

# Safety for Robotics with TI mmWave

How can radar increase robot productivity while  
maintaining operators' safety

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# Agenda

- Safety in Europe and the EU and applicability to robots
- What can be achieved with TI mmWave for robot safety
- TI offering
- How to get started



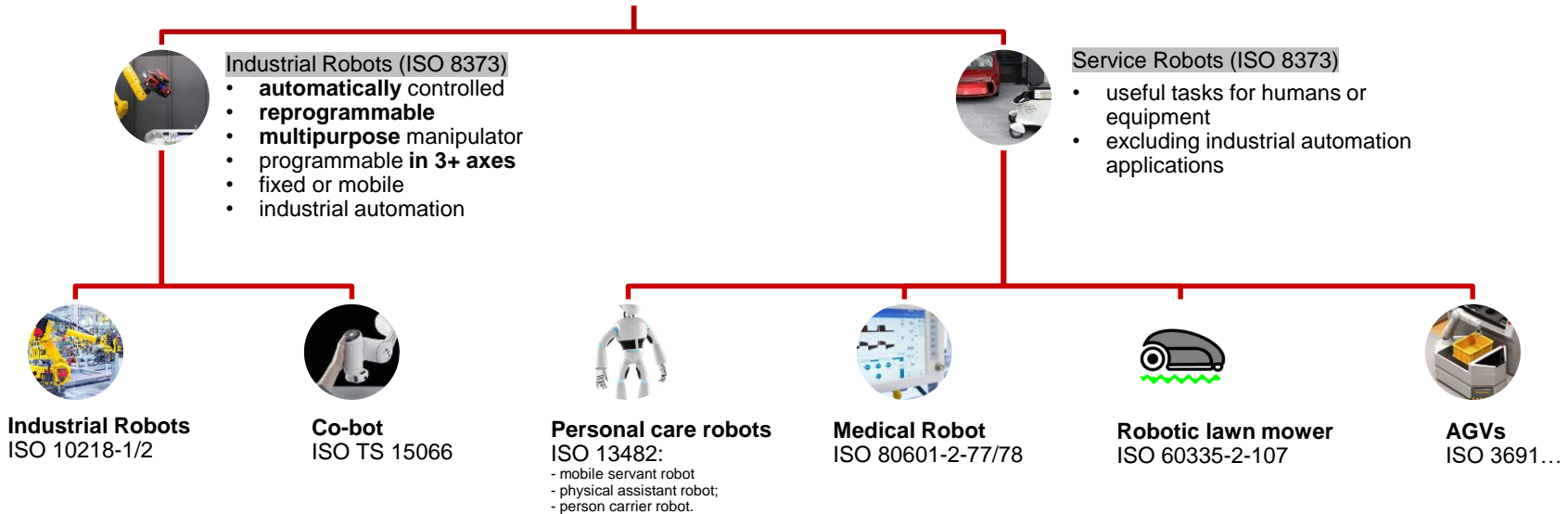
# Safety in Robotics, but what is a robot ?



## Robots



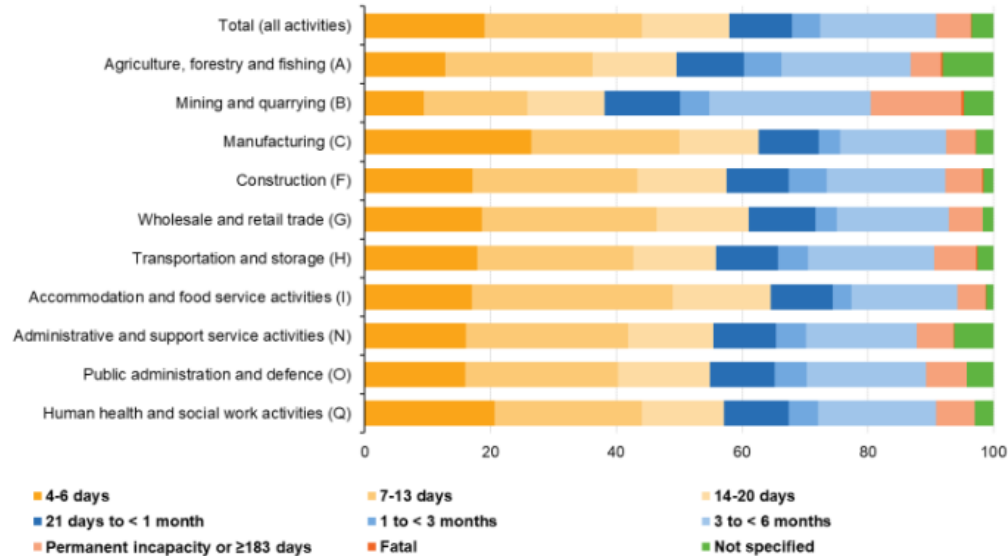
Autonomous vehicles



# Safety goals in Europe reduce number of injuries

## Accidents at work by severity and economic activity, EU, 2019

(% of accidents for each activity)



Source: Eurostat (online data code: hsw\_n2\_04)

eurostat

Figure 2: Accidents at work by severity and economic activity, EU, 2019  
(% of accidents for each activity)

Source: [https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Accidents\\_at\\_work\\_-\\_statistics\\_by\\_economic\\_activity#Developments\\_over\\_time](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Accidents_at_work_-_statistics_by_economic_activity#Developments_over_time)

# Positioning safety in Europe: starts with EU Machine directive

IEC 61508 ✓

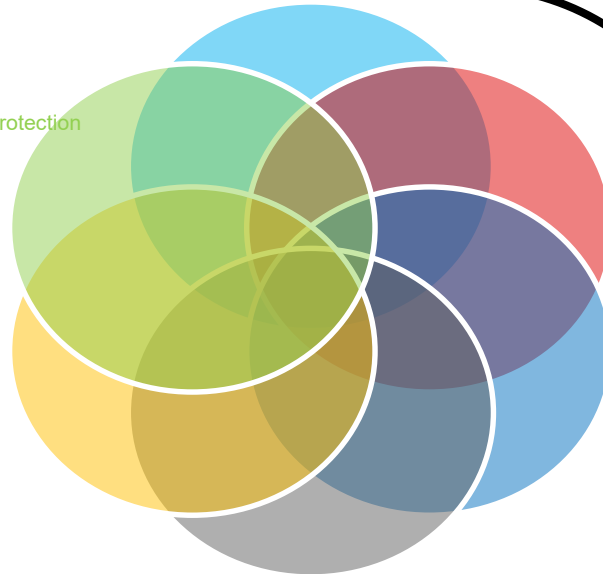
Apply, design, deploy and maintain automatic protection systems called safety-related systems

## Type B2 standards

- PPE specific safety features
- IEC 61496 ESPE
- Upcoming -5 for radar ✓

HOW

EU Machine Directive



## Type B1 standards

- Types of safety
- Minimum distance requirements can be found in ISO 13855

SAFETY ?

