THE IMPORTANCE OF ENGINEERING MODELS FOR THE PREDICTION OF DEBRIS AND THE IMPACT OF DEBRIS ON SPACECRAFT IN TERMS OF LEGAL AUTHORIZATION OF LAUNCH.

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ABSTRACT

The problem of space debris became a matter of concern for the international space community a few years ago, when Dr David Kessler presented his vision of Cassandran, known as Kessler's syndrome. It is clear to all researchers in this area that space law, which is becoming an increasingly important aspect of our lives from year to year, does not meet the needs of time and technological development. The only achievement in combating space debris following the adoption of the space treaties are soft-law measures such as the guidelines developed by IADC and COPUOUS and others of a similar nature. Although they are useful as a first step, they cannot be regarded as a sufficient tool. Their general nature can only indicate the path to be followed by much more specific technical tools, without which they will remain only an ambitious manifesto. The task of regulating technical requirements has been undertaken by some countries. Is it sufficient? The fundamental question is therefore about the importance and impact of technical requirements on the material consistency of space regulations and the risk management of space activities in terms of reducing space debris.

1 INTRODUCTION

The aim of the authors is to examine developments in this area, based on the space laws and technical measures adopted by some countries. The analysis undertaken by the authors focuses on the engineering standards of risk modelling expressed in the form of software tools or technical standards developed by certain countries, such as the USA, the United Kingdom, France and, finally, ESA. The aim of the authors is to analyse the consistency of these standards and their impact on the effectiveness of space debris prevention measures. A side issue, but equally important is the impact of the diversity of engineering standards on space law, such as the issue of convenience flags, etc., space insurance and others.

These two issues, taken together, give authors a clear view of future needs and approaches to risk assessment, definition of the alert code and final certification of launch. The authors take the view that nationalisation of the criteria for certification of compliance should not take place, due to the inherently international parameters of the risk related to debris, where even consistent national rules can give significantly different results depending on the technical risk assessment tools applied.

The issue of risk assessment examined by the authors seems to be important not only for the launching states, which bear ultimate liability for damages, but also for other stakeholders, such as insurers to which part of the risk is transferred, especially where liability insurance is a mandatory part of the licensing process). The adoption of consistent criteria for assessing the launch risk in terms of space debris is all the more important for the sustainable development of space exploration, the more numerous small satellites are launched.[14]

2 ASSUMPTIONS OF THE RESEARCH

Provisions of the international and national space laws with respect to the space debris issues are very general. It can be easily said that they are too general to provide for a coherent global approach to the ADR (active debris removal). Therefore, there is a need of investigating not only those laws, but also technical licensing requirements. The study focuses on CubeSats and Small / Medium satellites missions, taking into account their impact on space debris issues. Researchers have focused on this segment, due to the fact that bigger satellites are quite often developed for science or telecommunication, where the 'jurisdiction' of the final client as NASA and ESA is involved, basing on advanced criteria of risk assessment. In case of smaller objects private initiative is increasingly a segment that is now, to the authors' knowledge, mostly out of consistent control.

The basic questions are the following:

1. Are there clear criteria for missions operators / mission project managers?

3 Are there clear and coherent criteria between the countries?

4 Are there countries that adopted more or less stringent criteria, whose regulation can be followed ?

Basing on the above, the following hypothesis has been proposed:

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- The licensing approach is not clear.
- In various countries the ADR is based on rather general statements, than clear technical criteria;
- Satellite operators for CubeSats and SmallSats may be not subject to some of the regulations.

Based on these questions and hypotheses, the authors conducted a survey of international and domestic regulations. They found that in many cases national regulations refer to United Nations treaties. The authors collected all available documentation specifying criteria for evaluations, as well as access to such documents. The materials were categorized according to specific research criteria.

