9 Regulation of global navigation satellite systems

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9 Introduction

Global Navigation Satellite Systems (GNSS) and their applications become increasingly important for a wide range of everyday activities. Satellite navigation infrastructure is constantly being developed and anticipated to increase considerably in the near future. This chapter provides an overview of the relevant regulatory issues.

9.1 Technical overview

9.1.1 Definition and applications

GNSS can be defined as space-based systems designed to transmit signals in order to provide three main services: Position, Navigation, and Timing (PNT).1 GNSS consist of three main segments: the space, the ground and the user segment.

The space segment is comprised of a group of satellites (constellation) placed in Medium Earth Orbits (MEO). The satellites constantly emit positioning information, ephemeris,2 in a rigorously synchronous time. Satellites are equipped with identical atomic clocks, which are extremely precise and provide Coordinated Universal Time (UTC).

Anyone with an appropriate receiver can receive the satellite signals along with a time signal. In order for the user to pinpoint its exact location, the receiver has to simultaneously receive broadcasts from at least four navigation satellites. The receiver can then compute its own location, altitude speed and direction, by calculating the time taken by the signal to travel from the satellites to the receiver.3

In order to operate properly, the system needs terrestrial uplink stations and control centers. The ground segment, inter alia, monitors and controls the satellites, ensures the health of its


2 See ssd.jpl.nasa.gov/?glossary&term=ephemeris.

3 See gps.about.com/od/glossary/g/trilateration.htm.
components, makes clock corrections, synchronizes time across the constellation and resolves satellites’ anomalies. The ground stations’ main task is to safeguard the system’s accuracy by taking precise measurements of the navigation signals. In order to achieve this, a worldwide network of GNSS ground stations is needed.

The majority of GNSS systems are dual use: military and civil.

As to civil applications, GNSS is used for a wide range of applications. Transport by all means is extensively dependent on GNSS services. GNSS applications are also increasingly used in agriculture and fisheries, energy management, and surveying. Moreover, GNSS can be used to monitor the surface of the Earth, contributing to the prediction of natural disasters. Noteworthy is also the operational CORPAS-SARSAT system for Search and Rescue (SAR). GNSS satellites will host SAR payloads, to improve the performance of CORPAS-SARSAT by including SAR capability into MEO (MEOSAR).

9.1.2 Core-constellation systems and augmentation systems

A core-constellation system along with the receivers constitutes the basic GNSS. The augmentation systems improve the GNSS performances, by providing higher accuracy, availability, integrity and reliability.

9.1.2.1 Core-constellation systems

Global core-constellation systems are the U.S. NAVSTAR Global Positioning System (GPS) and the Russian GLONASS, which are currently operational. Under development are the European Union’s Galileo and the Chinese Beidou 2 – COMPASS. Furthermore, there is the Indian Regional Navigation Satellite System (IRNSS), a regional system.

GPS was developed initially for military purposes. In 1994, the US sent a letter to the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO) offering the GPS signals for the use of international aviation. GPS became fully operational in 1995. It includes at least 24 operational GPS satellites, in six orbital planes, which fly in MEO at an altitude of approximately 20 200 km. GPS PNT services are available to all, continuously and free of charge.

The Russian GLONASS, fully operational since 1995, offers also signals to ICAO free of charge. In May 2007, President Putin announced open access to GLONASS signals for civil, free and unlimited use. GLONASS comprises 24 Glonass – M satellites deployed in three circular orbital planes.

The European GALILEO is an initiative launched by the European Commission (EC) and the European Space Agency (ESA) and will be owned by the European Union (EU). Once

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4 CORPAS-SARSAT System is a satellite-based search and rescue system in Low Earth Orbit (LEO), which detects and locates distress signals. It is not a GNSS service itself. See www.cospas-sarsat.int/en/system-overview/cospas-sarsat-system.
5 See www.cospas-sarsat.int/en/2-uncategorised/177-meosar-system.
8 See UNIDROIT Study, supra note 7, at p. 5.
fully operational, it will comprise 30 satellites in three orbital planes, under civilian control. Five key services will be offered: open, safety of life, commercial, public regulated and SAR service. The open service will be interoperable with the GPS and GLONASS civil signal.

Beidou 2 – COMPASS is China’s GNSS. In accordance with Beidou 2 – COMPASS system’s construction plan, the initial satellite navigation system will provide coverage in the Asia-Pacific region and global coverage around 2020. It contains five geostationary orbit (GEO) satellites and 30 non-GEO satellites and will offer an open and an authorized service.

The Indian Regional Navigation Satellite System is a regional system consisting of seven satellites, some of which will be placed in GEO. It will provide an open service and an encrypted service, restricted to authorized users.

9.1.2.2 Augmentation systems

Core-constellation systems do not meet the necessary performance requirements for high-performance applications, like precision approaches of aircraft and dock maneuvering of ships. Therefore, augmentation systems have been developed to advance the services provided by the core constellations systems.

The US has developed the Wide Area Augmentation System (WAAS), to permit aircraft to rely on GPS through all phases of flight. WAAS consists of a space segment comprising three GEO satellites and a ground segment.

Russia is developing the System for Differential Corrections and Monitoring (SDCM) which will augment both GPS and GLONASS. SDCM space segment will be comprised of three GEO satellites plus one spare satellite.

The European Geostationary Navigation Overlay Service (EGNOS) has been operational since 2009. It augments GPS signals in Europe and will augment Galileo’s signals when the latter becomes operational. It consists of three GEO satellites and a number of ground stations.

