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Artificial Intelligence in Space: Overview of the European Space Agency and its Role in the AI Environment

Abstract

ESA was established on 30 October 1980. It currently has twenty-three Member States, and its mission is to shape the development of the European space capability and to ensure that investment in space is continued in the direction of bringing benefits to European citizens and the world. Artificial intelligence (AI) can be seen as intelligence exhibited by machines that can observe, perceive and act upon their environment to maximise their chance of success at a given goal. AI can be an important and enabling technology for space missions, bringing added value for scientific return and for the efficiency of the mission itself. The most successful AI implementations are still rarely used in the space industry today, as the models developed within the neural network are not human-readable. Despite the challenges, there are examples where AI is successfully being demonstrated in the space sector through ESA's own activities. The fast-evolving field of space research and technology, AI, and the related applications are raising numerous doubts and debates while challenging the adequacy of traditional space law. There is a looming concern as to whether the legal framework is up to date to meet the challenges that may arise within the AI and space sector, and what can be done to meet those challenges accordingly and on time. Others also argue that, in addition to liability concerns, ensuring confidentiality and data protection are some of the more acute issues in the context of AI.

Key words

European Space Agency, space research, artificial intelligence, space law, legal challenges.

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1. Introduction

The present article provides a general overview of the European Space Agency (ESA) as an intergovernmental organisation, together with its mandate, structure, and the main elements of its inner workings. It is essential to understand the purpose of ESA and its role in the current landscape of space research and technology, in which one of the topical areas of discussion is artificial intelligence (AI). The article introduces how ESA is either affected by or acting upon the current status of AI in space developments. The most important and visible projects of ESA that have been based on the use of AI, either in their development stages or in their operational phases are presented.

The article discusses ESA's current role in the international environment as one of the leading and most innovative space agencies in the world, as well as future challenges and solutions related to the use of AI in space, in which ESA may have to play a crucial role, not only technically, but equally in establishing and promoting the necessary legal framework. The objective of the article is to confirm the increasing use of AI in ESA's activities and whether or not current special regulations are sufficient for the rapid developments of AI in space research and technology. If the latter fails to be the case, the article will present some of the solutions that could bring regulation to a satisfactory level on which society at large can rely and from which it can benefit.

The article's objective is achieved through collecting the necessary information on ESA, AI and the interconnection between the two while analysing the currently available legislation on AI—namely AI in space—in international and regional environments through a comparative method and deduction.

1.1. Key definitions

European Space Agency: ESA is an international organisation with 23 Member States. By coordinating the financial and intellectual resources of its Members, it can undertake programmes and activities far beyond the scope of any single European country.[1]

Artificial Intelligence: the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages.[2]

Space Law: the body of law governing space-related activities. Space law, much like general international law, comprises a variety of international agreements, treaties, conventions, and United Nations General Assembly resolutions as well as rules and regulations of international organisations.[3]

The views expressed herein are a collection of information already available in the public domain, and can in no way be taken to reflect the official opinion of the European Space Agency.

1 ESA (without a date).

2 OxfordLanguages, 2024.

3 UN Office for Outer Space Affairs, 2024.

2. European Space Agency as an Intergovernmental Organisation

For over five decades, the European Space Agency (hereinafter ESA) has been—and continues to be—the heart of European space research and technology. It is an intergovernmental organisation that comprises twenty-three Member States[4] and is Europe's gateway to space. It was established out of the merger between the previous European Space Research Organization (ESRO) and the European Launcher Development Organization (ELDO),[5] on 30 May 1975,[6] through the signature of the Convention for the establishment of a European Space Agency (hereinafter ESA Convention) by the ten founding Member States.[7]

Its mission is to shape the development of Europe's space capability and to ensure that investment in space continues to deliver benefits to the citizens of Europe and the world, while its purpose is to promote cooperation among European States in space research and technology and their space applications, exclusively for peaceful purposes.[8] By coordinating the financial and intellectual resources of its members, it can undertake programmes and activities far beyond the scope of any single European country.[9]

In addition to the mandate and purpose described above, ESA shall also facilitate the exchange of scientific and technical information related to space research and technology and their space applications.[10]

ESA's activities and programmes fall into two categories—"mandatory" and "optional". Programmes carried out under the General Budget and the Space Science programme budget are "mandatory"; they include the Agency's basic activities (studies on future projects, technology research, shared technical investments, information systems and training programmes, as well as basic infrastructure and general services).[11] All Member States contribute to these programmes on a scale based on their Gross National Product

4 As of August 2017, the Member States are Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, and the United Kingdom, while Slovenia officially became ESA's 23rd full Member State on 1 January 2025. Slovakia, Latvia, and Lithuania are Associate Members. Canada takes part in some projects under a cooperation agreement. Bulgaria, Croatia, Cyprus, and Malta have cooperation agreements with ESA. ESA (without a date).

5 ESA Convention, Article XIX.

6 ESA Convention entered into force on 30 October 1980.

7 Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Sweden, Switzerland, and the United Kingdom.

