The Proposal for System of Mitigation of Space Debris

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SCHEME

INTRODUCTION

Objective of this project

The aim of the thesis is to describe and propose new solutions for space debris mitigation. In the first section of the tesis we aim to sufficiently describe problem of space debris, solutions, international agreements and companies dealing with this problem nowadays. In the second section we aim to propose new department of UNOOSA which would aim to regulate and finance space debris mitigation and propose new concepts which would save materials on the orbit thus there would be decrease in space debris creation.

Why are humans still not removing space debris?

Scientists have come up with some practical and theoretical ideas how would be possible to terminate space debris. There comes a problem that theoretical ideas in form of lasers, gels and methods which would be realised from Earth´s surface are cheaper but require long and expensive research. Practical ideas in form of „garbage satellites“ which would mechanically take debris down into the atmosphere, are also economically unmanageable with current technology. Problem is that development of theroretical ideas and realisation of practical ideas is not producing anything from scientific or economical point of view so program for space debris mitigation is not moving anywhere.

Why is space debris threat for next generation space explorations?

Many experts are warning that increasing number of space debris on Earth´s orbit which is increasing due to launching more and more satellites is going to be more dangerous in close future. Biggest problem are non-working satellites in high altitudes where atmosphere is not able to retard their revolution following with disappearance in the atmosphere.

Explosions of fuel tanks of satellites, rocket stages and registered collisions between satellites like Iridium - 33 and Cosmos – 2251 collision in 2009 create cloud of small debris which can cause chain reaction which would destroy all Earth´s orbit satellites and impede next space research for several generations.

Public opinion says that there would be created some kind of ring similar to planet Saturn´s one so space debris is not actually any problem. On the other hand due to activity of the Earth´s gravity and Moon there would be created „a coat“ from debris which would be regularly distributed, cover Earth´s orbit and impede rocket flights and launches of new space appliances.

RECENT EVENTS CONCERNING SPACE DEBRIS

Alert at ISS

The requirement of moving the Station out of the path of a potential debris threat is not uncommon.

The huge structure of the ISS, racing around the planet at 17,500 mph, is routinely threatened by what are called conjunction threats, usually from items tagged under the MMOD (Micrometeoroid Orbital Debris) designation.

The larger pieces of debris – usually originating from expended satellite and rocket hardware – are tracked by Space Command/NORAD, allowing for any threats to spacecraft to be known in advance, providing them a heads up to move into a different path and thus avoid a collision.

Break-up of US satellite

The US Air Force's Defense Meteorological Satellite Programme Flight 13 (DMSP-13) broke up into some 40 pieces on 3 February 2015. The military weather satellite was in a low-Earth orbit – commonly used by Earth observation missions and some communication satellites – at more than 800 km altitude.

CURRENT NUMBER OF SPACE DEBRIS, ITS OBSERVATION AND SYSTEMS OF MITIGATION

Space agencies and private companies from various countries have proposed a variety of methods to clean up the mess. Scientists in Japan presented a paper that recommended installing lasers on the International Space Station to nudge debris into the Earth's atmosphere, where it would burn up harmlessly. NASA scientists recently proposed doing the same thing using ground-based lasers. In March, the European Space Agency experimented with nets designed to capture moving debris. In January the Japan Aerospace Exploration Agency unveiled an electrodynamic tether which, when tied to a piece of space junk, would cause it to slow down and fall into a lower orbit. Space agencies across the globe are considering other options too. Dead satellites located in geosynchronous orbit (about 36,000km above the surface of the Earth) are sometimes pushed into a "graveyard orbit" about 300km further out. New technologies allow rockets that have delivered their payloads to reignite their engines, lower their orbits and then burn up in the Earth's atmosphere. Many countries have agreed that satellites should be designed to burn up harmlessly in the atmosphere within 25 years of their operational lifespan coming to an end

