National Transportation Safety Board

Managing Risk of ADS Testing

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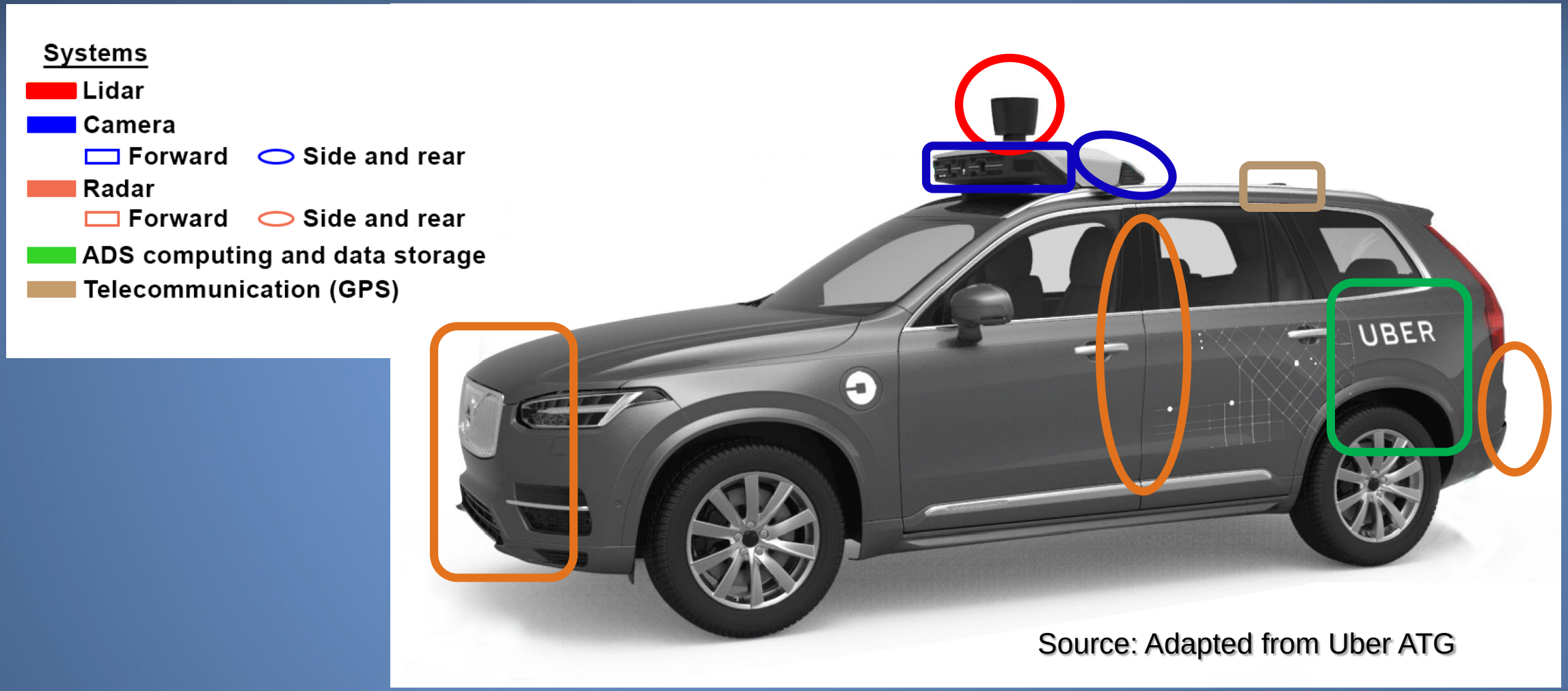
Overview

- Uber ATG test vehicle
  - Uber ATG developmental ADS
  - Volvo collision avoidance systems (CAS)
- ADS functionality at time of crash
- Postcrash changes

Test Vehicle: ADS Sensors



Source: Adapted from Uber ATG

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Factory-Installed CAS

- Volvo collision avoidance/ mitigation systems
  - Forward collision warning
  - Automatic emergency braking
- Active assistance systems disabled during ADS operation
  - Challenges due to radar frequency interference

