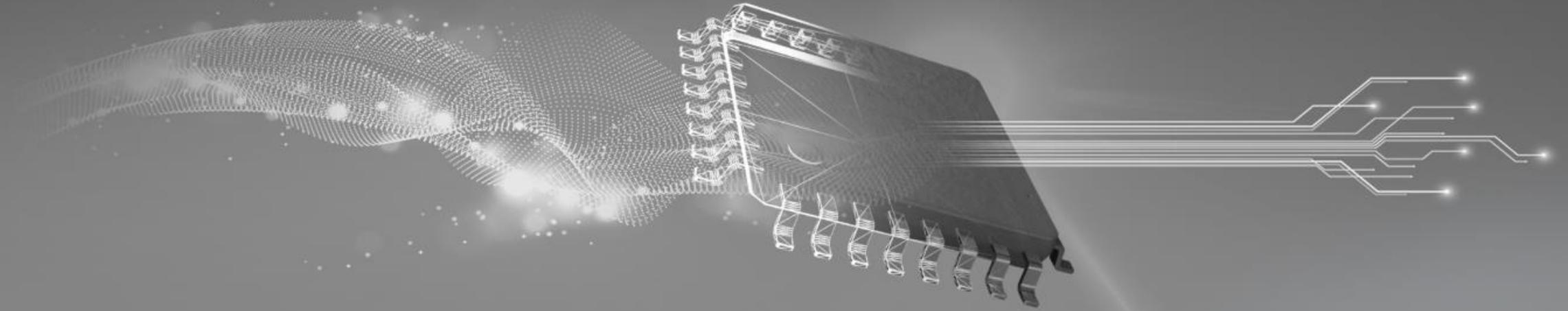TI TECH DAYS

Introduction to Texas Instruments 60-GHz radar sensors

Kishore Ramaiah

mmWave Sensors – Technology Overview, TI Advantages and Applications

What is mmWave Technology	• mmWave sensors provide **range**, **velocity** and **angle** for detected objects with high accuracy • mmWave technology **works in challenging environmental conditions** such as darkness, extreme bright light, dust, rain, snow and extreme temperatures
Texas Instruments' mmWave Advantages	• **Single-chip, Low-power** sensing solution achieved through RFCMOS technology • **Integrated processing** solutions remove the need for an external processor in the system • **Scalable Portfolio –** SW re-use across Automotive & Industrial platforms, regardless of band • **Antenna on Package** – Optimized solution simplifies design & manufacturing challenges • **Imaging Radar –** Lidar-like performance at the right price point

mmWave Applications

Automotive

Industrial

Outdoor

Indoor
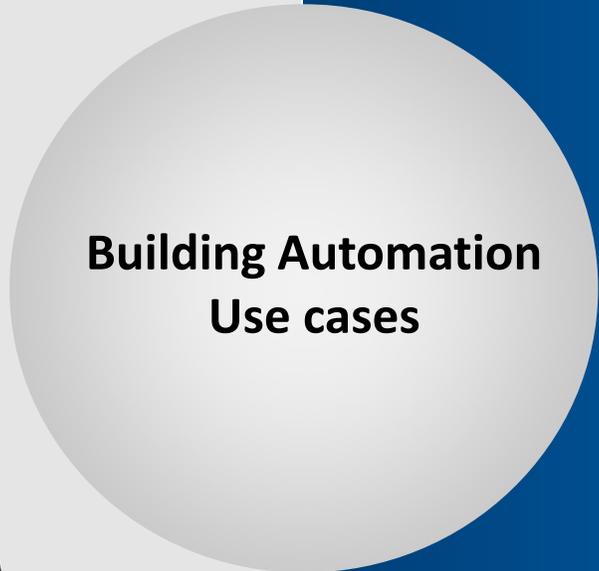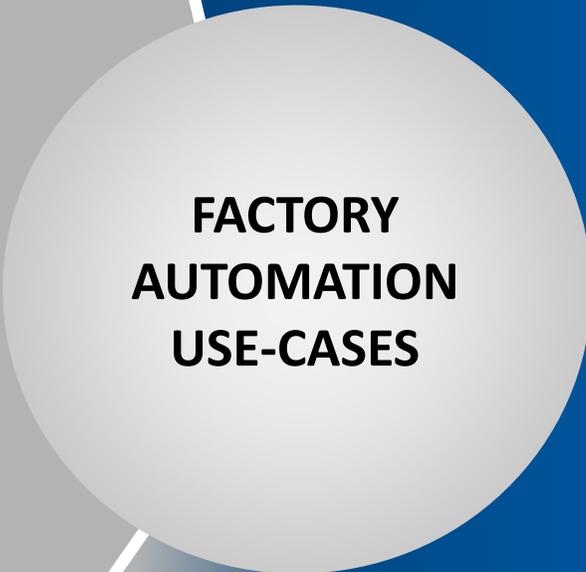
Last-mile Delivery
Food / Package delivery, sidewalk drive

