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/Canadian Space Agency mission) in 2006. Another NASA mission, Glory, is to be introduced into the A-Train in 2009, bringing the total to 6 satellites and 15 instruments that will be providing concurrent science data.

Flying satellites in constellations provides 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 close proximity. Initial results from the A-Train (especially following the CALIPSO/CloudSat launch) attest to the tremendous scientific value of constellation flying. Another advantage of flying satellites in a constellation is risk reduction. That is, a failed launch or a system failure in a single satellite with multiple instruments would lead to loss of all observations, whereas the same type of failure in a single constellation satellite will not impact the other constellation missions.

Constellation mission design is driven by science requirements. The placement of the satellites in the A-Train was dictated by the requirements of the various science teams to do coincidental measurements with specific instruments on other satellites. For example, the CloudSat and CALIPSO mission teams requested a location as close to Aqua as possible in order to take advantage of observations from MODIS and the other Aqua instruments.

Guidelines and agreements between mission teams should be established early to ensure that the constellation will be operated safely and effectively. Using the A-Train as a guide, this paper describes the process that facilitates coordination among the mission teams to ensure orbital safety, while allowing the teams to maintain autonomy over their missions. A key element in the A-Train coordination process is a clearly defined path for requesting changes to orbital positions or operations based on science team needs.

The agencies involved in a constellation should have a replenishment strategy so that the constellation can continue its observations with the addition of new instruments to replace original instruments as they reach their end of life. New instruments should be selected to complement or extend existing observational capabilities.