ADS Basic Operation

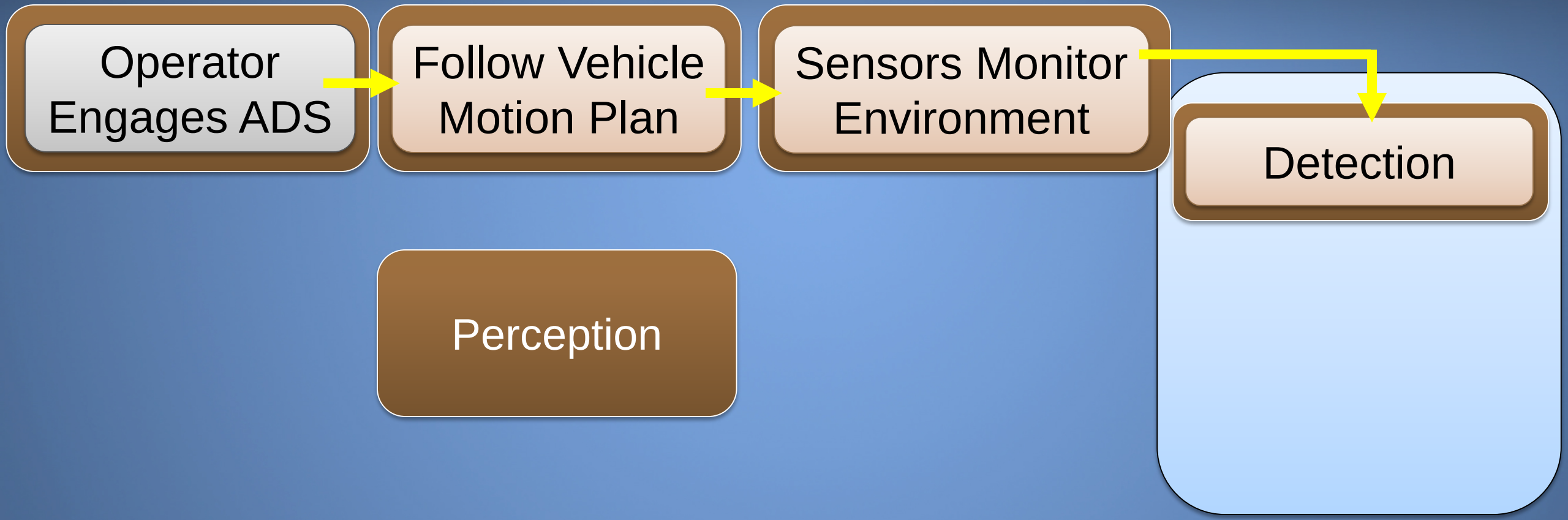
- ADS could be engaged only on premapped route
  - High-definition maps developed by Uber ATG
- ADS designed to perform all driving tasks
  - Change lanes, make turns, stop
  - Monitor environment, detect objects
- Vehicle operator monitored environment
  - Operator is part of the system

ADS Motion Plan and Perception

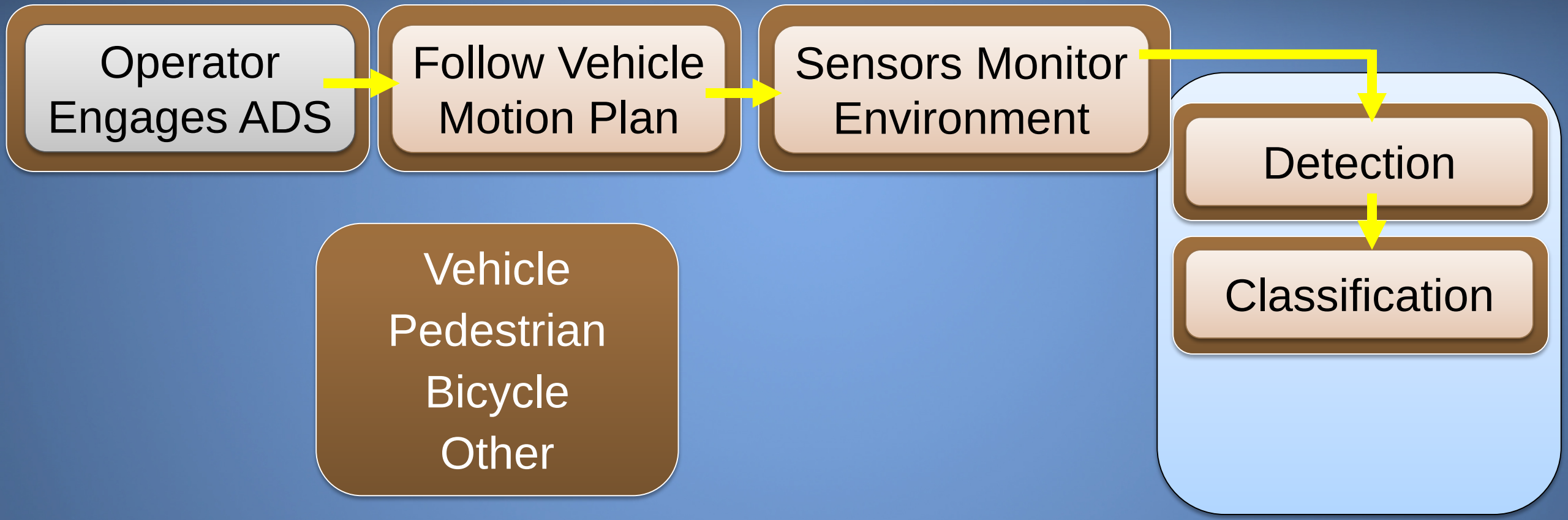
Operator Engages ADS → Follow Vehicle Motion Plan

