Take My Network to the Moon

WInnForum Tech Talk Series #2
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Deploying the first cellular communication network on the Moon

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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

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

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 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

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

**Radio Site:**
Radio modules, system modules, antennas

**Backhaul:**
Microwave, fiber, ethernet, Satellite, etc.

**Core network (EPC):**
MME, P-GW, S-GW, PCRF, HSS

**Transport**
Fiber, cable, etc.

**Internet**
Content, applications, services, CDNs, ...

**LTE Users:**
Smartphones, tablets, modems, Mi-Fi, ...

[Diagram showing the components of a traditional LTE/4G network]
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)
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
What Nokia LTE/4G network for space looks like

Rover

LTE Radio Interface

Lander

LTE BTS with Integrated EPC

Mission Control (Earth)

Direct to Earth Link

Ground Station

Ground Network Control

LTE User Equipment

LTE UE Antennas

LTE BTS Antennas

Nokia LTE Solution Components
Nova-C Lander (Intuitive Machines)

Rover (Lunar Outpost) with LTE UE

LTE Antenna

LTE BTS

Launch date is planned for mid 2023
System concept – simplified system architecture

Lunar Surface (Remote Network)

LTE UE – Rover
- Omni Antennae
- LTE User Equipment
- Remote O&M
- Secondary RF Comms

LTE BTS – Lander
- Omni Antennae
- LTE Base Station with Integrated EPC
- Remote O&M
- Secondary RF Comms
- Direct-to-Earth Comms

Ground Network
- Ground Station
- Ground O&M

- HW & SW from Nokia
- SW from Nokia
- 3rd Party HW and SW
- LTE Radio Links
- Other RF Links
Reliability assurance: a key element for a successful mission

Overall reliability testing approach

Development Testing → Qualification Testing → Acceptance Testing

Test Sequences

- Acceleration (all HW)
- Sin Vibration (all HW)
- Random Vibration (all HW)
- Shock (all HW)
- Thermal Vacuum (BTS/UE)
- Radiation (BTS/UE)
- Multipaction (BTS)
- EMC/ESD (BTS/UE)
Lunar surface 4G/LTE propagation and coverage simulation analysis
Based on Nokia Bell Labs developed semi-analytical model
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

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

Commercial Clearpath Husky Robot
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
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.