

comma.ai

openpilot

Hardware and Software

[Video 1](#), [Video 2](#)

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Hardware



panda

giraffe



Toyota



Honda



Chrysler

Jeep



Acura



Lexus

Tesla AutoPilot (Closed Source), Baidu Apollo Pilot (CS)

References: comma.ai, [Wikipedia](https://en.wikipedia.org/wiki/Autonomous_driving), open websites, publications ...?

Hardware 1: EON

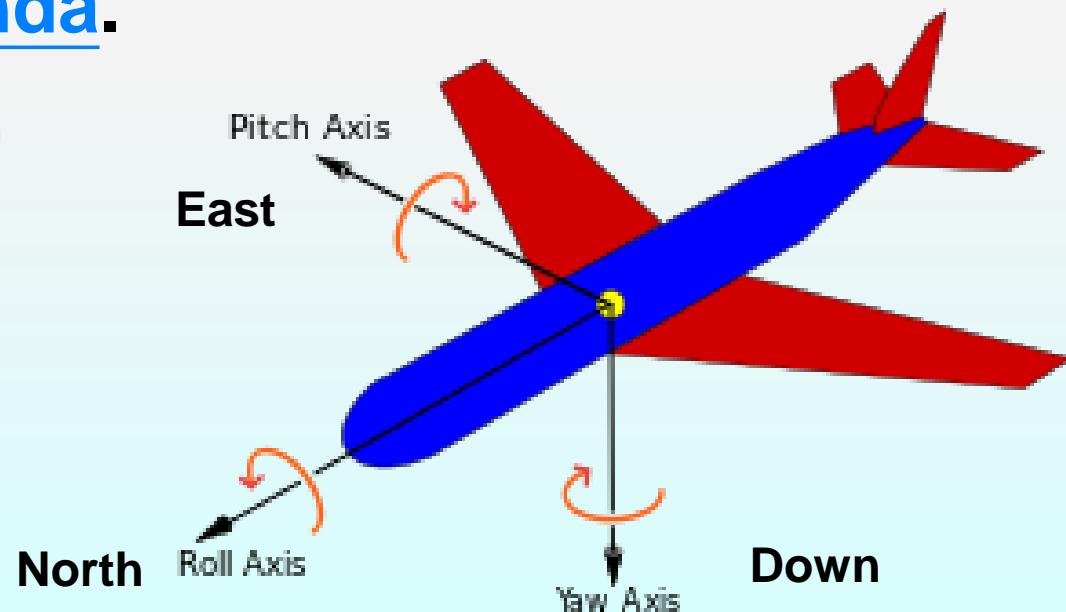
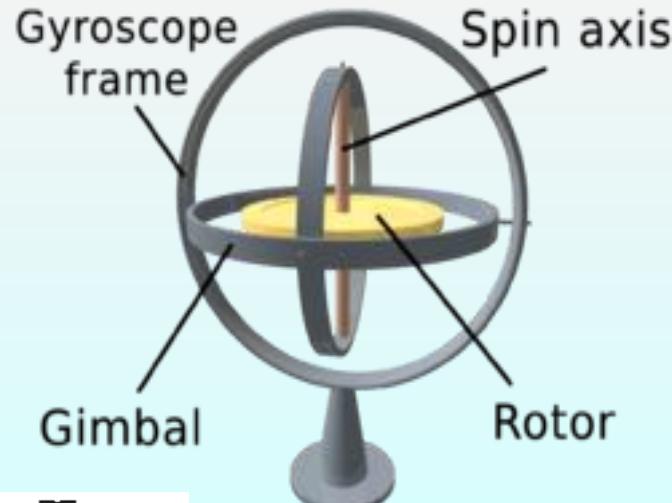
EON includes free **cloud** storage of recent drives, **driver** facing camera and ability to **review** drives



