CHARACTERIZING THE LUNAR NIGHT SURVIVAL CHALLENGE

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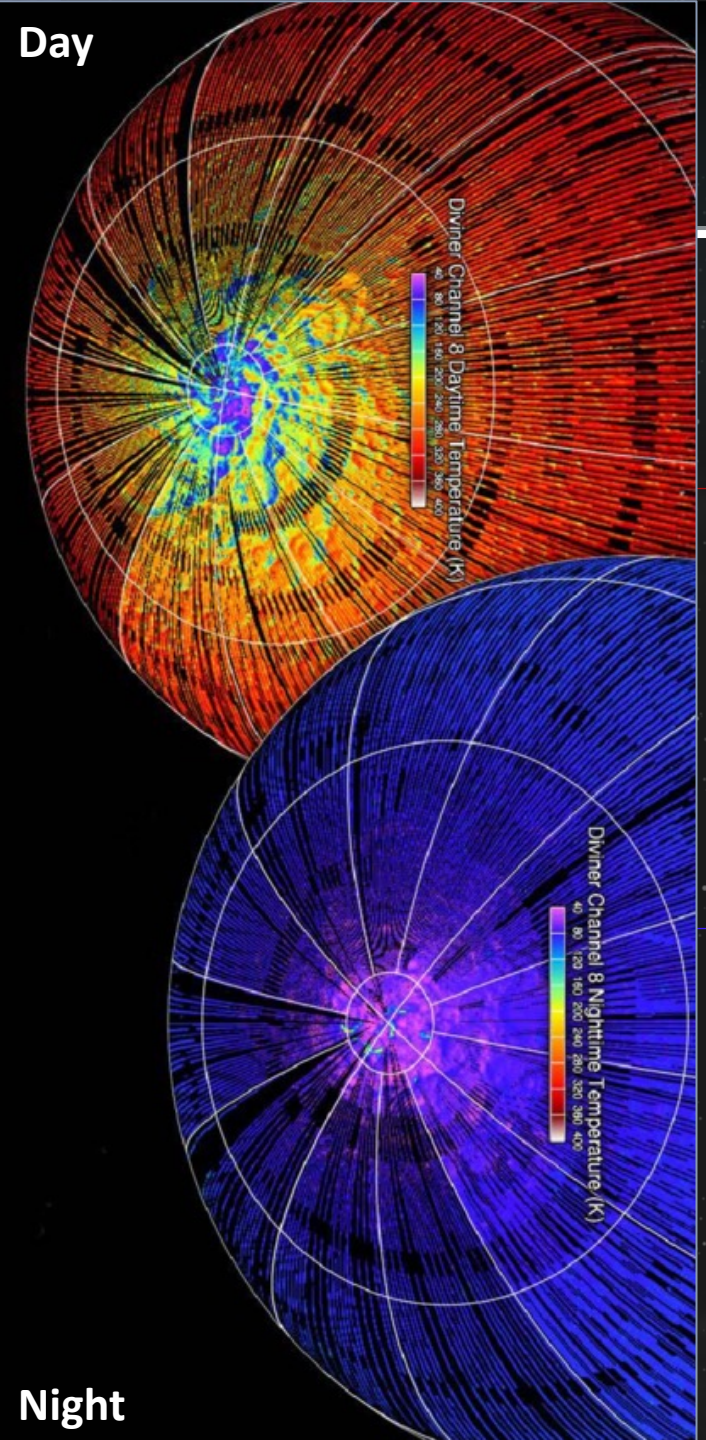
Lunar Night as an Operational Environment

- The Moon is an extremely hostile environment for both humans and tech

Communications	Very little comms. infrastructure past GEO
Landing	Always risky, most landers untested
Regolith	Properties largely unstudied, very sharp, gets everywhere, plumes
Vacuum	Lack of atmosphere
Radiation	No protective atmosphere to deflect high-energy radiation
Lack of Maintenance	If spacecraft power fails, no way to resolve issues
Irregular Solar Exposure	Lunar day and night last 14 days each
Thermal Fluctuations	Temperatures range from -180°C to 120°C, and change rapidly from day to night
Electric Charging	Surface subject to multiple types of charging events
Moonquakes	Moonquakes due to impacts, geological activity and thermal flux