8 ESA Convention, Article II.

9 ESA (without a date).

10 Article III, ESA Convention.

11 ESA (without a date).

(GNP),[12] and they amount to about 20% of the funding ESA receives from its Member States.[13]

The other programmes, known as 'optional', are only of interest to some Member States, who are free to decide on their level of involvement. Optional programmes cover areas such as Earth observation, telecommunications, integrated applications, human and robotic exploration, satellite navigation and space transportation. Similarly, the International Space Station and microgravity research are financed by optional subscriptions.[14]

Another, third source of ESA funding stems from third-party activities, where ESA manages space-related activities on behalf of organisations such as the European Union (EU) or Eumetsat. Examples include Galileo, parts of Copernicus, and recurrent Meteosat and Metop satellites. The industrial participation in these activities is regulated by each respective agreement.[15]

For both mandatory and optional projects, the industrial activity in each Member State must be commensurate with that Member State's funding of each project. In this sense, programmes are independent of each other, and excess activities in one may not compensate for a low (with respect to the funding) participation in another.[16] Contributions are not only financial but can also be technological or industrial. Activities may be related to advanced research, project-related technology developments, production, operations, support, and services. ESA aims to make maximum use of the industrial and research potential and capabilities available in each Member State, whilst supporting the Member State's interests and priorities.[17]

To this end, ESA's industrial policy[18] has four specific aims: to meet the European space programme requirements in a cost-effective manner;[19] to improve the worldwide competitiveness of European industry;[20] to ensure that all Member States participate in an equitable manner, with regard to their financial contribution, in implementing the European space programme;[21] and to exploit the advantages of free competitive bidding in all cases[22]. To monitor industrial policy, ESA permanently reviews the industrial po-

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12 *Ibid.*; ESA Convention, Article XIII.

13 ESA (without a date); ESA Convention, Article V(1)(a).

14 ESA (without a date).

15 *Ibid.*

16 *Ibid.*

17 *Ibid.*

18 ESA Convention, Article VII and Annex V.

19 *Ibid.*, Article VII(1)(a).

20 *Ibid.*, Article VII(1)(b).

21 *Ibid.*, Article VII(1)(c).

22 *Ibid.*, Article VII(1)(d).

tential and industrial structure in relation to the Agency's activities.[23] A very distinctive characteristic of ESA and its industrial policy is the so-called geographical distribution,[24] whereby the distribution of contracts placed by ESA should ideally result in all countries having an overall return coefficient (i.e. the ratio between a country's percentage share of the total value of all contracts awarded among Member States and its total percentage contributions) of 1.

The Council is ESA's governing body and provides the basic policy guidelines within which ESA develops the European space programme. Each Member State is represented on the Council and has one vote, regardless of its size or financial contribution.[25] The executive branch of the organisation is vested in the Director General, who is the chief executive officer and the legal representative of ESA, and who is responsible for the execution of ESA's programmes and policies.[26]

ESA has a legal personality,[27] and ESA, its personnel, experts and representatives of its Member States enjoy legal capacity, privileges and immunities.[28] Furthermore, the agreements concerning ESA's establishments are implemented directly between ESA and the respective host nation(s).[29] Its legal subjectivity is further defined in Annex I to the ESA Convention, where it is stated that ESA has a legal personality and specifically has, among other things, the ability to conclude agreements or contracts, acquire and dispose of movable and immovable property and be a party to legal proceedings.[30]

3. Artificial Intelligence within ESA

3.1. Definition and Branches of Artificial Intelligence

It is no surprise that AI can be an important and enabling technology for space missions, bringing added value for scientific return and for the efficiency of the mission itself. Latency, mission design, development, operations, data exploitation, proficiency and availability are all factors in space missions that can benefit from the introduction of AI.[31]

Already in 2003, with the vision that ESA is rich in data, the organisation started to consider the use of AI in very specific use cases, mainly focused on enhancing ground op-

[23] ESA (without a date).

[24] ESA Convention, Annex V, Article IV.

[25] ESA Convention, Article XI; ESA (without a date).

[26] ESA Convention, Article XII.

[27] *Ibid.*, Article XV(1).

[28] *Ibid.*, Article XV(2).

[29] *Ibid.*, Article XV(3).

[30] *Ibid.*, Annex I, Article I.

[31] Fratini, 2019, p. 6.

erations tasks with some examples including spacecraft health management and support to operations decision processes.[32]

The initial proofs of concept for introducing AI in space were accomplished mostly in the area of space operations with acknowledged success, and eleven applications have been deployed in operations in support of seventeen missions. In addition, ESA holds a leading position worldwide in AI applications for early detection and anomaly investigation, with two patents.[33]

However, to properly contextualise the role of AI, specifically its role in the space sector, a first definition of AI had to be established. One such definition within the space research community was given in the AI for Earth Observation (AI4EO) research and development (R&D) community consultation, where AI can be seen as:

> "intelligence exhibited by machines that can observe, perceive and act upon their environment to maximize their chance of success at some goal. It refers to the capacity of an algorithm for assimilating information to perform tasks that are characteristic of human intelligence, such as recognizing objects and sounds, contextualizing language, learning from the environment, and problem solving."[34]

Furthermore, the term AI can be seen as:

> "comprising all techniques that enable computers to mimic intelligence, for example, computers that analyse data or the systems embedded in an autonomous vehicle. Usually, artificially intelligent systems are taught by humans—a process that involves writing an awful lot of complex computer code."[35]

While the foundations for the AI definition have been laid, ESA has also introduced some of the AI technologies and identified areas of development, operation and exploitation of ESA space missions where these technologies might enhance existing approaches or even be game-changers.[36]

Four main application areas were identified in ESA for AI-oriented activities, namely the development area (design, operation concepts, quality assurance, etc.), operations area (mission planning support and optimisation, automated operations, ground stations management, etc.), exploitation (Earth observation data, space science data, navigation science data, etc.) and other areas such as research, education and training, knowledge management, etc.[37]

The broad scope of domains where AI can be applied has also been recognised by the 2019 ESA Technology Strategy, admitting the significance of the emerging AI sector:

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32 *Ibid.*, p. 7.

33 *Ibid.*

34 AI4EO Workshop, 2018, p. 3.

35 ESA, 2023.

36 Fratini, 2019, p. 4.

37 *Ibid.*, p. 6.

> "Given the real-life benefits already seen by early adopters, artificial intelligence (AI) is considered to be at the core of the next wave of digital disruption, accelerating competition and speeding up digital transformations."[38]

The leading position that ESA has in the AI field was reiterated through the aforementioned ESA Technology Strategy, since ESA has been at the cutting edge of academic AI research related to space, while European space industry and services capitalise on previously academic-driven research.[39] The importance of AI for both the present and the future is evident from the plan for a 30% improvement in spacecraft development by 2023, where technology development from all competence domains will be critical to achieving this goal. This success largely depends on the further development of digital engineering, automation and artificial intelligence.[40] AI is also envisaged to contribute significantly to achieving a 30% faster development and adoption of innovative technology.[41]

3.1.1. Machine Learning

AI can be achieved through machine learning (ML), which "simply" means teaching machines to learn for themselves. It is a way of "training" a relatively simple algorithm to become more complex using huge amounts of data fed into the algorithm, which then adjusts and improves itself over time.[42]

The AI for Earth Observation (AI4EO) workshop provided, among other terminology, the definition of the machine learning aspect of AI, identifying it as:

> "a branch of AI relying on algorithms that are capable of learning from both data and through human interactions (e.g. supervision) to enable prediction, but is also used for data mining (i.e. discovery of unknown properties and patterns). ML is a field of statistical research for training computational algorithms that split, sort, transform a set of data in order to maximize the ability to classify, predict, cluster or discover new patterns in target datasets. ML is all about using computers to learn how to deal with problems without programming. In fact, ML generates models by taking some data for training a model, and then makes predictions."[43]

ML has been used for Earth Observation data exploitation even before the advent of cloud computing and big data technologies. Experiments based on the classification of satellite images with very shallow (two layers max) neural networks were performed

38 ESA, 2019, p. 17.

39 *Ibid.*

40 *Ibid.*, p. 25.

41 *Ibid.*, p. 26.

42 ESA, 2023.

43 AI4EO Workshop, 2018, p. 3.

using ERS-1/2[44], ENVISAT[45] and Copernicus[46] products for specific test sites. From the early 2000s onwards, there have been a consistent number of projects where simple neural networks were applied to ESA data, for example SAR/ASAR[47] data for recognising oil spills and ships, data mining applied to optical data at different resolutions, inversion of atmospheric measurements, etc.[48]

Tools based on neural networks have been also assessed for Earth Observation ground segments even before the deployment in space of the first Copernicus components. Activities have been kicked-off (especially for optical missions) to enhance cloud and shadow detection by feeding simple Neural Networks with morphological information together with pixel measured counts.[49]

3.1.2. Deep Learning

Another branch of AI is the so-called deep learning (DL), a specialised technique within machine learning, whereby the machine utilises multi-layered artificial neural networks to train itself on complex tasks such as image recognition. This can happen via supervised learning (for example, feeding the system Moon and Earth pictures until it can successfully identify both) or via unsupervised learning (for example, the network finding the structure by itself). Some examples of DL include online translation services, and navigation systems for self-driving cars or spacecraft.[50]

The AI for Earth Observation (AI4EO) workshop defined deep learning as:

> "a type of ML algorithm that aim to solve the same kind of problems by mimicking the biological structure of the brain and construct hierarchical architectures of increasing sophistication […] Today, DL is reaching high-level accuracy going beyond human performance, holding promises that they could substitute handcrafted feature extraction, thereby enabling totally automatic image recognition of big data (including Earth Observation) and opening huge opportunities for new science and business."[51]

Researchers and engineers have attempted to apply these new DL techniques to problems related to vegetation and/or water monitoring, object recognition and land use classification from space, while the tools made available by ESA for the elaboration of Copernicus data were also based on the first neural networks algorithms.[52]

44 ESA – earth online, (without a date).

45 *Ibid.*

46 ESA, (without a date).

47 ESA – earth online, (without a date).

48 Fratini, 2019, p. 7.

49 *Ibid.,* pp. 7 and 8.

