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Space Debris Remediation: an International Relations Approach

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"Master of Science"

supervised by
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Vienna, 08.06.2015

Affidavit

I, **Anastasia Medvedeva**, hereby declare

1. that I am the sole author of the present Master's Thesis, "SPACE DEBRIS REMEDIATION: AN INTERNATIONAL RELATIONS APPROACH", 76 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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Abstract

This thesis reviews the issue of space debris remediation from the point of Regime theory of International Relations. The main principle of the Regime theory lies in the idea that the key to successful intergovernmental cooperation is in creating an intergovernmental regime. So far, there is no efficient regime to govern the problem of space debris remediation.

Since the beginning of human space exploration in 1957, the orbital environment around Earth has been constantly cluttered with human-made waste. With new satellites launched onto orbit every year, the space available for new technology becomes limited and the possibility of collision between space objects grows. Thus, a regime is necessary to govern the process of space debris remediation through an intergovernmental agreement, which would include provisions on legislation, funding, liability concerns among many other aspects.

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List of abbreviations

ADR	Active Debris Removal
AIAA	American Institute of Aeronautics and Astronautics
ATK	Alliant Techsystems Inc.
COBRa	A concept of contactless deflection of an asteroid with electrical propulsion from GMV, Poletecnico di Milano and TAS-I
CSA	Canadian Space Agency
DARPA	Defense Advanced Research Project Agency
DEOS	Deutsche Orbitale Servicing Mission
DAD	Drag Augmentation Device
DRS	De-orbit and Recovery System
ELDO	European Launcher Development Organization
EOL	End of Life (operations)
ENVISAT	Environmental Satellite (ESA)
ESA	European Space Agency
EU	European Union
GDP	Gross Domestic Product
GEO	Geosynchronous Orbits
GLONASS	Russian Global Navigation Satellite System
Gold	Gossameter Orbit Lowering Device
GNC	Guidance, navigation and control
GMV	Grupo Mecánica Vuelo (Spanish: Flight Mechanics Group)
GPS	Global Positioning System
IAA	International Academy of Astronautics
IADC	Inter-Agency Space Debris Coordination Committee
ILA	International Law Association
ISS	International Space Station
LEO	Low Earth Orbits
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NGO	Non-Governmental Organization
OSS	On-Orbit Servicing
OST	Outer Space Treaty, formally the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies,
RRM	NASA Robotic Refueling System
ROSCOSMOC	Russian Space Agency
SIS	Space Infrastructure Servicing
SSO	Sun Synchronized Orbit
TASI	Theoretical Advanced Study Institute in Elementary Particle Physics, Department of Physics, University of Colorado Boulder
UN	United Nations Organization
UN GA	Unite Nations General Assembly

UNEP	United Nations Environmental Programme
UNCOPUOS	United Nations Committee on the Peaceful Uses of Outer Space
UNISPACE	United Nations Conferences on the Exploration and Peaceful Uses of Outer Space
UNOOSA	United Nations Office for Outer Space Affairs
USSPACECOM	NASA catalog number, US SPACE COM object number, Catalog number
WTO	World Trade Organization

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1. Introduction and State of the Art

1.1. Overview of the problem

In the past fifty years, space activities have been rapidly expanding worldwide, resulting in a massive increase in space traffic. This causes Earth orbits to become steadily crowded by a fast growing population of space debris. The situation was very concisely addressed by Lt. General Larry James from the Joint Functional Component Command for Space, who stated the following: “In 1980 only ten countries were operating satellites in space. Today, nine countries operate spaceports, more than fifty countries own or have partial ownership in satellites and citizens of thirty nine nations have traveled in space. In 1980, we were tracking approximately 4,700 objects in space; 280 of those objects were active payloads/spacecraft, while another 2,600 were debris. Today we are tracking approximately 319,000 objects; 1,300 active payloads and 7,500 pieces of debris. In 29 years, space traffic has quadrupled” (James, 2009). James made a very concise statement about the speed of growth of the orbital population. Unless direct measures of remediation are implemented in the next two decades, the future of human space exploration and orbital operations is in jeopardy, to the extent of becoming impossible.

In 1978, Donald J. Kessler and Burton G. Cour-Palais made a prediction about the problem of the instability of orbital debris population. The theory was later named the Kessler Syndrome. The effect can be described by a situation when the amount of orbital debris reaches the point where objects begin to collide randomly, creating a cascade of uncontrollable collisions with catastrophic consequences.

There are three basic scenarios for orbital accidents of man-made technology: an explosion of a spacecraft, collision of fragmentational debris and a functional or non-functional satellite, and a collision between two large objects. The probability of the latter is the highest. The probability of an accident with a certain object is proportionate to the amount of other objects floating on the same orbit, their sizes and functionality. According to the theory of Donald J. Kessler the collision rate of space objects is a function of the number of objects in the area, assuming that the ratio of the large fragments to intact spacecraft is constant with time (Kessler and Cour-Palais, 1978). With every new satellite introduced in orbit, the probability of collision between space objects goes up. Hypothetically, if the amount of payload in orbit grows by a certain percent, the collision probability for one object increases by that percent as well. But, it is twice as probable that two large object collide.

Recently, several modeling studies of space debris have shown that the Low Earth Orbit (LEO) has already reached that level of instability. According to recent modeling research conducted by the Inter-Agency Space Debris Coordination Committee (IADC), even with 90% compliance of the commonly adopted mitigation measures and with measures taken to prevent future explosions, LEO debris population could grow another 30% in the two centuries coming. Since such conclusions were made, it became clear that the existing legal base, including that adopted by the IADC or United Nations (UN) Agencies, is insufficient to stop the orbital population from colliding or growing even further. Catastrophic collisions are predicted to happen as often as every 5 to 9 years. With such perspective at hand, space debris remediation should become the main tool at stabilizing the LEO and Geostationary Earth orbit (GEO) environment.

Other researchers suggest that the Kessler Syndrome has been put into action by several major fragmentation instances in 2007 and 2009. In this perspective, some studies show that for a sustainable future in orbit on the long term, remediation rules should be applied in an international agreement. To be completely effective, at least 5 large objects should be de-orbited annually, vacating space on the most populated orbital regions. Thus, both mitigation and remediation are of absolute necessity to ensure the possibility of safe space activities. According to the IADC, space debris mitigation "consists of all efforts to reduce the generation of space debris through measures associated with the design, manufacture, operation, and disposal phases of a space mission", while space debris remediation is defined as "efforts to manage the existing space debris population through active space debris removal with emphasis on densely populated orbit regions" (IADC, 2013). In other words, mitigation is a long-term policy of implementing rules and regulation of how the space environment should be preserved by, for example, restraining from further pollution via inactive satellites. Remediation, on the other hand, implies direct measure of removing debris by de-orbiting or burning the waste in Earth's atmosphere.

The worst debris-generating event in history of space exploration was in 2007, when China destroyed one of its meteorological satellites during an anti-satellite missile test. Then, Fengyun-1C was exploded by a ground-based missile (Liou and Johnson, 2009). This incident has been described as the “largest debris ever recorded” (Carrico et al., 2008) and is responsible for 18% of the entire population in orbit (Johnson et al., 2008). In its report, the US Space Surveillance Network confirmed tracking 2317 space pieces of debris resulting from the incident. The data, collected from the Haystack (X-band) radar, estimated the amount of debris larger than one centimeter left after the explosion to be at least 150 000 pieces (Liou and Johnson, 2009).

Another collision worth mentioning happened in 2009, when the American Iridium 33 communication satellite crashed with a decommissioned Soviet communication satellite, Cosmos 2251. That event added 1 658 trackable objects to the US catalogue (Kelso, 2009).

The question of Active Debris Removal (ADR) plays an important role in solving the possible space debris crisis. But cleaning space requires technologies most of which are still in development, millions of dollars for construction, revision of the existing legislative framework for space issues and clarification of responsibility and liability clauses. Pollution of earth orbits originates from all space-faring nations, and international Treaties rule that all states should be responsible for their own litter. On the other hand, taking into consideration all the liability concerns around space debris removal, it remains unclear whether countries should bear the burden of cleaning up their own junk or rather have an international body to control remediation activities.

The first step, according to many, should be in stabilizing the current orbital environment. This is usually understood that the international society should aim at, in the long term, keeping a constant number of catalogued objects in orbit. On the other hand, this would also mean stabilizing and controlling the amount of debris in size range between 1 cm and 5 cm. Until today, ADR research has been centered on bigger objects, 10 cm or more, which makes it that much harder to make assumptions on detecting and cataloguing objects of smaller size. A new set of analysis and technology is required to work with smaller objects.

Two main models, proposed by NASA and ESA, have made separate estimations as to what level the problem of space debris shall unravel in the next several decades.

LEGEND, a parametric simulation conducted by NASA in 2005, underlined the inevitability of future growth of orbital debris. With the calculated rate of future launches, environmental projections for the next 200 years, based on different rates of debris removal from orbit together with various selection criteria for such removal, were compared with the baseline scenario. The baseline scenario suggests that at the end of a space mission's life cycle, the spacecraft and its upper stages are moved to 25-year decay orbits. According to the model, in certain critically overpopulated orbits the rate of generation of new debris bigger than 10 cm in size would exceed the natural rate of decay of objects in orbit. The most striking result, shown by LEGEND, was that a removal rate of five objects per annum will be vital in the course of the next two centuries (Liou et al., 2010).

The Debris Environment Long-Term Analysis (DELTA) is a model created by the European Space Agency. This model confirmed the LEGEND findings, stating that a uncontrollable increase of debris will lead to "collisions becoming primary debris source within less than 50 years" and, "the removal of mass from orbit turns out to be the most effective way of preventing this collisional cascading process from setting in" (ESA, 2013).

Judging from the reviewed theories and models, the importance of retrieving mass from orbits and settlement of an international remediation mechanism becomes vivid.

1.2. Hypothesis

The issue of space debris becomes a heavily discussed topic on the international arena with every new satellite launched, as orbital space is limited while there is no limit for states in creating debris. This is the main reason why many private and state actors have started addressing the problem of remediation as an urgent necessity. Both the private sector and governmental agencies are now exploring and starting to invest in soliciting request of proposals for developing the necessary technologies and legislation.

With the increasing proliferation in the population of space debris in Earth orbits, remediation activities can no longer be an issue left to be solved by future generations; a solution is needed in the course of the following decade. With this in mind, several questions remain unclear: who will control the remediation process? How it should be handled from a legal and technical standpoint? When such activities should begin? And who will fund such activities? To understand the scope and necessary measures for ensuring successful space debris remediation, current space policies and activities could be approached from the terms of the Regime theory of International Relations.

In this regard, the central hypothesis of this study is that amongst International Relations theories, the Regime theory provides the most suitable approach to understand the issue of space debris remediation and to design possible ways of dealing with it on the intergovernmental level.

The existing corpus *juris spatialis* is often criticized for its incapacity to keep pace with the rapid technological advancements and modern commercialization of the field (Benkö and Schrogl, 2005). Among the multiple space governing agencies and international organizations, none is fully responsible for space litter. Also, there is no clear definition of space debris – which is in its own way a huge setback for the process of remediation.

The existing framework of international space law does not permit interception with space objects without prior consent of the launching state. If an object was to be removed without proper authorization from the launching state, such action would be regarded as an internationally wrongful act according to Article VIII of the Outer Space Treaty (OST), as "a State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body" (UNOOSA, 1967). However, such actions could be precluded by defense purposes in a given situation. Thus, to create a smooth and clear remediation procedure, it is essential to create unambiguous interpretations of the existing space legislation, which would be able to cope with potential legal controversies in the area. And, in order for the required legislation to be applied effectively, there should be a body to monitor and implement it.

1.3. Scope

The aim of the study is to review the applicability of the Regime theory of International Relations to the issue of space debris remediation.

Today, there are two main approaches to solving the problem of space debris: through remediation and mitigation. Remediation means applying methods of Active Debris Removal (ADR) – do-orbiting of payload, sending objects to burn in Earth's atmosphere (via atmospheric drag), removing debris to so-called graveyard orbits, etc. Mitigation, on the other hand, is the process of implementing requirements, rules and regulations to ensure the safety of Earth's orbital environment from further pollution by ensuring end-of life passivation of spacecrafts, designing payload to be able to remove itself at the end of mission, through space debris environmental modeling, etc.

One of the central goals of the thesis is to study the legal, economic and political sides of space debris remediation. Additionally, this study will include evaluating of the role of space-faring nations and the private sector in solving the issue of remediation. The importance of private and state incentive will be looked at in the perspective of the growing importance of orbital clean-ups, collisions, and overpopulation. The thesis will include a discussion of the possible international mechanisms of enforcement and implementation of the process of remediation. Lastly, this paper will analyze the necessity and probability of creation of a space debris governing regime within the scope of the Regime theory.

1.4. Methodology

The data for the study has been gathered from several media. The primary tool for data gathering was library research, several legal databases, publications on the Internet and interviews. The primary sources included treaties, customary international law, judicial decisions, international legal declarations and resolutions. Secondary sources were books on international legislation and the history of space issues, journal articles, statistics and reports. Finally, the most recent data was compiled from online sources, such as international space agencies (ESA, NASA, ROSCOSMOC, etc.) and international organizations (Inter-Agency Space Debris Coordination Committee, United Nations Office for Outer Space Affairs, United Nations Committee of the Peaceful Uses of Outer Space, etc.).

1.5. Introduction into the subject

1.5.1. Historical overview

Since the launch of the first Russian satellite Sputnik 1 in 1957 (Stoiko, 1970), the population of man-made objects in Earth orbit has been increasing. Even when the lifetime of such objects is over, they continue to rotate around the planet, posing navigational threats to active technology and other space assets, including human and robotic missions.

While the amount of orbital debris grows alarmingly, the number of space-faring countries also expands. Eventually, the inadequacy of the existing space legislation may cause “the tragedy of the commons” in Earth’s orbits (Hardin, 1968), which from some angles resembles “the tragedy of the anti-commons” by preventing the creation of an optimal utilization of common space (Heller, 1998). While China, EU states, Russia and the US are the main space polluters, the questions of who and under which legislation should be responsible for cleaning it up remains open. The estimated number of such waste stands roughly at 300,000 units, and is large enough to completely destroy an active satellite in a collision.

The danger of space debris has reached the level at which it poses a great threat for provisional satellite services, integrated into operations of the global economy and such military and public services as US GPS or Russian GLONASS. While some researchers suggest that even annual clean ups would be sufficient enough to ensure the safety of satellites and significantly stabilize the space debris environment, most countries prefer to postpone such activities due to high costs and free riders problem. This master thesis explores the possibilities of treating the issue through the framework of the Regime theory of International Relations.