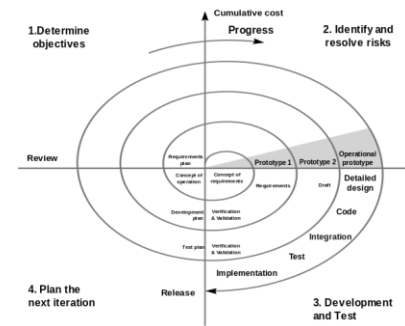
Risk Assessment  
(ISO 12100)

WHICH  
PRODUCT

## Type C standards

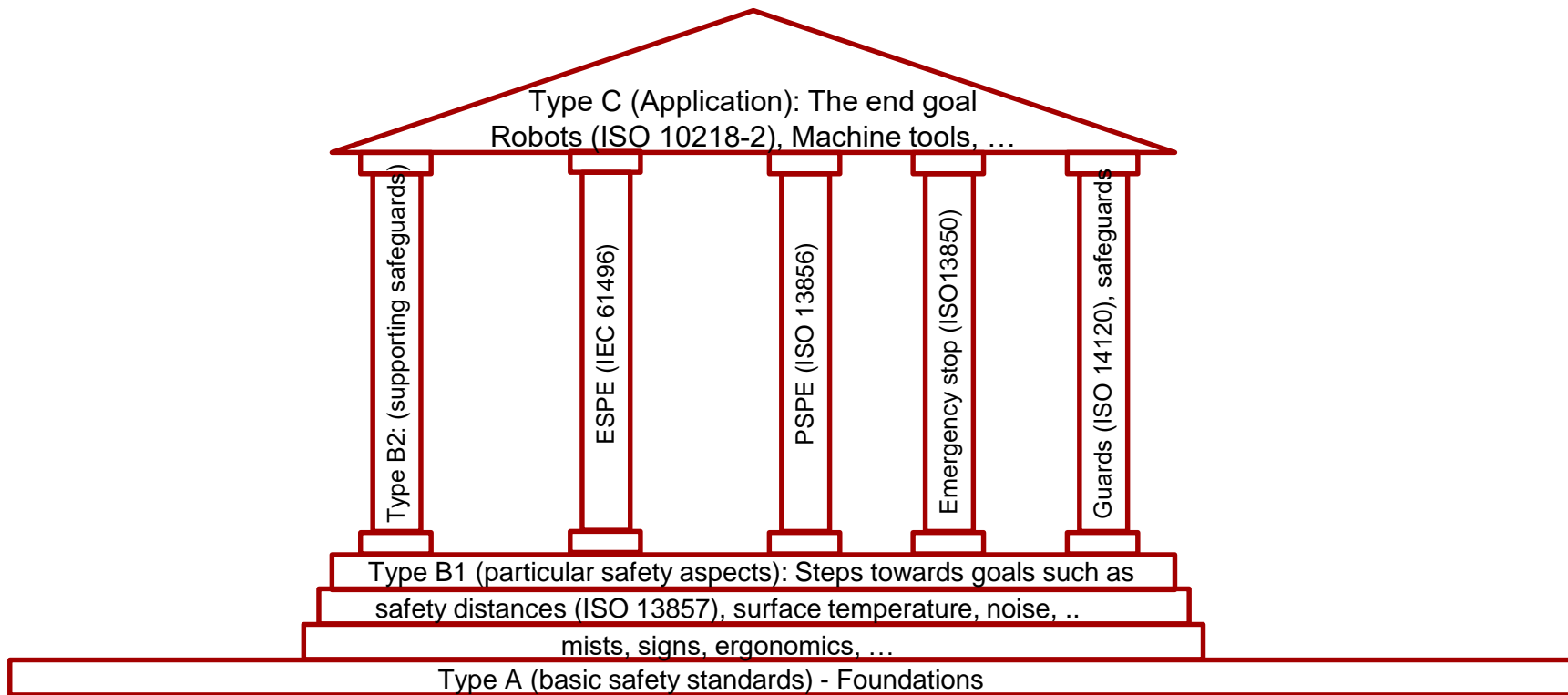
- Machine centric
- ISO 10218-2: industrial robots
  - EN 12978 – doors and gates

WHAT  
SAFETY  
MEASURES

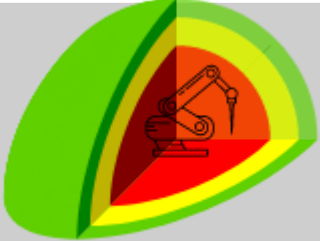





By Conny derivative work:  
Spiral\_model\_(Boehm,\_1988), Public Domain,  
[Link](#)

# Safety standards Industrial Robots specifics

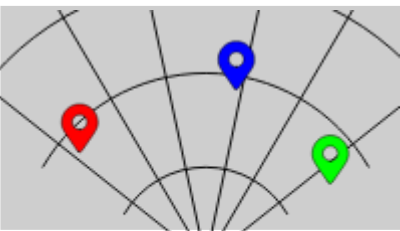
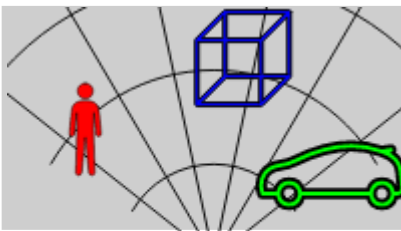

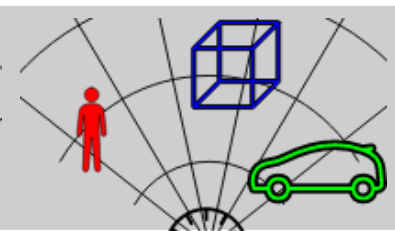


# Key considerations for industrial robots

4D area scanner	Environmental Resilience	Safety (SIL)	IEC61496-5 ready
			
<p>4D volume scanning allows the benefits of both light curtains and area scanners by covering a full volume for additional workers protection and breathing / micro-motion detection</p>	<p>Reliably detects human even in presence of dust which otherwise might trigger false positives with optical solutions.</p>	<p>TUEV SIL2 certificate available as well as all related safety collaterals</p>	<p>TC44 has released the IEC61496-5 for radar to national committees</p>
<p>TI lab offers SW on ti.com demonstrating feature for <a href="#">Area scanner</a>. Commercial solutions launched in 2021.</p>	<p>60GHz radar is an ISM band free to use for static installation. TI experiments on ti.com demonstrating <a href="#">resistance to rain</a>.</p>	<p>Commercially available products for ESPE type 3.</p>	<p>expected to be published by e/o 2022</p>



# Key considerations for wheeled service robots (AGV)

4D Target Detection	4D Imaging radar	Slope Gradient and Cliffs	odometry fusion
			
<p>Detects targets and their position allows to plan navigation around those obstacles</p>	<p>With angular resolution at or below 1 degree, comes the ability to detect boundaries and navigate more accurately in busy environments.</p>	<p>Detects cliffs and measures positive and negative slopes ahead</p>	<p>Fusion of odometry data (AGV speed) allows to estimate respective speed of targets.</p>
<p>Feature complete demonstration code available from TI and multiple third parties.</p>	<p>In production in adjacent markets (ADAS). Publicly available supporting collateral from TI and 3P vendors</p>	<p>TI experiment offers <a href="https://www.ti.com">SW on ti.com</a> demonstrating cliff detection.</p>	<p>In production in adjacent markets (ADAS). Ask your TI representative for detailed information.</p>

# TI mmWave Sensors for Safety applications



# TI mmWave Overview for Robotics

## What is mmWave Technology

- mmWave is defined as the **RF band of spectrum** between 30GHz and 300GHz
- mmWave sensors provide **range, velocity and angle** for detected objects with high accuracy
- Achieve increased reliability over optical sensors in **challenging conditions** such as rain, dust, smoke, complete darkness or in the glare of sunlight

