The use of Global Navigation Satellite Systems (GNSS) for air navigation purposes: benefits, vulnerabilities of the systems and legal issues

by

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ABSTRACT

The existing air navigation services have many shortcomings and a reform was necessary. The new systems (CNS/ATM systems) will be largely dependent on Global Navigation Satellite Systems (GNSS) which can bring significant benefits to air navigation in terms of safety, efficiency, capacity, and economy. However, GNSS have weaknesses which can be reduced but will never be fully eliminated. Depending solely on a system that can be disrupted is not acceptable for safety of life applications, such as aviation. The implementation of GNSS also raises unique legal issues and ICAO has been working on the establishment of a legal framework for GNSS since 1992. Nevertheless, disagreement between states on the need for an international convention remains significant. Legal discussions should not slow down the implementation of GNSS which, when used in conjunction with terrestrial navigation aids, have the potential to revolutionize air navigation.

RÉSUMÉ

Les services de navigation aérienne actuels ont de nombreuses faiblesses et une réforme était nécessaire. Le nouveau système (CNS/ATM) reposera dans une large mesure sur l'utilisation des systèmes mondiaux de navigation par satellite qui apporteront d'importants bénéfices à la navigation aérienne en termes de sécurité, d'efficacité, de capacité, et d'économies. Cependant, les systèmes mondiaux de navigation par satellite comportent des faiblesses qui peuvent être réduites mais ne seront jamais complètement éliminées. Dès lors, pour des activités où des vies sont en jeu comme c'est le cas en matière d'aviation, on ne peut accepter de se baser uniquement sur des systèmes qui ne sont pas totalement fiables. L'utilisation des systèmes mondiaux de navigation par satellite soulève également des problèmes juridiques. L'OACI travaille sur l'établissement d'un cadre juridique en la matière depuis 1992. Cependant l'opposition entre les Etats quant à la nécessité d'une convention internationale demeure. Les discussions d'ordre juridique ne devraient pas ralentir l'application des systèmes mondiaux de navigation par satellite qui, associés aux instruments terrestres, ont la possibilité de révolutionner la navigation aérienne.

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INDRODUCTION

Global Navigation Satellite Systems are used to pinpoint the geographic location of a user's receiver anywhere in the world. They provide accurate position, velocity, and time information. They have many applications and are notably used in civil engineering, surveying, mapping and Earth science, agriculture and management of natural resources, disaster management, transportation, and telecommunications. The current Global Navigation Satellite Systems are the American GPS and the Russian Glonass. Both systems are provided on a world-wide basis, free of charge. In addition, Europe is developing its own: Galileo. It is a joint initiative of the European Commission and the European Space Agency and, unlike Glonass and GPS, will be civilian-operated and commercially-oriented, with a view to the generation of profit. Since the existing systems cannot meet the requirements of civilian users in term of accuracy, integrity and availability, these basic constellations are augmented by overlay systems, which are currently being implemented or developed in the United States, Europe, Japan and India.

Global Navigation Satellite Systems are expected to bring tremendous benefits to air navigation in terms of safety, efficiency, capacity and economy. Indeed, the present air navigation services system has reached its limits, leading to airspace congestion, traffic delays and increasing operating costs for airlines. A reform was therefore necessary. Global Navigation Satellite Systems will be at the heart of the the new systems named Communications, Navigation, Surveillance/Air Traffic Management (CNS/ATM).

While Global Navigation Satellite Systems represent a breakthrough in air navigation, they also have weaknesses. These points of vulnerability can be reduced but will never be fully eliminated. Thus, a key issue is whether GNSS should become the sole means used for air navigation. In other words, we must question whether we can safely be totally dependent on Global Navigation Satellite Systems in aviation and, if not, what the appropriate solution should be.

Moreover, the implementation of Global Navigation Satellite Systems raises unique legal issues. For the majority of users, the systems are owned, controlled and operated by foreign states. This is an unprecedented situation in the provision of air navigation services. User states are notably concerned about issues such as universal access, continuity of services, respect for state sovereignty, certification, and cost allocation. Liability is the predominant issue and the subject of significant disagreement. Is the existing regime sufficient to cover all aspects of Global Navigation Satellite Systems? If not, is an international convention necessary? How about the proposition of a contractual framework as an alternative solution?

This thesis will outline the benefits of Global Navigation Satellite Systems for air navigation, while pointing out their vulnerabilities which raises the question of their use as a sole means for air navigation, and addressing the legal issues. Chapter one presents Global Navigation Satellite Systems as a key element of air navigation services. Chapter 2 outlines the vulnerabilities of GPS which will be overcome or reduced with the introduction of Galileo. Moreover, their combined used will offer great opportunities. The question of whether Global Navigation Satellite Systems can be used a sole means for air navigation or if there is a need for a back up system is also addressed. Finally, Chapter three is dedicated to the legal issues.

CHAPTER 1: GLOBAL NAVIGATION SATELLITE SYSTEMS: A KEY ELEMENT OF THE AIR NAVIGATION SERVICES

The existing air navigation services have many shortcomings and a reform was necessary. The new systems, named Communications, Navigation, Surveillance/Air Traffic Management (CNS/ATM), will combine new procedures and technologies which will be largely dependent on Global Navigation Satellite Systems. GPS and Glonass are the current Global Navigation Satellite Systems, and Europe is developing its owned (Galileo). The basic constellations are augmented by overlay systems since they cannot meet the requirements of civilian users in term of accuracy, integrity and availability.

1/ The constraints with the present aviation infrastructure

The present air navigation services system has reached its limits, leading to airspace congestion, traffic delays, and increasing operating costs for airlines. Safety, regularity and efficiency of the system are threatened. Mr Jack Howell, Director of the Air Navigation Bureau of the International Civil Aviation Organization, used the word "crisis" to qualify the situation in 1998: "I know crisis is a strong word, but I am afraid this is the appropriate word"[1].

Several constraints of the present navigational infrastructure are identified[2]. Firstly, there are limitations to line-of-sight systems in term of propagation, distance,

[1] Jack Howell, "Address" (presented at the Official Opening of the world-wide CNS/ATM Systems Implementation Conference, Rio de Janeiro, 11 May 1998), online:ICAO <http://www.icao.int/icao/en/ro/rio/danb.htm> (date accessed: 03/09/2005).

[2] *Ibid.*

accuracy and reliability. Indeed, the current ground-based navigation aids have a limited coverage. They are blocked by the horizon or high terrain, and cannot be implemented over large parts of the Earth. The air navigation services system already requires thousands of air traffic control units, ground-based relay stations and radio beacons. In addition this technology, dating from the 1940s, is outdated. Thus, the system is unable to meet the increasing air traffic demand.

Secondly, there are shortcomings with respect to communications. Voice is primarily used to communicate between the ground and the aircraft. Nevertheless, voice communications are not suitable for data transmission since the rates of transfer of information are limited. Communications also suffer from poor quality and limited range. Moreover, the radio channels are overloaded. They are limited resources, and the frequency spectrum is already well diminished.

Thirdly, there is a discrepancy between national air navigation services systems. Each State organizes air traffic control above its territory, leading to disparities in the rules and organizational arrangements. Fragmentation of air traffic control has negative impacts in term of safety, regularity and efficiency.

The shortcomings of the existing system also lead to financial losses for the air carriers due to airspace congestion and traffic delays. According to R. Colin Keel and Kyle B. Levine: "One element of the airline's cost structure, however, is largely beyond the control of the airlines: the air traffic control system (ATC). The current ATC, administered by the FAA, has proven to be a burdensome component of the carrier's operating costs, accounting for losses, in some estimates, up to 5 billion annually."[3]. Air traffic congestion and delays also harm the environment due to increase in fuel consumption and gas emissions.

Europe especially suffers from the inefficient control system.

Since 1999, on average one flight out of four is delayed by over fifteen minutes. And airlines lose 1.3 to 1.9 billion euros a year because of delays (time wasted and inefficient use of aircraft and staff)[4].

At the end of 1999, the European Commission launched a reform with the view to creating a Single European Sky. The implementation of a more effective and integrated air traffic management architecture regardless of national borders will help to improve safety, create additional capacity and increase the overall efficiency of the air traffic management system[5].

2/ CNS/ATM Systems

In 1983, the International Civil Aviation Organization established the Special Committee on Future Air Navigation Systems (FANS Committee). The Committee had the task of studying, identifying, and assessing new concepts and technologies in the field of air navigation[6].

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3 R.Colin Keel & Kyle B. Levine, "US Airlines on Course for Free Flight", JALC vol 62 No 3.

4 European Union, Delegation of the European Commission to the USA, News Releases, "One single sky for the whole EU" (10 December 2003), online: European Union <http://www.eurunion.org/news/press/2003/2003075.htm> (date accessed: 03/09/2005).

5 The legislative package for the Single European Sky comprises four regulations:
EC, *Commission Regulation 549/2004 of the European Parliament and of the Council of 10 March 2004 laying down the framework for the creation of the single European* sky, [2004] O.J. L.96/1.
EC, *Council Regulation 550/2004 of the European Parliament and of the Council of 10 March 2004 on the provision of air navigation services in the single European* sky, [2004] O.J. L.96/10.
EC, *Council Regulation 551/2004 of the European Parliament and of the Council of 10 March 2004 on the organisation and use of the airspace in the single European sky*, [2004] O.J. L.96/20.
EC, *Council Regulation 552/2004 of the European Parliament and of the Council of 10 March 2004 on the interoperability of the European Air Traffic Management network*, [2004] O.J. L.96/26.

6 ICAO, *Global Air Navigation Plan for CNS/ATM systems*, ICAO Doc 9750 AN/963, (2002) at I-1-

It was recognized that the existing navigational infrastructure was limiting efficiency and capacity. The Committee concluded that it was therefore necessary to develop new systems (essentially based on satellite technology) to overcome these limitations and consider air traffic management on a global scale. This would require a multidisciplinary approach.

Thus, in July 1989 the Special Committee for the Monitoring and Co-ordination of Development and Transition Planning for the Future Air Navigation System (FANS Phase II Committee) was established by the International Civil Aviation Organization Council acting on recommendation of the FANS Committee[7]. It completed its work in 1993, recognizing that implementation of technologies and expected benefits would evolve over a period of time. Moreover, since the considered technology was being available, work should begin.

The FANS concept was endorsed by the Tenth Air Navigation Conference in 1991[8]. It was renamed the Communications, Navigation, Surveillance/Air Traffic Management systems, and involves a complex and interrelated set of technologies which are largely dependent on satellites.

The conference adopted recommendations which continue to guide for the planning, implementation and transition to the CNS/ATM systems.

The 29th session of the International Civil Organization Assembly approved two resolutions which support the speedy implementation of CNS/ATM systems. These resolutions were consolidated at the 31st session of the International Civil Organization Assembly[9].

1, online: IBAC <http://www.ibac.org/Library/ElectF/CNS_ATM/9750_2ed.pdf> (date accessed: 03/09/2005).

7 ICAO, *Global Air Navigation Plan for CNS/ATM systems*, ICAO Doc 9750 AN/963, (2002) at I-1-1, online: IBAC <http://www.ibac.org/Library/ElectF/CNS_ATM/9750_2ed.pdf> (date accessed: 03/09/2005).

8 *Ibid* at I-1-2.

9 *Ibid* at I-1-2.

The first plan of action was the ICAO Global Co-ordinated Plan for Transition to ICAO CNS/ATM Systems, which was part of the FANS II phase. In 1996, the Council directed the International Civil

Aviation Organization Secretariat to revise the Global Plan as a "living document". The Global Air Navigation Plan for CNS/ATM Systems accepted by the Council in 1998[10] therefore addresses technical, operational, economic, financial, legal and institutional elements and offers practical guidance and advice to regional planning groups and states on implementation and funding strategies. CNS/ATM systems are to be implemented on a global basis following the regional planning process.

There is a consensus on the fact that there is no legal obstacle to the implementation of CNS/ATM systems and that there is nothing inherent in these systems which is inconsistent with the Chicago Convention[11].

The CNS/ATM concept can be defined as followed: "Communications, navigation, and surveillance systems, employing digital technologies, including satellite systems together with various levels of automation, applied in support of a seamless global air traffic management system."[12]. This seamless system will improve safety, regularity, and efficiency of air navigation services and will be able to meet the growth in air traffic demand. It is more responsive to the needs of the users.

The CNS/ATM systems comprise four key elements.

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10 ICAO, *Global Air Navigation Plan for CNS/ATM systems*, ICAO Doc.9750 AN/963, (2002), online: IBAC <http://www.ibac.org/Library/ElectF/CNS_ATM/9750_2ed.pdf> (date accessed: 03/09/2005).

11 *Ibid.*

12 Executive summary of the Global Plan, world-wide CNS/ATM Systems Implementation Conference, Rio de Janeiro (11May 1998), online: ICAO<http://www.icao.int/icao/en/ro/rio/execsum.pdf> (date accessed: 30/09/2005).

The first element is Communications[13]. The latter will increasingly be carried out through digital data link. The quality of communications will be improved and the number of available channels will be multiplied. Moreover satellites voice and data communications, which will ensure global coverage, will be introduced. A great benefit of the future system will be an improved interface between the ground and the air with automated systems.

With respect to Navigation[14], area navigation capabilities (RNAV) will be progressively introduced along with Global Navigation Satellite Systems (GNSS) which provide world-wide navigation coverage. Most ground-based navigation infrastructure could be removed and replaced by satellite navigational assistance.

The third element is Surveillance[15]. The most important change will be the introduction of automatic dependent surveillance (ADS). Keeping track of an aircraft will be realized through the transmission of position and other useful information contained in the flight management system via satellite and other communication links to an air traffic control unit.

The fourth element is Air Traffic Management[16]. It means more than Air Traffic Control. Indeed, it will include air traffic services, airspace management and air traffic flow management in order to ensure the safe and efficient movement of aircraft during all phases of operations.

The combination of new technologies and procedures will allow an operating and efficient global air traffic system. These new technologies include Global Navigation Satellite Systems, which are a key component of the CNS/ATM systems.

[13] *Ibid.*; ICAO, *Global Air Navigation Plan for CNS/ATM systems*, ICAO Doc.9750 AN/963, (2002), online: IBAC <http://www.ibac.org/Library/ElectF/CNS_ATM/9750_2ed.pdf> (date accessed: 03/09/2005).

[14] *Ibid.*

[15] *Ibid.*

[16] *Ibid.*

3/ Global Navigation Satellite Systems: the key element of the CNS/ATM systems

Global Navigation Satellite Systems are used to pinpoint the geographic location of a user's receiver anywhere in the world. They provide accurate position, velocity, and time information.

