Autonomous Driving: The Good The Bad and The Ugly

When do you [illegible] product?

Xiaodi Hou

TuSimple

Building an autonomous truck

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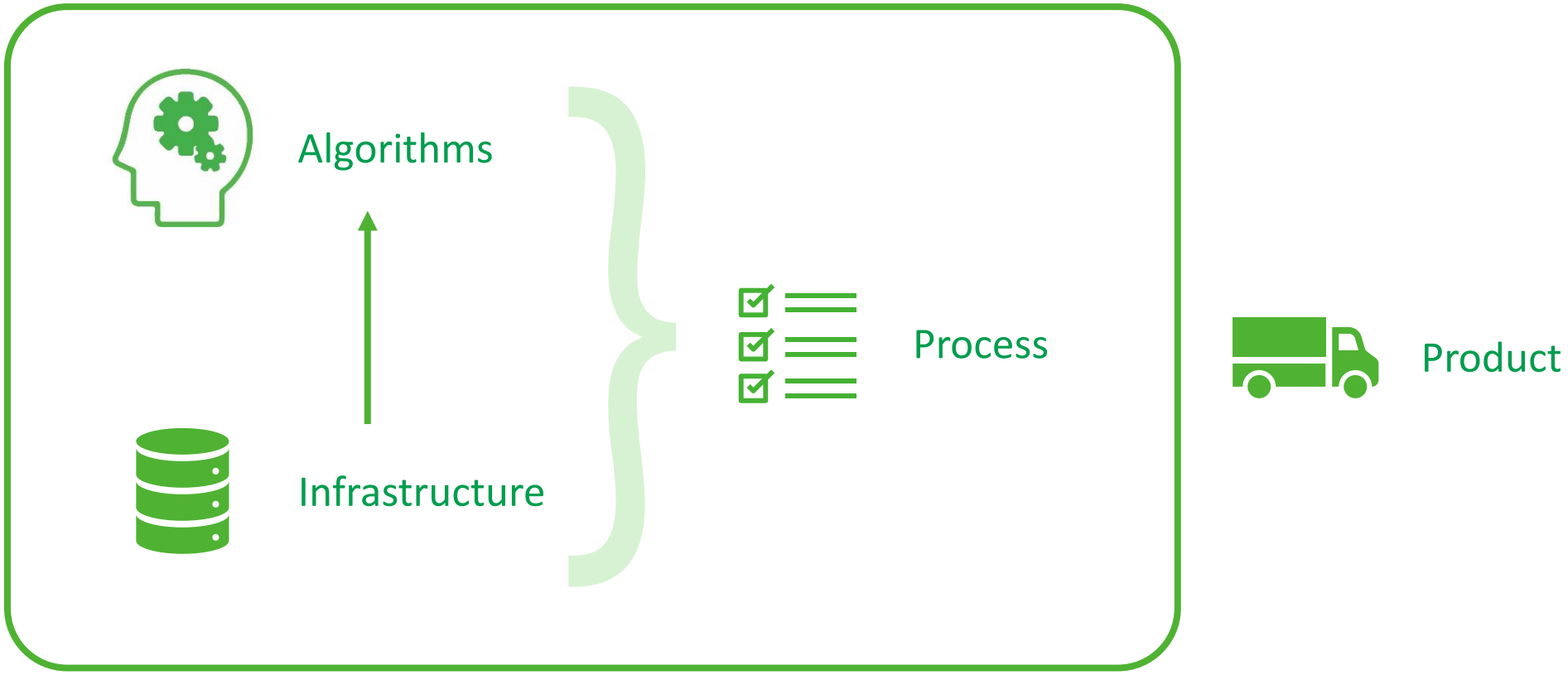
4 pillars of autonomous driving



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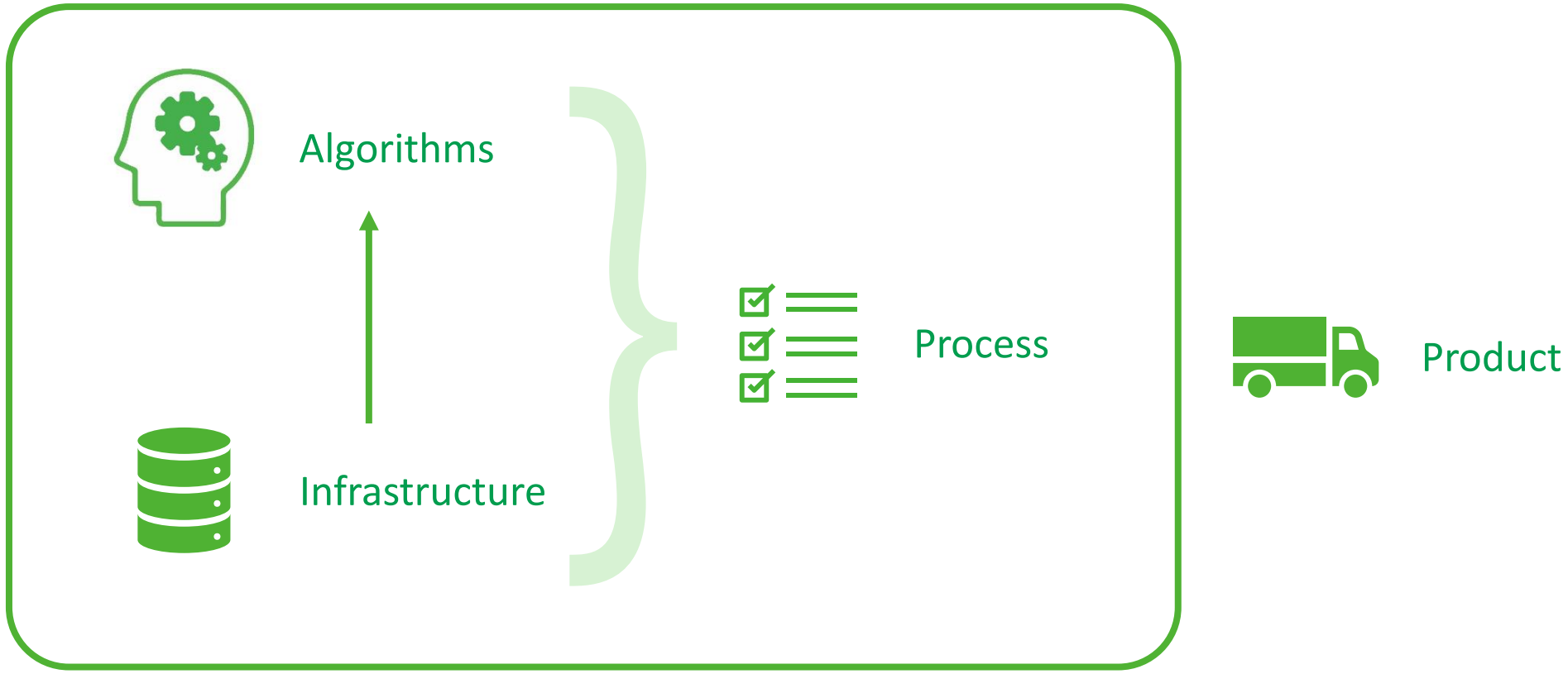
Algorithms



