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CHAPTER 12

GLOBAL NAVIGATION SATELLITE SYSTEMS

Introduction

The global navigation satellite system (GNSS) was identified as a potential benefit of space quite early in the space age.[1] Accurate knowledge as to the location and velocity of spacecraft is an essential. One spin-off from the technology required to provide such data has proved to be a most interesting matter of law - satellites providing accuracy of time and location for terrestrial purposes.[2] Interest in GNSS has increased in recent years UNISPACE III, 1999, providing an impetus on the international stage.[3]

Global Navigation Satellite Systems are space-based positioning and navigation systems designed to provide worldwide, all weather, passive, three-dimensional position, velocity and timing data.[4] Originally designed for military purposes, they are now also commonly used for many civilian purposes including the navigation and positioning of airplanes, ships,[5] trains,[6] cars and the fleet management of trucks,[7] as well as satellites. Fishermen,[8] farmers,[9] surveyors[10] and hikers use the systems. They can be used to track

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[1] J.T. Hayward, 'Space Technology for World Navigation' in S. Ramo, ed. *Peacetime Uses of Outer Space*, (New York: McGraw-Hill, 1961) 55-84; Jenks, 268-9.

[2] Time is now set internationally by reference to Coordinated Universal Time (UTC), the successor of Greenwich Mean Time since 1961, which is determined by a complex scientific process, world-wide accuracy being coordinated and maintained by time signals. Curiously one of the first problems caused by space technology was the interference of Sputnik I signals with the time broadcasts. Radiolocation remains important, particularly for aviation, the five volumes of Annex 10 to the Chicago Convention detailing PANS and SARPS on 'Aeronautical Telecommunications' (See *infra* n. 87). Particular spectrum bands are allocated within the ITU Radio Regulations for GNSS services.

[3] See *Report of the Action Team: Follow-Up to the Third United Nations Conference on the Exploration and Peaceful Uses of Space (UNISPACE III)*, (UN: ST/SPACE/24, 2004) ('UN Report, 2004').

[4] E. D. Kaplan and C. Hegarty, *Understanding GPS: Principles and Applications*, 2d ed. (Boston: Artech House, 2005).

[5] See Galileo Applications: http://www.galileoju.com/doc/Maritime.pdf.

[6] See Galileo Applications: http://www.galileoju.com/doc/Rail_Applications.pdf.

[7] See Galileo Applications: http://www.galileoju.com/doc/Road_Applications.pdf.

[8] See Galileo Applications: http://www.galileoju.com/doc/Agriculture%20&%20Fisheries.pdf.

[9] See Galileo Applications *supra*; J.C. Kluge, 'Farming by the Foot: How Site-Specific Agriculture can Reduce Nonpoint Source Water Pollution' (1998) 23 *Colum. J. Env. L.* 89-135.

individuals,[11] including children[12] and criminal offenders,[13] and questions of human rights and privacy can arise.[14] The technology is even used to time-stamp contractual agreements, which can be crucial for example in currency and other financial transactions.[15]

The service offered by GNSSs can be viewed as being similar to the Internet. Both are global, easily accessible with appropriate technology, and free. The use of GNSSs is spreading almost as quickly and as widely as that of the Internet. Its technology is developing rapidly. Both GNSS and the Internet are dual use; that is both have military and civilian uses, and the military had a significant role in their creation. Their universal adoption and acceptance have not been without legal controversies but these have not stopped their progress. Both have developed with considerable speed, and in fact, the two are beginning to be integrated.[16] And like the Internet, GNSS offers immediate economic benefits which will further develop.

GNSSs operation has three major segments: the space segment, its control and the service users. Precise timing is the basic component of satellite navigation. Atomic

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[10] P.B. Larsen, 'Use of Global Navigation Satellite System (GNSS) Evidence for Land Surveys: Legal Acceptability' (1995) 38 *Proc. IISL* 285-93.

[11] K.E. Edmundson, 'Global Positioning System Implants: Must Consumer Privacy be Lost in Order for People to Be Found?' (2005) 38 *Ind. L. Rev.* 207-38.

[12] A UK retailer, Bladerunner, sells jackets which can be tracked by GPS technology and appropriate mapping tools: http://www.bladerunner.tv/product/details.php?id=CHILDRENS. In December 2007 it was suggested that sufferers from Alzheimer's could be similarly tracked were they to wander from their accommodation. The idea will spread.

[13] Some US states (e.g. Florida, Missouri, Ohio, Oklahoma, South Carolina and Wisconsin) require sex and other offenders to be so tracked after liberation: cf. http://www.isecuretrac.com/, a provider of the technology. See also *Mickelson* v. *US*, 433 F.3d 1050; 2006 U.S. App. LEXIS 256, where the Court of Appeals for the Eighth Circuit permitted GPS tracking as a condition of release of a convicted person. In *R. (on the Application of Gulliver)* v *Parole Board* [2006] EWHC 2976 (Admin), shows the use of similar tracking in the UK.

[14] *US* v *Garcia*, (2007) 434 F.3d 994, cert. denied, US Sup. Ct. 1 Oct 2007; 2007 U.S. App. LEXIS 2272, held that the use of a GPS tracking device attached to the defendant's car was not a violation of the Fourth Amendment of the US Constitution prohibiting unreasonable searches and seizures. In *Garcia*, *Kyllo* v. *US*, (2001) 533 U.S. 27; 121 S. Ct. 2038; 150 L. Ed. 2d 94; 2001 U.S. LEXIS 4487, in which the Fourth Amendment was held to be breached by the use of a thermal-imaging device on a house where the growing of marijuana was suspected, was distinguished. See Case Note: (2006-2007) 120 *Harv. L. Rev.* 2230-7. See also *Hinkley* v. *Roadway Express*, 2007 U.S. App. LEXIS 21938, on the use of GPS data for disciplinary purposes (appeal pending). Cf. 'On Your Tracks: GPS Tracking in the Workplace', (US) National WorkRights Institute: http://www.epic.org/privacy/workplace/gps-traking.pdf;

[15] Cf. http://www.galileoju.com/doc/Finance_Banking_Insurance.pdf; and http://www.gpsclock.com/gps.html.

[16] Several recently announced mobile phones have a global positioning facility.

clocks on the satellites keep nearly perfect time within nanoseconds. Timing is monitored by a ground control segment that corrects as required. GNSS may be active or passive. In an active system (the Chinese Bedou) a ground receiver interrogates a satellite, and its position is then determined by an interactive process. In a passive system (GPS, GLONASS and Galileo) each satellite in the system continuously broadcasts signals that are intercepted by receivers operated by the users. Depending on the precise location of each satellite, its signal will reach a particular receiver at a marginally different time. The ground terminal receiving equipment is most accurate if signals from three or more satellite are being received. The receivers are pre-programmed to compare the signals and, by integrating the precise times of their reception, to establish where in three dimensions the receiver is located. That data is then mapped on to normal terrestrial cartographic coordinates. Suffice it to say that in the near future it will be possible to pinpoint the location of an object or a person to an accuracy of one centimetre.[17]

The Systems

1. GPS

The US space-based radio navigation system, the Global Positioning System (GPS) [18] was inaugurated by the orbiting of a total of eleven satellites in the period 1978-85, security considerations being a major emphasis in its development. From 1989 to 1994 the system was expanded to its present configuration, and with later satellites being orbited to replace failing ones. The GPS system comprises a minimum of twenty four satellites in six orbital planes, each with a period of twelve hours in a circular 20,200 km/10,900 nm orbit inclined at 55 degrees (Medium Earth Orbit, MEO).[19] Currently (2008) several (7) additional satellites provide an increased accuracy and also can be deployed readily whenever a GPS satellite fails. GPS has a number of ground stations round the world that monitor the system. A master control station at Colorado Springs checks the satellite clocks and orbits and updates the navigation message of each satellite.[20] Any updating message is transmitted to the satellite by a radio signal from ground antennas at the monitoring stations.