LeEco Le Pro 3 手機

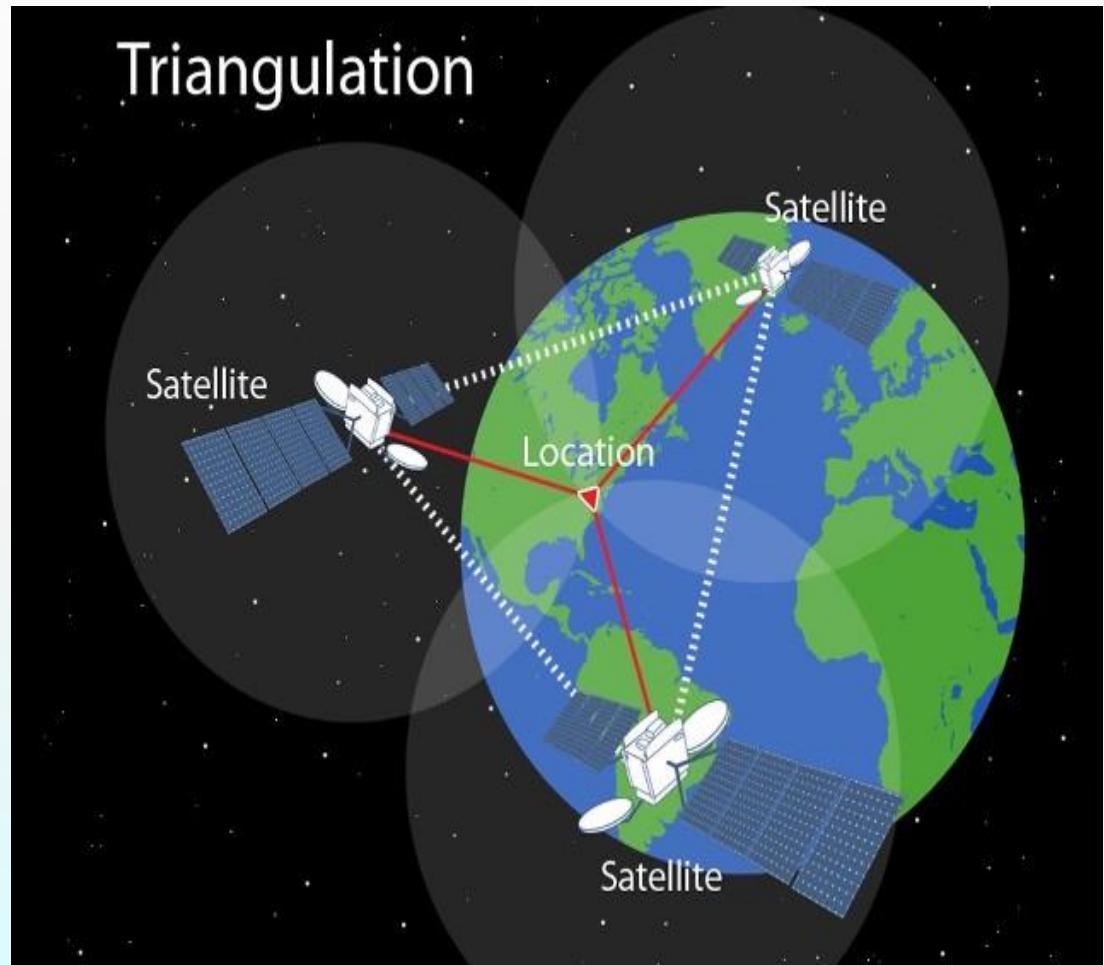


EON has **sensors** similar to those of any modern **smartphone** including a road-facing **camera**, phone **GPS**, thermometers and 9-axis **IMU** (inertial measurement unit). Additionally, the EON captures raw **GNSS** measurements and all **CAN** (Controller Area Network) data sent by the car with a comma **grey panda**.