A satellite navigation system consists of a space segment (typically 24 navigational satellites in orbit at an altitude of about 20,000 km), a ground or control segment (tracking stations placed at different locations over the Earth's surface to monitor the position and health of the satellites, send data to a central station for processing and then relay accurate measurements of each satellite's position to the satellite for incorporation into its navigational signal), and a user segment (users of the system equipped with terminals).

Satellite-based navigation systems use a version of triangulation to locate the user, through calculations involving information from a number of satellites. Each satellite transmits coded signals at precise intervals. The receiver converts signal information into position, velocity, and time estimates. Using this information, any receiver on or near the earth's surface can calculate the exact position of the transmitting satellite and the distance (from the transmission time delay) between it and the receiver. Coordinating current signal data from four or more satellites enables the receiver to determine its position.

Global Navigation Satellite Systems have many applications. They are notably used in civil engineering, surveying, mapping and Earth science, agriculture and management of natural resources, disaster management, transportation, and telecommunications.

They are at the heart of the CNS/ATM infrastructure allowing improvements in communications, navigation and surveillance. They have also been recognized as a key component in the Eurocontrol/ECAC ATM 2000+ strategy[17].

Global Navigation Satellite Systems will bring significant benefits in terms of safety, efficiency, capacity, and economy[18].

Safety will be improved by standardizing and enhancing operational procedures. Providing vertical guidance on approach procedures where no guidance exists today will have a positive impact on the risk of controlled flight into terrain. Improved communications, navigation and surveillance will allow more autonomous operations of aircraft, lightening the controller workload. In addition, separation between aircraft will be reduced. Increased airspace capacity will lead to less congestion.

Then, user preferred routings and trajectories will be possible using a global navigation system. Airlines will be able to fly more efficient routes, thus reducing their fuel consumption, operating costs, and minimizing delays. Further economies will be experienced from reduced airborne equipage requirements.

Passengers should enjoy lower fares and rates, as well as time savings.

The CNS/ATM systems will also bring environmental benefits thanks to reductions in fuel consumption and atmospheric emissions.

Finally, air navigation services providers will have a safer and more cost-efficient infrastructure, which will also make a positive contribution to the economy of the state and the entire region.

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17 Roderick D. Van Dam, "GNSS and Aviation: Eurocontrol's perspective" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1.

18 IATA, *Navigation Aids Transition Roadmap*, Issue V2.1 (2005) [draft document], online: IATA <http://www.iata.org/NR/rdonlyres/E0C4AEC5-28EB-4E88-B80C-182E03F97C8F/0/NavAids_draft_V2_1_Sep122005.pdf> (date accessed: 01/09/2005); Federal Aviation Administration, Fact sheets, "Total Transportation Applications and Benefits" (17 December 2001), online: FAA <http://gps.faa.gov/Library/other-text.htm> (date accessed: 02/09/2005).

A CNS/ATM infrastructure based on Global Navigation Satellite Systems is especially interesting in developing countries where the ground-based navigational aids are limited or non existent[19]. Lack of financial resources, political tensions, and remoteness of some areas make the maintenance of conventional navigation aids extremely difficult.

The use of Global Navigation Satellite Systems is not dependent on or restricted to the availability of these ground infrastructures, and would therefore provide significant benefits in developing countries. The benefits include: improved navigation coverage, safety, and cost savings through less reliance on traditional navigation systems. However, the implementation of Global Navigation Satellite Systems requires considerable investment and developing countries may not have enough financial and human resources.

Since 2003, successful flight trials have been performed in Africa using EGNOS (the European Geostationary Navigation Overlay System), in cooperation with French and African civil aviation authorities, European partners, and the International Civil Aviation Organization partners in the African and Indian Ocean region (AFI). Recently, an ATR 42 test aircraft flew from Senegal to Kenya using the EGNOS signal continuously and operated Approach with Vertical Guidance landings[20].

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19 Tom Kok, "Implementing GNSS in (African) Aviation: an overview of Regulatory and Operational Demands" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1

20 Galileo Joint Undertaking, Press Release, "Flying with more safety through Africa using European satellite navigation" (23 May 2005), online: EUROPA <http://www.europa.eu.int/comm/dgs/energy_transport/galileo/documents/doc/press_release_african_demo.pdf> (date accessed: 23/09/2005).

4/ Global Navigation Satellite Systems and augmenting systems

The current global navigation satellite systems are the American GPS and the Russian Glonass. Europe is developing its own: Galileo. Since the existing systems cannot meet the requirements of civilian users in term of accuracy, integrity and availability, the basic constellations are augmented by overlay systems.

GPS

The United States Global Postioning System (GPS) is a constellation of 24 satellites that orbit the earth and make it possible for people with ground receivers to pinpoint their geographic location[21].

The constellation, completed in 1995, consists of 21 satellites and 3 spare satellites that circle the Earth every 12 hours from an altitude of nearly 20,000 km. They are spaced so that from any point of the Earth four satellites will be above the horizon. Each satellite contains a computer, an atomic clock, and a radio.

On the ground, the receiver contains a computer that triangulates its own position by getting bearings from three of the four satellites. The result is a geographic position (longitude and latitude). The location accuracy is from 100 to 10 meters for most equipment, and can be pinpointed to within one meter with special military-approved equipment. If the receiver is equipped with a display screen that shows a map, the position will be shown on it. And if you are moving, the receiver can also calculate your speed, direction of travel and give you estimated times of arrival to specific destinations.

[21] U. S. Coast Guard Navigation Center, GPS Frequently Asked Questions, online: U. S. Coast Guard Navigation Center <http://www.navcen.uscg.gov/faq/gpsfaq.htm> (date accessed: 13/10/2005).

Formally named NAVSTAR, GPS was developed as a military system by the Department of Defense, in order to provide military forces with precise information for navigation, targeting, and troop coordination, thereby reducing reliance on land-based navigation systems. Today, the system is also available for general use around the world.

GPS provides two categories of services: a Standard Positioning Service (SPS) available free of charge to anyone in the world, and the Precise Positioning Service (PPS), available only to authorized US and Allied military and selected federal government users.

SPS signal accuracy was intentionally degraded to protect national security interests. This process, called Selective Availability (SA), has been deactivated since May 1st 2000, so that positioning to an accuracy of between 7 and 20 meters can now be achieved with GPS alone.

Enhancements of GPS are planned through the transmission of a third civil signal on the L5 band and a new generation of GPS satellites (the fifth generation) providing a more resistant, precise and reliable signal[22].

The United States GPS policy of 1996 reflects its concern about national security and its objectives to retain exclusive control over its positioning system and to establish it as a global monopoly[23].

First, GPS "will remain responsive to the National Command Authority". The President of the United States can therefore turn off, degrade or spoof the system over all or part of the orbit without any prior notice.

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22 M. Sirak, "USA Set Sights On GPS Security Enhancements" (16 January 2002) Jane's Defense Weekly 30; US Coast Guard Navigation Center, GPS modernization, online: NAVCEN <http://www.navcen.uscg.gov/gps/modernization/default.htm> (date accessed: 12/10/2005).

23 Dr Wulf V. Kries, "Some comments on the U.S. Global Positioning System Policy" (1996) ZLW 45. Jg.

In the policy statement of March 1996[24], foreign participation is not envisaged for national security reasons. Control of the system is assured by the Department of Defense. GPS is a military system and will not be internationalized.

The system is also provided for non military use "on a continuous, world -wide basis, free of direct users fee", in order to reduce incentives for the entry of competitors, since it is difficult to compete against a free service.

Another measure to deter international competition is "to discontinue the use of GPS Selective Availability within a decade". Selective Availability was deactivated by the President on May 1st, 2000 and has not been used since that date. The Government stated it had no intent to ever use it again.

Finally, the fact that the Government will "advocate the acceptance of GPS and U.S. Government augmentations as standards for international use" clearly shows its willingness to establish a monopoly. The International Civil Aviation Organization was invited by the United States to adopt GPS, and this offer was formally accepted by the Council in October 1994[25]. This policy did not prevent the creation of other systems such as Galileo which should be operational in 2008.

On December 8th, 2004, the President signed the new U.S. Space-based positioning, Navigation, and Timing Policy[26]. The Interagency GPS Executive Board, which was established in 1996 to manage GPS and its U.S. Government augmentations is replaced by a National Space-Based Positioning, Navigation, and Timing Executive Committee, co-chaired by the Deputy Secretaries of Defense and

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24 U.S. *Policy statement on GPS of March 29 1996* (1996), online: spacenews <www.spacenews.com/gps96.txt > (date accessed: 3/10/2005).

25 Committee on the Peaceful Uses of Outer Space, Legal subcommittee, 642nd Mtg., (3 April 2001), online: OOSA <http://www.oosa.unvienna.org/Reports/transcripts/lsc/2001/LEGALT_642E.pdf.> (date accessed: 01/09/2005).

26 U.S. Space-based positioning, Navigation, and Timing Policy (15 December 2004), online: OSTP <http://www.ostp.gov/html/FactSheetSPACE-BASEDPOSITIONINGNAVIGATIONTIMING.pdf> (date accessed: 23/09/2005).

Transportation. GPS will continue to be available for free. It is important to note that the policy does not rule out charges levied against states.

President Bush also declared that GPS would be temporarily disabled during a national crisis to prevent terrorists from using it[27].

The policy also maintains the commitment not use Selected Availability "designed to degrade globally the Standard Positioning Service" of GPS[28]. Selected Availability will not be used globally, but nothing is said about its use at a national level.

GLONASS

Glonass (GLObal Navigation Satellite System) is the Russian space-based navigation system, comparable to the U.S. GPS system. It is managed for the government by the Russian Space Forces.

Like GPS, the fully operational constellation consists of 21 satellites and 3 on-orbit spares. The satellites orbit the Earth at an altitude of 19,100 km (slightly lower than the GPS satellites)[29]. The system has two types of navigation signals: standard precision navigation signal (SP) (which is available to the civil users on a continuous, worldwide basis), and high precision navigation signal (HP)[30].

The constellation was to be completed in 1995[31]. However, only eight satellites were in operation in 2002, rendering the system almost useless. Since the economic situation in Russia has improved, the country was able to launch three Glonass

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27 Ted Bridis, "White House wants plans for GPS shutdown" (15 December 2004), online: MSNBC <www.msnbc.msn.com/id/672038> (date accessed: 7/09/2005).

28 U.S. Space-based positioning, Navigation, and Timing Policy (15 December 2004), online: OSTP <http://www.ostp.gov/html/FactSheetSPACE-BASEDPOSITIONINGNAVIGATIONTIMING.pdf> (date accessed: 23/09/2005).

29 Andrei D; Kuropyatnikov, "The problem of the legal regulation of GLONASS" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1.

30 *Ibid.*

31 *Ibid.*

satellites in December 2003 as well as in December 2004 and three other satellites will be put into orbit on 25 December 2005. Today, the constellation includes 14 satellites among which 13 are operational[32]. Thanks to cooperation with India[33], Glonass is planned to be operational again in 2007 with eighteen satellites. The constellation should be completed in 2011[34].

The United States and the Russian Federation intend to cooperate to maintain radio frequency compatibility and promote interoperability of GPS and Glonass for civil use[35].

The 1995 Decree of the Russian Federation Government *On executing works in use of the Glonass system for the sake of civil users*[36] aims to further develop GLONASS and to provide use of the system by civil users. A Coordination Council on the Glonass system use by the national and international civil users has to be set up with membership of representatives of Russian Federation Ministries of Transportation and Defence, Russian Space Agency, and of the State Committee on the defence-oriented industries. The Decree also foresees the submission to the International Civil Aviation Organization and to the International Maritime Organization the materials to conclude the agreements relating to the Glonass system use as one of GNSS elements.

In an exchange of letters with the International Civil Aviation Organization in 1996,

32 Glonass constellation status, online: Glonass Center <http://www.glonass-center.ru/nagu.txt> (date accessed: 12/10/2005); Russian News and Information Agency Novosti, "L'agence spatiale russe Roskosmos adopte un calendrier des lancements pour décembre 2005 (officiel)", online: RIA Novosti <http://fr.rian.ru/science/20051123/42191291.html> (date accessed: 21/12/2005).

33 India and Russia will build and launch satellites together.

34 Galileo Industries, News, "Glonass, un triplet en orbite" (12 January 2005), online: Galileo industries <http://medis-sat.de/galileo/galileo.nsf/pages/7D2C1D4AF81C5243C1256F870031CA4D?open&e> (date accessed: 22/08/2005).

35 US Department of State, Press statement, "United States-Russian Federation Joint Statement" (2004), online: United States Department of State <http://www.state.gov/r/pa/prs/ps/2004/39748.htm> (date accessed: 11/10/2005).

36 Russian Federation Government, Decree *On executing works in use of the Glonass system for the sake of civil users* (7 March 1995), online: Russian Federation Ministry of Defense <http://www.glonass-center.ru/decree.html> (date accessed:08/09/2005)

Russia offered Glonass system for the use by the international civil aviation community free of direct charge[37]. In 1997, the Decree of the Russian Federation Government approved a federal program of using Glonass for the benefit of civil users.

The economic situation in Russia in the 1990s rendered the Glonass system almost useless, but the Russian Government tried to save the system. The 1999 Decree of the President and two Decisions of the Government of the Russian Federation confirm the dual purpose of Glonass, call for international participation, and establish the Russian Space Agency. The latter is responsible for the civil use of Glonass as well as for international cooperation[38].

The Russian military is still interested in the system. Indeed, in 2003, an order was signed to equip the military troops with Glonass navigational receivers by late 2005. Today, Russia intends to find resources for making Glonass fully operational. The global navigation satellite system may become, along with export of weapons, an additional source of financing for the modernization drive in the Russian armed forces.[39]

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[37] Committee on the Peaceful Uses of Outer Space, Legal subcommittee, 642nd Mtg., (3 April 2001), online: OOSA <http://www.oosa.unvienna.org/Reports/transcripts/lsc/2001/LEGALT_642E.pdf.> (date accessed: 01/09/2005); ICAO, *Exchange of Letters between ICAO and the* Russian *Federation*, 4 June and 29 July 1996, ICAO State Letter LE 4/49.1-96/80 (dated 20 September 1996).

[38] Andrei D; Kuropyatnikov, "The problem of the legal regulation of GLONASS" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1.

[39] Andrei Garavski, "Glonass is our hope"(30 December 2003) Krasnaya Zvezda.

GALILEO

Galileo is a joint initiative of the European Commission and the European Space Agency. Unlike Glonass and GPS, it will be civilian-operated and commercially-oriented with a view to the generation of revenues.

