

Speaker



Hanwen Cao
Wireless System Innovation Lab Lead
Huawei Munich Research Center

5G-ACIA

Use Cases and Requirements for Integrated Sensing and Communication (ISAC) in Connected Industries and Automation

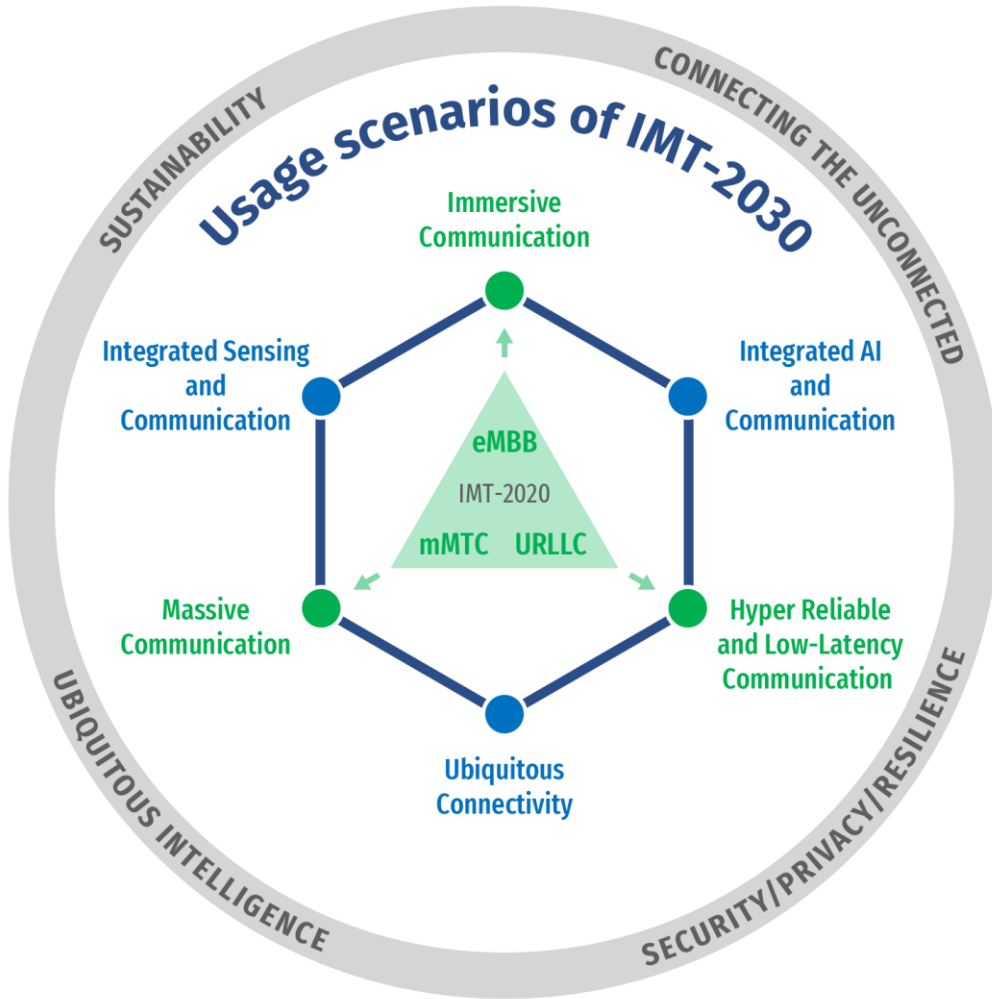
Hanwen Cao

Outlines



- ISAC brief introduction
- 5G-ACIA's work on ISAC use cases
- Use case demos
- Takeaways

Cellular Network Evolution: IMT-2030 Framework



Recommendation ITU-R M.2160-0

New Usage Scenarios

- Integrated AI and Communication
- Ubiquitous Connectivity
- Integrated Sensing and Communication (ISAC)