Japan has created the MTSAT Satellite Based Augmentation System (MSAS), to augment GPS signals and provide coverage for the hemisphere centered on 140°, which includes Japan and Australia. It consists of two GEO satellites and network of ground stations. In addition, Japan is developing the Quasi Zenith Satellite System (QZSS), a regional SBAS system consisting of three satellites in periodic Highly Elliptical Orbit (HEO), so that one satellite always appears near the

13 See www.isro.gov.in/irnss-programme.
14 These requirements include: accuracy, i.e. the difference between estimated and actual GNSS-user position; integrity, i.e. the measure of trust that can be placed in the correctness of the information supplied by the total system, including the ability of the system to alert the user when the system should not be used for the intended operation; continuity, i.e. the capability of the system to perform its function without unscheduled interruptions during the intended operation; availability, i.e. the time during which the system is simultaneously delivering the required accuracy, integrity and continuity. See ICAO, Global Navigation Satellite System (GNSS) Manual, 1st ed, ICAO Doc 9849/AN/457 (Montreal: ICAO, 2005), para 4.2 [ICAO GNSS Manual].
15 See www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gns/waas/.
16 See www.sdcm.ru/index_eng.html.
19 See www.navipedia.net/index.php/MSAS_Architecture.
zenith above Japan. It enhances GPS availability and performance over Japan and Oceania.

The Indian *GPS Aided GEO Augmented Navigation system* (GAGAN) has been jointly developed by the Indian Space Research Organization (ISRO) and the Airports Authority of India (AAI). It consists of three Geostationary Navigation Payloads and a network of ground stations. The Indian Directorate General of Civil Aviation has certified GAGAN for use in aviation.

### 9.1.3 International cooperation on GNSS

The increasing importance and use of GNSS in many domains has necessitated international cooperation, which has taken two forms: the establishment of the International Committee on GNSS, and the conclusion of bilateral agreements on interoperability and compatibility.

#### 9.1.3.1 International Committee on GNSS

The International Committee on GNSS (ICG) was established by the United Nations (UN) General Assembly Resolution 61/111 of 14 December 2006. The ICG is an informal body, founded on a voluntary basis. Its mission is to enhance cooperation in space-based PNT services for the benefit of particularly developing nations. It promotes interoperability, compatibility and transparency between the providers of the different global, regional, and augmentation navigation satellite systems.

All countries or entities that are either GNSS providers or users of GNSS services are eligible to participate. ICG’s Providers Forum serves for coordination and cooperation to improve overall service provision between countries operating GNSS systems or with plans to develop one. ICG’s work plan addresses, through special working groups, various aspects of GNSS.

#### 9.1.3.2 Bilateral agreements

GNSS constellations are most effective, when they can be used in combination with each other. To that effect, States operating core constellations have concluded bilateral agreements on interoperability and compatibility.

Compatibility is the ability of space-based PNT services to be used either independently or together, without causing any interference to each separate service or signal and without affecting national security. Interoperability is the ability to use combined services from different systems, to benefit from improved capabilities.

To achieve compatibility and interoperability, coordination is crucial. Hence, satellite navigation service-providers conclude bilateral agreements, as this appears to be the optimal way to eliminate disclosure of classified information.

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21 See www.navipedia.net/index.php/GAGAN.
25 Ibid.
The US has concluded bilateral arrangements ("Joint Statements"), which encourage cooperation and address issues of compatibility and interoperability between GPS and other systems. The US has concluded Joint Statements with Australia, China, Europe, India, Japan, and Russia.27

The EU and its Member States have concluded agreements with China, Israel, India, Ukraine, Morocco, Korea, Norway, and Switzerland. These agreements not only address issues of interoperability and compatibility, but also encourage scientific research and trade. In 2004, the EU signed a historic agreement with the US establishing cooperation between GPS and Galileo.28

9.2 Cross-sector international rules applicable to GNSS

9.2.1 Space law

GNSS satellites, being objects launched in outer space, trigger the applicability of the international space legislation. However, the rapid technological advances and the massive use of outer space give rise to several legal considerations.

9.2.1.1 Authorization and supervision

The Outer Space Treaty (OST)29 applies to activities undertaken in the "exploration and use of outer space".30 Article VI of OST establishes the international responsibility of the States Parties for national activities in outer space, undertaken both by governmental and non-governmental entities, and for authorizing and continuously supervising such activities.31 The same article applies also to international organizations conducting such activities as well as their Member States, which are Parties to the OST.32 The latter provision covers Galileo and EGNOS owned by the EU. Therefore, in case of damage occurring as a result of GNSS activities, the OST holds responsible the State or the international organization involved.

9.2.1.2 Liability

As to liability, Article VII OST provides that a State Party is internationally liable for damage caused by a space object or its components parts, launched into the outer space.33 Article VII along with Article VI OST aim to ensure that States are both responsible and liable with respect to damage resulting out of their national activities.34 Article VII OST can be considered a generic rule (lex

27 See www.gps.gov/policy/cooperation/. Yet, since April 2014, the US-Russia cooperation is on hold.
30 Ibid., art XIII.
31 Ibid., art VI.
32 Ibid.
33 See Ibid., art VII.
34 Armel Kerrest & Lesley Jane Smith, in Stephan Hobe et al., eds, Cologne Commentary on Space Law (Cologne: Heymanns, 2009) vol 1, Article VII OST, para 2.
generalis), which has been elaborated by the Liability Convention (LC).\footnote{Convention on the International Liability for Damage Caused by Space Objects, 29 March 1972, 961 UNTS 187 [Liability Convention].}

The LC provides a twofold liability scheme based on the location and the type of damage. \textit{Strict liability} applies to a launching State for damage caused by its space object on the surface of the Earth or to an aircraft in flight (Art. II). In cases of damage caused by a space object, elsewhere than on the surface of the Earth, to a space object of another launching State or to persons or property on board, the liability is limited to cases of fault (Art. III).

In both cases of liability, the damage has to be caused by a space object launched by the State against whom the claim is brought. The question in relation to GNSS is whether the LC applies when damage is caused by a satellite signal.\footnote{See Arnel Kerrest & Lesley Jane Smith, in Stephan Hobe et al., eds, Cologne Commentary on Space Law (Cologne: Heymanns, 2013) vol 2, Article II LC, paras 110 et seq.} In order to answer this question, “space object” and “damage” should be defined.