NASA and space debris

In 1995 NASA was the first space agency in the world to issue a comprehensive set of orbital debris mitigation guidelines. Two years later, the U.S. Government developed a set of Orbital Debris Mitigation Standard Practices based on the NASA guidelines. Other countries and organizations, including Japan, France, Russia, and the European Space Agency (ESA), have followed suit with their own orbital debris mitigation guidelines. In 2002, after a multi-year effort, the Inter-Agency Space Debris Coordination Committee (IADC), comprised of the space agencies of 10 countries as well as ESA, adopted a consensus set of guidelines designed to mitigate the growth of the orbital debris population. In February 2007, the Scientific and Technical Subcommittee (STSC) of the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS) completed a multi-year work plan with the adoption of a consensus set of space debris mitigation guidelines very similar to the IADC guidelines. The guidelines were accepted by the COPUOS in June 2007 and endorsed by the United Nations in January 2008.

ESA and space debris mitigation

Since the mid-1980s, ESA has been active in every area of research, development, technology and operations related to space debris. Since 2006, the Space Debris Office, at ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany, has operated as a self-standing entity within the Ground Systems Engineering Department of ESA's Directorate of Human Spaceflight and Operations.

The main source of information on large space debris is the US Space Surveillance Network (SSN). As of September 2012, SSN tracked, correlated and catalogued around 23 000 space objects larger than 5–10 cm in Earth orbit (around 17 000 of which were published). Debris environment models can be used to estimate total numbers, resulting in 30 000 larger than 10 cm, 750 000 larger than 1 cm, and more than 166 million larger than 1 mm.

The Inter-Agency Space Debris Coordination Committee (IADC), the most-recognised international entity on space debris, has produced a set of mitigation guidelines, which also served as input to a set of Space Debris Mitigation Guidelines adopted by the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS). The related key recommendations are:

- Limit debris release during normal operations;
- Minimise the potential for break-ups during operational phases;
- Limit the probability of accidental collisions;
- Avoid intentional destruction and other harmful activities;
- Minimise the potential for post-mission break-ups resulting from stored energy;
- Limit the long-term presence of spacecraft and launch vehicle orbital stages in protected regions after the end of their missions.

Studies at NASA and ESA show that with a removal strategy focusing on large target masses, the environment can be stabilised, if about 10 objects are removed from LEO per year with the following priorities:

- objects with a high mass (largest environmental impact in terms of critical-size fragments);
- objects with a high collision probability (orbiting in densely populated regions);
- objects at high altitudes (long orbital lifetime of fragments)

ACTIONS BEING TAKEN BY ESA

ESA´s space debris software

A new website enables rapid updates for experts using ESA's suite of space-debris software tools to perform risk assessment and analysis of debris mitigation actions for missions currently in orbit and to be better prepared for future ones.

Researchers using ESA's space-debris software tools can now download the newest versions as well as access updates and technical support via a dedicated website, the Space Debris User Portal. / https://sdup.esoc.esa.int/web/csdtf/home /

Shields protecting spacecraft from a space debris

Small pieces of space debris travelling at 8km/s velocity can cause huge damages of a spacecraft. Instead of using huge layers of metal on a spacecraft there are being used more sophisticated thin metal sheat protective layers, which can protect a spacecraft while not increasing its mass that much. They are used just on manned spacecraft nowadays. These protective layers still increase mass and volume particularly, which increases the price of every rocket launch of this kind of mission, these extra costs could be however used for something more useful.

Remove debris

"RemoveDebris" is an European Union (EU) Framework 7 (FP7) research project to develop and fly an in-orbit demonstrator mission that aims to de-risk and verify technologies needed for future Active Debris Removal (ADR) missions.

The mission has as its primary aim, the raising of Technology Readiness Levels (TRL), and gaining on-orbit experience with:

– A debris capture system based on a Net

– A debris capture system based on a Harpoon

– Visual Based Navigation (VBN) using Optical, Infrared and LIDAR cameras

– Deployable drag augmentation devices (Sails)

The core concept behind the mission, is to use a small-satellite (~100kg) as a 'mothership', on which the payloads are carried, and from which CubeSats (~3kg) are released and used as 'pseudodebris' targets.