The rationales for Galileo are political, technological, economic and social[40]. Europe wants to be independent from GPS and Glonass since the military operators of these systems give no guarantee to maintain an uninterrupted service. Galileo also represents a boost for the European industries. The programme will benefit Europe's economy and bring better and new services for the citizens.

In addition, Galileo will considerably increase the efficiency of the transport system which is a crucial tool for a deeper European economic and social integration. The European Community White Paper on European Transport policy for 2010 identifies GNSS as a critical technology that could revolutionize the transport infrastructure[41].

Discussions on a European Global Navigation Satellite System started in the 1990s, and the Galileo programme was presented by the European Commission in its communication of 10 February 1999[42]. It would be developed in four phases and funded by both public subsidies and the private sector (Public-Private Partnership).

The Council resolution of 19 July 1999[43] formally established the involvement of the

[40] Gustav Lindstrom & Giovanni Gasparini, "the Galileo system and its security implications" (2003), online: Institute for Security Studies, <http://www.iss-eu.org/occasion/occ44.pdf> (date accessed: 23/09/2005).

[41] EC, Commission, *White paper on European Transport Policy for 2010: Time to decide*, COM(2001)370, [2001] at 101.

[42] EC, *Commission Communication COM(1999)54 of 10 February 1999 involving Europe in a new generation of satellite navigation services*, [1999], online: EUROPA <http://europa.eu.int/comm/dgs/energy_transport/galileo/doc/com_1999_54_en.pdf> (date accessed: 23/10/2005).

[43] EC, *Council Resolution of 19 July 1999 on the involvement of Europe in a new generation of satellite navigation services-Galileo-Definition phase*, [1999] OJ C 221 3.8.1999/1.

European Community in Galileo and initiated the definition phase of the programme (definition of goals and feasibility of the programme).

The European Space Agency was involved in the programme by the approval of the GalileoSat Program Declaration by the Ministerial Conference in May 1999.

The results of the definition phase were set out in the Commission communication of November 2000 [44]. The strategic and economic importances of the programme were reaffirmed and the Commission endorsed a proposal that the programme be continued.

In 2002, the Transport Council decided to launch the development phase of Galileo and released 450 millions euros for its funding[45](100 millions euros had been released in 2001[46]).

The development and validation phase (2002-2005) covers the definition and the manufacture of the system components (satellites, ground components, user receivers). It includes the putting into orbit of prototype satellites and the creation of a minimal terrestrial infrastructure.

The partners are the European Commission, the European Space Agency, the Galileo Joint Undertaking, with a participation of the private sector·

The European Commission is responsible for the political dimension of Galileo. It initiated in different studies on the architecture, the economic benefits and the user needs. The Commission also takes important legislative initiatives such as the proposal to establish a Joint Undertaking. Finally, it provides an important financial contribution with the European Space Agency to the Galileo programme.

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44 EC, *Commission communication to the European Parliament and the Council on Galileo COM(2000)750 of 22 November 2000*, [2000], online: EUROPA <http://europa.eu.int/comm/dgs/energy_transport/galileo/doc/gal_com_2000_750_en.pdf> (date accessed: 23/09/2005).

45 EC,*Conclusions of the Transport Council of 26 March 2002 on the Galileo satellite Radio-Navigation Programme*, online: EUROPA <http://www.europa-web.de/europa/03euinf/26verkehr/galiconc.htm> (date accessed: 30/09/2005).

46 EC, *Council Resolution of 5 April 2001 on Galileo*, [2001] OJ C 157 30.5.2001/1

The European Space Agency is in charge of the definition, the development, and the validation of the space segment and related ground element.

The Galileo Joint Undertaking was created by the Council in 2002[47]. It is composed of the European Community represented by the European Commission and the European Space Agency. They may be joined by the European Investment Bank. The Joint Undertaking presides over the implementation of the development phase and prepares the management of the deployment and operational phases of the programme.

It also had the task to select a consortium to operate the system. On 27 June 2005, the joint bid of the two leading competitors, Eurely and iNavSat[48] was accepted[49].

In 2004, the Transport ministers agreed to set up a Community agency, the Supervisory Authority, to supervise the deployment and operation phase.

It lead to a Council Regulation in July 2004[50], according to which the Authority will have the tasks to conclude the concession contract with the consortia chosen (Eurely and iNavSat), and run the system's financial management. Moreover, it will be in charge of frequency certification and security issues. Property acquired by the Galileo Joint Undertaking will be transfered to the Supervisory Authority. The Executive Director has been nominated and the concession contract shall be signed by the end of 2005[51].

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47 EC, *Council regulation 876/2002 of 21 May 2002 setting up the Galileo Joint Undertaking*, [2002]O.J.L. 138/1.

48 The core members of Eurely are Aena, Alcatel, Finmeccanica and Hispasat.
The core members of iNavSat are EADS Space, Inmarsat and Thales.

49 "EADS, Alcatel win permission for EU satellite offer (update 2)", online: Bloomerg.com <http://www.bloomberg.com/apps/news?pid=10000085&sid=aXmntXzOylMg&refer=europe> (date accessed: 13/09/2005).

50 EC, *Council regulation 1321/2004 of 12 July 2004 on the establishment of structures for the management of the European satellite radio-navigation programmes*, [2004] O.J.L. 246/1.

51 Europa, News, "Galileo nomination of the Executive Director of the Supervisory Authority" (17 May 2005), online: Europa<http://europa.eu.int/comm/space/news/article_2265_en.html> (date acessed: 21/09/2005).

The Galileo programme is open to the participation of third countries in the construction, development, and management of the system. Five countries have already joined the Galileo programme: China, Israel, Ukraine, India, and Morocco. Discussions are under way with Argentina, Brazil, Mexico, Norway, Chile, South Korea, Malaysia, Canada and Australia[52]. Cooperation with third countries brings several benefits: financial contribution to the Galileo programme, market development opportunity and boost of the European industry, fewer barriers to the services offered by Galileo, and support from third countries within the international bodies responsible for frequency allocation[53].

Galileo is designed to be compatible and interoperable with GPS. After several years of negotiation (it started in 1999), an agreement on this matter with the United States was concluded on 26 June 2004[54]. It will be further discussed in Chapter II.

The deployment phase of the programme (2006-2007) will consist in gradually

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[52] Europa, Press release, « EU and Morocco reach agreement on Galileo » (8 November 2005), online: EUROPA <http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/05/1384&format=HTML&aged=0&language=EN&guiLanguage=en> (date accessed: 21/11/2005), Europa, Press release, "Galileo: European Commission proposes to open negotiations with Argentina on satellite navigation" (4 April 2005), online: EUROPA <http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/05/386&format=HTML&aged=0&language=EN&guiLanguage=fr> (date accessed: 12/10/2005); Europa, Press release, "EU and Ukraine seal Galileo and aviation agreement" (3 June 2005), online: EUROPA <http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/05/666&format=HTML&aged=0&language=EN&guiLanguage=fr> (date accessed: 12/10/2005); Europa, Press release, "La famille Galileo s'agrandit: L'UE et l'Inde concluent un accord" (7 September 2005), online: EUROPA<http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/05/1105&format=HTML&aged=0&language=FR&guiLanguage=en> (date accessed: 12/10/2005).

[53] EC, *Commission communication to the European Parliament and the Council of the 6 October 2004 Moving to the deployment and operational phases of the European satellite radionavigation programme COM(2004)634* , [2004], online: Europa <http://europa.eu.int/comm/dgs/energy_transport/galileo/documents/doc/com_2004_636_en.pdf> (date accessed: 23/09/2005).

[54] Europa, News, "Galileo and GPS will navigate side by side: EU and US sign final agreement" (28 June 2004), online: Europa <http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/04/805&format=HTML&aged=0&language=EN&guiLanguage=f> (date accessed: 23/09/2005).

launching the operational satellites and installing the complete ground infrastructure. Two thirds of the estimated cost (2.1 billion euros) will be borne by the concession holder. The remaining third (700 million euros) will be financed by the European Union[55].

The commercial operation phase should start from 2010. It was originally scheduled for 2008 but has been posponed because of financial and political difficulties[56].

It will be funded by the private sector. However, exceptional financial help from the Community during the first years of the operational phase is envisaged.

Sources of the private sector funding will include income from royalties on the software used to equip the receivers, income from businesses using protected signals, and loans from the European Investment Bank[57].

Galileo development and deployment costs have been evaluated by the Commission at 3.2 billion Euros. It is equivalent to only 150 kilometres of semi-urban motorway. Various studies show that the programme is economically viable. The Pricewaterhouse Coopers study, based on updated forecasts for a period of 20 years, shows a benefit/cost ratio of 4.6[58].. 3 billion receivers and revenues of 275 billion euros per year are expected by 20020 worldwide. Moreover, it is estimated than Galileo will create more than 150,000 jobs in Europe[59].

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55 EC, *Commission communication to the European Parliament and the Council of the 6 October 2004 Moving to the deployment and operational phases of the European satellite radionavigation programme COM(2004)634*, [2004], online: Europa <http://europa.eu.int/comm/dgs/energy_transport/galileo/documents/doc/com_2004_636_en.pdf> (date accessed: 23/09/2005).

56 Christian Lardier, " Démarrage difficile pour Galileo" *Air and Cosmos* 2006 (18 November 2005) 36.

57 *Ibid.*

58 Inception Study to Support the Development of a Business Plan for the Galileo Programme (20 November 2001) Executive Summary, TREN/B5/23-2001; Galileo study Phase II (17 January 2003) Executive Summary, online: <http://europa.eu.int/comm/dgs/energy_transport/galileo/doc/gal_phase2_exec_summ.pdf> (date accessed: 30/09/2005).

59 Europa, communiqués de presse,"EU and Ukraine seal Galileo and aviation agreement" (3 June 2005), online: Europa

When fully deployed, Galileo will consist of 27 operational satellites and three spares, positioned in three circular Medium Earth Orbit planes at an altitude of 23616 km above the Earth, at an inclination of 56 degrees relative to the equatorial plane. Two Galileo Control Centers (GCC) located in Europe will receive data from a global network of 20 Galileo Sensor Stations (GSS), in order to synchronize the time signals of satellites with the ground station clocks, and to calculate data about system integrity. 5 S-Band and 10 C-Band up link stations around the globe will manage the flow of data between the satellites and the control centers[60].

With Galileo, the service's availability will be guaranteed in almost any circumstances, and the users will be informed within seconds of a failure of any satellite. Moreover, Galileo will pinpoint a geographical position to within a single-meter, which is unprecedented for a publicly available system.

Four navigation services and one search and rescue service will be provided[61]:

-The Open Service: it will result from the combination of open signals, and will provide position and time performances. It will be free of user charge.

-The Safety of Life Service: it will improve the open service performances providing timely warnings to the user when it fails to meet certain accuracy requirements. A service guarantee should be provided for this service.

-The Commercial Service: it will provide access to two additional signals. It is envisaged to include service guarantees and a limited broadcasting capacity for messages from services centers to users.

<http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/05/666&format=HTML&aged=0&language=EN&guiLanguage=fr> (date accessed: 24/10/2005).

60 EC, *Commission communication to the European Parliament and the Council of the 6 October 2004 Moving to the deployment and operational phases of the European satellite radionavigation programme COM(2004)634* , [2004], online: Europa <http://europa.eu.int/comm/dgs/energy_transport/galileo/documents/doc/com_2004_636_en.pdf> (date accessed: 12/09/2005).

61 *Ibid.*

-The Public Regulated Service: it will be a secured (encrypted) service for authorized governmental users (for instance: police, fire, emergency response...).
-The Search and Rescue Service: each satellite will have its own transponder which will transfer distress signals from a user's transmitter to a rescue co-ordination center. Then the system will transmit a signal to the user to notify them that help is on the way. This service will contribute to enhance the performances of the COPAS-SARSAT Search and Rescue System.

The first satellite, GIOVE-A[62], will be put into orbit on 26 December 2005. It will be followed by the launch of the GIOVE-B in 2006 and four satellites in 2008 to guarantee the use of the frequencies allocated to Galileo at the 2003 World Radiocommunications Conference[63].

THE BEIDOU CONSTELLATION

Chinese policy is to obtain its own global navigation satellite system. In 2000, two experimental navigation and positioning satellites called Beidou ("big dipper") have been launched. The system will consist of two satellites in geosynchronous orbit, and the final constellation will include four satellites (two operational and two backups). However, to provide global signal coverage, satellites flying in other orbits around the world are needed[64]. China is also participating in the Galileo programme.

62 GIOVE stands for Galileo In Orbit Validation Element. It is also the Latin name for Jupiter, a planet studied by Galilee whose calculations are still used as a model with respect to Positioning.

63 Europa, News, "Galileo helps Europe find its place in satellite navigation" (16 February 2005), online: EUROPA <http://europa.eu.int/comm/space/news/article_2130_en.html> (date accessed: 12/10/2005); Russian News and Information Agency Novosti, "L'agence spatiale russe Roskosmos adopte un calendrier des lancements pour décembre 2005 (officiel)", online: RIA Novosti <http://fr.rian.ru/science/20051123/42191291.html> (date accessed: 21/12/2005); Christian Lardier, " Démarrage difficile pour Galileo" *Air and Cosmos* 2006 (18 November 2005) 36.

64 Chinese Defence Today, "BD 1 navigation satellite" (2002), online: Sinodefence <http://www.sinodefence.com/space/spacecraft/bd1.asp> (date accessed: 12/10/2005); Australian

THE AUGMENTATION SYSTEMS

The existing global navigation satellite systems cannot meet the requirements of civilian users in term of accuracy, integrity, and availability. For this purpose, the basic constellations are augmented by an overlay system. With respect to air navigation, augmentation systems are required for advanced navigational applications such as Approach with Vertical Guidance (APV). APV provides guided and stabilized vertical guidance on approaches where currently no guidance exists, and is envisaged to replace the Instrument Landing System.

Satellite-Based Augmentation Systems (SBAS) are networks of ground relay stations and geostationary satellites which receive satellite navigation signals and transmit corrected time and distance measurements. The user's receiver applies the correction message to improve the accuracy of its position. These augmentation systems are currently being implemented in the United States of America, Europe, Japan and India.

WAAS[65] (Wide Area Augmentation System) is a space-based GPS augmentation system operated by the Federal Aviation Administration (FAA). The FAA began the development of the system in 1995. It provides increased accuracy, availability and integrity for all phases of flight in the National Airspace System, including vertical guidance for precision approach applications. It also supports arrival and departure procedure, parallel runway operations, missed approaches, vertical takeoffs, and enhanced surface movement operations.WAAS is accurate within three

Department of Transport and Regional Services, "Emerging Global Navigation Satellite Systems (GNSS) Platforms", online: AGCC <http://www.agcc.gov.au/gnss/gnss_platforms.aspx#beidou> (date accessed: 12/10/2005).

