

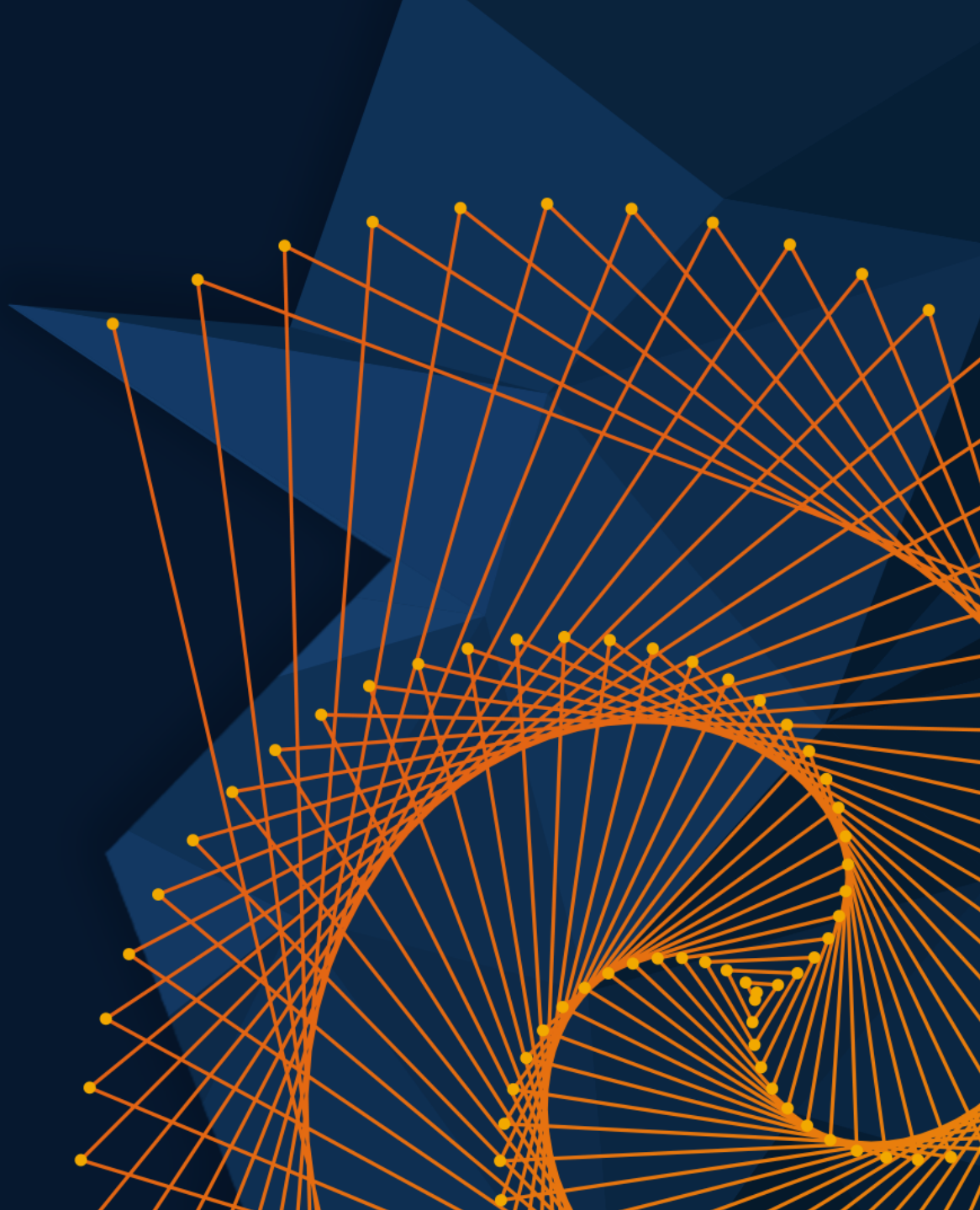
MATLAB EXPO

2024.06.11 | 그랜드 인터컨티넨탈 서울 파르나스

MATLAB을 활용한

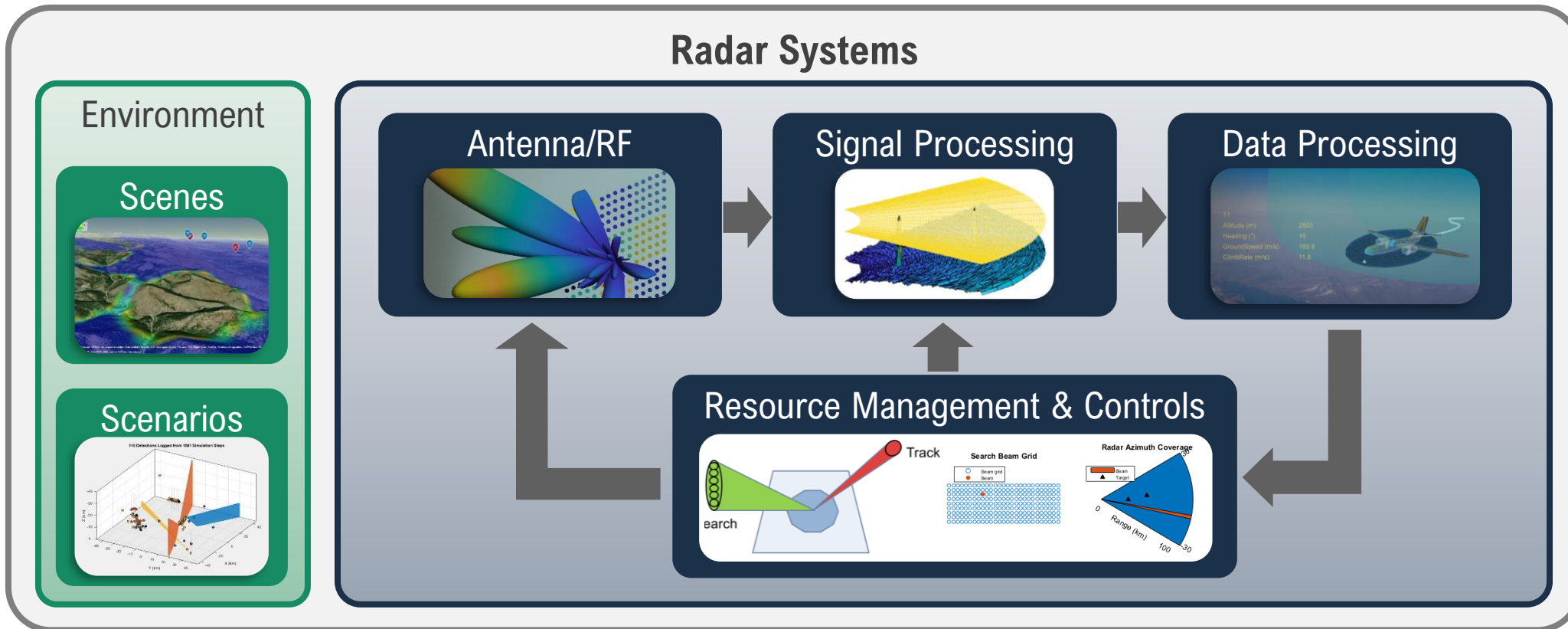
TI mmWave 레이더 개발

서기환, MathWorks

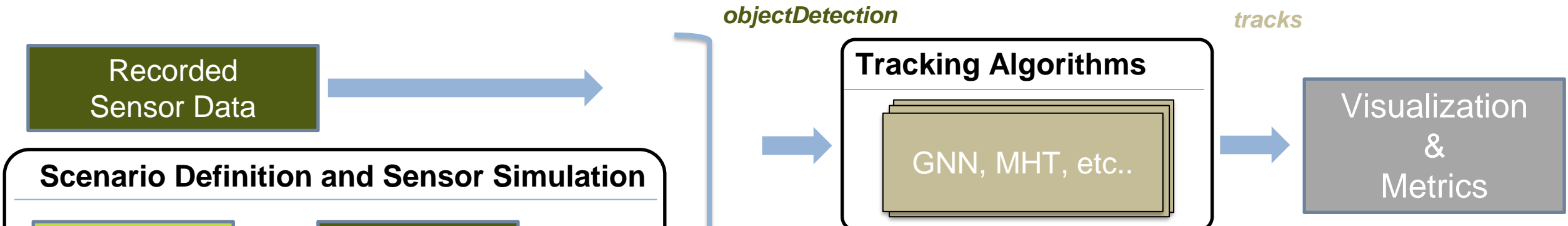


Develop Radar Systems

with MATLAB and Simulink

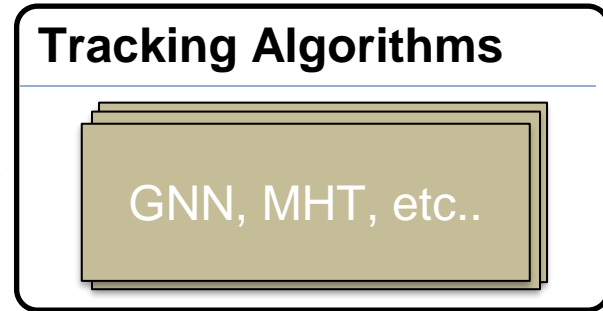
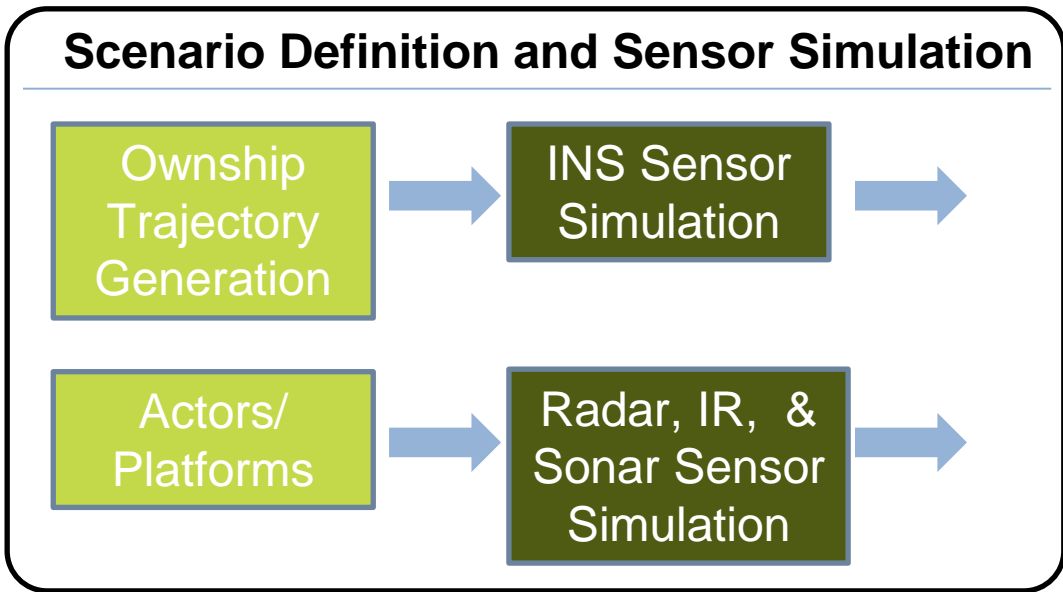


Tracking Algorithm Development Workflow

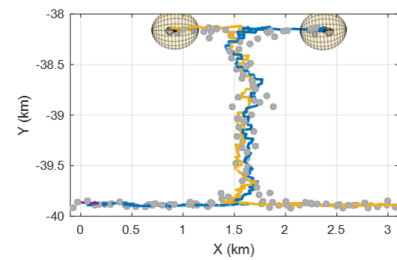
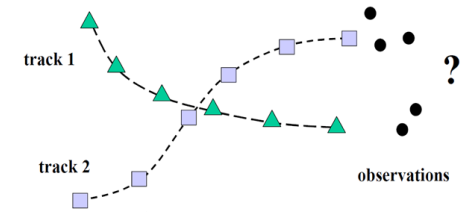
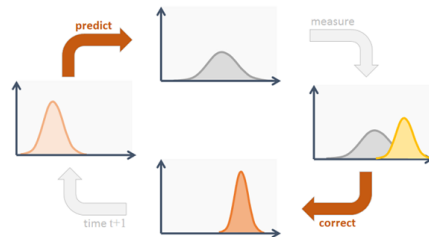


objectDetection

tracks



A rich library of tracking algorithms



Filters

- Alpha Beta filter
- Kalman filters
 - Linear, EKF, UKF, CKF, MSCEKF
- Particle filter
- Multiple models
 - GSF, IMM