CURRENT SOLUTIONS FOR SPACE DEBRIS REMOVAL FROM PRIVATE SECTOR

ASTROSCALE

Astroscale is a company with residence in Singapure because of its neutrality and ability to negotiate with all states of the world. Residence of technological development is located in Japan. Astroscale´s objective is to develop system for active space debris removal called Space Sweepers.

Astroscale is developing system of Mother and Boy satellite. Where Mother satellite is going to be released with 6 Boys on the board. Mother satellite is equiped with orientation system so it is able to locate and get close to specific space debris. After Mother gets to chosen space debris the Boy will be released to adhere to the debris with the silicon adhesive compound lined at the front disk.

Boy is packed with solid-fuel propellant, Boy is equipped with thrusters that can produce up to 100m/s to deorbit a 50kg debris. These debris will eventually burn out during atmospheric re-entry. The technology of the Mothership and Boy will target critical debris heavier than 100kg in Geostationary orbit to reduce the probability of further collision in future.

Realisation

Astroscale is planning to demonstrate its system in 2017 by launching nanosatellite with one mounted boy. Objective of this demonstration will be to catch specific space depris and roll it down with potential burn in atmosphere. For full practical realisation of Astroscale´s program capital is required. Capital for Astroscale´s program may be provided by ISDR.

Partners and team

Astroscale has developed its team among institutions listed below to pursue realisation of Space Sweepers program. Team composes of University proffesors and engineers from private and public sector.

東京大学 THE UNIVERSITY OF TOKYO PROF NAKASUKA LAB / ASSOC. PROF KOIZUMI LAB	KYUSHU UNIVERSITY PROF HANADA - SPACE SYSTEMS DYNAMICS LAB
首都大学東京 TOKYO METROPOLITAN UNIVERSITY ASSOC. PROF SAHARA LAB	TOKYO UNIVERSITY OF SCIENCE PROF KIMURA LAB
Kyutech Kyushu Institute of Technology ASSOC. PROF IWATA - MICRO SATELLITE TESTING LAB	YUKI YUKI PRECISION

ADASTRA

VASIMR® technology can be efficiently applied to remove orbital debris from low Earth orbit (LEO) by means of a high power, solar electric propulsion (SEP) space tug. AARC examines the capture and controlled deorbit of 19 known large pieces of orbital debris, drifting in various high inclination orbits. The chosen objects are mainly spent Zenit rocket upper stages larger than a full size school bus, weighing approximately 8 tons.

This mission concept utilizes the company's multipurpose, 200 kW SEP VASIMR® space tug to lower the orbital altitude of the Zenit targets for a controlled chemical de-orbit over the Pacific Ocean. To accomplish this de-orbit, the reusable tug is fitted with a specialized service module (SM) consisting of a solid rocket motor (SRM) tray, loaded with 20 SRM units (19 plus a spare) and a detachable, short-range, "chemical robotic pod" (CRP) for proximity operations near the target body. For each of the 19 targets, the tug first climbs to the orbit of the drifting Zenit (~800 km) where the CRP is released to capture, stabilize, and bring the target back to a hard docking with the tug. At capture, the CRP also robotically installs a fresh SRM unit onto the Zenit rocket nozzle. With the Zenit attached, the tug brings it down to approximately 400 km for release at a point where the newly fitted SRM ignites, bringing the Zenit to a controlled atmospheric re-entry. The VASIMR® tug then climbs back, making a plane change, as required, to capture the next target and repeat the process.

Ground based space debris removal

Earth-based Lasers: A ground-based laser could de-orbit space debris by robbing it of a bit of the momentum it needs to continue orbiting the Earth. Light exerts pressure, so to de-orbit an object such as the discarded ASTRO-F satellite lens cap – 31 inches (80 centimeters) wide and 11 pounds (5 kilograms) in mass – a laser beam of about 5-to-10 kilowatts would be shined upon it for about two hours.