2. RESEARCH CRITERIA

In order to evaluate the available documentation, clear and consistent criteria had to be defined. Each national regulation was subjected to the same evaluation scheme, which made it possible to evaluate and compare the results of the studies. The criteria that were taken into account were defined with some specific optics. The authors came out with the assumption that the technical criteria should be analyzed from the perspective of the Mission Operator or Project Manager, who is looking for specific and precise requirements that must be fulfilled from a legal and technical point of view.

Based on this approach, an important consideration is to whom the criteria are applied. If the criteria under the jurisdiction of a national agency are defined only for large system or mission integrators, this leads to the exclusion of small satellites from technical compliance (and also from the scope of this study). Once the regulation is implemented, directly or indirectly, the important question of who is responsible for meeting the criteria arises. Knowing that the regulation applies to the given operation, it is necessary to establish the basis for the documentation (its scope and methodology) that must be prepared and provided to meet the criteria. Within this question, it is important to know to whom the operator should provide such data. The next questions relate to mission location, re-entry into orbit, and final disposition. The last one refers to the software or computational methodology to be used for mission evaluation.

All criteria applied by the authors have been presented in Table 1

Table 1: Criteria of Investigation

Criteria of investigation
•To whom the criteria is applied •Entities responsible to fulfil the criteria •Documentation required to satisfy the criteria •Requirements LEO missions •Requirements for GEO missions •Re-entry requirements •Software / Methodology for parameters estimations

3. LEGAL GROUNDS FOR ASSESSING THE DEBRIS RISK AND LAUNCH AUTHORIZATION

The work carried out to identify technical regulations and guidelines has focused on the study of international and national legislation. This is because international instruments in the space sector are not directly applicable to private entities. On the other hand, national regulations refer to United Nations treaties, which are the basic principles of space exploration. The question to be answered based on this part of the study is whether technical requirements are part of space law at the international or national level, and whether the regulatory effort made by some states is sufficient to ensure consistency at the global level. A fundamental question seems to be the relevance and impact of technical requirements on the substantive consistency of space regulations and the risk management of space activities in terms of space debris mitigation.

3.1. International legal framework

The legal consideration must begin by outlining the international framework that exists in the field of space debris prevention and mitigation, which may have implications for the research objective of this study. Thus, in terms of licensing, insurance and technical obligations, the main internationally binding documents have been identified, i.e. „Outer Space Treaty" dated 1967 (OST), „Convention on International Liability for Damage Caused by Space Objects" dated 1972 (LC) and „Convention on Registration of Objects Launched into Outer Space" dated 1975 (RC). Although the obligation to preserve the space environment derives from the basic principles of the OST, such as freedom and equality of use and exploration, the treatment of space as the common heritage of mankind, and the prohibition of its appropriation, more specific provisions are necessary to clarify legal obligations. We can find them in Article IX of the Treaty, which states that States Parties "shall conduct all activities in outer space, including on the Moon and other celestial bodies, with due regard to the respective interests of all other States" and that "harmful contamination" of outer space and celestial bodies should be avoided (Article IX, sentence 2, OST), and where an activity has the potential to cause "harmful interference with the activities of other States Parties", consultations should be undertaken before it is carried out or continued (Art. IX sent. 3 and 4 OST)[1]. The other space treaties, including LC and RC, though provide for more specific duties of the launching states with respect to the registration of the space objects, as well as liability for damages caused by them, do not clarify any obligations with respect to the debris prevention.

Given these limited formulations, there is a general consensus in space law doctrine that space treaties neither explicitly prohibit space debris nor impose an obligation on states and their space entities to remove space objects from orbit. It should be noted that even the concept of space debris was not defined, as it did not exist at the time the treaties were drafted [1,2]. It is also important to consider that there is little chance of adopting amendments to existing treaties or agreeing on a new treaty specifically governing space debris.

