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Ukraine's 2025 Public-Private Partnership Reform and the Space Sector: Regulatory Opportunities and Implementation Constraints

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Law No. 4510-IX on Public-Private Partnership has recast the legal framework for long-term cooperation between public authorities and private investors in Ukraine. The reform is significant for the space sector, where major projects require substantial capital, specialised technology and sustained public oversight. This article examines the opportunities created by the new Law and the limits imposed by the administrative-law regime governing strategic space activity. The analysis is doctrinal and functional. It reads Law No. 4510-IX together with Ukrainian legislation on space activity, public finance, procurement, State secrecy, export control, administrative procedure, intellectual property and technology transfer, as well as relevant European and international standards. The article argues that the reform provides a more coherent basis for project preparation, effectiveness analysis, competitive selection, contractual risk allocation and public support. It also permits software, information systems, equipment and components to form part of a PPP object. These features are capable of supporting projects in satellite communications, Earth observation, ground infrastructure and related information

services. Their use remains subject, however, to the competence of public authorities, sectoral permits and declarations, certification, registration, security restrictions, export control and continuing State supervision. The practical value of the reform will therefore depend on the coordination of general PPP legislation with special space and security law, reliable budgetary planning, institutional capacity and the protection of results of space activity.

Keywords: public-private partnership; state-private partnership; space sector; Ukraine; Law No. 4510-IX; administrative law; national security.

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Introduction

The space sector combines scientific research, industrial production, communications, defence capability and the provision of public services. Its projects are usually capital-intensive, technologically complex and long-term. They may also involve classified information, dual-use technology and infrastructure whose operation affects national security. Public funding remains indispensable, but it is rarely sufficient to meet the sector's investment and modernisation needs. Cooperation with private undertakings is therefore not an optional feature of contemporary space policy; it is one of the means by which States obtain finance, technology and specialised expertise.

Public-private partnership (PPP) offers a legal structure for such cooperation when a private party invests in a project, assumes part of the project risks and undertakes long-term responsibility for creating, maintaining or operating an asset or service. It should not be confused with any contract involving a public authority and a business. International guidance treats PPP as appropriate only where it is affordable, institutionally manageable and more effective than implementation without a private partner (OECD, 2012; World Bank, 2017). These conditions are especially demanding in the space sector because technical failure, regulatory delay or loss of control over strategic technology may have consequences beyond the commercial interests of the parties.

Ukrainian legal scholarship has long identified fragmented legislation, inconsistent strategic planning, limited private investment and weak institutional coordination as obstacles to the development of national space activity (Drozd, 2019; Malysheva, 2024; Kostenko, 2024). The adoption of the Law of Ukraine on Public-Private Partnership No. 4510-IX on 19 June 2025, which entered into force on 31 October 2025, changed the general legal framework within which those problems must now be considered. The Law repealed the 2010 statute on state-private partnership and introduced a more detailed scheme for project preparation, analysis, selection, contracting, support and monitoring (Law No. 4510-IX, 2025).

The reform does not create a separate category of space PPP. It does, however, cover fields directly relevant to space activity, including security and defence, scientific and scientific-technical activity, electronic communications, digital infrastructure, information technology and cybersecurity. It also permits software, information systems, equipment and components to form part of a PPP object. The legal question is therefore not whether the Law can apply to space-related projects, but how its general rules interact with the sector's special administrative-law regime.

Ukrainian positive law now uses public-private partnership as the statutory category. In doctrinal terms, state-private partnership is treated as a specific form within that broader

category for strategically important projects in which the State is the decisive public actor and retains sovereign powers of authorisation, supervision and security control. It is not a separate contractual form outside Law No. 4510-IX. It reflects the substantive feature emphasised in the security-centred approach to the space sector: private investment is admitted within a framework in which the State continues to bear international responsibility and to protect national security.

The article asks what opportunities Law No. 4510-IX creates for cooperation with private investors in Ukraine's space sector and which administrative, financial and sector-specific constraints may limit its practical use. The analysis is based on doctrinal interpretation, comparison of the former and current PPP regimes and a functional examination of the relevant public authorities and legal procedures.

1. From State-Private to Public-Private Partnership in Ukrainian Law

The replacement of the term state-private partnership with public-private partnership marks a change in the statutory language of cooperation between public authorities and private undertakings. The broader term corresponds to European usage, where PPP denotes long-term cooperation involving a public authority or public entity and a private party for infrastructure or services (European Commission, 2004). It places the public interest, rather than the institutional form of a particular State body, at the centre of the legal definition.

That change does not eliminate the specific role of the State in strategic sectors. Law No. 4510-IX permits several categories of public partner, but competence remains linked to the legal regime of the relevant asset and the authority empowered to manage it. Article 10 provides that a project is prepared exclusively on the initiative of the public partner. Where State property or a national security capability is involved, the public side will ordinarily be represented by the State through the competent authority or public-sector entity (Law No. 4510-IX, 2025: art. 10). The projects considered in this article – defence communications, national Earth-observation capability, orbital control, launch-related infrastructure and classified systems – fall within that state-centred part of the statutory framework.

Article 4 reinforces the need for a differentiated approach. The Law expressly identifies sectors relevant to space capability, but Article 4(2) preserves prohibitions and restrictions established by other legislation (Law No. 4510-IX, 2025: art. 4). The general PPP regime must therefore be applied together with rules on space activity, national security, State secrets, export control and strategic property. The Law enables partnership; it does not displace the special legal status of the activity or the object.

This distinction is central to the administrative-law analysis. The system of public bodies involved in space partnership includes authorities of general, sectoral and special competence. The first group determines strategic and security priorities; the second forms or implements policy in the relevant field; the third performs registration, permitting, certification, control and supervision. These functions may intersect within one project, but they retain separate legal bases. A PPP agreement cannot replace an administrative act or predetermine a regulatory decision, and a sectoral authorisation does not by itself establish that PPP is the appropriate form of implementation.

The 2025 reorganisation of central executive authorities illustrates the practical importance of institutional clarity. Cabinet Resolution No. 905 transferred the relevant functions of the former Ministry for Strategic Industries to the Ministry of Defence and placed the direction and coordination of the State Space Agency of Ukraine within the governmental scheme through

the Minister of Defence (Cabinet of Ministers of Ukraine, 2025). Resolution No. 281 remains the Agency's organic regulation, although parts of its text continue to refer to the former ministry and minister (Cabinet of Ministers of Ukraine, 2015). This formal inconsistency does not remove the Agency's powers, but it complicates the allocation of responsibility for policy formation, policy implementation and the management of State assets.

The resulting model is neither a return to direct administrative command nor an abandonment of State authority. It combines contractual cooperation with public-law limits. That combination reflects the security-centred approach developed in this analysis: in the space sector, partnership must serve national security, technological development and the public interest, while the State remains responsible for the exercise of sovereign regulatory powers.

The administrative-law mechanism is wider than the agreement itself. It operates through normative and individual acts, organisational measures, administrative services, registration, certification, permits and control. Coordination and persuasion are important where the State seeks to attract investment and support innovation, while coercive measures remain necessary as a security safeguard. The reform strengthens the contractual and coordinating elements of this mechanism, but it does not convert public powers into contractual rights. This is why the legality of a project depends not only on the wording of the agreement but also on the competence, procedure and form through which each public decision is adopted.

2. Regulatory Opportunities Created by Law No. 4510-IX

Law No. 4510-IX establishes a more coherent project cycle than the previous legislation. Article 3 identifies private investment, the long duration of the PPP term and the transfer to the private partner of part of the risks connected with financing, creation, construction, maintenance, management or operation of the PPP object (Law No. 4510-IX, 2025: art. 3). These characteristics distinguish PPP from the ordinary acquisition of goods, works or services. A space project may fall within the regime where private finance is combined with long-term responsibility for an operational capability such as a ground complex, communications system, data infrastructure or control facility.

The concept of the PPP object is also broad enough to reflect the technological composition of contemporary space systems. Article 6 covers existing and newly created movable and immovable property and expressly includes software, information systems, equipment, components and vehicles used to provide socially significant services (Law No. 4510-IX, 2025: art. 6). A project need not therefore be reduced to a single building or item of machinery. It may comprise the interconnected physical and digital elements required to deliver a space-related service.

Project preparation remains a public responsibility. Under Article 10, the initiative belongs to the public partner. The authority must identify the public need, determine the competent public body and select the lawful form of implementation. Private expertise may inform that process, but it cannot substitute for the public decision. This allocation of responsibility is consistent with the administrative-law character of partnership: the State may cooperate with business, yet the decision to use public assets, assume long-term obligations or provide State support must remain within statutory competence.

Article 11 makes the effectiveness analysis the principal ex ante safeguard. On the basis of the feasibility study, it addresses the financial model, forms of support, social and environmental consequences, fiscal effects, technical solutions, comparison with implementation without a private partner and the identification and management of risks (Law No. 4510-IX, 2025: art.

11). For a space project, the analysis must take account of its capital intensity, technological complexity, long development cycle, dependence on specialised infrastructure and security requirements. The point is not to add a separate space procedure, but to apply the statutory analysis to the actual characteristics of the sector.

Article 13 provides for open tendering, restricted tendering and competitive dialogue, while the detailed procedure and the features applicable to security and defence projects are to be established by the Cabinet of Ministers (Law No. 4510-IX, 2025: art. 13). On 22 June 2026, the Ministry of Economy, Environment and Agriculture published a draft resolution approving the Procedure for Determining a Private Partner (Ministry of Economy, Environment and Agriculture of Ukraine, 2026). As at 15 July 2026, the Law was in force, but the principal secondary procedure remained at the draft stage and settled administrative practice had not yet formed. Early application of the reform therefore depended on careful interpretation of the directly applicable provisions and on the subsequent completion of subordinate regulation.

The Law also simplified the contractual framework. Article 5 provides for two basic forms: a concession agreement and a PPP agreement. It permits those agreements to contain elements governed by other legislation, which is important for projects combining infrastructure, services, technology and intellectual-property arrangements (Law No. 4510-IX, 2025: art. 5). This flexibility does not remove mandatory rules. A mixed agreement remains subject to the applicable PPP or concession regime and to the special law governing each component.

Public support is addressed more comprehensively than under the former statute. Article 43 includes State and local guarantees, co-financing, availability payments, payments for project results or socially significant services, demand support, provision of goods or services, related infrastructure and grants (Law No. 4510-IX, 2025: art. 43). These instruments are relevant where the State is the principal user of a strategic service and the private market cannot by itself support the investment. Their inclusion in the Law does not amount to a budgetary appropriation. Each payment or guarantee must have a lawful financial basis and must be included in public planning.

Risk allocation is a further advantage of the reform. Article 34 requires the agreement to address the PPP object and its legal regime, performance indicators, project risks, public support, payments, monitoring and termination. It also permits provisions on innovation and the use of intellectual-property rights (Law No. 4510-IX, 2025: art. 34). The statutory model supports a fair allocation in which design, construction, financing, maintenance and operational risks may be placed on the private partner, while sovereign regulatory powers and security decisions remain with the competent public authorities. This approach preserves the concern with technological, commercial and international risks, but expresses it in the legal terms used by the current Law.

The reform also develops electronic procedures and aligns Ukrainian PPP law more closely with European standards. The transitional provisions envisage staged use of electronic systems, while the general approach to concessions reflects the transparency and operating-risk principles of Directive 2014/23/EU. The Government's report on implementation of the EU–Ukraine Association Agreement for 2025 treated the adoption of the new Law as progress but also recognised the need for further regulatory work (Directive 2014/23/EU, 2014; Government Office for Coordination of European and Euro-Atlantic Integration, 2026). European materials remain comparative and interpretive benchmarks; the legal basis for a Ukrainian project is the enacted national framework.

Control does not end when the agreement is signed. Article 54 places the performance of PPP agreements and the related project risks within a statutory monitoring framework (Law

No. 4510-IX, 2025: art. 54). This reflects the role of information and analytical support as a continuing part of administrative-law regulation. Reliable information is needed not only for project appraisal but also for assessing performance, public expenditure and compliance with the agreed allocation of responsibilities. Contract monitoring must nevertheless remain separate from sectoral supervision, which is exercised under the Space Activity Law and other special legislation.

The principal achievement of Law No. 4510-IX is thus not the automatic creation of investable space projects. It is the replacement of a fragmented scheme with a clearer legal structure for preparation, selection, contracting, support and monitoring. Whether that structure works in the space sector depends on the capacity of public authorities and on their coordination with the rules governing strategic activities.

3. Contractual Models and Strategic Space Assets

The choice of contract must correspond to the economic structure of the project. A concession is appropriate where the private party receives the right to operate works or services and bears genuine operating risk under the Concession Law (Law No. 155-IX, 2019). A PPP agreement is more suitable where the State remains the principal user and the private partner's revenue is derived mainly from support payments linked to operational effectiveness, demand or use of the PPP object. Strategic space services may often have this second structure because access to the system or its data cannot always be opened to a broad commercial market.

Mixed contracts are particularly relevant to space activity. A single project may involve construction, maintenance, software, the provision of data, licences, technology transfer and financial arrangements. Article 5 permits those elements to be combined, and Article 32 allows the agreements necessary for implementation, including financing, direct and grant agreements (Law No. 4510-IX, 2025: arts 5 and 32). The legal effect is coordination, not exemption. Intellectual property, export control, security, and space law requirements continue to apply to the relevant parts of the transaction.

PPP must remain distinct from public procurement. Article 2 excludes the selection of the private partner, performance of the PPP agreement and the provision of PPP support from the Public Procurement Law (Law No. 4510-IX, 2025: art. 2). Procurement is appropriate where a public authority buys equipment, works, research or services without the combination of private investment, long-term integrated responsibility and transfer of part of the project risks required by the PPP regime (Law No. 922-VIII, 2015). A complex or technologically advanced purchase is not a PPP merely because it concerns space activity. Conversely, a genuine long-term infrastructure project should not be reduced to a series of unrelated purchases.

The distinction from privatisation is equally important. Under Article 6, the transfer of an existing object to a private partner does not transfer ownership or terminate the title of the State, a territorial community or a public-sector company. An object designated for privatisation cannot simultaneously be a PPP object, and alienation is restricted during the term of the agreement (Law No. 4510-IX, 2025: art. 6). These rules correspond to the security-centred position developed in this analysis: private capital may be used without relinquishing public ownership of strategic space assets.

Ownership alone, however, does not exhaust the question of public control. The contract and the applicable administrative regime must preserve the State's ability to supervise the use of the object, protect restricted information and ensure that strategic technology is used in accordance with law. This public-law control is a defining feature of state-private partnership

in the space sector. It is not a contractual privilege that may be waived by the public partner, but a consequence of statutory competence and national-security responsibility.

Intellectual property forms part of this structure. Article 34 permits the parties to regulate the use of intellectual-property rights, but it does not prescribe one model for all projects. The agreement must identify the relevant results of space activity, the rights held before the project and the rights created during its performance. It must also take account of the public interest in continued use of strategically important results and of the private partner's legitimate interest in protecting and commercialising its technology. Ukrainian scholarship has emphasised the administrative-law protection of trade secrets and industrial property in space activity (Daderko, 2018; Harbuz, 2018).