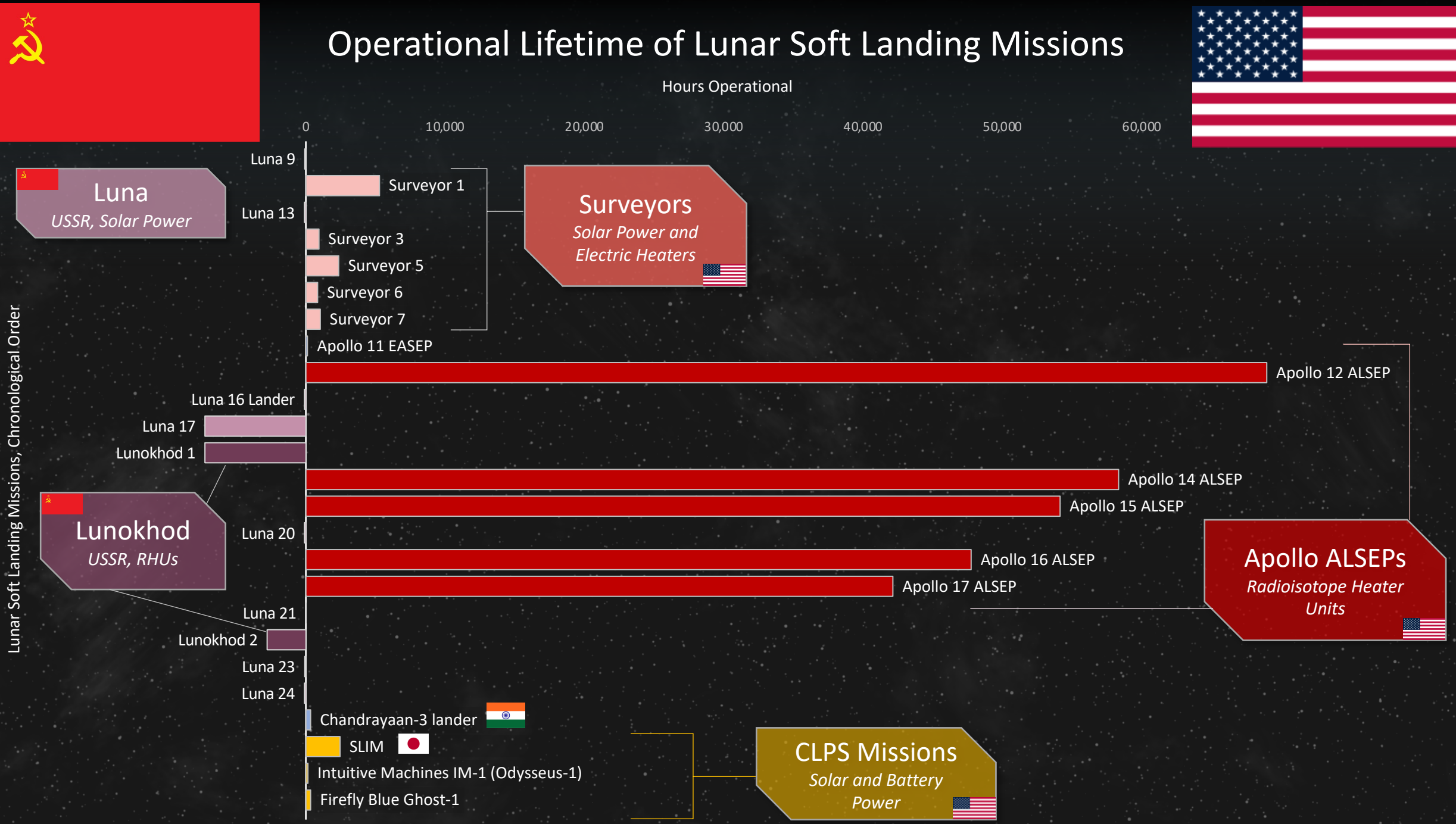
- Service providers need to survive all of these challenges and more



