Low Cost Communications Support of Lunar Missions

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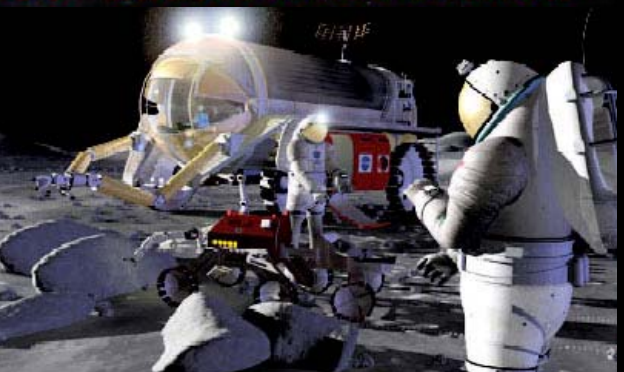
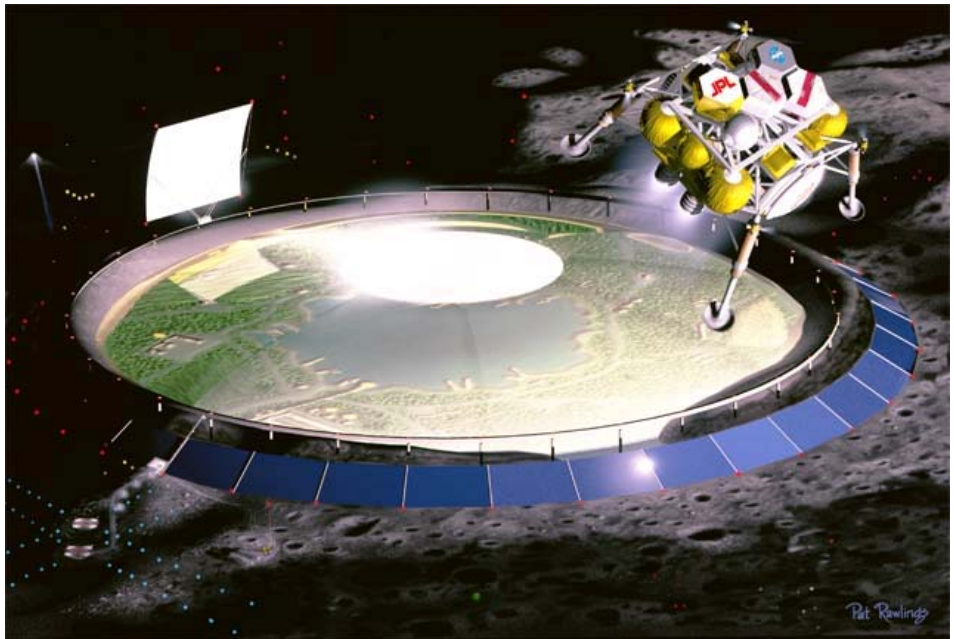
NASA Exploration Program – Moon



- NASA embarked on *vision for exploration* last year
  - Return humans to Earth's Moon as a stepping stone to sending humans to Mars by ~2030
- This is a very big stepping stone
  - We will NOT do this the same way as in 1969
- NASA's new lunar program
  - Intense robotic exploration of the Moon
    - NASA has set up the Robotic Lunar Exploration program (RLEP) with the Lunar Reconnaissance Orbiter (LRO) as the first mission in 2008
  - New human transportation system
    - Project Constellation
  - Infrastructure set up in advance for humans
    - Including communications – even on the backside
  - Human return to the Moon
  - Extended duration human lunar exploration
  - Testing of technologies and processes needed for human Mars missions
    - In situ resource utilization
    - Communications

Guessing the Lunar Mission Set

- Without any real missions defined, we needed to guess the mission set in order to set some requirements for a communication system
- We based this exercise on scientific goals as well as "getting ready for Mars"
  - We assumed science interests will be at the lunar south pole due to likely presence of water
- Our conclusions included
  - Robotic exploration will focus on the south pole
  - Human exploration will occur at either the south pole or on the nearside