Speed changes, turn locations

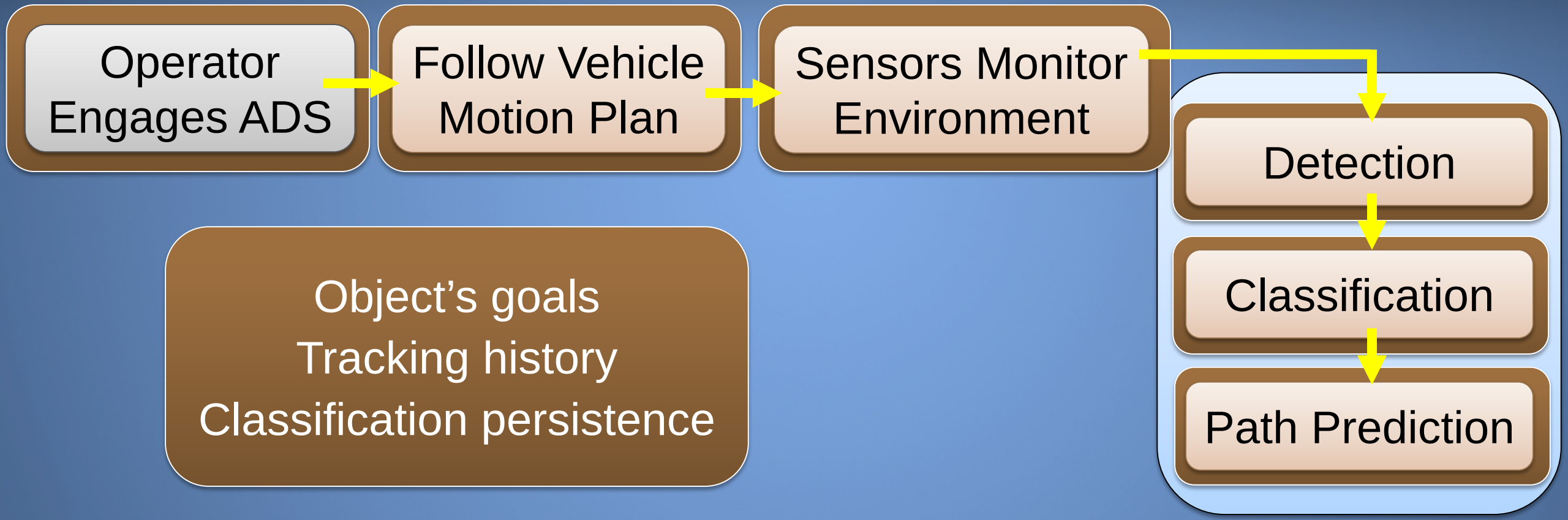
ADS Motion Plan and Perception



ADS Motion Plan and Perception

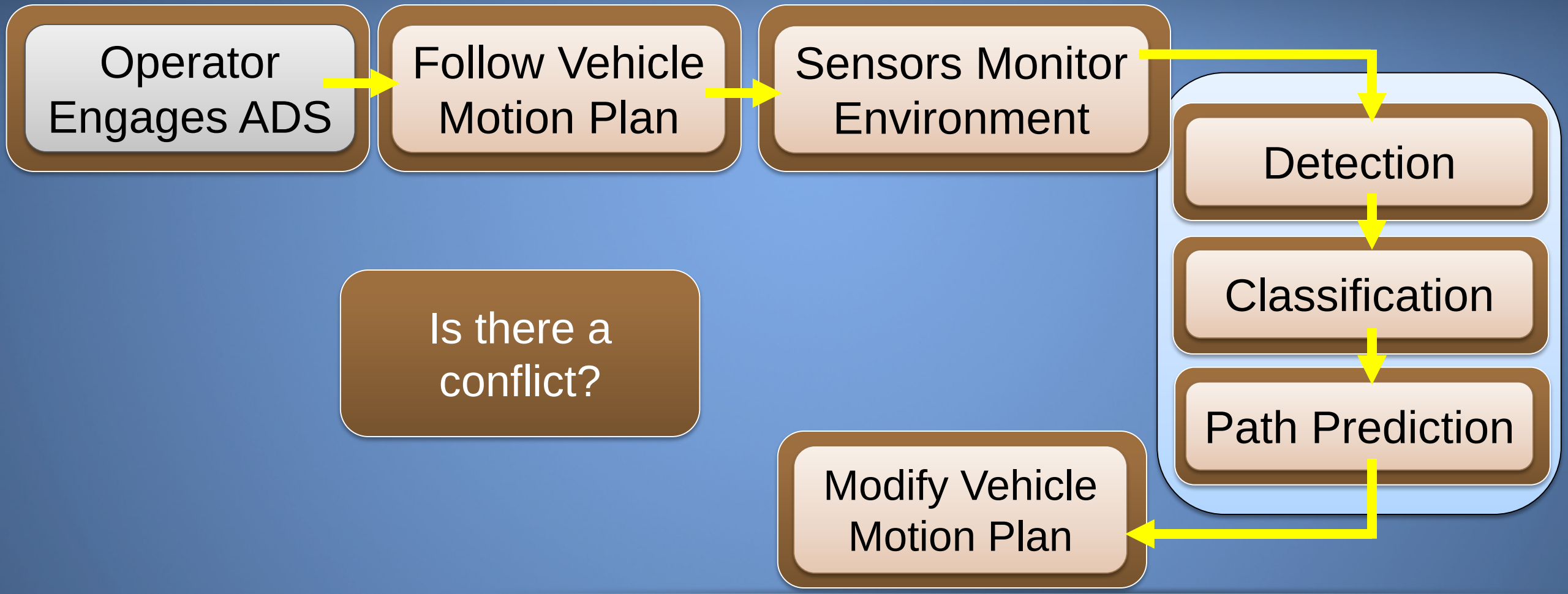


ADS Motion Plan and Perception



Object's goals
Tracking history
Classification persistence