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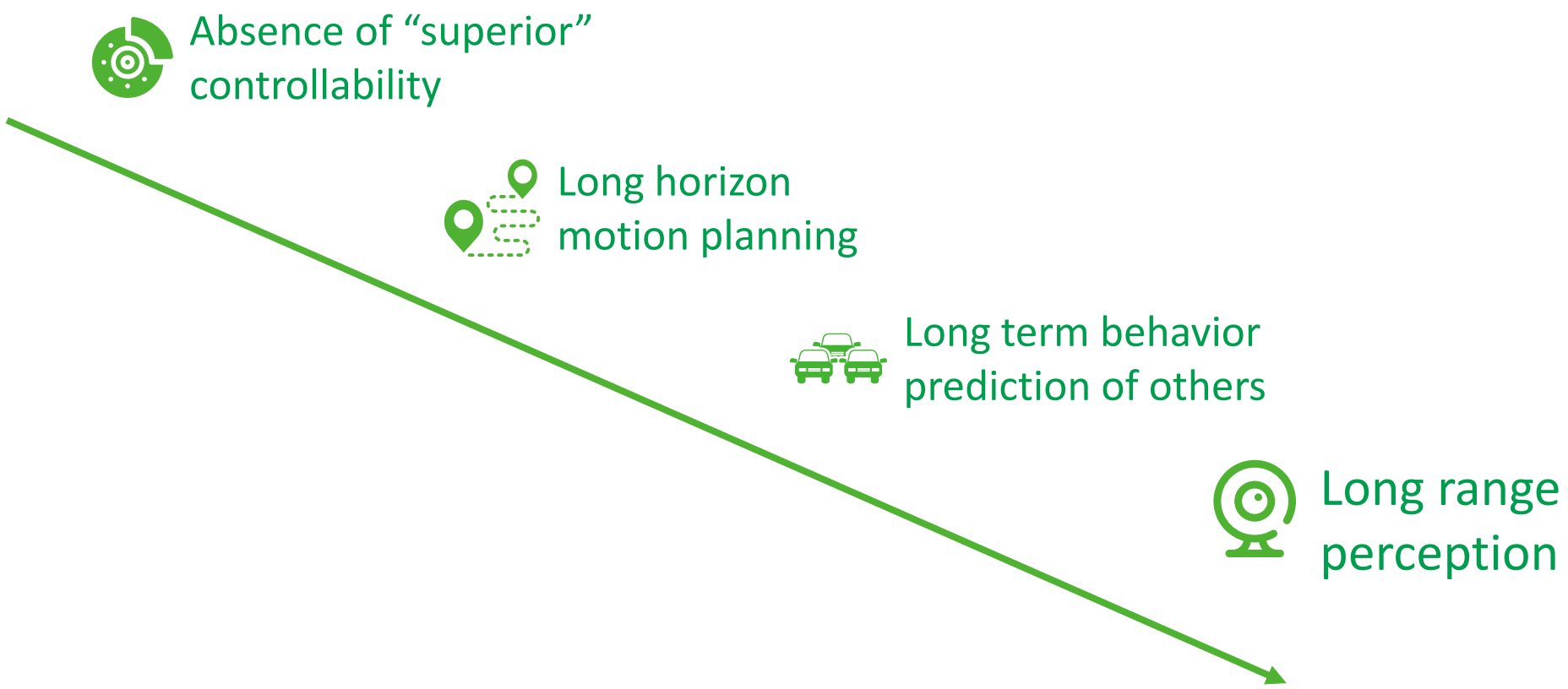
Algorithms

- “Typical” challenges
  - Detection, tracking, localization, pose estimation, planning, control…
- More for trucks!
  - Wider, and longer (430% of a Camry), slow accelerate/decelerate
  - Fuel matters

Perception for trucks



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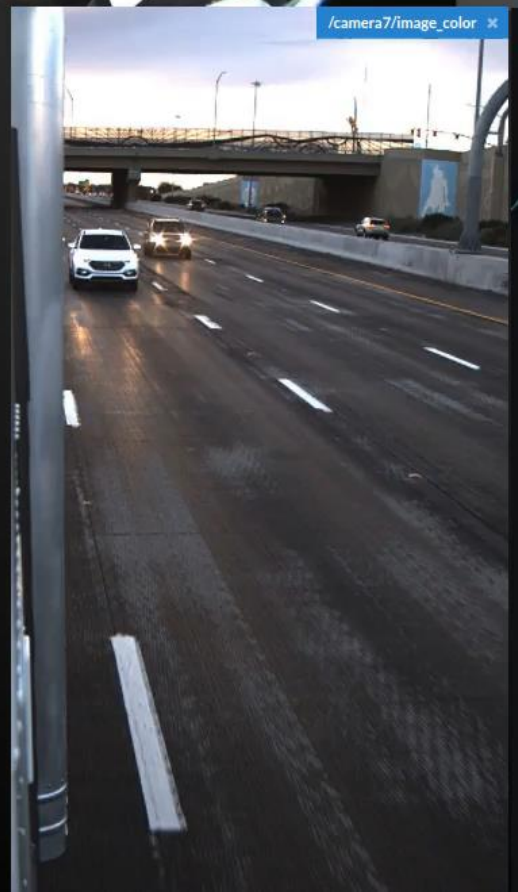
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200m
100m


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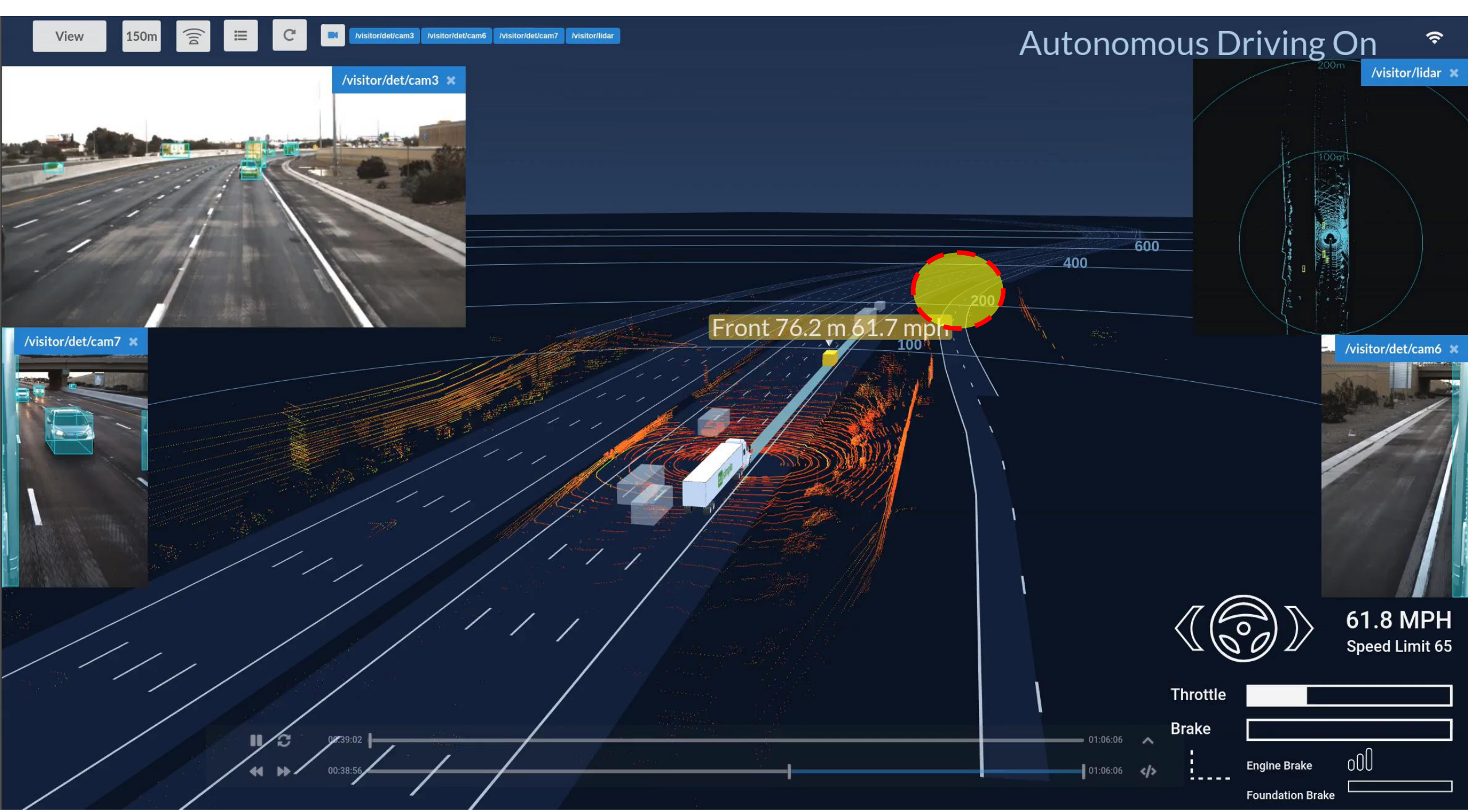
A superior pilot uses his superior judgement to avoid situations which require the use of his superior skill.

