Progress toward Simultaneous Communications with Multiple Smallsats via a Single Antenna

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Why Try to Simultaneously Support Multiple Spacecraft with a Single Antenna? (1/2)

Large Demand for Antennas:

+ cubesats

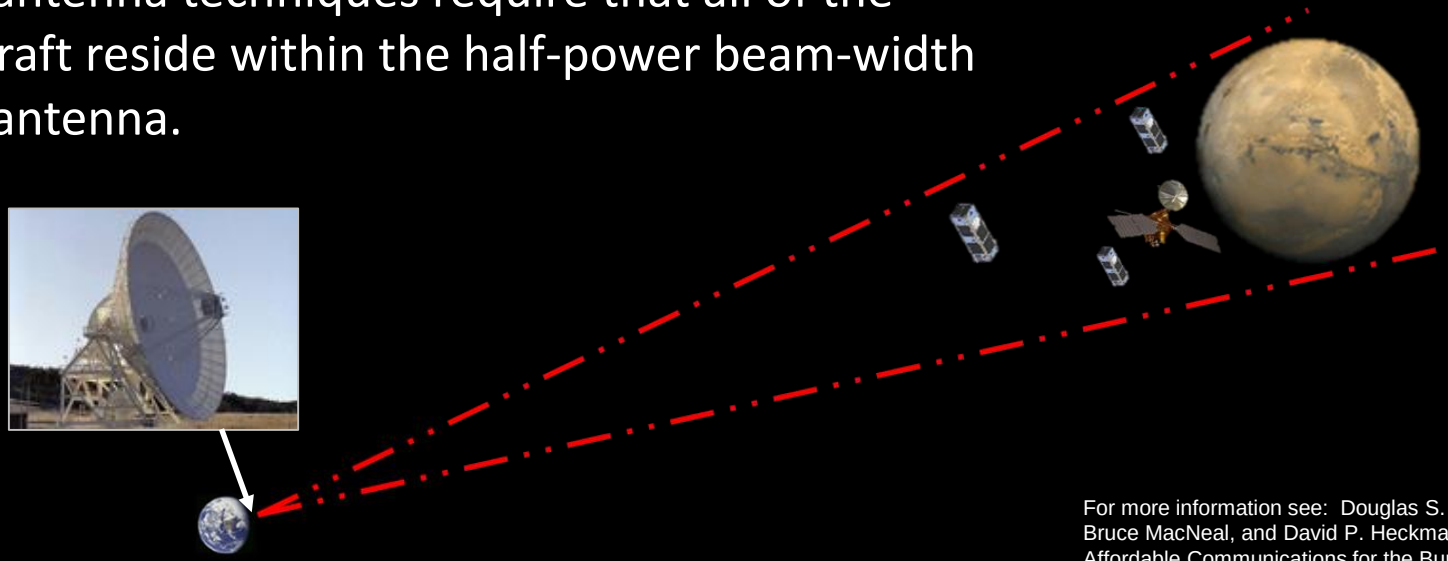
Why Try to Simultaneously Support Multiple Spacecraft with a Single Antenna? (2/2)

Limited Supply of Antennas:

- DSN has ~13 antennas to support 30-40 spacecraft.
- Smallsat exploration beyond GEO will add to spacecraft numbers.
- Supporting multiple spacecraft at same time with 1 antenna reduces contention.
- For antenna users, it also reduces attributed cost.

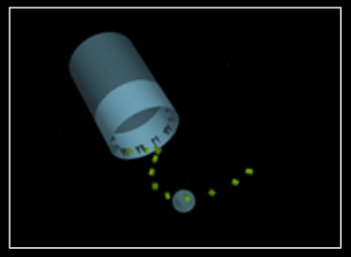
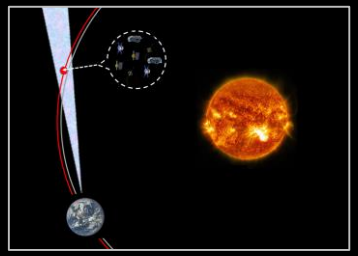
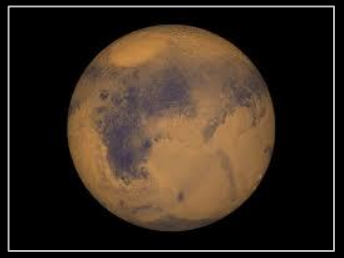
Under What Circumstances Can Multiple Spacecraft be Supported with a Single Antenna?

