Working Toward More Affordable Deep Space Cubesat Communications: MSPA and OMSPA

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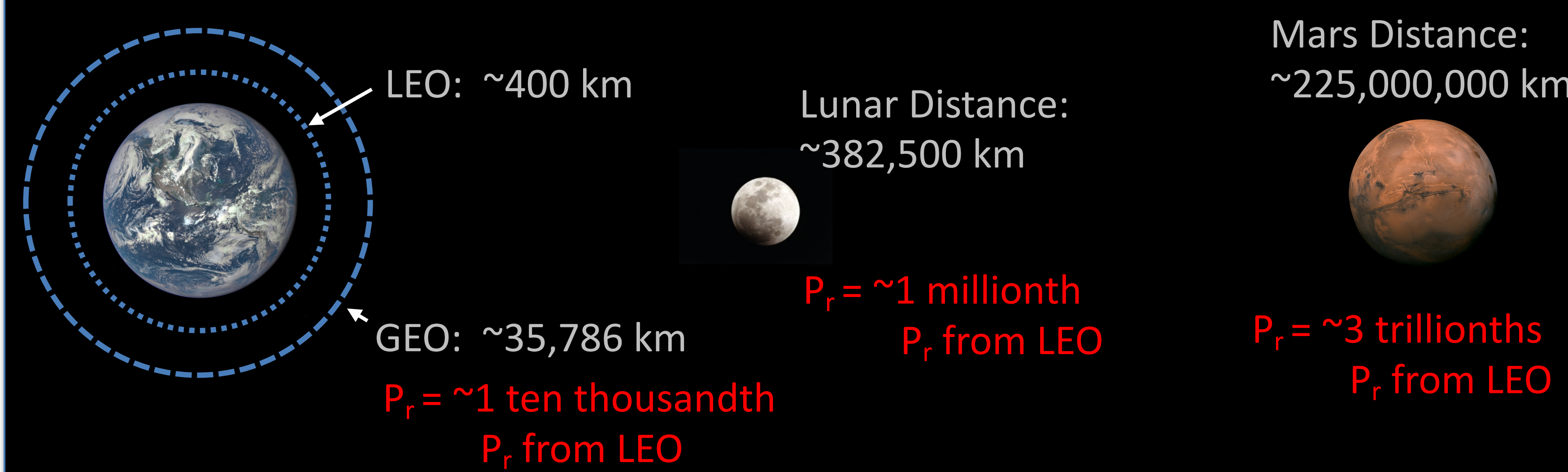
The Deep Space Challenge

$$P_r = \frac{P_t \, G_t \, A_e}{4\pi \, R^2}$$

Received power is inversely proportional to the square of the distance.



Communicating beyond GEO takes large antennas, low-noise receivers, and powerful transmitters.

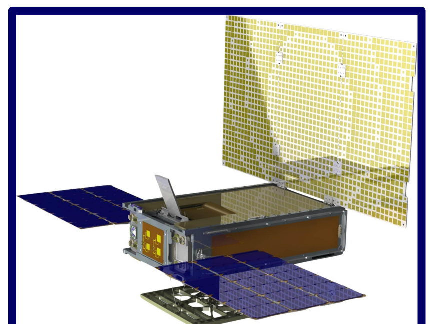
The Scaling Problem

Mars Reconnaissance Orbiter

Credit: Images from mars.jpl.nasa.gov/MRO.