-- Frank Borman


View
150m
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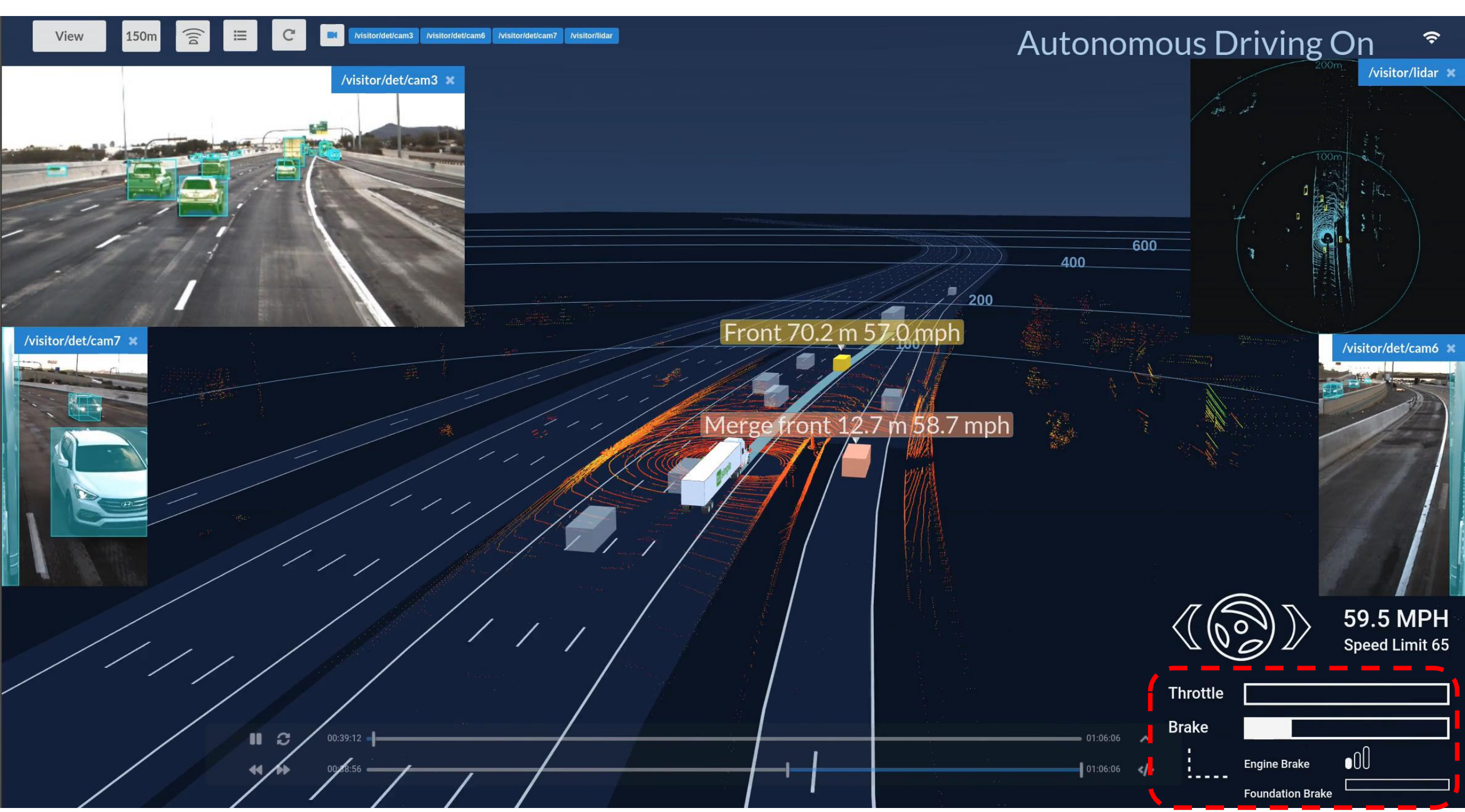
/visitor/det/cam6
/visitor/det/cam7
/visitor/lidar
Autonomous Driving On
/visitor/det/cam3
/visitor/lidar
200m
100m
600
400
200
100
Front 76.2 m 61.7 mph
/visitor/det/cam7
/visitor/det/cam6
00:39:02
01:06:06
00:38:56
01:06:06
61.8 MPH
Speed Limit 65
Throttle
Brake
Engine Brake
Foundation Brake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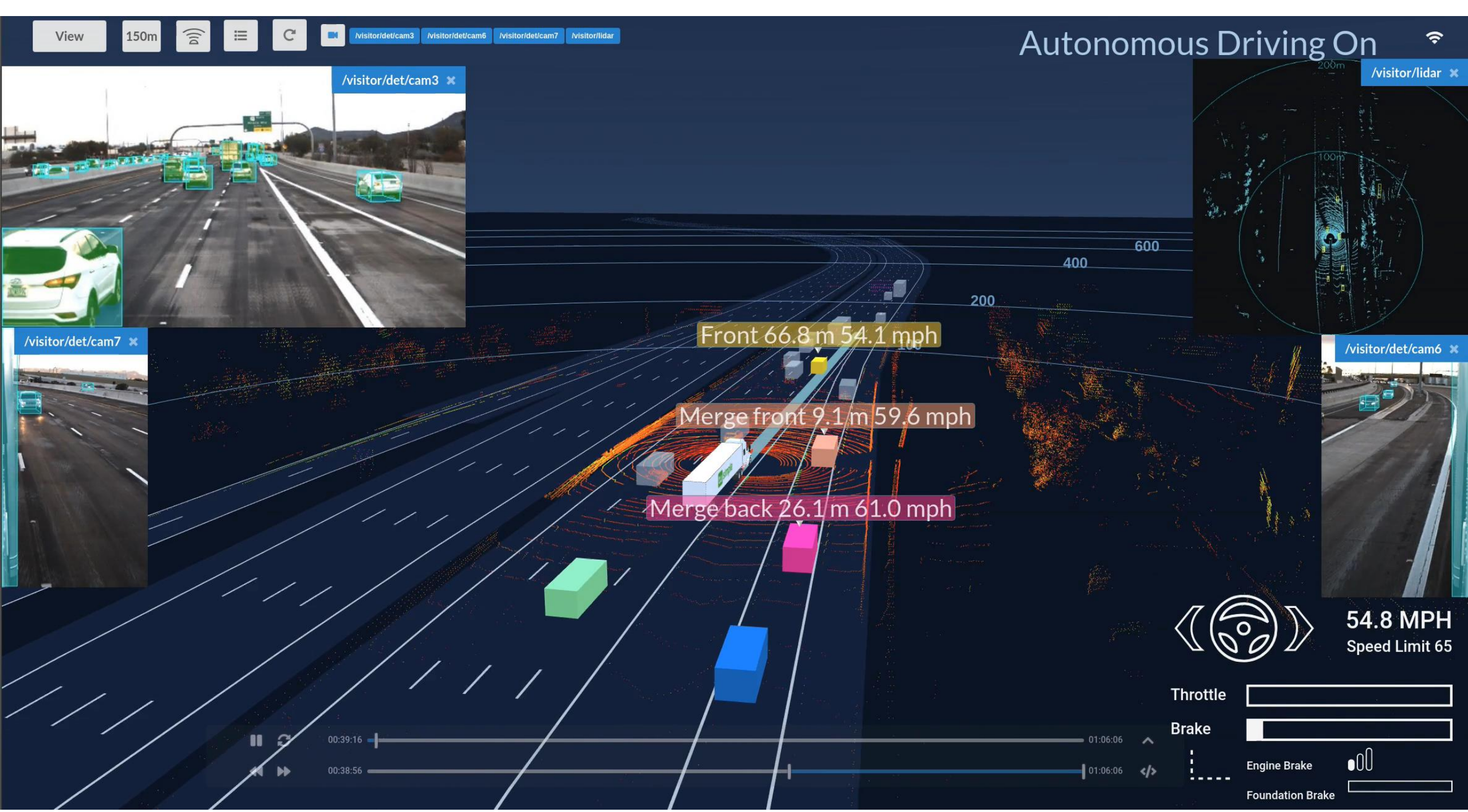
/visitor/lidar
Autonomous Driving On
/visitor/det/cam3
/visitor/lidar
200m
100m
600
400
200
Front 70.2 m 57.0 mph