Single antenna techniques require that all of the spacecraft reside within the half-power beam-width of the antenna.



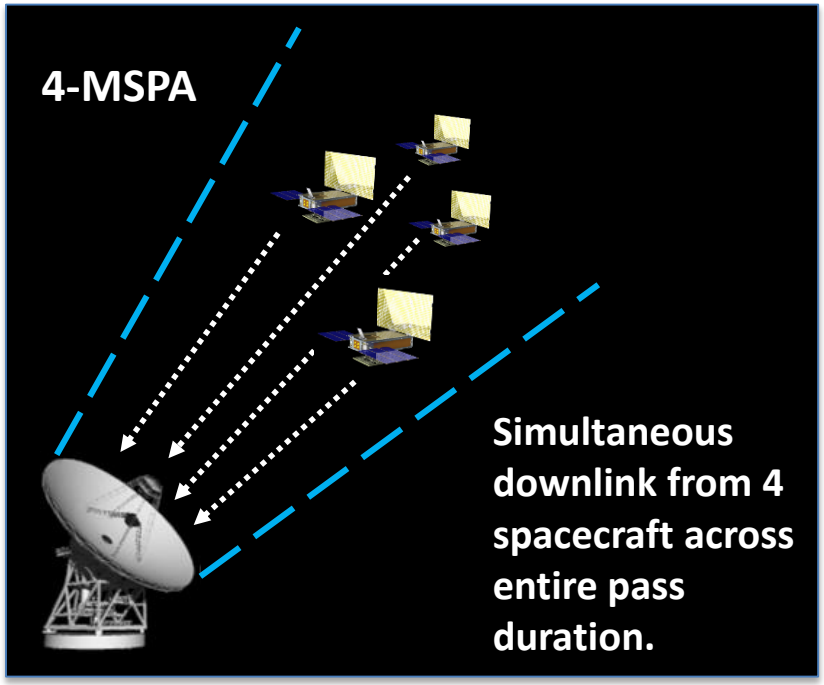
For more information see: Douglas S. Abraham, Bruce MacNeal, and David P. Heckman. "Enabling Affordable Communications for the Burgeoning Deep Space Cubesat Fleet", SpaceOps 2016 Conference, SpaceOps Conferences, (AIAA 2016-2625) http://dx.doi.org/10.2514/6.2016-2625

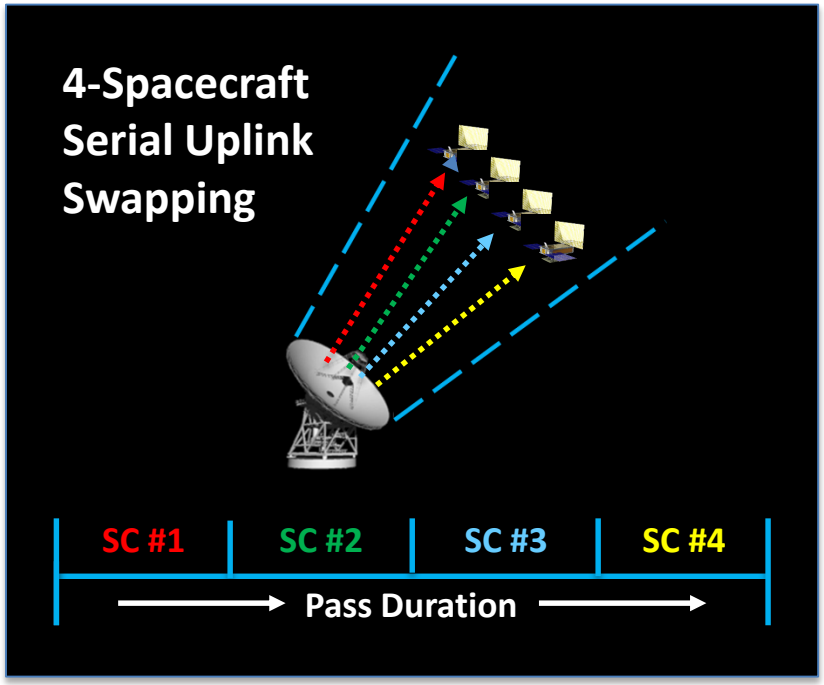
Cases where in-beam some or all of the time:

Secondary Payload Deployments	Constellations	Mars	Venus
			
~Hours to Days	Design Dependent	Always	Always

Funded Techniques for EM-1's Cubesat Deployments

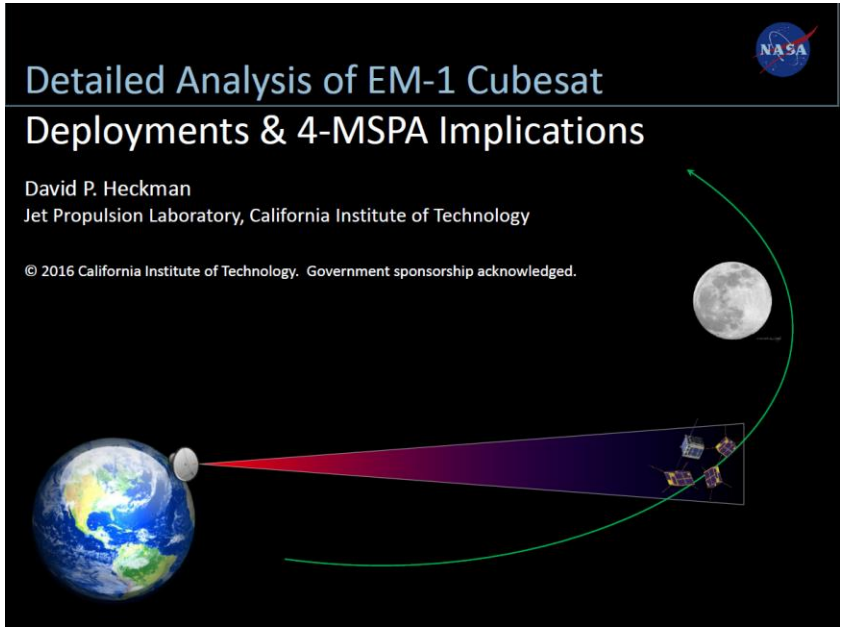
Multiple Spacecraft Per Antenna (MSPA) is a scheduled downlink event where spacecraft simultaneously transmit down through the same antenna to separate receivers, one for each spacecraft. The uplink is sequentially time-shared.

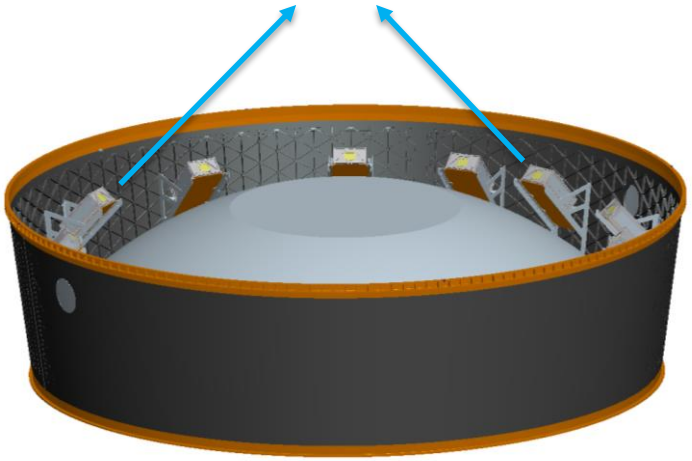




- **Upgrade from 2-MSPA to 4-MSPA implemented at all three DSN Complexes.**
- **Upgrade to 4-spacecraft serial uplink swapping to be implemented in 2017.**

