# 5G AT SEA

# ENABLING SHIPBOARD PERSONAL WIRELESS COMMUNICATIONS

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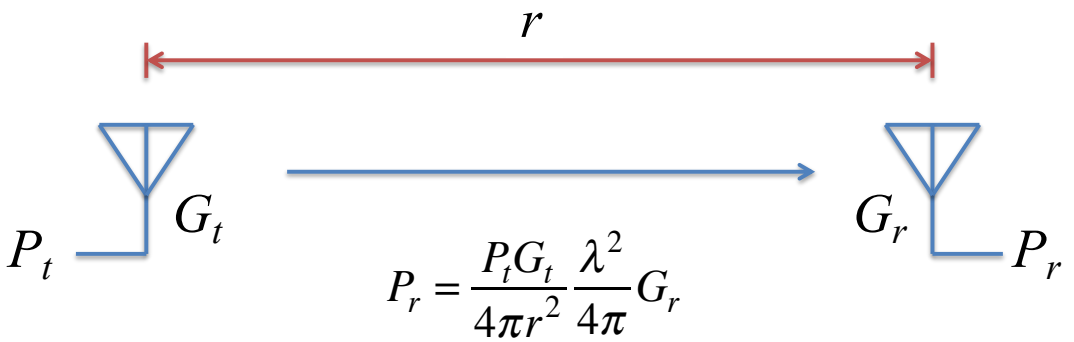
## Wireless Propagation 101

- In free space, wireless propagation is easily predicted by the Friis transmission formula:



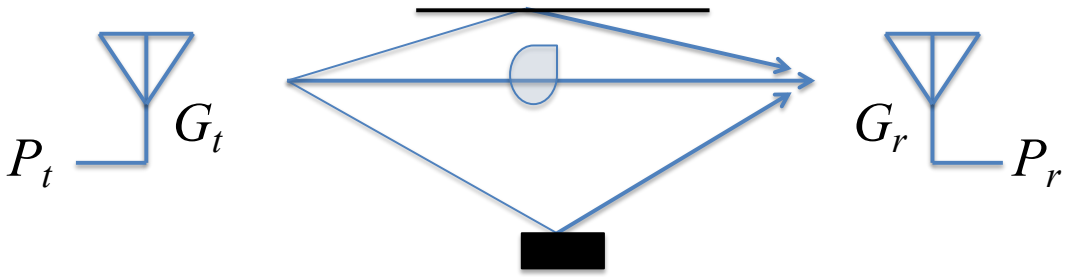

- Practical settings, including shipboard environments, are much more complicated.
- Knowledge of the propagation environment is required to predict signal strength, signal distortion, and interference.



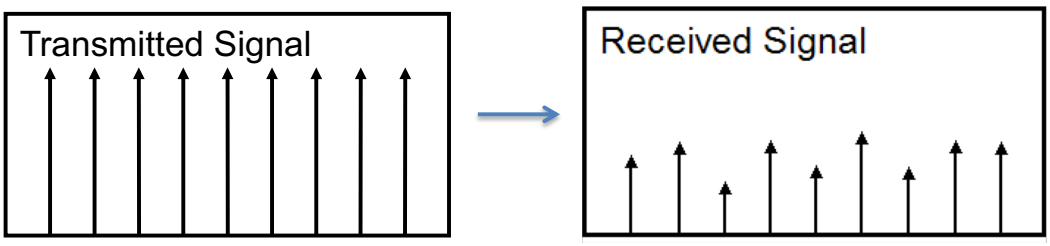


## Wireless Propagation 101

- *Propagation impairments* such as excess path loss and multipath propagation place fundamental limits on the performance of wireless communications systems.
- As wireless systems become more complex, they become increasingly sensitive to the consequences of multipath propagation, including delay spread and angle of arrival effects.



## Wireless Propagation 101




- Channel impairments can be visualized by observing the effect of sending a set of fixed tones over a wireless link.
- Before any data can be recovered from an actual transmission, the receiver must take steps to *mitigate* the impairments.
- The severity of the impairments dictates the cost and complexity of the mitigation strategy.





## Wireless Propagation 101

- Propagation researchers seek to reveal the statistical patterns that appear when we consider large sets of propagation data across a range of usage scenarios.
- The resulting propagation models capture our knowledge and understanding of the propagation environment in a form useful in both simulation and design.
- Effective propagation models help designers manage risk:
  - Will the wireless link be reliable?
  - Will it meet expectation and deliver revenue?
  - Will it be over engineered or barely adequate?

