

# MATLAB EXPO 2019

## Sensor Fusion and Tracking for Autonomous Systems

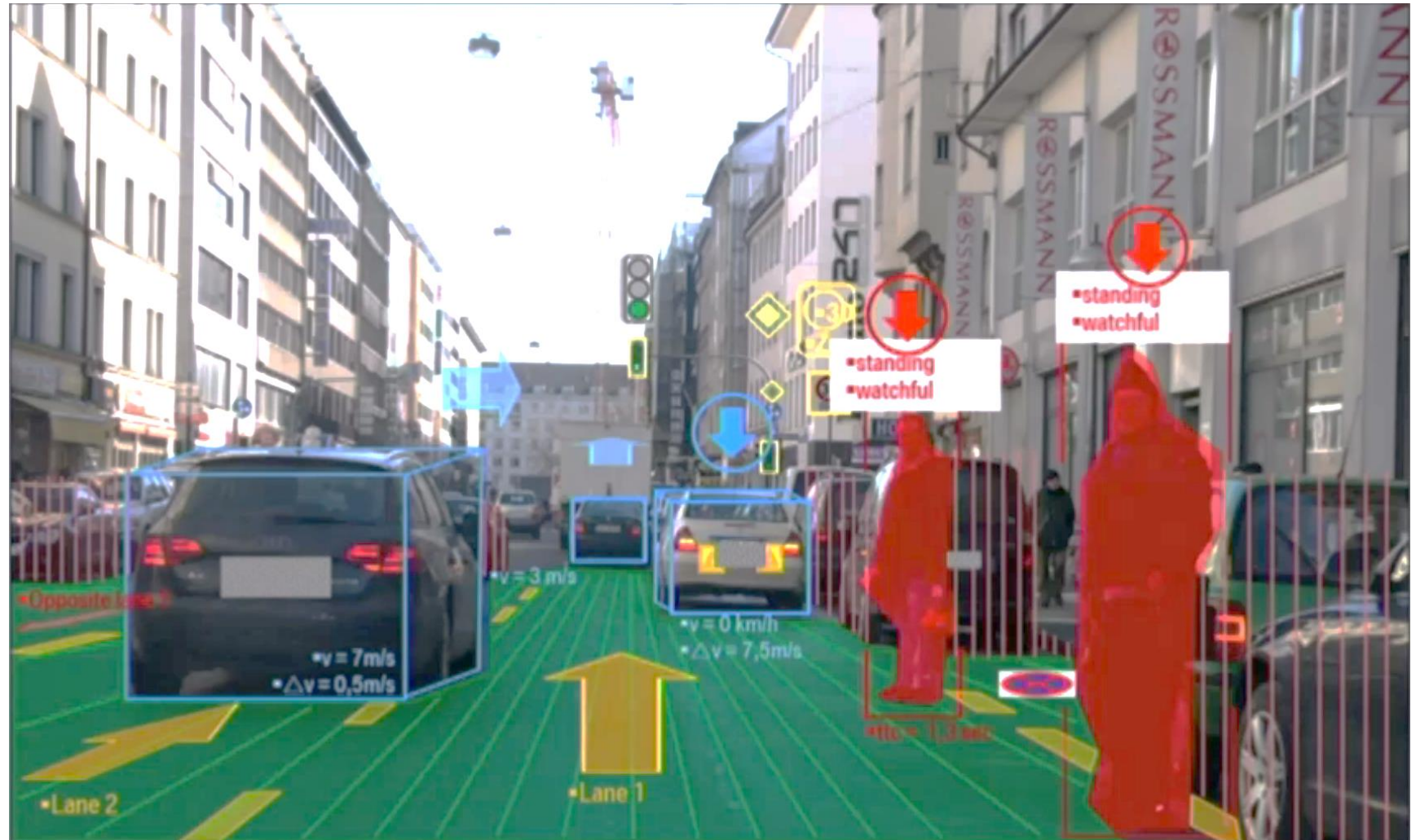
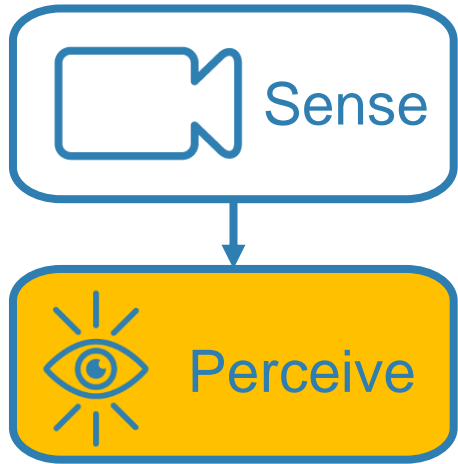
Gerald Albertini  
[galberti@mathworks.com](mailto:galberti@mathworks.com)



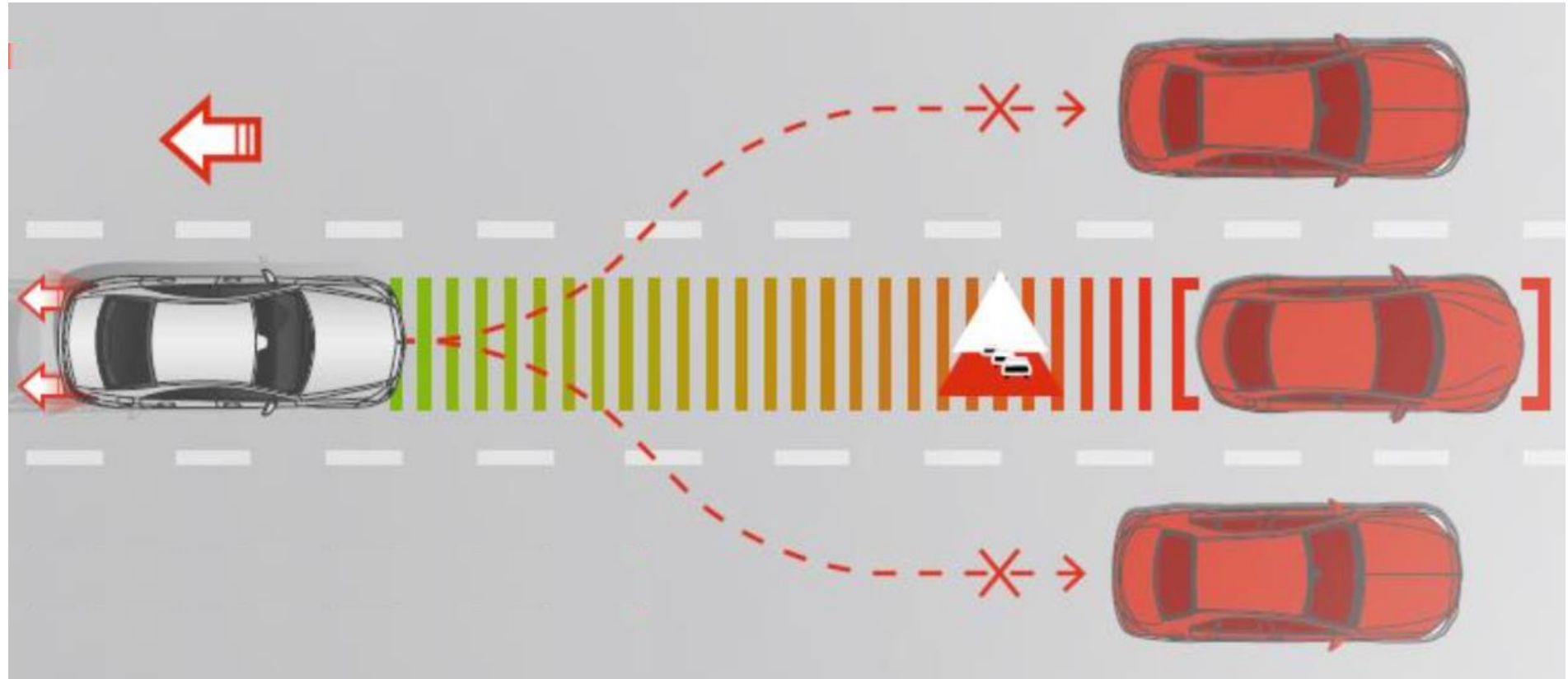
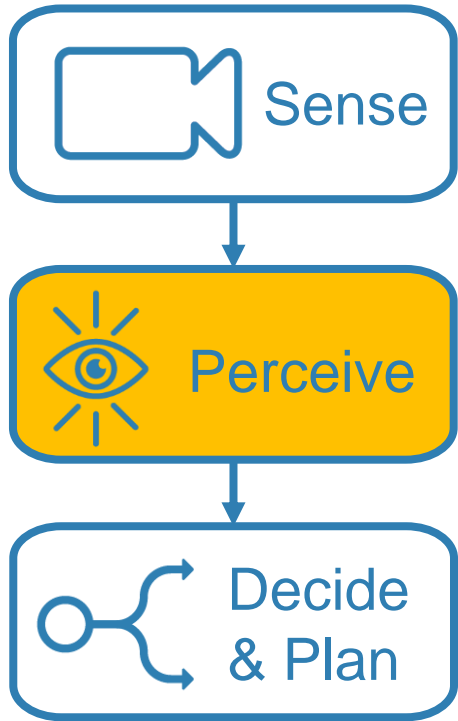
# Capabilities of an Autonomous System



