ACHIEVING A SUSTAINABLE SPACE ENVIRONMENT

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In the 50 years since the launch of Sputnik, the world has made great strides in the development and use of the space environment. Developed nations, especially, have become highly dependent on space applications for communications, broadcast services, navigation and daily weather forecasts, among other useful services. Developing states as well are increasing their dependence on such systems. Today, however, growing numbers of in-orbit spacecraft, increasing amounts of orbital debris and the threat of space weapons in orbit endanger the future use of outer space.

Some 830 working satellites now orbit Earth, providing benefits in the form of useful services, scientific observations and peacekeeping. This chapter outlines the primary threats to future space activities and explores the steps that will be needed to ensure the continued peaceful use of outer space. In particular, it examines orbital debris mitigation, cooperative space situational awareness and space traffic management. It analyses the opportunities and challenges faced by the space community in addressing these important steps to a sustainable space environment.

BENEFITS FROM SPACE ACTIVITIES

Since October 1957, the use of the orbital Earth environment has grown substantially to the point that governments, the private sector and the world's militaries now depend on satellites and their associated ground systems to provide numerous social and economic benefits.

Yet the benefits are not solely economic in nature. Position, navigation and timing (PNT) systems provide numerous non-quantifiable social benefits around the world, including enhancing safety of life and property and easing the plight of lost drivers everywhere. In the United States, satellite systems now provide more than 90% of the data that feed into the models for the US National Weather Service forecasts.[1] Further, space systems enhance

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the ability to secure borders, fight natural disasters and reduce fraud in agricultural support systems.

The striking thing about space systems today is that many of the benefits they provide are so suffused throughout society that we hardly even notice that they derive from satellite systems. Whether the application is on-line banking, cell phone use or using a credit card to purchase fuel from the local service station, citizens both of developed and developing countries are making increasing use of such services. In the future, the nascent use of satellite services in tele-health and tele-education is expected to grow, bringing numerous benefits to rural communities around the world and reducing the gap between rich and poor. Additionally, in some cases satellites offer developing countries the opportunity to catch up to more developed countries in communications and natural resources management without going through an initial stage of expensive infrastructure development.

THREATS TO CONTINUED USE OF THE ORBITAL SPACE ENVIRONMENT

Operating spacecraft successfully has always been a challenge because outer space is a risky place where spacecraft designers need to plan for extreme vacuum, extreme cold and a high radiation environment, among many other engineering issues. The design challenges the space environment pose have been largely, if expensively, solved. However, recently, orbital crowding, growing clouds of orbital debris and the threat of destructive space weapons have added to the threats faced by the systems that we depend upon daily.

Increasingly crowded orbits

Outer space is vast and mostly empty, with collisions between working satellites only a remote possibility. However, certain choice orbits are becoming sufficiently crowded that satellite-to-satellite collisions are increasingly possible. For example the sun-synchronous polar orbits that Earth observation satellites use to provide valuable reconnaissance, weather and commercial information to users are particularly at risk.

As a case in point, on 4 July 2007, the US National Aeronautics and Space Administration (NASA) found it prudent to move the US–Canadian

CloudSat satellite in order to avoid a possible collision with the Iranian SINAH-1 remote-sensing satellite. CloudSat, launched in April 2006, is an experimental satellite devoted to providing, among other things, new data about the relationship of clouds to storms using advanced radar. SINHA-1 is Iran's first remote-sensing satellite, launched in October 2005. The manoeuvre reduced the risk of collision.

A few days later, NASA moved CloudSat back into its earlier position in order to synchronize its orbit with the Cloud-Aerosol Lidar and Infrared Pathfinder (CALIPSO) satellite, a joint project between NASA and the French Centre national d'études spatiales. Working together, the two satellites provide "new, never-before-seen 3-D perspectives of how clouds and aerosols form, evolve, and affect weather and climate".[2]

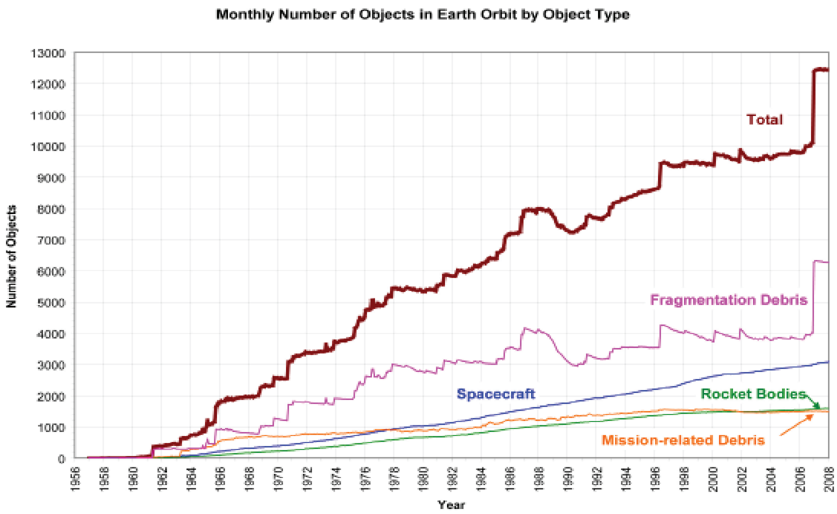
Not only would a collision between the US and Iranian satellites have dealt a significant blow to climate science and Iran's nascent remote-sensing efforts, it would likely have added to the significant political tension between the two countries.

