Inside a Self-Driving Uber

Matt Ranney
March 6, 2018

1.3 million people die in car crashes every year.

NHTSA

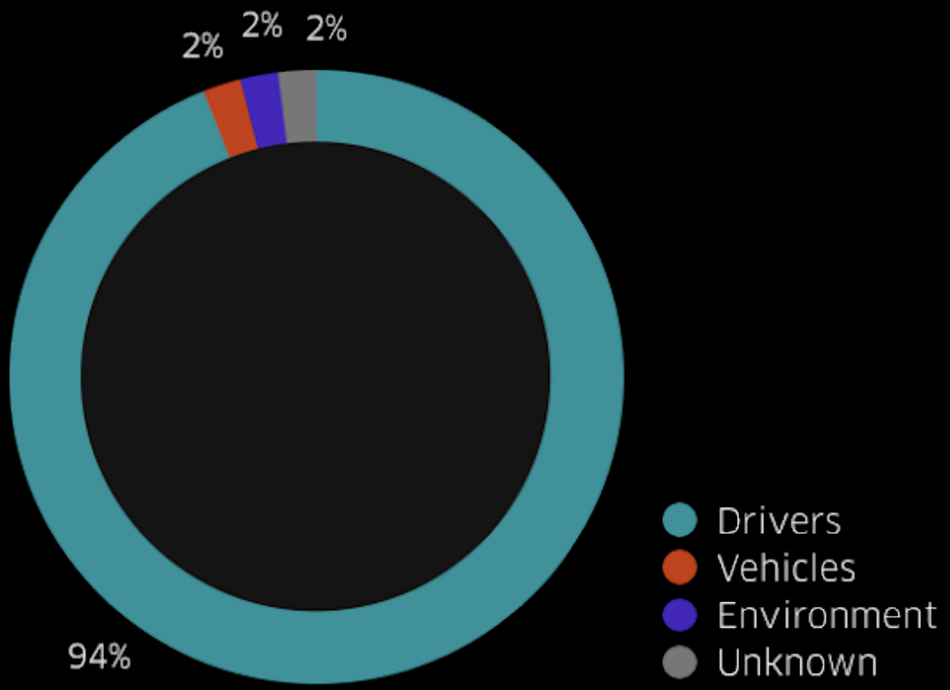
Top 10 Leading Causes of Death in the United States in 2015, by Age Group[1]

National Highway Traffic Safety Administration's National Center for Statistics and Analysis

RANK	Cause and Number of Deaths											Years of Life Lost[2]
	Infants Under 1	Toddlers 1–3	Young Children 4–7	Children 8–15	Youth 16–20	Young Adults 21–24	Other Adults 25–34	Other Adults 35–44	Other Adults 45–64	Elderly 65+	All Ages	
1	Perinatal Period 11,613	Congenital Anomalies 389	Malignant Neoplasms 360	**MV Traffic Crashes 744**	**MV Traffic Crashes 3,114**	**MV Traffic Crashes 3,415**	Accidental Poisoning 11,231	Malignant Neoplasms 10,909	Malignant Neoplasms 159,176	Heart Disease 507,138	Heart Disease 633,842	Malignant Neoplasms 23% (9,426,319)
2	Congenital Anomalies 4,825	Homicide 329	**MV Traffic Crashes 279**	Malignant Neoplasms 694	Suicide 2,441	Accidental Poisoning 2,820	Suicide 6,947	Accidental Poisoning 10,580	Heart Disease 111,120	Malignant Neoplasms 419,389	Malignant Neoplasms 595,930	Heart Disease 19% (7,767,386)
3	Heart Disease 292	Accidental Drowning 316	Congenital Anomalies 168	Suicide 663	Homicide 2,027	Suicide 2,798	**MV Traffic Crashes 6,281**	Heart Disease 10,387	Chronic Liver Disease 22,152	CLRD[5] 131,804	CLRD[5] 155,041	CLRD[5] 5% (1,880,774)
4	Homicide 263	Malignant Neoplasms 273	Accidental Drowning 163	Homicide 307	Accidental Poisoning 1,075	Homicide 2,601	Homicide 4,863	Suicide 6,936	CLRD[5] 131,804	Stroke 120,156	Stroke 140,323	Accidental Poisoning 4% (1,832,709)
5	Septicemia 180	**MV Traffic Crashes 249**	Homicide 136	Congenital Anomalies 261	Malignant Neoplasms 614	Malignant Neoplasms 747	Malignant Neoplasms 3,704	**MV Traffic Crashes 4,652**	Diabetes 20,378	Alzheimer's 109,495	Alzheimer's 110,561	Suicide 4% (1,553,110)
6	Influenza/ Pneumonia 174	Heart Disease 132	Exposure to Smoke/Fire 70	Heart Disease 202	Heart Disease 352	Heart Disease 607	Heart Disease 3,522	Homicide 2,895	Accidental Poisoning 19,452	Diabetes 56,142	Diabetes 79,535	Stroke 4% (1,528,047)
7	Stroke 89	MV Nontraffic Crashes[4] 88	Heart Disease 61	Accidental Drowning 160	Accidental Drowning 261	Accidental Drowning 210	Chronic Liver Disease 844	Chronic Liver Disease 2,861	Stroke 17,423	Influenza/ Pneumonia 48,774	Influenza/ Pneumonia 57,062	MV Traffic Crashes 3% (1,349,898)
8	Nephritis/ Nephrosis 85	Influenza/ Pneumonia 76	CLRD[5] 55	CLRD[5] 135	Congenital Anomalies 181	Congenital Anomalies 159	Diabetes 798	Diabetes 1,986	Suicide 16,490	Nephritis/ Nephrosis 41,258	Nephritis/ Nephrosis 49,959	Diabetes 3% (1,237,459)
9	**MV Traffic Crashes 57**	Exposure to Smoke/Fire 73	MV Other/ Nontraffic Crashes[4] 43	MV Other/ Nontraffic Crashes[4] 91	MV Other/ Nontraffic Crashes[4] 101	MV Other/ Nontraffic Crashes[4] 129	Stroke 567	Stroke 1,788	**MV Traffic Crashes 10,043**	Septicemia 30,817	Accidental Poisoning 47,478	Chronic Liver Disease 2% (940,717)
10	Malignant Neoplasms 53	Perinatal Period[6] 45	Influenza/ Pneumonia 41	Exposure to Smoke/Fire 69	Accidental Falls 83	Accidental Falls 128	HIV 529	HIV 1,055	Septicemia 8,316	Accidental Falls 28,486	Suicide 44,193	Perinatal Period 2% (922,063)

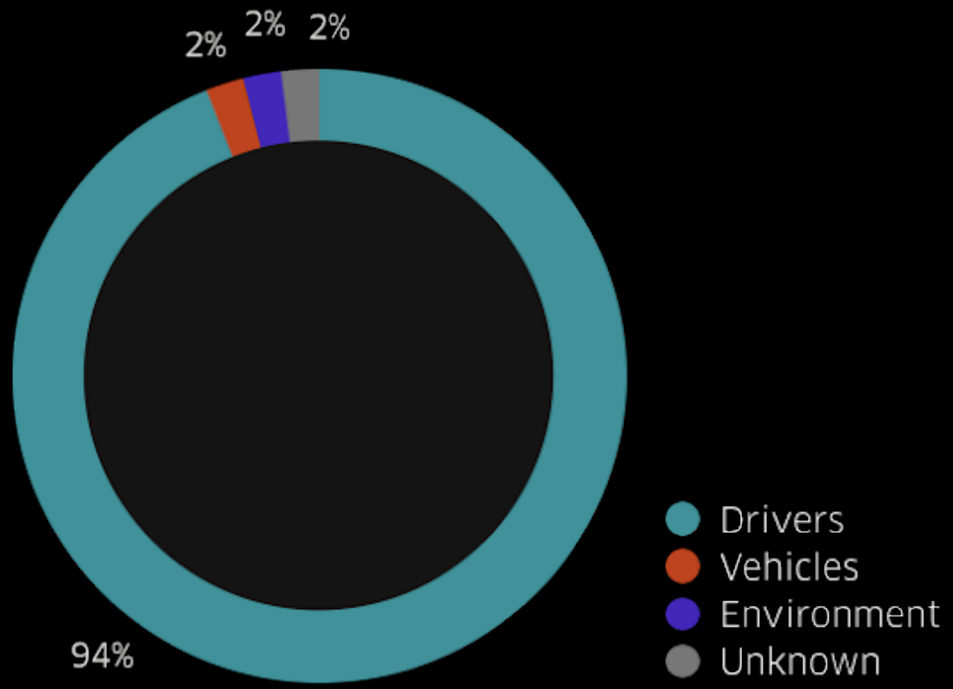
source: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812499

Drivers are the leading cause of critical pre-crash events

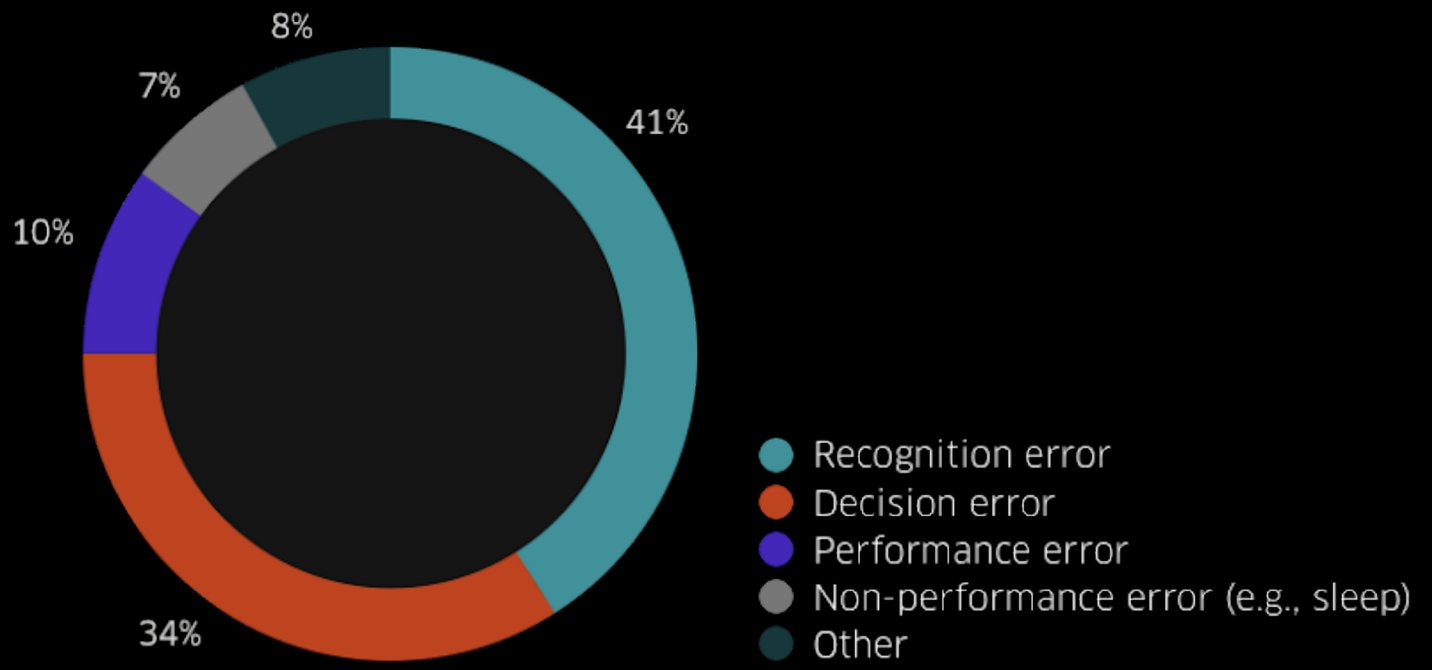


source: US National Highway Traffic Safety Administration
US only statistics for crash event causes

Drivers are the leading cause of critical pre-crash events



Recognition & decision error are the leading causes for these events



source: US National Highway Traffic Safety Administration
US only statistics for crash event causes

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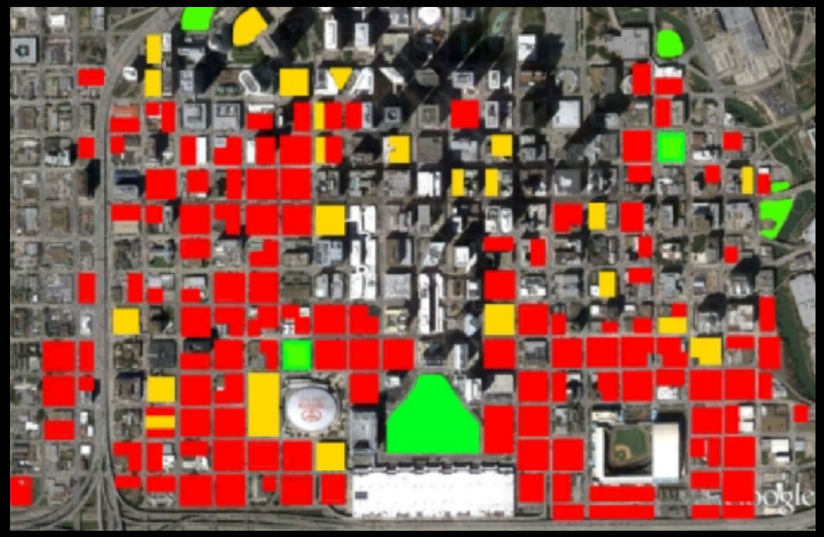


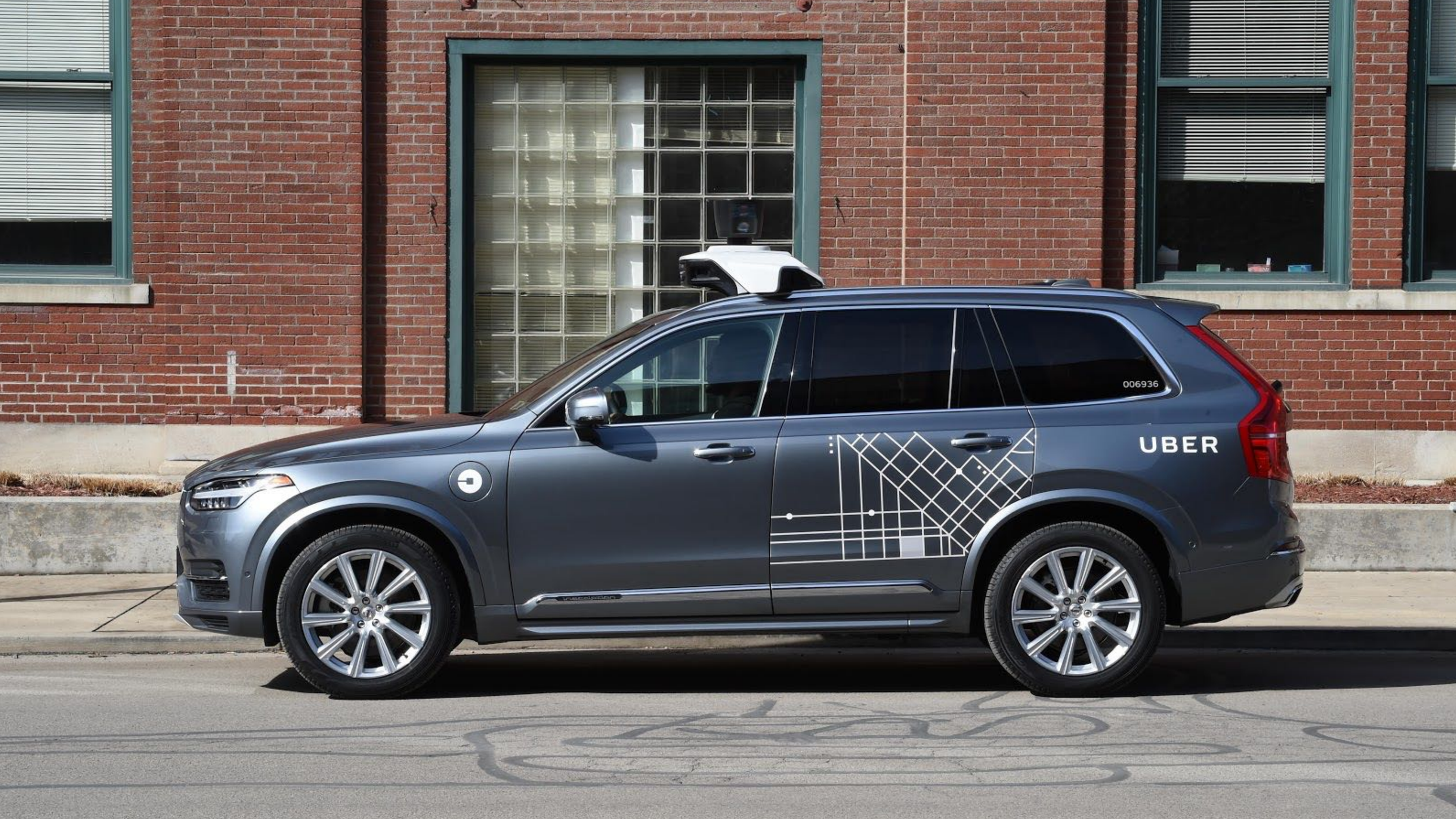
Houston, TX

Little Rock, AR

Source: Old Urbanist and photoLith

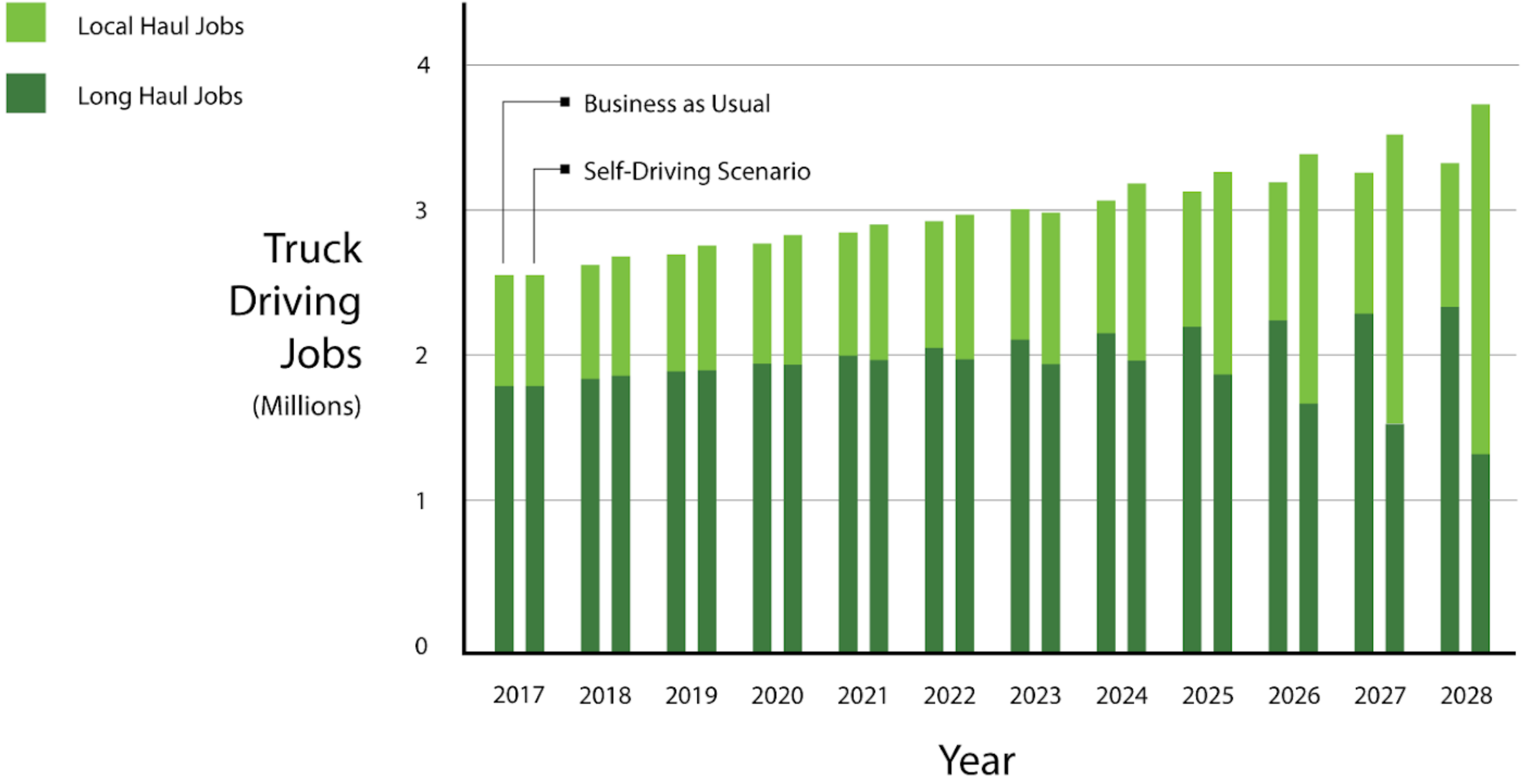
Self-driving cars will make our roads safer.