## Why choose TI mmWave for Robotics?

- **Single-chip, low-power radar** sensing solution achieved through RFCMOS technology
- **Integrated processing** solutions remove the need for an external processor in the system
- IEC 61508 **SIL2 certified devices** capable of human presence detection capability
- **Sample applications** for safety-guards, and mobile robotics running on low-cost EVM's
- **Scalable Portfolio:** Software re-use across frequency bands
- **Antenna on Package:** Optimized solution simplifies design & manufacturing challenges

## mmWave Robotics Applications

### Industrial & Collaborative Robots

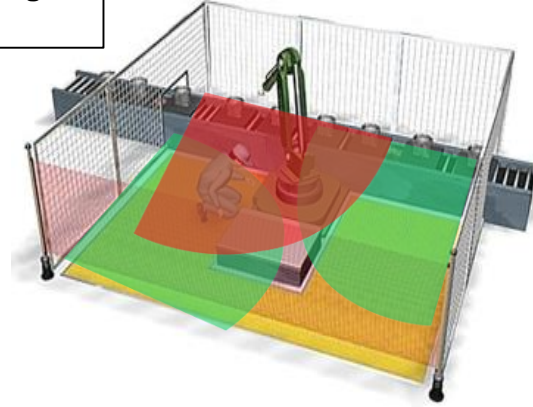
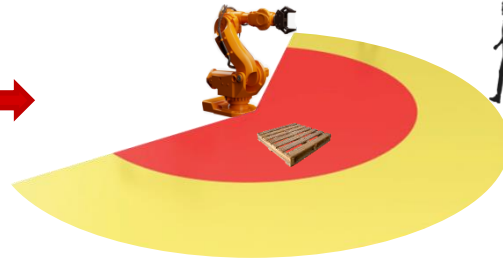
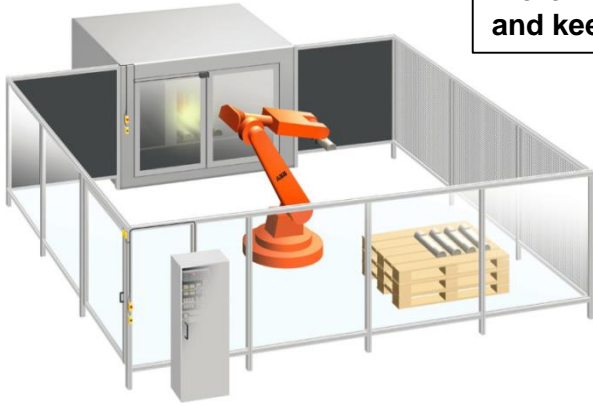


### Mobile Robots [AGVs & AMRs]



# Human safety Safety Guards

As the increasing use of robotics aims for reducing cycle time, more human collaboration and therefore the need for detecting and keeping humans safe becomes ever more critical.



## Ultrasonic Challenges

- Slow to detect moving obstacles
- Not good at sensing objects that deflect/absorb sound waves
- Sensitive to mechanical vibration

## Optical (NIR) challenges

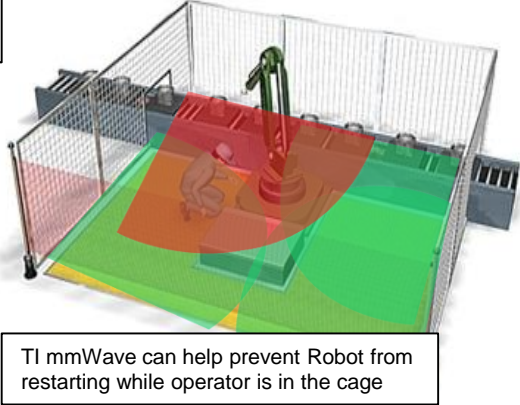
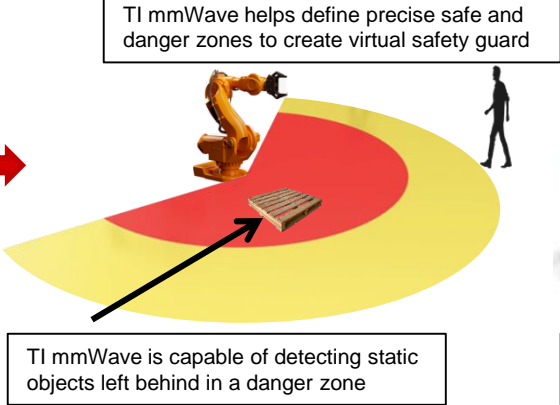
- Objects below or above sensing planes will be missed
- Limited angular resolution in elevation
- Muting is only available in 2D

## Vision challenges

- Compute complexity for position and speed estimation (when possible) is high
- Environment and privacy

# Getting Started with 4D Safety Guards using TI mmWave

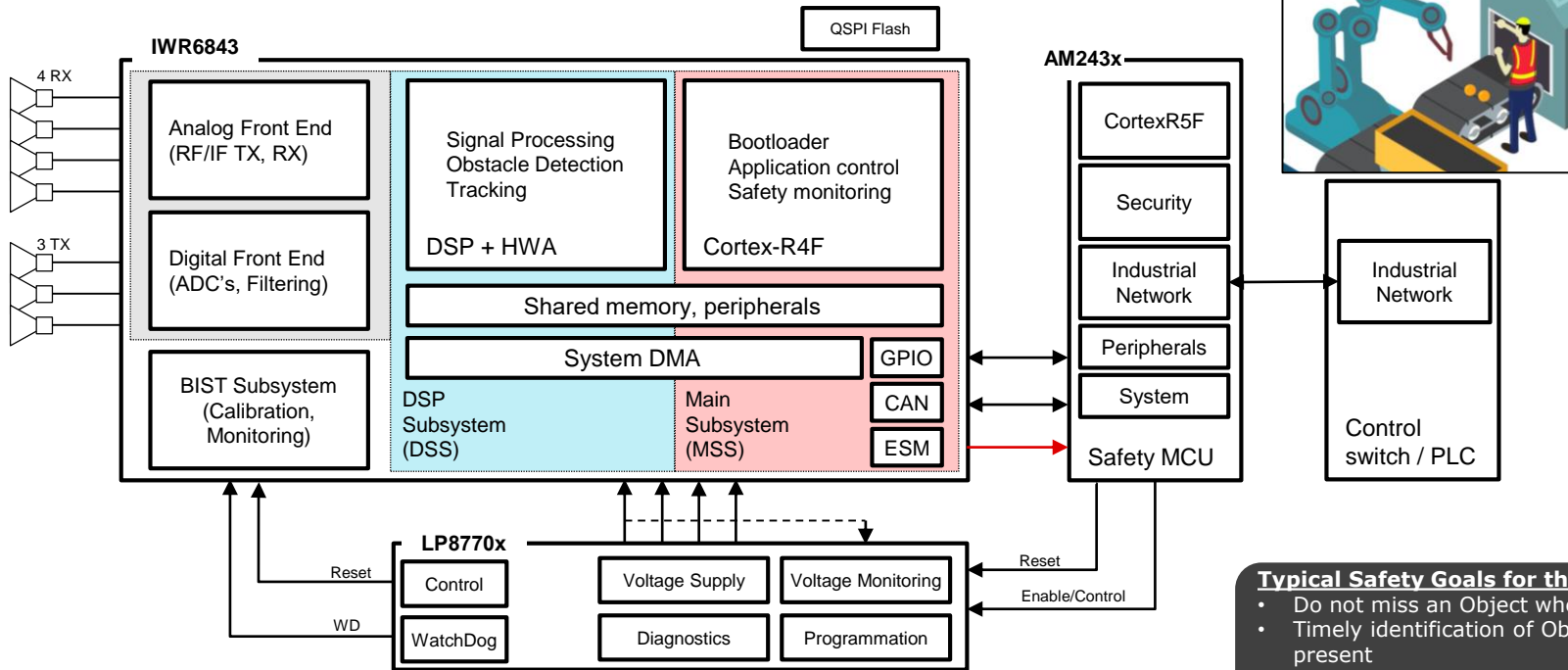
Enable increased human-robot collaboration and productivity while ensuring safety around industrial robots with SIL 2 certified TI mmWave sensors that provide a robust, lower cost, smaller footprint alternative



