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SPACE DEBRIS MITIGATIONS VERSUS REMOVAL, ECONOMICAL AND TECHNICAL CONSIDERATIONS

Saul Daniel Santilan Gutierrez
UNAM Facultad de Ingenieria UAT, Juriquilla, Queretaro Mexico email: saulsan@unam.mx
Monica Aparicio Estrada Monica
UNAM Facultad de Ingenieria UAT, Juriquilla, Queretaro Mexico email: monica,ae@comunidad,unam.mx
Jorge A. Ferrer Perez
UNAM Facultad de Ingenieria UAT Juriquilla Queretaro Mexico email: ferrerp@unam.mx
Chavez Carmona Rafael G
UNAM Facultad de Ingenieria UAT Juriquilla, Queretaro,Mexico email: rchavez@comunidad.unam.mx
Romo Fuentes Carlos
UNAM Facultad de Ingenieria Juriquilla,QUeretaro Mexico UAT crf2000@unam.mx
Ramirez Aguilar Jose Alberto
Alvar Saenz Otero
Massachusetts Institute of Technology, SSL Department, Cambridge, MA, USA email: alvarso@mit.edu

ABSTRACT

Whereas space debris removal has captured public imagination and several ideas are under research and development, such measures faces great challenges in technical complexity, cost and risk. Notwithstanding those factors, the constant ingress to our atmosphere of spacecraft debris and the extensive use of the LEO orbit would not allow space fairing nations to give up on them yet. This paper proposes the adoption of mitigation as a concept that should be incorporated earlier in the space missions, because technically and economically feasible measures are becoming a reality for recent developments for nanosatellites and small satellites in LEO Orbit. There are new technologies available in the navigation and propulsion systems that could offer in a near future a practical way for controlling the space debris generated by several missions. While cleaning the space is an issue that must be solved responsibly and cannot be ignored, we need to understand as a community that the removal of space debris requires resources that at the best are available, but have not been proven successfully yet, and the technical complexity and risk involved can make several missions unfeasible in the short term. The application of the concept of sustainable development techniques to space engineering is not straightforward, however it can provide different insights and open new venues for developing policies for the long term development of space technology as a sustainable resource. The concept of recycling has not meaning in the space area products, however, some concepts, like a planned product cycle introducing the concept for a planned disposal of the remains of a mission could make more sense now than few years ago. The present work is part of a research conducted at UNAM to find out how the concept of sustainable development could be adopted in a space mission, and develop one mission incorporating such concepts, at a reasonable cost.

BACKGROUND

Space debris is a problem that need to be addressed, not only for the ethical and technical challenges that it had brought to the space community, but for the consequences that can affect in the short term the development of small satellites, nanosatellite and picosatellite missions.

While the launching of nanosatellites from the space station and small launchers have been envisioned by several companies and space agencies to get in the region of 300 km orbit, the trend to privatize space development in the western world, and the increase of space fairing nations developing nanosatellites and microsatellite missions as a viable resource for remote sensing and other applications have triggered a growing number of missions in other LEO orbits. However the development of nanosatellites without navigational controls have been received with some criticism, especially for the big agencies of the first space fairing nations that are monitoring space debris and the members of the ISS project, which requires constant adjustments to its orbit.

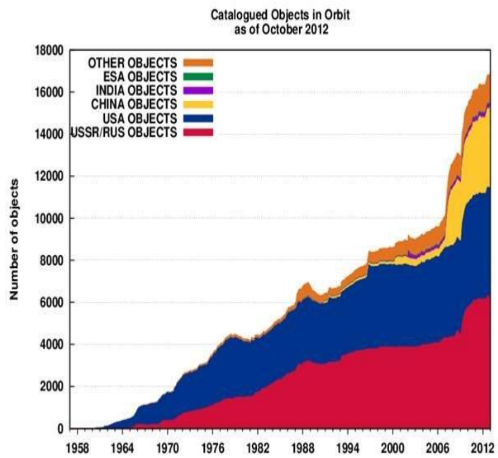

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Figure 1 Catalogued objects in orbit until 2012, ESA http://www.esa.int/Our_Activities/Operations/Space_Debris/About_space_debris

As a matter of fact, space debris has grown, however it is debatable that the major growth is due to nanosatellite missions, especially after the destruction of satellites by missiles, launched experimentally by different nations [Davies Leonard,2007][Fox News, 2008].

The reasons for the differentiation of space debris origins is needed, because nanosatellites launched in the region of 325 km or less will last only for 4 to 6 months in most of the useful orbits.

