https://ntrs.nasa.gov/search.jsp?R=20200001648 2020-03-28T19:12:23+00:00Z

National Aeronautics and Space Administration

NASA

ESC Exploration & SPACE Communications

More than you ever imagined...

LunaNet: A Flexible and Extensible Lunar Exploration Communication and Navigation Infrastructure

Dave Israel | NASA/GSFC Code 450

March 9, 2020

LUNANET
STATUS: ONLINE
1000.456.3.C
-210°C
NAVIGATION
SHOEMAKER
EVA-1
LRV1
SHACKLETON
CURRENT SPACE WEATHER CONDITIONS:
Solar wind speed: 421 km/sec Noon: 10.7 cm
Solar Wind Magnetic Fields: Bt 7 nT, Bz 6 nT Radio Flux: 74 sfu
SOLAR FLARE MONITOR
SOLAR FLARE PROBABILITY = 1%
PREDICTION HORIZON: 24 HR
All-Clear [M & X]
Generated by ASAP
NO SUNSPOTS DETECTED
SOLAR FLARE MONITOR
SOHO- EIT 171
2019-05-15 04:00:00.0
2019-05-15 18:37 UTC
SOLAR X-ray Flux (1- minute da
WATTS M-2
May 13
May 14
May 15
UNIVERSAL TIME
X-RAY FLUX
PROTON FLUX

LUNANET

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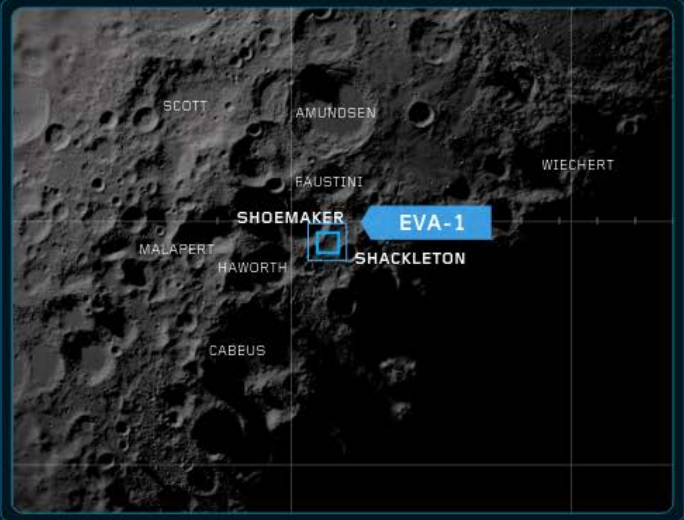
NAVIGATION



SOLAR FLARE MONITOR

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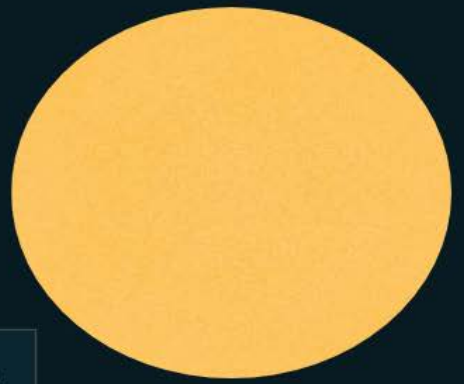

NO SUNSPOTS DETECTED

SOLAR FLARE MONITOR | SOHO- EIT 171

2019-05-15 16:37 UTC

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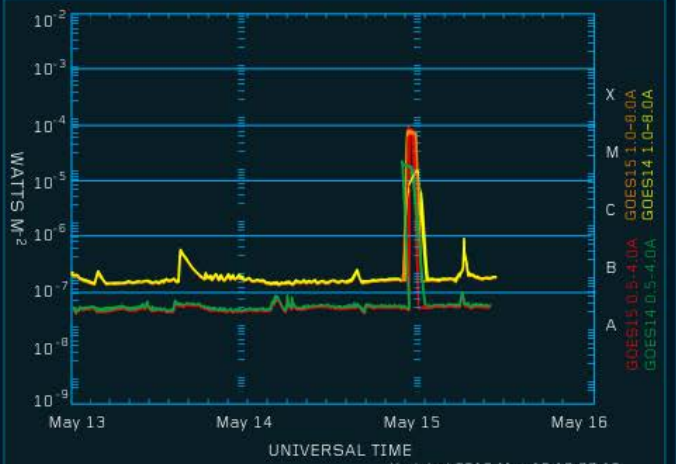
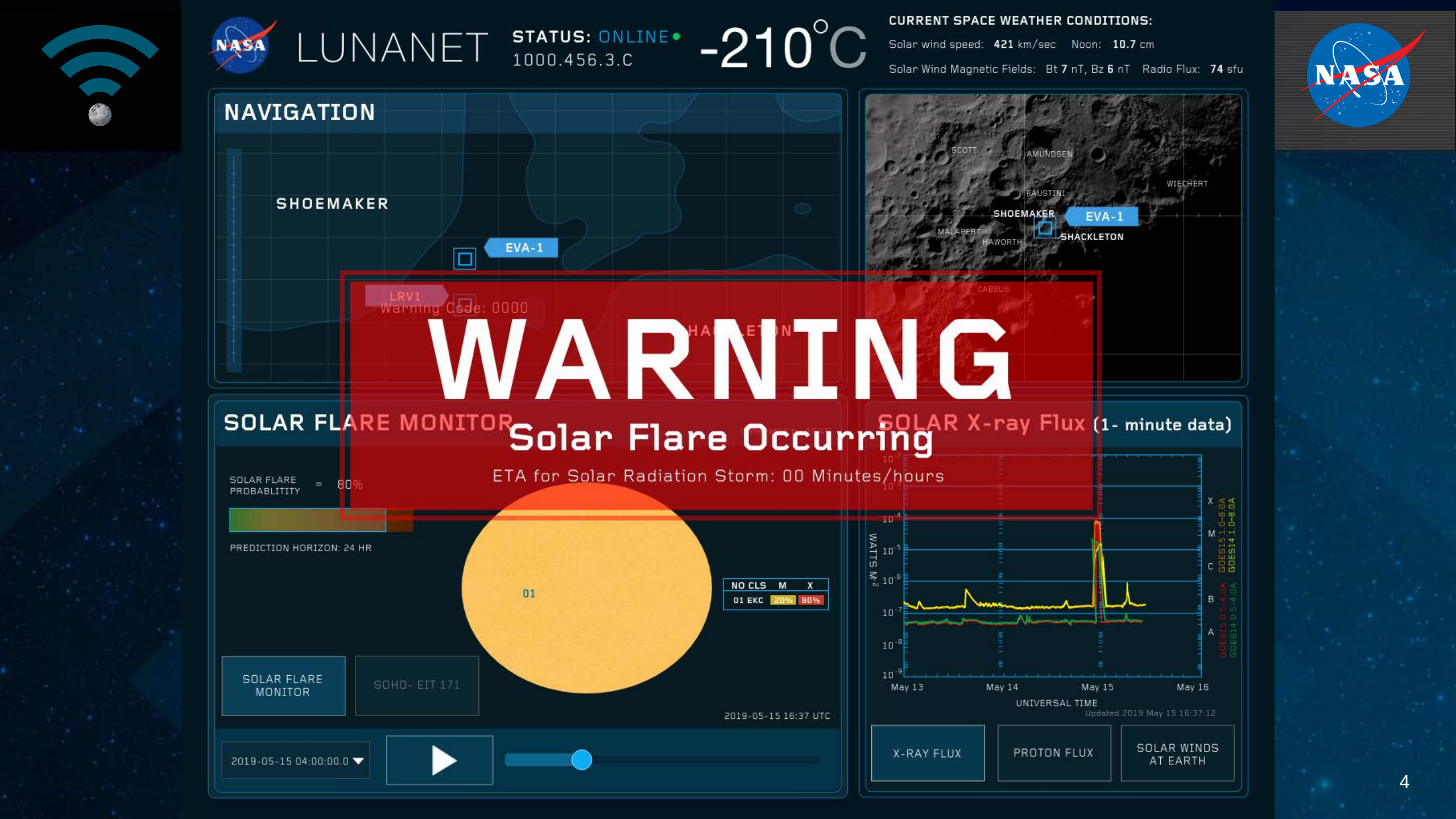
SOLAR X-ray Flux (1- minute data)