TI mmWave features	Robotics Benefits
4D presence (XYZV) + static object detection	<ul style="list-style-type: none"><li>Detect person/object (moving/static) in danger zone to trigger appropriate robot response</li><li>Facilitate quicker changeovers and save floor space</li></ul>
IEC 61508 SIL 2 certified	<ul style="list-style-type: none"><li>Robust workplace safety with safe human presence detection</li></ul>
Gauge approaching object trajectory and speed	<ul style="list-style-type: none"><li>Dynamically adjust size of safety zones based on speed of approach</li><li>Ignore objects whose trajectory is not towards the zones</li></ul>
Wide azimuth area coverage up to 130°	<ul style="list-style-type: none"><li>Reduce number of sensors for area scanning reducing overall system cost</li></ul>
Robust in challenging environmental conditions	<ul style="list-style-type: none"><li>Increase reliability over existing LIDAR sensors that struggle with dust/smoke</li></ul>

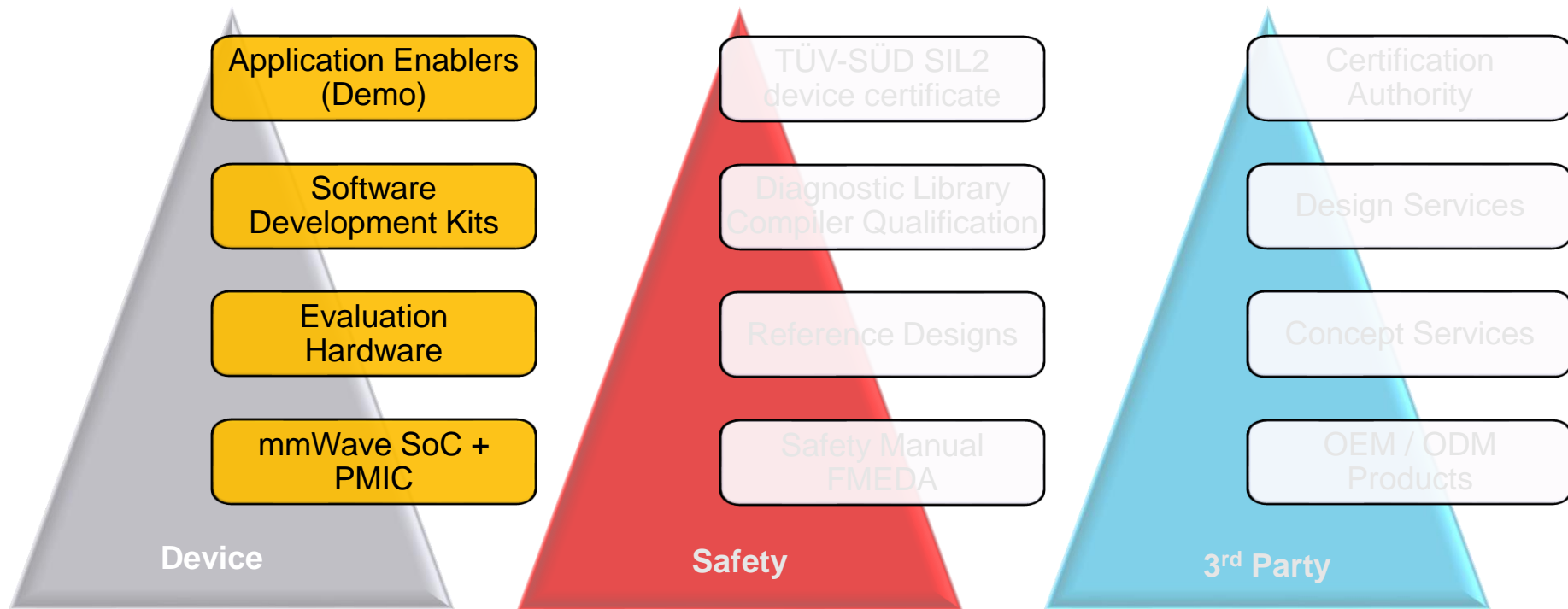
# TI mmWave Sensors → Products

## Safety guard example



- Typical Safety Goals for the Product**
- Do not miss an Object when it is present
  - Timely identification of Object when it is present
  - Do not detect/misidentify an object if it is not present

# TI mmWave Safety – SoC and related deliverables



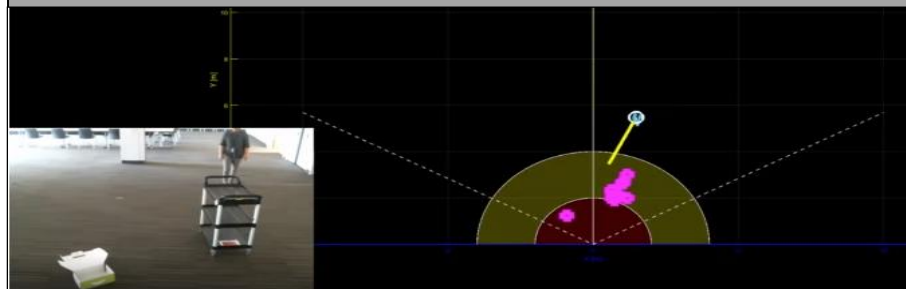
Items in RED require TI Safety NDA

# Getting Started with 4D Safety Guards using TI mmWave

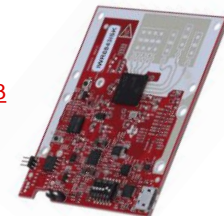
- **Safeguard personnel** by providing free, safe access to collaborative robots resulting in **higher productivity** and **reduced downtime**
- **Detect static objects** such as boxes, carts, or other equipment that have been left behind while ignoring permanent static objects in the scene
- Watch [Area Scanner use case video to learn more](#)

	Deployment WW		Deployment in Japan
<b>Deployment examples</b>	<ul style="list-style-type: none"> <li>• Overhead mount</li> <li>• Wide elevation FOV for near range &lt; 0.5m</li> </ul>	<ul style="list-style-type: none"> <li>• Side mount</li> <li>• Mounting close to the floor</li> </ul>	<ul style="list-style-type: none"> <li>• 77GHz required</li> </ul>
Tuning range	60-64 GHz.		76-81 GHz
Offering	<a href="#">TIREX Lab</a>	<a href="#">TIREX Lab</a>	<a href="#">TIDEP -01003</a>
Hardware	<a href="#">IWR6843AOPEVM + MMWAVEICBOOST</a>	<a href="#">IWR6843ISK + MMWAVEICBOOST</a>	<a href="#">IWR1443BOOST</a>
Max. Range (resolution)	10m (0.15m)		10m (0.15m)
Max. Field of View (resolution)	130° x 130° (30° angular resolution)	120° x 30° (15° angular resolution)	120° x30 (15° angular resolution)

