ARTIFICIAL INTELLIGENCE AND SPACE SITUATIONAL AWARENESS: DATA PROCESSING AND SHARING IN DEBRIS-CROWDED AREAS

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ABSTRACT

Decades of activity in space by public and private actors have created a considerable amount of space debris, hence posing a growing threat. These high-speed projectiles of a potentially destructive capability have characteristics which make them extremely hard to study and track.

Artificial Intelligence (AI) as applied in space robotics appears to be promising for outer space exploration, related data processing and space debris mitigation enabling considerable progress for further developments. Nonetheless, the use of AI for debris data sharing and monitoring raises particular concerns, such as in relation to the applicable regulatory regime, the appropriate liability regime or the rules possibly applying to debris data sharing and processing.

In the context of a growing interest in outer space activities, answers to these issues are expected to impact heavily on the attitude of all involved stakeholders.

1. INTRODUCTION: DEFINING THE THREAT

Over the past decades, a considerable and constantly growing amount of debris is being concentrated in Outer Space, originating mainly from the fragmentation of spacecraft and launch vehicles. Once in orbit, they consist in uncontrolled and non-cooperative elements, orbiting at a high speed and eventually further degrading under conditions of real microgravity; in this sense, their identification, control and management become a challenge from every perspective. Hence, the main objective remains not only to estimate their position, orientation and speed in order to avoid collision with working space objects (such as satellites) resulting to their damage, but also to maneuver so as to avoid the creation of further debris and/or reduce the collision risk below an acceptable level.

Space debris identification and tracking is therefore of paramount importance for the security of space assets and success of space missions in general. As a matter of fact, it is a subject of vivid discussions amongst policy makers and space actors since the '80s [1]. However, particular characteristics related to debris themselves, but also related to Outer Space environment; make it difficult for policy-makers to adopt a truly uniform approach and an adapted regulatory framework, to facilitate the safe use and exploration of Outer Space to the benefit of all.

First, as regards space debris *per se*, they consist in a category encompassing completely different types of elements and pieces, which have been voluntarily or accidentally abandoned in Outer Space. They differ in nature and size, varying from quite small elements [2] to very large pieces, all of them however able to pose numerous threats to space assets (even to the International Space Station) and persons, in the event a collision occurs [3]. In addition to that, their key characteristic is that they gain high speed once in orbit, to reach a maximum velocity which in turn increases further their potential dangerousness. In this sense, they become–by the laws of physics– totally uncontrolled and non-cooperative, with a behavior and trajectory difficult to evaluate or predict, thereby increasing the risk of collisions and the creation of further debris [Kessler syndrome]. Overall, it is clear that once separated from the space object they used to be part of, a clear responsibility for controlling them –in order to avoid any

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type of damage– is thus far hard to conceive.

Second, the specific physical characteristics of Outer Space make it an unfriendly and difficult environment to operate in, such as temperature, micro-gravity, difficult communication conditions with the Earth etc. Overall, several operations and activities still remain a challenge, especially in the event a manned mission is required. Against this background, not only estimates on debris position, trajectory and speed but also activities aimed at their removal [ideally, by avoiding the creation of further debris] remain up to date a key objective, initially from a practical standpoint.

Third, from a legal perspective, the key issue that has hitherto impeded progress in space debris mitigation is the lack of clear and binding rules to address the threat of space debris, eventually due to the fact that the international community was possibly unaware, at first, of the growing risk they would pose to space activities [4]. Effectively, the treaties forming the foundation of international space law–such as, the *Outer Space Treaty (OST)* signed in 1967 and specifically regulating activities in this new environment, considered by scholars as the "Magna Carta of Space" [5]– do not define the term 'space debris' at all. Despite that, it is clear that the idea is referred to, through the use of similar concepts, such as 'component parts' of a space object, 'parts thereof' etc. [6]. However, to fill this legal vacuum, several States, organisations and space actors have adopted or proposed their own definition of space debris [7], in an effort to build further on the existing rules of International Space Law and join efforts towards a sustainable use of Outer Space. It is nonetheless a common view that the definition of debris is more or less covered by the definition of non-functional 'space objects'[8], therefore allowing for International Space Law to eventually apply.

