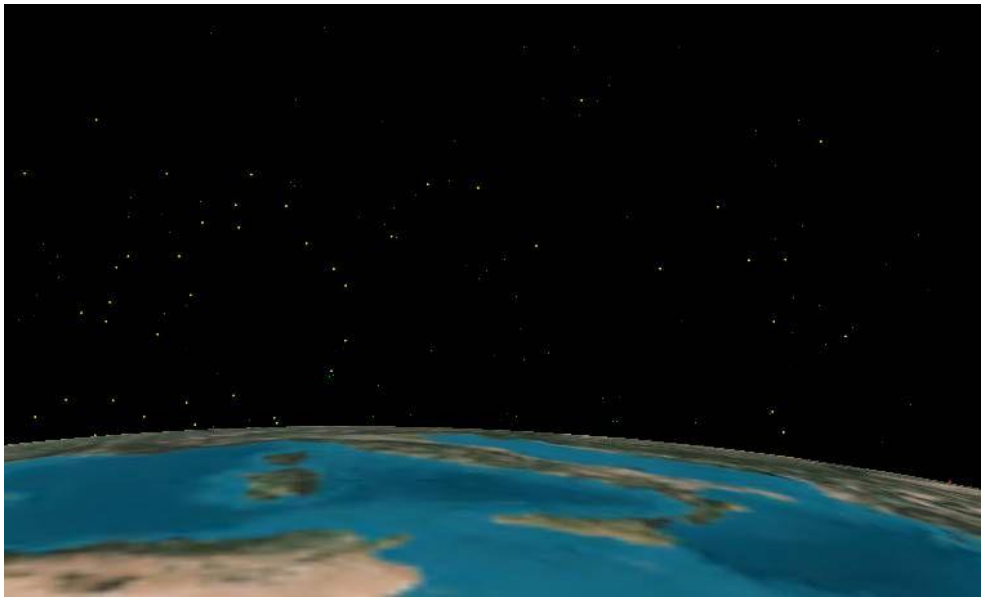
Exploded in Space!



The picture shows an unusual perspective for the current debris distribution over Europe. The shown objects are debris elements dramatically exaggerated to enhance visibility, the celestial background (stars) have been removed. The picture is taken horizontally across Europe from a tangent altitude of approximately 1000 km. (STK-generated image courtesy of Analytical Graphics, Inc, for more information please visit also http://www.CenterForSpace.com)

SpaceOps News (SoN) had the opportunity to discuss some operational aspects of the recent occurrences where two satellites (A-Sat and USA 123) were destroyed by human intervention, adding more space debris to an environment which should be kept as debris-free as possible, due to the various hazards posed by impacts of known or unknown size with satellites (manned or unmanned). The interview was conducted via e-mail with two experts on space debris:
Dr. Dave Finkleman (Senior Scientist) from the "Center for Space Standards and Innovation" (CSSI), Analytical Graphics, and
Dr. Heiner Klinkrad (Head of Space Debris Office), ESA/ESOC.

SoN: What orbits or spacecraft are more dangerous in the sense that one would have no other choice than to destroy a satellite (either by impact or by "self-destruction")?
Dr. Finkleman: IADC guidelines and international standards counsel against intentionally destroying any satellite. Therefore, intentional destruction is a last resort when no there are truly no other alternatives. There are objective dangers and subjective dangers. Objective dangers are those you are aware of and can prepare for to minimize risk. Subjective dangers are unanticipated and demand judgment to mitigate consequences. I believe that almost all dangers in orbit are objective. The risk can almost always be mitigated by design practices, diligent satellite control, and timely warning provided by trustworthy sensors and organizations. The most dangerous orbit regimes are those that are most heavily populated: geostationary orbits, sun synchronous orbits, and low Earth orbits. But the world is still a long way from crowding that might preclude further relatively safe population of any orbit regime. For example our assessments for the ISS and USA 193 debris over the period 20 March through 1 April 2008 yielded only one approach within 10 km over that entire time span. The closest approach was 9.91 km between mean orbits and posed no danger at all. However, collaboration is essential. Any spacecraft operated without regard to the presence of others makes an orbital regime dangerous.
Dr. Klinkrad: I cannot think of any scenario at all where the externally induced or self-induced destruction of a spacecraft or orbital stage would mitigate a risk in orbit. An intercept of such an object would correspond to the worst possible case: a collision in orbit. This is exactly what we try to avoid by space

debris mitigation measures.
The engagement of the USA 193 satellite was justified by the USA purely on grounds of re-entry related risks to the population on ground. The expected risk reduction on ground was found to justify the temporary increase of collision risk on orbit (e.g. for the ISS) due to mainly short-lived fragments.

SoN: What are the major alternative courses of action to remove debris from heavily populated orbital regimes?