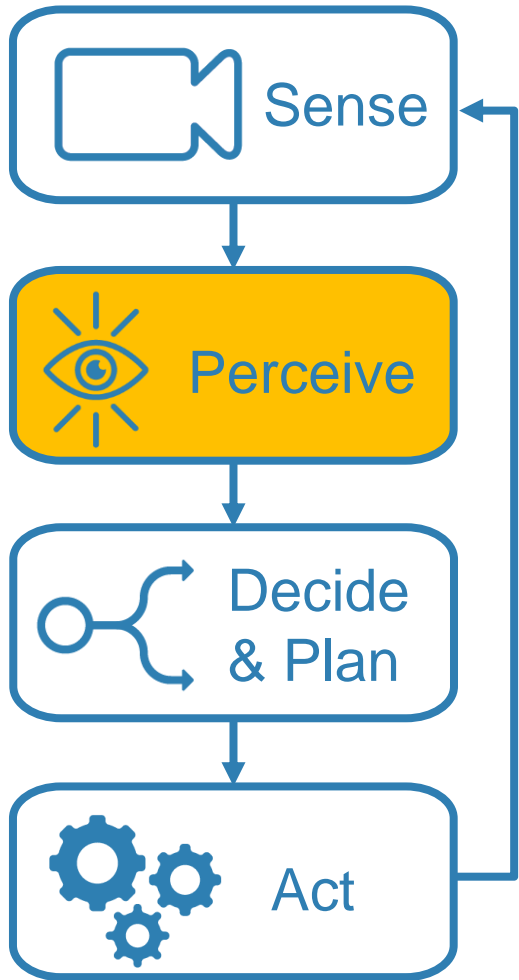
# Capabilities of an Autonomous System



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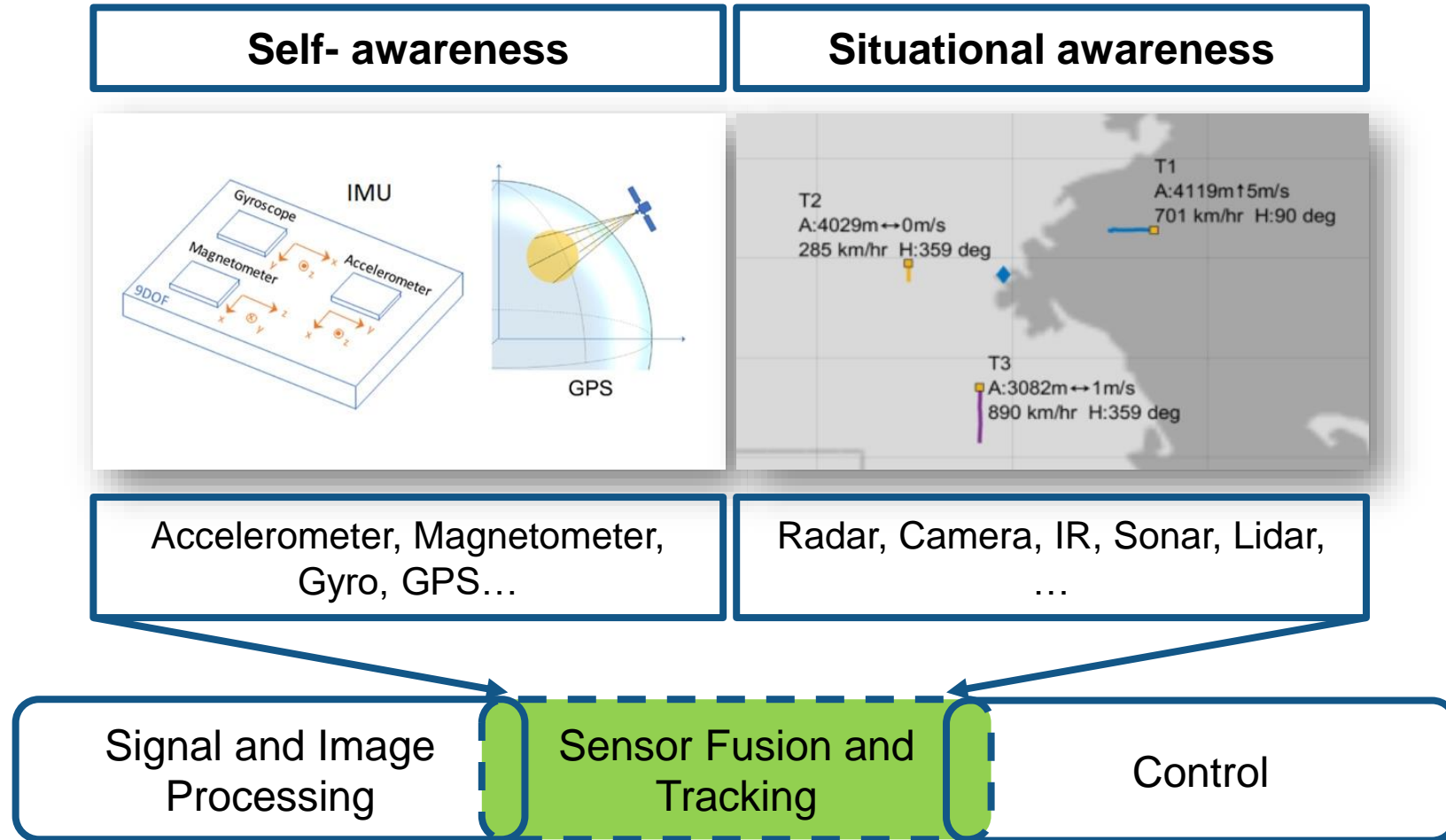
# Capabilities of an Autonomous System



# Agenda

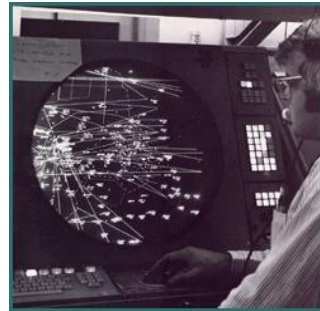
- Introduction
- Technology overview of perception
- Algorithm development for sensor fusion and tracking
- Q&A
- Resources for further exploration

# Sensor fusion and tracking is...

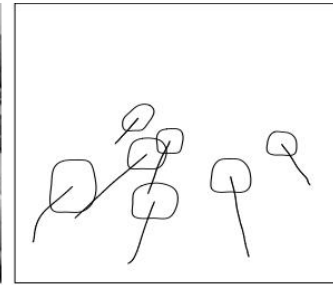
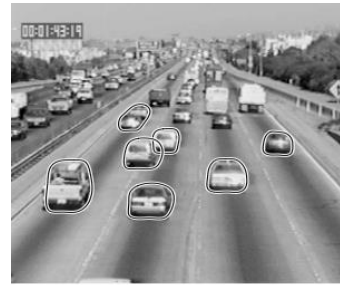


# Timeline of Technology Advances

Multi-object tracking



Air Traffic Control

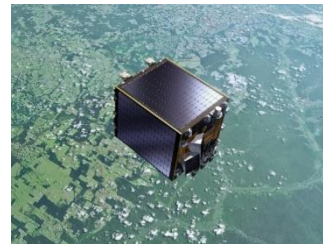


Computer Vision for Transportation

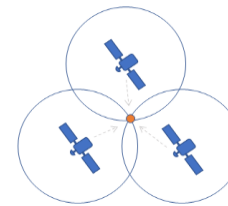


Multi-sensor Fusion for Autonomous Systems

Localization



Military



Commercial

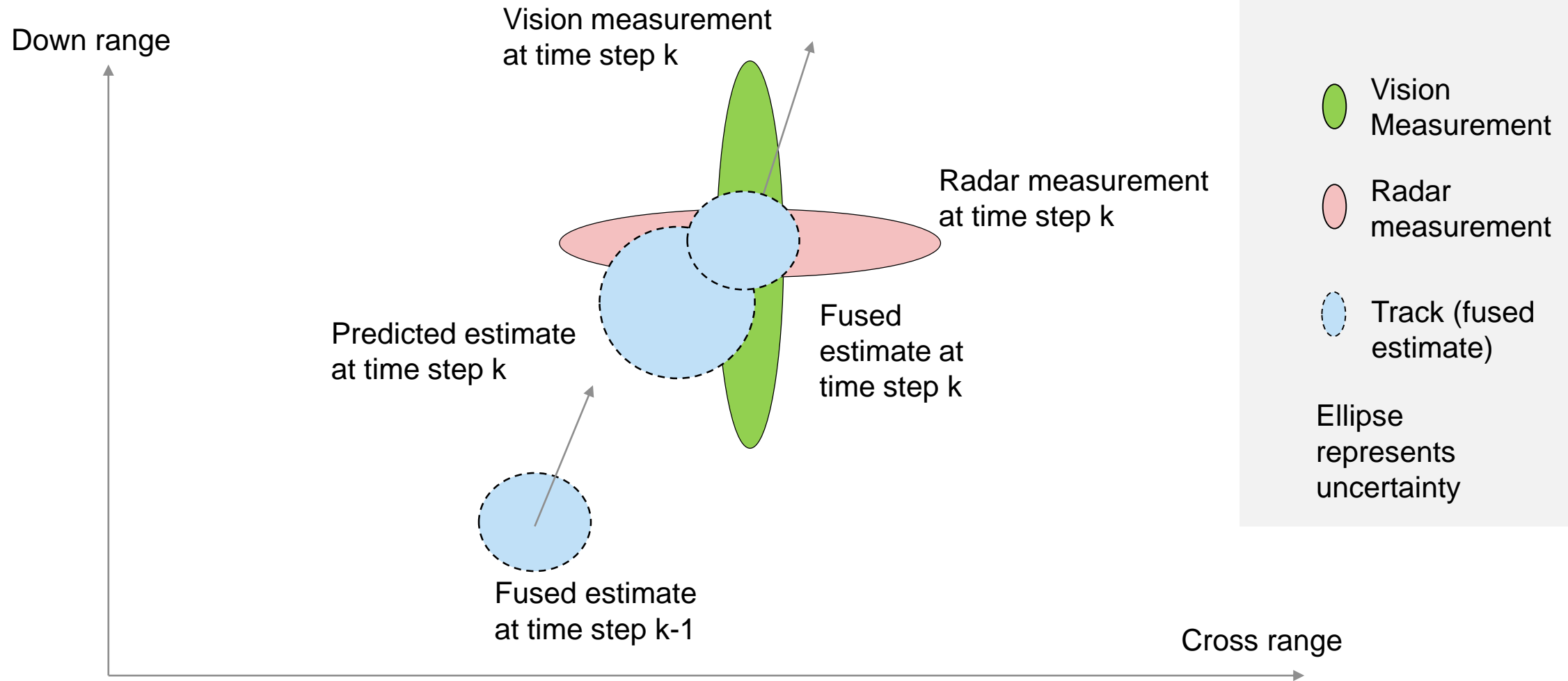


Ubiquitous

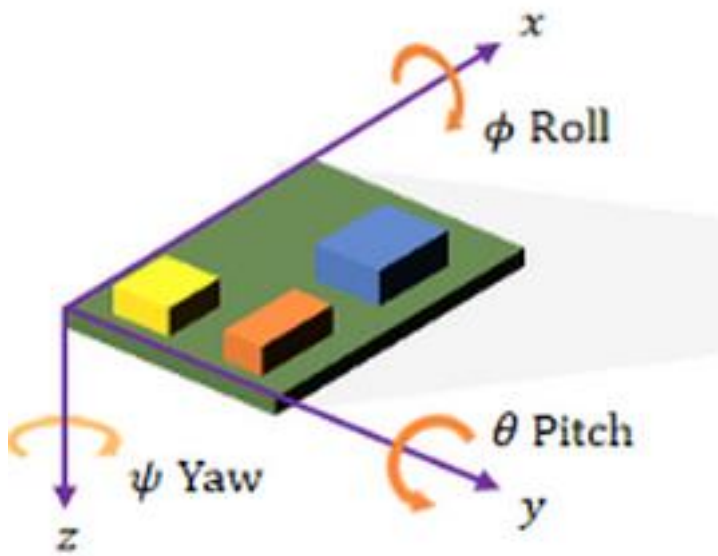
Today



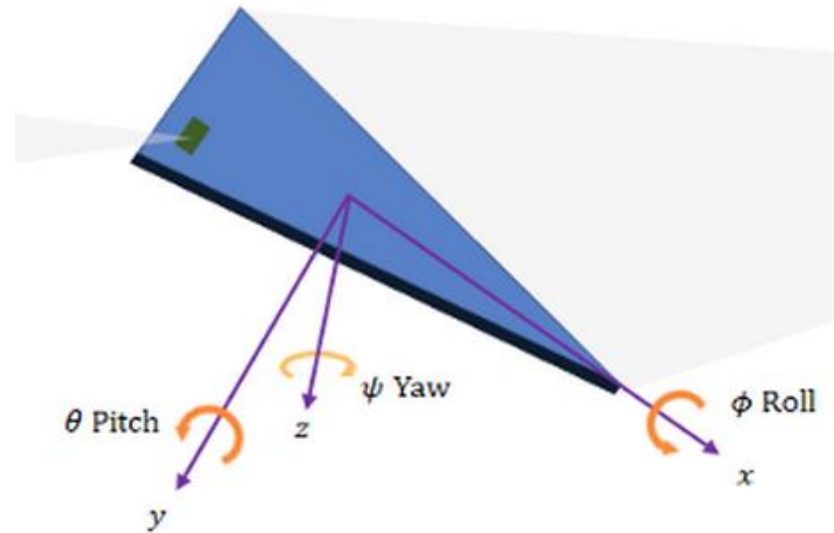
# Fusion Combines the Strengths of Each Sensor



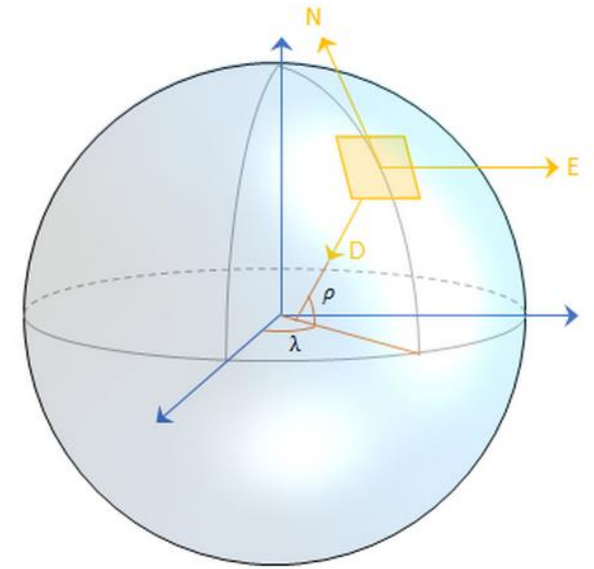
# What is Localization?