Self-driving cars will give us our time and space back.


006936
UBER

Cesar Chavez St
Potrero Avenue
NEXT EXIT
SPEED LIMIT 50

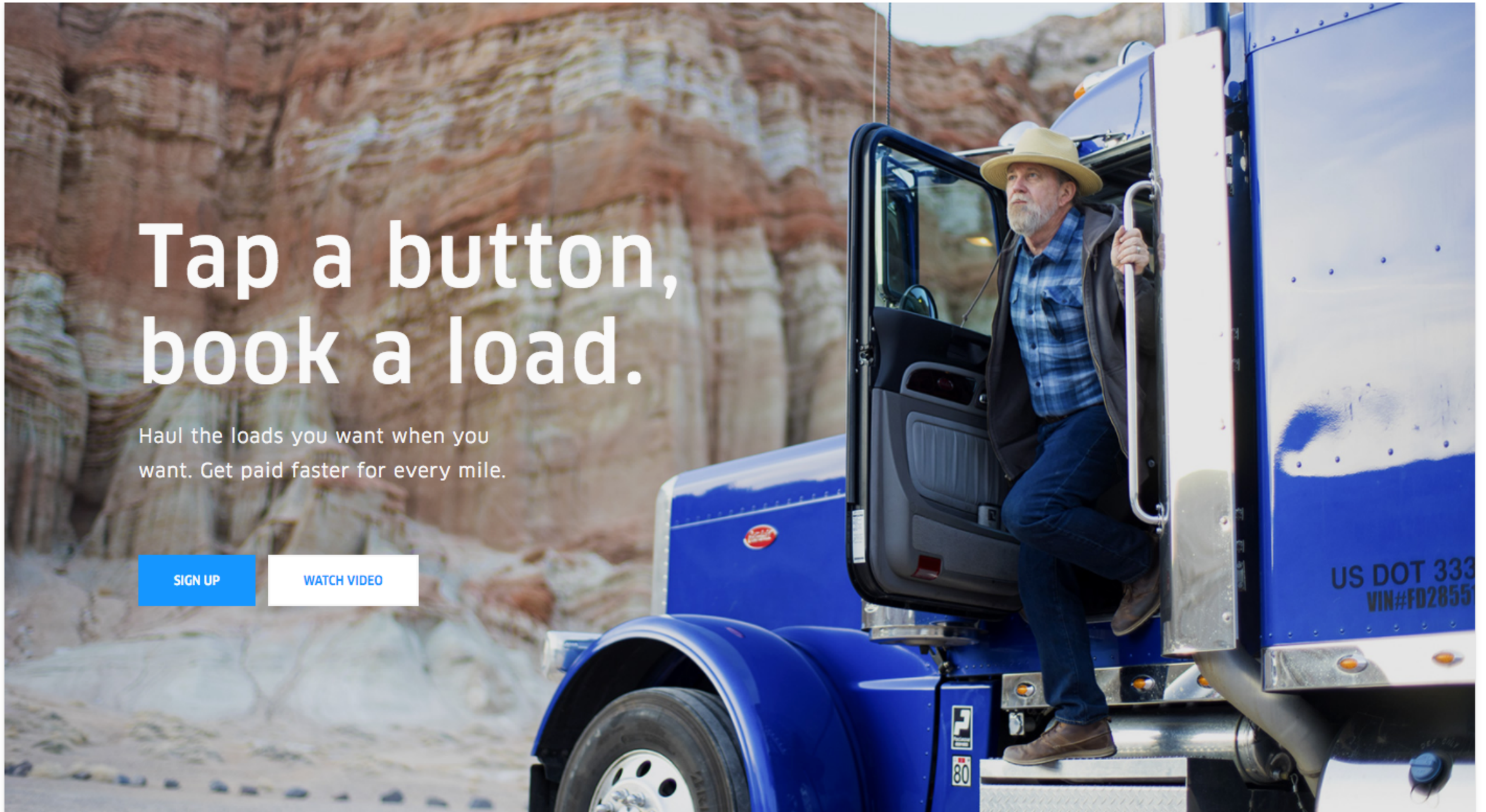
Cesar Chavez St
Potrero Avenue
NEXT EXIT
SPEED LIMIT 50



Source: https://medium.com/@UberATG/the-future-of-trucking-b3d2ea0d2db9

UBER FREIGHT

Product FAQ Careers Contact SIGN UP



Tap a button, book a load.

Haul the loads you want when you want. Get paid faster for every mile.

SIGN UP WATCH VIDEO

Hardware

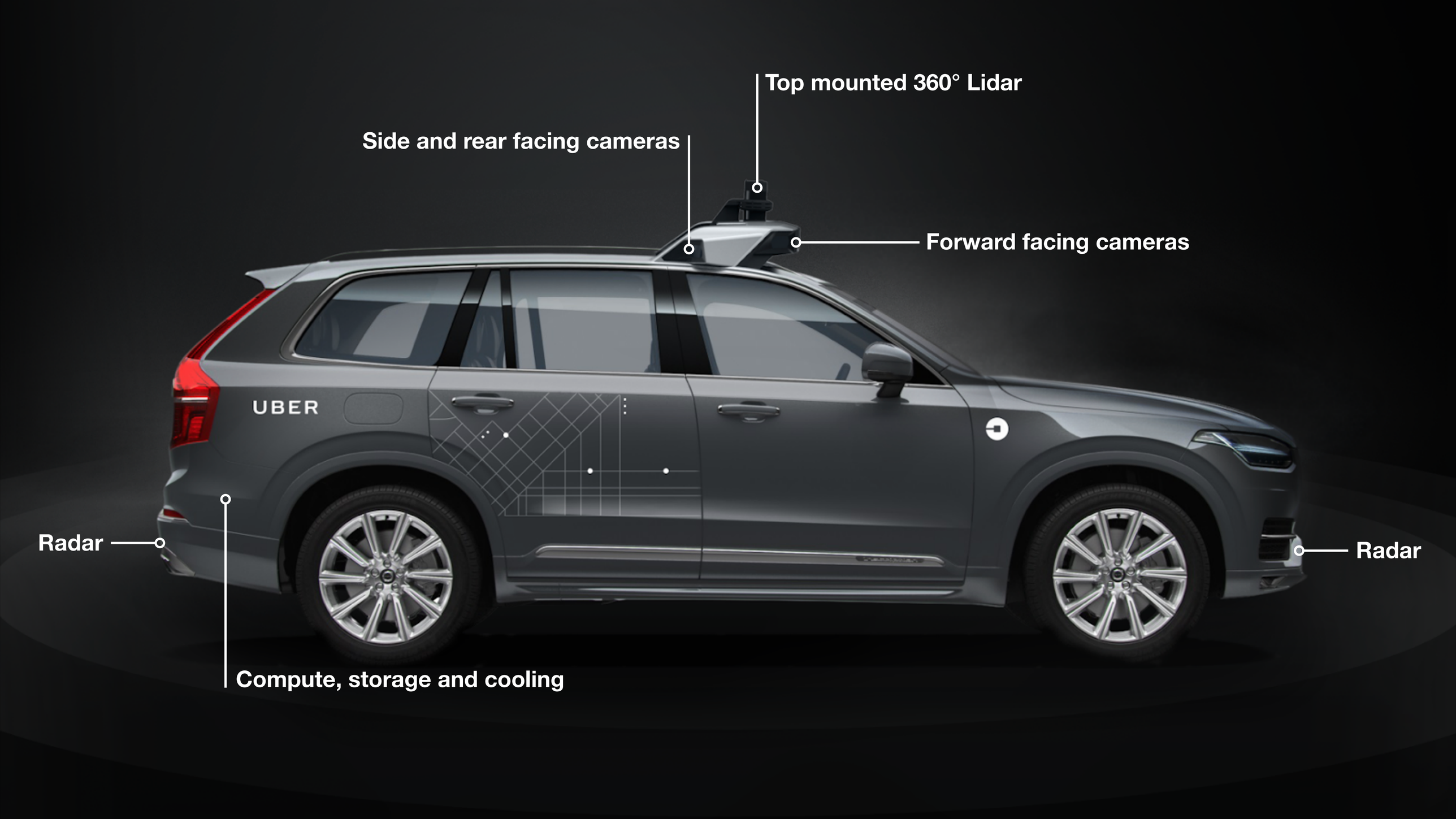
UBER

Top mounted 360° Lidar
UBER

Top mounted 360° Lidar
Forward facing cameras
UBER

Top mounted 360° Lidar
Side and rear facing cameras
Forward facing cameras
UBER

Top mounted 360° Lidar
Side and rear facing cameras
Forward facing cameras
UBER
Radar
Radar


Top mounted 360° Lidar
Side and rear facing cameras
Forward facing cameras
UBER
Radar
Radar
Compute, storage and cooling

You got a
Self-Driving Uber!
REQUEST DIFFERENT UBERX
SOUNDS GOOD!

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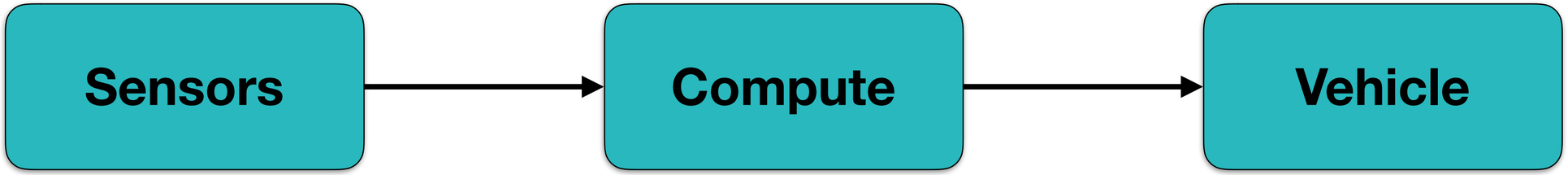
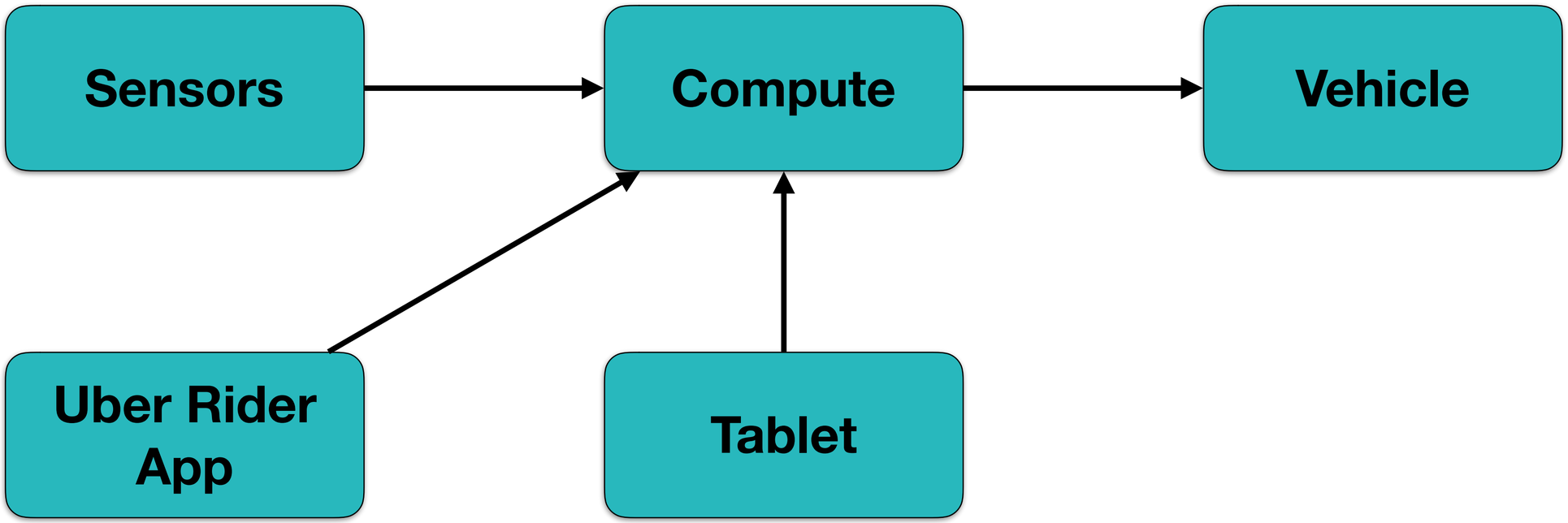
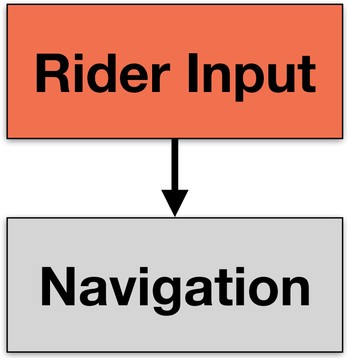
SOUNDS GOOD!