ADS Motion Plan and Perception



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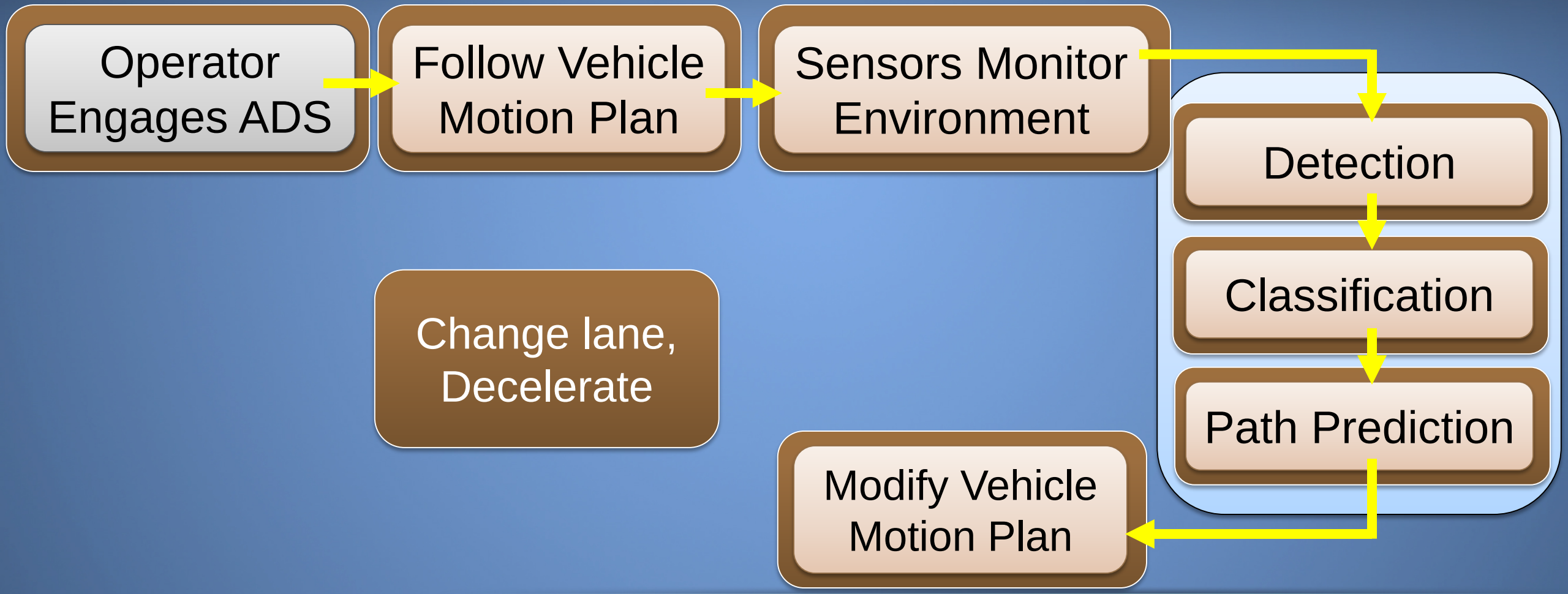
ADS Motion Plan and Perception



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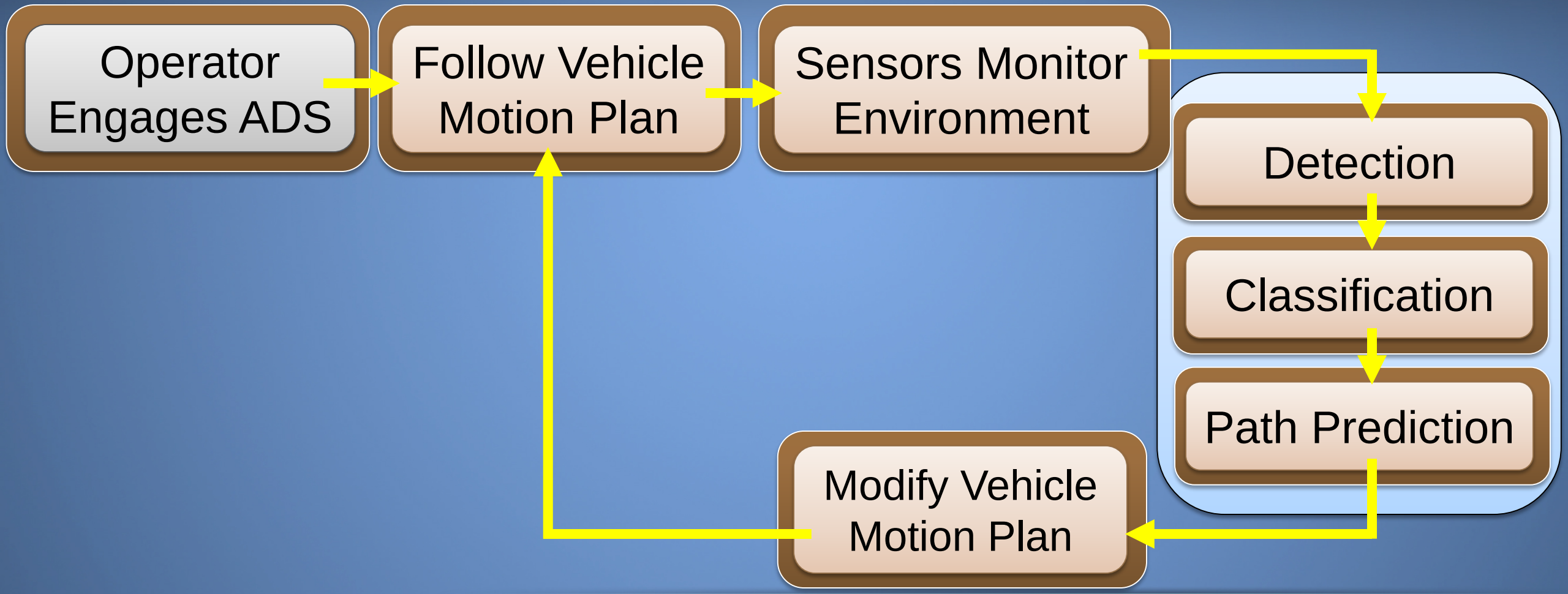
ADS Motion Plan and Perception