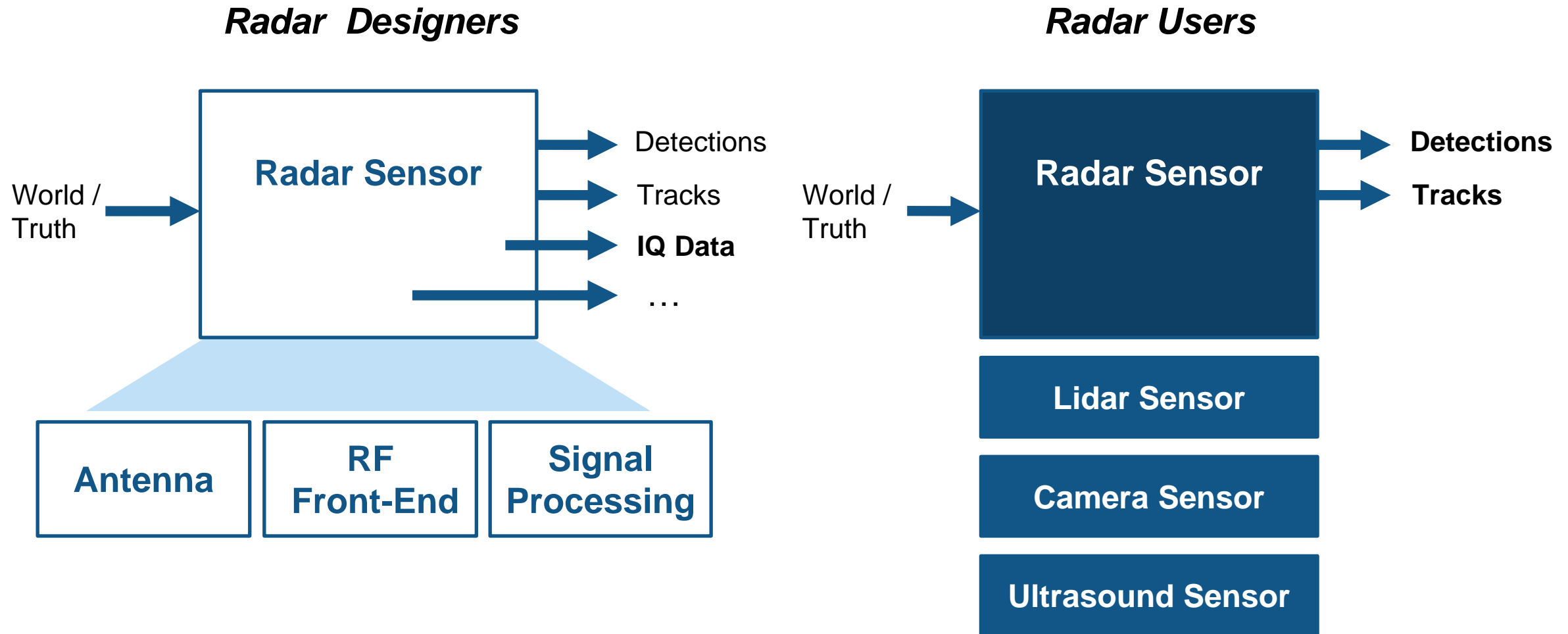
Data Association

- 2D assignment
- S-D assignment
- K-best assignment

Trackers

- GNN, JPDA, PHD
- MHT (track-oriented)
- Trackers components
 - History and score logic
 - etc.....

Two Personas using Radar Sensor Models



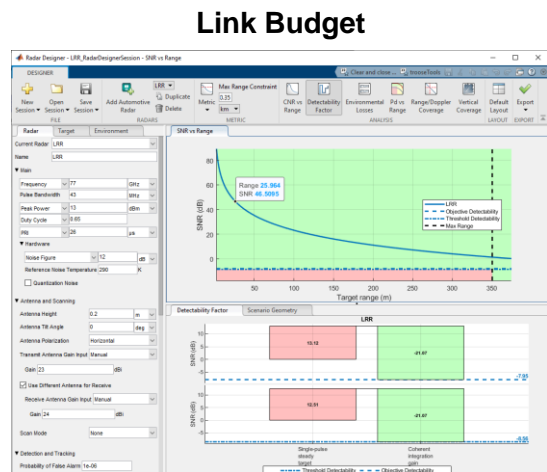
Three Abstraction Levels for Support of Full Radar Life Cycle

Less



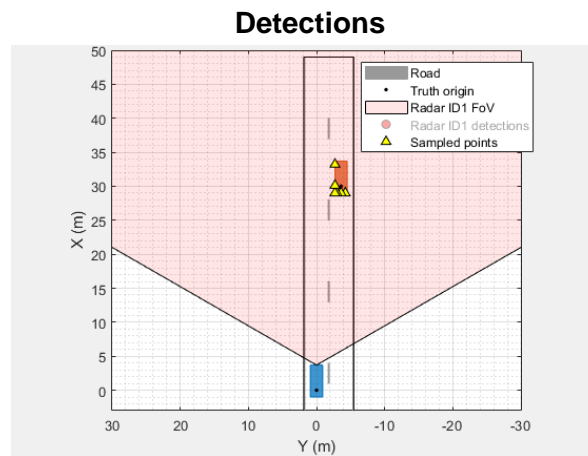
More

Power-level



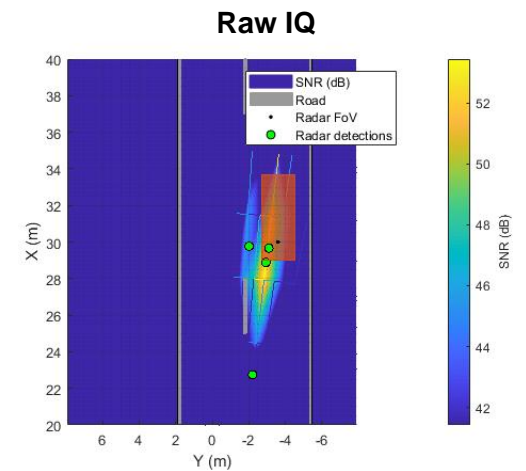
Applications: Concept Dev/Design, Systems Analysis

Measurement-level



Applications: Systems Analysis, Scenario Analysis, Tracker Design

Waveform-level

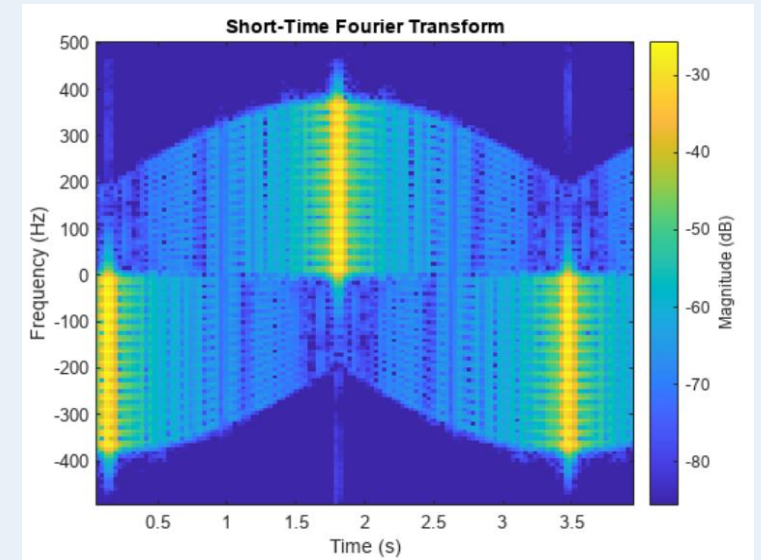
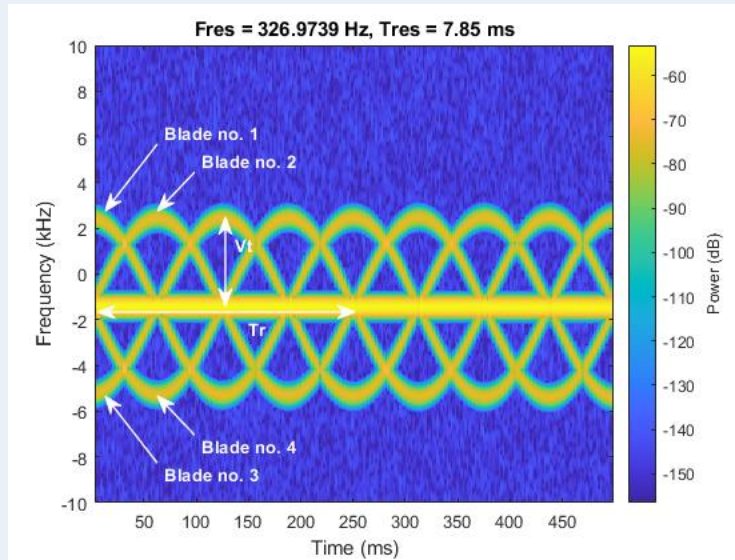
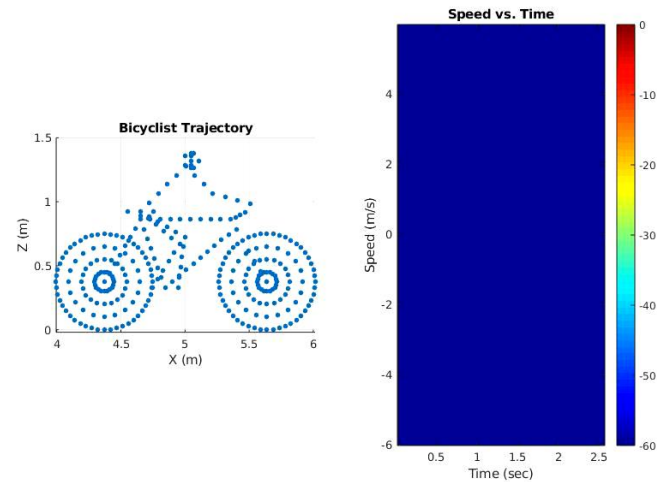
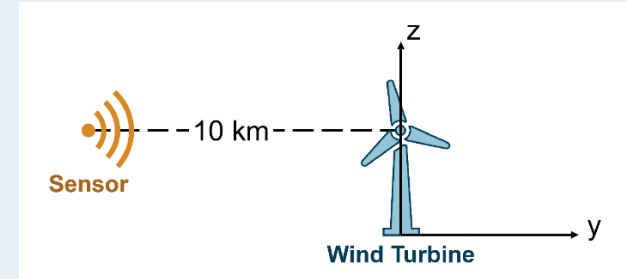
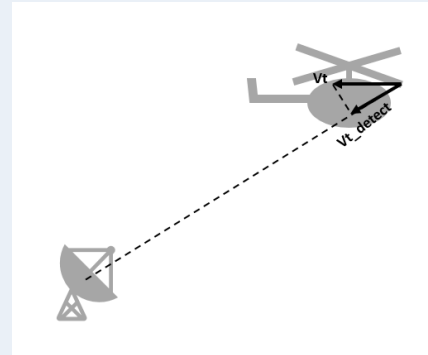
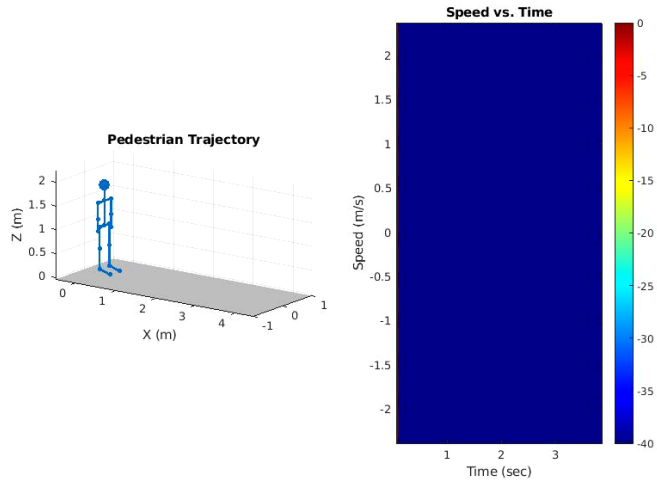


