Take My Network to the Moon

WInnForum Tech Talk Series #2

WInnForum Standards™

WIRELESS INNOVATION FORUM®

Webinar Administrivia

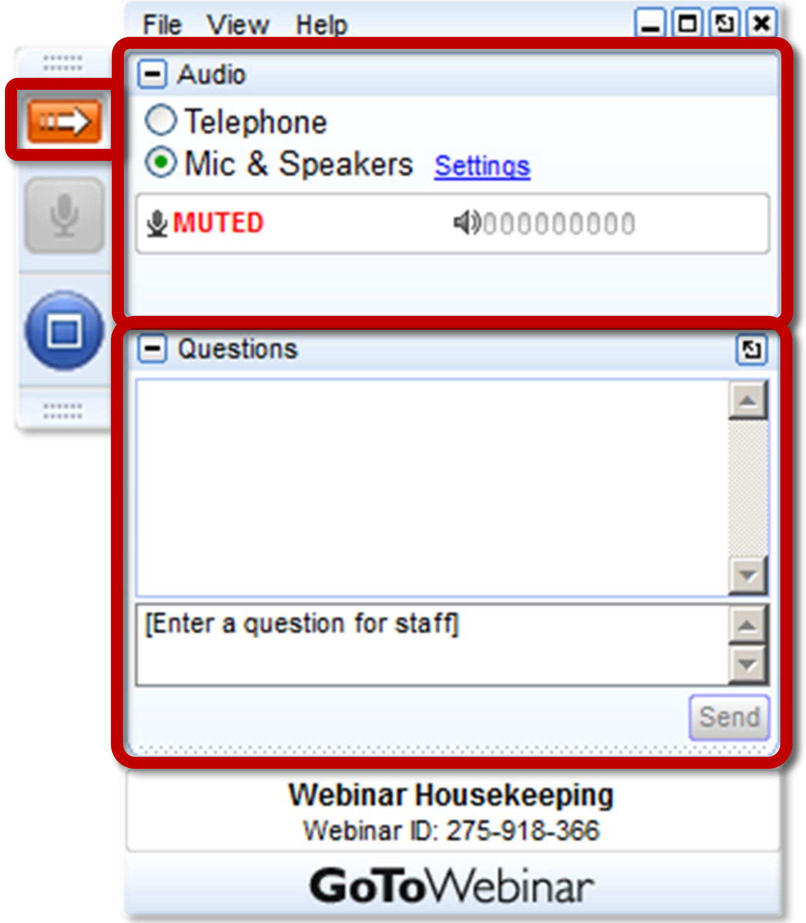
Slides presented during this webinar will be posted here:

- http://www.wirelessinnovation.org/webinars

Recorded Webinar will be available on the Forum's You Tube Channel:

- https://www.youtube.com/channel/UCYUeZvOuJTP27OzoKsyys0w

Email Lee.Pucker@wirelessinnovation.org if you need more information



Today's Moderator

Andrew Clegg

Spectrum Engineering Lead, Google

Chief Technology Officer, The Wireless Innovation Forum

WInnForum Standards™

Slide 3

WIRELESS INNOVATION FORUM

Communications in Extreme Environments

Deploying the first cellular communication network on the Moon

Thierry E. Klein, PhD

President, Bell Labs Solutions Research

Nokia Bell Labs

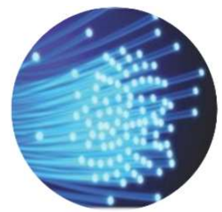
thierry.klein@nokia-bell-labs.com

Bell Labs: An unrivalled track record of industrial research

Our innovations have been changing the way we live for more than 95 years

Transistors

Satellite comms

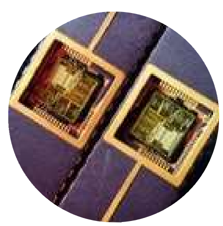


Laser/fiber optics

Charge-coupled devices

Cellular communications

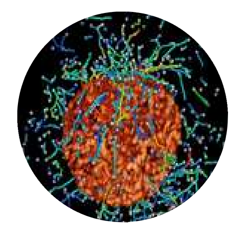
Unix/C/C++



Coherent optics

Solar cells

Neural Networks



Super-resolution microscopy

Nokia Bell Labs pioneering innovations have been at the center of space exploration

Discovering Radio Astronomy and Cosmic Microwave Background Radiation

Nobel Prize in 1978 for proving the Big Bang Theory

Inventing the Science of Radio Astronomy

Radio astronomy was born in Bell Labs at 1930s that has become the basic investigative technique in Astronomy and Astrophysics

Arno Penzias and Bob Wilson won the Nobel Prize in 1978 (Physics) for the discovery of Cosmic Background Radiation

Solar Cells

1954: Bell Labs demonstrates the first practical silicon solar cell

Adjusting the Bell Solar Battery to make the first sun-powered telephone call in 1955

Bell Labs announced the invention on April 25, 1954 in Murray Hill, New Jersey. They demonstrated their solar panel by using it to power a small toy Ferris wheel and a solar powered radio transmitter.