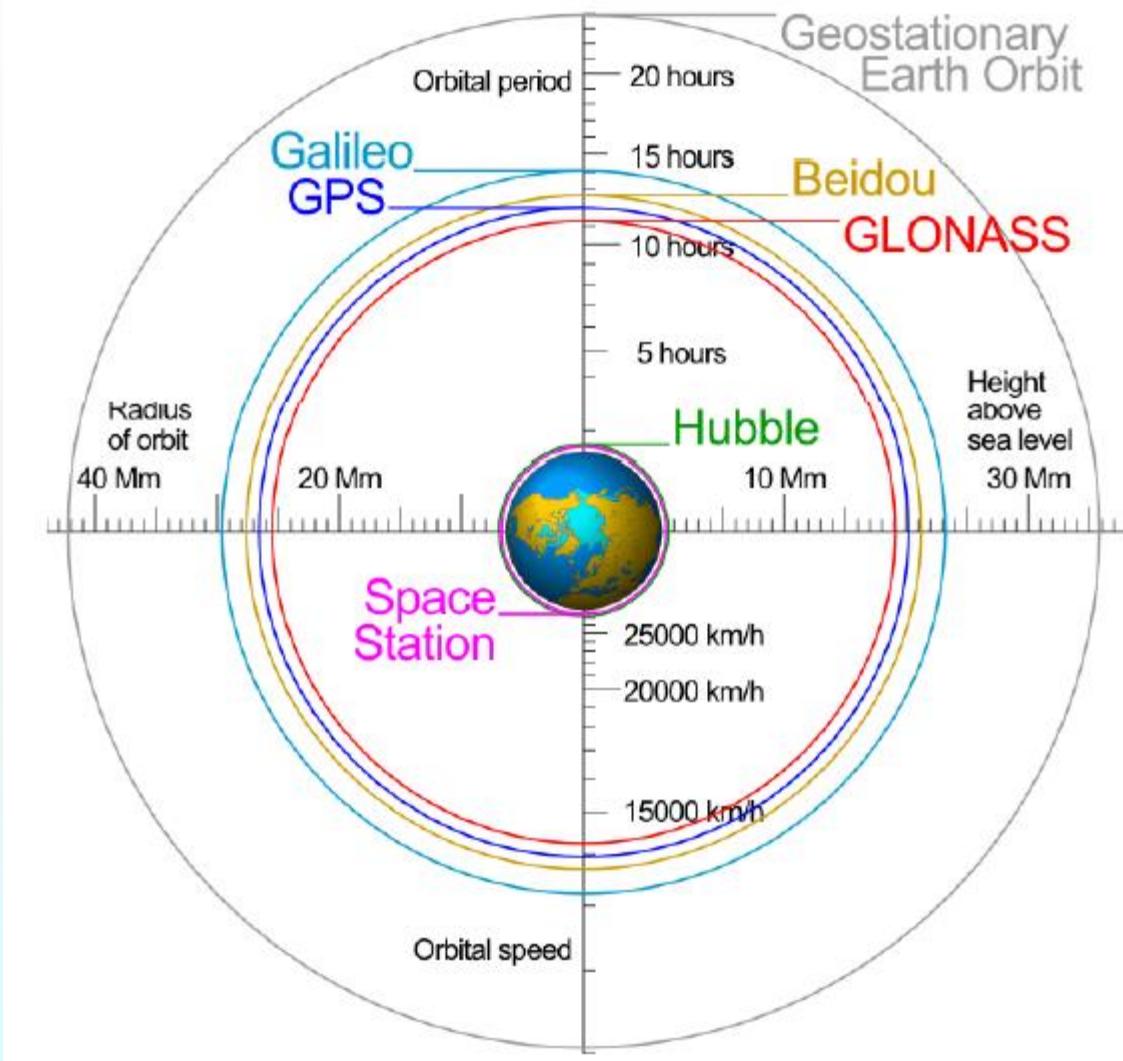


Phone GPS

1. Latitude (deg)
2. Longitude (deg)
3. Speed (m/s)
4. UTC_timestamp (s)
5. Altitude (m)
6. Bearing (deg)



GNSS (Global Navigation Satellite System)



<https://www.gsa.europa.eu/european-gnss/what-gnss>

Hardware 2: panda

A **controller interface** to communicate with your car. It allows you full access to the many communication **CAN buses** of your car from a computer or a phone.

panda+[cabana](#) is like **fitbit** for your car. Track your RPMs, MPG, cornering G-force, battery life, and so much more. Panda also work as a **CAN** to USB adapter.

CAN is a **protocol** used in the automotive industry to send signals between sensors.



It supports 3x CAN, 2x LIN, 1x GMLAN USB A, Wi-Fi (White Panda only), High Precision GPS (Grey Panda only). It also charges a phone. On the computer side, it has both USB and Wi-Fi. It uses an [STM32F413](#) for low level stuff and an [ESP8266](#) for Wi-Fi. They are connected over high speed SPI, so the panda is actually capable of dumping the full contents of the busses over Wi-Fi, unlike every other [dongle](#) on amazon. ELM327 is weak, panda is strong. It is 2nd gen hardware, reusing code and parts from the [NEO](#) interface board.

STM32 is a family of 32-bit [microcontroller integrated circuits](#) by [STMicroelectronics](#). A **microcontroller (MCU)** for *microcontroller unit*) is a tiny [computer](#) on a single [integrated circuit](#).



12VIN
rated from
5.5-18V

GMLAN shares the CAN2 port of the STM32F, cannot have both enabled; must enable PU on B12

Both LIN buses are connected thru a transceiver; L is on USART3, K is on UART5

PWR

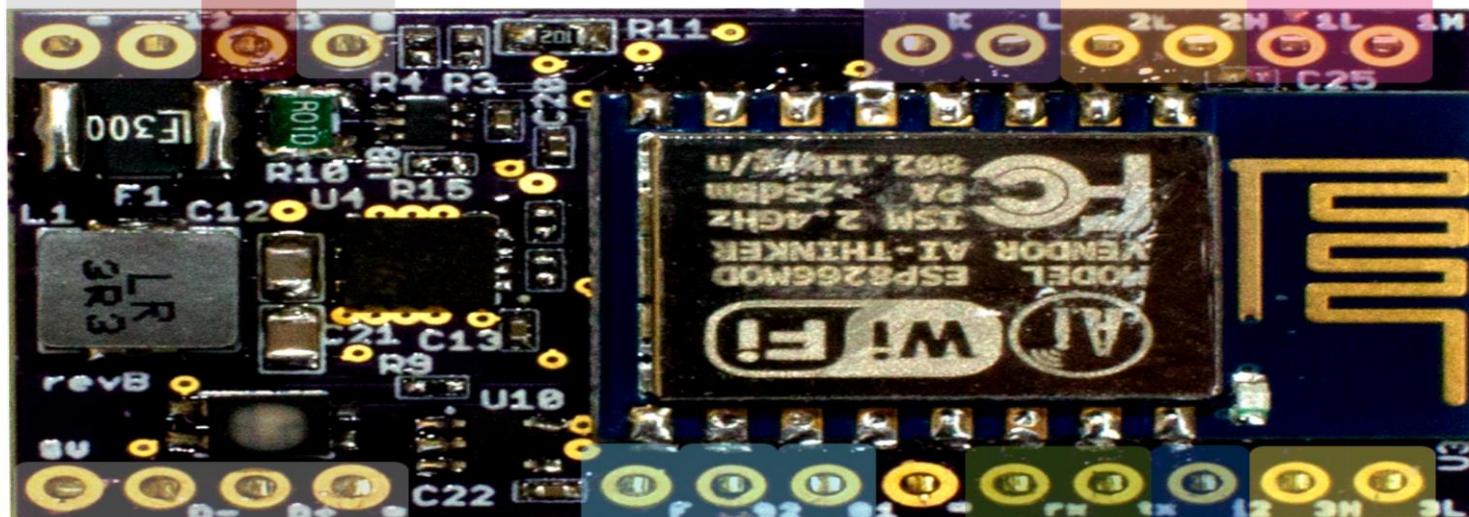
GND

12VIN

GMLAN B12,B13

boot0

pull boot0 high to enter DFU mode; only required for initial flashing



these pins are directly connected

connected thru a prebiased npn transistor; use internal PU resistor on A1 to sense when 12V signal is high

STM32F pin connections

Microcontrollers are used in automatically controlled products and devices, such as **automobile** engine control systems, implantable **medical** devices, **remote** controls, **office** machines, **appliances**, power tools, toys and other embedded systems.