Technology transfer may be incorporated into a mixed PPP agreement, but it remains governed by special law. Following the entry into force of Law No. 4585-IX on 12 December 2025, the Technology Transfer Law does not apply to the transfer of technologies or the exercise of economic intellectual-property rights by entities forming part of Ukraine's security and defence sector. The exclusion is based on the status of the entity, not merely on the intended use of the technology (Law No. 143-V, 2006: art. 2, as amended by Law No. 4585-IX, 2025). Civilian participants and transactions outside that sector may remain subject to the general regime. In either case, the agreement cannot replace an export authorisation, security decision or other mandatory act of public administration.

4. Implementation Constraints in the Ukrainian Space Sector

4.1. Institutional and Procedural Capacity

The effectiveness of the new Law depends on the institutions that apply it. Space projects require knowledge of public property, finance, technology, national security, intellectual property and international cooperation. Those functions are divided among several authorities. The Ministry of Defence, the State Space Agency, the Ministry of Finance and other competent bodies must act within their statutory roles and coordinate decisions that affect the same project. Recurring institutional reform, overlapping powers and weak coordination remain persistent obstacles to the development of the sector.

Law No. 4510-IX allows several public partners to participate in one project if their cooperation is regulated before the competition (Law No. 4510-IX, 2025: art. 12). This mechanism may be useful where State property, budgetary commitments and sectoral competence are distributed among different bodies. It does not remove the need to identify which authority may initiate the project, manage the asset, enter into the agreement or exercise regulatory powers. Unclear competence creates procedural risk and weakens responsibility for the result.

Administrative procedure also remains relevant. Public decisions concerning project initiation, appraisal, selection and sectoral authorisation must be adopted by the competent authority and, where the Law on Administrative Procedure applies, must comply with legality, proportionality, participation and reason-giving requirements (Law No. 2073-IX, 2022). Judicial protection is available for the categories of public-law dispute assigned to administrative courts (Code of Administrative Justice of Ukraine, 2005). These safeguards confirm that the PPP agreement is only one element of the administrative-law mechanism.

Institutional capacity also depends on information and personnel. Information and analytical support requires the collection, processing and use of reliable and timely data for managerial, scientific and technical decisions. Applied to PPP, this means that the public authorities must be able to assess the project, monitor its implementation and distinguish commercially sensitive or classified information from data required for public accountability. The repeated reorganisation of public bodies has weakened institutional continuity, while the technical character of space activity increases the need for specialised staff. Completing the reform of the competent authorities and preserving professional expertise are therefore substantive conditions of implementation, not merely questions of internal administration.

4.2. Financial and Budgetary Credibility

The financing of long-term space projects is constrained by the public-finance system. Support mechanisms under Article 43 create legal possibilities, but they do not themselves allocate money. Availability payments, guarantees, co-financing and payments for project results must be authorised under the Budget Code and reflected in medium- and long-term fiscal planning (Budget Code of Ukraine, 2010). The effectiveness analysis must therefore assess not only the expected benefits of private investment but also the State's future payment obligations and fiscal risks.

This issue is particularly acute in the space sector. Projects have long implementation periods, high initial costs and uncertain technological or commercial outcomes. Wartime conditions add risks of physical damage, interruption of supply, loss of communications and changes in security requirements. Stable public financing and credible State support are therefore conditions for attracting private capital. A formal guarantee that is not supported by lawful budgetary arrangements will not provide an investor with reliable protection.

Private finance should not be treated as an end in itself. PPP is justified only where the allocation of responsibilities and risks offers a better means of achieving the public objective. Public support must not remove the private partner's responsibility for performance, and the use of a long-term agreement should not conceal costs that will ultimately be borne by the budget.

4.3. Sector-Specific Space and Security Regulation

The Space Activity Law remains the basic sectoral statute. Private entities may take part in space activity, but the State retains regulatory powers in order to protect national interests and fulfill international obligations. A Ukrainian private entity generally submits a declaration before carrying out space activity. Specified operations require permits, including tests of launch vehicles or spacecraft, launches, control of space objects in orbit and re-entry. The Law also provides for certification, registration of unique space objects and safety supervision (Law No. 502/96-VR, 1996: arts 9-1, 10, 12–13 and 20).

These procedures are separate from the selection and performance of a PPP agreement. The award of the agreement cannot bind the regulator to grant a permit or certificate. Nor can contractual monitoring replace State supervision. This distinction gives practical effect to the administrative-law concept developed here: cooperation with a private partner operates within, not instead of, the public regime governing space activity.

State-secrecy and export-control legislation may restrict access to information, participation in particular activities and international transfers of controlled goods, technologies, technical

data or services (Law No. 3855-XII, 1994; Law No. 549-IV, 2003). The competitive process and the agreement must therefore be organised in a manner consistent with the classification of information and the applicable control regime. Transparency remains important, but it cannot require the publication of classified specifications or controlled technical information.

Article VI of the Outer Space Treaty provides the international foundation for continuing State involvement. Ukraine is internationally responsible for national activities in outer space, including those carried out by non-governmental entities, and must authorise and continuously supervise such activities (Outer Space Treaty, 1967: art. VI). A PPP agreement can distribute contractual duties and risks, but it cannot transfer this international responsibility or remove the State's regulatory relationship with the operator.

4.4. Intellectual Property and Technology Transfer

The legal protection and commercial use of results of space activity are central to partnership. Software, technical documentation, inventions, databases, industrial designs, know-how and confidential information may represent a substantial part of the project's value. Unresolved questions remain concerning the ownership, protection and commercialisation of results created with public resources. Those questions cannot be answered by a general reference to intellectual property in the PPP agreement.

The parties must determine which rights are brought into the project and how rights in newly created results are to be exercised. The arrangement should preserve the private partner's incentive to invest while ensuring that the State can use strategically important results for the public purpose for which the project was undertaken. Where State secrets, controlled technology or results created within the security and defence sector are involved, the allocation of rights is constrained by mandatory legislation.

Technology transfer remains a means of commercialising and using space-related results, but its legal regime depends on the participants and the nature of the technology. The amendment made by Law No. 4585-IX requires particular care because it removes security-and-defence-sector entities from the general Technology Transfer Law. Transactions outside that exclusion continue to be governed by the ordinary legislation. In both cases, intellectual-property clauses must be coordinated with State-secrecy rules, export control and the administrative powers of the competent authorities.

5. Directions for Further Development

The reform of PPP legislation does not remove the wider problems of administrative-law regulation in the space sector. Those problems fall into three connected areas: the normative, institutional and infrastructural foundations of regulation. That structure remains appropriate after the adoption of Law No. 4510-IX.

The normative priority is to align the general PPP framework with space, security, budgetary and intellectual-property legislation. Ukraine still requires a coherent long-term strategy for space activity and the removal of conflicts in terminology and legal regimes governing results of space activity. Approximation to European standards should continue without treating EU instruments as a substitute for national legislation. In the medium term, systematic codification in a Space Code could consolidate the status of public authorities, the regime of space objects, PPP forms, intellectual property, export control and legal responsibility.

State policy must also connect legal reform with the practical development of the sector. The national space programmes have repeatedly been affected by insufficient funding and discontinuity of priorities. A long-term policy should therefore link public support to clearly defined scientific, security and economic objectives, encourage the lawful commercialisation of results of space activity and maintain international cooperation. This does not require the State to relinquish control. It requires public authorities to use financial, organisational and legal instruments in a coordinated manner so that private capital contributes to the modernisation of national capabilities rather than replacing strategic planning.

International cooperation remains part of this policy because Ukraine's space industry depends on access to scientific networks, foreign markets and joint technological programmes. Cooperation with European and other international partners should be developed within the applicable security and export-control rules. In that setting, PPP can support integration into international projects while the State retains responsibility for the protection of national interests and compliance with its international obligations.

Institutional reform should be completed rather than repeatedly restarted. The powers of the Ministry of Defence, the State Space Agency and other bodies must be clearly coordinated, and obsolete references in subordinate legislation should be removed. Institutional reform also requires professional staffing, continuity in the public service, cooperation between State and private institutions and engagement with international organisations. These measures are necessary because a sophisticated contractual model cannot compensate for weak public administration.

The infrastructural dimension includes information and analytical support, training and the dissemination of knowledge about space activity. Reliable data are required for strategic planning, appraisal and supervision. Education and professional development are equally important for public officials, researchers and businesses involved in the sector. This dimension also includes the legal protection and commercialisation of results of space activity, cooperation between research institutions and business, and public understanding of the sector's economic and security significance. These measures form the practical environment in which the new PPP legislation can operate without weakening public control.

Conclusions

Law No. 4510-IX gives Ukraine a clearer statutory basis for long-term cooperation with private investors in the space sector. Its provisions on private investment, duration, risk transfer, effectiveness analysis, contractual forms, public support and the composition of PPP objects are capable of supporting projects in communications, Earth observation, ground infrastructure and related technologies. Public-private partnership is the statutory category, while state-private partnership denotes its security-centred form in strategic space projects where the State remains the decisive public actor.

The reform does not displace the administrative-law regime of space activity. Competence, permits, declarations, certification, registration, budgetary authority, State secrecy, export control and continuing supervision retain independent legal force. The practical use of PPP will therefore depend on institutional capacity, reliable public financing and a legally sound allocation of risks and intellectual-property rights.

Further development should proceed along three connected directions: improvement of the normative, institutional and infrastructural foundations of regulation. This requires

coordination of PPP and special space legislation, completion of institutional reform, stronger information and professional capacity, and the systematic organisation of space law.

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Recasting Ukraine's Law on Space Activities in the Light of EU Space Governance Standards [1]

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The article examines the need to recast Ukraine's Law "On Space Activities" in light of the transformation of national, European and international approaches to the regulation of space activities. It argues that the Ukrainian legislative model established in the 1990s was historically justified, since it was aimed at preserving industrial, scientific and technological capacity after the dissolution of the Soviet Union. That model, however, was primarily sectoral and administrative: it focused on state programmes, licensing, certification and coordination of enterprises rather than on authorisation and continuing supervision of operators.

The article traces the evolution of Ukrainian space regulation from the establishment of the National Space Agency of Ukraine to the deregulatory reforms of 2015–2025. Particular attention is given to the partial dismantling of the previous licensing system and the incomplete formation of a modern permit-based regime for private space activities. The study further analyses the relevance of the EU Space Act Proposal, ESA Zero Debris Charter and European sustainability-oriented soft-law instruments. It concludes that fragmented amendments are no longer sufficient. Ukrainian space legislation requires broader recasting around authorisation, continuing supervision, liability allocation, cybersecurity, sustainability and proportional regulation of different categories of operators.

Keywords: Ukrainian space law; Law on Space Activities; EU Space Act Proposal; administrative procedure; space governance; operator-based regulation; space sustainability.

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Introduction

Ukraine's space legislation was formed under conditions in which space activity remained closely connected with the functioning of the industrial and scientific complex inherited after the dissolution of the Soviet Union. In the 1990s, the primary task of the State consisted in preserving technological capacity, maintaining production and research relations between enterprises, and ensuring implementation of national space programmes. Under such conditions, space activity was regarded mainly as an object of state administration and state industrial policy. The Law of Ukraine "On Space Activities" of 1996 reflected this approach quite clearly. Its provisions were directed towards organisation of state management in the field of space activity, coordination of enterprises and preservation of scientific and technical potential (Law of Ukraine No. 502/96-VR, 1996).

Over time, however, the organisation of space activities became considerably more diverse. Commercial launch services, private satellite systems and space-based data services gradually acquired practical importance alongside traditional state programmes. Ukrainian scholarship likewise increasingly connects development of the national space sector with technological transformation of satellite systems, dual-use infrastructure and new models of commercial activity (Lykhova et al., 2023). Under such conditions, national space legislation could no longer function merely as an instrument of sectoral administration and industrial coordination. Increasingly, it became necessary to regulate operators, missions, operational risks and continuing supervision of non-governmental space activities.

The Outer Space Treaty of 1967, together with the Liability Convention of 1972 and the Registration Convention of 1975, continues to establish the basic legal principles governing responsibility, liability and jurisdiction in outer space (United Nations, 1967, 1972, 1975). In particular, Article VI of the Outer Space Treaty obliges States to authorise and continuously supervise national activities in outer space, including activities carried out by non-governmental entities (United Nations, 1967). While the normative content of Article VI remains relatively stable, its practical implementation has become considerably more complex in an environment characterised by commercial launch operators, satellite constellations, in-orbit servicing missions and privately operated space-based data and communication infrastructures. In many jurisdictions, including Ukraine, domestic legislation was not originally designed for this type of operational environment.

The discussion surrounding reform of Ukrainian space legislation has therefore gradually moved beyond purely doctrinal debate. Ukrainian legal scholarship increasingly examines national space law as an autonomous and developing direction of contemporary jurisprudence rather than merely a specialised segment of industrial regulation (Sliusarenko, 2023). The issue has also entered the sphere of practical legislative planning. The Plan of Legislative Work of the Verkhovna Rada of Ukraine for 2026 links reform of space legislation with European integration and improvement of state administration in the field of space activities (Verkhovna Rada of Ukraine, 2026).

At the same time, developments within the European Union increasingly reshape the broader regulatory environment. The EU Space Act Proposal 2025 reflects an emerging transition towards harmonised European regulation centred upon authorisation, continuing supervision, cybersecurity, resilience and sustainability of space activities within the internal market (European Commission, 2025). As noted by the European Parliamentary Research Service, the proposal is directly connected with gradual harmonisation of national regulatory approaches governing space activities and services within the Union (European Parliamentary Research Service, 2025).

Against this background, fragmented amendments to the Law of Ukraine "On Space Activities" appear increasingly insufficient. The problem therefore concerns not merely modernisation of several administrative procedures, but transformation of the legislative logic underlying Ukrainian space regulation itself. The present article proceeds from the assumption that Ukrainian space legislation requires broader legislative recasting centred upon authorisation, continuing supervision, liability allocation, cybersecurity and sustainability-oriented regulation of operators. The article combines doctrinal legal analysis, historical reconstruction of the development of Ukrainian space legislation and comparative analysis of emerging European regulatory approaches to space activities.

Formation of the System of State Regulation of Space Activities in Ukraine: From Institutional Establishment to the Sectoral Administrative Model (1992–2015)

The formation of Ukrainian space legislation took place under conditions in which space activity remained closely connected with preservation of the industrial and scientific potential inherited after the dissolution of the Soviet Union. During the first years of independence, the State faced the task of maintaining technological capacity, maintaining technological and production relations between enterprises, and ensuring continuation of national space programmes. Under such conditions, space activity was perceived primarily as a sphere of state administration and state industrial policy rather than as a field of autonomous commercial operations.

An important step in the institutionalisation of state administration in this sphere was the establishment of the National Space Agency of Ukraine by Presidential Decree of 29 February 1992 (President of Ukraine, 1992). The newly established body was entrusted with functions characteristic of a central authority of sectoral administration, including coordination of enterprises and organisations involved in space activity, development of state policy proposals, preservation of scientific, technical and industrial potential, organisation of international cooperation and supervision over compliance with international legal obligations in the field of outer space activities. In institutional terms, the Agency was conceived primarily as a body of state administration of the scientific and industrial space sector rather than as an independent regulatory authority in the contemporary sense. Such an approach corresponded to the structure of the Ukrainian space industry of that period and to the broader administrative organisation of the post-Soviet economy.