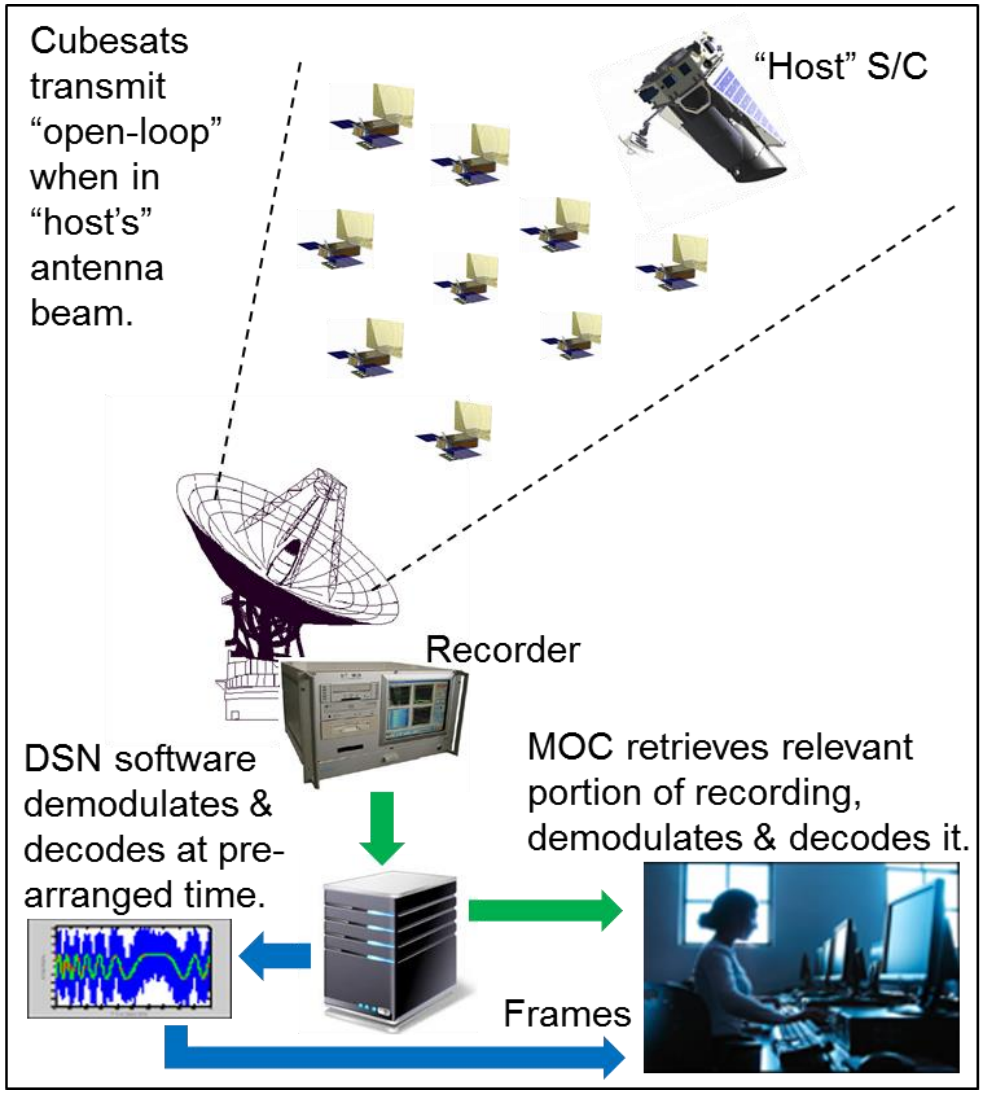
Projected 4-MSPA In-beam Time During Cubesat Deployments





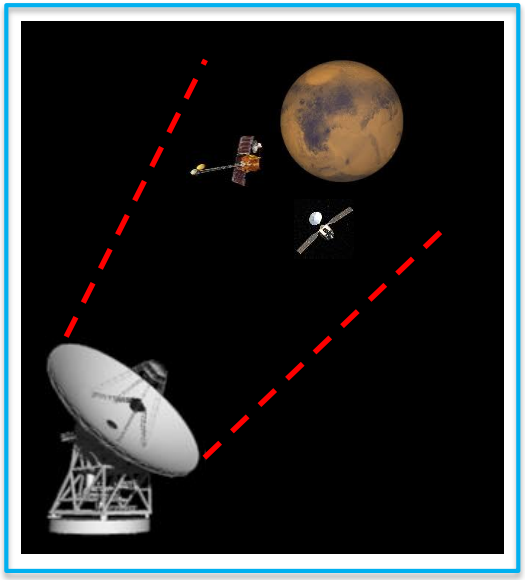
- Performed 4-body analysis of EM-1 cubesat deployments for 3 potential "bus stops" on each of 2 different SLS-supplied trajectories.
- Monte Carlo runs used to account for random dispersions in cubesat speeds and deployment angles.
- Bottom Line: For the trajectories and cubesat deployment information available at the time, cubesats deployed at a given bus stop would likely remain in-beam for many hours, if not days (or at least until the first TCM).

Unfunded Technique #1 beyond EM-1: OMSPA



- Opportunistic MSPA (OMSPA) replaces the multiple receivers at an antenna with a single recorder.
- Because smallsats transmit "open loop" while in-beam with a scheduled user, their downlinks do not compete with the scheduled user's use of the antenna – their use is opportunistic.
- As long as each smallsat has gone through the appropriate frequency assignment process, there are almost no limits on the theoretical number of in-beam users.
- Data recovery from the recorder and subsequent demodulation and decoding does introduce latency – limiting applicability to routine science downlink.