Applications: Algorithm Development, End-to-End Performance Assessment

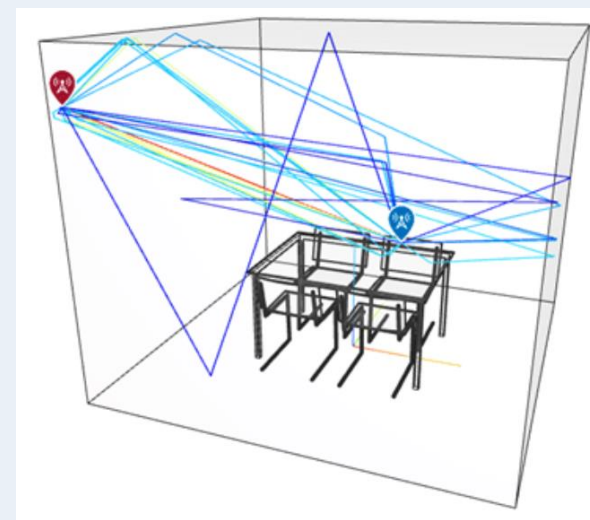
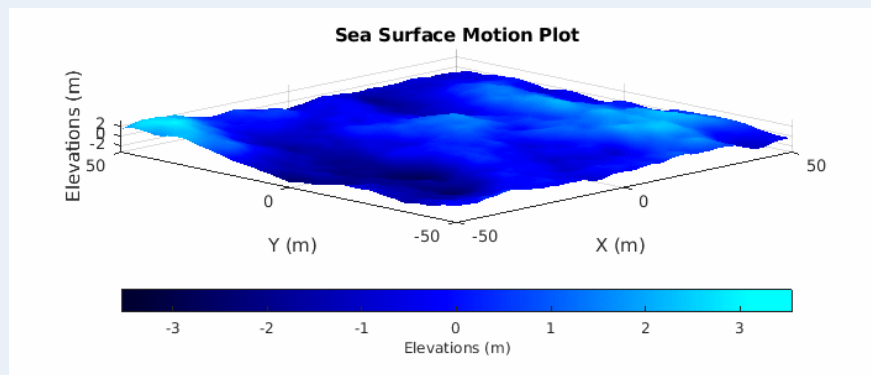
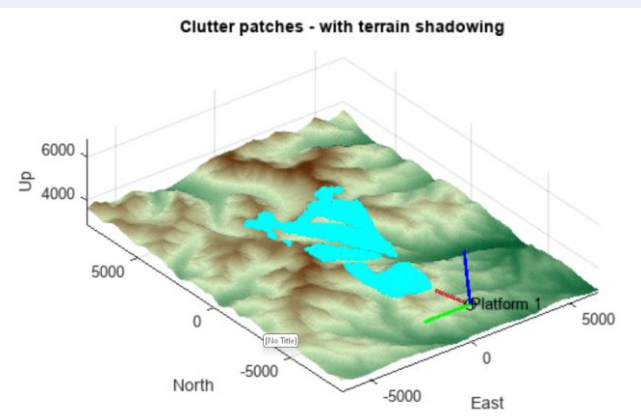
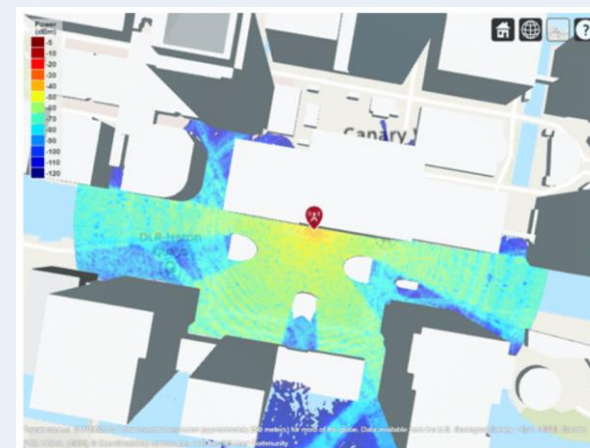
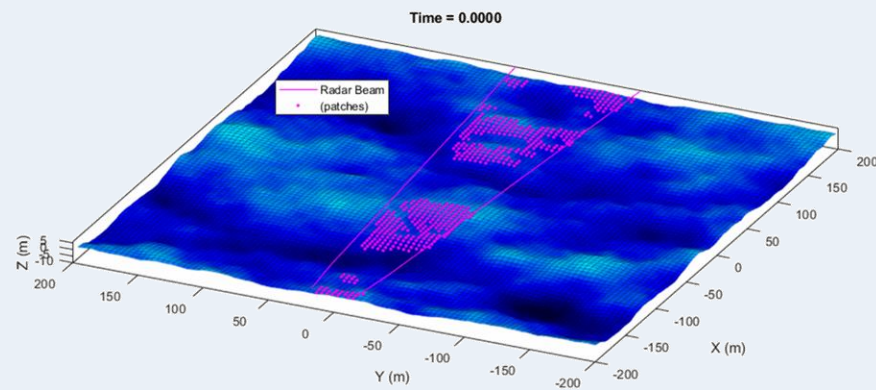
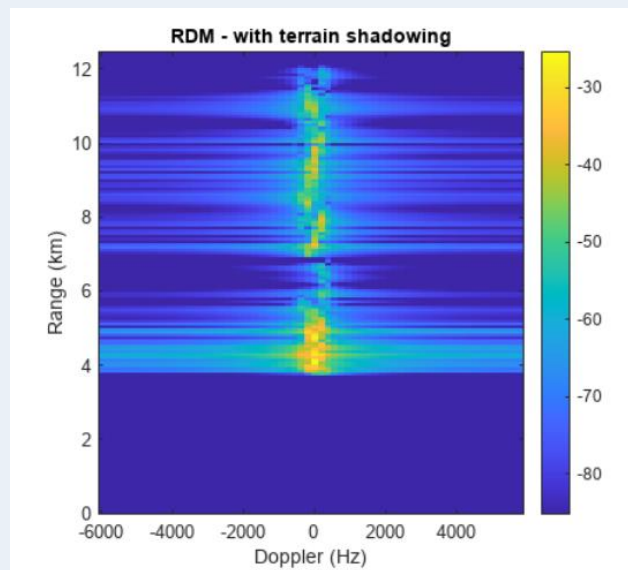
* See *Design and Simulate an FMCW Long-Range Radar (LRR) Example* [here](#)

Radar Data Synthesis

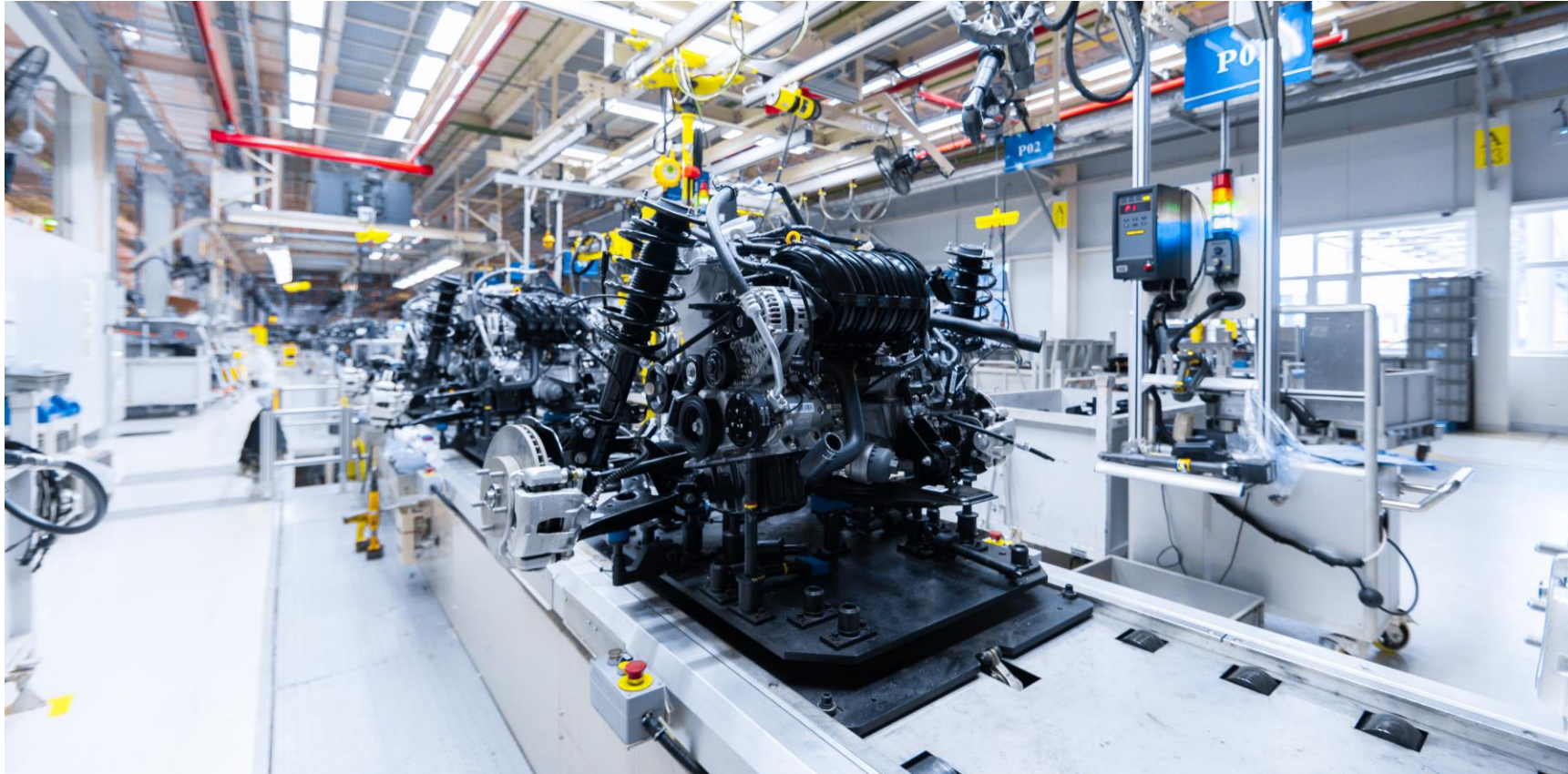
Micro-Doppler signatures



Clutter and Channel Modeling



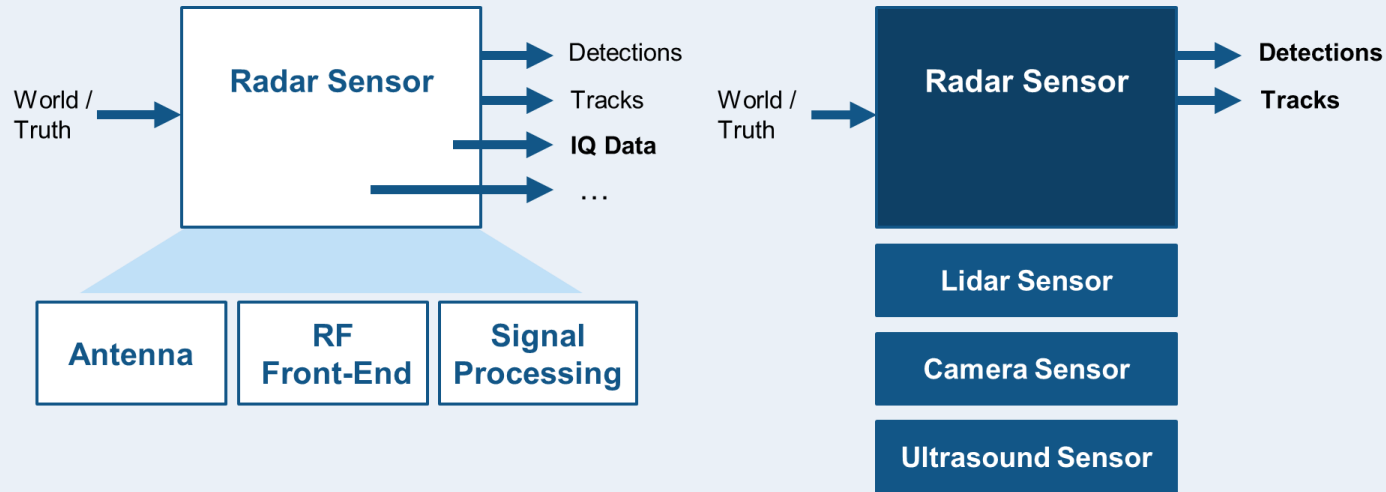
The Reality is...