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# Wireless Channel Models must support many user communities, *each with unique needs and requirements,* across many *deployment scenarios* & over *the entire product or system development life cycle*.

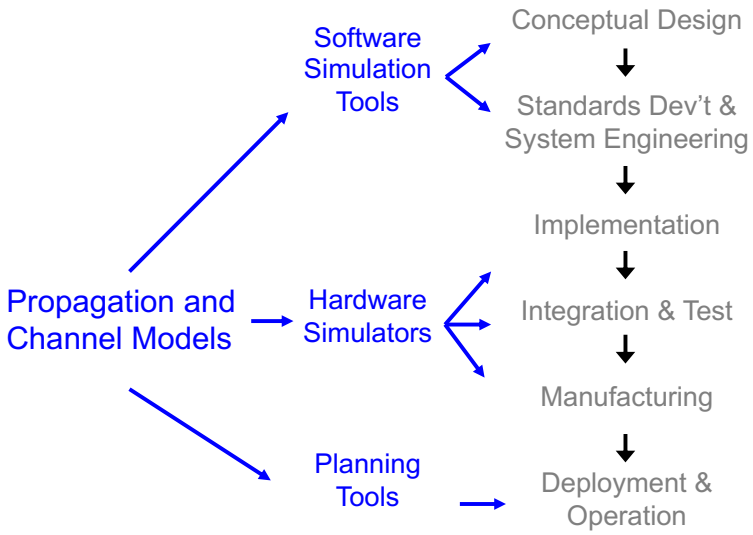
## Shipboard Deployment Scenarios

Topside / EXCOMM
- Satellite
- Radar
- Tactical
- Long-Haul

Belowdecks / INTERCOMM
- Operations
- Structural Health
- Equipment
- Environment

PERSCOMM
- Personal Communications
- Nomadic Console
- Safety & Infotainment

## The Product or System Development Life Cycle



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Wireless Channel Models must support many user communities, *each with unique needs and requirements,* across many *deployment scenarios* & over *the entire product or system development life cycle*.

## Needs and Requirements

Conceptual Design → Standards Dev't & System Engineering → Implementation → Integration & Test → Manufacturing → Deployment & Operation

**TYPE I** (e.g., 3GPP)
- Site General
- Fair Comparison
- Simulation vs. Simulation
- TTD – 18 months

**TYPE II**
- Site General
- Performance Prediction
- Simulation vs. Lab Test
- TTD – a few years

**TYPE III** (e.g., map-based)
- Site Specific
- Performance Prediction
- Simulation vs. Field Test
- TTD – several years

**Site General** – broadly applicable to a class of environment

**Site Specific** – specific to particular building and terrain layouts

**Fair Comparison** – only sufficient to predict *relative* PHY/MAC performance.

**Performance Prediction** – sufficient to accurately predict *absolute* PHY/MAC performance

**TTD** – Time to Develop: determined by a combination of urgency and required effort.

## Primary Stakeholders

**TYPE I** **SDOs, e.g., 3GPP**

**TYPE II** **Equipment Developers**

**TYPE III** **Planning Tool Developers**

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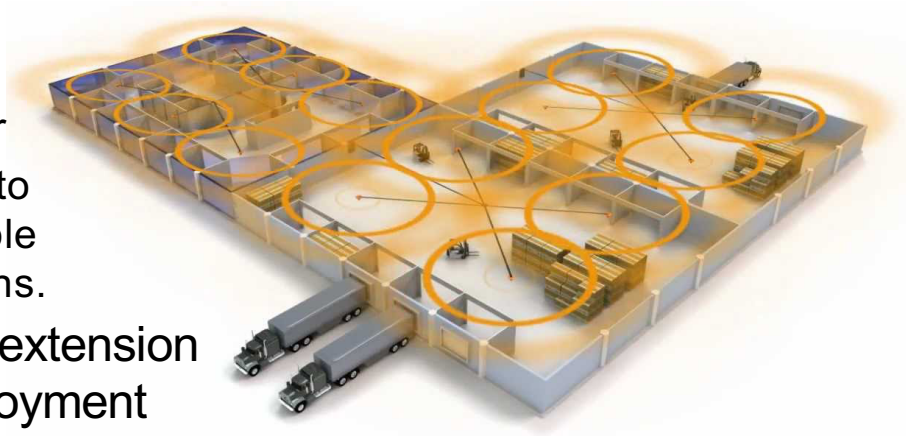
# Advanced Distributed Antenna Channel Sounders

- A DAS distributes multiple antennas from a single base station throughout a service area in order to:
  1. limit wireless coverage to particular areas.
  2. reduce shadow fading due to obstacles and barriers
  3. reduce the transmit power level required to maintain reliable communications.