1.5.2. Data on the currently existing amount of space objects and debris

The so-called artificial debris can mostly be found in orbit around Earth and creates a more serious threat to the planet, compared to the naturally produced debris by asteroids, comets and other celestial bodies. Artificial human-made waste can also be found on the moon, where the amount of debris is estimated at over 100,000 kilograms left after more than 50 lunar landings and expeditions – and even though it is not orbiting the planet, it still remains under responsibility of states of registration (Johnson, 1999). The process of the creation of space debris in Earth’s orbit and the ways to study it, analyze the risks it imposes and develop strategies to cope or remove it are highly technical and very costly. In approaching any of these matters, an individual has to have at least a basic understanding of not only the problem itself, but of laws of physics and technologies.

Since the first satellite incident in 1961 and up until the beginning of 2003, over 180 spacecraft and rocket fragments have been floating in orbit. Out of the 9,000 objects, registered and watched by USSPACECOM, about 40% are catalogued as objects remaining after breakups or collisions. But this count does not include the multitude of particles less than one centimeter, since these are almost impossible to be detected from Earth.

In the end of 2014, both NASA and ROSCOSMOS (TASS, 2015) published their reports on man-made objects in Earth orbit. But the presented data varied in the reports of the agencies. The Russian Federal Space agency stated that there are 17,119 objects, with 1,321 active and the rest labeled as debris. The available statistics of tracked and identified debris show that out of the total 6,260 objects were launched by Russia, 4,555 by the United States, and 3,632 by China.

According to NASA, there are 16,906 objects in orbit. Russia and the former USSR countries are the main contributors to the number of existing space junk – with 6,351 inactive objects registered in their name. The US is the “owner” of 5,038 pieces of debris, and China – 3,756.

1.6. Problem of estimation of existing space debris

1.6.1. Registration

Every object launched into space is required to be registered under several international agreements and organizations. Any craft, intended to function in orbit, should have a launching state responsible for its activities in orbit.

One of the main international agreements on the issue is the 1974 Convention on Registration of Objects Launched into Outer Space (UNOOSA, 1999). Adopted by the UN General Assembly, the agreement aims to ensure and facilitate the registration of objects by launching states and international organizations. The convention not only provides information on registration of objects, but also covers such aspects as change of supervision over the launched craft.

The registration process ensures that the launching state provides necessary information to UNOOSA, as well as taking responsibility for all activities of the craft in orbit. This includes the spaceship’s technical characteristics and functions, date and location of launch, and basic orbital parameters (such as its apogee, perigee, and nodal period).

1.6.2. Classification

Orbital debris is traditionally classified by its location in orbit and size.

In the space area around Earth there are two main orbits where debris is of the most concern. These are the Low Earth Orbits (LEO) from 2,000 to 5,500 kilometers above the planet and the Geosynchronous Orbits (GEO) starting from as far as 36,000 kilometers away (Wright et al., 2005). The amount of debris is considered to be almost the same, but the danger imposed is different, as in the LEOs perturbations of orbital waste is due to the effects of atmospheric drag, whereas in GEOs it is the gravitational forces of both Earth and Moon.

All man-made objects in orbit could be placed into two main groups: the functional apparatus and debris – nonfunctional spacecraft or residue of their presence. The types of space debris are reviewed in Table 1. below.

Table 1. Classification of orbital objects

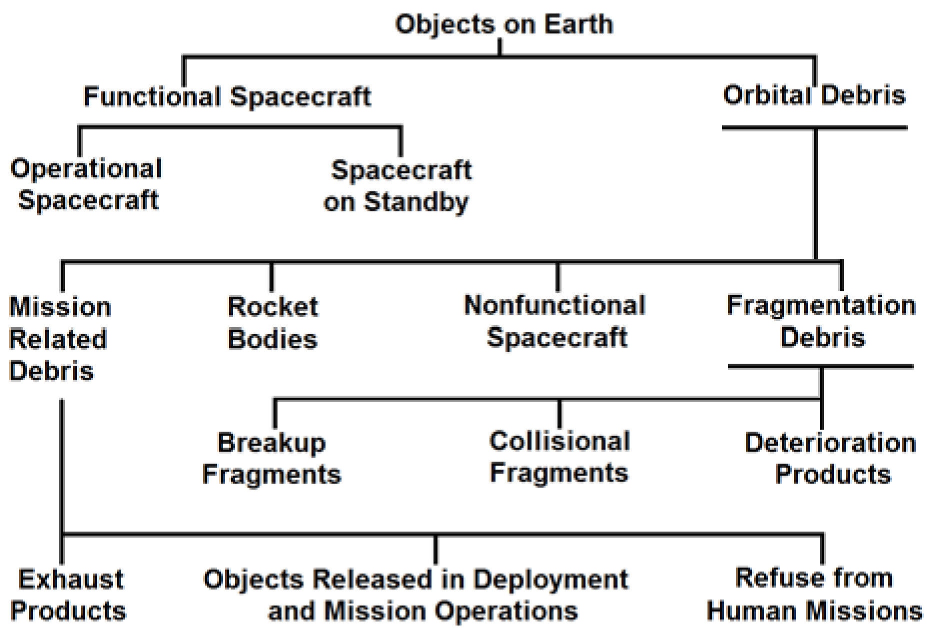

Table 2. shows the estimated number of space debris objects, ranging in size and possible impact if collides with spacecrafts or rockets:

Table 2. The Estimated number, size, measurement and effect of space debris in Earth orbit

Size (cm)	Number of objects (pieces)	Measurements	Effect
> 10	> 9000	Radar	Can break up a satellite
1-10	>1 e 5	Optical telescope	Penetrate satellite walls

0.1 – 1	> 3 e 7	Statistical Estimate	Surface or component damage
< 0.1	10 e 9 – 10 e 14	Long Duration Exposure Facility (LDEF)	Sensor interference

1.6.3. Detection

One of the main aspects of space debris remediation and ADR is detection. Prior to launch, all space objects are required to be registered and catalogued. As soon as they arrive in their orbit, space surveillance networks maintain and control their location and activities. Such networks are to a certain extent limited to larger objects. But as soon as there is an explosion or collision resulting in complete or partial fragmentation of the craft, such networks can no longer monitor the object's orbital activity.

Surveillance networks are limited to objects larger than 10 cm in the LEO and greater than 1 m in the GEO. Such thresholds of sensitivity are a compromise between performance and system cost. In cases when objects are impossible to detect by usual technology due to their small size, experimental sensors with higher sensitivity are used.

In case of the GEO, debris as small as 10 cm can be detected by ground-based radars. These can also monitor LEO debris as small as a few millimeters. Another technology – in-situ impact detectors – can detect fragments, which are only a few micrometers in size. Telescopes, on the other hand, are mostly used for GEO and high-altitude debris detection.

Another important tool in tackling the problem of detecting small debris are the so-called "beam-park" experiments. In such technology, the radar bean is maintained in a fixed angle with respects to Earth and all objects passing through the beam are registered. From the backscattering of the radar signal, information on the objects' orbital parameters can be gathered. In this kind of observation, objects up to 2 cm can be detected at a distance of 1000 km. Data from beam-park experiments is later used for creating space debris models. Since this technology was implemented, every coming day of observations brings new data on the number and characteristics of existing debris: in some orbits and regions, twice as much debris is detected as was previously predicted in models.

Space debris models play a vital role in estimating the number of orbital junk. Most models use the numbers of catalogued population as a basis and add fragments of known breakups up to 50 cm in size to account for the miscalculations in the catalogues. For pieces of debris over 50 cm, the breakup model parameters are re-adjusted so that the theoretical population fits the one, suggested by catalogues (Mehrholz et al., 2002). For objects between 1 mm and 50 cm, observation data is sparse and uncertainties in the models increase dramatically as the size of objects decreases.

2. Legal aspects

2.1. Legal Definition of the term “space object”

Space debris is one of the most prominent problems associated with space activities. The term “space debris” includes objects as big as spent satellites, ejected instrument covers, upper stages of rockets, and as small as paint particles, fuel droplets and tiny fragments left after explosions and collisions (Viikari, 2008). In other words, anything becomes space debris the moment it is launched into space. As currently there is no clearly established method for ADR, every object is doomed to orbit Earth for eternity. Other terms used to describe space debris include space litter, garbage, junk, trash or refuse.

Despite the existence of multiple international space treaties and declarations, there is still no clear definition or an adequate description of space debris. Some researchers suggest the reason for this lies in the possible confusion over the literal meaning of “debris” (U.S. Congress, 1990), as well as the uncertainty about the scope of the objects to be included in the term.

The Convention on the Establishment of a European Organization for the Development and Construction of Space Vehicle Launchers (ELDO) proposes a definition of a “space vehicle” in Article XIX of the Annex: “a vehicle designed to be placed in orbit as a satellite of the Earth or another heavenly body, or to be caused to traverse some other path in space.” (ELDO, 1962).

In 1963, Belgium submitted a working paper on the unification of rules governing liability for damage caused by space vehicles at the second session of the UNCOPUOS Legal Sub-Committee. In that document, a “space device” was characterized as “any device which is intended to move in space, remaining there by means other than the reaction of the air”.

Article I of Annex I of the Final Acts of the International Radio Regulations suggests implying the term “spacecraft”, which is defined as follows:”a man-made vehicle, which is intended to go beyond the major portion of the Earth’s atmosphere”.

Nevertheless, the key term to defining space debris is the one of a “space object”. If the notion of space debris is incorporated into the term of a space object, some international treaties may apply. But if the terms are not associated, parties must look to other sources for a remedy.

In most national and international legislations, the term “space object” is used. One of the main definitions of a “space object” is provided by the Convention on International Liability for Damage Caused by Space Objects (1972), and states that “the term ‘space object’ includes parts of a space object as well as its launch vehicle and parts thereof” (Article 1 (d)). The Registration Convention contains the same definition in its Article I (b). According to some researches, this definition is not fully concrete, as the word “include” in it “makes a precision to a definition to be found somewhere else” (Benkö and Schrogl, 2005). Despite this, as is explained further, there is no concrete definition of a space object in international legislation. The incorporation provisions of the Registration and the Liability Conventions have proved to be too controversial to ensure the success of either of them leaving the content up for debate.

The same could be said in the matter of defining what a “space object” really is. In both Treaties, “space object” is defined as the whole body of what is sent into space as well as its separate fragments. Though, both documents fail to give a more precise description.

Some nations’ domestic space law has different definitions, which may cause legal inaccuracy in some cases. For example, Austrian legislation provides a similar definition to the one in the Liability Convention, describing a “space object” as an object “launched or intended to be launched into the outer space, including its components”. Even though the wording is similar to the one in the Convention, it may represent a precedent for the customary use of the term.

In the legislation of the Russian Federation, “space objects” are listed as immovable property together with property, land, ships and others, without any further description or definition of the term (The Civil Code of the Russian Federation, 2015).

During the Third Session of the UNCOPUOS Legal Sub-Committee in 1964, Canada and Australia issued a report, proposing that a “space object” means “an object or any of its component parts which a launching state has launched or attempted to launch into outer space”. In the course of the same Session of the Legal Sub-Committee, Hungary presented a draft agreement on liability, suggesting that “space objects” are “space ships, satellites, orbital laboratories, containers and any other devices designed for movement in outer space and sustained there otherwise by the reaction of air, as well as the means of launching of such objects".

Three years later, during the Sixth Session of the same Sub-Committee, Argentina issued a different definition. "The term 'space vehicle' means any device launched by man exclusively for peaceful purposes, for the exploration or use of outer space, including the Moon and other celestial bodies, as well as the equipment used for launching an propulsion and any parts detached therefrom".

In 1963, the UN General Assembly passed the Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space. This document became the precursor to the Outer Space Treaty, which was signed in 1967. A "space object" was not defined in the Declaration; instead, it was referred to as an "object launched into outer space and … their component parts". On adopting the Outer Space Treaty, the UN General Assembly included the term "space object" to Article VII and Article VII, agreeing on the common definition of "an object launched into outer space", and extending the term to incorporate also the "objects landed or constructed on a celestial body". The definition in Article VIII of the OST has also been mentioned in the Moon Treaty, when referring to "vehicles, equipment, facilities, stations and installations". It is also worth mentioning that the Moon Treaty addresses "space objects" as "man-made space objects" in Article 3 (2) (Hobe, 2007).

Howard A. Baker created the functional approach to defining a "space object". The author described the term as any space instrument in its "operational state" (Baker, 1988). Baker suggested understanding a "space object" as any object intended for launch (in orbit or beyond); launched (in orbit or beyond); or assembled in space, and any instruments used as a means of delivery of any of the objects as defined prior. Also, according to Baker, the definition should include any part thereof or "any object on board which becomes detached, ejected, emitted, launched or thrown, either intentionally or unintentionally, from the moment of ignition of the first stage boosters".

Overall, there has not been yet found a single definition of a "space object" in international law. It also remains unclear as to when an object or its parts cease to become a "space object". Keeping that in mind, one may come to the conclusion that there is no change in the status of space objects, fragmented or not. All objects on space will continue to be regarded as "space objects" under international law – thus, *de jure* jurisdiction and all control are retained by the state of registration.

After revising the broad understanding of a "space object" and its derivatives in various treaties and agreements, one may come to the conclusion that, first of all, existing interpretations of the term fail to give a full and exact description as to what exactly is to be understood under the notion and as to what apply the legislation. This may lead the launching states or states of registration to apply the law differently in construction, assembling and use of their object in outer space (Hurwitz, 1992). What also remains unclear is whether all fragmentational debris and microparticulate matter should be included – as these objects represent about half of the orbital debris population.

Having outlined the current legal perspective on the definition of a "space object", the following section will concentrate on the problem of defining space debris and space debris remediation.

2.2. Legal definition of the terms "space debris"

One of the first mentions of orbital debris was made in 1963 in the text of the Treaty Banning Nuclear Weapon Tests in the Atmosphere, Outer Space and Under Water. In Article 1 (b), the Treaty places a prohibition on nuclear explosions in the atmosphere, outer space and under water, as well as "in any other environment if such explosion causes radioactive debris to be present outside the territorial limits of the State under whose jurisdiction or control such explosion is conducted". This is the only mention of debris in the Treaty, giving no explanation as to what the term "debris" actually incorporates.

The initial bases for a future instrument on space debris were proposed at the 64th International Law Association (ILA) Conference in 1990. The Space Law Committee of the ILA initiated the drafting process of an international instrument on space debris, hoping to create guidelines to be adopted in the course of the following ILA conference in 1992. The following definition was proposed: "Space debris means man-made objects in outer space, other than active or otherwise useful satellites, when no charge can reasonably be expected in these conditions in the foreseeable future" (Boeckstiegel, 1995).