Smaller spacecraft are generally cheaper to build and launch. But,

Mars Cubesat One



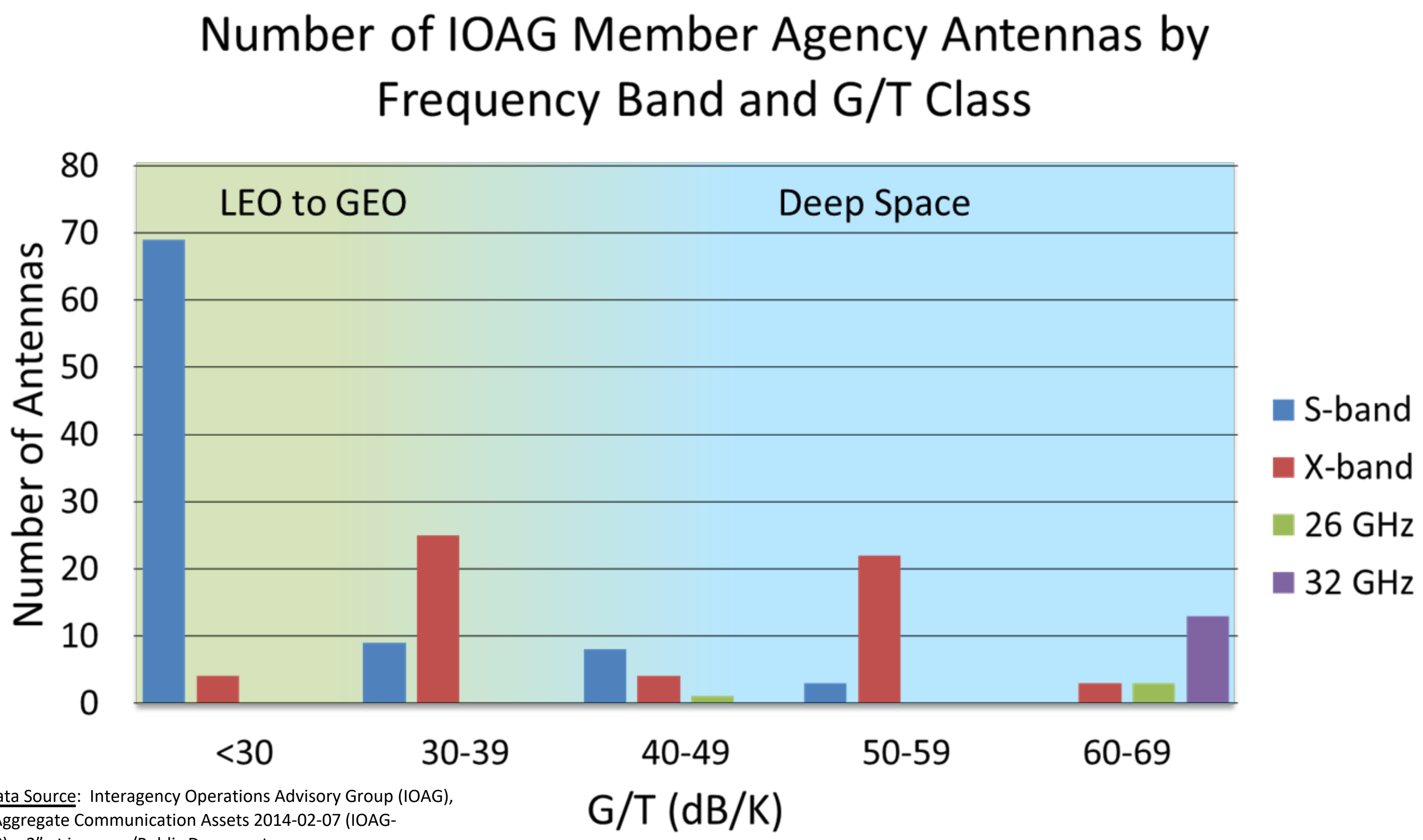
Credit: Images from jpl.nasa.gov/cubesats.

Smaller solar arrays mean less available transmitter power.

Smaller spacecraft have less area to devote to antennas.

The ground-side communications burden must increase to compensate.