Updated 2019 May 15 16:37:12

X-RAY FLUX | PROTON FLUX | SOLAR WINDS AT EARTH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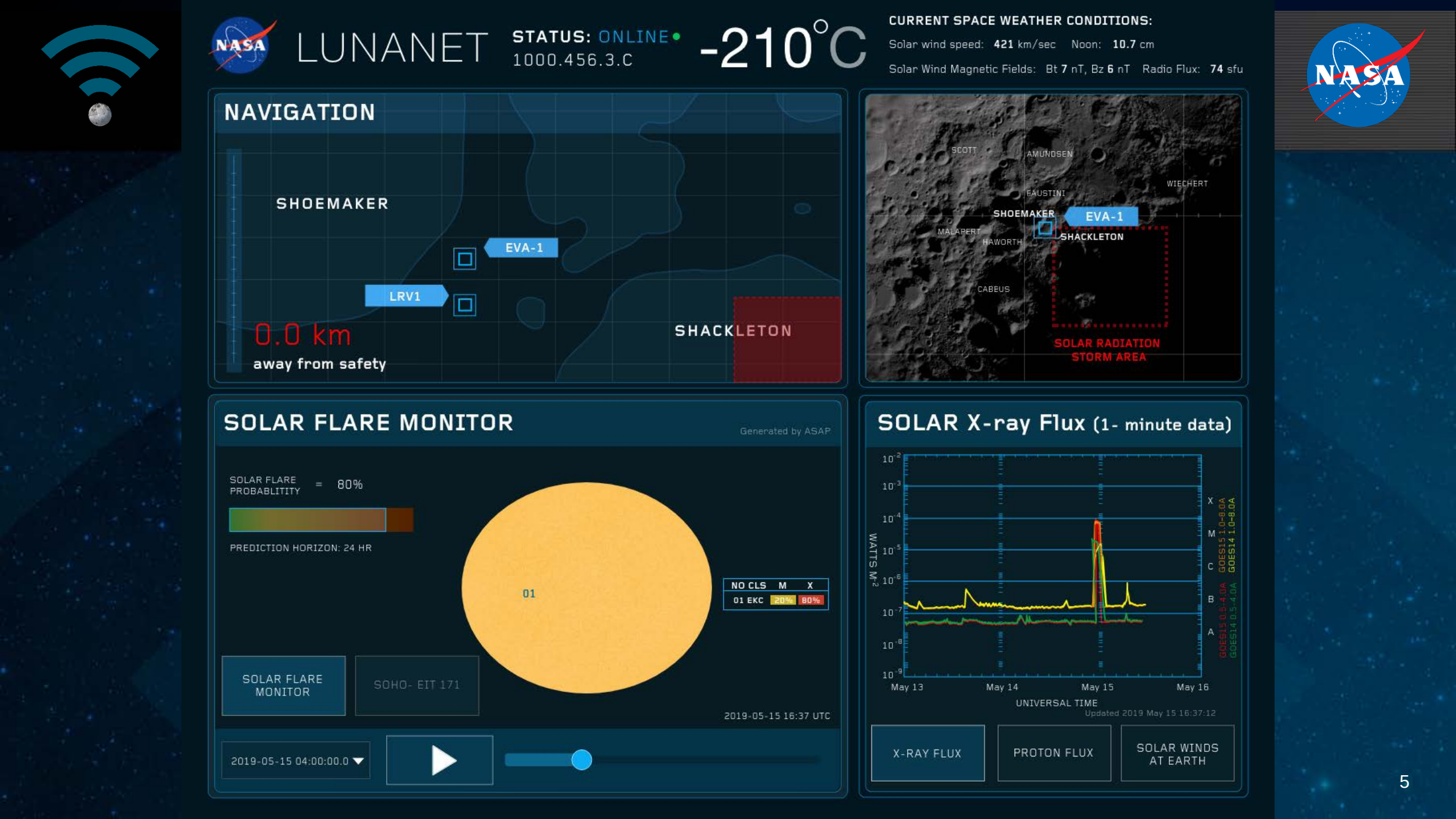
NAVIGATION
SHOEMAKER
EVA-1
LRV1
Warning Code: 0000
SCOTT
AMUNDSEN
WIECHERT
FAUSTINI
SHOEMAKER
EVA-1
MALAPERT
HAWORTH
SHACKLETON
CABEUS
WARNING
Solar Flare Occurring
ETA for Solar Radiation Storm: 00 Minutes/hours
SOLAR FLARE MONITOR
SOLAR FLARE PROBABLITITY = 80%
PREDICTION HORIZON: 24 HR
01
NO CLS M X
01 EKC 20% 80%
SOLAR FLARE MONITOR
SOHO- EIT 171
2019-05-15 16:37 UTC
2019-05-15 04:00:00.0
SOLAR X-ray Flux (1- minute data)
WATTS M-2
May 13
May 14
May 15
May 16
UNIVERSAL TIME
Updated 2019 May 15 16:37:12
X-RAY FLUX
PROTON FLUX
SOLAR WINDS AT EARTH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NAVIGATION
SHOEMAKER
EVA-1
LRV1
0.0 km
away from safety
SHACKLETON
SCOTT
AMUNDSEN
WIECHERT
FAUSTINI
SHOEMAKER
EVA-1
MALAPERT
HAWORTH
SHACKLETON
CABEUS
SOLAR RADIATION STORM AREA
SOLAR FLARE MONITOR
Generated by ASAP
SOLAR FLARE PROBABLITITY = 80%
PREDICTION HORIZON: 24 HR
01
NO CLS M X
01 EKC 20% 80%
SOLAR FLARE MONITOR
SOHO- EIT 171
2019-05-15 16:37 UTC
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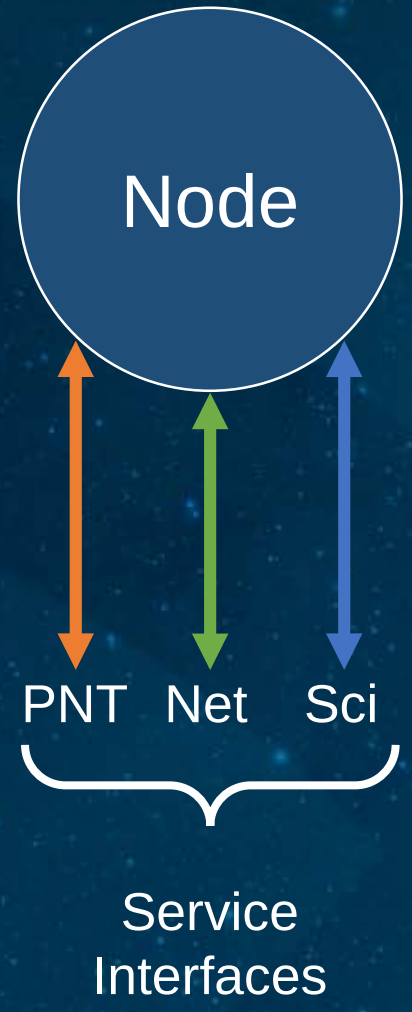
X-RAY FLUX
PROTON FLUX
SOLAR WINDS AT EARTH

