Floating Space Debris contaminating the Beach of Earth : Toward the time/space theory for complexity green criminology

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1 Introduction

Environmental harms/crimes have diverse aspects, phases and dimensions. On the one hand, we find national, intra-/inter-regional, and trans-regional phenomenon. It is necessary to view environmental harms/crimes from a trans-spatial perspective. On the other hand, learning lots of things from ruins and remnants of past environmental destructions, we are apprehensive that environmental catastrophes might occur in the near future. It is necessary to view past/present/future environmental harms/crimes from a time-series perspective. Finally, a way of fission and fusion of time/space theory for complexity green criminology will be suggested.

2 Swell of spase debris

2.1 Space junk has reached "tipping point"

The committee of NRC insists that the amount of debris orbiting the Earth has reached "a tipping point" for collisions, which would in turn generate more of the debris that threatens astronauts and satellites. We need a new strategic plan for mitigating the hazards posed by spent rocket bodies, discarded satellites and thousands of other pieces of junk flying around the planet at speed of 17,500 miles per hour (Committee:1).

The problem of space debris is similar to a host of other environmental problems and public concerns characterized by possibly significant differences between the short- and long-run damage accruing to society.

Damage related to atmospheric concentrations of greenhouse gases, storage of nuclear waste and long-lived pharmaceutical residue in underground aquifers. Each has small short-run effects but, if left unaddressed, will have much larger impacts on society in the future.

2.2 ESA Space Debris Office

Since the mid-1980s, ESA (European Space Agency) has been active in all relevant research, technology and operational aspects

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related to space debris. Agency expertise is mainly concentrated at the European Space Operations Center (ESA/ESOC), Darmstadt, Germany, and the European Space Research and Technology Center (ESA/ESTEC), Noordwijk, The Netherlands (ESA).

The team at ESOC have developed long-standing experience in the area of:

- Rader and optical measurements and their simulation
- Development of space debris and meteoroid environment and risk assessment model
- Analysis of debris mitigation measures and their effectiveness for long-term environmental stability
- In-orbit collision risk assessments
- Re-entry safety analyses
- Space debris database issues (ESA)

2.3 50 years of space activity

ESA explains that, with increasing space activities, a new and unexpected hazard started to emerge: space debris. In almost 50 years of space activities, more than 4,800 launches have placed some 6,000 satellites into orbit, of which only a minor fraction - about 800 - are still operational today. Besides this large amount of intact space hardware, with a total mass of about 5,500 tonnes, several additional objects are known to orbit the Earth. More than 12,000 in total are regularly tracked by the US Space Surveillance Network and maintained in their catalogue, which covers objects larger than approximately 5 to 10cm in low Earth orbit (LEO) and 30cm to 1m at geostationary altitudes (GEO) (ESA).

It continues, only 6 percent of the catalogued orbit population are operational space craft, while 38 percent can be attributed to decommissioned satellites, spent upper stages and mission-related objects (launch adaptors, lens covers, etc.). The remaining 56 percent originate from more than 200 in-orbit fragmentations which have been recorded since 1961. Except for a few collisions (less than 10 accidental and intentional events), the majority of the 200 break-ups ware explosions of spacecraft and upper stages. These are assumed to have generated a population of objects larger than 1cm on the order of 600, 000. Only near sizes of 0.1mm to 1mm may be the sporadic flux from meteoroids, which prevail over man-made debris (ESA).

Moreover, the main cause of in-orbit explosions is related to residual fuel that remains in tanks or fuel lines once a rocket stage or satellite is discarded in Earth orbit. Over time, the harsh space environment can deteriorate the mechanical integrity of external and internal parts, leading to leaks and/or mixing of fuel components, which could trigger self-ignition (ESA).

3 Sources of debris fragments

3.1 Anti-satellite test: 25 percent more debris

ESC explains sources of debris fragments that the resulting explosion can destroy the source object and spread its mass across numerous fragments with a wide spectrum of masses and imparted velocities. Besides such accidental break-ups, spacecraft interceptions by surface-launched missiles have been a major contributor in the recent past (ESA).