DEVELOPMENT OF INTERNATIONAL COLLABORATION

United Nations Committee for Peaceful Uses of Outer Space

In 1958, shortly after the launching of the first artificial satellite, the General Assembly in resolution 1348 (XIII) established an ad hoc Committee on the Peaceful Uses of Outer Space (COPUOS), composed of 18 members, to consider the activities and resources of the United Nations, the specialized agencies and other international bodies relating to the peaceful uses of outer space, organizational arrangements to facilitate international cooperation in this field within the framework of the United Nations and legal problems which might arise in programmes to explore outer space.

In 1959, the General Assembly established COPUOS as a permanent body, which had 24 members at the time, and reaffirmed its mandate in resolution 1472 (XIV). Since then, COPUOS has been serving as a focal point for international cooperation in the peaceful exploration and use of outer space, mantaining close contacts with governmental and non-governmental organizations concerned with outer space activities, providing for exchange of information relating to outer space activities and assisting in the study of measures for the promotion of international cooperation in those activities.

The work of COPUOS has been assisted by the two subcommittees, the Scientific and Technical Subcommittee and the Legal Subcommittee. The complex issues which have arisen alongside the development of space technology are the main concern of the two COPUOS Subcommittees, which met for the first time in Geneva in 1962 and then regularly each year.

Members of COPUOS are States and since 1959, the membership of COPUOS has grown continuosly, currently it has 77 members, which makes COPUOS one of the largest Committees in the United Nations. In addition to States a number of international organizations, including both intergovernmental and non-governmental organizations, have observer status with COPUOS and its Subcommittees.

UNOOSA provides the Secretariat services to COPUOS and its two Subcommittees, which continue to serve as a unique platform for maintaining outer space for peaceful purposes at the international level.

UNOOSA´S SPACE DEBRIS MITIGATION GUIDELINES

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

- **Guideline 1: Limit debris released during normal operations**

Space systems should be designed not to release debris during normal operations. If this is not feasible, the effect of any release of debris on the outer space enviroment should be minimized.

- **Guideline 2: Minimize the potential for break-ups during operational phases**

Spacecraft and launch vehicle orbital stages should be designed to avoid failure modes which may lead to accidental break-ups. In cases where a condition leading to such a failure is detected, disposal and passivation measures should be planned and executed to avoid break-ups.

Historically, some break-ups have been caused by space system malfunctions, such as catastrophic failures of propulsion and power systems. By incorporationg potential break-up scenarios in failure mode analysis, the probablility of these catastrophic events can be reduced.

- **Guideline 3: Limit the probability of accidental collision in orbit**

In developing the design and mission profile of spacecraft and launch vehicle stages, the probability of accidental collision with known objects during the system´s launch phase and orbital lifetime should be estimated and limited. If available orbital data indicate a potential collision, adjustment of launch time or an on-orbit avoidance manoeuvre should be considered.

Some accidental collisions have already been identified. Numerous studies indicate that, as the number and mass of space debris increase, the primary source of new space debris is likely to be from collisions. Collision avoidance procedures have already been adopted by some member States and international organizations.

- **Guideline 4: Avoid intentional destruction and other harmful activities**

Recognizing that an increased risk of collision could pose a threat to space operations, the intentional destruction of any on-orbit spacecraft and launch vehicle orbital stages or other harmful activities that generate long-lived debris should be avoided. When international break-ups are neccessary, they should be conducted at sufficiently low altitudes to limit the orbital lifetime of resulting fragments

- **Guideline 5: Minimize potential for post-mission brak-ups resulting from stored energy**

In order to limit the risk to other spacecraft and launch vehicle orbital stages from accidental break-ups, all on-board sources of stored energy should be depleted or made safe when they no longer required for mission operations or post-mission disposal.