Framework and Architecture

The LunaNet architecture is based on nodes capable of providing a combination of standard services.

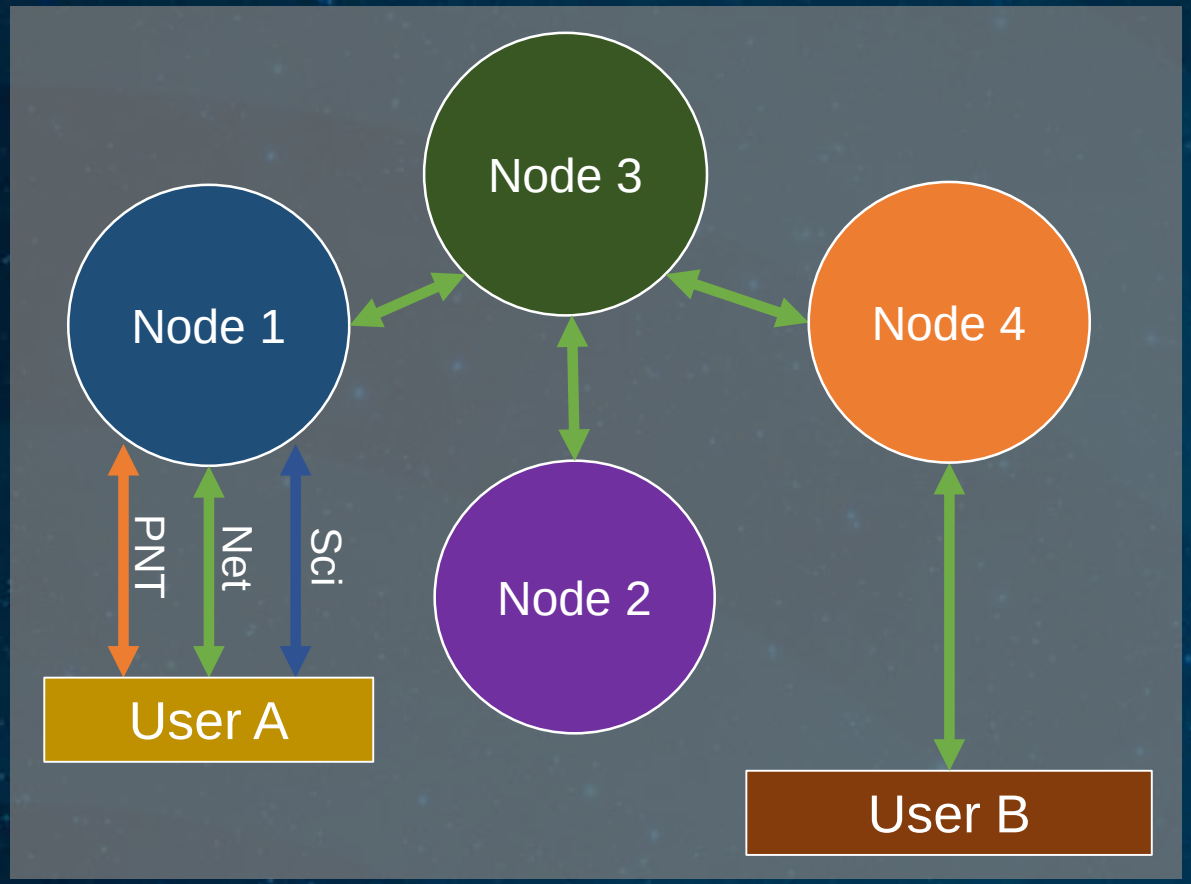
There are three standard service types:

1. **Networking Services (Net):** Data transfer services capable of moving data between nodes in a single link or over a multi-node, end-to-end path.
2. **Position, Navigation, and Timing Services (PNT):** Services for position and velocity determination, and time synchronization and dissemination. This includes search and rescue location services.
3. **Science Utilization Services (Sci):** Services providing situational alerts and science measurements for human and asset safety and protection. Science instrument data will also allow for further research, increasing return on investment overall.

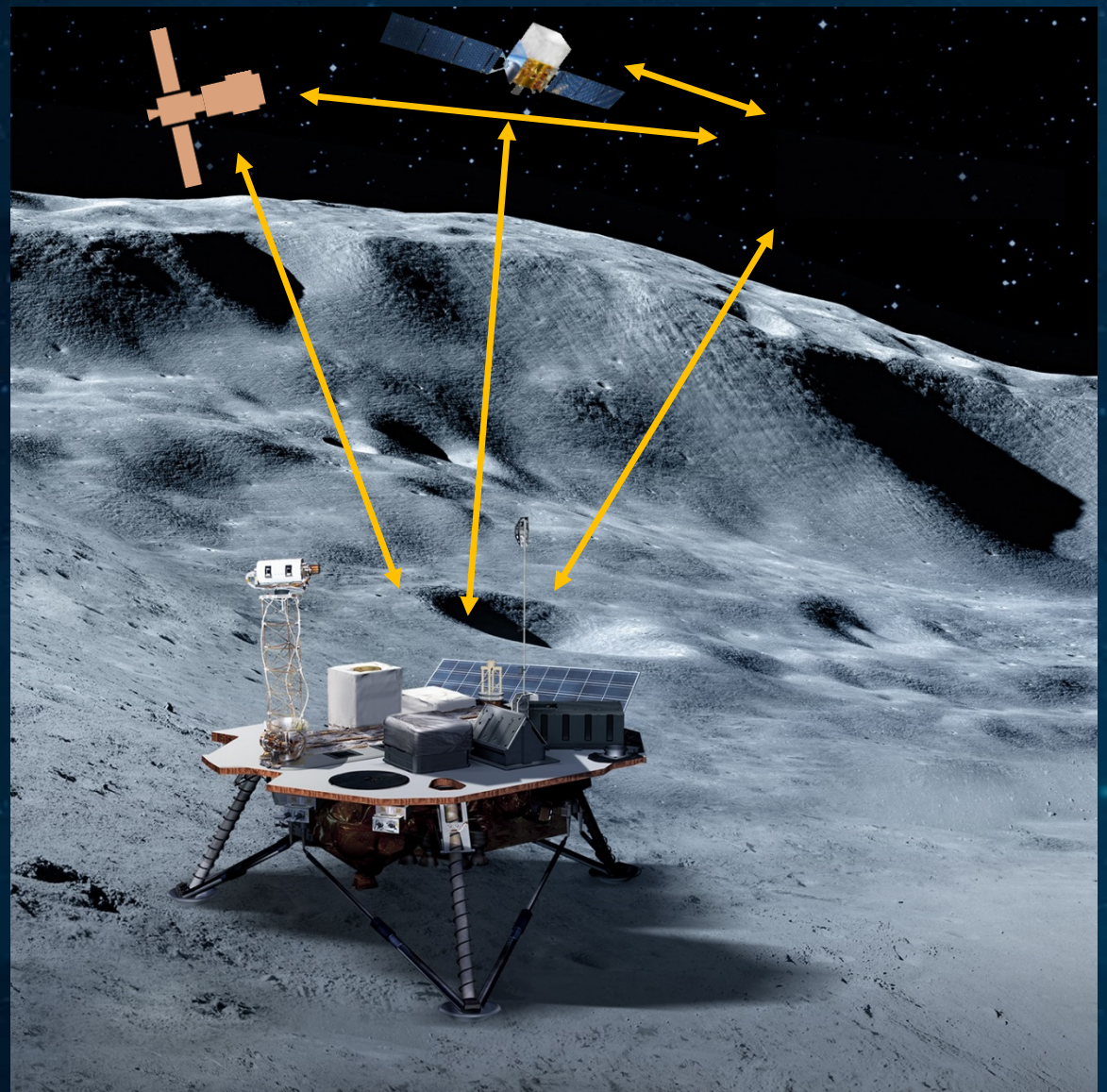


Framework and Architecture Example

1. User A communicates with User B over multiple nodes providing networking services
2. Node 1 is simultaneously providing PNT and Science Utilization Services
3. The combination of nodes could be a heterogenous set of assets:
   a. Commercial, Government, International, or other
   b. Spacecraft in any orbit or surface elements
   c. Dedicated spacecraft or hosted payloads