Those first silicon solar cells were about 6 percent efficient at converting the energy in sunlight into electricity, a huge improvement over any previous solar cells.

The first silicon solar cells were expensive to produce, and early efforts at commercialization were not initially a huge success. But within a few years solar cells were commonly used to power satellites, and other applications followed

Telstar

1962: The first Communications Satellite by Bell Labs

http://ieeexplore.ieee.org/document/6769376/

Bell Labs created and manufactured the first communication satellite for TV broadcast

The satellite was operated by NASA and paved the way to modern communication satellites

Telstar provided the first transatlantic television feed

World’s Ultra Compact LTE Network (UCN) deployments

Near space and airborne missions

Loon launch site. Picture courtesy of Google Project Loon

Mission to the Moon

Nokia developed LTE technology for this project

Mission overview:

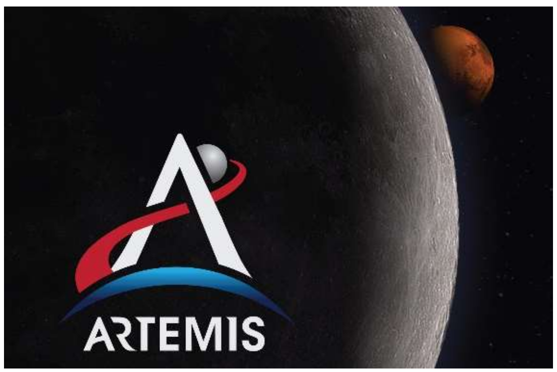
- Land in Taurus-Littrow Valley (Apollo 17 landing site)
- Establish LTE network on the Moon
- Deploy two Lunar Rovers to explore lunar surface
  - UL HD Video Transmission from the rovers to the lander
  - DL rover remote control
- Remote LTE network management from Earth
- Mission duration of 1 lunar day-light

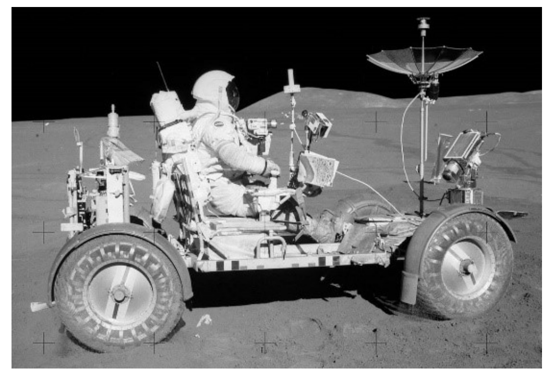
https://www.nokia.com/about-us/news/releases/2018/02/27/nokia-is-selected-by-vodafone-to-be-its-technology-partner-for-mission-to-the-moon-project/

Latest developments in NASA's key space programs

NASA Artemis Program: "Together with commercial and international partners, NASA will establish a sustainable presence on the Moon to prepare for missions to Mars."

NASA Tipping Point: "NASA seeks industry-developed space technologies that can foster the development of commercial space capabilities and benefit future NASA missions."





Paradigm shift: from proprietary, custom-solutions to services

Why LTE (and 5G) for space communications?

Mature and proven technology
>4 billion LTE subscribers globally

Continually maintained and evolved
A technology used world-wide with ample support

Path to 5G
Well defined evolution path in 3GPP standards. User Equipment multi-RAT (LTE and 5G) support by default

An all-IP technology
Endless possibilities of integrations with other technologies and applications

