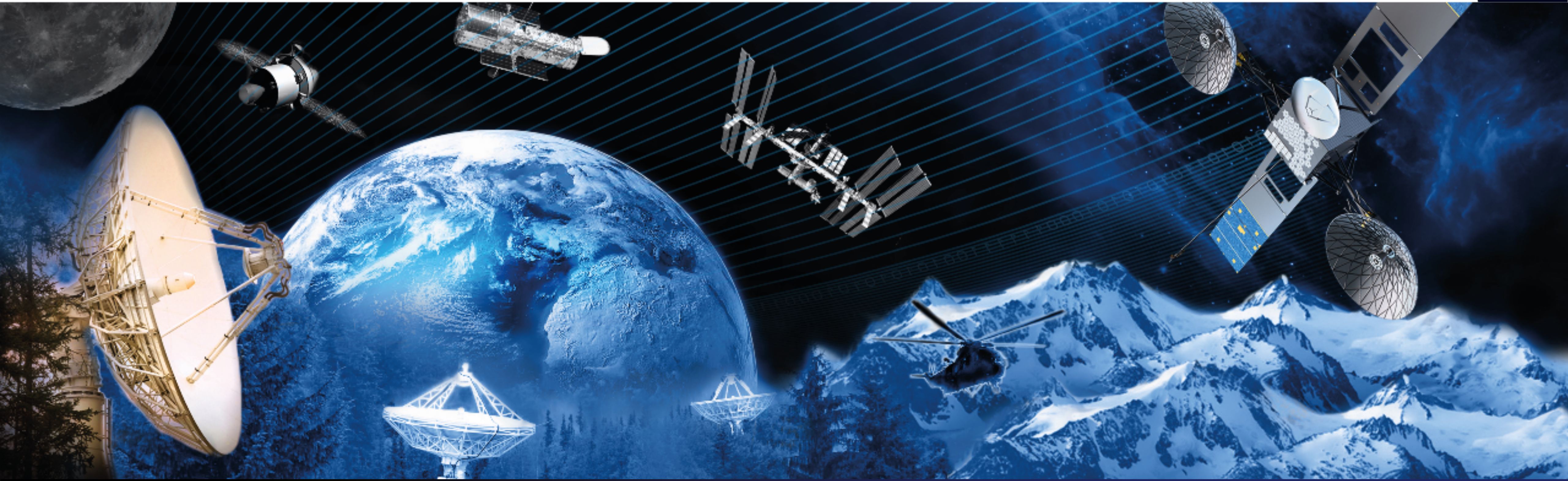
National Aeronautics and
Space Administration

ESC
Exploration & SPACE
Communications

More than you ever imagined...

LunaNet: Lunar Communications and Navigation Architecture




LUNANET
STATUS: ONLINE
1000.456.3.C
-210°C
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
NAVIGATION
SHOEMAKER
EVA-1
LRV1
SHACKLETON
SOLAR FLARE MONITOR
SOLAR FLARE PROBABLITITY = 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
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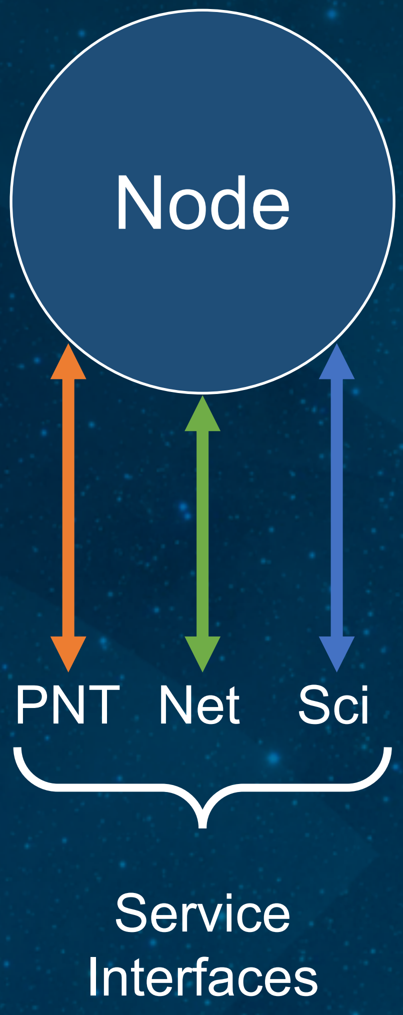
SOLAR X-ray Flux (1- minute da
WATTS M-2
May 13
May 14
May 15
UNIVERSAL TIME
X-RAY FLUX
PROTON FLUX