Inertial Sensor



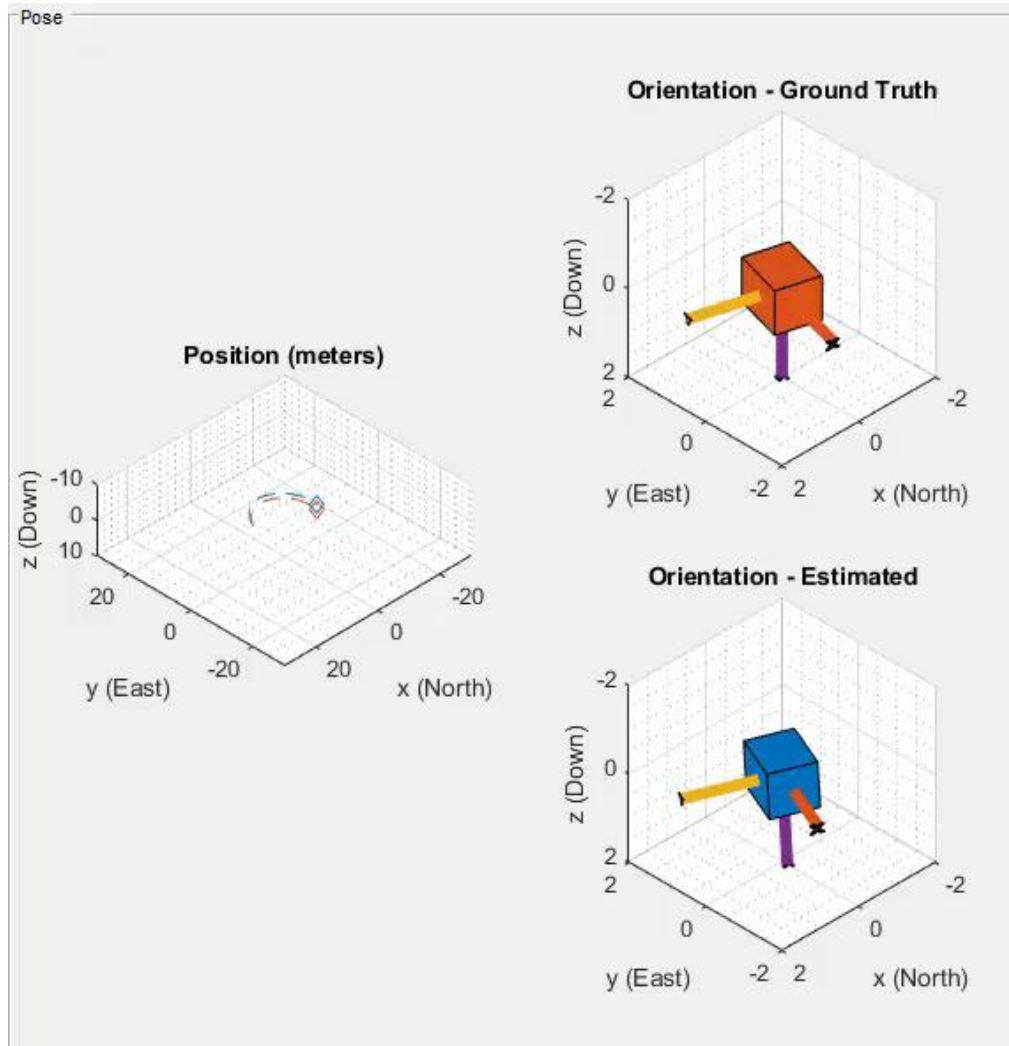
Attitude



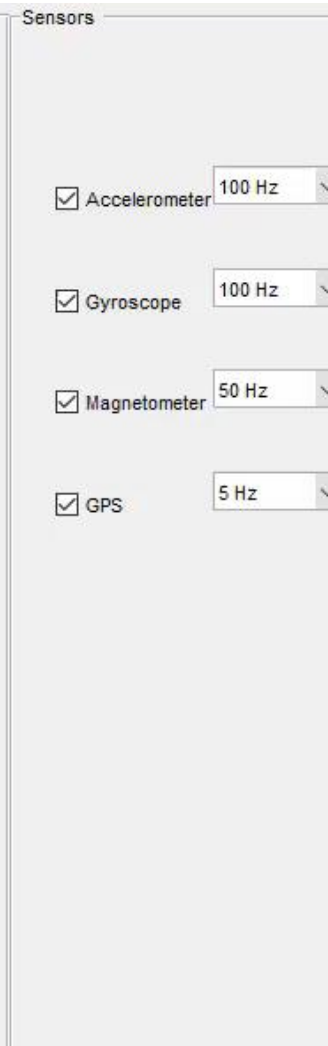
Position

# Fusing Sensor Data Improves Localization

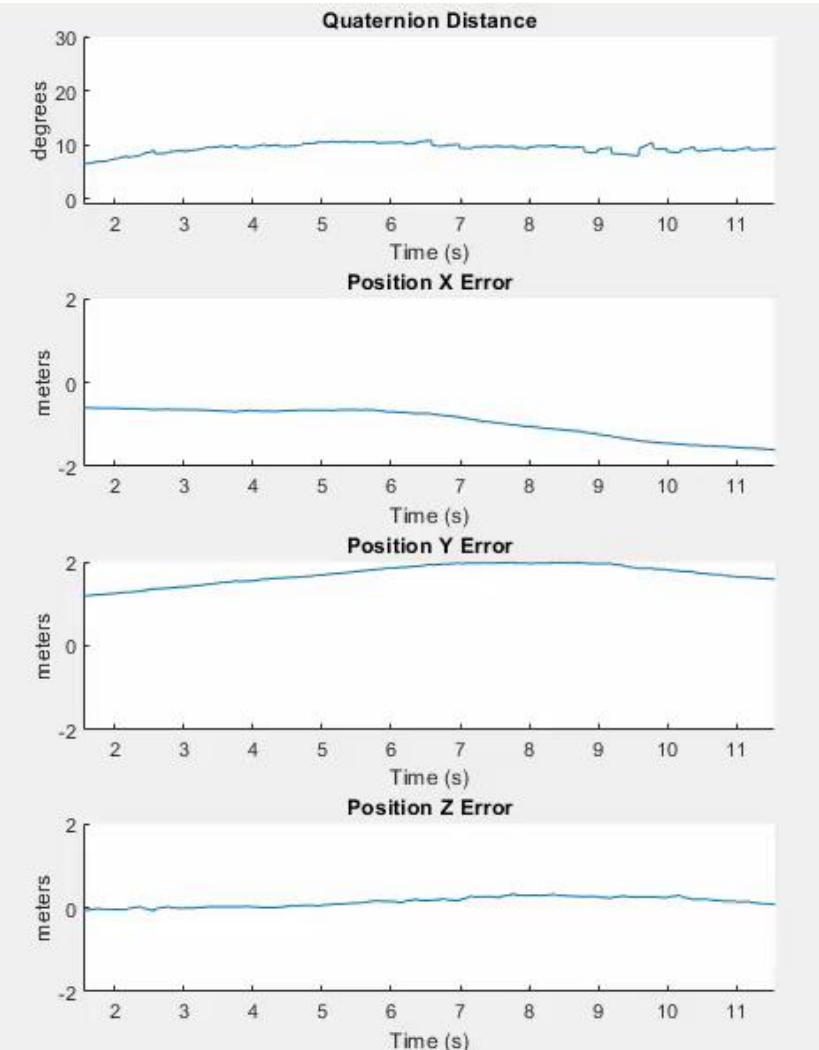
## Ground truth vs. Estimate



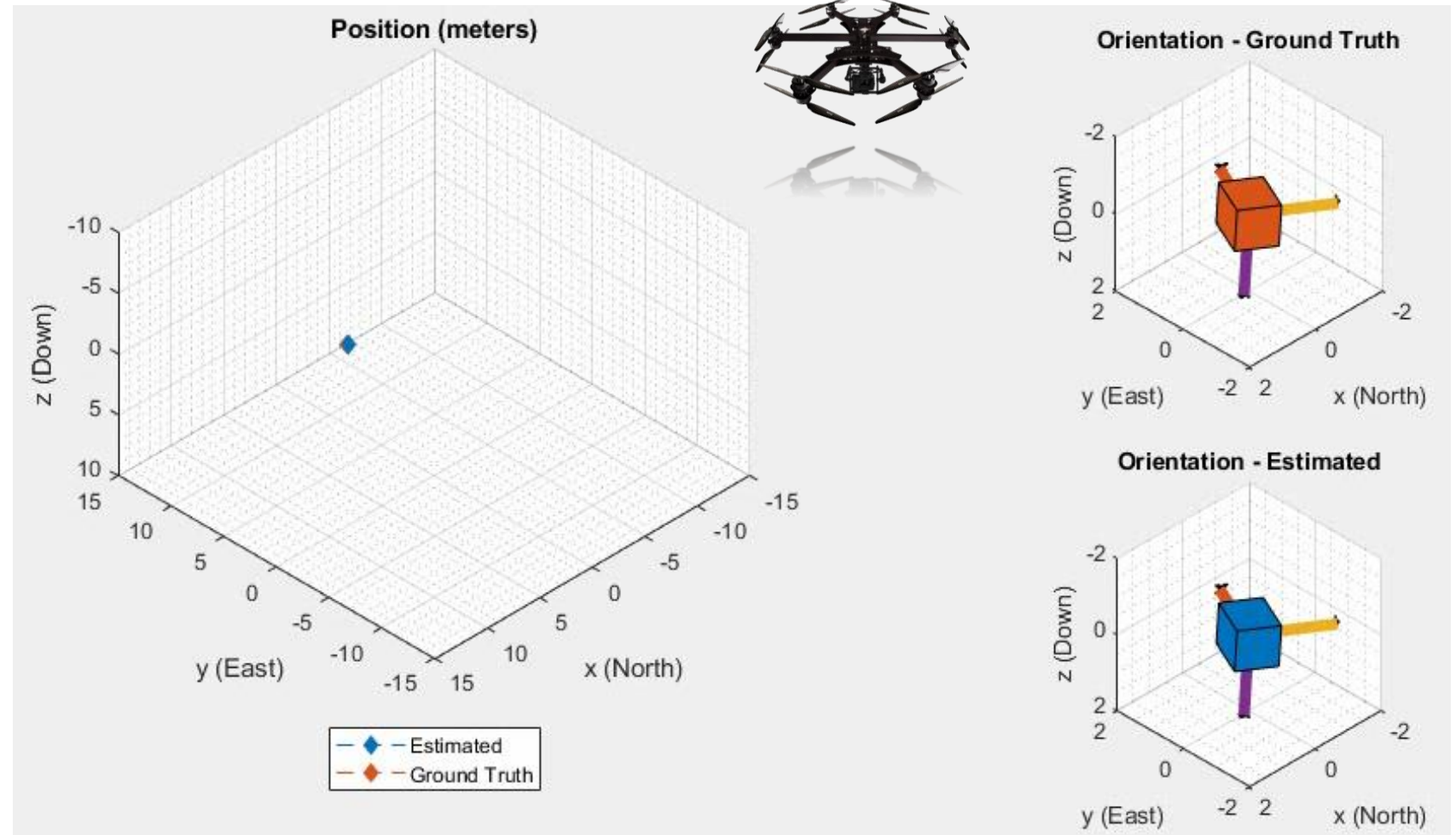
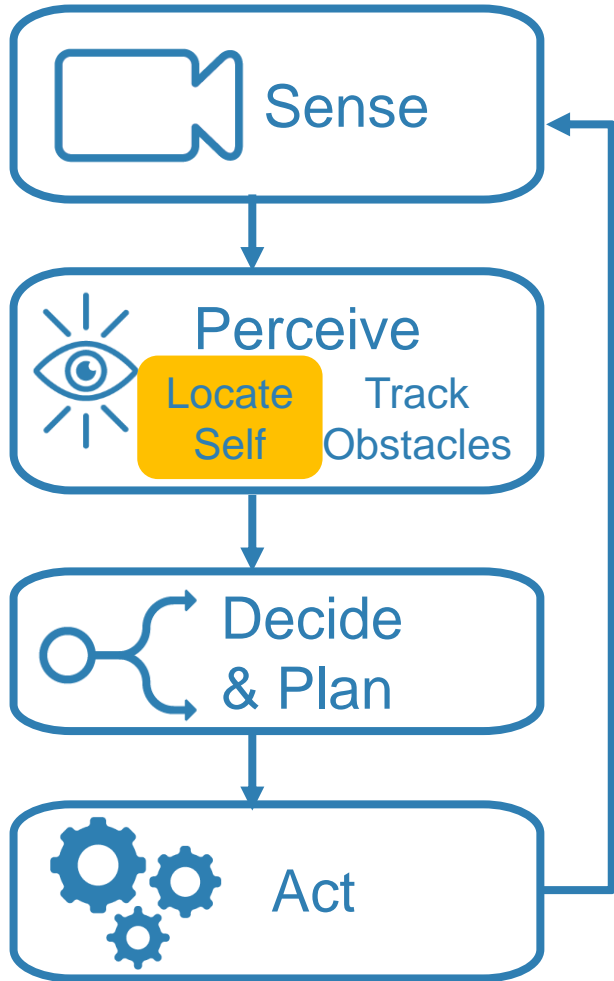
## Sensors