Following this reasoning, it is therefore argued that the binding obligation for space actors to take measures as to avoid damages being caused by their space objects in the context of Outer Space activities [otherwise to pay compensation for losses that occurred] [9], is of some help to as well address the threat of increased debris quantities in the most frequently used orbits (namely, in the lower earth orbit/LEO and the geostationary earth orbit/GEO).

However, the liability regime of launching States is in reality twofold, as it results from the OST, art. VII and from the relevant articles of the *Liability Convention signed in 1972*, namely from art. II for damage caused on the surface of Earth [in this case, an absolute liability regime applies] and from art. III for damage caused elsewhere [here, a fault based liability regime] [10]. Hence, in relation to damage cause by space debris, it is clear that space actors would be liable for damage caused by their space objects in Outer Space, in their original condition (ex. orbiting satellites) or after their fragmentation (ex. space debris). On this basis, the key issue would be that, taking into account that damage due to space debris will occur in Outer Space, liability could be imposed only in the event of real proven fault, which is a problem *per se*.

In reality, the question which then arises as to what might be considered as a fault, in relation to space debris, namely in relation to human made elements [which resulted from the voluntary or accidental fragmentation of space objects and have become uncontrollable once in orbit], has many implications. By way of illustration, we should not only define with precision which type of fault or neglect –on the part of the owner of the object–would be required [i.e. implying that such fault or neglect can avoided], but in addition to that, the space element should be able to be recognized, in order to identify the owner; taking then into account the presence of quite a few very small debris in orbit, it is clear that the latter would be in some cases impossible to achieve.

This difficulty resulted in the fact that there is no clear and binding obligation to prevent the creation and/or to remove space debris [11]. Effectively, art. III of the Liability Convention clearly focuses on "the fault of a launching State (resulting) in a collision between space objects in outer space", rather than on any failure to adopt preventive measures allowing avoiding the collision [12]; it remains a challenge to determine and agree upon the contours of any type of responsible behavior that space actors should adopt while using and exploiting Outer Space and its resources.

In addition to that, and from a practical point of view, it is clear that even a full implementation of the general obligation of due diligence cannot (in this context) really be considered as feasible, due to the fact that space debris are by definition uncontrollable pieces of space objects. In reality, the obligation of due diligence arising from general International Law, refers to "elements under a State's jurisdiction and control that it has *power over* or has the *capacity to influence*" [13]; the complete opposite of space debris.

Nonetheless, and despite these challenges, it appears to be a clearly growing international consensus that space activities need to be managed so as to minimize debris generation and risk [14], which is understood as a general obligation to mitigate and prevent the creation of debris. This common approach is eventually based on the principle of liability of space actors for damages caused by their objects in Outer Space, but it is also related to the general obligation established in OST, art. IX. In particular, article art. IX of the OST provides that States ought *first* to avoid the harmful contamination of outer space, as well as any type of adverse changes in the environment of Earth [e.g. possibly applying in the event of uncontrolled reentry of space orbits into the atmosphere], and *second* to consult with other space actors before implementing any possibly harmful space activities they have planned.

Accordingly, in line with the reasoning that space actors –due to their fundamental obligation to explore and use Outer Space taking into account the benefit and the interests of all countries [established in OST, art. I but as well arising from customary international law]– should take into account the growing threat of space debris while planning their space missions, several non-legally binding documents were adopted, such as the *Space Debris Mitigation Guidelines adopted in 2007*, the *EU Code of Conduct for Space Debris Mitigation adopted in 2004* etc., in an effort to establish recommendations and to promote good practices and lessons learned in relation to debris mitigation efforts.