50 ESA, 2023.

51 AI4EO Workshop, 2018, p. 3.

52 Fratini, 2019, p. 7.

3.2. Proven AI Application Examples in ESA Projects

There are examples where AI has been, and still, is successfully demonstrated in the space sector through ESA's own activities. Although it may seem like a big step to move from basic activities to real space applications, ESA is already starting to use AI in its space missions as well.[53]

3.2.1. Data Handling: ϕ-sat-1 (Phisat-1)

ϕ-sat-1 (pronounced phisat-1) is artificial intelligence technology carried on one of the two CubeSats that make up the Federated Satellite Systems mission (FSSCat). The FSSCat mission is based on two CubeSats, each about the size of a shoebox, which use state-of-the-art dual microwave and multispectral optical sensors to measure, for example, soil moisture, ice extent, ice thickness, urban heat islands, and to monitor changes in vegetation and water quality. To take FSSCat to the next level, ESA worked with partners to develop ϕ-sat-1 to not only give FSSCat more spectral capabilities, but also to improve the efficiency of sending vast quantities of data back to Earth.[54]

ϕ-sat-1 is the first artificial intelligence to be carried on a European Earth observation mission. Its hyperspectral camera images in the visible, near-infrared and thermal-infrared parts of the electromagnetic spectrum, acquiring an enormous number of images of Earth. However, some images will not be suitable for use because of cloud cover. To avoid downlinking these less-than-perfect images, the ϕ-sat-1 artificial intelligence chip filters them out so that only usable data are returned. This will make the process of handling all these data more efficient, allowing users more timely access to information, ultimately benefiting society at large.[55]

3.2.2. Operations: Mars Express

Another example of AI application is Mars rovers, which can navigate around obstacles by autonomously finding their way across "unknown" fields. Intelligent data transmission software on board the rovers removes human scheduling errors that might otherwise cause valuable data to be lost, and increases the volume of useful data that arrives from our planetary neighbour.[56]

In addition to the rovers exploring Mars on its surface, ESA's orbiter Mars Express has been using its sophisticated instruments since January 2004 to study the atmosphere, surface and subsurface of Mars, confirming the presence of water and looking for other signatures of life on and below the rocky terrain. The spacecraft generates huge volumes of scientific data, which must be downloaded to Earth at the right time and in the correct

53 ESA, 2023.

54 ESA, (without a date).

55 *Ibid.*

56 ESA, 2023.

sequence. Otherwise, data packets can be permanently lost when the limited on-board memory is overwritten by newly collected data. Traditionally, data downloading was managed using human-operated scheduling software to generate command sequences sent to Mars Express, instructing it when to dump specific data packets.[57]

A new "smart" tool, dubbed MEXAR2 ("Mars Express AI Tool"), has been developed and successfully passed initial testing and validation. It is now an integral part of the Mars Express mission planning system. MEXAR2 works by considering the variables that affect data downloading—including the overall science observation schedule for all Mars Express instruments—and then intelligently projecting which on-board data packets might later be lost due to memory conflicts. It then optimises the data download schedule and generates the commands needed to implement it. By doing so, the MEXAR2 tool has reduced the mission planning team's workload by about 50 percent compared to the old manual method. AI provides solutions for complex problems and has now entered the space mission operations field as a value-adding technology. Mars Express represents the very first European deep-space exploration mission to fly using an AI tool on the ground.[58]

3.2.3. Deep-Space Operations: Hera

Hera is the first probe to rendezvous with a binary asteroid system, to examine the aftermath of the first kinetic impact test of asteroid deflection,[59] which was performed by NASA with its Double Asteroid Redirection Test (DART) in September 2022.[60] ESA's Hera planetary defence mission will make use of AI as it steers itself through space towards an asteroid, taking a similar approach to self-driving cars. While most deep-space missions have a definitive driver back on Earth, Hera will fuse data from different sensors to build up a model of its surroundings and make decisions on board, all autonomously.[61]

3.2.4. Guidance, Navigation & Control (GNC), and Visual Operations: ClearSpace-1

> "In more than 60 years of space activities, more than 6,050 launches have resulted in some 56,450 tracked objects in orbit, of which about 28,160 remain in space. Only a small fraction—about 4,000—are intact, operational satellites today."[62]

As this ever-increasing threat of space debris is more pressing than ever, ESA decided to tackle the issue with the world's first space debris removal mission, ClearSpace-1.

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57 ESA, 2008.

58 *Ibid.*

59 ESA, (without a date).

60 NASA, 2024.

61 ESA, 2023.

62 ESA, (without a date).

Its objective is to be the first mission to remove a piece of space debris from orbit and to rendezvous with, capture and safely bring down a large derelict object for a safe atmospheric re-entry. The object in question is a 112 kg defunct rocket part—the Vespa upper stage (launched in 2013)—with the target object altitude ranging from 664 to 801 kilometres.[63] Crucial technologies include the advanced guidance system, navigation and control systems, the robotic arms used to capture space debris, and vision-based artificial intelligence, equipped with an AI camera to locate the debris.[64] All these cutting-edge technologies were developed as part of ESA's Clean Space initiative.[65] [66]