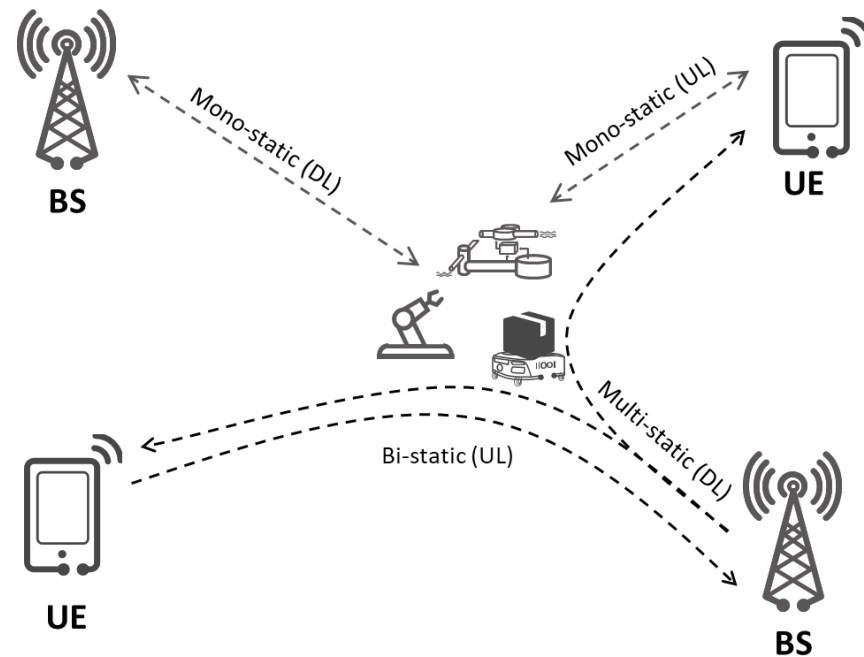
ISAC Technologies Overview

Same cellular network infrastructure providing both wireless communication and sensing services.

- Unified network infrastructure
- Unified spectrum resource
- Unified standard framework

Sensing applications:

Object/human detection and tracking, gesture sensing, vital sign sensing, 2D/3D environment reconstruction, imaging, material sensing, Micro-Doppler sensing, Object size measurement, Sensing for improving communication/localization, Integration of non-3GPP sensors



Integrated, networked and coordinated

- Multi-static, bi-static, mono-static & multi-view: enhanced coverage, diversity and reliability
- Multi-modality: enhanced capabilities by non-3GPP sensing
- Highly coordinated: interference free

Three Levels of integrations:

- **Application Level:** Sensing and communication systems are separate, exchanging external sensing data.
- **Spectrum Level:** Signals are multiplexed in time, frequency, and space, sharing spectrum and some hardware.
- **Full Integration:** Systems fully integrate, sharing information across layers, modules, and nodes.

ISAC – State of Play



Very hot topic in research:

- Projects: SNS Hexa-X I/II, TIMES, 6G-DISAC, BMBF COMSENS, etc.
- Orgs: one6G, IMT-2030 6G PG, IEEE ComSoc, etc.



ETSI ISG ISAC

- Use cases
- Channel modelling
- System/RAN architectures
- ...

ETSI ISG THz

Numerous ISAC use cases defined in the report ETSI GR THz 001



3GPP

- Rel-19: TR22.837: 32 use cases; TS22.137: service requirements; TS38.901 channel modelling
- Rel-20: TR22.870: 20 use cases; TR23.700-14 system aspect study; TR 38.765 ISAC for NR; SA3 security aspects