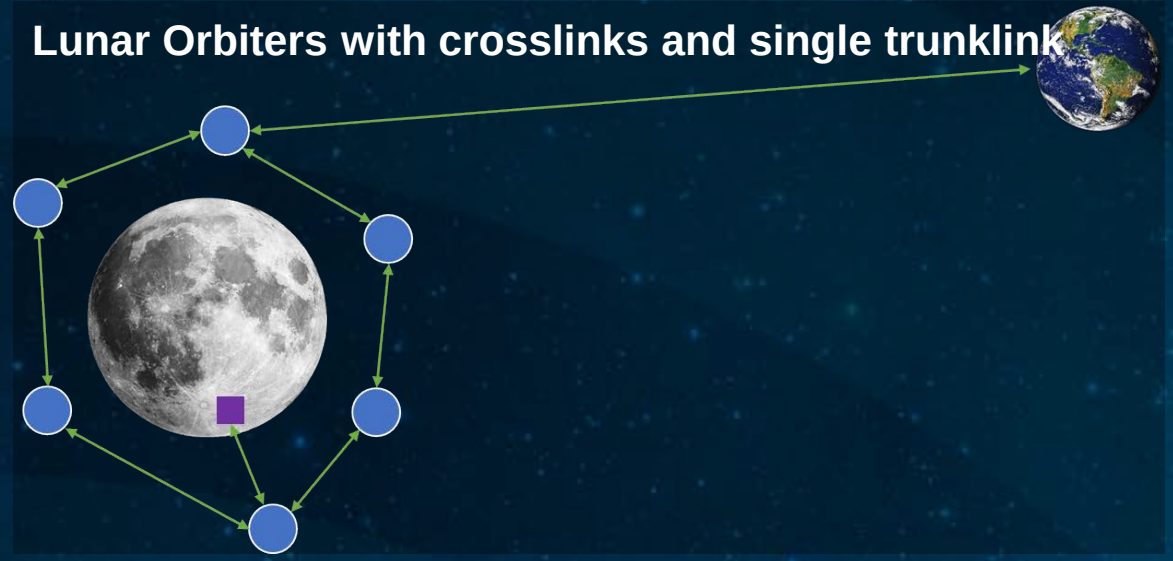
Any Link Provides LunaNet Access



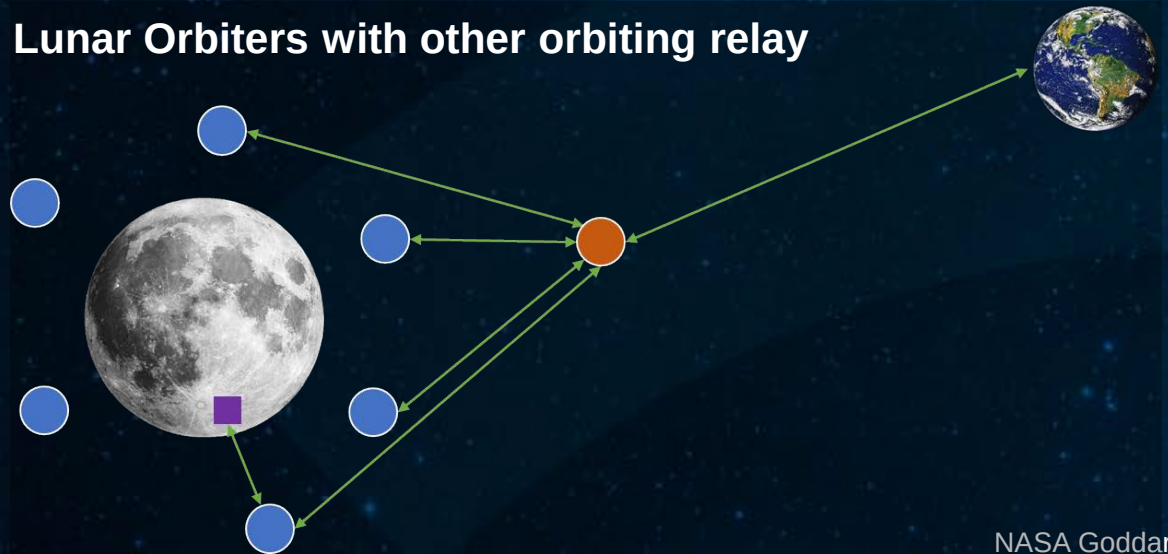
LunaNet Instantiation Examples

Direct Links to Earth Only

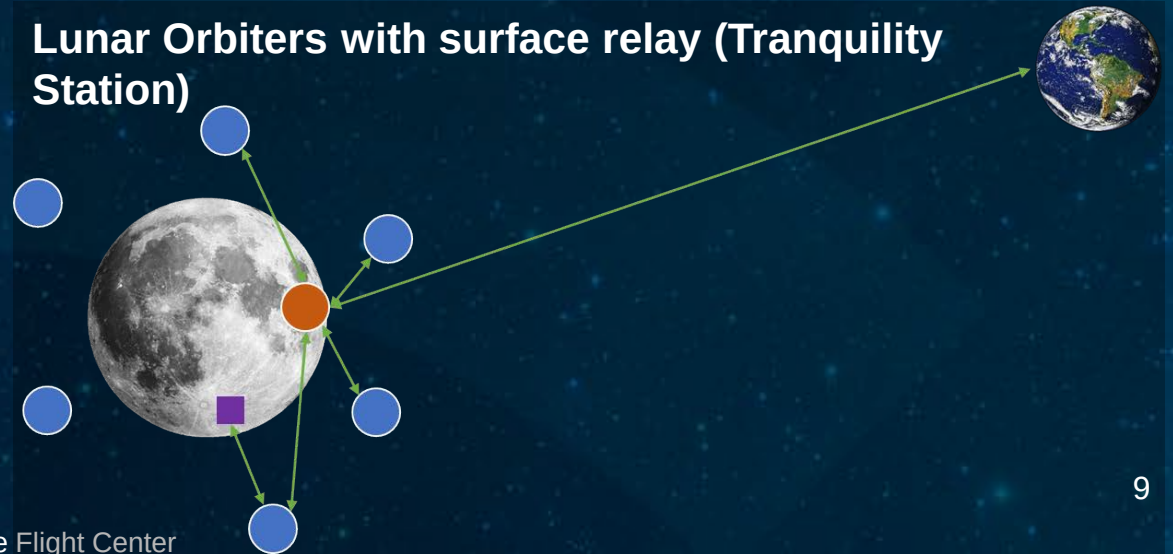
Lunar Orbiters with crosslinks and single trunklink



Lunar Orbiters with other orbiting relay



Lunar Orbiters with surface relay (Tranquility Station)