An **embedded system** is a controller with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints.

Microcontrollers were originally programmed only in assembly language, but various high-level programming languages, such as **C**, **Python** and **JavaScript**, are now also in common use to target microcontrollers and embedded systems.

Arduino mBot Workshop Slides - NUS Wiki

Arduino Part 1

[Arduino For Beginners - Makerspaces.com](#)

[You can learn Arduino in 15 minutes. -](#)

[YouTube](#)

[Arduino Programming Part 1 - Portland State University](#)

[Microcontroller presentation - SlideShare](#)

[Arduino - SlideShare](#)

[Introduction to arduino - SlideShare](#)

[Intro to the Arduino](#)

Hardware 3: giraffe

An **adapter** board that lets you read **CAN buses** that aren't exposed on the main **OBD-II** connector (on-board diagnostics, on-board computer system).



Functionality:

It **passes** through the **signals** to the **existing driver assistance system**. Or turn the switches off and **block** the signals. It's like unplugging, but better. Or **proxy** the signals through your panda. When used with a panda you get more signals and access to read from your **car's radar**. Also has a fake ethernet port with access to CAN1, CAN2, Ignition detect, +12v, and ground.

The OBD **laws** require that all components and subsystems which have an **emission** impact and which are connected to an **Engine Control Unit (ECU)** need to be monitored and diagnosed.

Sensors: O₂ sensor, temperature sensors, pressure sensors, etc.

Actuators: Fuel injectors, ignition coils, throttle blades, cam phasers, EGR valve, etc.

Subsystems:

Fuel Injection System

Ignition system

Exhaust gas cleaning system

Canister purge (**Evaporative** Emission Control) system



Setup EON



- 1. Mount**
- 2. Connect**
- 3. Calibrate**



comma.ai GitHub Software

[openpilot](#)

open source driving agent

 C  12.5k  3k

[comma2k19](#)

A driving dataset for the development and validation of fused pose estimators and mapping algorithms

 Jupyter Notebook  257  47

[opendbc](#)

democratize access to car decoder rings

 Python  392  423

[panda](#)

code powering the comma.ai panda

 C  756  283

[cabana](#)

CAN visualizer and DBC maker

 JavaScript  40  20

[explorer](#)