In 1999, the Scientific and Technical Subcommittee of UNCOPUOS published the Technical Report on Space debris. This became one of the first documents from the

UN on the issue, which sparked discussion on the topic of congestion in outer space. In the report, the Subcommittee released a definition of "space debris", which they believed could be used internationally: "Space debris are all manmade objects, including their fragments and parts, whether their owners can be identified or not, in Earth orbit or re-entering the dense layers of the atmosphere that are non-functional with no reasonable expectation of their being able to assume or resume their intended functions or any other functions for which they are or can be authorized." And, as was mentioned in the report itself, at the time the document had been passed, there was no consensus on the definition of the term (UNCOPUOS Scientific and Technical Subcommittee, 1999).

Another definition was proposed by the International Academy of Astronautics. According to the IAA, orbital debris is "any man-made Earth-orbiting object which is non-functional with no reasonable expectation of assuming or resuming its intended function, or any other function for which it is or can be expected to be authorized, including fragments and parts thereof. Orbital debris includes non-operational spacecraft, spent rocket bodies, material released during planned space operations, and fragments generated by satellite and upper stage breakup due to explosions and collisions" (Flury and Contant, 2001).

One of the main definitions of space debris belongs to the Inter-Agency Space Debris Coordination Committee. In 1999, the Inter-Agency proposed the "IADC Space Debris Mitigation Guidelines", creating a document in accordance with the national legislations of all member agencies. The definition is more concise than its predecessors, and reads: " Space debris, also known as orbital debris, are all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional" (IADC, 2013).

The work of the IADC gave initiative to UNCOPUOS to create a Space Debris Working Group, which later published a draft set of "high-level qualitative guidelines" based on the ones from the Inter-Agency. The draft document was adopted by the UNCOPUOS in 2007 and was later adopted at the UN General Assembly in Resolution 62/217. The General Assembly highlighted the importance of the agreement and stressed the necessity for all Member States to implement the guidelines within national legislation. The definition of space debris in the Resolution has the exact same wording as the one issued by the IACD. Nevertheless, it is important to note, that the definition has been incorporated in the "Background" part of the Guidelines, and is explicitly limited to the purpose of the Agreement by a preceding proviso (UN, 2007).

The UN Guidelines are not legally binding under international law, but they have been compiled in a way to reflect all Member States' domestic legislation, as well as the existing practices of several international and national agencies and organizations. The document specifies that "Member States and international organization should voluntarily take measures … to ensure that these Guidelines are implemented" (UN, 2007). The Guidelines prove to have a technical nature, which could be explained by the fact that they have been adopted by the Scientific and Technical Subcommittee without direct involvement of the Legal Subcommittee. Thus, the Guidelines are soft law, which cannot enforce any rights or obligations on Member State, but are vital for international development and cooperation. On the other hand, these Guidelines serve as the first attempt of discussing the importance of space debris at the United Nations General Assembly – making the issue a notion of an international public order.

The definition of space debris in the UN Guidelines are also a first step towards creating a minimal standard of care for the space environment among the Member States – which brings to the forefront the problems of space debris mitigation and remediation.

However, some difficulties may arise due to the problem of end of lifetime of space objects and their furnishing update information. As every launched object has to be registered with the UN under the Registration Convention, some launching states have chosen to advocate for furnishing updated information on their objects' functionality. States may make declarations about the imminent decay of space objects or their end of mission. For instance, such statements have been made by Sweden (Astrid, Freja and Twele-X satellites) and Italy (Beppo Sax).

An example of a domestic definition of space debris is the one proposed by NASA. According to the Agency orbital debris "are all man-made objects in orbit about the Earth which no longer serve a useful purpose" (NASA, 2012). The Agency also lists the following as orbital debris:

- derelict spacecraft and upper stages of launch vehicles,
- carriers for multiple payloads,
- debris internationally released during spacecraft separation from its launch or during mission operations,

- debris created as a result of spacecraft or upper stage explosions or collisions,
- solid rocket motor effluents,
- tiny flecks of paint released by thermal stress or small particle impacts.

A definition of space debris was also proposed by Lieutenant Colonel Joseph S. Imburgia: “all man-made objects, including fragments and elements thereof, in Earth orbit or reentering the atmosphere, that are non-functional, regardless of whether the debris is created accidently or intentionally; the term includes but is not limited to, fragments of older satellites and rocket boosters resulting from explosions or collisions, as well as any non-functional space object, such as dead satellites, spent rocket stages or other launch vehicles, or components thereof” (Imburgia, 2011). This is a definition, created as part of a proposal for an international treaty, aimed at dealing with space waste in terms of liability and responsibility for the current and future littering objects in Earth orbit.

Existing proposals for space debris legislation usually focus on the issue of responsibility and liability for accidents and damages occurring in space, but they rarely propose solutions in the sense of remediation. Also, taking into consideration the scope of the problem, it is challenging to expect all the states involved to ratify any given international agreement, given the level of competition of geopolitical interest of the countries, which are parties to the UNCOPUOS or UN Member States in general.

Some experts suggest a different – more practical – approach to solving the issue of defining space debris. They propose to seek a solution through addressing the problem of ownership. As was already mentioned, removing of any human-made waste from orbit is closely intertwined with salvage rights to that waste, as noted in Article VIII of the Outer Space Treaty. Thus, the owner (private entity or a government) should be addressed before any action is taken towards floating waste. From this point of view, the following must be taken into consideration; space debris is an object in space (by Article I of the Liability Convention and Article I of the Registration Convention), no longer performing its original functions, defined as an object re-entering Earth’s atmosphere, or remaining in orbit, in outer space or on other celestial body (including the Moon). Any space object is to be created and launched through the actions or inactions of a state, company or other, it may be of an economic, historic or national security value to the launching party. Thus, any on0orbit activities should be coordinated through a responsible body, to ensure proper notification and cooperation between space-faring states.

Even if there were a commonly accepted definition of space debris, it would not by itself solve all the issues around space debris. The definition would still depend on the wording in national legislation. Moreover,the problem of determining national origin or the responsibilities and liabilities of the launching state would remain undetermined and, thus, unknown, even though international efforts are placed in proper registration and detection of space objects.

An appropriate definition of space debris should not only take into account the body of international space law, but should also be able to provide a basis for decision making for a state to decide if the object in question is of value, or whether it could be considered as debris and be removed from the orbit. Moreover, even if a definition was to incorporate all of the previously mentioned elements, it would still not be capable of solving all of the legal issues incorporated into the process of space debris remediation. In other words, a definition itself should be part of a quasi-legal protocol or an annex to one or multiple treaties, existing or probable. Only this would ensure space debris removal. The main goal should be in creating a regulation or law to ensure and inspire space debris remediation, instead of creating precedent for placing blame on a state or private actor.

2.3. Space debris remediation

2.3.1. Defining space debris remediation

Since the beginning of the age of human exploration of space, over 4,800 launches were made, placing more than 5,000 satellites into orbit, and about only 1,000 remain functional to date (Wormnes et al., 2013). The total weight of all objects in orbit is estimated at about 6,000 tones, creating a huge problem of space pollution and giving the issue a global character. With every coming day, the risk of collision of orbital fragments becomes a greater threat to operate safely in space.

Because of the high risk of collision, in 2009 alone the U.S. military had to maneuver over 1,000 satellites. And with every new satellite launched, the danger of an incident raises dramatically.

One of the main space objects closely watched by operators on Earth is the International Space Station (ISS). Each year, the trajectory of all debris in the surroundings of the Station is closely monitored to avoid any possibility of incident. Despite all efforts, annually the orbit of the ISS is slightly adjusted to prevent any accident. Maneuvers by the ISS are preformed when the probability of running into debris are greater than 1 in 100 000, and the impact is anticipated to create significant impact to mission objectives. Once the collision possibility surpassed 1 in 10 000, consequences are estimated to put the human mission at risk. In March, 2009, the ISS crew had to take refuge in the Soyuz rescue vehicle after a 13 cm piece of debris was discovered to be following the station's trajectory (O'Hara, 2010).

In this regard, and due to the level of risk increasing with every new space object sent from Earth, the following question has been raised before the international community: if the rate of launches remains the same, and no objects are removed at the end of their life cycle, how long until Earth's orbits become overpopulated and the Kessler syndrome occurs? Because, as was mentioned in the first chapter, once the Kessler syndrome takes place, there is closely nothing that could be done to revert it.

In order to avoid the dramatic consequences of orbital overpopulation, serious measures must be taken. Today, there are limited ways to decrease the risks or effects of collisions:

- Removal of large potential colliders does not seem practically feasible today, due to operational and programmatic constraints;
- Collision avoidance is possible only with large debris catalogues, but requires access to precise orbital data for the largest debris, through propagation of orbital tracks based on large observation facilities;
- Shielding of critical spaceships is possible up to a low energy limit only: debris larger than 1 or 2 cm impacting an active spacecraft may have deadly effect;
- Mitigation is by far the most efficient strategy: limiting the number of orbital debris in the critical zones for long term stability of the orbital population (ESA, 2006).

The International Academy of Astronautics came up with a set of recommendations for space debris mitigation, which aim at ensuring that the amount of debris does not increase any further – which is one of the main aspects of preventing any catastrophic event in the orbital environment. Firstly, the Academy suggests ensuring no further operational debris is generated by developing missions, conceived according to the "clean space" principles, which would not leave long-term orbital debris, such as clamp bands, fairings, etc. Secondly, launching parties should make sure there is no risk of explosion following the end of a mission by eliminating internal energy of any spacecraft or upper stages. This could be done by dumping residual propellants, depleting pressurants, etc. And, the third proposition was to ensure the protection of the two main orbital regions – the LEO and the GEO – due to their high economical importance. In other words, creation of any space debris in these orbits should be eliminated and prohibited. This recommendation seems hardly realistic today, but they must be followed through in the two next decades (ESA, 2006).

Today, space debris mitigation measures are discussed on various levels by international organizations and governments. But there is a second aspect of ensuring a safe future for space activities – space debris remediation.

The IADC defines space debris remediation as follows:

"Space debris environment remediation consists of efforts to manage the existing space debris population through active space debris removal with emphasis on densely populated orbit regions" (IADC, 2013)

Space debris remediation should be an action plan to clean up Earth's orbits, exploring and applying various methods and techniques to remove junk from the planet's orbital environment by burning it in the atmosphere (for the LEO), moving objects to grave-yard orbits (for the GEO), or dumping large vehicles in individually prescribed way (e.g. decommissioning of ENVISAT).

As practice shows, non-binding preventive measures taken in the past decade in form of various mitigation guidelines have not been effective enough to cope with the dramatic situation in Earth's orbital environment. Available models and scientific analysis have shown that the only possible way to solve the existing crisis is to ensure secure and sustainable use of orbital space through space debris remediation in the form of active space removal of orbital debris and on-orbit satellite servicing (Liou and Johnson, 2008).

One of the main issues about imposing remediation guidelines or rules is that of jurisdiction. As there is no legal definition of space debris, it remains unclear who has control over process and how. If remediation is to become a regulation, which all space-faring states will have to abide to, the first decision to be made should deal with the issue of who will have the authorization to remove orbital debris. As provided in Article VIII of the Outer Space Treaty, the State of registry of an “object launched into outer space” has the right to enforce national legislation upon the object and the human mission on it. This provision raises two issues: if space debris should be treated as the provision implies, and whether control and jurisdiction over orbital objects is permanent.

According to the legal perspective, both active and non-active objects should fall under Article VIII. However, there are ongoing debates on the appropriate method of distinguishing between functional and non-functional payload. There have been suggestions that a test of “effective physical control” should be applied, but this method has its own hurdles. First of all, lawyers insist that jurisdiction and control over space objects, debris or not, should remain in the hands of launching states. According to the existing legislation, ownership of a space object is permanent, no matter whether it is used or whether it is active or not, as the right of possession, use or disposal remains with the party of registration. Thus, an international organization, entity or a state are obliged to address the launching state for consent to interfere with the object in any manner.

Creating a doctrine of permanency of space debris objects will most probably slow down any attempts to minimize the quantity of orbital junk, as it would only apply to objects, which could be detected. The only two exceptions to such doctrine are the following.

In case of abandonment: according to maritime law, once a ship is abandoned by its crew with no intent to return to it and reactivate it, the vessel becomes a derelict subject to salvage. In case of space object it remains unclear, if abandonment would be a sufficient enough justification for space debris removal without the consent of the launching state.

The second exception is address in Article IX of the Outer Space Treaty:

“In the exploration and use of outer space, including the moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of co-operation and mutual assistance and shall conduct all their activities in outer space, including the moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty” (NASA, 2006).

This provision of the Outer Space Treaty obliges the state parties to cooperate, provide mutual assistance and to have due regard for the corresponding interests of other state parties. Some assume these legal obligations place under jeopardy the absolute nature of jurisdiction, control and ownership, as the application of the provision may have its limitations (U.S. Congress, Office of Technology Assessment, 1990). Firstly, some experts have expressed the opinion that corresponding interests exclude threats posed by orbital debris (Cristol, 1982). Secondly, the Outer Space Treaty ensures competing interests among states, but does not provide any rules for designating priority among these interests, which include the right to hazard-free space navigation and the right to leave an inactive object in orbit. Thus, suggestions on removal of hazardous payload without the launching state's consent have limited effectiveness. At best, they refer to inactive objects and other space debris, without offering any preventive measures – only compensation after removal – thus, not introducing proper remediation or mitigation requirements and rules.

Before removing any orbital debris or placing liability measures on a state of registration after collision, a method of identifying the responsible side should be introduced. The identification of space objects is under the jurisdiction of the Registration Convention.

There are two main phases to the process of identification of space objects. At first, the objects need to be detected and later identified by their launching states. The Registration Convention contains no provisions on how the objects should be detected and has little description of an identification system of launching states: unless the payload was placed on the registration list at launch, it is almost impossible to identify where it came from. Also, the Outer Space Treaty has no implication on untraceable manifestations of space debris. But, without proper identification, the Liability Convention cannot be applied, because there is no certainty about the state of registration. The Outer Space Treaty also lacks provisions on compulsory markings of payload. It only states that markings must be registered if applied – thus, making the most convenient way of identification voluntary. Still, while large payload can be identified rather easily, smaller space objects are hard to mark, and particulate orbital debris can only be identified by the state of registration.

