esa

protecting space missions

→ THE CHALLENGE OF SPACE DEBRIS

European Space Agency

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→ WHAT IS SPACE DEBRIS?

Satellites orbiting Earth serve many purposes, including space science, Earth observation, meteorology, climate research, telecommunications, navigation and human space exploration. As a resource for collecting scientific data, satellites offer unrivalled possibilities for research and exploitation, both scientific and commercial. However, in recent decades, increased space activities have led to the emergence of an unanticipated and underestimated hazard: **space debris**.

In almost 60 years of space activities, more than **4900 launches** have placed some **6600 satellites into orbit**, of which about 3600 remain in space. Less than a third – about 1100 – are still operational. This large amount of 'dead' space hardware has a total mass of more than 6300 tonnes. More than **17 000 orbital objects** are being tracked and catalogued by the US Space Surveillance Network. This covers objects larger than about 5–10 cm in **low-Earth orbit** (LEO, up to 2000 km above Earth), and objects of 0.3–1 m at geostationary altitudes (GEO, about 36 000 km).

These debris objects are a clear and present threat to new and existing space missions, because at typical collision speeds of 10 km/s in LEO, even a 1 cm nut can hit with the energy of an exploding hand grenade. Impact by larger debris at orbital velocity can cause a catastrophic break-up – meaning destruction of a spacecraft. Each collision also creates more debris, which can lead to a cascade of more collisions.

In addition to the hazard in space, large debris objects that reenter Earth's atmosphere in an uncontrolled way, such as defunct satellites, rocket bodies and large fragments, can pose risks to people on the ground, because they can be too big to burn up completely.

ESA is leading the effort to tackle the problems of space debris by:

- monitoring, controlling and tracking space objects;
- developing technologies to mitigate and remediate space debris;
- pushing for worldwide cooperation.

MITIGATE: to avoid creation of additional space debris in future.

REMEDIATE: to remedy the existing situation by actively removing space debris.

→ RESEARCHING SPACE DEBRIS

Solving the space debris problem will require much more information than is available today. Since the 1980s ESA has been methodically researching space debris in three main ways: through **observational measurements**, **by modelling** and **by testing out** effective means of protection. This research and testing is overseen by **ESA's Space Debris Office**.

MODELLING

ESA is developing software models to characterise the debris environment and its likely evolution over time. The Agency uses a time-dependent dynamic debris model with a detailed traffic model and release-event data to predict the effectiveness of proposed debris mitigation measures on the stability of the debris population, as well as to perform long-term forecasts and trend analyses.

MEASUREMENTS

There are practical lower limits to the size of debris that can be catalogued and tracked continuously. Knowledge of subcatalogue debris populations (as well as natural micrometeoroids) is acquired in a statistical manner, employing optical telescopes such as ESA's Optical Ground Station to sample debris in GEO down to 10 cm, and using ground-based radar to detect LEO debris down to a few millimetres. Additional inputs come from analysis of retrieved space hardware and through *in situ* impact-detection sensors.

Space Debris Office: Space.Debris.Support@esa.int

PROTECTION

The consequences of impacts on satellites can range from small surface pits from micrometre-sized objects, via clear penetrations for millimetre-scale items, up to mission-critical damage for projectiles larger than a centimetre. ESA uses hypervelocity impact tests in association with damage assessment tools to predict the potential risks and define effective protection.
For crewed spacecraft, the multi-layer 'Whipple shield' is favoured, based on a design originally devised for flying through cometary dust.

RELEASE EVENT: an event that generates debris, such as through an explosive break-up, a collision, or an intentional release.

WHIPPLE SHIELD: a bumper, such as a thin sheet of aluminium, and a space or filling between the bumper and the wall of the spacecraft to disperse any fragments that make it past the bumper.

↑ Whipple shielding after impact test / Whipple shield innermost layer after test

→ MONITORING AND TRACKING DEBRIS

Since 2009, ESA's Space Situational Awareness Programme has overseen an investment of **€100 million** from **18 Member States**, aiming to develop Europe-wide warning systems for space weather, near-Earth objects and objects left in orbit by human activities.

The Programme's **Space Surveillance and Tracking segment** is working to federate current European tracking capabilities and to develop new sensors and processing technology, so as to generate timely and accurate data and information on objects of human origin orbiting Earth, and to predict related hazards to infrastructure in orbit and on the ground.

↓ Test radar in Spain

LEO IS THE MOST HIGHLY CONGESTED REGION IN SPACE

75% OF ALL CATALOGUED OBJECTS ARE IN LEO

Space Situational Awareness: www.esa.int/ssa

→ OPERATING IN THE SPACE ENVIRONMENT

ESA is working to monitor and control the risks of operating in an environment containing debris. There is a **data exchange agreement** between ESA and the US.

COLLISION AVOIDANCE

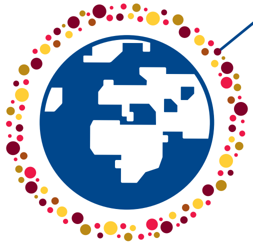
Avoiding collisions is an important mitigation measure, requiring the orbits of the objects to be known with sufficient accuracy.