65 Federal Aviation Administration, WAAS, online: FAA <http://gps.faa.gov/programs/ (date accessed: 10/10/2005).

meters or less. Receivers do not need to purchase any additional equipment or pay fees to utilize WAAS.

The augmentation system was commissioned for instrument flight use in the United States in July 2003. It is under continual development and is expected to be fully operational in 2006.

The European Geostationary Navigation Overlay Service (EGNOS) is a joint project of the European Space Agency, the European Commission and Eurocontrol. Today, EGNOS is being developed under the European Space Agency management. It is the precursor to and will be integrated in Galileo[66].

EGNOS consists of two Inmarsat[67] geostationary satellites, one from the European Space Agency[68], and a network of ground stations. It is aimed to transmit a signal containing information on the reliability and accuracy of the positioning signals sent out by GPS and Glonass, and to provide accuracy to within five meters or less. It will become fully operational for the benefit of air transport at the end of 2006[69].

The system covers all European states and could include other regions such as South America, Africa, and parts of Asia and Australia.

The Japanese MSAS (Multifunctional Transport Satellite-based Augmentation System) features a geostationary satellite-based design similar to WAAS. It is aimed to provide accuracy to within five meters or less. Currently under development, it will expand safety and air traffic capacity in the Asia -Pacific regions.

Japan is also developing an advanced space-based augmentation system for GPS, the

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[66] European Space Agency, EGNOS, online: ESA <http://www.esa.int/esaNA/egnos.html> (date accessed: 13/10/2005).

[67] International Maritime Satellite Organization.

[68] The satellite is called Artémis.

[69] Matthieu Quiret "Le GPS européen émet ses premiers signaux" *Les Echos* (30 March 2005), 12.

Quasi-Zenith Satellite System (QZSS)[70] , with limited navigation capabilities. The service, planned for 2008, could be augmented with the geostationary satellites in MSAS[71]. It will be supplementary to and inter operable with GPS, and is supported by the United States[72].

GAGAN (GPS Aided Geo Augmented Navigation) is the satellite-based augmentation system for the Indian region. It is a joint program undertaken by the Indian Space Research Organization (ISRO) and Airport Authority of India (AAI). GAGAN consists of a network of ground stations and a navigation payload on board the Indian geostationary satellite GSAT-4. It is primarily meant for civil aviation but could benefit other users. GAGAN is expected to be operational by 2008[73].

Space Based Augmentation System provides near Category 1 performance accuracy levels. However, it is the most expensive augmentation system since it is satellite based, and for this reason is not supported by the International Air Transport Association[74].

Ground Based Augmentation Systems (GBAS) provide differential corrections

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70 Jun-Ten-Cho in Japanese.

71 Dr Ivan G. Petrovski, "QZSS-Japan's new integrated communication and positioning service for mobile users (2003), online: GPS world < http://www.gpsworld.com/gpsworld/article/articleDetail.jsp?id=61200> (date accessed: 07/09/2005).

72 US Department of State, Press statement, "Joint statement of the United States of America and Japan on Global Positioning System cooperation" (2004), online: U.S. Department of State <http://www.state.gov/r/pa/prs/ps/2004/38773.htm> (date accessed: 12/10/2005).

73 K. N. Suryanarayana Rao, S. Pal, "The Indian SBAS System-GAGAN" (Presented to the India-United States conference on space science, applications and commerce, June 2004), online: AIAA <http://www.aiaa.org/indiaus2004/Sat-navigation.pdf.> (date accessed:03/09/2005); ICAO Assembly, 35th session plenary, *A brief on GAGAN*, ICAO Doc. A35-WP/229 (2004) online: ICAO <http://www.icao.int/icao/en/assembl/a35/wp/wp229_en.pdf> (date accessed: 01/09/2005).

74 IATA, *Navigation Aids Transition Roadmap*, Issue V2.1 (2005) [draft document], online: IATA <http://www.iata.org/NR/rdonlyres/E0C4AEC5-28EB-4E88-B80C-182E03F97C8F/0/NavAids_draft_V2_1_Sep122005.pdf> (date accessed: 01/09/2005).

to users via a localized VHF data broadcast. LAAS[75] (Local Area Augmentation System) is a ground based GPS augmentation system being developed by the Federal Aviation Administration. It is a complementary program to WAAS, delivering instrument navigation in an airport terminal area for the most demanding landing applications. It is expected to provide the required integrity and accuracy to support Category I and eventually Category II and III precision approaches. However, the LAAS program is still in the research and development phase. GNSS Category II and III approaches may not be available before 2010- 2015[76].

Ground Based Augmentation Systems are less expensive than Space Based Augmentation Systems with a similar capability. Nevertheless, their introduction should be endorsed on the basis of performance and only when a credible business case is presented with the participation of all stakeholders showing the system as a cost effective alternative to Category II and Category III ILS[77].

An integrated transition from ground based to satellite based navigational aids is supported by the International Air Transport Association[78]. The most obsolete ground infrastructure should be first de-commissioned or not replaced. Then, the number of other navigational aids should be gradually reduced as the satellite based navigation services are introduced. Indeed, the Association calls for the full decommissioning of Non Directional Beacons by 2010 and the full decommissioning of VORs by 2015. It also advocates a phased withdrawal of Category I ILS starting no later than 2012.

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[75] Federal Aviation Administration, WAAS, online: FAA <http://gps.faa.gov/programs/ (date accessed: 10/10/2005)

[76] Bob Jeans, John Dyson & Abdy Shand, "GNSS precision approach operations may not be widespread before 2015" (2002)57.3 ICAO Journal 7.

[77] *Ibid.*; IATA, *Navigation Aids Transition Roadmap*, Issue V2.1 (2005) [draft document], online: IATA <http://www.iata.org/NR/rdonlyres/E0C4AEC5-28EB-4E88-B80C-182E03F97C8F/0/NavAids_draft_V2_1_Sep122005.pdf> (date accessed: 01/09/2005).

[78] *Ibid.*

This transition should be implemented worldwide, under the auspices of the International Civil Aviation Organization. The latter was asked to develop a global road map, to adjust the Regional Plans to reflect regional planning schedules for the decommissioning of navigational aids, and to develop international guidelines covering legal, institutional, economic and technical aspects of the process[79].

Global Navigation Satellite Systems and their augmentation systems will bring significant benefits to air navigation. The question at hand is if they make all terrestrial navigational unnecessary? Can we safely be totally dependent on Global Navigation Satellite Systems in aviation?

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[79] ICAO, Eight meeting of the Communications/Navigation/Surveillance and Meteorology Sub-Group(CNS/MET SG/8) of APANGIRG, CNS/MET SG8-IP/33 (2004), online: ICAO <http://www.icao.int/icao/en/ro/apac/2004/cnsmet_sg8/ip33.pdf> (date accessed: 3/10/2005).

CHAPTER II: CAN GLOBAL NAVIGATION SATELLITE SYSTEMS BE THE SOLE SERVICE NAVIGATION SYSTEM?

While Global Navigation Satellite Systems are a breakthrough, they have shortcomings. Galileo will be able to overcome or mitigate GPS vulnerabilities, and their combined used will offer great opportunities. Can they become the sole means for air navigation or is there a need for a back up system?

1/ GPS vulnerabilities

Global Navigation Satellite Systems, including GPS, are extremely vulnerable to interference (unintentional and intentional) because of the ultra low power of the signals. The satellites transmit only 20 watts and the power of the signal received on earth is only one ten quadrillionth of a watt. Among the other vulnerabilities, GPS accuracy and geographic reliability are questionable, satellite failure is not unusual and the United States has the prerogative to turn the system off or degrade the signal for any national security reasons. All of these shortcomings make total dependency on GPS unacceptable.

Studies have been carried out on GNSS and GPS vulnerabilities and associated mitigation measures. In the United States, the Presidential Commission on Critical Infrastructure Protection of 1998 (PCCIP) identified GPS as one of the most significant vulnerabilities of the country and directed the Secretary of Transportation to undertake a study on this matter.[80] In 2001, the Volpe Center, a research and development arm of the Department of Transportation, released a report entitled

[80] U.S., Presidential Commission on Critical Infrastructure Protection, Appendix C, *Selected Excerpts from the Report on Critical Foundations Protecting America's Infrastructure"* (1998), online: PCCIP<www.pccip.gov/report_index.html> (date accessed: 15/10/2005).

"Vulnerability Assessment of the Transportation Infrastructure Relying on the Global Positioning System" (The Volve Report).[81] Work has also been carried out by the International Civil Aviation Organization[82] and the European Union[83].

Unintentional Interference

Global Navigation Satellite Systems, including GPS, are subject to unintentional interference[84]. Firstly, atmospheric and ionospheric variability, such as storms or scintillation impacts, as well as solar activity, can cause interference with GPS signals. Radio frequencies represent another source of unintentional interference, and satellite signals can be disturbed by television broadcasts, microwave communication links and consumer-grade equipment such as television antennas. Communication satellites may also interfere with GNSS signals since they operate on the same band. Eventually, spectrum congestion significantly increases the risk of interference.

The risk of unintentional interference is important but could be managed through mitigation measures such as on board techniques including inertial navigation systems (but they are limited by the rate of drift and their costs) or better frequency management.

In this regard, the actual system has limitations. The use of the radio-electric spectrum

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[81] U.S., John A. Volpe National Transportation Systems Center,"*Vulnerabilty Assessment of the Transportation Infrastructure Relying on the Global Postioning System*" (29 August 2001), online: navcen <http://www.navcen.uscg.gov/archive/2001/Oct/FinalReport-v4.6.pdf> (date accessed: 17/10/2005).

[82] GNSS vulnerability study has been carried at by the Global Navigation Satellite System Panel.

[83] G. Lindstrom & G. Gaspirini, "The Galileo satellite system and its security implications" (2003), online: Institute for Security Studies, <http://www.iss-eu.org/occasion/occ44.pdf> (date accessed: 23/09/2005).

[84] ICAO Secretariat, "Vulnerabilities do not compromise ultimate goal of implementing global GNSS systems" (2003)58.5 ICAO Journal 12.

is internationally coordinated by the radio-communication sector of the International Telecommunication Union through a frequency planning process (allotment, allocation, assignment) and a system planning process in three steps (advanced publication, coordination, notification).

In case of harmful interference, complaints are directed from the harmed party to the alleged author. It is a State-based procedure. However, Global Navigation Satellite Systems signals are expected to be received by a large population of users worldwide who are not necessarily experts, thus making the location and elimination of the sources of interference difficult. Moreover, the current mechanism for the elimination of harmful interference is not legally binding. It is left to the good faith of States. A more expeditious procedure is therefore needed.

With respect to the monitoring of interference, a proposal to create channel(s) dedicated exclusively to the broadcasting of information on every Global Navigation Satellite System integrity and availability with a safety status granted by the International Telecommunication Union (implying a more stringent duty of care from States) has been brought forward.[85]

Intentional interference

Intentional interference is a more serious issue. It includes jamming, spoofing and physical destruction of the GPS infrastructure.

The low power of the Global Navigation Satellite Systems signals make jamming easy, even using cheap equipment. Simple noise jammers can disrupt signals

[85] Michel Delarche, "Interfering with interference: the case for better protection of GNSS signals" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1.

for hundreds of kilometres. For instance, the one on sale at the Moscow Air Show in 1997 kills military and civilian frequencies of GPS for 200 hundred kilometres, working with only 5 watts. It costs 3,500 dollars, but you can make one with parts purchased at your local radio store for only 50 dollars[86]! In addition, jammers can operate on several frequencies simultaneously. The duration of a jamming event has to be taken into consideration. Indeed, brief interruptions are less serious. However, interruptions have different consequences, depending on the type of activity relying on Global Navigation Satellite Systems. With respect to aviation, loss of GPS signal is a threat to safety of life.

The Department of Defense takes the issue seriously by periodically interfering with the GPS signals in order to develop anti-jamming technology as well as to train its forces to recognize jamming and switch to back up systems[87]. Directional antennas and tunable filters are examples of counter measures.

The success of the jamming exercises allowed for the deactivation of Selective Availability (GPS signal accuracy was intentionally degraded to protect national security interests) on 1 May 2000. As Longhorne Bond stated: "It is good news for the military but it is a wake-up call to civil users. JAMMING WORKS"[88].

A second source of intentional interference is spoofing[89].

A spoofer transmits erroneous data by imitating the Global Navigation Satellite

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[86] Langhorne Bond, "Coming to terms with the GNSS sole means problem" (Paper delivered to the Air Traffic Control Association, Vienna, Austria, 9 June 1999) [unpublished]; Langhorne Bond, "Pitfalls on the road to the golden age of navigation" (Presented to the Royal Institute of Navigation, Church House, London, 1 November 1999) [unpublished].

[87] Langhorne Bond, "An open letter to the secretary of transportation and the secretary of defense pointing out safety concerns with the 1998 federal radionavigation plan " (1999) [unpublished].

[88] Langhorne Bond, "Red on the radar screen: GPS dependency grows" (Paper delivered to the Air Traffic Control Association, Dublin, Ireland, 20 July 2001) [unpublished].

[89] *Ibid.* ; Langhorne Bond, "Coming to terms with the GNSS sole means problem" (Paper delivered to the Air Traffic Control Association, Vienna, Austria, 9 June 1999) [unpublished]; Langhorne Bond, "Pitfalls on the road to the golden age of navigation" (Presented to the Royal Institute of Navigation, Church House, London, 1 November 1999) [unpublished].

System signals. It is a real danger since the false signals are indistinguishable from the real ones. This can be compared to computer attacks with viruses.

Spoofing jammers are more complicated and more expensive than "regular" ones, but have devastating effects. For instance, a one watt spoofer on Logan Airport in Boston can confuse GPS receivers at a line of sight distance of 350 miles (40, 000 feet)[90].

The potential mitigation aids are airborne collision avoidance, situation awareness and separation assurance[91].

Attacks on satellites, including GPS satellites, are a serious threat.

This issue has been addressed in the Rumsfeld commission report of 2001, which explains how satellites can be attacked on space. It also lists GPS satellites as a potential target[92]. Vulnerabilities in transportation and communication systems are an opportunity for terrorist organizations and rogue states who will seek to exploit them. The terrorist attacks on September 11th 2001 are an example. GPS is exposed to both attacks on its satellites and destruction of its infrastructure. China is about to develop anti-satellite weapons that could be deployed to immobilize the GPS system[93]. If this occurs, GPS signals would be lost perhaps worldwide and for an indeterminate time, leading to dramatic economic, environmental consequences and loss of lives.