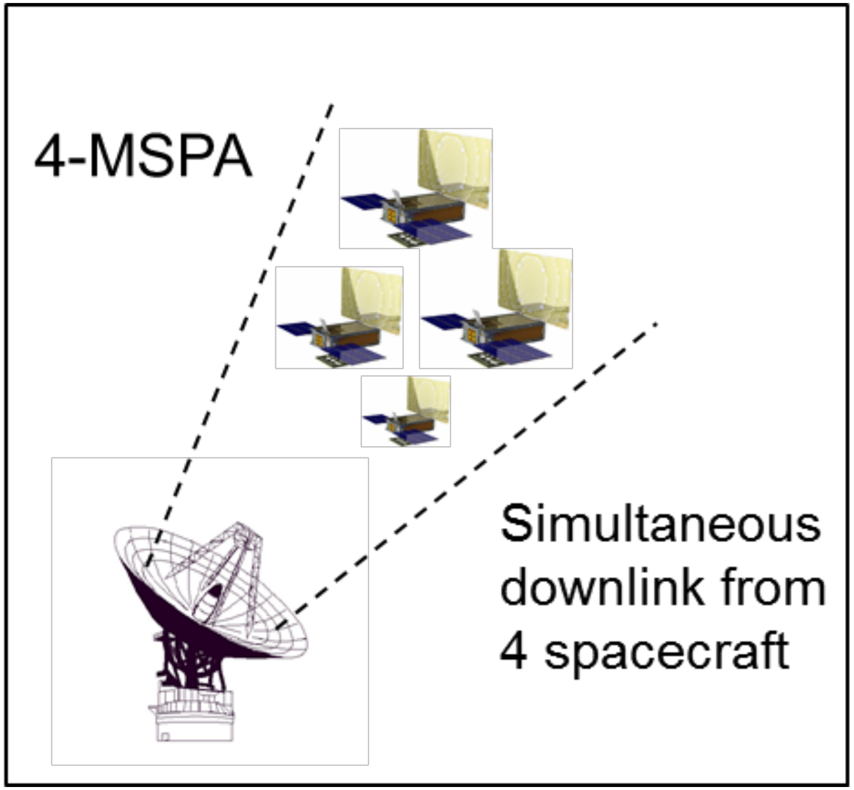
Ground Antenna Supply

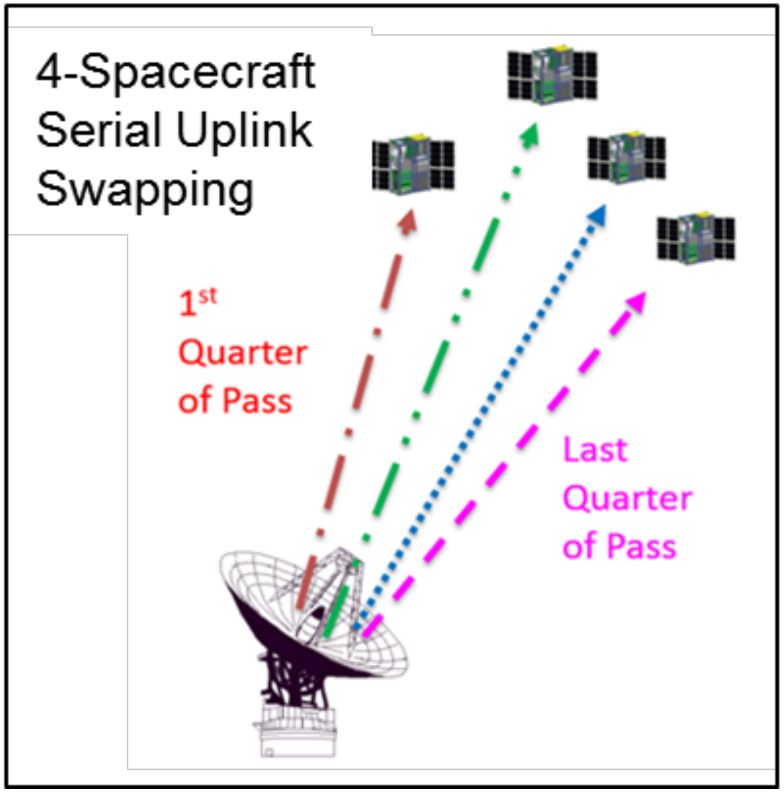


Data Source: Interagency Operations Advisory Group (IOAG), "Aggregate Communication Assets 2014-02-07 (IOAG-18)_v2" at ioag.org/Public Documents.

The world's supply of deep-space-capable antennas is limited. We need to make efficient use of what we have.