Scalable
Bandwidth, data-rates, number of users, power, deployment options

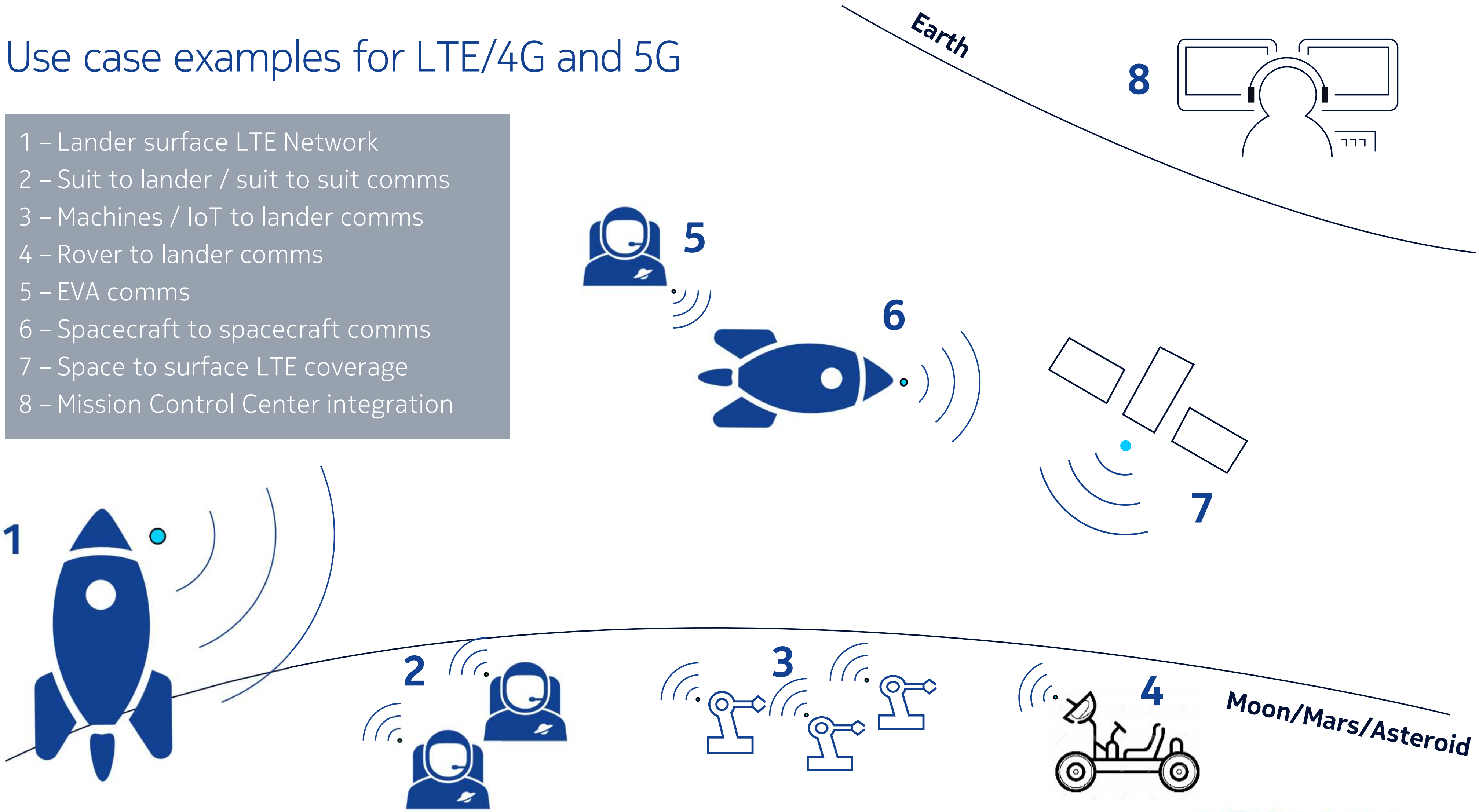
Robust technology
OFDMA-based, protection against multi-path, highly efficient

Mobility
From static users to high-speed mobility scenarios with seamless data handovers

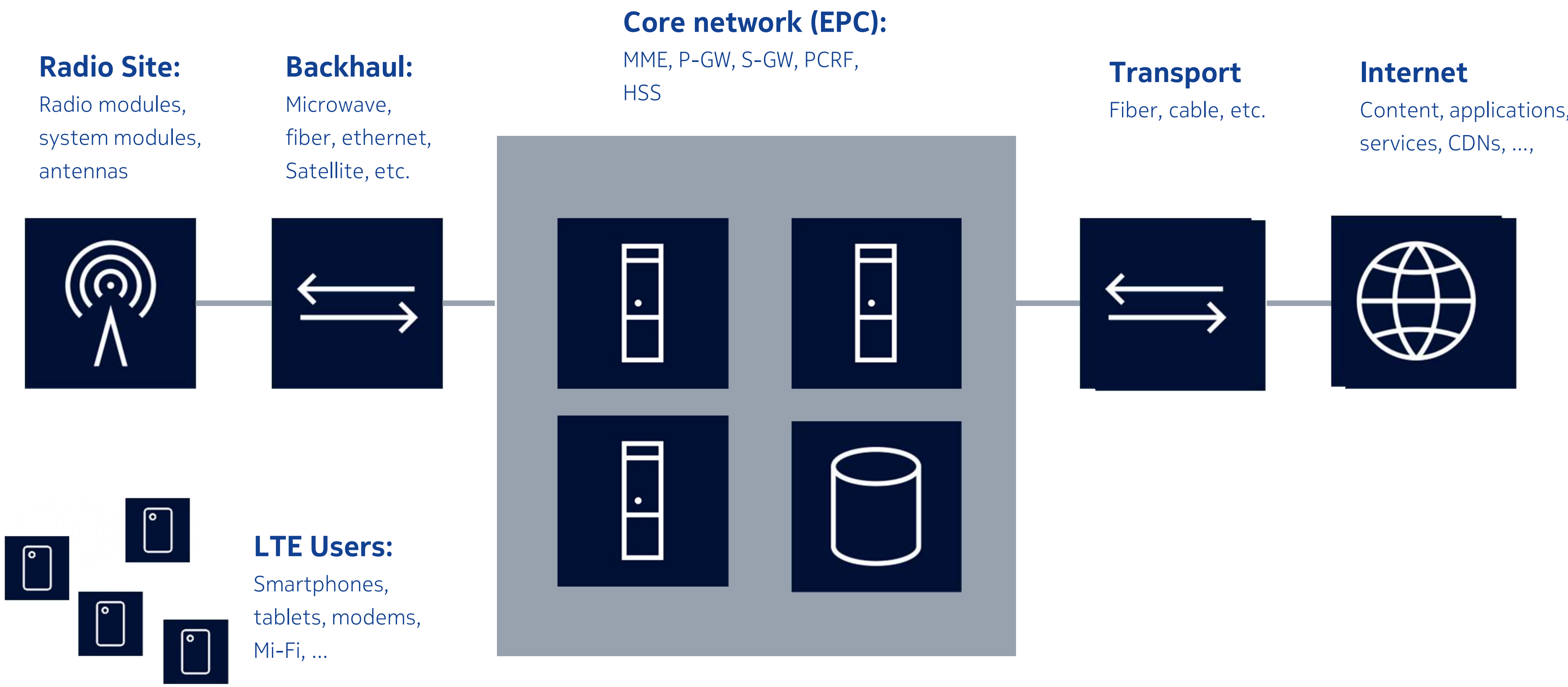
Quality of Service
Built-in dynamic QoS enabling user, service and bearer differentiation, admission control, etc.