The growing dependence on GPS makes the United States and its allies even more vulnerable to anti-satellite attacks.

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90 Langhorne Bond, "Red on the radar screen: GPS dependency grows" (Paper delivered to the Air Traffic Control Association, Dublin, Ireland, 20 July 2001) [unpublished].

91 V. Iatsouk, "GNSS spectrum and signal vulnerablity issues" (Presented at the ATN/GNSS seminar, Varadero, Cuba, 6 to 9 May 2002), online: ICAO, <http://www.icao.int/icao/en/ro/nacc/meetings/atngnss2002/gnss_52_iatsouk.pps> (date accessed: 12/10/2005).

92 Langhorne Bond, "A new dawn for world radionavigation" (Paper presented to the ATCA European conference, Berlin, Germany, 11 July 2002) [unpublished].

93 T.D. Lehrman, "Privatizing the GPS: opportunity or fully?"(2004) XXIX Annals of Air and Space Law 275.

Mediocre varying position accuracy and questionable geographic reliability of GPS

These two shortcomings have been identified by the European Commission[94]. Indeed, even with the end of Selective Availability, GPS position accuracy still varies between 7 and 20 meters depending on the time and place.

Moreover, the geographic reliability of the US system is questionable. GPS coverage is limited in northern regions, which are nevertheless used as aviation routes. Several interruptions of the GPS signal have been reported by the Iceland aviation authorities. Over urban regions, GPS coverage is only 50 per cent (GPS alone).

Satellite malfunctioning

Satellite failure is not unusual. For instance, GPS service was disrupted for 18 minutes over the territories of Oklahoma, Kansas and Nebraska in 2000 due to satellites malfunctioning[95].

The United States can degrade the accuracy of GPS or turn it off

According to the Presidential Decision Directive of 1996, GPS "will remain responsive to the National Command Authority". The President of the United States can therefore turn off, degrade or spoof the system over all or part of the orbit without any prior notice[96]. The United States has no intention to renounce this freedom. The

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94 G. Lindstrom & G. Gaspirini, "The Galileo satellite system and its security implications" (2003), online: Institute for Security Studies, <http://www.iss-eu.org/occasion/occ44.pdf> (date accessed: 23/09/2005).

95 Directorate-General Energy and Transport,"The European dependence on US-GPS and the Galileo initiative", online: Europa <http://europa.eu.int/comm/dgs/energy_transport/galileo/doc/gal_european_dependence_on_gps_rev22.pdf> (date accessed: 12/10/2005).

96 U.S. *Policy statement on GPS of March 29 1996* (1996), online: spacenews

country owns and controls GPS and therefore has the right to turn it off anytime. Moreover, it may be necessary to deny the use of the system for national security reasons since GPS is vulnerable to interruption and use by terrorists.

The U.S. space-based positioning, navigation, and timing policy of 2004[97] restates this policy. The Government shall

> [d]eny to adversaries position, navigation, and timing services from the Global Positioning System, its augmentations, and/or any other space-based position, navigation, and timing systems without unduly disrupting civil, commercial, and scientific uses of these services outside an area of military operations, or for homeland security purposes.

The wording "without unduly disrupting" is not precise. However, this statement clearly means that the system can be altered to protect the country from adversary use of GPS.

Therefore, can States be totally dependent on a system which can be turned off or degraded by the provider? Independence is the main reason for Europe developing its own Global Navigation Satellite System, Galileo. The United States policy on GPS needs more transparency, including clear procedures for giving notice in case of signal shutoff or degradation. Otherwise, states will switch to alternatives such as Galileo[98].

Increasing dependence on GPS

GPS applications are developing in many sectors such as surveying, mapping, construction, mining, transportation, Internet products and services, mobile computing, and wireless communications... It could become an essential tool for business and daily activities. Just like mobile phones, reliance on GPS is growing and

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<www.spacenews.com/gps96.txt > (date accessed: 3/10/2005).

97 U.S. Space-based positioning, Navigation, and Timing Policy (15 December 2004), online: OSTP <http://www.ostp.gov/html/FactSheetSPACE-BASEDPOSITIONINGNAVIGATIONTIMING.pdf> (date accessed: 23/09/2005).

98 T.D. Lehrman, "Privatizing the GPS: opportunity or fully?"(2004) XXIX Annals of Air and Space Law 275

may turn into a dependence. However, economic and social consequences of losing GPS are higher as reliance on the system increases. For instance, the cost of a GPS malfunction or shut down to European economies has been estimated between 130 and 500 million euros per day[99].

The United States refuses to share responsibility for the operation and control of GPS provisions

The United States provides GPS free of charge, and therefore does not accept to share responsibility for the operation and control of GPS provisions. With respect to GNSS applications to air navigation, GPS represents for the United States nothing more than another Air Navigation Services tool[100]. Thus, in case of damages caused by deficiencies in the provision of GNSS signals, claims fall under the Federal Tort Claim Act. It is a fault-based regime with unlimited liability. Negligence of the provider State has to be proven, as in the case of poor maintenance or failure to warn of a system malfunction. The Government will be held liable when the alleged damage has been caused by a negligent or wrongful act or omission by government employees acting within the scope of their duties. However, this immunity waiver does not apply to conduct that is not mandatory, and does not cover claims for monetary damages arising in a foreign country[101].

States cannot have total confidence in a system which does not offer them appropriate bases for compensation in case of liability of the provider for a GPS malfunction.

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[99] G. Lindstrom & G. Gaspirini, "The Galileo satellite system and its security implications" (2003), online: Institute for Security Studies, <http://www.iss-eu.org/occasion/occ44.pdf> (date accessed: 23/09/2005).

[100] ICAO, *Exchange of letters between ICAO and the USA*, State Letter LE4/49.1-94/89 attachment 1 (27 October, 1994).

[101] Smith v. United States, 507 U.S. 197 (1993). The Federal Tort Claim Act does not apply to governmental negligent acts outside U.S. territory.

GPS is facing competition

In addition to GPS vulnerabilities, the system is threatened by competition from other Global Navigation Satellite Systems, especially Galileo, and from augmentation systems.

According to T.D. Lehrman, privatization of the system has a number of benefits[102]. First, involvement of the private sector would improve the efficiency of the system and make GPS able to compete with Galileo. Second, a clear separation between the private and military sectors would both improve national security and responsiveness to the needs of civil users. Third, its continuous availability would increase confidence from other states And user fees could be charged to finance the system and enhance it.

Three options are envisaged: a phased privatization (concession or private ownership, government oversight with respect to national security), the licensing of competitive radio-navigation providers (development of parallel satellite networks), and a phased sale of the current system upon the completion of a new defense navigation network[103].

The U.S. Global Positioning System therefore has serious vulnerabilities. Galileo will be able to overcome or mitigate them.

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102 T.D. Lehrman, "Privatizing the GPS: opportunity or fully?"(2004) 29 Annals of Air and Space Law 275.

103 *Ibid.*

2/ Galileo: a system able to overcome GPS shortcomings

Galileo will be able to cover GPS shortfalls with respect to accuracy, reliability, interference, and liability. It will also optimise search and rescue missions.

With respect to position accuracy and geographical reliability, Galileo will bring significant improvements. First, it will be able to pinpoint a geographical position to within a single-meter. Second, a better coverage will be provided in northern regions as well as in urban regions (95 per cent coverage)[104].

The risk of unintentional interference will be reduced through the provision of additional frequencies allocated by the International Telecommunication Union during the 2003 World Radio Communications Conference[105].

Moreover, Galileo will offer a service guarantee in terms of accuracy, availability, continuity and integrity of the signal for certain services such as safety of life and commercial services. Integrity information on Galileo satellites will be provided (Integrity monitoring). In case of failures or malfunctions of the system (a satellite is not functioning or is no longer monitored), the users will be immediately alerted. Safety will be considerably improved. In aviation, the service will allow users to react rapidly to malfunctions due to a time to alert of less than 10 seconds[106].

It will be more difficult to interfere with Galileo since the signals will be broadcast on increased bandwidths (larger than for GPS). In addition, encryption of

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[104] EC, *Commission communication to the European Parliament and the Council-State progress of the Galileo programme COM(2002) 0518 of 15 October 2002*, [2002] O.J. C.248/2.

[105] Europa, News, "Galileo helps Europe find its place in satellite navigation" (16 February 2005), online: EUROPA <http://europa.eu.int/comm/space/news/article_2130_en.html> (date accessed: 12/10/2005).

[106] Directorate-General Energy and Transport, "The European dependence on US-GPS and the Galileo initiative", online: Europa <http://europa.eu.int/comm/dgs/energy_transport/galileo/doc/gal_european_dependence_on_gps_rev22.pdf> (date accessed: 12/10/2005).

the Public Regulated Service signals (for authorized governmental users) will considerably reduce the risk of jamming and spoofing[107].

With respect to liability, the service guarantee will provide a legal framework for users to obtain compensation from the operator for damages due to improper functioning of Galileo[108]. A "guarantor" will therefore assume responsibility for failure, disruption or provision of a service not meeting the performance required. A compensation mechanism, as well as jurisdiction and recourse mechanisms, will be established.

Eventually, Galileo will offer a search and rescue service which will significantly improve the current COSPAS-SARSAT system. The two systems will be compatible. Thanks to Galileo, alerts will be detected and located faster (no more than 10 minutes) with an accuracy of only a few meters[109].

Galileo will cover some GPS shortcomings and mitigate its vulnerabilities with respect to interference but will not eliminate them totally. The combined use of the European and American systems is therefore interesting.

<u>3/ Benefits from the combined use of GPS and Galileo</u>

An agreement between the United States and the European Union was reached on 26 June 2004[110] which, among others, confirms that GPS and Galileo will be compatible and interoperable. The combined use of the two systems will bring several benefits.

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[107] *Ibid.*
[108] *Ibid.*
[109] *Ibid.*
[110] *Agreement on the Promotion, Provision, and Use of Galileo and GPS Satellite-Based Navigation Systems and Related Applications*, United States and European Union, 26 June 2004, online: IGEB<http://pnt.gov/2004-US-EC-agreement.pdf> (date accessed: 24/09/2005).

The agreement between the United States and the European Union on the Promotion, Provision, and Use of Galileo and GPS Satellite-Based Navigation Systems and Related Applications

The United States initially opposed Galileo since it would duplicate and compete with GPS. It tried to demonstrate that there was no need for an alternative system when GPS could be improved and me made widely available[111] When the United States realized that in spite of these efforts Europe was determined to launch its programme, it accepted to negotiate an agreement to ensure that the two systems would be fully compatible and interoperable.

Discussions started in 1999. The United States raised concerns about trade-related, technical and security matters. First of all, Europe should not use regulation and standards which impose the use of Galileo and discriminate against GPS manufacturers, service providers and users. Users should be able to choose one of the systems or the combination of the two without any restriction. The United States also wanted to protect national and North Atlantic Treaty Organization military forces. Europe had to ensure that Galileo would not interfere with the GPS signal and that nothing would prevent the United States from turning off or altering the system for security reasons[112].

At the end of a round of negotiations held in Brussels on 23 and 24 February 2004[113], the United States and the European Union agreed to establish a common civil

[111]Directorate-General Energy and Transport,"The European dependence on US-GPS and the Galileo initiative", online: Europa <http://europa.eu.int/comm/dgs/energy_transport/galileo/doc/gal_european_dependence_on_gps_rev22.pdf> (date accessed: 12/10/2005).

[112] US Department of State, Media note, "U.S. Global Positioning System and European Galileo System" (2002), online: United States Department of State <http://www.state.gov/r/pa/prs/ps/2002/8673.htm> (date accessed: 11/10/2005).

[113] Europa, Press release, "Loyola de Palacio welcomes the outcome of the EU/US discussions on Galileo" (25 February 2004), online: EUROPA<http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/04/264&format=HTML

signal for the GPS and Galileo open services and confirmed the suitable baseline signal structure for the Galileo Public Related Service. It will be possible to optimize these structures to enhance performances of the system. GPS and Galileo will be fully interoperable and compatible. Interoperability means the two systems will be able to be used together "to provide better capabilities at the user level than would be achieved by relying solely on one service or signal". Compatibility refers to the ability of the systems to be used "separately or together without interfering with each individual service or signal, and without adversely affecting navigation warfare"[114]. The United States and Europe also reached an agreement on the principle of non-discrimination in trade in satellite navigation goods and services. In order to protect navigation warfare capabilities, both parties committed not to disturb the others signal. Finally, agreement was reached whereby no restrictions for the use of or access to respective open services would be implement for end users.

The summit held in Ireland ended with the conclusion of the *Agreement on the Promotion, Provision, and Use of Galileo and GPS Satellite-Based Navigation Systems and Related Applications* on 26 June 2004[115]. It includes the principles on which the United States and Europe had agreed in February.

Users will be able to use GPS and Galileo in a complementary way with the same receiver[116].

&aged=0&language=en&guiLanguage=en> (date accessed: 12/10/2005); The United States Mission to the European Union, "US, EU announce GPS/Galileo agreement" (26 February 2004), online: USEU<http://www.useu.be/Galileo/Feb2604JointUSEUGalileo.html> (date accessed: 24/09/2005).

[114] U.S. Space-based positioning, Navigation, and Timing Policy (15 December 2004), online: OSTP <http://www.ostp.gov/html/FactSheetSPACE-BASEDPOSITIONINGNAVIGATIONTIMING.pdf> (date accessed: 23/09/2005).

[115] *Agreement on the Promotion, Provision, and Use of Galileo and GPS Satellite-Based Navigation Systems and Related Applications*, United States and European Union, 26 June 2004, online: IGEB<http://pnt.gov/2004-US-EC-agreement.pdf> (date accessed: 24/09/2005).

[116] Europa, Press release, "Galileo and GPS will be able to navigate side by side: EU and US sign final agreement" (28 June 2004), online: Europa <http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/04/805&format=HTML&aged=0&language=EN&guiLanguage=en> (date accessed: 12/10/2005).

According to United States Secretary of States Colin Powell: "The agreement manages to balance the competition that is inherent in the commercial dimension of satellite navigational technology with the cooperation necessary for the security dimension."[117]

Following this agreement, four working groups have been established to ensure continuous benefits from the cooperation. A first group will work on interoperability issues so that the two systems remain interoperable and a second one will deal with the modernization of the infrastructure. The third and fourth groups will respectively focus on non discrimination and security issues[118].

Improvements resulting from the combined use of GPS and Galileo

The joint use of GPS and Galileo has many advantages[119]. Performance will be improved since the two systems together will allow for an increased coverage of the service (95 per cent of coverage), which provides coverage in many urban areas where GPS alone is not sufficient.