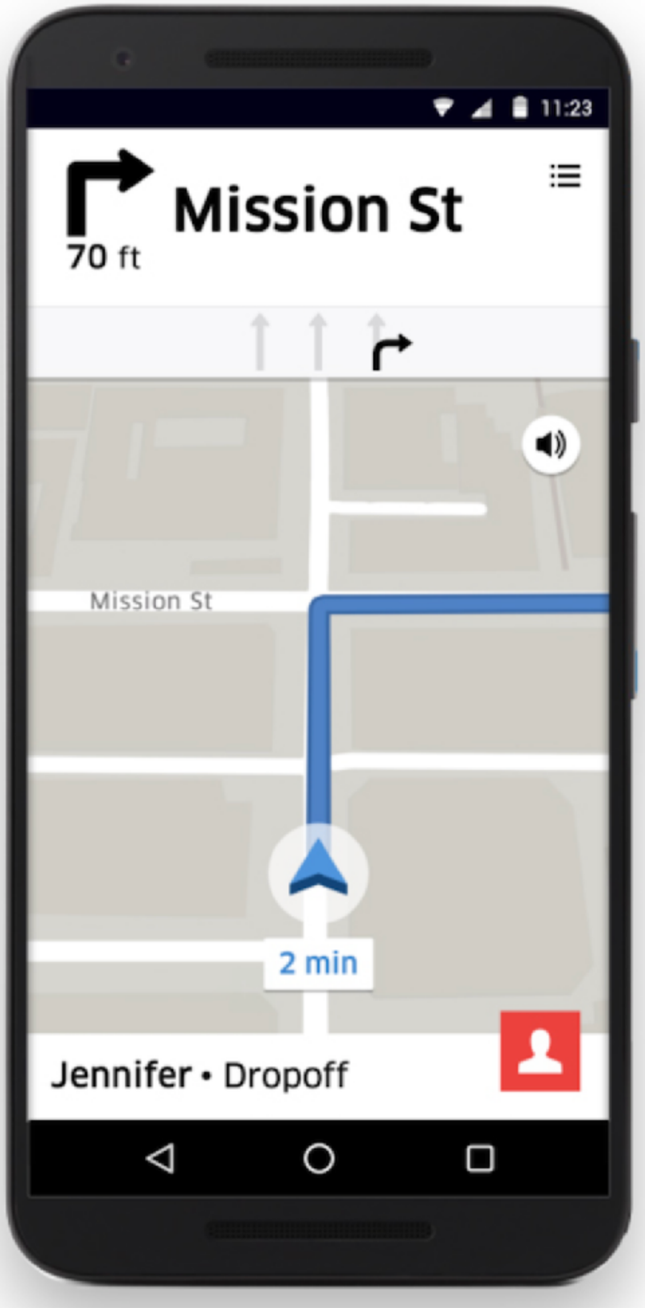

Sensors
Compute
Vehicle

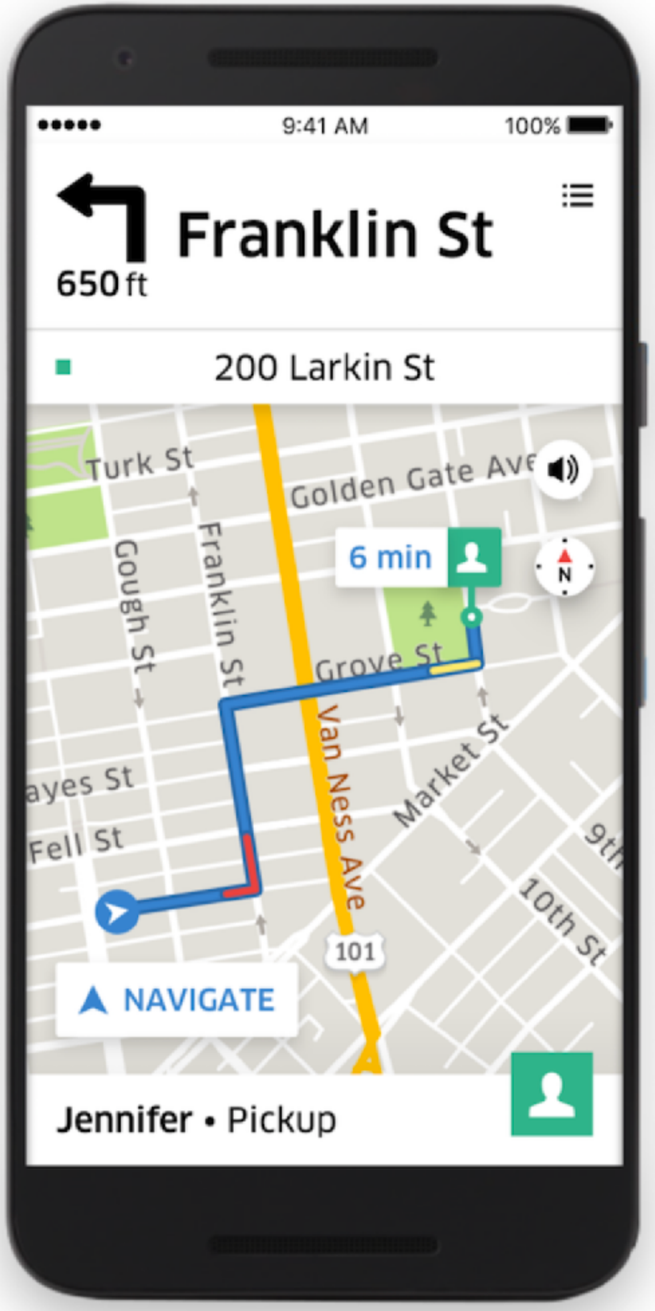

Sensors
Compute
Vehicle
Uber Rider App
Tablet

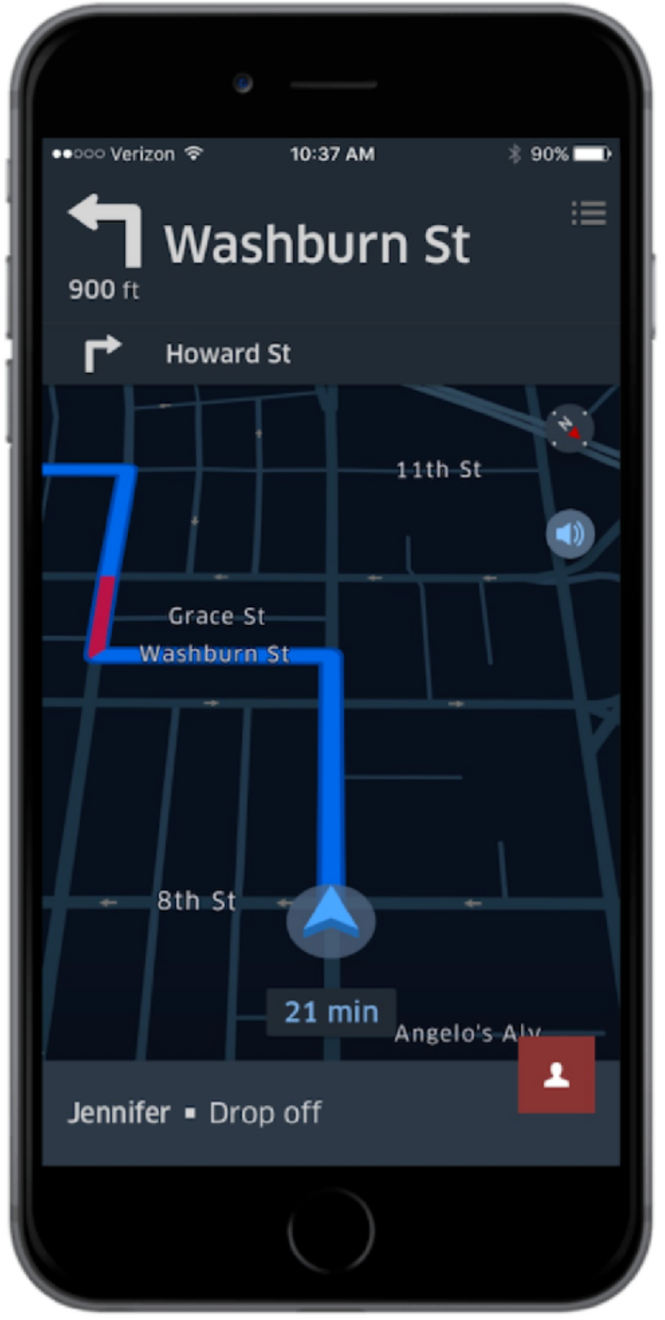
Software

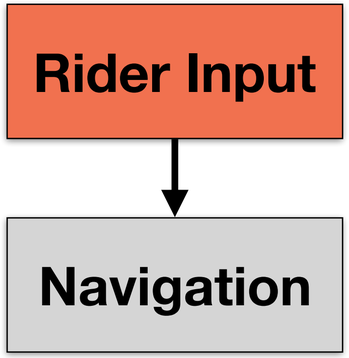
Rider Input

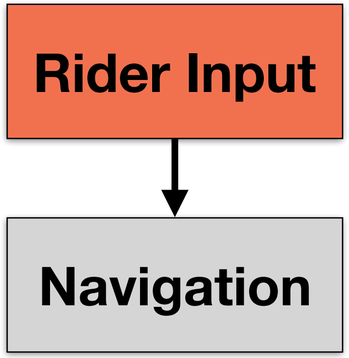

Rider Input
Navigation


11:23
Mission St
70 ft
Mission St
2 min
Jennifer • Dropoff

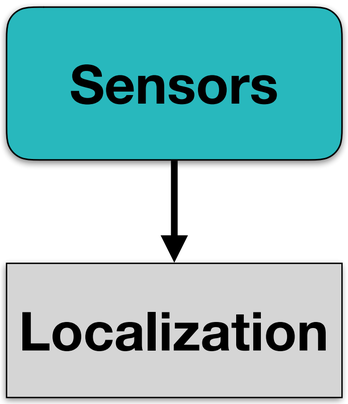

9:41 AM
100%
Franklin St
650 ft
200 Larkin St
Turk St
Golden Gate Ave
Gough St
Franklin St
6 min
Grove St
Van Ness Ave
Market St
Fell St
10th St
101
NAVIGATE
Jennifer • Pickup

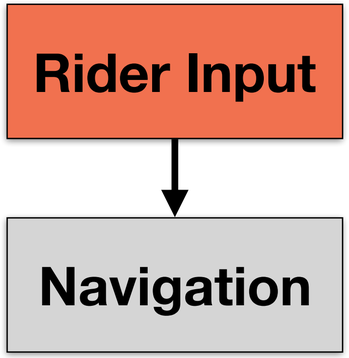

Verizon
10:37 AM
90%
Washburn St
900 ft
Howard St
11th St
Grace St
Washburn St
8th St
21 min
Angelo's Aly
Jennifer ▪ Drop off

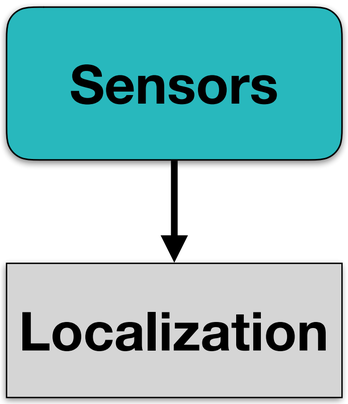

Rider Input
Navigation

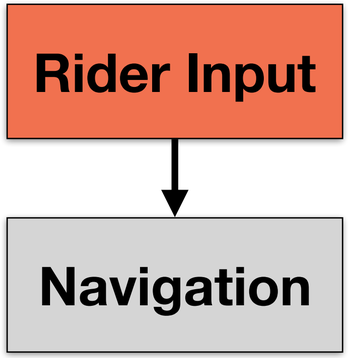


Sensors


Sensors
Localization


Rider Input
Navigation


Sensors
Localization


Rider Input
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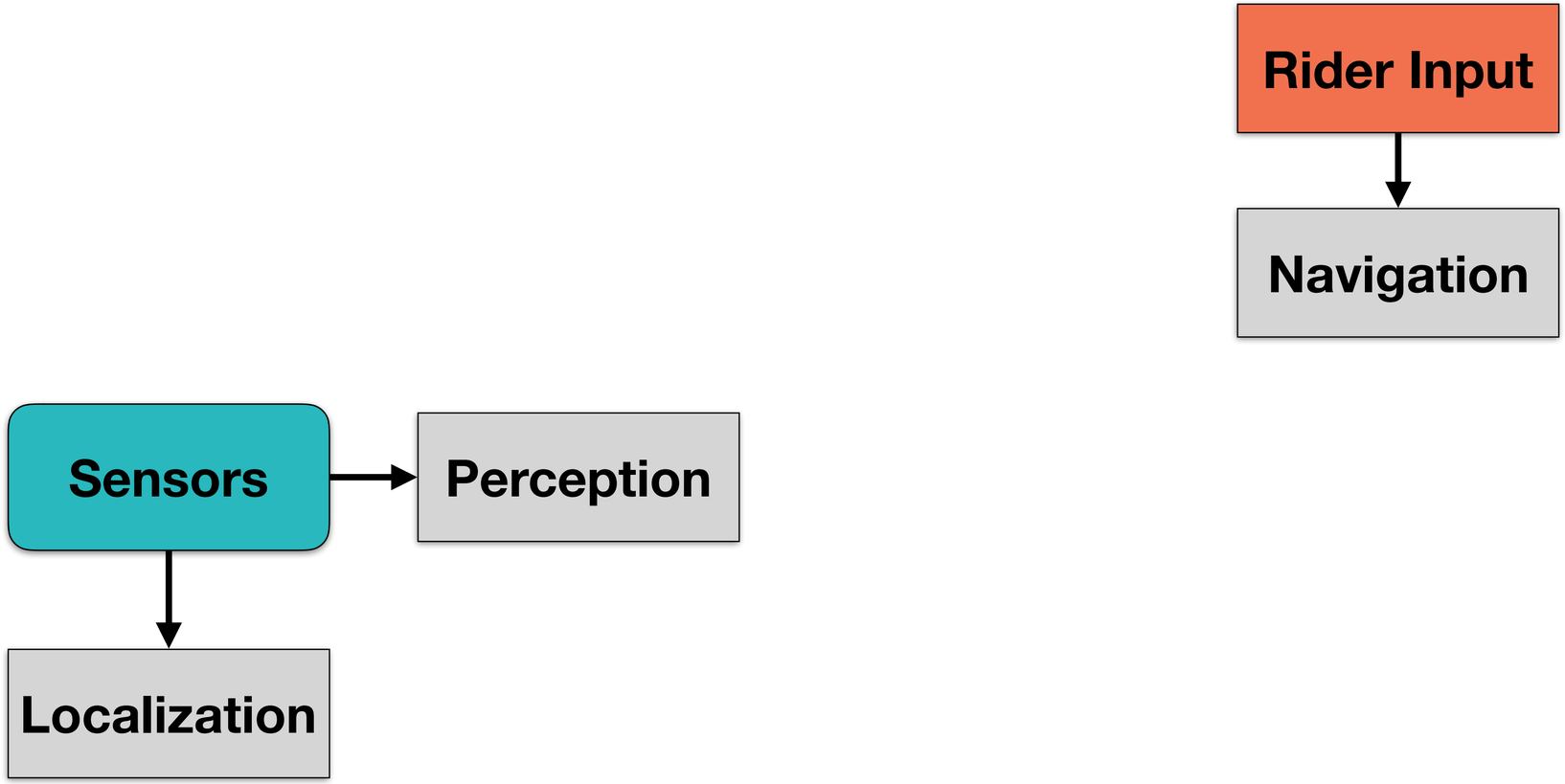
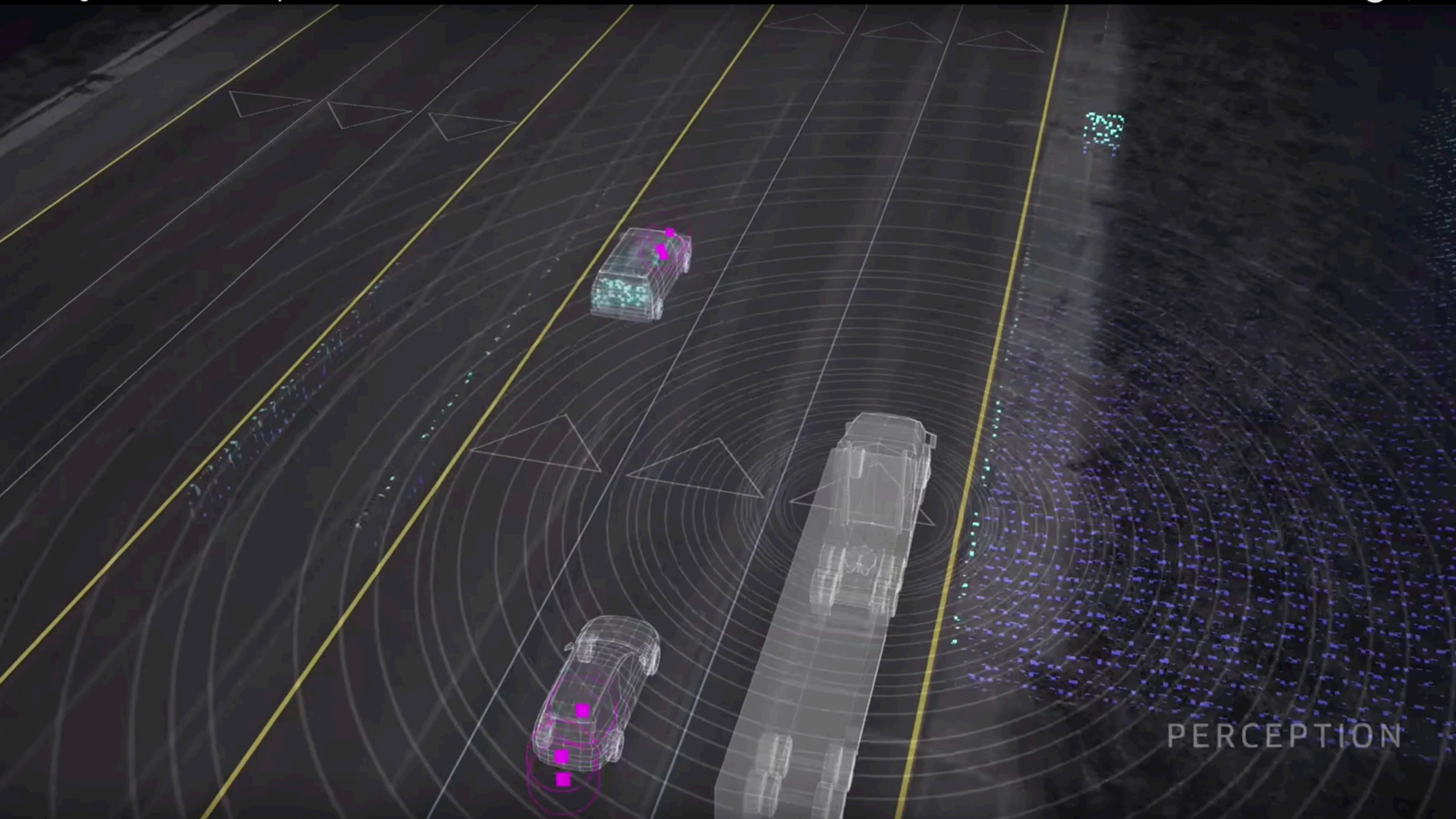