Use case examples for LTE/4G and 5G

1 – Lander surface LTE Network
2 – Suit to lander / suit to suit comms
3 – Machines / IoT to lander comms
4 – Rover to lander comms
5 – EVA comms
6 – Spacecraft to spacecraft comms
7 – Space to surface LTE coverage
8 – Mission Control Center integration



What a traditional “Earth” LTE/4G network looks like



NASA selected Nokia to build first ever cellular network on the Moon

- To **integrate Nokia's LTE/4G** network assets onto Intuitive Machines' **Nova-C lander** and Lunar Outpost's **MAPP Rover**
- To **deploy and establish an LTE/4G** network on the Lunar **south pole**
- To **verify the LTE/4G network performance** in short-range and long-range surface communications scenarios
- To enable **advancement of the technology readiness** of LTE technology and pave the way for future missions and commercial opportunities
- The **target launch date is mid 2023** and the Lunar mission duration is expected to last up to 12 days (during lunar day)

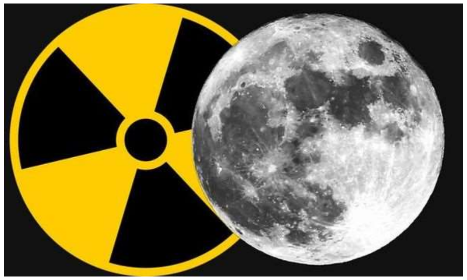
Nokia will deploy the first LTE/4G communications system in space, providing critical communication capabilities on the lunar surface

What are some of the key challenges?

Environment

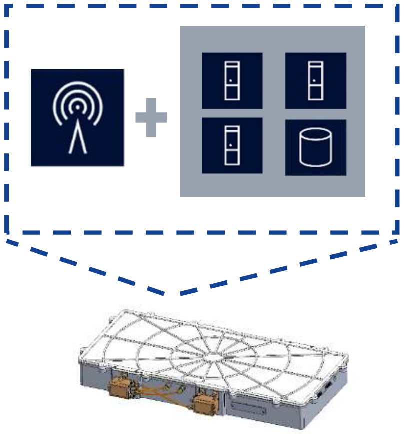
- Survival of launch, transit, landing and operations on the Moon
- Thermal-mechanical design for space

Radiation



- Single events upsets (SEU) caused by cosmic galactic rays, solar flares
- Spot shielding, SW robustness features