Combining GPS and Galileo is also easier and cheaper than developing alternative systems. It will notably benefit equipment manufacturers.

Having two independent but interoperable systems will enhance the safety and reliability of the service. If one system fails, the other system will be able to

[117] The United States Mission to the European Union, "Powell hails US-UE agreement on GPS-Galileo cooperation" (29 June 2004), online: USEU<http://www.useu.be/Galileo/June2904PowellGalileoAgreement.html> (date accessed: 24/09/2005).

[118] The United States Mission to the European Union, "US, EU announce GPS/Galileo agreement" (26 February 2004), online: USEU<http://www.useu.be/Galileo/Feb2604JointUSEUGalileo.html> (date accessed: 24/09/2005).

[119]Directorate-General Energy and Transport,"The European dependence on US-GPS and the Galileo initiative", online: Europa <http://europa.eu.int/comm/dgs/energy_transport/galileo/doc/gal_european_dependence_on_gps_rev22.pdf> (date accessed: 12/10/2005).

compensate. It is crucial for the safety of life applications which require high levels of accuracy, availability, continuity and integrity of service. Terrorist attacks will be less likely to happen since both GPS and Galileo would have to be neutralized in order to disrupt the overall system. The combined use of GPS and Galileo will mitigate their vulnerabilities.

Eventually, having a redundant system will boost the confidence of the users in GPS and Galileo. The number of applications and users worldwide should considerably increase. With GPS alone, users cannot have total confidence in the system since it can be turned off or degraded anytime by the United States for security reasons. If this happens, Galileo will fill the gap.

Many benefits will result from the combined use of GPS and Galileo. But is it enough to make Global Navigation Satellite Systems the sole means for air navigation?

4/ The sole means issue: is there a need for a back up system?

Global Navigation Satellite Systems is a wonderful technology which will bring significant benefits to air navigation. However, this technology has limitations. GPS is a vulnerable system. Its shortcomings will be overcome or reduced by Galileo and the combined use of the two systems. Thus, should Global Navigation Satellite Systems become the sole means, that is, the only navigation capability available on board the aircraft or is there a need for a back up system? "Sole means" is different from "sole service" which means that navigation satellite systems are the only radio-navigation service provided external to the aircraft[120].

[120] Eurocontrol, "GNSS Aviation Needs, A Common Aviation Community Position" (2002) [unpublished].

According to Walter Blanchard, instead of developing back up systems (for instance, ground-based radio aids) which would probably be less reliable than Global Navigation Satellite Systems, one should focus on the co-use of GPS, Galileo and Glonass as one integrated system[121].

Nevertheless, Global Navigation Satellite Systems cannot be the sole means for air navigation as long as not all countries are equipped. And developing countries may lack financial and human resources to do so. Moreover, the combined use of GPS and Galileo will reduce their vulnerabilities but will not eliminate them. No system is fully reliable. Depending solely on a system that can be disrupted is not acceptable for safety of life applications such as aviation. The Volve Report clearly rejects the sole means doctrine where the loss or degradation of the GPS signal could lead to major economic and environmental damages as well as loss of life, and stresses the need for back up systems[122]. The report also recommends that a comprehensive analysis of potential back up systems to GPS be conducted. The Department of Transportation released a report in 2004 on this matter which points out the importance of maintaining the availability of terrestrial back up systems.

Redundancy is the best safeguard. But this does not mean a parallel Global Navigation Satellite System has to be developed. So what is the solution? A mixed system, that is, a mix of satellite and terrestrial navigation aids seems to be the appropriate solution[123]. A reduced terrestrial infrastructure should remain. Safety,

[121] Walter Blanchard, "Would GNSS need a back up?" (2005), online: GMAT<http://www.gmat.unsw.edu.au/wang/jgps/v3n12/v3n12p39.pdf> (date accessed: 23/09/2005).

[122] U.S., John A. Volpe National Transportation Systems Center,"*Vulnerabilty Assessment of the Transportation Infrastructure Relying on the Global Postioning System*" (29 August 2001), online: navcen <http://www.navcen.uscg.gov/archive/2001/Oct/FinalReport-v4.6.pdf> (date accessed: 17/10/2005).

[123] Langhorne Bond, "Coming to terms with the GNSS sole means problem" (Paper delivered to the Air Traffic Control Association, Vienna, Austria, 9 June 1999) [unpublished]; Langhorne Bond, "Pitfalls on the road to the golden age of navigation" (Presented to the Royal Institute of

performance and cost effectiveness considerations are crucial in the selection of the terrestrial navigation aids to be retained.

With respect to navigation, VOR (VHF Omni-directional Radio Range) is safe but expensive and inaccurate. It should be withdrawn. Most of its users are small general aviation aircraft. Eurocontrol has decided to phase it out and the Federal Aviation Administration plans to decommission half of these navigation aids[124].

DME/DME (Distance Measuring Equipment) is a safe and high accuracy system. It can be used as a back up system to Global Navigation Satellite Systems for en route and terminal operations. Most modern aircraft are already equipped with a Flight Management System which relies exclusively on DME/DME. The Federal Aviation Administration and Eurocontrol have decided to retain the use of DME/DME[125].

Precision approach is mandatory for safety of flight in bad weather and terrestrial navigation aids must remain as back up systems. ILS (Instrument Landing System) and MLS (Microwave Landing System) are the existing terrestrial precision landing aids. ILS is one of the best aviation safety technologies and will continue to be used. MLS is interesting for the most crowded airports since it is less vulnerable to interference than ILS. It should remain too[126].

Augmented Global Navigation Satellite Systems are expected to provide the required integrity and accuracy to support Category I and eventually Category II and III precision approaches. They become duplicative since ILS and MLS will remain. However, augmented systems are a breakthrough where the ground-based navigational aids are limited or non existent as it is the case in developing countries.

Navigation, Church House, London, England, 1 November 1999) [unpublished]; Langhorne Bond, "Loran and GPS in aviation" (Presented to the Air Navigation Commission of the International Civil Aviation Organization, Montreal, Canada, 23 February 2000) [unpublished].

124 *Ibid.*

125 *Ibid.*

126 *Ibid.*

Loran is a multi-modal system which offers a great potential in terms of accuracy, coverage and cost[127]. It has been qualified by the Royal Institute of Navigation "an ideal and complementary backup to GNSS". It is, according to the Federal Aviation Administration, "the best theoretical backup" to GPS[128].

Indeed, Loran has a high accuracy. Today , it can pinpoint a geographical position to within 0.25 mile. It is sufficient for air navigation operations[129]. Direct routing is also possible with Loran. In addition, the system has a large coverage. Its signal is available on the earth surface and in the atmosphere and, unlike VOR, is not lost if the aircraft is out of sight of the transmitter. The United States and Canada can be covered by only 29 transmitters, whereas 1200 VOR/DME sites are needed to provide similar aviation coverage! With respect to situation awareness and collision avoidance, Loran can take over in case of GPS failure. It can also carry out GPS augmented messages thanks to Eurofix, a system developed by the University of Delft in Holland. Loran is qualified to support non precision approaches. It is equipped with the Automatic Blink System (ABS) which monitors the integrity of the signal and alerts the user in case of disruption. Unlike GPS, Loran is controlled by the host country. The latter would not be dependent on a system that can be suddenly turned off and degraded by the United States. Eventually, Loran is inexpensive. A transmitter, which has a very long range, costs only 10 million dollars. Today, the

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[127] Langhorne Bond, "Coming to terms with the GNSS sole means problem" (Paper delivered to the Air Traffic Control Association, Vienna, Austria, 9 June 1999) [unpublished]; Langhorne Bond, "Pitfalls on the road to the golden age of navigation" (Presented to the Royal Institute of Navigation, Church House, London, England, 1 November 1999) [unpublished]; Langhorne Bond, "Loran and GPS in aviation" (Presented to the Air Navigation Commission of the International Civil Aviation Organization, Montreal, Canada, 23 February 2000) [unpublished].

[128] International Loran Association, "The ILA perspective", online: ILA <http://www.loran.org/library/july2004persp.htm> (date accessed: 23/09/2005).

[129] Langhorne Bond, "Coming to terms with the GNSS sole means problem" (Paper delivered to the Air Traffic Control Association, Vienna, Austria, 9 June 1999) [unpublished]; Langhorne Bond, "Pitfalls on the road to the golden age of navigation" (Presented to the Royal Institute of Navigation, Church House, London, England, 1 November 1999) [unpublished]; Langhorne Bond, "Loran and GPS in aviation" (Presented to the Air Navigation Commission of the International Civil Aviation Organization, Montreal, Canada, 23 February 2000) [unpublished].

system is being modernized. Already 120 million dollars have been invested in Loran. The annual operation costs of the enhanced system should be about 15 million dollars[130].Technical and economic evaluations of enhanced Loran have been conducted with success in 2004[131].

Loran is a high performance and cost effective system. It should therefore be integrated in the radio navigation system mix as a back up system to Global Navigation Satellite Systems.

The sole means doctrine was supported by the Federal Aviation Administration. It included the decommissioning of the terrestrial navigation aids and their replacement by augmentation systems (Wide Area Augmentation System and Local Area Augmentation System). The sole means doctrine ended with the Volve Report and was abandoned by the Federal Aviation Administration. A reduced terrestrial infrastructure will remain[132]. Back up systems are favoured by pilots, controllers and Eurocontrol[133]. Their use are mentioned in the 1998 *Charter on the Rights and Obligations of States relating to GNSS* of the International Civil Aviation Organization to ensure integrity, accuracy and reliability of the services[134].

Global Navigation Satellite Systems are a tremendous technology and the key element of the CNS/ATM systems. But they remain vulnerable systems, and it would not be safe to rely exclusively on them. In addition, their implementation gives raise to legal issues.

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130 *Ibid.*

131 *Ibid.*

132 Langhorne Bond, "The hidden cost of the lack of ATC safety regulation" (Paper delivered at the North American Safety Conference, Atlanta, USA, 5 February 2003) [unpublished]

133 Langhorne Bond, "Techno-skepticism-a reality check" (Presented to "Communication for safety", Dallas, USA, 21 April 2004) [unpublished]

134 Ludwig Weber & Jiefang Huang, "ICAO and GNSS"(2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1.

CHAPTER III: GLOBAL NAVIGATION SATELLITE SYSTEMS-INSTITUTIONAL AND LEGAL FRAMEWORK

The implementation of Global Navigation Satellite Systems raises significant legal issues. For the majority of users, the systems are owned, controlled and operated by foreign states. This is an unprecedented situation in the provision of air navigation services. User states are notably concerned about issues of universal access, continuity of services, respect of state sovereignty, certification, cost allocation and liability. The work of the International Civil Aviation Organization with respect to the establishment of a legal framework for Global Navigation Satellite Systems deserves attention and commentary, notably with respect to the liability issue. However, hypothetical legal considerations should not become a pretext to slow down the implementation of Global Navigation Satellite Systems

1/ The role of the International Civil Aviation Organization with respect to the establishment of a legal framework for Global Navigation Satellite Systems

The International Civil Aviation Organization has been working on the establishment of a legal framework with respect to Global Navigation Satellite Systems since 1992[135]. A two-step approach was adopted: the elaboration of a legal framework for existing systems and the development of a more complete instrument for the future[136]. Fundamental principles emerged from this process and were

[135] ICAO, Council, 136th session, *Summary Minutes with Subject Index*, ICAO Doc. 9606-C/1107, C-Min.136/12 (1992) at 76.

[136] ICAO, *Report of the 29th session of the Legal Committee*, ICAO Doc. 9630-LC/189 (1994).

embodied in the1994 *Statement of ICAO policy on CNS/ATM Systems Implementation and Operation*[137]. These principles included: safety of international civil aviation as the paramount principle in the provision and use of Global Navigation Satellite Systems, universal accessibility without discrimination, continuous availability of services, respect of state sovereignty, user charges, certification and validation of the system. The International Civil Aviation Organization also exchanged letters with the United States in 1994 and with Russia in 1996. Both countries offered their respective systems to the international aviation community free of charge[138].

A panel of legal and technical experts (LTEP) was established by a Council decision on 6 December 1995[139]. to consider possible types and forms for a legal framework with regard to Global Navigation Satellite Systems[140]. The Panel's task was to examine whether the existing legal framework, the Chicago Convention, was sufficient to govern Global Navigation Satellite Systems, or whether new provisions were needed.

A controversy emerged as a result of this matter[141]. According to a few countries, including the United States, Global Navigation Satellite Systems are nothing more than another air navigation tool. The existing legal regime is sufficient.

By contrast, since Global Navigation Satellite Systems are under the control of a limited number of States, Europe and some developing countries called for the establishment of an appropriate legal framework providing guarantees to the users.

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[137] ICAO, *Statement policy on CNS/ATM Systems Implementation and Operation*, ICAO Doc. LC/28-WP/3-2 (28 March 1994).

[138] ICAO, *Exchange of letters between ICAO and the USA*, ICAO Doc. State Letter LE4/49.1-94/89 attachment 1 (14 and 27 October, 1994); ICAO, *Exchange of Letters between ICAO and the R*ussian *Federation*, 4 June and 29 July 1996, ICAO State Letter LE 4/49.1-96/80 (dated 20 September 1996).

[139] Assad Kotaite, "ICAO's role with respect to the institutional arrangements and legal framework of GNSS" (1996) XXII Annals of Air and Space Law 94.

[140] ICAO, Council, 146th session, *Summary of Decisions*, ICAO Doc. C-DEC 146/11 (1995).

[141] ICAO, *Report of the World-wide CNS/ATM Systems Implementation Conference* (15 May 1998), online: ICAO <.http://www.icao.int/icao/en/ro/rio/finrep.html#ag1> (date accessed: 10/10/2005).

The majority view supported the elaboration of an international convention as a long term solution to the legal and institutional issues.

The results of the work of the Panel were presented to the ICAO World-wide CNS/ATM Systems Implementation Conference in 1998[142]. They comprise a *Draft Charter on the Rights and Obligations of States relating to GNSS services*, together with recommendations with respect to certification, liability, administration, financing, cost recovery and the future operating structures of the navigation systems. The draft "Charter" reaffirms the principles embodied in the 1994 *Statement of ICAO policy on CNS/ATM Systems Implementation and Operation*. However, neither the Panel nor the Rio Conference was able to put an end to the controversy mentioned above.

Following the recommendation of the Conference, the *Charter on the Rights and Obligations of States relating to GNSS services*, was adopted unanimously by the Assembly (Resolution A 32-19) in October 1998[143], demonstrating the willingness of states to agree on standards of conduct. Nevertheless, the text is a resolution and lacks of binding force.