Two services are provided by GPS, the Standard Positioning Service (SPS) and the Precise Positioning Service (PPS). The Standard Positioning Service is available to

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[17] *Seattle Times*, 7 November, 2005 at C1.

[18] On GPS see http://www.gps.gov/; UN Report, 2004 (n. 3) 5-19, paras 10-71; B.M. Orschel, 'Assessing a GPS-based Global Navigation Satellite System within the Context of the 2004 US Space-based Positioning, Navigation and Timing Policy' (2005) 70 *J. Air L. & Comm.* 609-35.

[19] US Federal Radionavigation Plan (2005) at 2-2 - 2-3. http://www.navcen.uscg.gov/pubs/frp2005/2005%20FRP%20WEB.pdf.

[20] This is necessary because an orbit, and therefore the accuracy of its signalling as received on earth, can be affected by gravitational anomalies, the pressure of the solar wind, and other factors. Though the orbit may be affected minimally, uncorrected signals, travelling at the speed of light, will misinform a receiver.

all users without restriction,[21] whereas the Precise Positioning Service is available only for US military services, for US government use and for authorized foreign governments and military forces. The latter Service uses a special code (the P-code), which, being encrypted, is more difficult to jam than the civilian code (the C/A code – sc. the 'coarse acquisition' code). Each GPS satellite transmits signals on two L-band radio frequencies, L.1 in the 1559-1620 MHz band and L.2 in the 1215-1260 MHz band. A third civil signal, L-5, is scheduled to transmit at1176.45 MHz in the 1164-1215 MHz band. GPS provides global coverage which, for civilian use is accurate to 13 metres (best)/ 36 metres (worst) horizontally, and 22 metres (best)/ 77 metres (worst) vertically. Reliability is 99.94%.[22]

GPS is constantly being upgraded. The first GPS Block IIR-M satellite which has two civilian signals effectively separating future military and civilian GPS service was launched in 2005, and GPS is entering into its third phase of development (GPS III). GPS III satellites will have a greater capability than their predecessors and will be more resistant to jamming than the current satellites. The initial contract for the GPS III satellites includes twelve satellites and launching will start in 2014.[23]

Military uses of GPS are extensive. Soldiers use GPS positioning to locate themselves on the ground. Military air planes navigate by GPS. Bombs may be guided by GPS not to mention cruise missiles. Many military uses remain secret.[24] In terms of volume civilian use of GPS now surpasses the military use. The duality of the civilian and military uses of GPS is both an advantage and a disadvantage to civilian users. It is an advantage because GPS is funded by the military and might well not exist but for the military connection. However, the military connection can be a liability because of the technical capability of the military pre-emption of GPS, and the degrading or withdrawal of the civilian service.[25] That said, GPS is free and the US government does not plan to

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[21] The specific capabilities of this Service are available in 'Global Positioning System Standard Positioning Service Performance Standard' (2001) – http://www.navcen.uscg.gov/gps/geninfo/2001SPSPerformanceStandardFINAL.pdf.

[22] SPS Standard (n. 21) 15, Table 3-6; Figures A-5-1/2 (pp. A-5-6) show how GPS accuracy degrades as a function of latitude. See also US Report, 2004 (n. 3) 16-17, paras 61-3. Cf. discussion in M. Bourbonniere, 'Law of Armed Conflict (LOAC) and the Neutralisation of Satellites or *IUS in Bello Satellitis*' (2004) 9 *J. of Conflict & Security L.* 43-69 [Lyall/Larsen 515-41].

[23] *Space News*, 17 September, 2007 at 21, and 14 November, 2005 at 9. The first GPS-III satellite was launched on 15 March 2008. The whole GPS system will convert to GPS-III by 2014. The introduction of upgraded GPS technology may be compared with the Galileo plans for introduction of its upgraded technology that will begin about 2020. See *infra*.

[24] *Space News*, 12 November, 2005 at 16. See discussion of military uses of outer space in Chapter 16.

[25] We state this, notwithstanding the White House announcement of 18 September 2007, that procurement of new GPS-III satellites will not have the ability to degrade the civilian signal for the Standard Positioning Service: http://www.whitehouse.gov/news/releases/2007/09/20070918-2.html. Time will tell. As it is no intentional degradation of GPS signals has occurred since May 2000. That said

impose user charges for the system.[26] The US military GPS provider is of the view that if the GPS service is free for all users, then the civilian users do not have a legal basis for complaint if the service is faulty. The US provider has no appetite for negligence claims from civilian users.[27]

Within the US the GPS system is the responsibility of a number of US agencies, with the Department of Defense as lead, as is clear from the Federal Radionavigation Plan[28] although that Plan is the responsibility of three Departments, those of Defense, Transportation and Homeland Security. A National Space Based Positioning Navigation and Timing Committee (the National PNT EXXCOM) established in terms of the 2004 Policy Statement on such matters and chaired by the Deputy Secretaries of Defense and Transportation, makes recommendations to the various agencies involved.[29] The Federal Communications Commission has also a role.

The US Global Positioning System (GPS) is likely to remain the primary common world-wide radio navigation system in the short term until the European Galileo system begins to function, the Russian GLONASS recovers its global capability, and other systems including the Chinese are globally operational.

2. GLONASS

GLONASS, begun by the former USSR, is the Russian counterpart to GPS and like it is of military origin.[30] It was designed and is intended to be a global system with

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occasionally the GPS system suffers degradation for civilian services when the system is being tested or re-calibrated. In the UK Ofcom provides an email service to provide notice of such tests: http://www.ofcom.org.uk/static/subscribe/select_list.htm. In addition it is known that the weak GPS signals can be interfered with including by small portable equipment: Google 'GPS jamming'. Cf. E.S. Waldrop, 'Integration of Military and Civilian Space Assets: Legal and National Security Implications' (2004) 55 *Air F.L. Rev.* 157-231 at 207-8. See also Chapter 16 *infra*.

[26] See Presidential Policy Statement on US Space-Based Positioning, Navigation and Timing Policy, December 15, 2004, at III, bullet point 2: http://pnt.gov/policy/ or http://ostp.gov/html/FactSheetSPACE-BASEDPOSITIONINGNAVIGATIONTIMING.pdf.

[27] J. Huang, 'Development of the Long-term Legal Framework for the Global Navigation Satellite System' (1997) 22-I AASL 585; E.S. Waldrop, supra n. 25 at 213-5; B.E. Ehrhart, ' A Technological Turned Legal Nightmare: potential Nightmare Liability of the United States Under the Federal Torts Claims Act for Operating the Global Positioning Service' (2000) 33 *Vand. J. Transnat. L.* 371-425.