SWAP



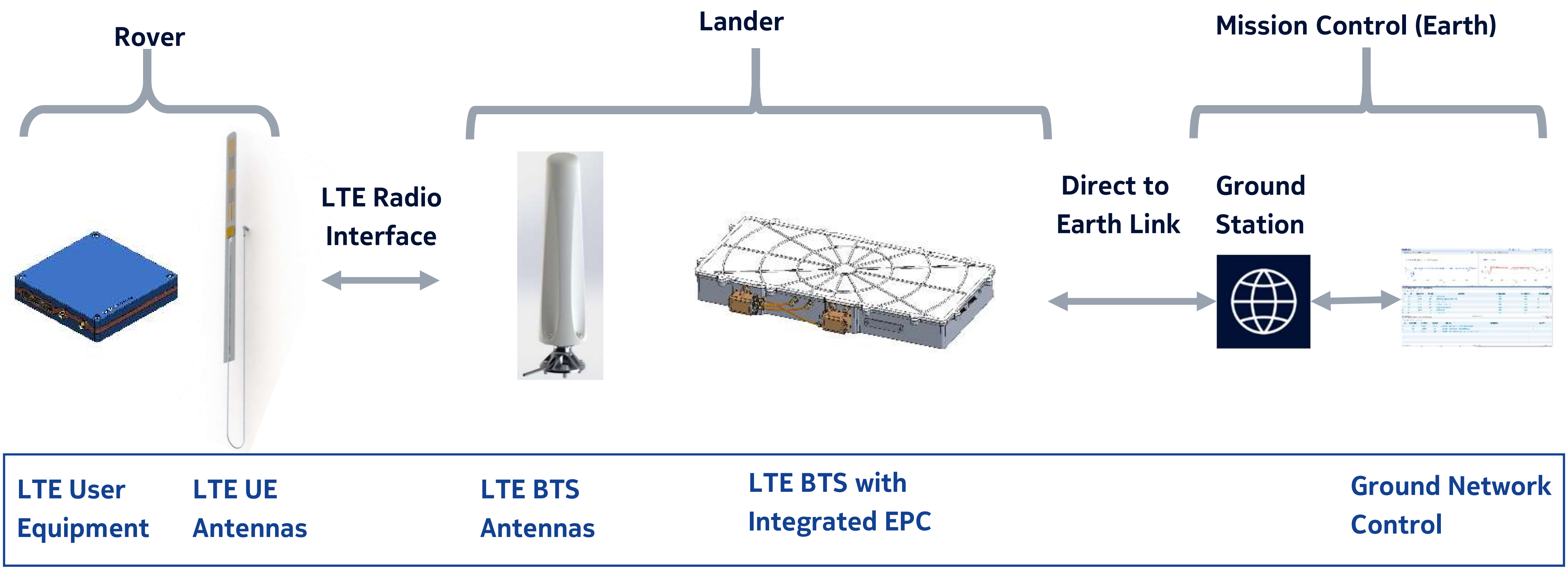
- Size, weight and power need to be kept to the minimum
- Integration of SW, lightweight HW components

Remote Control

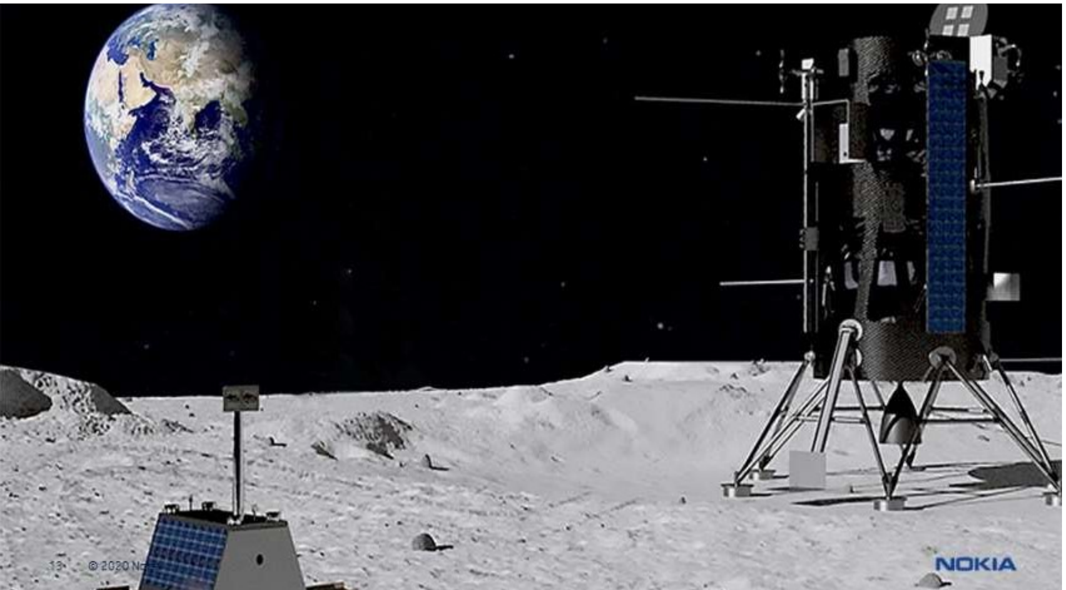
- Remote operation over long-latency, low-data-rate link
- Custom Operations and Maintenance SW solution