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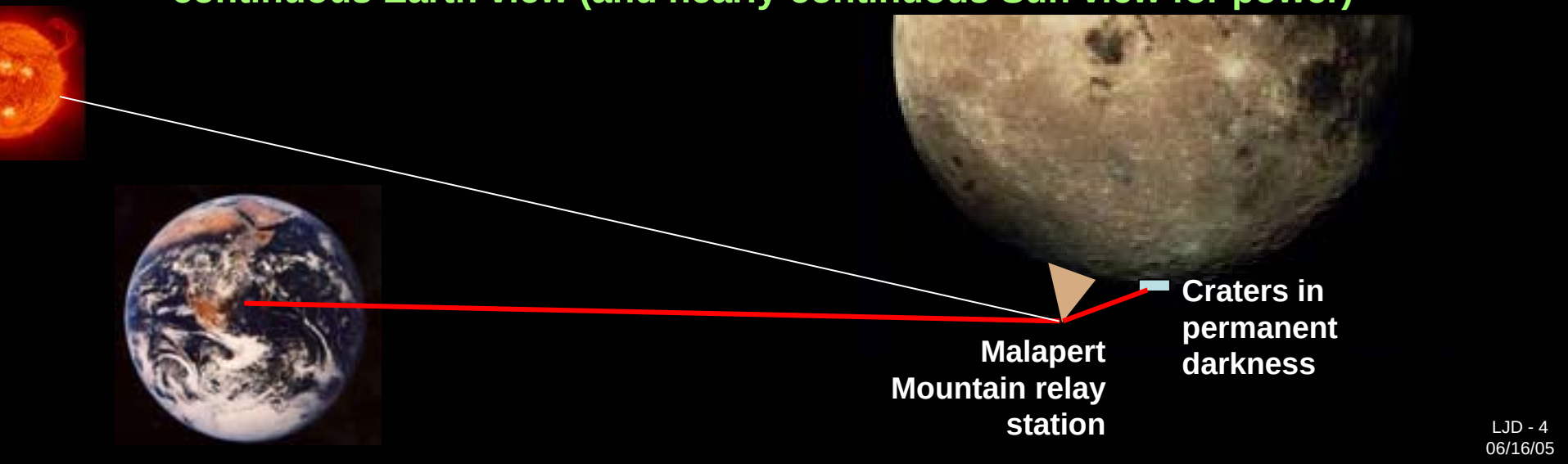
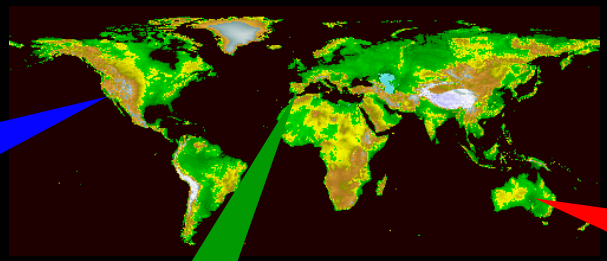
Overall System Architecture

- Two basic communication services: low rate TT&C & high rate links
- Navigation will be provided through radiometrics
- Earth-based stations will provide most of the support
  - Three sites, spaced ~120° apart around the Earth will suffice
- A lunar relay constellation will be needed to provide backside coverage
  - Support critical maneuvers out of sight of the Earth stations
  - Support science missions on the backside
- A lunar surface relay might support intense exploration at the South pole
  - Malapert Mountain has good views to deep south pole craters and also has continuous Earth view (and nearly-continuous Sun view for power)