In consequence, on international level we have to base solely on non-binding instruments such as rules adopted by IADC or 2007 UNCOPUOS Space Debris Mitigation Guidelines. Looking at the scope of application of the guidelines, on the basis of the criteria adopted by the authors, as first the scope of application should be distinguished. "*The IADC Space Debris Mitigation Guidelines are applicable to mission planning and the design and operation of spacecraft and orbital stages that will be injected into Earth orbit. Organisations are encouraged to use these Guidelines in identifying the standards that they will apply when establishing the mission requirements for planned spacecraft and orbital stages. Operators of existing spacecraft and orbital stages are encouraged to apply these guidelines to the greatest extent possible*." Basing on the above, we can state that no exception is made for small satellites, which also results from the broad definition of the spacecraft, being just "*an orbiting object designed to perform a specific function or mission*" and divided only to functional or non-functional. Also the debris have been defined in a broad way, as "*all man made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non functional.*" The guidelines also provide for a general guidance for action to be taken by the satellite operators in order to implement the goal of preventing and minimising the debris. It is said that :during an organisation's planning for and operation of a spacecraft and/or orbital stage, it should take systematic actions to reduce adverse effects on the orbital environment by introducing space debris mitigation measures into the spacecraft or orbital stage's lifecycle, from the mission requirement analysis and definition phases. In order to manage the implementation of space debris mitigation measures, it is recommended that a feasible Space Debris Mitigation Plan be established and documented for each program and project. The Mitigation Plan should include the following items: **(1) A management plan addressing space debris mitigation activities (2) A plan for the assessment and mitigation of risks related to space debris, including applicable standards**". No further criteria for assessment were proposed. With this in mind, the guidelines, while useful as a first step, cannot be considered a sufficient tool. Their general nature can only point the way for more detailed technical tools to follow.

A consequence of the above state of international law is the lack of consistent technical benchmarks with sufficient granularity, resulting in launch states adopting different (or no) definitions of spacecraft, the concept of space debris, and deciding on the adoption of preventive and mitigation measures at the national level. No consistency is observed in the inclusion of small satellites in the regime. Although all states should be interested in adopting similar measures and tools, enabling the avoidance of liability on the basis of fault (if the damage was caused in outer space - according to the LC) is an insufficient argument, and practice shows that the lack of international consistency in this regard tends to lead to differentiated requirements and flags of convenience. [3]. This in turn proves to be counter-effective on global scale.
Below, the authors attempted to compare some of the leading national space legislations Final assessment was focused on gaps and other possibilities and its impact on the general and global coherence.

3.2. National legal framework

The study was conducted for each country separately. During the research work, the authors also paid attention to the availability of regulations. This parameter is not easy to evaluate objectively, but in the end it can be important, especially in the case of a new branch of the space market, which is newspace commercial activities. The researchers were not able to survey all countries, but focused on the most active ones.

3.2.1. United States of America

The set of U.S. standards and procedures is very consistent. A researcher or potential mission operator can easily find the required information, required documentation, or required software [8]. Standards and procedures are available, but access to software is limited and NASA must be contacted.
Documents investigated are:

- NPR 8715.6B, NASA Procedural Requirements for Limiting Orbital Debris and Evaluating the Meteoroid and Orbital Debris Environment,

- NASA-STD-8719.14B, Process for Limiting Orbital Debris
- Commercial Space Launch Act of 1984, as amended (CSLA) and recodified in 51 USC Ch. 509 §§ 50901 to 50923

3.2.2. The Republic of France

The French regulations based on
- LOI no 2008 - 518 du 3 juin 2008 relative aux opérations spatiales.

The document gives the framework, however within this document mission operator will not find required technical information, how should apply for licensing or what documentation has to provide. To get this knowledge has to base on:
- Arrêté du 31 mars 2011 relatif à la réglementation technique en application du décret n° 2009-643 du 9 juin 2009 relatif aux autorisations délivrées en application de la loi n° 2008-518 du 3 juin 2008 relative aux opérations spatiales

Based on these two regulating documents all required information can be found.