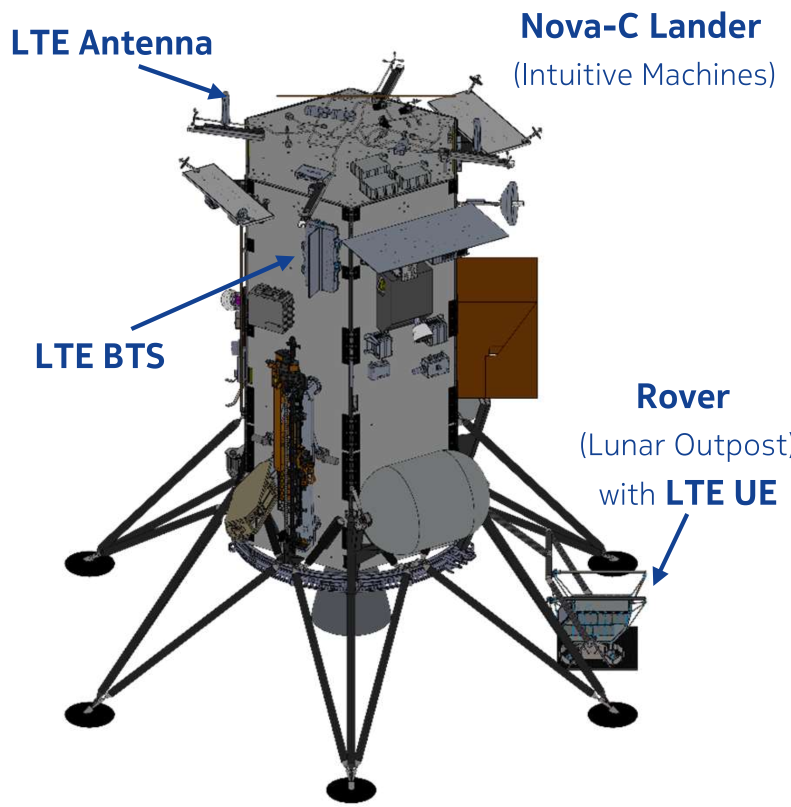
NOKIA Bell Labs

What Nokia LTE/4G network for space looks like



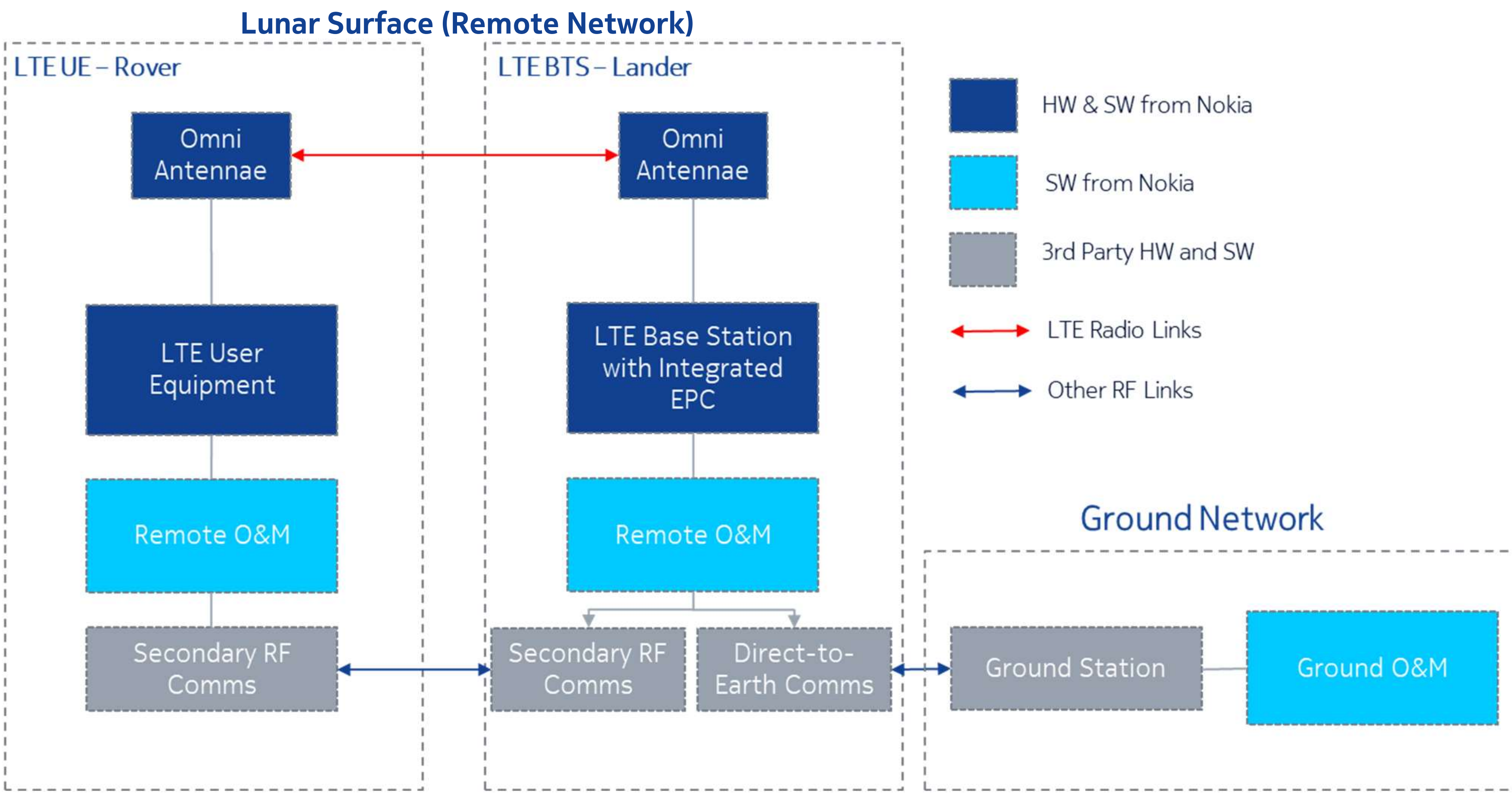
