

# Communications for the Smart Society in Motion

## The Journey from 4G to 6G

29<sup>as</sup> Palestras sobre Comunicações Móveis  
Instituto Superior Técnico – Universidade de Lisboa

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# José Rodríguez-Piñeiro

Associate Professor, Master advisor, Tongji University

- ❑ External Research Fellow, University of A Coruña (Spain)
- ❑ External Lecturer&Research Fellow, National University of Asunción (Paraguay)
- ❑ Visiting Researcher, Technische Universität Wien (Austria)
  
- ❑ Elected Member of the IEEE Vehicular Tech. Society Propag. Committee
- ❑ “Beatriz Galindo” Fellow (Spain, 2023)
- ❑ China Foreign Experts Bureau for Foreign Young Talents fellow (2018, 2022)
- ❑ Outstanding postdoctoral fellow at Tongji University (2020)
- ❑ “FPU” Fellow (Spain, 2012)
  
- ❑ Led 7 Projects, team member of 50+ projects
- ❑ 80+ publications and 5 granted patents
- ❑ h-index: 16





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# 01 Motivation



# Communications for the Smart Society in Motion



- Tomorrow's society is envisioned more and more as lots of people constantly on the move
- Daily commuter traffic from suburban and rural areas to urban ones is dramatically increasing
- People use mobile devices for work and entertainment during transportation

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- More and more, communications not required to individuals, also machine-to-machine communications for the safety of transportation or autonomous vehicles
- **We rely more and more on communications: communications become more critical**
- **We need to ensure reliability of communications after natural disasters, in crowded events...**

# Communications for the Smart Society in Motion



**Let's have a journey on the evolution from 4G to 6G for the Smart Society in Motion**



# 02 **The Start of the Journey**



# 4G: High-Speed Train Communications

- Communications for the High-Speed Train were a key case of study for 4G



# 4G: High-Speed Train Communications



Train accident at Angrois, Galicia, Spain  
(2013/07/25)

- Communications for the High-Speed Train were a key case of study for 4G
- Not only providing services for the passengers, but also for critical (safety-related) applications
- Critical applications were based on a system derived from 2G: GSM for Railways (GSM-R)
- GSM was at the end of its life
- Train-dedicated communication system has a very expensive maintenance (few manufactures have the license to build GSM-R equipment)

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- Can we use LTE for critical High-Speed Train Communications?
- Can we use off-the-shelf LTE, i.e., not a dedicated communications protocol?
- **The answer is: we don't know.**

# 4G: High-Speed Train Communications



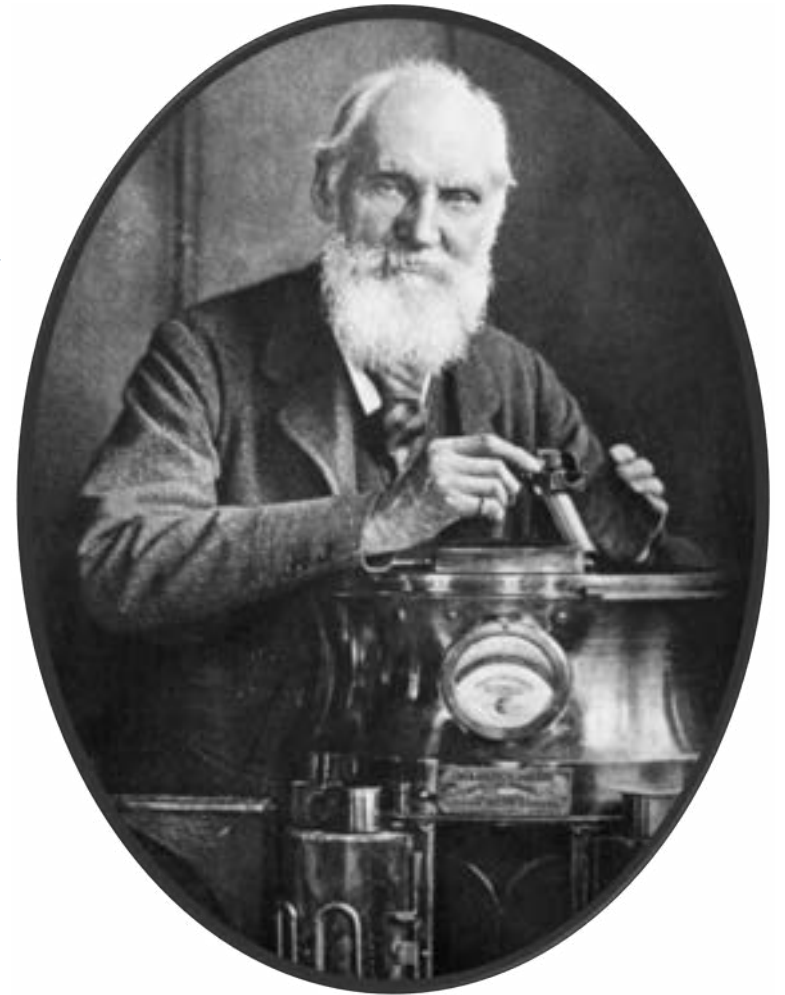
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- **The answer ~~is~~ was: we don't know (2014).**
- **The answer is: Yes, we can!**