Merge front 12.7 m 58.7 mph
/visitor/det/cam7
/visitor/det/cam6
00:39:12
01:06:06
00:38:56
01:06:06
59.5 MPH
Speed Limit 65
Throttle
Brake
Engine Brake
Foundation Brake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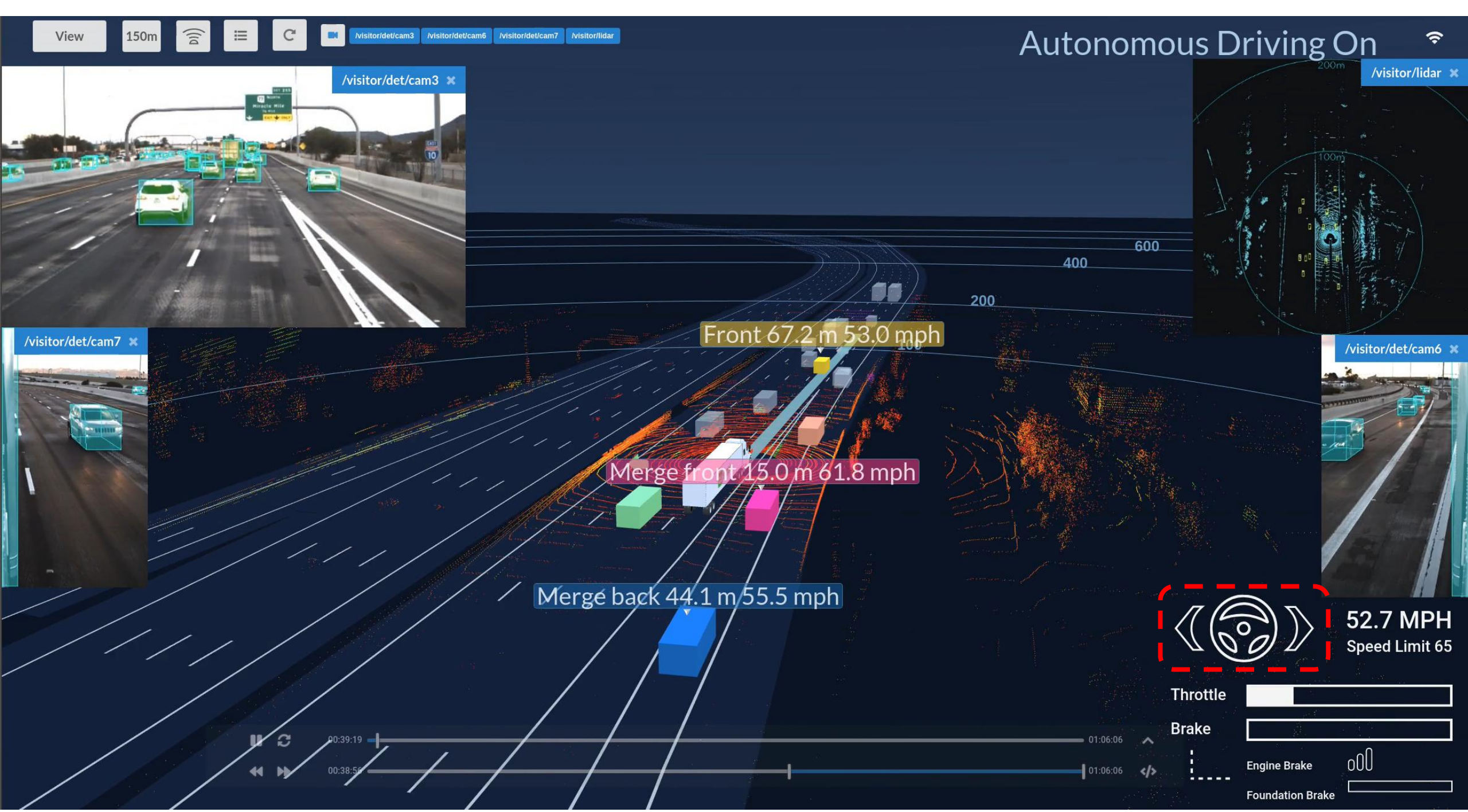
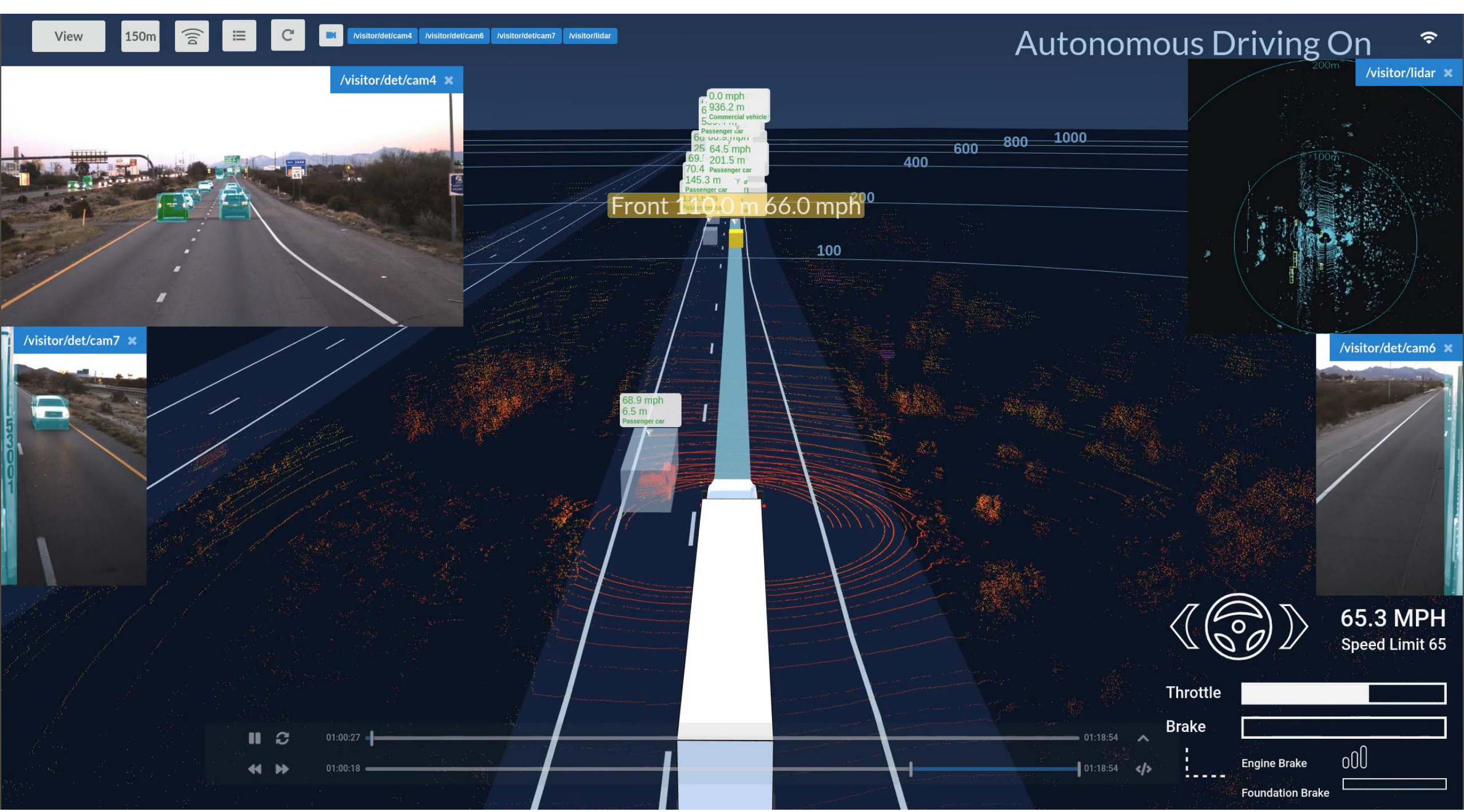
/visitor/det/cam7
/visitor/lidar
Autonomous Driving On
/visitor/det/cam3
/visitor/lidar
/visitor/det/cam7
/visitor/det/cam6
200m
100m
600
400
200
Front 66.8 m 54.1 mph
Merge front 9.1 m 59.6 mph
Merge back 26.1 m 61.0 mph
00:39:16
01:06:06
00:38:56
01:06:06
54.8 MPH
Speed Limit 65
Throttle
Brake
Engine Brake
Foundation Brake