Autonomous Delivery
On the road delivery

Off-Highway Vehicle
Construction tasks

Robotic Lawn Mower
Autonomous Lawn mowing

Level Sensing
Fluid / Solid Level Transmitter

Industrial Robots
Manufacturing

Collaborative Robots
Palletizing, pick and place, process tasks

Logistics Robots
Order picking, inventory delivery

Driverless Forklifts
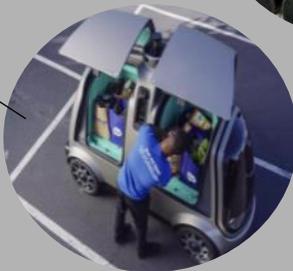Loading/unloading pallets, lifting/transporting heavy loads

Retail / Healthcare Robots
Inventory tracking, material delivery and transport

Cleaning Robots
Commercial and personal floor cleaning

FACTORY AUTOMATION USE-CASES

TEXAS INSTRUMENTS

4

60/77Ghz Radar – Portfolio Overview

AWR – Automotive
IWR- Industrial

Pin-to-Pin Compatible

mmWave Front end

mmWave Point Cloud Sensor + HWA + MCU

mmWave Sensor + MCU + DSP

mmWave Application Sensor + HWA + MCU + DSP

60GHz

xWR6443
- 4RX
- Calibration Monitoring Engine
- R4F
- 3TX
- 60-64GHz Synth
- 1.4MB
- 15MHz IF
- FFT
- SPI
- LVDS
- CAN

xWR6843 / AOP
- 4RX
- Calibration Monitoring Engine
- R4F
- DSP
- 3TX
- 60-64GHz Synth
- 1.75MB
- Beam Steering
- FFT
- SPI
- LVDS
- CAN

Delta from IWR6443

77GHz

xWR2243
- 4RX
- Calibration Monitoring Engine
- 3TX
- 76-81GHz Synth
- 20MHz IF
- SPI
- CSI2

xWR1443
- 4RX
- Calibration Monitoring Engine
- R4F
- 3TX
- 76-81GHz Synth
- 576KB
- 15MHz IF
- FFT
- UART SPI
- CSI2 LVDS
- CAN

Delta from AWR2432

xWR1642
- 4RX
- Calibration Monitoring Engine
- R4F
- DSP
- 2TX
- 76-81GHz Synth
- 1.5MB
- 5 MHz IF
- Crypto
- UART SPI
- LVDS
- CAN

Delta from IWR1443

xWR1843 / AOP
- 4RX
- Calibration Monitoring Engine
- R4F
- DSP
- 3TX
- 76-81GHz Synth
- 1.75MB
- 10MHz IF
- Crypto
- Beam Steering
- FFT
- SPI
- LVDS
- CAN

Delta from IWR1642

Common Component / Reusable Software (SDK)

- **Frequency regulation agnostic design :** Pin 2 Pin compatibility with 60GHz and 77GHz sensors.

- **One Software Investment:**   Common software API and framework across 60GHz and 77Ghz devices make software re usable and portable across devices.