The LC does not define “space object”. Art. I clarifies that the term “includes component parts of a space object as well as its launch vehicle and parts thereof”. It is unclear whether intangible parts of a space object, such as signals, are included. Similarly, there is an ambiguity regarding the definition of damage, which Art. I LC defines as “loss of life, personal injury or other impairment of health; or loss of or damage to property”. This definition leaves open the question whether the LC covers damage caused not by physical contact with the space object.\footnote{See supra note 34 at paras 57–58.}

There is no consensus as to what types of damage are covered by the LC. Some authors suggest that the LC refers only to direct physical damage resulting from the fall or collision of space objects.\footnote{See e.g. Sergio M Carbone & Maria Elena De Maestri, “The Rationale for an International Convention on Third Party Liability for Satellite Navigation Signals” (2009) 14:1–2 Unif L Rev 35 at 38; Stephen Gorove, “Cosmos 954: Issues of Law and Policy” (1978) 6:2 J Space L 137 at 141; Kaiser, supra note 26 at 19–20.} Others support a broader interpretation and suggest that damage resulting from the malfunctioning of a space object is also recoverable under the LC.\footnote{See e.g. Carl Q Christol, “International Liability for Damage Caused by Space Objects” (1980) 74:2 AJIL 346 at 362; BD Kofi Henaku, “The International Liability of the GNSS Space Segment Provider” (1996) XXI:A Ann Air & Sp L 170; Lesley Jane Smith, “Legal Aspects of Satellite Navigation” in Frans von der Dunk & Fabio Tronchetti, eds, Handbook of Space Law (Cheltenham: Edward Elgar Publishing, 2015) 554 at 585 [Smith, “Legal Aspects”].} They invoke the travaux préparatoires of the Liability Convention and the victim-oriented character of the Convention as stated in its preamble.\footnote{See Liability Convention, supra note 35, Preamble.} Hence, a broad interpretation, which encompasses damage from intangible electromagnetic waves, appears a reasonable one.\footnote{For an extensive analysis, see Elena Campanelli & Brendan Cohen, “The Notion of ‘damage’ Caused by a Space Object under the 1972 Liability Convention” in Corinne M Jorgenson & International Institute of Space Law, eds, Proceedings of the International Institute of Space Law 2013 (The Hague: Eleven International, 2014) 29 at 34–44.}

Moreover, proving primary causation between the erroneous signal and the damage would be challenging. Since damage may be the result of a chain of events, it should be established that it was caused by the erroneous signals and that the causal link was not broken by another, overriding event.\footnote{Kerrest & Smith, supra note 34 at paras 57–58.} Thus, claimants should prove that damage was due to a defective signal and not a malfunction of the receiver, an atmospheric disturbance that affected the signal or any other cause. Besides, a user may suffer damage after receiving signals from more than one...

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operators, e.g. GPS and GLONASS, making it difficult to determine which operator, if at all, is at fault.

It should be noted that claims under the Liability Convention concern only international liability between States. A user that wants to sue a GNSS operator will have to refer to national civil liability law. The LC's short limitation period of one year [Art. X (1)] may also constitute an incentive to bring claims before national courts.

9.2.1.3 Registration and return of space objects

According to the Registration Convention, all space objects, thus also GNSS satellites, launched into Earth orbit must be registered by the launching State in an appropriate national registry and in the central Register maintained by the UN Secretary General. Registration indicates the potentially liable launching State of a space object. Furthermore, the State of registry retains jurisdiction and control over the GNSS satellites in accordance with Article VIII of the OST.

The Rescue Agreement is relevant as to the return of GNSS satellites on Earth. It provides that States shall, upon request, assist the launching State in recovering space objects that return to Earth beyond its territorial limits.

9.2.2 Frequency allocation

The International Telecommunication Union (ITU) provides the global regulatory framework for frequency allocation. In particular, ITU is responsible for the allocation and assignment of global radio spectrum and satellite orbits, to avoid harmful interference. ITU’s International Radio Regulations are set by decisions of ITU’s Member States (MS) during ITU-R World Radiocommunications Conferences (WRC) conducted every four years. The MS ratify the WRC decisions and transfer them into national law.

In order to minimize interference, ITU retains a system of registration and coordination for notified stations and radio systems by MS. In case of harmful spectrum interference, the States or organizations concerned co-ordinate the technical details bilaterally.

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44 Convention on Registration of Objects Launched into Outer Space, 14 January 1975, 1023 UNTS 15 [Registration Convention].
45 Ibid., art II.
46 See Outer Space Treaty, supra note 29, art VIII.
47 Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, 22 April 1968, 672 UNTS 119 [Rescue Agreement].
48 See Ibid., art 5.
In relation to GNSS, ITU has been working on the allocation of the radio-frequency bands used by the Radio Navigation Satellite Services (RNSS), as the use for other purposes of frequencies suitable for GNSS services increases. For example, the WRC held in 2000 in Istanbul approved new frequency allocations to RNSS in the bands 1164–1215MHz, 1260–1300MHz, 1300–1350MHz, and 5000–5150MHz, to support the growth of RNSS taking into consideration the upcoming development of new GNSS systems, like Galileo.52

9.2.3 International trade law

9.2.3.1 Market access

The World Trade Organization (WTO) is an intergovernmental organization that establishes global trade rules to facilitate trade and dispute resolution among nations.53 The core of these rules are the WTO Multilateral Agreements, which bind all WTO Member States (MS)54 and guarantee non-discriminatory trade rights, transparent trade policies and efficient dispute resolution. The most important of them are: the Agreements on trade of goods, especially the 1994 GATT;55 the GATS on services;56 the TRIPS on intellectual property;57 the Trade Policy Review Mechanism;58 and the Dispute Settlement Understanding.59

GATT, GATS and TRIPS contain general principles, additional agreements and annexes on specific sectors, and detailed schedules of commitment of each country regarding access of foreign products and service-providers to its market.60

In addition, there are two plurilateral agreements in force: the Agreement on Trade in Civil Aircraft61 and the Agreement on Government Procurement.62 WTO MS are not obliged to become parties to these agreements.