The institutional foundations established in the early 1990s were subsequently reflected in the Law of Ukraine "On Space Activities" adopted in 1996 (Law of Ukraine No. 502/96-VR, 1996). The Law became the first comprehensive legislative act regulating space activities in independent Ukraine and laid the basis for the national administrative and legal regime in this field. At the same time, its legal construction clearly reflected the institutional priorities of the period in which it emerged. Considerable attention was devoted to state regulation of space activities, implementation of national space programmes, licensing, certification, registration of space objects and coordination of enterprises operating within the space sector.

The Law was therefore oriented primarily towards administration of the sector itself rather than supervision of individual operators or mission-based activities. The central role belonged to the State and to bodies exercising public-administrative competence in the field of space activities. The legal structure was built around categories such as state regulation, competence of executive authorities, certification, licensing and control over economic activity.

The category of a private operator of space activity did not occupy a central place within the original legislative structure.

This approach was generally understandable for the period in which the Law was adopted. In the 1990s, the Ukrainian space sector remained centred around state enterprises, industrial production chains and state programmes. Private participation in space activity was limited both nationally and internationally, while commercial launch services and private satellite systems had not yet acquired their later practical importance within the international space sector. Such legislative approaches were not unusual for national space legislation of that period.

The administrative orientation of Ukrainian space legislation became even more visible in presidential acts adopted in 1997 and 1998 concerning further development of space technologies and improvement of the efficiency of space activities (President of Ukraine, 1997; President of Ukraine, 1998). These acts strengthened the existing logic of state administration in the space sector. Their provisions focused on technological development, support of the national space industry, coordination of state policy and preservation of strategic scientific and production potential. In this respect, the presidential acts are important primarily as historical sources demonstrating the role assigned by the State to the space sector during the late 1990s. Space activity was treated as a strategically important sphere of technological and industrial policy requiring direct state coordination, preservation of scientific and production capacity and implementation through public-administrative mechanisms.

The administrative structure established by the Law of 1996 was further specified in Resolution of the Cabinet of Ministers of Ukraine No. 798 of 4 June 1998 "On Measures of State Regulation of Space Activities" (Cabinet of Ministers of Ukraine, 1998). The Resolution regulated the procedure for issuing licences for space activities and further defined the competence of the National Space Agency of Ukraine in the sphere of licensing and administrative control. In doctrinal terms, this act reflected the classical administrative-law construction characteristic of that period: determination of competence of executive authorities, implementation of state functions through executive bodies, licensing powers and control over compliance with licensing conditions in the space sector.

Particular importance during this period belonged to licensing mechanisms. The Joint Instruction of the Licensing Chamber of Ukraine and the National Space Agency of Ukraine of 19 November 1998 – currently no longer in force and used here solely for historical and doctrinal analysis – established licensing conditions for business activities related to space activities (Licensing, 1998). Licensing functioned mainly as an administrative mechanism granting business entities the right to conduct certain types of economic activity in the space sector. The central role belonged to compliance with licensing conditions and administrative control exercised by competent public authorities.

The same approach was reflected in Resolution of the Cabinet of Ministers of Ukraine No. 1698 of 14 November 2000 approving the list of licensing authorities, which included the National Space Agency of Ukraine among the state bodies exercising licensing powers in the relevant sphere (Cabinet of Ministers of Ukraine, 2000a). At that stage, legal regulation remained centred primarily on licensing and administrative control over enterprises engaged in space activities.

Standardisation and certification occupied an important place within the system of state regulation of space activities. Ukrainian legal scholarship regarded certification and standardisation as elements of state regulation and technical control over space objects and technologies (Yeshchuk & Novikova, 2019). In practice, the legal mechanisms operating during this period were directed mainly towards compliance with technical requirements,

certification procedures and administrative supervision over industrial activity connected with the space sector.

The same approach remained visible in the Law of Ukraine "On State Support of Space Activities" of 2000 and in Resolution No. 404 of the Cabinet of Ministers of Ukraine concerning preservation and further development of unique objects of space activities (Law of Ukraine No. 1559-III, 2000; Cabinet of Ministers of Ukraine, 2000b). The space sector continued to be viewed primarily as a strategic scientific and industrial sphere requiring state support, preservation of scientific and technical potential and coordination by public authorities.

This understanding of space activity was reflected in Ukrainian legal scholarship as well. Researchers connected the early development of national space legislation with mechanisms of state support and sectoral administration of the space industry (Zhuravlov & Halunko, 2019). From the standpoint of administrative law, the model formed during the period 1992–2015 created a coherent system of state management in the field of space activities. It determined the competence of public authorities, established licensing and certification procedures, provided for registration of space objects and ensured administrative control over enterprises operating in the space sector.

At the same time, the legal construction of this model remained closely connected with the industrial organisation of the sector and the system of state programmes characteristic of that period. Regulation was directed mainly towards coordination of enterprises, implementation of state programmes and control over economic activity in the space industry. In institutional terms, Ukrainian space legislation functioned primarily as a mechanism of state administration and support of the space sector. Questions related to supervision of non-governmental activities, authorisation of particular operations and other forms of operational regulation became more visible somewhat later, together with the gradual expansion of commercial participation in space activities and further transformation of the space sector itself.

Transformation of the Authorisation and Licensing Model of Space Activities: Deregulation or Loss of Regulatory Capacity? (2015–2025)

A new stage in the development of Ukrainian space legislation began after 2015. Unlike the earlier period, the central issue no longer concerned preservation of the industrial structure inherited from the Soviet period. Legislative reform increasingly focused on deregulation, reduction of administrative barriers and liberalisation of economic activity. In the space sector, however, such changes created a more complicated legal situation. Space activity remained connected with international responsibility of the State, technological risks, dual-use technologies and security interests. Under these conditions, simplification of administrative regulation did not automatically mean creation of a modern regulatory model.

An important institutional step during this period was adoption of Resolution of the Cabinet of Ministers of Ukraine No. 281 of 14 May 2015 approving the Regulation on the State Space Agency of Ukraine (Cabinet of Ministers of Ukraine, 2015). The Resolution formally reorganised the institutional status of the Agency and repealed earlier acts connected with the National Space Agency of Ukraine. At the same time, the reform remained largely organisational. The State Space Agency of Ukraine retained functions connected with the formation and implementation of state policy in the space sector, coordination, and international cooperation. Yet the institutional reform was not accompanied by the creation of a new regulatory architecture adapted to the gradual expansion of private and commercial space activity.

The problem therefore did not concern the renaming or reorganisation of the Agency as such. The deeper issue consisted in the absence of a comprehensive transition from the earlier sectoral-administrative model towards a modern system of operator-based regulation. The Agency did not receive a clearly developed system of powers connected with technical assessment of missions, continuing supervision, post-authorisation monitoring or risk-oriented oversight of private operators.

A much more significant change came with adoption of the Law of Ukraine "On Licensing of Types of Economic Activity" No. 222-VIII in 2015 (Law of Ukraine No. 222-VIII, 2015). For the space sector, this reform extended beyond general deregulation of economic activity. The earlier licensing architecture governing space activities was substantially transformed, resulting in a significant reduction of licensing mechanisms that had previously formed part of the sectoral model of state regulation.

These changes caused criticism in Ukrainian legal scholarship. N. R. Malysheva and A. M. Hurova reasonably noted that deregulation in the space sphere could not be assessed only through the category of freedom of entrepreneurial activity (Malysheva & Hurova, 2016). Space activity has another legal nature. It is connected with international obligations of the State, export control, technological safety, dual-use technologies and potentially significant risks for third parties. Because of this, mechanical transfer of general deregulatory approaches into the space sector inevitably created regulatory gaps.

The key problem after 2015 did not consist in deregulation as such. The more fundamental issue was that dismantling of the previous licensing architecture was not accompanied by formation of a coherent system of authorisation and continuing supervision corresponding to Article VI of the Outer Space Treaty. The earlier licensing model functioned primarily as an instrument of sectoral administrative control over economic activity. Once significant parts of that model were removed, Ukrainian legislation did not simultaneously develop a modern supervisory framework centred upon mission-based authorisation, technical assessment of operations, continuing supervision of operators, reassessment of operational risks and state intervention powers throughout the lifecycle of space activities. As a result, deregulation partially reduced administrative barriers, yet it also exposed structural gaps in the national system of implementation of international obligations connected with supervision of non-governmental space activities.

Part of these problems was later addressed by the Law of Ukraine No. 143-IX of 2019 concerning state regulation of space activities (Law of Ukraine No. 143-IX, 2019). The Law abolished the state monopoly in most areas of space activity and opened this sphere to private operators. Simultaneously, a permit regime was introduced for particular types of space activities.

This was already a different regulatory logic. Still, the reform remained incomplete. In modern space law, authorisation is normally connected not only with admission to activity, but also with assessment of a concrete operation, technical characteristics of the mission, insurance, allocation of liability and subsequent supervision by the State. Ukrainian legislation approached such a model only fragmentarily.

Further procedural regulation appeared in Resolution of the Cabinet of Ministers of Ukraine No. 197 of 26 February 2020 approving the procedure for issuing, refusing and cancelling permits for certain types of space activities (Cabinet of Ministers of Ukraine, 2020). The Resolution defined the applicant, the list of required documents, grounds for refusal, cancellation procedures and possibilities for appeal. In administrative-law terms, the permit acquired the features of an individual administrative act.

Yet the procedure itself remained relatively narrow. The main attention was concentrated on obtaining permission to start activity. The Resolution did not establish a full system of continuing supervision after authorisation. Questions of operational intervention, modification of mission conditions, ongoing monitoring or reassessment of technical risks were regulated only superficially. In essence, the permit still functioned mainly as an instrument of admission to activity.

An important general change occurred with adoption of the Law of Ukraine "On Administrative Procedure" in 2022 and Law No. 4017-IX connected with its implementation (Law of Ukraine No. 2073-IX, 2022; Law of Ukraine No. 4017-IX, 2024). These acts introduced common procedural standards for the activity of public administration in Ukraine. Although the legislation is not sector-specific, it is also relevant for the sphere of space activities, since authorisation and supervisory decisions increasingly acquire the characteristics of administrative acts requiring procedural guarantees, proper reasoning and compliance with general principles of public administration.

Still, the general procedural framework could not resolve the specific regulatory problems of space activities. Space operations involve technological risks, safety issues and international responsibility that require special rules concerning technical assessment, supervision and control throughout the duration of the activity itself.

The limits of purely deregulatory logic become even clearer in light of legislation governing international transfers of military and dual-use goods. The Law of Ukraine "On State Control over International Transfers of Military and Dual-Use Goods" No. 549-IV of 2003 demonstrates that space technologies remain closely connected with export control and national security policy (Law of Ukraine No. 549-IV, 2003). This concerns remote sensing technologies, satellite communications, launch technologies, and other systems capable of both civilian and military application.

Under such conditions, space activity could no longer be treated simply as an ordinary sphere of economic activity. During 2015–2025, the previous model of sectoral administrative control was substantially weakened. A new model based on full authorisation and continuing supervision, however, was formed only partially.

European Transformation of Space Regulation and the Need for a Full Recast of the Law of Ukraine "On Space Activities"

Reform of Ukrainian space legislation increasingly develops under the influence of changes taking place within European regulation of space activities. Revision of separate procedures or redistribution of competences between public authorities no longer changes much. The assumptions underlying regulation itself are changing.

The Law of Ukraine "On Space Activities" belongs to another institutional and technological period. Its legislative construction reflected the organisation of the sector characteristic of the 1990s – state programmes, preservation of industrial capacities, administrative coordination of enterprises, domination of state-owned actors. The law proceeded from the understanding of the space sector primarily as a strategic branch of industry requiring administrative management and state coordination. In many respects, this reflected the post-Soviet structure of the sector itself.

Contemporary European regulation develops from different premises. Attention shifts towards operators, particular missions, orbital risks, circulation of space-based data, continuity of satellite services. Cybersecurity appears within the same legal field together with debris

mitigation and technical safety requirements. This is already visible in the EU Space Act Proposal presented by the European Commission in 2025 (European Commission, 2025).

The proposal itself is built largely around the functioning of the internal market for space services and space-based data. Fragmentation of national legislation is treated there primarily as a practical obstacle for operators functioning across several jurisdictions. Different authorisation procedures. Different supervisory structures. Different approaches to continuing supervision and technical certification. Regulatory fragmentation here already affects financing, insurance mechanisms, contractual relations and participation in cross-border projects.

Earlier national legislation was constructed mainly around administration of a domestic industrial sector. The future European approach increasingly concerns continuing supervision over activities taking place within a shared orbital space saturated with commercial operators, interconnected infrastructures and permanent circulation of data. The European Parliamentary Research Service directly notes that the future framework extends beyond the traditional licensing model and includes supervision, registration, orbital traffic management and enforcement mechanisms (European Parliamentary Research Service, 2025). In some situations, the regime may also apply to operators from third countries providing services within the European Union.

Territoriality therefore functions differently here than within classical administrative regulation.

Safety, resilience and sustainability form the core structure of the future European approach. Yet the content of these categories changes as well.

Safety concerns not merely technical reliability of a space object. Collision avoidance, trackability, orbital traffic management and debris mitigation increasingly become elements of one authorisation regime and one supervisory structure. Resilience concerns continuity of services, cybersecurity obligations and protection of critical infrastructure. Sustainability introduces requirements connected with environmental impact, end-of-life disposal and reduction of debris generation in orbit (European Commission, 2025). Public interest in space activities is no longer confined to industrial policy or state supervision over enterprises. The orbital environment itself gradually becomes an object of regulatory protection.

Soft-law instruments play an important role here, sometimes earlier and more effectively than binding legislation itself. The Sofia Guidelines for a Model Law on National Space Legislation adopted by the International Law Association in 2012 formulated what later became standard structural elements of national space legislation: authorisation, continuing supervision, registration, liability, insurance, transfer of ownership and control over space objects (International Law Association, 2012). Yet the more important point lies elsewhere. National legislation is increasingly viewed as an internal administrative mechanism through which States organise continuing supervision over non-governmental activities in outer space and implement obligations arising from international space law.

A similar tendency appears in the COPUOS Guidelines for the Long-Term Sustainability of Outer Space Activities adopted in 2019 (United Nations Committee on the Peaceful Uses of Outer Space, 2019). Sustainability already moves beyond political declarations and voluntary policy formulations. It enters the sphere of authorisation requirements, supervisory standards and continuing control over national activities.

The ESA Zero Debris Charter of 2023 reflects much the same shift (European Space Agency, 2023). Earlier approaches concentrated mainly upon mitigation of debris after completion of missions. Current approaches are operationally broader and considerably stricter already at the stage of mission planning itself. Responsibility increasingly concerns the entire operational

lifecycle. Mission-end obligations. Reduction of debris generation from the beginning of orbital activity rather than afterwards.

Continuing supervision again appears central. From the standpoint of administrative law, these developments are important for another reason as well. Regulation of space activities no longer functions through one vertically organised authority acting more or less in isolation. Regulatory competence becomes institutionally dispersed. Export-control procedures, cybersecurity structures, insurance mechanisms, technical certification, registries and international coordination procedures increasingly operate within the same supervisory field, although not always coherently.