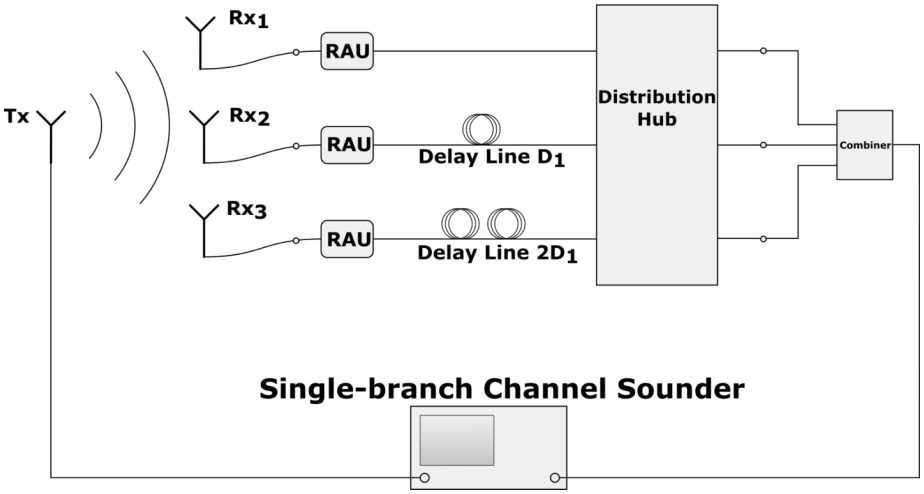
- DAS is a natural extension of small cell deployment strategies that can further improve capacity & reliability.



# Advanced Distributed Antenna Channel Sounders

We were the first to demonstrate use of *optical time division multiplexing* to *replace mechanical switches* in a DAS channel sounder and thereby allow separation of channel responses in time.

*In certain cases, the delay line multiplexer can be employed on the transmitting branch, too!*

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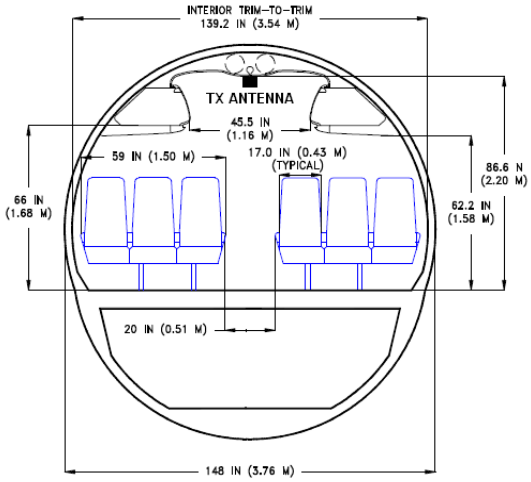
# UWB Radiowave Propagation within the Passenger Cabin of a Narrowbody Aircraft

- This ground-breaking work sought to determine how human presence affects wireless propagation within the confined space of the passenger cabin of a narrow body airliner.
- Measurement data was collected with the cabin empty, half full and full.
- Path loss and channel impulse response were compared across a multiplicity of propagation paths.

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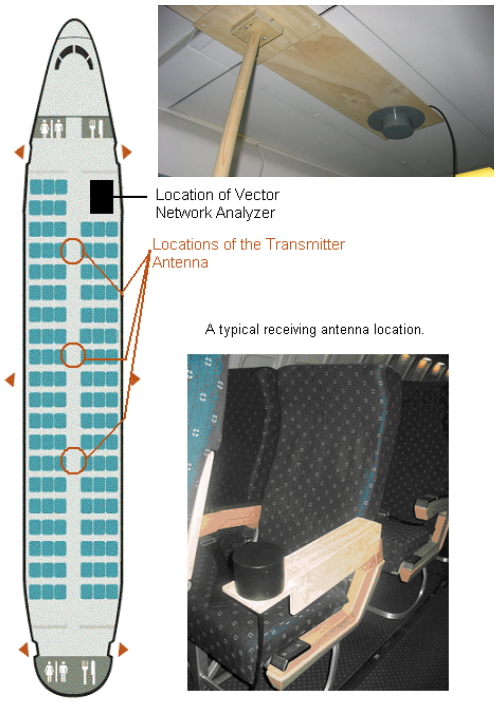
# UWB Radiowave Propagation within the Passenger Cabin of a Narrowbody Aircraft


- The results showed that human presence has a significant impact on path loss and channel impulse response and must be accounted for when assessing a wireless deployment.
- The work was recognized with the RWP King Best Paper Award of the IEEE Antennas and Propagation Society.