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*“[...] when you cannot measure it, [...] your knowledge is of a meagre and unsatisfactory kind [...].”*

--Lord Kelvin

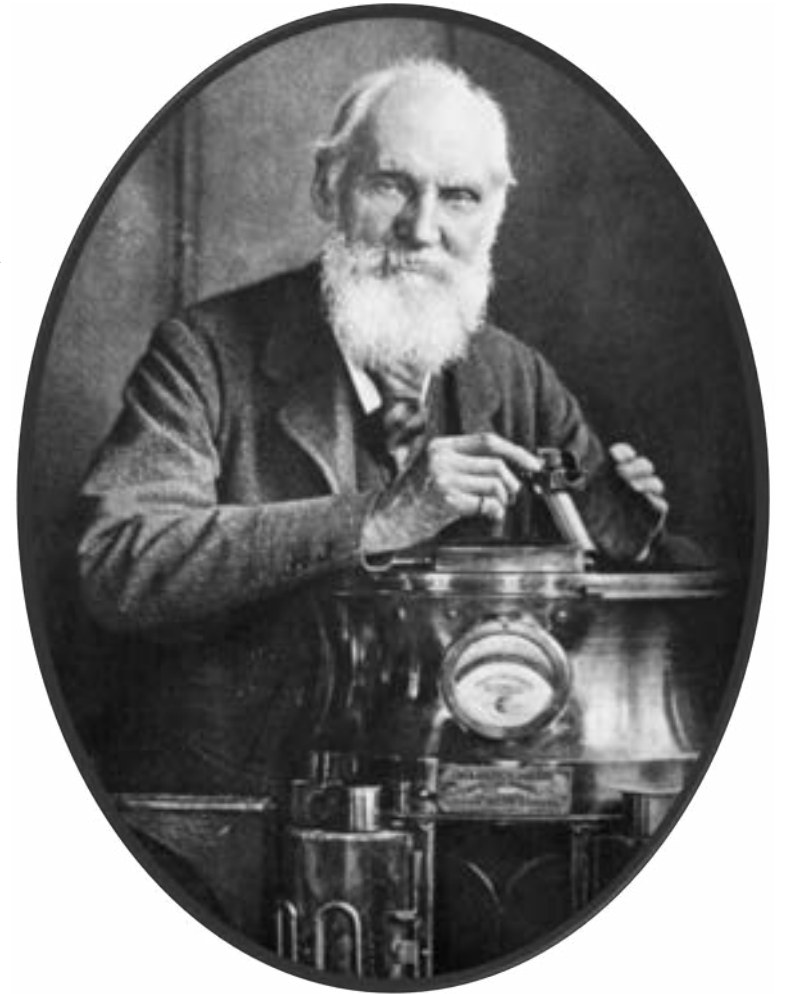


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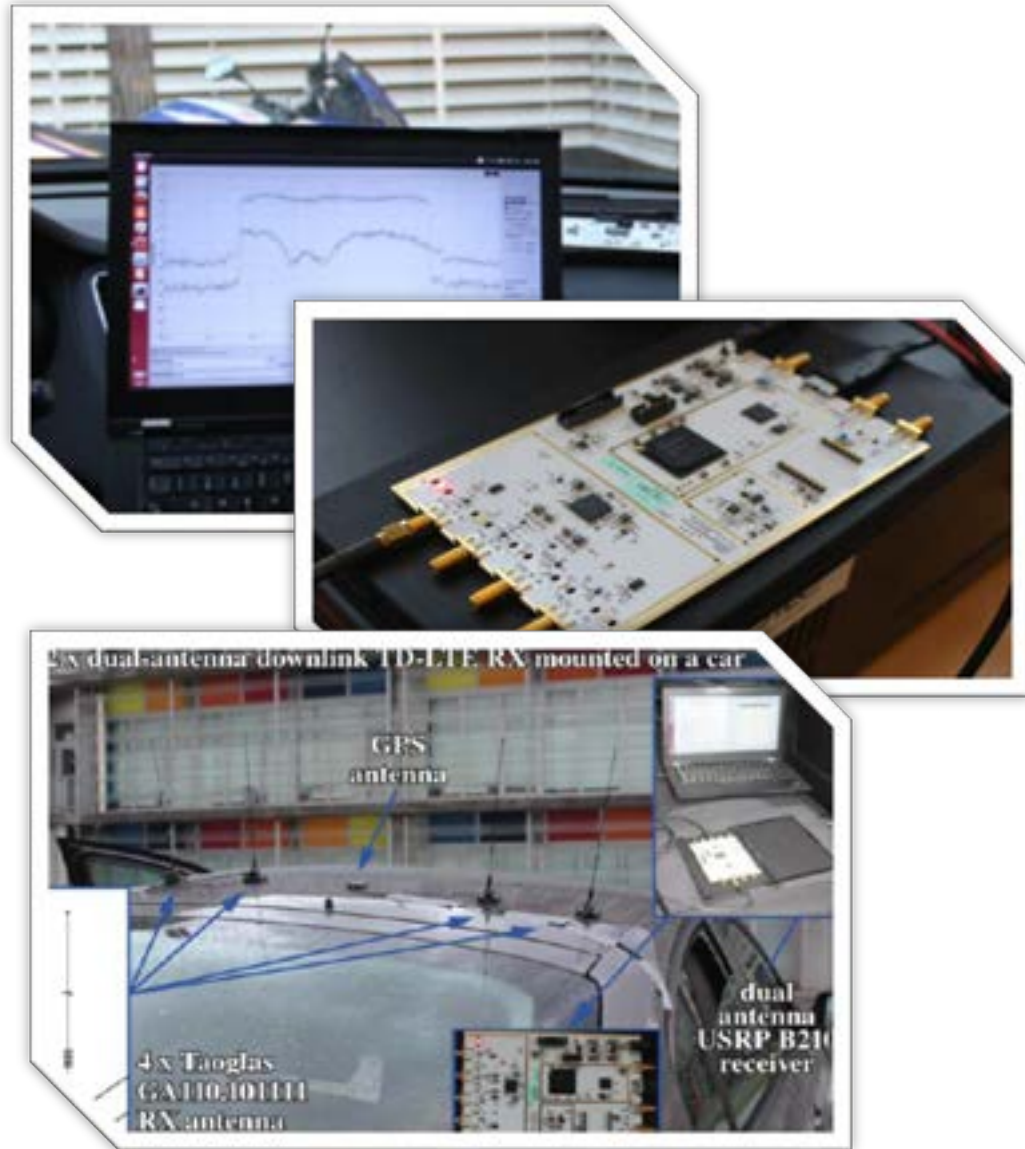
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... often quoted as **“If you cannot measure it, it is not science”**



# 4G: High-Speed Train Communications



## GTEC 5G Simulator and GTEC 5G Testbed

- Variable number of nodes (TX or RX)
- Very compact nodes (two of them can be carried in a aircraft cabin-sized suitcase)
- Robust software (able to work for a whole session of 5 hours uninterruptedly, hundreds of GB of data)
- Compatible with 4G and 5G standards, and continues to evolve

**Available online (open source):**

[https://bitbucket.org/tomas\\_bolano/gtec\\_testbed\\_public.git](https://bitbucket.org/tomas_bolano/gtec_testbed_public.git)



# 4G: High-Speed Train Communications



- **1st evaluation of 4G Communications for High-Speed Train in Spain (2014)**
- Statistical propagation channel models and communications performance evaluation results for general and critical communications