- **Safety story:** ASIL B safety level for automotive and SIL-2 for industrial applications.
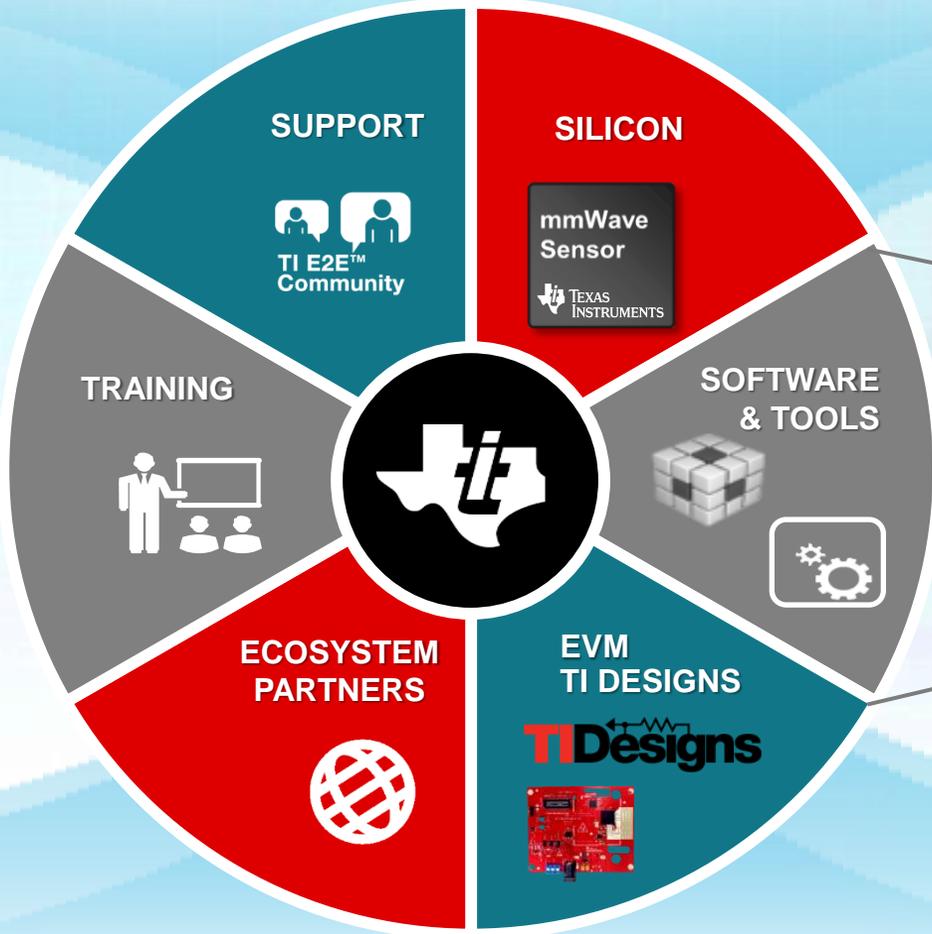
TEXAS INSTRUMENTS

mmWave Sensors – Whole Product

INCABIN SENSING

AUTOMOTIVE

BUILDING AUTOMATION

FACTORY AUTOMATION

SUPPORT

TI E2E™ Community

SILICON

mmWave Sensor

TRAINING

SOFTWARE & TOOLS

ECOSYSTEM PARTNERS

EVM TI DESIGNS

TI Designs

Leverage software and tools ecosystem
- **to guide customers through development path**
- **simplify barrier to entry**
- **and reduce time to market**

TEXAS INSTRUMENTS

mmWave Software Development Kit

Demonstration Application, TI-Designs

Traffic Monitoring	People Tracking/ Counting	In Cabin Sensing	SRR/MRR
	Robotics	Vital Signs	
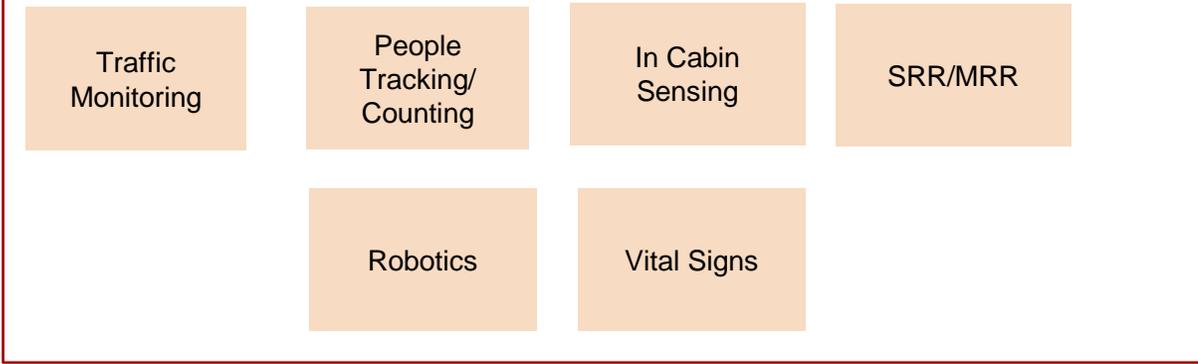
- o Key End-Equipment Demonstration Applications
- o Distributed on TI-Designs, TI-REX as examples and references
- o Built on top of mmWave SDK

mmWave Foundational Embedded Software Product(s)

mmWave SDK		MCAL	Safety Software

Radar Portfolio

TEXAS INSTRUMENTS

- o **mmWave SDK** provides:
  - o Foundational platform software (TI-RTOS, drivers, tools, examples, …)
  - o mmWave Framework and alogrithms
  - o OOB application & PC visualizer
- o Fully Open Source and on ti.com
- o Scalability and portability across mmWave portfolio
- o Easily available on TI Resource Explorer

TEXAS INSTRUMENTS

Occupancy Detection using TI mmWave

Sense presence, absence, precise position and count of people/objects with high sensitivity to fine motion achieving very low False Detections. Reduce building energy losses without invading into privacy of people

Direct A/C airflow

Energy efficient Smart A/C

Simple Lighting control

Smart Lighting, office desk space hoteling, Fall monitoring

Wall Mount People Tracking and Counting Reference

8m range, sense precise position +/- 10cm and count with accuracy of 90% for <5 people and 85% up to 9 people in the room with count density of 3 people per m2.