Framework and Architecture

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

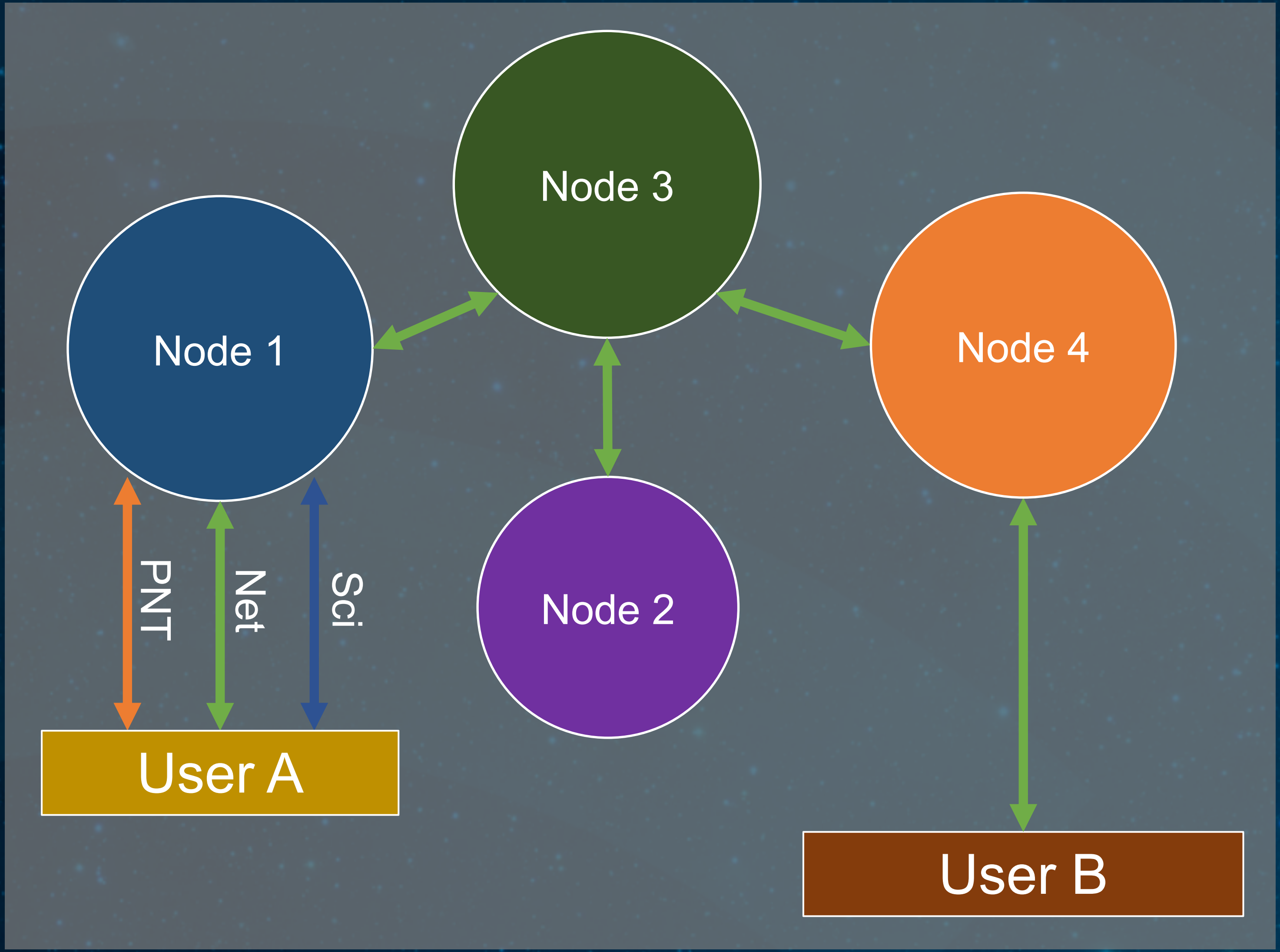
There are three standard service types:

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.



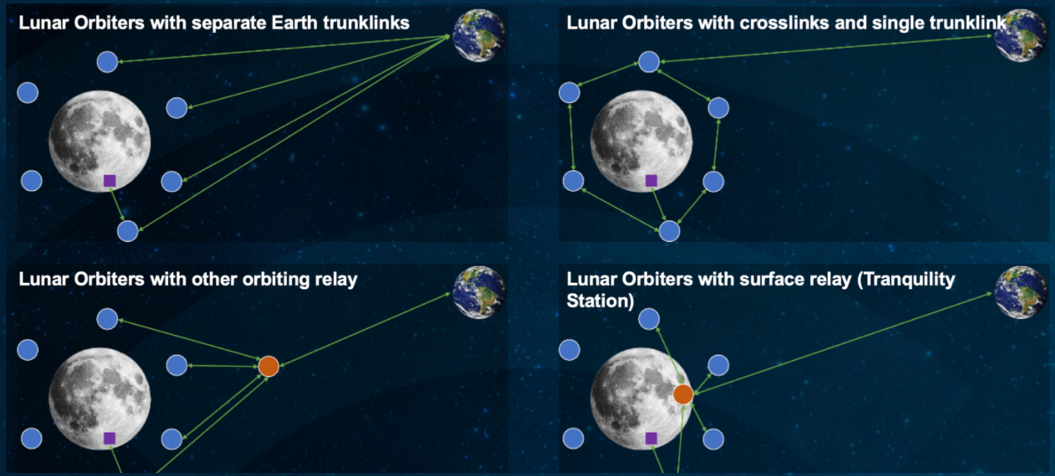
Framework and Architecture Example

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



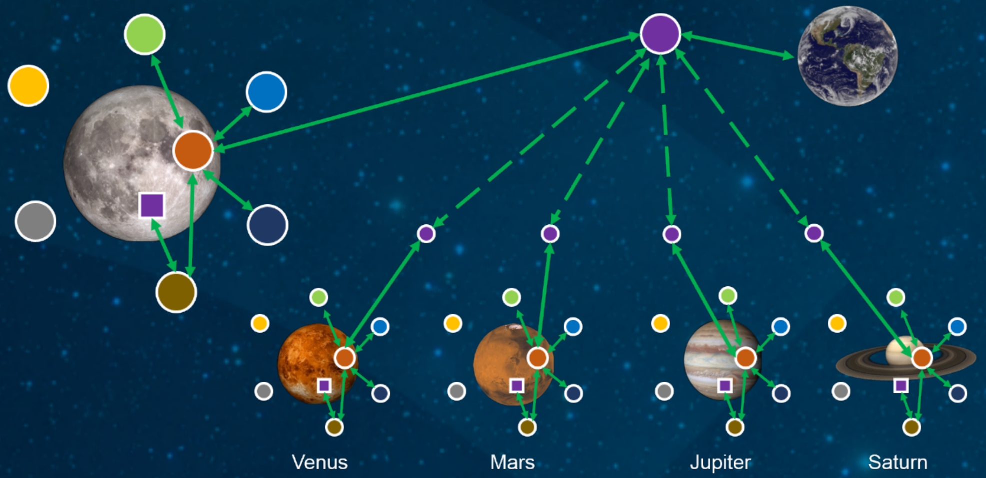
Scalable Architecture Approach

1. Establish Approach
   a) Instantiation of the Space Mobile Network framework, fully consistent with NASA SCaN architecture and the currently defined International Lunar Communications Architecture.
   b) Initial investment into solar system architecture
   c) Reduces risk for commercial elements
   d) Fosters commercially sourced supply chain for components, subsystems, services, and other needs.
2. Initial Capability
   a) Leverages existing technology and components
   b) Operations demonstrations and first uses
   c) Establishment of organizations and organizational interfaces
3. Established Infrastructure
   a) Increased coverage and performance driven by user needs
   b) Defined standard, roles, and ops concepts to enable broader partnerships, including commercial elements
4. Extended Infrastructure
   a) Coverage and performance increased based on user needs
   b) Built out through combination of element providers leveraging available resources