## Partners

renfe

adif



Alcatel-Lucent



UNIVERSIDAD  
POLITÉCNICA  
DE MADRID



UNIVERSIDADE DA CORUÑA



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# High-Speed Train Communications: Evolution to 5G

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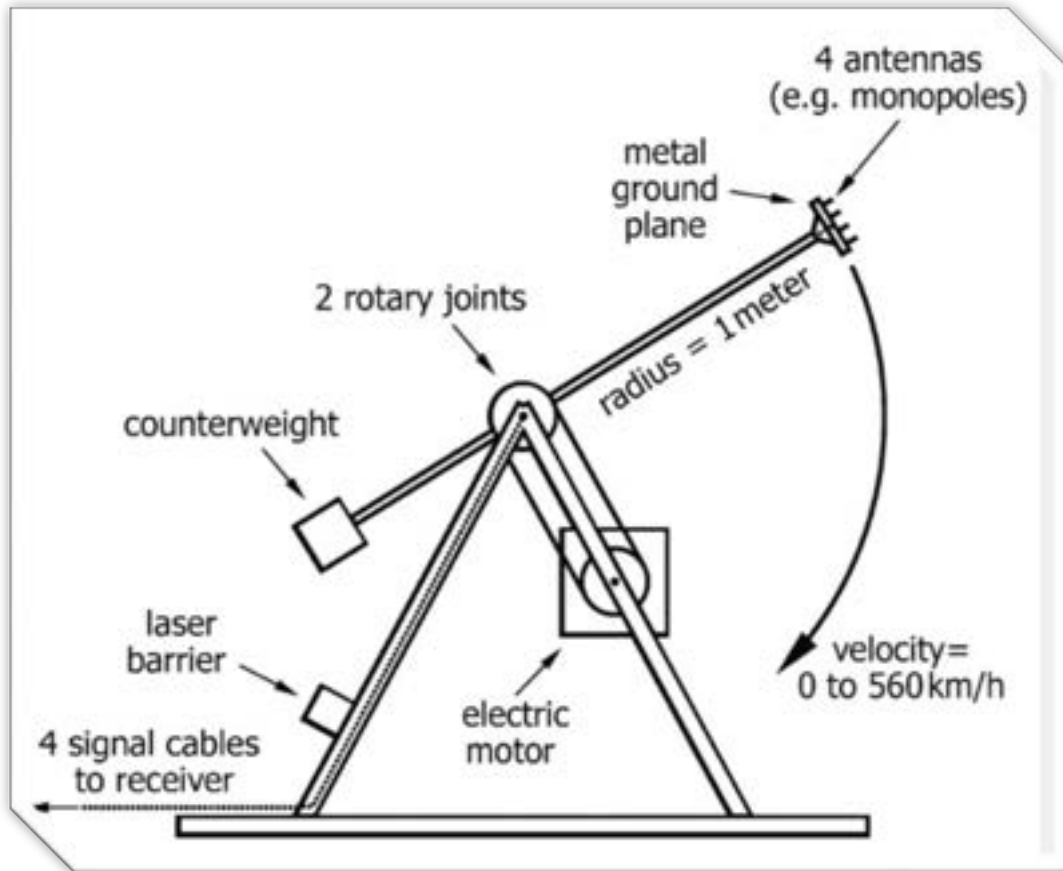
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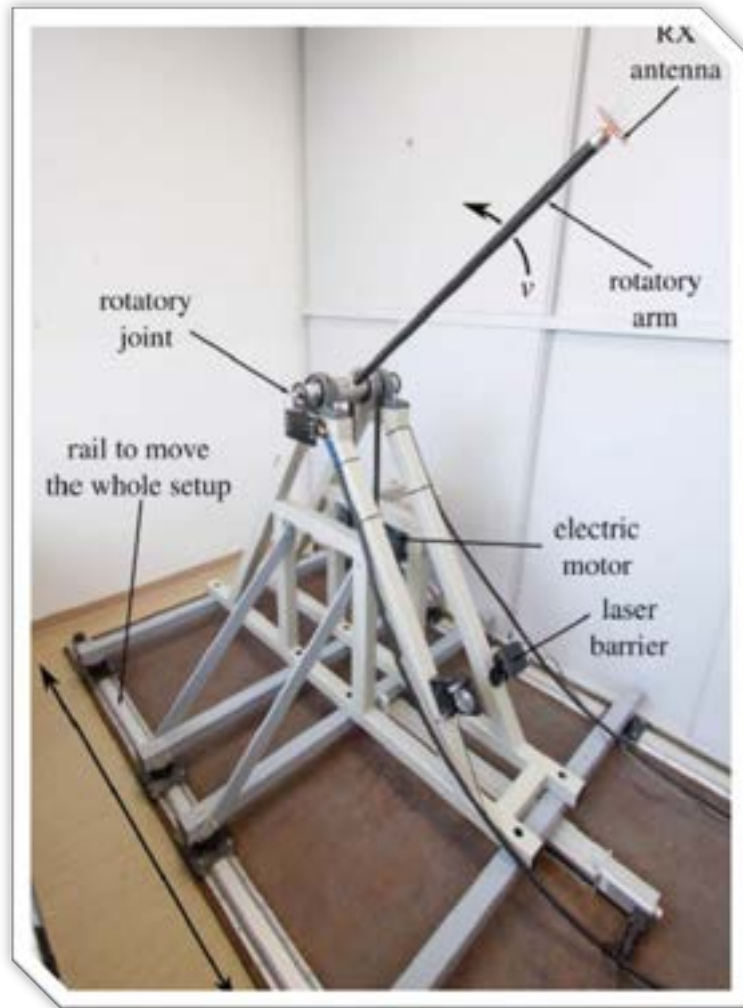