Overhead mount People Tracking and Counting Reference

4m radial range, sense precise position +/- 20cm and count with 85% accuracy for up to 9 people in the room with count density of 2 people per m2.

Zone Occupancy/Area Scanner Reference

FOV up to 130 deg both in Azimuth, Elevation enables to cover 8 parking spots for Occupancy Detection with single mmWave sensor

| TI mmWave features	Occupancy sensing benefits
Beam forming for improved detection areas - 3D presence + Static object detection + Classification +Tracking	• Detect and Track multiple people/objects (moving/static) in the area of interest with position and angle information. Enable stance/fall detection using 3D detection
Detects fine motion (such as typing) as well as immune to environmental conditions	• Increase reliability over existing PIR/Camera sensors which suffer from false detections in challenging environments like bright daylight, shadows and pictures of human

TEXAS INSTRUMENTS

Mobile Robot Sensing with TI mmWave

Complement or displace established sensor solutions like ultrasonic with TI mmWave sensors that can solve the most challenging AGV and AMR sensing problems including safe human presence detection and autonomous navigation

Automated Guided Vehicle (AGV)

- Requires "tracks" for guided navigation
- Stops upon obstacle detection
- Problems that need to be solved (sensors used today):
  - Safe human presence detection (LIDAR)
  - Collision avoidance (LIDAR/Ultrasonic/Radar)
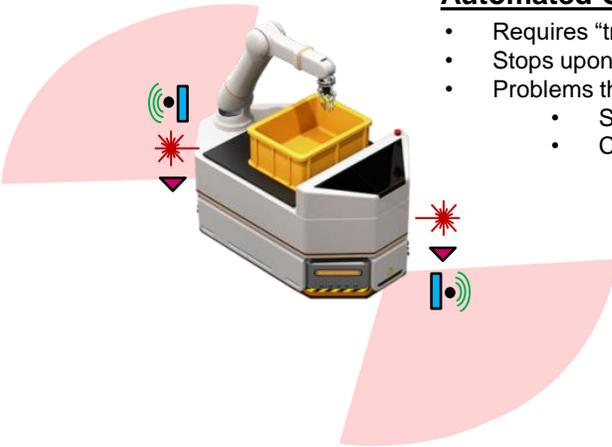
Autonomous Mobile Robot (AMR)

- Sensor based autonomous navigation
- Can maneuver around people and obstacles
- Problems that need to be solved (sensors used today):
  - Safe human presence detection (LIDAR)
  - Mapping & Localization (Stereo camera / LIDAR / Ultrasonic/Radar)
  - Collision avoidance (Stereo Camera / LIDAR / Ultrasonic / Radar)
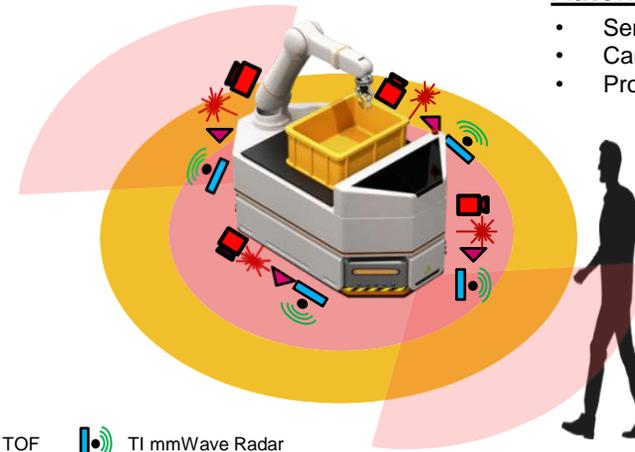
▼ Ultrasonic   ✳ LiDAR   ◼ Stereo Camera or 3D TOF   ▸)) TI mmWave Radar

| TI mmWave features	Robotics Benefits
3D presence detection	• True 3D information (range, velocity & angle) of objects vs. LIDAR/ToF used mainly for distance measurement • Quickly detect and prevent possible collisions minimizing machine downtimes
Accurate glass detection	• Ensure reliable detection of glass walls/doors over existing sensors that "see" through them
High angular resolution <2°	• Achieve LiDAR like performance at a lower cost with imaging radar or camera + mmWave radar fusion
Cliff detection	• Eliminate dedicated cliff detect sensors with obstacle + cliff detection on single TI mmWave sensor
Wide azimuth area coverage up to 120°	• Reduce number of sensors for area scanning reducing overall system cost
Robust in challenging environmental conditions	• Increase reliability over existing vision and LiDAR based sensors in conditions such as rain, dust, smoke, complete darkness or in the glare of sunlight