Machine Perception

- Challenges of machine perception
- There are no production-level automation vehicles
- Expected failures and limitations of a developmental ADS
  - Managing safety risk during testing

Detection

Classification

Path Prediction

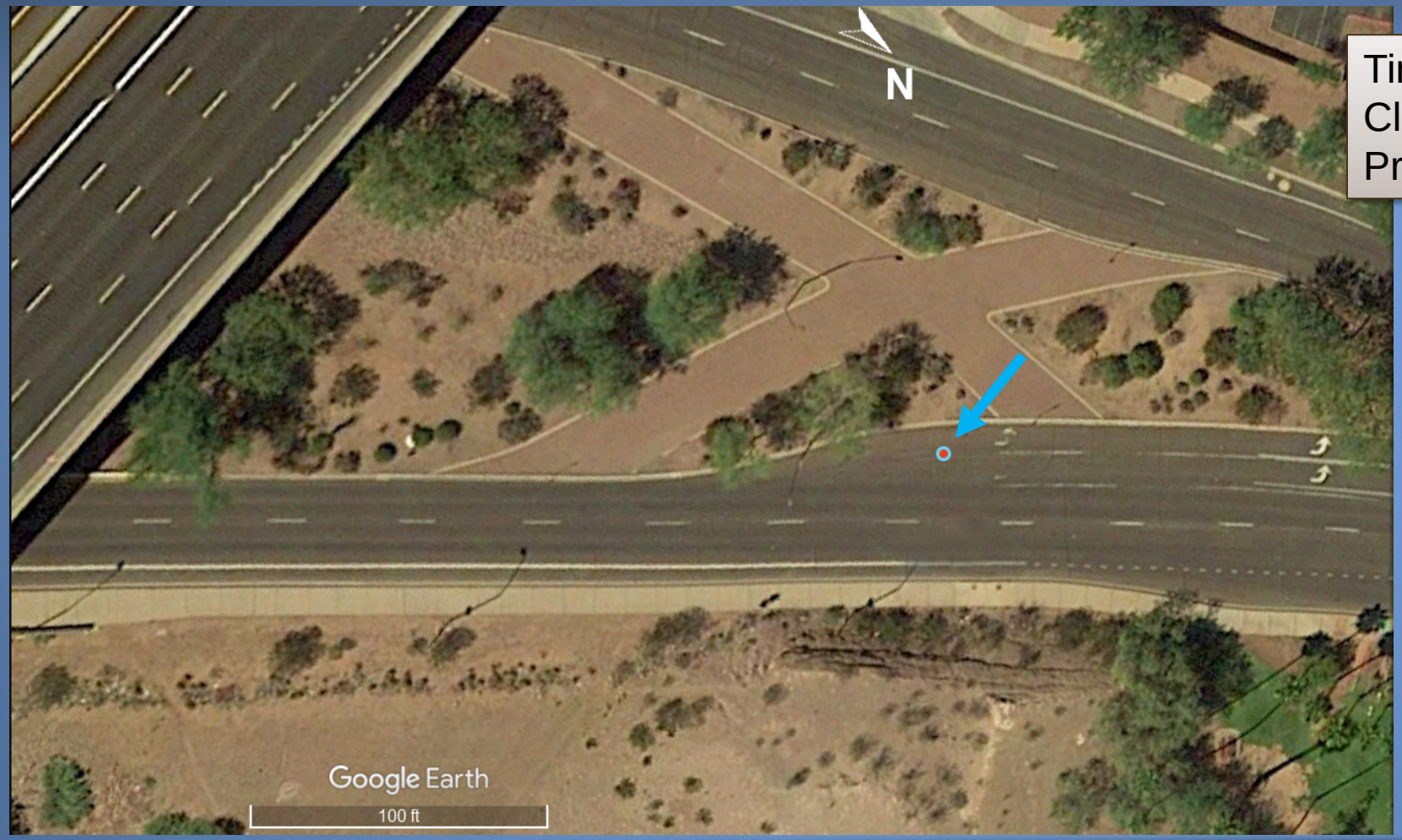
ADS Design: Perception

- Some objects not assigned inherent goal
  - Unknown objects
  - Pedestrian outside crosswalk not assigned goal of crossing street
- Tracking history not considered when classification changes
  - Predicted path depended on object's goal

ADS Design: Emergency Situations

- Situations that require hard braking (> 0.71 g)
  - Braking suppression for 1 second
  - Concerns about false alarms
- If hazard remained, system would:
  - Engage maximum braking only if crash could be avoided
  - Alert operator if crash could not be avoided