## Get started with mmWave for Safety Guards [TIDEP- 01010: Area Scanner using mmWave](#)



1. **Discover** more about mmWave radar sensors and available resources [here](#)
2. **Evaluate** the performance  
[IWR6843 AOP](#)  
[IWR6843 ISK](#)  
[IWR1443 BOOST](#)  
[Area scanner Lab with static object detection using IWR6843](#)
3. **Design** custom boards with IWR6843 silicon  
[Online datasheet & other technical documents](#)  
[IWR6843 IEC61508 SIL 2 certificate](#)  
[Hardware design checklist](#)
4. **Accelerate** path to production with 3P solutions  
[Industrial mmWave third-party search tool](#)

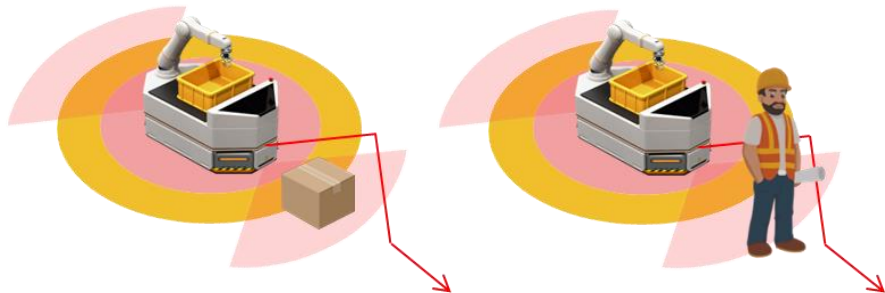




# Mobile Robot Sensing with TI mmWave

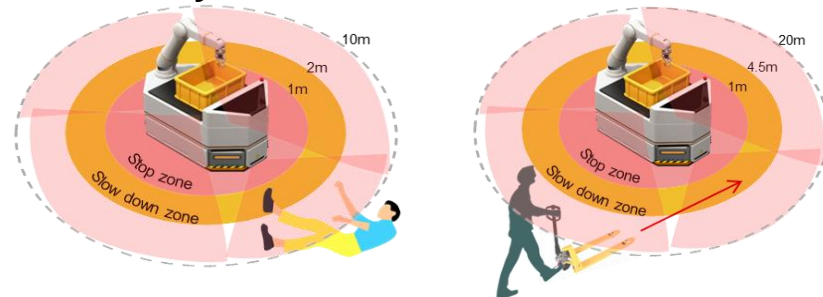
Complement or displace established sensor solutions like ultrasonic with **SIL 2 certified TI mmWave sensors** that can help solve the most challenging AGV and AMR sensing problems including human presence detection and autonomous navigation

## Sense and Avoid



Detect humans/obstacles and navigate around them to avoid collisions

## 360° Safety Bubble



Slow down and stop the robot when humans is detected within safety bubble.  
Robot resumes only when any human is outside of safety bubble

### TI mmWave features

### Robotics Benefits

- |                                    |                                                                                                                                                                                                                                                               |
|------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| "3D radar" presence detection      | <ul style="list-style-type: none"><li>• True 3D radar information (range, velocity &amp; angle) of objects vs. LIDAR/ToF used mainly for distance measurement</li><li>• Quickly detect and prevent possible collisions minimizing machine downtimes</li></ul> |
| IEC 61508 SIL 2 certified          | <ul style="list-style-type: none"><li>• Replace more expensive safety certified LiDAR sensors for human presence detection</li></ul>                                                                                                                          |
| Accurate glass detection           | <ul style="list-style-type: none"><li>• Helps ensure reliable detection of glass walls/doors over existing sensors that tend to "see" through them</li></ul>                                                                                                  |
| Wide azimuth area coverage         | <ul style="list-style-type: none"><li>• Create 360 degree detection zones around the robot to help prevent collisions with humans to minimize injury and reduce machine downtimes</li></ul>                                                                   |
| Robust in challenging environments | <ul style="list-style-type: none"><li>• Increase reliability over existing vision and LiDAR based sensors in conditions such as rain, dust, smoke, complete darkness or in the glare of sunlight</li></ul>                                                    |

# TI mmWave 360° Safety Bubble Offering for AGVs/AMRs

- Improve worker safety with 360° human presence detection and collision avoidance even in the most challenging environmental conditions

• Watch [360° safety bubble performance video](#)

	IWR6843ISK	IWR6843AOP
Tuning range	60-64 GHz.	60-64 GHz.
Offering	<a href="#">TIREX Lab</a>	<a href="#">TIREX Lab</a>
HW / EVM	4x <a href="#">IWR6843 ISK</a>	4x <a href="#">IWR6843AOP</a>
Field of View	360° Horizontal, 30° Vertical (15° angular resolution)	130° x 130° (30° angular resolution)
Max Range (Resolution)	10m (configurable) (0.047m)	10m (configurable) (0.047m)
Warning Zone (Slow Down)	2m (configurable)	2m (configurable)
Danger Zone (Stop)	1m (configurable)	1m (configurable)

## Get started with mmWave for Robotics

[TIREX - Lab: 360° Safety Bubble with ROS using mmWave](#)



1. **Discover** mmWave offering for [robotics](#)
2. **Evaluate** the performance  
[IWR6843 AOP](#)  
[IWR6843 ISK](#)  
[360° Safety Bubble performance video](#)  
[360° Safety Bubble with ROS Lab](#)  
[360° Safety Bubble Lab FAQ](#)
3. **Design** custom boards with IWR6843 silicon  
[Online datasheet & other technical documents](#)  
[IWR6843 IEC61508 SIL 2 Certificate](#)  
[Hardware design checklist](#)
4. **Accelerate** path to production with 3P solutions  
[Industrial mmWave third-party search tool](#)

