Formation flying DTUsat

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Introduction

This CubeSat proposal is to demonstrate formation flying between two satellites with the precision needed in future focusing hard x-ray and gamma-ray missions where the optic and the detector part will be flying on two separate satellites.

To make efficient focusing optics for x-rays it is necessary to work within the region of total reflection where the photons enter at very shallow grazing angels. This angle gets smaller with increasing x-ray energy and thus demands large focal lengths of tens of meters. Focusing optics have already been flown on missions such as Einstein, Rosat, Chandra, and XMM-Newton. These satellites have been looking at the soft x-rays from 0.05 keV to 10 keV, while hard x-ray and gamma ray missions, like Integral, have used coated masks to produce shadow images on the detectors. Coded mask apertures do not require large focal lengths but are severely background limited and thus have a low sensitivity.

Grazing incidence optics on depth graded multilayer coatings makes it possible to focus hard x-rays at reasonable graze angles. This has been demonstrated on balloon flights like HEFT and InFOCuS and the first satellite, NUSTAR, using depth grated multilayers coatings for at x-rays up to 80 keV is expected to fly in 2009. On HEFT and InFOCuS the focal lengths were about 6 m and on NUSTAR it will be 10 m. These focal lengths still allow 'one spacecraft' designs but demands for higher energies and a greater effective areas pushes the focal length beyond its structural limit. The solution is to separate the focusing optic and the detector on two different satellites and fly them in formation. This is the plan for XEUS, an ESA x-ray satellite planed for flight in 2020, which has a focal length of 50 meters. The two spacecraft have to remain in a relative position with respect to each other with an accuracy of 1 mm^3.

The demand for long focal lengths is growing many astrophysical fields and a large fraction of future conceptual designs include a free-flying option. Free flying and the actually formation flight is not looked upon as a too severe challenge. However, formation flying of this sort has never actually been done.

Basic Guidelines

The idea of this CubeSat proposal is not to fly two separate satellites at 50 m apart, but to prove the concept of formation flight of two crafts separated by a smaller manageable distance. One of the prerequisites for formation flight is that the distance and movement of the two crafts can be solved. This detection and calculation of position is one of the main challenges.

To fly formation one needs to have two parts. That can be done as a double CubeSat that separates in orbit or by a single CubeSat releasing a smaller part. This part could be tethered to the CubeSat.

If the released part is a small reflecting area - a dead block - the lasers and detectors have to sit in the same CubeSat. If a double CubeSat is used the lasers could sit in the "free falling" part and the detectors in the moving part. After detection of the position, rotation and tilt between the two pieces an onboard self-correcting algorithm must be designed to work in concert with an active propulsion system, calculating a response to keep the relative position within given parameters. Naturally the second prerequisite for formation flying is thus the ability to correct and reposition the crafts. This requires some sort of active propulsion system for example electronic, dry or liquid.

If one wants to scale the experiment and make it more realistic in respect to the requirements of real formation flight satellites, the crafts need to have the ability to point at a certain point on the sky and hold that in formation formation. It is clear that the 'dead block' solution cannot do this. To do a fully pointing craft it therefore becomes necessary to mount sensors and propulsion systems on both crafts.

Summary

Formation flying, although dubbed as 'possible' has yet to be proven. The demands on accuracy are on the order of mm[3] over distances of hundreds of meters. Such distances are probably not achievable with the CubeSat design, nor is the behavior of CubeSat's maneuverability in the space environment directly scalable to a full-sized mission, however on the technical side the distance measurement, and re-positioning technique will certainly be scalable.

Based on the dimensions of CubeSat, a dead block configuration is possibly the best solution. In this case one craft moves in freefall, while the second craft keeps up the alignment.

Regardless of the accuracy achieved, a successful flight will be a major achievement in space science and a step towards its utilization on a larger scale.