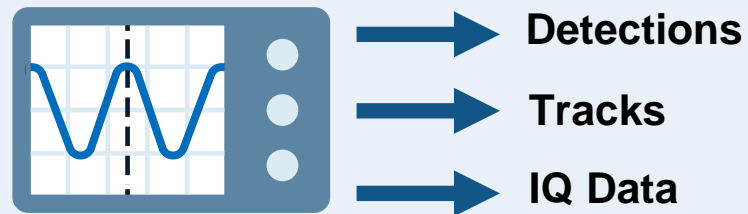
How can we model this environment?

Test and Verification of the Radar

Radar Sensor Models

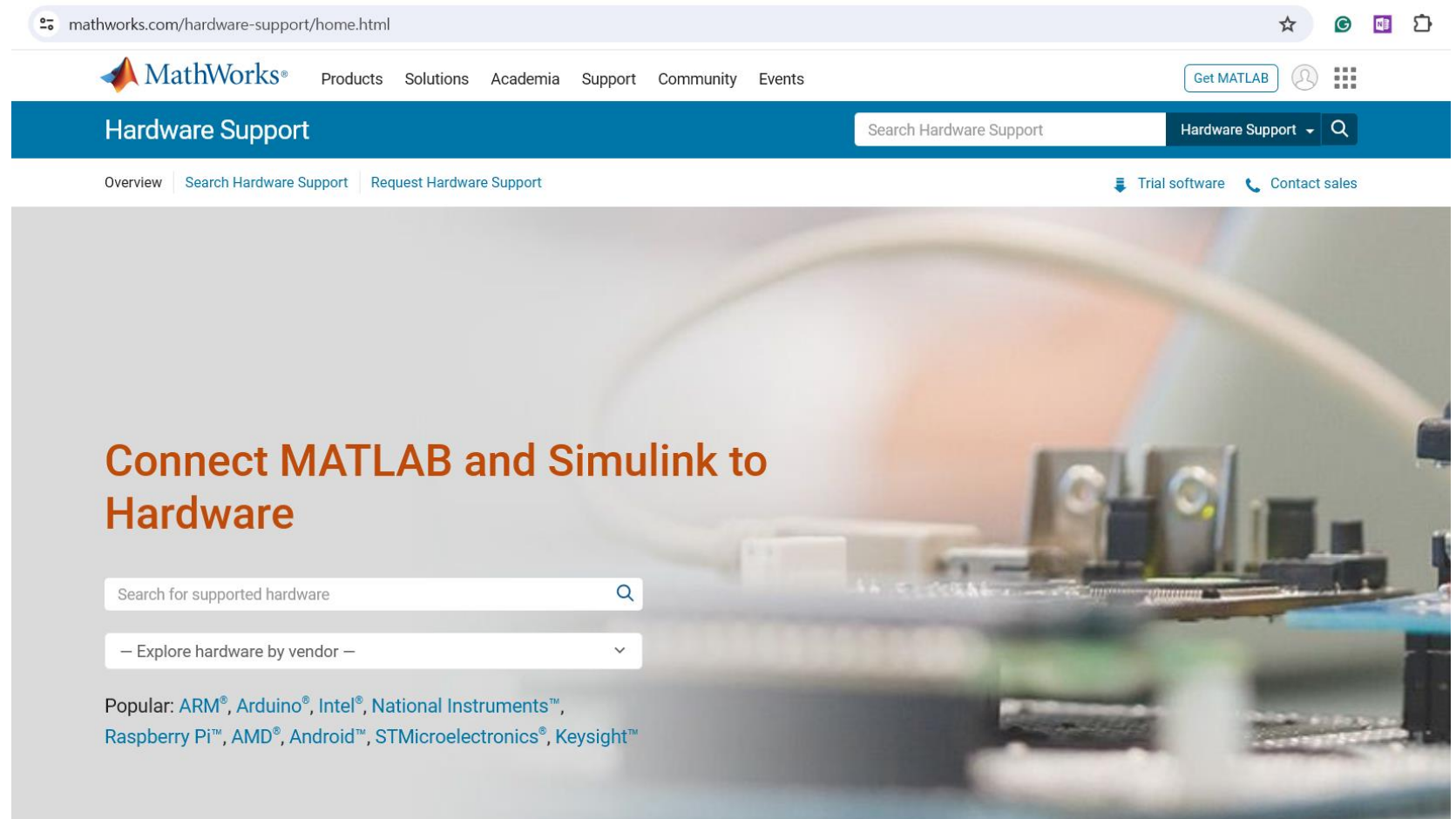


Physical Radar Hardware



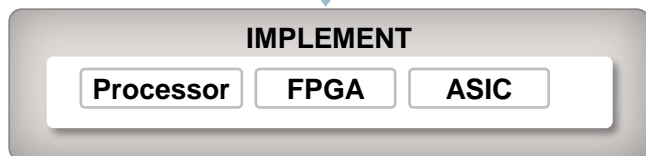
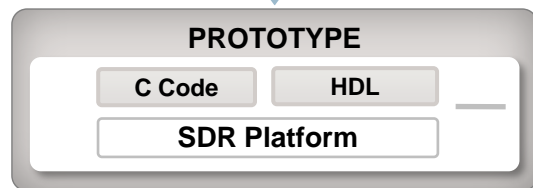
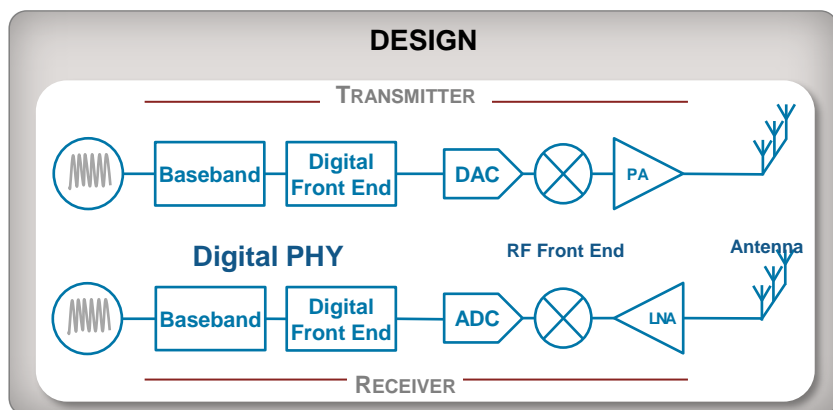
Connect MATLAB to Hardware

- Live Data Streaming to and from Hardware
- Generating Code and Targeting Hardware



The screenshot shows the MathWorks Hardware Support page. The browser address bar displays `mathworks.com/hardware-support/home.html`. The MathWorks logo is in the top left, with navigation links for Products, Solutions, Academia, Support, Community, and Events. A "Get MATLAB" button and user profile icons are in the top right. The main header is "Hardware Support" with a search bar containing "Search Hardware Support" and a dropdown menu for "Hardware Support". Below the header, there are links for "Overview", "Search Hardware Support", and "Request Hardware Support", along with "Trial software" and "Contact sales" buttons. The main content area features a large background image of a circuit board with a magnifying glass. The headline reads "Connect MATLAB and Simulink to Hardware". Below this is a search bar with the placeholder "Search for supported hardware" and a dropdown menu for "Explore hardware by vendor". At the bottom, a list of popular hardware vendors is shown: ARM®, Arduino®, Intel®, National Instruments™, Raspberry Pi™, AMD®, Android™, STMicroelectronics®, and Keysight™.

Before TI Radar Support

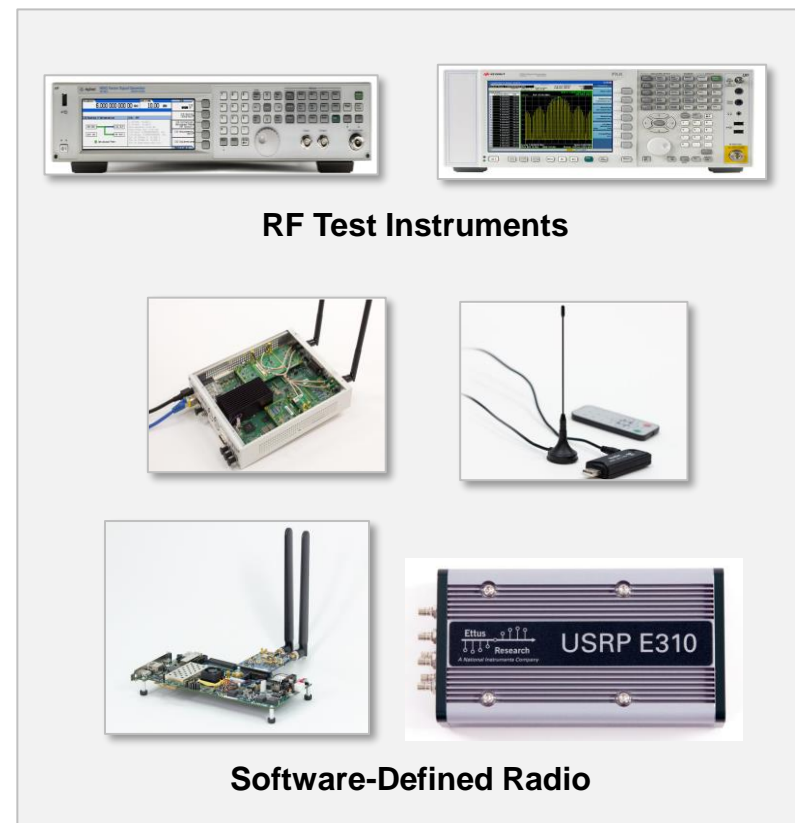


HDL and C code generation

Instrument Control Toolbox

SDR Support Packages
Communications System Toolbox

Fixed-Point Designer
SoC Blockset
HDL Coder
Embedded Coder
Wireless HDL Toolbox




Multi-vendor hardware support

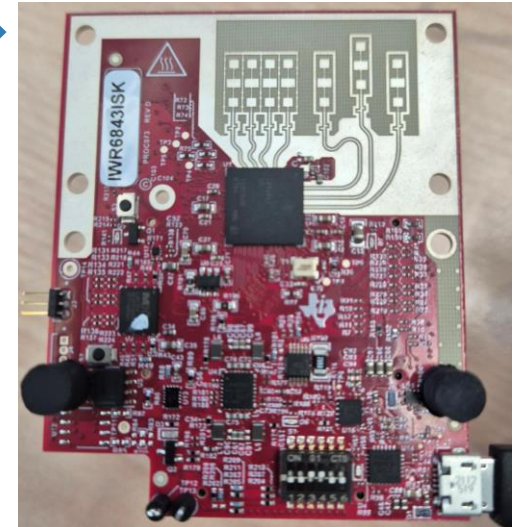
Getting Started with TI mmWave Radar Sensors