Rider Input
Navigation
Sensors
Perception
Localization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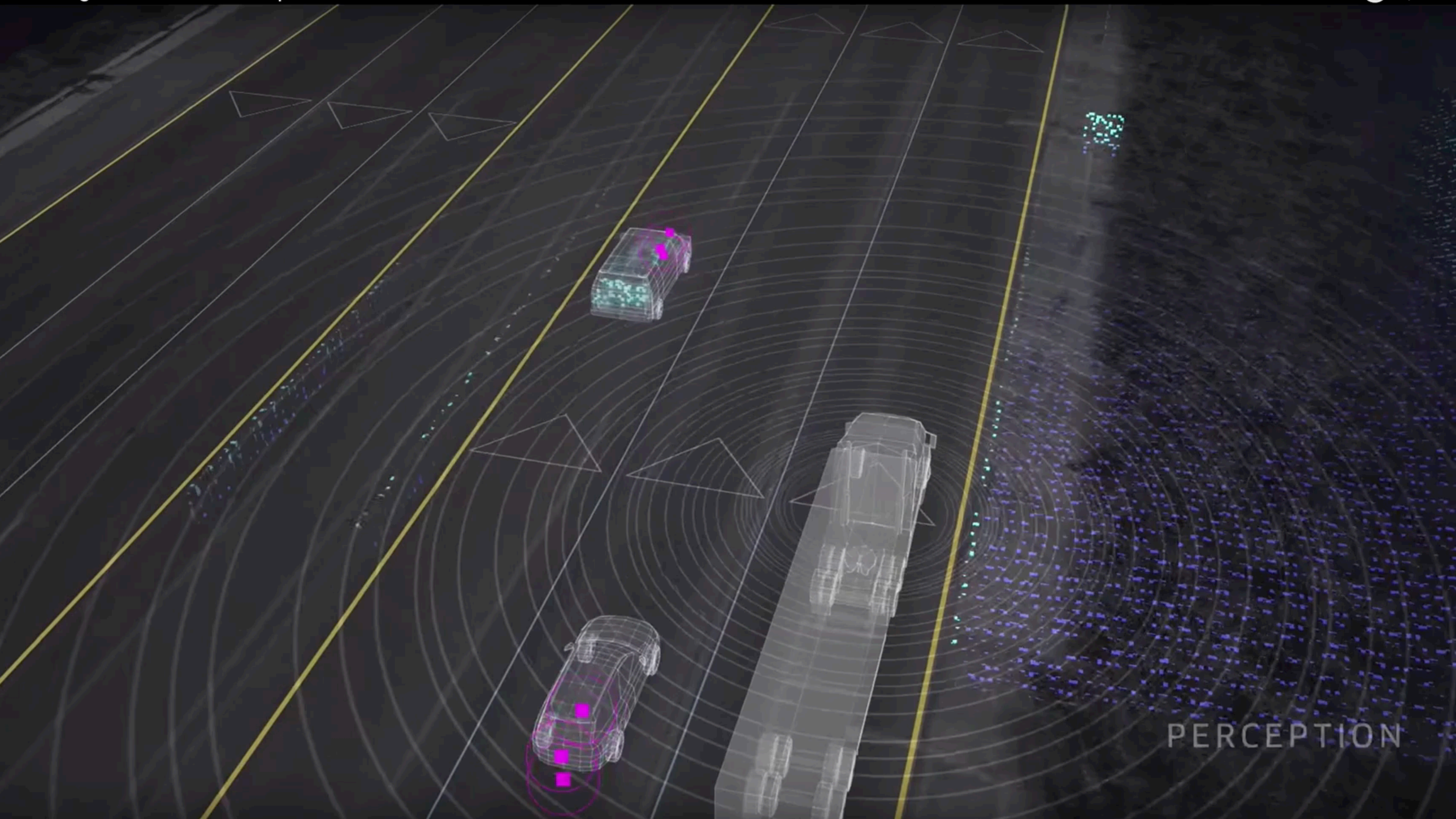
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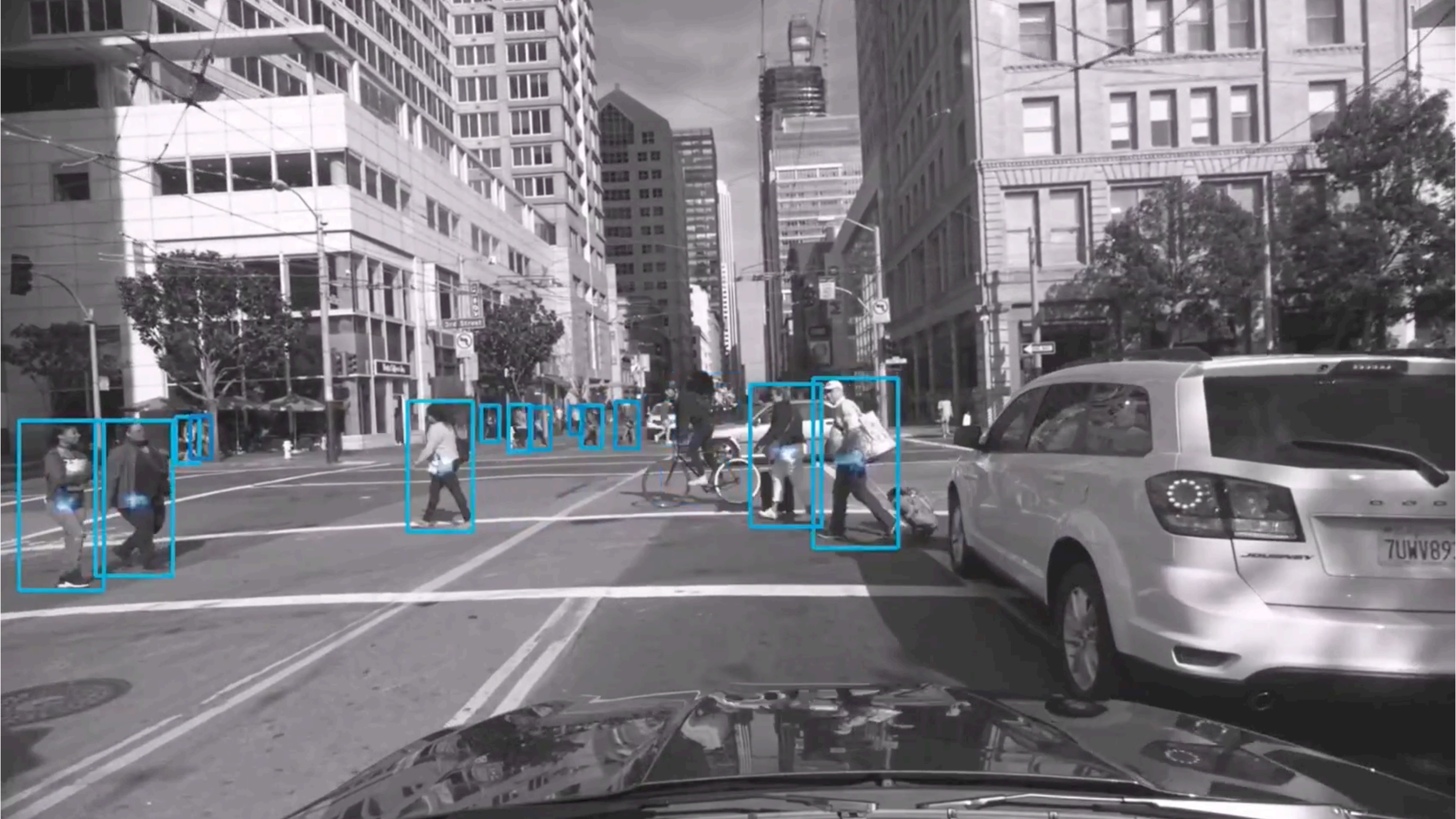
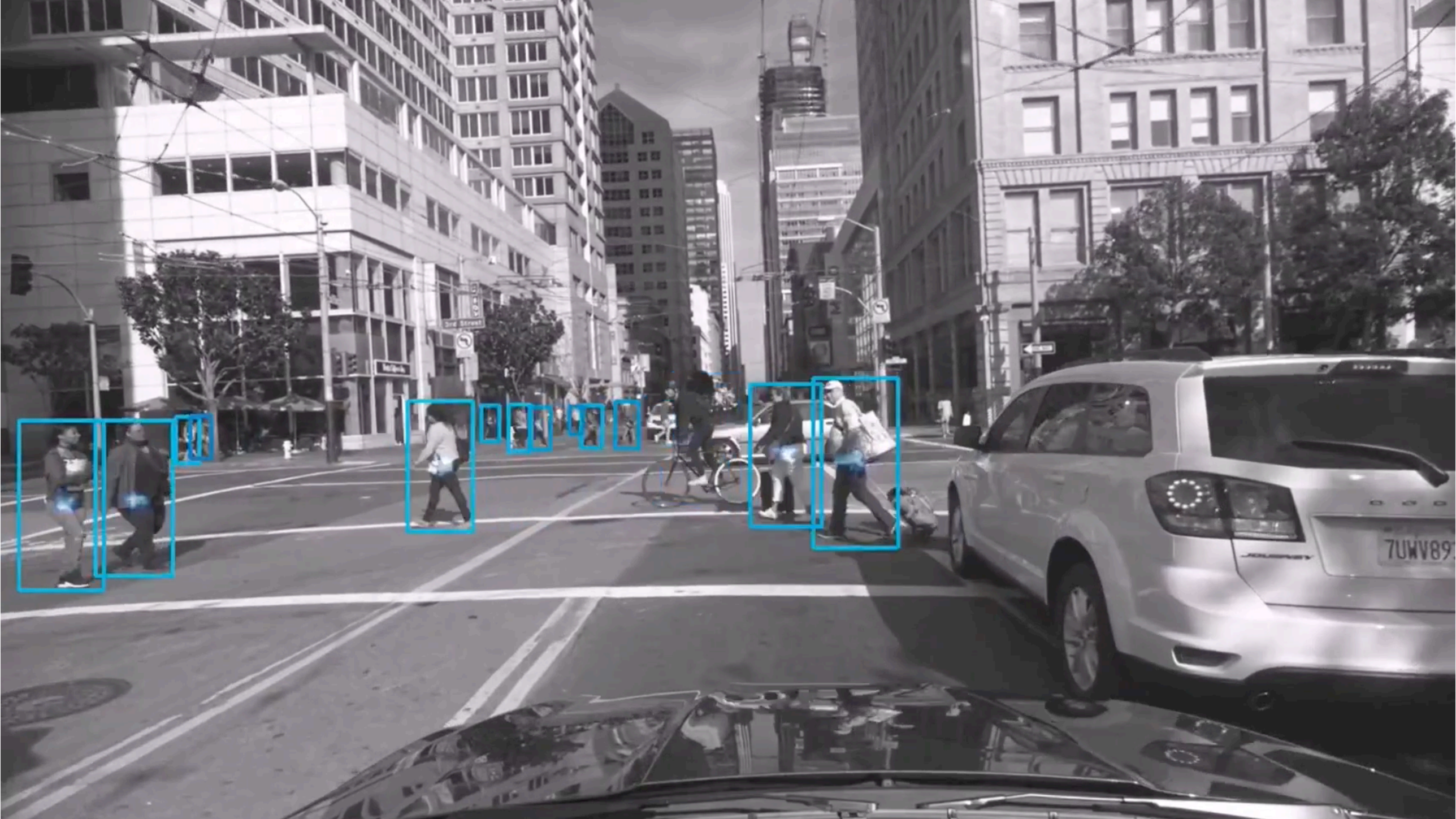
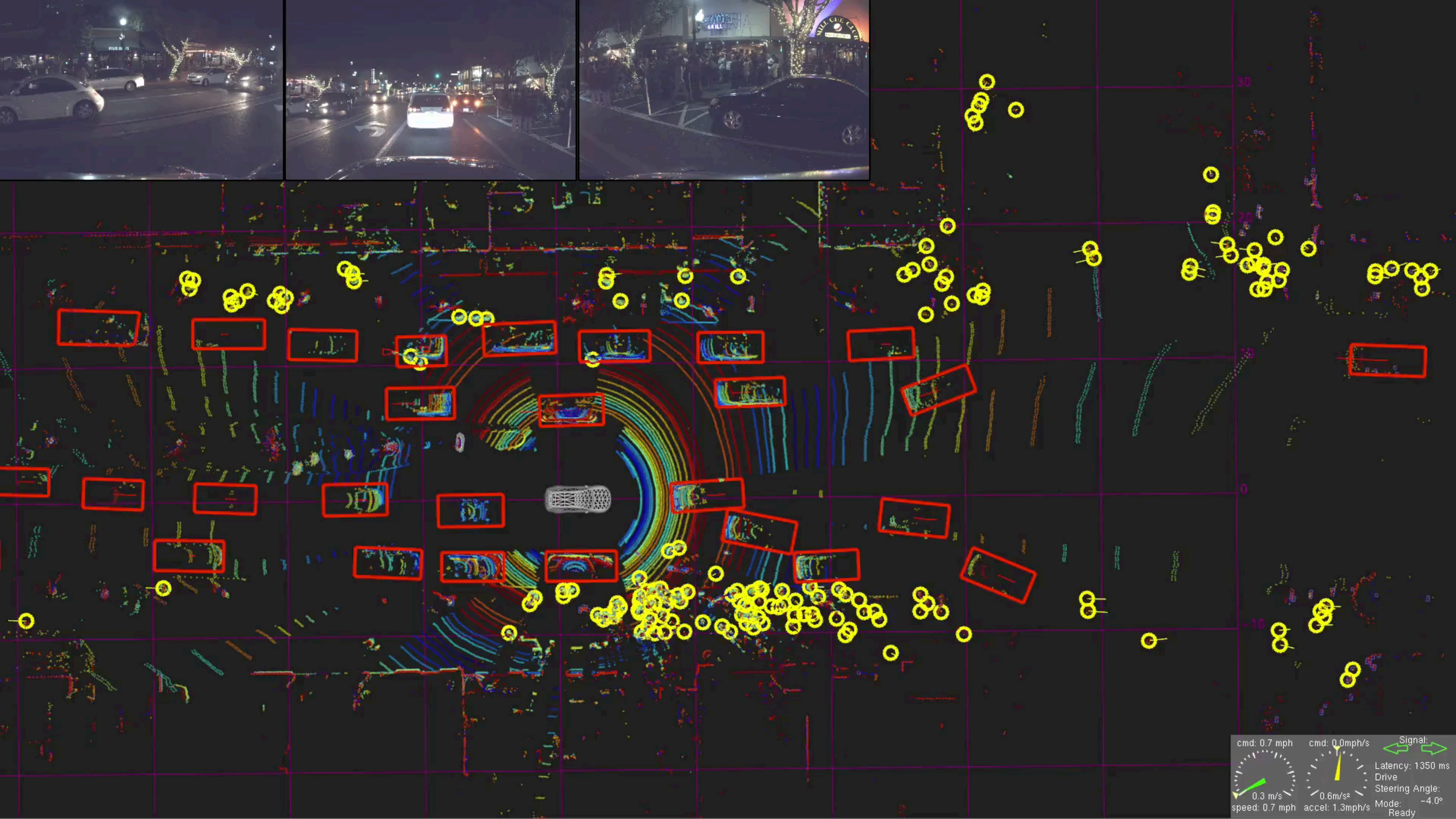




AUTO TECH
9th Street

AUTO TECH
9th Street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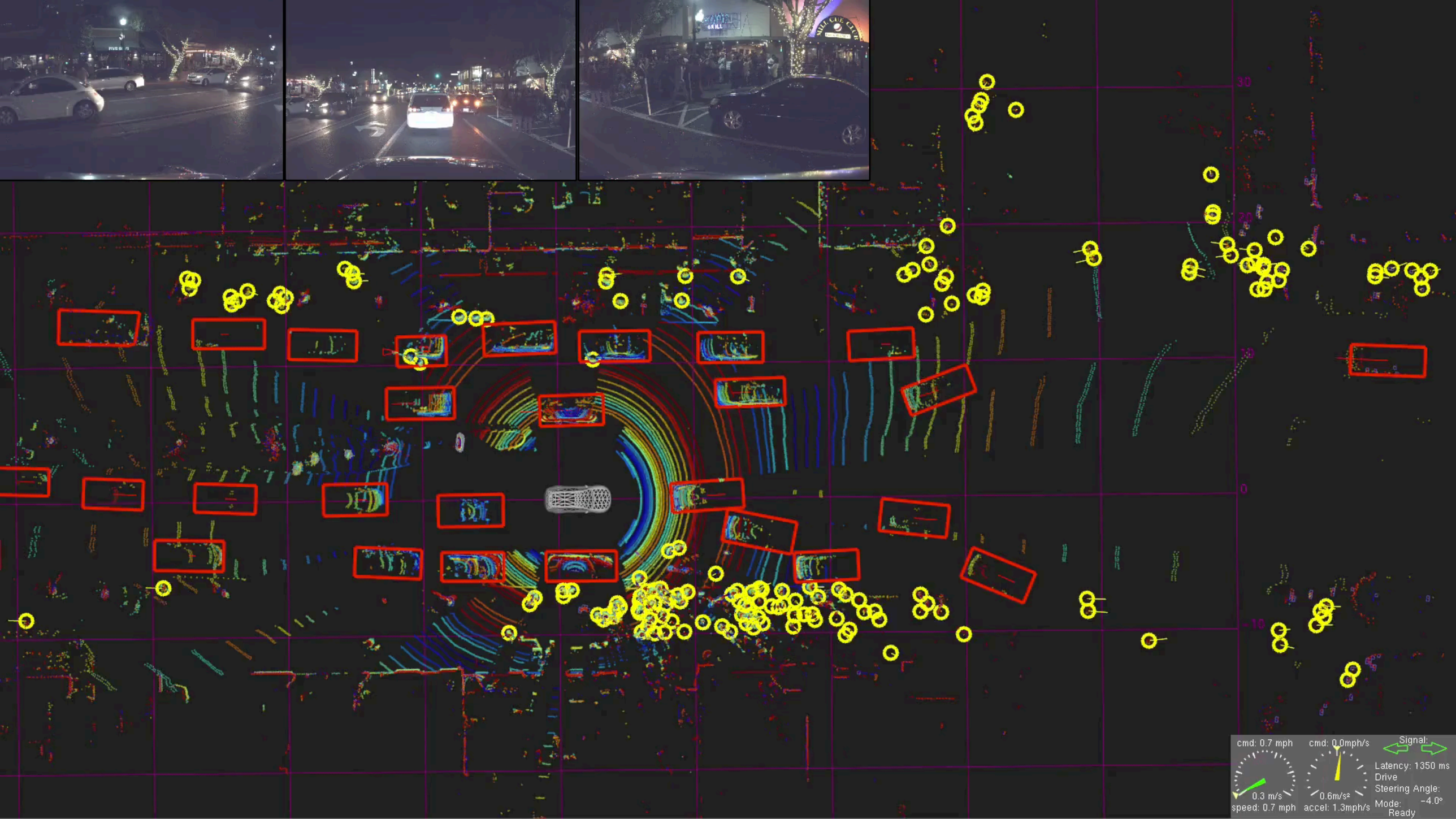
0.3 m/s
speed: 0.7 mph
cmd: 0.0mph/s
0.6m/s²
accel: 1.3mph/s
Signal:
Latency: 1350 ms
Drive
Steering Angle:
Mode: -4.0°
Ready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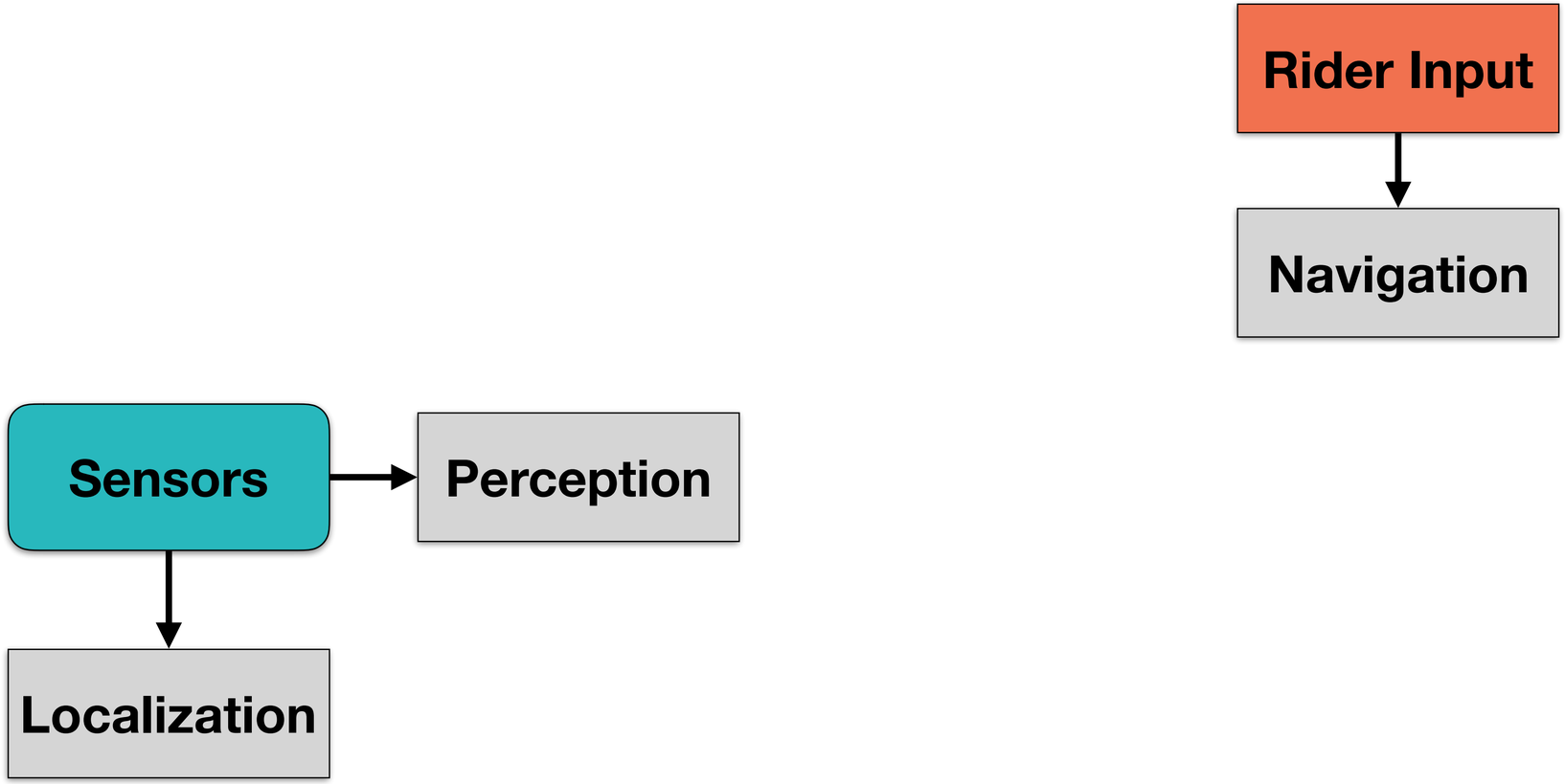
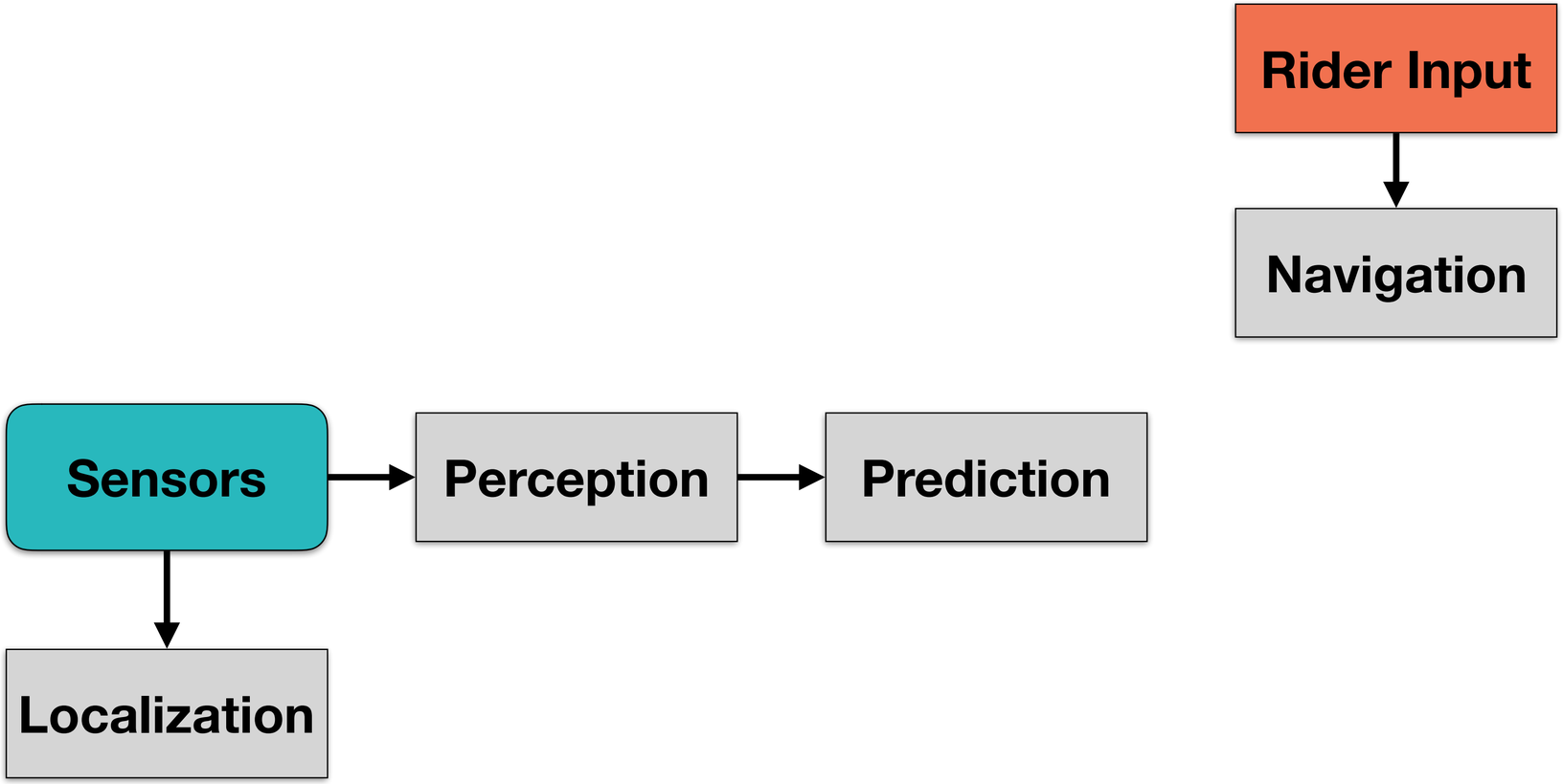