REENTRY PREDICTION

Objects of significant size (1 m or larger) enter Earth's atmosphere in an uncontrolled way about once a week. ESA monitors entering objects in order periodically to refine the predictions provided to national alert centres.

CONTROLLED REENTRIES

Controlled reentries always target uninhabited ocean areas. The 'debris fall-out zone' covers a large area and during the preparation phase needs to be analysed, sized and its location optimised. During a reentry operation, the associated danger area needs to be communicated to the authorities in charge of local air and sea traffic, in order for them to issue warning messages.



29 000

HUMAN-MADE OBJECTS LARGER THAN 10 CM ARE IN ORBIT, BOTH DEAD AND OPERATIONAL

TOOLS AND MODELS

ESA has developed a number of software tools and models to allow mission planners to estimate the risks to their mission. These also help with estimation of propulsion budgets for collision avoidance, optimisation of disposal strategies, orbital lifetime estimations and on-ground casualty expectation analyses. These tools are available from ESA's Space Debris User Portal.

↑ Close flyby between Envisat and an upper stage on 21 January 2010

i **Space debris office:** www.esa.int/debris
Space Debris User Portal: sdup.esoc.esa.int

→ REGULATIONS AND COMPLIANCE

ESA's current **policy for space debris mitigation** establishes the existing ECSS-U-AS10C/ISO24113 standard as the baseline space debris mitigation requirements for ESA projects. **ESA's Independent Safety Office** is the internal technical authority responsible for maintaining these standards, supervising verification of compliance and the processing of waivers.

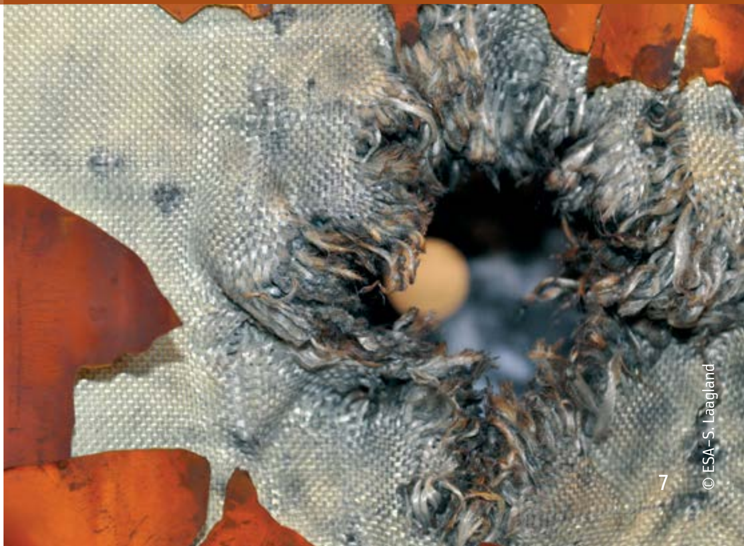
The Office works to ensure that all ESA projects remain compliant with the debris requirements by approving a debris mitigation plan in the early stages of each project and then monitoring its implementation.

The Independent Safety Office also maintains links with other national and international regulatory bodies concerned with space debris regulations.

↑ ATV-5 reentry seen from space
↓ ATV shielding material after impact test

A 1 cm

OBJECT CAN STRIKE A SATELLITE WITH THE FORCE OF AN EXPLODING HAND GRENADE



➜ TECHNOLOGIES FOR DEBRIS MITIGATION

cleansat

LEO altitudes are threatening to become clogged with debris, especially in the popular polar orbits. Compliance with space debris mitigation requirements makes significant demands on LEO satellites, especially large ones.

To help with this, **ESA's Clean Space Office** has begun the CleanSat project, to support European industry at the design stage in developing future LEO spacecraft that are fully compliant with debris mitigation regulations.

The aim is to upgrade LEO platforms in a coordinated European approach through the creation of common technologies and building blocks, fostering shared supply chains, in order to reduce the development costs and recurrent costs.

There are four key areas of interest to CleanSat, below.

PASSIVATION

Explosions of satellites are a major source of debris. Passivation reduces the likelihood of a satellite exploding in the future by deactivating its power systems and batteries and venting any leftover propellant.

DEORBITING SYSTEMS

International debris guidelines require satellites to remove themselves from LEO within 25 years of their end of life, either to a graveyard orbit or to reentry. Promising methods to achieve this without detracting from mission efficiency include solid rocket motors or drag sails and tethers.

DESIGN FOR DEMISE

Many satellites will eventually reenter the atmosphere (in either a controlled or uncontrolled manner). The design aim is to ensure that they pose no risk to people on the ground, by using materials and designs that are likely to burn up entirely so that nothing is left to hit the ground.