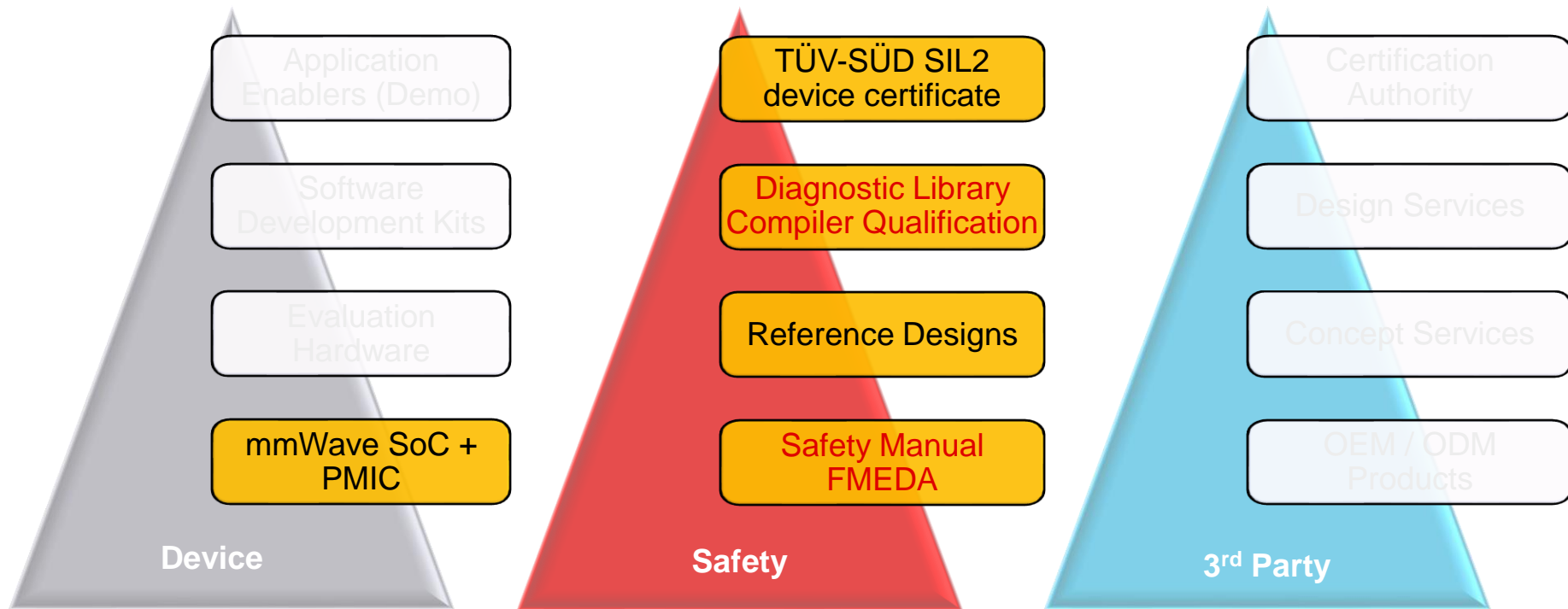


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# Safety certification of TI mmWave Sensors

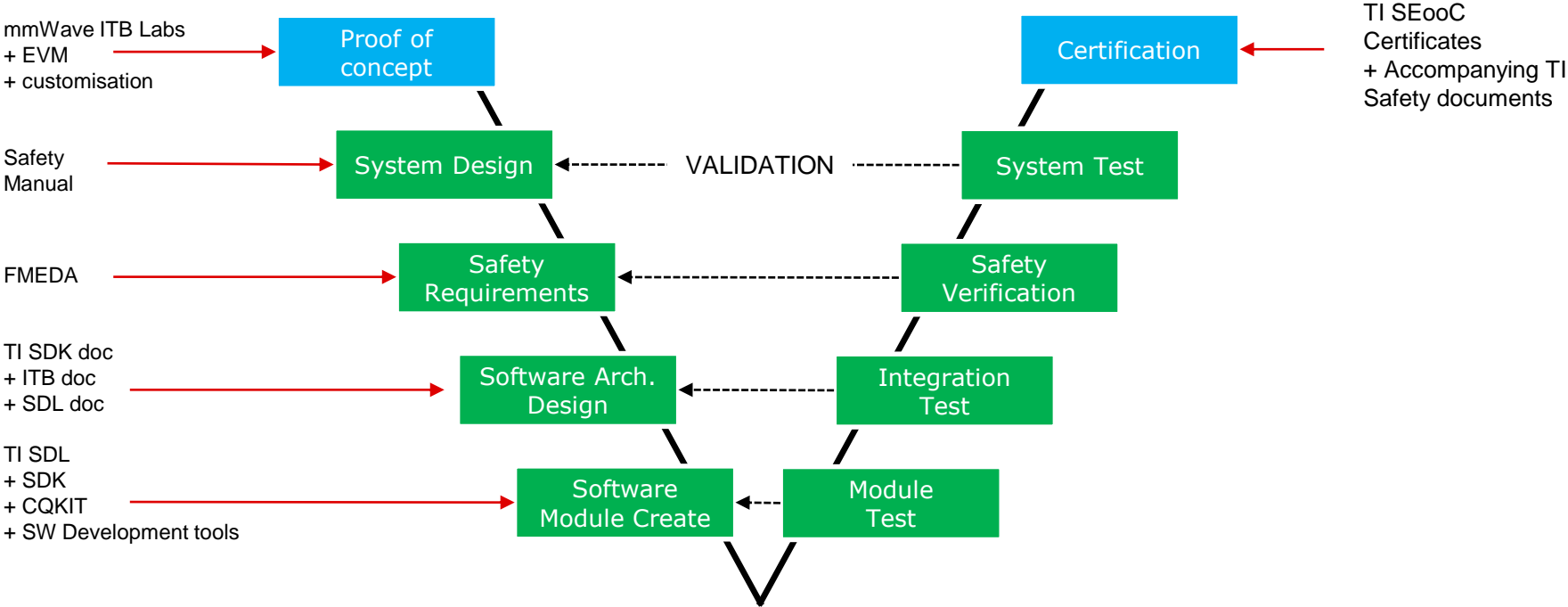


# TI mmWave Safety Offer – 61508 deliverables



Items in RED require TI Safety NDA

# Safety development flow TI Offering



IEC 61508-3: Software systematic capability and the development lifecycle (the V-model)

# TI mmWave Main Functional Safety deliverables

\*

## Safety Manual for mmWave Devices

### User's Guide



- Overview of the safety architecture for management of random failures
- The details of architecture partitions, implemented safety mechanisms such as monitoring, diagnostics, and recommended usage
- Failure modes and failure rates

\*

## Safety Analysis Report (FMEDA)

### Excel Spreadsheet



- Summary of failure rates of the SoC estimated at the chip level taking into account customer use-case (Mission Profile, Temperature Profile, Failure rate Models etc.)
- Failure rates and diagnostic coverage for each sub-system on the device including custom module selection according to customer use-case.

## Application notes White Papers

### Reference



- **TIDUEY9**: mmWave Diagnostic and Monitoring Reference Design
- **SLYP674**: Enabling Functional Safety in TI mmWave Devices
- **SLOA294**: Understanding Functional Safety FIT Base Failure Rate Estimates per IEC 62380 and SN 29500
- **SSIY007**: Streamlining Functional Safety Certification in Automotive and Industrial

# TI mmWave Product & Process Certification

## Hardware Development Process

## Software Development Process

## Development Process Certification

- TÜV-SÜD certified the Hardware functional safety development process in 2013 for:
  - IEC 61508 SIL-3
  - ISO 26262 ASIL-D
- TÜV-SÜD certified the Software functional safety development process in 2019 for
  - IEC 61508 SIL-3
  - ISO 26262 ASIL-D

## Product Certification

- TÜV-SÜD certified the listed 60/77Ghz TI mmWave devices:
  - Hardware Integrity up to SIL2
  - Systematic Capability SIL3

**CERTIFICATE**  
No. Q4B 13 03 84071 001

Holder of Certificate: Texas Instruments Incorporated  
12021 Southland Freeway, Dallas TX 75247 USA

Factory(ies): Texas Instruments Incorporated  
12021 Southland Freeway, Dallas TX 75247 USA  
Texas Instruments Deutschland GmbH  
Heggenhahn 1, 80504 Freising, GERMANY

Certification Mark:

Scope of Certificate: QRAS AP00210

Applied Standard(s): IEC 61508-2:2010  
IEC 61508-1:2010  
ISO 26262-1:2018  
ISO 26262-2:2018

The Certification Body of TÜV SÜD Product Service GmbH certifies that the company mentioned above has established and is maintaining a functional safety management system which meets the requirements of the listed standards. The results are documented in a report. See also notes center!