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**...and a bit CRAZY**
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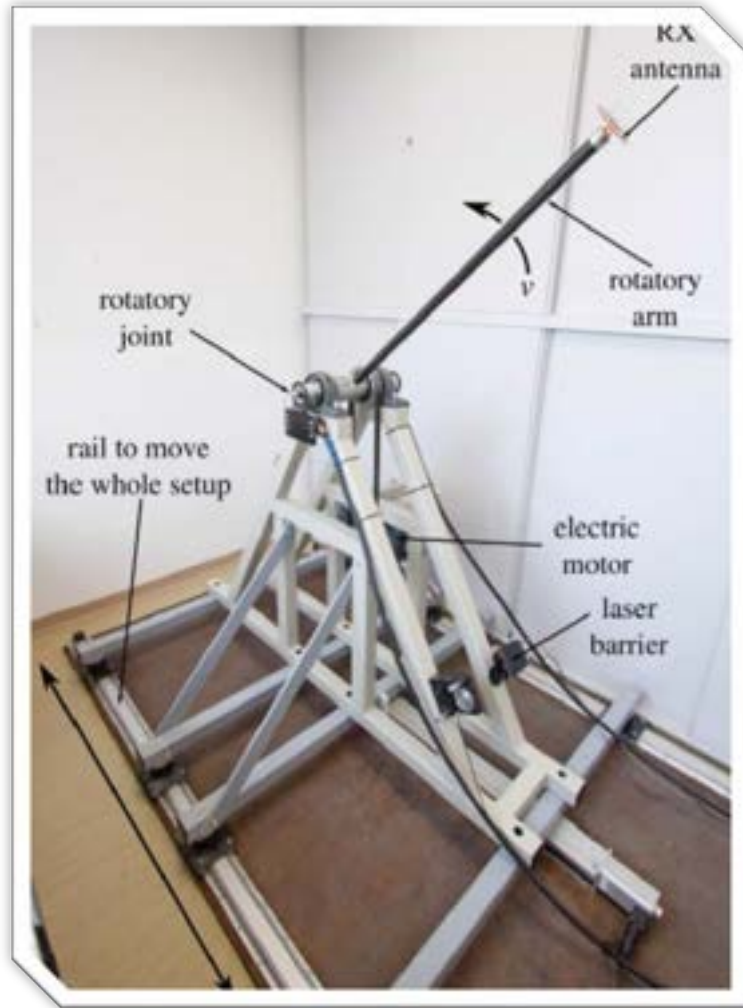