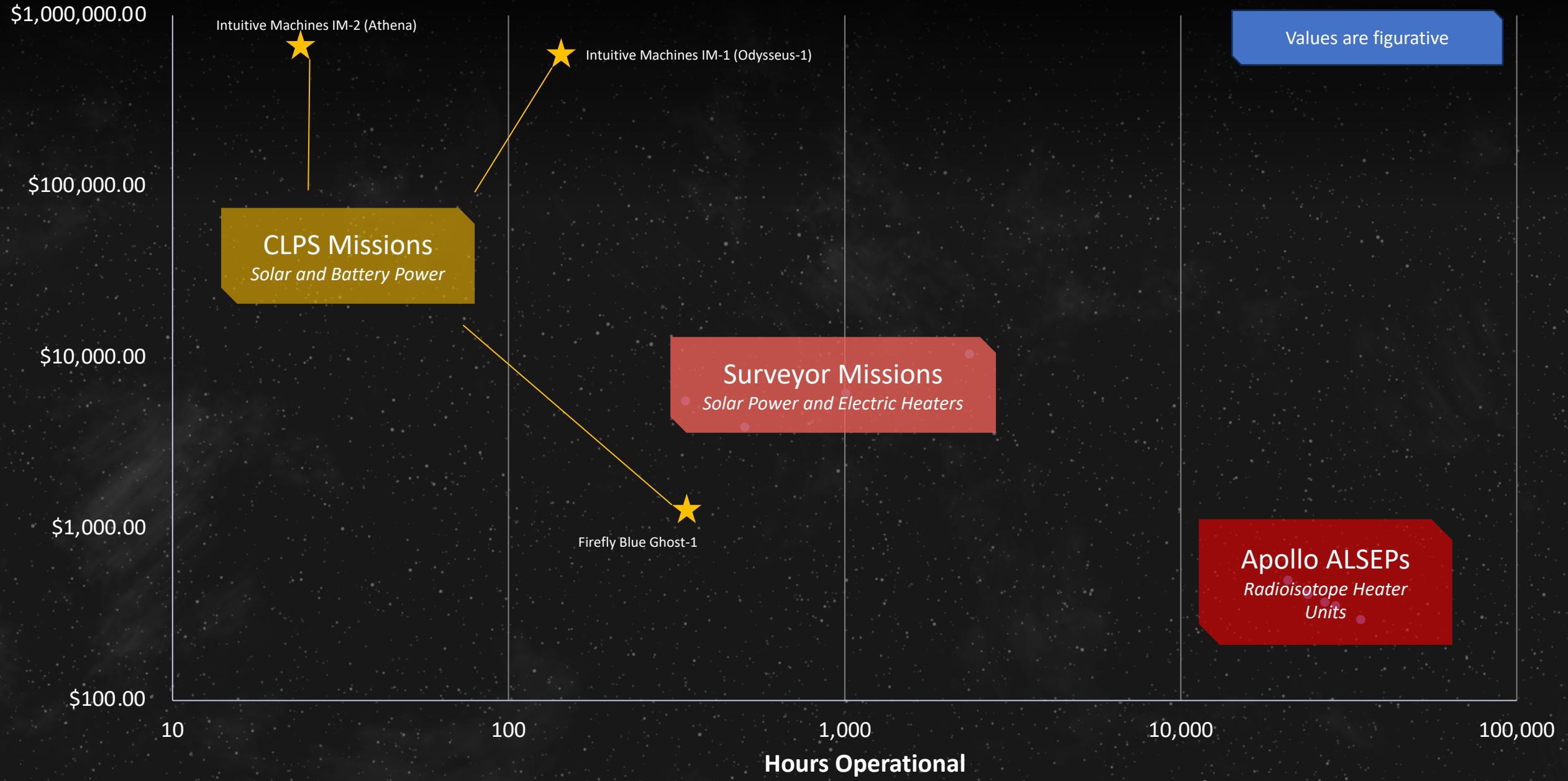
Impacts on Technology

- Electronics
  - Electrical Resistivity decreases at low temperatures
  - Components such as DC/DC converters lose stable voltage regulation, increasing chance of shorts
  - Semiconductors behave as insulators at low temperatures
- Batteries
  - Battery cases can crack open due to differences in CTE
  - Lithium-ion battery liquid electrolyte solutions are prone to freezing
    - Changes the chemical structure of the solution, even after it melts