Nokia LTE Solution Components





Launch date is planned for mid 2023

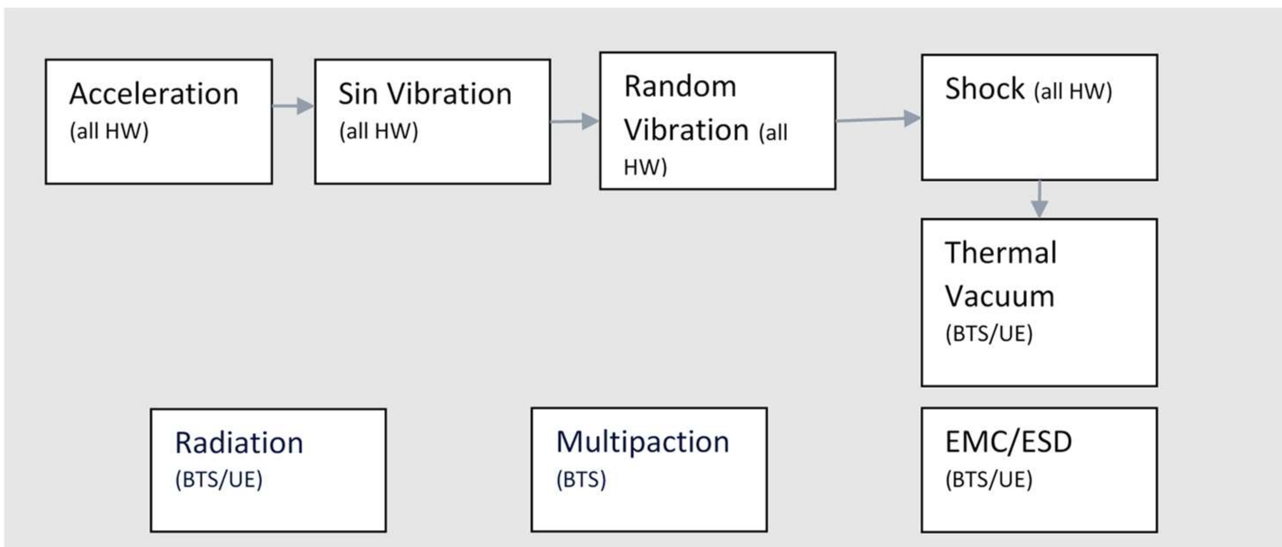
System concept – simplified system architecture



