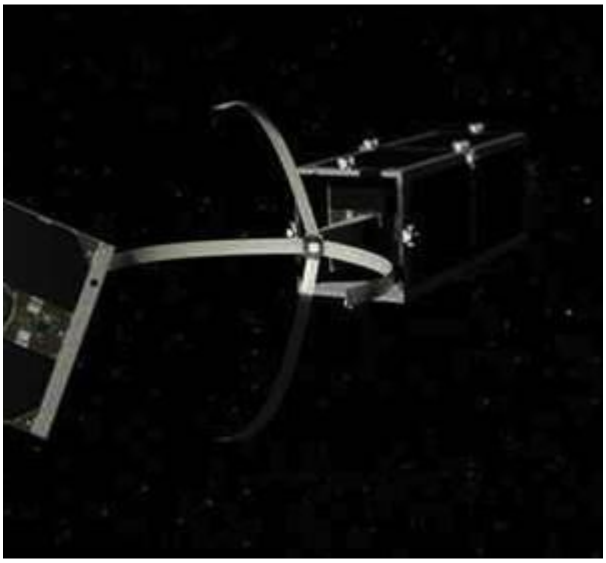
The Space Review essays and commentary about the final frontier in association with SPACENEWS



A proposed Swiss satellite to deorbit cubesats is one of several technologies being proposed or developed to clean up orbital debris, which could have additional economic benefits as well. (credit: EPFL)

Why technological innovation and increased cooperation regarding space debris are vital

by Nayef Al-Rodhan
Monday, February 26, 2018

The issue of space debris is increasingly gaining relevance in discussions on space security. In the 2016 Space Security Index report, mitigating the adverse impacts of space debris is claimed to be the "most critical challenge to the security and sustainability of outer space." Recently, the threats to space assets posed by the increasing number of uncontrolled objects in orbit have been poignantly demonstrated. In 2016, a millimeter-sized particle of space debris crashed into a solar panel of the European Space Agency's (ESA) Sentinel-1A satellite and a mysterious piece of debris crashed in Myanmar, thought to be from a Chinese satellite. Earlier that year, in May, a window of the ISS was cracked by a small piece of debris.

Over the last half-century, humans have become increasingly reliant on space technologies in telecommunication and national security applications, among many others. Such applications rely heavily on communication with satellites. Although states devote vast resources into putting satellites into space, far less effort is made to protect them from the growing amount of space debris in low Earth orbit (LEO).

Most of the debris in space is in LEO, which is the region which extends from the minimum altitude for a stable orbit, about 200 kilometers, up to 2,000 kilometers above the Earth. Because LEO is used for many of Earth's space systems applications, including remote sensing and telecommunication constellations, and also crewed space vehicles, debris in this region is the most problematic. Geostationary orbit, on the other hand, is 35,768 kilometers above the surface of the Equator and has far less debris congestion. Thus, currently, debris does not hinder our usage of this orbit.

Although states devote vast resources into putting satellites into space, far less effort is made to protect them from the growing amount of space debris in low Earth orbit.

There are more than 500,000 tracked objects larger than a marble, and millions of smaller untrackable objects orbiting the Earth at speeds of up to 28,000 kilometers per hour. The US government's Space Surveillance Network (SSN) uses approximately 30 sensors around the world to track and catalogue the positions and velocities of more than 16,000 of these objects orbiting the Earth. The tracking system registers around 400,000 observations per day, tracking objects as small as five centimeters in LEO and as large as one meter in geosynchronous orbit.

But there are limitations. A major concern, as noted by the US Strategic Command, is the virtual impossibility of knowing where every piece of debris will land if it deorbits. Many factors can change the trajectory of an object on its reentry into the atmosphere and, given that most of the sensors are located in the Northern Hemisphere, they lose real-time positioning of many objects for a few hours at a time.

Security issues

Human activity in space has generated a massive amount of space debris, which has doubled in quantity over the last 15 years. The congestion of orbits is dangerous for both satellites and the International Space Station (ISS). In fact, a single event or collision between objects can seriously increase the amount of debris in space. The 2007 Chinese anti-satellite (ASAT) test, in which China purposefully destroyed one of its own defunct weather satellites, created around 2,000 pieces of debris large enough to be tracked by SSN. Additionally, in 2009 the commercial communications satellite Iridium 33 collided with a non-operational Russian satellite (Cosmos 2251), increasing the total amount of space debris by 65% in the last 8 years. The US weather satellite that exploded in orbit due to a power system failure in February 2015 also created debris, although a smaller amount than these collisions.