Once the problem of identification is solved, the next step would be in deciding which debris should be prioritized for removal. Yet, there is no consensus on which types of space debris should be taken care of first.

2.3.2. Prioritizing space debris removal

Space debris can be categorized into three main groups, based on size and the damage it may cause in case of a collision: it could be minor damage, major damage, end of mission, or total destruction. If an accident happens between a space object and a piece of debris larger than 10, and there is a high probability of total destruction of both. The accident is likely to increase the amount of orbital litter by thousands of new units. When objects crash with debris between 1 and 10 cm in size, the consequences could be lethal to the spacecraft, but there is a smaller possibility of debris generation. If objects of less than 1 cm crash into a spacecraft, the object could be shielded; and the accident is unlikely to create a significant amount of debris.

Table 3. Characteristics of debris and its impact in case of collision

Size	Lethal to Operational Spacecraft	Number in Orbit	Traceable	Leftover Lethal Fragments
Small < 5 mm	Not	Millions	No	No
Medium 5 mm - 10 cm	Sometimes	~ 500 000 in LEO	No	Maybe
Large > 10 cm	Yes	~ 21 000	Yes	Yes 10 - 100 000

If the goal is to prevent uncontrolled growth of the orbital debris population and to ensure the safety of on-orbit operations, space debris with the biggest mass should be on the top of the priority list for removal (Weeden, 2010). Since the biggest objects might create the most debris in the future, removing them will reduce the possibility of generation of large quantities of space junk.

But, considering the danger imposed to the operational spacecraft in overpopulated orbits in the near future, the priority should be shifted to the small non-functioning objects (1-10 cm) in heavily utilized orbits. Such objects are not being tracked by Space Situation Awareness techniques, meaning that the bigger objects cannot maneuver in order to avoid collision.

Active removal of large orbital debris and small objects requires different technologies and techniques. Taking into consideration the budget constraints associated with space debris removal, one way or another, the size of objects up for removal will have to be prioritized. Even if the size of the prioritized objects were to be set, there would still be issues concerning which objects should be removed first within the size group. These arguments are an important concern when the goal is to maximize the benefit of expensive ADR operations.

The bigger the object, the greater amount of debris it can generate in a possible collision. In this regard, space debris specialists suggest that the mass times collision probability (M x P_c) is the best metric when deciding which large debris should be removed first (Liou, 2010).

This approach has two main challenges. First of all, the collision probability calculation varies depending on the model and technique applied. The second challenge is the political side of the issue: Russia is the launching state for most of the objects with highest priority – defunct satellites and large rocket bodies (See Table 4). With this in mind, it becomes clear, that without an international agreement, identifying the method of selecting objects for removal, choosing to de-orbit the biggest bodies could hinge on an underlying political motivation. This motivation could cause some states to be blamed for acting to certain geopolitical ends – and will place issues of intelligence gathering among others on center stage.

Table 4. Estimation of space debris origins (States of registry) (Dunstan and Werb, 2009)

Inclination	Number of Objects	Total Mass (tons)	Country of origin
81 - 83	739	817	> 97% Russian (or Soviet)
69,9 - 74,1	644	480	> 95% Russian (or Soviet)
96 - 103	316	322	U.S. - 155 objects (~ 85 tons) U.S. Allies - 80 objects (~85 tons) Russia - 42 objects (~93 tons) China - 39 objects (~59 tons)

Lastly, orbital mechanics should be taken into account. During the process of de-orbiting or removing a spacecraft, it must be ensured that the space object makes necessary maneuvers in order to eliminate any possibility of collision with various other objects on the way. Such maneuvers, especially inclination change, require expenditure of fuel. Thus, isolated space object with a high M x Pc values are more expensive to remove than those with a lower M x Pc value, but which are clustered with other debris.

2.4. Conclusions

As per currently existing legislation, the launching state, which holds jurisdiction and control over a certain space object, is the state of registration that carried out the launching of the payload into space. If a state, or a state-licensed actor, expresses the desire to remove or service an object, it can only do so with permission and consent of the launching party, which will grant the removing side legal jurisdiction and control over the space object in question.

Today, the international community is faced with the issue of facilitating the mechanism of seeking and granting permission for space debris removal as well as establishing the rules for jurisdiction and control of the underlying processes. When removing a satellite, there will always be the necessity of crossing orbits above or below, which increases the risk of collision during removal activities in terms of liability. Thus, rules of regulation and guidelines in case of an accident are also something included into future legislation for space debris remediation.

As there is still no internationally recognized legal definition of space debris, the term “space object” continues to connote legal liability for the launching states associated with the object in question. Thus, if space debris is to be regarded as a constituent category of space objects, certain liability complications arise for the launching states: if there is any damage caused in the process of space debris removal, there must be concise legislation as to how to deal with the accident.

On the other hand, if international guidelines or legislation on space debris removal were to be created, it would be entailed with each space-faring State unilaterally implementing, as part of its licensing process, similar provisions that would enable to be in coherence with the international space debris remediation legislation.

3. Economic and Technological Aspects of Space Debris Remediation

3.1. The present and future of space debris

The highest densities of space debris are in the near-polar orbits at altitudes of from 8,000 to 10,000 kilometers. These are known as "critical orbits", as the amount of debris on them has reached the level when the rate of creation of new waste in collisions exceeds that of natural removal resulting from atmospheric drag (Ansdell, 2010). Most of the current collisions happen as a result of the fragmentation events of the past, which have left an excessive amount of debris in the regions of their occurrence. Without remediation, debris can remain in orbit for decades.

There are significant technical and economic barriers for developing, launching and operating active debris removal systems. The efforts and cost of debris tracking and maneuvering to avoid collision increase with the density growth of space debris in Earth orbits. The amount of money and time, spent on developing and deploying technology for space debris remediation, varies from concept to concept, from model to model. Details on the costs of such missions are rarely open to the public, due to certain constrains within the industry. However, the rough estimation stands at around $10 000 per kilogram at the stage of launching, which brings the total expenditure for development, deployment and operation to the order of millions of dollars.

Another serious issue is the similarity between space debris and space military devices. What is yet to be discussed is how to differentiate between a useful object and a useless one. With an extensive ongoing discussion on space weapons – the question of their presence, use and detection in space – remaining unsolved (Moltz, 2011). And while space debris is undefined on the international legal level, the possibility of removing something from orbit is also under question, as any technology applied to remove or de-orbit and object could also be described as a weapon from a certain perspective.

Still, the main challenge is the process of implementing active space debris removal as such. Many space debris experts believe that the process of remediation must begin within the two following decades at the latest. On the other hand, there is no real incentive for investment or private interest in the topic. The truth is rather unsettling: little will be done in the area of space debris remediation, until there is a real threat to human life (human space missions) or vital technology (GPS, mobile services, military or meteorological observations). But by the time humanity is faced with one of the dangers, the situation may deteriorate to the point of no return.

The space environment is on the brink of suffering from the "tragedy of the commons", due to the overexploitation of its resources, as legislation lacks control, clear regulation and provisions on liability and responsibility. All this drives many experts to the conclusion that those in power are not likely to take any measures in the direction of space debris remediation, not until there is an absolute must. The situation with orbital debris is often compared to that of climate change; the failure of governments to take responsibility and act swiftly and preemptively is now putting in jeopardy the future of human life on Earth. Therefore, policy makers must take necessary actions and prevent the possible catastrophic effects on Earth orbits while there is still a possibility for something to be done.

Nevertheless, there is another aspect of space debris remediation, which could assist a faster implementation of the technologies. In cases of re-fuelling and on-orbit satellite servicing, the short-term benefits are in mission life extension. Thus, the operator has the possibility of de-orbiting of objects for disposal. Extending the active life of a satellite has a direct impact on the income for commercial and governmental spacecrafts. In this regard, there is a business case for creating on-orbit satellite servicing (UNCOPUOS, 2012).

3.2. Economic side of space debris remediation

3.2.1. Evaluating the economic dimension of space debris remediation

There are several main economic challenges for Active Debris Removal. First of all, it is necessary to develop cost-effective means of ADR. All space-faring nations and actors, today or in the future, would benefit from debris removal activities. But ADR requires significant investments, with long-term and far-fetched benefits. Private investors have little interest in financially supporting space debris removal, as well as funding technological development or construction: there is no immediate visible economic profit. But, keeping in mind the number of commercial satellites, providing TV, mobile and other services, the necessity of the involvement of the private sector is obvious: some companies launch tiny satellites with short life cycles. Most of this technology remains in orbit, because there is no economic benefit to the companies to shorten the lifetime of an object by saving fuel to move the payload into a graveyard orbit or burning it in the atmosphere after the object’s time is up. Thus, commercial satellites continue to rotate around the planet in the form of debris until there is sufficient legislation and technology to remove them.

On the other hand, it is the LEO orbit where the situation is critical. And there, commercial satellites do not constitute the majority – most of the population in the orbit is made up by satellites launched by governments. Still, a public intervention would be necessary, at least to trigger the development of ADR technology and to support the emerging market.

Eventually, the demand for ADR would dramatically increase after a catastrophic event, which would create a large amount of new debris and change the ADR cost/benefit ration (Innocenti et al., 2013). But there are still other, less dramatic elements, which could force the establishment of a market for ADR services.

3.2.2. Public funded research

In the field of creating a commercial market for ADR and On-Orbit Servicing (OSS), NASA has taken a strong public lead (Kallender-Umezu, 2011). In 2010 the Goddard Space Flight Center made a conclusion that there is a large class of commercial satellites that are economically viable to be serviced, and also that removing specific classes of GEO satellites is important and even critical to US national interests.

The study stressed the importance of setting a partnership between the government, industry and scientists for a successful fulfillment of ADR and OSS programs. Over forty responses in favor of cooperation within such projects were received from the industry and 14 from government agencies.

The US government funds two major projects, which should benefit the ARD/OSS technical sides. One of them, the Robotic Refueling Mission (RRM) – a technology for possible robotic refueling of the International Space Station (ISS) – was first tested on satellites in 2012 (NASA, 2012). The data, received during the project, was made public for encouraging commercial OSS. The second project – the DARPA Phoenix program is set to begin by 2015, and will demonstrate technologies, which could be able to harvest valuable fragments from no longer active satellites in the GEO for recycling and re-use purposes.

3.2.3. Investment and insurance

The scope of economic and scientific studies has made it possible to estimate the cost and potential commercial viability of ADR and OSS. The ADR/OSS business model requires costly research, a proper policy and legal framework to protect and support the involved parties, sufficient funding and efficient targets and aims. The most basic evaluation showed that the cost of space debris removal must be much lower than the cost of launching technology per kilogram.

First of all, a market for space debris remediation should be created. The probability of creation of such a market exists for the GEO, but there is no real incentive in developing one for the LEO due to lack of commercial interest. Some twenty spacecrafts are launched annually into the GEO, while about 150 non-active objects are floating in the so-called graveyard orbits. Between 2006 and 2010, over $700 million were spent out of U.S. tax-payers' money for satellite failures, including incidents of spacecrafts being placed into wrong orbits. Every year, several GEO satellites end up being placed into the wrong orbit, close to twenty run out of fuel before getting into place, and about thirteen become non-operational at launch or shortly after. In 2008-2009, four GEO satellites were retired without carrying out any end of life (EOL) operations. If the estimates prove right, up to 140 satellites will benefit from OSS services in the nearest future.

Nevertheless, the challenge of determining the value of servicing remains unknown. The easiest way would be to compare the cost of OSS with the cost of replacing a failed satellite or the potential cost of an expired satellite return.

In 1999, the Orion 3 satellite, which was placed into the wrong orbit, caused a loss of $150 million, plus the $80 million of launch cost. Adding to that, insurers lost $265 million and another $645 million of projected revenue were never gained (NASA SSCO, 2010). Research conducted in 2005 showed that if the currently available OSS technologies had been used since 1995, the 162 satellites launched since then would have the cost of $20.48 million per spacecraft. Commercial telecom satellites build up approximately 75% of the whole annual commercial space revenue, but their life expectancy is massively dependent on fuel. As required by UN mitigation rules, satellites sacrifice about 6 months of their operation time in order to have enough fuel to reach the graveyard orbit. This means that up to $50 million in revenue is lost per satellite.

In 2010, NASA announced results of a study, which states that using new spacecraft architecture for refueling and servicing could significantly reduce the cost of a space mission.

Unfortunately, all studies in the past several decades only considered GEO. Whereas researching LEO, "populated" by smaller untracked objects, is considered to be neither cost-effective nor practical.

As long as the Liability Convention is implied, the price of a project for the commercial parties usually overweights all risks, as the compensation payments and faults are hard to establish without appropriate agreements. Consent of the launching state is needed in the case the satellite will have to de-orbit, is damaged or destroyed. Once an agreement is signed, the parties know their part in case of an accident or unsuccessful launch.

Another hindering element in the puzzle is the governments, who do not want to disclose military information or approve removal of military satellites due to secrecy. Furthermore, new types of insurance policies are necessary for coping with ADR/OSS projects.

There are also positive tendencies in terms of insurance, as the coverage for rare and catastrophic incidents usually makes it second largest expense for satellite operators. Today, approximately 10-15% average premium of a space project pays for the launch of the craft and the initial operations, held in the first year (Kunstadter, 2009). And only about 1.5% of the annual value of the satellite – which is a small amount of the total premium – covers the future on-orbit operations. If the risk of collision rises to approximately 1.5% per annum, insurance rates are also likely to increase (McKnight, 2010).

As soon as an insured satellite collides with another object, the urgency for ADR/OSS is most likely to rise. In the past several years, insurance companies have been estimating the business potential of the ARD/OSS market, which could boost the diversification of portfolios and opportunities of new regulations and policies, possibly resulting in lower premium rates via reduced claim payments. Still, the balance of cost and benefit should not be an issue for the insurance market in terms of ARD/OSS, according to insurance experts.

3.2.4. Who should pay for ADR?

ADR should be a service available for "customers" (in the face of launching states) freely on the market. There is going to be a provider of technologies and apparatus, and a client –a paying state actor or a private corporation. In this regard, there are two aspects of this trading relationship. The first is in developing and deploying ADR technologies. The other is in the value ADR activities provide, and the profit they may bring. In order to carry out ADR activities, there should be a certain legal and policy framework, which should include provisions on taxation and licensing of ADR and OSS activities. The revenue from taxation and such could be invested in future missions, partially or wholly, depending on the state of economy of a certain country or budget possibilities of a private entity. At the same time, a private or state actor, responsible for placing an object in orbit, should take care of all of the expenses related to removing or servicing the object – in the future or in the past. Another possibility is to impose a tax and choose an entity to take care of satellite disposal – as an offer on demand.