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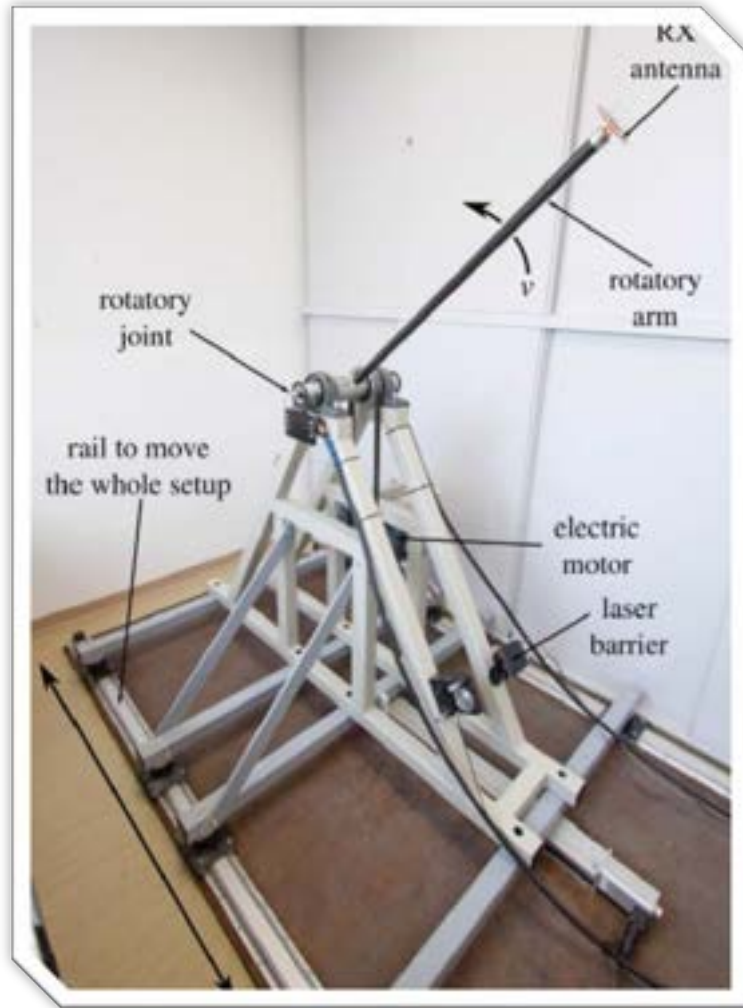
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- **1st evaluation of 5G communications in high-speed environments in Europe (2015)**
- Yes, we can use 5G as well!

03

# The Current Moves





... more 5G

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... more 5G

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# 5G: Unmanned Aerial Vehicles (UAVs)



- Due to their decrease in size and cost, and the improvement in their autonomy, UAVs recently used for many applications:
  - Rescue operations
  - Precision farming
  - Topography
  - Etc.
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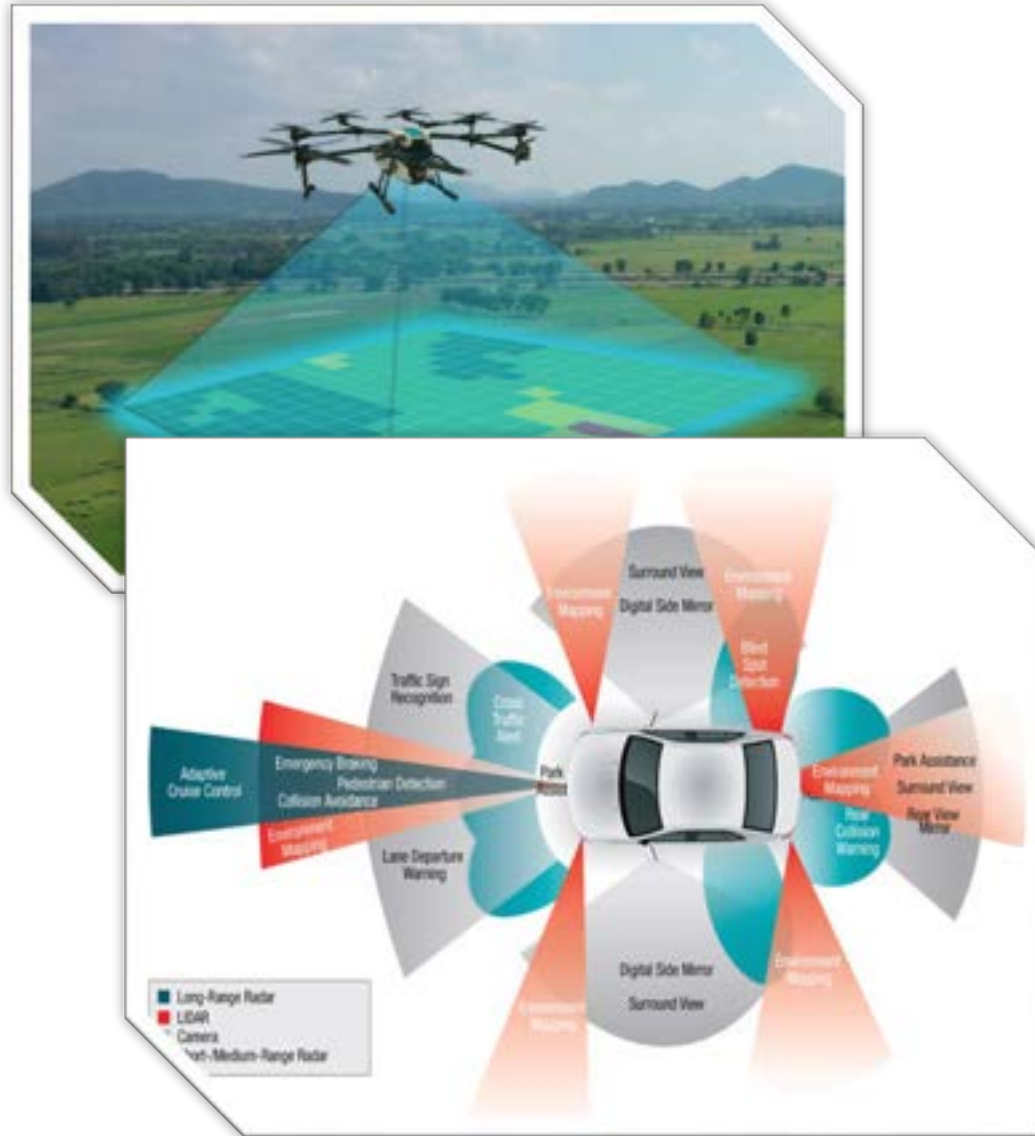