Black describes such systems as polycentric regulatory regimes in which legitimacy, expertise and responsibility become distributed among multiple actors rather than concentrated exclusively within the state apparatus (Black, 2008). For Ukraine, this observation already carries direct practical significance. This is particularly relevant in relation to continuing supervision, supervisory competence, and allocation of regulatory functions between different public authorities.

The earlier legislative construction based mainly upon issuance of permits by one administrative body appears progressively less adequate. This becomes especially visible in relation to cybersecurity obligations, technical monitoring, dual-use review procedures and continuing supervision mechanisms, which in practice already extend beyond the competence of the space agency itself.

The limitations of the Law of Ukraine "On Space Activities" therefore concern not merely several outdated provisions or absence of particular modern procedures. The problem lies deeper. It lies in the legislative construction itself and in the assumptions on which that construction was originally based.

Even outside the formal framework of EU accession, compatibility with emerging European regulation already carries practical significance. Participation in European supply chains, access to insurance markets, cooperation with European operators and attraction of investment increasingly depend upon predictability of supervisory procedures and confidence in the national authorisation regime. Fragmentary amendments alone will hardly resolve these problems.

Contemporary regulation of space activities already requires mission-based authorisation, continuing supervision, operational traceability, cybersecurity obligations, sustainability requirements and mechanisms of liability allocation integrated into one supervisory structure. The existing law was designed for another technological structure of the sector and another regulatory environment altogether.

Questions of authorisation, registration, liability allocation, cybersecurity review and supervision of dual-use activities can hardly remain dispersed indefinitely between separate legislative acts and subordinate procedures. Yet another problem emerges here as well. The future system cannot simply reproduce identical compliance burdens for all categories of operators. Universities, research institutions and smaller operators objectively possess different operational capacities and different levels of risk. Whether the existing legislative structure is capable of accommodating such differentiation at all remains increasingly doubtful.

Conclusions

Development of Ukrainian space legislation reflects broader changes in the legal nature of space regulation itself. The original legislative model of the 1990s had its own historical

rationality. At that stage, preservation of industrial infrastructure, technological capacities and scientific potential inherited after the collapse of the Soviet Union constituted one of the principal objectives of state policy. Space law therefore functioned mainly as an instrument of administration within a strategic industrial sector.

Today this logic no longer fully corresponds to the organisation of contemporary space activities. Commercial operators, private satellite services, circulation of satellite data, dual-use technologies and complex operational risks increasingly determine the structure of the sector itself. The central legal figure also changes. Regulation becomes connected less with enterprises of the space industry as such and more with operators conducting particular missions under conditions of technological and legal risk.

For this reason, isolated amendments to the Law of Ukraine "On Space Activities" are increasingly incapable of resolving the broader regulatory problem. A legislative model originally designed for administration of a predominantly state-centred industrial sector cannot easily be transformed into a contemporary space act through fragmentary revisions.

The European approach reflected in the EU Space Act Proposal demonstrates another regulatory logic. Safety, resilience and sustainability increasingly function as organising categories of space regulation. Authorisation becomes linked with continuing supervision, operational monitoring, cybersecurity obligations, debris mitigation and assessment of long-term operational risks connected with space activities. At the same time, contemporary European space governance increasingly develops around risk-based and proportionate supervision adapted to different categories of operators and missions.

The future Ukrainian Space Act therefore concerns not merely modernisation of several administrative procedures. The matter is deeper than technical legislative updating. It concerns reconstruction of the legislative architecture through which the State implements authorisation and continuing supervision of national space activities under contemporary technological and geopolitical conditions. Predictability of authorisation and supervision here acquires direct practical significance. Without it, participation in insurance markets, European industrial cooperation and cross-border space activities becomes increasingly difficult. Mere amendment of separate provisions will hardly resolve these problems.

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Risk-Based Model for the Legal Regulation of Artificial Intelligence in Space Activities

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The increasing integration of artificial intelligence into space activities enhances the autonomy, efficiency, reliability, and scientific potential of space missions. At the same time, the use of AI for spacecraft control, autonomous navigation, data processing, robotic exploration, mission planning, and life-support systems generates complex legal, technical, organisational, cybersecurity, and data-related risks. This article aims to substantiate a risk-based model for the legal regulation of artificial intelligence in space activities and to identify its principal characteristics. The research applies systemic, comparative legal, formal legal, analytical, and risk-oriented methods.

The study demonstrates that the existing framework of international space law establishes fundamental principles applicable to AI-enabled space activities but does not adequately address algorithmic autonomy, dynamic system behaviour, limited human intervention, opacity of decision-making processes, and the allocation of responsibility among multiple actors. The risks associated with space-based AI are classified into four interconnected levels: institutional and governance risks; systemic and mission-level risks; operational and assurance-related risks; and cyber, information, and data-oriented risks.

It is argued that legal requirements should be differentiated according to the autonomy of the AI system, the criticality of its functions, the probability and severity of potential harm, and the possibility of effective human oversight. The proposed model is characterised by its multilevel, mission-centric, proportionate, life-cycle-oriented, evidence-based, preventive, and adaptive nature. It also requires controlled autonomy, continuous monitoring, independent verification and validation, clear allocation of obligations and liability, integrated cybersecurity safeguards, and international regulatory interoperability.

Keywords: artificial intelligence; space activities; risk-based regulation; international space law; legal liability; human oversight; cybersecurity.

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Introduction

Any new technology which has captured the attention and imagination of human beings has often subsumed, until the last century, within its legal framework at the international level, domestic or State-level governance systems, and pertaining to core aspects of its regulations; further leaving its implementational aspects to States and their governments. Thus, when space technologies were new and being introduced during the Cold War era, marked by increasingly volatile and ever-changing political commitments and stances of sovereign nations and the international community, binding treaties were adopted and enacted to govern space technologies to maintain certainty. However, since the 1980s, there have been other objects and subjects of its legal regulation, thus constituting and comprising what we refer to as the global space governance system. Artificial intelligence ('AI') technologies and systems, preceded by cyber activities, are the newest domains that need urgent attention of the international community, including international space law and policy enthusiasts, academicians, technical experts and social scientists, and law and policy-makers. In brief, AI systems are being developed with the core objective of mimicking the capabilities of the human mind artificially through machines (Mishra, 2022).

Artificial intelligence is gradually becoming one of the defining technological components of modern space activities. The use of AI in autonomous navigation, spacecraft control, the processing of large datasets, fault prediction, mission planning, the robotic exploration of space objects, crew life-support systems, and operational decision-making significantly expands the capabilities of both public and private actors engaged in space activities. At the same time, the increasing autonomy of AI systems, their integration into critical processes, and the limited possibilities for human intervention in the space environment give rise to a new category of legal risks that must be appropriately regulated.

1. The concept of AI-system and its impact on space activities

George Boole was the first to describe a formal language for logical reasoning in 1847. The next milestone in artificial intelligence history was in 1936, when Alan M. Turing described the Turing-machine. Warren McCulloch and Walter Pitts created the model of artificial neurons in 1943, and in 1944 J. Neumann and O. Morgenstern developed the theory of decision, which provided a complete and formal framework for specifying the preferences of agents. In 1949, Donald Hebb presented a value-changing rule for the connections of the artificial neurons that provided the chance of learning, and Marvin Minsky and Dean Edmonds created the first neural computer in 1951. Artificial intelligence (AI) was born in the summer of 1956, when John McCarthy first defined the term. It was the first time the subject caught the attention of researchers, and it was discussed at a conference at Dartmouth. The next year, the first general problem solver was tested, and one year later, McCarty regarded as the father of AI, announced the LISP language for creating AI software. Lisp, which stands for list processing, is still used regularly today. Herbert Simon stated in 1965: "Machines will be capable, within twenty years of doing any work a man can do." However, years later, scientists realized that creating an algorithm that can do anything a human can do is nearly impossible. Nowadays, AI has a new meaning: creating intelligent agents to help us do our work faster and easier (Benko, 2009; Russel & Norvig, 2005; McDaniel, 1994; Shirai & Tsujii, 1982; Mitchell, 1996; Schreiber, 1999).

Artificial Intelligence is an area of computer science that raises many questions in philosophy, neuroscience, and cognitive science. It is also an area of technological innovation that has completely transformed some aspects of human life and continues to do so. Several broad projects are pursued within AI, depending on whether one is using AI systems to model human psychology or to describe idealized rationality, and depending on whether the focus is on the behavior of a model or also on its internal structure. There are many successful approaches to AI, including symbolic systems and connectionism, and these approaches often compete to explain the full range of cognitive capabilities. There are also philosophical debates about whether it is possible in principle to build a genuinely intelligent computer system. Whereas many approaches to AI have advocated strict divisions of labor between disciplines, we endorse explanatory pluralism, which uses varied approaches to model disparate aspects of cognition and leverages the rich array of AI methods to provide broader insights into the mind and brain (Noelle, 2022).

Artificial Intelligence (AI) refers to computer systems designed to perform tasks that typically require human intelligence. These tasks include visual perception, speech recognition, decision-making, and language translation. AI encompasses various techniques such as machine learning, neural networks, and deep learning, which enable systems to think and act in an intelligent manner (Rothman, 2018; Hulsen, 2023).

The concept of AI involves foundational elements such as agents, logic, search algorithms, and reasoning under uncertainty. These components form the basis for practical applications and algorithms within the field. AI also covers subdisciplines like automated planning, intelligent agents, information retrieval, and natural language and speech processing, which contribute to the system's ability to interact with and interpret complex data (Chowdhary, 2020; Ertel, 2024).

AI systems are often developed through examples and case studies that illustrate fundamental principles and real-world applications. This approach helps in understanding how AI can be implemented to solve practical problems and build intelligent networks (Rothman, 2018; Nagy, 2018). The field also addresses recent developments including constraint satisfaction problems, adversarial search, game theory, and statistical learning theory, which expand the capabilities and theoretical underpinnings of AI (Chowdhary, 2020).

In summary, AI is a multidisciplinary area focused on creating systems capable of intelligent behavior by employing various algorithms and learning techniques. It integrates theoretical foundations with practical applications to enable machines to perform tasks traditionally requiring human cognition.

Artificial intelligence is applied to many fields and contributes to many important applications and research areas, such as intelligent data processing, natural language processing, autonomous vehicles, and robots. The adoption of artificial intelligence in several fields has been the subject of many research papers. Still, recently, the space sector is a field where artificial intelligence is receiving significant attention (Russo, 2022).

The concept of Artificial Intelligence (AI) for space encompasses the application of AI techniques to address various challenges in space sciences and operations. AI is increasingly recognized for its potential to enhance mission design, space exploration, and Earth observation by enabling intelligent data processing, autonomous decision-making, and automation in complex and remote environments (Russo, 2022; Ieracitano, 2023; Chien, 2014). This involves developing systems capable of operating independently in hostile or inaccessible conditions, thereby reducing human intervention and operational costs (Chien, 2014).

AI's role in space extends to improving the reliability and safety of missions by managing risks associated with hardware, software, and human factors. For example, NASA has

employed AI systems in the Mission Control Center to support flight decisions during space shuttle missions, and ongoing efforts aim to integrate AI frameworks to enhance resilience and performance in current and future missions such as the James Webb Space Telescope and Artemis programs (Kalia, 2025). These frameworks address challenges like automation uncertainties, cognitive biases, and complex mission architectures (Kalia, 2025).

The space sector's evolving value chain benefits from AI through cross-sector and cross-border collaborations, where AI and machine learning contribute to transforming space technologies and big data management. Applications include AI-driven Earth observation data analysis, robotics for space exploration, astrophysics research, in-orbit servicing, and safety improvements in space tourism (Madi, 2024). The interdisciplinary nature of AI in space involves contributions from engineers, risk analysts, policy makers, and computer scientists, highlighting the multifaceted impact of AI across technical and regulatory domains (Madi, 2024).

Overall, AI for space is conceptualized as a set of intelligent tools and methodologies aimed at enhancing operational autonomy, safety, data utilization, and mission efficiency in the space domain, while addressing the unique challenges posed by space environments and mission complexities.

Artificial Intelligence (AI) systems in space activities refer to software or machines that exhibit intelligence by reasoning, making decisions, analyzing data, perceiving, and acting in ways similar to human beings. These systems are increasingly integrated into space exploration and settlement, providing sophisticated tools that enhance or replace human competences in various space-related tasks. AI enables intelligent machines to support astronauts and space missions by processing data, assisting in decision-making, and performing autonomous operations essential for living and working in space environments (Kumar, 2018).

The impact of AI on space activities is multifaceted. AI technologies contribute to the transformation of the space sector by supporting Earth observation through big data analysis, enabling robotic exploration, and facilitating emerging markets such as in-orbit servicing and space tourism safety. These applications demonstrate AI's role in improving mission efficiency and scientific return, as well as addressing complex challenges in space operations. The integration of AI spans across the space value chain, involving cross-sector and international collaborations, and is relevant to engineers, policy makers, and technical experts (Madi, 2024).

The European Space Agency (ESA) exemplifies the use of AI in space missions, where AI systems observe, perceive, and act upon their environment to maximize mission success. However, the adoption of AI in space is still limited by challenges such as the interpretability of neural network models and legal concerns. Issues related to liability, confidentiality, and data protection arise as AI applications evolve, raising questions about the adequacy of existing space law frameworks to address these new challenges (Singer, 2024).

In summary, AI systems in space activities function as intelligent tools that enhance operational capabilities and scientific outcomes. Their impact extends from data processing and robotic exploration to safety and legal considerations, reflecting a growing but complex integration of AI in the space domain.

2. Main areas of use of AI in space activities

Artificial Intelligence is applied in various critical areas of space activities, enhancing operational efficiency, safety, and scientific outcomes. One primary area is spacecraft operations, where AI integrates data acquisition, processing, decision support, and feedback

mechanisms to improve predictive maintenance, anomaly detection, navigation, and control. This integration contributes to increased reliability and safety in mission execution. AI also plays a significant role in spacecraft health monitoring and organizational processes, supporting mission success through improved system management (Dhar, 2025).

The ambitious short-term and long-term goals set by various national space agencies require a radical advance of new technologies into the space sector, one of which is undoubtedly the development of intelligent space agents. In recent years, this has led to increasing interest in artificial intelligence across the entire aerospace community. Indeed, technologies and machines that can independently perform various functions in areas such as space, where conditions are hostile and dangerous to human life, are increasingly used. Therefore, one of the complicated legal problems of our time is the increasing use of and dependence on technology and processes related to artificial intelligence and space technologies (Soroka & Kurkova, 2019).

In planetary missions, AI facilitates autonomous navigation and data processing, enabling spacecraft to operate with reduced human intervention. Machine learning and deep learning techniques support scientific discovery, predictive analytics, and mission planning, thereby enhancing decision-making capabilities in complex and remote environments. Emerging AI technologies, such as quantum and neuromorphic computing, are also explored for their potential to advance data processing and autonomous decision-making in space missions (Ojo, 2024).