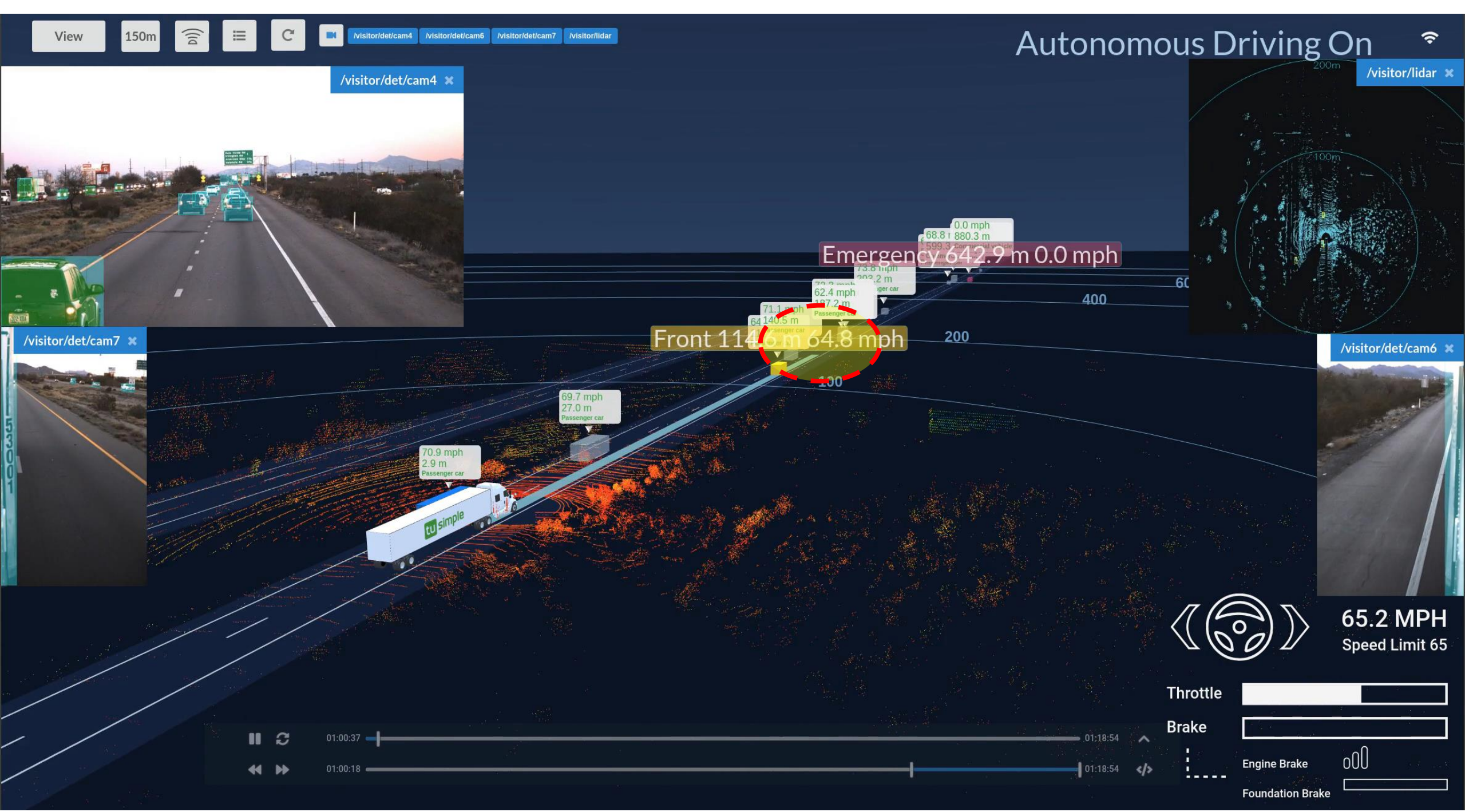

View
150m
/visitor/det/cam3
/visitor/det/cam6
/visitor/det/cam7
/visitor/lidar
Autonomous Driving On
/visitor/det/cam3
/visitor/lidar
200m
100m
600
400
200
/visitor/det/cam7
Front 67.2 m 53.0 mph
/visitor/det/cam6
Merge front 15.0 m 61.8 mph
Merge back 44.1 m 55.5 mph
52.7 MPH
Speed Limit 65
Throttle
Brake
Engine Brake
Foundation Brake
00:39:19
01:06:06
00:38:56
01:06:06

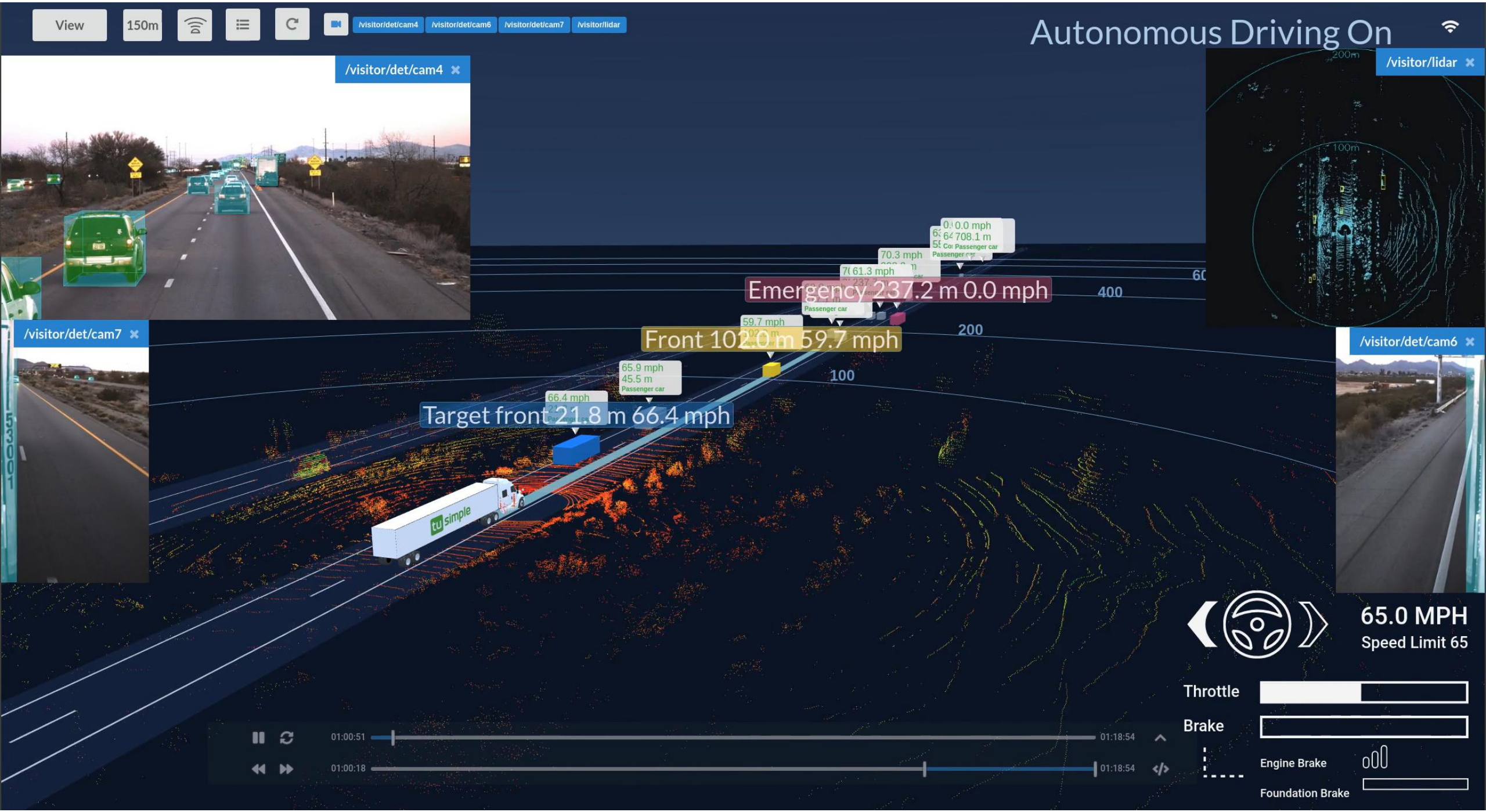
The more boundless your vision, the more real you are.