Required MathWorks® Products

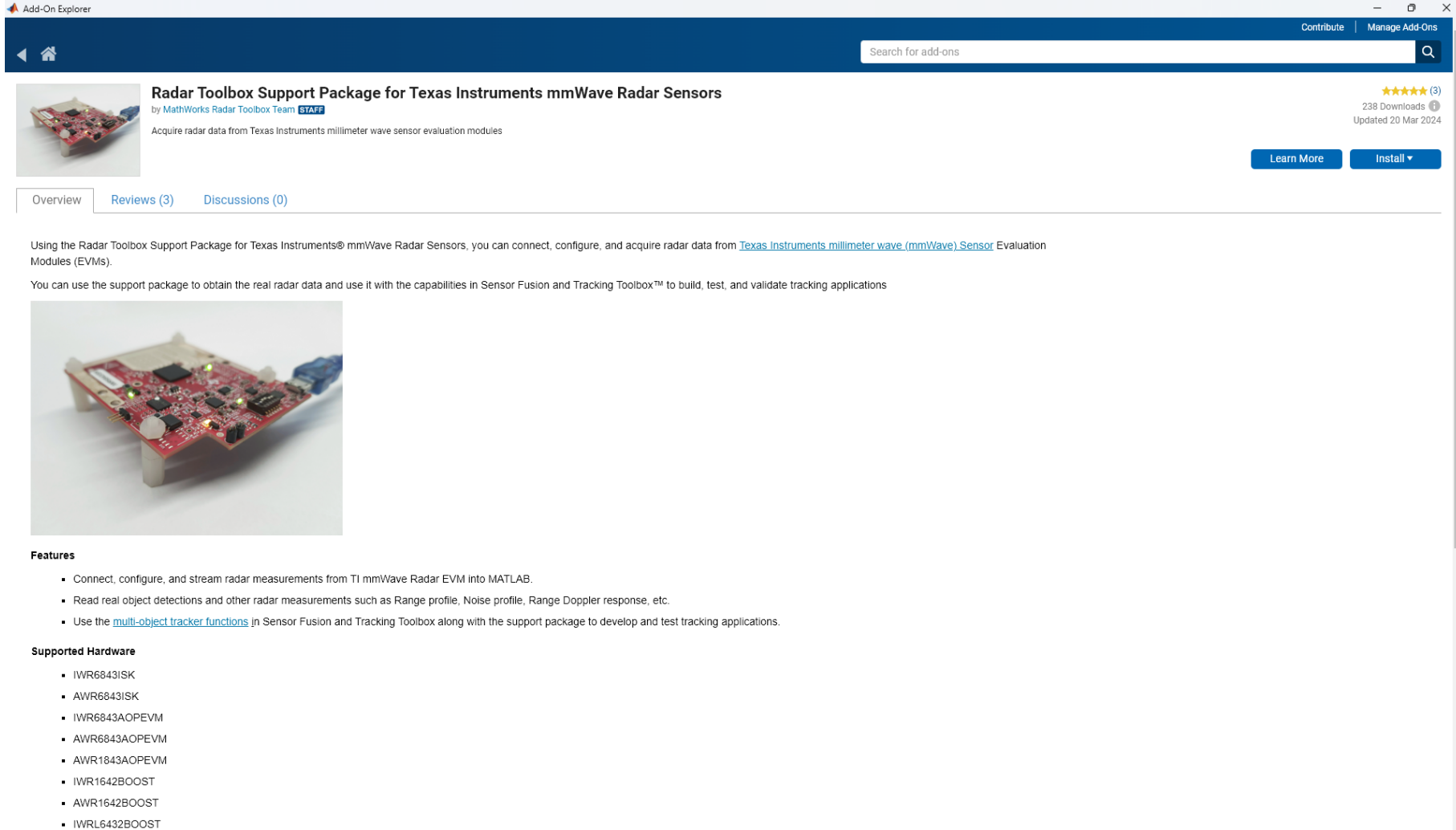
- MATLAB®
- Radar Toolbox
- Radar Toolbox Support Package for Texas Instruments mmWave Radar Sensors

The support package provides support for these EVMs:

- TI IWR6843ISK 
- TI AWR6843ISK
- TI IWR6843AOPEVM
- TI AWR6843AOPEVM
- TI AWR1843AOPEVM
- TI AWR1642BOOST
- TI IWR1642BOOST
- TI IWRL6432BOOST



Support Package for Texas Instruments mmWave Radar Sensors



The screenshot shows the MATLAB Add-On Explorer interface. At the top, there is a search bar with the text "Search for add-ons". Below the search bar, the main content area displays the details for the "Radar Toolbox Support Package for Texas Instruments mmWave Radar Sensors". The package is authored by the "MathWorks Radar Toolbox Team" and is marked as "STAFF". It has a rating of 5 stars (3 reviews), 238 downloads, and was last updated on 20 Mar 2024. There are "Learn More" and "Install" buttons. The "Overview" tab is selected, showing a description of the package's functionality and a list of features and supported hardware.

Radar Toolbox Support Package for Texas Instruments mmWave Radar Sensors
by MathWorks Radar Toolbox Team **STAFF**
Acquire radar data from Texas Instruments millimeter wave sensor evaluation modules

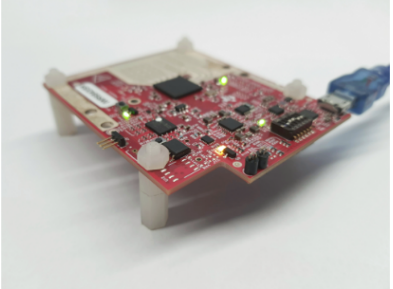
★★★★★ (3)
238 Downloads
Updated 20 Mar 2024

Learn More Install

Overview Reviews (3) Discussions (0)

Using the Radar Toolbox Support Package for Texas Instruments® mmWave Radar Sensors, you can connect, configure, and acquire radar data from [Texas Instruments millimeter wave \(mmWave\) Sensor Evaluation Modules \(EVMs\)](#).

You can use the support package to obtain the real radar data and use it with the capabilities in Sensor Fusion and Tracking Toolbox™ to build, test, and validate tracking applications



Features

- Connect, configure, and stream radar measurements from TI mmWave Radar EVM into MATLAB.
- Read real object detections and other radar measurements such as Range profile, Noise profile, Range Doppler response, etc.
- Use the [multi-object tracker functions](#) in Sensor Fusion and Tracking Toolbox along with the support package to develop and test tracking applications.

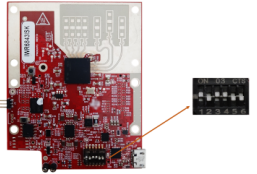
Supported Hardware

- IWR6843ISK
- AWR6843ISK
- IWR6843AOPEVM
- AWR6843AOPEVM
- AWR1843AOPEVM
- IWR1642BOOST
- AWR1642BOOST
- IWRL6432BOOST

Hardware Setup screens

Hardware Setup
 Enable Flashing Mode > Flash Binary > Enable Functional Mode > Verify Radar Data Acquisition
Enable Flashing Mode (Step 1 of 3)

Set the switches as shown in the image below



Switch	State
S1.1	On
S1.2	Off
S1.3	On
S1.4	On
S1.5	Off
S1.6	Off

About Your Selection
 Prepare the radar board to download binary by setting the switches on board.

What to Consider
 Switch positions are same for IWR6843ISK, AWR6843ISK, and IWR6843ISK-ODS boards

< Back Cancel Next >

Hardware Setup
 Enable Flashing Mode > Flash Binary > Enable Functional Mode > Verify Radar Data Acquisition
Enable Flashing Mode (Step 2 of 3)

Connect the micro-USB cable to the Radar device at the connector shown and then to a PC. LEDs on the device should turn on.

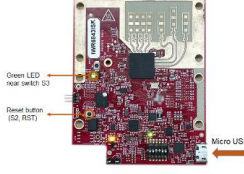


What to Consider
 Communication and power supply to the radar device is via the USB connection.

< Back Cancel Next >

Hardware Setup
 Enable Flashing Mode > Flash Binary > Enable Functional Mode > Verify Radar Data Acquisition
Enable Flashing Mode (Step 3 of 3)

Reset the board by pressing and releasing the reset button 'S2' shown in the image. The green LED near S3 will toggle off and on when the switch is pressed and released.



What to Consider
 Resetting ensures the switches are latched correctly.

< Back Cancel Next >

Hardware Setup
 Enable Flashing Mode > Flash Binary > Enable Functional Mode > Verify Radar Data Acquisition
Flash Binary

Choose config port: COM8 Choose data port: COM9 Refresh

Click 'Refresh' to update the config and data ports

To flash binary to the board, click 'Flash Binary'

Flash Binary

About Your Selection
 Select the serial ports and flash mmWave demo binary (Out-of-box demo) to the Radar board

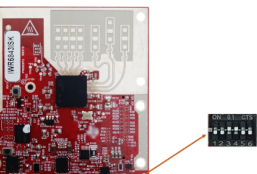
What to Consider
 Config port name will be seen as either User UART or Enhanced COM port in Device manager. Data port name will be seen as either Data Port or Standard COM port in Device manager.

Ensure that you do not have any other connections to specified serial ports.

< Back Cancel Next >

Hardware Setup
 Enable Flashing Mode > Flash Binary > **Enable Functional Mode** > Verify Radar Data Acquisition
Enable Functional Mode (Step 1 of 3)

Set the switches as shown in the image below



Switch	State
S1.1	Off
S1.2	Off
S1.3	On
S1.4	On
S1.5	Off
S1.6	Off


About Your Selection
 Prepare the radar board to configure and read data from the radar board by setting the switches on board.

What to Consider
 Switch positions are same for IWR6843ISK, AWR6843ISK, and IWR6843ISK-ODS devices

< Back Cancel Next >

Hardware Setup
 Enable Flashing Mode > Flash Binary > **Enable Functional Mode** > Verify Radar Data Acquisition
Enable Functional Mode (Step 2 of 3)

Connect the micro-USB cable to the Radar device at the connector shown and then to a PC. LEDs on the device should turn on.




What to Consider
 Communication and power supply to the radar device is via the USB connection.

< Back Cancel Next >

Hardware Setup
 Enable Flashing Mode > Flash Binary > **Enable Functional Mode** > Verify Radar Data Acquisition
Enable Functional Mode (Step 3 of 3)

Reset the board by pressing and releasing the reset button 'S2' shown in the image. The green LED near S3 will toggle off and on when the switch is pressed and released.



What to Consider
 Resetting ensures the switches are latched correctly.

< Back Cancel Next >

Hardware Setup
 Enable Flashing Mode > Flash Binary > **Enable Functional Mode** > **Verify Radar Data Acquisition**

Verify connection

Choose config port: COM5 Choose data port: COM6

Click 'Test Connection' to check if MATLAB acquires data from TI mmWave Radar sensor.

Test Connection

About Your Selection
 When you click 'Test Connection', MATLAB completes the configuration of the TI mmWave radar sensor and reads the data. If you observe that the format of the received data is as expected, the Hardware Setup is successful.

< Back Cancel Next >

mmWaveRadar Object

```
>> rdr = mmWaveRadar("TI IWR6843ISK")

rdr =

mmWaveRadar with properties:

    BoardName: "TI IWR6843ISK"
    ConfigPort: "COM7"
    DataPort: "COM8"

    ConfigFile: "C:\Prototype\MaxRangResolution.cfg"

    SensorIndex: 1

    MountingLocation: [0,0,0]
    MountingAngle: [0,0,0]

    UpdateRate: 1
    RangeResolution: 4.400000e-02
    RangeRateResolution: 1.300000e-01
    AzimuthResolution: 14
    ElevationResolution: 25
    MaximumRange: 10
    MaximumRangeRate: 5
```

Show all [properties](#) all [functions](#)

```
>> [objDets, time, measurements, overrun] = rdr()

objDetections =
    3x1 cell array
    {1x1 objectDetection}
    {1x1 objectDetection}
    {1x1 objectDetection}

time =
     6

measurements =
    struct with fields:
        RangeProfile: [256x1 double]
        NoiseProfile: [256x1 double]
        RangeDopplerResponse: [256x16 double]
        RangeAngleResponse: [256x63 double]
        RangeGrid: [256x1 double]
        DopplerGrid: [16x1]
        AngleGrid: [64x1]

overrun =
     1
```

TI mmWave Radar Board Configuration

mmWave Demo visualizer application

- Platform
- Antenna Config
- Desirable Config
- Frequency Band

Save config to PC (.cfg)

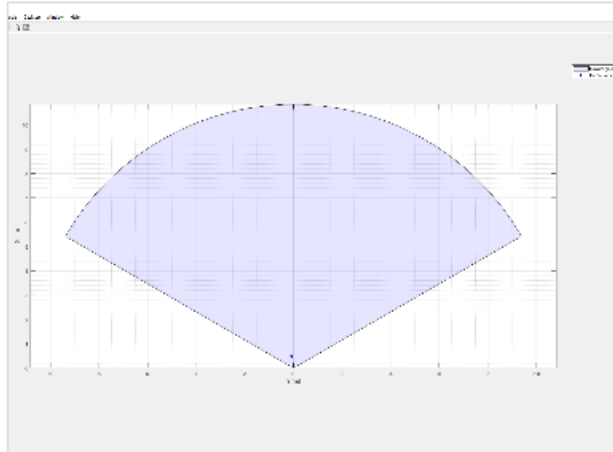
The screenshot displays the 'mmWave Demo Visualizer' application interface. The top navigation bar includes 'Options' and 'Help'. The main configuration area is titled 'Configure' and is divided into several sections:

- Setup Details:**
 - Platform: xWR16xx
 - SDK version (*): 3.6
 - Antenna Config (Azimuth Res - deg): 4Rx,2Tx(15 deg)
- Desirable Configuration:**
 - Desirable Configuration: Best Range
 - Frequency Band (GHz): 77-81
 - Calibration Data Save/Restore: None | 0x1F0000
- Scene Selection:**
 - Frame Rate (fps): Slider from 1 to 30, set to 10
 - Range Resolution (m): Slider from 0.977 to 0.061, set to 0.15
 - Maximum Unambiguous Range (m): Slider from 5 to 50, set to 50
 - Maximum Radial Velocity (m/s): Slider from 0.32 to 5.89, set to 3.1
 - Radial Velocity Resolution (m/s): 0.39
- Plot Selection:**
 - Scatter Plot
 - Range Profile
 - Noise Profile
 - Range Azimuth Heat Map
 - Range Doppler Heat Map
 - Statistics
- RCS:**
 - Desired Radar Cross Section (sq. m): 0.5
 - Maximum Range for desired RCS (m): 38.298
 - RCS at Max Unambiguous Range (sq. m): 1.452631
- Console Messages:** A large empty text area for displaying messages.

