

NASA Deep Space Communications: Future Mission Trends and Their Implications

Douglas S. Abraham^{*}, Yijiang Chen[†], David P. Heckman[‡], Leslie Heid[§], Andrew Kwok^{**}
Bruce E. MacNeal^{††}, Kristy Tran^{‡‡}, Hua Xie^{††††}
Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109

In support of NASA's Space Communications and Navigation (SCaN) Program Systems Engineering (PSE) Office, the Jet Propulsion Laboratory (JPL) periodically models and analyzes projected future-mission demand on the Deep Space Network (DSN) out to a thirty-year horizon. These efforts culminate in a set of capacity, spectrum, capability, and network loading trends and associated implications that can then be used to inform decisions regarding the DSN's evolution. This paper describes the findings and recommendations emerging from the latest iteration of these studies. These are always presented to SCaN for strategic planning and programmatic decisions.

On the whole, three key factors appear to be driving how the DSN will need to evolve in the future: (1) unparalleled growth in the number of robotic spacecraft; (2) the emergence of relatively short but tracking-intensive human lunar exploration missions requiring DSN support in the coming decade, followed by an increasing cadence of robotic and then human exploration missions to Mars; and (3) dramatic data rate and associated data volume increases. The growth in robotic spacecraft numbers is projected to substantially raise the level of "base load" demand on the network. On top of this, the intensive tracking associated with each 2-to-4 week human lunar mission is projected to create periodic peak demand levels well in excess of what the DSN has historically supported. To the extent that these missions and certain types of robotic science missions also require much higher data rates, larger-bandwidth uplink and downlink frequencies (e.g., 22/26 GHz) will be needed. And, the data volumes associated with these higher data rates will likely create data handling and management challenges far greater than what NASA has previously had to contend with for deep space missions. In the human Mars exploration era, these higher data rates, in combination with the extreme range distance when Mars is far from Earth, will necessitate arraying up multiple antennas in order to close the communications links – potentially exacerbating any unresolved antenna-hour demand issues in that timeframe.

These findings suggest that, in addition to its planned Lunar Exploration Ground System (LEGS – a subnet of new antennas anticipated to be 18m-class or slightly larger apertures), NASA should: (1) pursue commercial and international/university partner antenna agreements for backfilling antenna-hour supply shortages during peak demand periods; (2) implement ways to use existing antennas more efficiently (e.g., by improving antenna beam-sharing capabilities and equipping more antennas with expanded frequency band capabilities); (3) mitigate increases in "base load" demand by building two additional antennas per Deep Space Communications Complex beyond what is currently planned; and (4) introduce new technologies and systems that will change and optimize the architecture and operations of deep space communications. Example new technologies and systems include: "trunk link" relays at the Moon and Mars that "funnel" all the data from each of these planetary locations down to a single in-view antenna (or antenna array), Delay Tolerant Networking (DTN), optical communications, and greater reliance on autonomous spacecraft and ground systems. SCaN-funded studies are currently in work to further investigate and refine these suggested measures.

^{*} Systems Engineer, Customer Interface Management Office, Interplanetary Network Directorate.

[†] Optical Engineer, Communications Architecture & Operations Group.

[‡] Telecommunications Engineer, Telecommunications Architecture Group.

[§] Engineering Graduate Student, Telecommunications Architecture Group.

^{**} Systems Engineer, DSN Systems Engineering Group.

^{††} Systems Engineer, Telecommunications Architecture Group.

^{‡‡} Telecommunications Engineer, Telecommunications Architecture Group.

^{††††} Telecommunications Engineer, Information Processing Group.

^{†††††} The order of authors is arranged alphabetically. Each author's contribution is of significant value.

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