--Deepak Chopra


View
150m
/visitor/det/cam4
/visitor/det/cam6
/visitor/det/cam7
/visitor/lidar
Autonomous Driving On
/visitor/det/cam4
/visitor/lidar
/visitor/det/cam7
/visitor/det/cam6
0.0 mph
936.2 m
Commercial vehicle
Passenger car
64.5 mph
201.5 m
Passenger car
145.3 m
Passenger car
Front 1[illegible].0 m 66.0 mph
68.9 mph
6.5 m
Passenger car
400
600
800
1000
200
100
65.3 MPH
Speed Limit 65
Throttle
Brake
Engine Brake
Foundation Brake
01:00:27
01:18:54
01:00:18
01:18:54


650m away
200m
100m


View
150m
/visitor/det/cam4
/visitor/det/cam6
/visitor/det/cam7
/visitor/lidar
Autonomous Driving On
/visitor/det/cam4
/visitor/lidar
200m
100m
/visitor/det/cam7
/visitor/det/cam6
Emergency 642.9 m 0.0 mph
0.0 mph
880.3 m
62.4 mph
Front 114.5 m 64.8 mph
69.7 mph
27.0 m
Passenger car
70.9 mph
2.9 m
Passenger car
400
200
100
65.2 MPH
Speed Limit 65
Throttle
Brake
Engine Brake
Foundation Brake
01:00:37
01:18:54
01:00:18
01:18:54


View
150m
/visitor/det/cam4
/visitor/det/cam6
/visitor/det/cam7
/visitor/lidar
Autonomous Driving On
/visitor/det/cam4
/visitor/lidar
/visitor/det/cam7
/visitor/det/cam6
Emergency 237.2 m 0.0 mph
Front 102.0 m 59.7 mph
Target front 21.8 m 66.4 mph
65.9 mph
45.5 m
Passenger car
66.4 mph
59.7 mph
70.3 mph
0.0 mph
708.1 m
Passenger car
400
200
100
65.0 MPH
Speed Limit 65
Throttle
Brake
Engine Brake
Foundation Brake
01:00:51
01:18:54
01:00:18
01:18:54

From algorithm to product

- Effective algorithms always have an impact on products
- Why most academic papers are not applicable
  - False positive/false negative cost
  - Indirect implications/narrow application
  - Computational/implementation cost

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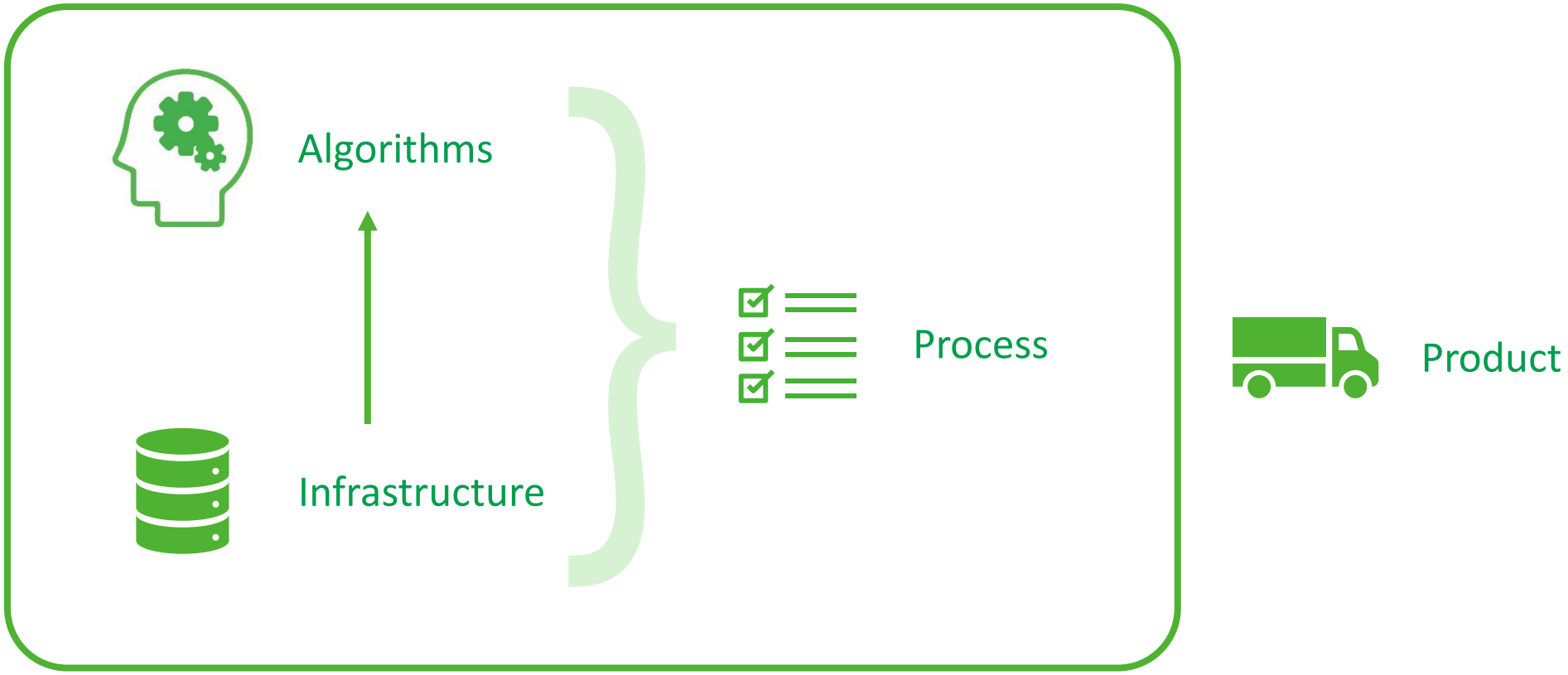
Infrastructure and process



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What do we need

- Infrastructure
  - Big data, deep learning
  - Simulation, real-time systems
- Process
  - Data annotation, vehicle testing
  - Continuous integration, benchmarking

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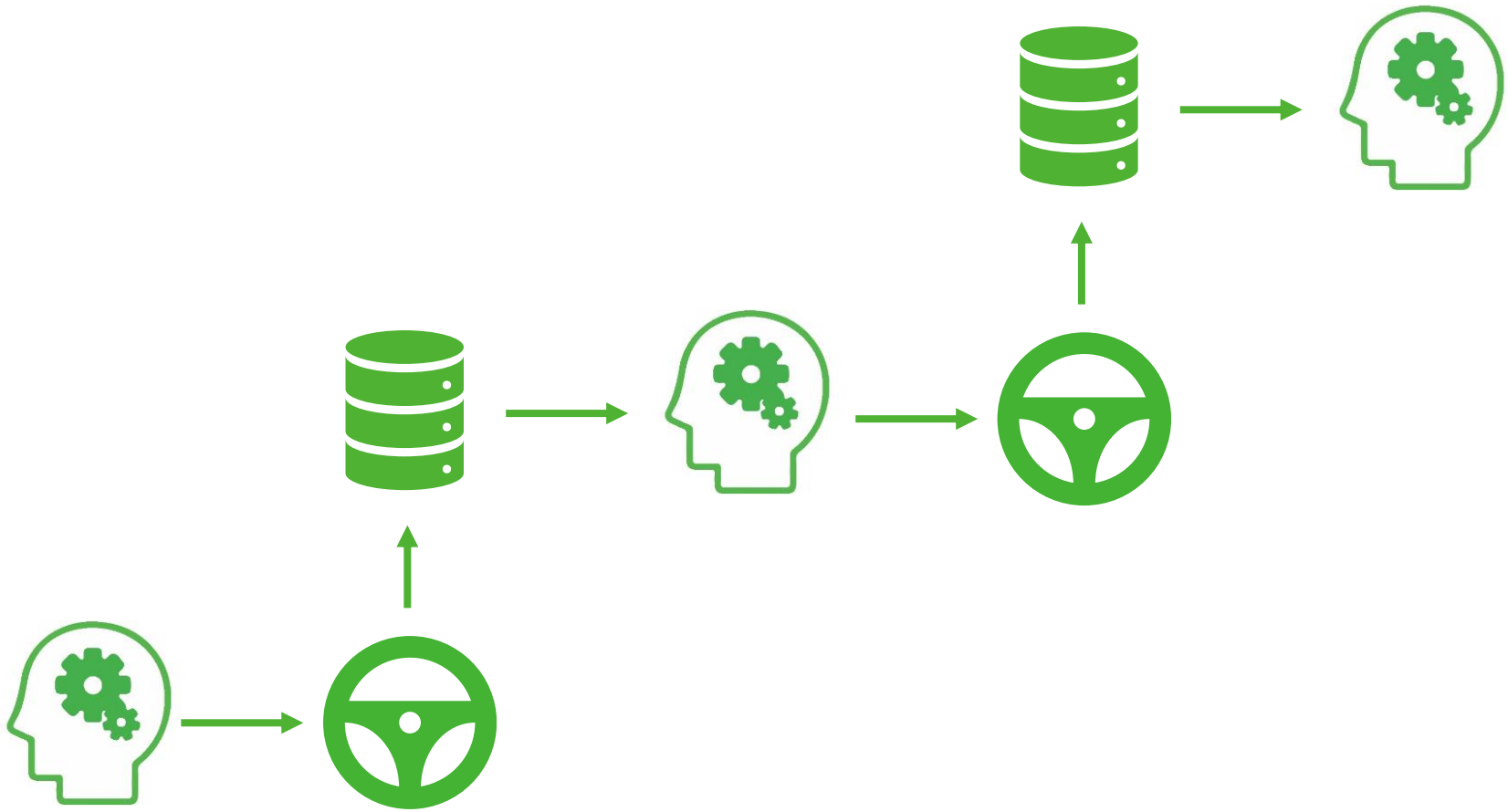
What do we REALLY need



