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AURORA
We Do Self-Driving Cars

Content

Aurora’s Mission

Deliver the benefits of self-driving technology

Safely, Quickly and Broadly

The Challenge

[Autonomy is] the mother of all AI projects, probably one of the most difficult AI projects to work on.

- Tim Cook, CEO Apple Inc.

A self-driving car will be the most complex computer system the world has ever done.

- Jensen Huang, CEO Nvidia

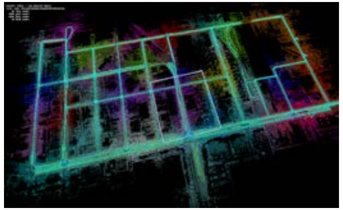
[Publicly-disclosed AV technology investments] approach $80 billion dollars. The trend indicates that investment in 2018 should be substantially more than the $80 billion disclosed from 2014 to 2017, and continue upward for some period of time.

- Brookings Institute

The Product: a world class self-driving solution for our partners

Self-driving hardware design

Self-driving software system



Data services to support operation by our partners

The Founders

Chris Urmson, Chief Executive Officer

- Led Google's Self-Driving Car program growing from 6 to 600+ people
- Director of Technology for Carnegie Mellon's DARPA Grand and Urban Challenge Teams
- 60+ patents and 50+ publications
- PhD Robotics, Carnegie Mellon
- 15 years of experience leading automated vehicle programs

Drew Bagnell, Chief Technical Officer

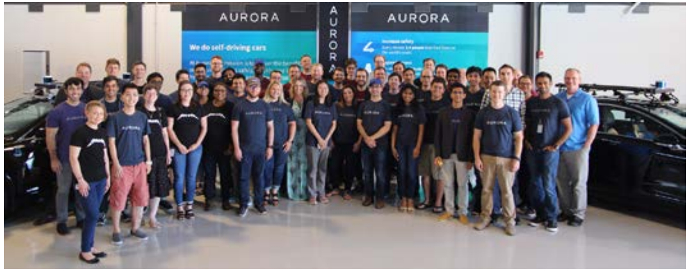
- Led perception and overall autonomy architecture for Uber SDV program
- Ran research lab as associate professor at Carnegie Mellon for over a decade: intersection of ML and robotics working both theory and fielding commercial systems
- Over 150 publications, including twelve best papers awards at the top venues in Robotics and Machine Learning (e.g. ICML, RSS, ICRA)
- PhD Robotics, Carnegie Mellon
- 20 years of experience developing and applying ML techniques to robotics

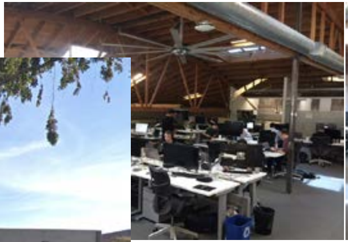
Sterling Anderson, Chief Product Officer

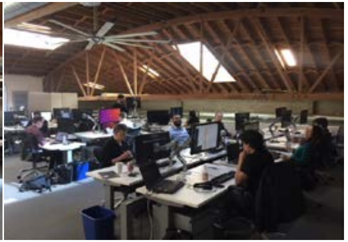
- Led Tesla's Autopilot Program
- Launched Tesla Model X
- Four issued AV patents and 15+ publications
- PhD Robotics, MIT
- 10 years of mobile robotics experience, 3 years of experience delivering automotive products

By the Numbers

- Founded in late 2016
- 150 people
  - Growing at ~ 3% per week in 2018
  - >400 years of autonomous vehicle experience
  - >1,000 years of software development experience
- 3 sites with 70,000 sq feet of office and garage space
  - 30,000+ sq feet of R&D garage space
  - Diverse weather and road conditions testing across 10 towns/cities