LunaNet Services: Networking

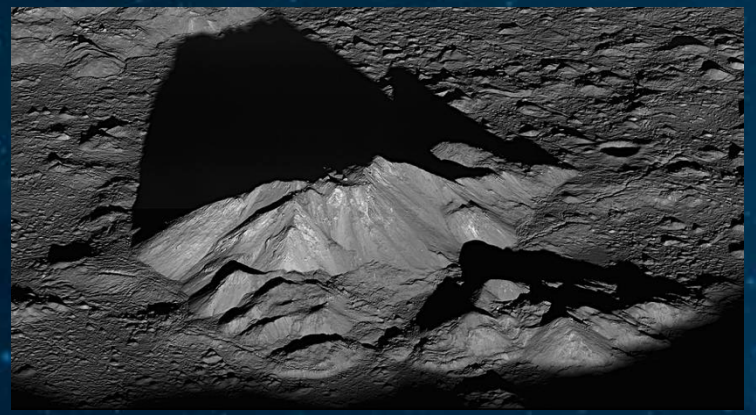
Apollo Era Communications

- Direct link with Earth available from near side of Moon for primary communications
- Telemetry transmission
- Low resolution video / voice

LunaNet

- Network-based communications capable of multi-hop store and forward data delivery (delay and disruption tolerant networking)
- Access to the network may be provided by lunar surface or orbiting relays, along with direct links with Earth
- Support for data rates high enough to carry multiple high definition video streams for multiple users

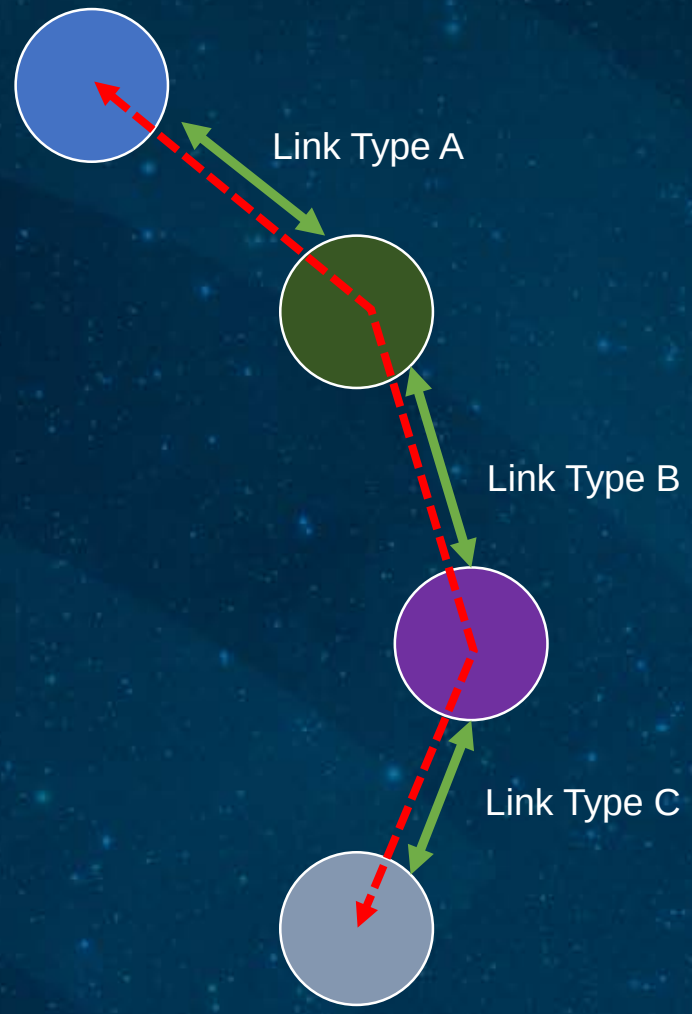
Apollo 11 Video Snap



LRO Examples

LunaNet Services: Networking

1. Data services may be provided at different *layers*:
   a. Fundamental communications capabilities will be provided by DTN Bundle Protocol-based networking services.
   b. Some portions of LunaNet may route by IP packets, but IP is not guaranteed to provide full end-to-end data delivery to all nodes in the larger network.
   c. Some intermediate nodes may switch or forward data at the link or lower layer to enable speed or interoperability.
2. Interoperability between immediate neighbors with a standardized network layer allows the LunaNet architecture to be assembled through multiple infrastructure systems independent of frequency band, type of spacecraft, or provider.
3. The security objectives of confidentiality, integrity, and availability will be applied to all data carried across LunaNet.

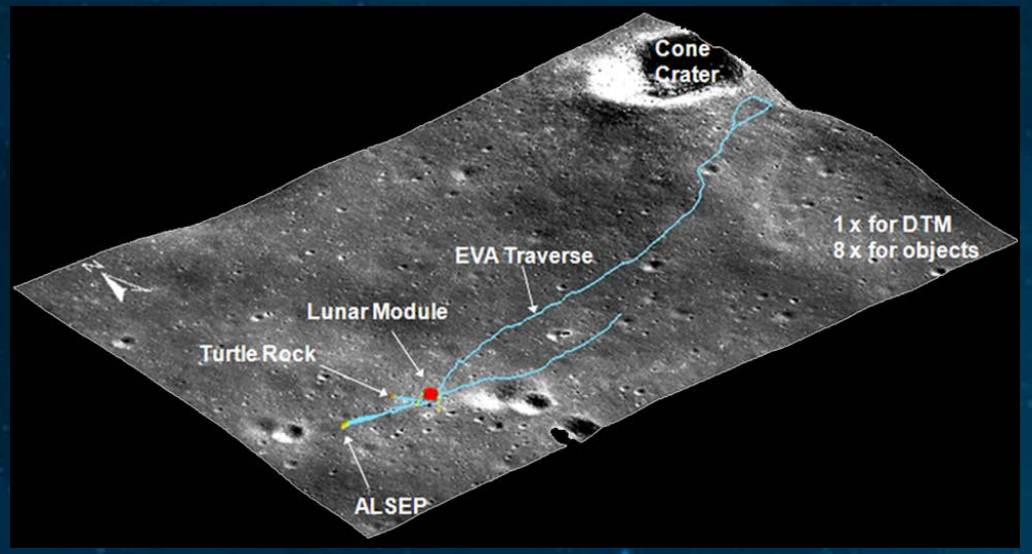


LunaNet Services: PNT

Apollo 14 EVA Example:

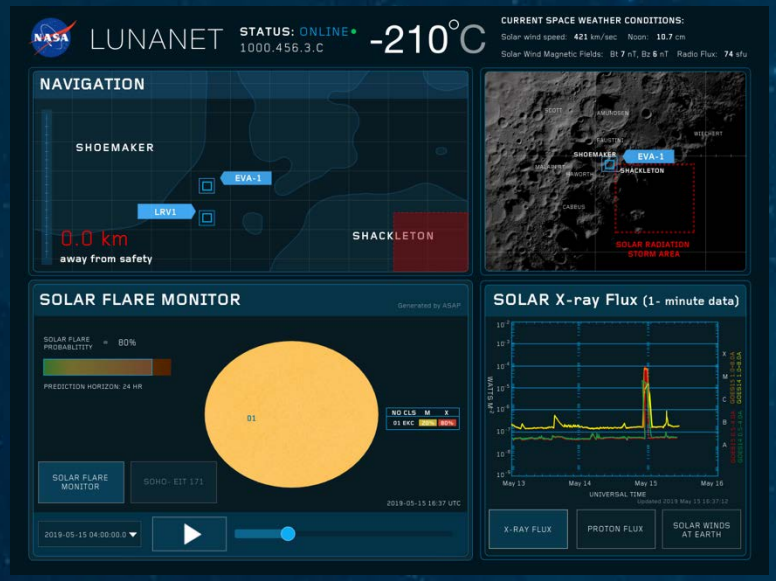
Two EVAs:

- EVA 1: Successful deployment of the Apollo Lunar Surface Experiments Package
- EVA 2: Crew hoped to reach the rim of Cone crater
  - Crew lost sight of crater rim along local ridges
  - Traditional visual landmark navigation performs poorly on lunar surface due to feature and color homogeneity
  - Had to turn back to conserve oxygen and supplies to return to lander
  - LRO high res photos revealed they were within 30 yards of rim



LunaNet

- Enables surface navigation
- Location tracking, including Search and Rescue (SAR)
- Time Reference Distribution
- Relative navigation
- Autonomy
- Time keeping and dissemination (traceability to GPS time)



LunaNet Services: PNT

Small Receiver, RF or optical, provided by Comm

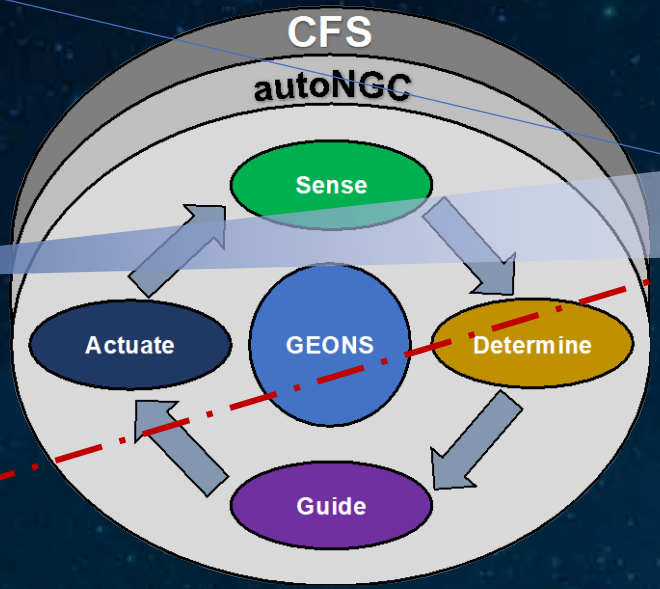
Freq Std

NavCube

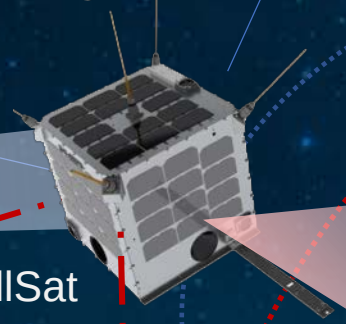
Miniature Integrated Star Tracker

While shown separately, the Frequency Standard, RF comm receiver and GNSS receiver can be integrated into one mechanical unit.

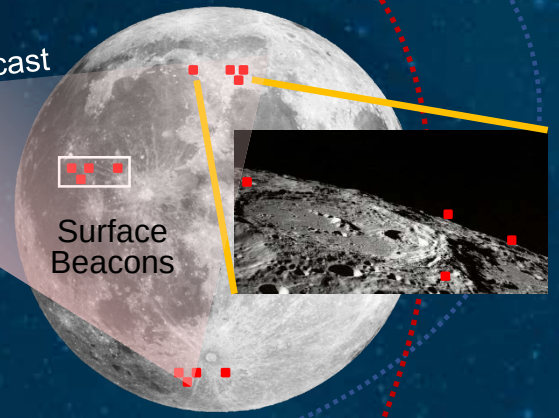
GPS Constellation, sidelobe



SmallSat



Broadcast



Earth Ground Station asset with reference time and frequency source

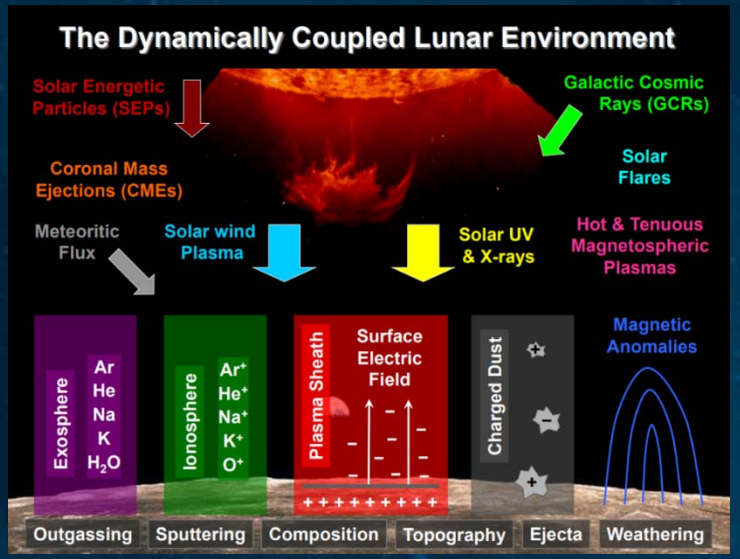
Gateway

LunaNet Services: Science Utilization

Apollo missions flew during Solar Cycle 20 – not as active as later cycles. Apollo missions flew during Solar Maximum – peak through declining phase – yet to be repeated by any subsequent missions