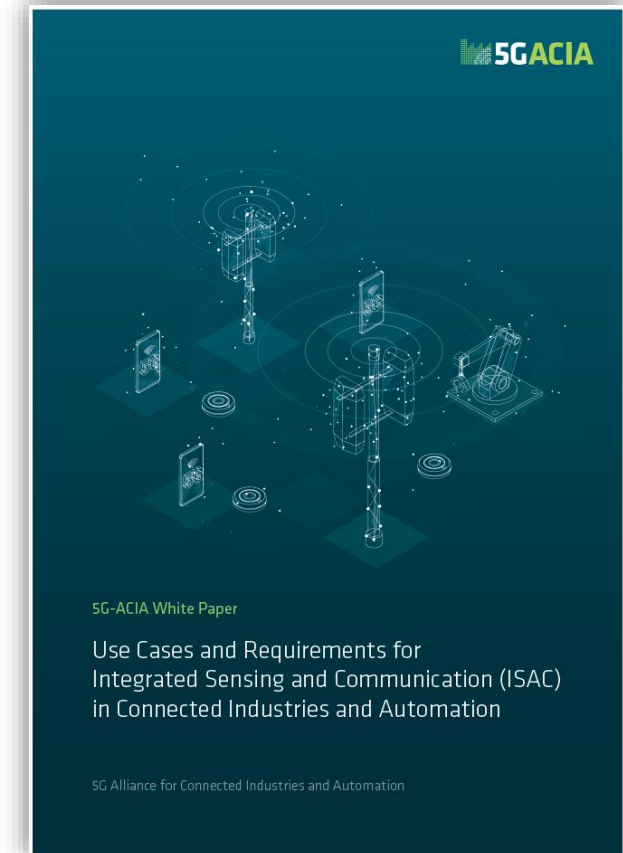


IEEE

- 802.11bf WiFi Sensing task group: specification approval is expected in June 2025
- IEEE ComSoc Emerging Technology Initiative ISAC

5G-ACIA's focus on ISAC

- A work item on ISAC use cases and requirements was started September 2023.
- Great supports and contributions from AI-Link, Bosch, CMCC, Ericsson, Fraunhofer, Infineon, ITRI, Nokia, Orange, Rockwell, Siemens, Trumpf and Huawei (Rapporteur), etc.
- The whitepaper is published in January 2025
- Liaison interactions with ETSI ISG ISAC, ETSI ISG Terahertz and 3GPP



<https://5g-acia.org/whitepapers/use-cases-and-requirements-for-integrated-sensing-and-communication-isac-in-connected-industries-and-automation-2/>

Benefits of ISAC for Industrial Automation

Unified Infrastructure

The unified cellular infrastructure for both wireless communication and sensing services. A direct benefit for cost optimization.

High Sensing Performance

- Comprehensive solution including multi-node, multi-static and multi-modality sensing
- The utilization of wide-range of RF spectrum for sensing with interference coordinated

Suitable in Harsh Environment

RF based technologies are well-suited for environments with dust, heat, humidity, and low-light condition, etc.

High Data Security

An unified and trusted environment for collecting and transferring sensing data.

Privacy Protection

Unlike cameras, microphones, and wearable devices, RF sensing minimizes privacy concerns.

ISAC Applications for Industries

Detection and Tracking of Ground/Aerial Vehicles and Humans

- Traffic monitoring
- Intruder detection

Tracking and Size Measurement of Goods

- Goods sorting
- Inventory monitoring

Human-Machine and Machine-Machine Collaboration

- Gesture / posture sensing
- Collision avoidance

Safety and Health at Work

- Vital signs sensing
- Fall detection

Environmental Mapping

- NLOS mapping
- Radio map for improving communication

Predictive Maintenance

- Machinery condition monitoring
- Pipe condition monitoring
- ...

Quality Inspection

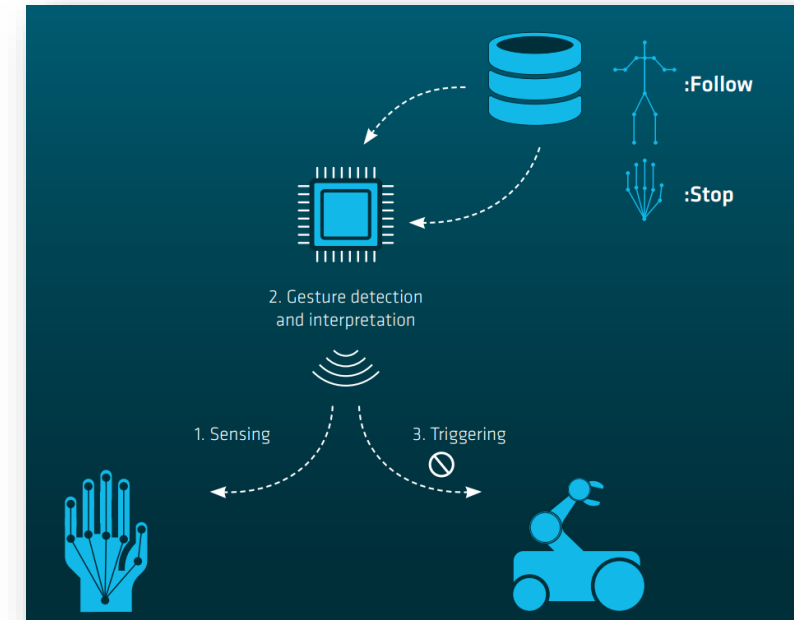
- Internal defect detection
- Coating and painting measurement