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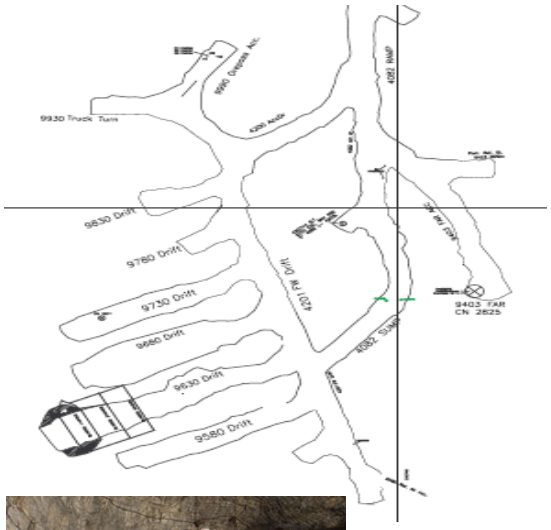
# Wi-Fi Propagation in Underground Mines

- Conventional IEEE 802.11n MIMO Wi-Fi access points do not perform well in underground mines.
- Our channel modelling studies revealed this is because the angle of arrival distributions in such confined spaces are much narrower than above ground.
- We found that doubling or even tripling the antenna spacing can reduce the correlation between different branches and vastly improve performance.

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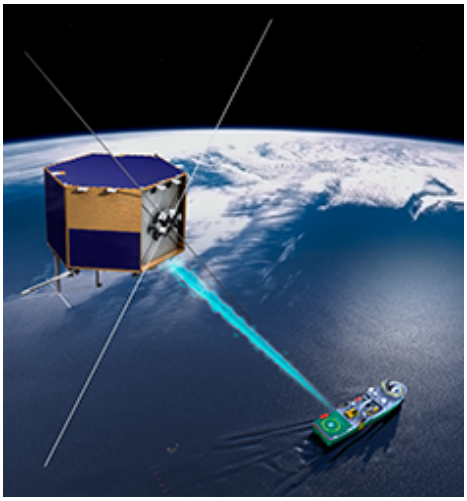
We conducted the first simulation studies that revealed the full extent of the impact of rain fading on mmWave links from Earth to satellites in LEO.

The results:

- contributed to the design of the Cascade payload on Canada's Cassiope satellite, and,
- are well aligned with NASA/ESA plans for remote sensing downlinks as well as 3GPP - TS22.261 and the 5G satellite access initiative.



Cassiope/Cascade exchanging data with a shipboard terminal.

**Some of Our Collaborators and Sponsors (Past and Present)**

MDA | 5G Millimeter-Wave Channel Model Alliance | NIST National Institute of Standards and Technology | Aalto University | Communications Research Centre Canada | CSA ASC | ROGERS

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# 5G Wireless

- represents a fundamental break from previous generations of cellular technology.
- creates a single wireless standard that can satisfy the broadest range of cost-performance goals achieved to date.
- can complement existing shipboard communications capabilities.

## Do emerging shipboard *personal wireless* use cases map onto 5G Wireless usage scenarios.

- Yes, the use cases map almost perfectly

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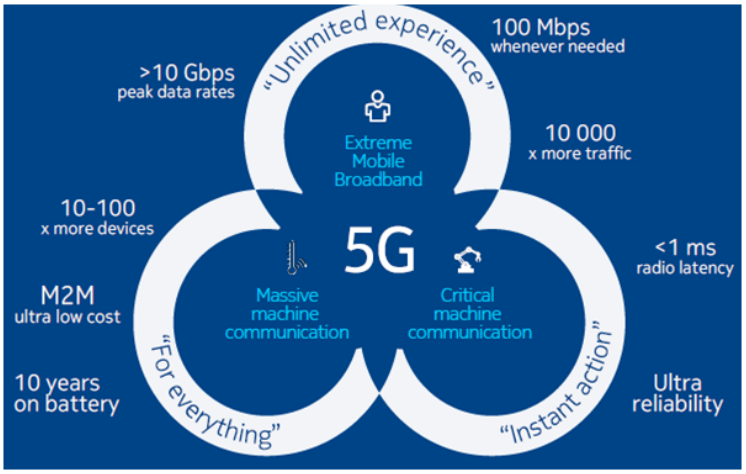
**Remote Video Presence**
***Boarding Parties***
***& Hazardous Environments***

**Personal Communications**
***Infotainment***
***& Crew Welfare/Retention***




**Sensors**
***Structural, Environmental &***
***Equipment Health Monitoring***
***and Crew Safety***

**Teleoperation**
***Remote Operations***
***Remote Consoles***
***Hazardous Environments***

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# Will 5G Wireless Devices and Networks Function in Shipboard Environments?