2. TECHNICAL SOLUTIONSAND SPACE SITUATIONAL AWARENESS [SSA]

Despite the absence of a legally binding obligation towards States to address the growing risk of space debris, the real threats posed to the successful realization of space missions created a pressing need for solutions in real terms. In order to ensure the safety of space missions and activities, space-faring States and space actors tried to find workable solutions.

First, from a scientific and practical perspective, scientists worked frantically on developing techniques which are principally aiming at identifying and tracking [with the ultimate objective to remove] any type of space debris. To mention only a few examples, amongst various solutions, such systems may eventually consist in *Electro Dynamic Debris Elimination* [i.e. a technology using the Earth's magnetic field for propulsion, in order to make debris change their trajectory]; in *Tether-Based De-Orbit Systems*, which is a structure based on electro dynamic Techniques [here, the concept is to allow a robotic device to attach a tether to a derelict satellite or debris element]; in *Much Higher-Powered Ground-Based Lasers*, aimed also at de-orbiting space debris of a small size; in *Tether-Deployed Nets*[in the effort to reach space debris *via* controllable nets, this solution is based on low technology, and is currently mostly at the planning phase] etc. [15]. The major disadvantages of all these technologies is that many of them are, apart from expensive, still in a first experimental stage; they are not yet actively used, as additional research and development would be required to have truly accessible and operational systems, for most of them.

However, in addition to that technical issue, and much more importantly, the key weaknesses of those systems is that they consist in solutions or installations designed to collect (derelict and uncontrollable) space objects, namely space debris, but space objects after all. In this sense, they could all very well be used in order to collect working space objects, such as satellites, with the same ease of execution. It is therefore clear, from this specific perspective, that most of them could be easily used as space weapons, to gather, amass or simply cause damage to other working space objects (ex. foreign satellites).

Consequently, a vital question arises as to who [i.e. space actor, international organization or other] would be legally authorized to use such systems or technology, with the intent to remove the pieces of debris [16] abandoned in Outer Space. It is in reality argued that these technologies should in any case be "designed and operated on an international basis, in such a manner that it would not be considered a space weapon" [17].

Second, from a different perspective and at an enhanced level, based this time on a concerted and long-term effort, the attempt is made to better identifying the threat posed to space activities by debris or other hazards in Outer Space. In particular (and contrary to many technical solutions, aiming principally at collecting or de-orbiting the debris), the objective here is to collect, process and share information on debris, asteroids, solar flares and other threats to space activity, with the intent of sharing them amongst States [18] and mostly act in a preventive manner. This activity falls under Space Situational Awareness (SSA), despite the fact that there are no commonly accepted and legally binding definition of SSA yet [to provide *inter alia* one example of diverging approaches, the EU definition of SSA is wider than that used in the U.S.] [19].

In practice though, several formal definitions of SSA have been proposed and eventually adopted *via* the numerous agreements which regulate the use of the various SSA systems, currently implemented by space agencies and organisations, and principally referring to it as the activity of collecting and disseminating space weather data as well as natural and human made threats existing around the Earth and in Outer Space [20]. On this basis, SSA systems allow for the assessment of the collision risk and of the re-entry of space objects into the Earth's atmosphere; the generation of collision avoidance alerts of space activities; the detection and characterization of in-orbit fragmentations, break-ups or collisions etc. [21].

At the same time, due to the fact that Space Situational Awareness is principally an ancillary activity to the exploration and exploitation of Outer Space *stricto sensu*–and in this sense, mostly aiming at mapping human made space debris and/or other threats to space missions– it has been argued by scholars that, to a certain extent, namely "(w)ith the exception of the operation of space objects carrying space-based sensors, space situational awareness *is not a space activity* in the meaning of the Outer Space Treaty and thus the concepts of responsibility and liability for space activities, as established in the Outer Space Treaty, do not apply [22]".