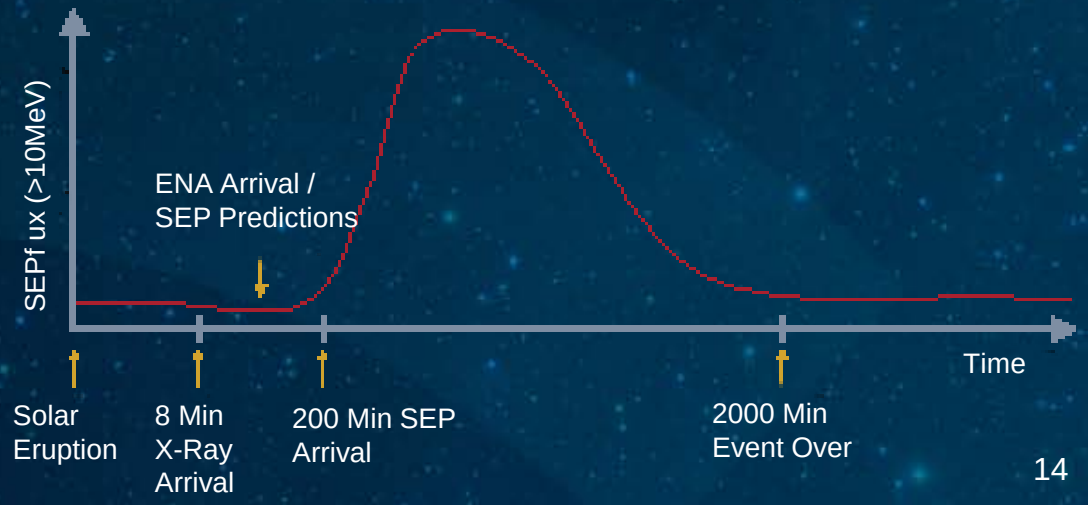
The Apollo mission fortuitously managed to avoid any truly extreme interplanetary conditions, such as the solar flares and CMEs during August 1972

In 1969, weeks after the crew returned a major Coronal Mass ejection event was recorded.



LunaNet:

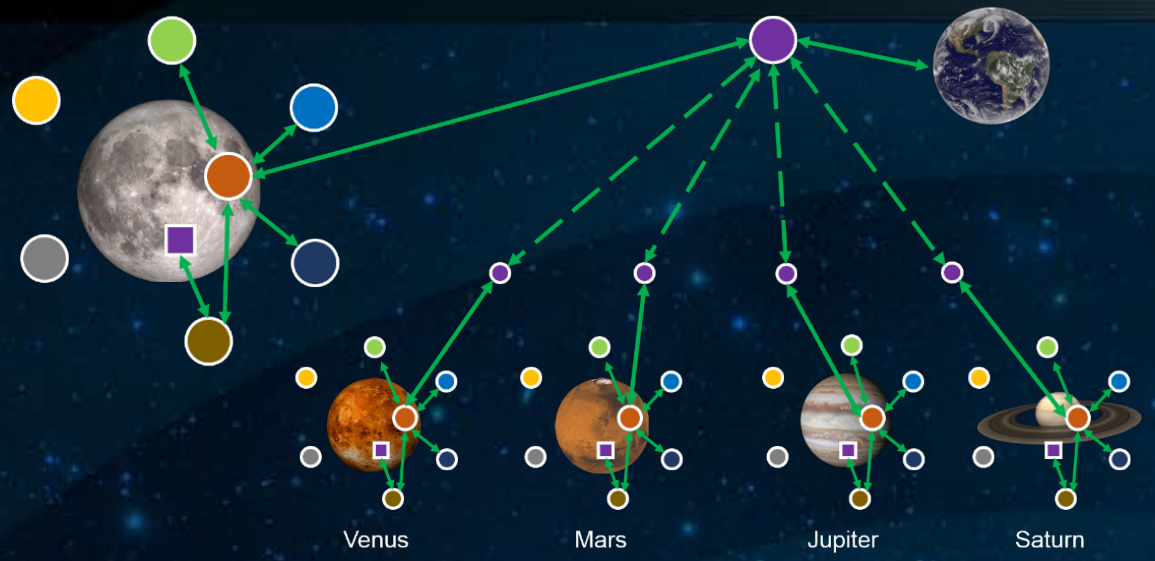
1. Early warning of solar event onset
2. Utilization of soft X-ray and Solar Energetic Particle (SEP) monitoring via a heterogeneous configuration
    1. X-rays arrive in 8 minutes after event starts
    2. Arrival of Solar Energetic Particles (SEP) in 200 minutes after event starts



LunaNet Infrastructure Disaggregation

- The LunaNet infrastructure may be comprised of nodes with varying degrees of service provision capabilities
  - Allows the LunaNet flight elements to range from smallsats to larger spacecraft
  - For example, some orbiting elements may provide PNT services only, while others may primarily provide high rate communications links
- The overall LunaNet infrastructure performance is the aggregation of all of the nodes.

Conclusions



- LunaNet is a scalable architecture for the provision of Network, PNT, and Science Utilization Services
- The infrastructure can be built up over time as mission requirements and operations concepts evolve
- Infrastructure nodes can be provided by any combination of NASA, commercial, or other partner sytems
- The LunaNet architectural approach is applicable to any planetary body to establish the Solar System Internet

Questions?

David Israel

301.286.5294
david.j.israel@nasa.gov
Exploration and Space
Communications Architect

https://esc.gsfc.nasa.gov/projects/TEMPO?tab=lunanet