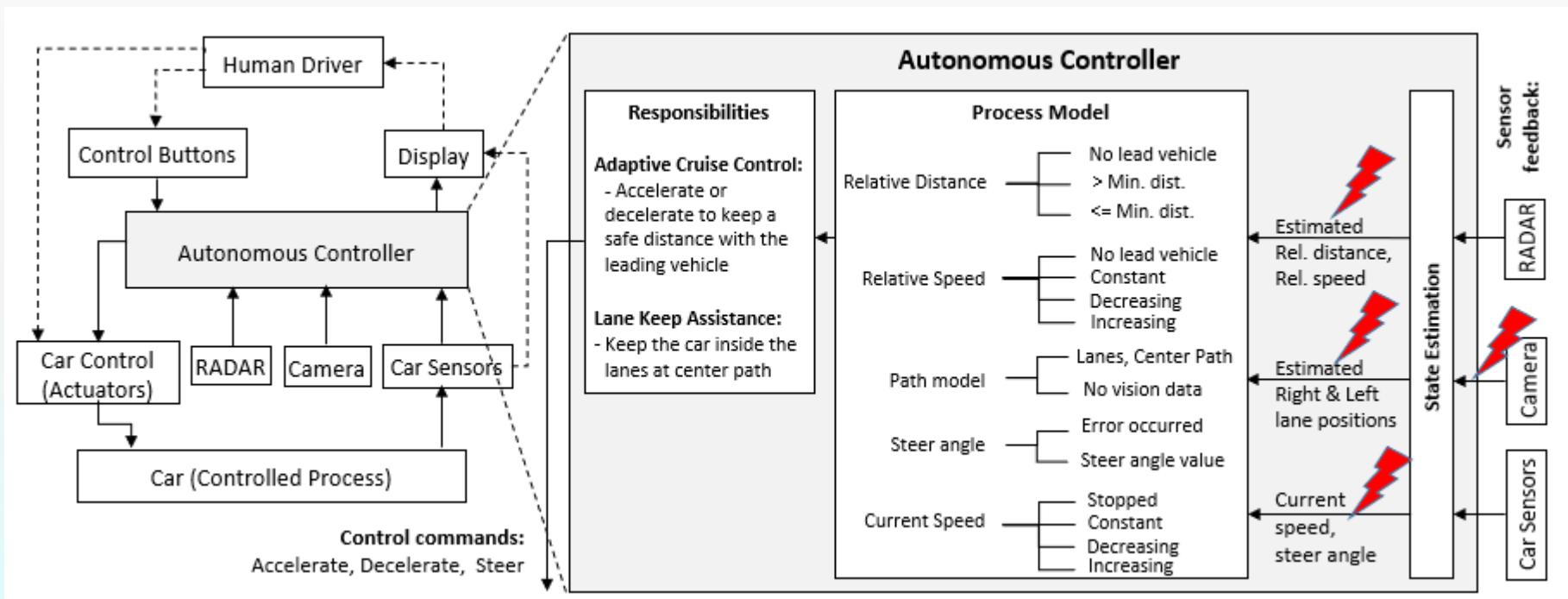
explorer of your comma drives

 JavaScript  37  18 15

Software 1: openpilot

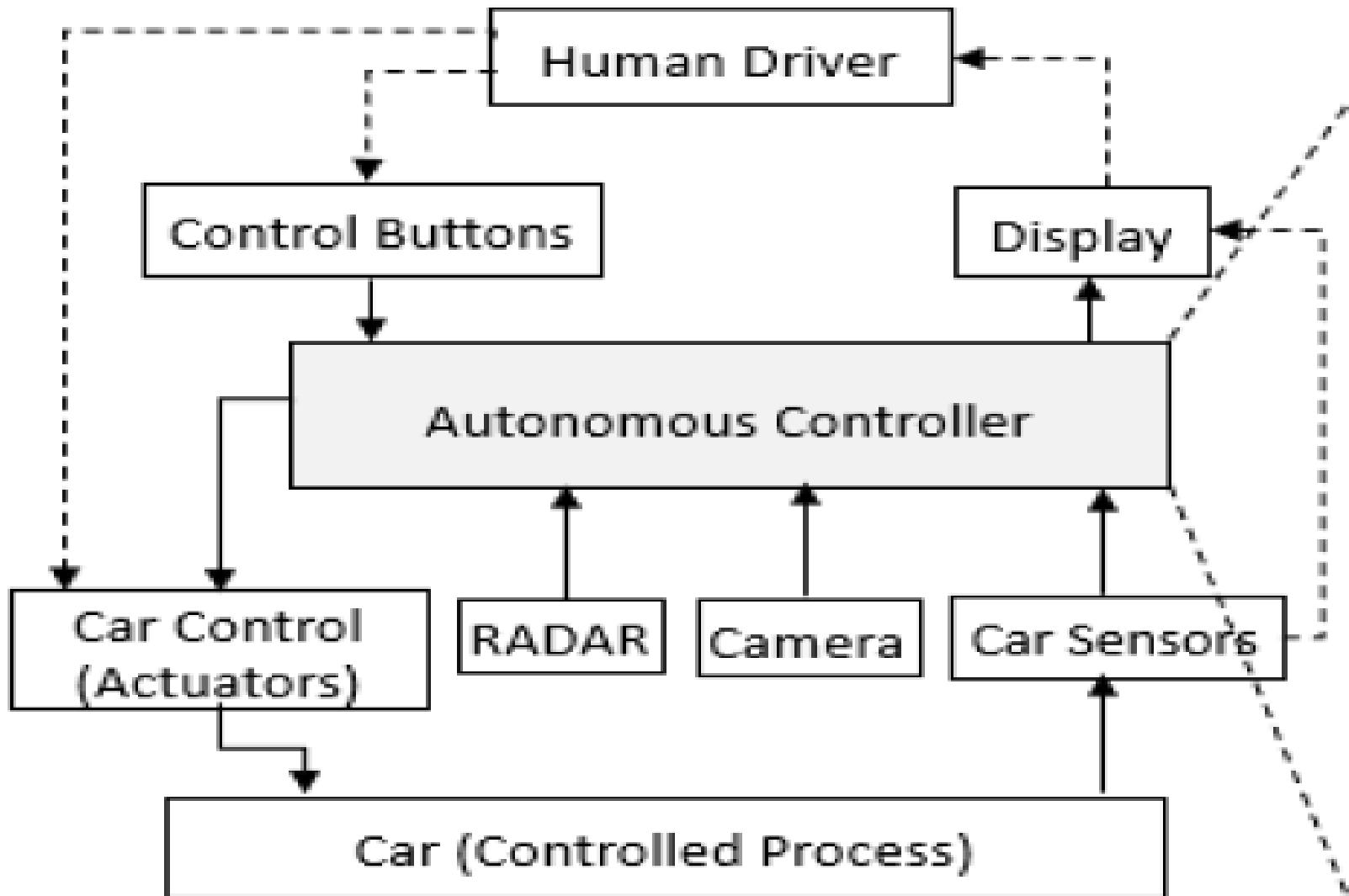
Open Source Driving Agent

Train a Deep Neural Network to Steer



2018 (Auto) (Comma) Experimental Resilience Assessment of An Open-Source Driving Agent





Control commands:
Accelerate, Decelerate, Steer



Autonomous Controller

Responsibilities

Adaptive Cruise Control:

- Accelerate or decelerate to keep a safe distance with the leading vehicle

Lane Keep Assistance:

- Keep the car inside the lanes at center path



Process Model

Relative Distance

- No lead vehicle
- > Min. dist.
- ≤ Min. dist.