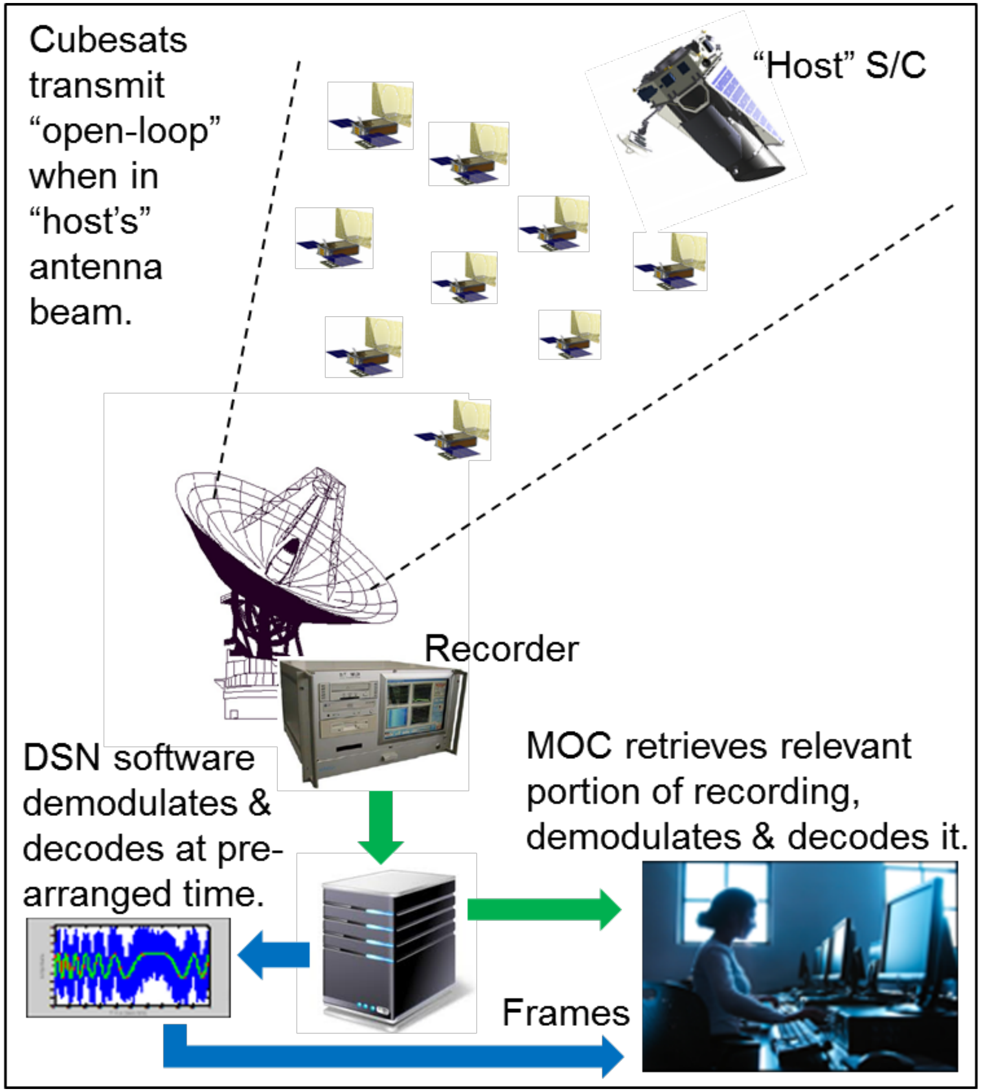
Multiple Spacecraft Per Antenna





- **2-MSPA is a scheduled downlink event where two spacecraft simultaneously transmit down through the same antenna to two separate receivers, one for each spacecraft.**
- **The DSN is moving to a 4-MSPA capability.**

Opportunistic MSPA



OMSPA is a proposed future DSN capability.

Two service modes:
- Self-service
- Frame service

Would enable user base to be larger than the "scheduled" user base, without a proportional increase in DSN costs.

Would have a higher downlink data latency than MSPA.

Benefits to Cubesat Users

1) Enhanced Antenna Availability

- 4-MSPA for critical events where low-latency is important.
- OMSPA for routine science downlink.

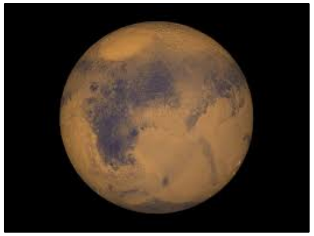
2) Reduced Antenna Scheduling Coordination

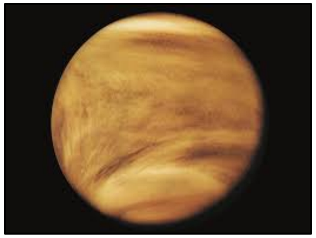
- OMSPA occurs outside the scheduling system; depends only on being in the beam of a scheduled spacecraft.
- No scheduling contention with other missions during OMSPA.