    - Causes the battery to discharge to unhealthy levels before recharge
- Material Properties
  - Extreme temperatures cause materials to contract and expand unevenly
    - Breaks circuit boards, wires, soldered joints, etc.
    - Delaminates solar panels
  - Specific heat decreases at low temperatures
  - Thermal conductivity changes
    - Increase for pure metals, ceramics, and silicon
    - Decreases for metal alloys

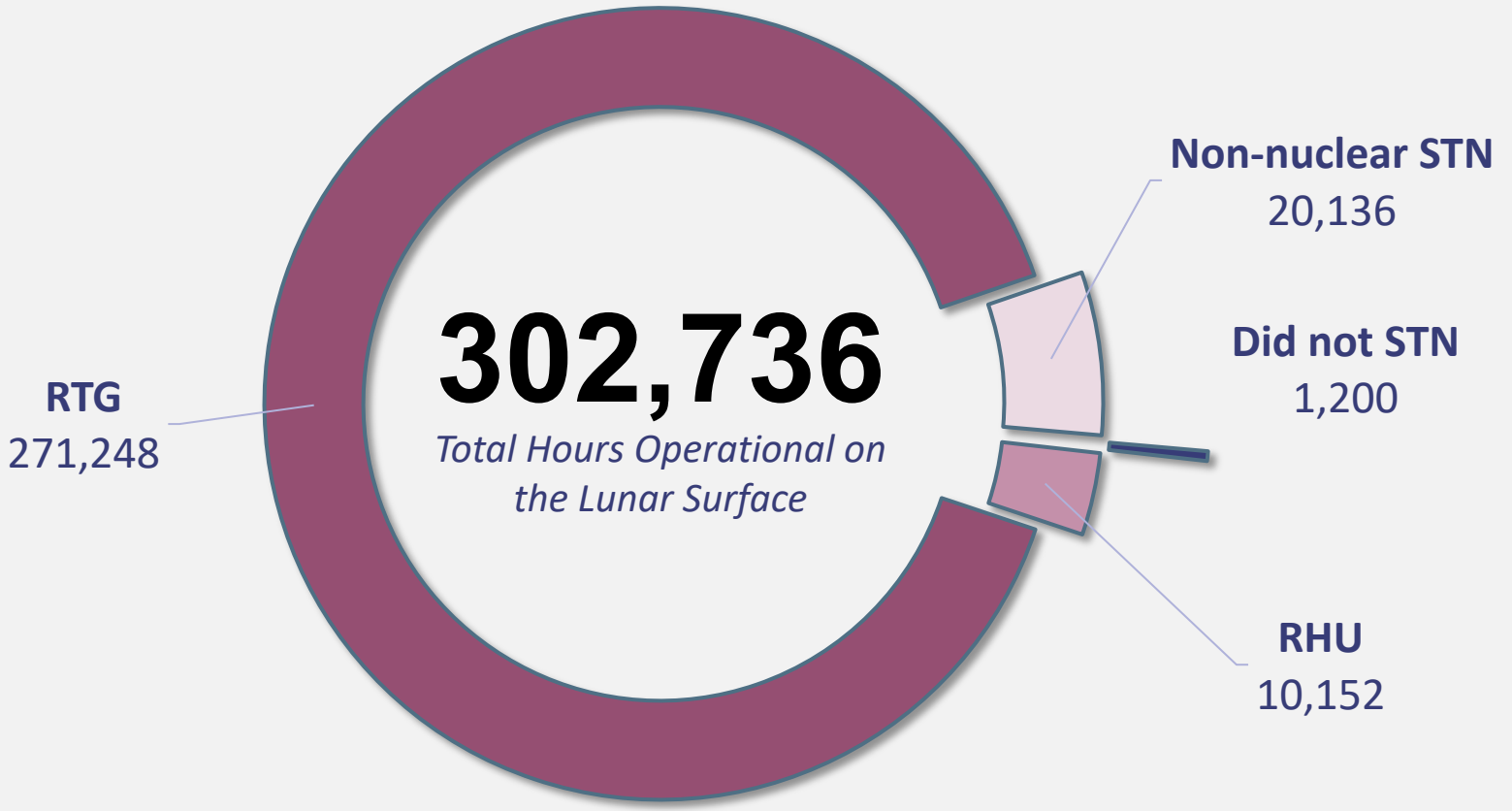
Operational Lifetime of Lunar Soft Landing Missions