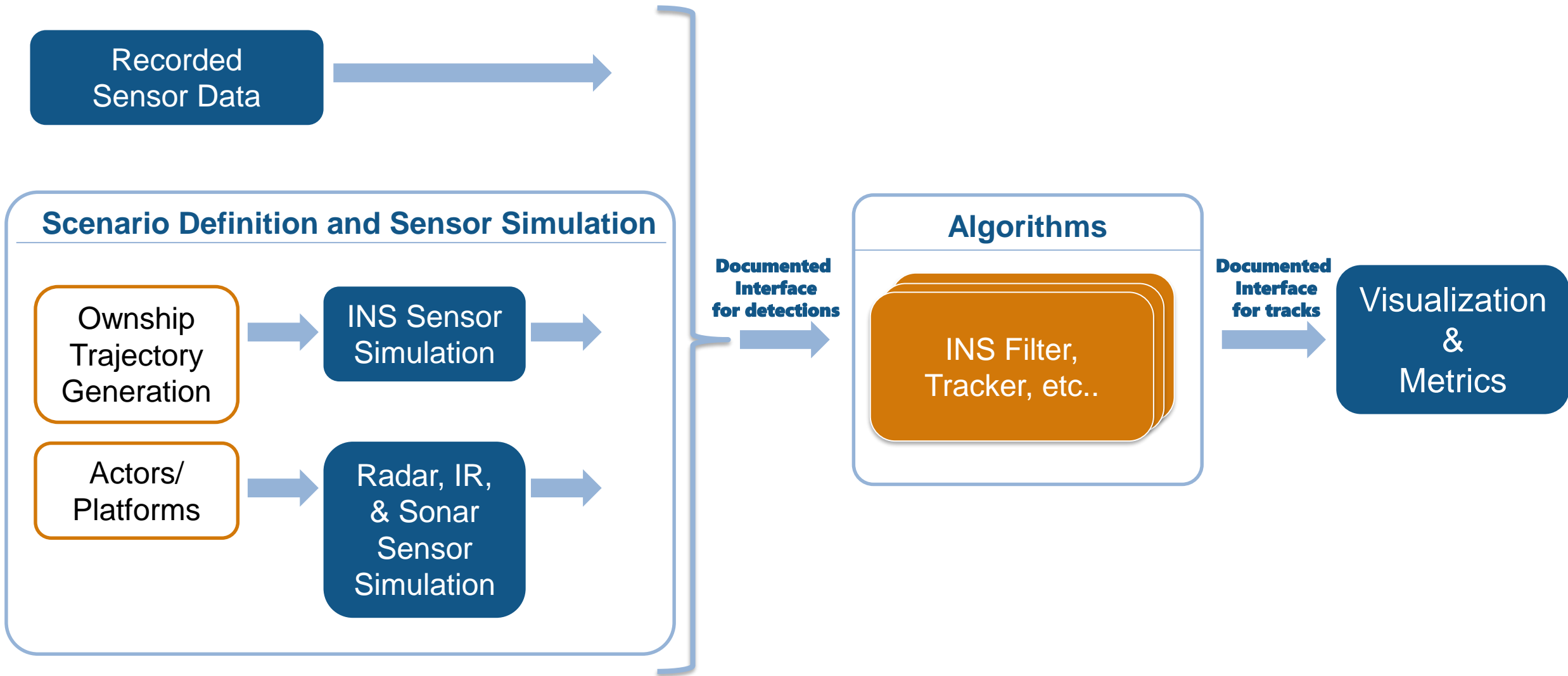
## Error Measurements



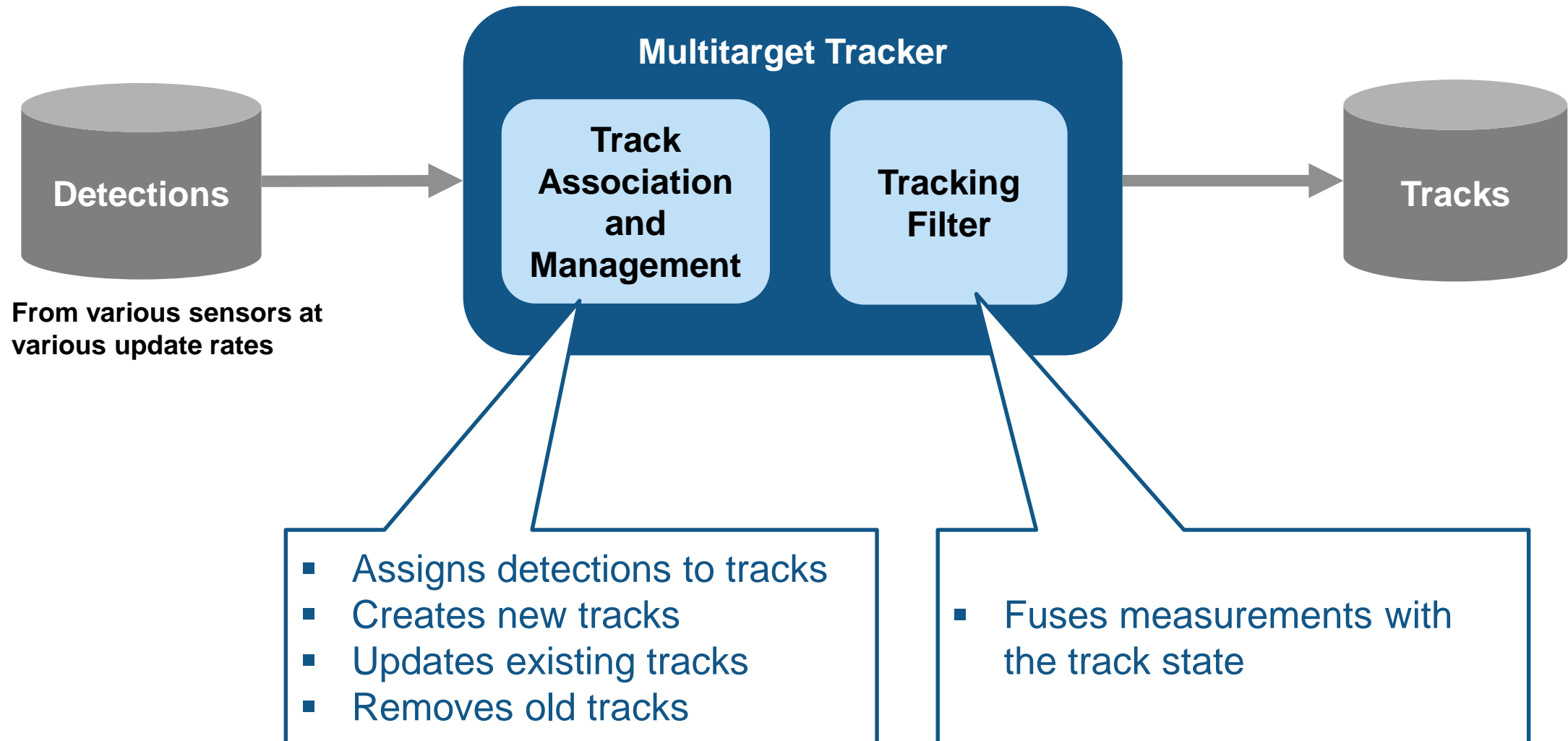
# Fuse IMU & GPS for Self-Localization of a UAV