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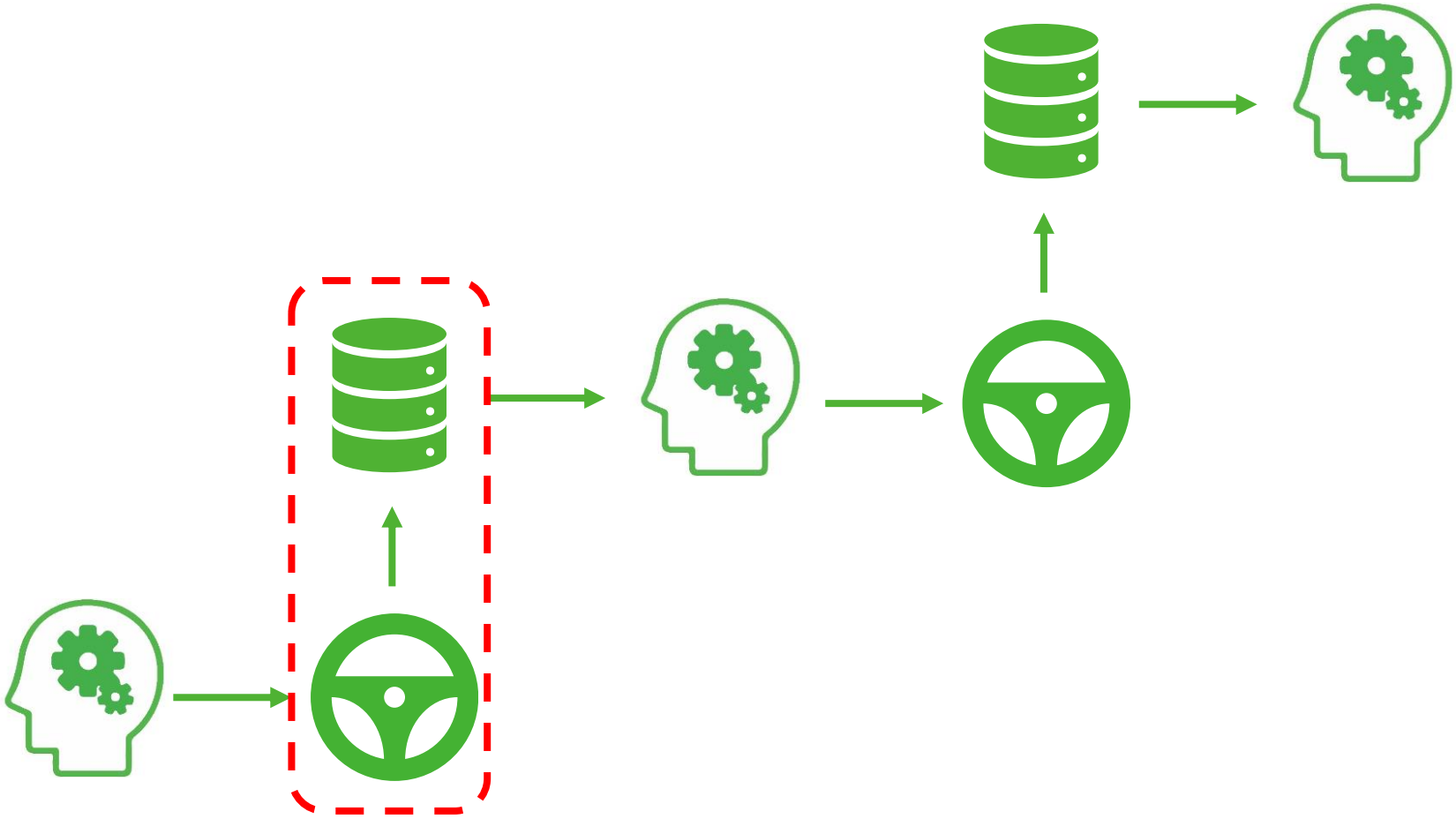
On big data



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Trucks can generate big data cheaply

- Mileage accumulation:
  - 45 miles/hr * 20hr/day * 25day/mo = 22,500 miles/mo
- Cost-per-mile
  - $1.8/mile operating cost - $1.6/mile revenue = $0.2/mile
- Sampling density
  - Fixed routes (1D structure)

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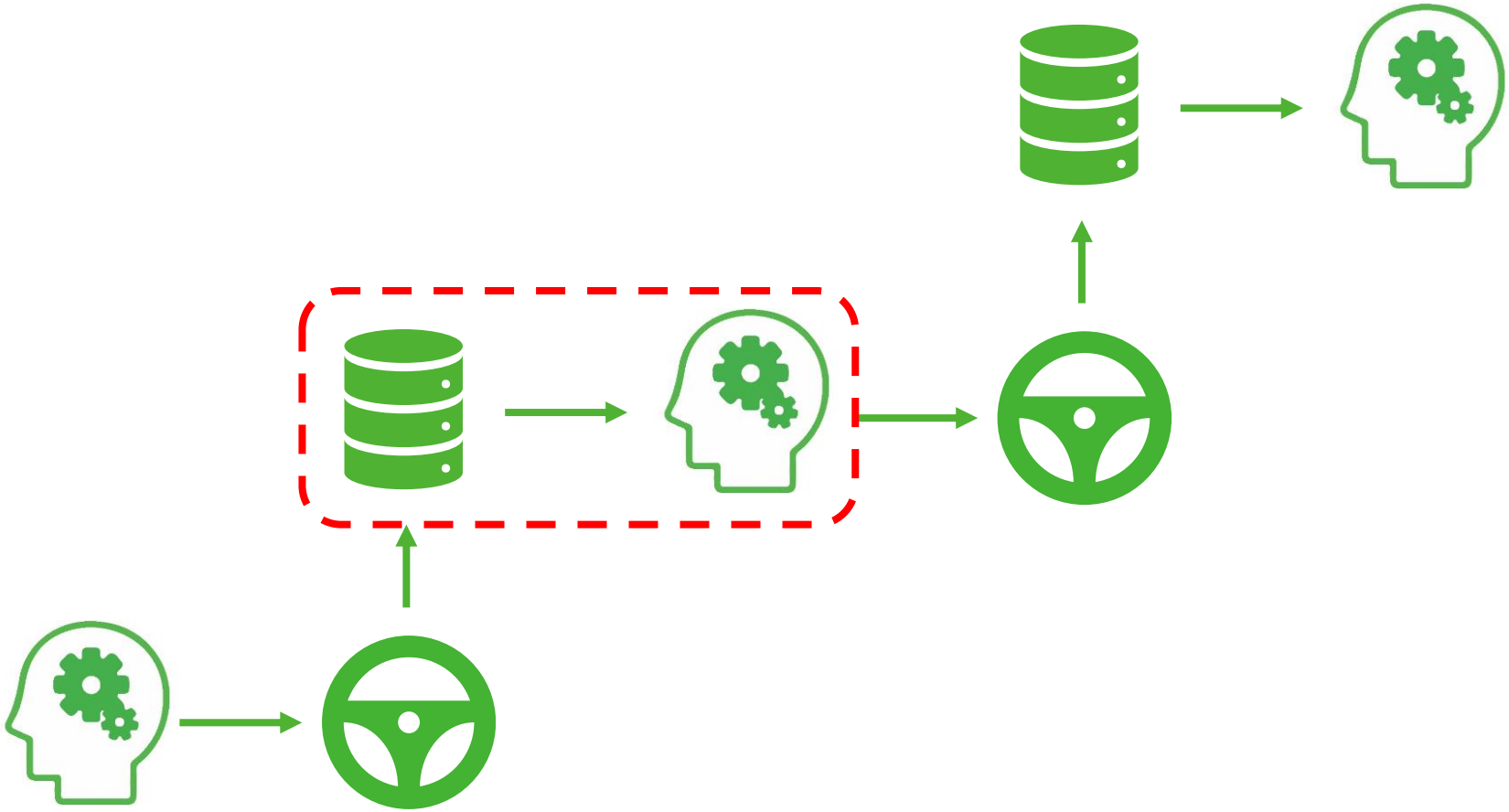
On data digestion