Automation through AI is recognized as a means to address the increasing complexity and cost of space missions. Intelligent systems capable of independent decision-making are necessary for operating in remote and hostile environments, reducing the need for constant human control and intervention (Chien, 2014). This is particularly relevant for future missions involving human crews beyond low Earth orbit, where AI is expected to support autonomous biomonitoring, research, and healthcare independent of Earth-based resources (Space, 2023).

In deep space exploration, AI applications include hyperspectral imagery analysis and autonomous robotic systems. Hyperspectral algorithms assist in the capture and interpretation of space images, while robotic systems contribute to efficient exploration activities on planetary surfaces such as Mars. These AI-driven technologies aim to improve the understanding of the solar system and support long-term exploration strategies (Omar, 2021).

Overall, AI is utilized in spacecraft operations, autonomous navigation, data analysis, mission planning, health monitoring, robotic exploration, and autonomous life support systems, reflecting its multifaceted role in advancing space activities.

3. Applicability of international space law to the use of AI

The implementation of AI systems in the sector of space activities (although equally applicable to all sectors) has various nuances, such as the introduction of objective 'expert legal knowledge'. In Machine learning phases, the international community is (and will further be) required to constitute and determine space-specific «high level objectives». Because this technology (along with other new technologies, such as cyber technology) knows no state boundaries, it has the potential to upend traditional and historical ways of law-making, both at the international and State government levels. A top-down approach is not only forthcoming but also unsustainable and unsuitable; thus, it also lays the foundations for a bottom-up approach involving all stakeholders at all stages of the AI life cycle. In view of the constantly changing and evolving subjective and objective international standards for regulation of space

conduct, the researcher wishes to also introduce the need for socio-legal research, particularly highlighting the need to be in sync with legal consciousness approaches. In doing so, one can locate and deal with ongoing issues and future challenges for conceptualizing an international rules-based order for the introduction and operation of AI technologies in space activities. The new space era 4.0 is also marked by increasing private sector presence and operations in space activities, with supervisory roles being played by State governments. This submission would thus capture some of the modifications or interpretational nuances which may be required in the context of interpretation and regulation of the binding international treaties applicable to the space ecosystem (Mishra, 2022).

The applicability of international space law to the use of artificial intelligence (AI) involves several considerations related to existing treaties, regulatory gaps, and the evolving nature of AI technologies in space activities. Current international space law, including foundational treaties such as the Outer Space Treaty and the Liability Convention, does not explicitly regulate AI but provides principles that could inspire the development of AI-specific legal frameworks aimed at harm prevention and responsible use in space (Ramuš, 2023; Treaty, 1967; Convention, 1972). These treaties establish general obligations and liability rules that may be adapted to address AI's autonomous functions and potential risks.

Existing international space law mechanisms are identified as insufficient for regulating dual-use AI systems, particularly regarding definitions, responsibility codification, and control of autonomous actions. This insufficiency highlights the need for new legal approaches that focus on prohibiting specific harmful outcomes, such as orbital debris creation or uncontrolled autonomous attacks, rather than regulating AI technology per se. Proposals include international agreements with annexes listing prohibited AI uses and accountability mechanisms for states, which could complement or extend current space law (Koskina, 2026).

The integration of AI in space activities raises challenges related to military applications, autonomy, and power imbalances. The 1967 Outer Space Treaty's provisions on peaceful use, control, and non-discrimination are tested by AI-enabled autonomous weapons and military systems, which are not explicitly addressed in existing law. This situation calls for future legal frameworks that consider both terrestrial and space contexts, including principles from international humanitarian law and emerging AI regulations like the European AI Act, which currently excludes military AI systems (Bratu, 2026).

AI should be understood as a system designed by humans, which, by analyzing the environment, is capable of acting (without active control or supervision from an individual) or being idle autonomously to achieve a specific goal. From the point of view of AI legal regulation, the main concern is that currently the definition of AI cannot be specified at the global level, and its normative definition is rare. Still, there are some examples, like the Artificial Intelligence Act, which laid the foundation for the legal regulation of AI use, if not at the global level, but at least at the European one. Still, there are some examples, like the Artificial Intelligence Act, which laid the foundation for the legal regulation of AI use, if not at the global level, but at least at the European one. This issue is indirectly raised in the Guiding Principles on Business and Human Rights, but mostly it has a national background (Soroka, 2022; Regulation, 2024).

Furthermore, the rapid development of AI and autonomous systems in space missions and potential human colonies necessitates new legal standards beyond traditional space law. These include cybersecurity, environmental protection, data governance, and ethical considerations specific to AI behavior and decision-making in space environments (Pagallo, 2024). The evolving space governance system must adapt to these technological changes, incorporating

bottom-up approaches involving multiple stakeholders and addressing socio-legal dimensions such as ethics, environmental costs, and data privacy (Mishra, 2022).

In conclusion, while international space law provides foundational principles applicable to AI use in space, it currently lacks specific provisions to fully regulate AI technologies and their dual-use nature. There is an ongoing scholarly and policy discourse advocating for the adaptation and expansion of space law frameworks to address AI's unique challenges, emphasizing harm prevention, accountability, and ethical governance.

4. Risk system for using AI in space activities

AI is a future technology that, even today, expands the boundaries of human perception and enhances capabilities where, a few years ago, there seemed to be no prospects for a full and comprehensive study. Moreover, one can hardly imagine the development of the space industry without AI, although there are still some issues from the point of view of legal problems and risks (Soroka et al., 2022).

We propose a classification of the various risks associated with the use of AI in space activities, which may be broadly divided into four levels. The first layer is institutional and managerial risks. NASA's OIG says NASA "has not adopted a standard definition of AI" and lacks an "AI-specific classification mechanism," which is exactly the sort of gap a risk system has to close. The space-focused Trusted AI work says to "estimate the level of trust required as a function of mission criticality and key stakeholders," and frames its guidance as "best practices" for the people who review and fly these systems (National, 2023; Slingerland, 2022). The corresponding conclusion was formed in 2022, however, in connection with the adoption of the Artificial Intelligence Act (2024), the problem has acquired another dimension – the problem of a clear division of competence between developers, operators, customers, regulatory authorities and other participants in space activities. This level also includes the risks of uncertainty of requirements for the permissible degree of autonomy, the required level of reliability and trust in the system depending on the criticality of the mission, the nature of the functions performed and the range of interested parties.

The second layer is hazard analysis at the mission level, not just the model level. An aerospace FMEA paper adapts FMEA to the aerospace domain, identifies 23 AI-related failure modes, and says the unmitigated risk can be "medium to critical." A separate space-exploration paper flags "aggregate and cross-cutting risks associated with hardware, software, firmware, and human interactions," which is the right mental model for space autonomy: the failure is usually sociotechnical, not just algorithmic (Khalil, 2026; Kalia, 2025).

The third layer is assurance before and during operation: simulation, verification and validation, independent monitors, and a fail-safe fallback to human or conventional control. The xAI space papers say autonomous capabilities must be reliable enough to "run spacecraft systems" without human input when necessary, and that confident use of these systems depends on "understanding risks and quantifying the uncertainties that produce those risks" (Allen, 2025).

The fourth layer is cyber, information and data-oriented risks. A recent space-safety review says "AI cyber security is becoming an important aspect to ensure space safety and operational security" and argues for "technical standardisation"; a newer governance framework says the architecture should "integrate governance structures, reliability and safety engineering practices, data and ML lifecycle controls, cybersecurity mechanisms, and decision-intelligence feedback loops into a single architectural view" (Yettapu, 2023).

Thus, the system of risks associated with the use of AI in space activities may be broadly divided into four levels: (1) institutional and governance risks; (2) systemic risks; (3) operational and assurance-related risks; and (4) cyber, information, and data-oriented risks. All levels of the risk system are interdependent. Accordingly, a risk-based model for the legal regulation of artificial intelligence in space activities should provide for a comprehensive assessment of risks, their periodic reclassification, the differentiation of regulatory requirements depending on the criticality of the functions performed, and the mandatory documentation of measures aimed at preventing, minimising, and controlling potential adverse consequences.

5. Features of a Risk-Based Model for the Legal Regulation of Artificial Intelligence in Space Activities

A risk-based model for the legal regulation of artificial intelligence in space activities should be based on the recognition that legal requirements applicable to AI systems cannot be identical for all technologies, actors, and space missions. The extent of regulatory intervention should be determined with due regard to the level of autonomy of the system, the criticality of the functions it performs, the scale of potential adverse consequences, the possibility of human intervention, the nature of the data being processed, and the operating conditions of the space object. Accordingly, the greater the potential risks associated with the use of AI to human life and health, space infrastructure, the outer-space and terrestrial environments, information security, or mission continuity, the stricter the requirements governing the development, testing, certification, deployment, and oversight of such a system should be.

We propose the following features of a risk-based model for the legal regulation of artificial intelligence in space activities:

1) multilevel nature of regulation, encompassing a set of interrelated institutional, systemic, operational, cyber, information, and data-oriented risks. Each level of risk should be assessed in conjunction with the other elements of the space system;
2) mission-centric nature of legal regulation. The object of assessment should be the entire space mission into which the AI system is integrated. The reliability of an algorithm does not guarantee mission safety where risks arise from the interaction between software, hardware, communication channels, the ground segment, operators, external information systems, and the conditions of the space environment. Therefore, the legal assessment should cover the entire sociotechnical system within which the AI operates;
3) differentiation of legal requirements according to the criticality of the functions performed. For highly critical functions, enhanced requirements should be established in relation to accuracy, reliability, explainability, resilience, redundancy, verification, certification, and the capacity for the safe termination of system operation;
4) regulation of AI throughout its entire life cycle. Risks should be assessed at the stages of system design, data preparation and selection, model training, testing, integration into the space system, launch, operation, updating, modification, and decommissioning. A risk-based model should provide for continuous monitoring, reassessment of conformity, and periodic risk reclassification;
5) clear allocation of competence, obligations, and legal liability among all participants in the life cycle of an AI system. Legal regulation should define the functions of developers, data providers, integrators, space technology manufacturers, operators,

customers, owners of space objects, independent auditors, certification bodies, and public regulatory authorities;

6) combination of preventive and adaptive regulation. Space missions are characterised by high costs, the difficulty of remedying malfunctions after launch, and the potentially irreversible nature of their consequences. Priority should therefore be given to the early identification, prevention, and minimisation of risks. A risk-based model should combine stable baseline obligations with mechanisms allowing the timely revision of technical standards, risk criteria, and oversight procedures;
7) mandatory application of verification, validation, and independent safety assurance procedures for AI systems;
8) provision of controlled autonomy for AI systems. The permissible degree of autonomy of an AI system should be determined according to the criticality of the mission, communication latency, the possibility of timely operator intervention, and the nature of potential consequences. Critical operations should be supported by independent monitoring mechanisms and the capacity to transition to a backup mode, conventional algorithmic control, or human oversight;
9) evidence-based approach to risk management. Developers and operators should document the rationale underlying the classification of the system, the results of risk assessments, the characteristics of datasets, testing procedures, identified limitations, known failure scenarios, risk-mitigation measures, software modifications, and incidents occurring during operation;
10) integration of cybersecurity, information security, and data governance into a unified system of legal safeguards;
11) need for the international interoperability of regulatory requirements. Space activities generally involve actors from different states, the use of transnational infrastructure, data exchange, and the joint management of missions. National rules governing AI should therefore be aligned with international space law, the general principles of state responsibility for national space activities, requirements relating to the registration and supervision of space objects, and international technical standards.

Thus, a risk-based model for the legal regulation of artificial intelligence in space activities should be comprehensive, multilevel, mission-centric, and life-cycle-oriented. Its principal purpose is to establish a legally defined mechanism for the timely identification, assessment, allocation, minimisation, and control of risks.

Conclusions

Existing international space law contains general principles applicable to the use of artificial intelligence in space activities. These include the principles of the peaceful use of outer space, the international responsibility of states for national space activities, the proper supervision of non-governmental entities, liability for damage, international cooperation, due regard for the interests of other states, and the prevention of harmful contamination of the outer-space and terrestrial environments. However, these provisions were formulated before the emergence of autonomous systems and do not take into account the specific features of algorithmic decision-making, machine learning, dynamic changes in system behaviour, the opacity of certain models, and the difficulty of establishing a causal link between the operation of AI and adverse consequences. International space law therefore retains its

regulatory significance but requires functional reconsideration, further specification, and supplementation with specialised legal, technical, and organisational mechanisms.

A risk-based model should form the basis of the appropriate legal regulation of artificial intelligence in space activities. Such a model should provide for the differentiation of legal measures depending on the level of system autonomy, the criticality of the functions performed, the scale of potential harm, operating conditions, the possibility of human control, the nature of the data being processed, the duration of the mission, and the system's capacity to affect other space objects, people, infrastructure, and the environment. Accordingly, legal regulation should be proportionate to the level of risk: the greater the probability of serious, systemic, or irreversible consequences, the stricter the requirements governing the development, testing, certification, operation, monitoring, and termination of the system should be.

The proposed classification of risks associated with the use of artificial intelligence in space activities encompasses four interrelated levels: institutional and governance-related; systemic; operational and assurance-related; and cyber, information, and data-oriented. Institutional and governance-related risks arise from the absence of harmonised terminology, an unclear allocation of competence, insufficiently defined requirements concerning permissible levels of autonomy, and the lack of specialised mechanisms for classifying AI systems. Systemic risks are associated with the complex interaction between software, hardware components, communication channels, ground infrastructure, operators, and the external environment. Operational and assurance-related risks concern deficiencies in verification, validation, testing, independent auditing, monitoring, and safe backup-control procedures. Cyber, information, and data-oriented risks include the possibility of external interference, data manipulation, model compromise, and breaches of the confidentiality, integrity, and availability of information.

A risk-based model for the legal regulation of artificial intelligence in space activities should apply throughout the entire life cycle of an AI system – from defining its intended purpose, designing the system, and developing datasets to training, testing, integration, launch, operation, updating, modification, and decommissioning. In this regard, the necessary elements of a risk-based model for the legal regulation of artificial intelligence in space activities include continuous monitoring, reassessment of conformity, periodic risk reclassification, the documentation of incidents, and the mandatory review of risk-management measures following significant changes to the system.

A key condition for the effectiveness of the proposed model is a clear allocation of powers, obligations, and legal liability among all participants in the AI life cycle. The legal status and limits of liability should be defined for model developers, data providers, integrators, manufacturers of space technology, operators, customers, owners of space objects, independent auditors, certification bodies, and public regulatory authorities. Ultimate legal liability should remain connected to the acts or omissions of natural and legal persons and to the international obligations of the states under whose jurisdiction or control the relevant space activities are conducted.

Of particular importance is the introduction of a controlled-autonomy regime for AI, under which the permissible degree of independence of an AI system should be determined with due regard to the criticality of the operation, the remoteness of the space object, communication latency, the possibility of timely operator intervention, and the severity of potential consequences.

Therefore, a risk-based model for the legal regulation of artificial intelligence in space activities should be regarded as a comprehensive legal mechanism for the timely identification, assessment, classification, allocation, minimisation, and control of risks. The defining

characteristics of a risk-based model for the legal regulation of artificial intelligence in space activities are its multilevel nature, mission-centric approach, proportionality, whole-life-cycle orientation, controlled autonomy, evidence-based character, combination of preventive and adaptive regulation, clarity of liability, and international interoperability. The introduction of such a model is capable of ensuring a balance between promoting technological innovation and protecting human life and health, space infrastructure, information security, the outer-space and terrestrial environments, as well as the legitimate interests of states, private operators, and other participants in space activities.