In this specific context, and as regards more precisely the idea of a responsibility for low quality or non-reliable information provided to users –following the collection and/or processing of data in the context or *via* Outer Space–, the prevailing view seems to be that such liability should not be established, despite some opposite views [such as, *inter alia*, those put forward in the discussion on damage caused by reliance on faulty GNSS]. From a legal perspective, this approach appears to be correct and is in line with a strict reading of articles II and III of the Liability Convention, and on the view that space actors are only liable for direct damage caused by their space objects [therefore, not by false information] [23]. On the other hand, not only is expert opinion certainly divided in the legal community, but it may be argued that this approach is not (from a certain perspective) well adapted to the constantly changing circumstances, the dynamics of the space activity and the increased dependence of activities on Earth from the use and exploitation of space resources *lato sensu*.

Applied now *in concreto* to SSA data, the idea of a general duty to collect and share information on space debris and threats is in reality gaining in importance [24], and appears to be possibly grounded –according to scholars–on OST, art. IX [25], which is the key reference for the effective protection and sustainable use of Outer Space. For mostly practical reasons, this duty is in fact growingly implemented by States through their effective participation in SSA regional systems and their acceptance of the corresponding SSA agreements, such as –for instance–the SST Directive.

At the same time, responsibility for low quality or non-reliable information on space debris or threats provided to users is expressly excluded in many of the SSA Agreements. It is effectively interesting to note that, it is often clearly established (in these agreements) that the providers [e.g. participating member States and agencies in the SSA consortium] shall not be held liable for "any inaccuracy *of the information provided* through the SST services [26]".

In reality, collecting and disseminating this type of space data remains a challenge *per se* for many reasons: the small size of debris cannot allow their easy identification [in addition to the fact that, despite the rules established in the Registration Convention, the registration of space objects is not a universal State practice; therefore, many object are non-identifiable in the first place] [27]. Furthermore, even if they have been properly registered, the information required and provided on the basis of the *Registration Convention signed in 1975* is not sufficient to allow tracking space objects with precision, nor locating them in orbit at a future date [28], in addition to the practical difficulty to track debris because of their high orbital velocity. Finally, effective access to this type of information is an issue *per se*, due also to the high sensitivity of SSA data [29]; in reality, such data may easily concern sensitive information related to foreign satellites, operations etc. Overall, a blind reliance on a foreign SSA system may easily result in political and/or economic dependence on the provider. Following this reasoning, space-faring States and international organisations usually prefer to develop their own SSA systems, while enhancing the beneficial synergies and cooperation with international partners.

Even so, in this fragile data gathering and processing context, a revolutionary technology comes now to the fore. Artificial intelligence, based on the possibility for autonomous conduct and self-improvement, by processing an infinite amount of data –and without being always dependant on communication with the Earth–, changes the reality on the ground.

3. APPLICATION OF AI TO SSA FOR SPACE DEBRIS MITIGATION

3.1 The problem of defining AI

For the purposes of the present research, AI has been addressed as a means to intensify the beneficial outcome of Space Situational Awareness systems in the context of space debris mitigation activities. In this regard, AI as an enabling factor of SSA related space debris mitigation conduct raises regulatory concerns related to the delimitation of its concept, as well as to the potential requirement for introducing adapted rules for the regulation of its operation and consequences.

From a policy perspective, AI has been increasingly used as an *umbrella term* to cover a diverse universe of AI-based or AI-operated systems [30]. This lack of precision is parallel to the ongoing controversy over what could be represented at a technical/scientific level by the term AI and on the basis of which criteria [31].

However, for the purposes of promoting regulation of AI the complex issue of delimitating the scope of the said regulation should be assessed as a priority. In addition, any such outcome should balance an acceptable degree of legal certainty and clarity with a certain flexibility so as not to discourage innovation and quickly turn any attempt of regulation obsolete before technology advancements.

Determining a legal definition of AI for the purposes of regulation and enforcement is a challenging task which may result to the rejection of an all-encompassing definition for a wider concept of AI in favor of more restrictive approaches for defining specific use cases and applications of AI [32].