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“Divide and conquer”?

- Software engineering methodology
- Easy to scale-up the dev team
  - 3x resources = 3 problems to be solved (patched) simultaneously
- Steady progress
  - Regression test

“Divide and conquer” won’t work

- AI systems are not typical software systems
  - Every node contributes to the **noise**, without making an **error**
  - Team division precludes architectural evolution
- How many cases must a system fix, before you call it level-4?
  - Every “fix” is a technical debt, making future fixes harder

TuSimple's design philosophies

- AI engineering is missing

  coding : software engineering

  algorithm : AI engineering

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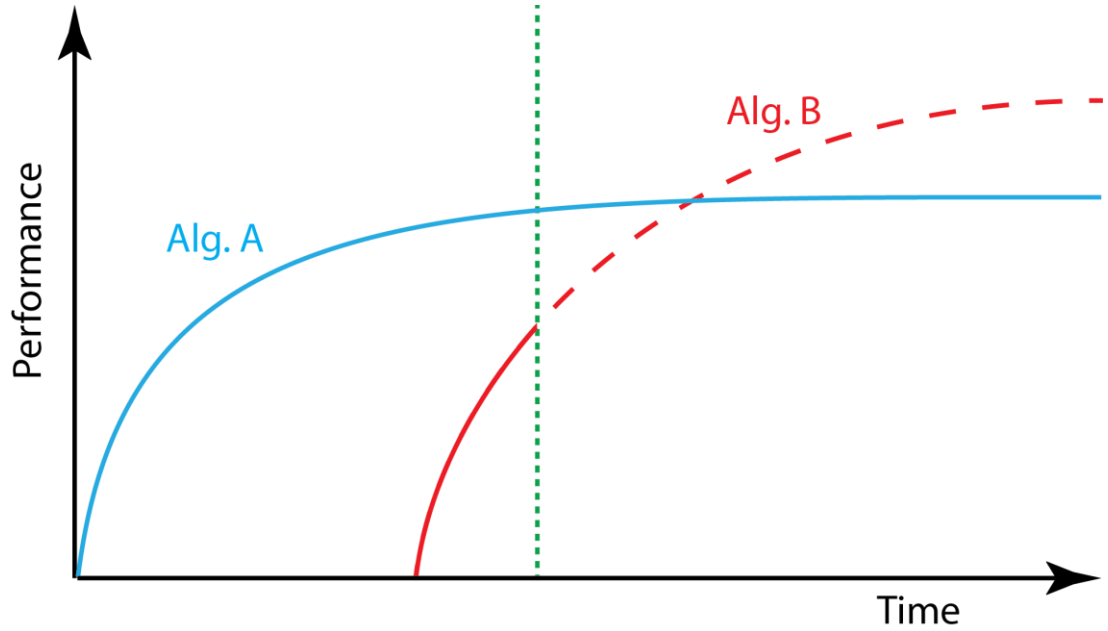
TuSimple's design philosophies

- All about **generalization**
  - Each corner case is a reminder
  - Regression tests



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The evolution of autonomous driving systems

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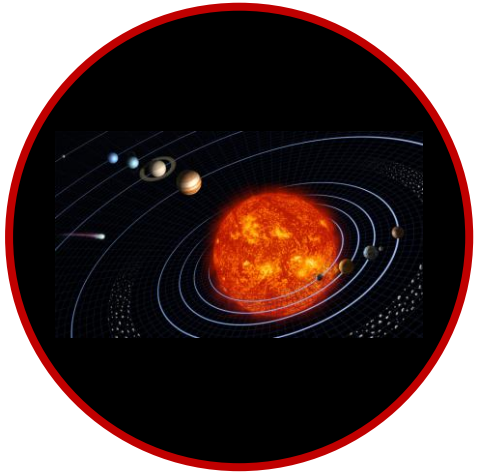
The Kardashev scale

Type I civilization: 10^{16} W



Type II civilization: 10^{26} W

Type III civilization: 10^{36} W

Comparable infrastructure & process



	Single vehicle	5 vehicle fleet	50 vehicle fleet
Raw data transfer	Flash disk	Command-line + networking	Fully automated pipeline
Algorithm deployment	In vehicle deploy/debug	Manual deployment of packages	Fully automated pipeline
Road testing	Superior driver	Superior driver + protocol	Protocol-based test + conservative AI
Data digestion	Naked eye	Hashtag	Statistical learning based development

No matter how much funding, or how many algorithm geniuses you have, you can’t build a level 4 product with shaky infrastructure/process.

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The missing evaluation metrics

How about Miles-Per-Intervention (MPI)

§ 227.50. Reporting Disengagement of Autonomous Mode.

(a) Upon receipt of a Manufacturer's Testing Permit or a Manufacturer's Testing Permit - Driverless Vehicles, a manufacturer shall commence retaining data related to the disengagement of the autonomous mode. For the purposes of this section, “disengagement” means a deactivation of the autonomous mode when a failure of the autonomous technology is detected or when the safe operation of the vehicle requires that the autonomous vehicle test driver disengage the autonomous mode and take immediate manual control of the vehicle, or in the case of driverless vehicles, when the safety of the vehicle, the occupants of the vehicle, or the public requires that the autonomous technology be deactivated.

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Interpretations

disengagements are not related to safety. Our test drivers routinely transition into and out of autonomous mode many times throughout the day, and the self-driving vehicle's computer hands over control to the driver in many situations that do not involve a failure of the autonomous technology and do not require an immediate takeover of control by the driver.

and other vehicles drifting into the AV's lane. [redacted] regularly reviews autonomous mode disengagements to assess which events are required to be reported. Most of our disengagements do not involve a failure of the autonomous technology and do not require an immediate takeover of control by the driver. As our self-driving technology continues to grow more

How far are we to achieve driverless automation?

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Two types of the fleet

- Validation
  - Stable release of hardware + software
  - Sufficient coverage of the operational design domain
  - Significant sampling density

Two types of the fleet

- Development
  - Ex[illegible]ed t[illegible]
  - Rapid [illegible]ions
  - S[illegible]ific don[illegible] and scenarios to check

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Understanding interventions

- Inefficient maneuvers: benign
  - waiting too long, detour, slowing down, stopped at the roadside
- Traffic rule violations: costly
  - Stopped in the lane, failed to yield
- Accidents: critical

We need a better MPI metric

Critical intervention (Cal. DMV)

Costly intervention

Benign intervention

- Why do we care?
  - Regulators, insurance companies, investors, and AI companies

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Thanks

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