LunaNet Architecture Highlights

LunaNet Scales to the *Solar System Internet*



Communications - Networking

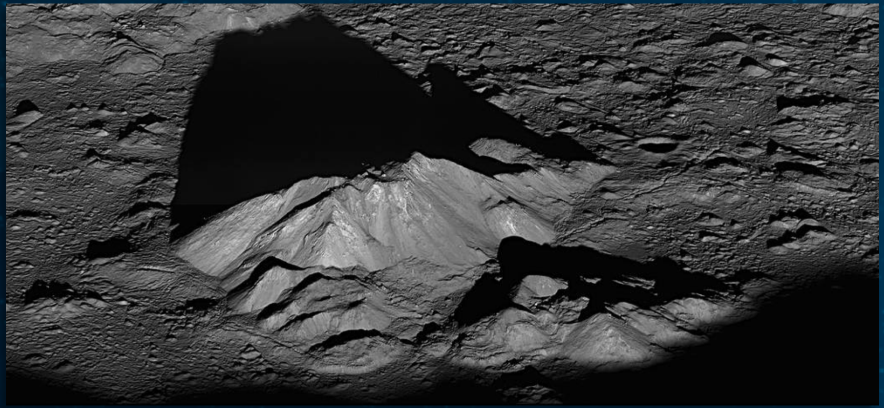
Unified S-Band System Developed for Apollo

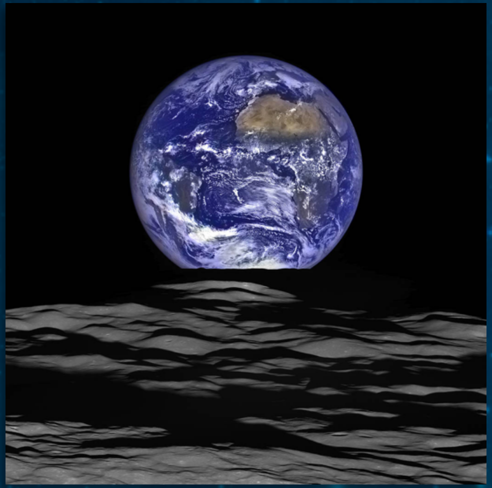
1. Combines Tracking, Telemetry, and Control into one system
2. Added capability for voice and television, emergency comm.
3. Was capable of 51.2 kilobits/sec telemetry transmission
4. Low resolution video / voice

LunaNet

1. High definition video
2. Relay data between assets / spacecraft
3. Multi-hop store and forward networking (delay and disruption tolerant)
4. Data aggregation and distribution

Apollo 11 Video Snap





LRO Examples

Position, Nav and Timing (PNT)

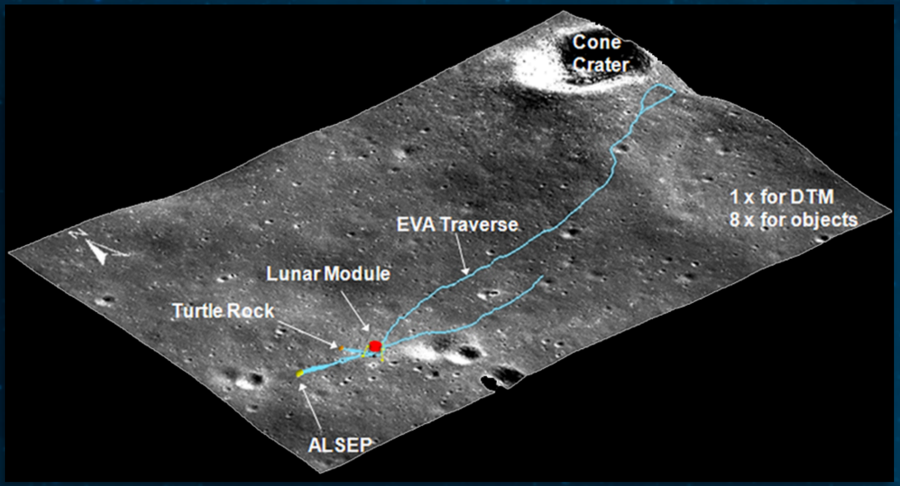
Apollo 14 EVA Example

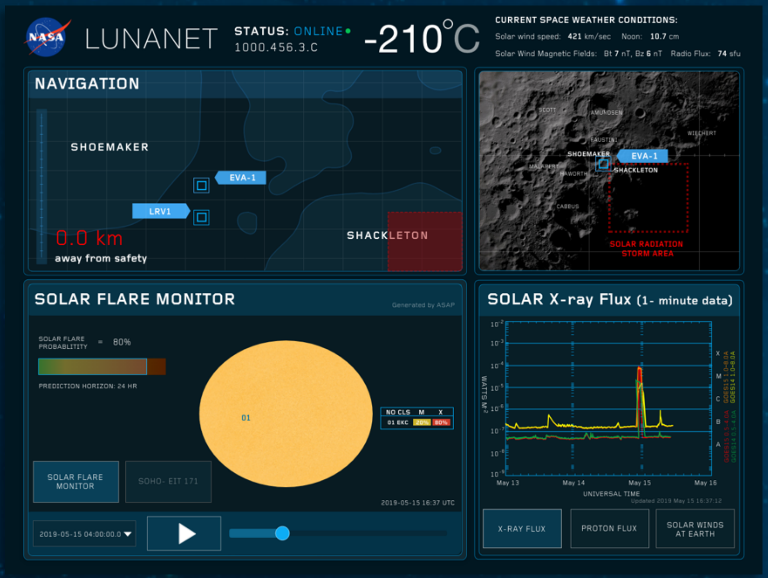
Two EVAs:

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

LunaNet

1. Enables surface navigation
2. Location tracking, including Search and Rescue (SAR)
3. Time Reference Distribution
4. Relative navigation
5. Autonomy
6. Time keeping and dissemination (traceability to GPS time)





Science Utilization: Deep Dive

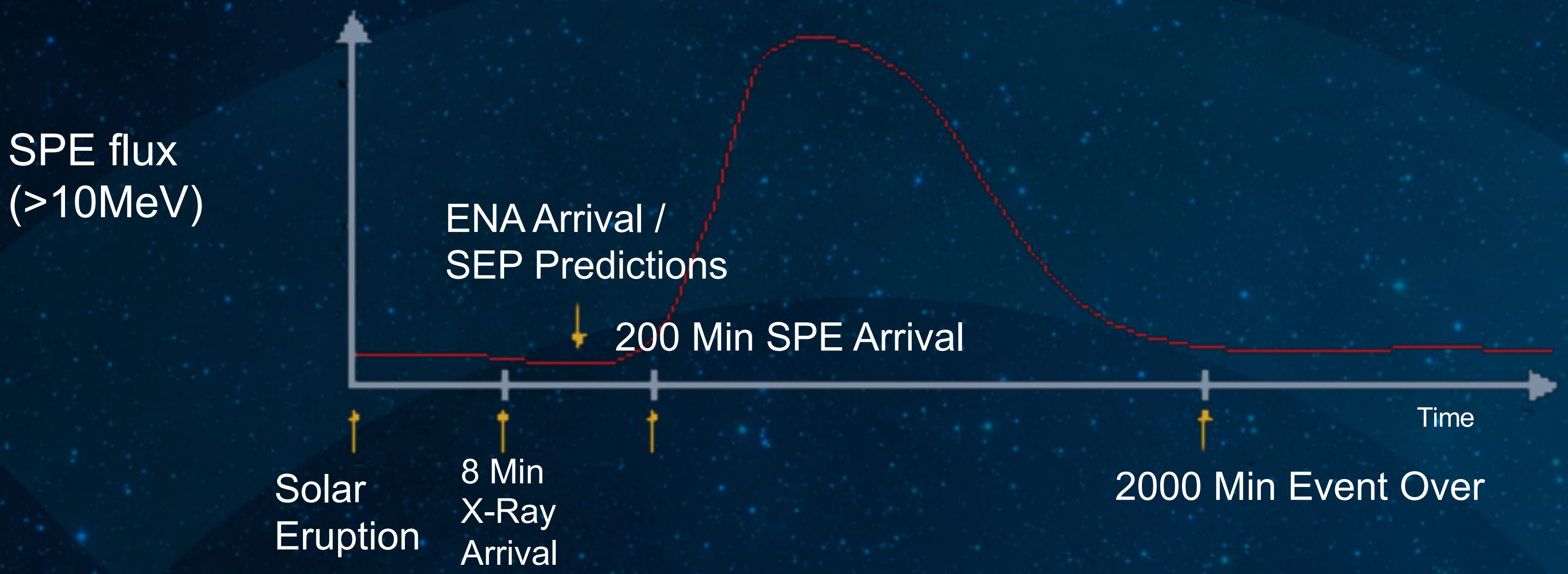
Science Utilization Services – Space Weather

1. Protecting spacecraft crews from energetic space radiations that can cause both chronic and acute health risks will be a critical issue for missions beyond low Earth orbit.
2. Exposure to Solar energetic Particle Events (SPEs) can lead to acute ration syndrome effects that can be mission- or life-threatening.
3. An important component of reducing this risk is to provide real-time space weather information to potentially vulnerable crews so they can seek shelter.

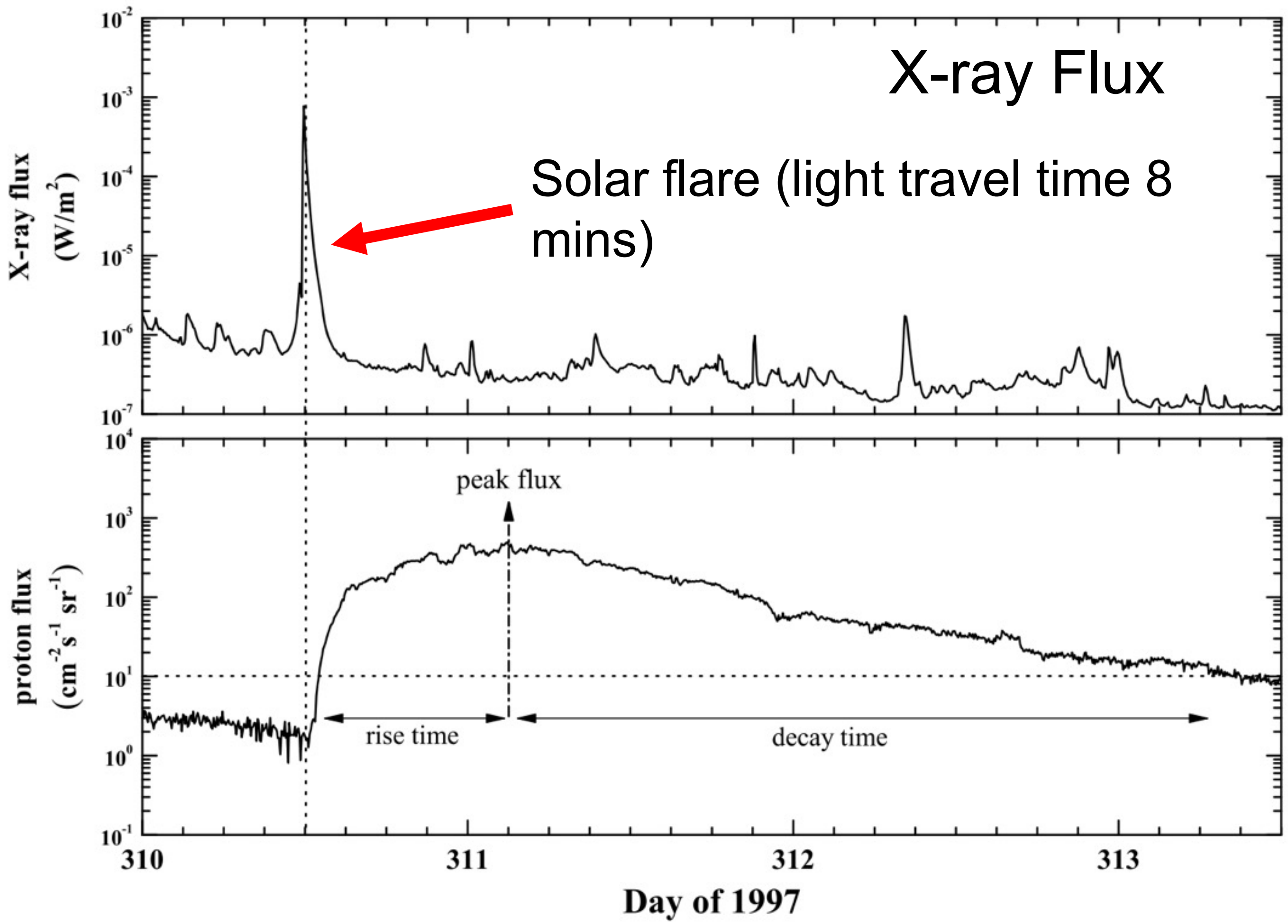
Science Utilization Services – Space Weather