In this regard, different approaches have been pursued as to the scope of an AI definition for regulatory purposes and the most predominant discourse is taking place in the European Union (EU) legal order with policy recommendations to the European Parliament (EP) favoring the development of specific definitions of AI applications against a broader approach suggested by the High-Level Expert Group on Artificial Intelligence (AI HLEG) [33].

3.2 Global approaches to regulate AI

Regulatory work to address AI operation and its effects has been strongly encouraged at international level as a precondition for fostering economic growth, with the G7 concluding to an indicative statement [34] in this regard:

"Supporting economic growth from AI innovation is about using AI applications to help improve economic performance. [….] G7 countries recognize that market-led AI innovations will positively impact all of our countries in key areas such as health, the environment, transportation, manufacturing, agriculture, security and governance. These gains will be realized through policies that *foster entrepreneurship in AI technologies*, that prepare people for social and labour market demand changes, including those who are at risk of being left out, as well as policies that build open and fair market environments, including the promotion and protection of *free flow of information*. *This approach includes opposition to data localization requirements that are unjustifiable*, taking into account legitimate public policy objectives, as well as generally applicable policies that require access to, or transfer of, source code of mass market software as a condition of market access, while recognizing the legitimate interest of Governments in assessing the security of these products. Such an approach creates a business environment that invites innovation while providing predictability in commercial relations, *including in law*."

A more precise engagement to develop legislation *for a coordinated approach on the human and ethical implications of Artificial Intelligence, focusing also on the use of big data for fostering innovation* was announced in the political guidelines for the 2019-2024 Commission [35]. The dense work of the EU institutions and the specially appointed High-level expert group on artificial intelligence (AI HLEG) for delivering the said engagement has rightfully attributed to the EU a role of frontrunner in addressing regulatory concerns from AI operations [36].

At present, pending the publication of the European Commission's proposal on an AI regulatory regime, legally binding rules to address AI generated risks and harmful effects are being processed. Relevant regulatory discussions at EU level focus on the *adequacy of civil liability regimes to address the harmful effects of emerging digital technologies*. In this context, strict liability has been considered as an appropriate response to the risks of emerging digital technologies, if operated in non-private environments and may typically cause significant harm, circumstances that could share common features with AI systems operating in outer space activities' context [37].

Besides, however, the hard law considerations, regulation of AI has been mostly in the spotlight of soft law, namely of value-based instruments setting principles of trustworthy and ethical AI systems. The relevant work of the EU [38] and the OECD [39] provides a comprehensive set of guiding principles which focus on elevating respect for human dignity and autonomy, ethical values and fundamental human rights as a centerpiece to AI systems' development and use ("human-centric approach")together with considerations for ensuring accountability and transparency for AI use.

Finally, hard law regulation and soft law principles are supplemented by the development of AI technical or ethical standards, with the global initiative of the Institute of Electrical and Electronics Engineers (IEEE) on ethically designed AI offering a comprehensive principled framework for autonomous and intelligent systems [40].

4. REGULATION OF AI-BASED DATA PROCESSING FOR SPACE DEBRIS MITIGATION

4.1 Legal obligations for space debris mitigation and SSA data sharing & disclosure

For the purposes of advancing SSA for space debris mitigation activities, AI can achieve exponential results when combining machine learning and automated decision-making techniques. The capacity to collect and analyze large data volumes, predict a certain course of action and make autonomous decisions enables more accurate and timely identification of space debris orbits and collision risks prediction, as well as crucial distinction between non-functional & functional space objects [41].

AI's data collection and analysis' capacity is a key element for achieving more robust compliance to a certain space mitigation conduct, segregated in two sets of activities: 1) prevention and limitation of on-orbit collisions and 2) pertinent cooperation, meaning notification of related risks and data exchange.

The applicability of international space law regime to the aforesaid AI-based data processing/sharing activities for space mitigation purposes provides the broader legal basis of freedom to explore and use Outer Space exempt from any interference, in conjunction with the legal duty for international cooperation and use of outer space for the benefit of all (Art. I OST). However, the broad concepts expressed under this context do not provide a solid regulatory framework for SSA data sharing activities.

