Press Release:
Earth Observer-1 Formation Flying, A NASA First

NASA's first-ever autonomous formation flying mission is now under way. With the launch of NASA's Earth Observer-1 satellite, called EO-1, NASA's Goddard Space Flight Center located in Maryland is demonstrating the capability of satellites to react to each other and maintain a close proximity without human intervention. This advancement allows satellites to autonomously react to each others orbit changes quickly and more efficiently. It permits scientist to obtain unique measurements by combining data from several satellites rather than flying all the instruments on one costly satellite. It also enables the collection of different types of scientific data unavailable from a single satellite, such as stereo views or simultaneously collecting data of the same ground scene at different angles.

Formation Flying is exactly that, satellites flying in a predetermined formation, and maintained in that formation by using onboard control. Therefore, when one satellite moves, the others move to coordinate their measurements. EO-1 was launched this past December as a technology mission designed to fly in formation with another NASA satellite called Landsat-7. Both satellites carry instruments that enable scientists to study high-resolution images and climatic trends in the Earth's environment. The EO-1 satellite flies only 60 seconds (450 kilometers) behind Landsat-7 and maintains the separation within 2 seconds. This separation is necessary for EO-1 to observe the same ground location through the same atmosphere region. It also demonstrates significantly improved return of science data. The mission allows engineers to compare technological advances made in ground observing instruments that are smaller, cheaper, and more powerful. EO-1 also demonstrates technologies for propulsion, onboard processing, and data storage.

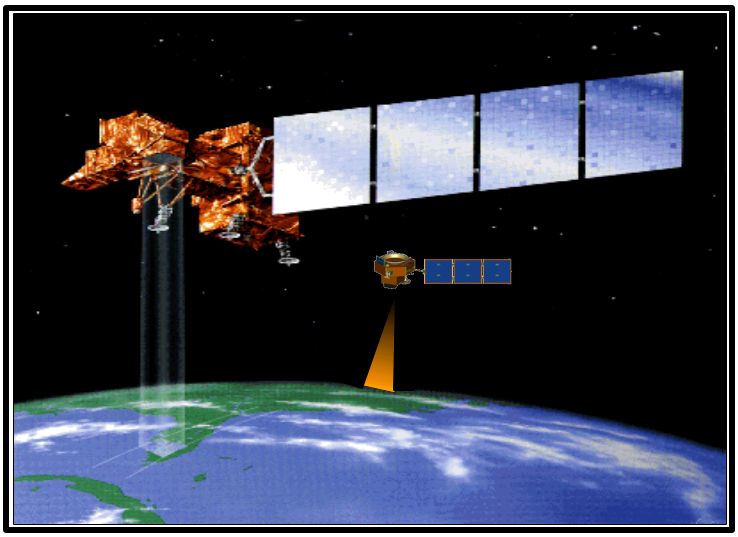
Previously, satellites did not communicate directly with each other, did not plan and execute orbital maneuvers onboard, nor were they equipped to autonomously accommodate the actions of any other satellite in support of a desired scientific experiment. Onboard EO-1 is an advanced technological controller that is capable of autonomously planning, executing, and calibrating satellite orbit maneuvers. On EO-1 it is used for the computation of maneuvers to maintain the separation between the two satellites. The idea and mathematical algorithm for this NASA first was developed by Dave Folta, John Bristow, and Dave Quinn, Aerospace Engineers at the Goddard Space Flight Center (GSFC). It is designed as a universal 3-Dimensional method for controlling the relative motion of multiple satellites in any orbit. Their idea was then combined with a new flight software that is the predecessor of a GSFC sponsored commercial software call FreeFlyer produced by Lanham, MD based *a.i.-solutions inc*. This flight software provides for the ingest of real-time navigation data from the onboard Global Positioning System (GPS), the transfer of data from the maneuver algorithm for maneuver commands, onboard predictions of where the satellites will be in the future and actual onboard commanding of the thruster firings.

Because maneuver calculations and decisions can be performed onboard the satellite, the lengthy period of ground-based planning currently required prior to maneuver execution will eventually be eliminated. The system is also modular so that it can be easily extended to other mission objectives. Furthermore, the flight controller is designed to be compatible with various onboard navigation systems.

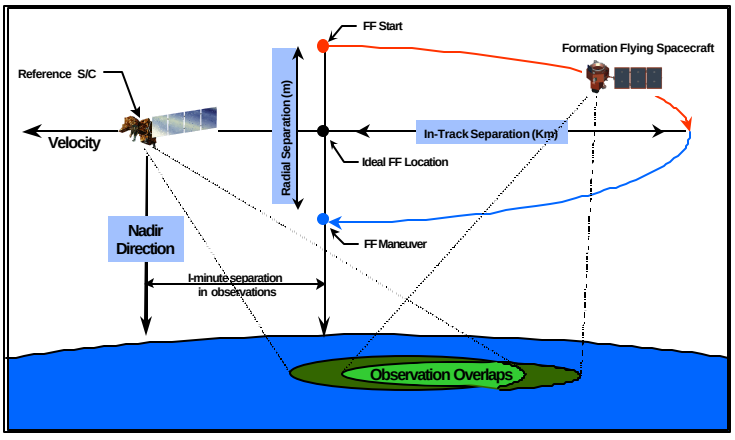
Formation flying technologies are primarily concerned with the maintenance of the relative location between many satellites. Much shorter and more precise baselines can be established between the satellites. The satellites can then be combined as part of a "virtual satellite" that should provide previously unobtainable science data using mass produced, single-string, relatively cheap satellite. Multiple scientific instruments often present competing and conflicting requirements on a satellite design and its operation. So much science at stake for a single satellite often requires a great deal of onboard redundancy, which imposes its own overhead on the design process. Separating scientific payloads onto several simpler single-string satellites can accomplish the same complex missions without the added design and operational overhead, while risking only one payload at a time. The proposed approach for onboard formation control will enable a large number of satellites to be managed with a minimum of ground support. The result will be a group of satellite with the ability to detect errors and cooperatively agree on the appropriate maneuver to maintain the desired positions and orientations.

Another reason to use formations is due to the sensitivity of scientific instruments which can often be increased by expanding the effective observation baselines (separation distances). This can be achieved by distributing the scientific instruments over many separate satellites. The formation flying technologies flown onboard EO-1will make these missions routine and cost effective.

Since this technology is now fully developed and demonstrated, synchronous science measurements occurring on multiple space vehicles will become commonplace and the concept of Earth observing 'virtual platforms' will become a reality. In the process, this technology enables the development of autonomous rendezvous. Scientific payloads could be launched from any launch vehicle, rendezvous with and join a formation already in place, and then autonomously maintain this condition or respond to specific requests for science data collection by altering its own orbit. Thus, this technology addresses all of the NASA directives to build revolutionary satellite that are better, faster, and cheaper.



EO-1 Following Landsat-7 satellite in orbit



Orbit Mechanics of EO-1 Formation Flying

In the above figure, EO-1 starts a formation at the red dot location, behind Landsat-7 by 450 kilometers and above by ~50 meters. Due to the differences in the drag accelerations from the atmosphere, the EO-1 satellite orbit decays slight faster. While above Landsat-7, EO-1 is moving away from Landsat-7. After several days of atmospheric drag, EO-1 will be below Landsat-7 and will move towards it. When EO-1 is outside the required distance or if the Landsat-7 satellite have maneuvered away, EO-1 will autonomously compute and perform a maneuver to reposition it to an initial condition to repeat the relative motion.