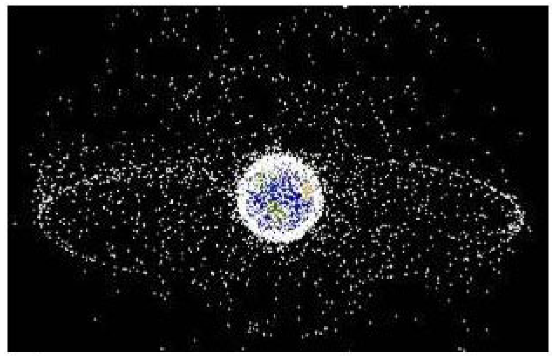
Managing Satellites' End of Life: Critical for the Future of Space

by Laurence Lorda

"Space for the Earth" has been chosen as CNES' signature for defining its politics over the next few years. But what space? The conquest of this new territory by man has led to a considerable number of objects of all sizes being put into orbit. Those greater than 10cm number more than 9000 circling above us: launcher stages, extinct satellites and other detritus from human activities that end up invading useful orbits. The fault of a lack of political resolve to limit proliferation of debris, this phenomenon may lead to access to space becoming significantly more complex than it already is today.



Debris

In the absence of international laws or treaties on the subject, the main space agencies have grouped together under the umbrella of the IADC (Inter-Agency Debris Coordination Committee), and within this committee have defined a number of recommendations aimed at limiting debris. These recommendations follow a few simple principles, such as not voluntarily creating debris in space (e.g. by not adding covers for protecting instruments purely during launch), using materials adapted to minimise debris production (special paints, shielding) and to protect as far as possible the zones in space that are of particular use commercially or scientifically. This latter protection is managed principally through managing satellite end of life. Once their operational activities completed, satellites turn into uncontrolled debris and present a non-negligible risk of collision with satellites still in activity. As they are typically in the orbits of greatest use, the risk is all the more critical as the smallest collision in such orbits could lead to a cloud of much smaller debris, thus much harder to follow and avoid, and no less dangerous as a consequence of the high kinetic energy resulting from the high speed (from 3km/s in geostationary orbit up to 8km/s in low earth orbits). The interest in moving satellites out of the orbits of interest at the end of their lives is therefore clear.

The rules recognised by the IADC on the subject are the following:

- In a Low Earth Orbit (LEO), the IADC recommends that satellites are deorbited, i.e. that they return and burn up in the earth atmosphere, within 25 years of end of useful life. For this, two scenarios are foreseen: either a direct re-entry, rapid but costly in fuel, achieved by a strong braking manÏuvre such that the satellite re-enters the atmosphere within a few hours; or an indirect re-entry, much slower but much more economic, consisting of placing the satellite in an orbit sufficiently low that the natural effects of atmospheric drag will result in a re-entry within the 25 year limit.
- In a Geostationary Orbit (GEO), deorbitation is accepted as not feasible due to the cost of fuel required. The IADC proposes, as a consequence, a boost of the spacecraft into a graveyard orbit, at least 300km above the geostationary orbit. This ensures the satellite will not return to the operational orbit even taking into account orbital perturbations, consisting principally of solar radiation pressure at such altitudes.

The manœuvres necessary for such rules clearly imply a cost. The key is therefore to ensure the different actors in space accept such costs - and this is not a simple task in an increasingly competitive domain where each kilo of fuel put into orbit must be paid for.

Conscious of this difficult task, CNES in cooperation with its partners has been proving for some years that the management of the end of life of spacecraft is indeed possible without impacting nominal mission operations. With ASI (the Italian Space Agency), the BNSC (British National Space Centre) the DLR (German Space Agency) and ESA (the European Space Agency), the French Space Agency has also participated in the definition of a European code of conduct for space debris, that provides further precision and completion to the IADC guidelines, and CNES was the first agency to sign the code officially, in October 2004, making it applicable to all new CNES projects.

The effort is equally not limited to projects currently under development, as CNES has decided to put the principles of the code into practice for satellites already in flight, as will now be elaborated upon with a few examples: for low earth orbits, the deorbitation of SPOT 1 in 2003 is such a case. Despite the satellite, launched in 1986, having been developed long before the implementation of the IADC, CNES decided to use it as an example by applying the above rules to its end of life. The last reserves of hydrazine were consequently used to perform the retrograde burn necessary to bring the orbit perigee down to 574km. This has placed SPOT1 on an orbit that will result in an atmospheric disintegration within 20 years, instead of the 200 that would have been required for the initial orbit.

More recently, the DEMETER mission has given the opportunity to demonstrate the application of the international recommendations with regard to the non-proliferation of debris. Launched in 2004 on the Russian Dnepr launcher, the DEMETER satellite (Detection of Electro-Magnetic Emissions Transmitted from Earthquake Regions) is the first project from CNES' Myriad microsatellite design. It is designed to detect possible ionospheric perturbations due to terrestrial seismic activity, with the aim of trying to find a possible pre-seismic perturbation that could ultimately allow an earthquake warning system to be developed.