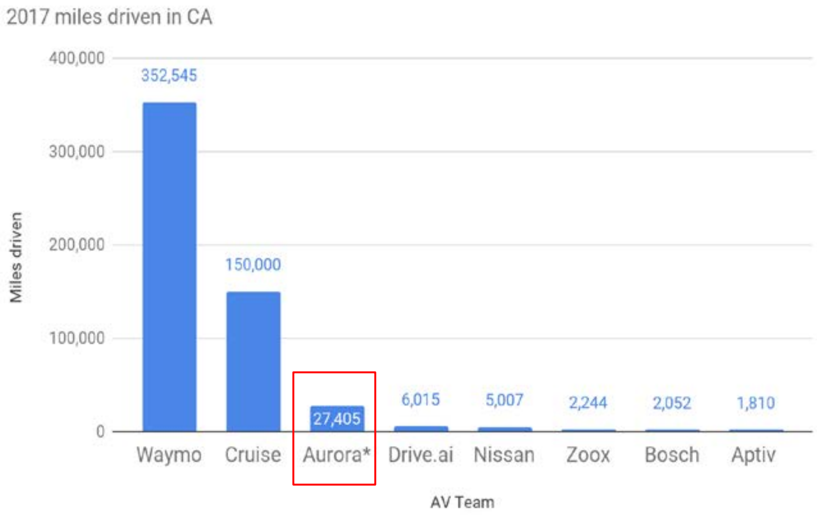


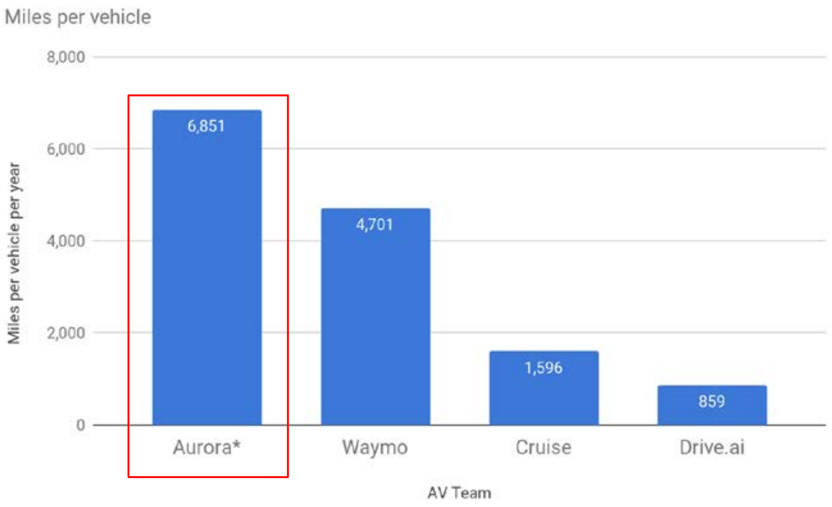


Aurora Experience

Year One (2017)

- Aurora's self-driving system was designed **from the ground up** starting Jan 2017
- Public road testing **began** ~September 2017
- With only **four months**, **four vehicles** and **fewer than 100 employees**, Aurora drove more autonomous miles* than any other group that submitted a California DMV report other than Google and GM