Sensing for Improving Localization and Communication

- Integrating passive sensing and active localization
- Communication enhancement using sensing information

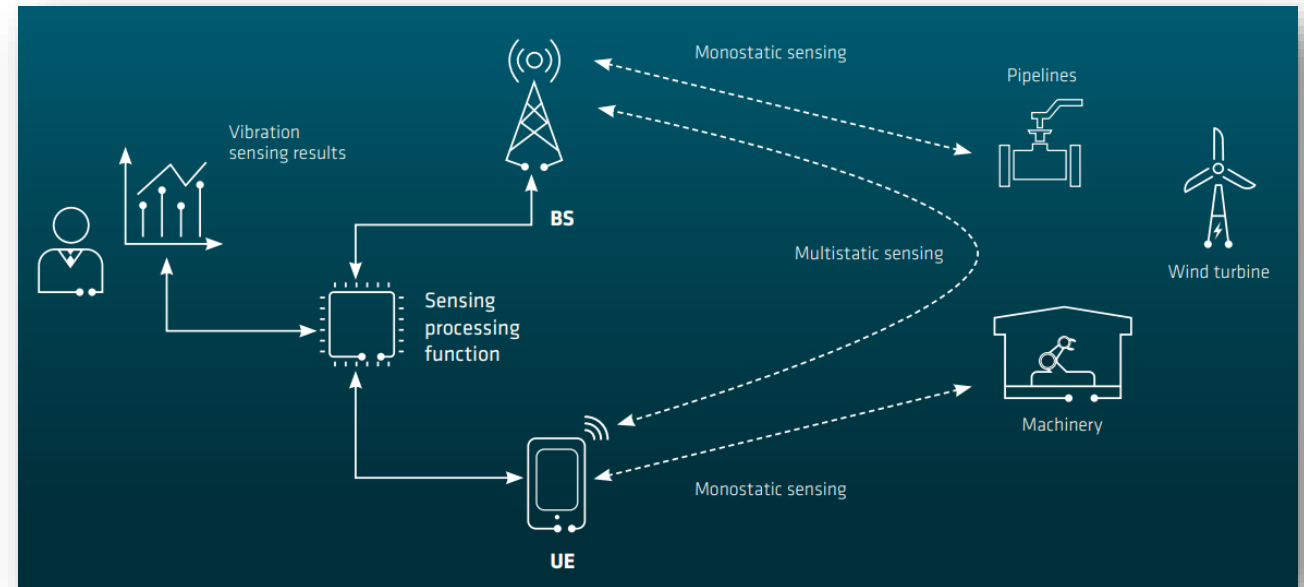
Use Case 1: Gesture Recognition in Industrial Environment

- Gesture recognition allows workers to interact with machines in a touchless manner, enhancing safety and efficiency in environments where physical contact may be restricted or cumbersome. It provides intuitive control for operations, improving overall system performance.
- **Challenges:** Gloves, noise, and safety constraints make touch or voice interfaces impractical in industrial settings, requiring precise gesture recognition.
- **ISAC Functionalities:** ISAC leverages cellular networks, combining RF signals and other sensors to enable accurate gesture recognition.