3.2.5. Satellite Autonomy: Transfer Lab

Furthermore, in relation to space debris, satellites orbiting Earth also require greater autonomy, as they need to make more frequent collision avoidance manoeuvres to evade increasing amounts of debris. In January 2021, ESA and the German Research Center for Artificial Intelligence (DFKI) established a technology transfer lab that works on AI systems for satellite autonomy and collision avoidance capabilities, among other aspects.[67] The Transfer Lab at DFKI in Kaiserslautern creates a framework in which scientists from both organisations research AI systems for the interpretation of complex, extensive data from Earth observation, and for collision avoidance of satellites.[68]

3.2.6. Autonomous Image Processing: HyperScout Imager

The HyperScout imager, tested in orbit aboard the Gomx-4B cubesat, acquires and processes hyperspectral environmental imagery on an autonomous basis.[69] It is a "linear variable filter" instrument, meaning each horizontal line of pixels it observes is seen at a different wavelength from 400 to 1000 nanometres). The onward movement of the satellite allows the rapid build-up of a complete hyperspectral image. The instrument targets specific regions across the globe, aiming to highlight rapid changes such as flooding, fire hazards, or variations in vegetation, or land cover and use between acquisitions.[70]

3.2.7. Database Development & Exploitation: MiRAGE

As the institutional focal point for the European space sector and industry, ESA also supports start-up companies to increase their worldwide competitiveness. One example

63 *Ibid.*

64 Abashidze, Ilyashevich & Latypova, 2022.

65 Space Explored, 2020.

66 ESA, 2014.

67 ESA, 2023.

68 German Research Center for Artificial Intelligence, 2021.

69 ESA, 2019, p. 17.

70 ESA, 2018.

is an Italian start-up company, AIKO, which develops state-of-the-art AI for space applications for mission autonomy with their MiRAGE library. MiRAGE—also known as Mission Replanning through Autonomous Goal gEneration—is a software library that enables autonomous operations for space missions.[71]

By shifting decision-making on-board the satellite, the MiRAGE library eliminates the decision-making loop in the ground Mission Control Centre for all the events that were accounted for during spacecraft development, including failures, events related to mission objectives, or events generated by other elements in a constellation. Operators can focus on more critical decisions requiring ground intervention. The result is increased efficiency, with mission objectives being fulfilled sooner, and downlink bandwidth being occupied only by relevant data.[72]

3.2.8. Visualisation & Forecasting: Digital Twin of Earth

ESA is currently working towards a Digital Twin of Earth, a replica constantly fed with Earth observation data and artificial intelligence to help visualise and forecast natural and human activity on the planet to better understand Earth's past, present and future. In September 2020, ESA launched several Digital Twin Earth Precursor Activities to explore some of the main scientific and technical challenges in building a digital twin of Earth. These activities included: Forest, Hydrology, Antarctica, Food Systems, Ocean and Climate Hot Spots, each addressing a different scientific, technical, and operational challenge regarding the Digital Twin of Earth, including the role of AI and consistent data, stakeholder engagement scientific credibility and the role of sectorial models.[73]

3.3. Challenges for the Present and Future

Despite some of these useful applications of AI in space exploration and research, the most successful AI implementations based on machine learning (ML) or deep learning (DL) are rarely used in the space industry today, as the models developed within the neural network are not human-readable and thus far have been impossible to replicate.[74]

In addition, before ML and DL can fully take over the space sector, the complex models and structures needed must be improved, as well as the reliability and adaptability required in the new software.[75]

AI—and in particular ML—still has some way to go before it is extensively used for space applications; however, it is already being implemented in new technologies.

71 *Ibid.*

72 *Ibid.*

73 ESA, 2021.

74 ESA, 2023.

75 *Ibid.*

One area in which the application of AI is being thoroughly investigated is satellite operations, specifically in support of large satellite constellations, which includes relative positioning, communication, end-of-life management, etc.[76] Another example of ML application is approximating complex representations of the real world, namely in analysing massive amounts of Earth observation data or telemetry data from spacecraft, or when transmitting data from Mars rovers, which is essentially done through AI.[77]

Therefore, confidence is growing that AI can be of support for future space missions, although some critical concerns still loom—particularly where an application provides too many false positives rendering it difficult to accept as an operational aid. Simultaneously, AI has made significant progress in recent years, aided by increased computational power and miniaturisation. These advances will enable the progressive introduction of AI on board spacecraft, in support of specific mission operational tasks.[78]

4. ESA and AI in the Legal Environment

4.1. ESA in the International Space Law Environment

The first section above elaborated on the ESA's legal personality: ESA and its personnel, experts, and representatives of its Member States enjoy privileges and immunities. Its legal subjectivity is further defined in Annex I to the ESA Convention, where it is stated that ESA has a legal personality and specifically has, among others, the ability to sign agreements/contracts, including those that fall within international law.