3.2.3. The United Kingdom

The web site of the UK Government in comprehensive and coherent way, guides the mission operation or project manager through the license application procedure.
- https://www.gov.uk/guidance/apply-for-a-license-under-the-outer-space-act-1986
- Guidance for License Applications Outer Space Act 1986, last update 2018
- Space activity License, The Secretary of State for Business, Energy & Industrial Strategy
- Fact Sheet, The USL Space Agency's New Requirements for In-orbit Third Party Liability Insurance

The UK defines criteria under which the application will be submitted. The criteria are not defined explicitly, however they refer to the ISO standard or ECSS (European Cooperation for Space Standardization). Such approach is not so convenient as in USA or France, because requires to refer to many technical regulation not collected in one place.

3.2.4. Austria

Austrian Space Law includes two main regulations, which was investigated by the authors.
- Bundesgesetz über die Genehmigung von Weltraumaktivitäten und die Einrichtung eines Weltraumregisters (Weltraumgesetz) Austrian Federal Law on the Authorisation of Space Activities and the Establishment of a National Registry (Austrian Outer Space Act) StF: BGBl. I Nr. 132/2011 (NR: GP XXIV RV 1466 AB 1585 S. 135. BR: AB 8628 S. 803.)
- Gesamte Rechtsvorschrift für Weltraumverordnung, Fassung vom 08.04.2021

The regulations specified in the above documents are clear for formal aspects, responsibilities, and to whom the operator should submit the documentation. However, the researchers were not able to find the technical criteria that should be fulfilled during mission planning and design. The dossier submitted to the Minister of Transport, Innovation and Technology will forward the documents to the Austrian Space Agency or ESA for evaluation.

3.2.5. India

Though India is very active within the space sector and can be called a space faring country, no space law has been adopted till date. The Indian Space Research Organisation (ISRO) is the key government body that offers launch services to domestic and foreign entities. ISRO regulates all elements of the Indian Space industry and operates under the Department of Space. So far the ISRO has launched over 300 foreign satellites of 33 different countries.[3]

The lack of the regulation undoubtedly causes serious regulatory uncertainty for commercial companies not only in the Indian space industry, but also it has an impact on the global space industry. Although the Indian government formulated different policies to provide regulatory guidance on various commercial space activities, these policies are not providing a robust legal framework. Though there are works on a draft Space Activities Bill for consultation in 2017, it has no binding force and cannot be relied on as a source of the technical requirements for obtaining a launch authorization, this being therefore highly discretionary. From one side then, India can be seen as a more flexible launch destination, from the other it causes unpredictability not only just on local but also on a global scale.

The example of potential danger to the global space exploration ventures is the (already) famous launch of Swarm satellites. The US start-up from Silicon valley applied for a launch license in 2017 with the intention to launch their SpaceBees by ISRO. The company itself being under jurisdiction of the US received a denial from FCC in December 2017, with the justification that the SpaceBees would be too small to be tracked reliably by the U.S. Space Surveillance Network, a military-operated system. It was assessed as creating a dangerous situation, in which satellite operators might be unable to anticipate and avoid collisions with the SpaceBees.[4] Though, Swarm disregarded a decision by the FCC and launched the satellites anyway aboard an Indian polar satellite launch vehicle.[5] Needless to say that such an approach, not even potentially, but effectively threatens the global efforts in implementing ADR and it shows the significance of the coherent technical regulations on a global scale, which may be achieved only through adopting coherent national space laws on the level of technical regulations. In the case of India, the ratification of the space treaties proved to be far from sufficient to ensure the technical standard of the space objects launch from their territory.

3.2.6. Other analysed Countries

Researchers have also analyzed countries such as Italy, Germany and Poland. Some of the regulations adopted in these countries refer to UN treaties, but no specific national space laws have been adopted to date. The most regulated area is the communication bands. Due to the increased space traffic, this area needed to be regulated. Lack of domestic space law should be seen as a major drawback for space operators and the global community, for the reasons described in the Indian case.