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Some Trends on Current Developments in International Space Law

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This article examines the contemporary evolution of international space law (ISL), identifying key trends that characterize its current state and future trajectory. It argues that, following a highly productive formative period in the 1960s–1970s marked by the adoption of five core UN treaties, ISL has entered a prolonged phase of stagnation at the universal level. Despite continuous deliberations within the UN Committee on the Peaceful Uses of Outer Space (COPUOS), no new binding international instruments have been adopted for decades, due in part to the consensus-based decision-making procedure, which increasingly acts as a structural constraint on normative development.

In response to this regulatory gap, alternative mechanisms have emerged. The article highlights three interrelated trends shaping modern ISL: the expansion of "soft law," the substitution of international regulation by fragmented national legal regimes in areas requiring universal governance, and the emergence of plurilateral ("club-based") models of cooperation, such as the Artemis Accords and parallel initiatives. The increasing reliance on national legislation is thus not merely a reflection of state activity, but a compensatory and potentially problematic shift, whereby states unilaterally regulate matters that, by their nature, demand coordinated international legal solutions.

Particular attention is paid to unresolved issues such as the delimitation of outer space, the legal regime of space resources, and space debris mitigation, which expose the limitations of the existing framework. The article concludes that the current multi-layered and decentralized regulatory system risks undermining legal certainty and coherence in space governance. It advocates for a renewed commitment to the progressive development of ISL through binding international norms, potentially in the form of an additional protocol to the Outer Space Treaty, alongside a reconsideration of decision-making procedures within relevant international institutions.

Keywords: international space law; regulatory stagnation; consensus principle; soft law; regulatory substitution; national space legislation; fragmentation of legal regimes; space governance; space resources; space debris; delimitation of outer space; plurilateral cooperation.

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Introduction

International Space Law (ISL), as one of the youngest branches of public international law, began to take shape in the 1960s and 1970s, in parallel with the dawn of the space age in human history. At that time, space activities were effectively concentrated within two powers – the USSR and the United States, which possessed comparable scientific and technical capabilities and were engaged in intense competition for access to outer space. At the same time, neither had guarantees of strategic supremacy, which objectively led to an interest in establishing universal rules of conduct in this new environment.

Recognition of the need for legal regulation of the exploration and use of outer space contributed to the fact that the basic principles of international legal regulation of space activities were developed in a relatively short historical period – in fact, over the course of twelve years, moreover, the first space related treaty was drawn up also less than ten years after the launch of the earth's first artificial satellite (Cheng, 1997). The body of regulations formed during this time was characterized by conceptual balance and a focus on establishing fundamental principles designed to prevent the dominance of any state, regardless of its level of technological development (Kopal, 2011). An important role in this process was played by the practice of reaching consensus within the United Nations, which, although not originally enshrined in its founding documents, had already become the leading procedural approach to decision-making in the UN Organizations, particularly in the field of space activities. The use of consensus helped ensure that the interests of a wide range of states were taken into account, including developing countries, which were viewed as potential beneficiaries of the results of space exploration and future participants in space activities. Thus, five universal international treaties on outer space were adopted, forming the basis of the modern international space legal order.

As a reminder, these include:

- the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty) (The Treaty, 1967), which established the fundamental principles of space law, including the freedom to explore outer space, the prohibition of national appropriation of outer space, and its use exclusively for peaceful purposes;
- Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space (Rescue Agreement), (Agreement, 1968), which specified provisions regarding the provision of assistance to astronauts as "messengers of humanity";
- Convention on International Liability for Damage Caused by Space Objects (Liability Convention), (Convention, 1972), which established a special regime of international legal liability of states for damage caused by space objects;
- The Convention on Registration of Objects Launched into Outer Space (Registration Convention), (Convention, 1975), aimed at ensuring transparency in space activities through an international registration mechanism;
- The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Agreement), (Agreement, 1979), which contains provisions regarding the legal regime of natural resources of celestial bodies, although it has not gained widespread recognition among leading spacefaring nations.

During this initial, most successful period of the "first generation" of the ISL formation (Gorove et al., 1986), its regulatory framework was established, and its fundamental principles

and institutions were enshrined; these continue to play a regulatory role even today, despite significant changes in the nature and participants of space activities.

From the early 1980s, no universally binding international instrument has been adopted in the field of space activities. Instead, during the 1980s and 1990s, there was active development of "soft law" instruments in specific areas of space activities: international direct television broadcasting (Principles, 1982), remote sensing of the Earth (Principles, 1986), and the use of nuclear power sources (Principles, 1992). This period is generally considered to mark the formation of the second generation of the ISL. Some scholars believe that a profound crisis in the development of IHL had already begun during this period (Jakhu, 2009; Hobe, 2009: 351-359). I consider such an assessment somewhat premature in terms of timing. Although the relevant "soft law" sources that were taking shape at that time are not legally binding by nature and do not establish strict requirements, they should not be underestimated. They nevertheless have regulatory significance, as they provide states with clear guidelines and recommendations regarding their activities in the development and application of space technologies (Marboe, 2012). Moreover, they have certain advantages over treaty instruments, namely: their universal nature (they are addressed to all subjects of the international space law community, not just its participants); they do not require signature or ratification; in general, the procedure for their adoption is significantly simpler and more flexible than the corresponding procedure for adopting or amending international treaties.

A real deep crisis in the development of the ISL appears to have begun in the 21st century. For more than a quarter of century, no significant event has occurred that could be characterized as its progressive development. At the UN level, a series of General Assembly resolutions have been adopted that contain virtually no regulatory provisions. They can rather be classified as acts interpreting the existing norms of international treaties and guiding states toward the development of their own space legislation and the improvement of its application. These include, in particular, the following UN General Assembly Resolutions: "Application of the concept of the "Launching State," (2004), "Recommendations on enhancing the practices of States and International Intergovernmental organizations in registering space objects," (2007), "Recommendations on national legislation relevant to the peaceful exploration and use of Outer Space".

The development of ISL over the past 30 years can thus be characterized as stagnation. This is particularly evident in the activities of the UN COPUOS, especially its Legal Subcommittee. Here, certain issues crucial for the further development of ISL have been discussed without significant progress for decades: they are carried over from one session's agenda to the next, numerous working groups are established, questionnaires are sent to member states, and national experiences are compiled. However, no substantial results that could serve as a foundation for the progressive development of ISL have been observed. Thus, some "soft law" instruments adopted during the 1980s and 1990s were established as temporary measures, serving as guidelines for further revision until the establishment of an international binding instrument in the relevant field. In some cases, this was explicitly stated in the texts of these documents themselves and later confirmed in UN General Assembly resolutions. This includes, in particular, Principle 11 of the Principles Concerning the Use of Nuclear Power Sources in Outer Space, which establishes the need for the Committee on the Peaceful Uses of Outer Space to review the relevant Rules no later than two years after their adoption (Principles, 1992). However, despite the fact that the item "Review and possible revision of Principles Governing the Use of Nuclear Power Sources in Outer Space" remained on the agenda of the Legal Subcommittee until 2020, and calls for the development of a binding instrument in this

area were made throughout this period (A/AC. 105/942, 2010, para. 81; A/AC 105/1045, 2013 paras. 99, 100, 102), no substantial progress was ever made on this issue. The only tangible outcome of years of discussions on this issue in both UNCOPUOS subcommittees was the development by the Scientific and Technical Subcommittee, in collaboration with the IAEA, in May 2009 of a technical document titled "Safety Framework for Nuclear Power Source Applications in Outer Space." (Safety, 2009) However, as explicitly stated in this Framework, it "does not supplement, alter or interpret any of those principles (Principles, 1992). This document is not legally binding. According to Gob Escolar, Reynders, and Summerer, "… even though the NPS Safety framework is not legally binding, it might well turn out to be de facto as effective. In addition, the legally non-binding technical provisions as contained in the NPS Safety framework could under certain conditions gain legal significance and force, by either evolving into customary international law, should it be possible to establish the required State practice and opinion iris, or ultimately by the adoption of explicit treaty law based on the NPS Safety Framework. Such legally binding international standards are still missing and, despite the calls for implementing the NPS Principles and/or NPS Safety Framework into a hard law instrument, no such efforts are currently being undertaken" (Cologne, 2015). It should be noted that this issue remained on the LSC agenda until 2020, after which it was moved to the item "General exchange of information on non-legally binding United Nations instruments on outer space" (International, 2025). However, no progress toward the elaboration of a binding instrument in this area has been observed.

Another, perhaps the most striking example of stagnation in the work of the Legal Subcommittee is the issue of the definition and delimitation of outer space, which warrants closer examination. This issue was raised in the COPUOS Legal Subcommittee as early as during the drafting of the first generation of space treaties, that is, in 1959, but was postponed due to a lack of common understanding among member states. The true starting point for consideration of this issue should be considered 1983, when, pursuant to UN General Assembly Resolution 38/80 "International Cooperation in the Peaceful Uses of Outer Space" (International, 1983), a working group was established within UN COPUOS and its subcommittees. The working group was established to develop a clear definition of outer space, which is considered essential for managing activities beyond Earth's atmosphere, particularly in light of the increasingly intensive use of outer space for various purposes, including communications, navigation, and scientific research. The main positions of member states center on two approaches: spatial and functional.

States that adhere to the functional approach view outer space and airspace from a legal perspective as a single supraterrestrial space that does not require delimitation. They view activities above the Earth not in terms of the altitude at which they are carried out, but in terms of their nature and function. They believe that establishing boundaries is impossible and unnecessary, as it would complicate existing activities and hinder scientific progress in the exploration of outer space.

States that support the spatial approach including Ukraine (A/AC.105/1112/Add.11, 2022) draw attention to the fundamental differences in the legal regimes governing outer space and airspace and their implications, particularly the need to define spatial boundaries and the applicability of the principle of freedom of exploration of outer space, on the one hand, and the principle of state sovereignty over their national airspace, on the other. Among the main arguments of these states is the difference in the legal regimes of air and space law, since Article II of the Outer Space Treaty provides that outer space is not subject to national appropriation, while Article 1 of the Convention on International Civil Aviation (Convention, 1944) provides for the full sovereignty of states over the airspace located above their territory.

Over the past few decades, various proposals in support of one approach or another to the delimitation of airspace and outer space have been formally put forward in the Legal Subcommittee. Among these proposals were demarcations based, for example, on establishing an upper limit to national sovereignty; on dividing the atmosphere into layers; the theory of navigable airspace was put forward, i.e., the maximum flight altitude of aircraft based on the aerodynamic characteristics of aircraft, the so-called "von Kármán line"; on the lowest perigee of an orbital satellite; on the Earth's gravitational effects; on the possibilities for effective control; on the division of space into zones; and several others.

In recent years, some states have begun to advocate a third position – the need to combine the two approaches and establish a combined spatial-functional regime that would, on the one hand, define the upper boundary of airspace and the lower boundary of outer space, and, on the other hand, would establish international norms regulating the passage of space objects through airspace – including that of foreign states – during their launch and reentry to Earth, provided that such space activities are peaceful in nature, conducted in accordance with international law, and respect the sovereign interests of the relevant states.

The absence of international legal regulation of this issue leads some states to resort to national regulation by establishing a clear boundary of national airspace in their national laws. Most states have, in this regard, established a lower boundary of outer space that does not exceed the lowest perigee of an artificial Earth satellite, i.e., 100 ± 10 km above sea level (see, for example, the recent Act on Space Activities of the Slovak Republic, which entered into force on February 1, 2025, defines outer space in Section 2(3) as "the space located at an altitude of more than 100 km above sea level," "Outer space means the space exceeding 100 km above sea level" (Slovak, 2024). However, there are also states whose definitions of outer space in national legislation are based on the use of other criteria, ranging from the establishment of a relatively low altitude above mean sea level to encompass airspace designated for aviation, to delimitations at very high altitudes that exceed even some of the most important near-Earth orbits. At the same time, the vertical spatial boundary of state sovereignty, where established at the national level, is generally determined with due regard to local and national interests and often differs in both nature and spatial scope. Such national practices of States are continuously summarized by the relevant working group, and numerous summaries are issued on this basis (A/AC.105/C.2/L.302, 2017). However, even today, after more than 40 years, a consensus has not been reached, and the issue remains on the agenda of the Legal Subcommittee.

The trend of substituting the regulation of relations belonging to the international legal level with fragmented national regulation is not merely harmful but also dangerous, as it creates legal conflicts, particularly in determining the subjects of liability, given that ISL provides for specific features of the exercise of international legal responsibility depending on the location (space) where damage is caused by a space object: airspace or outer space. The lack of clear legal certainty in this matter will increasingly have a negative impact on the development of suborbital space activities as well.

Total stagnation in the development of international space law is evident in virtually all areas of space activity regulation. Moreover, this trend is intensifying against the backdrop of ever-new challenges facing the international community in the 21st century. In recent decades, space activities have undergone a qualitative transformation linked to their commercialization, the growing number of actors – including private entities – the intensified use of near-Earth space, the gradual transition toward the practical exploitation of celestial bodies' resources, and trends toward the militarization of space. A significant portion of these issues could not realistically be addressed by the foundational international treaties of the 1960s and 1970s, which were

formulated under fundamentally different technological and political conditions. As a result, an increasing number of states are adopting their own space legislation, which reflects the specifics of their domestic space policy, the focus of development on a particular segment, and the overall state of the country's space activities. This results in national legislations incorporating unique models for the formulation and implementation of universal space law norms that should be subject to international legal regulation. Such processes occur, in particular, in the regulation of space debris mitigation and space environmental safety standards, given that gaps in the international legal framework arise here, in particular, due to the absence of a clear, universal legal mechanism for the national registration of space objects, which complicates procedures for notification, consultation, and liability in the event of a collision threat, as well as the possible removal from orbit of an object that has become space debris, the regulation of the disposal of objects after missions, and so on. In light of this, for example, Chinese legislation on the prevention of space debris (Chinese, 2019) has established its own rules regarding space debris, which in certain respects contradict the Guidelines on Space Debris Minimization, developed under the auspices of the Inter-Agency Space Debris Coordination Committee and the United Nations Committee on the Peaceful Uses of Outer Space, thereby interfering in relations of a global nature that require coordinated efforts within international frameworks. Regulatory competition also arises among jurisdictions regarding export controls on space technologies (in particular, the scope of entities involved in technology transfers, the definition of "sensitive" technologies, and dual-use technologies). Some spacefaring nations are establishing their own rules in areas such as liability, registration of space objects, cybersecurity (Duggal, 2017), and other issues that ideally should be harmonized through international treaties to ensure fair and mutually beneficial management of outer space.