Space law is a branch of international law which has the specificity of being influenced by other sources of law, both of a public and private character. There are many laws and regulations that should also be applied, particularly in view of the increase in privatisation, and, as such, the law applicable to space activities is not and should not be limited only to outer space law.[79]

When discussing space law, it is important to bear in mind at all times three important points:

– the "territory" that space law regulates—outer space including celestial bodies—is outside the sovereignty of states;
– outer space activities are to be conducted for the benefit of, and in the interests of, all states, irrespective of their degree of economic or scientific development;
– outer space activities are the "province of all humankind".[80]

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76 *Ibid.*

77 *Ibid.*

78 Fratini, 2019, p. 8.

79 ESA, (without a date).

80 *Ibid.*

Factors such as the increase in daily activities dependent on space technology, the national interests of the countries involved, and the commercialisation/privatisation of outer space have all resulted in the political will that implemented the treaties and principles we have in place today.[81]

The United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS) was set up by the General Assembly of the United Nations in 1959 to govern the exploration and use of space for the benefit of all humanity. COPUOS was tasked with reviewing international cooperation in the peaceful uses of outer space, and for that very purpose had the merit of adopting five treaties and principles: Outer Space Treaty;[82] Rescue Agreement;[83] Liability Convention;[84] Registration Convention;[85] and the Moon Agreement.[86]

ESA has enjoyed special observer status in COPUOS since 1972[87] and has declared rights and obligations for three out of the five treaties (i.e. Rescue Agreement, Liability Convention, Registration Convention),[88] and its accession to a treaty has the same consequences as an individual country acceding to or ratifying a treaty. However, the concern remains—as with all international treaties—that not all countries are parties to these legal instruments. With the interdependence of law and technology, and the increased repercussion of space activities on the ground, it is hoped that more countries will become aware of the necessity for this legal framework set up by COPUOS, while "it is to be hoped that ESA will be an example for other international organisations."[89]

Another example of ESA leading the way is ESA's own "Resolution of the Council of the European Space Agency on the Agency's Legal Liability" from December 1977, which defines the consequences of the legal responsibilities of ESA in the event of injuries and damages caused by ESA to one of the Member States, legal or natural persons, or any other third party. This shows ESA's willingness and preparedness to address and implement the legal framework needed for activities undertaken within the space sector.

81 *Ibid.*

82 The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, 610 UNTS 205, entered into force on 10 October 1967.

83 The Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, 672 UNTS 119, entered into force on 3 December 1968.

84 The Convention on International Liability for Damage Caused by Space Objects, 961 UNTS 187, entered into force on 1 September 1972.

85 The Convention on Registration of Objects Launched into Outer Space, 1023 UNTS 15, entered into force on 15 September 1976.

86 The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, 1363 UNTS 3, entered into force on 11 July 1984.

87 United Nations, Office for Outer Space Affairs, (without a date).

88 Committee on the Peaceful Uses of Outer Space, Legal Subcommittee, 2022, p. 10.

89 ESA (without a date).

Considering that the liability aspect of entities is of major importance, especially in the international space law environment, it is also worth noting (with respect to ESA) the 2011 Draft Articles on the Responsibility of International Organizations (DARIO) adopted by the International Law Commission. Within its provisions, it is defined that every internationally wrongful act of an international organisation entails the international responsibility of that organisation,[90] and the two elements which entail this international responsibility are that the wrongful act or omission is attributable to the organisation under international law, and that the act or omission constitutes a breach of an international obligation of that international organisation.[91] DARIO concludes by stating that these draft articles do not apply where and to the extent that the internationally wrongful acts and international responsibilities are governed by special rules of international law.[92] *Lex specialis*, in this case, could be the Liability Convention.

4.2. Current Legal Challenges for AI and Its Space Applications

4.2.1. Adequacy of the Current Legal Framework for AI in Space

While international space law provides relevant treaties and principles, more will need to be done in terms of the evolving space technologies, specifically with the emergence of AI in the last few decades. The fast-evolving field of space exploration, AI, and related applications is raising various concerns about whether the legal framework is up to date to meet the challenges that may arise within the AI and space sector, and what can be done to address those challenges on time.

Experts in the field are in agreement when discussing the two sides of the coin that is AI: on the one hand, one cannot deny the benefits that AI and its evolution brought during these last few decades—not only to our everyday life but to space missions as well, where huge potential nonetheless still awaits to be fully exploited. On the other hand, a number of issues are arising simultaneously with the increasing use of AI, therefore challenging the adequacy of traditional space law to address these problems.[93] It is to be noted that, as it stands now:

> "the increasing autonomy of AI-deployed space objects, coinciding with the associated decreasing role of human 'control', does not sit squarely in sync with existing space law concepts, particularly with respect to liability for damage caused by space objects, and the obligations of states for continuing supervision of national activities in space as well as for controlling space objects".[94]

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90 Article 3.