Once the paying party is established, the price should be negotiated. The cost should depend on an assessment of the object's value by the stakeholder, which, when estimated, could be used to determine the cost of the necessary operations. If the cost of the activity is lower than the value proposition and less than the cost of any alternatives available on the market, the activity should be followed through and the stakeholders would use their payer structure to finalize the service agreement (Emanuelli et al., 2013).

The value of debris removal could be estimated by the level of risk it poses on object in the close vicinity. There are three main factors to establish the value proposition: the used time horizon, the manner of approaching the risk level and the stakeholders themselves.

While determining the value proposition, the collision risk due to debris and its potential growth should also be taken into consideration. Apart from that, the time-discounted value of the payload at risk, present and future, should also be accounted for. Lastly, the cost of preventing operations should be included. Here, all scenarios should be reviewed: if the object is in actual danger, and possible collisions or accidents with debris which has not yet been formed.

One of the essential problems in the realization of ADR is the development of applicable technology. Here, stakeholders are rarely interested in financially supporting a project, which could be tested properly on Earth, nor has a clear short-term economic benefit. In this regard, demonstrating missions could be put into place, showing the stakeholders the ADR process, allowing basic approximation of the mission costs and resolving some of the operational and technical issues. Some of the space agencies, ESA and NASA included, fund private and university research, covering the costs for development and also raising public awareness about the issue.

There are also propositions of various potential market mechanisms, which could attract investment now against future earnings. These include space services futures exchange markets – with futures on insurance contracts; investment funds whose long term profit would depend on the cost of providing services from space; venture risk investment in firms working on debris control; trading orbital rights – better control of orbital pollution and object placement; catastrophe bonds. The bonds could be inspired by the Kyoto Protocol – limiting access to space for those who do not carry out remediation activities, and setting pollution limits. Or they could work through long-lasting loans for companies, carrying out remediation activities or developing debris control and removal technologies (Pastor Vinader, 2013). All these would inspire the non-existant market for space services to emerge, ensuring that the market is ready by the time remediation activities are no longer unavoidable.

3.2.5. Where to place space debris?

Under the interdisciplinary approach of space debris mitigation, there are two kinds of mitigation measures to be taken (Sethu and Singh, 2014):

- Debris prevention: curbing generation of new potentially harmful waste;
- Removal of debris: limiting generation of potentially harmful waste over the long term.

In this section, only the removal options will be revised.

Debris removal is understood as any end-of-life procedures of removing a no longer functional object off its operatiin orbit. The most common technologies of debris removal are: transfer to a disposal orbit above LEO, controlled or uncontrolled atmospheric re-entry, or direct retrieval (Johnson, 2007). Uncontrolled de-orbiting, also known as atmospheric re-entry, is a process when an object is maneuvered to a lower orbit, for which the atmospheric drag decays the payload within a certain time period, usually around 25 years. Controlled de-orbiting means a direct retrieval and change of orbit (Burkhardt et al., 2002). Object from GEO are usually moved into so-called graveyard orbits, which are also sometimes called junk or disposal orbits. These are located significantly above synchronous orbits, making them supersynchronous.

When de-orbiting or sending a space object for atmospheric re-entry, the IADC Debris Mitigation Guidelines should be followed. These guidelines were also adopted by the UNCOPUOS and the Recommendations of the International Telecommunication Union. The Guidelines contain rules and requirements, which should prevent space debris from disrupting normal operations by colliding with other objects, functional or otherwise. They include such requirements, as special design of space systems with minimal effect on the outer space environment; preventing spacecraft and their orbital stages from failure model, leading to accidental break-up during operational stages; limitation of long-term present of any object in LEO after end of life cycle – obliging the launching party to remove the payload in a controlled or uncontrolled manner in other orbits or by atmospheric re-entry, and ensuring no damage could be caused to the surface of the Earth or humans on the planet; dislocating objects after their end-of-life in orbits higher than the GEO in order to prevent possible collision with other spacecrafts in GEO; etc (IADC, 2007).

As of today, these Guidelines are not in the form of international customary law – but they remain one of the only instruments for space debris mitigation. Thus, these rules are not legally binding on space-faring nations.

The space environment cannot be fully cleared of space debris, and the creation of new waste is widely regarded as inevitable. The current goal is to reduce the possibility of large undetected collisions in the main orbital regions, thereby preventing irreversible damage to vital Earth technology and navigation and to safeguard the life of human missions in space. Unfortunately, as long as there is no legally binding document to ensure the reduction of space debris creation, or a binding obligation for mitigation and remediation, very little is done for saving Earth's space environment.

3.3. Technological feasibility of space debris remediation

Active debris removal is a variety of technologies, which focus on controlled re-entry and capture of orbital debris in LEO, and also has a number of synergies with on-orbit servicing of space systems, which mostly focuses on GEO. In order for ADR to be successful, a number of technical issues must be addressed.

First and foremost, cost-effective and reliable technologies need to be further developed, including the procedures for guidance, navigation and control (GNC). These include capture mechanisms, navigation sensors, fine relative GNC with uncooperative target and control of the compound, and image processing algorithms. The most challenging processes of ADR are the proximity operations and controlled re-entry. Here, partial of end-to-end demonstration missions need to be developed. And, lastly, ADR operations need to be conducted when there is a better understanding of orbit and attitude evolution of target debris and how to conduct their measurements.

After the success of NASA and DARPA's Orbital Express project, universities and companies rushed to propose a multitude ways to clean up LEO and to promote ADR/OSS systems for GEO. Another project of DARPA – the Phoenix Program – is intentioned to recycle space assets. These include antennas, solar arrays and other components of defunct or not functional space objects. The program is designed to "develop and demonstrate technologies to cooperatively harvest and re-use valuable components from retired, non-working satellites in GEO and demonstrate the ability to create new space systems at greatly reduced costs" (DARPA Phoenix Satellite Program, 2011).

Even though cleaning up LEO is economically inefficient and impractical, several programs were proposed to help create norms for a basis for the commercial ADR market for the orbit. École Polytechnique Fédérale de Lausanne works on the CleanSpace One project, which aims at launching a small satellite in 2016 for removing one of the already floating satellites in the 630-750 kilometer orbit.

The CleanSpace One project is planned to be held in cooperation with Swiss Space Systems (S3). This firm develops a CubeSat Deorbit and Recovery System (DRS) that uses an inflatable cone to de-orbit and CubeSat-class spacecraft (Andrews et al., 2011). Sponsored by DARPA and NASA, this project aims at reaching the ISS with a mission via a SpaceX Dragon craft (carrier of both people and cargo for the ISS, developed by Space Exploration Technologies, Inc.) (SpaceX, 2014). From a technological standpoint, the light DRS is a wiser solution, as the machines weigh only 1.5 kg. In March 2014, the first 33 CubeSat DRS were sent to the ISS. The estimated cost of one DRS is between $3-4 million, while revenue could be as high as $100,000 per system.

Drag Augmentation Devices (DAD) are another type of ARD/OSS technology. The Gossameter Orbit Lowering Device (GOLD), created by an American company – Global Aerospace Corp., is a package attached to a rocket's upper stage or a spacecraft body, which inflates a large but lightweight balloon to increase drag (Nock et al., 2010). This technology is mainly aimed at use in the LEO for moving expired rocket stages and satellites for up to 1,200 km. The system itself weights 54 kg with an envelope to capture a satellite of 37 meters in diameter. This allows the device to de-orbit a one ton satellite in one year, possibly allowing to drag even bigger objects. The pending costs of GOLD are $1-3 million or $1-5 million per a ton-class satellite with a launch cost of $10,000-20,000 per kilogram. Every launch would cost approximately an additional $100,000 in insurance. This project is due to be brought into life in the near future, as soon as there is sufficient funding.

The Deutsche Orbitale Servicing Mission (DEOS) was created as a result of the 2010 German space strategy. The goal of the mission is to "demonstrate the availability of technology and verify procedures and techniques for rendezvous, capture, maintenance and removal of an uncontrollable satellite from its operational orbit through demonstration mission" (Sommer et al., 2012). The main idea is in creating two separate robotic systems, a DEOS Manipulator and Gripper. The concept is in first stabilizing an object, and then the payload is dragged and placed into an area of atmospheric drag or receives service for future manipulations in orbit.

Another project – NASA's Robotic Fueling System (RRM) – is a joint program between NASA and the Canadian Space Agency. This project aims to "demonstrate and test tools, technologies and techniques needed to robotically refuel satellites in space – especially satellites not designed to be services" (NASA, 2015). The RRM is used for refueling and servicing the ISS with Dextre (a Canadian robotic twin-armed handyman on the ISS), but later will also be used for other spacecraft for the same purposes.

U.S. Space and ATK Space Systems have developed a satellite life extension service – ViviSat. This technology "provides in-orbit satellite life extension and protection services", as well as "enable satellite operators to significantly extend satellite mission length, activate new markets, drive asset value and protect their franchises"

(ViviSat, 2014). The services, provided by ViviSat's Mission Extension Vehicle, prolong the life cycle of the large base of GEO spacecrafts, when the latter need fuel or other servicing.

A Canadian aerospace company MacDonald, Dettwiler and Associates Ltd. is developing a satellite servicing technology, Space Infrastructure Servicing (SIS), from their experience with designing the robotic arms for the Space Shuttle and the ISS (Foust, 2012). Like the ViviSat technology, SIS can refuel and repair a communication spacecraft in GEO.

Clean Space, an initiative at the European Space Agency, is devoted to "increasing attention to the environmental impact of its (ESA's) activities, both on Earth and in space (ESA, 2013) through implementation of specific technology roadmaps. One of the main branches of Clean Space is in creating technologies for space debris remediation. These technologies include pulling with tethers – which are some of the most promising for actively controlling a piece of debris while re-entering or de-orbiting of space objects. Another technology is capture of debris using throw nets: when a net ejector mechanism releases a net to capture and drag an object for de-orbiting. There is also the concept of Harpoons, which can penetrate objects and later pulling them. The only set back of this technology is the high possibility of creating residual waste after penetration.

Pushing technologies are an alternative to the pulling ones, but these face difficulties in rendezvous and capturing phases, while de-orbiting is not an issue. The initial concepts of pushing technologies were based on existing qualified actuators and sensors.

ESA also develops contactless technologies. One of them is the ion-beam shepherd: expelling charged particles via the Lorentz or Coulomb forces at high velocities – thus, accelerating the "targeted" spacecraft. Within the ESA General Studies Program – SysNova – the COBRa project was created in cooperation with GMV, TAS-I and Politecnico di Milano. This technology relies on the use of a conventional chemical propulsion system to modify the orbital velocity of a 100 kilogram object in SSO, and should use chemical propulsion instead of the electrical one (as opposed to ion-shepherd technology).

Other projects and developments of ESA include the solid propulsion de-orbitation kit, GNC, expanding foams and HybridSail (Wormnes et al., 2013).

Cranfield University is developing the Icarus "de-orbit sail", which is designed as "a low cost practical way of removing satellites from orbit at the end of their mission" (Cranfield University, 2014). The first payload was launched from Baikonur, Kazakhstan in 2014 with the UK's Tech-DemoSat-1 satellite. Built entirely by the university's student body, the goal of the technology is in moving non-active payload from populated orbits.

3.4. Conclusions

The main problem of space debris is not in the lack of technology, but in the lack of funding. Several proposals from different countries have been introduced, but then they were quietly forgotten due to the absence of investment. Thus, the importance of the public sector initiative becomes vital in solving the issue of space debris.

It seems that if one of the major global space agencies or governmental organizations becomes involved enough, the commercial market might get a chance for existence. But, on the other hand, governmental support in this cause is of utmost importance. Unless a national agency will choose to help with commercialization, providing legal help via an anchor tenant agreement, or fund a business model – neither ADR nor OSS can be successfully developed.

Additionally, the legal and political barriers in the area should be eliminated. From the publicly available information it becomes clear that all the commercial projects developed to solve existing problems of ADR and OSS are blocked at the level of regulatory and legal approval, as both are there only to oversee the possibility of liabilities. Thus, even if funding is provided, there remains the inconsistency of legal and liability frameworks, as up until now even the definition of space debris has not been established on an international level. Even though international organizations on space waste exist – such as the UN Debris Mitigation Guidelines and the Inter-Agency Space Debris Coordination Committee – many of the states, involved into space activities, have not ratified any of the multilateral treaties, thus making cooperation and liability responsibility sometimes impossible. There are no guidelines and rules of space debris removal, or a committee to draft a necessary resolution. In case of attributed debris in LEO and GEO, the launching state should be responsible for removing it or contracting a party to do so. The Secure World Foundation – an American space sustainability think-tank – works under the UN and the U.S. government, states that an essential step should be taken towards opening up the space market for private initiative, if state governments cannot deal with the cause (Weeden, 2010). This NGO is calling upon the international community to develop:

- the "best practices" or "rules of the road" and documents for ADR operation;
- creation of specific Transparency and Confidence-Building Measures of space debris;
- drafting and ratification of a legal basis for future agreements between launching states and third parties, contracted for removing the debris;
- specification of liability rules and consequences in order to later be able to distinguish the party of failure (the state or a contracted third party).

The Aerospace Corporation has developed a road map with similar proposals (Ailor, 2011):

- creating a legal framework to enable removal of space debris;
- developing a space waste removal "X-Prize" as a reward for successful activities;
- ratification of international treaties which address issues of dual-use of ADR and OSS;
- creating a legal framework to reach out to the "owners" of small debris in order to remove it;
- design a unified system of fixtures and approaches to facilitate servicing of objects in orbit and their removal;
- setting a minimum goal for the number of debris to be removed before ~2025;
- creating of an international long-term fund for cleanup of orbital debris.

Going back to the question of funding, it is important to underline once again that for the commercial systems to function, the cost of removal space debris from orbit should be lower than the launch costs per kilogram. Otherwise there is no economic sense, as there will not be a competitive market. According to experts, without government funding it will be very difficult to conduct such business. As noted earlier, removal of small and untracked objects from the lower orbits is impractical and a waste of money. There are two main approaches in solving this issue: either a state or an organization shall be responsible for creating debris and fund the removal of objects; or a "fair share" approach, where both public and private initiatives will contribute in the ADR/OSS activities in proportion to their involvement, interest and capabilities.

Several proposals have been made in terms of forming a global funding system for space debris removal. One of them comes from the Space Frontier Foundation, which is one of the major space foundations in the U.S. The idea is to set up an Orbital Removal and Recycling Fund (ODRRF), which would encourage private companies to catalogue orbital debris for liability, insurance and future removal purposes to later (Dunstan and Werb, 2009). The budget of the fund should be made up of donation of the launching states and satellite operators.