By far the largest percentage of the catalogued space debris population originated from fragmentation of spacecraft and launch vehicle orbital stages. The majority of those break-ups were unintentional, many arising from abandonment of spacecraft and launch vehicle orbital stages with significant amounts of stored energy. The most effective mitigation measures have been the passivation of spacecraft and launch vehicle orbital stages at the end of their mission. Passivation requires the removal of all forms of stored energy, including residual propellants and compressed fluids and the discharge of electrical storage devices.

- **Guideline 6: Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth (LEO) region after the end of their mission**

Spacecraft and launch vehicle orbital stages that have terminated their operational phases in orbits that pass through the LEO region should be removed from orbit in controlled fashion. If it is not possible, they should be disposed of in orbits that avoid their long term presence in the LEO region.

When making determinations regarding potential solutions for removing objects from LEO, due consideration should be given to ensuring that debris survives to reach the surface of the Earth does not pose an undue risk to people or property, including through enviromental pollution caused by hazardous substances.

- **Guideline 7: Limit the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous Earth orbit (GEO) region after the end of their mission**

Spacecraft and launch vehicle orbital stages that have terminated their operational mission phases in orbits that pass through the GEO region should be left in orbitsthat avoid their long-term interference with GEO region.

For space objects in or near the GEO region, the potential for future collisions can be reduced by leaving objects at the end of their mission in an orbit above the GEO region such that they will not interfere with, or return to, the GEO region.

LIST OF MECHANISMS FOR SPACE DEBRIS MITIGATION

National mechanisms of members of the United Nations Committe of Peaceful Uses of Outer Space:

1. Algeria – not adopted yet
2. Argentina – not adopted yet
3. Australia - Australia's Satellite Utilisation Policy – 2013, Guidelines for Applicants seeking to apply for an Overseas Launch Certificate
4. Austria - Austrian Outer Space Act of 2011
5. Belgium - Law of 17 September 2005 on Activities of Launching, Flight Operation or Guidance of Space Objects (revised by the Belgian Parliament on 1 December 2013), Royal Decree of 19 March 2008
6. Canada - Canadian Remote Sensing Space Systems Regulations – 2007, Canadian Space Agency adoption of the IADC Space Debris Mitigation Guidelines – 2012, Canadian Client Procedures Circular (CPC) for Licensing of Space Stations – 2014
7. Chile – not adopted yet, discussions of creation national mechanism inthe future
8. Czech Republic - not adopted yet, discussions of creation national mechanism inthe future
9. France - French Space Operations Act n°2008-518 of 3rd June 2008
10. Germany - Product Assurance and Safety Requirements for DLR Space Projects: April 2012 (Issue 7.0)
11. Italy – in development
12. Japan - JAXA-Management Requirements (JMR-003B), revised in 2011
13. Mexico - not adopted yet, discussions of creation national mechanism inthe future
14. The Netherlands – none, focus on international cooperation in European contexts within ESA, the European Organization for the Exploitation of Meteorological Satellites
(EUMETSAT) and the EU.
15. Nigeria - National Space Research and Development Agency Act 2010 No.9 A 1255
16. Poland – in development

17. Slovak Republic – not adopted yet, negotiations of its membership into the European Space Agency
18. Spain – not adopted yet
19. Switzerland – not adopted yet
20. United Kingdom - Outer Space Act 1986 (OSA)
21. United States of America – U.S. National Space Policy, Presidential Policy Directive 4 (PPD-4), 2010, U.S. Government Orbital Debris Mitigation Standard Practices, 2001

    Other mechanisms of USA:

    - Space Launch Act of 1984, as codified and amended, Title 51 United States Code (U.S.C.), Commercial Space Transportation, chapter 509; Title 51 U.S.C., Commercial Space Launch Activities, Sections 50901-50923
    - National and Commercial Space Programs Act (NCSPA) of 2010, Title 51 U.S.C., Subtitle VI
    - Federal Aviation Administration (FAA) Regulations, Title 14, Code of Federal Regulations (CFR), Parts 415.39, 417.129, 431.43
    - Title 51, U.S.C., National and Commercial Space Programs, Subtitle VI, Earth Observations, Section 60122
    - National Oceanic and Atmospheric Administration, Department of Commerce Regulations, Title 15, CFR, Part 960, Licensing of Private Land Remote-Sensing Space Systems; Final Rule
    - NOAA Satellites: Per National Environmental Satellite, Data, and Information Service (NESDIS) Policy NQP-0304, NOAA follows NASA policy and best practices for decommissioning and disposal for the fleet of U.S. meteorological satellites NOAA operates
    - National Aeronautics and Space Act, Title 51 United States Code Sec. 10101, et seq.
    - NASA Procedural Requirements for Limiting Orbital Debris, NPR 8715.6A, 2007; revised 2009
    - NASA Process for Limiting Orbital Debris, NS 8719.14A, 2007; revised 2011
    - Communications Act of 1934, as amended, Title 47 U.S.C., Section 301 et. seq.
    - Federal Communications Commission (FCC) Regulations, Title 47, CFR, Parts 5, 25, and 97; initial publication at 69 Federal Register 54586 (September 9, 2004)
    - Title 10 United States Code
    - DoD Directive 3100.10 (Space Policy), 2012; DoD Instruction 3100.12 (Space Support), 2000
    - The U.S. Geological Survey follows the U.S. best practices for operations and end of life disposal for the Landsat land remote sensing satellites.

International space debris mitigation mechanisms:

1. European Code of Conduct for Space Debris Mitigation
2. ESA Space Debris Mitigation for Agency Projects
3. Inter-Agency Space Debris Coordination Committee Space Debris Mitigation Guidelines

4. International Telecommunications Union (ITU) Recommendation Environmental protection of the geostationary-satellite orbit
5. Space Debris Mitigation Guidelines of the United Nations Committe on the Peaceful Uses of Outer Space

PROPOSAL OF FURTHER INTERNATIONAL COLLABORATION

We recommend that COPOUS will have predicted the lifespan and space debris creation risk before the start of a particular mission registered. We propose that COPOUS would financially penalize those (owners of the missions e.g. space agencies, companies etc.) whose mission would create an space debris on the orbit. And from money from the penalties the COPOUS would finance projects whose aim is to mitigate the space debris.

International Space Debris Regulation (ISDR)

For above mentioned mechanisms, we propose to establish an international organisation under the auspices of COPOUS for space debris mitigation and prevention of creating new orbital space debris where all members of COPOUS shall be registered for further collaboration.

Proposed organisation would be named as International Space Debris Regulation (ISDR) because its main objective would be to regulate, mitigate, and prevent creation of new space debris by human.

Principle of ISDR´s objective would be to have registered all flights above outer space boundary (cca 100km), these registrations are now being practised but in ISDR shall be registered whether given flight creates any kind of debris on Earth´s orbit. In case when debris (not operating satelite, stage of rocket etc.) maintains on Earth´s orbit longer than set period of time (e.g. 1 year) and is not removed by its creators, creators would pay fine set by UN (e.g. penalty for every kg of debris and altitude where debris is located).

Money gained from these penalties would be used for research of new methods for space debris termination and financing current technological programs for space debris trapping.

ISDR is solution for lack of capital for space debris mitigation which is reason why humans are still not terminating space debris. ISDR may solve space debris problem in a way that space programs will not create space debris anymore because of threat of high fine from ISDR.

PROPOSAL OF NEW GENERATION SATELLITES

There should be measures taken in technical concepts of satellites too, in order to make production of them more enviromentally friendly. An example of such measure is shown in our appendixes.