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- Service provision by UAVs after natural disasters or in saturated environments is a key scenario in the 5G standard
- Question in hand is as usual: can we use 5G for UAV communications?
- **1st available study on performance, latency and reliability of communications for UAVs**

# 04 The Path yet to Explore

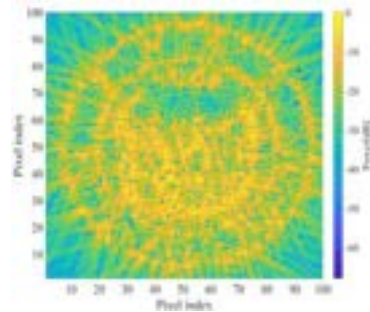
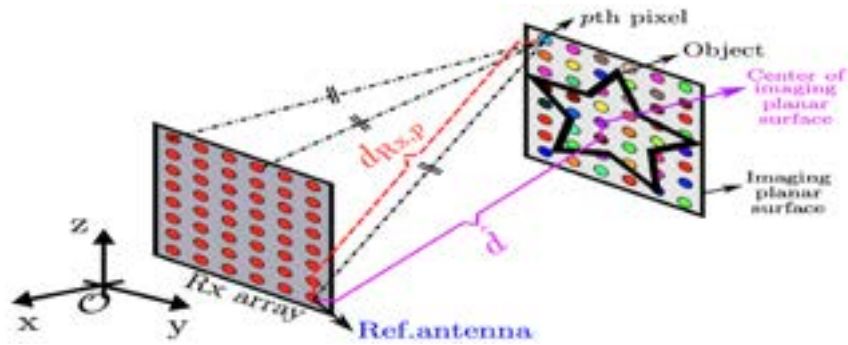


# 6G: Joint Communication and Sensing for Vehicles



- 6G promises support for Joint Communication and Sensing (JCAS)
- Many of the applications for UAVs and other autonomous vehicles are related with the sensing of the environment
- The usage of cameras for sensing raises privacy concerns