There are three key parameters to guide crew action in deep space missions (*Parker et al.,* 2018):

- Solar X-ray detection indicating that a major eruption has taken place.
- Predictive information about a possible associated solar energetic particle (SEP) event.
- Observation of the onset and progress of the SEP event at the location of the vehicle.



X-ray Flux

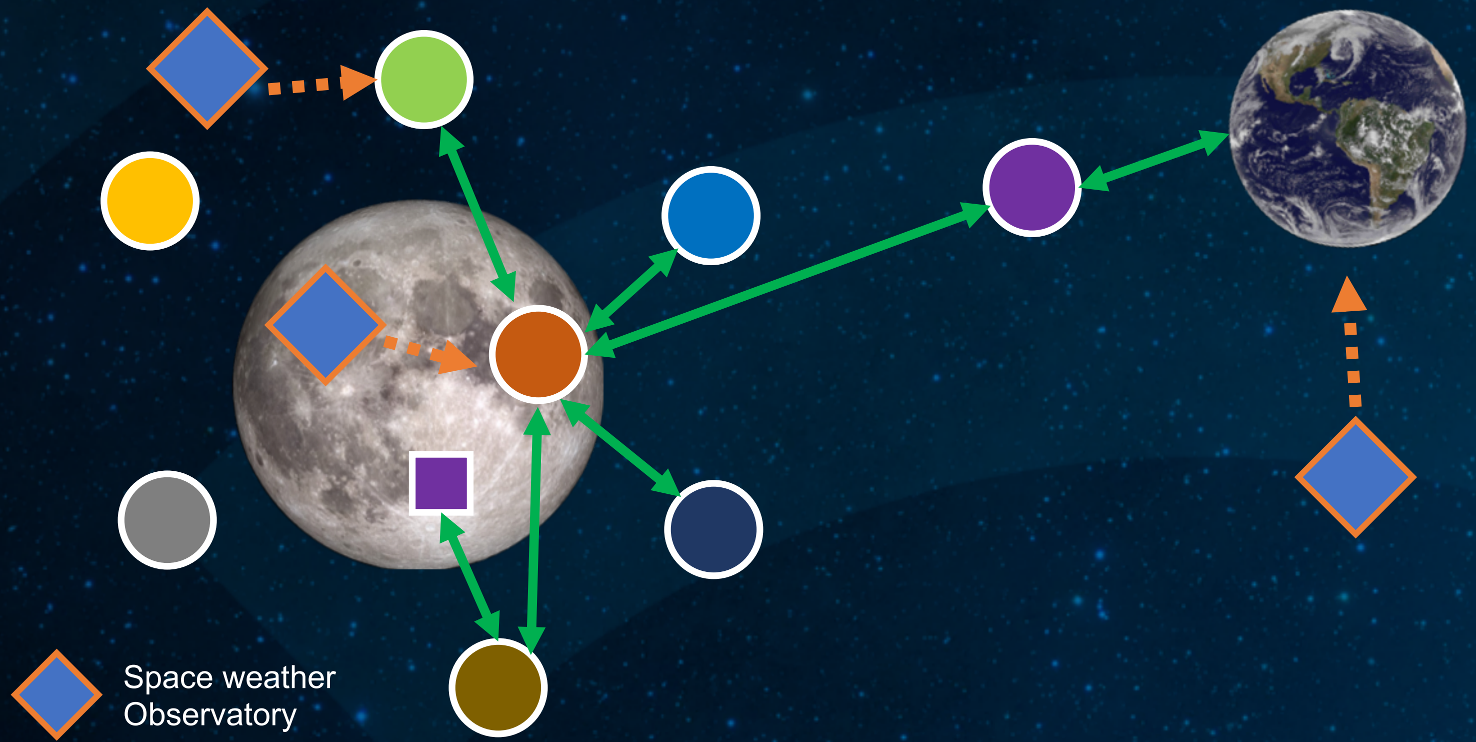


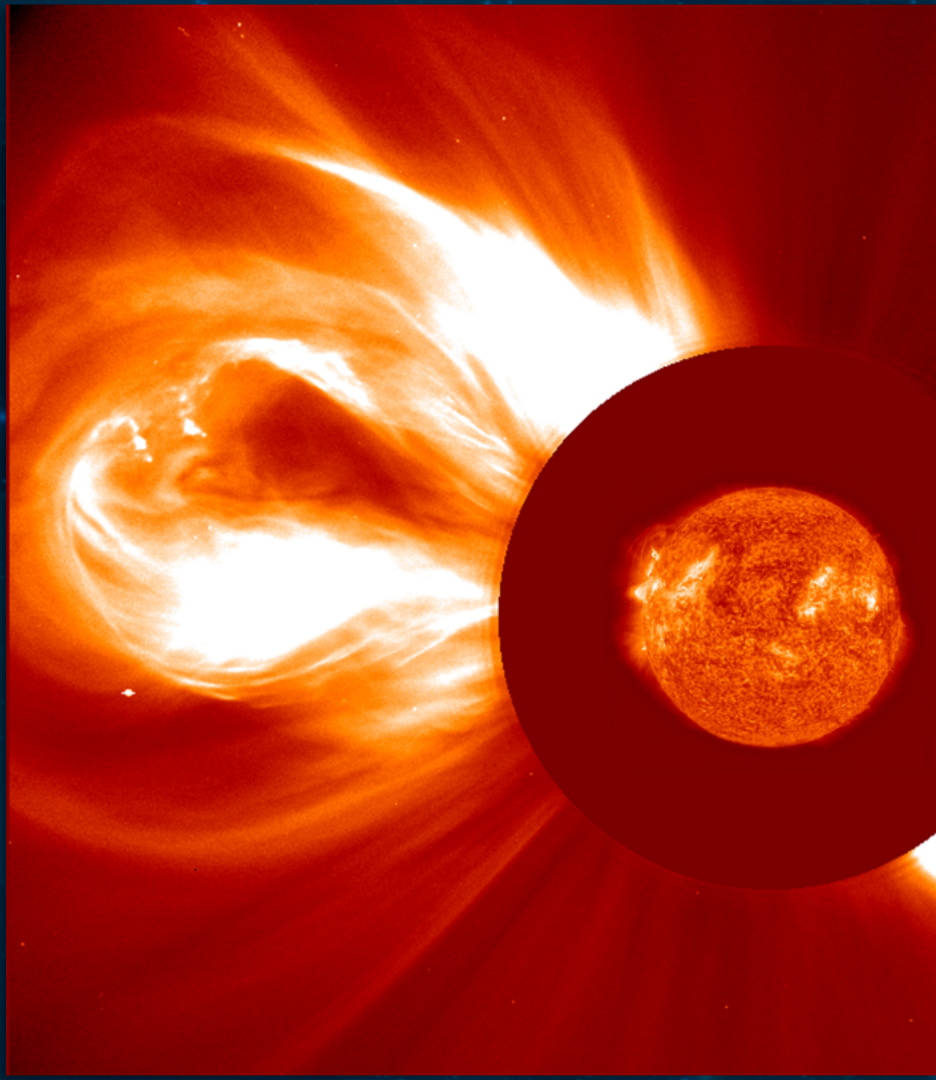
(top) GOES X-ray flux and (bottom panel) solar proton flux of a well-connected SPE on 6 November. The dot vertical line indicates the peak time of its d X-ray flare. The dot horizontal line indicates the threshold (10 pfu) of SPE.

LunaNet Supports Space Weather

Observatories communicating to LunaNet with space weather information.