Low Cost Comm Support of Lunar Missions Using the Deep Space Network

- NASA's Deep Space Network (DSN) has three communications complexes, ~120° apart around the Earth
- Well-developed infrastructure already exists at these locations
  - Power, roads, communication lines, permits, trained staff, …
- The DSN provided support to the Apollo lunar missions, as well as providing the only NASA support to all lunar missions since the end of Apollo
- Current DSN antennas can support the new lunar missions at S-band
  - Some antennas can be easily upgraded to the new Ka-band (26 GHz) high bandwidth links we expect for these applications



Goldstone
Operated by CSOC for NASA/JPL

Madrid
Operated by INSA for INTA

Canberra
Operated by Raytheon for CSIRO

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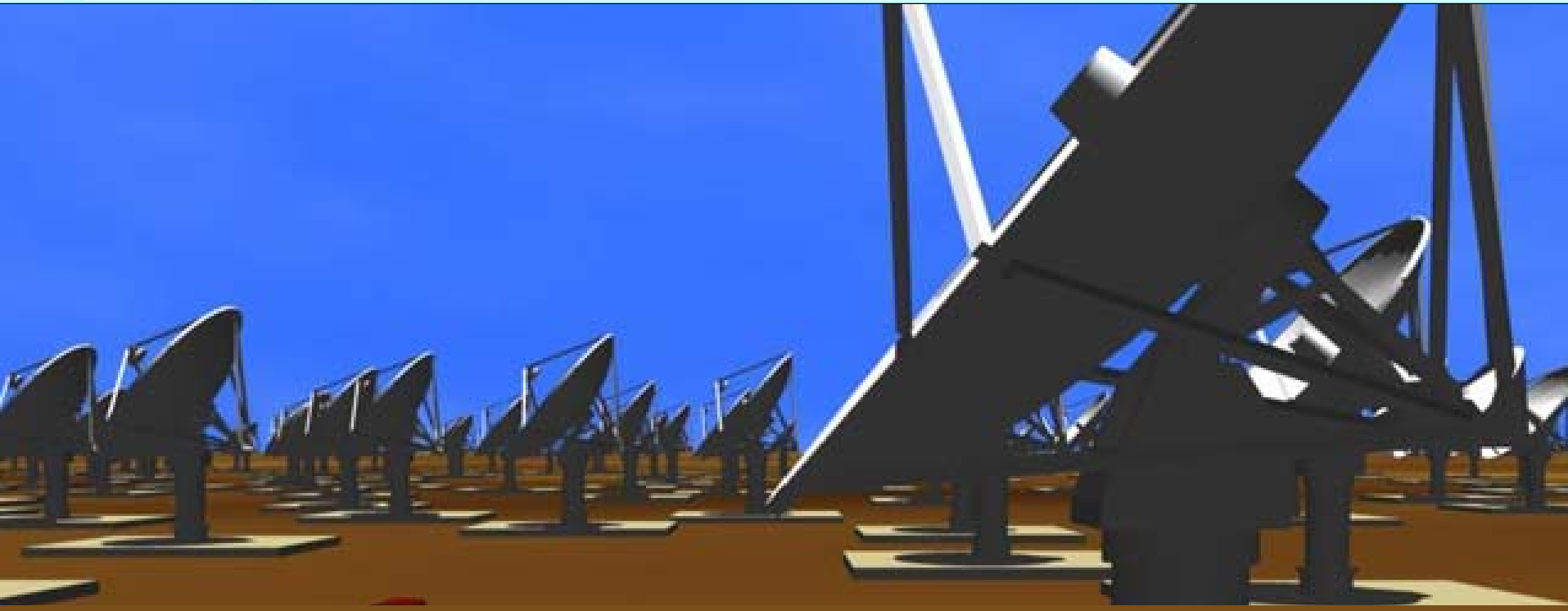
The DSN Array



- Increasing ability to communicate with deep space by 1,000x by 2030 in response to future mission requirements
- The DSN Array is one of the cornerstones
  - Will increase the DSN's effective aperture by 10 and enable comm to 40 GHz
- JPL has developed inexpensive, mass-producible antennas systems
- 12m element size chosen for the array
  - Based on cost and performance trades optimized for the deep space challenge