LIST OF SOURCES

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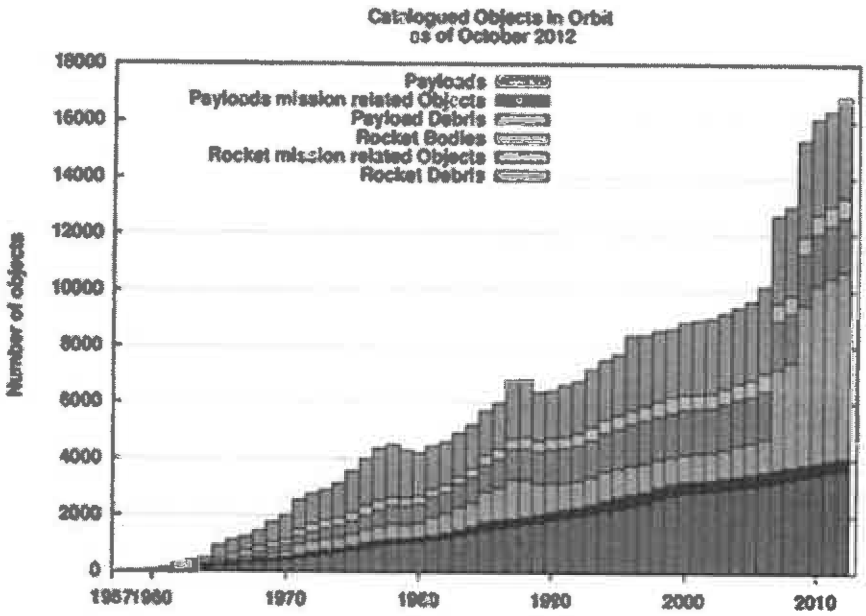
16. http://www.unoosa.org/oosa/en/ourwork/copuos/history.html
17. **United Nations Office For Outer Space Affairs: Space Debris Mitigation Guidelines of the Comittee on the Peaceful Uses of Outer Space: 2010. 4s. Austria**
18. http://orbitaldebris.jsc.nasa.gov/library/Space%20Debris%20Mitigation%20Guidelines_COPUOS.pdf
19. http://www.unoosa.org/oosa/en/COPUOS/Legal/debris/index.html

APPENDIXES

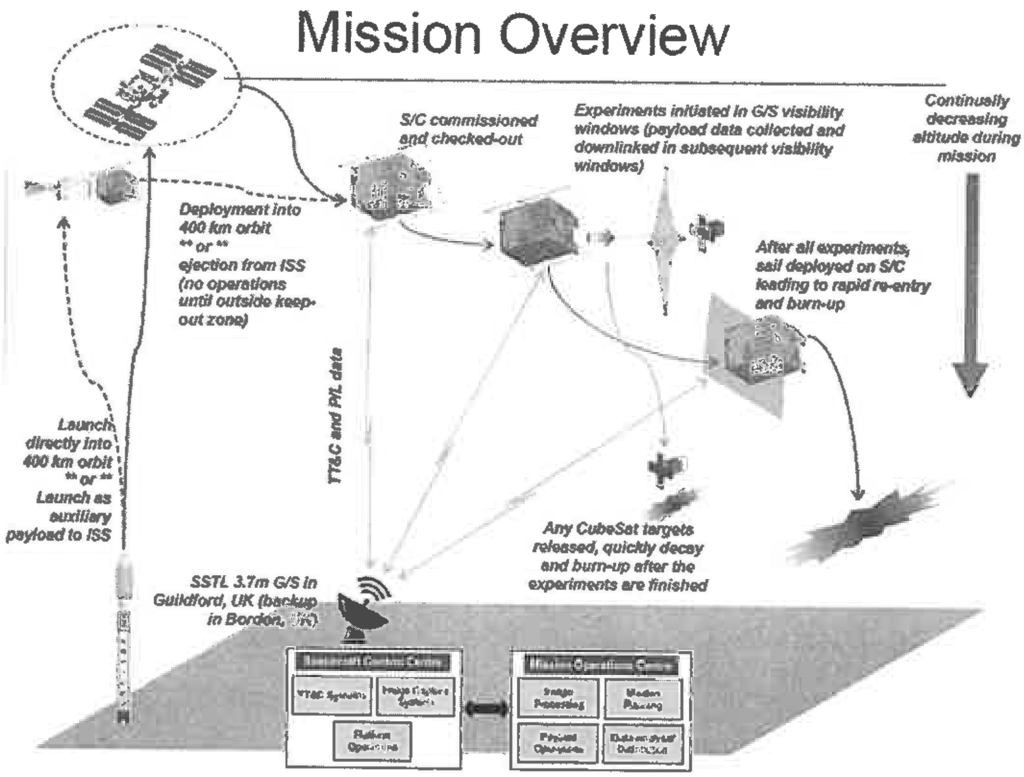
1. Appendix A - Number of Space debris increasing over time (ESA´s measures)
2. Appendix B - ESA´s Remove Debris demonstration plan
3. Appendix C - Ground based space debris removal
4. Appendix D - Proposal of new generation satellites