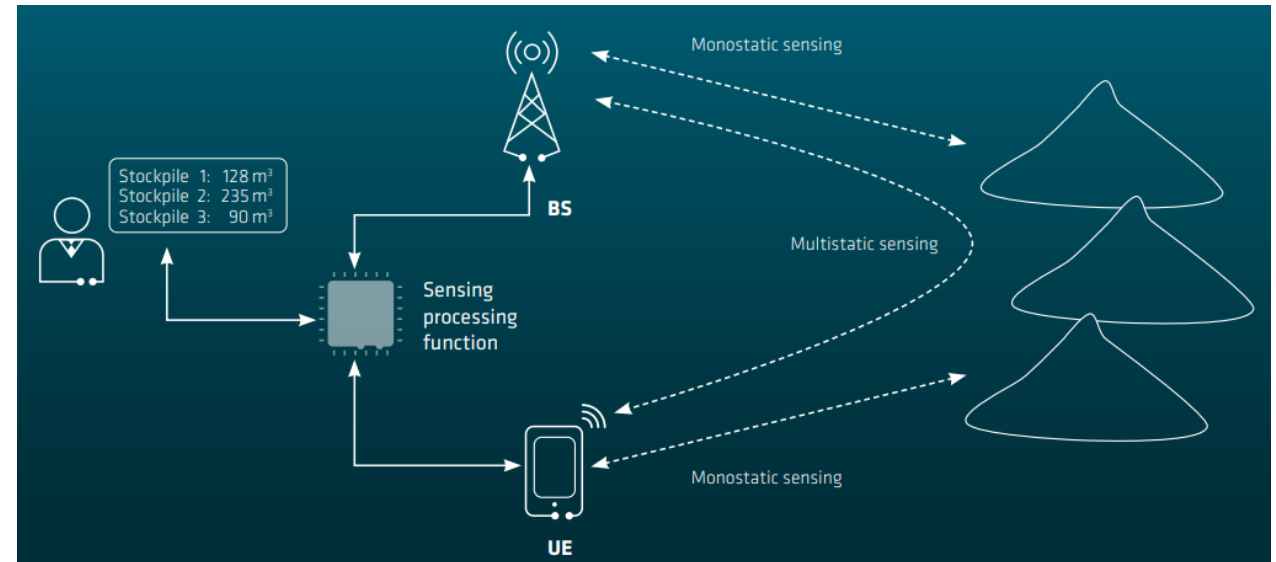
Use Case 2: Vibration Monitoring in Industrial Environment

- Vibration monitoring is key to maintaining machinery, pipelines, and buildings, preventing damage and improving operational efficiency.
- **Challenges:** Conventional vibration detection methods often require direct contact with equipment, which is impractical in harsh, hard-to-reach, or hazardous environments.
- **ISAC Functionalities:** ISAC utilizes the Doppler frequency processing of RF signals enabling vibration detection at longer distance and through non-conductive materials.



Use Case 3: Stockpile Monitoring

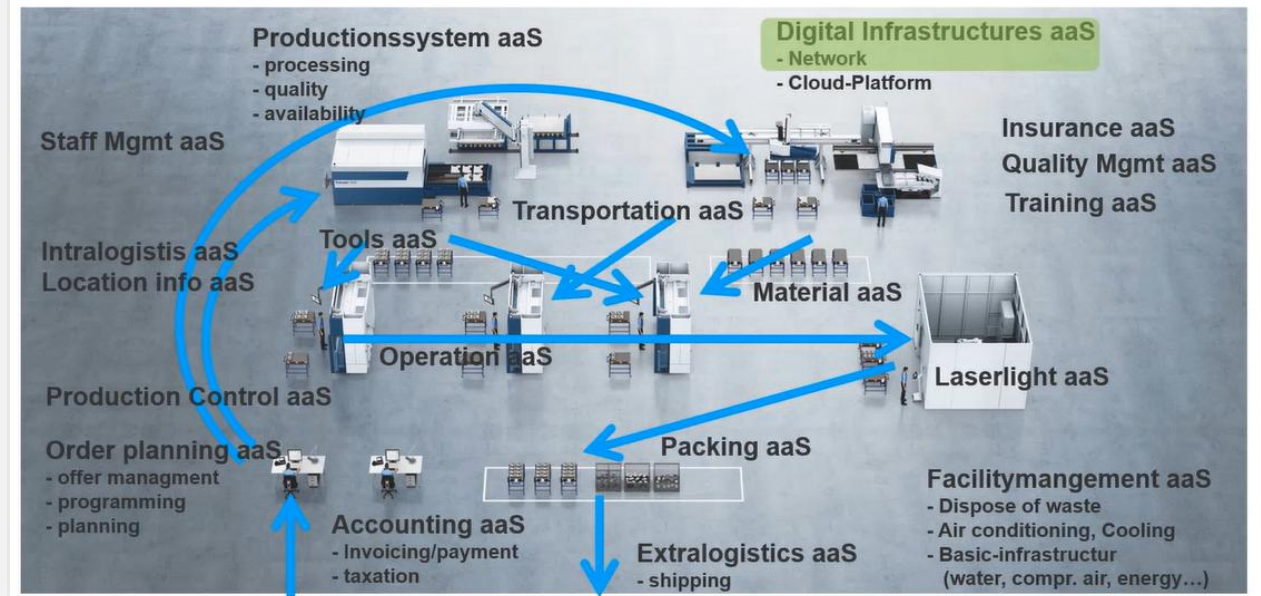
- Stockpile monitoring is crucial for efficient inventory management, safety, and optimizing operations, ensuring materials are available and preventing shortages or overstocking.
- **Challenges:** Conventional stockpile monitoring technologies struggle in harsh conditions such as dust, smoke, and low-light environments, reducing their accuracy and effectiveness.
- **ISAC Functionalities:** ISAC continuously monitors stockpile conditions using RF signals, enabling precise measurement of height and volume even in challenging environments.