*Annualized

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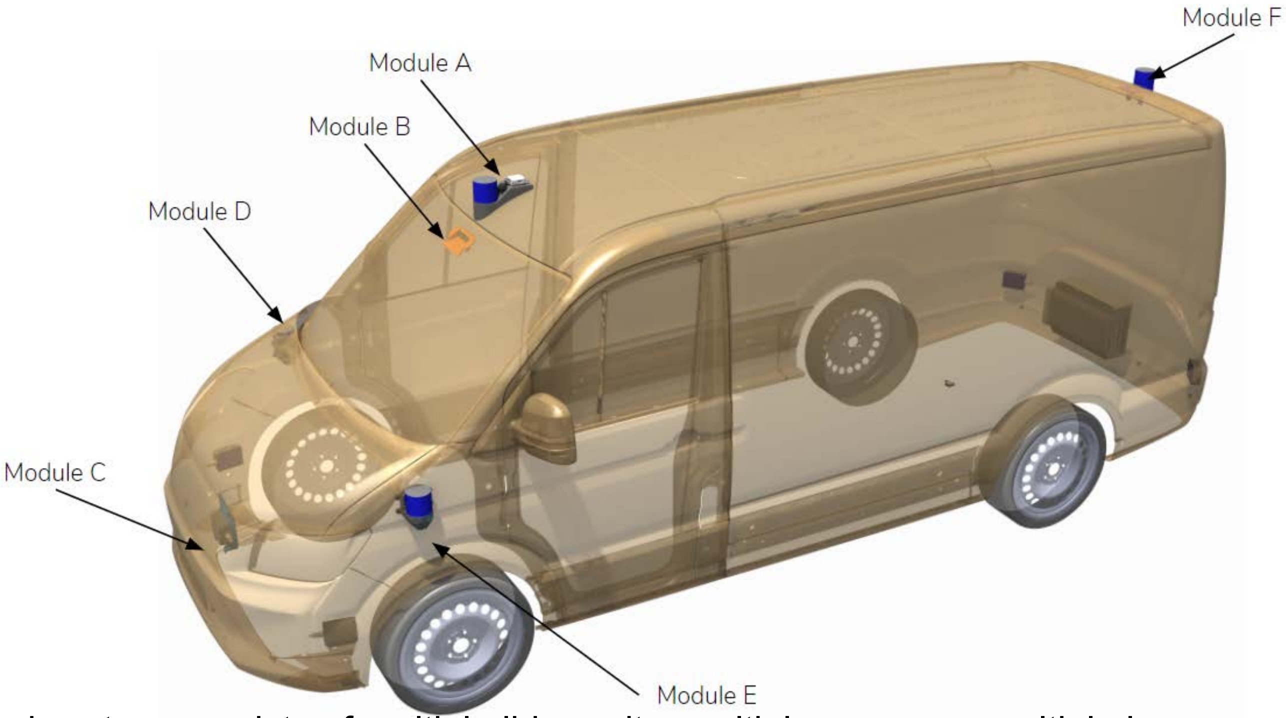
Introduction to Aurora

Introduction to Aurora’s Technology

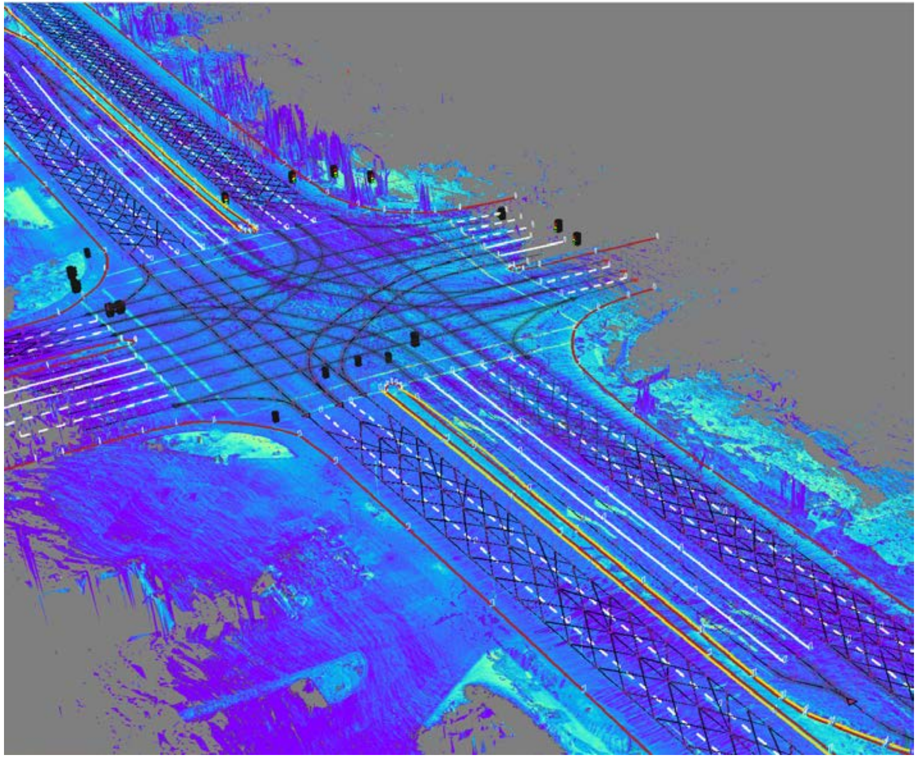
Roadmap for our Partnership

Sensors



- Standard system consists of multiple lidar units, multiple cameras, multiple long -range radar units, an IMU, and a siren sensor
- Grouped into 6 distinct modules plus corner installations around the vehicle (generic vehicle pictured)
- Designed to provide sufficient coverage and range for generalized on-road operation up to 75 mph