9.2.3.1.1 Principles and structure of the WTO framework

The WTO legal framework is characterized by general principles, followed by a common structure of the WTO Treaties.

53 The WTO is the successor of the General Agreement of Tariffs and Trade, which was signed in 1947. The GATT system was developed through a series of international negotiations, known as rounds. The WTO’s agreements are often called the Final Act of the 1986–1994 Uruguay Round of trade negotiations. The Doha Round started in 1994 and has not been completed yet.
54 All WTO Agreements have the form of Annexes to Final Act Embodying the Results of the Uruguay Round of Multilateral Trade Negotiations, 15 April 1994, [Final Act of Marrakesh].
58 1869 U.N.T.S. 480.
60 For a brief explanation of the structure of the WTO Multilateral Agreements, see www.wto.org/english/thewto_e/whatis_e/tif_e/agrm1_e.htm.
The principle of the *Most Favored Nation* (MFN) requires that any preferential treatment granted by a State to another State regarding international commerce is unconditionally and automatically expanded to all other WTO MS. Exceptions are allowed, yet only under strict conditions.  

Under the principle of *National Treatment*, WTO MS are obliged not to discriminate between foreign and domestic goods, services or intellectual property rights, but only after these have entered the domestic market – which means that the principle does not apply to customs duties.  

Moreover, WTO Treaties contain *Schedules*, which are the specific sectors to which MS accept to apply the Treaty provisions, as well as *Commitments*, which contain concrete measures that each MS agrees irrevocably to adopt in compliance with the Treaty provisions, to facilitate trade liberalization in its territory.

### 9.2.3.1.2 GNSS and WTO treaties

The General Agreement on Tariffs and Trade (GATT) 1994 incorporates the provisions of the GATT 1947, the predecessor of the WTO, and concerns international trade in products. In general, it provides for fair and transparent trade regulations, including taxation, import duties, subsidies and anti-dumping measures. However, it does not affect national security measures (Art. XXI). Given that GNSS use includes national security applications, this exception may play an important role in the international trade of the related equipment.

The General Agreement on Trade in Services (GATS) is the equivalent of GATT in services. It also provides for fair and transparent trade regulations and practices (Art. III). Governmental services offered outside market conditions are excluded from its scope [Art. I(3)]. GATS is especially important for PNT services based on GNSS signals, which are the majority of GNSS applications.

The Technical Barriers to Trade Agreement (TBT) aims at ensuring that technical regulations, standards, testing and certification procedures are not misused to create artificial trade barriers and give domestic products an unfair advantage (Arts 2 and 3). It obliges States to lay down transparent and fair procedures on quality assessment of products (Art. 10). The TBT plays a significant role in areas where certification is necessary to ensure high quality of safety critical products, for example aviation and maritime safety.

The Agreement on Government Procurement (GPA) aims at ensuring that government procurement rules and procedures are transparent, promote international competition, and do not result in discriminations against foreign suppliers (Arts 6 et seq.). The GPA is important for GNSS signals of increased accuracy designed for public services, like the GALILEO PRS signal.

The Agreement on Civil Aircraft applies to civil aircraft, engines and components (Art. 1). It requires Member States to eliminate any custom duties imposed thereon (Art. 2.1), and to ensure that government-directed procurement and inducements to purchase shall not discriminate in favor of domestic sources (Arts 4 et seq.). The Agreement covers also GNSS avionics [Art. 1.1(c)].

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63 Art. I GATT 1947; Art. II GATS; Art. IV TRIPS.
64 Art III GATT; Art. XVII GATS; Art. III TRIPS.
65 General Agreement on Tariffs and Trade, 55 UNTS 194 (1947).
66 GATT 1947, Arts VI et seq.
9.2.3.2 Intellectual property rights (IPRs)

IPRs are the legal rights that result from intellectual activity in the industrial, scientific, literary and artistic fields.\(^67\)

Although IPR acquisition and protection are regulated by national legislation, there are global uniform rules on IPRs, which determine a minimum of IPR protection. Additionally, there are regional uniform rules as well as internationally coordinated filing procedures.\(^68\)

International cooperation and coordination on IPR is managed by the World Intellectual Property Organization (WIPO), a specialized agency of the UN.\(^69\) WIPO administers a series of IPR treaties,\(^70\) the most important of which are the Paris Convention on Industrial Property\(^71\) and the Berne Convention on Copyright.\(^72\) Equally important is the TRIPS Agreement, concluded in the framework of the WTO,\(^73\) mainly in order to enhance and modernize the existing conventions.

IPRs are distinguished into *industrial property rights* (which comprise rights like patents, utility models, trademarks and industrial designs, granted in principle through a formal filing procedure) and *copyright*, which protects literary and artistic works, including software and databases, without necessitating any formal registration.\(^74\)

9.2.3.2.1 General principles

The international IPR conventions allow us to deduce some general principles that govern IPRs, which are:

**Territoriality:** The parameters for the protection of IPRs, such as conditions, extent, content, and duration of protection, are determined by the law of the State from which protection is asked.\(^75\)

**National treatment/assimilation:** Protection of IPRs is granted to foreigners under the same conditions as to own nationals.\(^76\)

**Most favored State:** In accordance with the WTO legal framework, Article 4 of TRIPS prescribes that any preferential treatment granted by a Member to the nationals of any other country shall be accorded immediately and unconditionally to the nationals of all other Members.

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68 See e.g. Convention on the Grant of European Patents (European Patent Convention), 5 October 1973, 1065 UNTS 255.