TEXAS INSTRUMENTS

Safety Guards using TI mmWave

Enable increased human-robot collaboration and productivity while ensuring safety around industrial robots with SIL 2 capable TI mmWave sensors that provide a robust, lower cost, smaller footprint alternative to expensive LIDAR sensors
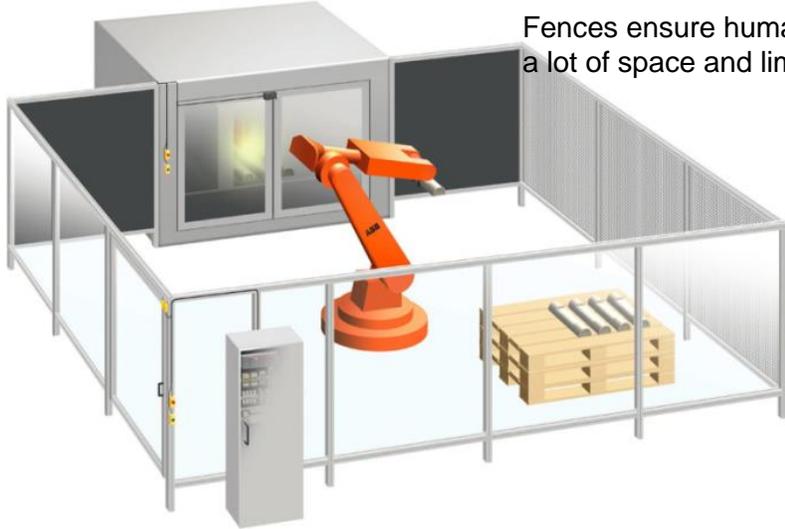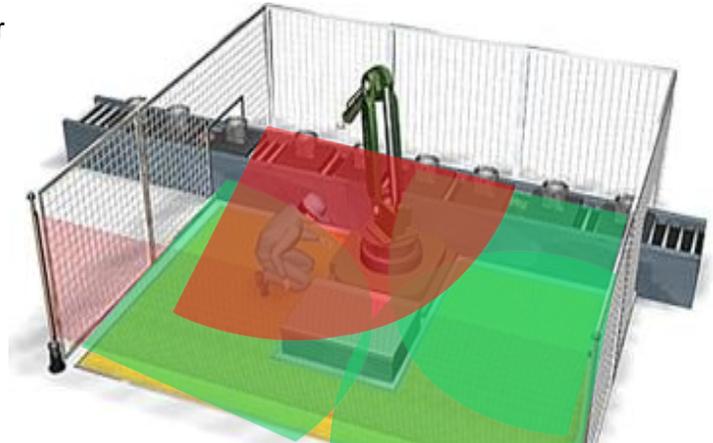
Fences ensure human safety but take up a lot of space and limit productivity
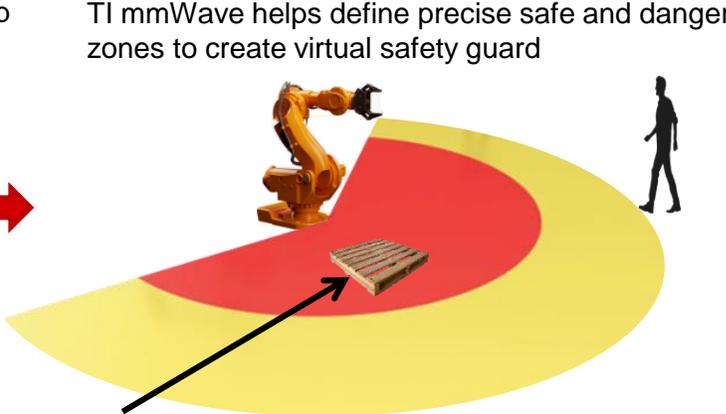
TI mmWave helps define precise safe and danger zones to create virtual safety guard