At the bottom of the configuration area, there are three buttons: 'SEND CONFIG TO MMWAVE DEVICE', 'SAVE CONFIG TO PC', and 'RESET SELECTION'. A 'CLEAR CONSOLE' button is located at the bottom right of the console area.

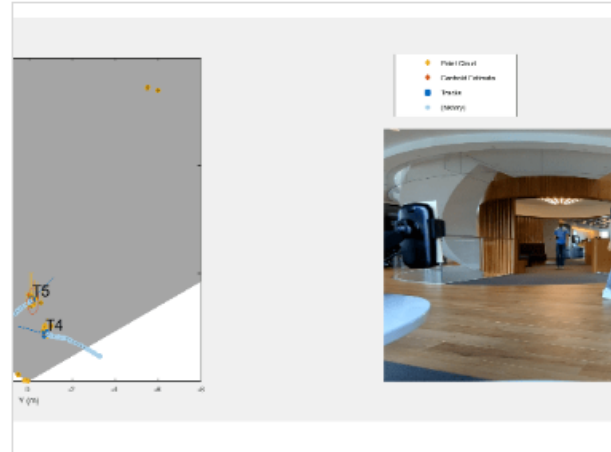
(*) For SDK 2.1 LTS release, please use this link: https://dev.ti.com/gallery/view/mmwave/mmWave_Demo_Visualizer/ver/2.1.0/

TI mmWave Radar Examples



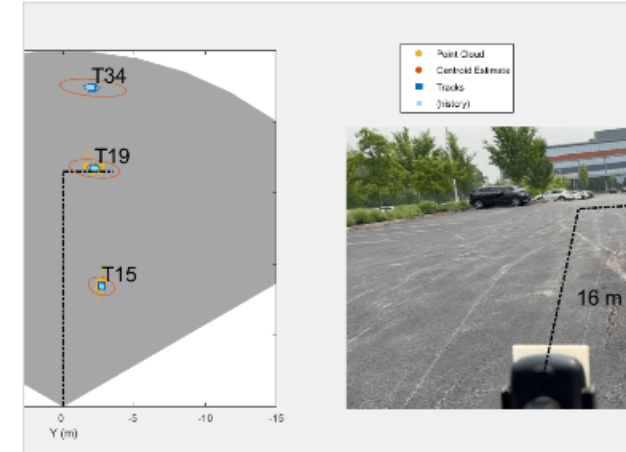
Getting Started with Radar Toolbox Support Package for Texas Instruments mmWave...

Use Radar Toolbox Support Package for Texas Instruments® mmWave Radar Sensors to configure and read detections (point cloud data) and



People Tracking Using TI mmWave Radar

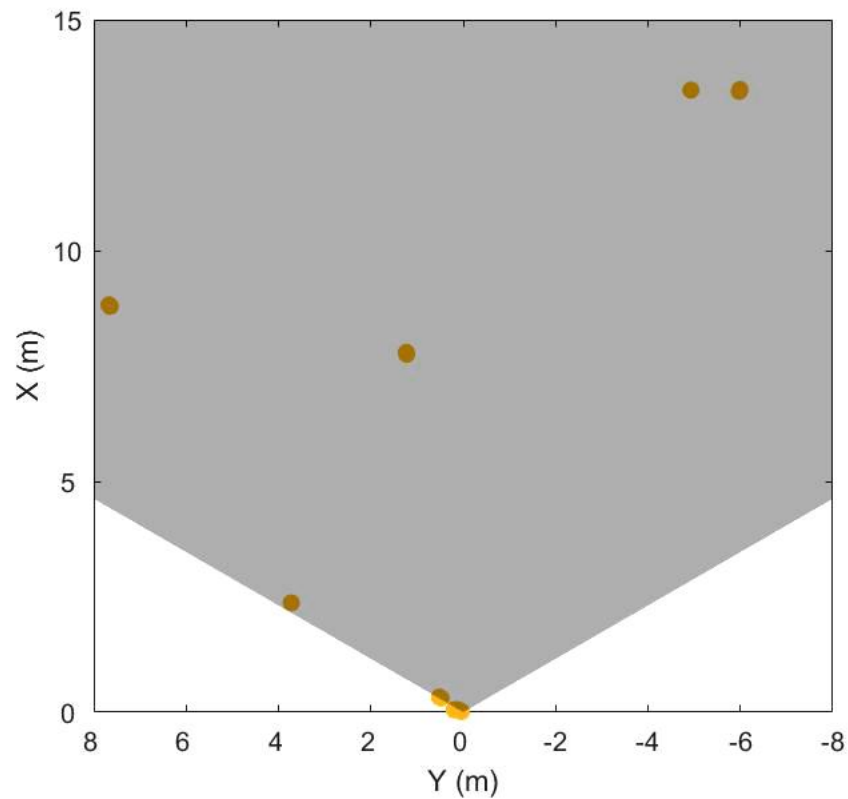
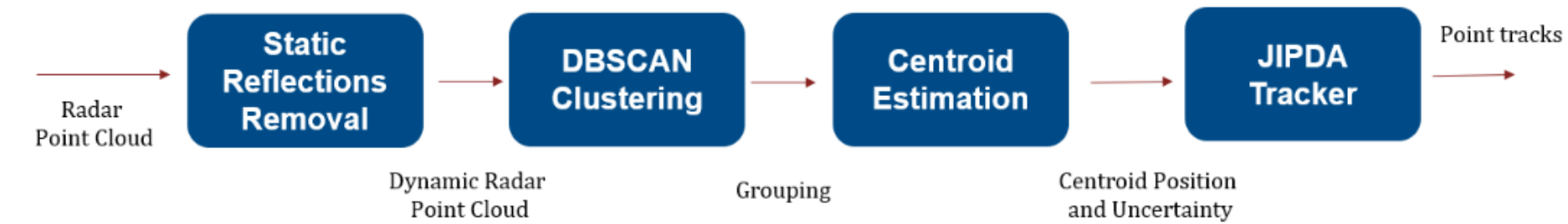
Use data captured using the Texas Instruments (TI) mmWave radar for tracking people in an indoor environment. You learn how to use a



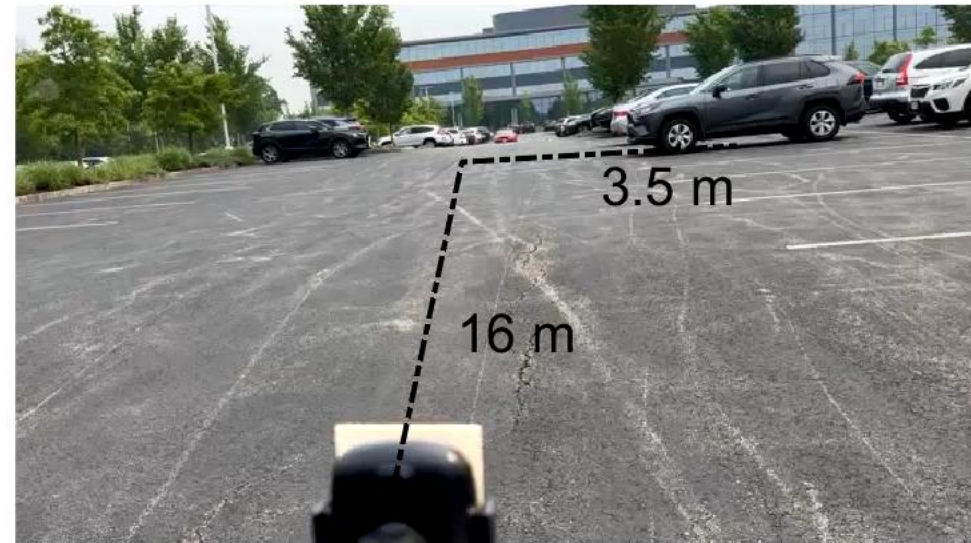
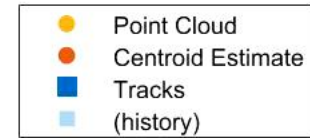
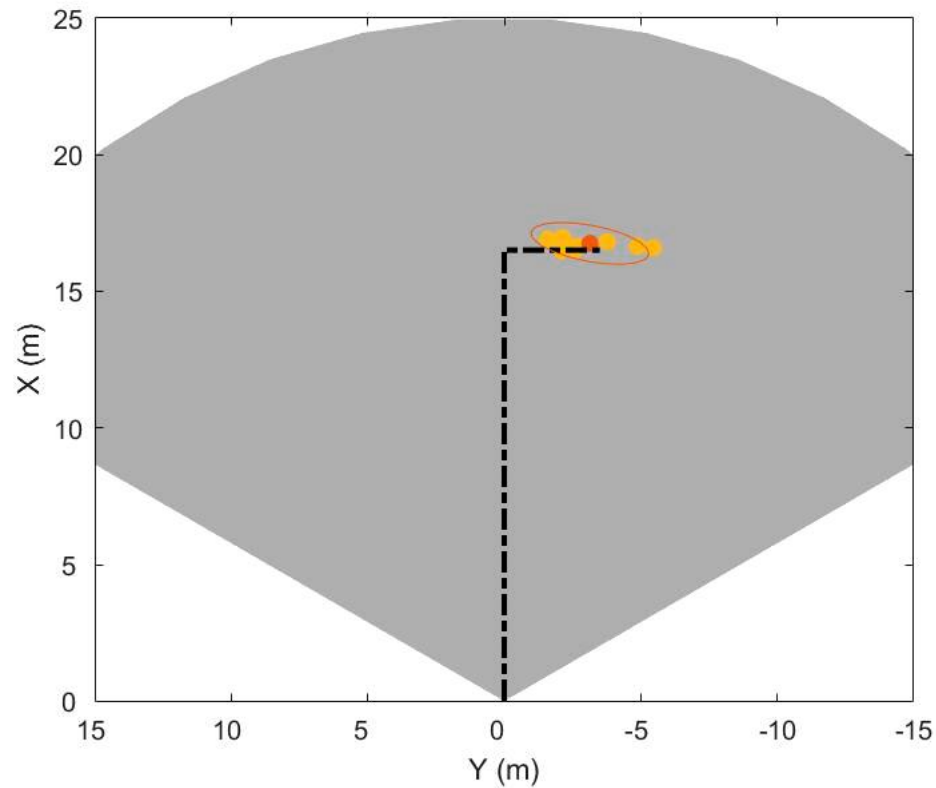
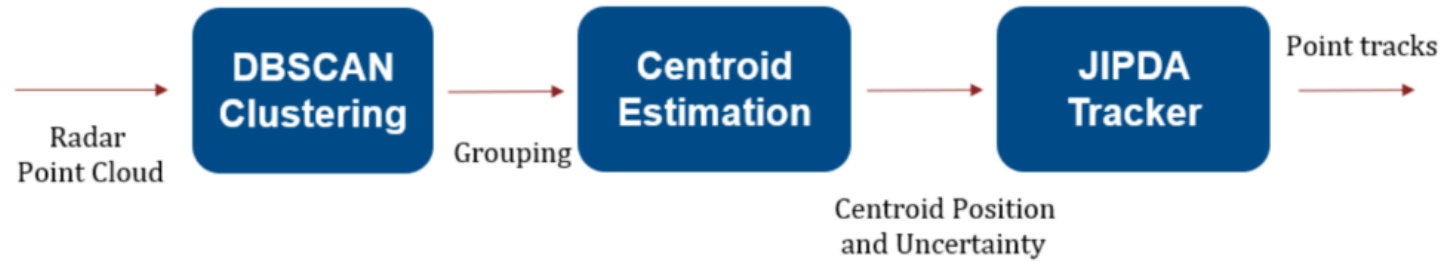
Track Objects in a Parking Lot Using TI mmWave Radar

Use data captured using the Texas Instruments (TI) mmWave radar for tracking objects in a parking lot. You learn how to use a processing chain