Use Case 4: ISAC for Optimizing the Flexible Production Flows

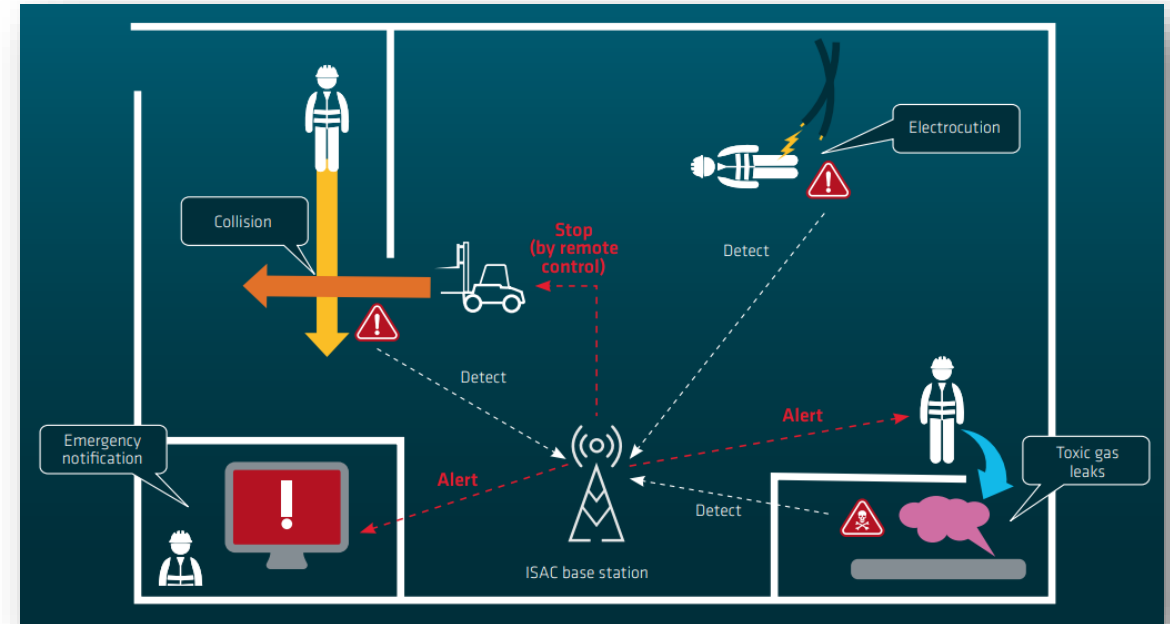
- **"XaaS" (Production as a Service)** model integrates modular production services like logistics and staff management through a digital infrastructure.
- **ISAC Functions:**
 - ISAC technology continuously monitors the movements of humans, carts, and AGVs, enhancing safety and efficiency.
 - Prevents accidents by detecting proximity risks and triggering alarms or machinery shutdowns.
 - Identifies bottlenecks and inefficiencies, optimizing production flows and reducing downtime.
 - Increases productivity, shortens lead times, and improves resource utilization.

XaaS-approach in the Smart Factory - Production as a Service



Use Case 5: ISAC for Hazard Prevention in Industrial Environments

- Ensuring the safety of workers is crucial in industrial environments to prevent potentially fatal accidents and property damage, requiring continuous improvement in safety measures.
- **Challenges:** Conventional hazard detection methods are limited in their ability to monitor complex environments, especially in cases of falls, collisions, or toxic gas leaks, and often struggle with low visibility or difficult-to-reach areas.
- **ISAC Functionalities:** ISAC uses radio sensing and other integrated sensors for providing alerts for potential hazards such as falls, collisions, or hazardous environmental conditions. It can also predict dangerous scenarios, ensuring timely intervention to prevent accidents.