Perception and Motion During the Crash



Time to crash: 5.6 seconds
Classification: Vehicle
Predicted path: None

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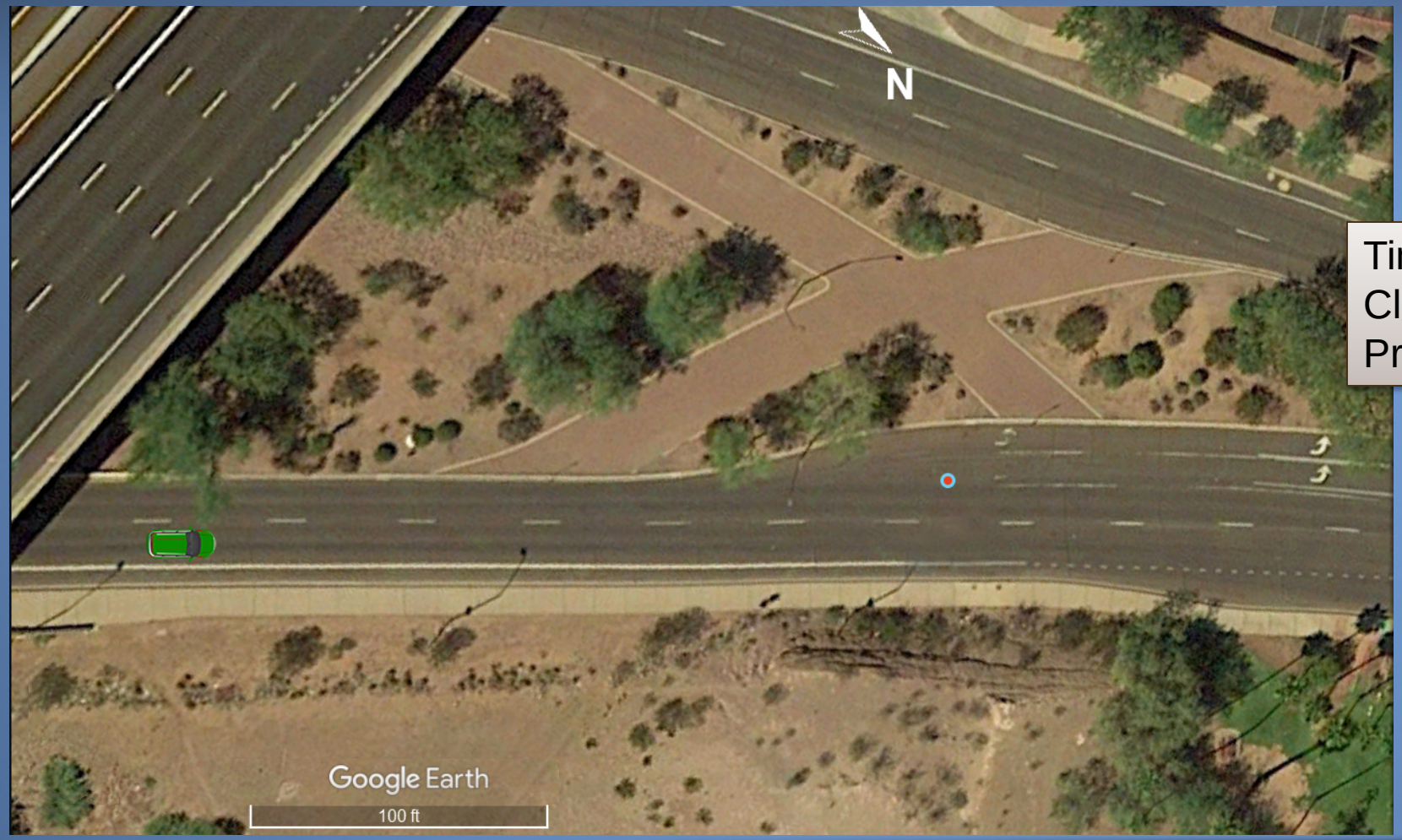
Perception and Motion During the Crash



Time to crash: 3.9 seconds
Classification: Vehicle
Predicted path: Left lane

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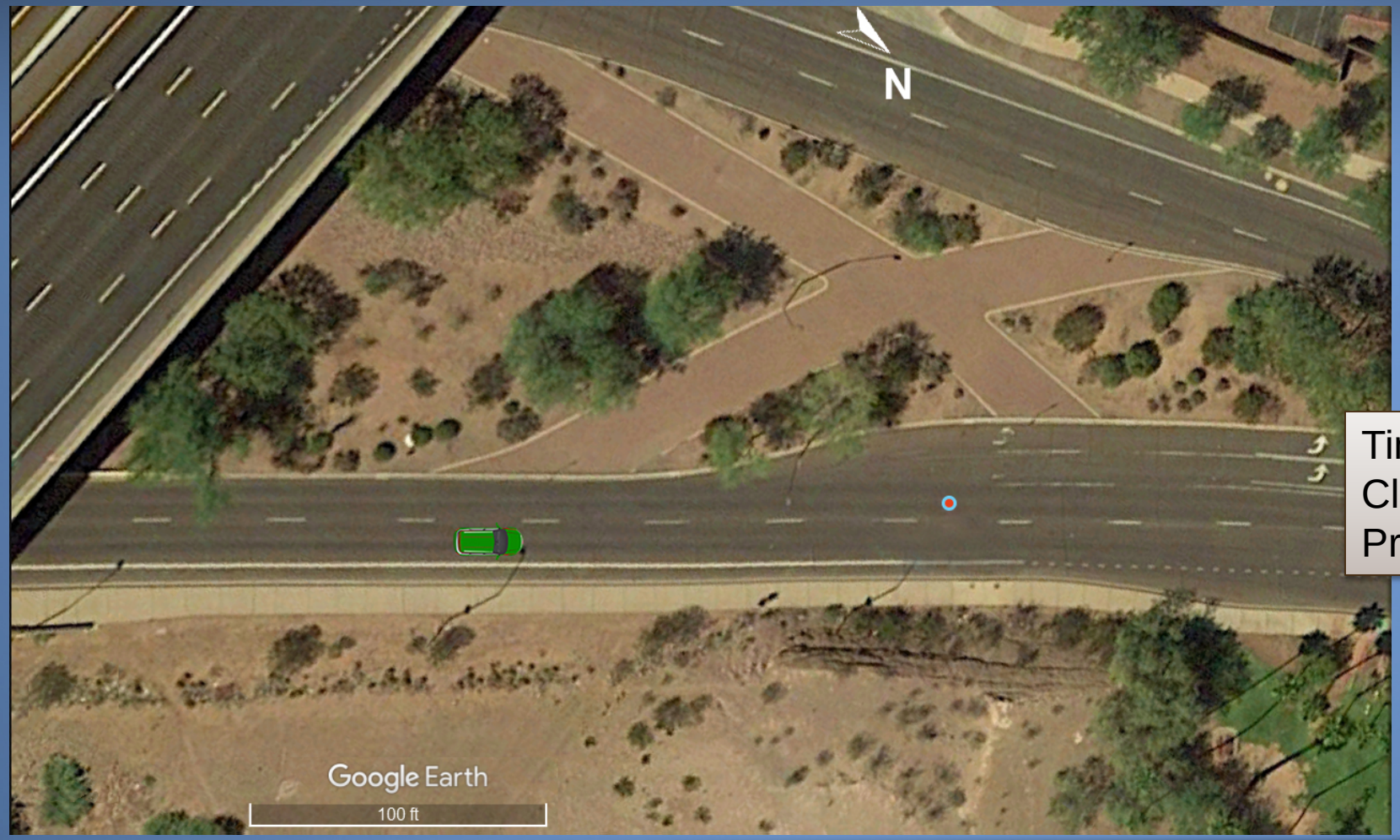
Perception and Motion During the Crash