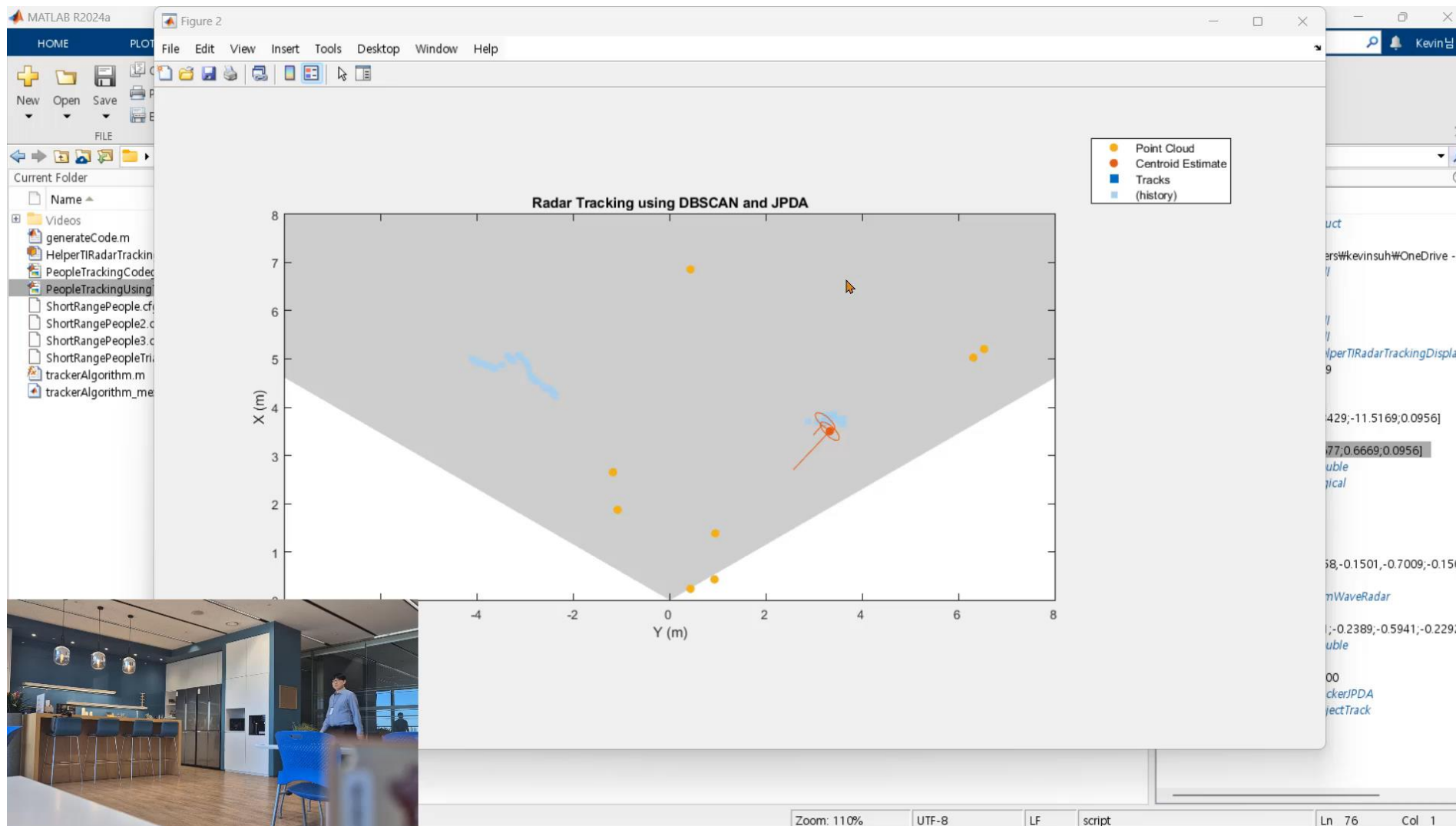
People Tracking Using TI mmWave Radar



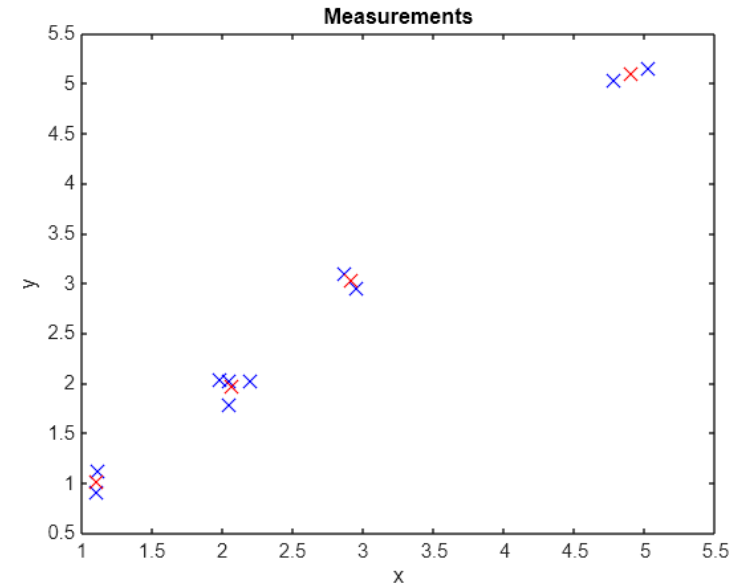
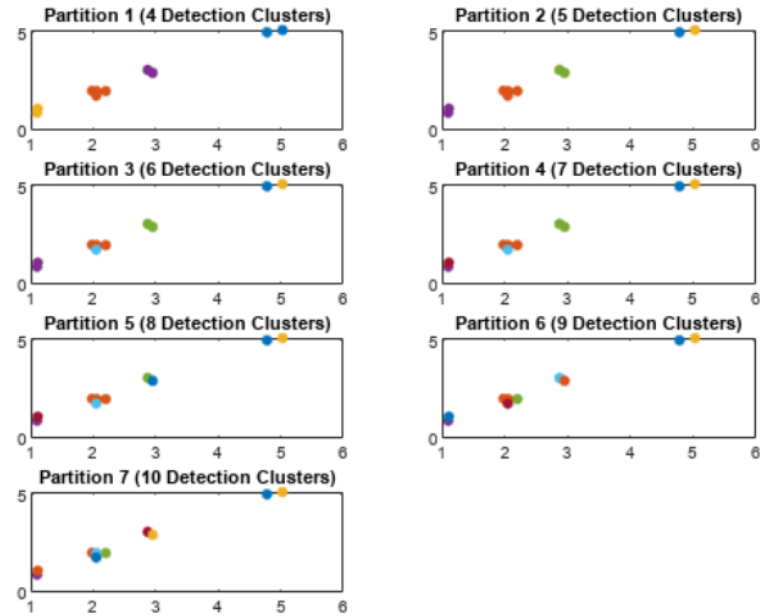
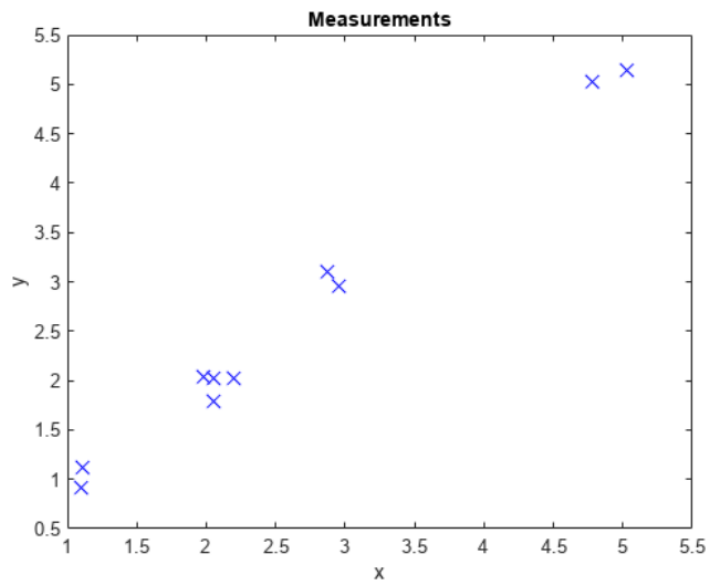
Track Objects in a Parking Lot Using TI mmWave Radar



Live Demo at the Demo Booth



DBSCAN Clustering – Centroid Estimation

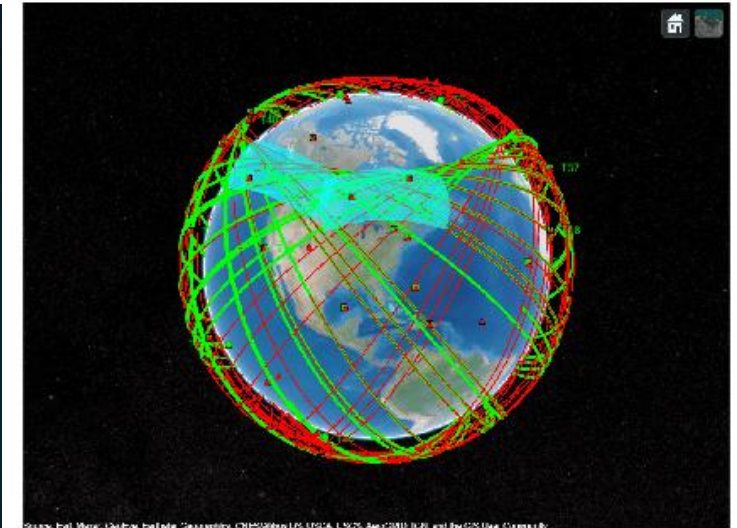
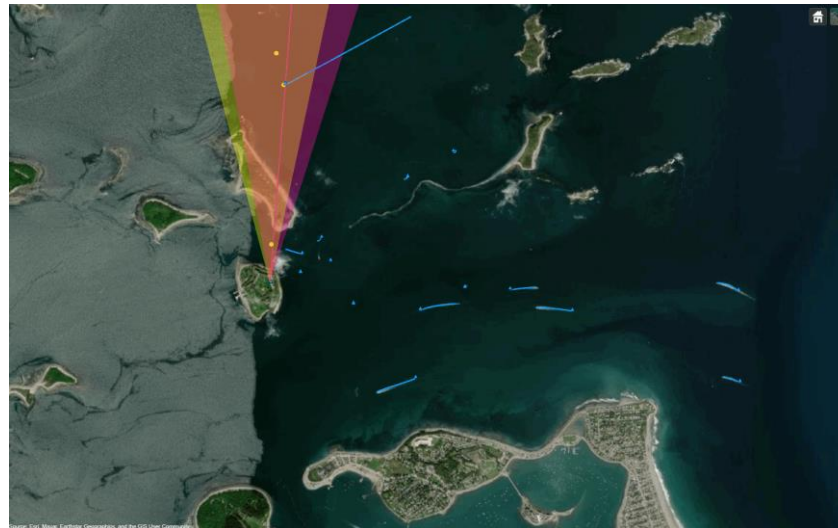
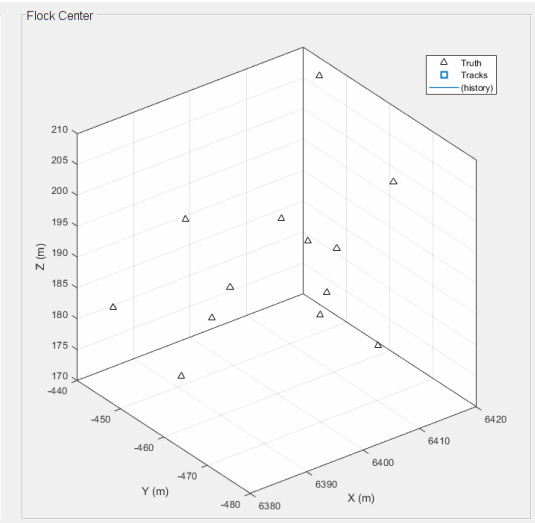
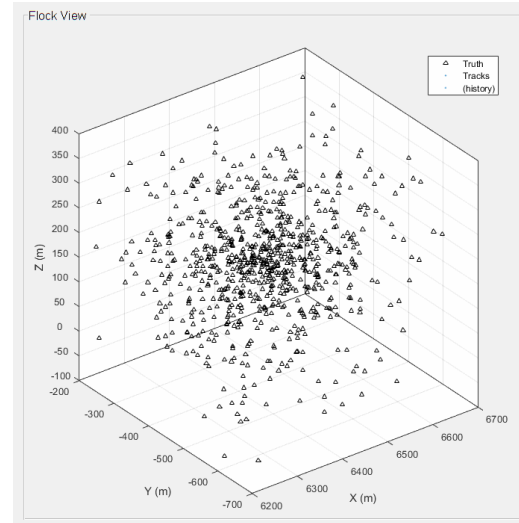
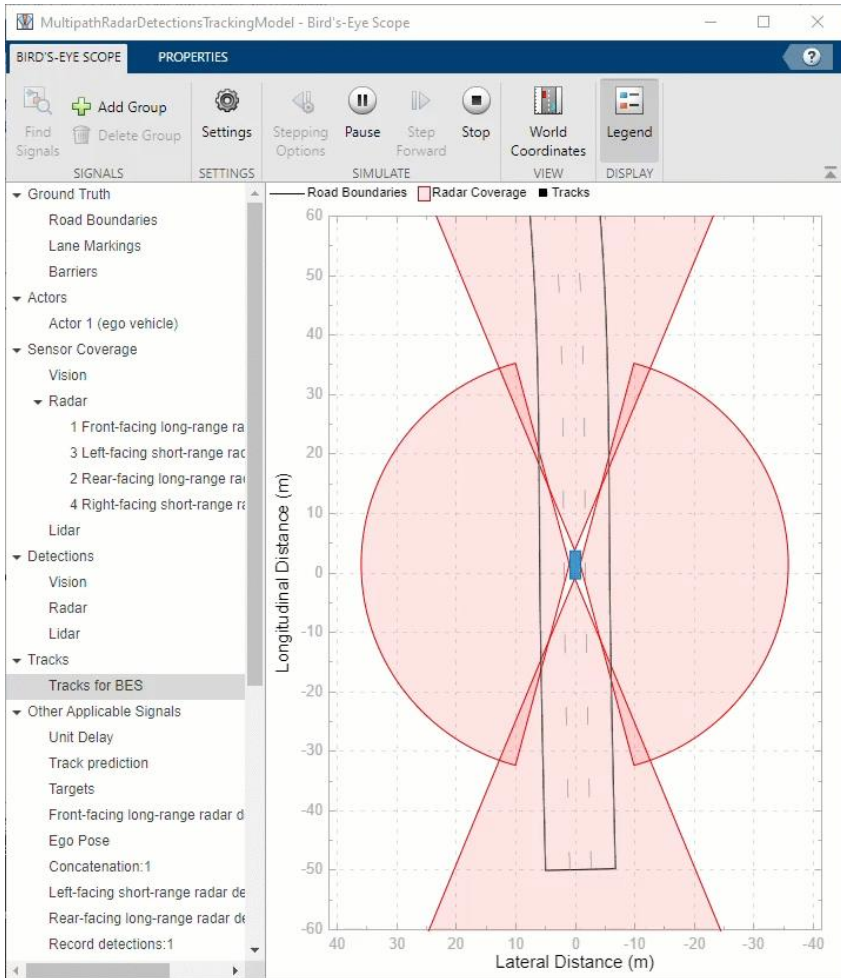