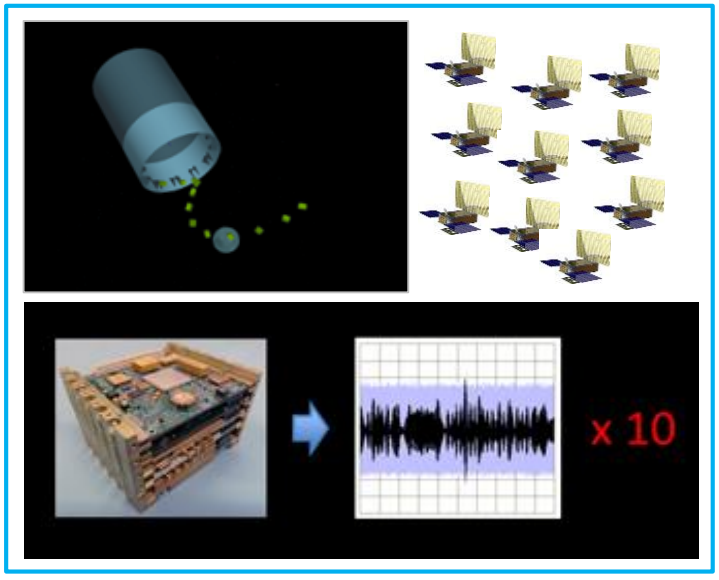
OMSPA Demonstration Status



2014: OMSPA Demo #1 Proof-of-Concept Demo

Purpose: Show that an opportunistic, open-loop transmission in another spacecraft's scheduled beam can be recorded, recovered, demodulated and decoded within a reasonable timeframe.

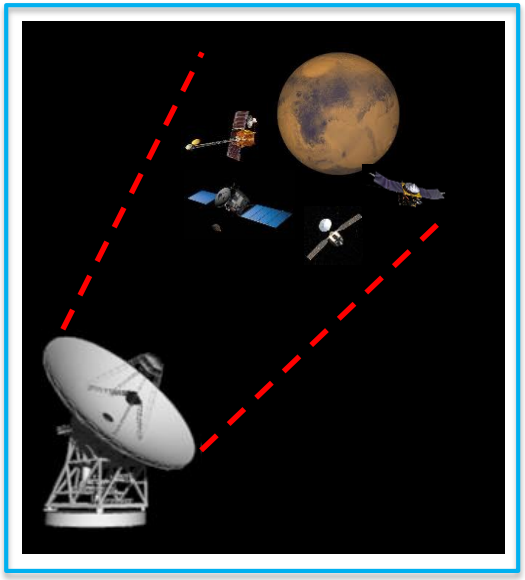
Status: Successful



2016-2017: OMSPA Demo #2 Cubesat Deployment Simulation

Purpose: Simulate the recording of Doppler-shifted transmissions from 10 cubesats during deployment and demonstrate the ability to recover, demodulate and decode all 10 transmissions.

Status: In Progress



2017: OMSPA Demo #3 Multi-Spacecraft Demo

Purpose: Demonstrate that real, multiple spacecraft transmissions can be recorded, recovered, demodulated and decoded within a reasonable timeframe.

Status: In Progress

Douglas S. Abraham, Susan G. Finley, David P. Heckman, Norman E. Lay, Cindy M. Lush, and Bruce E. MacNeal, "Opportunistic MSPA Demonstration #1: Final Report," Interplanetary Network Progress Report, 42-200 (February 2015). http://ipnpr.jpl.nasa.gov

