Constellations: A new paradigm for Earth observations

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The last decade has seen a significant increase in the number and the capabilities of remote sensing satellites launched by the international community. A relatively new approach has been the launching of satellites into heterogeneous constellations. The first significant earth observing constellation began with the launch of USGS's Landsat-7 and NASA's Earth Observing System (EOS) Terra satellites in 1999 into a 705 kilometer altitude sun-synchronous orbit. These were joined the following year by NASA's Earth Observing-1 (EO-1) satellite and Argentina's CONAE satellite, SAC-C, resulting in a full-fledged orbiting constellation. All 4 missions cross the equator within minutes of each other at the mean local time (MLT) range of 10:00 a.m. - 10:30 a.m. Hence, the group is known as the "Morning Constellation".

In 2002, a second constellation began forming with the launch of NASA's EOS Aqua satellite, followed 2 years later by EOS Aura. The two missions also fly in 705 kilometer altitude sun-synchronous orbits like the Morning Constellation, but cross the equator at an MLT range of about 1:30 p.m. – 2:00 p.m. so this constellation is known as the "Afternoon Constellation". The science community refers to it by its more popular name, the "A-Train". A third satellite, PARASOL, managed by the French Space Agency, CNES, joined the A-Train in 2004, followed by CALIPSO (a joint U.S./French mission) and CloudSat (a joint NASA/Colorado State University/U. S. Air Force mission) in 2006. Two more NASA missions are to be introduced into the A-Train in 2009, Glory and the Orbiting Carbon Observatory (OCO), bringing the total to 7 satellites and 16 instruments that will be providing near-coincident science data.

Constellations provide the scientists a capability to acquire science data, not only from specific instruments on a single satellite, but also from instruments on other satellites that fly in the same orbit. Initial results from the A-Train (especially following the CALIPSO/CloudSat launch) attest to the tremendous scientific value of constellation flying.

This paper provides a history of the constellations (particularly the A-Train) and how the A-Train mission design was driven by science requirements. The A-Train has presented operational challenges which had not previously been encountered. Operations planning had to address not only how the satellites of each constellation operate safely together, but also how the two constellations fly in the same orbits without interfering with each other when commands are uplinked or data are downlinked to their respective ground stations.

This paper discusses the benefits of joining an on-orbit constellation. When compared to a single, large satellite, a constellation infrastructure offers more than just the opportunities for coincidental science observations. For example, constellations reduce risks by distributing observing instruments among numerous satellites; in contrast, a failed launch or a system failure in a single satellite would lead to loss of all observations. Constellations allow for more focused, less complex satellites. Constellations distribute the development, testing, and operations costs among various agencies and organizations – for example, the Morning and Afternoon Constellations involve several agencies within the U.S. and in other countries.

Lastly, this paper addresses the need to plan for the long-term evolution of a constellation. Agencies need to have a replenishment strategy as some satellites age and eventually leave the constellation. This will ensure overlap of observations, thus providing continuous, calibrated science data over a much longer time period. Thoughts on the evolution of the A-Train will also be presented.