The accumulation of space debris coupled with the increasing number of actors and objects in space is increasing the likelihood of collisions. This trend could eventually lead to a situation known as the Kessler Syndrome: a chain reaction in which the ever increasing amount of space debris collisions generates such a high amount of fragments that LEO becomes completely impenetrable. In 1978 Kessler predicted this phenomenon would occur around the year 2000. His prediction has not yet materialized, but there are reasons to suggest we may be nearing the tipping point. Crossing the tipping point would leave the majority of space assets in LEO vulnerable to destruction from space debris, potentially crippling the industries and applications that rely on them. In response to this threat, numerous new technologies have been invented to clean up the debris currently in LEO and beyond.

Proposed technologies

Clean Space One EPFL: To be launched in 2018, the CleanSpace One satellite aims to grab pieces of space debris using a "claw-like" grasping tool and carry them into the atmosphere, where they will burn up. Given the velocity of space debris fragments, the project represents an impressive engineering endeavor.

SpaDE Raytheon BBN Tech: Space Debris Elimination (SpaDE) is a system proposed by Raytheon BBN Technologies and the University of Michigan whereby debris is removed from orbit by firing pulses of atmospheric gases into the path of targeted debris. These focused pulses will increase atmospheric drag to the point where the deorbit rate exceeds the debris generation rate. Ostensibly, the pulses will be shot from high-altitude balloons stationed somewhere between 25 and 35 kilometers above the Earth. To avoid compounding the problem of space congestion and collision potential, the pulses will fall back into the atmosphere.

Sails: Sail technology offers a sustainable and prudent plan for long-term space debris mitigation. The gossamer sail attached to the satellite enhances drag and reduces the amount of time for the satellite to return to Earth. Sails will thus offer a valuable new satellite de-orbiting technique by means of atmospheric drag augmentation. While many satellites rely on propellant-based maneuvering thrusters that often no longer function at mission's end, a sail would allow for the gradual, sustainable, and reliable re-entry of unwanted satellites. Eventually, sail technology could be developed to attach to existing space junk to remove it from orbit. This technology was developed by the University of Surrey (UK) and has been tested by ESA since 2013.

Gecko Technology (NASA): Inspired by the gecko's ability to stick to sheer surfaces, gecko technology harnesses gravity-defying adhesive forces. NASA's design could enable the trapping of objects that are spinning rapidly, which makes them harder to catch. As part of NASA's Phoenix program, a gripper was developed and successfully tested in microgravity, where it was able to clasp and hold on to objects of up to 115 kilograms. In March 2016, NASA also sent gecko technology to the ISS for testing.

Currently, states seldom cooperate in their various debris-tracking programs, resulting in the development of national projects that are both lengthy and costly endeavors.

EUSO Telescope: Initially developed to detect ultraviolet light, the Japanese EUSO telescope will also play a role in tackling the problem of space debris. Advances in optics have equipped the telescope with the ability to spot space debris. An attached laser beam could then be used to deorbit individual pieces of debris. The laser is made using optical fibers, and its pulses can swiftly decrease an object's orbital velocity so that it reenters the Earth's atmosphere. A smaller model of the telescope will initially be installed on the ISS. If successful, it will be replaced by a larger version which will be able to deorbit debris with a range of around 100 kilometers.

Space Sweeper with Sling-Sat: This Texas A&M project focuses on inefficiencies in transportation in space debris clean-up efforts. The idea is to exploit the momentum imparted by the capture and ejection of one piece of debris to propel the machine onto the next space junk object. The system offers a low-cost, sustainable strategy for debris collection due to low fuel costs. Astroscale, a

Singapore-based private company, is currently developing a satellite equipped with magnets which can pick up several pieces of debris and drag them into before dragging it into the atmosphere where it will burn up in re-entry.

ElectroDynamic Debris Eliminator: Another method of space debris cleaning which is not far from implementation is the EDDE solar-powered net. This is a net anchored by a sequence of nanosatellites that are connected by electrically-conducting tape that can stretch up to three kilometers in length. The net can be remotely piloted, thanks to a low-thrust propulsion system. The EDDE functions by ensnaring debris in one of its nets and dragging it into a lower orbit where the fragment burns. The EDDE then repeats this operation.