In search of a more suitable legal basis for addressing data collection and sharing activity in the context of a space debris mitigation conduct, OST Articles IX, V and XI, elaborating further on the principle of international cooperation, are of relevance [42].

The vague framing of these provisions cannot, however, be construed as formulating a certain obligatory content in favor of the establishment of a clear binding rule and correlating legal duty for space debris mitigation, as well as of an international obligation to share and disseminate SSA data. These general in nature stipulations for international cooperation do not correspond to specific conduct requirements and to a certain standard of care that must be met [43].

In the absence of hard law regulation, space mitigation conduct corresponding to SSA data sharing activity remains to be regulated under the auspices of the bilateral or multilateral framework of SSA data sharing agreements or under not legally binding, soft law provisions of international instruments.

In particular, both the set of Space Debris Mitigation Guidelines developed by the Inter-Agency Space Debris Coordination Committee (IADC) [44] and those adopted by the United Nations Committee on the Peaceful Uses Of Outer Space (COPUOS) [45] call for a certain conduct to *prevent on orbit collisions* and to *limit the probability of accidental collision in orbit*:

IADC Space Mitigation Guideline 5.4 - Prevention of On-Orbit Collisions: "*In developing the design and mission profile of a spacecraft or orbital stage, a program or project should estimate and limit the probability of accidental collision with known objects during the spacecraft or orbital stage's orbital lifetime. If reliable orbital data is available, avoidance manoeuvres for spacecraft and co-ordination of launch windows may be considered if the collision risk is not considered negligible. Spacecraft design should limit the probability of collision with small debris which could cause a loss of control, thus preventing post-mission disposal*."

COPUOS Space Mitigation Guideline 3 - Limit the probability of accidental collision in orbit: "*In developing the design and mission profile of spacecraft and launch vehicle stages, the probability of accidental collision with known objects during the system's launch phase and orbital lifetime should be estimated and limited. If available orbital data indicate a potential collision, adjustment of the launch time or an on-orbit avoidance manoeuvre should be considered. Some accidental collisions have already been identified. Numerous studies indicate that, as the number and mass of space debris increase, the primary source of new space debris is likely to be from collisions. Collision avoidance procedures have already been adopted by some Member States and international organizations*."

In addition, the recent *Guidelines for the Long-term Sustainability of Outer Space Activities,* adopted by COPUOS in its 62nd session (June 2019) [46] call for a certain conduct to monitor the orbital and physical properties of space debris and promote the sharing and dissemination of data in support of international cooperation on managing orbital debris population:

"Guideline B.3 - Promote the collection, sharing and dissemination of space debris monitoring information: *States and international intergovernmental organizations should encourage the development and use of relevant technologies for the measurement, monitoring and characterization of the orbital and physical properties of space debris. States and international intergovernmental organizations should also promote the sharing and dissemination of derived data products and methodologies in support of research and international scientific cooperation on the evolution of the orbital debris population.*

The abovementioned international instruments reflect a wider acceptance of the international community and can be regarded as reflecting soft law considerations [47].

Further evidence in favor of delimitating a certain State conduct for SSA data sharing and dissemination for space mitigation purposes can be retrieved from the emerging soft law instrument of the UN GA 4th Committee draft Resolution on international cooperation in the peaceful uses of outer space [48] stating that:

"*14. Considers that it is essential that Member States pay more attention to the problem of the gradually increasing probability of collisions of space objects, especially those with nuclear power sources, with space debris, and other aspects of space debris, calls for the continuation of national research on this question, for the development of improved technology for the monitoring of space debris and for the compilation and dissemination of data on space debris, also considers that, to the extent possible, information thereon should be provided to the Scientific and Technical Subcommittee, and agrees that international cooperation is needed to expand appropriate and affordable strategies to minimize the impact of space debris on future space missions;*".

In addition, the - dormant - draft International Code of Conduct for Outer Space Activities equally acknowledges specific State conduct for space debris mitigation and relevant SSA data sharing activity [49].