TI mmWave is capable of detecting static objects left behind in a danger zone

SIL 2 capable IWR6843 can ensure Robot doesn't restart as long as operator is in the cage

TI mmWave features	Robotics Benefits
3D presence + static object detection	• Detect person/object (moving/static) in danger zone to trigger appropriate robot response • Facilitate quicker changeovers and save floor space
Gauge approaching object trajectory and speed	• Dynamically adjust size of safety zones based on speed of approach • Ignore objects whose trajectory is not towards the zones
Wide azimuth area coverage up to 130º	• Reduce number of sensors for area scanning reducing overall system cost
Robust in challenging environmental conditions	• Increase reliability over existing LIDAR sensors that can't see well through dust/smoke

TEXAS INSTRUMENTS

Evaluation – How to get started

| Occupancy Detection	Mobile Robot Sensing	Safety Guards

Occupancy Detection

1. **Discover** mmWave offering for occupancy detection here
2. **Evaluate** the performance
   1. IWR6843 ISK (Wall mount)
   2. IWR6843ISK-ODS (Overhead mount)
   3. Wall Mount People Counting using IWR6843
   4. 3D Overhead People Counting using IWR6843

3. **Design** with IWR6843 silicon
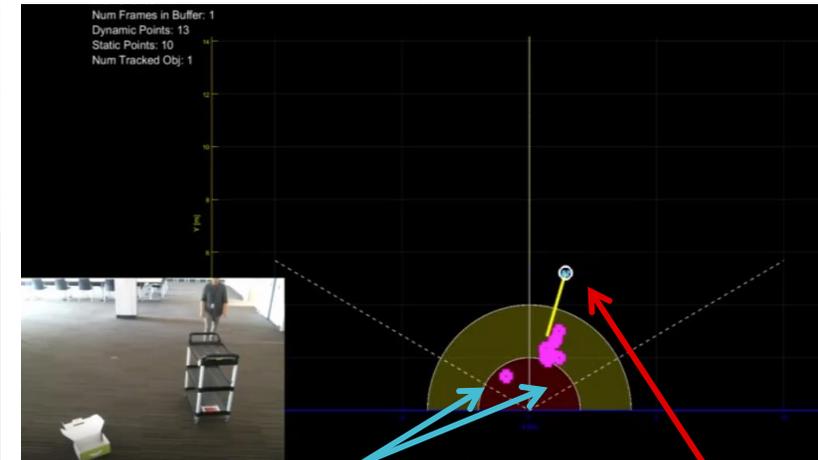   1. Online datasheet & other technical documents
   2. Hardware design checklist
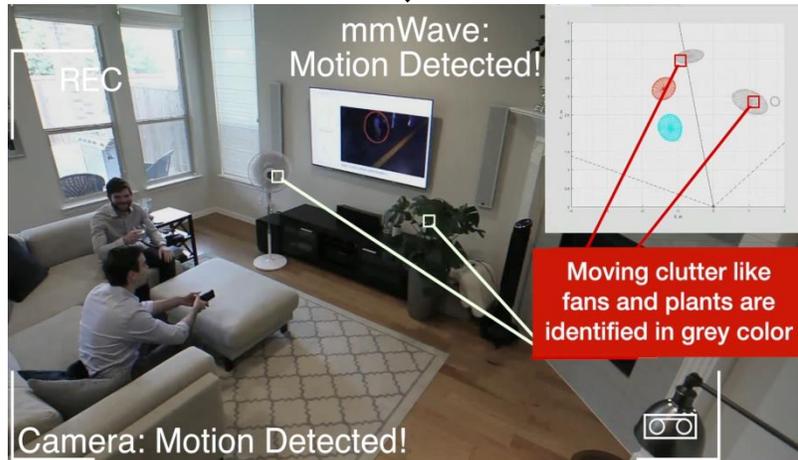
Mobile Robot Sensing

1. **Discover** mmWave offering for mobile robotics here
2. **Evaluate** the performance
   1. IWR6843 ISK (60GHz)
   2. IWR1843 BOOST (77GHz)
   3. Sense and Avoid Lab [IWR6843 and IWR1843]
   4. Detecting walls of different materials experiment