- 5G Wireless was designed to work in conventional propagation environments and may not function reliably under shipboard conditions.
- 5G deployment practices and upcoming 5G Releases can be upgraded to meet performance, reliability and security requirements aboard ship.
- **Channel models applicable to shipboard environments are urgently required to support 5G development for reliable operation under shipboard conditions.**

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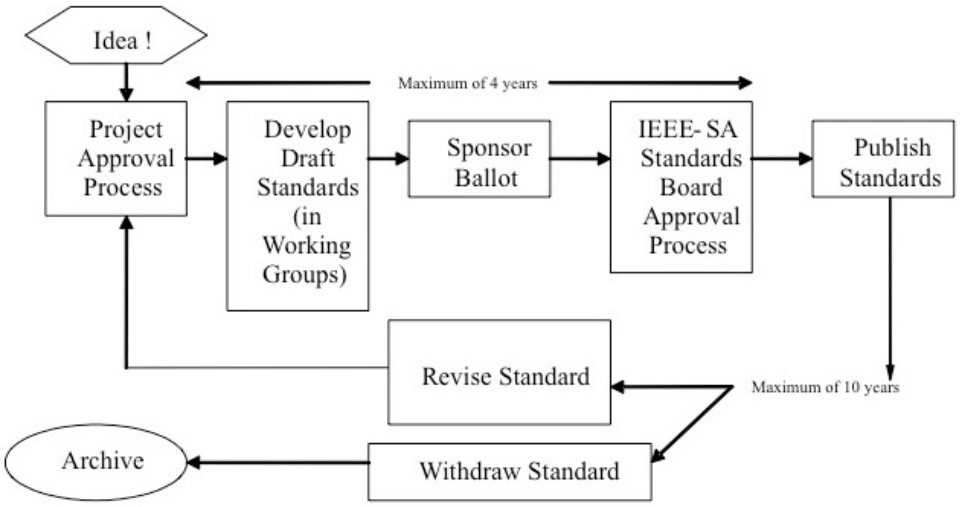
A **5G(N) Study Group** would document the use cases & performance requirements and develop the wireless channel models required to support development of **an IEEE Standard on shipboard deployment practices** & future releases of LTE.

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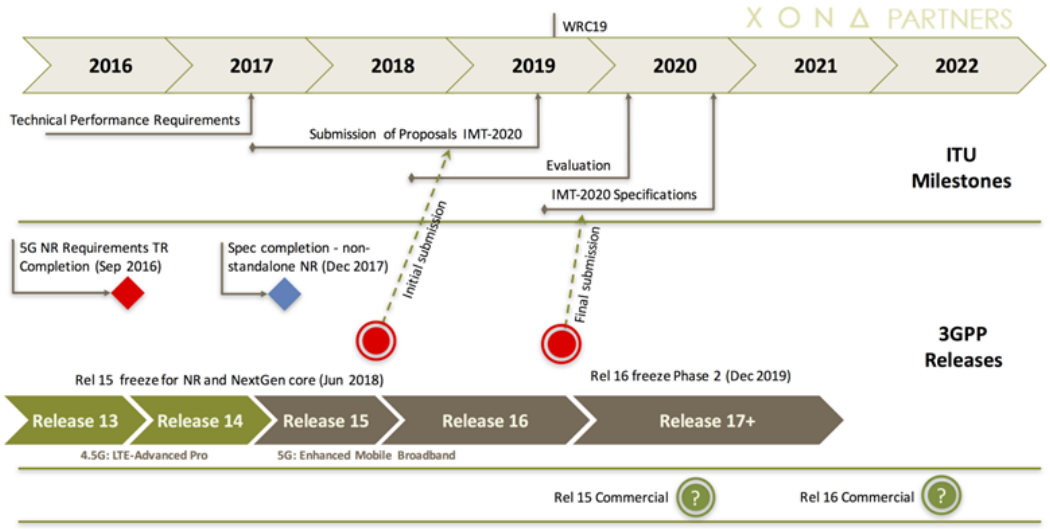


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# Let's innovate!

- DATAR – 1950s
  Digital Automated Tracking and Resolving
- SHINCOM – 1970s
  Shipboard Internal Communications
- SHINPADS – 1970s
  Shipboard Integrated Processing And Display System

- 5G(N) – 2020s
  Personal Communications in Shipboard Environments

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