The geosynchronous orbit (GSO) that is home to the world's communications and many weather satellites is also crowded. Commercial communication satellite operators are becoming concerned that in the foreseeable future, when making needed orbital manoeuvres, they will collide either with other working satellites, or even with defunct ones that have remained in GSO. Although these satellite operators know where their satellites are located with considerable precision, they do not necessarily know the positions of other working satellites with sufficient precision. Over time, as the valuable GSO becomes even more crowded, the risk of collisions will increase.

Growth of orbital debris

Orbital debris is an even greater threat to working satellites (see Chart 1). Debris creation is an unavoidable by-product of launching and operating spacecraft in Earth orbit. The process of releasing a spacecraft from the protective shell used during launch leaves a variety of small pieces in orbit. Upper-stage rocket bodies also stay in orbit, and have been known to explode, even after years in outer space. In addition, spacecraft batteries may fail and explode, spreading fragments of the satellite in ever increasing arcs around the initial orbit. Finally, orbital tests that have destroyed satellites by the Soviet Union in the 1970s, the United States in the 1980s and the Chinese in 2007 have left thousands of additional pieces of debris in orbit.

Chart 1. The yearly growth of objects in Earth orbit



Source: National Aeronautic and Space Administration, Orbital Debris Quarterly News*, vol. 12, no. 1, p. 12, January 2008. Information on classified satellites is withheld, as are the orbital elements of debris of uncertain provenance.*

Debris experts estimate that more than 17,000 pieces of debris 10cm in length or greater now speed around Earth in various orbits. The number of untrackable smaller bits is orders of magnitude greater. Yet, even small debris fragments can be highly destructive because the impact velocities between debris and a satellite approach an average of 10km per second. Such hypervelocity impacts can shred a satellite and leave it in bits, adding to the amount of debris in orbit.

Starting in the 1990s, the world's major spacefaring countries developed a series of measures to limit the creation of orbital debris from normal space operations. These measures have reduced, but not eliminated, the creation of new debris. Hence, debris experts expect the orbital debris population to increase steadily as more countries enter the world of space activities.

The threat of space weapons

The most serious threats to the continued sustainability of space activities are certain types of anti-satellite weapons, the most destructive of which can leave thousands of additional pieces of debris in orbit. As an example of the threat of debris creation, on 11 January 2007, China intentionally destroyed an aging Chinese weather satellite, Fengyun-1C. That incident added some 2,400 pieces of trackable debris to the deadly mix already in sun-synchronous polar orbit, sharply increasing the long-term danger to working satellites.[3] The satellite was orbiting at an altitude of about 800km and orbital debris at those altitudes takes tens of years to fall back to Earth. In the meantime satellites that we depend on for critical environmental, security and business-related information are at increased risk (notice the increase during 2007 in Chart 1).[4]

The United States and the Soviet Union had both tested anti-satellite weapons in the past, but had shut down those programmes for fear of creating more orbital debris. However, on 21 February 2008, the United States shot down an errant US satellite. The official reason given for this action was to prevent it spreading its large load of highly toxic fuel on the Earth's surface.[5] The United States justified the action on the basis of public safety and the fact that its orbit had declined to a relatively low 270km by time of impact, yet to much of the world, this action looked very much like an anti-satellite test.

Space weapons are of concern because many types, especially kinetic energy weapons, can leave huge amounts of debris in orbit. This debris spreads widely throughout its orbit, creating hazards for satellites orbiting nearby.

STEPS TOWARD THE SUSTAINABLE USE OF THE SPACE ENVIRONMENT

The Secure World Foundation is committed to assisting effective measures to achieve a sustainable space environment. Reaching this goal includes the following steps:

Limiting orbital debris formation

Fortunately, even non-experts have come to realize that it is important to keep space debris to the absolute minimum. That is why, after years of study and discussion, the United Nations Committee on the Peaceful Use of Outer Space (COPUOS) passed a non-binding resolution in June 2007 formally calling for the reduction of debris generation and the study of means to remove debris from orbit. The UN General Assembly accepted the resolution in October 2007. COPUOS followed closely the recommendations of the Inter-Agency Space Debris Coordination Committee (IADC), the group of spacefaring states that had been working on the development of debris mitigation guidelines for well over a decade.

Passage of this resolution was an important, perhaps crucial, step in providing long-term governance of our orbital environment. Part of the impetus behind its passage was apparently the 2007 Chinese incident mentioned above, which highlighted the seriousness of the debris problem and shocked many of the COPUOS delegates. However, this non-binding resolution is not enough. For these guidelines to be effective, each state will need to adopt binding national regulations at least as strong as the UN debris guidelines.