Dr. Klinkrad: The first line of defense against the increase of orbital debris is a reduction of their growth rate. This can be done by reducing the number of mission-reacted objects released into orbit during the launch, deployment and operation of a spacecraft. This can also be done by passivating spacecraft and orbital stages at their end-of-mission (removing all sources of latent energy, such as residual propellants, pressurants, battery charges, etc.), thus avoiding explosions on orbit (about 200 so far), which at present are the largest single source of orbital debris (which represent 94% of all cataloged objects on orbit). The ultimate goal will be to remove mass from
orbit, particularly from densely populated altitude regions.
Else, this left-behind mass would cause catastrophic collisions, first in between intact objects and explosion fragments, then in between intact objects and the resulting collision fragments, and finally in between collision fragments themselves. At that point certain altitude regions might be lost for safe space operations.
If spacefaring nations do not react soon, then within a few decades on-orbit collisions will start to dominate the debris environment. To avoid this from happening, space debris mitigation guidelines have been developed at the IADC (inter-Agency Debris Coordination Committee), at UNCOPUOS' Scientific & Technical Subcommittee, within Europe (European Code of Conduct on Space Debris Mitigation), and at national level.
The most effective requirements for the protection of the orbital environment are (1) the limitation of orbital lifetimes of LEO spacecraft and orbital stages to less than 25 years after their mission completion, and (2) the re-orbiting of GEO spacecraft at the end-of-life to a graveyard orbit approximately 250 to 300 km above the GEO ring. Such measures will reduce the collision rates in densely populated orbital regions. Ultimately, however, one would need remediation measures to actively remove dead mass. This, however, is a technically and economically demanding exercise, with legal implications to be observed.

Dr. Finkleman: The best alternative is not to create debris. The problem is currently not so serious that any action is required to purposely remove debris. End of life disposal of mission oriented satellites should be considered throughout development and operation. The energy required for safe disposal of a geostationary satellite is less than 1% of the energy required to launch and operate it throughout its life. There is also a natural cleansing over time as the orbits of individual debris elements disperse due to gravitational perturbations. I do not foresee the investment in intentional removal, robotic or otherwise, being justified relative to the space debris collision risk now or in the next decades.

SoN: Do you think the existing space debris activities of the United Nations are sufficient to influence the forming of international decision-making and damage regulation bodies?

Dr. Finkleman: " The Committee on the Peaceful Uses of Outer Space was set up by the General Assembly in 1959 (Resolution 1472 (XIV)) to review the scope of international cooperation in peaceful uses of outer space, to devise programmers in this field to be undertaken under United Nations auspices, to encourage continued research and the dissemination of information on outer space matters, and to study legal problems arising from the exploration of outer space." It has encouraged research, but other matters are entwined with national sovereignty and commercial interests, which are arguably not within the scope of the United Nations. There are five space relevant treaties (Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies; Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space; Convention on International Liability for Damage Caused by Space Objects; Convention on Registration of Objects Launched into Outer Space; and Agreement Governing the Activities of States on the Moon and other Celestial Bodies), none of which address space debris except to assign liability for

damage. My opinion is that the United Nations is not the appropriate body to influence whatever action might be appropriate to manage space debris.

Dr. Klinkrad: As part of the United Nations' Treaties there is a "Convention on the International Liability for Damage Caused by Space Objects". It regulates liability issues due to re-entering space objects (Article II) and for the damages 'elsewhere than on the surface of the Earth' (Article III), e.g. due to debris-generating events in orbit. In the latter case, it must be demonstrated that resulting damage was caused by a fault of the launching State.

SoN: Could Earth or ISS-based debris removal become a commercial market in the future?

Dr. Klinkrad: Some companies are already looking at this issue, particularly for the commercially attractive GEO region. Related concepts foresee e.g. space tugs to capture and remove non-functional payloads and orbital stages, and release them in the GEO graveyard, before returning to GEO to continue their mission. The GEO region is also technically attractive due to the limitation of orbital inclinations to less than 15 deg (this is a result of Sun and Moon attraction, and the Earth oblateness potential). Hence, relative velocities are small, and rendezvous maneuvers can be accomplished more easily. For LEO satellites and orbital stages the situation is more complicated, due to a wide range of orbital inclinations, and due to a wide range of relative velocities. Hence, rendezvous operations require much more propellant, and the commercial interest may not be as high as for GEO. – An ISS-based debris-removal system in particular will not be very effective, since the ISS operates at an altitude for which the collision risk with space debris (and hence the potential for rendezvous operations) is about one order of magnitude smaller than in densely populated LEO regions. – The International Academy of Astronautics is presently working on a position paper on "Space Debris Remediation". It will address a wide range of questions and possible answers related to space debris environment control.

Dr. Finkleman: I do not think so. Space operations for any purpose are expensive (both in terms of the energy required and in monetary terms). It seems not a wise investment when one could launch and operate a productive mission instead. Finally, if sound design and management practices are instituted, it should not be necessary.

SoN: Dr. Finkleman, Dr. Klinkrad - thank you very much for your interesting answers on a subject which obviously has to be closely observed in the future.

It shall be pointed out that the SpaceOps community considers the subject of space debris as very important and relevant for developing future operations concepts and strategies, therefore the upcoming SpaceOps Symposium at Heidelberg (12 – 16 May), Germany (http://www.aiaa.spaceops2008) will dedicate a special forum for presentations and discussions (see topic: "End of Life Operations & Space Debris").

Interview: Dr. Joachim Kehr, Editor SpaceOps News