1. Some may have better view of the event than others
2. Some may only provide part of the information needed.



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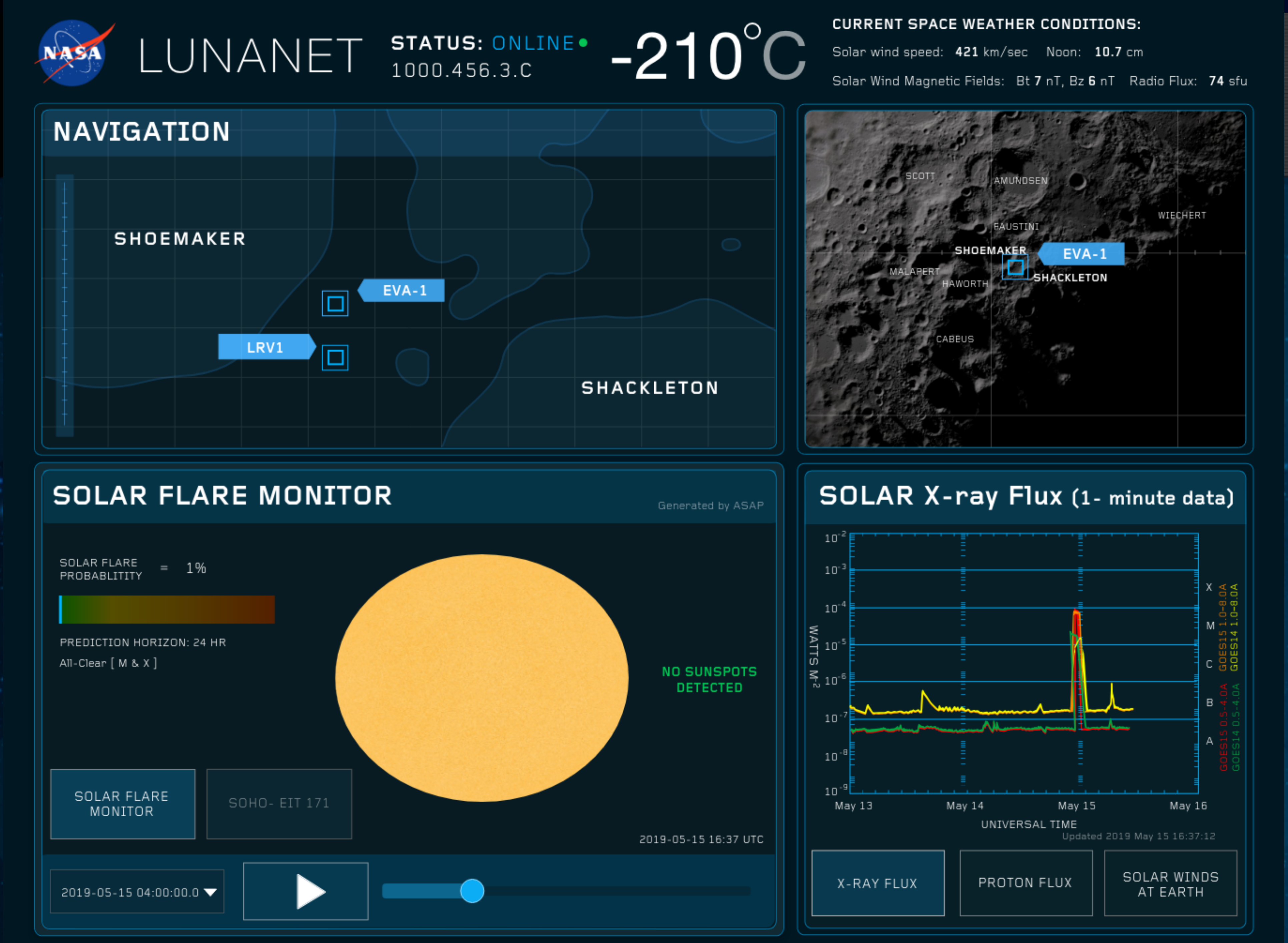
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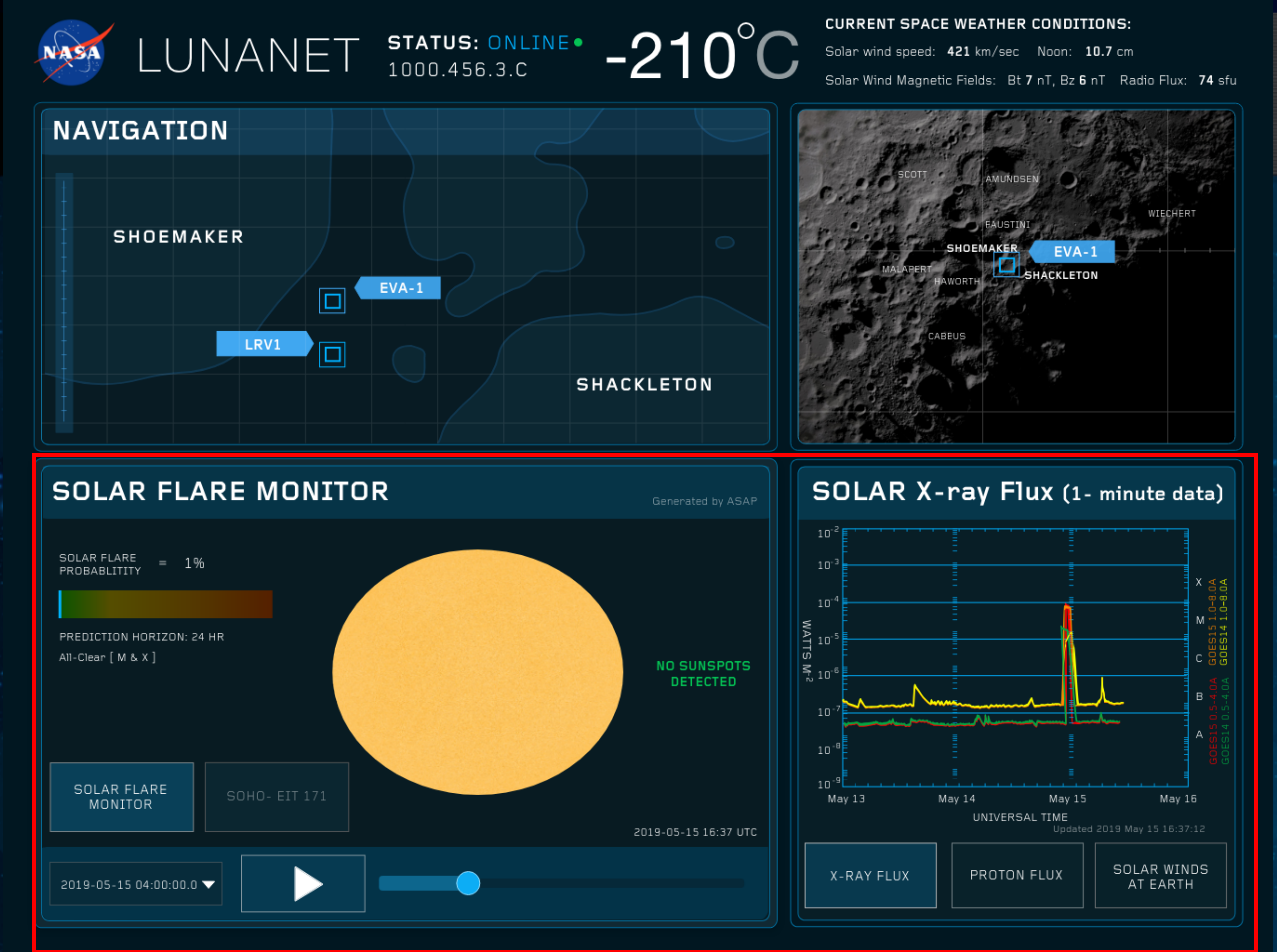
SOLAR WINDS AT EARTH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GOES14 1.0-8.0A