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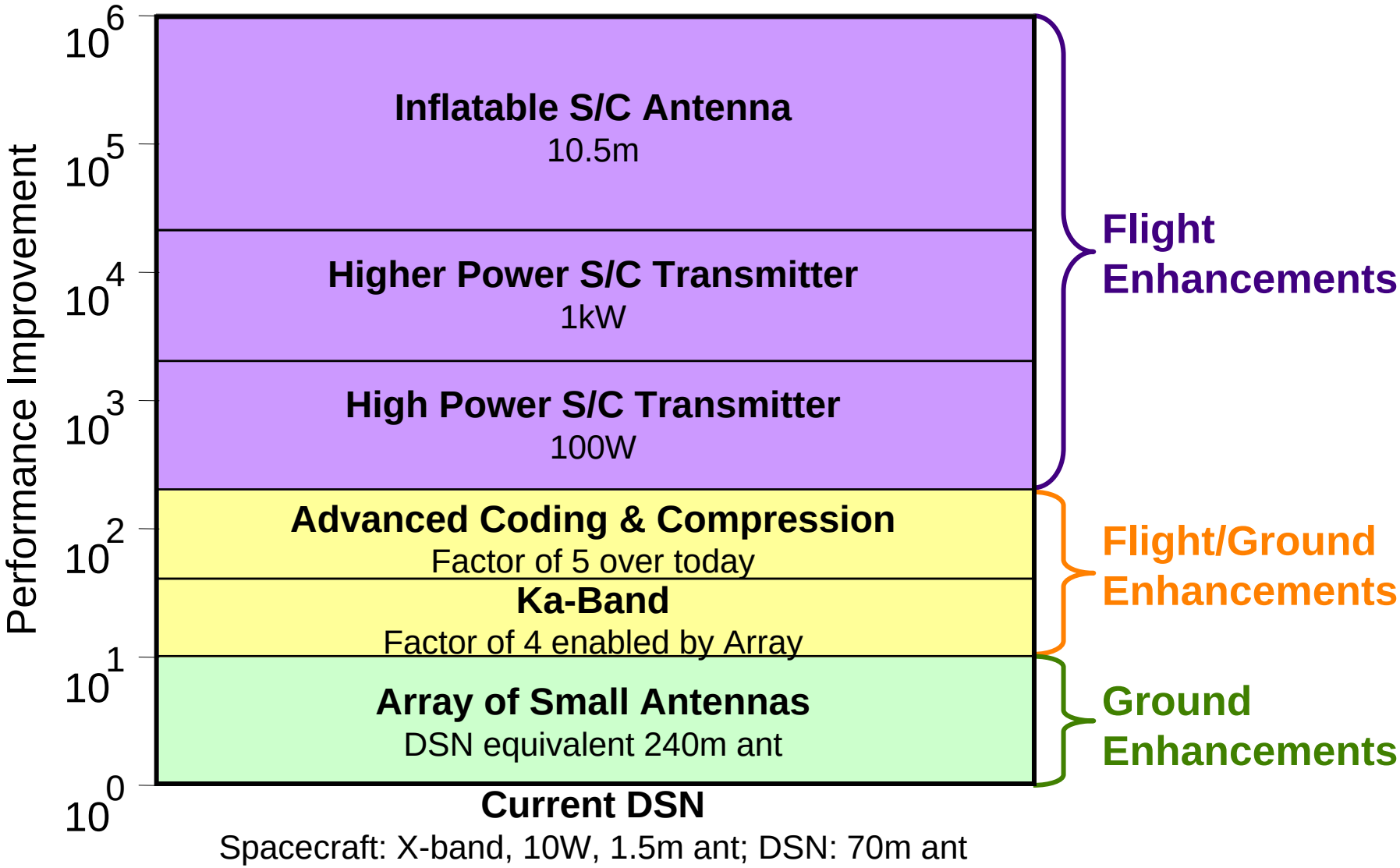
Projected RF Communication Performance Increases