However, these missions are still representing a risk if the nanosatellite do not have a navigational control or a similar measure contemplated, because the LEO orbit is cluttered with small, micro and nanosatellites, plus debris from launchers, old satellites, collisions and old satellites in natural reentry orbits.

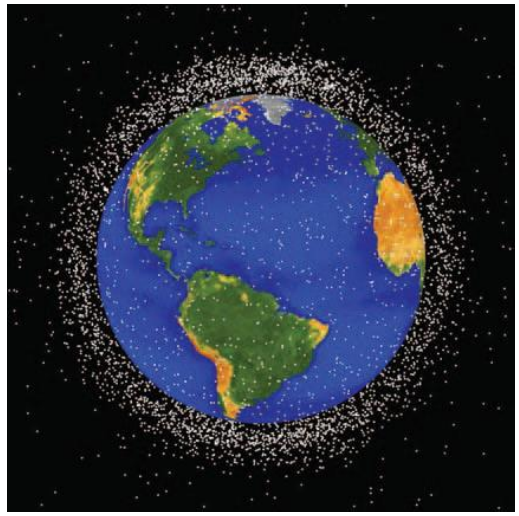

Figure 2 Computer-generated image of objects in low earth orbit that are currently being tracked. Only about 5 percent of these objects are functional satellites; the rest is debris. (The dots are not drawn to scale with Earth.) Credits nasa,gov

While some voices are targeting nanosatellite missions for having more regulatory measures prior to launching, in fairness it should be pointed that the countries that produced most of the debris are the same that are asking for new regulatory frameworks.

Our proposal centers in a better use of technology and development of skills for monitoring the operation, navigation and the development of a culture for sustainable development using the concept of planned life cycle.

We are facing conflicting requirements as a space community, experiments had shown the capabilities for micro and nanosatellite as a viable resource for remote sensing and even space exploration, Rosetta [D.J Scheere e all , 1998] is a great example on how the shift of technology have enable missions that seemed out of reach years ago by using small satellites.

However, the growing interest and planning for nano and picosatellites needs to be addressed, not in regulatory way, but in a more positive way. The trend to develop swarms, constellations and autonomous navigation distributed functionality in several satellites for collaborative missions can be alleged not be harmful if the launch is limited to closer orbits and a very strict monitoring, although the relation of information/life of spacecraft it´s critical and we do not avoid the problem of cluttering orbits with objects with limited capabilities in the latter cases.

To date few experiments for removal of space debris have been reported successful due to complications in navigation, synchronization, coupling and transport for a reentry orbit safely. The complexity of such missions is very high and risky, however not giving up on th removal of debris is critical or the long term use of the space [ESA 2014]

PROPOSAL

Regulations are always a difficult task when different interests have to be taken into account, while some countries and international entities are pushing for measures to avoid cluttering the LEO orbit (Figure 1) and regulate the development of nanosatellite missions, there is a great trend to increase these type of missions due to cost, affordability and technical complexity by universities and new space fairing nations.

New regulations for the use of electromagnetic spectrum (UIT) and restrictions for trading components related to satellite technology development has not deter the development of new projects from different nations, furthermore the amount of missions is growing and in many cases developed nations are embracing such missions for their economic feasibility and speed of development. Furthermore a growing market for systems and even missions is being developed at the moment and the use of (**C**ommercial **O**ff **T**he **S**helf) COTS technology has opened the possibility of having missions in the 2 -5 years endurance for nanosatellites and small platforms.

Nanosatelites and university projects

The growing demand and the consolidation of several small companies from diverse countries, offering heritage components and systems, have increased the reliability of many missions-

However, sometimes university projects sometimes have not considered the end of life for the spacecraft, leading to results that cannot match the current practice of a natural deorbit in less than 25 years [Kroning et all,2013] with such small devices flying without controls, a more expensive mission for debris recovery resulted from a university project Although there is a growing risk for collisions, bringing back the Kessler syndrome into consideration [Kessler,1978]

Recent new developments for active systems that can produce controlled deorbiting, amongst them attitude controls, navigation sensors and propulsion, for nano and microsatellites [CAN-2X, 2012] [Shiroma and Thakker, 2009][Lozano et all] are becoming soon a commercial reality and the possibility of thinking of missions with a planned life and disposal is becoming feasible Fig. 2..