5G-ACIA ISAC Use Cases Reflected in the New Use Cases of 3GPP & ETSI

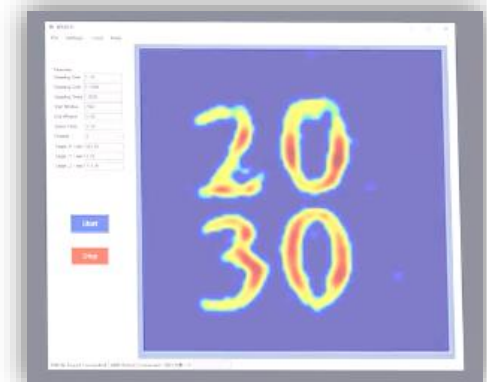


Use Case 1: Gesture Recognition in Industrial Environment	ETSI GR ISC 001: 5.1 Use case on human motion recognition	3GPP TR22.870: 7.16 Use case on enabling non-3GPP wireless sensing
Use Case 2: Vibration Monitoring in Industrial Environment	ETSI GR ISC 001: 5.13 Use case on micro-deformation sensing	3GPP TR22.870: 7.14 Use case of infrastructure collapse monitoring
Use Case 3: Stockpile Monitoring	ETSI GR ISC 001: 5.4 Use case for high-resolution topographical maps	3GPP TR22.870: 7.5 Use case on environment object reconstruction
Use Case 4: ISAC for Optimizing the Flexible Production Flows	ETSI GR ISC 001: 5.12 Use case on real time cyber-physical systems in industrial worksites	3GPP TR22.870: 7.13 Use case on collaborative robots using digital twinning (also in ETSI GR ISC 001: 5.10)
Use Case 5: ISAC for Hazard Prevention in Industrial Environments	ETSI GR ISC 001: 5.6 Use case on real-time monitoring of health hazard and disaster risk	ETSI GR ISC 001: 5.8 Use case for outdoor healthcare sensing and monitoring
		3GPP TR22.870: 7.7 Use case on intelligence leveraging nearby entities for real-time awareness

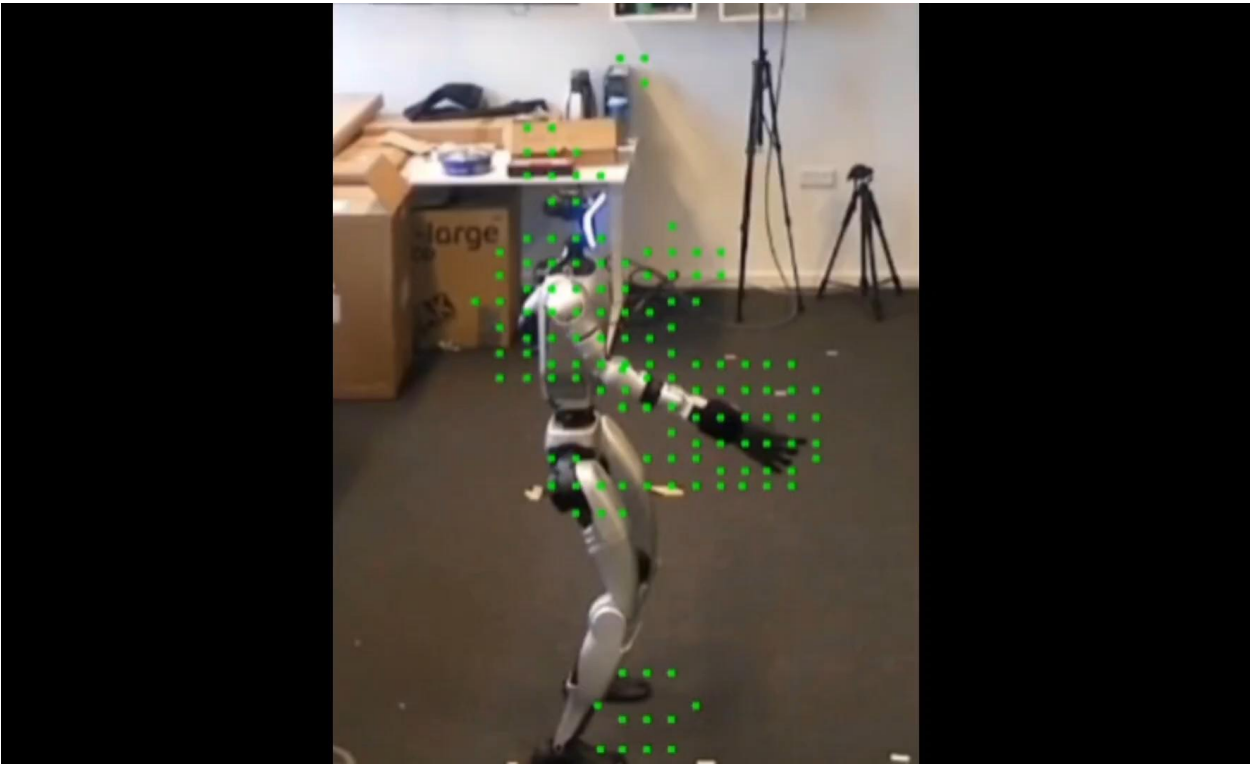
ISAC Demo – High resolution penetrative imaging