Report No.: 77945271  
Valid until: 2016-03-31

Date: 2013-03-12  
Page 1 of 1

TÜV SÜD Product Service GmbH

**CERTIFICATE**  
No. Q4B 88888 0058 Rev. 00

Holder of Certificate: Texas Instruments Inc.  
12021 Southland Freeway, Dallas TX 75247-4138, USA

Factory(ies): Texas Instruments Inc.  
12021 Southland Freeway, Dallas TX 75247-4138, USA

Certification Mark:

Scope of Certificate: SafeTI™ functional safety software development

Applied Standard(s): IEC 61508-2:2010  
IEC 61508-1:2010  
ISO 26262-1:2018  
IEC 61508-2:2010

The Certification Body of TÜV SÜD Product Service GmbH certifies that the company mentioned above has established and is maintaining a management system which meets the requirements of the listed standards. The results are documented in a report. See also notes center!

70307541  
2022-04-24

*Peter Döb*  
(Peter Döb)

Certification Body • Rheinstraße 65 • 80339 Munich • Germany

### Device Certificate

**CERTIFICATE**  
No. Z10 088989 0022 Rev. 00

Holder of Certificate: Texas Instruments Inc.  
12021 Southland Freeway, Dallas TX 75247-4138, USA

Certification Mark:

Product: Safety components  
Safety MCUs

Model(s): IWR1843 IWR2243 IWR4843

HW1843
HW1843-040A
HW1843-040A-X
HW1843-040A-X
HW2243
HW2243-040A
HW2243-040A-X
HW2243-040A-X
HW4843
HW4843-040A
HW4843-040A-X
HW4843-040A-X

Parameters: Hardware Integrity up to SIL 2  
Systematic Capability SIL 3

Tested according to: IEC 61508-2:2010  
IEC 61508-1:2010

The product was tested on a voluntary basis and complies with the essential requirements. The certification mark shown above can be affixed on the product. It is not permitted to alter the certification mark in any way, to add the certification number and not transfer the certificate to third parties. This certificate is valid until the listed date, unless it is cancelled earlier. All applicable requirements of the testing and certification regulations of TÜV SÜD Group have to be complied with. See also: www.tuev-sued.com

Test report no.: Z1080700  
Valid until: 2022-01-17

Date: 2022-01-20

*Christoph Dörner*  
(Christoph Dörner)

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TÜV SÜD Product Service GmbH • Certification Body • Rheinstraße 65 • 80339 Munich • Germany



# TI mmWave FuSa Responsibilities

TI

- **Delivers** H/W and S/W in compliance to TI's Function Safety processes FMEDA, Safety Manual, Certificates ,CSP, SDL, Component HW/FW ...
- **Maintains** hardware and software products
- **Supports** customer's system-level Functional Safety certification

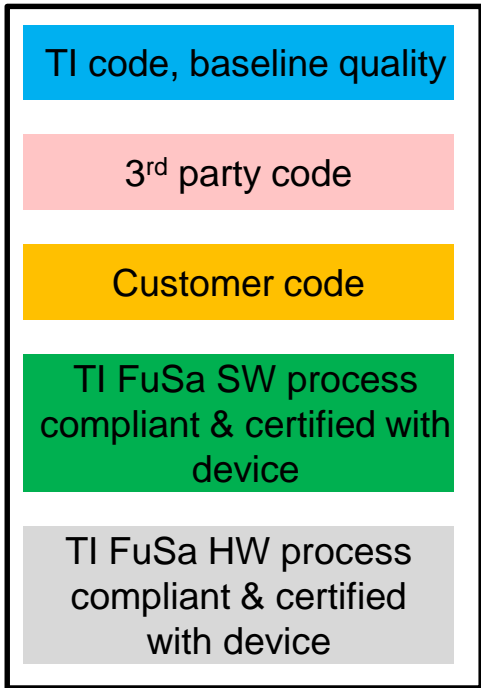
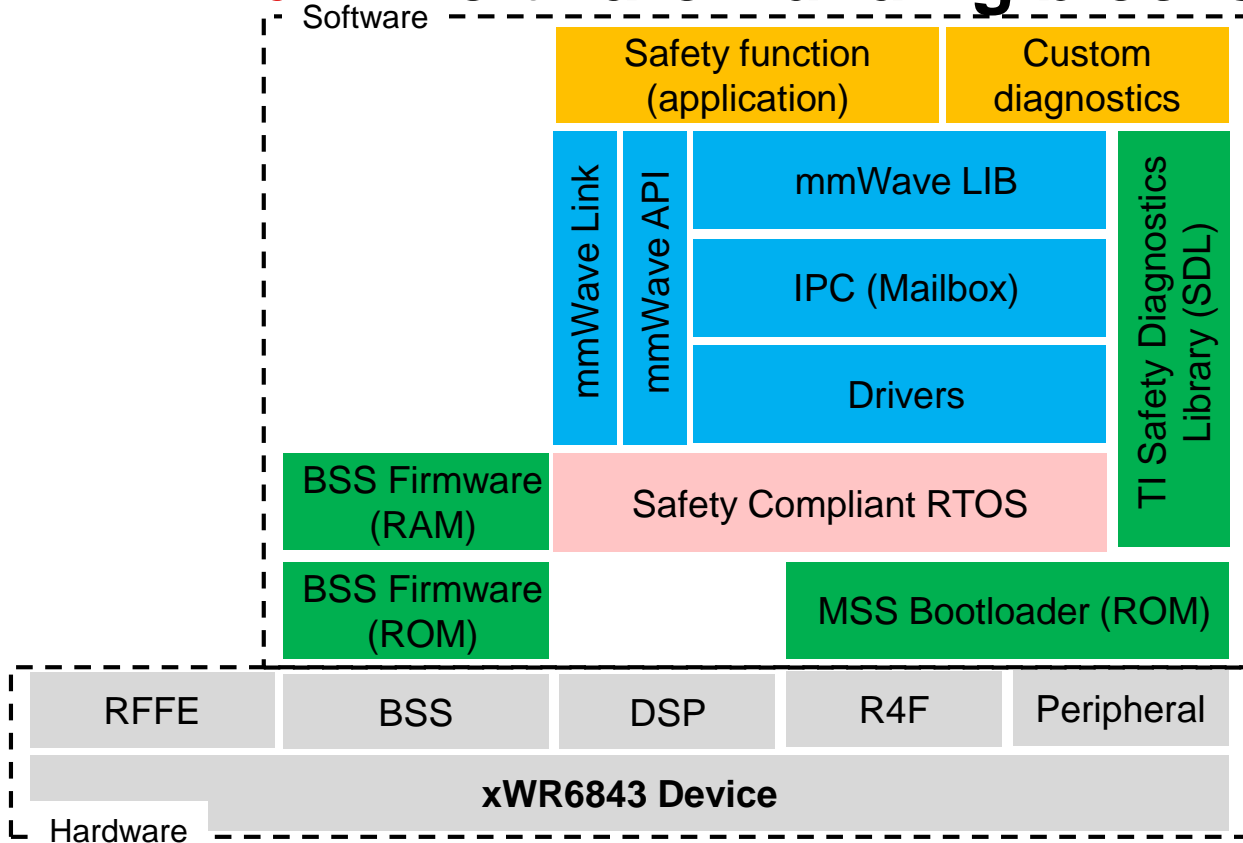
**Assessor**  
(ie TUV)