70 See www.wipo.int/treaties/en/.


73 Supra note 57.

74 See WIPO Handbook, supra note 67, paras 1.4–1.5.


76 See e.g. Berne Convention, art 5(1); Paris Convention, art 2; TRIPS, arts 3(1), 9.
Procedural rules and priority: IPRs are protected according to the date they are acquired, that is on a priority basis. Although such a date depends on national law, the international conventions on industrial property establish uniform procedural rules and facilitate claims of priority rights based on the date of the first filing.77

9.2.3.2.2 IPR aspects of GNSS

The provision of GNSS services and applications incorporates IPRs concerning both the hardware78 and the software.79 The most pertinent IPRs are patents, utility models, copyright, and trade secrets.

Patents protect inventions, which are innovative solutions to technical problems.80 Utility models are also solutions to technical problems, yet the innovation requirements are lower, and they last for a shorter time.81 Copyright protection is important as to software and databases related to GNSS services.82 Trade secrets are secret information of commercial value and are protected without any filing requirements.83

The serious implications IPRs may have on GNSS were demonstrated in 2012, when it became known that Ploughshare Innovations, an R&D subsidiary of the UK Defense Ministry, had asked royalties from US companies, based on a patent it had obtained by the European Patent Office, regarding aspects of modulation signals that enable the interoperability between the open signal of GPS (L1C) and Galileo (E1).84 These had been developed by a joint EU-US taskforce on the basis of a 2004 US-EU cooperation agreement,85 whose members comprised employees of the UK Defense Ministry. The claims caused grave concerns in the US and the EU, among fears that such patents could seriously undermine the use of free GNSS signals.86 In 2013, the US and the UK settled the issue as to the GPS civil signal, agreeing to ensure that the signal remains “perpetually free and openly available worldwide”.87

9.2.4 GNSS liability

Liability arising from the provision of GNSS services is connected to the vulnerabilities of satellite signals to disruption and loss of signal. The main vulnerabilities are: ionospheric effects, which affect the propagation of the signal; interference from other electromagnetic emitters

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77 See e.g. *Paris Convention*, art 4; *TRIPS*, art 2(1).
78 For example, transmitters, receivers, clocks, processors, etc.
79 For example, programs for integrity monitoring, data-user interface, and warning systems.
80 See e.g. *TRIPS*, art 5(1).
81 Usually 7–10 years, against the 20-year protection usually accorded to patents.
82 *TRIPS*, art 10.
83 *TRIPS*, art 39.
84 See “Modulation signals for a satellite navigation system”, European Patent No. 1830199 (1 September 2004) (patent granted on 1 February 2012).
(e.g., TV signals); increased solar activity, which may interfere with all electronic systems; jamming, which intentionally prevents receivers from receiving signals; spoofing, which is the intentional emission of legitimate-looking false signals to the receiver; and, degradation or interruption of the GNSS constellation because of lack of funds or national emergencies. 88

GNSS-related liability may take various forms, depending on the circumstances of the particular case. There are no international uniform rules thereon, despite the efforts undertaken in the past by the International Civil Aviation Organization (ICAO) and the International Institute for the Unification of Private Law (UNIDROIT). 89 The arising issues could be distinguished into procedural and substantive. A separate, yet related, issue is insurance coverage.

The analysis considers only claims presented before national courts. Issues concerning international liability between States are analyzed in the sections on space law. 90

9.2.4.1 Procedural issues

9.2.4.1.1 Sovereign immunity

Since GNSS are used also for military applications, they are controlled by governmental authorities. Therefore, in the event of an accident, claimants would have to overcome sovereign immunity.

Sovereign immunity prevents national courts from establishing jurisdiction over acts and omissions of another State. There is no universal agreement on the exact content of international law in this regard. However, a generic consensus has been reflected in the Convention on Jurisdictional Immunities of States and their Property, 91 which reflects significantly current international law. According to Article 10 of the Convention, immunity cannot be invoked for commercial transactions of the State with foreign nationals, unless otherwise agreed.

The existence of a commercial transaction between the signal provider (State) and the user is doubtful, especially concerning the open signal, which is made available for free to everyone. Nevertheless, even if there is a commercial transaction, the free use of the open signal combined with the declaration that the State accepts no related liability, can be interpreted as an agreed recognition of State immunity.

9.2.4.1.2 Competent courts

The courts competent to rule on liability claims will be determined by the national law of the court seized on the case (lex fori). In most States, jurisdiction belongs to the courts of the place where the defendant has its principal place of business or registered seat. 92 Contractual claims


90 Supra section 9.2.1.


will be judged by the courts of the State designated by the parties or, absent that, by the courts of the place of contractual performance. Jurisdiction on tortious claims usually belongs to the courts of the place where the harmful event took place (e.g., aircraft accident) and/or the harm occurred (e.g., the place where the injured person died).

The number of potentially competent courts may encourage claimants to choose the jurisdiction most convenient to their interests (forum shopping). Nevertheless, this creates legal uncertainty, increases litigation cost and affects the insurability of claims. Therefore, the designation of a single competent jurisdiction through an international convention has been proposed.

9.2.4.1.3 Applicable law
The law applicable to the case depends also on the nature of the claim. Contractual claims are often governed by the law designated by the parties or by the law of the State closest connected to the dispute, which is highly case-dependent. Extra-contractual claims are usually governed by the law of the State where the harmful event occurred.

9.2.4.1.4 Recognition and enforcement of judgments
Recognition and enforcement of judgments are important for the effective protection of claimants’ rights in cases involving multiple jurisdictions. The related requirements are set by national legislation, yet there are also regional instruments. In general, most jurisdictions require that the judgment is final and conclusive, has been rendered by a competent court, the defendant has been given proper notice of the suit and the opportunity to be heard, and the judgment does not offend the public order of the forum. Sometimes reciprocity is also necessary.