Space Fence: Another effort to monitor space debris is the Space Fence program developed by Lockheed Martin for the US military, which "will make 1.5 million observations a day to detect, track, measure and catalog items as small as a baseball and will support catalog growth to 200,000 objects." This project aims to increase the amount of space objects we are currently able to survey by a factor of ten.

Space Surveillance Telescope: The Defense Advanced Research Project Agency (DARPA) has created a large telescope with the purpose of monitoring objects the size of softballs in geosynchronous orbit to avoid potential damaging collisions with its military and commercial satellites. DARPA is also investigating robotic tools which could be used in orbit to service dead satellites and do repairs.

Another solution could be to use powerful lasers on the ground or in space to vaporize space debris. However, the distinction between anti-satellite laser weapons and debris-cleaning lasers would be very difficult to establish, which would raise many security issues.

Escaping the stalemate: the way forward

There are two main approaches to the issue of space debris congestion: cleaning debris with new technologies and implementing programs to prevent the creation of more debris.

Currently, states seldom cooperate in their various debris-tracking programs, resulting in the development of national projects that are both lengthy and costly endeavors. For example, in 2012 the European Space Agency (ESA) developed its own Space Surveillance and Tracking (SST) program and Japan expects to be able to track debris by 2019. To prevent collisions, there is a need for a Space Situational Awareness System (SSAS), where all space asset orbital information is shared.

Outer space is arguably the last true global commons and it is crucial that it remains a resource to be used by all for the benefit of humanity.

Such a system has obvious security implications and raises the issue of prioritization between national and global security. A solution to this predicament would be to entrust an international regulatory body, such as the UN, with the oversight of satellite coordination. Such supranational regulation would allow for the safer maneuvering of satellites and reduce the likelihood of accidents. It would also increase information-sharing and communication between space actors, which is an important factor in avoiding the creation of new space debris. Together, the US and the Commonwealth of Independent States own over two thirds of the world's 4,000 orbiting satellites (the US has slightly more.) These states consequently have a both disproportionately large responsibility and interest in maintaining a sustainable space environment. Perhaps a deal between the major spacefaring actors could lay the foundations for a global regulatory body. To this end, the space debris mitigation guidelines were agreed upon at the UN in Vienna. In 2013, a UN group of governmental experts on outer space worked on transparency and confidence-building measures (TCBMs) in outer space activities. The European Union has also established an initiative for an International Code of Conduct for Outer Space Activities.

To ensure that space remains accessible to all, it is imperative that all states, especially those with many satellites, take concrete steps to ensure that congestion does not become a reality. Tackling this issue is crucial for businesses and geopolitics alike, and will require consensus and cooperation beyond any zero-sum calculations. Outer space is arguably the last true global commons and it is crucial that it remains a resource to be used by all for the benefit of humanity. The nature of challenges coming from space debris requires solutions based on a "cooperative-security" concept that I previously called the "multi-sum security principle": in a globalized world affected by global and transnational phenomena, we cannot think of security as a zero-sum game involving states alone. Rather, security has more facets (human, environmental, national, transnational, transcultural) and achieving collective security involves achieving it *with* others and not against them.

The issue of debris in space is a classic illustration of the value of the Multi-Sum Security Principle. There are no relative gains concerning space debris. A tiny metal shard traveling at 28,000 kilometers per hour will not discriminate between a Russian satellite and a US one. States have clear incentives to cooperate on issues like debris mitigation, not only to make satellite orbits safer, but also to create a precedent of international trust and sustained cooperation.

Ingenious technological solutions from inventors in the startup community, university labs, and technology companies are abundant. What remains to be done is for states to commit tocustomize and use these technologies collaboratively, and without delay. This can also be a turning point for revalidating the notion of space as a global commons: a notion that came under serious threat with theincreasing potential forspace militarization.

Prof. Nayef Al-Rodhan (http://www.sustainablehistory.com/ & https://oxford.academia.edu/NayefAlRodhan) is Honorary Fellow at St Antony's College, University of Oxford, and Senior Fellow and Head of the Geopolitics and Global Futures Programme at the Geneva Centre for Security Policy. He is the author of Meta-Geopolitics of Outer Space. An Analysis of Space Power, Security and Governance *(Basingstoke: Palgrave Macmillan, 2012). Tweet @SustainHistory.*