[28] US Federal Radionavigation Plan (2005): http://www.navcen.uscg.gov/pubs/frp2005/2005%20FRP%20WEB.pdf.

[29] See Presidential Statement, *supra* n. 26. EXXCOM members include the Departments of Commerce, Defense, Homeland Security, State, and Transportation, together with the Joint Chiefs of Staff and NASA: see http://pnt.gov/site.shtml

[30] The acronym GLONASS is derived from the Russian 'GLObal NAvigation Sputnik Systems'. As to the system see UN Report, 2004 (n. 3) at 19-25, paras 72-114; and http://www.GLONASS-ianc.rsa.ru.

approximately the same number of satellites as GPS. GLONASS satellites orbit in three planes separated by 120° in medium earth orbit (MEO) at c. 19100 km., with a period of eleven hours fifteen minutes, and an inclination of 68.4°.[31] GLONASS was made freely available to civilian use when the US GPS was so opened. It provides a standard precision navigation signal for civilians and a high precision navigation signal access to which is restricted. The accuracy of the civilian signal is 25 metres horizontal and 60 metres vertical with a service performance of 95%.[32] According to the UN Report of 2004, intentional degradation of the civilian service is not applied,[33] but as seen in the following paragraph that policy was departed from. The system transmits signals at L-1 (1.6GHz) and L-2 (1.2 GHz) frequencies and performance is monitored and corrected through ground stations in Russia and a central control station in the Moscow region.

The GLONASS system achieved a full complement of satellites in the 1990s, but the lifetime of the satellites was then only three to four years. The number of active satellites dwindled since, because of political and economic difficulties in the former USSR in the 1990s, GLONASS did not renew its system or substitute active satellites for those going out of service. The remaining active satellites were concentrated over the territory of the former USSR in order that the USSR successor states could use them for navigation within their several territories. For a time public access to GLONASS was also restricted for reasons of national security. However, Russian Defence Minister Ivanov announced on November 15, 2006 that restrictions on public access would be removed on January 1, 2007.[34] He also announced that while the then current number of satellites in orbit had declined to fourteen, the constellation would be increased to eighteen satellites which would be sufficient to cover all Russian territory.[35] The system is intended to be restored to its full complement of twenty-four satellites by the end of 2008.[36]

3. Galileo

Now expected to go into service in 2013 at the earliest, Galileo will be the European contribution to GNSSs.[37] It is planned as a thirty satellite system orbiting in medium earth orbit (MEO). Although global Galileo will be a system less complex than GPS and

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[31] UN Report, 2004 (n. 3) 21, para 86. As noted in the following text above, recent orbits were in a more elliptical configuration in order to provide service to the USSR successor states. When global service is resumed this will be re-adjusted.

[32] UN Report, 2004 (n. 3) 22-3, para 99.

[33] Ibid.

[34] 'Access Restrictions on Best GLONASS Signal to End', *Space News*, 20 November. 20, 2006, at 7.

[35] The GLONASS system is also to be made available for India from 2008.

[36] Information in these paragraphs is compiled from a variety of media sources and Wikipedia.

[37] Galileo is a joint effort between the European Union (EU) and the European Space Agency (ESA) and is to be funded by the EU (*Space News*, 1 June 2008 at1). As the major funding source the EU is the dominant partner. As to the structure of Galileo see *infra*.

is designed to serve only civilian users. This makes a significant difference to system cost. As of 2007 Galileo was planned to cost 3 billion Euros (c. US$ 4 billion): by contrast since 1974 the US government spent US$ 16.3 billion in building and deploying GPS.

A number of reasons, not always self-consistent, lie behind the decision to build Galileo given that civilian European users could access either GPS or GLONASS.[38] These include, first, the alternatives are controlled by the US and Russian military services and are subject to the decisions of their governments. Second, while both services are currently 'free to user' that might not continue; other governments could be asked for a subvention. Third, although access to the other systems is not at present degraded for civilian use, access in the future might be so restricted, or even interdicted.[39] Fourth, when the EU was starting to consider such matters the Europe Union Task Force felt that Russia's then political and financial problems made investment in GLONASS risky and not a credible alternative to GPS.[40] Fifth, it was considered unlikely that the US would not share control of its system. Europe would be better to have control of a separate navigation and positioning and timing service.[41] Sixth, the experience of a European augmentation to GPS has shown the advantages of a positioning more accurate than that available from civilian GPS.[42] An even more accurate service is needed for aviation, navigation and various safety services. Seventh, European space industries and services could be stimulated by the construction and operation of a European GNSS system. Eighth, there were and are legal questions as to potential liabilities arising from reliance on a malfunctioning system, as to which see *infra*.

In terms of its history, Galileo began as part of an EU Commission programme for the greater efficiency of European transportation systems and the greater mobility of people and goods.[43] A major step was the approval of the Commission Communication

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[38] 'EU Galileo Task Report to Commissioner Neil Kinnock', 4 June, 1999. Cf. 'Involving Europe in a New Generation of Satellite Navigation Systems', EU Commission 1999 (54 Final); *Project 2001: Workshop on Legal Framework for Privatising Space Activities*, Vienna, 1999, (Cologne: Inst. of Air and Space Law, 2000) 210-48.

[39] Although the US has said that this capability would be omitted from the GPS III satellites (n. 25, *supra*), a local jamming system could selectively deny service to civil users within a specific area. Note also that Russia did restrict civilian use of its system in the 2000s (*supra*, n. 34). Last the US Presidential Policy Statement of 2004 on GNSS (*supra* n. 26) indicates in Sec. II and Sec. III bullet point 3 that the US will develop its capability to prevent the hostile use of GNSS services generally, and according to Sec. VI may deny access to GPS under appropriate circumstances.

[40] EU Task Force, (n. 38) at para 3.2.

[41] Similar reasoning lies behind the Chinese and Indian developments noted *infra*.

[42] Egnos: See 'Augmentation', *infra*.

[43] European Parliament and Council: Decision No. 1692/96/EC, 23 July 1996; OJ L, 228, 9.9.96. See also Commission Doc. COM (1999) - 54 Final, 10 February 1999, 'Involving Europe in a New Generations of Satellite Navigation Services', *Project 2001: Workshop on Legal Framework for Privatising Space Activities*, Vienna, 1999, (Cologne: Inst. of Air and Space Law, 2000), 210-48.

on Galileo of 22 November 2000 which rehearses the history in its Introduction.[44] Thereafter, it has to be said, matters became complex. As Galileo was to charge for some of its services, it was hoped that the costs of the enterprise would be contributed to a major extent by the private sector. That has not, however, happened, and in June 2007 the EU Council decided to terminate negotiations with possible private partners.[45] It now seems that the EU itself will fund the project, aided by ESA.[46] But it has to be said that as we write the future structure of Galileo is obscure. A Galileo Supervisory Authority was established to own the system by EU Council Regulation No. 1321 (2004) of 12 July 2004, which also provides for the participation of non-EU states that are members of ESA (Norway and Switzerland).[47] Headquartered in Brussels the Galileo Supervisory Authority consists of an Executive Director, a Management Team supervising various departments,[48] an Administrative Board on which contributing states and the EU Commission are represented, a Technical and Scientific Committee and a System Safety and Security Committee. In May 2007 the Authority signed a cooperation agreement with ESA which clarifies their relationship. Procurement is based on EU rules.[49] Since 2005 China has been associated with Galileo in research and development through an EU/China agreement on industrial and technical cooperation, but at present China is not represented in the official structure.