3) Reduced Aperture Fees

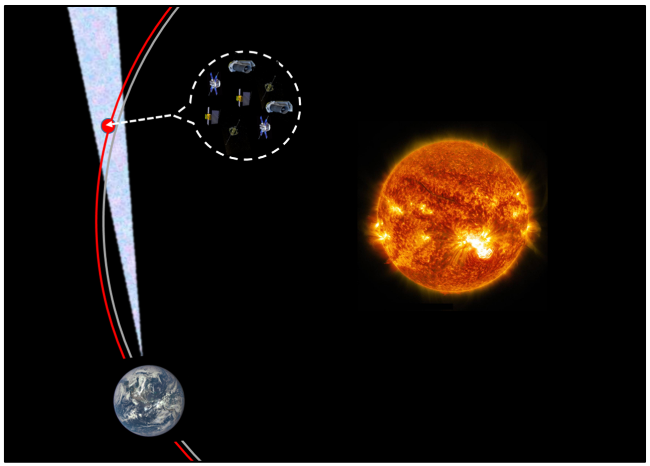
- While NASA missions do not actually pay these fees, they do factor into a mission’s bottom-line cost during the proposal phase.
- While not yet decided, 4-MSPA will likely enable downlink-only at ¼ the base fee.
- While not yet decided, OMSPA might ultimately involve a nominal, flat monthly charge to recover the costs of the recorders, secure internet server, and their maintenance.

Example In-Beam Destinations

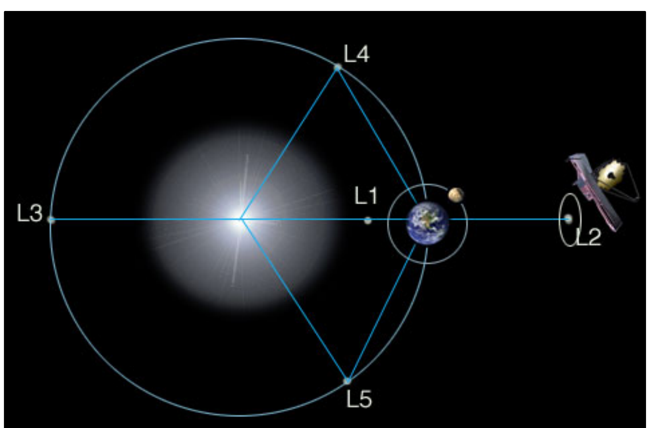




Cubesats at Mars or Venus are always in the beam of other spacecraft at these locations.



A constellation or “flotilla” of cubesats deployed into an Earth Trailing Orbit (ETO) will remain in beam of one-another with few maneuvers and little navigation.



Very low-energy trajectories can take cubesats into SEL1 or SEL2 halo orbits timed to reside in proximity with (and in beam with) large observatory spacecraft.

Credit: http://jwst.nasa.gov/orbit.html

Data Rate & In-Beam Range

Assumed Spacecraft Telecom Design	Transmitter Power(W)	Antenna Gain (dBi)	Band (Frequency, GHz)	Location	Earth→SC Range (AU, average)	Earth→SC Range (km, average)	Supportable Downlink Data Rate (bps)	Max Range from OMSPA Host (km)
Lunar Flashlight (earlier design)	1	5	X-Band (8.48)	Moon	0.0026	388,954	280,000	224
Lunar Flashlight (earlier design)	1	5	X-Band (8.48)	SEL 1,2	0.01	1,495,979	19,000	862
Lunar Flashlight (earlier design)	1	5	X-Band (8.48)	ETO	0.1	14,959,787	100	8,616
MarCO	4.5	28	X-Band (8.43)	Mars	1.7	254,316,380	1000	146,476
MarCO	4.5	28	X-Band (8.43)	Venus	1.1	164,557,658	2200	94,778
MarCO	4.5	28	X-Band (8.43)	ETO	0.1	14,959,787	318,000	8,616
MarCO	4.5	28	X-Band (8.43)	SEL 1,2	0.01	1,495,979	31,000,000*	862
MarCO	4.5	28	X-Band (8.48)	Moon	0.0026	388,954	480,000,000*	224
Mars Reconnaissance Orbiter	100	46	X-Band (8.43)	Mars	1.7	254,316,380	1,300,00	146,476

Calculations assume a DSN 34m ground antenna.
*Of course, the spacecraft electronics won't support this rate.

Cubesats at the example destinations are capable of quite useful data rates and can still stay reasonably far from other spacecraft sharing the beam.

Conclusions

- 4-MSPA and OMSPA minimize the requirement for building expensive new antennas while potentially offering prospective user missions enhanced antenna availability and reduced attributed aperture fees.
- OMSPA also potentially offers prospective user missions freedom from antenna scheduling contention over the time periods that it is applied.
- Cubesat mission designers can realize these benefits by selecting destinations that maximize their in-beam time with other spacecraft.
- For the example destinations in this study, cubesats can achieve very useful data rates and remain reasonably far from the other in-beam spacecraft.