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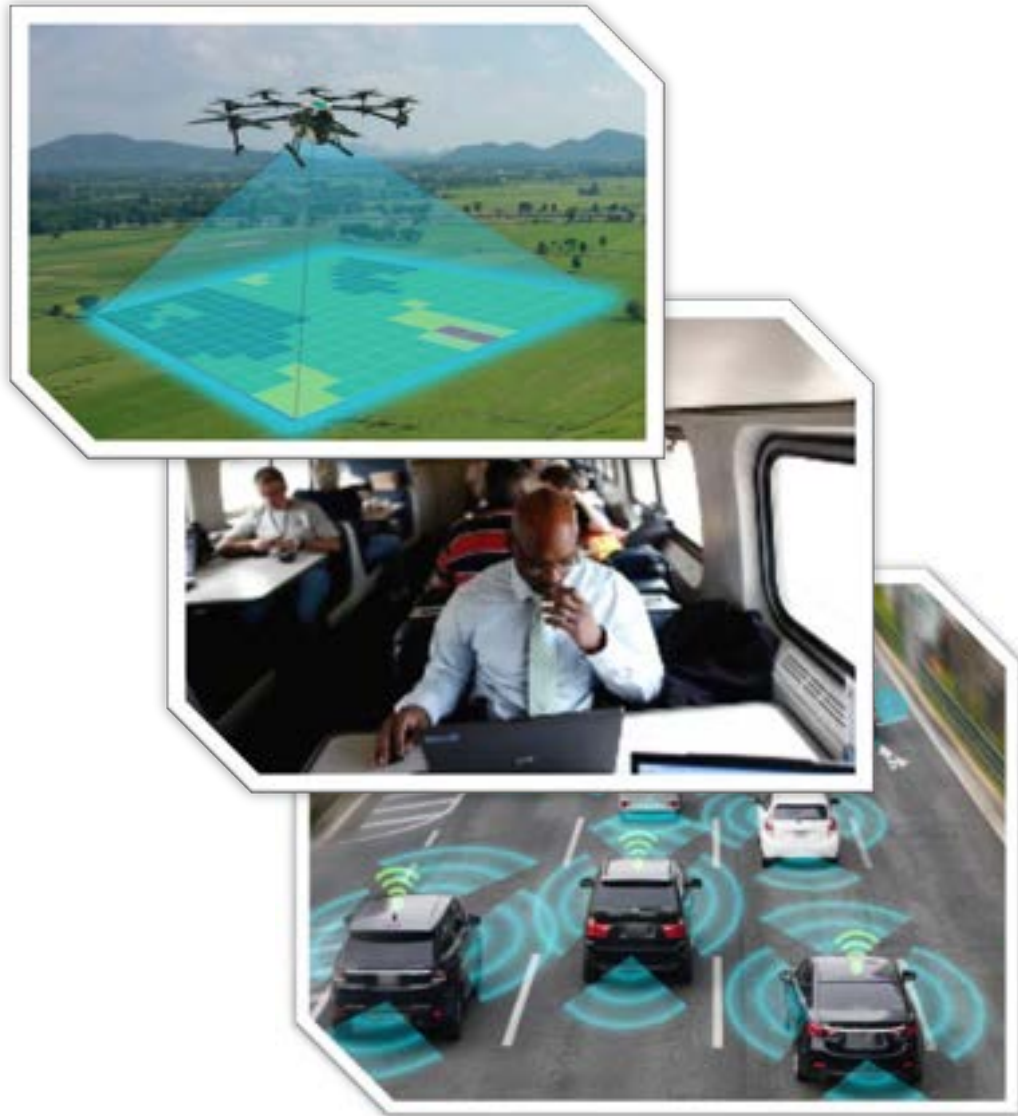
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- The usage of cameras for sensing raises privacy concerns
- JCAS allows for reducing the size of the equipment, the weight, the consumption and the signal processing operations; also reduces the amount of components required and in general improves sustainability
- Preliminary works on JCAS for UAVs and cars were already started

# 05 **Outlook**



# Outlook

- Communications are an enabling technology for daily services in smart societies in motion
- Communications are much more than best-effort connections and entertainment services
- Critical and safety-related applications become more and more dependent on the communication technologies



# Outlook



- Communications are an enabling technology for daily services in smart societies in motion
- Communications are much more than best-effort connections and entertainment services
- Critical and safety-related applications become more and more dependent on the communication technologies
- New standards provide new capabilities, which inevitably bring new challenges, application uses and scenarios as well
- Careful design and validation of prospective mobile technologies, especially for critical applications, is essential
- Empirical research is essential for applications that require certifying the fulfillment of certain criteria

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