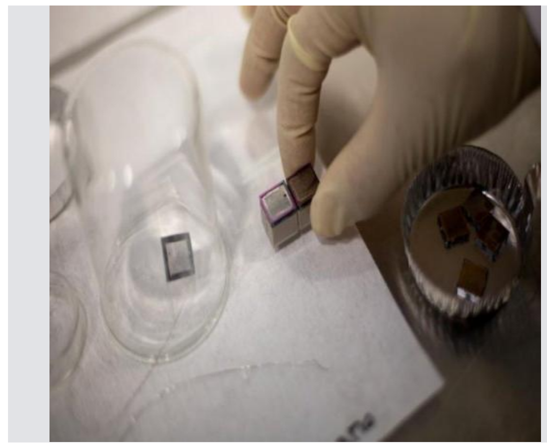

Figure 3 *A pair of mini ion thrusters, including their propellant tanks, is prepared for tests. Credit: M. Scott Brauer* Science Daily, taken from Lozano et all

Active controls can be feasible in a near future and get better solutions than passive deorbiting methods, although we need to consider cost and operational issues.

The challenge of disposing of nanosatellites orbiting at 300 km or under Is not under question, many of these missions last between 4 to 6 months and they finally burnt in the upper layers of the atmosphere during re-entry, On the contrary, the mission need to provide valuable information in order to be cost effective and that has a big burden for new space fairing nations that can be addressed with the lowering of cost for components and the increase availability of COTS systems and components with space heritage.

Microsatellites

While cubesats had success for many applications, the current state of the art in instrumentation and optics is creating many opportunity for satellites in the region of the 30 -60 kgs.

However every mission is tailor made and the cost for launching as a secondary cargo sometimes makes harder to develop such missions if not funded by governments for specific applications.

Satellites in these weight range and dimensions (50 cm per side) require a closer examination during the design phase, in order to select materials and components that can be burnt in the upper layers of the atmosphere during entry. However these are contradictory requirement with the launch and resistance for space weather operations.

On the other hand they have the possibility of incorporate navigation controls and propulsion for keeping them in orbit makes feasible the use of heritage components and systems for a 2-5 years life span and have some possibilities to operate them in a controlled way at the end of their lifespan.

Space debris from satellites could be mitigated if a controlled life span concept is introduced, before a satellite present some degree of failure in essential systems or if it reaches a life expectancy, it can be steered into orbits that can decreased the risk of collision with other satellites or spacecraft.

This approach increases the technical demands on the mission, plus a constant monitoring and control for their navigation. If the integration of navigation and/or propulsion systems can reach the border of 10-15% of the total design cost for a flight model, economical feasibility could be achieved for mitigation using active systems.

Currently we are planning a mission for testing the feasibility of the mitigation approach in a microsatellite, in order to assess the supplementary cost and the coordination and efforts for monitoring and develop the end of life route for a planned deorbit.

The mission Quetzal [Romo et all] is planned to be sponsored by government agencies for remote sensing and pollution monitoring, UNAM will work with other universities and international collaboration would be seek for the monitoring and orbiting from a flight control center and to acquire the skills for assessing the benefit/cost for a mitigation approach.

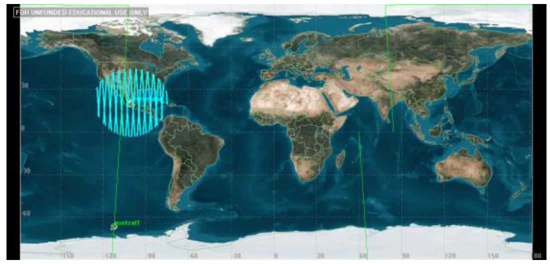

Figure 4 Orbit simulation for the Quetzal mission at 600 kms height.over Mexican territory

The mission is for a microsatellite in the region of the 39-35kg, using COTS components and orbit in between 500 to 700 km,

A cost for the mission during the design stage is estimated at a maximum of the 15%of the total amount for the integration of navigation and/or propulsion system for a calculated deorbit.

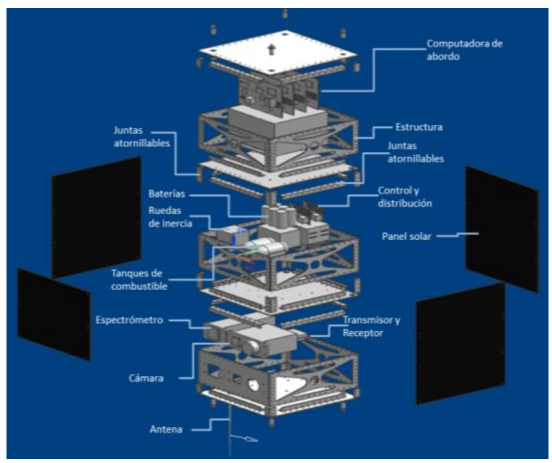

Figure 5 Satellite Quetzal First design. There still an ongoing revision of the scientific payload for reducing its size and energy budget.