The current plan (2008) is that Galileo will offer several kinds of GNSS services providing different levels of accuracy. This may alter before the system goes active, but at present planned services consist of: an open access service (corresponding to the GPS Standard Positioning Service); a safety of life service (which GPS is also to offer on the L5 frequency); an encrypted high accuracy commercial service for which Galileo will charge fees; and a Public Regulated Service (PRS) to be used by government agencies which will also be encrypted.[50] Galileo intends to guarantee the quality of the high-end

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[44] COM 2000, 750 Final: http://ec.europa.eu/dgs/energy_transport/galileo/doc/gal_com_2000_750_en.pdf

[45] Council Resolution on Galileo: 2805th Transport, Telecommunications and Energy Council Meeting, Luxemburg, 6-8 June, 2007: http://ec.europa.eu/dgs/energy_transport/galileo/documents/doc/council080607en.pdf

[46] 'Progressing Galileo: Re-profiling the European GNSS Programmes', Commission Communication, COM(2007) 534, 19 July 2007; related Staff Working Document ((SEC(2007) 1210); 'Council Conclusions on the European Galileo and EGNOS satellite-navigation programmes', 2821st Transport, Telecommunications and Energy Council Meeting, Luxembourg, 1-2 October 2007; http://ec.europa.eu/dgs/energy_transport/galileo/documents/doc/council_conclusions_021007.pdf.

[47] Galileo Supervisory Authority: http://www.gsa.europa.eu/

[48] The Departments are: Technical, Concession, Market Development, Finance and Administration, Legal, and Personnel.

[49] See http://www.gsa.europa.eu/go/gsa/procurement.

[50] Cf. the terms of the Cooperation Agreements, *infra* n. 60. *Space News* 27 June 2008 carried an item indicating that the encrypted Galileo signal would be used to a considerable extent by the military. See also the 'PACIFIC' Project (PRS Application Concept Involving Future Interested Customers) - http://www.prs-pacific.eu/.

service. It will therefore accept liability for defective high quality service, a liability which GPS will not contemplate. Galileo expects that its guarantees high-end services will attract users and will motivate high-end users to pay its charges.

It has to be said that originally the US was not in favour of the emergence of Galileo.[51] However, the US does recognise that for the foreseeable future there will be more than one GNSS system.[52] Accordingly the US and the Galileo states entered into an agreement in June 2004.[53] That said, the inception of Galileo may run into difficulties. Even as it was being planned the US raised difficulties as to the radio frequencies which Galileo might use.[54] Galileo will have to subcontract for GNSS equipment, and may have to go to the US for some material. But because most space assets also have military uses the US has a strict national security policy on the export of space assets.[55] Before granting export licenses for US GNSS equipment, the US government may insist that Galileo space assets be assembled in the US.[56] Furthermore, the US Government might veto launches of US-built Galileo space assets by Chinese launch vehicles. This could cause problems because of the financial stake in Galileo acquired by China in recognition of which it might seek to influence the selection of launch providers.[57] Again, Galileo will encounter competitive pressure from GPS in its efforts to keep on upgrading its

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[51] The Presidential Policy Statement of 2004 on GNSS (*supra* n. 26), indicates that the US intends GPS to remain dominant. There are also considerations of a useful market for US technology if Galileo were to be abandoned.

[52] Presidential Policy Statement of 2004 on GNSS (*supra* n. 26) Sec. III para 1 list as one of the goals of US GPS policy (no. (4)) the provision of 'civil services that exceed or are competitive with' foreign GNSSs. Under Sec. III bullet point 6, while encouraging the foreign development of GNSS services based on GPS, the US also seeks to ensure that foreign GNSSs will be interoperable with civil GPS. This will inter alia provide mutual back-up of separate systems: see *infra* 'Inter-operability and Redundancy' following n. 74. At a minimum the US would want to see the mutual compatibility of systems to avoid interference or hostile interference.

[53] 'Agreement on the Promotion, Provision and Use of Galileo and GPS Satellite Based Navigation Systems and Related Applications' UKTS European Communities No. 2 (2008), Cm. 7384.

[54] The matter was solved in July 2007 with an EU/US agreement on frequency usage: http://useu.usmission.gov/Dossiers/Galileo_GPS/default.asp; http://useu.usmission.gov/Dossiers/Galileo_GPS/Jul2607_Civil_Signal_Accord.asp; http://www.msnbc.msn.com/id/19976802.

[55] See Chapter 14, Space Activities and International Trade Law, and Chapter16, The Military Use of Outer Space.

[56] However, Sec. V of the Presidential Policy Statement of 2004 on GNSS (*supra* n. 26) does indicate some flexibility. On export controls see Chapters 14 on International Trade and 16 on Military Uses of Outer Space. Cf. the *Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies: Basic Documents*, Issue 7, 2007, http://www.wassenaar.org/publicdocuments/index.html.

[57] Chinese satellite launch prices are very competitive. For the EU/China cooperation agreement (separate from financial matters) see *infra* n. 60. The involvement of China raised questions of technology transfer and secrecy.

services. As noted, the US is moving to GPS III, a new generation and higher level of technology. Galileo will have to make a similar technological leap in order to stay competitive with GPS - an expensive undertaking. In any event, the initial system of 30 satellites necessary to establish Galileo will all be identical and are expected to serve at least until 2020. The opportunity for Galileo to launch a new generation of technology will therefore not occur until after 2020. We would note that NATO uses GPS, which could encourage the EU if under financial pressure, to abandon Galileo.[58] The UK Parliament House of Commons has strongly queried whether the Galileo project should go ahead.[59] It does, however, look likely to progress, cooperation agreements having been negotiated with a number of potential users other than the EU members.[60] On the other hand none of these agreements is yet in force.

4. BeiDou

The Chinese BeiDou system is under development.[61] Of military origin it is under military operational control. The first phase, Beidou-1, consisting of four satellites (BeiDou 1-A to 1-D) were launched in 2000-2007 to geosynchronous orbit.[62] Unlike GPS, GLONASS and Galileo, therefore, Beidou-1 is accessible only within the area of its satellite visibility and signal direction (70°E – 140°E and 5°N – 55°N). As noted above, unlike the other systems the mode of operation of BeiDou-1 is active, not passive. A signal is sent from a user terminal on the ground to the satellites,[63] which calibrate their reception of it and transmit the result to a central ground station, which then calculates the location of the origin of the original user signal. That datum is then communicated to

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[58] It must be said that abandonment does not now appear very likely. The time to abandon would have been with the collapse of the joint-undertaking between government and private investment in 2007. The juggernaut seems to have acquired momentum. See *supra* n. 46.

[59] (UK) House of Commons Transport Committee, Session 2006-2007, 12 November 2007, HC 53 -'Galileo: Recent Developments' - http://www.publications.parliament.uk/pa/cm200708/cmselect/cmtran/53/53.pdf. The Committee had earlier expressed reservations as to the project in House of Commons Transport Committee, Session 2003-04, 'Galileo', HC 1210 (not available electronically).