Rider Input
Navigation
Sensors
Perception
Localization


Rider Input
Navigation
Sensors
Perception
Prediction
Localization

AUTONOMOUS
Angle
0.00 °
Speed
1.07 MPH
0.48 M/S
SOCR LIMIT
- MPH
Tempe Bicycle
(Rural & University)
E University Dr
S Rural Rd
mapbox

AUTONOMOUS
Angle
0.00 °
Speed
1.07 MPH
0.48 M/S
SOCR LIMIT
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Tempe Bicycle
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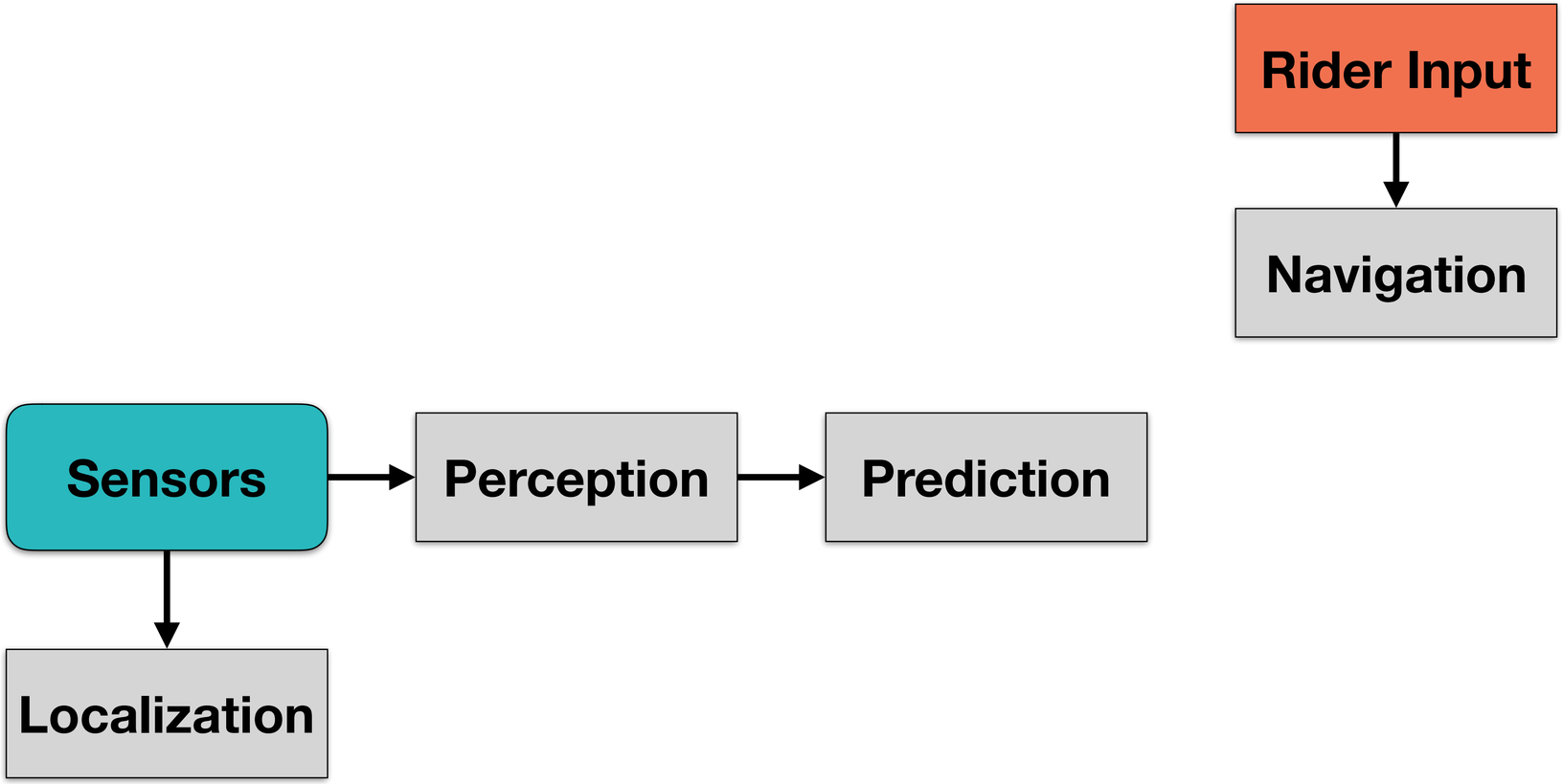
E University Dr
S Rural Rd
mapbox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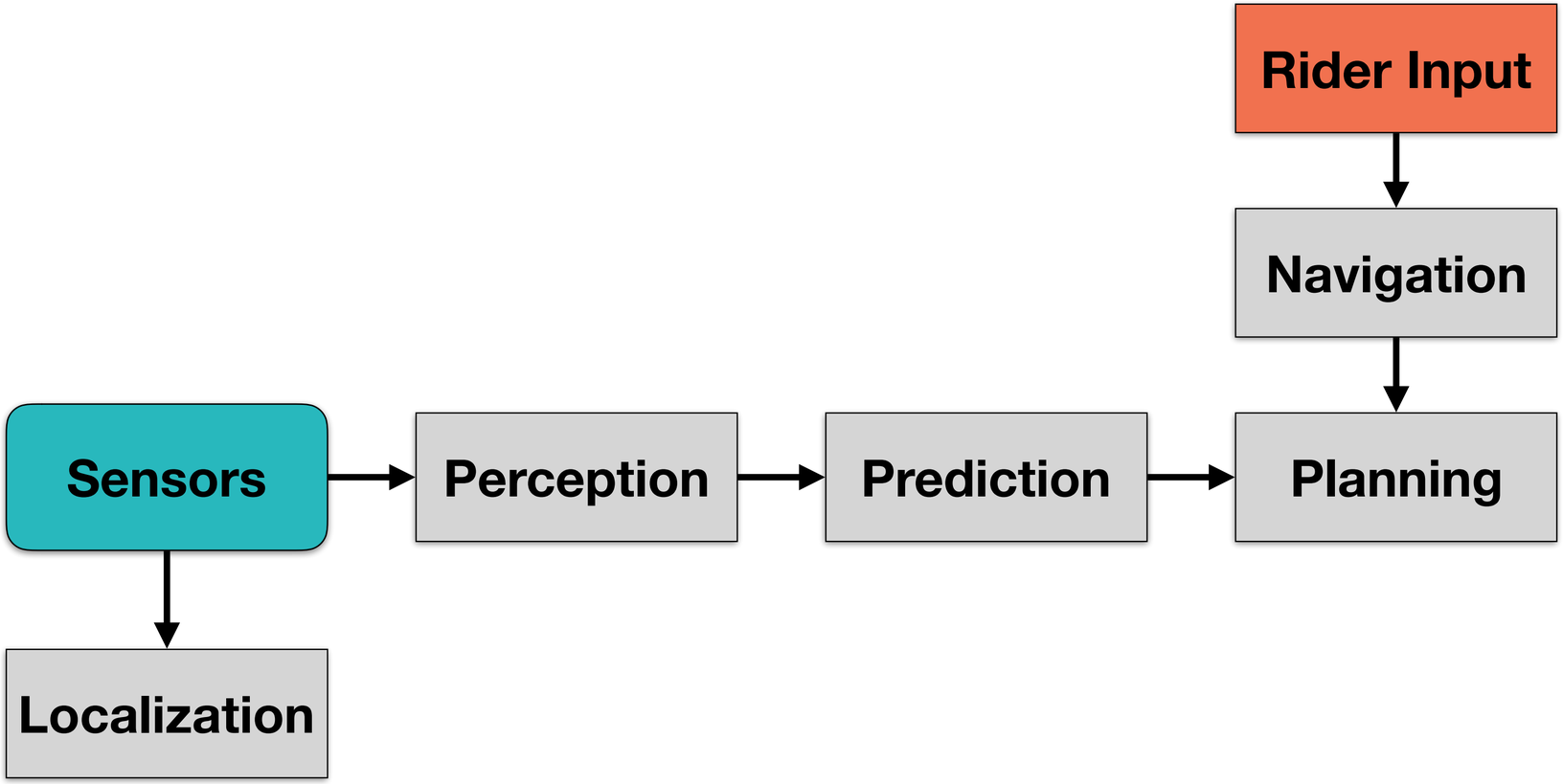
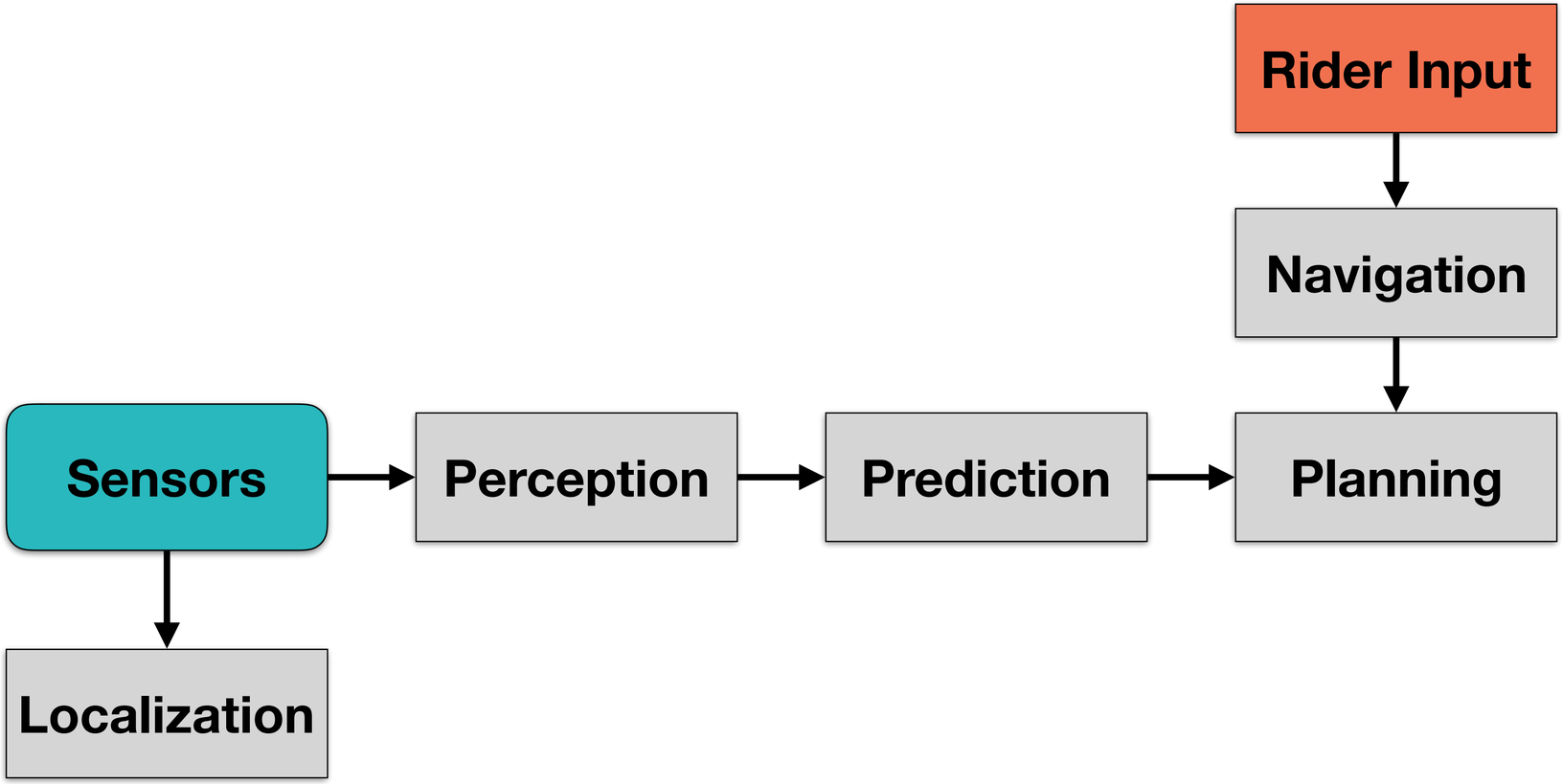
Navigation
Sensors
Perception
Prediction
Localization


Rider Input
Navigation
Sensors
Perception
Prediction
Planning
Localization

AUTONOMOUS
Angle
14.4 °
Speed
26.9 MPH
12.0 M/S
SOCR LIMIT
- MPH
E Wilshire Dr
E Wilshire Dr
N 68th St
N 68th St
mapbox

AUTONOMOUS
Angle
14.4 °
Speed
26.9 MPH
12.0 M/S
SOCR LIMIT
- MPH
E Wilshire Dr
E Wilshire Dr
N 68th St
N 68th St
mapbox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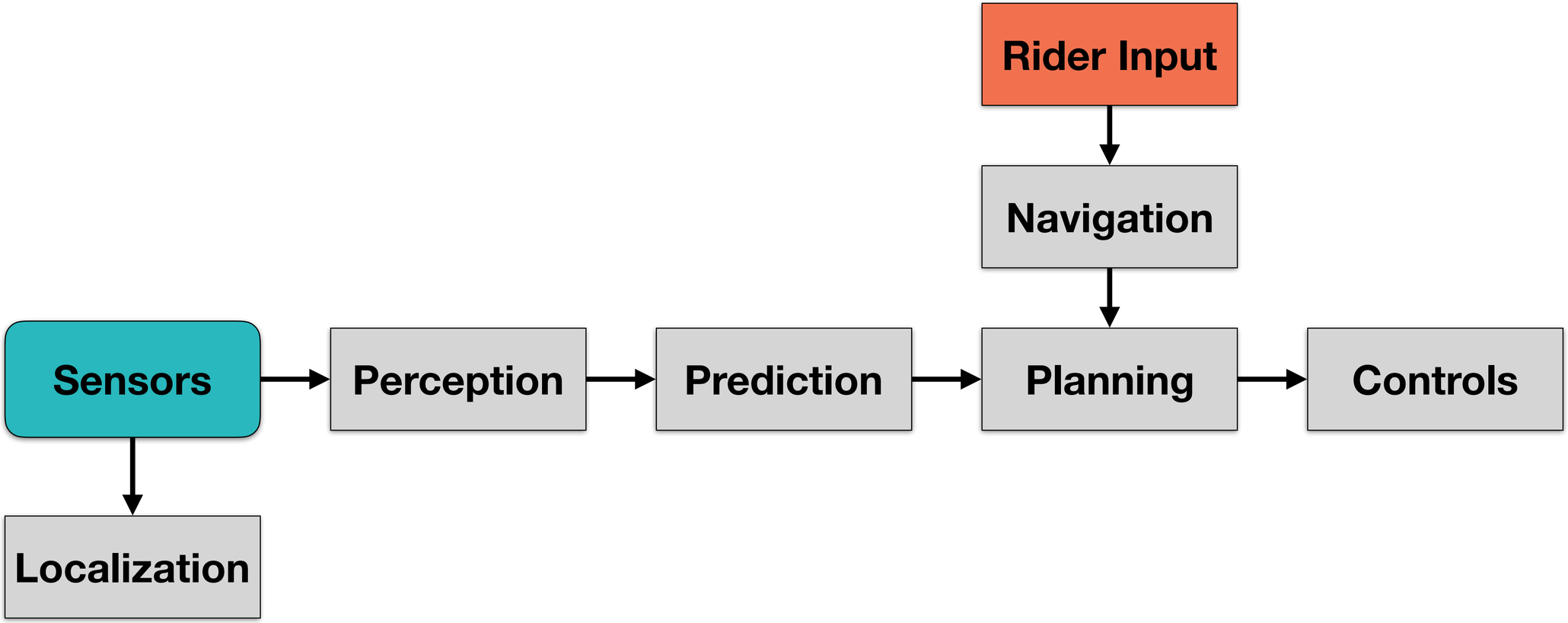
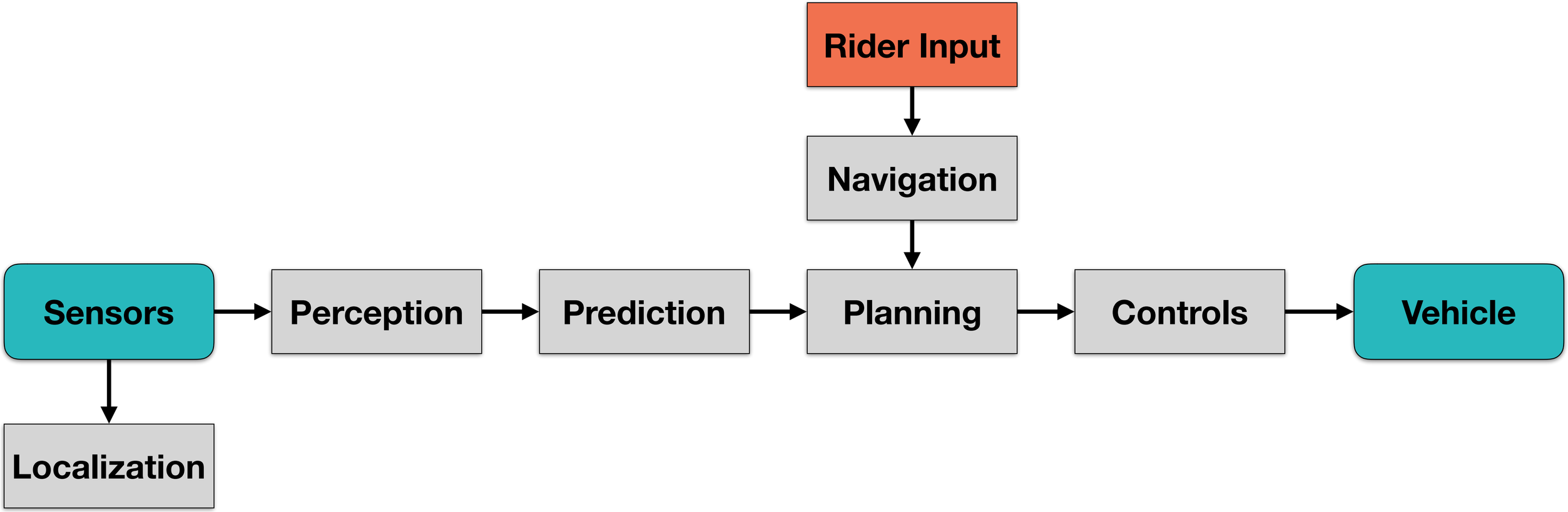
Navigation
Sensors
Perception
Prediction
Planning
Localization