9.2.4.2 Substantive issues
Substantive issues concern the requirements for establishing GNSS-related liability.

9.2.4.2.1 Basis and form of liability
The basis of GNSS liability depends on the cause of damage/injury and the relationship(s) of the parties in the case under examination. The damage/injury may be due to:

(a) A hardware malfunction of the space or ground segment, or the receiver of the end-user. In this case, the rules on product liability would apply. This would also be the case, if the

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95 See Magnus ibid. at 960, who proposes the courts of the place of the operator’s seat; Pietro Manzini & Anna Masiutti, “An International Civil Liability Regime for the Galileo Services: A Proposal” (2008) 33:2 Air & Space L 114 at 130–31, who prefer the courts of the place of the accident.
98 See Magnus, supra note 94 at 956.
hardware malfunction was caused by a software defect and the software can be deemed a component of the end product. However, it has been suggested that product liability claims will be limited in practice. They could be presented regarding GNSS receivers, but their success chances as to Signal in Space errors or malfunctions are very limited.99

(b) A software defect, irrespective of its incorporation into another product. In this scenario, we may have a form of liability for negligent misstatement/misrepresentation or for failure to warn, which could be a contractual or a tortious claim, depending on the jurisdiction and the circumstances of the particular case.

(c) A signal defect, for example a signal lacking the required accuracy. Such defect could be due to malicious interference of a third party, which could have been facilitated by the signal provider’s failure to adopt appropriate security measures, like encryption. In general, satellite signals are not considered products, but a form of service provision. Thus, there would be a case of improper service provision, which is usually a form of contractual liability, often subject to liability limitations and waivers.100 However, should the user present an extra-contractual claim against the satellite operator, the legal basis could be product liability, by analogy to liability for aeronautical charts.101

In practice, it will be very difficult to identify the exact cause of the damage, namely which segment/device/component malfunctioned. This is exacerbated by the interoperability of the open signal, which enables the end-user to receive signals from more core constellations.

9.2.4.2.2 Liability chain – persons liable
The occurrence of damage/injury may lead to a combination of claims, presented by different persons and on different bases. The persons liable will be determined by the applicable law and the circumstances of the case.

The damaged/injured person could turn against the vendor of the GNSS receiver (usually based on the contract of sale) or the provider of the GNSS service. These could present contractual regress claims against the manufacturer of the malfunctioned receiver or other hardware component. The hardware manufacturer might seek indemnification from the software manufacturer that caused the hardware to malfunction, based on the contract between them.

Notwithstanding issues of sovereign immunity, State liability is also conceivable, e.g. for negligent certification or for negligent supervision of the service provider, if such supervision duty arises from international conventions and has been reflected in domestic legislation.102 The uncertainty created in the identification of the persons liable has led to the suggestion that compensating the victims is best served by channeling liability to a single person and allowing for subsequent regress claims.103

102 See e.g. Outer Space Treaty, supra note 29, art VI; Convention on International Civil Aviation, 7 December 1944, 15 UNTS 295, art 38 [Chicago Convention].
103 Magnus, supra note 94 at 963–64, 966; Manzini & Masutti, supra note 95 at 123–25.
9.2.4.2.3 Negligence/fault
Negligence of the persons involved in a case plays also an important role. Negligence on the part of the defendant may be important, first in establishing a duty to compensate. Depending on the applicable law, liability can be fault-based or strict. However, even in cases of strict liability, the defendant may be exonerated upon proof of force majeure, like space weather. Moreover, the existence and the degree of the defendant’s negligence may determine the adjudication of mental damages or even punitive damages to the claimant.

Negligence on the part of the claimant could reduce the amount of compensation due (comparative negligence) or even exempt the defendant completely (contributory negligence). Such would be the case, if the claimant violated safety provisions that required use of GNSS-based navigation in combination with other navigational aids, or if the claimant ignored warnings of temporary signal degradation, for example owing to maintenance works or adverse space weather.

9.2.4.2.4 Particularities of the open signal
The open signal of the core satellite systems presents additional challenges. The signal is provided “as is”, which means that the providers do not accept any responsibility for its quality and warn users that they use it at their own risk. It has also been observed that, largely because of the prior accessibility to GPS, there is a tendency to regard GNSS as a self-understood gratuitous public service.

In practice, this could bar recovery for defective open signals, although claimants could invoke counter-arguments, such as the existence of a commercial transaction. Moreover, it is likely that courts will accept at least comparative negligence of the claimant based on his/her decision to use a signal without any quality guarantees.

9.2.4.3 Relationship with existing international conventions
GNSS-related damage/injury may result in liability of the operator of the affected transportation mode (aircraft, ship, rail, etc.) or installation (nuclear facility, airport, etc.). In such cases, compensation for claimants may be based on special international instruments regulating the operator liability. The operator could subsequently seek regress against other persons or entities liable.

9.2.4.4 Insurance
Standard third-party liability insurance for GNSS failures is not available yet. Insurance contracts are expected to provide limited coverage according to the service offered. De lege

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104 Especially, solar storms could seriously affect electronic devices both in space and on Earth or cause a degradation of the signal quality through interaction with the ionosphere of the Earth.
105 See UNIDROIT Study, supra note 7, para 205.
107 See section 9.2.4.1.1, above; UNIDROIT Study, supra note 7, paras 206–07.
109 See UNIDROIT Study, supra note 7, para 175, which suggests that such right should be recognized even if not explicitly foreseen in the applicable international convention.
110 Smith, “Legal Aspects”, supra note 39 at 593–94.
ferenda, compulsory third-party liability insurance requirements for GNSS providers are intertwined with the problems of GNSS-related liability issues.\textsuperscript{111}

9.2.4.5 Conclusion on GNSS liability

The international community appears reluctant to adopt uniform rules on GNSS liability. Instead, States have opted for an \textit{ad hoc} treatment of liability issues, which is connected to their desire to ensure maximum flexibility and safeguard their national security interests given the dual use of most GNSS constellations. However, such attitude leads to great legal uncertainty. Consensus on at least a model law on such issues, which would include obligatory insurance requirements, could prove very useful.