91 Article 4.

92 Article 64.

93 Bratu & Freeland, 2022.

94 *Ibid.*

In addition to the framework for liability for damages and its non-alignment with AI development and use, the introduction of AI systems into space activities entails other legal consequences and problems. First, as individual legal acts contain different approaches to defining AI, the main difficulty is to establish the essence of "artificial intelligence", since in order to regulate relations efficiently, it is necessary to understand what the subject and object of these relations are.[95] Second, and in addition to the very essence of AI, its legal status is currently also not defined. It is inappropriate to apply existing legal categories to determine the status of AI, given that its character is autonomous from humans and it makes decisions based on the ability to learn by itself.[96] Third, the use of AI in space carries a high risk in high volumes, which differ from those emerging from other aspects of everyday life. Fourth, the existing international treaties, specifically those regulating space activities, do not cover issues arising from the potential use of AI.[97]

Specifically, the latter—the current legal framework of international space law—has been the talking point of many specialised forums, one of which was organised by "Friends of Europe", where the present and upcoming issues of such a framework were addressed. Most participants agreed that the Outer Space Treaty has done a good job of keeping peace and order beyond the Earth's atmosphere; however, the treaty dates back to 1967, when satellite technology was in its infancy. Now, with more and more satellites in orbit and an increasing number of countries managing space-based assets, there is a pressing need to upgrade space governance.[98] These existing major treaties obviously do not contain provisions related to the use of AI, while acts of "soft law", which play a large role in the regulation of space activities, also do not contain provisions regarding the use of AI technologies.[99] A separate problem could also emerge where not all states carrying out space activities have the necessary level of development that allows the use of AI. The question arises whether it is possible to regulate the activities of states in the same way, or whether it is necessary to develop standards taking this difference into account.[100]

The debate further assessed the efficacy of the existing treaties and regulations and explored whether it was time for an upgrade and update, as well as how to craft an enforceable framework empowered to manage the warp-speed technological developments transforming the use of space in the 2020s. A broad agreement was reached that improvements in governing space are needed—and fast—while the Legal Counsel to ESA clearly stated that:

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95 Abashidze, Ilyashevich & Latypova, 2022.

96 *Ibid.*

97 *Ibid.*

98 Friends of Europe, 2021.

99 Abashidze, Ilyashevich & Latypova, 2022.

100 *Ibid.*

> "the global system is fit for today, for what we have done so far but [the] question is, is it still fit for tomorrow, for the technological advances that we're planning to do tomorrow? […] From what we see is happening, probably it will not be enough anymore, as we need more, with more precise principles, even regulations and […] more enforceable regulations and standards."[101]

The International Astronautical Federation (IAF) also gave floor to its 36th IAA/IISL Joint Roundtable, where participants discussed the legal challenges of autonomous intelligent systems in space. The premise was that artificial intelligence-based autonomous systems for space operations are opening up a whole new set of questions about how these interact with existing legal concepts and technical standards. Very little human intervention will be required beyond the programming, and one of the first questions is the extent to which the laws—particularly space laws—governing these technologies on Earth are relevant and applicable to these activities in outer space. It is becoming ever clearer that the growing reliance on autonomous technologies may require a fresh look at the traditional concepts behind the regulation of space activities, while recognising that the existing body of legal rules, regulations, and practices will eventually be impacted by these technical developments.[102]

> "This will inevitably also include how AI technologies relate to the traditional understandings of legal responsibility and liability under national and international space law."[103]

For example, if the machine is not considered a subject but only an object or instrument of the person who created it, this would not require any change to the existing legal framework as we know it. However, only recently, the question of the responsibility of the machine itself has arisen, which would stir up these traditional approaches.[104]

It has been reiterated and discussed in a similar manner across the field of legal experts due to the fact that the absence of special regulation in this area is inherently connected with the emergence of many difficult situations in the future:

> "in particular, the increasing use of artificial intelligence technologies in space activities raises questions in areas such as data protection, transparency and non-discrimination, cybersecurity, intellectual property, international responsibility and liability, etc."[105]

These areas are getting increasingly intertwined with space applications, similarly to other everyday applications that society at large depends on, but which might not have been considered or linked to space research before. Certain ethical and social risks also

[101] Friends of Europe, 2021.

[102] IAF, 2022.

[103] *Ibid.*

[104] Abashidze, Ilyashevich & Latypova, 2022.

[105] *Ibid.*

arise with AI development, for example its use with space technologies for purposes of law enforcement.[106] Other examples include:

> "'*facial recognition*'; lack of transparency (the subject is not informed that his or her personal data is being collected); tracking and de-anonymizing data; lack of access rights, correction and deletion of data (the so-called black-box effect); bias and discrimination, and, as a result, unreliable results and many others".[107]

Striking the right balance between using AI for preventing or solving crimes and avoiding violation of human rights should be a priority. To this end, elements such as discrimination and data protection are increasingly in the spotlight.[108]

4.2.2. Solutions to the Current Challenges and are They Sufficient?

The effects of space activities are becoming far-reaching, not limited to only a few select capable countries and organisations, but propagated all around the world. We are seeing an increase in public discourse surrounding AI and how to regulate it, and it is equally imperative that its "sub-chapter", *AI in space*, receives the same level of attention. Should the absence of special regulations persist and lag behind the aggressive timeline of AI technological development, we risk maintaining a legal void the space sector cannot afford.