[60] See the Co-operation Agreements on a Civil Global Navigation Satellite System (GNSS) between the European Community its Member States and 1. The Ukraine (Kiev, 1 December 2005) (UK) European Communities No. 11, (2007) Cm. 7199); 2. Israel (Brussels, 13 July 2004) (UK) European Communities No. 10, (2007) Cm. 7200); 3. Morocco (Brussels, 12 December 2006), (UK) European Communities No. 9, (2007) Cm. 7201); 4. China (Beijing 30 October 2003), (UK) European Communities No. 7, (2007) Cm. 7202); 5. The Republic of Korea (Helsinki, 9 September 2006, (UK) European Communities No. 8, (2007) Cm. 7203).

[61] The name 'BeiDou' (alt. 'BeDou') is derived from the Chinese name for the Great Bear constellation (alt. the 'Plough' or the'Big Dipper').

[62] Beidou 1-A is no longer in use. At present the system uses two satellites with Beidou 1-C as an in-orbit back-up.

[63] User terminals are much larger than those for GPS, and require 20 cm antennae.

the user via the satellite system. The satellites transmit at 2491 MHz and user stations at 1615 MHz. The system has three tracking stations, ground correction stations and mobile user stations. Accuracy is of the order of 100 metres, but this can be increased by differential methods. Up to 150 users can be served at any one time and up to 540,000 per hour. BeiDou-1 is to be replaced. The first satellite of the Beidou-2 (or 'Compass') system, which will be expanded into a global system, was launched in April 2007. BeiDou-2 will operate through a mixed configuration of thirty-five satellites, five in geostationary and thirty in medium earth orbit. As with other systems, one of its services will be restricted to military and government users, while another will provide a free service for civilian users within China affording an accuracy of 10 metres.[64]

Augmentation

The accuracy of existing GNSSs indicated in the separate outlines above is for many purposes insufficient. However, it is possible to 'augment' their accuracy making it possible, for example, for it to be used to land aeroplanes or manoeuvre large ships within docks.[65] This is done through sophisticated triangulation and the introduction of a third navigational and positioning reference point which may be on a satellite or may be provided by ground-based beacons. Various systems presently exist.

The Wide Area Augmentation System (WAAS) was developed and commissioned by the US Federal Aviation Administration (FAA) to interact with the GOS system for aviation purposes, but it can be used with any suitably adapted GPS receiver.[66] WAAS allows accurate vertical and lateral separation of airplanes for all phases of flight, except Category II and Category III flights - these involve landing at particular major US city airports. A Local Area Augmentation System (LAAS) will in the future provide the accurate GNSS augmentation landing at these airports. LAAS will use multiple land-based reference points located at airports. LAAS will be used for parallel runways, runway incursion warnings, high-speed turnoffs, missed approaches, departures, and all aircraft surface movements at the airports it will serve.[67]

Maritime navigation also requires GNSS augmentation, particularly in ports and in narrow navigation channels. The maritime differential service augments the accuracy

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[64] The information is this paragraph has been taken from the SinoDefence.com website: http://www.sinodefence.com/strategic/spacecraft/beidou1.asp and http://www.sinodefence.com/strategic/spacecraft/beidou2.asp, as well as gleaned from media sources and Wikipedia.

[65] The US Space-Based Positioning, Navigation, and Timing Policy Statement of December 15, 2004 (n. 26) Sec. I, defines GNSS augmentation as: 'space and/or ground-based systems that provide users of space-based positioning, navigation, and timing signals with additional information that enables users to obtain enhanced performance when compared to the un-augmented space-based signals alone. These improvements include better accuracy, availability, integrity, and reliability, with independent integrity monitoring and alerting capabilities for critical applications.'

[66] UN Report 2004 (n. 2) paras 176-81.

[67] US Federal Radionavigation Plan (2005) (n. 28) Ch. 3.

of GNSS by use of land-based reference beacons which transmit correction messages to maritime users. The US maritime differential GPS Service provides an accuracy better than 1 metre and is available for all US coastal areas and on US navigable rivers. This kind of GNSS augmentation is also available inland in the US through the use of inland towers as reference points. Thus augmented GPS is used for safety management of trains and for many emergency uses, for example to provide location services for ambulances and fire engines.

The European Geostationary Navigation Overlay Service (EGNOS) is an all-purpose augmentation system for all kinds of users and it will become an augmentation of Galileo when that system becomes operational.[68] EGNOS is a joint undertaking. The EU provides political and financial support for EGNOS under the Telematics Research Program for traffic management. ESA was responsible for the design and development of the EGNOS system. Eurocontrol developed the aviation certification requirements and tested the system.[69] EGNOS currently augments GPS by means of navigation payloads on INMARSAT III satellites. EGNOS may also be used to augment GPS outside of Europe.

China, Japan, India and some other countries are also establishing systems to augment GPS and eventually other GNSS systems as necessary.[70] Naturally Canada is extending its use of GPS with appropriate augmentation.[71] Using specifications based on the US WAAS Japan provides augmentation through its Multifunctional Transport Satellite programme (MSAS) and a Quasi-Zenith Satellite System (QZSS).[72] An Indian GNSS programme called GAGAN (GPS and Geo Augmented Navigation),[73] a project of the Indian Airports Authority and the Indian Space Research Organisation, is scheduled for certification in 2010.[74]

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[68] See http://www.esa.int/esaNA/egnos.html; www.Galileoju.com; UN Report 2004 (n. 2) paras 169-75.

[69] Eurocontrol deals with the safety of air navigation within Europe: http://www.esa.int/esaNA/egnos.html.

[70] UN Report 2004 (n. 2) paras 162-203. F. Lyall, 'Legal Issues of Expanding Global Satellite Communications Services and Global Navigation Satellite Services' (2001) 5 *Sing. J. Int. & Comp. L.* 227-45 at 230-3.

[71] UN Report 2004 (n. 2) paras 195-203.

[72] MTSAT Satellite-based Augmentation System: UN Report 2004 (n. 2) paras 162-4. On QZSS, see UN Report at 165-8. See also the annual 'Joint Announcement on US-Japan GPS Cooperation', http://www.mofa.go.jp/region/n-america/us/gps0705.html; http://www.state.gov/g/oes/rls/or/85848.htm and related Technical Working Group Statement; http://qzss.jaxa.jp/is-qzss/US-Japan_TWG_Statement_24May07Web_Version.pdf

[73] 'Gagan' is Hindi for 'Sky'.

[74] UN Report 2004 (n. 2) paras 182-94. http://www.india-defence.com/reports/2239; S.V. Kibe, 'Indian Plan for Satellite-Based Navigation Systems for Civil Aviation' (2006) *Online J. of Space Comm.*: http://satjournal.tcom.ohiou.edu/issue9/indian_plan.html. For US-India cooperation in GPS/GNSS see the Joint Statement, http://www.state.gov/g/oes/rls/or/81450.htm. India may later develop its own regional navigational satellite system.