Time to crash: 2.6 seconds
Classification: Bicycle
Predicted path: Static

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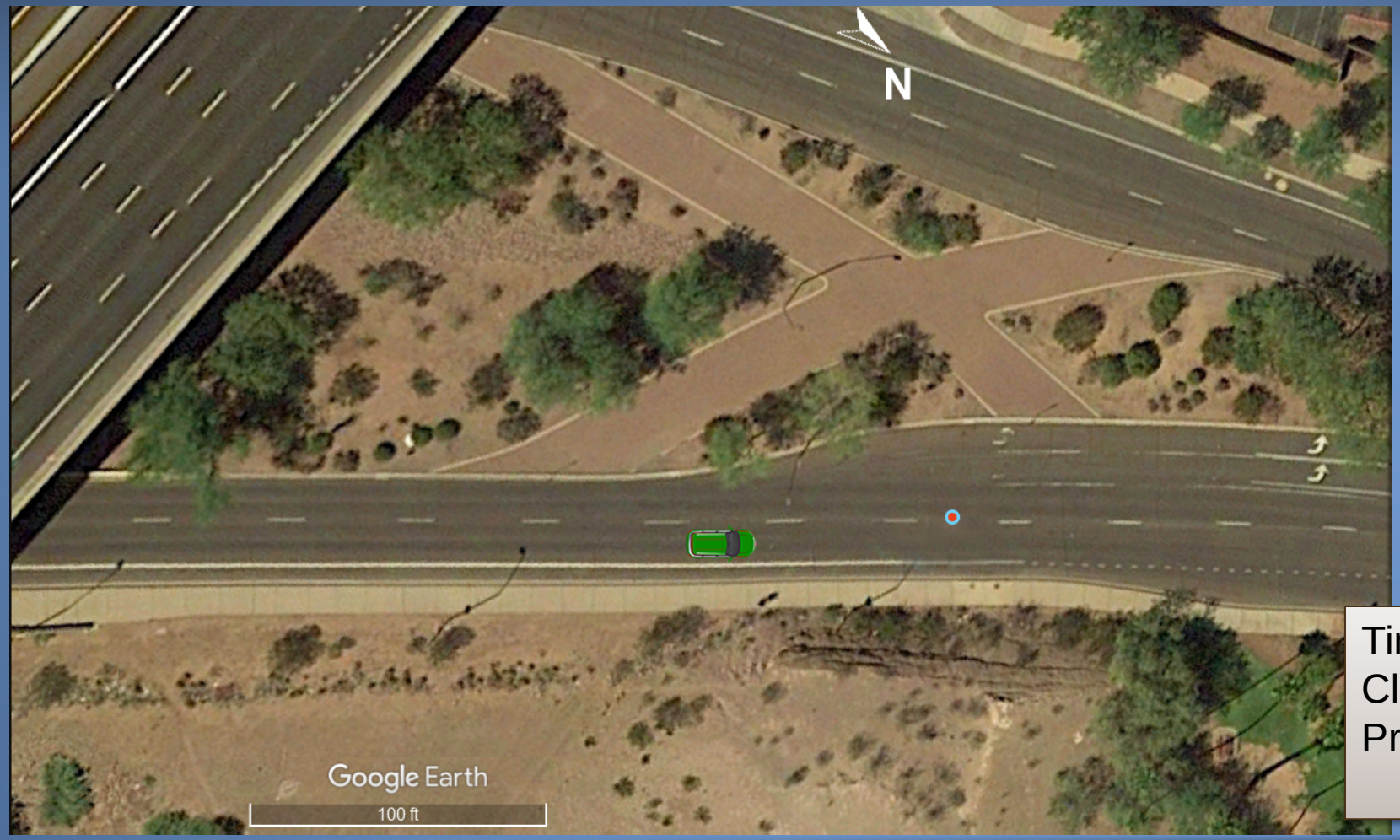
Perception and Motion During the Crash