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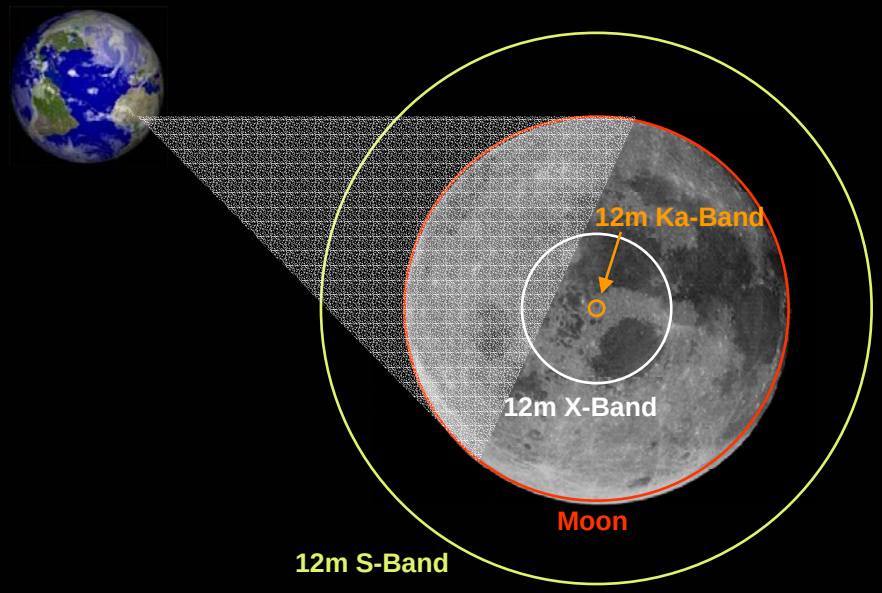
Earth Stations

- By leveraging the DSN Array effort, Earth stations for lunar support can be assembled from the array's basic 12m elements
  - For many missions, a single 12m antenna at Ka-band suffices
  - For the others, several 12m antennas may be arrayed to produce the required performance
- An additional advantage to the 12m size is that the S-band beam contains the Moon and reasonable lunar orbits
  - A single 12m antenna per site can provide TT&C to all missions on the nearside