Inter-operability and Redundancy

Logically only a single GNSS is required. Multiple providers use radio spectrum unnecessarily, their satellites occupy orbital positions, and their launches may well increase the space debris problem. But to argue for a single system is to ignore historical, economic and political realities. There are military reasons for the existence of GPS, GLONASS and BeiDou. Economics and politics are, however, not irrelevant, and these elements are certainly present for the civilian Galileo. However, as the global dependency on GNSSs increases, there are advantages in a multiplicity of systems. Provided that there is either interoperability or that users can access more than one system, a useful redundancy is created. GNSS is inherently fragile. Space debris can knock out satellites, as may solar storms. These last together with terrestrial interference, natural and artificial, may also degrade a GNSS or an augmentation signal.[75]

Under any of the foregoing scenarios the multiplicity of systems can provide mutual back-up,[76] an advantage increased were there to be full interoperability between them. The case of aviation is perhaps the clearest. On long-range flights an aircraft may pass through the operational area of all the GNSSs together with several area augmentations. A multiplicity of navigation systems requiring airplanes to change from one GNSS provider to another in mid-flight can create an air safety problem. The multiple providers seek to make seamless the use of the multiple systems so that users do not have to be conscious of shifting from one system to another. As we will see the International Civil Aviation Organization (ICAO) adopts uniform navigation standards and recommended practices for all the GNSS systems and the ICAO Assembly has adopted international GNSS guidelines.[77] Further cooperative steps are being taken through an informal and voluntary International Committee on Global Navigation Satellite Systems (ICG).[78] Wisely the US would as a minimum seek to ensure that non-

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[75] As noted, the GPS system is occasionally unavailable to civilian users when being tested and notice is provided to users in advance (*supra* n. 25).

[76] There are potential situations (e.g. very severe solar radiation, or massive space debris caused by military actions in outer space or the 'cascade effect' described in Chapter 10) which could adversely affect all the satellite systems simultaneously. In that case the GNSS users will have to fall back on the alternative methods of positioning, navigation and timing that existed before satellite navigation and positioning – if they can remember how to do them.

[77] See *infra* n. 87.

[78] The ICG is serviced by UN OOSA, and has a 'Providers Forum' in which desirable developments are discussed – see
http://www.unoosa.org/oosa/SAP/gnss/icg/providersforum.html#gps,
http://www.unoosa.org/pdf/icg/2007/icg2007-pfE.pdf,
http://www.unoosa.org/pdf/icg/2007/icg2007-jstatE.pdf and
http://www.unoosa.org/oosa/SAP/gnss/icg/providersforum.html.

GPS systems are at least mutually compatible so as to lessen the problems of mutual harmful interference or the hostile use of GNSSs.[79]

GNSS Law

UN COPUOS has evinced an interest in GNSSs, and has encouraged their development.[80] All states currently providing GNSS services are parties to the Outer Space Treaty, ARRA, the Liability Convention and the Registration Convention. As far as Galileo is concerned ESA has declared its acceptance of the rights and obligations of ARRA, the Liability Convention and the Registration Convention and the majority of ESA members and the EU are parties to the OST. Effectively therefore GNSS is subject to the normal rules as to the use of outer space.

As space objects GNSS satellites are subject to the various rules and requirements indicated in Chapter 4. GNSS satellites entered in the registry of a particular State Party remain subject to its jurisdiction and control while in outer space.[81] The nature of the ownership of a satellite does not change merely because it is in outer space (OST Art. VIII), but the financing of GNSS satellite systems remains subject to national laws. If the space protocol to the 2001 Convention on International Interest in Mobile Equipment (the Cape Town Convention) is in force for a party, then that Convention will apply to financial securities constituted over the satellite.[82] By OST Art VIII, a GNSS satellite found outside the state of registry, if requested, must be returned to that state after proper identification. By contrast, should ARRA apply, its Art. 5 provides that the State which finds a satellite is to make it available to its launching state, but that the expenses incurred in retrieval and return are to be borne by the launching authority.[83] Lost GNSS satellites are more likely to be found and retrieved and found on Earth following an unsuccessful launch rather than while in orbit.[84]

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[79] US Presidential Policy Statement, 2004, on GNSS (*supra* n. 26) Sec. III bullet point 6. See also *supra* n. 54 as to the US/EU agreement on frequency compatibility for GPS and Galileo.

[80] Cf. UNGA Res. 2223 (XXI), 19 December 1966, para 4.

[81] OST Art. VIII: Convention on the Registration of Objects Launched into Outer Space, 14 January 1975; 1023 UNTS 15; (1978) UKTS 70, Cmnd 7271; TIAS 8480; (1975) 14 ILM 43; (1979) 18 ILM 891.

[82] Convention on International Interests in Mobile Equipment, UN Doc. No. A/AC.105/C.2/2002/CRP.3, 16 November 2001: http://www.unidroit.org/english/conventions/mobile-equipment/main.htm. The draft Protocol as to Space Assets is at http://www.unidroit.org/english/publications/proceedings/2004/study/72j/s-72j-13rev-e.pdf. See also Chapter 14, International Trade.

[83] 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; 1969 UKTS 56, Cmnd. 3997; 19 UST 7570, TIAS 6559; 7 ILM 151; (1969) 63 AJIL 382. Cf. Chapter 4, Space Objects.

[84] Satellites in incorrect orbits have been recovered by the Shuttle in an operation paid for by their insurers, refurbished, and sold to other users.

Under OST Art. VI states 'bear international responsibility for national activities in outer space … and for assuring that national activities are carried out in conformity with' the Treaty. By OST Art. III state parties conduct their space activities in accordance with international law, including the UN Charter. This might be thought to impose some restrictions on GNSSs. The GPS, GLONASS and BeiDou systems basically provide a military service although civilians are permitted to use them, a permission that can be withdrawn. It follows that all the UN Charter provisions as to the maintenance of international peace and security (UN Charter Art. 1), non-intervention (Art. 2), the settlement of disputes (Art. 2), and non-aggression (Arts. 39-51) have relevance. The use of GNSS as part of a self-defence action would be sanctioned under Art. 51.[85] OST Art. IV provides that States Parties may 'not place in orbit around the Earth any object carrying nuclear weapons or any other kinds of weapon of mass destruction … .' In that some GNSS systems are dual-use serving both military and civilian purposes they could be used to guide weapons of mass destruction. It does not seem to be argued, however, that they therefore are part of these weapons and prohibited by OST Art. IV.

OST Art. 1 provides that 'use of outer space 'shall be carried out for the benefit and in the interest of all countries, irrespective of their degree of economic or scientific development.' Further 'outer space … shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law … .' Clearly while GNSS access remains free for civilian users a potential benefit for all is provided by GNSSs.[86] However, the language of OST Art. I does not specifically require that all countries or users shall have access to particular space benefits and that must include the GNSS systems. This could be important in international transport were a GNSS system to lock out a user. Notwithstanding, we note that in the case of aviation, the 1998 ICAO 'Charter on Rights and Obligations of States Relating to GNSS Services' states that States and aircraft 'shall have access on a non-discriminatory basis under uniform conditions, to the use of GNSS services.'[87] This obligation would apply to all ICAO members, which includes all current GNSS providers.

OST Art. IX, provides that States Parties shall conduct their activities in outer space "with due regard to the corresponding interests of all other States Parties to the Treaty.'[88] Consultation may be requested if a state suspects interference with its space

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[85] See Chapter 16 on military uses of outer space.