- **Certifies** TI's FuSa compliant development processes
- **Certifies** TI's products and assesses sub-systems/TI-Designs

**Customer**  
(with assessor  
/ 3<sup>rd</sup> party)

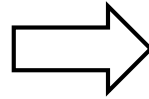
- **Establishes and follows appropriate development flow (ie V-model)**
- **Owens and completes** system level Safety analysis
- **Determines** system level FuSa requirements, safe state, etc.
- **Builds & certifies** FuSa systems that use TI products

# TI mmWave Software Building blocks



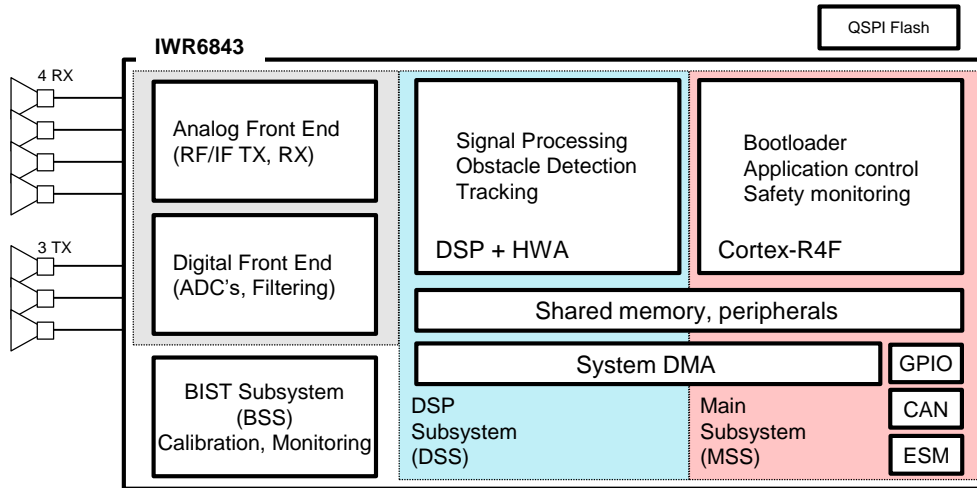
# TI mmWave Hardware Building blocks

**Application level monitoring and calibration:**  
TI firmware that keeps the device within performance limits across age and temperature.

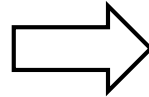


## **BIST Subsystem (BSS)**

- Initialize, monitor, and calibrate the RF/Analog modules including TX / RX Chain.
- Controls GPADC, DFE, chirp generation modules and Analog/DFE registers



**Safety Critical functionality (Summary):**  
Domain specific functionality to address safety and integrity of the device in boot and operation phases.



## **Analogue Front-End**

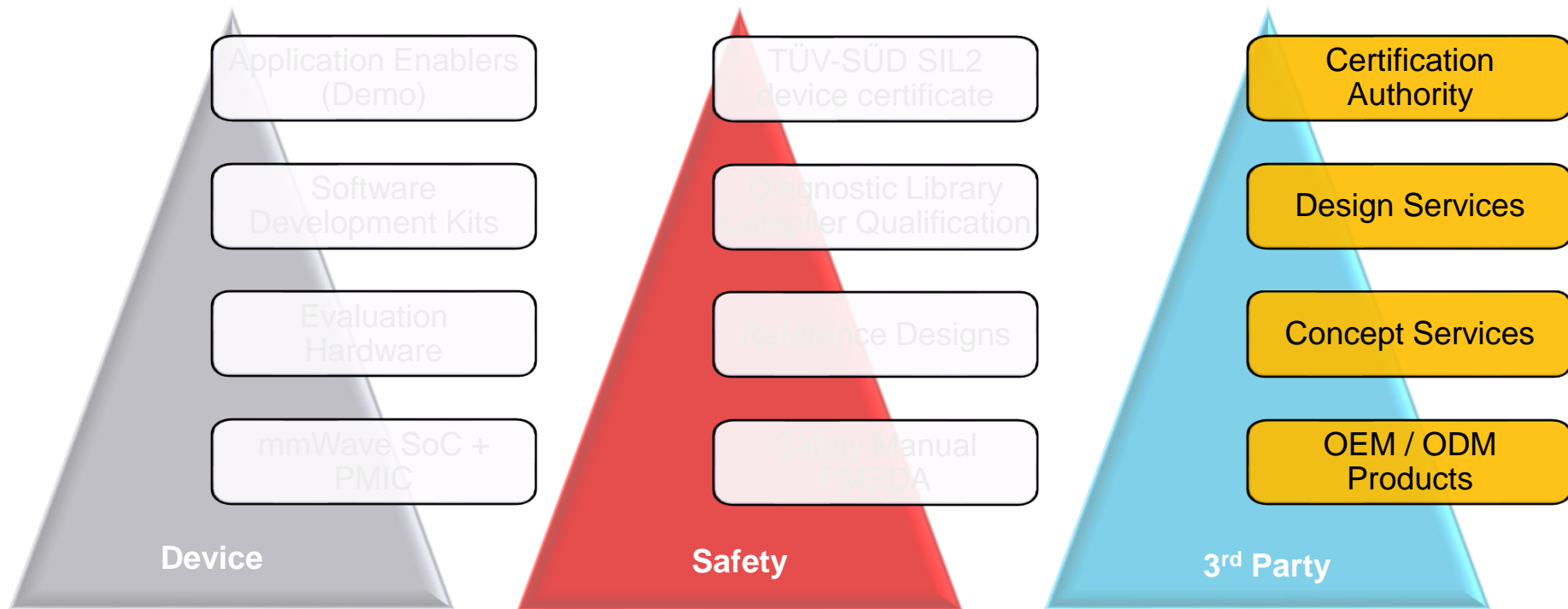
- Power, clock, temperature monitoring
- Frequency monitoring, RX saturation detect
- Ball break detection
- Loopback testing
- Fault injection

## **MSS, DSS, BSS Subsystems**

- Boot-time BIST
- ECC, CRC, and Parity checks
- Error monitoring and signaling
- Memory protection
- Illegal operation trapping
- Lock-step functionality

# 3<sup>rd</sup> Party Support

# TI mmWave Safety Offer – Third party support



Items in RED require TI Safety NDA

# FUNCTIONAL SAFETY PRODUCTS



- SIL 2 certified SBV System based on IWR6843
- CAT 3 PL d
- FCC

Series 200 from INXPECT

# FUNCTIONAL SAFETY design services

Creating safety.  
With passion.

NewTec

Specialist for the development of software and electronic systems.  
The focus is on functional safety and embedded security.

## Safety-Services

- Safety management assessment
- Safety management
- Safety risk assessment
- Safety requirements analysis
- Safety planning and concepts
- Safety engineering
- Software and hardware development
- Approval strategy

Content reviewed and approved by NewTec

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# Conclusion

- mmWave supports many existing and emerging robotics application:
  1. safety first sensing
  2. Robust to any interference safety sensing with fast response time
- Call to Action
  - Ask questions now
  - Send us an email at : [g-peake@ti.com](mailto:g-peake@ti.com) or [matthieu.chevrier@ti.com](mailto:matthieu.chevrier@ti.com)
  - Visit
    - <http://ti.com/mmwave>
    - <https://www.ti.com/technologies/functional-safety/overview.html> (is there a shortlink?)
  - will send follow-up email to those registered with details of what was presented