In recent years, national legislation has become particularly focused on regulating the use of space resources. For example, the U.S. Commercial Space Launch Competitiveness Act (Commercial, 2015) allows U.S. citizens and companies to extract and own space resources, including asteroids. And on April 6, 2020, U.S. President Donald Trump signed the executive order "Encouraging International Support for the Recovery and Use of Space Resources" (Encouraging, 2020), which encourages such extraction by private companies. The Luxembourg Space Law (Luxembourg, 2017) permits private individuals to own and exploit space resources. Japan's Act No. 83 of 2021 on the Promotion of Business Activities for the Exploration and Development of Space Resources (Act, 2021) is also aimed at encouraging private-sector participation in the exploration and development of space resources. Legislation in the United Arab Emirates is moving in the same direction, where Federal Decree-Law No. 46 of 2023 (UAE, 2023) was first adopted, subsequently expanded upon by UAE Cabinet Resolution No. 19 of 2023 (Aldabousi, 2025). It is clear that these issues cannot be resolved at the national level but require a unified approach based on international legal regulations.

Within the framework of the same "compensatory" regulation (in the absence of internationally legally binding instruments), there is a further development of "soft law," whose instruments are adopted largely under the auspices of the UN (Marboe, 2012). In addition, specialized institutions are emerging at the international, regional (particularly European), and subregional levels. The forms of such instruments are diversifying. These are no longer just declarations or resolutions, but also codes of conduct, guidelines, best practices, communications, platforms, policy guidelines, and so on. The priorities of space law regulation are shifting; the focus is gradually shifting toward ensuring the safety of space activities. "Soft" space law is currently being developed within the UN Committee on the Peaceful Uses of Outer Space (COPUOS), as well as within the Inter-Agency Space Debris Coordination Committee,

the International Organization for Standardization, the UN Disarmament Commission, the Conference on Disarmament, the Committee on Space Research (COSPAR), and several others. In recent years, these bodies have been developing non-binding regulations on the following issues: ensuring transparency and building confidence in space activities (A/RES/68/50, 2013); preventing the creation of space debris (Space, 2002); the long-term sustainability of space activities (Guidelines, 2021); the prevention and management of emergencies (GA Resolution 61/110, 2006); prevention of an arms race in outer space (Prevention, 2020), responsible conduct in space (A/RES/76/231, 2021), and several others.

According to Stefan Hobe, "soft law" instruments, while flexible and politically acceptable, cannot fully replace binding international obligations in areas involving significant risks and shared interests (Hobe, 2019: 91).

Finally, the third trend in the contemporary development of ISL is the emergence of plurilateral regulatory models, which also arise outside the universal mechanisms of the UN and are based on cooperation among a limited group of states united by common political and technological interests (let us call this "club-based" regulation). The phenomenon of concluding agreements among a limited group of states is not in itself anomalous in international law; it is established practice, provided that such agreements do not claim to establish a new universal legal regime for the entire international community. The problem arises when such mechanisms effectively begin to serve as a substitute for universal international legal regulation.

The most telling examples of this trend are, once again, contemporary initiatives in the field of space resource exploitation. These initiatives are structured around two alternative models. First and foremost, there are the Artemis Accords (The Artemis, 2020), initiated by NASA and signed by eight states at the level of space agency heads on October 13, 2020, with Ukraine becoming the ninth signatory to the Accords (Ukraine, 2020); as of the end of January 2026, 61 countries are signatories to the Artemis Accords (The Artemis, 2026).

In parallel, an alternative model of cooperation is taking shape within the framework of Russian-Chinese initiatives to establish an international lunar research station, based on the Memorandum of Understanding on Cooperation in the Construction of the International Lunar Research Station, signed by the China National Space Administration and the Russian State Corporation for Space Activities "Roscosmos" on March 9, 2021 (International, 2021a). Thirteen states have joined this project, and seven more are in the process of acceding (International, 2021 b). Within the framework of these two parallel initiatives, there is currently no consensus regarding the vision for the legal regime governing the commercial exploitation of space resources or the interpretation, in this context, of the basic provisions of the Outer Space Treaty, particularly Article II: "Outer space, including the Moon and other celestial bodies, shall not be subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means" (The Treaty, 1967), which lacks direct regulation of the legal regime governing the use of space resources. Is this an obstacle to their extraction on a commercial basis, or can all issues related to such extraction be resolved at the level of national legislation? The discussion continues both at the doctrinal level (Deplano, 2023; Atkins et al., 2022; Capurso, 2018), as well as for nearly 10 years within the Legal Subcommittee of COPUOS, where this issue is considered a standing item on the agenda and is being addressed by a working group established specifically for this purpose.

Without going into the details of the relevant discussions and debates (this issue is fully covered in the literature, particularly in relation to the Artemis Accords, and has also been addressed by the author of this article (Malysheva, 2021), and the relevant research is presented in this edition (Boamah, 2025)), we will focus on the formal legal aspects of

concluding such agreements. Neither the Artemis Accords nor the ILRS can be considered international treaties in the strict sense. These are memoranda of understanding that do not contain specific obligations but merely establish the fundamental principles of future projects. Based on these memoranda, diversified bilateral international treaties are concluded between the "core" participant and each of the partners, defining the framework and scope of their cooperation. Each of these bilateral treaties has its own specific features. Under the Artemis Accords, in particular, each treaty is concluded between NASA and the authorized agencies of the partner states. At the same time, these treaties are not symmetrical between NASA and the other contracting parties. The bilateral aspects of program participation detail the organizational, technical, and institutional frameworks for cooperation, the allocation of resources in accordance with the parties' contributions, and the role and responsibilities of each party regarding the design and implementation of the program. NASA serves as the backbone in establishing these relationships between the parties. All other partners act as secondary actors, whose rights, obligations, and responsibilities depend on the primary actor, which in a certain way undermines the general concept of international treaties, in particular the principle of equality of the parties.

It should be noted that this practice of concluding international agreements on space activities is not new in the context of international cooperation on the exploration and use of outer space for peaceful purposes. The first large-scale space project in which this framework was applied was the International Space Station (ISS) project, the establishment and operations of which are governed by two bodies of international law:

1) the norms of general international law and international space law developed under the auspices of the United Nations;
2) the norms of special treaty law and "soft law" established on a multilateral or bilateral basis by the parties to the ISS Agreement. In addition, each party to the ISS Agreement may enter into contractual relationships with third parties that do not participate directly in the Agreement but are interested in its activities or the use of its results. As noted in (The Artemis, 2020), this approach emphasizes international coordination and a more centralized management model, with a reduced role for private entities and a more cautious approach to the commercialization of resources.

An analysis of the formation and implementation of the international legal frameworks governing projects such as the ISS (Malysheva, 2012) or Artemis reveals a number of distinctive features or new legal phenomena that do not fully correspond to classical models of international treaty relations. These features indicate that both the form and content of international cooperation are becoming increasingly flexible and, in their development, are moving away from established legal doctrine, yielding to factors of pragmatism and expediency from the perspective of the interests that member states of a particular "club" seek to achieve.

In other words, this leads not only to the stagnation of universal treaty-based regulation, but also to the simultaneous emergence of new regulatory levels operating outside its scope, thereby forming alternative centers of space law-making that constitute a complex, multi-layered, and potentially conflicting system. As emphasized in (Jakhu & Pelton, 2017: 112–118), the current development of space activities is increasingly shaped by competition between various models of legal regulation that are emerging outside of universal mechanisms.

Due to rapid change and dynamic expansion, the governance system originally constructed under the framework of the five UN space treaties may require revisions and updates to effectively address current challenges (Atkin et al., 2022).

Given the above, it should be noted that the current stage of development in international space law is characterized by a combination of three interrelated trends: the expansion of the scope of "soft law," the growing role of national regulation, and the emergence of "club" (plurilateral) models of cooperation among states. Taken together, these trends indicate a departure from the universal treaty-based model that formed the foundation of the "first generation" of international space law. Such an evolution, despite its certain functional expediency, does not ensure an adequate level of legal certainty and unity of the legal regime of outer space, especially in areas affecting the common interests of the international community. In this regard, there is an objective need to return to the idea of the progressive development of international space law based on legally binding international norms. Such development cannot be considered sufficient to ensure effective legal regulation of space activities, particularly in areas affecting the common interests of the international community. In this context, a return to the idea of the progressive development of international space law through the elaboration of legally binding international norms on key issues of contemporary space activities appears justified.

This idea is not new; back in the 2000s, the UN COPUOS Legal Subcommittee discussed the development of a comprehensive convention on space law, modeled after the United Nations Convention on the Law of the Sea (Convention, 1982), which would cover all issues currently addressed by the five main UN space treaties, while also bringing within the scope of regulation a range of issues that have arisen for the global community over the past half-century. This proposal did not achieve consensus and was subsequently withdrawn from consideration. However, the objective need for a systematic update of the international legal framework governing space activities remains relevant. I consider the development of new international legal norms, which could be adopted as an additional protocol to the Outer Space Treaty, to be a more realistic approach under current conditions.

In this context, it is important to note the key institutional obstacle to such progress, which remains the practice of consensus-based decision-making within the UN Committee on the Peaceful Uses of Outer Space. Although this approach played an important role during the formative period of international space law, ensuring that the interests of all states were taken into account, in the current context it is increasingly becoming a factor that blocks the adoption of necessary decisions. The continued insistence on the exclusivity of the consensus procedure creates the risk of deepening the stagnation of international space law (Malysheva, 2015: 72–78). This necessitates a review of decision-making approaches within the relevant international institutions or the search for alternative mechanisms to ensure their effectiveness.

Conclusions

In light of the discussion in this article, it seems appropriate to identify the key drivers for the further development of the international legal framework governing space activities:

1. *Defining the scope of relations that require priority international legal regulation at the universal level.*

These include, first and foremost: issues related to the use of space resources, the prevention of space debris, ensuring the safety of space activities, the definition of the boundaries of outer space, the legal regime for suborbital flights, and several others. It is precisely these areas that, by their very nature, cannot be effectively regulated at the national or regional levels.

2. *The gradual development of legally binding international norms based on existing "soft law" instruments.*

In the current context, a significant portion of "soft law" norms can be viewed not as an alternative, but as a preparatory stage for the subsequent codification of relevant norms in the form of international treaties. This approach will allow for combining the flexibility of non-binding mechanisms with the need to ensure legal certainty.

3. *Ensuring coherence between national and international legal frameworks*.

The development of national space legislation must take into account states' international legal obligations and the principles of international space law. It is also advisable to develop international standards for harmonizing national legislation in key areas of space activities.

4. *Defining the limits of "club" regulation.*

The conclusion of agreements among a limited group of states is a legitimate instrument of international cooperation, provided that such agreements do not claim to establish universal norms and do not supersede generally binding international legal regulations. At the same time, it is necessary to ensure their compliance with the fundamental principles of international space law.

5. *Revision of decision-making procedures within international institutions, such as the UN COPUOS.*

The practice of consensus, which played a positive role during the formative stage of international space law, is increasingly becoming a factor that hinders its development in the current context. It is therefore advisable to consider the possibility of modifying this practice or introducing alternative decision-making procedures that would ensure a balance between taking into account the interests of states and the need for effective rule-making.

In conclusion, the further development of international space law needs to be based on a combination of the flexibility of new regulatory approaches with the restoration of the role of universal international legal regulation as a key instrument for ensuring stability, predictability, and fairness in the use of outer space.

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The Conceptual and Categorical Framework of International Space Law: Problems in Defining the Concepts of "Harm," "Potentially Harmful Interference," and "Harmful Interference" in Space Activities

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This article presents a comprehensive study of the legal nature of the concepts of "harm," "potentially harmful interference," and "harmful interference" in international space law. It is argued that the rapid development of space activities, increase in the number of space operators, commercialization of space, growing amount of space debris, development of technologies capable of actively influencing space systems, and intensification of geopolitical competition highlight the need to refine the conceptual framework of international space law. The evolution of the "harm" category from general theoretical legal concepts to its contemporary understanding in international space law is analyzed. The content of the concept of "potentially harmful interference" is examined as an independent legal category of a preventive nature, enshrined in Article IX of the 1967 Outer Space Treaty, as well as the origin and development of the category "harmful interference," which emerged in international telecommunications law and was integrated into the mechanism of international legal regulation of space activities.

It is established that these categories perform different functions within the mechanism of international legal regulation: the concept of "harm" underlies the institution of international liability, whereas "potentially harmful interference" and "harmful interference" ensure the implementation of preventive mechanisms aimed at preventing the occurrence of negative consequences.

Keywords: international space law, harm, potentially harmful interference, harmful interference, space activities, international liability, preventive legal regulation, space security.

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Introduction

Nowadays, the world is witnessing unprecedented challenges to the system of international law and the international legal order. The Russian Federation's armed aggression against Ukraine, territorial claims, and political statements by certain States regarding the possibility of revising existing borders demonstrate a crisis in the effectiveness of certain international legal mechanisms. These events highlight the need to rethink current principles, approaches, and doctrines, including in the field of international space law. Recent practice indicates that the existence of international treaties does not guarantee their proper implementation and compliance. Therefore, the effectiveness of international legal regulation depends to a large extent on the political will of States, their attitude toward international obligations, and their willingness to act in accordance with universally recognized principles of international law. It is the States themselves that determine the extent to which their national policies, legislation, and practical activities are consistent with international norms and the obligations they have undertaken.

In this context, the issue of improving international legal mechanisms to ensure the safety of space activities, the liability of States for violations of international rules, and the development of new approaches to regulating relations in outer space in the face of contemporary geopolitical challenges is of particular importance. After all, the rapid development of space activities, the commercialization of outer space, the growing number of State and private actors in space activities, and the intensifying competition for access to space resources make the issues of ensuring the safety of space activities and improving international legal mechanisms for liability for violations of established rules and standards increasingly relevant.

These issues are particularly relevant given the increasing number of space objects in orbit, the accumulation of space debris, the development of satellite systems for communications, navigation, and remote sensing of the Earth, as well as the emergence of new risks associated with the use of artificial intelligence, cyber threats, and the possibility of deliberate interference with the operation of space systems. At the same time, an analysis of the international legal instruments that form the basis of modern space law reveals the absence of a single, unified approach to defining such key concepts as "damage," "potentially harmful interference," and "harmful interference." Although these categories are widely used in international treaties, United Nations documents, acts of the International Telecommunication Union, and the national legislation of individual States, their meaning, scope, and criteria for application remain insufficiently defined.

In particular, the 1972 Convention on International Liability for Damage Caused by Space Objects defines the term "harm" as "loss of life, bodily injury, or other harm to health; or the destruction of or damage to the property of States, natural or legal persons, or the property of international intergovernmental organizations" (Convention, 1972). In other words, this article primarily covers cases of actual harm to life, health, or property. At the same time, the development of modern space technologies gives rise to situations where a threat to space objects or space infrastructure exists even before any actual negative consequences occur. In such cases, the categories of "potentially harmful interference" and "harmful interference" are no less important for the regulation of space activities under international law. The first is used in Article IX of the 1967 Outer Space Treaty as a basis for conducting international consultations in the event of a possible negative impact of one State's space activities on the activities of other States. In contrast, the term "harmful interference" is used in the instruments

of the International Telecommunication Union (ITU) to refer to interference that jeopardizes the functioning of radiocommunication services or significantly impairs their operation.

Consequently, the lack of unified approaches to understanding and applying these concepts creates significant difficulties both for legal practice and for the development of international cooperation in the space sector. In particular, this complicates the establishment of violations of international obligations, the determination of the grounds for States' liability under international law, the assessment of risks associated with space activities, and the development of effective mechanisms to prevent emergencies in outer space.