Some experts argue that instead of making the launching state pay for the existing and future debris, there should an incentive from the UNOOSA to create a new convention to specify the process of identification, registration and removal of the polluting objects. Apart from that, “cleaning” companies could be paid for their work per kilogram, ensuring their interests and devotion to the projects. Governments should encourage research, while taking care of that no new waste is place onto the orbit. This would build up real attention and interest around the problem.

As great wealth is invested into space missions and satellites, the amount of unused space around Earth grows smaller and smaller. And it is hard to tell how much longer it will take the governments to recognize the threat and start shifting their budget into the right direction. In the beginning of 2014, Japan launched the Space Tethered Autonomous Robotic Satelite-2 mission to tackle the space debris problem (Roppolo, 2014), while Russia announced a $10 million funding for the best space debris removal technology (Government of the Russian Federation, 2014). With the speed at which current science evolves, all people have to do it wait for funding. But there are hopes money will soon be where the technology is.

4. Analysis from the point of view of the Regime theory of International Relations

4.1. Introduction to Regime theory in International Relations

4.1.1. Regime theory

The Regime theory was created in late twentieth century by S. Krasner, R. Keohane, F. Kratochwill, O. Young and others. This theory is an approach in International Relations, which defines the essence of international cooperation to lie in international institutions and organizations, which create international law and have control over state governments in certain areas of their actions and national and international policies. Such organization and institutions are called regimes, which exist in different dimensions of intergovernmental cooperation: international trade – the World Trade Organization (WTO); intergovernmental military alliances - the North Atlantic Treaty Organization (NATO); intergovernmental organization to promote international cooperation and peace - the United Nations (UN). An international regime can be defined as follows: "[a set] of implicit or explicit principles, norms, rules, and decision-making procedures around which actors' expectations converge in a given area of International Relations" (Krasner, 1982). Regimes facilitate cooperation through fulfilling their mandates – which serve to the benefit of respective actors. Regimes strive to overcome the chaos of international anarchy, forcing governments to cooperate through treaties, agreements, etc. Also, regimes serve as a means of communication for each state involved about the actions of others – thus, governments themselves strive to create regimes for cooperation. As many actors have interest in a regime to succeed, there is little stimulus to put the set principles in jeopardy (Keohane, 2005). From this point of view, regimes, on the one hand, make governments believe there is less risk from their counterparts to break the set rules for cooperation, and, on the other hand, create a greater incentive for governments to honor the agreements themselves. Governments create international regimes by agreeing to certain principles, norms and rules, which are appealed to in decision making processes in conflict solving. Moreover, governments usually set up guidelines and procedural norms for future cooperation and adaptation to changing domestic and international legislation. When governments establish a new regime or join an already existing one, they yield certain sovereign rights and agree to responsibilities, counting on the fact that other member states do the same and honor the agreement. Such actions do not only ensure successful functioning of a regime, but also that all signatories receive the same amount of benefits as others – even if some counterparts acceeed later (Hasenclever et al., 1996).

Other authors suggest that regimes are consequences of multilateral agreements and deals made by governments. For instance, Joseph M. Grieco insists there is a connection between the current state of cooperation with prior made agreements. The author also underlines the important role of politics in the way actors benefit from any cooperation within a regime (Grieco, 1990).

The Regime theory is often criticized for not paying enough attention to the concept of power. On a global scale balance of power is regarded as the essence of regimes and as responsibility for shifts within them. States are concerned about their place in the global hierarchy, their role in the issue of balance of power, and this is a possible explanation for their unwillingness to share information about their internal and external policies and interests. The principles which determine their policies affect the benefits and losses any given state faces. Thus, sharing information and encountering loss are interconnected – this makes both the aspects an essential part of state policy (Krasner, 1991).

In her work, Helen Milner stresses the importance of the fact that even those, who criticize the Regime theory acknowledge the importance of the theory's underlying concepts and the idea that political and economic deals are reached easier within a regime (Milner, 1992). Marie-Claude Smouts argues that even though all criticism is viable, the Regime theory was the first to approach intergovernmental cooperation from an analytical point of view. The author believes that the theory's existence is important for understanding the role of legislation and jurisdiction as a regulating force, as well as the process of finding intergovernmental solution to conflicts and issues, which is not always prescribed by international law; and sometimes giving a solution to problems, which do not even have an international legal definition (Smouts, 1998). Smouts also mentions that recently there has been a slight change in the strictly mechanical approach to understanding regimes. In a certain way, today regimes are understood as something more than just international institutions. Within regimes, international cooperation receives a new legal basis and may also be analyzed from a sociological point of view. Also, now international cooperation can be brought to the forefront, as one of the main issues among balance of power and governmental strategies on the international arena.

The Regime theory was developed on the joining point of Neorealist and Neoliberal theories. Discussions on topics, existing in both schools, brought up the importance of multiple issues regarding international cooperation, which as a result produced a whole new theory. Still, a full understanding of international cooperation requires a deeper empirical analysis on underlying issues, which is most likely to reveal inconsistencies and gaps in the approaches of neorealism and neoliberalism.

Robert Powell has put forth three main weakness of the neorealist-neoliberal debate (Powell, 1994). First of all, describing the system of implication of anarchy, which is often misplaced, as it does not specify the kind of leverage a government has to reach its goals. In this regard, it is necessary to mention that R. Keohane expressed the opinion, that describing an international system as anarchy is pointless, as if the system of global governance is in anarchy, then it is hardly possible to explain international change – including changes in intergovernmental cooperation and institutions.

The second point made by Powell concerned the problem of absolute and relative gains, the discussion of which has brought little understanding to international cooperation. Such discussions mostly rely on the information on the strategic environment of a certain government. According to the author, the key to solving the problem is rooted in the fact that the interests of governments in relative gains are not constant due to the offense-defense balance, and the intensity of the security dilemma. This means that cooperation and interests in relative gains may change simultaneously, without any influence on one another.

Thirdly, the existence of regimes and institutions ensures mutual gains from international cooperation. There is a tension between coordination and distributions, leading some states to gain in one aspect, while others lose. Thus, the interest in having joint gains should create distributional disputes, which in turn impede cooperation.

These are the central issues of the Regime theory, which aims to understand the underlying reasons for existence of international organizations and institutions.

4.1.2. Regime theory and outer space politics

Understanding of the Regime theory is vital for comprehending the issues of space debris remediation. But, prior to discussing the hypothesis of this thesis, it is necessary to explain the main implications of the Regime theory to outer space politics.

The majority of works published within the domain of the Regime theory agree on the point that the international system is constructed by states, and these states operate to maximize their positions within a system of higher levels of governance. Each state makes its own calculations and thus establishes a certain behavioral pattern, acting in its own interests and pursuing its gains.

Of course, some actors on the global scale, whether speaking about their actions on the planet or in outer space, are presumed to be dominant. Nonetheless, all states possess sovereignty over distinct territory, which leads to discussions about how to govern and regulate the use of such inherently transnational areas as outer space. In this regard, regimes are vital, as they are one of the essential ways to ensure stability and peaceful use of the cosmos. Seeking an understanding of states' interests in cooperation for creating a system of global governance over outer space is vital, even though such a system is still non-existent in world politics.

Regimes for outer space are supported by international treaties, which give states sovereignty over their own space objects in orbit, despite the fact that those objects are no longer on the state's terrestrial territory. Through international legislation, states have established that outer space will be treated as neutral territory, leaving registered objects under the launching state's jurisdiction – thus, proclaiming them pieces of each state's sovereign territory.

The OST establishes that outer space is to be used only for "Peaceful Purposes" (Preamble), and that it is used for the "benefit of all peoples irrespective of the degree of their economic or scientific development" (United Nationas Office for Outer Space Activities, 1967). The Treaty also prohibits any state to lay sovereign claim to a celestial body. Thus, outer space was accepted as "neutral territory".

Regimes serve to establish cooperation amongst Earth-monitoring satellites, the ISS; they establish the notion of neutral territory and ensure the preservation of sovereignty over objects in space. This, from a certain angle, shapes a certain political space, making it a unique area for the application of international legislation.

Applying Regime theory to outer space politics allows scientists to analyze cooperation of the global commons through a state-centric lens. This approach has its advantages, such as facilitating the study of negotiations and diplomatic activities, and understanding reasons for cooperation. As Regime theory analyzes state behavior through meeting transcripts, organizational rules and decision-making procedures, it becomes possible to explain cooperation and governance in transnational issues of outer space.

But the conservatism of this approach also has flaws. Seeking an understanding of a government's adjustment to transnational issues, the concept of sovereignty might be put in jeopardy, sometimes ignoring a country's background and legislative past.

Even though Regime theory succeeds in explaining actor preferences, negotiations and outcomes, there is little insight into the bigger picture of the shifting nature of the relationship between sovereignty and territory in theory or in practice. While the theory in discussion focuses on explaining the negotiations behind the beginning of a regime, underlying processes may be ignored – even if they are significant or indicate malfunctions of a certain system of states. (Bormann and Sheehan, 2009).

Some researchers suggest that some actors prefer establishing "governance without government" of the outer space. Existence of such an approach is supported by the fact that constraints have been placed on a clear use of the cosmos by the multiple regimes active today.

Geopolitics plays an important role in the interest-development of actors. Some states can influence establishment of governance more easily than others, due to power asymmetries and technology – especially in terms of who has access to outer space first and who can launch spacecraft more often (Stuart, 2013).

Self-interest remains one of the main forces for creating a regime. Here, the concept of a regime comes close to being either an epiphenomenon or an intervening variable. If a regime is indeed considered as such, it means that the goal of such a regime is in benefiting at most the hegemonic actors. If a regime is an intervening variable, it should have more and more influence over state actions over time. This is an issue of whether it is the state influencing the regime or vice versa. Some authors suggest that all regimes come to life serving interests of a certain party among others, whilst with time the roles change and all actors are being influenced by the regime.

The first outer space regime was created under the OST, when the USA and the Soviet Union were striving to ensure the neutrality of the cosmos, thus preventing the weaponization of the outer space environment as well as securing the possibility of carrying out reconnaissance flights to surveille foreign countries' territories. In other words, the regime was epiphenomenal, as it served the interests of two states.

Nevertheless, today there are more parties involved and the many outer space regimes are slowly re-directed for creating a beneficial and safe environment for all.

4.1.3. Application of the Regime theory to space debris remediation

Space debris remediation should be regarded as an activity, beneficial to the human kind, all space-faring states and future generations – thus, a regime governing the problem should first and foremost be an intervening variable, ensuring that all parties comply and all parties benefit.

Here, it is necessary to mention the problem of the old and new space-faring countries in the world.

Today, it is no longer only China, Europe, Russia and the U.S. who launch objects into orbit. But they are still responsible for the majority of debris. Thus, making "newcomers", such as Argentina, India or others, pay the same fee as the "big three" could be regarded as unacceptable and unfair. In this regard, policy makers should ensure that the new space-faring nations receive sufficient benefits for what they invest. There are many possibilities on the table, but the main goal is in, on the one hand, inspire all parties to apply remediation measure, as well as ensure no one is forced to clean up after other actors. This may require extensive negotiations.

As was mentioned in previous chapters, there needs to be an international agreement about which debris has to be cleaned up first, and who is going to pay for it. Even though there have been many attempts to address this issue, one important aspect of it is yet to be discussed; it remains unclear, how the responsibility for space waste should be distributed among space-faring nations.

A diplomatic solution could be found in a balance between financial aid, technology exchange or performance of on-orbit servicing – but all this should be put into legal text and agreed on an international level.

During the Cold War, outer space served as another platform for the arms race between the West and the Soviet Union. Now, when there are strong predicaments of the Kessler effect taking place, the cosmos can no longer be regarded as a bottomless storage facility for "dead" technology, but should be regarded as an endangered environment. If there were to be a regime created to fulfill the remediation goals, it should not be based on interests of a single actor, but should be created to the benefit of all – space should become an area of global cooperation (economic, technological and scientific).

The study of currently existing legislation makes it clear that there is no policy capable of resolving the space debris problem. Terrestrial environmental controls provide minimal surveillance and have little influence on the existing situation, given the legislation at hand. The lack of proper legal control and weakness of treaties allows state actors to transfer costs to the commons – in the form of space debris (Roberts, 1992). According to Roberts, there is still hope for successful remediation, despite the market failures of the past fifty years of outer space misuse. If necessary scientific assessment of potential hazards was conducted, followed by a dispersing of gathered information to space-faring nations, there would still be a chance of preventing the "tragedy of commons". But, unlike the situation in 1992, when Roberts published the article, today there is enough accessible information, and yet – very little is done.

One of the main reasons for the meager efforts in space debris remediation is its short term economic inefficiency. This problem was carefully reviewed in chapter 3 of this thesis. Whether states, under an intergovernmental regime or single handed, start regulating the on-orbit traffic flow, removing inactive satellites, or creating graveyard orbits – it should be done in the next two decades at most.

If safe use of the space environment is to be ensured, there should be control over the traffic flow – preventing the orbits of getting over cluttered with both active and inactive objects. Some experts point out the fact that removal of inactive satellites could be prohibitively expensive, overweighing the short term environmental benefit. Thus, remediation should be legally enforced, if needed. Otherwise, some actors may choose to disregard the fact of its importance in the long run.

Another reason is in the issue of liability for space debris and any damage it may cause. Countries should be responsible for their payload in orbit, and this could be done by incorporating the costs for disposal into the initial cost/benefit analysis. Furthermore, the Liability Convention has limited application to the issue of space debris remediation – this means there should be a separate intergovernmental agreement solely dedicated to liability concerns. If not, such measures should be incorporated into the body an already existing treaty, ensuring implementation of the set rules by all space-faring parties.

Glenn Reynolds and Robert Merges proposed a plan, whereby if a space debris object (result of a collision or such) is unidentifiable and cannot be attributed to a launching state, its removal should be equally covered by all space-faring countries proportionally to their estimated contribution to the total orbital debris population (Reynolds and Merges, 1990). While this could be a viable solution, it could also lead to intergovernmental conflicts and encourage designers to create technology, which could be easily identified. Still, the allocation of "market shares" and liable sides is the key determinant in the success of space debris remediation.

4.2. Possibilities for creating a commonly accepted definition and legislation for space debris remediation

4.2.1. Military and security issues

Without surveillance from space, many military missions would not have taken place, unmanned aerial vehicles could not be operated and submarines would not be able to reach their operational depth. Space became an international tool for military control very soon after it became accessible, quickly acquiring the status of a lawful arena for military activities such as navigation, photo reconnaissance, interlligence gathering, ocean and on-shore surveillance, detection of nuclear explosions, early warning for ballistic missile attacks and many more. (Heintze, 1999).