- High mmWave frequency band
- Virtual antenna aperture creation with robotic motion
- 3GPP compatible PHY with OFDM/QAM



ISAC Demo – Point cloud for object and posture detection



- cmWave (FR3) frequency band
- Massive MIMO System
- 3GPP compatible PHY with OFDM/QAM

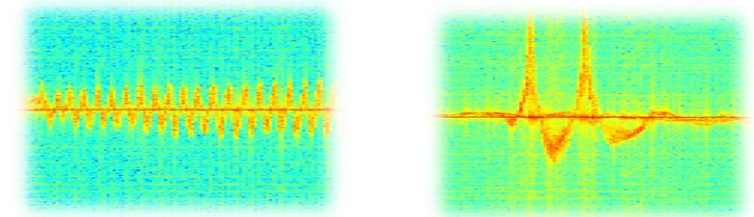


Multi-Object Detection			
Target	R(m)	H(°)	V(°)
#	Detection Value	Detection Value	Detection Value
1	3.354	11.183	-4.266
2	3.354	0.431	-0.673
3	3.660	15.728	-4.270

ISAC Demo – High Resolution Imaging



- High mmWave frequency band
- Doppler-Time Signal Processing
- 3GPP compatible PHY with OFDM/QAM



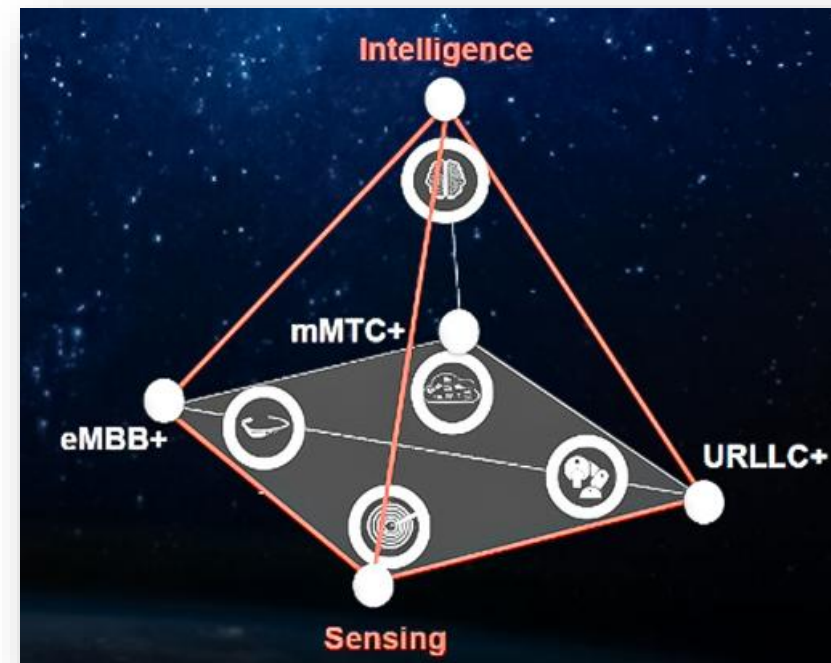
Doppler-time features of motions

Key Takeaways

- ISAC represents a pivotal emerging capability of Beyond 5G and in particular 6G cellular networks, with substantial ongoing efforts in research, standardization and real-world trials.
- For industrial automation, ISAC holds considerable potential to advance efficiency, quality, flexibility, safety, information security, and cost-effectiveness, etc.
- And when combined with AI, the integration of sensing and communication will unlock even greater transformative potential.

“The whole is greater than the sum of its parts.”

- Aristotle



Web Seminar Series 2025

Thank you for your attention!