3. **Design** with IWR6843, IWR1843 silicon
   1. IWR6843 datasheet & other technical documents
   2. IWR1843 datasheet & other technical documents
   3. Hardware design checklist
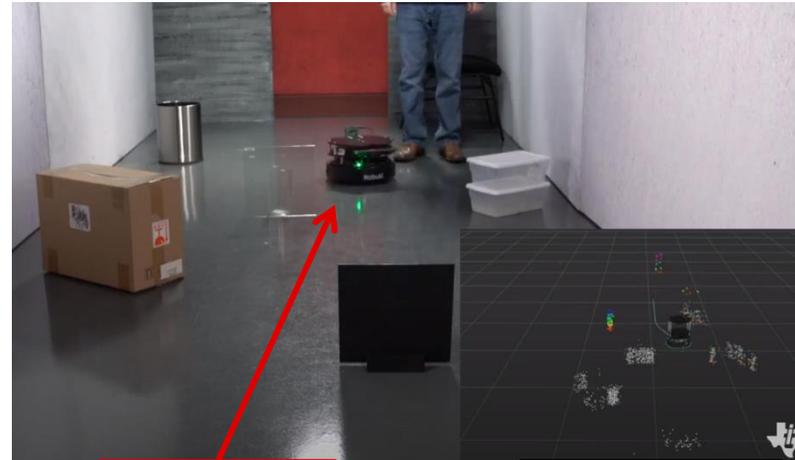
Safety Guards

1. **Discover** mmWave offering for safety guards page here
2. **Evaluate** the performance
   1. IWR6843 AOP
   2. IWR6843 ISK
   3. Area scanner Lab with static object detection using IWR6843

3. **Design** with IWR6843 silicon
   1. Online datasheet & other technical documents
   2. Hardware design checklist

REC
mmWave: Motion Detected!
Moving clutter like fans and plants are identified in grey color
Camera: Motion Detected!

"TURTLEBOT" ROBOT

POINT CLOUD VISUALIZATION

Num Frames in Buffer: 1
Dynamic Points: 13
Static Points: 10
Num Tracked Obj: 1

Static objects

Moving person

Incabin Sensing using TI mmWave

Detect Child left behind in a car to meet NCAP requirements. Detect occupant presence and position for seat belt reminder, air bag deployment control applications with potential to replace error prone passive weight sensors, without invading into privacy of people

Door sequencing and ultrasonic sensors are error prone and not accurate
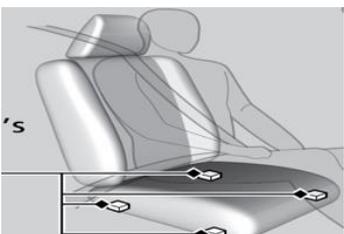
Multiple expensive weight sensors could indicate false occupancy when big objects occupy the seat

Front mount Occupant Detection

- Sensor Position: Headliner
- #of Occupant Detection: 5
- # Rows: 2
- Range: 5m – 7m with 4cm range resolution
- 120° x 30° field of view

Current TI SW status :

- Detection of 4 occupants across 2 rows
- 1ST row: 2 Adults, 2nd row: 2 adult/child
- Child in chid seat in 1st or 2nd row

Roof mount Occupant Detection

- Sensor Position: Roof above 2nd row
- #of Occupant Detection: 5
- # Rows: 2
- Range: 4m with 4cm range resolution
- 120° x 120° field of view

Current TI SW status :

- Detection of 2+ occupants in 1 rows
- Detect child anywhere in 2nd row including footwell
- Detect 1 adult and 1 child in 2nd row

TI mmWave features	Incabin sensing benefits
Detect very fine motions and ability to pass through solid material	• Ability to detect presence of newly born babies in rear facing child seat and covered with blankets. • Privacy is guaranteed.
3Tx - 4Rx and wide field of view	• Ability to detect occupants in multiple rows and also localize the presence of occupants
RFCMOS enables small form factor and integrated single chip solution	• Easy vehicle integration with CANFD interface connection directly to vehicle BUS
On chip crypto accelerator	• Enables secure boot of the image and hence thwarts hacking

TEXAS INSTRUMENTS

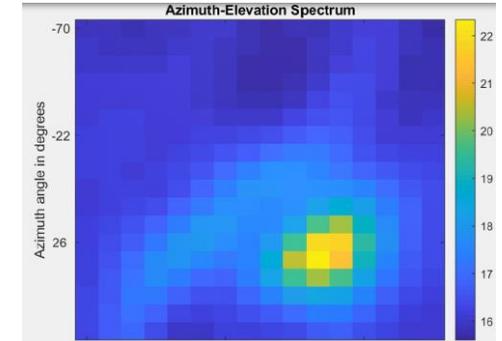# Child Presence Detection tests – Rooftop position