9.3 Sector-specific rules

9.3.1 Aviation law

GNSS has significant importance in aviation and is expected to become the cornerstone of future Air Navigations Services (ANS). Its advantages include the ability to support all phases of flight by providing seamless global navigation guidance; accurate aircraft guidance in remote and oceanic areas; use of efficient flight paths; improvement of airport usability and noise abatement; and, mitigation or even avoidance of the cost to replace traditional navigation aids.\textsuperscript{112}

Moreover, GNSS plays an increasingly important role in flight tracking and emergency locating of aircraft as part of the ICAO Global Aeronautical Distress and Safety System.\textsuperscript{113}

Due to the GNSS limitations on accuracy and integrity, a variety of augmentation systems are used. Apart from ground-based and space-based augmentation systems, aircraft-based augmentation systems are employed in aviation, which augment and/or integrate GNSS information with information available on board the aircraft.\textsuperscript{114}

9.3.1.1 PBN and ATM modernization

GNSS technologies and applications are the key enablers of the concept of Performance Based Navigation (PBN), which is the foundation of the worldwide Air Traffic Management (ATM) modernization efforts.

9.3.1.1.1 PBN

Under PBN, which is the opposite of the traditional sensor-based navigation, the requirements regarding the performance of aircraft navigation systems are identified in navigation specifications. PBN enables more efficient use of airspace and greater harmonization of regulatory requirements across States. Furthermore, operators can evaluate for themselves how to meet the specific requirements, choosing among the systems and technologies available, rather than being

\textsuperscript{111} See ibid. at 617; Masutti & Manzini, supra note 95 at 128; Magnus, supra note 94 at 966.

\textsuperscript{112} For details, see ICAO GNSS Manual, supra note 14, para 1.3.


\textsuperscript{114} See ICAO GNSS Manual, supra note 14 at para 2.2.
obliged to have specific pieces of equipment required by sensor-based navigation. PBN is based on the concepts of Area Navigation (RNAV) and Required Navigation Performance (RNP).

### 9.3.1.2 ATM modernization

The main ATM modernization efforts in place are NextGen in the US and the Single European Sky (SES) in Europe with its technological pillar SES ATM Research (SESAR). Both projects rely on PBN with extensive use of GNSS, to increase airspace capacity and improve efficiency of operations. They also attempt to integrate new technologies and operational concepts, such as ADS-B and 4-D trajectories, which take advantage of the increased GNSS coverage and availability resulting from the compatibility and interoperability of GNSS core constellations.

### 9.3.1.2 Global regulation of GNSS provision in aviation

From a regulatory view, global regulation of GNSS provisions belongs to the competency of ICAO. Many aspects of GNSS provision fall under the rules of the Chicago Convention. Furthermore, there are principles on GNSS policy as well as technical rules and guidelines on GNSS.

#### 9.3.1.2.1 Chicago Convention

Article 1 of the Chicago Convention (CC) recognizes the exclusive sovereignty of States over their national airspace. Article 12 obliges States to adopt measures on air traffic above their territory. Article 15 prohibits any discrimination between national and foreign aircraft when raising airport and similar charges, which include ANS charges. Article 28 lays down the duty of States to provide ANS in their territory and to publish aeronautical maps and charts. The combination of these Articles reveals that each State regulates the conditions and charges for providing GNSS in its territory and has to inform other States thereon.

Moreover, Article 30 CC permits the use of radio-transmitting devices only upon license from the State of registry, which applies to ADS-B devices.


116 RNAV is a navigational method that permits the operation of an aircraft on any desired flight path rather than on only a specific airway – see www.skybrary.aero/index.php/Area_Navigation_Systems. RNAV is accompanied by navigation specifications that allow the aircraft to operate safely in a specific route or a specific airspace concept. An airspace concept provides the outline and intended framework of operations within a specific part of airspace. It is developed to satisfy policy objectives, such as improved safety, increased air traffic capacity, etc. By areas of operation, aerospace concepts are distinguished into oceanic and remote continental, continental en-route, terminal and approach see *ICAO PBN Manual*, *supra* note 115, para 2.2–2.3.

117 RNP is an RNAV specification with the additional requirement of on-board performance monitoring and alert – *ICAO PBN Manual*, *supra* note 115, para 1.2.

118 Automatic Dependent Surveillance – Broadcast (ADS-B) is a surveillance technique that transmits the identity of the aircraft and data derived from GNSS Systems, especially position and velocity, to Air Traffic Control (ADS-B Out) and to other aircraft (ADS-B In) – see www.skybrary.aero/index.php/Automatic_Dependent_Surveillance_Broadcast_%28ADS-B%29.

119 A 4D trajectory integrates time into the 3D aircraft trajectory. It ensures flight on an optimum trajectory, provided that the aircraft meets accurately an arrival time over a designated point – see www.skybrary.aero/index.php/4D_Trajectory_Concept.
9.3.1.2.2 Policy principles

Based on the above provisions and considering the international nature of GNSS, the ICAO Assembly has laid down policy principles regarding the GNSS. These are established mainly in ICAO Assembly Resolution A32-19,\textsuperscript{120} the content of which can be summarized as follows.