Rider Input
Navigation
Sensors
Perception
Prediction
Planning
Controls
Localization


Rider Input
Navigation
Sensors
Perception
Prediction
Planning
Controls
Vehicle
Localization

Testing

ONLY
ONLY

ONLY
ONLY

AV System Overview
Data Flow in Action
Elliott Evans's screen

AV System Overview
Data Flow in Action
Elliott Evans's screen

VOLVO

VOLVO

Online Testing with real vehicles

Online Testing with real vehicles

- **Slow**

Online Testing with real vehicles

- Slow
- Expensive

Online Testing with real vehicles

- Slow
- Expensive
- Inconsistent

Online Testing with real vehicles

- Slow
- Expensive
- Inconsistent
- Poor Coverage

Online Testing with real vehicles

- Slow
- Expensive
- Inconsistent
- Poor Coverage
- Absolutely Necessary

Offline Testing with simulation

Offline Testing with simulation

- **Fast**

Offline Testing with simulation

- **Fast**
- **Cheaper**

Offline Testing with simulation

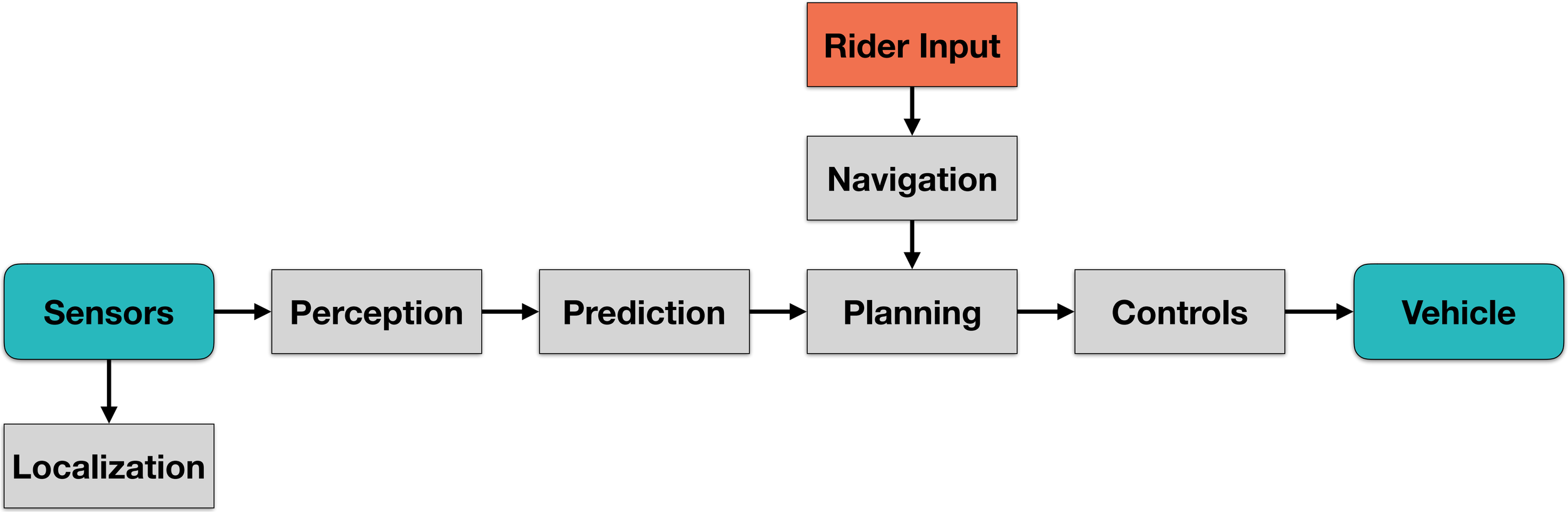
- Fast
- Cheaper
- Consistent

Offline Testing with simulation

- Fast
- Cheaper
- Consistent
- Full Coverage

Offline Testing with simulation

- Fast
- Cheaper
- Consistent
- Full Coverage
- Absolutely Necessary


Rider Input
Navigation
Sensors
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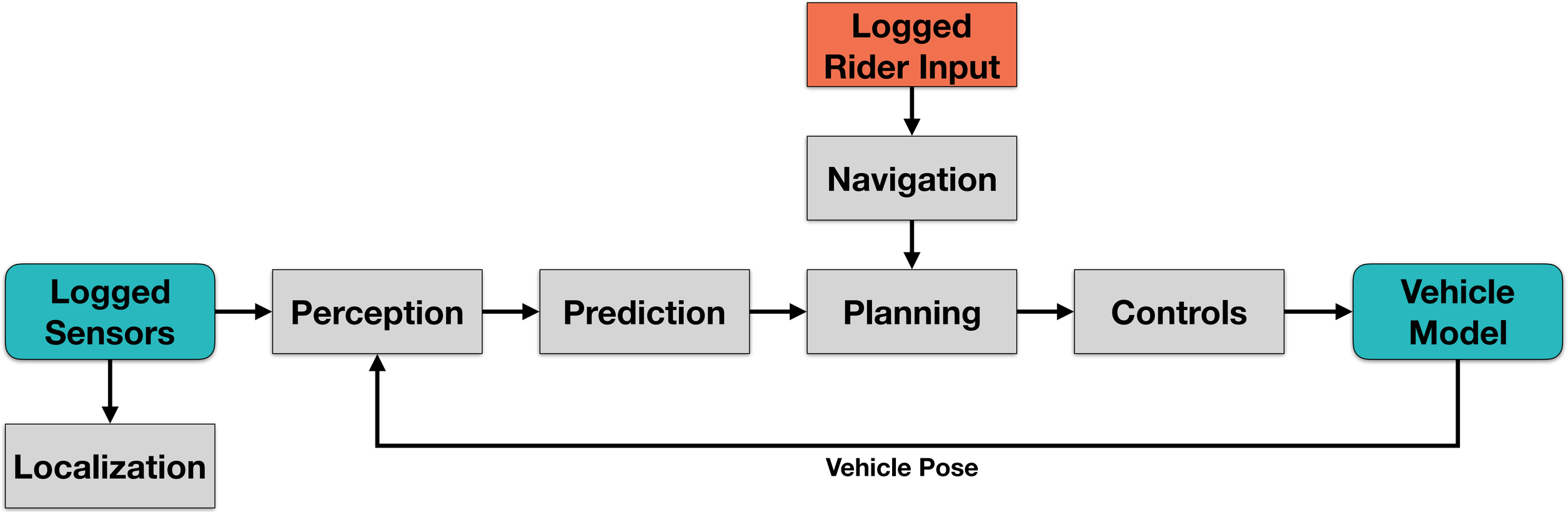
Planning
Controls
Vehicle
Localization


Logged Rider Input
Navigation
Logged Sensors
Perception
Prediction
Planning
Controls
Vehicle Model
Localization
Vehicle Pose

Log Sim

AUTONOMOUS
Angle
-21.1 °
Speed
- MPH
- M/S
SOCR LIMIT
- MPH
Dominick's
2 Wheelers
Little Caesars
E Broadway Rd
S Rural Rd
mapbox
00:00
00:01
00:02
00:03
00:04
00:05
00:06
00:07
00:08
00:09
00:10
00:11
00:12
00:13
00:14
Playforward
1190419440.10
Normal speed
No Lookahead

AUTONOMOUS
Angle
-21.1 °
Speed
- MPH
- M/S
SOCR LIMIT
- MPH
Dominick's
2 Wheelers
Little Caesars
E Broadway Rd
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00:04
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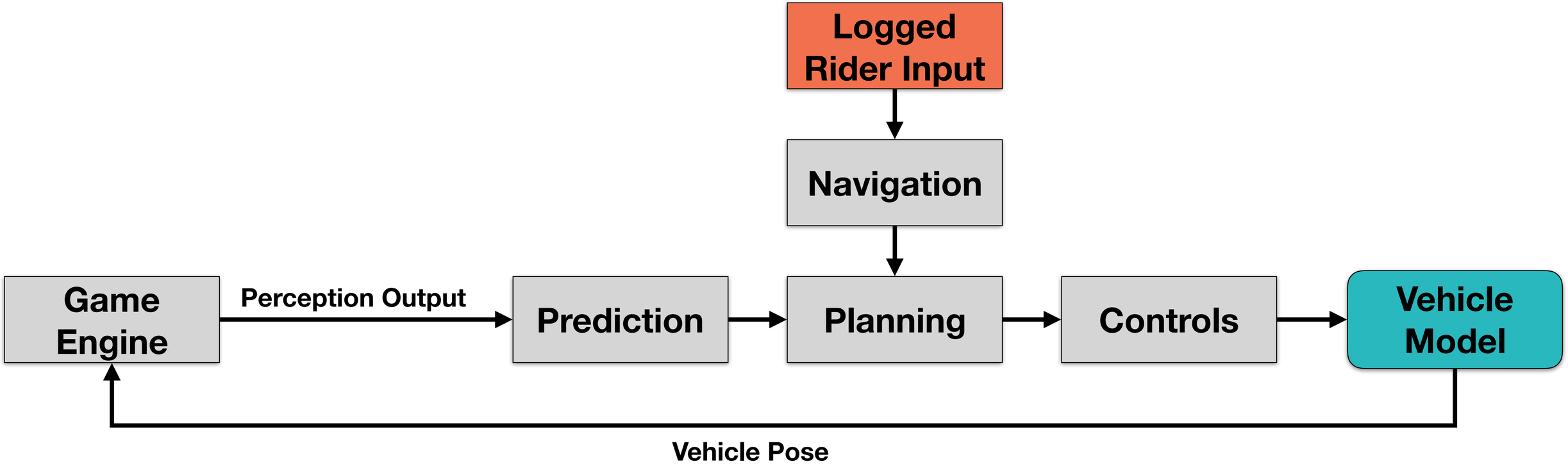
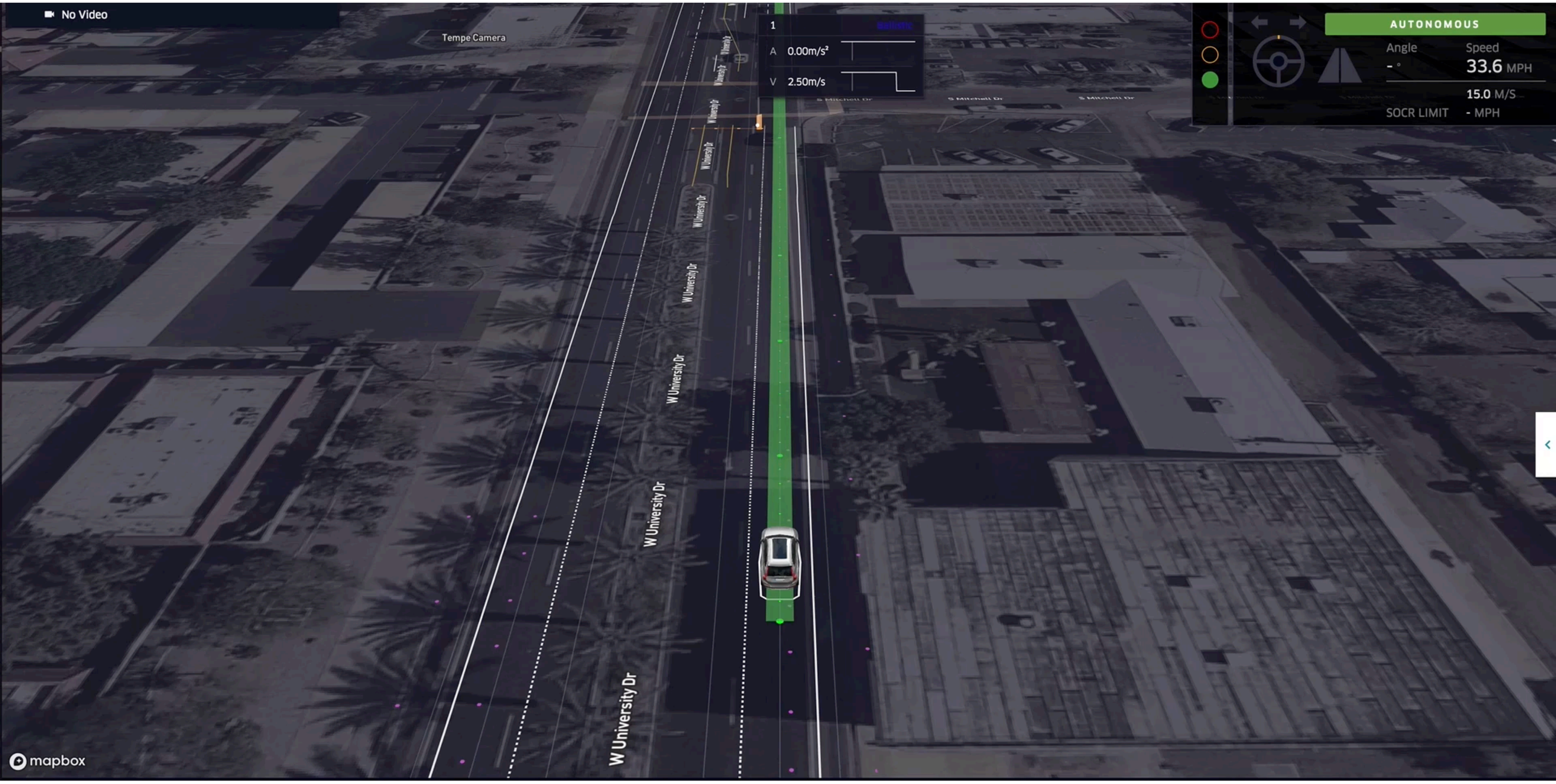
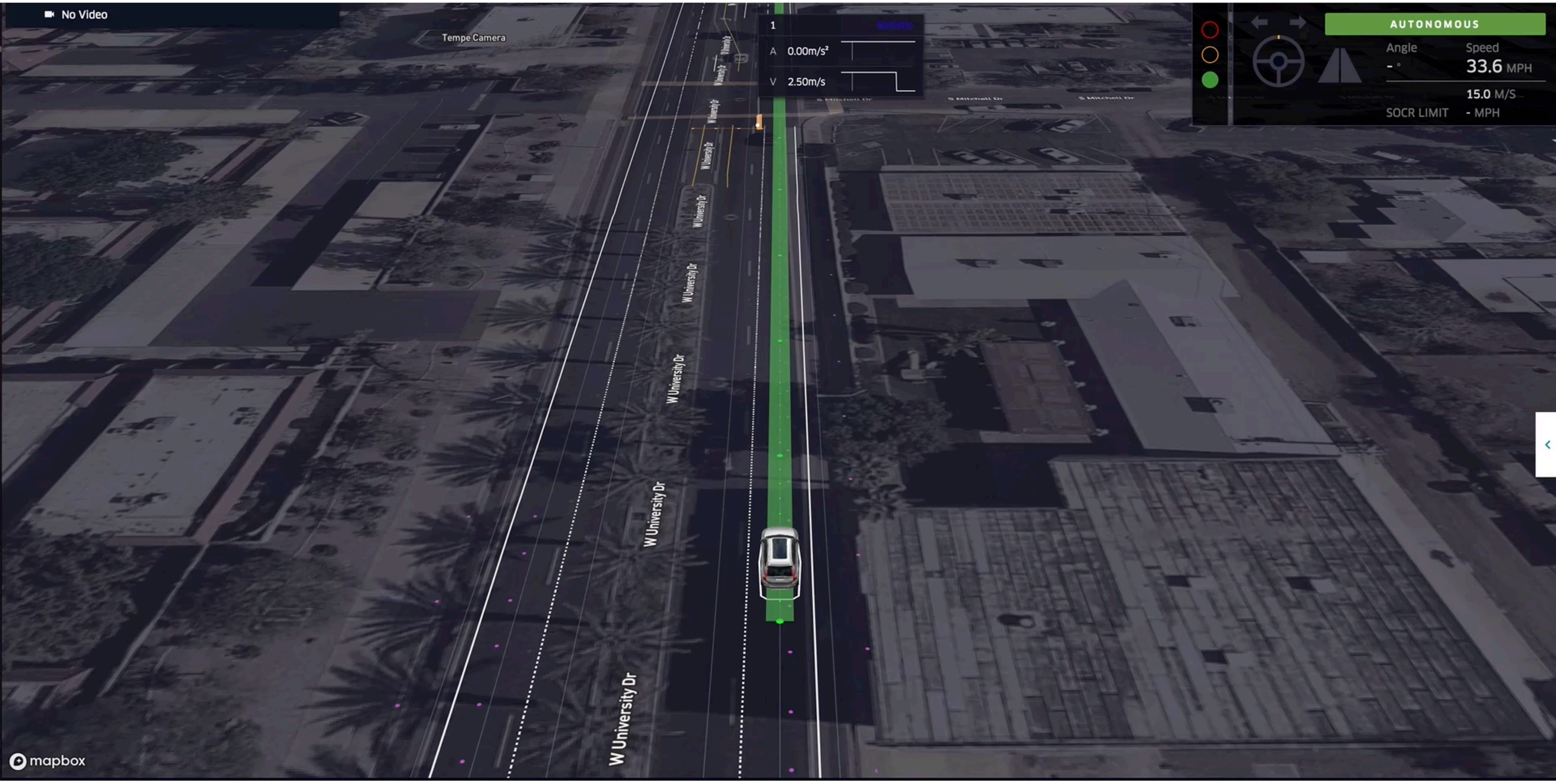
00:13
00:14
Playforward
1190419440.10
Normal speed
No Lookahead


Logged
Rider Input
Navigation
Game
Engine
Perception Output
Prediction
Planning
Controls
Vehicle
Model
Vehicle Pose

