BREAKTHROUGH SCIENCE ENABLED BY REGULAR ACCESS TO ORBITS BEYOND EARTH

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Introduction: Smaller satellites are becoming more and more capable of carrying out significant and vital scientific research [1]. One of their main advantages is their lower cost, especially the CubeSat format, but since their orbits are always determined by launches they ride-along on, their main numbers and influence has been primarily in low earth orbit (LEO), as those launches are the most common. The launches envisioned for the Deep Space Gateway (DSG), both initially to build it, and then to transfer astronauts, should similarly open up the potential for smallsats to access orbits beyond the Earth.

Once a rocket has reached the velocity to obtain lunar orbit, it opens up a slew of interesting other orbits, each with its own unique scientific advantage ranging from Heliophysics to Lunar and Planetary Science to Astrophysics. Below I document some of the main orbits achievable with lunar orbit achieving velocities, give examples of other, larger missions that have needed and benefitted from those orbits, and list some of the basic science advantages for those orbits.

Earth Leading/Trailing Orbits: Examples: Kepler Space Telescope, Spitzer Space Telescope, and STEREO A and B.

Potential Types of Science:

1. Long duration time series monitoring e.g. exoplanet transits or movies of the changing Sun.
2. Very cold and stable thermal environment for imaging and spectroscopy at longer infrared wavelengths.
3. 3D movies of the Sun.

Sun-Earth L1: Examples: Advanced Composition Explorer (ACE), Solar and Heliosphere Observatory (SOHO).

Potential Types of Science:

1. Solar particle and radiation monitoring
2. Solar atmospheric monitoring

Near Earth Orbits: Examples: Near Earth Asteroid Rendezvous (NEAR), Hayabusa

Potential Types of Science:

1. Asteroid surface mapping
2. Asteroid sample return

Impact on DSG: To achieve these orbits some additional Δv and trajectory alteration by the smallsat will be required as lunar orbit does not require full Earth escape velocity. How much Δv and alteration depends on the final orbit of the DSG. There may be a class of orbits for the DSG which will be very advantageous to helping achieve these smallsat orbits without significantly impacting the main objectives of the DSG. So those DSG orbits should be given additional weight in the final orbit determination.

Use of DSG as Communications Hub: Once these orbits are achieved, the science return will be based primarily on the rate of data return. Recent developments of compact optical communications will allow for a large amount of data to be returned by these small satellites without having to carry large radio transmitters. By using the DSG as an optical receiving station from which the data can then be relayed down to the Earth via radio, we would gain the advantages of both those communications techniques. Optical comm's high bandwidth would allow large data files to be transferred, while the radio downlink from the DSG will be less susceptible to weather conditions on the Earth and can have large dishes and high power to make very fast radio downlinks.

Conclusion: The DSG will require regular launches of lunar orbit achieving rockets which can carry one or more smallsats outside of Earth orbit as ride-along cargo. Depending on the final orbit of the DSG, with relatively small additional Δv and trajectory alteration by the smallsats, multiple different and scientifically advantageous orbits can be achieved. These orbits currently require a dedicated rocket launch or waiting for the rare outer planets mission for a ride-along. Much like the greater access to LEO for smallsats has led to a great increase of Earth science and heliophysics smallsats, access to orbits which are advantageous to solar, planetary, and astrophysics can lead to a significant increase in breakthrough space based science return in each of those categories.

Once these orbits are achieved, the science return for these missions will be dependent on their rate of data return. By using the DSG as an optical receiving station, large amounts of data can be downlinked from small satellites without requiring large radio dishes on those small satellites. The DSG can then downlink the data at radio wavelengths which are less susceptible to weather and at a much higher bandwidth than possible for smallsats.

References:

[1] National Academy of Sciences report: Achieving Science with CubeSats: Thinking Inside the Box (2016)