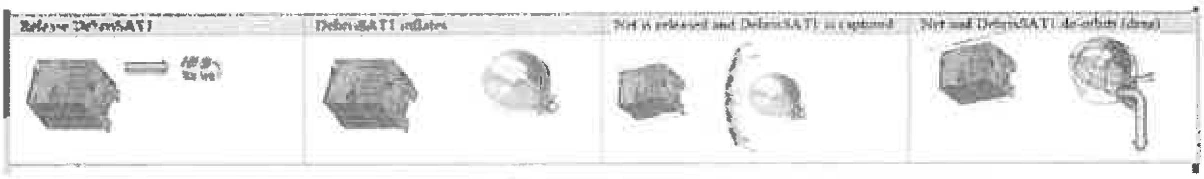
Sources of our appendixes are listed above.

Appendix A - Number of Space debris increasing over time (ESA´s measures)

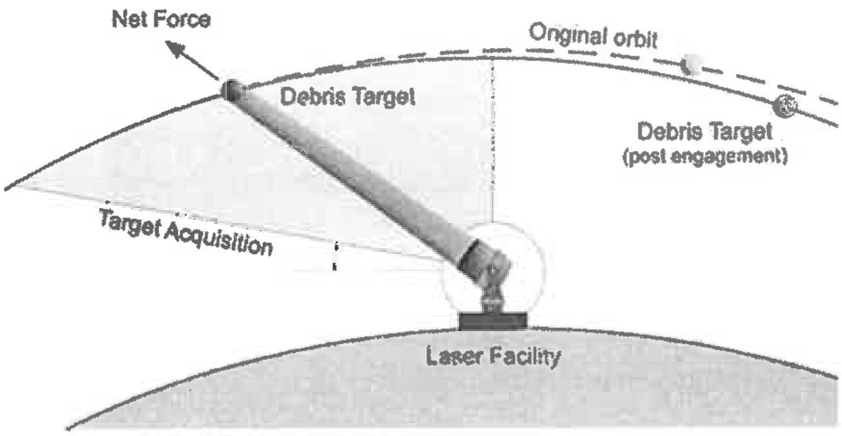


Appendix B - ESA´s Remove Debris demonstration plan





Appendix C - Ground based space debris removal



Appendix D - Proposal of new generation satellites

Block satellites

Space debris can be mitigated by building satellites with different buses that are being used currently. These kind of satellites would be more universal and relatively cheaper to build because they would not require any special design for every new one.

We propose to create company from financial resources of for example ISDR or others. This company would be named Blocksat. Objective of this company would be to build satellites from blocks.

These blocks would be mounted to special satellite bus designed for this purpose. Every different part of a satellite will be in one separated block, for example propulsion, transmittion, optics etc. would be separated. Blocks and satellite bus would be designed so they are easily mountable in space zero-gravity conditions using robotic appliances.

When any part of satellite breaks or satellite runs out of fuel, there would be Blocksat Engineer (BE) ready. BE would be special robotic satellite which would have new blocks and fuel on board. BE would be design to swap broken blocks with new ones and refuel satellite which it requires. On orbit refueling is tested by NASA nowadays. If it is preferable to maintain broken satellite on orbit, customer will order BE to repair it.