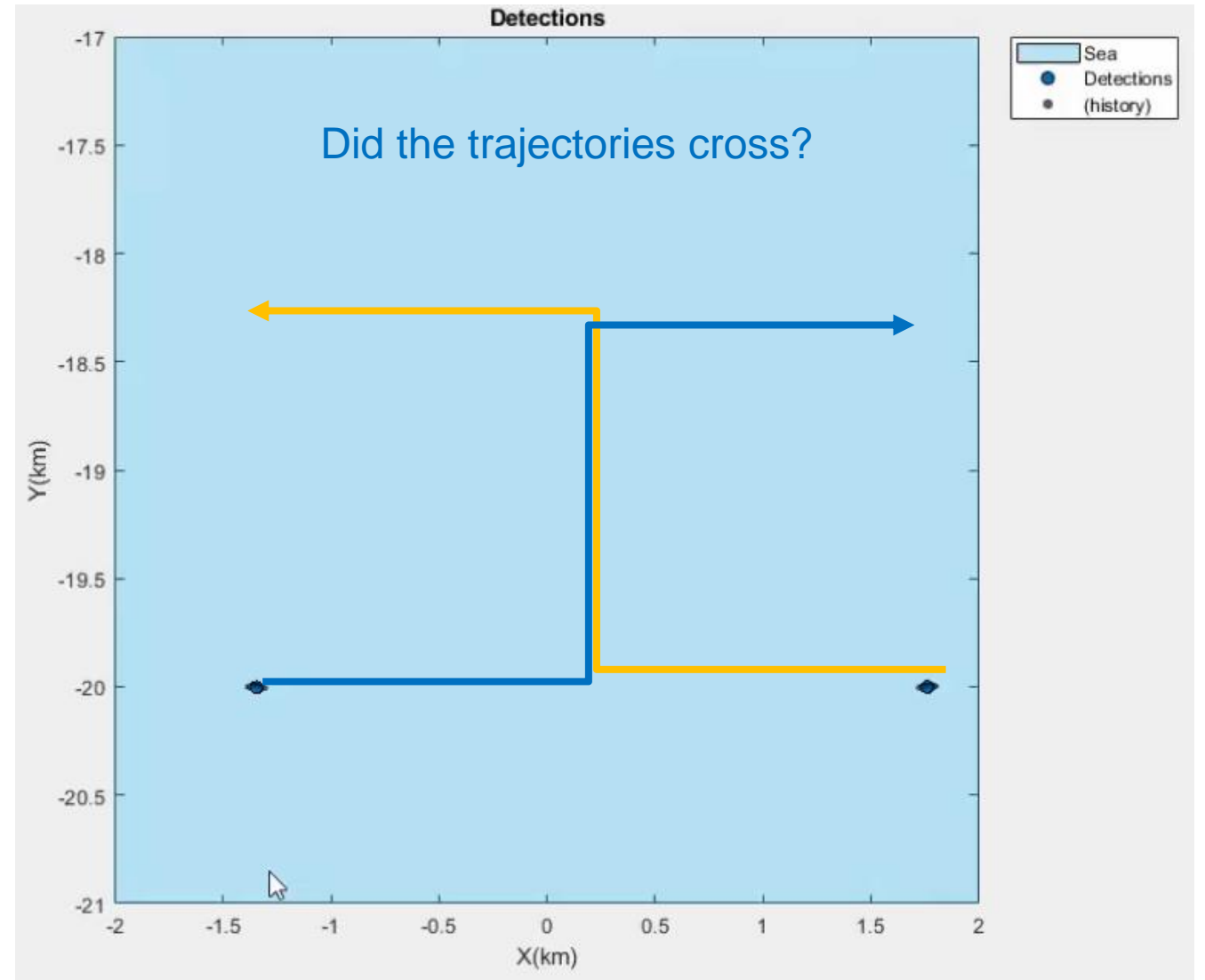
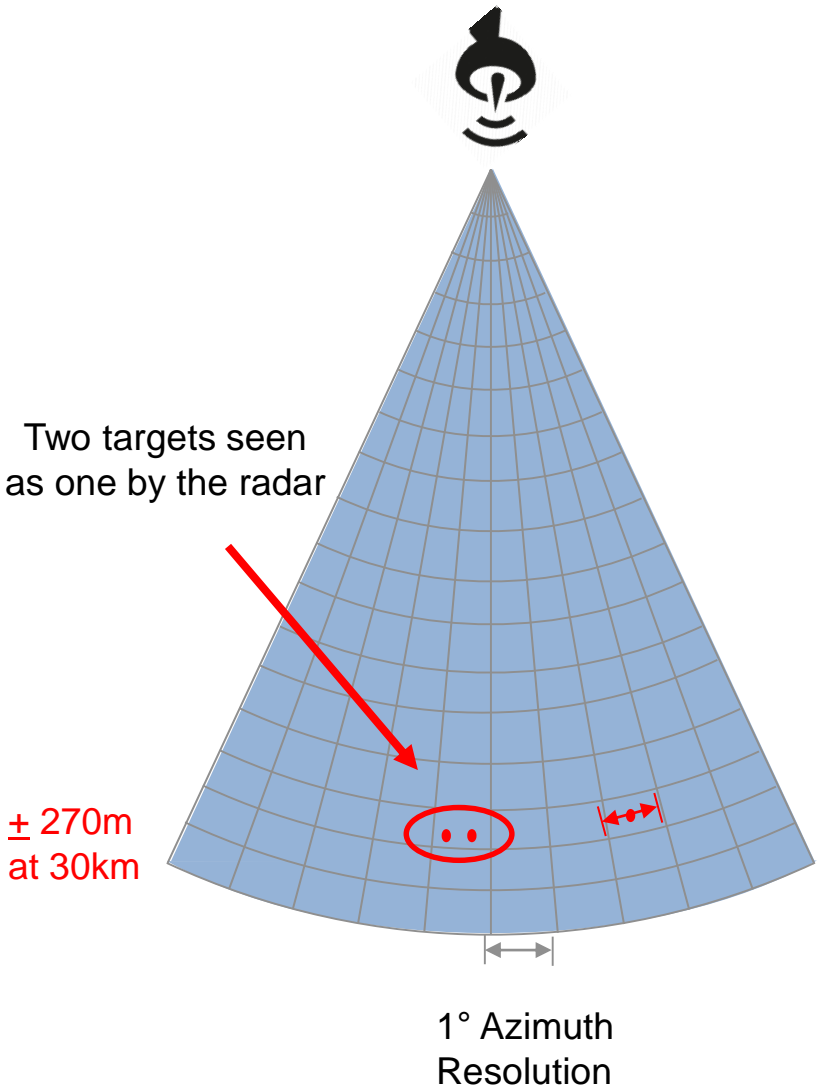
# Flexible Workflows Ease Adoption



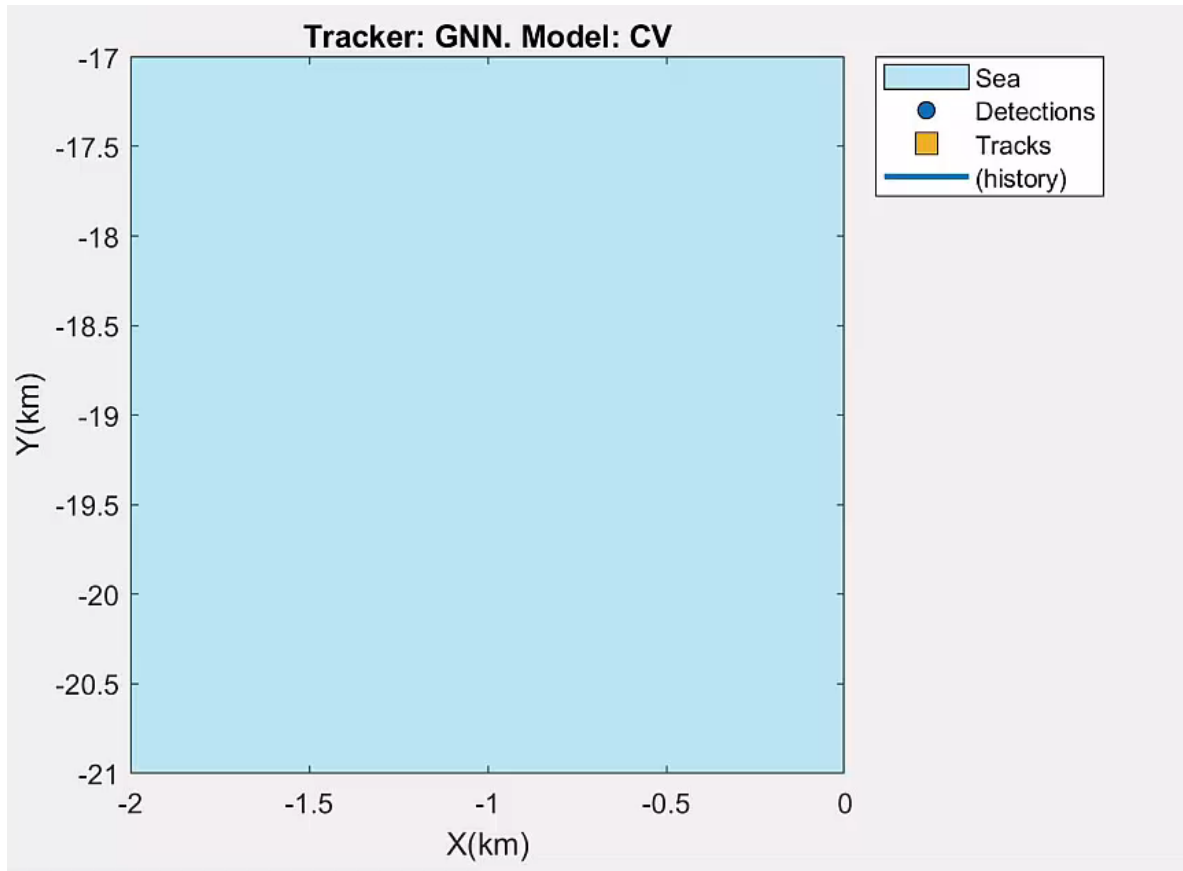
# A Multi-object Tracker is More than a Kalman Filter



# Performing What-If Analysis



# Performing What-If Analysis

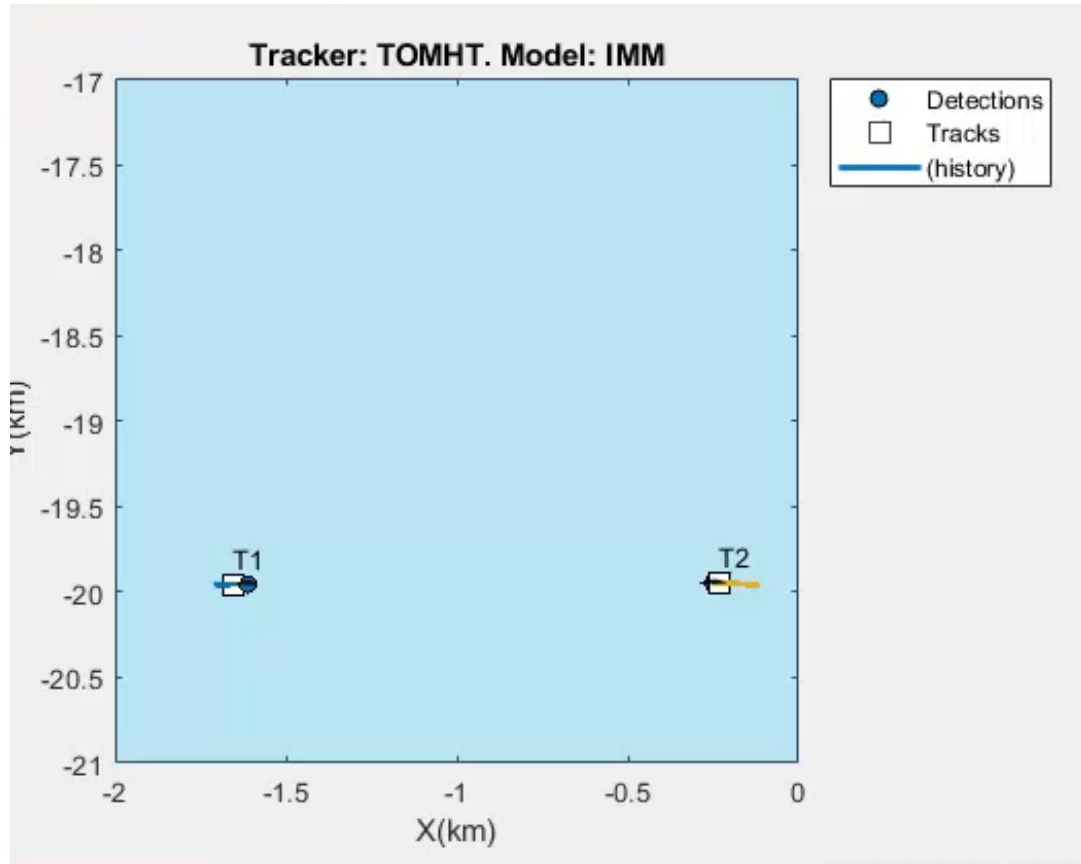


```
tracker = trackerGNN( ...
    'FilterInitializationFcn',@initCVFilter,...
    'MaxNumTracks', numTracks, ...
    'MaxNumSensors', 1, ...
    'AssignmentThreshold',gate, ...
    'TrackLogic', 'Score', ...
    'DetectionProbability', pd, ...
    'FalseAlarmRate', far, ...
    'Volume', vol, 'Beta', beta);
```

```
tracker = trackerGNN( ...
    'FilterInitializationFcn',@initIMMFilter,...
    'MaxNumTracks', numTracks, ...
    'MaxNumSensors', 1, ...
    'AssignmentThreshold',gate, ...
    'TrackLogic', 'Score', ...
    'DetectionProbability', pd, ...
    'FalseAlarmRate', far, ...
    'Volume', vol, 'Beta', beta);
```



# Performing What-If Analysis



```

tracker = trackerTOMHT( ...
    'FilterInitializationFcn', @initIMMFilter, ...
    'MaxNumTracks', numTracks, ...
    'MaxNumSensors', 1, ...
    'AssignmentThreshold', [0.2, 1, 1]*gate, ...
    'TrackLogic', 'Score', ...
    'DetectionProbability', pd, ...
    'FalseAlarmRate', far, ...
    'Volume', vol, 'Beta', beta, ...
    'MaxNumHistoryScans', 10, ...
    'MaxNumTrackBranches', 5, ...
    'NScanPruning', 'Hypothesis', ...
    'OutputRepresentation', 'Tracks');
  
```

# Comparing Trackers and Tracking Filters



False track  
Dropped track



TrackID	AssignedTruthID	Surviving	TotalLength	DivergenceStatus
1	2	true	190	false
2	NaN	false	77	true
8	3	true	111	false