Space situational awareness and space traffic management

Larger steps toward space governance are needed. As additional countries and private companies launch spacecraft into orbit, popular orbits like the polar, sun-synchronous and geosynchronous orbits are becoming a lot more crowded and will eventually need an international space traffic management system to keep these highly useful orbits relatively collision free.

As the case of the CloudSat and SINHA-1 satellites reveals, a quasi-space traffic management regime exists now, mostly controlled by the United States. The US Air Force maintains ground-based optical and radar observatories that keep track of the 18,000 or so working satellites and larger debris—so-called space situational awareness (SSA). Through NASA, it publishes an open catalogue of orbital elements that commercial and non-US satellite operators can use to guide their spacecraft and avoid collisions. However, this open catalogue holds much less information on orbits of working satellites and debris than the full catalogue (information on classified satellites is withheld, as are the orbital elements of debris of uncertain provenance). Commercial entities and non-US national agencies can request and receive guidance from the US Air Force in planning needed for spacecraft manoeuvres. However, satellite operators complain that the US Air Force is often slow to respond to requests. That is understandable, given the demands of maintaining SSA against ever increasing amounts of debris and satellites. The US Air Force budgets for maintaining such a capability have generally not kept up with the need for personnel and information tools.

Further, other countries do not want to depend on the United States for such critical information. As a result, several countries, including China, France, Germany and Russia are now developing or strengthening their own SSA capabilities. Because the US military advantage in maintaining a closed catalogue is therefore declining, it would be in the interest of the United States to lead the way in a cooperative programme for SSA, first with close allies, and then broadening to other space-capable nations as experience is gained. This could be an important first step in developing an international space traffic management system for outer space, a system that would provide much greater safety and security for the many Earth observation satellites in the increasingly crowded sun-synchronous polar orbits.

THE ROLE OF INTERNATIONAL COOPERATION IN ADVANCING THE SUSTAINABILITY OF SPACE ACTIVITIES

Improving the sustainability of space activities requires the countries using the space environment to cooperate on the development of technical standards, legal instruments and practices that will improve as far as possible the continued ability to conduct beneficial space activities and prevent the placement of weapons in space. Cooperation can take many forms, ranging from bilateral cooperation on specific projects to broad sharing of plans and coordination of research and applications projects. Examples include the Global Earth Observation System of Systems, the Committee on Earth Observation Satellites, and the IADC.

Each of these cooperative mechanisms makes possible the sharing of technical standards and plans and fosters greater transparency among nations, an essential ingredient in reducing tensions and promoting peaceful solutions.

CONCLUSION

We at the Secure World Foundation are convinced that ensuring the long-term sustainability of outer space activities is most effectively achieved through a bottom-up approach focused on vigorous efforts to reduce the further generation of orbital debris, development of a code of conduct for outer space (leading eventually to a space traffic management regime), and agreements to ban anti-satellite weapon development and tests.

For example, the Secure World Foundation has begun a major project focused on exploring the technical, political and economic issues of an international space traffic management scheme or system. There are many possible models for such a system, ranging from one modelled on air traffic control to a system of systems, where each spacefaring state agrees to provide data of sufficient accuracy and precision to an internationally endorsed entity that then provides space agencies and commercial spacecraft operators with operational orbital guidance for manoeuvres and collision avoidance. Whatever scheme is put into place must be technically and legally sound and politically acceptable.

In order to pursue this thrust and its many other activities, the Secure World Foundation maintains partnerships with a variety of organizations focused on the development of technical, legal and political means to ensure the long-term sustainability of outer space activities.

Any new venture can be dangerous and has risks. The out-of-control satellite that the United States destroyed in 2008 is an example of the many risks we face in the future use of outer space. The odds of dying in a car accident are far greater than being hit by a falling satellite, and yet we continue the use of the automobile. Societies throughout the world have developed rules and regulations to mitigate some of the dangers of the automobile (speed limits, drivers licenses, standards for production, stop signs, seat belt regulations) as well as consequences for violations (speeding tickets, jail, fines). We do not yet have related “rules of the road” for outer space. When a satellite fails, what is the proper procedure to mitigate possible danger to the population, who makes that decision and how can disagreements be resolved? These questions must be answered as we move forward into the next 50 years of space activities. No country can or should attempt to act as policeman of the world with regard to space security. The Secure World Foundation contends that because outer space is a global commons, answering these questions requires global participation.

Notes

1 James Heil, National Weather Service, Office of Climate, Water, and Weather Service, presentation at the Space Policy Institute workshop on "The Value of Improved Weather and Climate Information from Satellites in the Electric Power Industry", 29–30 March 2004, presentation available at <http://www.gwu.edu/~spi>.

2 See <www.calipso.larc.nasa.gov>.

3 Secure World Foundation, *Secure World Newsletter*, no. 10, <www.secureworldfoundation.org/Newsletter10.pdf>, July 2008.

4 Leonard David, "China's Anti-Satellite Test: Worrisome Debris Cloud Circles Earth", *Space.com*, 2 February 2007, <www.space.com/news/070202_china_spacedebris.html>.

5 James Oberg, "U.S. Satellite Shootdown: The Inside Story", *IEEE Spectrum*, 11 August 2008, <www.spectrum.ieee.org/aug08/6533>.