Sensor in Rooftop

Lying on seat

In Footwell

In baby seat covered by cloth

Detection in Azimuth angle plane

Sensor : AWR6843ISK EVM (FOV: 120 Azimuth x 30 Elevation)
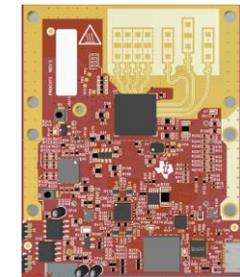**Car**: Mid size SUV with 2 rows
Baby doll: https://www.ashtondrake.com/products/301881001_lifelike-breathing-baby-doll.html
Position: Roof top/Ceiling (above headrest of 1st row)
Algorithm: 2D Detection in 1 rows (Rear seat)
Advantages:
• Can detect baby in footwell, baby in rear facing position
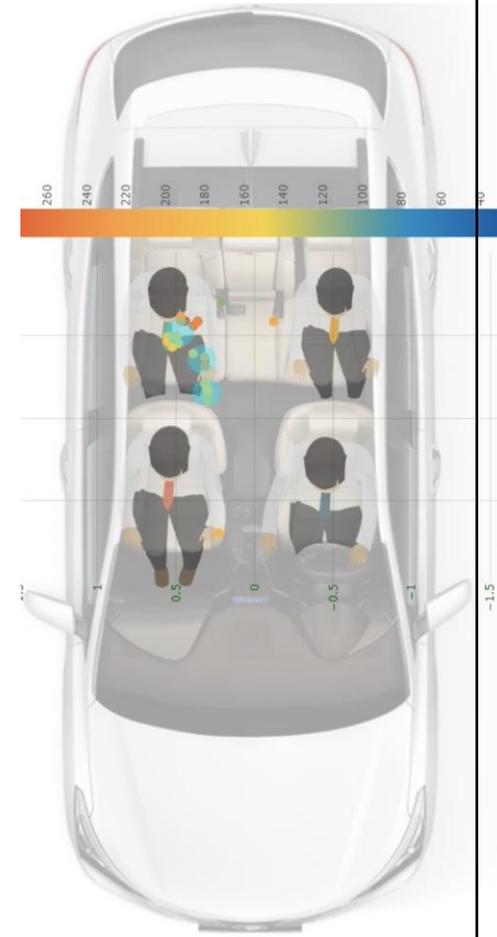• Can detect adult occupants

TEXAS INSTRUMENTS

AWR6843 application scalability

Intruder Detection

- Detects intruders around car
- Operates in low power mode (mW)
- Multi mode sensing

Multi-row Occupant Detection

- Detects/Localize 5 occupants in 2 rows
- Classify occupants
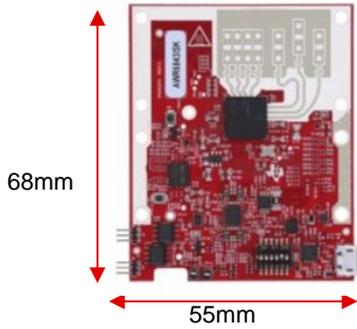
TEXAS INSTRUMENTS

Incabin sensing evaluation platforms

Discover/Evaluate/Design

1. **Discover** TI radar incabin sensing offering:
   - Vehicle Occupant Detection TI Design
   - Read Technical article

2. **Evaluate** the sensor performance**:**
   - Try our evaluation kit AWR6843ISK
   - Reference software on TI Resource Explorer
     - Front Mount:
       - Detect 2 Occupants in 1st row and 2 Occupants in 2nd row
     - Roof Mount: Detect 2+ occupants in 1 row, Child presence detect in 1 row including footwell

3. **Design** your sensor with confidence**:**
   - Reference board schematics & layout
   - Silicon to design your board: AWR6843AQGABLQ1

Evaluation Kit and Spec

68mm

55mm

http://www.ti.com/tool/AWR6843ISK

	AWR6843ISK
Azimuth FOV	120°
Elevation FOV	30°
Azimuth Angle resolution	15°
Elevation Angle resolution	58°
Sensor Position (Current SW Tested)	**Front:** Detect 4 Occupant (2 in each Row) **Roof:** Detect 2+ occupant in 1 row & CPD
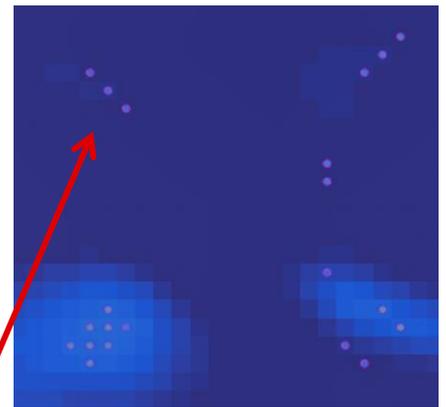
Baby

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Thank you for joining.

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