TruthID	AssociatedTrackID	TotalLength	BreakCount	EstablishmentLength
2	1	192	0	4
3	8	192	1	2

TrackID	AssignedTruthID	Surviving	TotalLength	DivergenceStatus
1	2	true	190	false
2	3	true	191	false

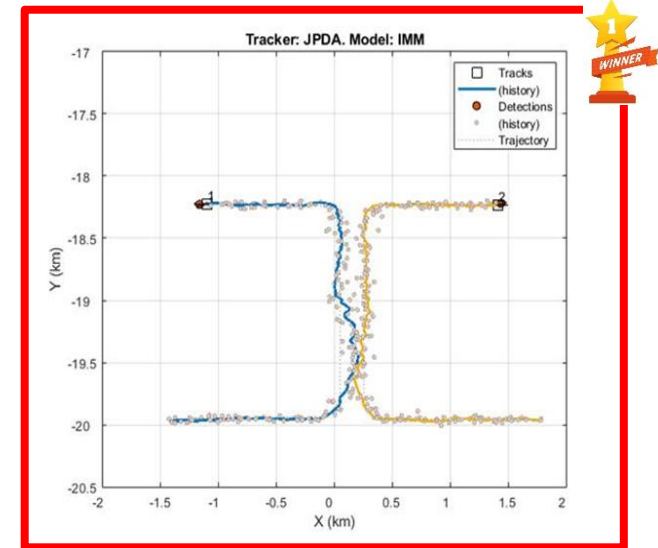
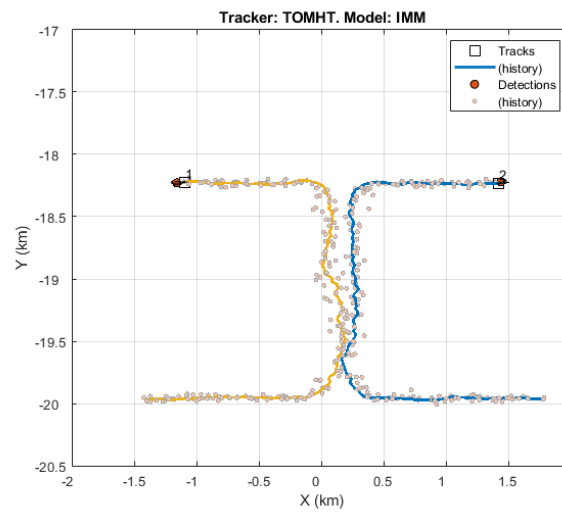
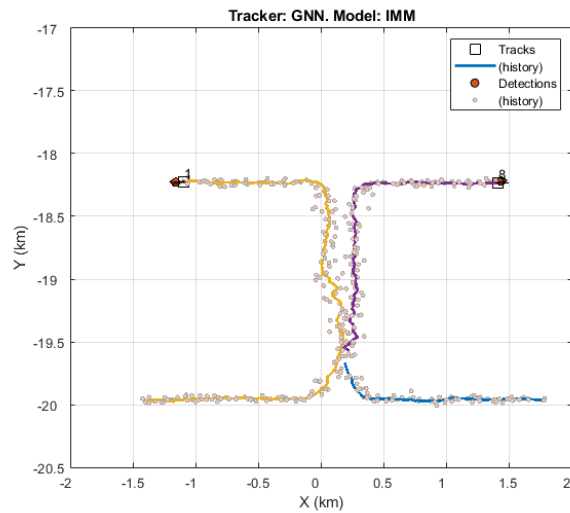
  

TruthID	AssociatedTrackID	TotalLength	BreakCount	EstablishmentLength
2	1	192	0	2
3	2	192	0	2

TrackID	AssignedTruthID	Surviving	TotalLength	DivergenceStatus
1	2	true	191	false
2	3	true	191	false

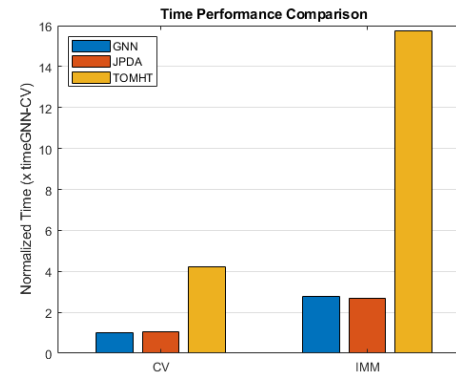
  

TruthID	AssociatedTrackID	TotalLength	BreakCount	EstablishmentLength
2	1	192	0	1
3	2	192	0	2



Slower

Faster



# Point object vs. Extended object

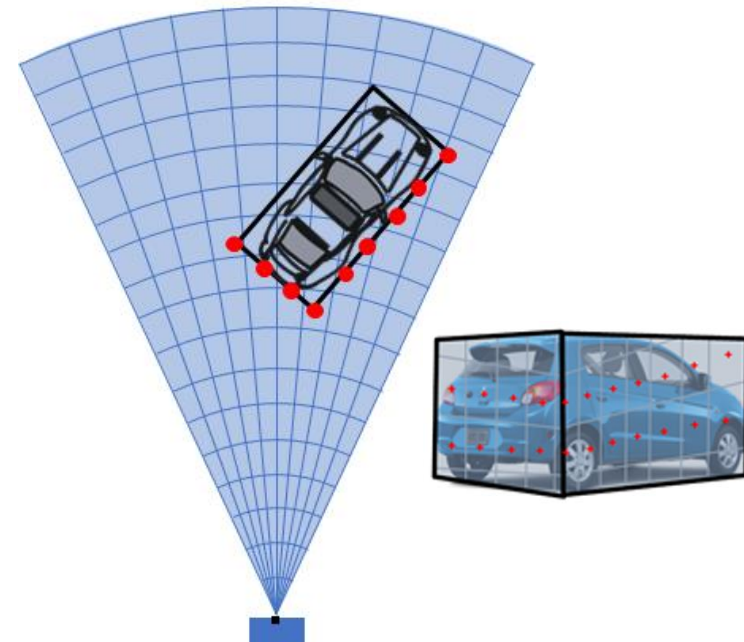
- **Point object**

- Distant object represented as a single point
- One detection per object per scan

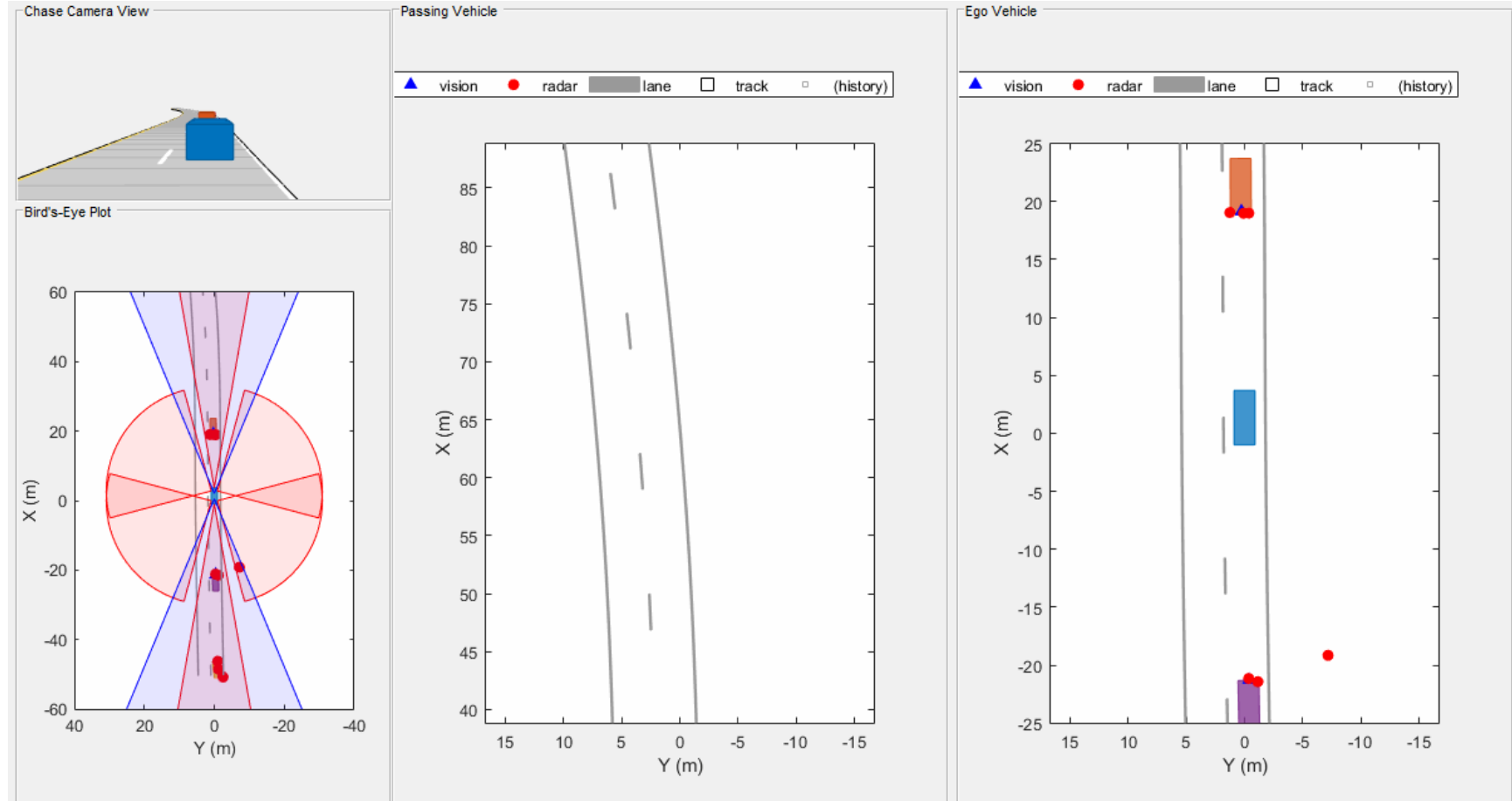
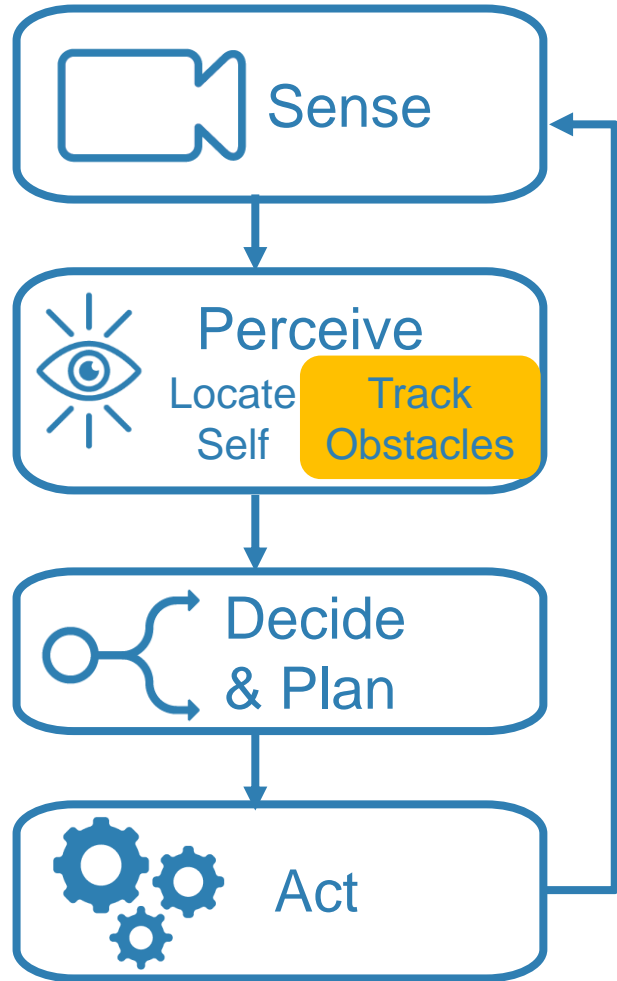