Cost per Data ($/MB) of USA Historic Missions



Total Hours Operational on Lunar Surface



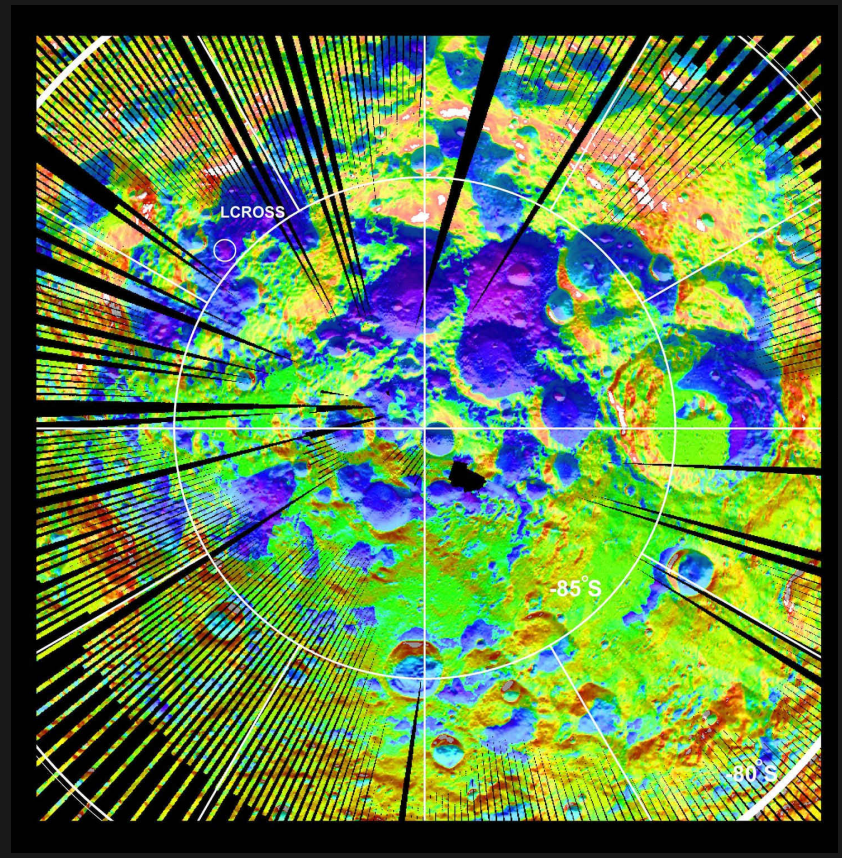
93%

Percentage of lunar surface operational hours enabled by RPS.

Total hours operational on the lunar surface (excluding human missions), by STN strategy.

Economic Benefit of STN - ISRU

- Many lunar missions are planned to land near the lunar South Pole
  - Scientific and economic interest due to presence of water ice
  - Ice is present in Permanently Shadowed Regions (PSRs), which are steep craters
- PSRs present unique challenges to spacecraft
  - Temperatures are relatively more consistent than surface, but colder in general
  - PSRs maintain a strong negative charge, which could interfere with electronics
  - Due to shadowed nature, solar power is challenging in these regions



We need to act now

- We've collected terabytes of lunar data - we'll need **petabytes** to de-risk a real lunar economy.
- **Budgets aren't growing**. We need affordable, scalable data collection within current limits.
- Start with making data affordable now, but future lunar infrastructure must also be **cost-effective to be viable**.
- Radioisotope power has already delivered long-term data at **~$100/MB**. With modern technology, this could be **~$10s/MB**.
- We don't need to reinvent the wheel - **we need to deploy what works**. Now.

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