In addition, the study of the categories of "damage," "potentially harmful interference," and "harmful interference" takes on particular significance in the context of ensuring space security. It is precisely these concepts that underpin mechanisms for risk assessment, the adoption of preventive measures, the development of international standards for safe conduct in space, and the determination of the limits of liability of States and private operators for the consequences of their activities. Establishing clear and uniform definitions of the categories under study is a necessary prerequisite for the further development of international space law and the improvement of national legislation in the field of space activities.

Theoretical and Legal Foundations of the Concept of Damage in Space Law

The Concept of Harm in General Legal Theory

The category of harm is one of the fundamental concepts of legal science and is a key prerequisite for the emergence of legal liability. It is precisely through this category that the law defines the limits of permissible conduct, justifies the need for State intervention, and establishes mechanisms for the protection of individuals' rights and legitimate interests.

The philosophical foundation of the modern understanding of harm is largely linked to the «harm principle», formulated by the English philosopher John Stuart Mill in his work "On Liberty" (Mill, 1859). According to this principle, an individual's freedom may be restricted only when his/her actions cause harm to others.

At the same time, the question of defining the nature of harm remains a matter of debate. In legal doctrine, harm is traditionally understood as adverse consequences arising from unlawful conduct and leading to a violation of rights, legitimate or legally protected interests (Von Bar, 2020; Simonović, 2020; Alle, 2020). Depending on the nature of such consequences, a distinction is made between property damage, moral harm, physical harm, environmental harm, reputational harm, and other types of harm.

At the same time, the meaning of this concept is not fixed and varies depending on historical conditions, social values, and the nature of the relationships within which it is applied.

The issue of defining harm takes on particular relevance in the sphere of international relations, where the consequences of individual States' actions can extend far beyond their national borders and affect the security of the entire global community. It is no coincidence that the researchers of international conflicts point out that human history has, to a significant extent, been marked by wars and violence.

In particular, Joseph de Maistre noted that "Unhappily, history proves that war is, in a certain sense, the habitual state of mankind, which is to say that human blood must flow without interruption somewhere or other on the globe, and that for every nation, peace is only

a respite" (de Maistre, 1974: 51). This approach demonstrates that the concept of harm has traditionally been associated primarily with physical losses, destruction, and human casualties. At the same time, this thesis also reflects the well-known principle of political and military thought – "Si vis pacem, para bellum» – which is based on the idea that ensuring security often requires a preemptive response to potential threats. However, advances in science and technology have given rise to new spheres of activity where harm may manifest not only in the form of direct material losses or physical impact, but also through the creation of threats, risks, and obstacles to the safe operation of complex technical systems. One such sphere is space activities, in which the issue of defining harm takes on particular legal significance.

Characteristics of harm as a legal category in space activities

Space activities have a number of characteristics that determine the specific legal understanding of harm. Firstly, the consequences of one entity's activities can simultaneously affect a large number of States, organizations, and private operators. Secondly, harm can occur both in outer space and on the Earth's surface. Thirdly, establishing a causal link between a specific activity and negative consequences is often difficult due to the technological complexity of space systems and the multi-party nature of space relations.

Unlike traditional areas of legal regulation, in space activities, harm is not always limited to the actual destruction or damage to property. It can be manifested in the form of disruptions to the functioning of space systems, threats to flight safety, loss of access to critical communication or navigation services, as well as the emergence of long-term risks to the use of outer space by future generations.

Therefore, if we generalize the existing approaches to understanding the concept of "harm," the following can be stated in the context of space activities:

1) harm exists only when there is a violation of a right, a legitimate interest, or another legally protected interest. In the context of space law, this means that harm can consist not only of the destruction of a satellite but also of a violation of a State's or operator's right to the safe use of outer space and compliance with the principle of «due regard»;
2) the content of the damage is not once and for all determined. Its limits depend on what interests society recognizes as requiring legal protection. For space activities, this allows the rationale for extending the traditional notion of damage to: damage to the space environment; damage to orbital safety; damage from space debris; damage to information and communication infrastructure; damage to navigation systems;
3) harm encompasses not only direct material losses but also intangible losses, including loss of opportunities, disruption of system operations, or restrictions on the exercise of rights. For example, loss of a satellite communication signal; temporary disruption of RNSS/GNSS systems; blocking of access to satellite services; loss of Earth remote sensing data (ITU, 2022). In such cases, the satellite may not be physically damaged, but harm is nevertheless caused;
4) harm must be legally relevant, as not every negative consequence is recognized as harm. To establish this, the following must be demonstrated: the existence of a protected interest; the fact of its violation; and a causal link between the action and the consequence. If the launch of a satellite by one State results in the loss of a commercial advantage for another operator, this in itself does not constitute harm.

However, intentional disruption of a competitor's satellite's normal operation may be considered a legally significant act that can be classified as causing harm;

5 one of the key conclusions of contemporary doctrine is a shift in emphasis from harm already inflicted to the prevention of potential harm. This approach is particularly important for space law. For example: dangerous satellite encounters; the formation of space debris clouds; testing of anti-satellite weapons; the risk of a Kessler syndrome cascade effect. In such cases, no actual damage has yet occurred, but there is a high probability that it will occur.

Thus, an analysis of contemporary doctrinal approaches to understanding the concept of «harm» indicates a gradual shift away from its narrow interpretation as exclusively actual material or physical losses. In modern law, harm is increasingly viewed as a violation of legally protected rights, interests, or benefits, which can manifest itself in both material and non-material forms. This approach is of particular importance for space activities, where negative consequences may arise not only as a result of physical damage to space objects, but also through the creation of risks to the safe use of outer space, interference with the functioning of space systems, generation of space debris, or restrictions on access to space services. In this regard, the traditional understanding of harm requires further development, taking into account the specific nature of space activities and contemporary challenges to space security.

"Potentially harmful interference" as a distinct category of space law

Unlike most branches of international law, where legal consequences are primarily linked to the fact of harm already caused, international space law established mechanisms to respond to the possibility of negative consequences even at the stage of its formation. This is due to the specific nature of space activities, the consequences of which can be transboundary in nature, affect an indeterminate group of entities, and pose threats to the entire space environment.

One of the first international legal instruments to use the term «potentially harmful interference» was the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (Outer Space Treaty). Of particular importance is Article IX of the Treaty, under which a State Party is obligated to conduct international consultations if it has reason to believe that its planned space activity or experiment may cause "potentially harmful interference" (Treaty, 1967) to the activities of other States in the peaceful exploration and use of outer space.

Thus, international space law links the emergence of certain legal obligations not to the actual occurrence of harm, but to the existence of a reasonable probability of its occurrence. The very use of the term "potentially harmful interference" indicates that, as early as 1967, States recognized the need to prevent risks before negative consequences arise.

At the same time, the Outer Space Treaty does not define the concept of "potentially harmful interference," which has been the subject matter of numerous scholarly debates. According to Sergio Marchisio (Marchisio, 2009) , the provisions of Article IX must be viewed as an expression of the principles of due regard for the interests of other States and international cooperation, which impose on States the obligation to assess the possible negative consequences of their activities even before they begin.

The concept of "potentially harmful interference" was further developed in the work of United Nations Committee on the Peaceful Uses of Outer Space (COPUOS). In particular, documents on the long-term sustainability of space activities and the guidelines for reducing space debris emphasize the need to assess risks, prevent collisions between space objects,

and minimize potential adverse effects on the space environment before they occur. However, it should be noted that the COPUOS LTS Guidelines (Long-term, 2026) are advisory and voluntary in nature and do not have contractual force.

The practice of space activities also demonstrates a gradual shift from responding to damage that has already been caused to managing the risks of its occurrence. Cases involving the creation of space debris are particularly illustrative. For example, the collision between the Iridium-33 and Cosmos-2251 satellites in 2009 (Johnson, 2009) was one of the first instances, in which actual damage to individual space objects transformed into a long-term potential threat to a large number of other space users. As a result, 1,800 pieces of debris measuring approximately 10 cm or larger were created (Johnson, 2009), which still pose a risk to space operations.

The tests of anti-satellite weapons (ASAT) (Anti-Satellite, 2026; Hoffmann, 2021) conducted by certain States in the 21st century, are even more revealing. Even if the immediate damage is limited to the destruction of a single spacecraft, the resulting debris can pose a threat to the operation of other space systems for decades. In such cases, the underlying problem is not so much the damage already caused as the scale of potential damage to the international space community.

The concept of "potentially harmful interference" in scientific doctrine encompasses both intentional and unintentional disruption of space services, including navigation, communication, and other critical services. Moreover, the mere threat of interference can pose a danger even before actual damage occurs.

When discussing the significance of "potentially harmful interference" for preventive legal regulation, it is important to note that, in the context of space activities, it serves as a legal risk indicator triggering the preventive mechanisms of international law even before actual damage occurs. It is precisely the existence of the risk of «potentially harmful interference» that justifies the need for international consultations, risk assessments, information exchange, space situational awareness, and the implementation of measures to ensure space security.

In fact, the category of "potentially harmful interference" serves as the legal basis for implementing the precautionary principle in space activities. Its significance is particularly growing amid the rapid increase in the number of space objects, development of satellite constellations, space commercialization, and emergence of new dual-use technologies.

Thus, "potentially harmful interference" is not merely a theoretical category but also an important instrument of modern international space law. Its use helps ensure a balance between freedom of space exploration and the need to protect the interests of other states, contributes to strengthening international space security, and creates the basis for the formation of an effective system of preventive legal regulation of space activities.

Harmful Interference: Concept and Significance

The category of "harmful interference" is one of the key concepts of modern space law, although its origin is linked not so much to space activities as to the international legal regulation of telecommunications. The development of this concept arose from the need to ensure the orderly use of limited natural resources, primarily the radio frequency spectrum, which is used by both terrestrial and space-based communication systems.

The first regulatory foundations for the category of "harmful interference" were laid by the International Telecommunication Union (ITU), which has been coordinating the use of radio frequencies since the early 20th century (Events, 2024). In ITU documents, the concept of

harmful interference is viewed as a threat to the effective functioning of radio communication systems and the safety of users of such services (Harmful, 2026a).

According to the findings of historical and legal research by Peter A. Tenhula and Carl R. Frank, the term "harmful interference" began to be used in international radio regulation documents after World War II. Prior to that, international conventions had used only the term "interference" without the adjective "harmful" (Tenhula & Carl, 2022).

The Atlantic City Radio Regulations (International Radio Conference, Atlantic City, 1947) are considered the first international document to establish the category of "harmful interference" (Tenhula & Carl, 2025). It was at the International Radio Conference in Atlantic City (1947) that the modern concept of "harmful interference" was first formulated, although its definition had not yet been definitively established. Subsequently, the concept underwent editorial refinements in the ITU Radio Regulations, and following the 1992 reform of the International Telecommunication Union, it was enshrined in the ITU Constitution and the Radio Regulations, where it is still used today.

For example, harmful interference is defined in No. 1.169 of the Radio Regulations (RR) and in No. 1003 of the ITU Constitution as "interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with the Radio Regulations." Harmful interference (including blocking, jamming, or degradation of service) can occur for a wide range of reasons, which may be either accidental or intentional. Both commercial services and critical safety-of-life applications may be degraded and affected (Radio, 2025).

An illustrative example of practical application of the "harmful interference" category is the mass jamming of Global Navigation Satellite System (GNSS) signals recorded by the International Telecommunication Union in 2021–2022. According to the ITU, 329 official reports of harmful interference were received in just one year, posing a threat to the operation of radio navigation services and flight safety (ITU, 2022).

Thus, in international telecommunications law, "harmful interference" was initially viewed as a technical problem related to the use of the radio frequency spectrum. At the same time, the development of space activities and the growing dependence of States on satellite technologies have gradually given this concept a broader legal meaning.

It should be noted that, in modern space law doctrine, the category of "harmful interference" is interpreted much more broadly than merely radio frequency interference. For example, in the reference work "A Lexicon for Outer Space Security," this category is defined as "… external blocking or reduction of services provided by space systems, which may be accidental or intentional, and include interference with any space services, ranging from commercial services to critical safety-of-life programs" (Harmful, 2026b).

Thus, while ITU documents were primarily focused on eliminating existing interference in the field of radio communications, Article IX of the Outer Space Treaty aims to prevent potential negative consequences even before the relevant activities begin.

However, despite the fact that Article IX of the Outer Space Treaty provides for international consultations in the event of potentially harmful interference, the consultation procedure under Article IX has never been formally implemented. This is acknowledged by leading experts in space law, including Sergio Marchisio, Ram S. Jakhu, and Frans von der Dunk. Instead, issues of harmful interference have been resolved through diplomatic channels, ITU mechanisms, or political consultations.

Thus, the category of "harmful interference" has evolved from a narrow technical concept in international telecommunications law into a comprehensive legal category in international space law. Its significance lies not only in protecting the operation of space systems but also in ensuring space security, implementing the principle of "due regard" for the interests of other States, and establishing mechanisms for the preventive regulation of space activities under international law. Although the concept of "harmful interference" has been successfully used in international telecommunications law for over 75 years and is actively applied by the International Telecommunication Union in resolving disputes regarding radio frequency interference, the mechanism for international consultations on "potentially harmful interference," as provided for in Article IX of the Outer Space Treaty, has never been formally implemented. This indicates a gap between the normative establishment of the preventive mechanism and its practical application, highlighting the need to clarify the meaning of the term «potentially harmful interference» and the procedures for its implementation in international space law.

Conclusions

The present study allows us to draw the following conclusions.

Firstly, it has been established that the concept of "harm" is one of the fundamental categories of international law, traditionally associated with the occurrence of negative consequences and the emergence of international legal liability. In the field of space activities, this category takes on a specific meaning, as it encompasses not only physical damage to space objects or property on Earth, but also functional, environmental, informational, and other negative consequences that may affect the safe and peaceful use of outer space.

Secondly, it has been argued that "potentially harmful interference" can be regarded as a doctrinal category that characterizes not the actual occurrence of negative consequences, but the existence of a reasonable probability of their occurrence. It is precisely this category that underlies the preventive mechanism enshrined in Article IX of the 1967 Outer Space Treaty, pursuant to which States are obligated to assess the potential risks of their space activities and conduct international consultations in the event of a possibility of causing "potentially harmful interference."

Thirdly, it has been established that the category of "harmful interference" historically developed within international telecommunications law and was subsequently integrated into international space law as one of the key instruments for ensuring space security. Unlike the concept of "harm," "harmful interference" characterizes a specific negative impact on the functioning of space systems, which does not always result in actual damage but is capable of creating conditions for such damage to occur.

To close the existing gap between the provisions of Article IX of the Outer Space Treaty and its practical application, it is advisable to develop an international procedural mechanism for conducting consultations on "potentially harmful interference." Such a mechanism could take the form of COPUOS Guidelines on the Application of Article IX of the Outer Space Treaty and provide for uniform criteria for identifying potentially harmful interference, a procedure for conducting a preliminary risk assessment (Space Harm Assessment), a procedure for notifying interested States, timeframes for consultations, and recommendations for preventing harm. This would transform the current declaratory mechanism for international consultations into an effective instrument of preventive international legal regulation of space activities.

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