Virtual Sim


No Video
Tempe Camera
1
A 0.00m/s²
V 2.50m/s
AUTONOMOUS
Angle
- °
Speed
33.6 MPH
15.0 M/S
SOCR LIMIT
- MPH
W University Dr
W University Dr
W University Dr
W University Dr
W University Dr
S Mitchell Dr
S Mitchell Dr
S Mitchell Dr
mapbox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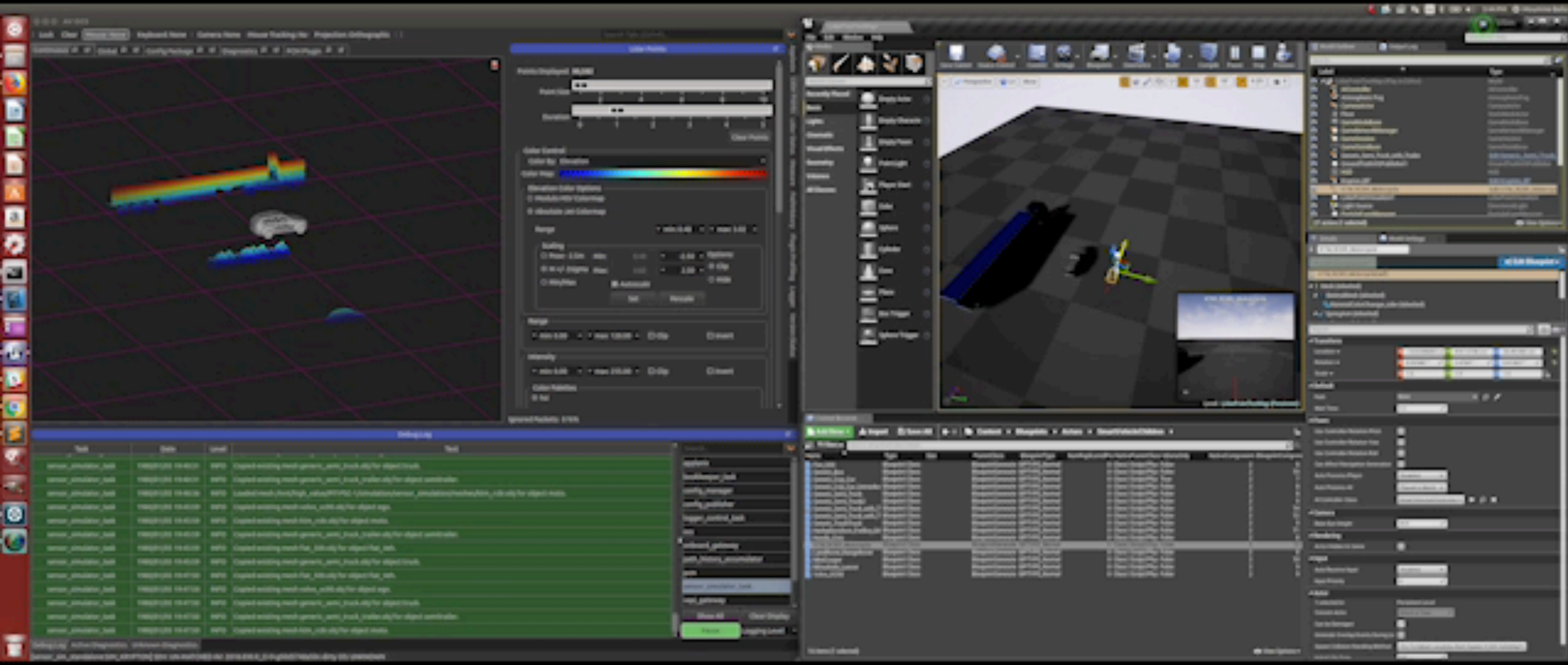
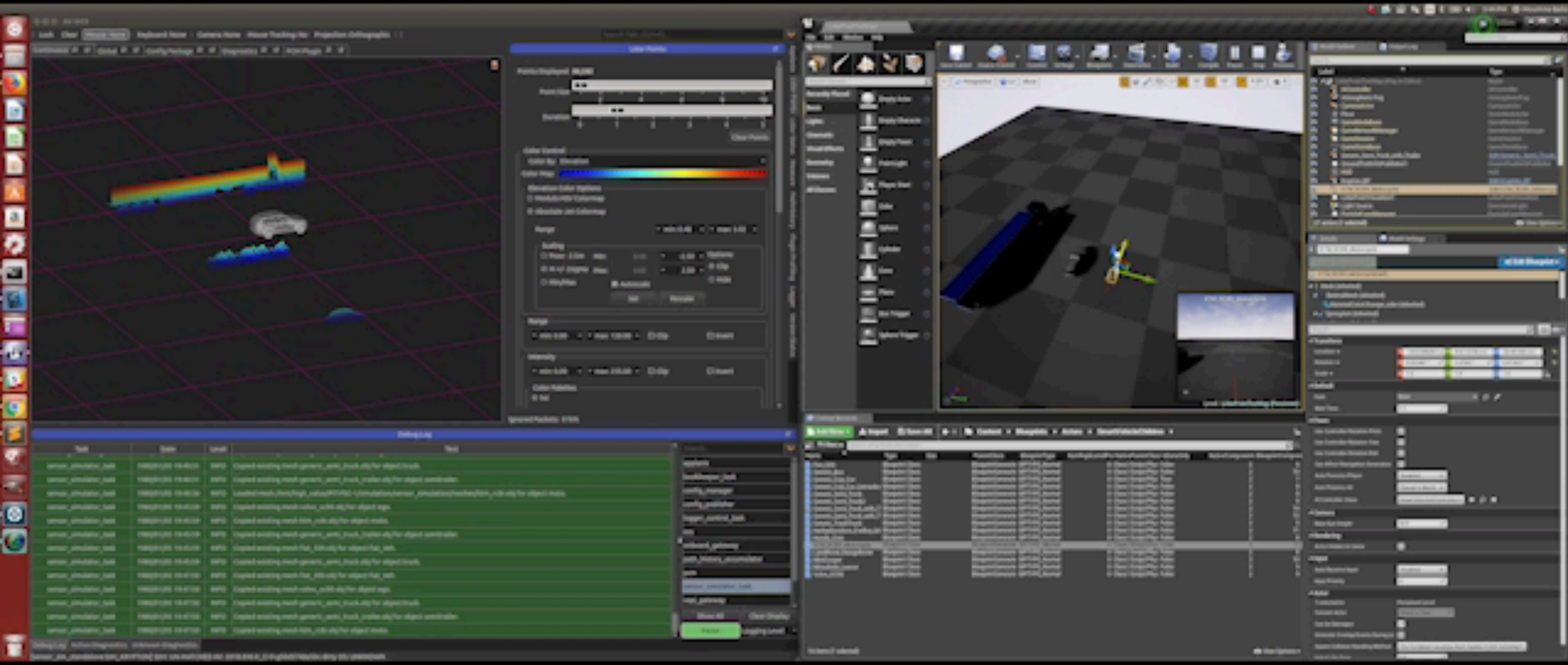
W University Dr
W University Dr
W University Dr
W University Dr
W University Dr
S Mitchell Dr
S Mitchell Dr
S Mitchell Dr
mapbox





Toolbar
Save Current
Source Control
Content
Settings
Blueprints
Cinematics
Build
Compile
Play
Launch
Viewport 1
Perspective
Lit
Show
Empty Actor
Empty Character
Empty Pawn
Point Light
Player Start
Cube
Sphere
Cylinder
Cone
Plane
Box Trigger
Sphere Trigger
World Outliner
Label
Type
Player Start
PostProcessVolume
Rock5
Rock8
Rock14
Rock18
Rock20
Rock21
Sky Sphere
SkyLight
SphereReflectionCapture
Landscape1
LandscapeGizmoActiveActor
mountains distance
17 actors
World Settings
Details
Selection object to view details
Output Log
Import
Save All
Content
Remote
pennytestbp
Filters
Show Redirectors
Map Build Data Registry
Vehicles
Models
Clutter
Foliage
Mountains
People
RoadBlocks
Roads
Rocks
SensorPods
Sensors
Vehicles
pennytestbp
sanitytest
USimObjects
Subtypal library
++ Classes
gine Content
gine C++ Classes
ndroidMedia C++ Classes
chVisCharacter C++ Classes
/ Content
19 items (1 selected)
view Options

Toolbar
Save Current
Source Control
Content
Settings
Blueprints
Cinematics
Build
Compile
Play
Launch
Viewport 1
Perspective
Lit
Show
Empty Actor
Empty Character
Empty Pawn
Point Light
Player Start
Cube
Sphere
Cylinder
Cone
Plane
Box Trigger
Sphere Trigger
World Outliner
Label
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PostProcessVolume
Rock5
Rock8
Rock14
Rock18
Rock20
Rock21
Sky Sphere
SkyLight
SphereReflectionCapture
Landscape1
LandscapeGizmoActiveActor
mountains distance
17 actors
World Settings
Details
Selection object to view details
Output Log
Import
Save All
Content
Remote
pennytestbp
Filters
Show Redirectors
Map Build Data Registry
Vehicles
Models
Clutter
Foliage
Mountains
People
RoadBlocks
Roads
Rocks
SensorPods
Sensors
Vehicles
pennytestbp
sanitytest
USimObjects
Subtypal library
++ Classes
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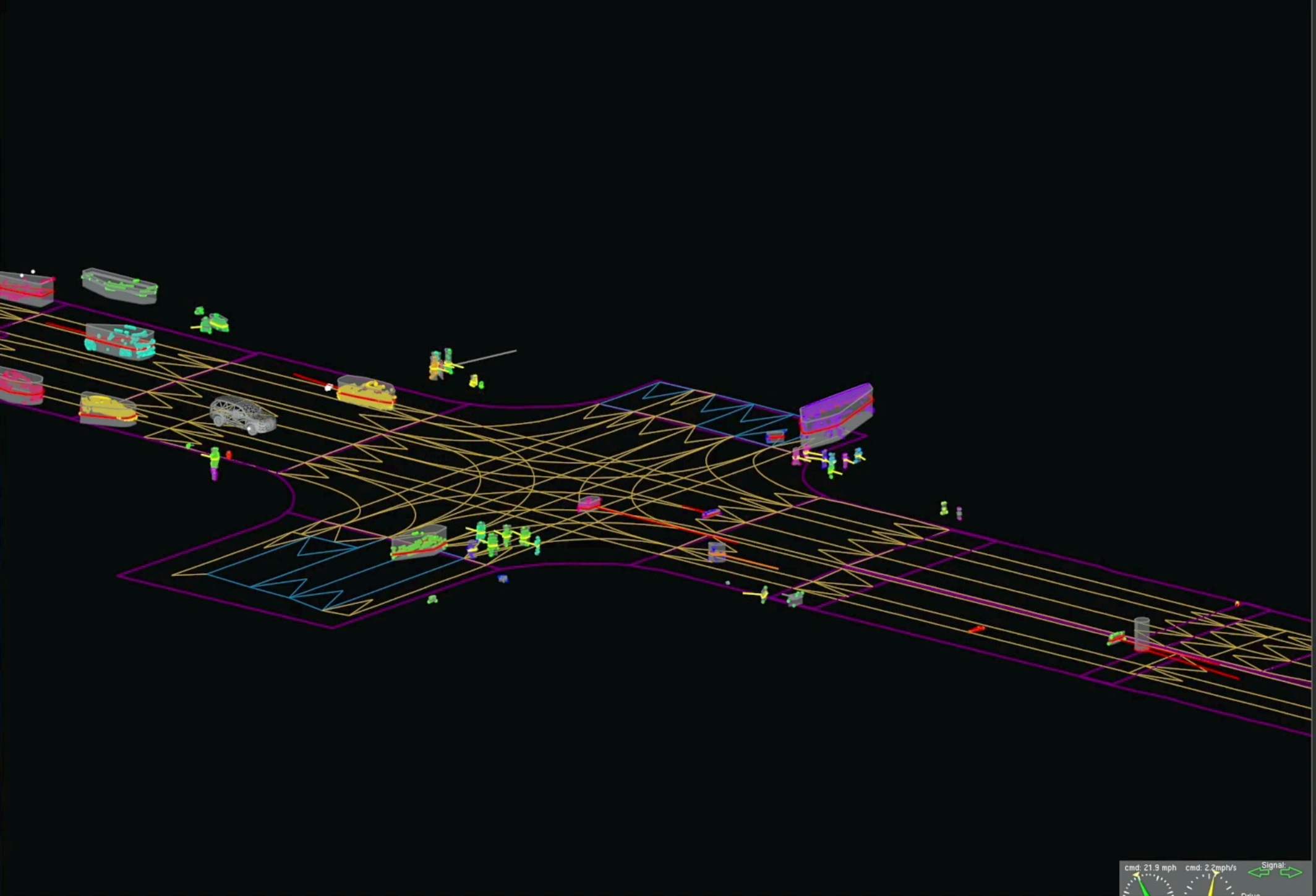
ndroidMedia C++ Classes
chVisCharacter C++ Classes
/ Content
19 items (1 selected)
view Options



Add Line

Point 1: Measure Frame continuous

Point 2: Add

Frames | Planes | Angles | Frame Edit | Models

Name	Frame	Normal	Offset
aligned_gr...	aligned_...	Z Axis	[0.000000, 0.000000, 0
local_ground	vehicle	Z Axis	[0.000000, 0.000000, 0

Add Plane

Attach Frame continuous

Normal Z Axis

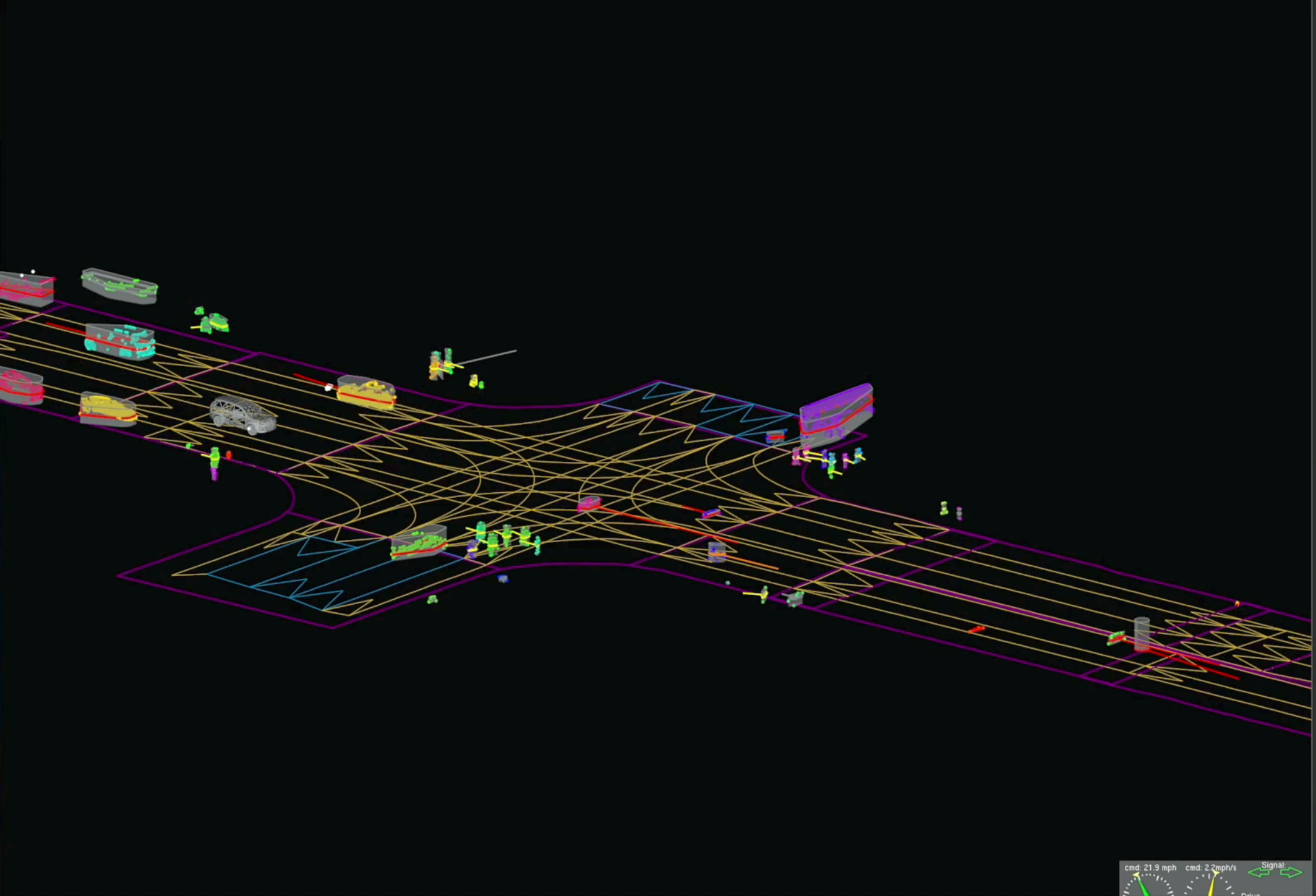
Log Player Controls

1192245989.4926 (2017/10/16 22:26:11 -0500)

Select channel to seek to...

Jump by(s) -10 -5 -1 +1 +5 +10 Play For(s): Jump To(s):

cmd: 21.9 mph cmd: 2.2mph/s Signal:



Add Line

Point 1: Measure Frame continuous

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Frames | Planes | Angles | Frame Edit | Models

Name	Frame	Normal	Offset
aligned_gr...	aligned_...	Z Axis	[0.000000, 0.000000, 0
local_ground	vehicle	Z Axis	[0.000000, 0.000000, 0

Add Plane

Attach Frame continuous

Normal Z Axis

Log Player Controls

1192245989.4926 (2017/10/16 22:26:11 -0500)

Select channel to seek to...

Jump by(s) -10 -5 -1 +1 +5 +10 Play For(s): Jump To(s):

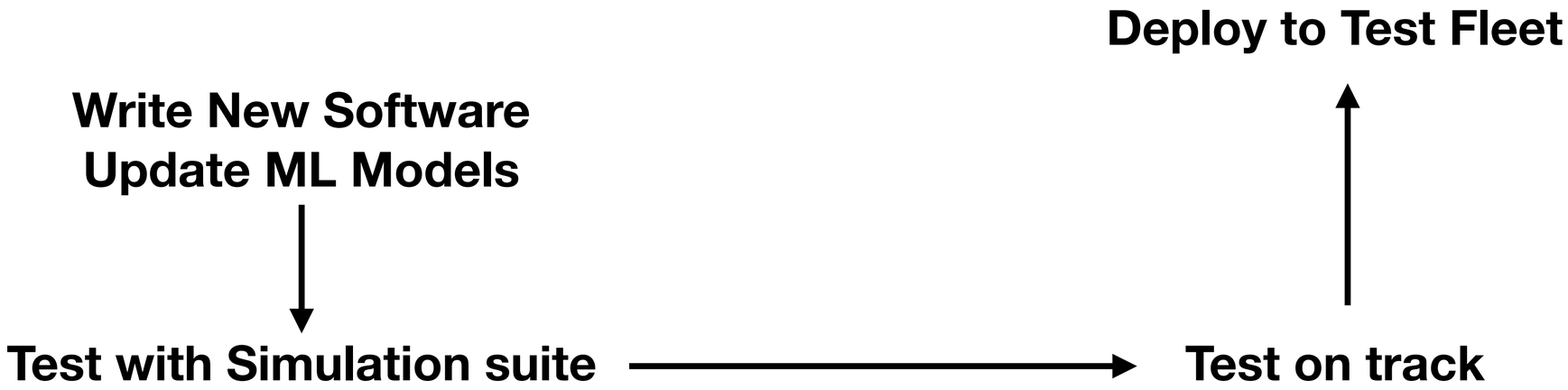
cmd: 21.9 mph cmd: 2.2mph/s Signal:

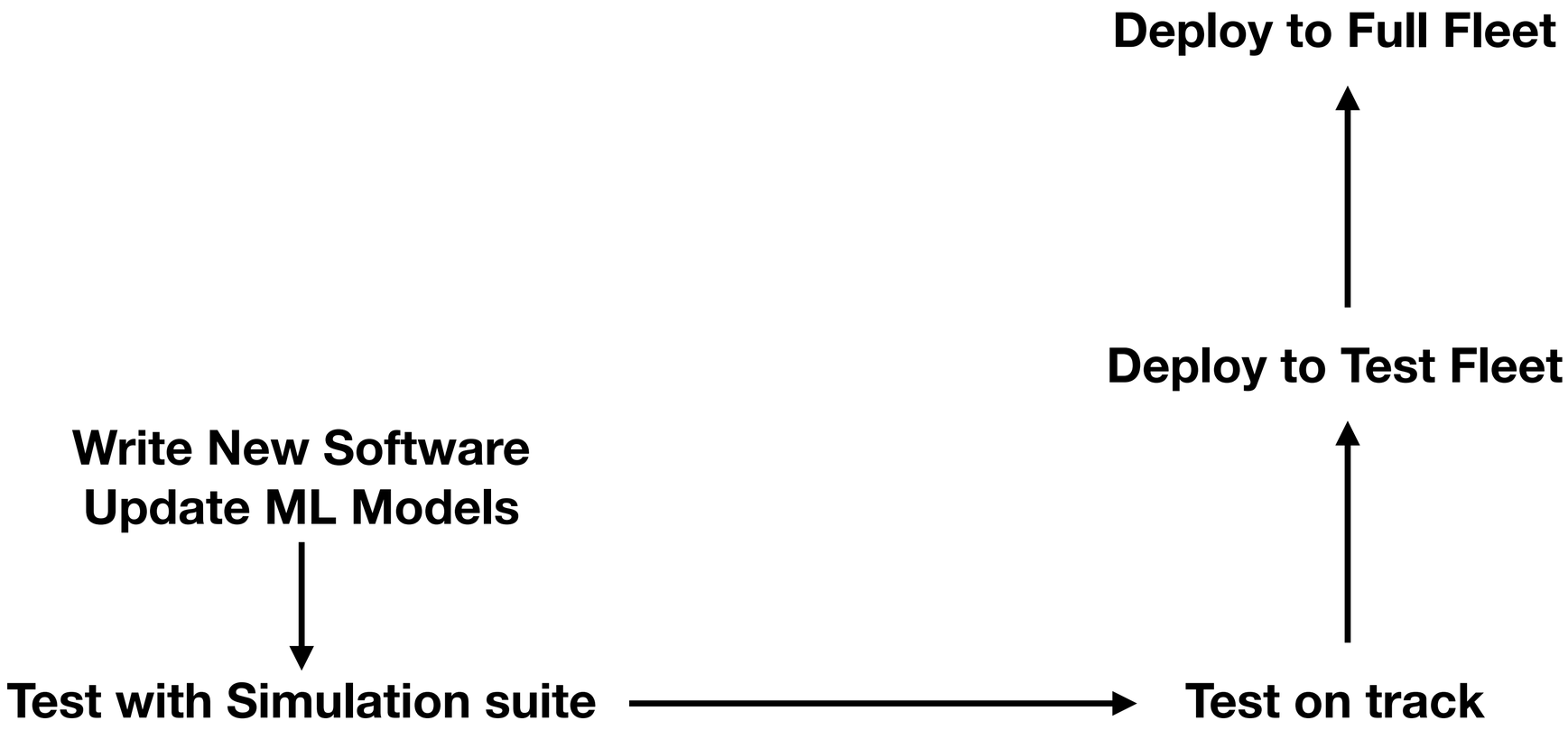
Write New Software
Update ML Models

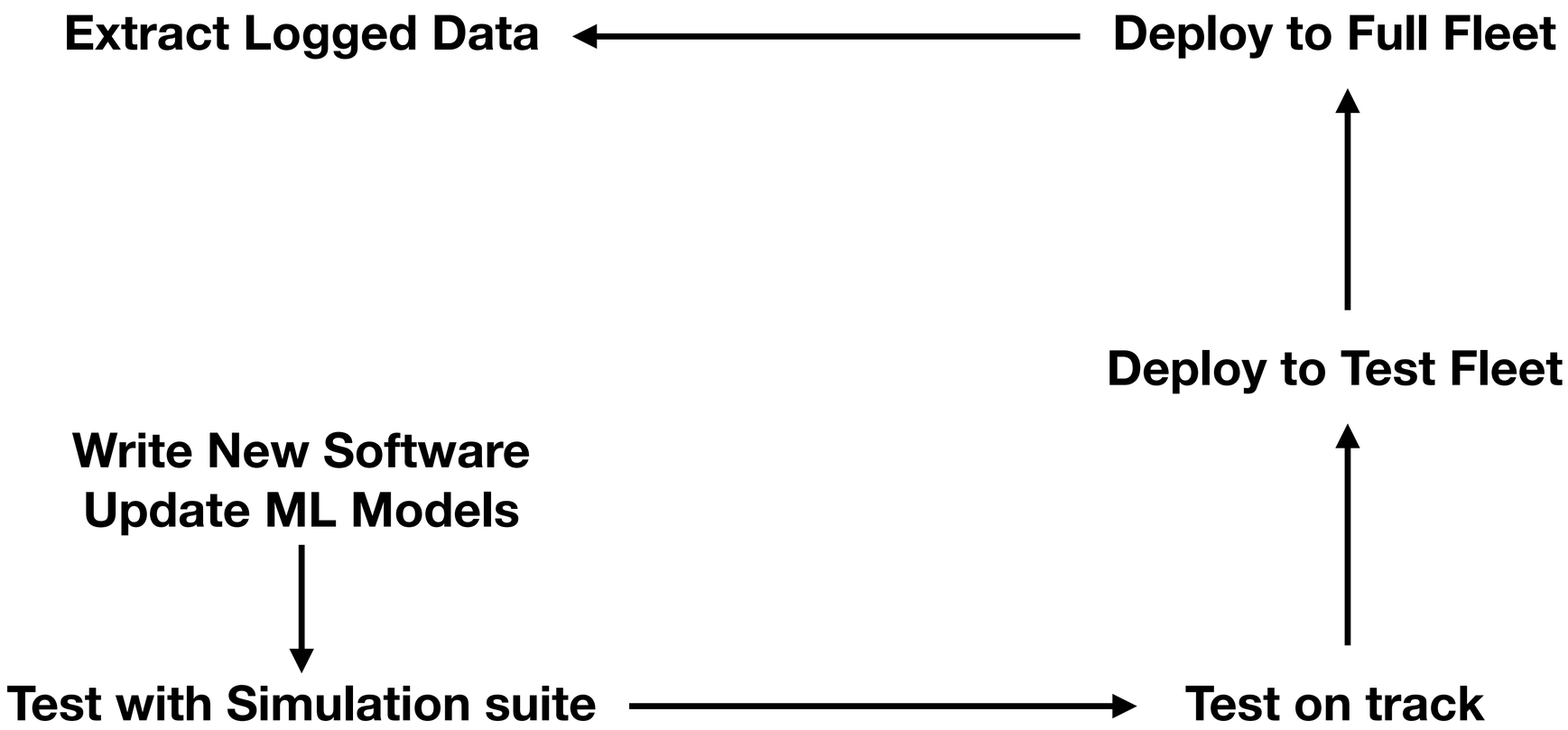
Write New Software
Update ML Models

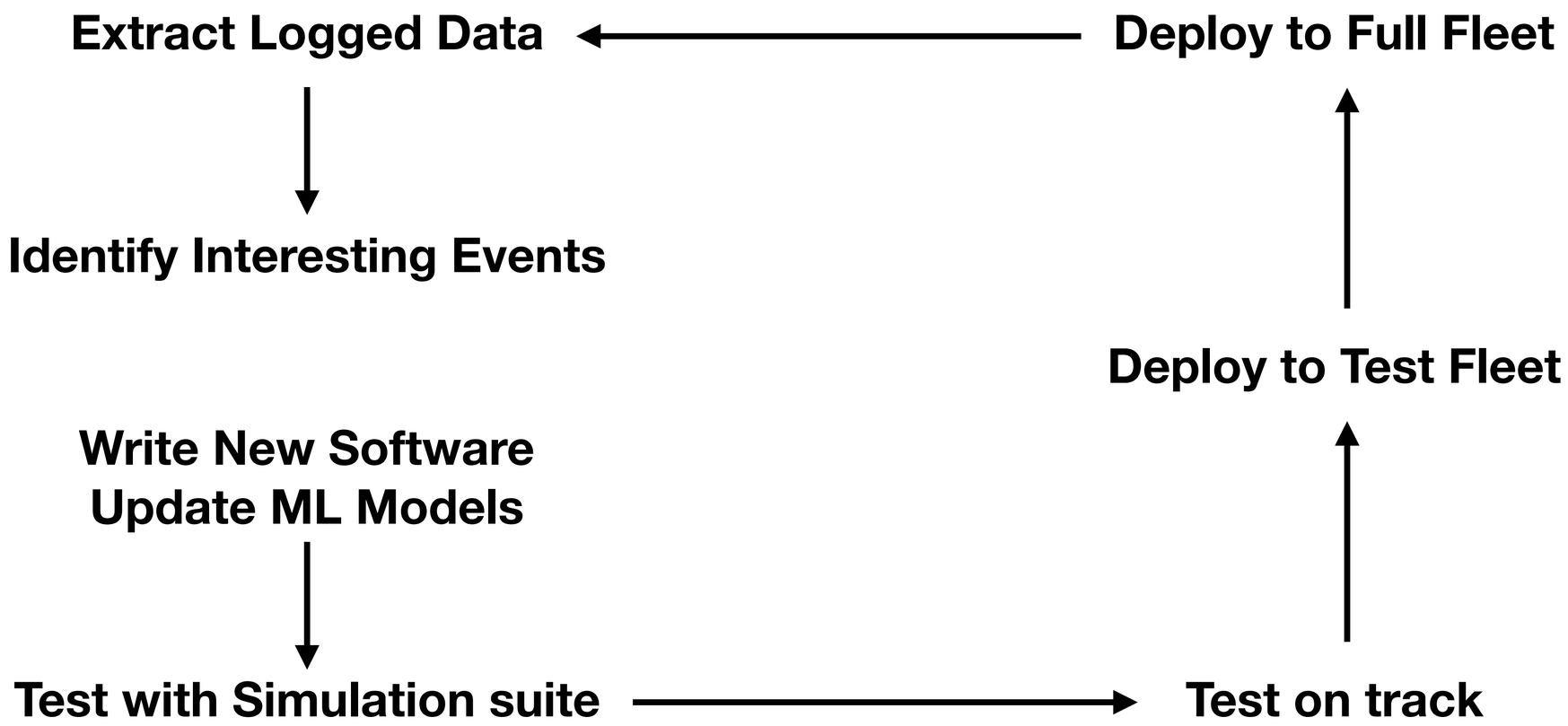
Test with Simulation suite

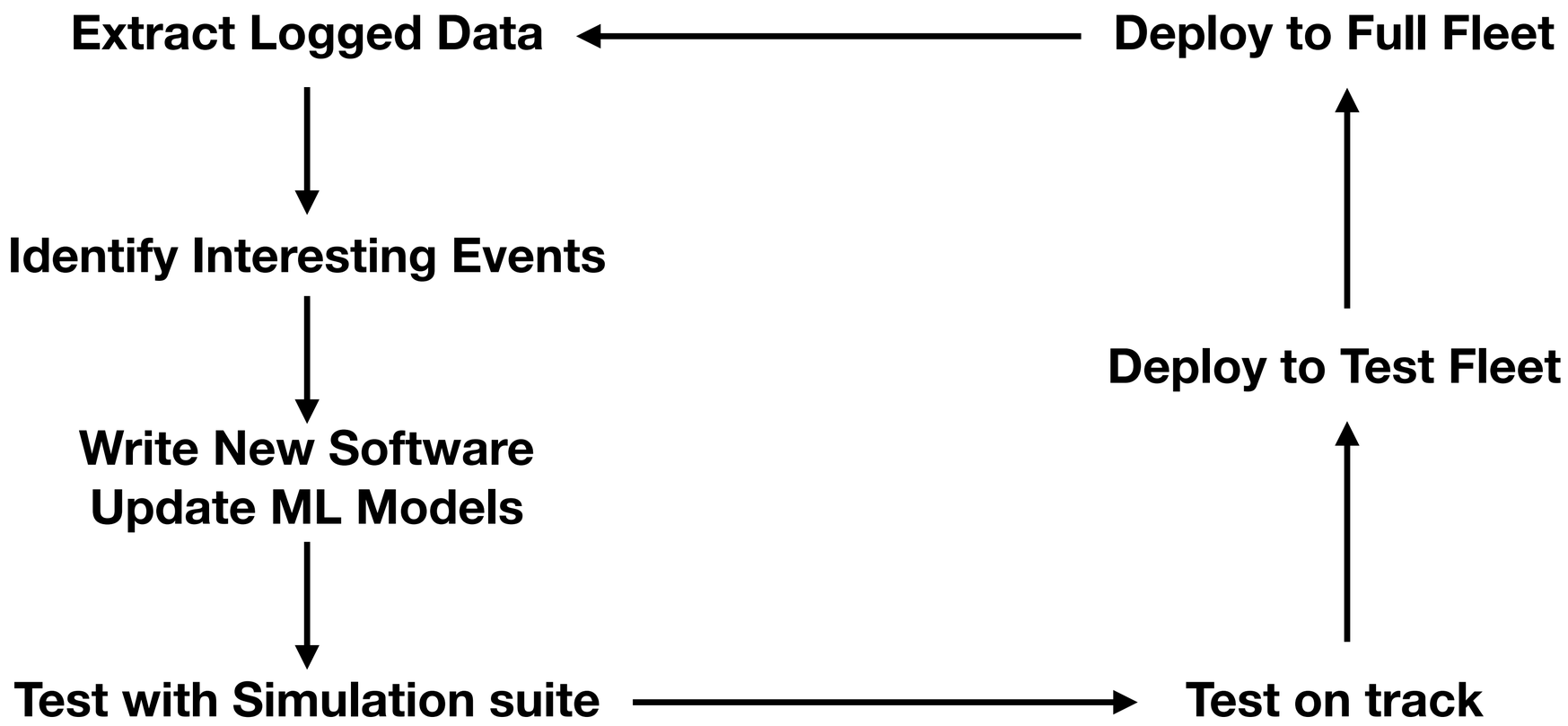
Write New Software
Update ML Models
Test with Simulation suite
Test on track


Deploy to Test Fleet
Write New Software
Update ML Models
Test with Simulation suite
Test on track


Deploy to Full Fleet
Deploy to Test Fleet
Write New Software
Update ML Models
Test with Simulation suite
Test on track


Extract Logged Data
Deploy to Full Fleet
Deploy to Test Fleet
Write New Software
Update ML Models
Test with Simulation suite
Test on track


Extract Logged Data
Deploy to Full Fleet
Identify Interesting Events
Deploy to Test Fleet
Write New Software
Update ML Models
Test with Simulation suite
Test on track

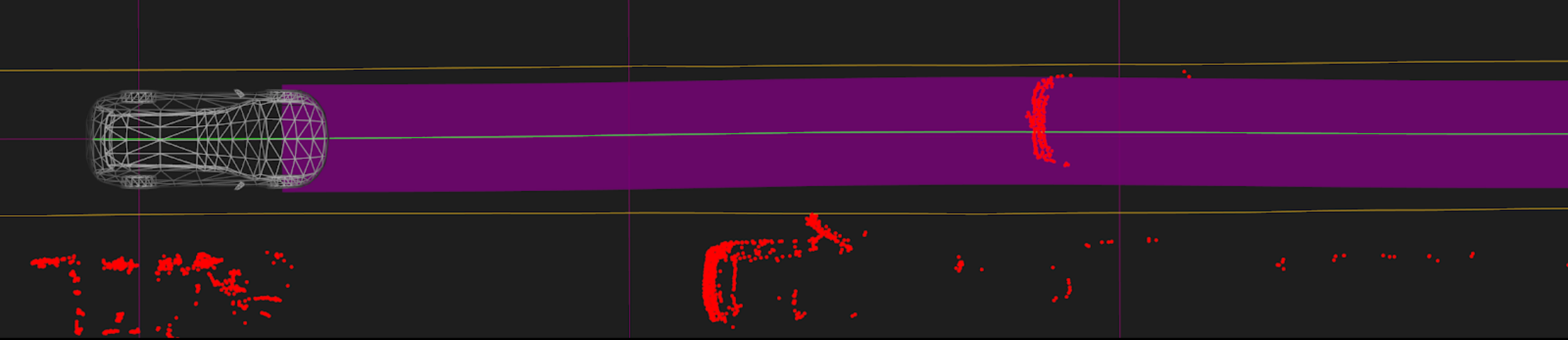

Extract Logged Data
Deploy to Full Fleet
Identify Interesting Events
Deploy to Test Fleet
Write New Software
Update ML Models
Test with Simulation suite
Test on track

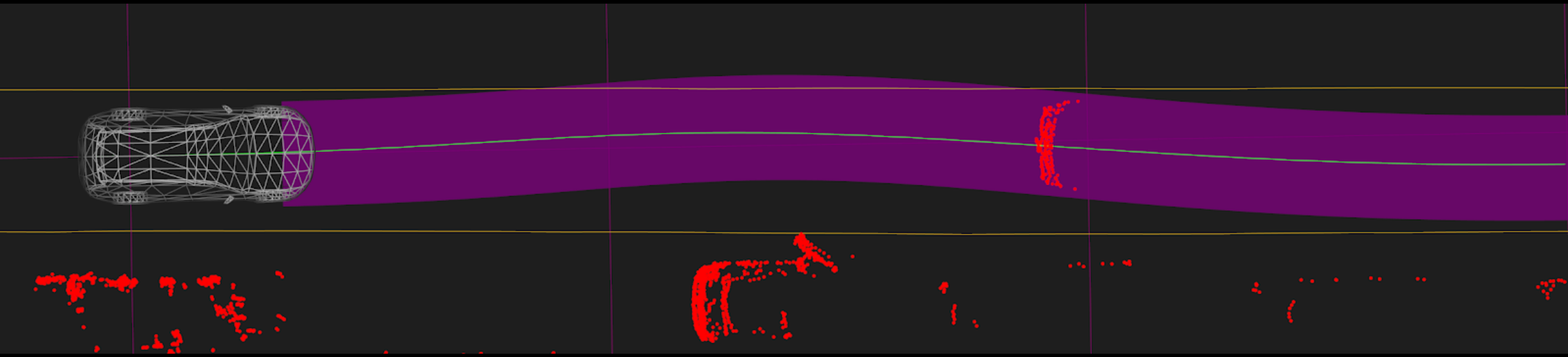
Close

Close

Close
FISH

Close

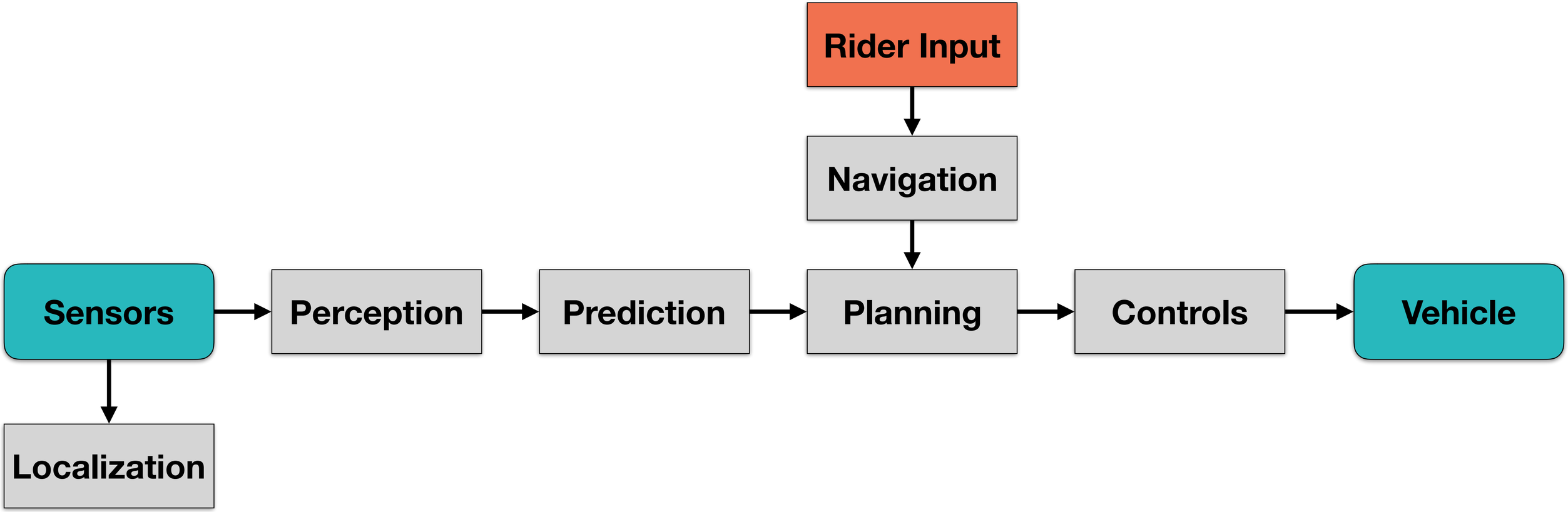




Please Help

E-STOP
43
4X4

Thanks


Rider Input
Navigation
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Perception
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Controls
Vehicle
Localization