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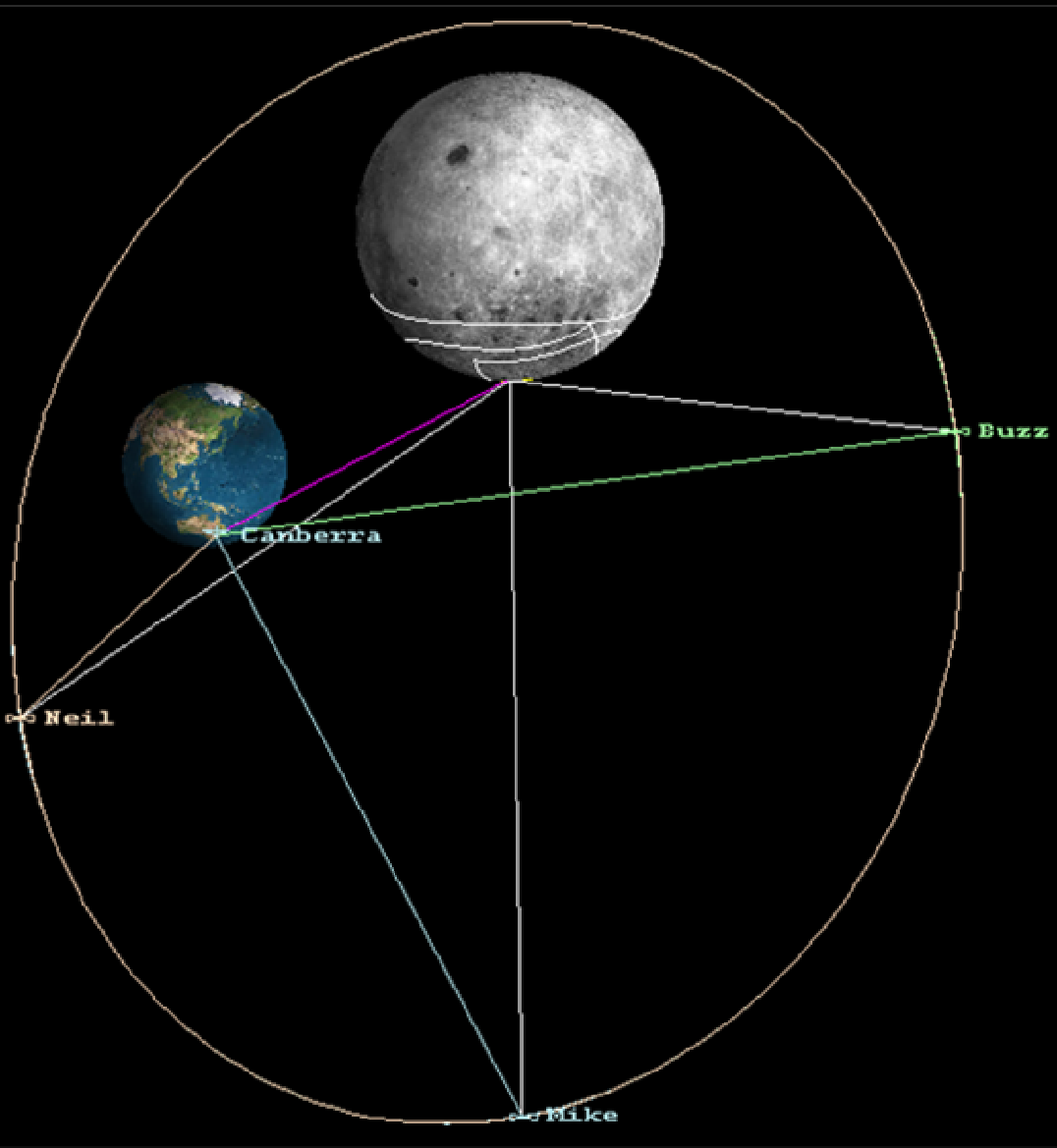
Lunar Relays



- We will begin building relay infrastructure by flying relays on all science orbiters
  - Just like Mars
- As the program grows, we will need dedicated relay capability
- Lunar orbiters provide the only solution with reasonable link distances
- Though a 5-spacecraft constellation could provide continuous support to all points on the Moon, two spacecraft suffice for support at the south pole
- A third orbiter provides the reliability required for human missions

Cost Savings From this Architecture

- Use of DSN sites
  - Preparation of new sites requires ~$50M per site
- Use of smaller antenna Earth stations
  - Using DSN array antennas will result in about a 70% operations and maintenance cost savings
- Use of DSN array antenna designs
  - Cost avoidance of ~$10M in new design work
- Tracking multiple users per antenna beam
  - With 4 channels of tracking, and all nearside spacecraft in a single beam at S-band, we avoid the cost of building 3 additional antennas per site (~$5M)
- Minimal lunar relay constellation
  - Using a 3-satellite constellation rather than 6 will save the cost of three spacecraft (~$300M)
- Use of lunar surface relays
  - Less operational expense and longer lifetime than orbiters
  - Could be deployed as part of a south pole rover mission