Developing the capability skills for running a coordinated effort with operations control centers for microsatellite and nanosatellite missions, coordinated with international observatories for debris monitoring is a work to be planned and developed within the mission to have the complete life cycle covered.

The possibility for developing missions that are at reasonable cost and still can provide enough valuable information for the sponsors, while adopting the approach of deorbiting using active systems, provides new insights for the mission planning and development. Although is a big challenge for the project and we are eager to develop it. The concept of having a planned mission where the control can be used for deorbiting in a controlled way the satellite is not new, however is has just recently proven or reported for small and nanosatellites, not using the sustainable development approach.

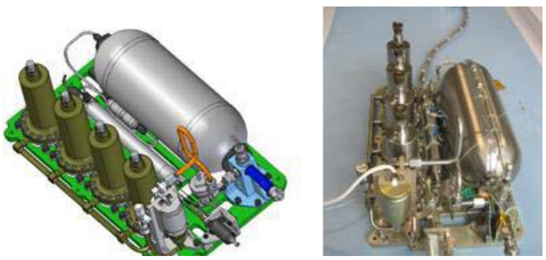

Figure 6 There are more comercialy available options for propulsion and control systems in the range of microsatellites, opening possibilities for the active system mitigation approach. Source SSTL US [13].

The space debris problem has not been addressed taking the experience from sustainable design, although less flamboyant, the mitigation approach using active systems in a microsatellite, could be implemented without causing excessive cost to the mission and decreasing the chances to produce space debris.

Approaches for incorporating dragging by curtains, inflatable devices or tethered systems [Lappas,2016][CAN X-7] have proved useful and feasible, however the associated penalties in cost, space and weight and the lack of navigational systems or the increase in complexity for navigation makes them difficult to adopt for missions over 700 km height in the case of nanosats, due to the lack of navigation and attitude control for maneuvering. They can become a liability for a collision with other missios operating in the same and lower orbits.

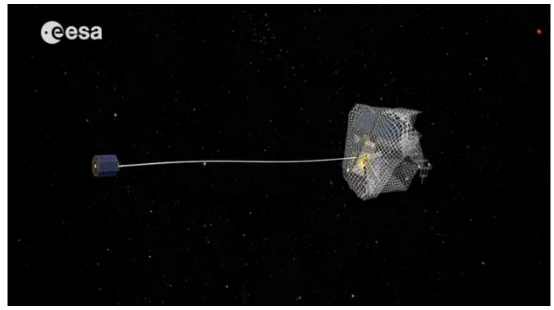

Figure 7 How to cath a satellite, ESA mission for netting a delrict satellite [ESA 2014]

Approaches for catching debris using nets [ESA 2014], clamps or other devices for handling space debris face the problems for detection, navigation, approaching and (if the object could be caught) the orbital mechanic for the coupled system, so the technical complexity is very high and the risk for recovering and maneuvering increases sharply. While some efforts seem to be progressing, the economic and technical feasibility does not seem to be widely available soon.

CONCLUSIONS

While total fairness could not be achieved in addressing the debris problem, we need to address it, from a more positive point of view and the technical know-how coming from developing missions incorporating planned life in a sustainable development approach would help create a culture that would address the problem in a more immediate way and establish a better and fairer arena for developments in universities ad new space fairing countries.

1. We need to favor nanosatellite mission in the lower orbits, trying to foster research in the technologies for navigational control and propulsion until they ca be implemented using a 10- to 15% of a typical mission cost during development. International cooperation should be enhanced for getting organizations in new space fairing nations for developing the capabilities for running operational control centers for microsatellite and nanosatellite missions, coordinated with international observatories for debris monitoring.

The incorporation of a project development phase contemplating the final stages of the life for the satellite, addressing the decision making for declaring the end of the useful life of the satellite while it is possible to deviate it to "safer orbits" and keeping the monitoring until deorbit could be assured without incident

Finally, the development of such measures, once mission are proven to be successful in developing at a reasonable cost, could attract more groups to develop missions with similar approaches in order to keep space debris controlled.

While technical solutions and natural reentry of debris would help stabilize the situation and provide a long term solution for the debris problem. The approach would not be cheap but practical and feasible.

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