[86] Cf. 'Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking into Particular Account the Needs of Developing Countries', UNGA Res. 51/122, 4 February 1997.

[87] ICAO 'Charter on the Rights and Obligations of States Relating to GNSS Services' ICAO Res. A32-19 (1998): in 'Assembly Resolutions in force (as of 8 October 2004)' ICAO Doc. 9848. GNSS is provided for in Annex 10 to the Chicago Convention detailing PANS and SARPS on 'Aeronautical Telecommunications'.

[88] Compare *UK* v. *Iceland*, 1974 ICJ 3 where the Court held that, on the high seas, States have 'the obligation to pay due regard to the interests of other States in the conservation and equitable exploitation of these resources.' This principle of customary law is articulated in Arts. 56-9 of UNCLOS, 1984: UN Convention on the Law of the

activities from those of another Party. Further, by OST Art. VII a state may be liable for damage caused by its space object. Liability is, of course, the material of the Liability Convention as well, another treaty which the GNSS providers have ratified.[89] What we may call 'normal liability' is not in question for GNSS – a crashing GNSS satellite will be dealt with under OST Art. VII or the Liability Convention, failing which the traditional rules as to inter-state damage. More interesting is the question whether GNSS providers have liability if their system fails or delivers inaccurate positioning thus causing damage to a user reliant on it.

The Liability Convention Art. II provides that a 'launching state shall be absolutely liable to pay compensation for damage caused by its space object on the surface of the Earth or to aircraft in flight.' Art. III holds a launching state liable for 'damage caused elsewhere than on the surface of the Earth to a space object of one launching State or to persons or property on board such space object by a space object of another launching state …' only if the damage is its fault or the fault of persons for whom it is responsible. What if an aircraft reliant on a faulty GNSS crashes or collides with another aircraft – is absolute liability to be imposed? What if a space-launch reliant on the GNSS of another state goes amiss through defective satellite signals? The language of Arts. II and III might at first sight appear to apply to damage caused by reliance on faulty GNSS. However, the Liability Convention has been interpreted by some to apply only to direct damage attributable to a crashing space object or a collision between space objects in outer space. On this view the Liability Convention would not apply to damage caused indirectly through an orbiting GNSS space object transmitting faulty navigation and positioning information.[90] On the other hand the language of the Convention does not specifically dictate such a narrow interpretation. Some are of the view that the Liability Convention applies to direct and indirect damages caused by space objects.[91]

Some states that are not party to the Liability Convention are parties to the OST. Its Art, VII holds launching states liable for damage caused on Earth, in airspace and outer space. Neither Art. VII nor its origin, para 5 of the UNGA 'Declaration of Legal Principle Governing the Activities of States in the Exploration and Use of Outer Space', UNGA Res. 1962 (XVIII) of 13 December, 1963, specify the narrow view of liability that is applied by some major space powers. It is an interesting question whether damages could be recovered from a state operating a faulty GNSS system either because of the fault itself (OST Art. VII), or because the fault indicates a failure properly to supervise and control its own space activities or those of its nationals under OST Art. VI.

Another question may be whether the national law of a GNSS provider can be brought into play. That is a matter for the several legal systems that may become

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Sea, Montego Bay, 1984, 1833 UNTS 3; (1999) UKTS 81, Cm. 4524. (1982) 21 ILM 1261.

[89] Convention on International Liability for Damage Caused by Space Objects, 29 March 1972; 961 UNTS 187; (1974) UKTS 16, Cmnd 5551; 24 UST 2389, TIAS 7762; (1971) 10 ILM 965; (1971) 66 AJIL 702.

[90] This is the US interpretation expressed at the Senate Hearings on the ratification of the Liability Convention.

[91] Cf. Cheng, 506. Several states party to the Convention have not expressed their views on this question.

involved. Some would probably refuse an action through applying a doctrine of 'sovereign immunity'.[92] Other states might apply a doctrine of 'injurious reliance' and allow an action. Again, action against the manufacturer of a defective satellite might be contemplated. The solution may be the drawing up of an international agreement on GNSS liability, akin to the Warsaw Convention (1929, as amended[93]) or the Conventions on Third Party Liability in the Field of Nuclear Energy.[94]

Other International Law

Radio is fundamental to all GNSSs and their augmentations. The navigation and positioning satellites cannot function without clear radio signals. Harmful interference with GNSS radio frequencies creates safety hazards for navigation of airplanes, ships and trains, its avoidance or elimination is therefore particularly important. GNSS radio signals are weak and as it happens the radio frequencies used by the service providers are all close to each other, increasing the potential of harmful radio interference between the GNSS providers themselves entirely apart from other terrestrial interference.

The international use of radio is a matter for the International Telecommunication Union (ITU) discussed in Chapter 8. Briefly, Art. 44.1 (195) of the ITU Constitution provides that ITU members shall limit their use of the radio spectrum to the absolute minimum necessary for the services since radio frequencies are a limited natural resource. As such frequencies are to be used rationally, efficiently and economically, and in conformity with the provisions of the Radio Regulations so that all may have equitable access to the resource (Art. 44.2 (196)). Causing harmful interference to other users of the radio spectrum is prohibited by Art. 45 of the ITU Constitution. Under the ITU Radio

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[92] Under the US Foreign Sovereign Immunities Act, 28 USC 1604 et seq., foreign governments enjoy immunity from suit in US courts. GPS is subject to the US laws on governmental immunity because it is provided directly by the government. US governmental immunity is governed by the US Federal Tort Claims Act (FTCA), 28 USC 1346, 1402, 2402–2405, 2671–2680. The FTCA permits the US government to be held liable for its negligent acts if those acts are not 'discretionary acts.' – a term which is not defined in the statute, but cf. *Dalehite* v. *United States*, 346 US 15 (1954); *United States* v. *Union Trust*, 350 US 907 (1955). GLONASS and BeiDou are governmental activities. Galileo may claim sovereign immunity although it will charge for high-end use: F.G. von der Dunk, 'Liability for Global Navigation Satellite Services: A Comparative Analysis of GPS and Galileo' (2004) 30 *J. Sp. L.* 129-67 (Lyall/Larsen 429-67) at 153-7 (written before the collapse of the projected public/private joint-undertaking arrangement).

[93] Convention for the Unification of Certain Rules Relating to International Transportation by Air, Warsaw, 12 October 1929; 137 LNTS 11; 49 Stat 3000; (1934) TS 876; 1933 UKTS 11, Cmd. 4284; (1934) 28 AJIL Supp. 84.

[94] Convention on Third Party Liability in the Field of Nuclear Energy, Paris , 29 July 1960, 956 UNTS 251; 1969 UKTS 69, Cmnd. 3755; (1971) 55 AJIL 1082. We believe that Supplementary Conventions of 1963 (1963) 2 ILM 685) and 1997 (1997) 36 ILM 1473) are not yet in force.

Regulations various spectrum bands are allocated to particular uses,[95] and states should assign frequencies to the users they license accordingly. Assignments in the space bands are given advance publicity through the ITU, and data as to frequencies and satellite orbits made known. Before a firm assignment is notified to the ITU Radiocommunication Bureau an assigning state should try to ensure that no interference will be caused to another user, entering into appropriate negotiations if needed. An assignment is processed by the Radiocommunication Bureau, and, if all is well, is entered on the Master International Frequency Register. Thereafter a registered assignment is entitled to protection from interference by later-comers.