3.2 First-ever in-orbit collision

ESA continues that the first-ever accidental in-orbit collision between two satellites occurred 10 February 2009 at

776km altitude above Siberia. An American privately owned communication satellite, Iridium 33, and a Russian military satellite, Kosmos 2251, collided at a relative speed of 11.7km/second. Both were destroyed, and a large amount of debris generated. Satellites launched into LEO are continuously exposed to aerodynamic forces from the tenuous upper reaches of the Earth's atmosphere. Depending on the altitude, after a few weeks, years or even centuries, this resistance will have decelerated the satellite sufficiently so that it re-enters into the atmosphere. At higher altitudes, i.e. above 800km, air drag becomes less effective and objects will remain in orbit for many decades (ESA).

3.3 "Kessler syndrome" : debris growth

As for "Kessler syndrome", ESC explains that, with today's annual launch rates of 60 to 70 and with future break-ups continuing to occur at mean historic rates of four to five per year, the number of objects in space will steadily increase. As a consequence of the rising object count, the probability for catastrophic collisions will also grow in a progressive manner (doubling the number of objects will increase the collision risk approximately four-fold).

It continues that, as the debris population grows, first collisions will occur. Such collisions will start prevailing over the now-dominating explosions within a few decades from now. Ultimately, collision fragments will collide with collision fragments, until the entire population is ground to sub-critical sizes. This self-sustained process, which is particularly critical for the LEO region, is known as the "Kessler syndrome". It is a scenario that must be avoided by the timely application of space debris mitigation and remediation measures on an international scale (ESA).

4 Following satellite re-entry

4.1 Re-entry events

According to ESA, everyday satellites, rocket stages or fragments thereof re-enter into the denser layers of the atmosphere, where they usually burn up. Shortly before re-entry, at about 120km altitude, space craft have velocities of typically 28,000km/hour. In the last 10 minutes before reaching ground, the dens atmosphere starts to heat up and decelerate the spacecraft. In the case of very compact and massive spacecraft, and if a large amount of high-melting material is involved (e.g. stainless steel or titanium), fragments of the vehicle may reach the Earth's surface (ESA).

It continues that well-known examples of large-scale re-entry events were Skylab (74tonnes, July 1979), Salyut7/Kosmos1686 (40tonnes, February 1991) and Mir (135tonnes, March 2001). In such cases, up to 20 to 40 percent of the spacecraft mass may impact the surface. ESA's ATV (Automated Transport Vehicle) performed a controlled and safe re-entry into an uninhabited area in the South Pacific Ocean on 29 September 2008. The re-entry break-up process was monitored from two observation aircraft (ESA).

4.2 Re-entry prediction capability and risk control

Concerning a re-entry prediction, ESA explains that, for people and property on the ground, the hazards posed by re-entering spacecraft or debris are extremely small. So far, there has been only one reported injury and no fatality. The controlled or uncontrolled re-entry of space systems is associated with a number of legal and safety aspects that must be considered. This risk due to re-entries can be determined through analysis of surviving fragments (if any), their dispersion across a ground swath, and the resulting casualty risk for the underlying ground population distribution. Re-entry maneuvers can be optimized to control the impact footprint (ideally over an ocean area), and thus maintain the casualty probability below an acceptable risk threshold (ESA).

It continues that, in the case of uncontrolled re-entries, the re-entry time window and impact footprint can be predicted and monitored. The quality of this process can be improved through tracking data and sophisticated orbit prediction tools. ESA has all necessary capabilities to provide analysis of both controlled and uncontrolled re-entries. This includes detailed simulations of the aero-thermal and structural break-up of satellites or orbital stages, the prediction of the orbit and attitude of each re-entry fragment, the identification of objects reaching ground and the analysis of associated risk potentials for the population in the entry ground swath (ESA).