Generally, there are also no restrictions for states to have space station for solely military purposes. Flying of aerospace planes in orbit also does not have legal prohibition. There is no strict position against anti-satellite weapons, except for the nuclear and space-based ones; also, camouflage could be used to cover up space missions. All this describes the grey areas in space legislation. Unless such vital issues are clearly defined in international legislation, there will be precedents of military actions in outer space not prohibited by law.

The only way to deal with space weaponization is through verification. If technology for verification were available, the process of restricting or prohibiting certain crafts by international legislation would be much easier. Verification should be carried out on-site, before launch for both military and civilian objects. Unfortunately, no such clause was included to the Registration Conventions, thus leaving the issue of distinguishing space weapons from other objects open.

In the context of space debris remediation, there are several important issues creating military and security concerns for governments.

First and foremost, space debris could be used or regarded as a potential weapon. Even the smallest pieces of debris, given their kinetic energy and unpredictable orbit, could be used to destroy satellites; all space-faring nations have access to this measure.

There are currently a little over thirty space-faring nations in the world, while only eight have launching sights (China, France, India, Israel, Japan, Russian and the U.S.). However, if any party was to employ a debris particle as a weapon, it would be difficult to detect from Earth or prevent damage. When talking about untraceable particles, the possibility of detecting such a threat comes close to impossible. And, even though any military activity is prohibited in space, in 2007 China had an anti-missile test, setting precedent for other countries and creating a necessity for other states to ponder about the safety of their objects on orbit. The use of anti-missile rockets creates a debate on whether space-faring states should engage in developing weapons (for self-defense or otherwise) usable in orbit; or rather create intergovernmental regulation against any military force in space. As soon as there are several weaponized space-faring nations, a new regime of balance of power in space should be created. The arms race, which is quite typical for terrestrial politics, could spill over into space – and then the control of space debris population is out of question. It is a well known fact that the 2007 Chinese explosions created an overwhelming amount of debris – it is hard to imagine what consequences could be caused by such “experiments” conducted by some or even all space-faring actors. Thus, attention would be shifted from cleaning the orbital environment to preparing oneself for the actions of others – or producing more debris instead of getting rid of it.

The second issue concerns surveillance and communication satellites, which provide governments with foreign intelligence and control over their own military, as well as helping international regimes monitor compliance with arms limitation agreements and application of directives and regulations. Such crafts usually operate on separate orbits, Molniya orbit for the USSR. Operating on highly elliptical orbits, these satellites spend most of their orbital period far away from Earth, coming close to the planet only in regions of geopolitical interest to their launching state. After the end of their life time, the satellites remain spinning on the same orbit, not allowing any other space objects to get the shots they used to make. In case of remediation, such technology, due to the amount of secrecy behind it, could only be removed by the launching state itself. Thus, the problem of remediation of these high-maintenance and top secret crafts cannot be done by any third party. On the other hand, there is difficulty associated with removing these objects to grave-yard orbits or burning them in the atmosphere; usually they are operated at very high speed. Even if a country would move it to a grave-yard orbit, there could be the possibility of another state's satellite coming too close and collecting data about the technology or simply destroying it. Here, concerns over state sovereignty and security become undeniable.

Another side of the military and security issues around space debris remediation is ensuring that during the process of removing and re-placing of orbital debris of one state, no damage is caused to active or non-active property of another. Here, the Liability Convention could also not be applied in full force: first of all, because it contains no provisions defining the concepts or the difference between a "space object" and "space debris". In this regard, legislation should be changed to provide a clear road map for lawyers and governments to act upon in the case of collision during remediation activity. If not, the whole possibility of remediation is at stake – with no regulation on the subject, no country would agree to move any object, having in mind the possible danger of irreversible damage. Also, in case of a third party performing removal or atmospheric re-entry of an object for a country, it is unclear who should be named liable in case of an accident. On the one hand, the service provider and the launching state should have a contract making the liability issue clear. On the other – the legal power of such agreements should be ensured by law.

Some experts say the military and security issues lie in the base of ensuring space debris remediation. If they are resolved on an intergovernmental level and respected by all signatories, the technological and economic problems could be solved rapidly. Once countries have mutual understanding of the legal aspects of remediation, there might be more incentive in carrying the process out. But while there is doubt about the safety of military secrets and state security, probably nothing can make remediation plans and technology come to life.

4.2.2. Public participation

Numerous research findings and policy trends serve as evidence of the importance of improving public involvement in decision-making on environmental issues (Beierle, 1998). Today policy makers prefer using the “decide, announce, defend” strategy, confronting the public only after determining a course of action. But, as has been seen in many instances, the public should have a say in how the environment is treated. For example, the UNEP Rio Declaration on Environment and Development clearly states in Principle 10 that “at the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities” (UNEP, 1992). As was previously mentioned, according to many experts the orbital environment around Earth is on the brink of the Kessler effect, still, the public is barely aware about the ongoing situation. This is often compared to how the situation around Global Warming was handled – which in reality is barely handled at all. The public first heard of the holes in the ozone layer long after there were actual holes in the atmosphere and people started reporting suspicious deterioration in their health – which means, the government failed to protect its citizens of “hazardous … activities” and their consequences.

The same can be seen with space debris: very few people put their heads up and think about the condition of the orbital environment. At this pace, the public will probably find out about the on-orbit overpopulation when their TV and Google Maps stop working - which will be almost too late for starting space debris remediation. According to the same Declaration, “states shall facilitate and encourage public awareness and participation by making information widely available”. If this provision were followed, the problem of technological advancement for governments could be facilitated: today, very few universities have joint programs with space agencies (ex. ESA, NASA in chapter 3) and such cooperation on national level could in certain ways facilitate and encourage governments to start remediation activities.

Moreover, public participation is a strong evidence of the state of democracy in a country. Allowing people to share their knowledge, expertise and skills recognizes the important role the public plays to and within the state (The Aarhus Convention Newcastle Workshop, 2000).

In case of space debris remediation, it is hard to predict whether the public will have a lively interest in expressing their opinions or joining the preparatory work for future legislation. As some experts note, the public, just as the governments, would need a trigger to start forcing the state or intergovernmental apparatus to take action. As was shown in history more than once, it takes a catastrophe for people to strive for change.

Non-governmental organizations also have their role in the area of space regimes. Such institutions as the American Astronautical Society, the British Interplanetary Society, the International Space Business Council and others which provide the public with information on space activities and issues via newsletters, events, and publications. Other NGOs have a more scientific and professional approach. These include the Center for Orbital and Reentry Debris Studies, which specializes in the areas of space debris, collision avoidance and re-entry failures. However, NGOs have very limited power over change in space related issues, especially when it comes to space pollution.

4.2.3. Discussion of the possible legislation

Judging by the current legal and political attitude towards space debris remediation, one may end up with the conclusion that necessary measures and policies will not be implemented at least for another ten to twenty years. As was previously stated in this thesis, there must be a grave enough trigger for states to create national or intergovernmental control over the deteriorating situation in the orbital environment. Thus, proper legislation is most likely to appear shortly after a major accident, involving space waste, or when remediation is the only option to save the possibility of outer space activities. One could suggest, that some leverage should be applied by an institution or entity to initiate the necessary working process within and among governments – but there are much more concerns over carrying out remediation than creating incentive for it to be applied.

There are different approaches as to in which form space debris remediation legislation should take.

Firsts of all, specialists insist on a clear distinction between space debris remediation and space debris mitigation. While international mitigation guidelines already exist (the UN, IADC), remediation remains much more of a concept with technology in the design stage. Creating an understanding within governments about the goals of mitigation and remediation would allow separate international cooperation in the two fields, ensuring a positive outcome of both processes. The commonly accepted opinion should be that both are vital, while remediation – as an assertive cleaning up scheme – should rather be followed by mitigation, where the main goal is in controlling the orbital environment from being an overpopulated hazardous space.

Regarding intergovernmental implementation, some experts suggest that the best option is to introduce space debris remediation in the form of international guidelines or soft law. This would allow signatory states to apply remediation principles at their own pace, depending on the availability of proper domestic legislation, technology and funding. On the other hand, soft law would imply that governments take the path of gradual cooperation of and involvement in the process of orbital cleaning.

Another positive side of soft law is in the fact that it would give necessary time for the industry to catch up with goals of remediation, thus allowing engineers and designers to develop a coherent and clear method of de-orbiting or moving satellites, ensuring a minimal probability for damage and loss of control over technology, placed in orbit for remediation purposes. As has been previously noted, there is a very high risk of collision with untracked or uncontrolled objects – which places a certain requirement for terrestrial surveillance to create safe passage for any debris under remediation. Remediation cannot be achieved without a harmonious relationship between individual states and states with their respective industries. Both domestic and international efforts count when it comes to the neutral territory of the cosmos.

Despite all the advanatages of gradual and voluntary implementation, the option of soft law is widely criticized for the lack of direct enforcement of decisions and legislation on governments. This means that implementation will be carried out in a selective manner: some governments will choose to abide, while others will only implement the legislation partially if at all. This will create a wave of misunderstanding and misuse of legislation, as well as leading to disputes over liability concerns and orbital remediation activities as a whole.

From this perspective it becomes clear that soft law could create a vicious circle around implementation of remediation, as governments will have to face contradictory positions and intergovernmental barriers on all levels of cleaning activities.

Another area for international dispute is rooted in the issue of funding space debris remediation. Today, there is not enough incentive to create a global fund for future investment in such activities. Thus, forcing countries to abide to legally prescribed donations for the cause would most likely create uproar from the new-comers among space-faring nations, who will not be willing to pay for the junk left in orbit by states with a longer space-faring history.

The possibility of creating hard law regarding remediation is also rather unlikely, as governments do not yet see short-term benefit or necessity for speedy remediation. Even if draft hard law were to be introduced to the UN GA, very few states would actually vote for it or ratifying the agreement – making the first step toward struggling against the dangers of space debris a failure in the face of UN member states.

Some analysts of the orbital environment suggest that the best possible measure to start the remediation process is in introducing a good alerting system, operating to the benefit of all governments and providing information on all objects in orbit. This would not only mean that there would be a stable regime overlooking all orbital activities, but also would require states to provide accurate launching information for proper registration. This brings the issue of remediation back to security and military aspects, consequentially requiring governments to share all data regarding their surveillance and top secret payload.

Another possibility would be to make up an agreement with similar goals and measures as the carbon tax. The carbon tax is "an environmental tax on emission of carbon dioxide and other greenhouse gases for the purpose of protecting the environment and slowing climate change by reducing greenhouse emissions" (Contraction and Convergence: Cliamre Truth and Reconciliation, 2012). In case of space debris remediation, the definition could be changed to an environmental tax on creating orbital debris by leaving inactive satellites or their parts in operational orbits, with the purpose of protecting the orbital environment and postponing overpopulation and reducing the chance of occurrence of the Kessler syndrome. According to William Nordhaus, a leading economics professor at the Yale University, the carbon tax scheme is much more effective than the Kyoto Protocol (Tickell, 2009). The professor claims the protocol's measures to be "inefficient and ineffective", due to the fact that the emissions reduction targets, set by the clean development mechanism in developing countries only account for a half of the global carbon dioxide pollution. Taxation on the other hand would be simpler and more effective. The same goes for space debris: taxation for space debris would not only create a global fund for remediation, but also create incentive for countries to ensure each object launched was designed for de-orbiting or otherwise. If all space objects, placed in orbit starting from now, would have the capacity of changing orbit or reaching the atmosphere for burning, the amount of newly generated waste would be brought to a minimum.

There are also propositions of creating a global code of conduct for solving the issue of space debris. One of them has been proposed by the EU. The International Code of Conduct for Outer Space Activities has a whole chapter on space debris mitigation, but does not contain provision on remediation. The same goes for Henry L. Stimson Center's Space Security Project Code of Conduct. The document proposes "executive-level, political commitment between states that sets out "rules of the road" for operations in outer space" (The Stimson Center, 2015). But, just as the EU one, there are no provisions on remediation. Nonetheless, if these agreements are successfully ratified by the international community, there will be a chance to create a similar measure for space debris remediation.

Codes of conduct have been successfully used in the history of International Relations: an example is the 1989 Prevention of Dangerous Military Practices Agreement, dealing with the threats of arms proliferation during the Cold War, signed by the Soviet Union and the US. However, there are difficulties in implementing such agreements, as they have no legally binding force (Sénéchal, 2009).

At this point of time, it is very hard to predict what kind of legislation will be implemented by governments. Due to the economic, political and technological issues associated with space debris remediation, the estimations are between ten to twenty years. Unless there is danger to military and weather surveillance, as well as public services, such as television or mobile coverage, there is not enough incentive for intergovernmental cooperation in the field. A regime will be required when at least one state comes close enough to implementing necessary legislation, due to technological success or danger imposed to one of its space objects. One thing is certain: a regime could be the only effective and plausible way for remediation activity to be conducted in Earth orbit.

4.3. A Regime for space debris remediation

The success of creating a regime for space debris remediation depends on several variables: state cooperation, legislation, funding, human resources, and time. A regime should comprise principles of work and cooperation, norms of action, rules of procedure and activities, decision-making regulations, etc.

At the moment, the most favorable option would be to create an intergovernmental convention with support of as many space-faring nations as possible. Such a convention would impose a set of international guidelines on governments with the goal of future remediation of orbital debris, along with a regime under which liability and compensation rules will be drawn for cases of breakage or collision in orbit.

The implementation of such a convention would in its turn require the existence of a body to control all activities under the regime – an intergovernmental committee or organization, which would receive reports and data, necessary for operation, from member states without constraints (on payload associated with military and security activities) and prerequisites. This should be a strong, well-crafted multilateral instrument which would make the processes of decision making, negotiating, cooperation and technology exchange run with less effort and in a smooth manner. The success of space debris remediation relies greatly on state cooperation, the willingness of governments to share information and to balance the long-term benefits with short-term costs. Otherwise, one of the already existing bodies, such as UNOOSA or UNCOPUOS could extend their mandates to include control over space debris remediation. These organizations under the UN already have clearly defined decision-making procedures, include space-faring nations as member states and have set annual budget donations. Also, there is no doubt in the importance of decisions, taken by the GA – which would ensure implementation for a space debris convention due to regulations and rules of the UN. The UN has also been involved in space regulation since the first satellite was launched into space, as well as has organized three United Nations Conferences on the Exploration and Peaceful Uses of Outer Space (UNISPACE).