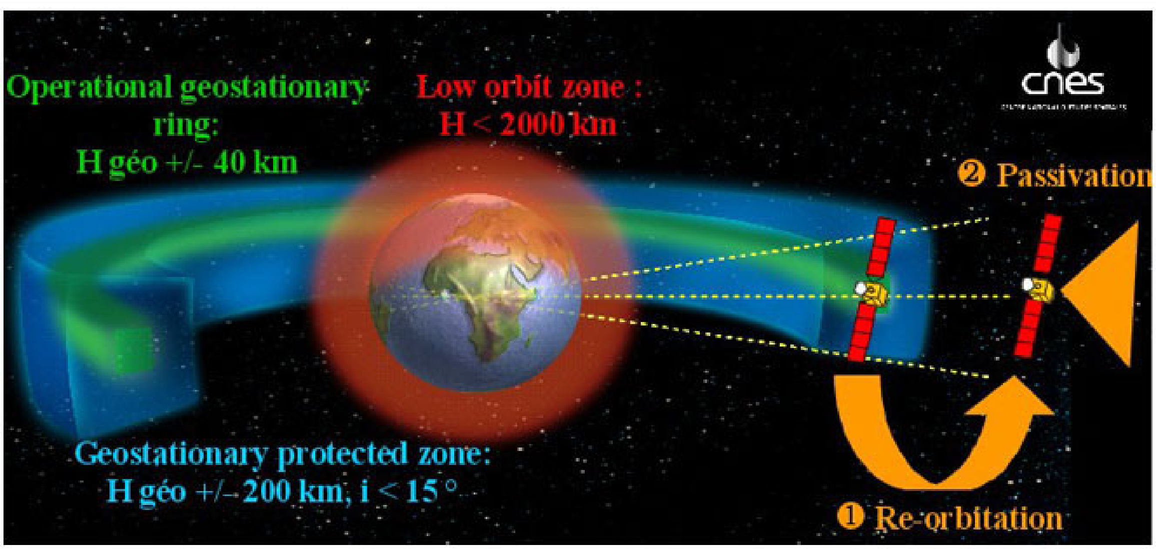
The nominal spacecraft lifetime is 2 years but tests performed prior to launch led to the conclusion that the diodes aimed at protecting the solar cells during partial eclipse could be damaged after a certain number of utilisation cycles. The failure of these cells could lead to loss of the solar arrays, and hence loss of satellite control through loss of power. If such a loss of control were to arise on DEMETER's nominal orbit, there would be no means to satisfy the requirements to ensure satellite orbit degradation and disintegration within 25 years. As the safe number of cycles would be reached quickly, a means to resolve the problem needed to be studied.

Demeter
Illustration courtesy ESA

The solution finally chosen, to manage the risk, was to reduce the DEMETER orbit from 700km to 660km, to be compatible with an atmospheric re-entry within 28 years in the case of loss of the spacecraft. This reduction in spacecraft orbit was the best compromise for both continuing the mission and respecting the principle of non-proliferation of on-orbit debris. After complex analysis of the manœuvres to perform to maintain mission and debris constraints, the operations were executed successfully between December 2005 and January 2006, allowing DEMETER's mission to continue whilst providing security for the case of an eventual loss of the spacecraft.

The challenge of the European Code of Conduct on space debris has also been met by CNES for geostationary satellites, in particular for the Telecom 2 fleet for which CNES provides stationkeeping support for France Telecom and the French Defence Agency. The challenge needed to be met most recently for the Telecom 2A satellite, that after 14 years of activity was coming to the end of its operational life. The objectives with regards to debris avoidance were identified on the one hand to put the spacecraft into a graveyard orbit as recommended by the IADC. This required performing a sequence of manoeuvres to raise the satellite's orbit by at least 300km, whilst maintaining a reasonable eccentricity. This was not sufficient however as at the end of life, the spacecraft would still have pressurised reservoirs containing unused fuel and helium pressurant at almost 14 bars. Due to the material degradation possible in the hostile space environment, it was recognised that the smallest mechanical failure or micro-fissure could lead to an explosion, resulting in a cloud of debris and also considerably polluting the commercially valuable orbits. A means to reduce this risk is to passivate the spacecraft fluids prior to power-down i.e. to empty all the reservoirs and depressurise them, to reduce the risk of explosion. Such a passivation is not without risk itself, however, any fluid release inducing a thrust on the spacecraft. It was therefore necessary to ensure such release would be in the correct direction so as not to degrade the achieved orbit, to ensure protection of the geostationary corridor, nor to degrade the attitude, with which the release direction and communications with Earth could be maintained.

In collaboration with EADS Astrium, the platform manufacturer, and after a complex and new analysis phase (as no such fluid passivation process had ever been conducted before on this type of spacecraft), a strategy taking into account all the constraints was developed. The successful execution crowned 15 days of intense operations, with TC2A left powered down and with empty reservoirs on a graveyard orbit 340km above the operational geostationary orbit, above the 300km recommended by the IADC.



Nouveau

D th p 2 y C h a a a e t th s i th it 8 geostationary orbit reboosts, two fluid passivations and, for three LEO satellites, a reduction in orbit in line with IADC recommendations. Above the satisfaction with the successful completion of end of life activities, these operations have allowed experience to be gained that will be essential for the future and has demonstrated to all organisations in space that respecting the recommendations for space debris are far from insurmountable even for spacecraft developed and launched long before the realisation of the problem. Let us hope that such efforts will not only allow us to promise future generations "space for the Earth", but a clean space too.

Laurence Lorda is part of the operational flight dynamics team at CNES, with primary responsibilities on Telecom 2 stationkeeping. She can be reached at **laurence.lorda@cnes.fr**.