A Secretariat Study group was established pursuant to the Assembly Resolution A32-20 to elaborate an appropriate long-term legal framework, including the consideration of an international convention[144]. The opposition between the States advocating the establishment of international convention and those who viewed the current legal regime as sufficient remained significant. Member states of the European Civil Aviation Conference proposed the development of a contractual framework as a

[142] *Ibid.*

[143] *Charter on the rights and obligations of the states relating to GNSS services*, ICAO Assembly Resolution A32-19, ICAO Assembly, 32nd session, ICAO Doc. A32-WP/24, Appendix A (1998).

[144] ICAO, *Development and elaboration of an appropriate long-term legal framework to govern the implementation of GNSS*, ICAO Assembly Resolution A32-20, ICAO Assembly, 32nd session, online: ICAO <http://www.icao.int/cgi/goto_m.pl?icao/en/trivia/ass_sess.htm> (date accessed: 21/11/2005).

temporary solution[145].

In 2001, the 33rd Session of the ICAO Assembly mandated the Study Group to finalize the concept of a contractual framework and study the possibility of an international convention[146]. The final report of the Study Group was presented to the 35th Session of the Assembly in 2004[147]. It included a *Draft contractual framework relating to the provision of GNSS services.* European states presented a list of the main elements to be included in an international convention. To date, no consensus has been reached on the need for an international convention. While some legal experts argue that an international instrument is desirable and necessary, others believe that the existing regime is sufficient to cover all aspects of Global Navigation Satellite Systems. Moreover, it is arguably overly premature to develop an international instrument since not enough experience has been gained with the implementation of Global Navigation Satellite Systems[148]. This question will be further analyzed when addressing the liability issue.

Fundamental principles of the Global Navigation Satellite Systems framework

Since the majority of user states do not have control over the space segments of the Global Navigation Satellite Systems, it is crucial to ensure universal accessibility without discrimination. Concerns that the systems maybe shut down for national security purposes or simply arbitrarily by provider states underlie this principle. The 1994 Council Statement affirms explicitly that the principle of universal accessibility without discrimination shall govern the provision of all air navigation

[145] ICAO, *Progress Report on the Establishment of a Legal Framework with Regard to CNS/ATM systems including GNSS*, ICAO Doc. A33-WP/34 (2001).
[146] *Ibid.*
[147] ICAO, *Final Report on the Work of the Secretariat Study Group on Legal Aspects of CNS/ATM Systems*, ICAO Doc. A35-WP/75 Appendix (2004).
[148] *Ibid.*

services by CNS/ATM systems. The offers by the United States and Russia are in line with this principle. It is also reaffirmed in the *Charter on the rights and obligations of the states relating to GNSS services* (Paragraph 2).

The remaining issue is how to provide a legal guarantee of this principle. Indeed, states cannot make important investments to modify the navigation systems on the basis of a fragile relationship that could be changed at any time. The *Charter on the rights and obligations of the states relating to GNSS services* is not legally binding, and the Standards and Recommended Practices (SARPs) of the International Civil Aviation Organization may not be an appropriate mechanism to deal with issues of accessibility because they are traditionally used to regulate technical matters. According to some states, only an international convention could fully guarantee the implementation of the principle of universal access[149].

Continuous availability of services is closely linked to universal accessibility. In the technical sense, continuous availability refers to the arrangements taken to minimize the impact of system malfunctions or failure and to achieve expeditious service recovery (such as a switch to backup systems). In the legal sense, continuity means non-interruption of the system for military, budgetary, or other non-technical reasons.

Both the United States and Russia have committed to take all necessary measures to maintain the integrity and reliability of the services. But their respective exchanges of letters with the International Civil Aviation Organization are not legally binding. They are only declarations of intention to provide the services on a continuous basis,[150] and

[149] Assad Kotaite, "ICAO's role with respect to the institutional arrangements and legal framework of GNSS planning and implementation" (1996) XXI Annals of Air and Space Law 94; Jiefang Huang, "Development of the long-term legal framework for the GNSS" (1997) XXII Annals of Air and Space Law 585; Paul B. Larsen, "GNSS: Universal technology under divisive legal regimes" (2002) XXVII Annals of Air and Space law 387.

[150] Paul B. Larsen, "GNSS: Universal technology under divisive legal regimes" (2002) XXVII Annals

the possibility remains that the United States and Russia could interrupt services for national security reasons. Unlike Glonass and GPS, Galileo will be civilian-operated, so national security should not be a threat to the continuity of the services. However, neither the 1994 Policy Statement nor the *Charter on the rights and obligations of the states relating to GNSS services*, which embody the principle of continuous availability, give an appropriate answer to the question: should states be allowed to put civil aviation in danger for military reasons?

No legal guarantee can fully ensure continuity of services. Indeed, as mentioned in Chapter II, Global Navigation Satellite Systems will never be totally reliable. A more appropriate solution to the issue of continuity of services would be technical, that is, a mix of terrestrial and satellite navigation aids.

The principle of complete and exclusive sovereignty of states over the airspace above their territory is a cornerstone of customary international law, and has been recognized by the Paris Convention of 1919 (Article 1) and by the Chicago Convention of 1944 (Article 1). This principle includes the right of a state to regulate and control the provision, operation and management of air navigation services within its territory.

However, in the case of Global Navigation Satellite Systems, space segments are controlled and operated by one or more foreign countries, and states must therefore rely on GNSS services provided by others. This situation gave rise to certain concerns with respect to state sovereignty. It is important to note that only the signals, and not the actual satellites, enter sovereign airspace. This situation is similar to that of communications satellites which orbit in non-sovereign outer space but conduct business in sovereign space. Like communications satellites, Global Navigation

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of Air and Space law 387.

Satellite Systems have not encountered major concerns[151].

The 1994 ICAO policy stipulates that implementation and operation of CNS/ATM systems which states have undertaken to provide in accordance with Article 28 of the Chicago Convention shall neither infringe nor impose restrictions upon the sovereignty of states, or their authority or responsibility in the control of air navigation and the promulgation and enforcement of safety regulations. The authority of states shall be preserved in the coordination and control of communications and in the augmentation, as necessary, of satellite navigation services[152]. This principle was reiterated in the exchange of letters between ICAO and Russia and between ICAO and the United States, as well as in the *Charter on the rights and obligations of the states relating to GNSS services* (Paragraph 3 b)[153].

To date, Global Navigation Satellite Systems services have been offered free of charge by the United States and by Russia. However, differentiated services will be offered by Galileo, two of which will be available in return for a fee. The levying of monetary charges is compatible with the principle of universal accessibility without discrimination as long as they are non-discriminatory, directly related to the services being provided and equitably apportioned among all categories of users[154]. Article 15 of the Chicago Convention provides a legal basis for the Council to provide some

[151] Paul B. Larsen, "Recent Changes in Space Law's Concept of Sovereignty" (1994) American Society of International Law Proceedings 264; Paul B. Larsen, "GNSS: Universal technology under divisive legal regimes" (2002) XXVII Annals of Air and Space law 387.

[152] ICAO, *Statement policy on CNS/ATM Systems Implementation and Operation*, ICAO Doc. LC/28-WP/3-2 (28 March 1994), paragraph 2.

[153] Paul B. Larsen, "GNSS: Universal technology under divisive legal regimes" (2002) XXVII Annals of Air and Space law 387; Prachee Kulkarni & Pablo Mendes de Leon, "Liability for damage in civil aviation within the context of GNSS" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1; Ruwantissa I. R. Abeyrantne, "State responsibility in classical jurisprudence: reflections on the Global Navigation Satellite System" (1998) XXIII Annals of Air and Space Law 1.

[154] ICAO, *Report of the rapporteur on the consideration, with regard to GNSS, of the Establishment of a legal framework*, ICAO Doc. LC/29-WP/3-1 (1994) paragraph 10; Paul B. Larsen, "GNSS: Universal technology under divisive legal regimes" (2002) XXVII Annals of Air and Space law 387.

guidance with respect to Global Navigation Satellite Services charges[155]. Indeed, "upon representation by an interested contracting State, the charges imposed for the use of airports and other facilities shall be subject to review by the Council". The term "other facilities" may well include Global Navigation Satellite Services elements. States recognized in the *Charter on the rights and obligations of the states relating to GNSS services* (Paragraph 6) that GNSS charges would have to be imposed in accordance with Article 15.

GNSS, like other navigation facilities, need to be certified by the relevant authorities to ensure that they comply with navigation performance criteria related to civil aviation safety. The main issues relate to the certification authority, the suitable institution for establishing standards of certification and the nature of these standards themselves[156].

First, should the International Civil Aviation Organization be a certifying agent or should certification be left to national governments? The International Civil Aviation Organization does not certify equipment or services, but could have a role in providing an institutional forum for exchange of information and in coordinating the matter of certification through regional planning and implementation groups[157].

Moreover, the multi-modal nature of Global Navigation Satellite Systems makes selection of a suitable authority for establishing standards of certification difficult. Indeed, GPS, Glonass and Galileo are not only used in aviation but have many applications. The International Civil Aviation Organization is competent for

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155 Assad Kotaite, "ICAO's role with respect to the institutional arrangements and legal framework of GNSS planning and implementation" (1996) XXI Annals of Air and Space Law 94.

156 Jiefang Huang, "Development of the long-term legal framework for the global navigation satellite system" (1997) XXII Annals of Air and Space Law 585.

157 ICAO, *Panel of Experts on the Establishment of a Legal Framework with Regards to GNSS*, report of the 1st meeting, ICAO Doc. LTEP/1 (25-30 November 1996).

establishing standards for aviation, but may not be the suitable agency with respect to other sectors of Global Navigation Satellite Systems applications. So would it be more appropriate to have a trans-modal convention or a sector-specific convention? Preference to date has been given to the latter option[158].

The nature of the standards of certification themselves was also controversial within the International Civil Aviation Organization. Some stakeholders argued in favour of standards from which no derogation would be allowed. But it was finally agreed than states should ensure that GNSS services comply with ICAO standards (principle affirmed in the *Charter on the rights and obligations of the states relating to GNSS services,*, Paragraph 4), and if these standards were not met Article 33 of the Chicago Convention would apply (states have the possibility in such circumstances to refuse to recognize the validity of the certificate).

Global Navigation Satellite Systems are navigation aids used by Air Traffic Services and fall under the umbrella of Annex 11 of the Chicago Convention on Air Traffic Services. Standards and Recommended Practices relating to Ground Based Augmentation Systems, GPS and Glonass have been included in Annex 11 by means of Amendment number 76 in 2001 and Amendment number 77 which came into force on 28 November 2002[159].

[158] Stephanie Andries, "The European Initiative Galileo: a European Contribution to the Global Navigation Satellite System (GNSS)" (2000) XXV Annals of Air and Space Law 43.

[159] F.G. Von Der Dunk, "Report on GNSS workshop 2002 Towards Implementation of GNSS for Civil Aviation, Madrid, 2-3 December 2002" (2003) XXVIII/3 Air and Space Law 188.

The issue of cost allocation

The allocation of Global Navigation Satellite Systems costs is another important issue. The International Civil Aviation Organization and Eurocontrol have undertaken studies on this matter.

In May 1996, The Air Navigation Services Economics Panel (ANSEP) released a *Report on Financial and related organisational and managerial aspects of GNSS provision and Operation*, addressing possible methods of Global Navigation Satellite Systems cost recovery for aviation[160]. Recommendation 3/16 of the World-wide CNS/ATM Systems Implementation Conference of 1998 directed the International Civil Aviation Organization to "address, as a matter of urgency, the issue of cost-allocation amongst all users of GNSS"[161].

The same year, a Task force was set up by Eurocontrol to develop methods for allocating the costs of Global Navigation Satellite Systems between civil aviation and other user categories, between states and between phases of flights (en route vs. approach/terminal phases)[162]. The Task force worked in collaboration with the International Civil Aviation Organization and the European Commission. The results of the 2000 Eurocontrol study entitled: "The allocation of GNSS (Global Navigation Satellite Systems) costs" correspond with Paragraph 32 of the *Statements by the Council to Contracting States on Charges for Airports and Air Navigation Services*. This states that "[i]nternational civil aviation should not be asked to meet costs which are not properly allocable to it"[163].

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160 Paul Nisner, "Future GNSS service needs to resolve issues of cost recovery and standardization" (2002) 57.3 ICAO Journal 14.

161 ICAO, *Conference on the Economics of Airports and Air Navigation Services* (Montreal, 19-28 June 2000) Agenda item 5.2, ICAO Doc. ANSConf-WP/65 (2000), online: ICAO <http://www.icao.int/icao/en/atb/ansconf2000/docs/wp65e.pdf> (date accessed: 21/11/2005).

162 *Ibid.*

163 *Ibid.*

The method selected by Eurocontrol is the "requirements-driven" method[164]. This is based on three elements: the number of users; the users' requirements by phase of operation or application (Non Precision Approach-like operations, Category I-like operations and Category II/III-like operations); and the incremental costs of providing levels of service to meet the users' requirements.

This method recognizes the multi-modal nature of Global Navigation Satellite Systems. Aviation is only one potential user and should therefore be treated in a fair and non discriminatory manner[165]. According to the methodology, users are regrouped in four categories: road, rail, maritime and aviation. The costs allocated to civil aviation have been estimated at 28 million euros (out of a total cost of three billion euros for Global Navigation Satellite Systems). Less than one percent of the cost should be borne by aviation users for a constellation of satellites providing Category I landing capability[166].

This method can also be used to allocate costs according to phases of flights and between states. The NPA-like requirement band would be used to evaluate the costs for the en-route phase of flights depending on the time spent in the system or the distance flown. The costs would be then allocated to the states or the providers of en-route Air Traffic Services. Costs for the approach/terminal phases would be determined according to the number of flights and in reference to the CAT I-like and CAT II/III like requirement bands. They would be allocated to the service providers (namely, states, Air traffic Service Providers, and airports).

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[164] The methods analysed by Eurocontrol included: number of users, direct benefits, infrastructure savings and requirements-driven method.

[165] Association of European Airlines, "Galileo SATNAV: airspace users position paper"(1st July 2003), online: ERAA <http://www.eraa.org/030702FINALjointpositiononGalileoEGNOS.pdf> (date accessed: 3/09/2005).

[166] *Ibid.*

The Air Navigation Services Economics Panel is still working on the cost allocation issue but has already endorsed a set of principles based on the Eurocontrol study[167]. First, basic Global Navigation Satellite Systems will be provided free of charge, with the possibility of imposing a licence or small equipment-related fee. More advanced services would be charged at the regional level and civil aviation users will contribute to the costs of these services in the regions where they operate through air navigation services charges. Allocation of the costs between civil aviation and other users should be based on the users' requirements and in consultation with civil aviation users. Ultimately, it is essential that a cost allocation scheme is agreed on and implemented promptly in order to facilitate the full use of Global Navigation Satellite Systems for aviation[168].