- **Extended object**

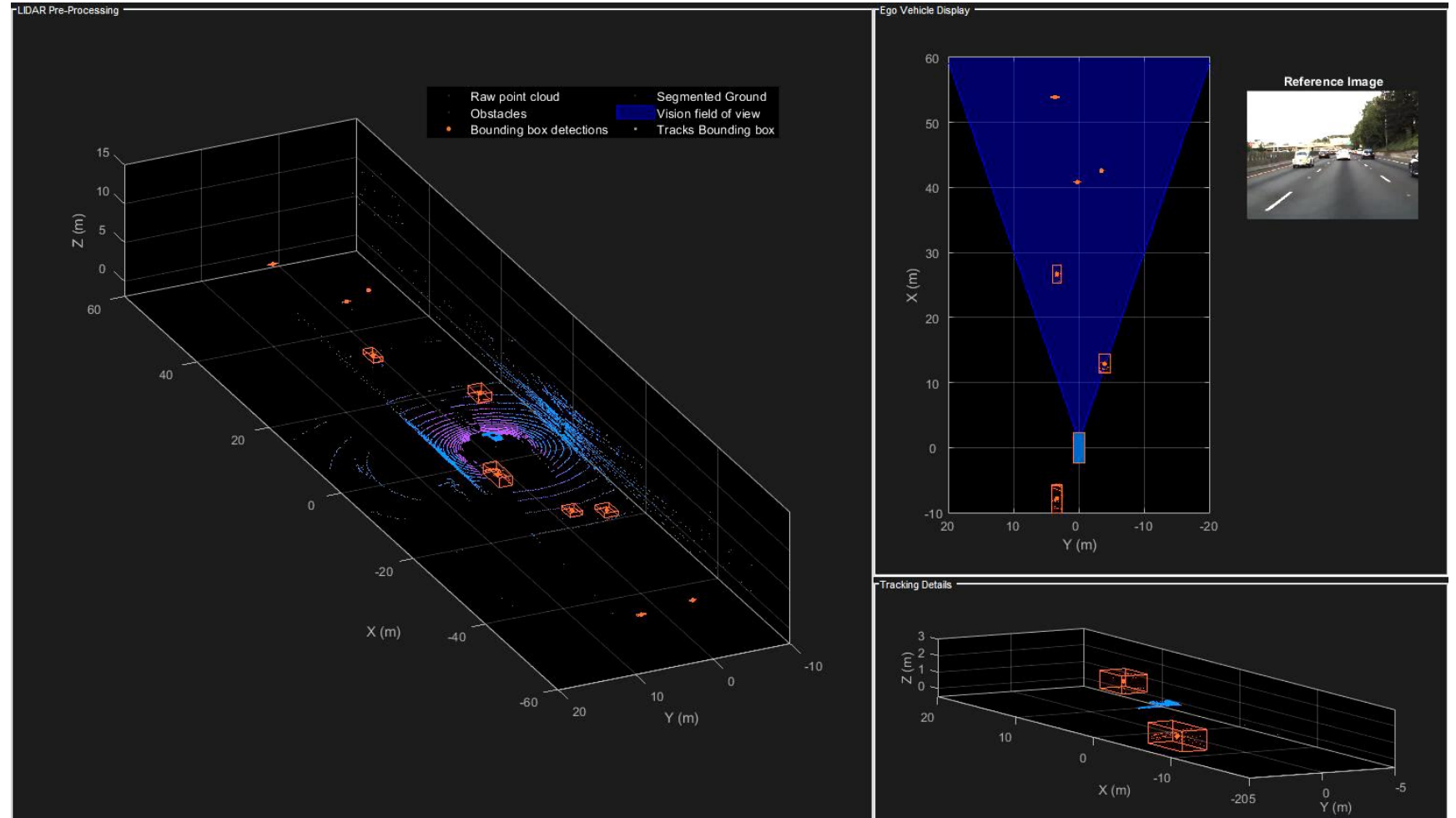
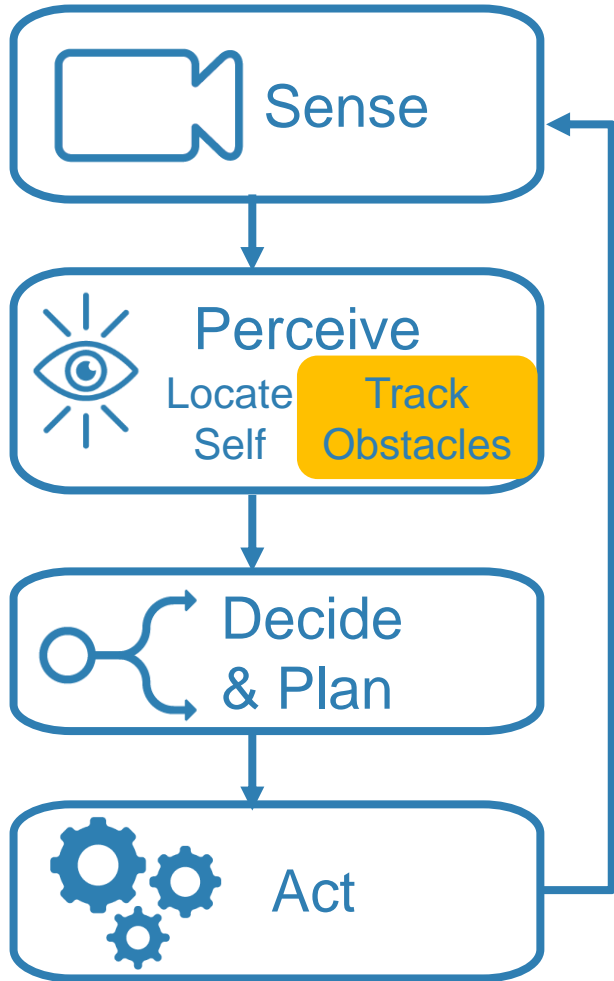
- High resolution sensors generate multiple detections per object per scan



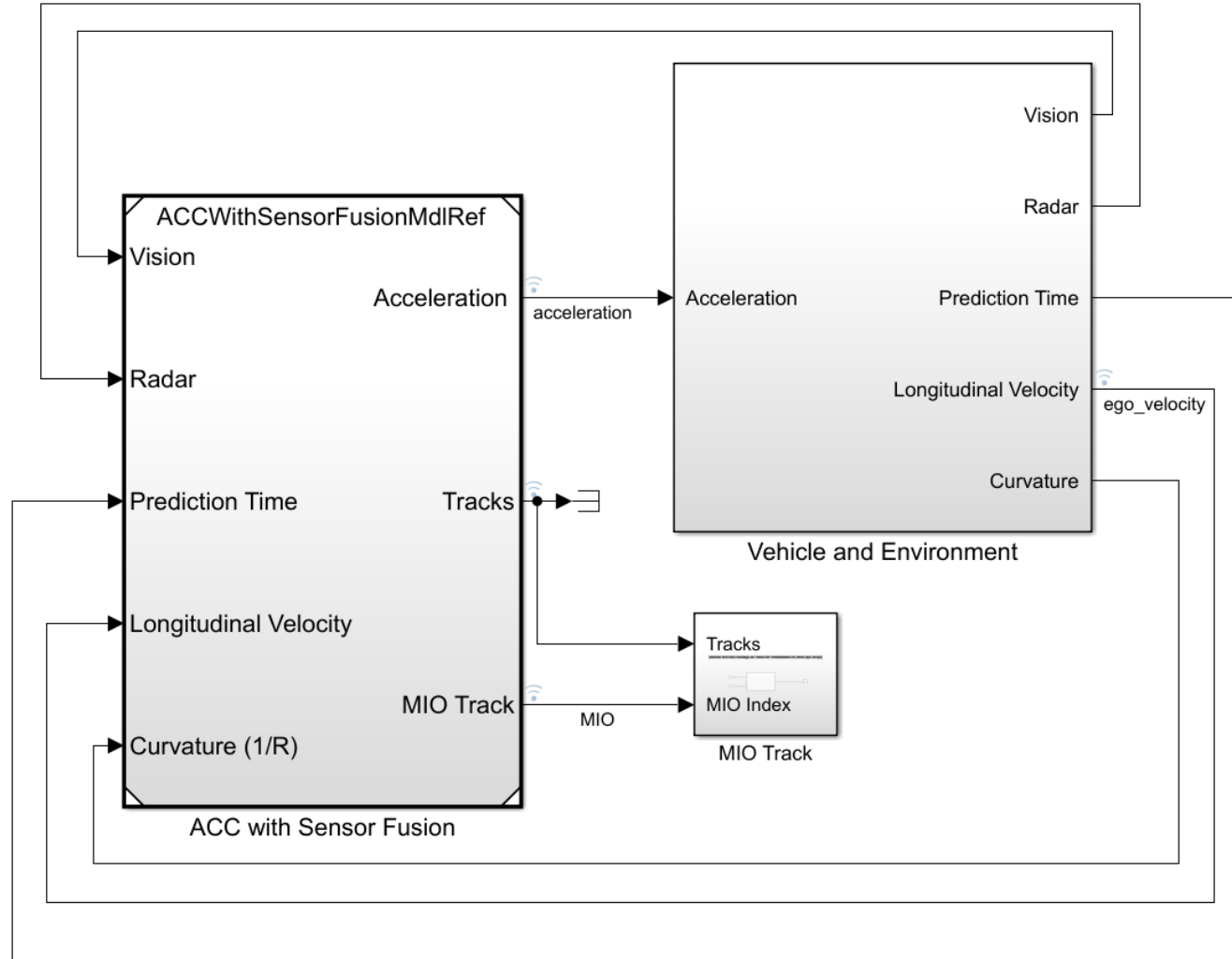
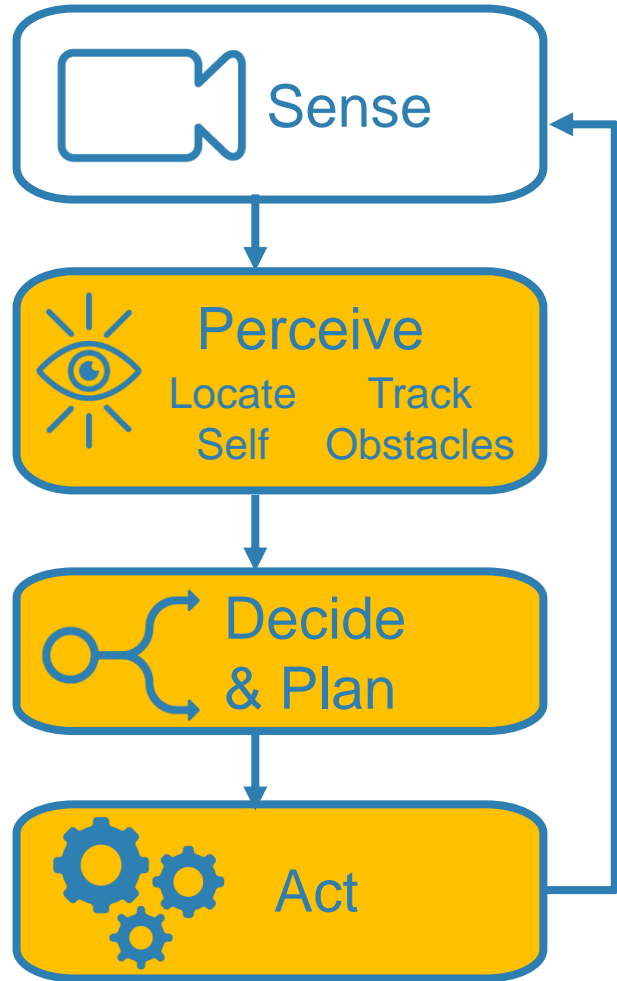
# Extended Object Tracking