HD Maps

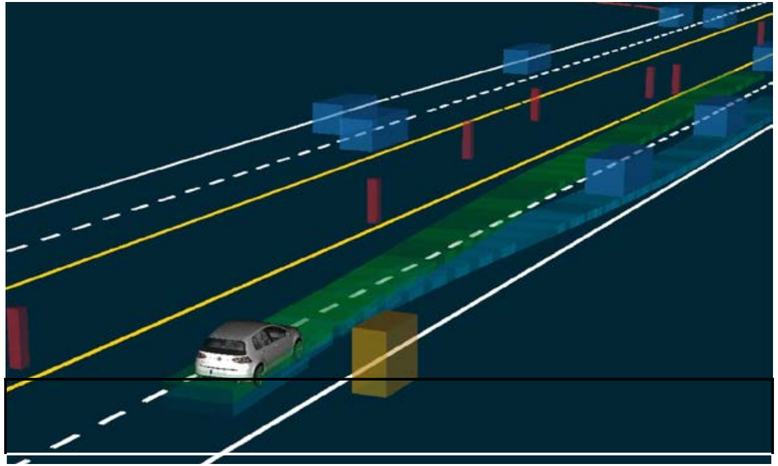


- A subset of our onboard sensors is sufficient for the collection of all data required to build an HD map
- HD Maps allow us to precisely localize the vehicle to within 10 cm
- System is largely agnostic to GPS; can maintain position in environments that deny it (urban canyons, rural areas, tunnels)
- Shown above is a subset of the maps produced, showing lane geometry, ground plane, traffic controls, intersections, speed limits

Computer

- Central compute unit
- Aurora’s design
- Autonomy sensors all connect direct to and our powered by this box
- Capable of self-driving operation with safety drivers this year

Simulation



Low fidelity scene for planning simulation

High fidelity synthetic image for perception simulation

- Designed to test interactions - a discrete event where the vehicle has to do something other than drive within the lane at steady speed
  - Highway interactions with other vehicles: Cut-ins, Hard braking vehicles, Contested lane changes and merges
  - Urban interactions with other actors: Pedestrians crossing/jaywalking, Cyclists in lane and lane changing, Vehicles partially in lane and lane hogging, Contested movements at intersections
- Not monolithic
- 18K daily experiments, 58K interactions, and growing each month (~4K new experiments a month)
- Space of potential experiences on the road is huge.

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Safety Case Approach

Two tiered functional safety approach:

- Development Safety concept to be used to aid in development of the production system, and allow road testing.
- Production Safety Concept to be used when vehicles go to production release.

Development safety concept:

- Will be used for development efforts through 2018
- Not intended for production release
- Requires Vehicle Operator
- Based on ISO 26262, but more tailored given this is not a production release system.

Production Safety concept:

- Developed in compliance with ISO 26262.
- SAE3061 and ISO/PAS 21448(draft) will be used as informative reference.
- No Vehicle Operator required.

Separate safety concepts are required because the use cases and goals are different. For example:

- Operator must always be able to take control of the vehicle.
- Passengers/operators must not be able to interfere with operation of the vehicle.

Safety Case Approach for Development

Manual Control Is Assured - Take over is always possible, the physical actuators take precedence over the electronic commands, even in the event that the Aurora Self Driving System does not relinquish control.

Emergency Disconnect - A mechanical interlock which returns the vehicle ECU’s to their series production configuration. This can be used to ensure the system cannot interfere with the manual operation of the vehicle.

Vehicle Operators - A trained and attentive person who monitors the local environment and ensures the safe performance of the vehicle.

Co-pilots - Trained personnel who monitor the performance of the Aurora Self Driving System and alert the Vehicle Operator of system misbehavior that may not otherwise be indicated by the HMI system.

Visual and Audio Alerts - A simple HMI system is included that allows the Vehicle Operator to determine the state of the vehicle based on visible indicators and audio alerts.

Operational Design Domain Constraints - That limit exposure to undue risk as determined by a Hazard and Risk Assessment (HARA). Either through avoidance, or training of the Vehicle Operator to take over control when certain situations are encountered.

Thank you