DESIGN FOR SERVICING

Design for servicing involves incorporating standardised features on future satellites, such as grips and handles, that will enable future 'active debris removal' by a mission such as e.Deorbit. It will also enable orbital servicing missions to capture satellites for removal or repair.

Clean Space initiative office: www.esa.int/cleanspace | cleanspace@esa.int

e.deorbit

Because of the tendency of every collision to generate more debris, it is not enough just to minimise debris production by future missions: the current debris population also needs to be reduced. Since 2012, ESA's Clean Space initiative has been designing a proposed mission called e.Deorbit, which will demonstrate the active debris removal of a large item of space debris from LEO.

The objective of the mission is to use a custom satellite to capture a heavy, ESA-owned item of debris and remove it from an altitude of 800–1000 km and a near-polar orbital trajectory. This removal will be performed by moving the item at high speed and high precision into Earth's atmosphere, causing it to burn up.

At this stage, the emphasis is on mastering various technologies to make e.Deorbit workable in practice. Some of the most important are described below.

TARGET CHARACTERISATION

Drifting satellites are prone to tumbling in unpredictable ways. The e.Deorbit satellite will have to identify the target – potentially autonomously – and then assess its condition and rate of spin before going on to perform a close approach.

CAPTURE MECHANISMS

The target item of debris next has to be captured and robustly secured. Capture mechanisms under study include nets, harpoons and robotic arms.

DISPOSAL METHODS

The combination of the removal craft plus the captured item of debris will then have to be manoeuvred in a safe, fully controllable manner, without posing any hazard to other space missions or to populations on the ground as they proceed to deorbit.

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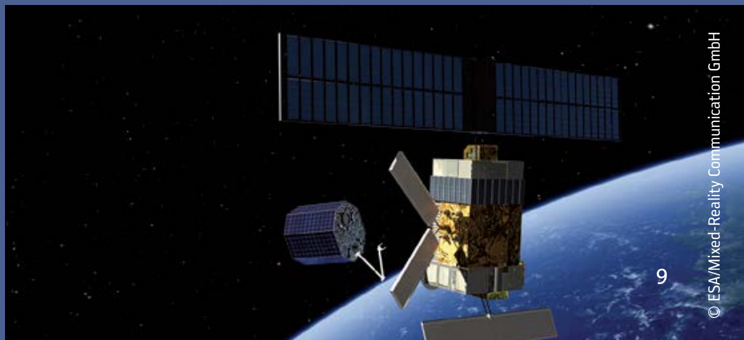

Cleaning space →

→ WORLDWIDE COOPERATION

Space debris is a problem to which all spacefaring nations have contributed, and it poses a risk to all space missions. Correspondingly, to develop countermeasures requires consensus, and knowledge to be shared among all countries that are involved.

The **Inter-Agency Space Debris Coordination Committee** (IADC) is internationally recognised as a centre of competence for space debris. It also influences mitigation activities at the United Nations **Committee on the Peaceful Uses of Outer Space** (UN COPUOS) Scientific and Technical Subcommittee. The IADC is the source of the mitigation proposals currently being discussed and implemented.

International consensus needs to be established not just on the definition of mitigation measures but also on the manner of their implementation. This is the goal of standardisation by important bodies like the **International Organization for Standardization** (ISO) and the **European Cooperation for Space Standardization** (ECSS). ESA is represented in these bodies.

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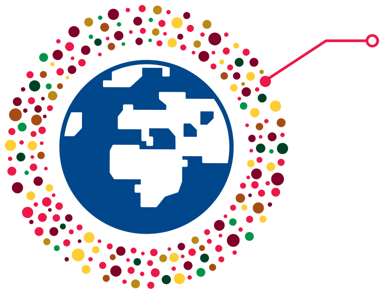

700 000

ITEMS OF DEBRIS LARGER THAN 1 CM ARE ESTIMATED TO BE IN ORBIT

↑ European Conference on Space Debris
← Trackable objects orbiting Earth

→ SPACE LAW AND LEGAL ASPECTS OF SPACE DEBRIS

Space debris and its mitigation and remediation are not just technical concerns, they raise legal questions as well: countries are liable for any damages they cause through their space activities. Space activities by private operators need to be authorised and supervised. **Satellites belong to someone even after they cease functioning.** Space debris mitigation is increasingly finding its way into laws and regulations, and the international community is exploring ways to make spaceflight safe, secure and sustainable – with help from the law.

ESA's Legal Services Department offers guidance to ESA's Directorates and Member States in matters of space law. Our space law experts work to:

- advise ESA's Programmes and Member States on legal questions related to space debris;
- assess and minimise the legal risks of space debris and its remediation;
- support the development and operation of future active debris removal missions;
- safeguard the application of international legal norms in relation to space debris mitigation and remediation;
- help formulate and implement the space laws of Member States, including those relevant to debris;
- keep an eye on legal developments;
- contribute to the international legal debate on space debris;
- maintain the legal register of all ESA space objects, including debris.

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↓ ↑ ESA Council at Ministerial Level, Luxembourg, on 2 December 2014

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