Notwithstanding the aforesaid broader regulatory context for AI-driven outer space data related activities, principle-setting instruments of a non-binding nature could provide an appropriate template for elaborating useful guidance when deploying AI-based outer space activities. In the context of these activities, value-based guidelines should adhere to a more "space-centric" approach elaborating on requirements more crucial to the sustainable use and accessibility of outer space, such as data governance principles for securing the quality and integrity of the data used for AI performance.

4.2. Establishment of liability for AI-related harm

Besides the regulatory context of the deployment of AI-based activities in outer space, liability related issues in relation to their harmful effects merit particular attention.

Depending on the legal circumstances, liability for outer space activities is considered under various contexts, namely it could be established under the international treaty instruments of the OST (Article VII) or the Convention on International Liability for Damage Caused by Space Objects (the "Liability Convention"), applicable to its State - parties, or under the traditional framework of general public international law applicable to the concept of state responsibility [ILC Articles]or, finally, under applicable national law.

The international space law liability regime, as elaborated further by the Liability Convention, is unique in introducing a fault-based liability regime and in terms of introducing a broader concept of state responsibility than the traditional notion construed under general international law. The particularity of the Liability Convention regime within the international responsibility framework has been also taken into consideration by the International Law Commission [50].

In this regard, the Liability Convention can provide a more advanced conceptual basis for addressing liability related concerns from AI-based operation in outer space. However, particular considerations demonstrate the boundaries of applicable state liability regime to outer space activities.

First, as referred above, regulatory work, currently driven by EU, on establishing specific liability rules for addressing risks of AI systems is favoring strict liability under certain circumstances, in particular for high-risk AI systems [51].

In its Resolution on Civil liability regime for artificial intelligence [52], the European Parliament opts for the strict liability of the *operator of a high-risk AI-system for any harm or damage that was caused by a physical or virtual activity, device or process driven by that AI-system*. When defining the notion of high-risk AI-systems it stipulates that "an AI-system presents a high risk when its autonomous operation involves a *significant potential to cause harm* to one or more persons, in a manner that is random and goes beyond what can reasonably be expected; considers that *when determining whether an AI-system is high-risk, the sector in which significant risks can be expected to arise and the nature of the activities undertaken must also be taken into account*; considers that the significance of the potential depends on the interplay between the severity of possible harm, the likelihood that the risk causes harm or damage and the manner in which the AI system is being used;".

Taking a similar approach on the conditions that could attribute strict liability for AI-based activity, the Report on *Liability for Artificial Intelligence and other emerging digital technologies* of the independent Expert Group on Liability and New Technologies set up by the European Commission concludes that "[9] Strict liability is an appropriate response to the risks posed by emerging digital technology, if, for example, they are *operated in non-private environments and may typically cause significant harm*.", while indicating autonomous vehicles or aircraft (drones) as suitable candidates for the application of strict liability regimes."[53]

The abovementioned considerations, albeit effective under regional EU jurisdiction, demonstrate a crucial trend in favor of attributing strict liability for AI-based activities with a *significant potential to cause harm* or, alternatively, that *may typically cause significant harm*, a risk which is intensified when operating in public spaces. The said circumstances are typically present in outer space activities. In essence, the expectation that States when involved in outer space operations have implicitly adhered to the risk of potential harm is regarded as an explanatory ground for the fault-based liability regime established by Article III of the Liability Convention for damage being caused elsewhere than on the surface of the Earth [54].

It, thus, follows that the Liability Convention's division between absolute/strict and fault-based liability, triggered solely on conditions of damage occurrence (surface of the Earth or elsewhere), is not appropriate to capture the broader risk-based concept of strict liability attributed to AI operations bearing a significant potential to cause damage, as those may typically be expected to cause such damage irrespective of the territory of the damage occurrence.