Time to crash: 1.5 seconds
Classification: Other
Predicted path: Static, partially on vehicle's path

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Perception and Motion During the Crash

Time to crash: 1.2 seconds
Classification: Bicycle
Predicted path: Fully on path of the vehicle
Braking suppression begins

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Perception and Motion During the Crash

Time to crash: 0.2 seconds
Classification: Bicycle
Predicted path: Fully on path of the vehicle
Braking suppression ends

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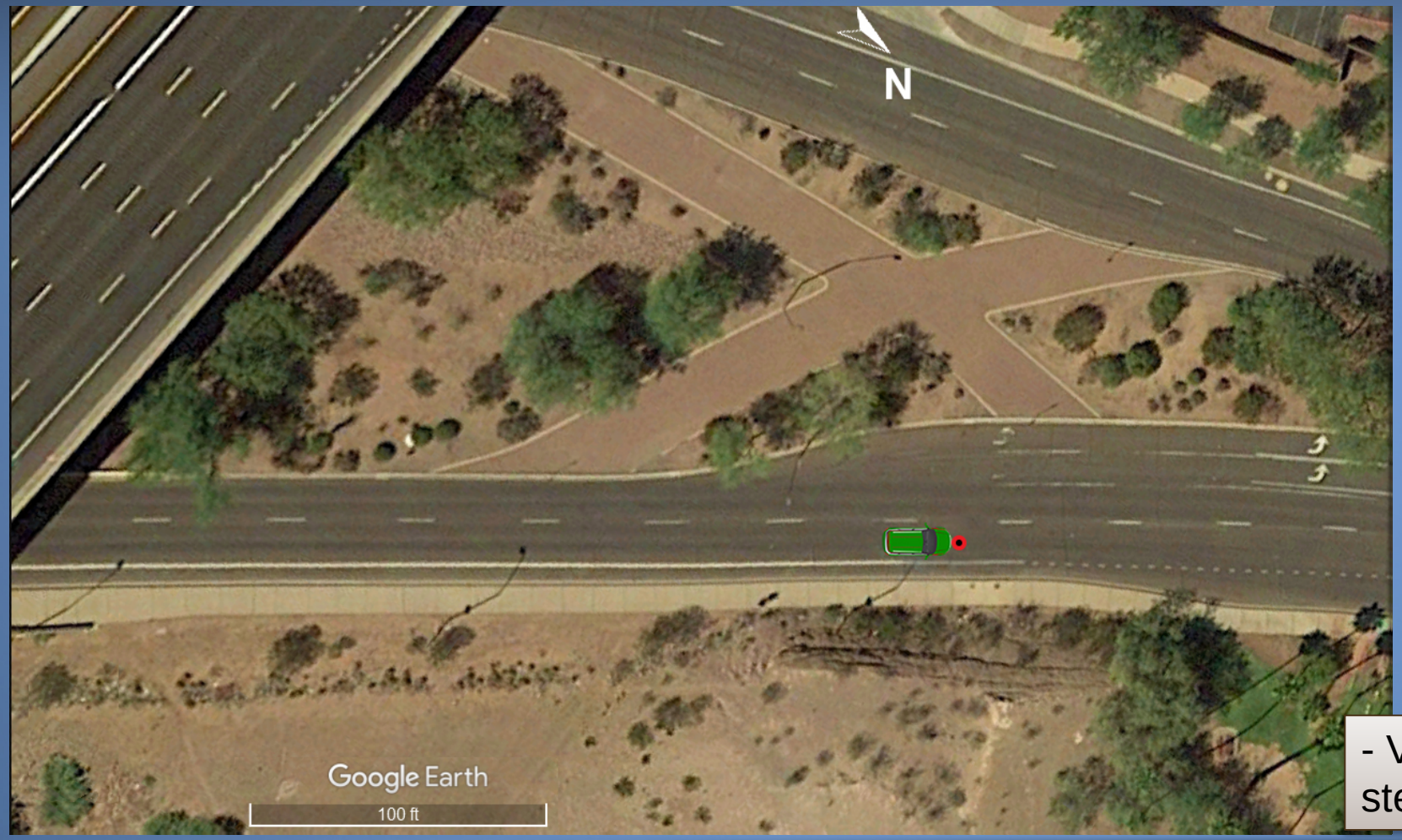
Perception and Motion During the Crash



- Vehicle operator initiated steering 20 msec before impact

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Risk Management at Time of Crash

- Reduced layers of safety redundancy – increased risk
  - No anticipation of pedestrians outside crosswalks
  - No emergency braking solely for crash mitigation
  - Deactivated Volvo AEB
- Adequacy of safety redundancies and mitigation strategies
  - Vehicle operator final countermeasure
  - Vehicle operator failed to respond

Postcrash Changes

- Comprehensive changes, including technical:
  - Pedestrians may be assigned goal of crossing midblock
  - Volvo AEB remains active during ADS operation
  - ADS emergency braking can activate solely for crash mitigation
  - No suppression of braking in emergency situations
- Some changes reduced risk of testing on public roads

Summary

- At time of crash
  - ADS limitations and design considerations limited layers of safety redundancy and increased risk
  - Vehicle operator was poor mitigation strategy
- Postcrash changes
  - Increased layers of safety redundancy in ADS design
  - Vehicle operators