4.3 European experts follow satellite re-entry in 2011

As for following satellite re-entry, ESA closely monitored the reentry on 24 September 2011 of the NASA's non-operational Upper Atmosphere Research Satellite (UARS), observatory satellite. The Agency's Space Debris Office worked with NASA and international partners known as the Inter-Agency Debris Coordination Committee (IADC) in a coordinated prediction and risk-assessment exercise. The precise reentry time and location of debris impacts from the 5.6-tonne satellite have not been determined. No injuries or damage have been reported (ESA).

5 Control of space debris

5.1 Future developments of European observation capacity

According to ESA, in 2009 ESA launched the Space Situational Awareness Preparatory Programme (SSA-PP), aiming to increase Europe's capabilities to detect, predict and assess the risk to life and property due to man-made space objects, reentries, on-orbit collisions, potential impacts of Near Earth Objects, and the effects of space weather.

A longer warning time and more accurate predictions will assist civil authorities to react in the most appropriate manner, protecting people and property on Earth (ESA).

5.2 Scanning the skies for debris hazards

ESA explains that the first European Space Surveillance Conference (ESS2011) was held 7-9 June 2011 in Madrid, Spain. Over 150 global experts met at an ESA-organized conference to share the latest research findings on space debris, surveillance technologies, orbital hazard detection and satellite safety. The conference spotlighted ESA's SSA programme, now in the preliminary phase, which aims to put in place a ‘three-legged’ system to warn of hazards posed by orbital debris, space weather and natural objects like asteroids that may strike Earth (ESA).

5.3 Complex engineering and scientific challenge

Concerning debris surveillance, ESA insist that a new generation of software was recently implemented to warn when satellites could be hit by orbiting debris. Debris surveillance is a complex engineering and scientific challenge in part due to the fact that even a tiny piece of debris - just 1 centimeter across - can seriously damage or even destroy a functioning satellite if it impacts at orbital velocities. Today, Europe cannot scan as much of space as necessary to provide comprehensive debris warning services to private and public spacecraft operators, like those flying telecommunication, climate and weather satellites. The design for next-generation debris surveillance and tracking systems will be proposed at the end of the current preliminary phase in 2012 (ESA).

5.4 Space Debris Mitigation Guidelines

According to UNOOSA, as the population of debris continues grow, the probability of collisions that could lead to potential damage will consequently increase. In addition, there is also the risk of damage on the ground, if debris survives Earth's atmospheric reentry. The prompt implementation of appropriate debris mitigation measures is therefore considered a prudent and necessary step towards preserving the outer space environment for future generations (UNOOSA).

It explains the rationale that a set of mitigation guidelines has been developed by the Inter-Agency Space Debris Coordination Committee (IADC), reflecting the fundamental mitigation elements of a series of existing practices, standards, codes and handbooks developed by a number of national and international organizations (UNOOSA).

The following guidelines should be considered for mission planning, design, manufacture and operational (launch, mission and disposal) phases of spacecraft and launch vehicle orbital stages:

Gl 1: Limit debris released during normal operations
Gl 2: Minimize the potential for break ups during operational phases
Gl 3: Limit the probability of accidental collision in orbit
Gl 4: Avois international destruction and other harmful activities
Gl 5: Minimize potential for post-mission break-ups resulting from stored energy
Gl 6: Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission
Gl 7: Limit the long-term interference of spacecraft and launch vehicle orbital stages with geosyncronous Earth orbit (GEO) region after the end of their mission (UNOOSA)

6 Conclusions

The hazard posed by space debris is becoming of increased concern to the scientific and commercial users of space. Apart from observable, cataloged objects, there is a much more abundant population of hazardous space debris which cannot be tracked. The special distribution and dynamics of the resulting population can be expressed in mathematical models, which can be used to determine the collision risk for a given space mission. The risk on orbit can be reduced by different debris mitigation measures, the effectiveness of which can be tested in long-term projections of the debris environment. Other mitigation measures can be defined for the risk reduction due to atmospheric reentry and ground impact. The space environment must be kept as clean as possible and at a safe level for future generations.

Note:

1) This paper is based on the paper titled 'Fission and Fusion of time/space theory for complexity green criminology', and presented at the 67th Annual Meeting of American Society of Criminology, Washington, D.C., November 16-19, 2011.

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