Relative Speed

- No lead vehicle
- Constant
- Decreasing
- Increasing

Path model

- Lanes, Center Path
- No vision data

Steer angle

- Error occurred
- Steer angle value

Current Speed

- Stopped
- Constant
- Decreasing
- Increasing

Estimated
Rel. distance,
Rel. speed

Estimated
Right & Left
lane positions

Current
speed,
steer angle

Sensor
feedback:

RADAR

Camera

Car Sensors

Software 2: openpilot-tools

openpilot PC simulator

Welcome to openpilot: Testing on PC

The simulator enables running **openpilot control software** without the actual car and radar sensors

2016 (Auto) (Video) (Comma) Learning a Driving Simulator

- <https://github.com/UVA-DSA/OpenPilot0.3.5>

2018 (Auto) (Comma) Experimental Resilience Assessment of An Open-Source Driving Agent



Software 3: comma2k19

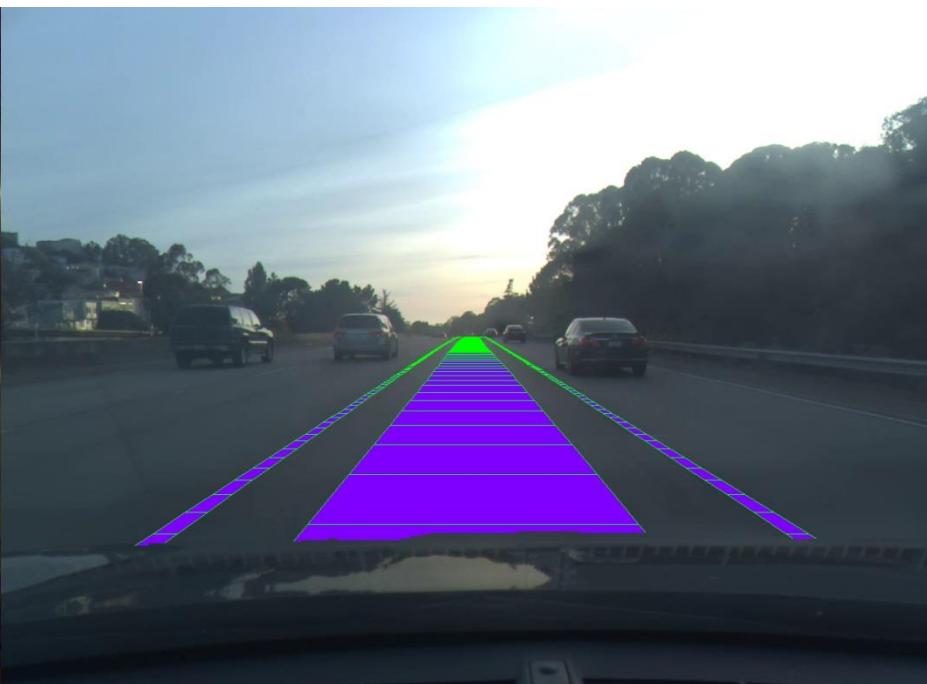
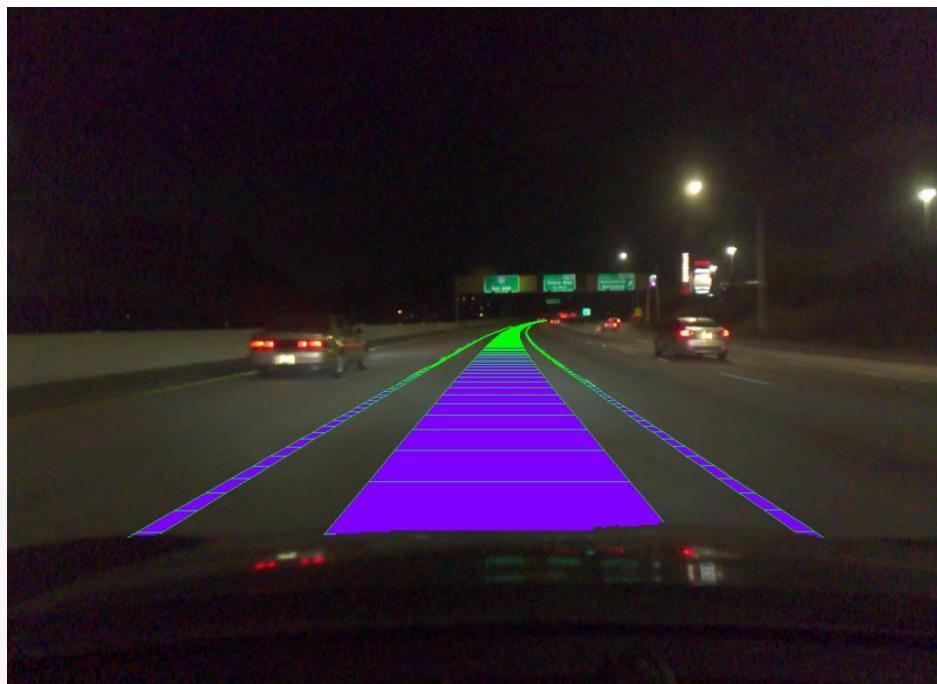
A driving dataset for the development and validation of fused pose estimators and mapping algorithms