Navigation Techniques for MSPA-Constrained Uplink

Lunar & Interplanetary SmallSat Navigation

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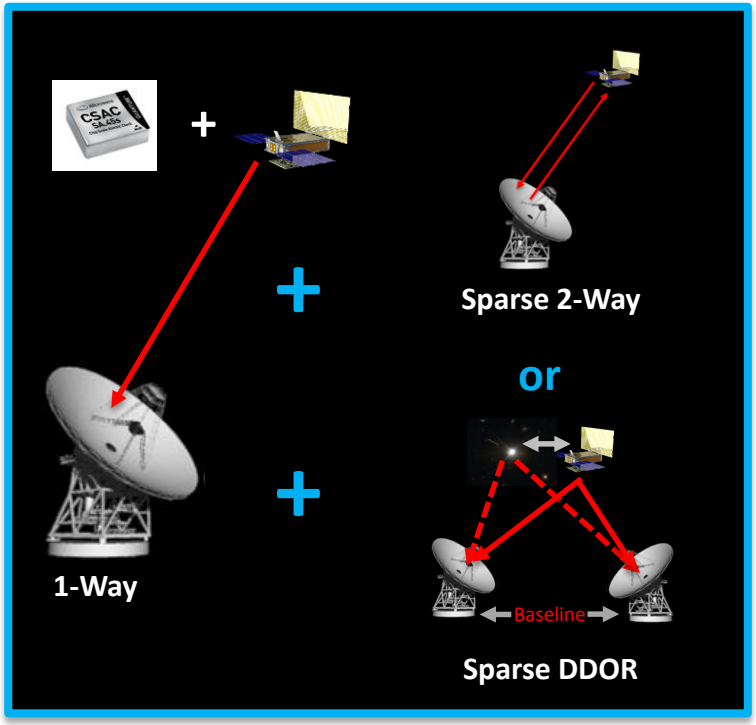
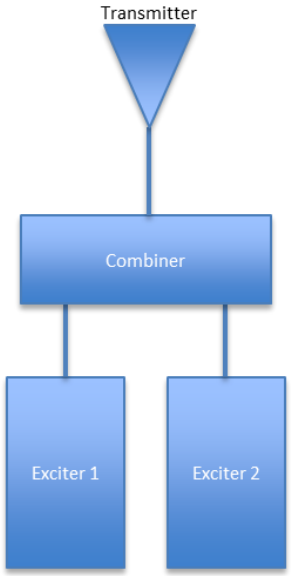


- MSPA with serial uplink swapping can constrain 2-way Doppler pass lengths and opportunities.
- Examined navigation performance of 1-way Doppler assuming Chip Scale Atomic Clock (CSAC), with sparse 2-way Doppler, and with occasional Delta Differential One-Way Ranging (DDOR).
- Generated a “catalogue” of options for DSN support to assist smallsat missions in planning their own support needs.

Unfunded Technique #2 beyond EM-1: MUPA

MUPA = Multiple Uplinks Per Antenna

- Would enable multiple, in-beam spacecraft to simultaneously command and obtain 2-way Doppler during MSPA.
- 3 Techniques Explored During 2016:

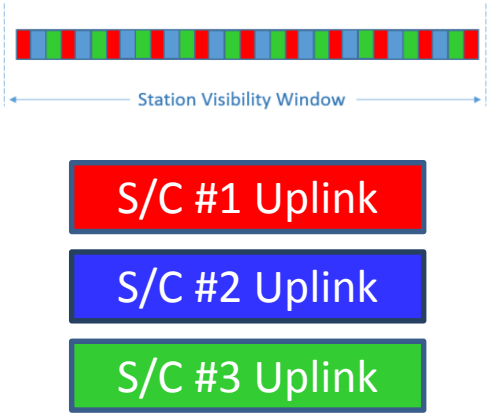


Multiple Exciters

Key Challenges:
Intermodulation Products; Only 2 Uplinks

Subcarriers Modulated onto the Carrier, with Each Subcarrier as an Assigned Uplink Frequency

Key Challenges:
Intermodulation Products; 2-4 Uplinks



Single Frequency Uplink with Time-Multiplexed Command Sequences Differentiated by Spacecraft ID

Key Challenge:
Will Require Spacecraft-Side Modifications

Summary

- Simultaneous, in-beam multi-spacecraft communications show great promise at certain destinations for reducing antenna contention and attributed antenna-time fees.
- Funded Techniques
  - The DSN has implemented 4-MSPA and will shortly have serial uplink swapping ready to go for the cubesats being deployed on EM-1.
    - Analyses suggest the deployed cubesats will remain in-beam until their first TCM.
- Unfunded Techniques
  - OMSPA is on a demonstration path for providing low-cost, routine science downlink to large numbers of in-beam spacecraft without any antenna-time scheduling contention.
  - Analyses suggest that 1-way Doppler with CSAC and some modicum of 2-way and/or DDOR measurements may be sufficient for smallsat navigation when relying on 4-MSPA or OMSPA for protracted time periods.
  - MUPA, in conjunction with MSPA, has the potential to enable multiple, in-beam spacecraft to communicate and navigate via a single antenna – though significant challenges remain and are under investigation.