Drafting, implementing and ratifying of any convention takes time. Organizing and gathering delegates for working on a convention requires states to send representatives to participate in discussions on a variety of topics. The dates and places should also be negotiated in advance, so that the delegates, sponsors, experts and representatives of NGOs and the general public can have access to the discussions. Therefore, there is always a certain amount of logistics behind any convention. Also, when planning negotiations of a new convention, the commercial market should be included to have a clear perspective of the state of technology and the space exploration market. As a result, the conception of an intergovernmental agreement may take years. Understanding the importance of rapid space debris remediation implementation, states should start considering starting all necessary negotiations as soon as possible – space debris in orbit increases exponentially with every year.

An already existing international organization could lead the process, such as IADC or UNCOPUOS. As for the states, which who should participate in the negotiations – these should be chosen from both the old and new space-faring countries. However, the US – one of the most prominent actors in space – has been reluctant to participate in drafting conventions on space debris mitigation – thus, they are seemingly unlikely to make input in developing one on remediation as well. The main reason for their lack of interest is the amount of debris they are responsible for. It is believed that Washington would rather adopt voluntary guidelines, instead of ratifying a legally binding regime (Sénéchal, 2009).

On the other hand, countries with rapidly developing space programs, such as Argentina, Brazil, India, Korea and others are more likely to get involved into the process, as it is in their interest that European countries, China, Russia and the US clean up their debris to make space for new technology.

One should keep in mind, that the broader the scope of the convention, the bigger will be the effort needed for its implementation. Thus, the purpose and aim of the document should be clearly outlined. In the case of space debris remediation, the following principles, norms, rules and decision-making procedures should become part of an intergovernmental agreement.

The regime's main role will be in ensuring mutual understanding and cooperation among space-faring nations, leading them to the achievement of a common goal – remediation. Thus, any difficulties arising from liability, finance or direct application of technology to space – all should be discussed in the convention, preventing any conflict or misunderstanding of sides. Another important role of the regime is in carrying out the remediation flights and controlling the situation in orbit.

Principles:

- Earth's orbital environment should be kept operational, seeking to avoid the possibility of Kessler syndrome.
- All space faring states should strive to ensure coherent and successful remediation. The more states ratify the convention, the easier it will be to catalogue

space objects and debris. The regime will also provide a stage for multilateral negotiation and dialogue – bringing to zero the possibility of malfunctions on state level.

For a convention to be successful there should be enough signatories to it. This requires that the national legislation of every ratifying state is in accord with the clauses of the future agreement. Thus, the participation of national space agencies is also of utmost importance.

- Creation of a separate definition for "space object", "space debris" and "space debris remediation". As there is no clear definition for the three terms, it is impossible to have an objective assessment or possibility to start drafting a concise convention. The first step in identifying the problem of space debris is in giving the issue an international legal character – in other words, by creating a legally recognized concept.
- Launched payload should be able to de-orbit or reach Earth atmosphere for burning after end of active life for preventing the possibility of collision or any damage to other operational or non-operational payload
- Adopting international disposal standards. Today, there is a broad discussion whether payload should be able to remove itself from orbit without any intervention by other technology. If launching parties were required to provide enough fuel for spacecraft to remove themselves from orbit, remediation with help of other machines would not be required. Thus, governments should inspire designers and engineers to develop technologies which will be able to perform necessary maneuvering for leaving orbits after the end of their active lives.

Creating a cooperation mechanism for space debris removal: today, not all space-faring nations have the technical and financial capabilities to carry out ADR themselves. Thus, the intergovernmental forum should outline the rules and procedures for technology exchange and financial support from one state to another.

Norms:

- Carrying out independent tracking and cataloguing of space debris. One of the main difficulties facing space debris remediation is the absence of a full and precise catalogue of existing orbital debris. In case of removing objects from orbit, engineers should be sure that there is no additional debris floating in orbit around the object which is being removed. Taking into consideration the fact that any inaccuracy in maneuvering could be fatal for both the remediation technology and the object involved, any possibility of inadvertent collision must be eliminated. Also, as governments decide on the sequence of objects for removal all together, there should be a catalogue outlining all payloads available for remediation at hand. If the is an object without a clearly defined launching states, its removal may cause uproar after the proprietor claims his rights to the object.

- Introducing a registration procedure for all objects launched onto orbit. Following the previous point, there should be a single international body for registration of all launch activities. As practice shows, existing space agencies and registration offices are incapable of providing concrete and precise data on the number of objects in orbit, thus creating difficulties in estimating the responsibility of lunching parties for their respectful waste.

- Preservation of the outer space environment. The main reason for implementing remediation guidelines or rules is in preserving the orbital space around Earth for future exploration. Unless the remediation process is implemented in the coming two decades, Earth orbits will become too overpopulated for safe existence of any new technology launched. Thus, preservation should be guaranteed.

  a. Creation of protected regions. The most important orbit for human space activities, such as SSO, LEO and GEO, should be safeguarded from any further pollution. For this, parties to the convention should be compelled to follow the set international standards of space debris remediation. Any objects placed on them should be removed after their life cycle is over. This should concern both state and private payload.

  b. In order to prevent further pollution, a mechanism of launch licensing or insurance should be implemented, depending on the acceptance of remediation principles by states and operators. In this case, if a state's industry is not ready to launch crafts with removal capabilities, the government should issue a payment or tax for the object to be removed at the end of its active life in orbit.

  c. Implementing a "carbon tax" scheme for states and private operators. Depending on the level of pollution, which was already emitted by state technology or is predicted for the future, governments should be obliged to commit to an emission trading system or emission tax, correspondent to the amount of pollution produced. This way, launching parties will be given financial incentives to fund remediation technologies.

- Prevent disastrous consequences, such as the Kessler syndrome. Every launching state or party is responsible for removal or de-orbiting of its objects and debris.

Rules:

In order for remediation to be successful, a clear goal for remediation should be introduced for annual achievement: five pieces of debris should be removed from orbit. Various studies have suggested that it indeed needs to be 5 objects removed annually, including an ESA report on technologies for space debris remediation (Wormnes et al., 2013). Unless legally prescribed remediation goals are introduced, there will be a recurring debate on how much money should be spent for remediation purposes annually, which debris should be removed, and which country should it belong to – and this will jeopardize the aims of creating such a regime.

- International disposal standards should be imposed alongside a cooperation mechanism for space debris removal. One of the main aspects in recognizing which debris should be removed from orbit – the weight of the object. The more the mass of junk payload – the bigger consequences of collision, from damage to the other craft and the amount of resultant new debris. For each object in orbit over a certain weight limit (5 tonnes), a collision probability study should be carried out. In this manner, states will be able to remove the heaviest and the most collision-likely object from orbit.
- Rules of liability for collisions and accidents prescribed in a convention or multilateral agreement.
- Setting up clear criteria of fault in space. As an international arena for implementing space debris remediation, the regime establishing convention should include clauses of liability, prescribing responsibilities of states of registration of debris as well as those carrying out removal activities.
    a. The rule of who is liable for damages or collisions should be clearly prescribed in the convention. Compensation mechanisms should also be discussed and become part of the convention's main body.

b. Penalties for not removing debris in due time and not changing or communicating the location of objects while other actors perform remediation activities.
c. A dispute settlement design should be elaborated to administer space debris claims. Such a mechanism should be designed in a manner that it can organize, manage and resolve complex claims (Sénéchal, 2009). It should ensure effectiveness and transparency of all processes for all governments and the public.
d. Damage assessment is another general mechanism which should be incorporated to a remediation regime. In order to find the guilty party in an issue of liability, there should be a simple and consistent mechanism to investigate claims and carry out accurate decisions.

- Technology control: launched payload should be able to de-orbit or reach Earth atmosphere for burning after end of active life.

Decision-making procedures:

- Priority list of targeted high risk fragments of objects according to which remediation activities will be planned and carried out should be created in consensus with all space faring nations. This list would outline the goals in space debris removal for the next decade, with the number of targeted objects to be removed in a year set at 5-10 (Kebschulla et al., 2014).
- A decision-making protocol is needed for settling liability and responsibility issues. The protocol should be established to be followed during remediation. In order to ensure safety for all objects in orbit, all launching parties should be informed of planned ADR, thus lowering the probability of collateral damage.
- A dispute settlement design to administer space debris claims with an objective damage assessment mechanism.
- Creating a global fund for space debris removal. Each country chips in depending on the amount of satellites in orbit. The sooner the fund is created by legally binding treaty – the easier it will be to cope with the cleaning by the time the technology is ready or when clean ups become unavoidable. Another possibility – pay a quota for each object launched (another possible confrontation between the old

and new launching states). Or the funding should represent a certain percentage of the state's GDP (UN system).

a. The development of new and reliable technology for active debris removal and on-orbit satellite servicing is considerably expensive. One of the solutions that have been proposed is the initiation of competition under a Global Economic Fund for Space Debris Removal, partially borrowing from the X-prize model.
b. All launch and space systems operators should contribute equitably – government and private – in proportion to their current share of the global launch and operations activities.
c. The fund can be expected to stimulate a diversity of international entities to compete in developing the needed technology; and the fund could be shut down when the mission is accomplished.

Establishing a space debris remediation regime is a time-consuming process, which requires involvement from all space-faring states for successful implementation. The key to creating a regime is in identifying the danger and investment losses – the sooner the better. Unless the process starts in the next ten years, the orbital environment will become overpopulated, this would lead to irreversible damage and close the door to humanity for any further exploration of space.

4.4. Conclusions

There is a clear necessity in creating a space debris remediation regime. But due to such factors as the state participation, funding, development of a necessary legal base, and others, the process of establishing such a regime continues to be a plan for the future. Unfortunately, humanity is running out of time in ensuring stability of the orbital environment, thus action should be taken in the following decades.

Establishing any regime takes time and a lot of effort. The fact that there are many liability, military and security concerns in removing waste from orbit also imposes certain constraints and limitations to the perspective of a functional agreement. The fact that many countries use space as a means of gathering intelligence on other states only makes the probability of prompt remediation less likely.

If a regime were to be created today, it could exist as part of mandate of another international organization – such as UNOOSA or UNCOPUOS. This seems like the most likely solution, as these institutions already have a decision making process, rules of procedure, state funding and legally binding power among their member states. On the other hand, incorporating a new agreement into the course of their work could be difficult – but still, it would require less effort and negotiation compared to establishing a whole new organization.

A space debris remediation regime requires global cooperation and involvement. Due to overlapping orbits, unstable technology, lack of funding, absence of initiative or of a commercial market, success of remediation is questionable. Once governments decide to stabilize the orbital environment, the path way is clear. At least twelve space treaties and agreements have been ratified, thus, with the right amount of incentive a space debris remediation regime is also possible.

5. Summary and Conclusions

This thesis reviews the issue of space debris remediation from the point of Regime theory of International Relations. The main principle of the Regime theory lies in the idea that the key to successful intergovernmental cooperation is in creating an intergovernmental regime. So far, there is no efficient regime to govern the problem of space debris remediation – and the main reasons are discussed in this paper.

Space debris remediation is starting to become a prominent issue on the international arena, attracting more and more attention from governments, NGOs and the private sector.

One of the main obstacles in creating a regime to implement space debris remediation is the absence of adequate legislation, including the fact that there is no legal definition of "space debris". This poses certain constraints in carrying out remediation activities, as without a proper legislative base, no object can be approached or removed from orbit. Any state, institution or private actor who may decide to perform remediation, can only do so with permission and consent from the launching party, the procedure of which should also be prescribed by law. Thus, developing proper and clear legislation is vital to creating a necessary regime. If space debris is to be regarded as a constituent category of space objects, certain liability complications arise for the launching states as well; if any damage is caused in the process of space debris removal, there must be concise legislation as to how to deal with the accident.

Once there is a definition of space debris and a sufficient number of states voice their interest in creating a regime, parties should decide upon the form in which the regime should be established. It could be implemented as soft law, hard law, a code of conduct, a set of guidelines, etc. But to make remediation efficient and effective, the agreement should be legally binding – in other words, all states signing and ratifying it should be bound to follow through. Remediation will only be successful in the case of global cooperation – thus, all space-faring nations should agree and act on all of the clauses and provisions of the created document.

Another problem associated with legislation, is that any intergovernmental agreement made for space debris remediation will require additional changes to the domestic legislation of signing states – requiring additional time and negotiations.

Space debris remediation is also impossible without sufficient funding. Investment is needed in development of legislation, technology, licensing, insurance and for the process of removing space debris from orbit itself. Today, ESA and NASA sponsor university projects instead of creating special teams for technology development. This is a viable option for many reason, as investing into work of students at various universities not only creates public awareness, but also creates private incentive to tackle the problem. Many university projects are later taken over by private companies, which in their turn are interested in gaining profit – stimulating the market for future development and investment. On the other hand, if the private sector had available technology, it would stimulate governments to work on necessary legislation. As it turns out, one cannot exist without the other, because if major global space agencies or governmental organizations become involved, the commercial market will evolve with changes in the legislation.

Despite the fact that there are several international instruments which could tackle the problem of space debris – such as the UN Debris Mitigation Guidelines and the IADC Guidelines – many of the states involved into space activities have not ratified any of them, thus putting cooperation and liability responsibility only possible between the compliant states. There are no guidelines and rules for space debris removal, nor a committee to draft a necessary resolution – a regime is yet to be built.

Depending on the type of a regime chosen to be introduced, there are several possibilities of funding remediation activities, including creating a global fund or involving state donations to the cause. A fund could be filled by taxing or licensing space-faring nations for launches and already existing inactive objects in orbit. If the regime is based on donations, it could function as the UN does, where every state invests a set amount, depending on its Gross Domestic Product (GDP), or based on the amount of launches and objects already in space. This should be done after a thorough investigation of the number of payload in orbit, functional and non-functional. Debris and active satellites should be catalogued in any case for remediation purposes, which include the processes of identification, registration and removal of space object.

The process of establishing a space debris remediation regime continues to be a plan for the future. As was previously stated, the danger of catastrophic activity or the Kessler syndrome is going to grow with every coming year. Experts estimate that at the current rate of annual launches, orbital space may become over cluttered with debris in the next 25 years. Thus, all liability, military and security concerns of removing waste from orbit should be resolved as soon as possible. A functional agreement needs to be implemented within the coming decade, in order to have a ready legal, economic and technological base for successful remediation.

A space debris remediation regime requires global cooperation, as any other critical issue humanity is faced with. Whether states decide to create a whole new entity or incorporate space debris remediation legislation within an existing body, all effort will be in vain unless all space-faring nations agree on implementing all provisions, vital for future use of the outer space environment.

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