Secondly, fault-based liability rules, as applicable under outer space treaty law, are inadequate in establishing a comprehensive standard of care eligible to demonstrate *in concreto* what should have been the proper course of action [55]. In contrast, the applicability of fault-based liability rules to AI-based operations, as those that are not considered as high-risk pursuant to the seemingly predominant EU distinction, require precision in setting the acceptable standard of care since AI's inherent complexity and triggered consequence of events leading to a specific result, as well as potential to develop functions without direct human control pose particular difficulties in determining and proving fault.

In this regard, the fault-based liability rule proposed by the European Parliament Resolution [56] provides as ground for liability release the proof of *due diligence observance* which is further designated as the cumulative performance of a series of actions ("selecting a suitable AI-system for the right task and skills, putting the AI-system duly into operation, monitoring the activities and maintaining the operational reliability by regularly installing all available updates").

Finally, the proliferation of emerging digital technologies is expected to render more relevant/significant in the future types of material or non-material damage (e.g. economic losses or damage to or destruction of data that could be considered a property loss) which are considered currently as falling outside the restrictive scope of recoverable damage under the Liability Convention [57].

5. CONCLUSIONS

The use of AI technology expands the boundaries of real-time exchange and accurate analytical processing of big data sets regarding space debris identification, location, and collision risks. These benefits can only be put to good use under a multilateral cooperation scheme of monitoring and communication/exchange of information [58]. Albeit the lack of explicit international legal obligations for space mitigation and SSA data sharing activities, State cooperation has been growing under multilateral/bilateral auspices of Space Situational Awareness data sharing agreements [59]. Notwithstanding the critical national security interests attached to SSA activities, emerging international practice in data sharing collaboration and the proliferation of outer space activities can build upon existing regional cooperation, as the European Space Agency (ESA) SSA Program, so as to establish an international partnership scheme for SSA monitoring and data sharing. The said mechanism should operate in the context of a multilateral framework of specific obligations for space debris mitigation and relevant SSA data processing activities that could, preferably, take the form of non-binding, yet agreed, international principles to be further enacted under national legislation, with Remote Sensing Principles serving here as a beneficial precedent [60].

In this context, specific AI regulatory concerns should also be addressed by adapted principles/guidelines of design and operation that elaborate further on aspects more crucial to the sustainable use and accessibility of outer space, such as the data governance and transparency element for AI deployment.

Finally, particular considerations emerge from liability implications related to harmful effects of AI deployment. As demonstrated by civil liability regimes under national jurisdictions and relevant work in progress, the harmful effects of AI-based systems in outer space operations merit adapted liability rules so as: a) Strict liability can be attributed in broader circumstances than those provided under the Liability Convention Regime, since AI systems operating in outer space activities could be considered, under circumstances, as high-risk, in terms of bearing a significant potential to cause harm or damage.

b) Fault-based liability rules establish a comprehensive standard of care eligible to demonstrate what should have been the proper course of action, taking into consideration AI operations' complexity.

c) Types of AI-related material or non-material damage considered currently as falling outside the scope of recoverable damage under the Liability Convention but expected to be more relevant/significant in the future due to the proliferation of emerging digital technologies, are further specified and appropriately addressed.

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[5] *Supra* [1], p. 49
[6] Such reference is made *inter alia*, in OST art. and OST, art. VIII. In addition to that, the term is mentioned in the Rescue Agreement, art. 5, in the Liability Convention, art. 1.d, in the Registration Convention, art. 1.b and in the Moon Agreement, art. 12 and 13.
[7] For a definition of space debris, see *inter alia* definition in COPUOS *Space Debris Mitigation*

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[8] *Supra* [3], Joel A. Dennerley J.A. p. 283 and also Weeden B., Overview of the legal and policy challenges of orbital debris removal, *SPACE POLICY* Vol. 27 (2011), 38-43.
[9] The liability regime consists in a specification within the meaning of OST, art. VII (damage caused "by such object or its component parts") and is further explained in the Liability Convention, art. II and art. III. The rules apply to damage caused by space debris, on the ground of art. I (d) of the Liability Convention.
[10] *Idem.*
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