Aviation safety is recognized as the paramount principle. All States, without any discrimination, should have access to GNSS services. State sovereignty within the national airspace remains unaffected. Every State providing GNSS services or under whose jurisdiction such services are provided shall ensure their continuity, availability, integrity, accuracy and reliability. The highest practicable degree of uniformity in the provision and operation of GNSS services must be ensured, including agreements on regional provision of GNSS services. Any charges for GNSS services shall be made in accordance with Article 15 CC. When providing GNSS services, States should have due regard to the interests of other States, and facilitate global planning and implementation of such services through international cooperation.\textsuperscript{121} The above principles have been reiterated with some variations in ICAO Assembly Resolutions A31-20 and A33-15.\textsuperscript{122}

9.3.1.2.3 SARPs

Standards and Recommended Practices (SARPs) are technical rules adopted under Article 37 of the Chicago Convention and are designated as Annexes to the Convention for convenience.\textsuperscript{123} They are not binding in strict legal sense; however, in practice, they carry tremendous weight.\textsuperscript{124}

Rules related to GNSS are foreseen mainly in Annex 10, volume I (Radio Navigation Aids). There are also relevant provisions in Annexes 2 (Rules of the Air), 4 (Aeronautical Charts), 6 Part I (International Commercial Air Transport – Aeroplanes) and Part II (International General Aviation – Aeroplanes), 11 (Air Traffic Services), 14 Vol I (Aerodrome Design and Operations), and 15 (Aeronautical Information Services). More details on these rules coupled with guidance on their implementation are contained in the ICAO GNSS Manual, and ICAO Circulars 257 and 278.\textsuperscript{125}

9.3.2 Maritime law

9.3.2.1 IMO policy

The International Maritime Organization (IMO) has laid down its GNSS policy in IMO regulations.
Assembly Resolution A.915(22).\textsuperscript{126} GNSS should serve mainly general navigation purposes (para. 3.1.1). However, precision applications are also envisaged and are currently employed using local augmentation systems, such as the EGNOS in Europe and the Maritime Differential GPS System or the WAAS in the US. The Resolution recommends that augmentation provisions should be harmonized worldwide, to enable ships to carry only one shipborne receiver (para. 3.1.3). Besides, GNSS should be reliable and of low user cost. Cost recovery and allocation methods should distinguish between maritime users that rely on the system for safety reasons and those that additionally benefit from the system in commercial or economic terms, taking into account also the interests of both shipping and coastal States (para. 3.1.5).

9.3.2.2 Operational requirements

IMO requires all ships constructed after July 1, 2002 and all passenger ships to have a GNSS receiver on board.\textsuperscript{127} There are also performance standards for such equipment regarding mainly accuracy, continuity and integrity monitoring.\textsuperscript{128} Furthermore, Appendices II and III of the IMO Resolution A.915(22) provide for minimum maritime user requirements for general navigation and positioning respectively.

9.3.2.3 Institutional requirements

IMO Assembly Resolution A.915(22) clarifies that IMO cannot provide and operate a GNSS. However, IMO should be able to assess and recognize that GNSS meets maritime user requirements, that internationally established principles on cost allocation and recovery as well as on liability are applied, and that GNSS services are provided to users on a non-discriminatory basis (para. 3.1.18).

9.4 From global navigation to cosmic navigation systems

The high effectiveness of GNSS for navigation on Earth has led scientists to search for similar navigation methods for exploration missions in deep space or on the surface of celestial bodies. The most promising method seems to be using radiation emitted by fast spinning and strongly magnetized neutron stars, called pulsars.\textsuperscript{129} Pulsars that emit X-rays are most suitable for this purpose, because their beamed periodic signals are so stable that have timing characteristics


\textsuperscript{127} International Convention for the Safety of Life at Sea, 1974, 1 November 1974, 1184 UNTS 278, c V, reg 19, para 2.1.6.


\textsuperscript{129} Neutron stars are the compact remnants of stars which had a mass about 8–30 times the mass of the Sun, expelled their matter in a super-nova explosion and their cores collapsed, with the protons and electrons essentially melting into each other to form neutrons. See Nola Taylor Redd, “Neutron Stars: Definition and Facts”, Space.com (31 July 2013) at www.space.com/22180-neutron-stars.html.
comparable to atomic clocks. Thus, they can be used as natural navigation beacons, quite similar to the use of GNSS satellites for navigation on Earth. By comparing pulse arrival times measured on board a spacecraft with predicted pulse arrivals at a reference location, the spacecraft position can be determined autonomously and with high accuracy everywhere in the solar system and beyond.  

X-ray pulsar navigation could replace the current standard method of deep-space navigation, which consists of combining radio data (obtained by tracking stations on Earth) with optical data from an on-board camera during encounters with solar system bodies. Nonetheless, the effectiveness of the current method decreases as the distance from Earth increases.

Conclusion

The importance of GNSS and its applications are rapidly increasing. Core constellation and augmentation systems expand and improve their performance, which is further enhanced through bilateral agreements on compatibility and interoperability. Nevertheless, the dual use of GNSS induces several restrictions in terms of international cooperation. States prefer to conduct bilateral, instead of multilateral, cooperation agreements on GNSS issues. At the same time, they are reluctant to agree on international uniform rules governing liability, despite the regulatory fragmentation and legal uncertainty created by the applicability of traditional choice-of-laws rules combined with sovereign immunity.

With respect to international space law, the main question is its ability to adequately address modern GNSS legal issues. To the extent feasible, we should interpret current space rules taking into account contemporary and future needs.

The increasing commercial importance of GNSS applications is also reflected in the efforts to protect IPRs, yet without affecting the availability of the Open Service, which has become a kind of a common good. At the same time, GNSS-related services and products have become part of the international discussion on unrestricted market access.

Satellite-based navigation becomes gradually the cornerstone of navigation systems in aviation and shipping. Technical standards are constantly developed, to meet current and anticipated needs, and ensure safe operations. Besides, the principles applied in GNSS are so successful that scientists study their employment for navigation in deep space.

In sum, GNSS are multi-faceted systems with numerous applications. There are no uniform rules, apart from some general sector-specific policy guidelines. This creates a complicated regulatory situation and legal uncertainty. However, the dual use of GNSS for both civil and national security applications, as well as vested national interests concerning international trade, do not allow for uniform rules to be developed and, even more, adopted to a global scale. Therefore, it would be more realistic to pursue unification mainly at regional level combined with non-binding international recommendations on regulatory best practices.

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131 The disadvantages of the current method relate to the dependency on ground-based control and maintenance, the increasing position and velocity uncertainty with increasing distance from Earth as well as the large propagation delay and weakening of the signals at large distances.