4. TECHNICAL REQUIREMENTS REVIEW

Based on performed analysis the researches prepared summaries of assessment adopted by each Country investigated with reference to the Criteria of Investigation (table 1).

Table 2 US Regulations – Research Criteria

USA - Regulations

Criteria	Statement	Reference Document
To whom the criteria is applied?	NASA programs and projects or NASA – sponsored objects launched into space	NPR 8715.6B
Responsible	NASA Project Manger responsible for the mission	NPR 8715.6B
Documentation	Orbital Debris Assessment Reports (ODARs) End of Mission Plans (EOMPS)	NPR 8715.6B
Debris on LEO	All debris released during the deployment, operation, and disposal phases shall be limited to a maximum orbital lifetime of 25 years from date of release.	NASA-STD-8719.14B –
GEO	Shall me removed from GEO to graveyard orbit and be there more than 100 years.	NASA-STD-8719.14B
Level of risk (probability)	Based on historical precedent and practice, an acceptable level of risk for released debris damaging another operational spacecraft is <10-6 (over the life of the decay).	NASA-STD-8719.14B
Re – entry	Successful re-entry probability shall be not less than 0,9. For controlled re-entries, the product of the probability of failure to execute the re-entry burn and the risk of human casualty assuming uncontrolled re-entry shall not exceed 0.0001 (1:10,000).	NASA-STD-8719.14B
Software	DAS – Debris Assessment Software ORSAT – Object Survival Analysis Tool	

Table 3 France Regulations – Research Criteria

FRANCE - Regulations

Criteria	Statement	Reference Document
To whom the criteria is applied?	Any operator who intended to launch from French territory or French jurisdiction French operator Any person having French nationality	French Space Operations Act
Responsible	Mission Operator - Authorized holder, Luncher Operator	F. S. O. Act
Documentation	Study of dangers (Articlle 32). Impact Study, Risk control plan. Specific requirements for Quality Management System CNES Best Practise Guide	decree n° 2009-643 of June 9, 2009
Debris on LEO	The probability of occurrence of accidental decay must be less than 10-3 until the end of the space object's life. Its calculation shall include failure modes of propulsion and power systems, mechanisms, and structures, but shall not take into account external impact. No longer present in Protected Region A twenty-five years after completing its operational phase in an orbit through Protected Region A.	decree n° 2009-643 of June 9, 2009
GEO	This orbit shall be such that, under the effect of natural disturbances, within 100 years after completion of the operation, the object will not return to Protected Region B.	decree n° 2009-643 of June 9, 2009
Level of risk (probability)	The probability of successfully completing the service withdrawal manoeuvres in 3, 4, and 5 of this section shall be at least 0.85.	decree n° 2009-643 of June 9, 2009
Re – entry	The 99.999% probability reentry zone shall not interfere with the territory, including territorial waters, of any State, except with the agreement of that State.	decree n° 2009-643 of June 9, 2009
Software	JAC Software – collision detection based on real time data. Possibility of Collision values defined in the software.	

Table 4 Great Britain Regulation – Research Criteria

Great Britain - Regulations

Criteria	Statement	Reference Document
To whom the criteria is applied?	The United Kingdom nationals, other Licensee	Outer Space Act
Responsible	Mission Operator - Licensee	GUIDANCE FOR LICENCE APPLICANTS
Documentation	SPACE ACTIVITY LICENCE ANNEX A: Licensing Questions • System qualification, history, and reliability • System and mission risk assessment • Safety plans and procedures • Safety requirements, constraints, rules and criteria • Safety organisation, roles, and authorities	GUIDANCE FOR LICENCE APPLICANTS
Debris on LEO	ISO 24113, "Space debris mitigation" ISO/TR 16158, Space systems — Avoiding collisions among orbiting objects ISO N615, "Disposal of spacecraft in LEO"	GUIDANCE FOR LICENCE APPLICANTS
GEO	ISO 26872, "GEO disposal"	GUIDANCE FOR LICENCE APPLICANTS
Level of risk (probability)	ISO 24113, "Space debris mitigation"	
Re – entry	ISO 27875, "Re-entry risk management"	
Software	Not found. Assessment is performer by UK Space Agency	