partitionDetections

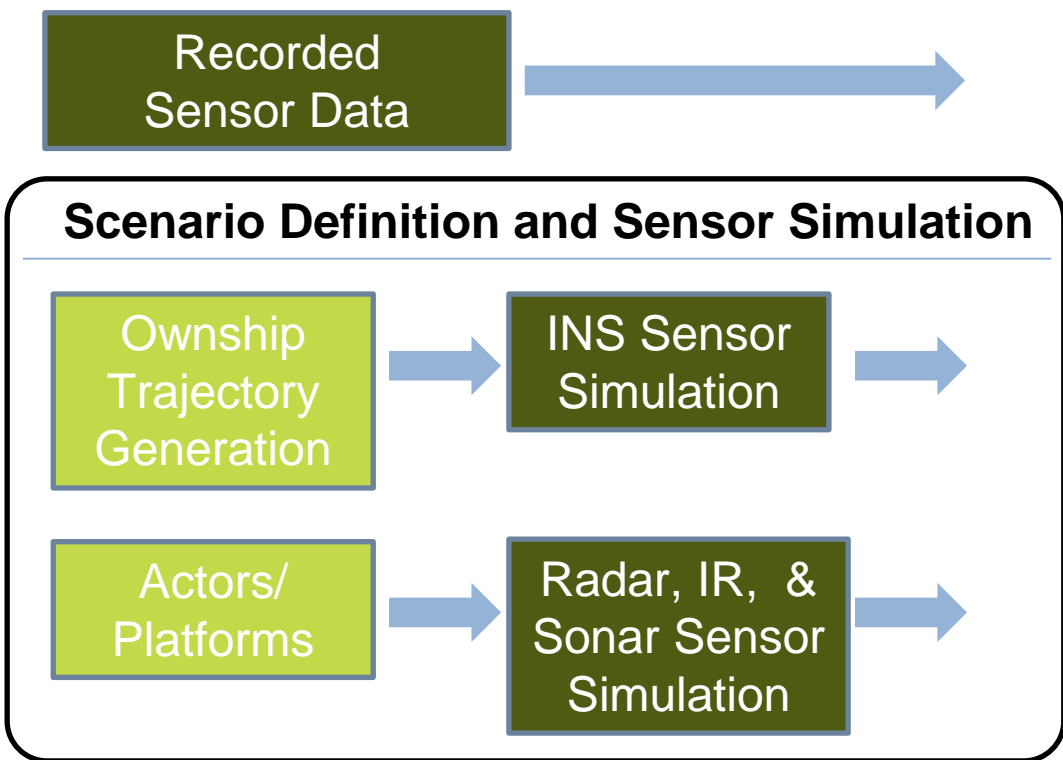


mergeDetections

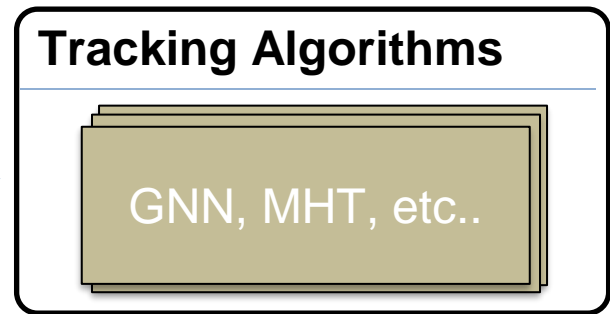
Trackers for Various Applications



Key Takeaways



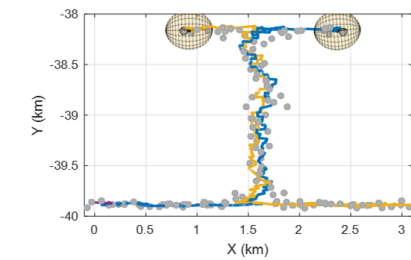
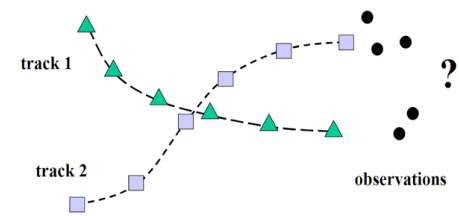
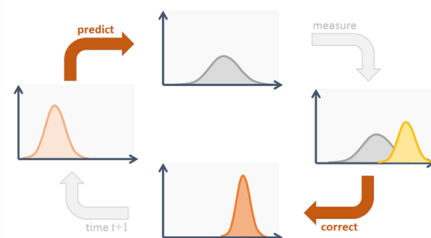
objectDetection



tracks



A rich library of tracking algorithms



Filters

- Alpha Beta filter
- Kalman filters
 - Linear, EKF, UKF, CKF, MSCEKF
- Particle filter
- Multiple models
 - GSF, IMM

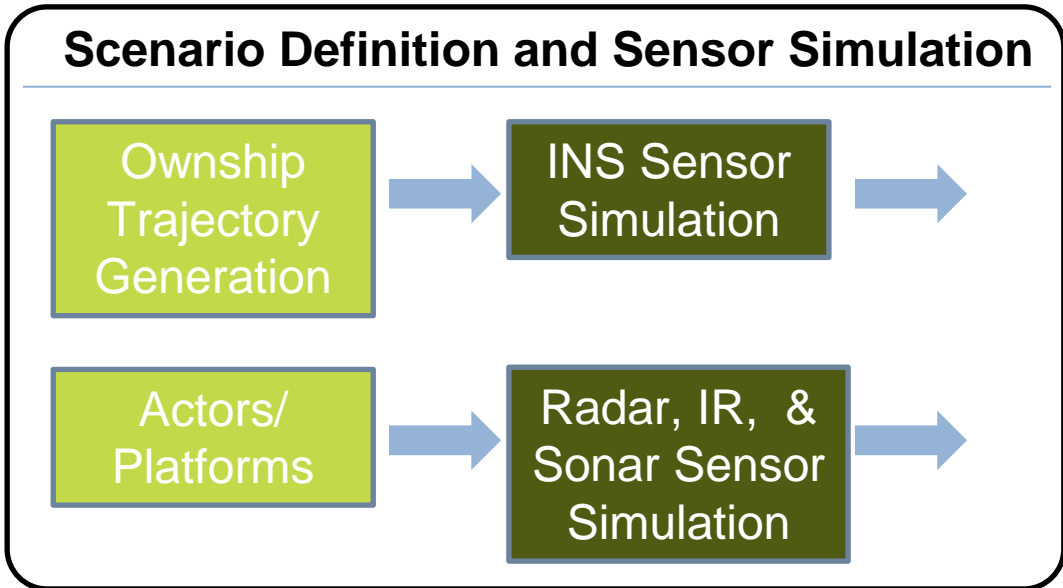
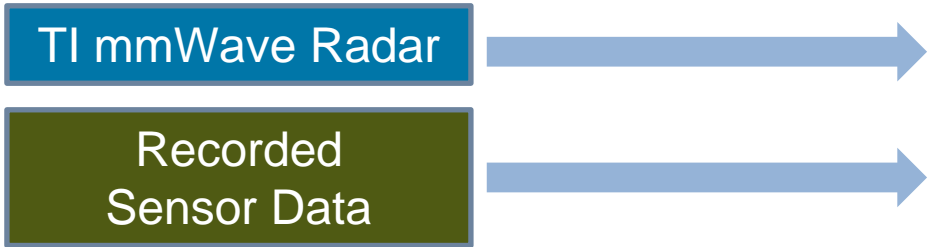
Data Association

- 2D assignment
- S-D assignment
- K-best assignment

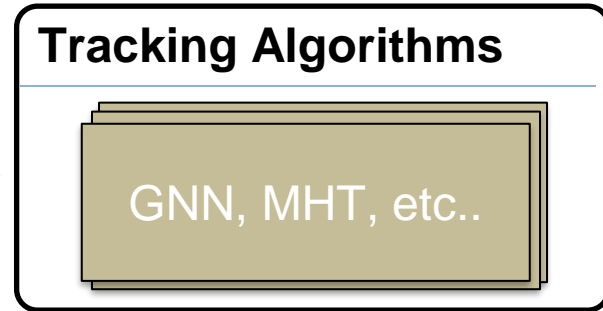
Trackers

- GNN, JPDA, PHD
- MHT (track-oriented)
- Trackers components
 - History and score logic
 - etc.....

Key Takeaways



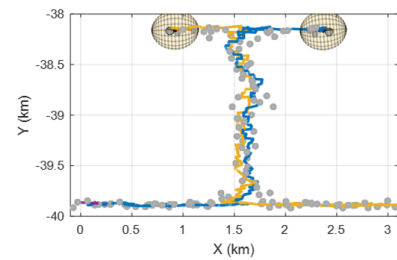
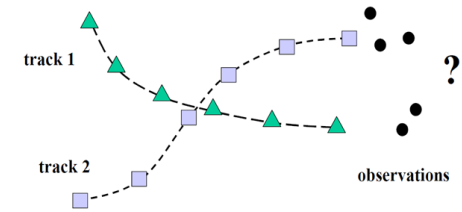
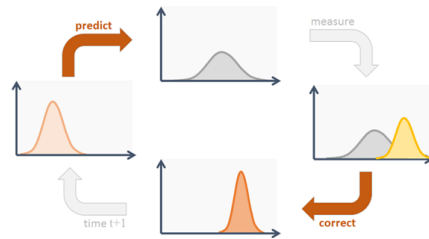
objectDetection



tracks



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MATLAB EXPO



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