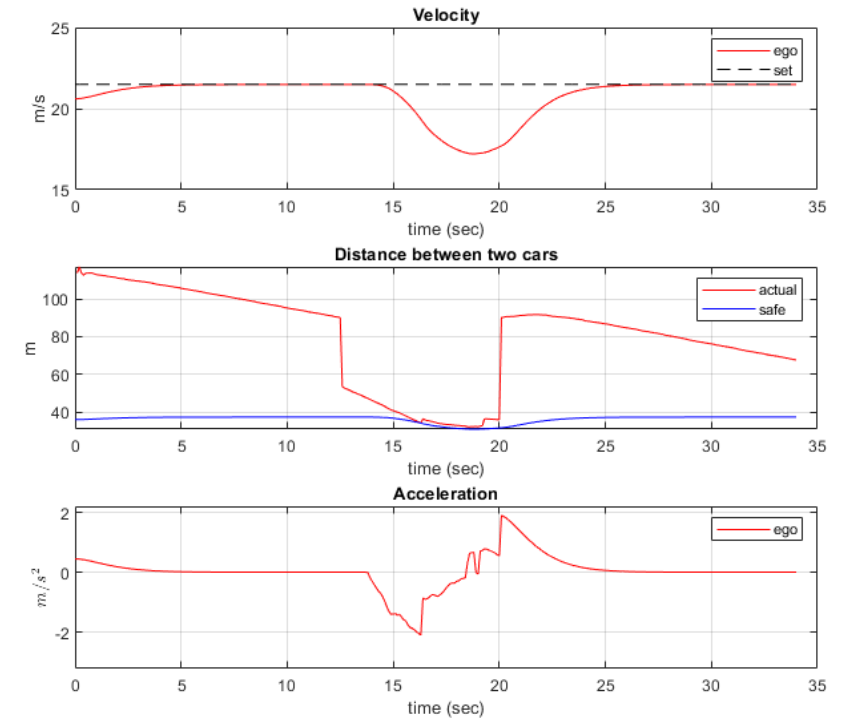
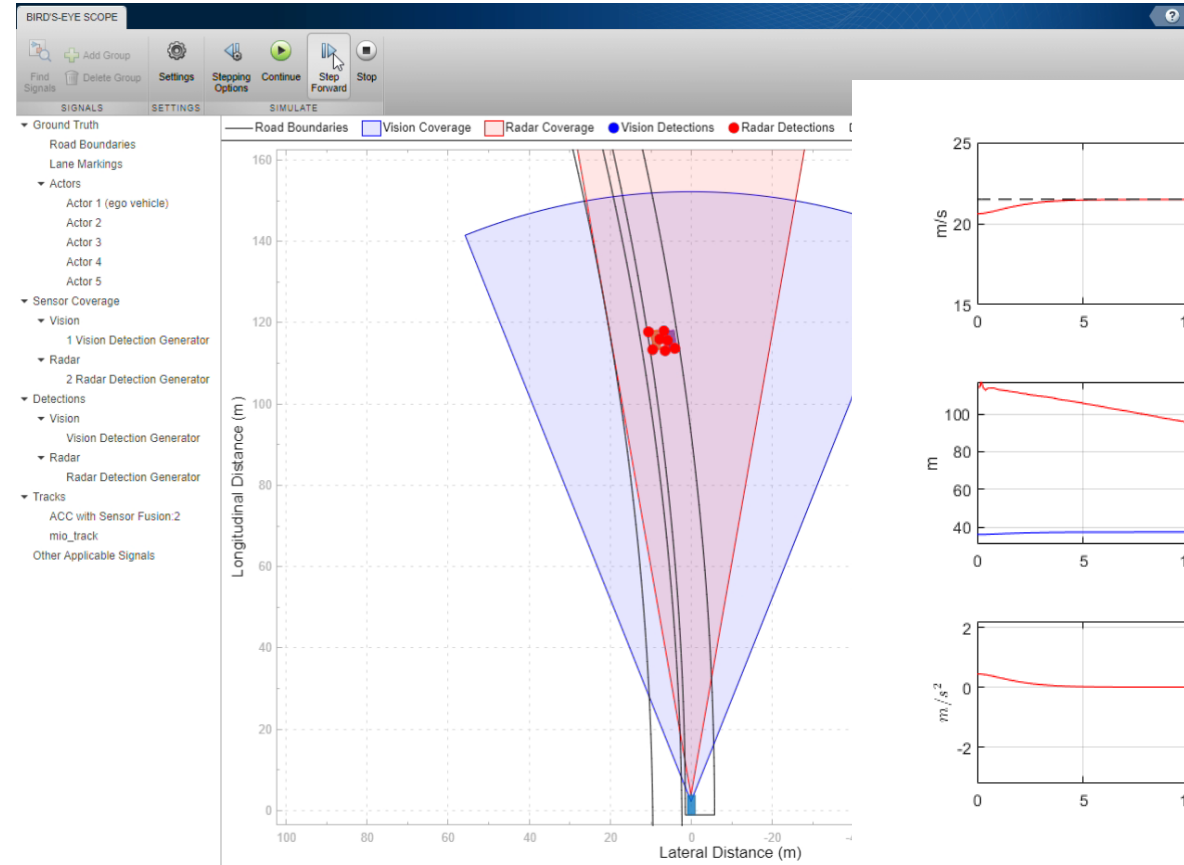
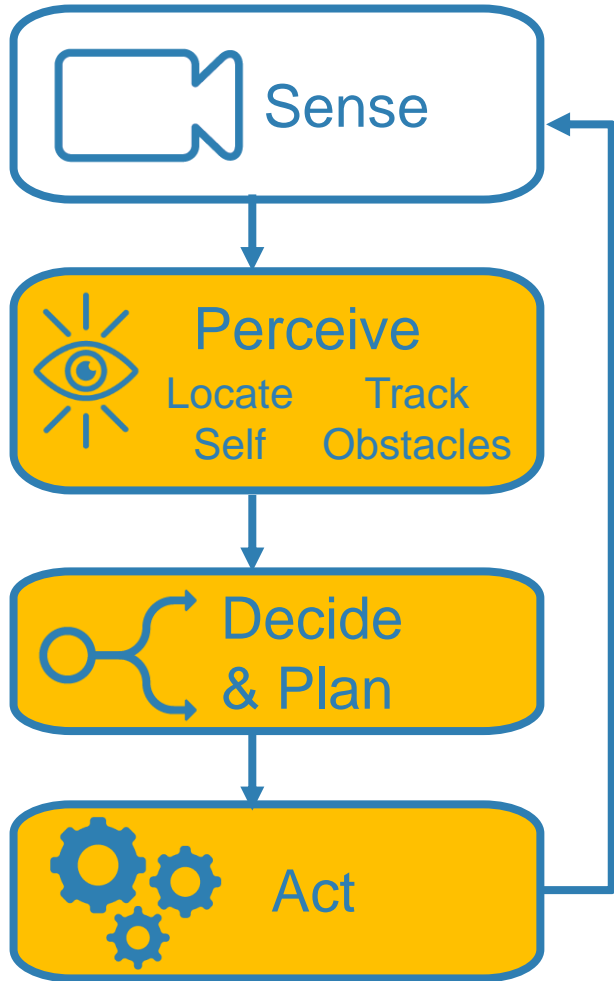
# Tracking with Lidar



# Connect to Decision Making / Control: ACC Demo



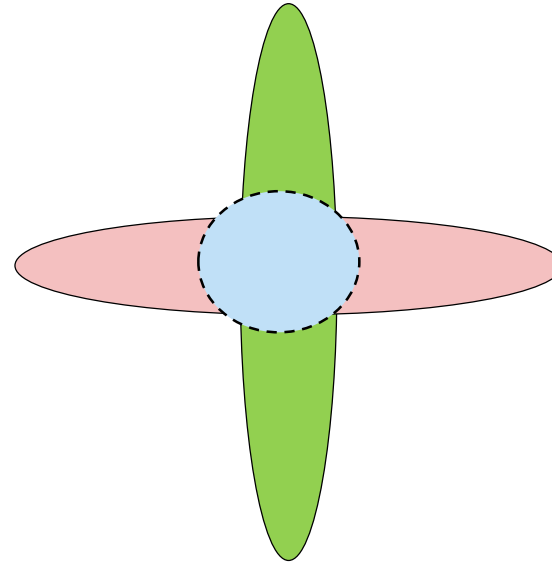
# Connect to Decision Making / Control: ACC Demo



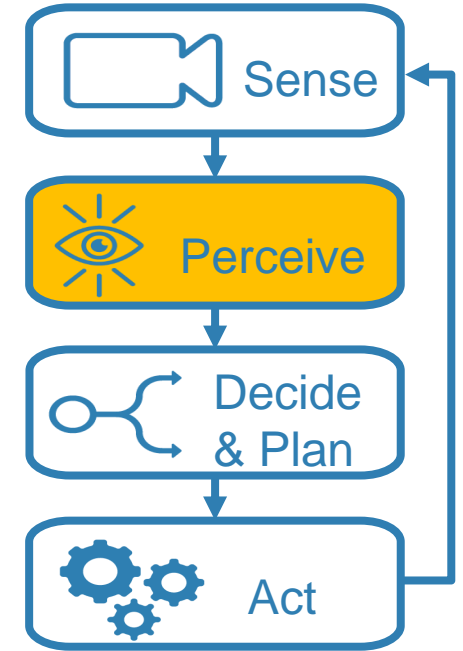
# Sensor Fusion and Tracking ...



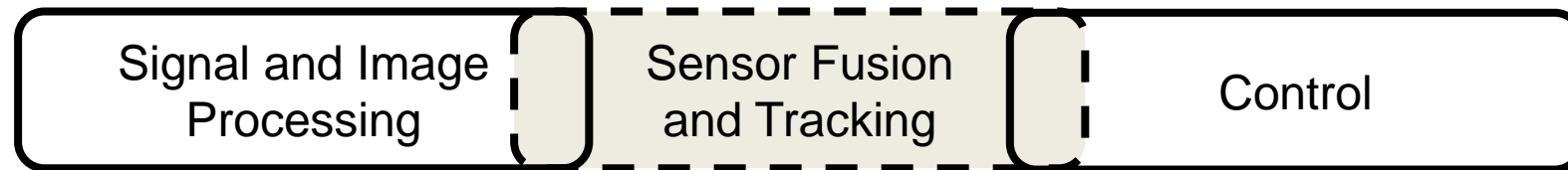
Is Ubiquitous



Leverages Sensor Strengths



Enables Autonomy





# Summary



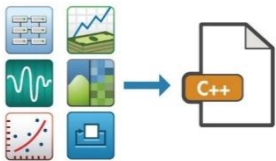
Improve your **development and test workflows** for localization and tracking. We provide not only algorithms but sensor models, scenario generation and metrics. **Integrate** with home grown tools and fill in gaps.



Our configurable tracking and fusion algorithms **enable re-use and sharing** across your organization and industry which will also improve overall efficiencies



Perform quick algorithm and system trade-offs **eliminate errors early** in the development cycle.



Direct path to move from tracker and fusion models to C-code for **prototyping and initial deployment**.

# Learn More

Sensor Fusion and Tracking Toolbox **NEW PRODUCT**

Automated Driving Toolbox **MAJOR UPDATE**

- Please visit our Technology Showcase for more details on the workflows

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Trial software Contact sales

z (Down)

3D Plot: Design and simulate multisensor tracking and navigation systems

Download a free trial

Map Data:

- T2: A:4029m → 0m/s, 285 km/hr, H:359 deg
- T3: A:3082m → 1m/s, 890 km/hr, H:359 deg
- T1: A:4119m 15m/s, 701 km/hr, H:90 deg
- T1: A:4119m 5m/s, 701 km/hr, H:90 deg

Legend:

- Ground
- ATC Tower
- Detections
- Targets
- Tracks
- Tracks (history)

<https://www.mathworks.com/products/sensor-fusion-and-tracking.html>