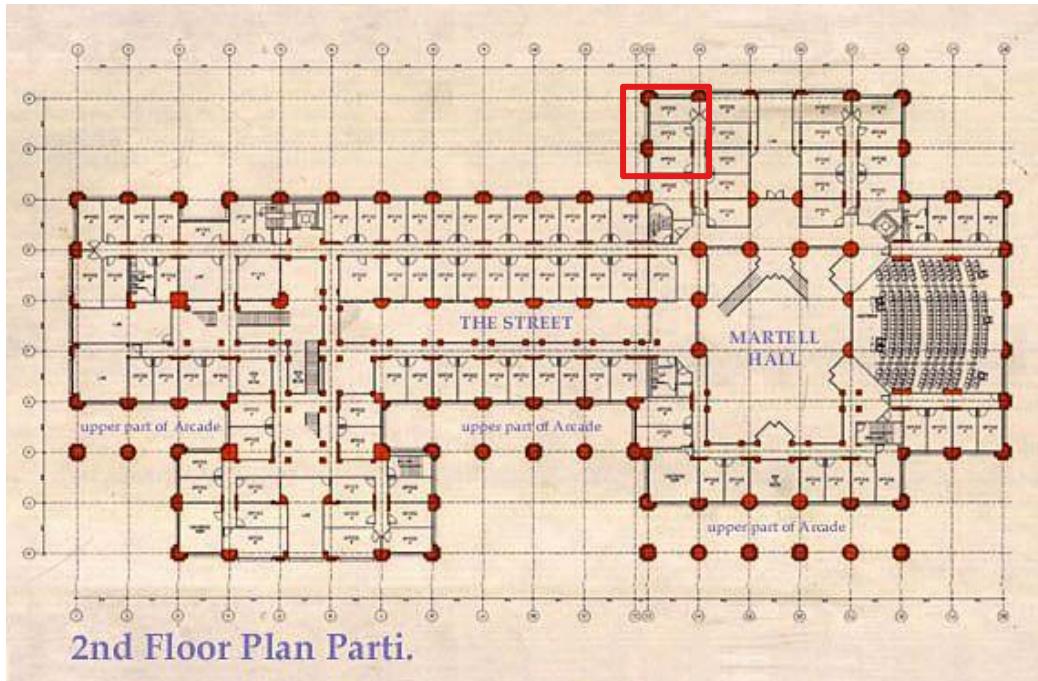
<https://lwn.net/Kernel/LDD3/>

Assignment 0 - Buy: Raspberry Pi Zero W (may need accessories)



See Canvas announcement titled “What to buy” for specifics on what actually to purchase

My Office: DH 2098



Next Lecture:

How Did We Get Here?

“Do you want to sell sugar water for the rest of your life, or do
you want to come with me and change the world?”

- Steve Jobs