Two other international organisations play an important role as to GNSS, the International Civil Aviation Organisation (ICAO) and the International Maritime Organisation (IMO).

Membership of the Convention on International Civil Aviation, Chicago, 1944[96] includes all states that provide GNSS services. ICAO *inter alia* regulates safety in the air at the international level. Its Art 28 requires ICAO parties to provide air navigation facilities in their territories that comply with the international standards and practices which ICAO establishes under powers conferred by Art. 37. In 1998 by Resolution A32-20 the ICAO Assembly instructed the ICAO Council and the Secretariat 'to consider the elaboration of an appropriate long term framework to govern the operation of GNSS systems, including consideration of an international convention for this purpose.[97] In the meantime Annex 10 to the Chicago Convention is the vehicle for establishing navigation standards for both GNSS and for augmented GNSS. That said, the Thirty-second ICAO Assembly also adopted a Charter on Rights and Obligations of States Relating to GNSS Services.[98] This Charter is not legally binding; it is not part of Annex 10 to the ICAO Convention. However, as the resolution of an Assembly with world-wide competence within its field, it may be considered to be significant. The major elements of the ICAO GNSS Charter are:

1. States recognize that 'the safety of international civil aviation shall be the paramount principle' in providing and using GNSS.
2. States and aircraft 'shall have access, on a non-discriminatory basis under uniform conditions, to the use of GNSS services.'

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[95] The most useful frequencies for GNSS are also sought by Mobile Satellite Service users and mobile phone service providers. That GNSS has major safety, emergency and guidance purposes argues they should be given priority within the allocation process.

[96] Convention on International Civil Aviation, Chicago, 7 December 1944, (1944) 15 UNTS 295; 61 Stat. 1180, TIAS 1591; (1953) UKTS 8, Cmd. 8742; 9 Hudson 168; 3 Bevans 944; (1945) 39 AJIL Supp 111; ICAO Doc. 7300/9, 2006: http://www.icao.int/cgi/goto_m.pl?icaonet/dcs/7300.html.

[97] ICAO Assembly Res. A32-20, 'Development and elaboration of an appropriate long-term legal framework to govern the implementation of GNSS': ICAO Assembly Resolutions in force (as of 8 October 2004) ICAO Doc. 9848.

[98] ICAO Assembly Res. A32-19, 'Charter on Rights and Obligations of States Relating to GNSS Services' Assembly Resolutions in force (as of 8 October 2004) ICAO Doc. 9848.

3. (a) States possess sovereignty over their own air space and the right to control aircraft operation in their sovereign airspace; and (b) GNSS providers shall not restrict States' control over their sovereign air space.
4. GNSS providers 'shall ensure the continuity, availability, integrity, accuracy and reliability of such services, including effective arrangements to minimize the operational impact of system malfunctions or failure, and to achieve expeditious service recovery. Such State shall ensure that the services are in accordance with ICAO standards.'
5. States shall 'co-operate to secure the highest practicable degree of uniformity of GNSS services' including regional and sub-regional services.
6. GNSS charges are to comply with Art. 15 of the Chicago Convention.
7. In planning and providing GNSS services states are to be 'guided by the principle of co-operation and mutual assistance'.
8. In providing GNSS States are to have due regard to the interests of other States.
9. States may provide GNSS services jointly with other states.

Much of this is unexceptionable. However, the suggestion in '1' that safety in civil aviation is the paramount principle in the provision and use of GNSS is at variance with reality. Other uses have an equal claim to importance. That said, we do recognise that the ICAO Communication, Navigation and Surveillance/Air Traffic Management (CNS/ATM) developments rely on GNSSs, and these developments are important.[99] ICAO continues to play an important role in the development and use of GNSSs.[100] In an effort to control GNSS use, as noted, under A32-20 ICAO is working on a broader legal framework in addition to its GNSS Charter which might include issues such as air navigation, regulation of GNSS providers, liability for faulty GNSS services,[101] and related issues. However, as noted, ICAO interests cannot take precedence over those of non-aviation users.

The International Maritime Organization (IMO)[102] is the maritime counterpart to ICAO and there is a considerable overlap in membership of the two organisations. Article 16 of the IMO Convention authorizes the IMO to regulate international maritime

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[99] CNS/ATM is a major development in aviation. See ICAO Assembly Res. A29-11 on 'Use of space technology in air navigation'; and A32-15 on consolidated policies and practices as to CNS/ATM.

[100] B.D.K. Henaku, *The Law on Global Air Navigation by Satellite* (Leiden: AST, 1998); J. Huang, 'Sharing Benefits of the Global Navigation Satellite System within the Framework of ICAO', (1996) 39 *Proc. IISL* at 128-31.

[101] We understand that liability may well not figure in any ICAO proposals since ICAO interest is limited to aviation, while GNSS has a plethora of users represented by many agencies both national and international. Again, relevant GNSS providers may claim state immunity and be unlikely to accede to any treaty-based variation of their rights.

[102] Convention on the International Maritime Consultative Organization (IMO), Geneva, 6 March 1948; 289 UNTS 48; 1958 UKTS 54, Cmnd. 589; 9 UST, TIAS 4044; (1959) 53 AJIL Supp. 516. The title of the organisation was changed to the International Maritime Organisation in 1975, effective 1982 (35 UST 497, TIAS 10374). For current text see http://www.imo.org/

safety. IMO establishes standards and practices for maritime transportation. Universality and uniformity of GNSS navigation standards for maritime transportation are as important for maritime navigation as are the ICAO standards for air navigation. IMO actively adopts and reviews maritime navigation rules and procedures for navigation by GNSS. GNSS search and rescue functions are also particularly important for maritime activities. In 1997 IMO established a maritime policy for all future GNSS systems,[103] and since 2000 it has required GNSS receivers to be carried on all ships engaged in international carriage.[104] The International Mobile Satellite Organization (INMARSAT) provides and supports global, regional and domestic satellite services, including radio determination and radio navigation. As noted in Chapter 11, Telecommunications Organisations, INMARSAT has been privatized but the organisation continues its GNSS maritime navigation and safety functions as well as its augmentation support of GNSS through EGNOS.

The Future

It seems clear that GNSS has an important future. The problems encountered by Galileo indicate that GNSS provision is likely to remain a matter of state action rather than private finance, let alone provision by private enterprise. State cooperation and the inter-operability of systems will be important. Cooperation will also have to extend to action within the ITU to set aside appropriate frequencies, and states will have to ensure that, as the ITU Constitution requires, the best use is made of these resources by the systems. There remains the worrying fact that GNSS is a dual-use facility, and the requirements of the military forces of all providers will remain a fundamental element. Such considerations take us into rather different territory (see Chapter 16). In the meantime we hope that GNSSs will continue to provide their variety of useful services.

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[103] IMO Res. A860(2), 27 November 1997. IMO Basic Documents.

[104] P.B. Larsen, 'Expanding Global Navigation Services', Proceedings of the Workshop on Space Law in the Twenty-first Century, UNISPACE III, July 1999, (UN: ST/SPACE/24, 2004) 155.