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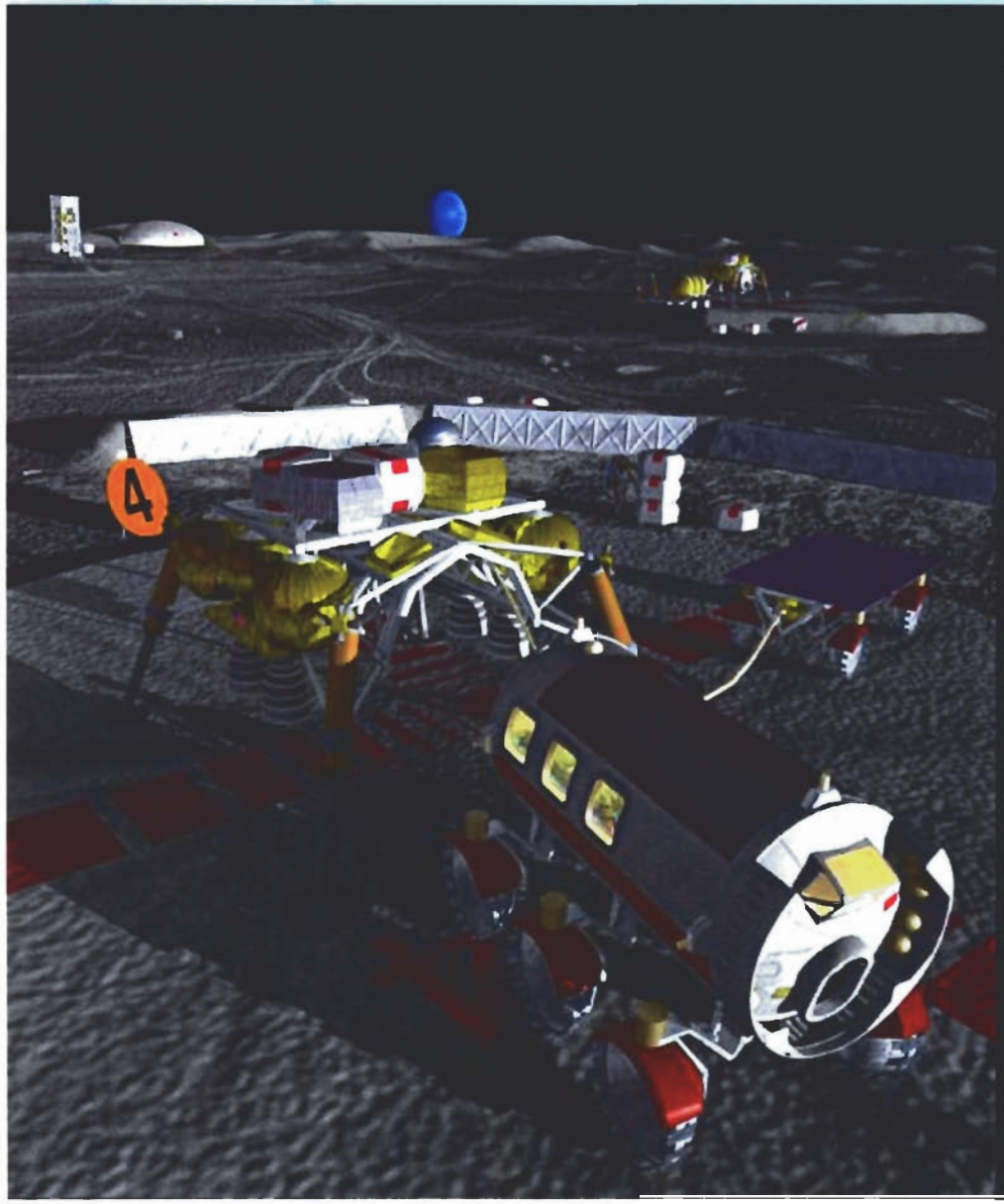
Conclusions



- We have developed an architecture to provide communication and navigation support to NASA's lunar exploration program
  - The architecture can be deployed quickly to support LRO and can grow to provide sup-port to human explorers at the Moon
  - Because this architecture is based heavily on the DSN array, it can also grow to support human exploration of the planets.
- The architecture, which consists of both Earth stations and lunar relays, has been developed to minimize cost to NASA.