To this end, issues related to the use of AI in space are increasingly being raised, and the need for a separate understanding of these issues at the international legal level is driven by the rapid development of technologies in this area, which can radically affect the process of space exploration and the diversification of types of space activities. Some examples also include national legal initiatives at the level of individual states.[109] As much as this is welcomed and encouraged, it can potentially lead to the dominance of the interests of individual states when carrying out activities in outer space.[110] In addition, there are initiatives from non-governmental organisations and academia, such as the Future of Life Institute, which adopted the *Asilomar Principles on Artificial Intelligence*; the University of Montreal, which prepared the *Montreal Declaration for a Responsible Development of Artificial Intelligence*; and Amnesty International and Access Now, which proposed the Toronto Declaration on *the protection of the rights to equality and non-discrimination in machine learning systems*. All these different initiatives should be carefully weighed to create a unified and harmonised approach, namely with a priority to adapt

106 Soroka & Kurkova, 2019, as cited in Abashidze, Ilyashevich & Latypova, 2022.

107 Gal *et al.*, 2020, as cited in Abashidze, Ilyashevich & Latypova, 2022.

108 Abashidze, Ilyashevich & Latypova, 2022.

109 Examples include: Executive Order 13859, "Maintaining American Leadership in Artificial Intelligence", 84 Fed. Reg. 3967 (Feb. 11, 2019); Order of the Government of the Russian Federation No. 2129-r of August 19, 2020 "On approval of the Concept for the development of regulation of relations in the field of artificial intelligence and robotics technologies for the period up to 2024"). Abashidze, Ilyashevich & Latypova, 2022.

110 *Ibid.*

already existing norms and principles for the protection of human rights and data protection when using AI.[111]

> "Given the interconnectedness of these areas of interstate cooperation, it is important to focus efforts on developing an intersectoral approach that will take into account the specifics of activities in outer space and, to the maximum extent, guarantee the observance and protection of human rights".[112]

Among other ideas put forward on how to tackle current legal challenges in governing AI in space are also calls for a global regulatory body to replace the current system based on national laws and add more efficiency to the treaties currently governing space, while highlighting especially the scale of private sector expansion as a problem.[113] Making space a political and policy priority, matched with resources comparable to other global regions, is key. If initiating solutions on a global level proves too ambitious (due to lack of political will, prioritisation of other matters, etc.), the resolution may lie in initiating solutions on a regional level first before being propagated to a global stage. To this end, the "Friends of Europe" forum and its participants were once again in agreement—this time about giving an effective political mandate to ESA and defining an EU-wide regulatory regime—both of which were considered essential foundation blocks for the future of space governance.[114] It has yet to be seen if there will be any specific political mandate given to ESA with respect to establishing a framework for AI in space and in what form, but certainly ESA, with its innovative and leading role in the larger scientific community, and with its ample heritage, present achievements, and future vision, is in a very good position to address the subject matter.

On the EU side, one step towards defining an EU-wide regulatory framework has already been taken, as it introduced the "EU AI Act", which is a proposed European law on AI, described by the EU as "the first law on AI by a major regulator anywhere."[115] Its purpose is clear from the title of the Act itself, which reads Regulation of the European Parliament and of the Council laying down Harmonised Rules on Artificial Intelligence (Artificial Intelligence Act) and amending certain Union Legislative Acts (COM/2021/206). Despite this encouraging step, a reader of the document will quickly realises that the AI it addresses does not cover AI used in space exploration or space applications and, as such, its relevance for the emerging AI legal environment in the space sector remains doubtful. A similarly encouraging, but incomplete, notion can be seen from the European Parliament resolution of 20 October 2020 with recommendations to the Commission on a civil liability regime for artificial intelligence (2020/2014(INL)).

[111] *Ibid.*

[112] *Ibid.*

[113] Friends of Europe, 2021.

[114] *Ibid.*

[115] The EU Artificial Intelligence Act.

This is a missed opportunity to take on board the imperative and topical technological and legal challenges that AI poses with its use in space research, especially with the increasing role the EU has in space through its EU Agency for the Space Programme (EUSPA) and its first integrated space programme created by the EU to support its space policy.[116] Considering that neither legal source mentions activities in space, the search for an appropriate platform, competent legal entity, or the necessary legislation to address these shortcomings on regional and international levels continues.

4.2.3. Conclusion

Despite the shortcomings of the current status of the AI sector in international space law, one can conclude that AI is a critical technology for Europe's space sector, whose growth should be accelerated by Europe strengthening its own AI capabilities. Not doing so, on the technical and legal side, would mean missing valuable opportunities for Europe to position itself in a rapidly changing AI landscape that is shaping the future. Some of the paths to be taken going ahead may be in fostering coordination and communication among the various entities that either use or conduct research in AI within ESA, or in identifying strategic initiatives to spread AI culture for innovation and to facilitate spin-off of ESA AI technology to external actors or spin-in of industrial AI technologies into ESA.[117]

The importance of AI is apparent, and the imperative goal that the legal aspects should follow the AI technical evolution—specifically in the space sector—is a responsibility the world should take on with full force. The gravity of the situation is perfectly described through the notion that:

> "AI is in the midst of a true renaissance becoming an integral part of our society, deeply transforming the way we work, operate, and live. Within the report 'AI for Earth' presented at the 2018 World Economic Forum, AI is even coined to be the new 'electricity' of the 4th Industrial revolution."[118]

116 EUSPA, 2021-2024.

117 Fratini, 2019, p. 7.

118 World Economic Forum WEF, 2018, p. 5, as cited in AI4EO Workshop, 2018, p. 3.

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