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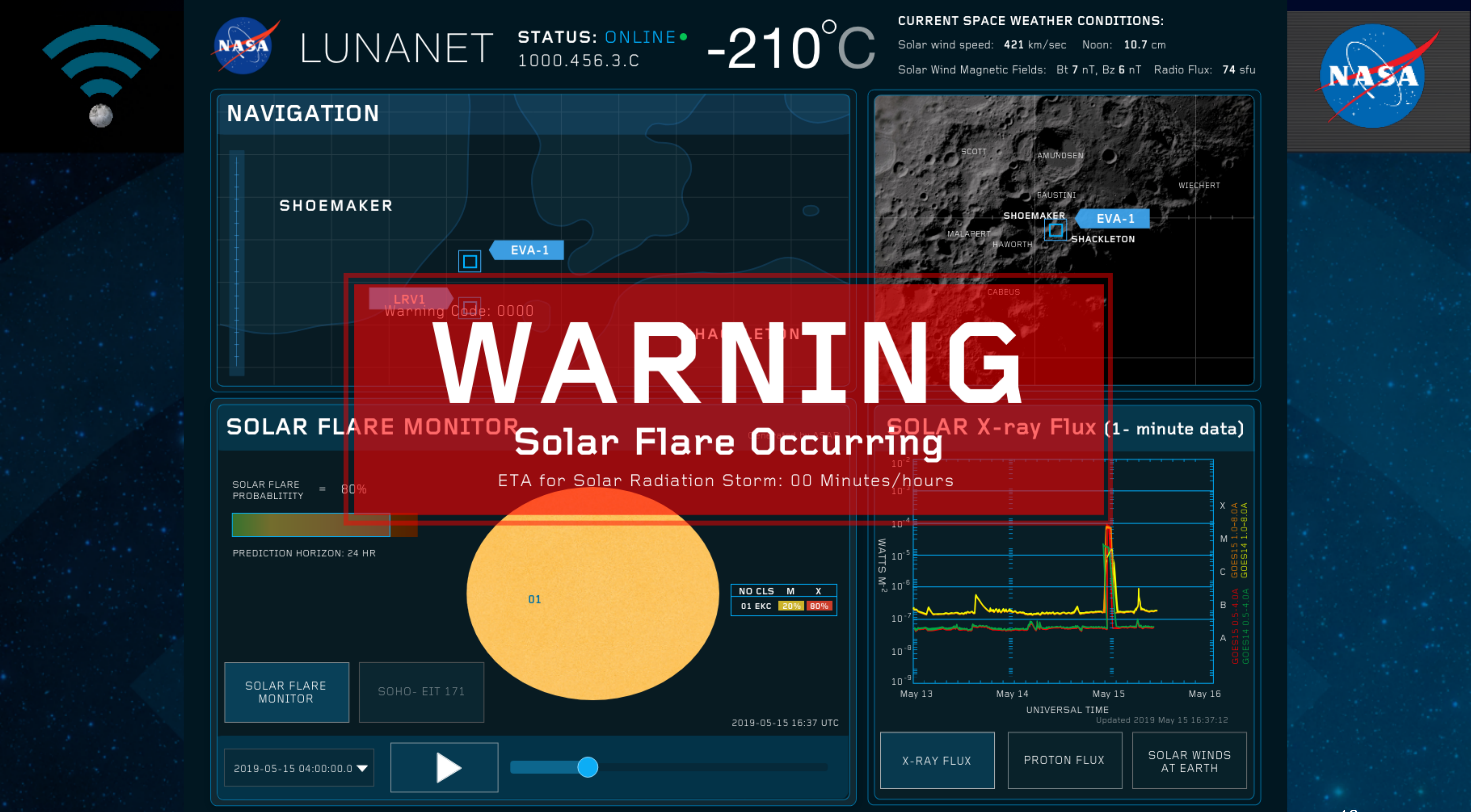
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EVA-1
MALAPERT
HAWORTH
SHACKLETON
CABEUS
Warning Code: 0000
WARNING
Solar Flare Occurring
ETA for Solar Radiation Storm: 00 Minutes/hours
SOLAR FLARE MONITOR
SOLAR FLARE PROBABLITITY = 80%
PREDICTION HORIZON: 24 HR
01
NO CLS M X
01 EKC 20% 80%
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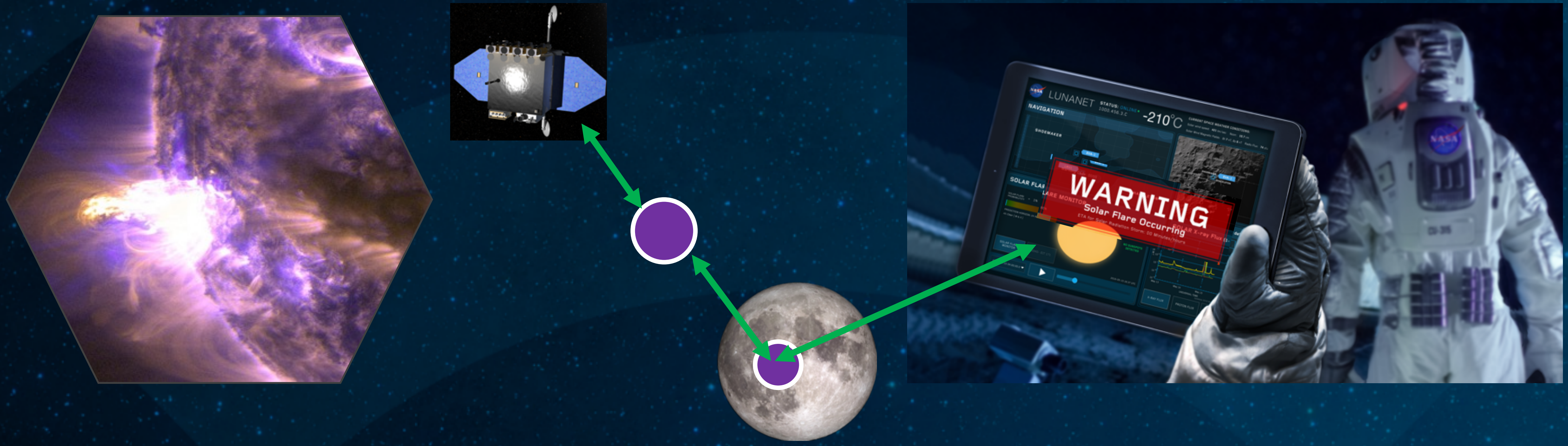
Summary

LunaNet provides an ideal platform to support space weather data.

1. Real-time and reliable information will be critical to astronauts. LunaNet infrastructures provides the infrastructure to disseminate that information.
2. LunaNet nodes might host payloads to gather space weather observations.



LUNANET

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