Table 5Austria Regulations – Research Criteria

Austria - Regulations

Criteria	Statement	Reference Document
To whom the criteria is applied?	Space activities carried our in Austria, on board of vessels or airplains registeres in Austria or Austrian citizen.	Austrian Federal Law on the Authorisation of Space Activities
Responsible	Operator – juridical person that carries out space actovities	Austrian Federal Law on the Authorisation of Space Activities
Documentation	Documentation is defined in § 10. „... more information, which the Minister for Transport, Innovation and Technology may determine, if necessary, in light of the technological state of the art, the international legal obligations or relevant decisions of international organisations."	Gesamte Rechtsvorschrift für Weltraumverordnung, Fassung vom 08.04.2021
Debris on LEO	Researches does not reached specific data. The defined Minister will ask for assessment Austrian Space Agency or ESA.	Gesamte Rechtsvorschrift für Weltraumverordnung, Fassung vom 08.04.2021
GEO	Researches does not reached specific data. The defined Minister will ask for assessment Austrian Space Agency or ESA.	Gesamte Rechtsvorschrift für Weltraumverordnung, Fassung vom 08.04.2021
Level of risk (probability)	Reserches does not reached specific data. The defined Minister will ask for assessment Austrian Space Agency or ESA.	Gesamte Rechtsvorschrift für Weltraumverordnung, Fassung vom 08.04.2021
Re – entry	Researches does not reached specific data. The defined Minister will ask for assessment Austrian Space Agency or ESA.	Gesamte Rechtsvorschrift für Weltraumverordnung, Fassung vom 08.04.2021
Software	Not found. Assessment is performer by UK Space Agency	Gesamte Rechtsvorschrift für Weltraumverordnung, Fassung vom 08.04.2021

5. ENGINEERING APPROACH

The national laws, space treaties and handbooks examined are in many cases very general. Even if we conclude that on a general legal ground such as space treaties, the requirements are coherent, they need to be confronted with how the regulations shall be applied in business reality. This reality shows that there is much room for improvement, and the path that researchers should follow should focus on methods for implementing technical measures to meet the international principles expressed in the space treaties.

In practice however, even if the satellite operator knows the local authority competent to proceed with the application for license (which is not so obvious in the countries that have not adopted space legislation), the technical requirements, criteria for the risk assessment and documentation necessary to this aim, remain a mystery They are evaluated without objective criteria and with a high degree of discretion, such as the criteria for the minimum level of probability to be provided for collision avoidance, re-entry or maintenance over GEO. Therefore, the authors believe that national requirements should go so far as to be based not only on UN legislation, but also on such precise criteria as those contained, for example, in ISO 24113 - which is also the subject of research in this study[6]. In ISO one can find values of required probability for LEO, GEO, and re - entry missions. The ISO proposed to define in the national law, so called "approving agent", who will define the way of calculation of probability. Such criteria we could find in US standards, French or UK regulations. Each of this country has own approving agent, National Agency.

6. COHERENT PROCEDURE PROPOSED

Based on their research and analysis, the authors identified a procedure that spacefaring states should follow to ensure a globally consistent national space law that serves the state and business, whose long-term interest is to launch satellites safely.

The first step is to ratify UN treaties on space debris mitigation and other relevant ones. Reference should be made in national law to the UN treaties. A competent minister should be identified in national law to oversee this process. Technical requirements can be adapted from ISO 24113 and other relevant standards. An "approval agent" should be defined. From an engineering perspective, it will be beneficial if a clear computational approach or software is available. The mission operator is able to assess whether the mission meets the requirements before a request for licenses is made. This approach will also increase technical excellence in the planning and design phase.