Reliability assurance: a key element for a successful mission

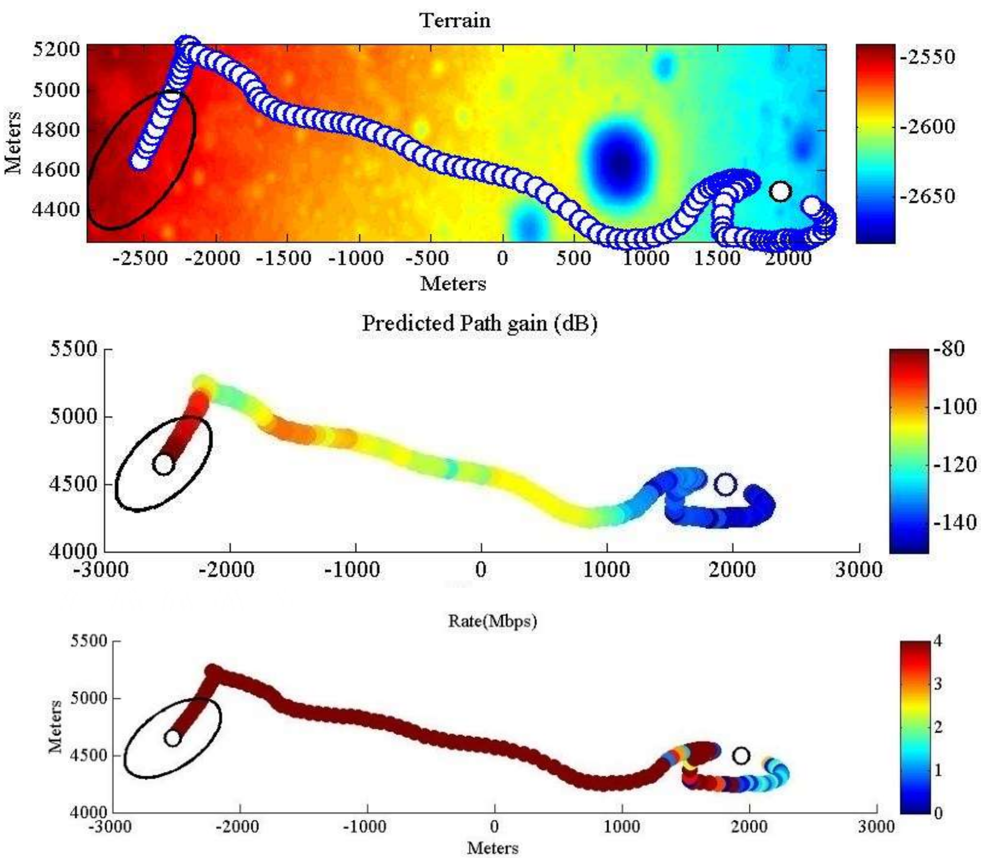
Overall reliability testing approach

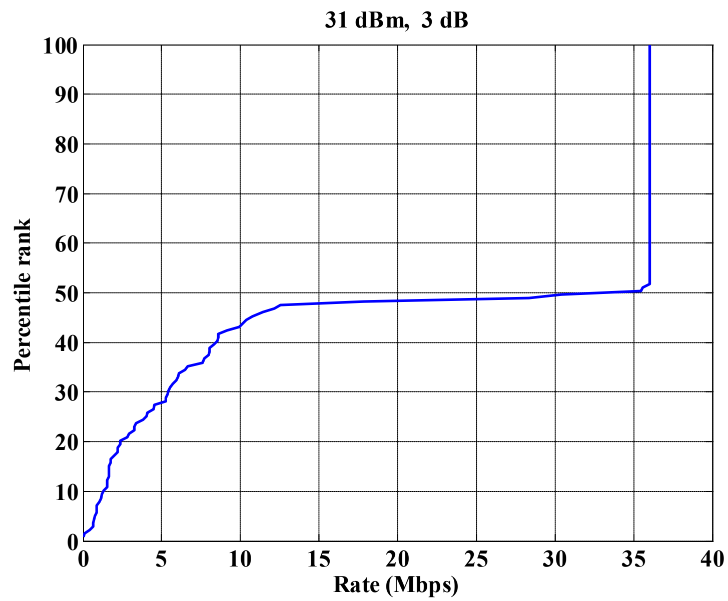
Test Sequences



Lunar surface 4G/LTE propagation and coverage simulation analysis

Based on Nokia Bell Labs developed semi-analytical model



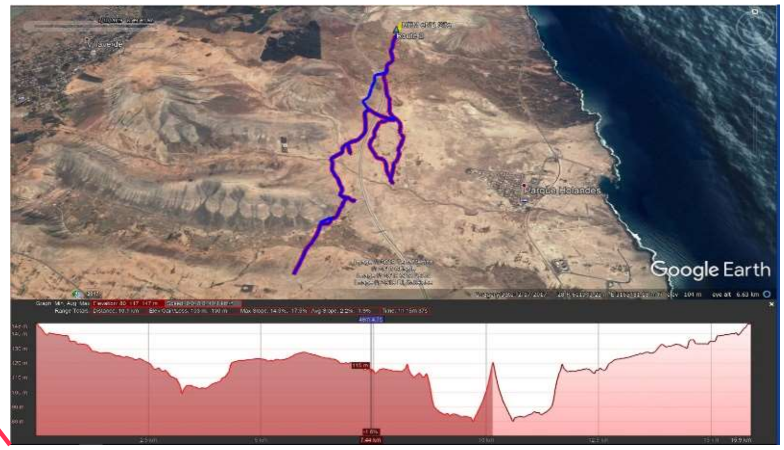


NOKIA Bell Labs

Nokia LTE/4G prototypes E2E tested in Fuerteventura, Spain in 2019

On a representative mission environment

Parque del Holandes,
Fuerteventura, Spain



Drive test route: ~5.2 km max distance

Commercial Clearpath
Husky Robot

Rover remotely controlled over deployed LTE network with UL HD video assistance for remote operator

Nokia LTE/4G for lunar surface communications
Summary

Nokia and Intuitive Machines will deploy the first LTE/4G network on the surface of the Moon in 2023. Nokia will provide a hardened, low power and low weight E2E LTE solution enabling mission critical lunar surface wireless communications

Hardware

- New components for mission-critical operation
- Designed to endure shock and vibration
- New thermal-mechanical design: light-weight, optimized heat dissipation

Software

- High-level of integration and robustness
- Enhanced operations and management providing resilient access over high-latency and lossy links
- System built on commercial off-the-shelf technologies

System design

- E2E system design and integration with mission partner lander and rover
- Extensive RF propagation simulations considering the lunar terrain, soil composition and surface curvature

NOKIA

Humankind’s fascination with space exploration is intensifying. We are sending more humans and more machines into space, not only to explore and study, but also to pursue new business ventures and experience the cosmos as tourists. Wherever these humans and machines go, they need to communicate, and we develop technologies to make the journey with them.