Publication: 2018 (Auto) (Comma) (Video) A

Commute in Data: The comma2k19 Dataset

Example Code, Dataset Structure, Log Format, Pose Format





The data is split into **10 chunks** of each about **200 minutes** of driving. **Chunks 1-2** of the dataset are of the **RAV4** and the rest is the civic. The **dongle_id** of the RAV4 is b0c9d2329ad1606b

Dataset_chunk_n

- | +- **route_id** (dongle_id|start_time)
- +-- **segment_number**
 - +- **preview.png** (first frame video)
 - +- **raw_log.bz2** (raw **capnp** log, can be read with openpilot-tools: logreader)
 - +- **video.hevc** (**video** file, can be read with openpilot-tools: framereader)
 - +- **processed_log/** (**processed** logs as numpy arrays, see format for details)
 - +- **global_pos/** (global **poses** of camera as numpy arrays, see format for details)



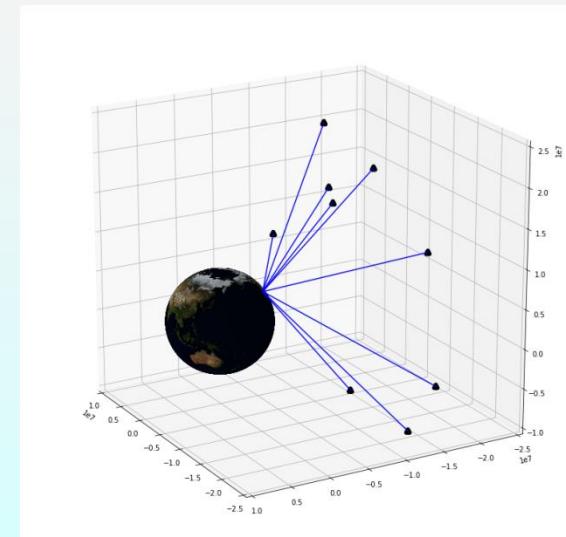
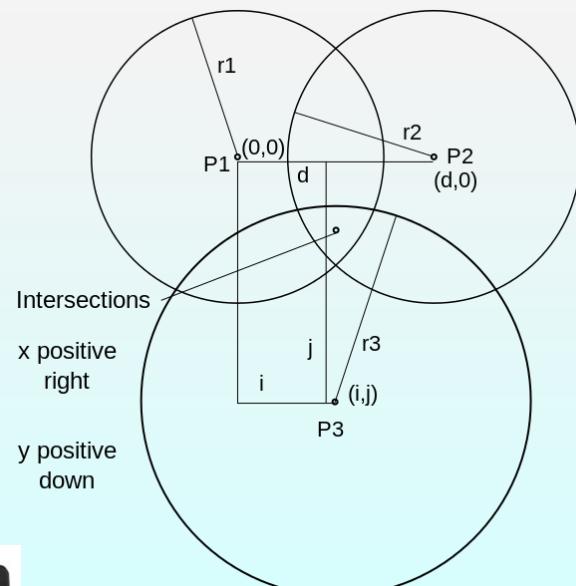
Software 4: laika

Simple Python GNSS processing library

Laika is an open-source GNSS processing [library](#). Laika is similar projects like [RTKlib](#) and [GPSTK](#), but in Python and with a strong focus on [readibility](#), [usability](#) and easy integration with other [optimizers](#). Laika can process [raw GNSS](#) observations with [data](#) gathered online from various analysis groups to produce data ready for [position/velocity](#) estimation. Laika is designed to produce accurate results whilst still being readable easy to use. Laika is the perfect tool to develop accurate GNSS-only or GNSS-fusion [localization algorithms](#).



The GNSS problem GNSS satellites orbit the earth broadcasting **signals** that allow the **receiver** to determine the **distance** to each satellite. These satellites have known **orbits** and so their **positions** are known. This makes determining the receiver's position a basic **3-dimensional trilateration problem**. In practice observed distances to each satellite will be measured with some **offset** that is caused by the receiver's **clock error**. This offset also needs to be determined, making it a **4-dimensional trilateration problem**.



Software 5: panda

A universal car **controller interface**

Directory structure

board -- Code that runs on the **STM32**

boardesp -- Code that runs on the **ESP8266**

drivers -- Drivers (not needed for use with python)

python -- **Python** userspace library for interfacing
with the panda

tests -- Tests and **helper** programs for panda



Usage (Python) To install the library:

```
# pip install pandacan
```

See [this class](#) for how to interact with the panda.

For example, to **receive** CAN messages:

```
>>> from panda import Panda >>> panda = Panda() >>>  
panda.can_recv()
```

And to **send** one on bus 0:

```
>>> panda.can_send(0x1aa, "message", 0)
```

Find user made **scripts** on the [wiki \(panda examples , candiff.py\)](#) Note that you may have to setup [udev rules](#) for Linux, sudo -i echo 'SUBSYSTEMS=="usb", ATTR{idVendor}=="bbaa", ATTR{idProduct}=="ddcc", MODE=="0666"' > /etc/udev/rules.d/11-panda.rules exit

Programming (over USB)

[Programming the Board \(STM32\)](#)

[Programming the ESP](#)



Software 5: opendbc

To democratize access to the **decoder ring of your car**

Files showing how to interpret **data** (**database CAN**)

DBC file basics

A DBC file encodes, in a humanly readable way, the information needed to understand a vehicle's **CAN** bus traffic. A vehicle might have multiple **CAN buses** and every CAN bus is represented by its own dbc file. Wondering what's the DBC file format? [Here](#) and [Here](#) a couple of good overviews.