Table 6 ISO 24113 Standard

International Standard – ISO 24113

Criteria	Statement	Reference Document
To whom the criteria is applied?	Regullatory entities / Licensing authorities national or international space agencies	ISO 24113
Responsible	Mission Operator - Licensee	ISO 24113
Documentation	Space Debris Mitigation Plan	ISO 24113
Debris on LEO	Life time no more than 25 years	ISO 24113
GEO	Remain outside the GEO protected region for at least 100 years.	ISO 24113
Level of risk (probability)	The probability of accidental break-up of spacecraft or launch vehicle orbital stage in Earth orbit shall be less than 10^-3 until its end of life. Successful disposal shall be at lease 0,9 at the end of life.	ISO 24113
Re – entry	Re – entry casulaity risk shall be 10^-4 – risk assesment shall be defined by approving agent.	ISO 24113
Software	Software / Calculations are delegated to the approving agent.	ISO 24113

7. INSURANCE IMPLICATIONS

As has been mentioned in the introduction, the issue of risk assessment for purposes of the licensing seems to be important not only for the launching states, which bear ultimate liability for damages, but also for other stakeholders, such as insurers to which part of the risk is transferred, especially where liability insurance is a mandatory part of the licensing process. The adoption of consistent criteria for assessing the launch risk in terms of space debris is all the more important for the proper insurance underwriting of the space ventures.[10] In this respect two perspectives may be considered [11].

On the one hand, precise risk assessment criteria at the licensing stage under national space law can significantly facilitate space mission insurance coverage, leading to greater availability of such insurance and lower rates. The more coherent the technical requirements could be on a global scale, the better the economies of scale could be in insuring space mission risks. This is due to the networking of insurance markets on a global scale. It would also allow for a snowball effect; the more space missions covered by insurance, the better the law of large numbers, which is so important for risk insurability, would apply. [12] Space projects involving the launch of megaconstellations of small satellites are particularly suited to achieve such a goal. A prerequisite, however, is that insurers can accurately assess the risk, and this depends on the predictability of technical requirements. The case of Spacebees serves here as a negative example in relation to the objective defined above.

On the other hand, it should not be forgotten that insurers are professionals in risk assessment and they were the first to develop risk management methods. Taking this into account, the space market, striving for consistent criteria of risk estimation for small satellite missions, should cooperate with insurers, taking advantage of their experience and in a way submit to technical requirements of risk insurability set by insurers. In this way, the risk insurability of small satellites could gradually improve, and meeting the technical requirements for licensing could at the same time mean meeting the conditions for mission risk insurability. The benefits of such a turn of events would be obvious. In this way, insurers could act as bottom-up legislators to the benefit of the entire market.[13] It is clear that such a result takes time to achieve.

8. CONCLUSIONS

The authors' research shows that there is no consistent global approach to technical requirements that includes engineering models for predicting debris and debris impact on spacecraft. The importance of this issue is obvious given the number of small satellites being launched today. This problem has not been addressed at the international level, and even when national regulations have been adopted, in most cases no parameters are available by which to measure compliance.

From over 100 countries that ratified OST, only about 30 adopted national space laws. In the other countries, space operators face the difficulty in such basic issue as identifying the authority responsible for authorising the space activity (so called 'approving agent'). Moreover, these the countries that adopted general space laws do not show sufficient coherence between each other as regards the technical criteria relating to the space debris risk avoidance and mitigation (even if some countries refer to ISO 24113). The clear criteria may be identified only in cases where missions are launched under ESA or NASA 'jurisdiction'. In other cases it is not possible to define the differences in the technical requirements between the countries according to coherent criteria, as the regulations are not clear, or do not exist.

Therefore, the hypothesis of the authors are confirmed:

- The licensing approach in most countries is not clear.
- No specific coherent measurable technical requirements exist
- It is not clear whether so called new space operators are under no technical or regulatory requirement.

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