How to start **reverse engineering cars**

[opendbc](#) is integrated with [cabana](#).

Use [panda](#) to connect your car to a computer.

DBC file preprocessor

Good practices for contributing to opendbc

Software 6: explorer

The frontend to the explorer web UI.
This a react app using Create React App

Environments, Libraries Used, Project Layout, How shit works, Development, Contributing, Create React App documentation, Table of Contents, Updating to New Releases, Sending Feedback, Folder Structure, Available Scripts, Supported Browsers, Supported Language Features and Polyfills, Syntax Highlighting in the Editor, Displaying Lint Output in the Editor, Debugging in the Editor,

....

Software 7: cabana

CAN visualizer and DBC maker

Setup: `yarn`, `yarn run sass`; **Development:** `yarn start`

Contributing: `yarn run test`; **Deploy to Production**

`npm version patch`

`git push origin master --tags # push version patch`

`yarn run deploy # builds and deploys to github pages`

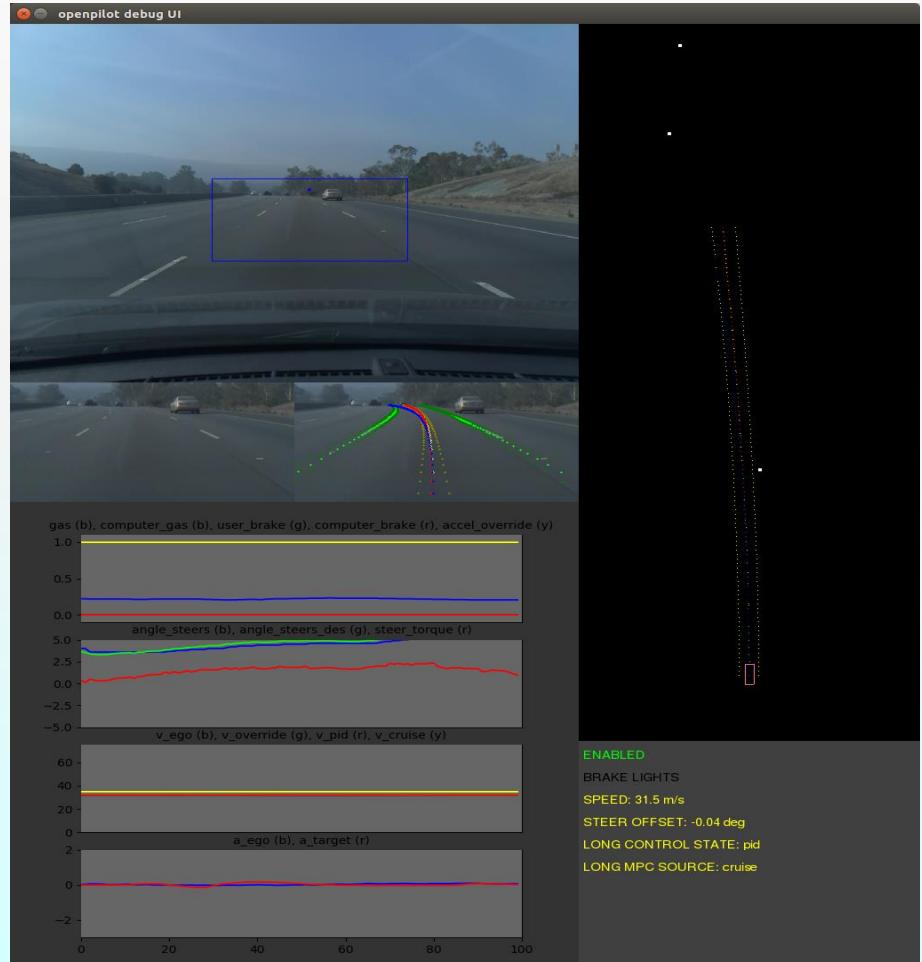
Yarn caches every package it **downloads** so it never needs to download it again. It also parallelizes operations to maximize resource utilization so install times are faster than ever.

npm is the world's largest **Software Registry**. The registry contains over 800,000 **code packages**. **Open-source** developers use **npm** to **share** software. Many organizations also use npm to manage private development.

Software 8: openpilot-tools

Why? We use **daily at comma.**

Example 1: replay driving data. Hardware needed: none.



Example 2: debug car **controls.**

Hardware needed: [panda](#), [giraffe](#),
USB joystick.

Reverse engineering steering
controls on a Cadillac CT6.



Example 3: stream replayed **CAN messages to EON**

Hardware needed:

2x [panda](#), [debug board](#), [EON](#)
[Dashcam DevKit](#).

Example 4: stream EON **video data to a PC**

Hardware needed: [EON](#)
[Dashcam DevKit](#), [comma Smays](#).

EON streaming video data to a
PC using a comma Smays.