2/ The liability issue

The question of liability for Global Navigation Satellite Systems is a predominant and contentious issue. There are several difficulties involved. First, the development of independent Global Navigation Satellite Systems such as Galileo, as well as augmentation systems, show that, at least in the short-term, there will not be one single system but rather "a cluster of different global and regional systems which could not function independently in the absence of the core elements"[169]. International coordination may be required to guarantee the effective operation of the system to the users worldwide.

Second, Global Navigation Satellite Systems have many applications and civil

[167] ICAO Assembly, 35th session, Economic Commission, Agenda item 28, *The importance of GNSS cost allocation*, ICAO Doc. A35-WP/229 (2004), online: ICAO <http://www.icao.int/icao/en/assembl/a35/wp/wp155_en.pdf> (date accessed: 21/11/2005).

[168] *Ibid.*

[169] ICAO, *Report of the Secretariat Study Group on Legal Aspects of CNS/ATM Systems*, 1st meeting, ICAO Doc. SSG-CNS/I-Report (3 April 1999).

aviation is only one potential user. The issue is whether there should be a separate and distinct liability regime for each category of users. To date, air navigation services are provided on a national basis and liability for these activities is a matter of domestic legislation. However, with the advent of Global Navigation Satellite Systems, states will be dependent on foreign entities for the provision of part of their air navigation services, creating a global dimension to the provision of such services.

In case of an accident caused by the malfunction or failure of Global Navigation Satellite Systems the following actors could be involved, each one subject to its own liability regime: the signal provider, the regional and local augmentation system operators, the national Air Traffic Control provider, the regulatory aviation administration of the state where the accident occurred, the air carrier, the aircraft operator, the aircraft and equipment manufacturers, and third parties interfering with the signals[170]. Currently, there is not a single, unified global liability regime, but rather a multiplicity of uncoordinated and sometimes inaccessible regimes. For this reason, some states are calling for an international convention regulating liability for GNSS.

A/ The existing liability regimes

This section will address the currently liability regimes of the different actors that may be involved in a Global Navigation Satellite Systems related accident.

The GNSS signal providers

GNSS signal providers are either states (for GPS and Glonass) or international

[170] Francis P. Schubert, "An International Convention on GNSS liability: *When Does Desirable Become Necessary?*", (1999) XXIV Annals of Air and Space Law 1.

organizations (for Galileo). Which regime should govern the liability of the providers? Are space law treaties applicable?

The principles established by the 1967 *Treaty on principles governing the activities of States in the exploration and use of outer space, including the moon and other celestial bodies* (Outer Space Treaty) applies to Global Navigation Satellite Systems. Under the terms of the Treaty, GNSS use of outer space "shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind" (Article I (1)). Provider states have a duty of care in the operation of Global Navigation Satellite Systems. The "common interest" principle can be considered as a principle of customary international law (or jus cogens), and thus applicable to all states (both contracting and non-contracting states)[171].

The second principle under the Treaty is the freedom of use and exploration (Article I (2)). Accordingly: "Outer space, including the moon and other celestial bodies, 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, and there shall be a free access to all areas of celestial bodies".

The principle of non-appropriation of outer space (Article II) also applies; providing that "Outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means". This principle is opposed to the principle of complete and exclusive sovereignty of states over the airspace above their territory, upon which air law is grounded.

[171] Ruwantissa I. R. Abeyratne, "State responsibility in classical jurisprudence : reflections on the Global Navigation Satellite System" (1998) XXIII Annals of Air and Space Law 1.

According to Article III, activities shall be carried out "in accordance with international law, including the Charter of the United Nations, in the interest of maintaining international peace and security and promoting international co-operation and understanding".

Under Article VI, contracting states "shall bear international responsibility for national activities in outer space, including the moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities". Authorization and continuing supervision by the appropriate state is required for activities of non-governmental entities in outer space. Finally, where activities are carried out in outer space by an international organization, "responsibility for compliance with this treaty shall be borne by both the international organization and by the States Parties to the Treaty participating in such organization".

Article VII imposes international liability upon the launching state(s) for damage caused to other contracting states and their natural or juridical persons:

> Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the moon and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including the moon and other celestial bodies.

Under the 1971 *Convention on the international liability for damage caused by space objects* (the Liability Convention), the launching state is liable for loss of life, personal injury or other impairment of health, damage to property of states or their natural or juridical persons, and damage to property of international organizations (Article I(a): definition of damage). The launching state is absolutely liable for "damage caused by its space object on the surface of the earth or to aircraft in flight" (Article II).However, with respect to damage caused in outer space or to another spacecraft in flight, liability is based on fault: "In the event of damage being caused elsewhere than on the surface of the earth [...], the [launching State] shall be liable only if the damage is due to its fault or the fault of whom it is responsible" (Article III).

The Liability Convention is therefore applicable to damages that directly result from the physical impact of a space object (direct damage). But what happens in instances of indirect damages? In other words, does the Convention cover the transmission of an erroneous or improper navigation signal resulting in a plane crash? The text is unclear but the majority view, including that of the United States[172], is that neither the text nor the spirit of the Liability Convention would cover indirect damages[173] since "this instrument is concerned with the consequences of direct physical impact with space objects launched by states"[174].

In case of accidents involving failure or malfunction of Global Navigation Satellite Systems, the liability of the signal provider is therefore governed under the provisions of its domestic law[175]. Victims will often have to commence action in a

[172] Paul B. Larsen, "GNSS International Aviation Issues" (1998) 3.02 IISL 185.

[173] ICAO, *Panel of Experts on the Establishment of a Legal Framework with Regards to GNSS*, report of the 1st meeting, ICAO Doc. LTEP/1 (25-30 November 2005).

[174] ICAO, *LTEP/Working Group on GNSS Framework Provisions*, ICAO Doc. LTEP-WG/II-WP/3 (22-25 April 1997); Francis P. Schubert, "An International Convention on GNSS liability: *When Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1; Roderick D. van Dam , "GNSS and Aviation: Eurocontrol's perspective" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1; Paul B. Larsen, "GNSS International Aviation Issues" (1998) 3.02 IISL 185; Ingrid Lagarrigue, "Are Existing Navigation Satellite Liability Provisions Adequate to Govern a Navigation Satellite Malfunction?" (February 2000) Outer Space Committee Newsletter.

[175] Francis P. Schubert, "An International Convention on GNSS liability: *When Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1; Roderick D. van Dam, "GNSS and Aviation: Eurocontrol's perspective" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1; Paul B. Larsen, "GNSS International Aviation Issues" (1998) 3.02 IISL 185; Ingrid Lagarrigue, "Are Existing Navigation Satellite Liability Provisions Adequate to Govern a Navigation Satellite Malfunction?" (February 2000) Outer Space Committee

foreign court (namely, the court of the provider state) since states usually submit only to the jurisdiction of their own courts.

The United States considers that GPS is subject to the same liability provisions as other air navigation aids. As such, liability in the United States is determined under the Federal Tort Claims Act. The Government will be held liable when the alleged damage has been caused by a negligent or wrongful act or omission by government employees acting within the scope of their duties. This is a fault-based regime with unlimited liability. However, this waiver of immunity does not apply to non-mandatory conduct, and it does not cover claims for monetary damages arising in a foreign country. In *Smith v. United States*, the Supreme Court held that the Federal Tort Claim Act does not apply to negligent government acts committed outside US territory[176]. As such, the existing legal regime in the United States does not provide sufficient guarantees to GNSS users worldwide[177].

The liability regime applicable in the Russian Federation with respect to the provision of Glonass signals is unknown, although it should be the same regarding deficiencies in the provision of air navigation services[178].

The *Treaty of Amsterdam*[179] and the *Convention for the establishment of a European Space Agency* (the European Space Agency Convention)[180] contain specific

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Newsletter.

176 *Smith v. United States*, 507 U.S. 197 (1993).

177 Francis P. Schubert, "An International Convention on GNSS liability: *When Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1; Paul B. Larsen, "GNSS International Aviation Issues" (1998) 3.02 IISL 185; Ingrid Lagarrigue, "Are Existing Navigation Satellite Liability Provisions Adequate to Govern a Navigation Satellite Malfunction?" (February 2000) Outer Space Committee Newsletter.

178 ICAO, *Exchange of Letters between ICAO and the Russian Federation*, 4 June and 29 July 1996, ICAO State Letter LE 4/49.1-96/80 (dated 20 September 1996); Francis P. Schubert, "An International Convention on GNSS liability: *When Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1.

179 *Treaty of Amsterdam, 2 October 1997, online: eurotreaties <http://www.eurotreaties.com/amsterdamtreaty.pdf> (date accessed: 21/11/2005).*

180 *Convention for the establishment of a European Space Agency*, 30 May 1975, CSE/CS(73)19 rev.7, online: ESA <http://esamultimedia.esa.int/docs/SP1271En_final.pdf> (date accessed: 21/11/2005).

provisions governing, respectively, the liability of the European Union and the liability of the European Space Agency.

According to Article 288(1) of the *Treaty of Amsterdam*, contractual liability is determined by the law applicable to the contracts in question. Article 288(2) regulates non-contractual liability, stating that the European Union "shall, [...] make good any damage caused by its institutions or by its servants in the performance of their duties". These articles could be applied to indemnify the victims of damage caused by a Galileo failure or malfunction[181].

The European Space Agency is immune from liability with respect to its non-commercial activity. However, this immunity is waived "in all cases where reliance upon it would impede the course of justice" and if "immunity can be waived without the prejudicing the interests of ESA" (Article III, Annex I, European Space Agency Convention). Currently, the European Space Agency cannot be held liable in case of a Galileo failure or malfunction since its immunity has not been waived. But Galileo is supposed to bring major commercial benefits, including the creation of thousands of jobs, and therefore GNSS activities could be categorized as a "commercial activity" for the purposes of the Convention. If this is the case, the European Space Agency will not be immune from liability[182].

Eurocontrol may also be held liable for a failure or malfunction of Galileo under the *Eurocontrol International Convention relating to co-operation for the safety of air navigation* (the Eurocontrol Convention)[183]. Article 28 of the Protocol of 1981 and Article 25 of the Protocol of 1997 also establish liability. Eurocontrol's

181 Ingrid Lagarrigue, "Are Existing Navigation Satellite Liability Provisions Adequate to Govern a Navigation Satellite Malfunction?" (February 2000) Outer Space Committee Newsletter.

182 *Ibid.*

183 *Eurocontrol International Convention relating to co-operation for the safety of air navigation*, 13 December 1960, online: FCO <http://www.fco.gov.uk/Files/kfile/CM5587,0.PDF> (date accessed: 21/11/2005).

contractual liability is governed by the law applicable to the contract in question. With respect to non-contractual liability, Eurocontrol must make reparation for "damage caused by the negligence of its organs or of its servants acting within the scope of their duties in so far as the damage could be attributed to them".[184]

Regional augmentation system operators

As noted above, the existing global navigation satellite systems cannot meet the requirements of civilian users, as is the case in air navigation, in terms of accuracy, integrity and availability. Therefore, the basic constellations are augmented by an overlay system. Augmentation systems are currently being implemented or developed in the United States, Europe, Japan and India.

The role of the regional augmentation system operator is to improve the quality of the Global Navigation Satellite Systems signal. In case of a deficiency in the provision of the end signal, the operator can potentially be held liable. Allocating liability between the primary provider and the augmentation system provider can be problematic, given that the impact of the latter operator on the end signal may be difficult to determine in practice.

Eurocontrol proposed a "contractual chain" model which aimed to simplify the legal procedure and channel liability to the appropriate actors (whether primary signal providers, augmentation system operators, or states and other entities)[185].

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184 Ingrid Lagarrigue, "Are Existing Navigation Satellite Liability Provisions Adequate to Govern a Navigation Satellite Malfunction?" (February 2000) Outer Space Committee Newsletter.

185 EU, Commission GNSS High level group, Working Group 1, *Definition of the Requirements for a Liability System for GNSS-2*, working paper 3 (5 March 1999) at 7; Francis P. Schubert, "An International Convention on GNSS liability: *When Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1; Prachee Kulkarni & Pablo Mendes de Leon, "Liability for damage in civil aviation within the context of GNSS" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1.

Non-provider states

As previously discussed, most countries will not provide Global Navigation Satellite Systems signals but rather will have to rely on signals and their augmentations provided by other states[186]. In the case of a Global Navigation Satellite Systems related accident occurring over the territory of a non-provider state, the liability of that state may be in question.

States have to fulfil legal responsibilities under Article 28 of the Chicago Convention. This requires states to take all practicable measures to provide within their territories "airports, radio services, meteorological services and other air navigation facilities to facilitate international air navigation, in accordance with the standards and practices recommended or established from time to time, pursuant to this Convention". States may delegate the provision of air navigation services to another entity, including a commercial or private operator[187], but remain ultimately responsible for damage under Article 28[188]. Accordingly the functions of service regulation and service provision can be seen as legally distinct. With the advent of Global Navigation Satellite Systems, part of the air navigation support will be delegated to and provided by foreign entities. However, "the implementation of GNSS leaves unaffected the responsibility of States under article 28"[189]. The provision of

[186] ICAO, *Final Report on the Work of the Secretariat Study Group on the Legal Aspects of CNS/ATM Systems"*, ICAO Doc. C-WP/12197 Appendix (2004); Francis P. Schubert, "An International Convention on GNSS liability: W*hen Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1.

[187] ICAO, Air Navigation Services Economic Panel, *Report on financial and related Organisational and Managerial Aspects of Global Navigation Satellite System (GNSS) Provision and Operation*, ICAO Doc. 9660 (May 1996).

[188] ICAO, *Report of the Secretariat Study Group on Legal Aspects of CNS/ATM Systems*, 1st meeting, ICAO Doc. SSG-CNS/I-Report (9 April 1999).

[189] ICAO, *Report of the Secretariat Study Group on Legal Aspects of CNS/ATM Systems*, 1st meeting, ICAO Doc. SSG-CNS/I-Report (9 April 1999); ICAO, *Final Report on the Work of the Secretariat Study Group on Legal Aspects of CNS/ATM Systems*, ICAO Doc. A35-WP/75 Appendix (2004).

Global Navigation Satellite Systems services by foreign entities is similar to the situation where responsibility for providing air navigation services is delegated by one state to another[190].

The meaning and extent of the responsibilities of non-provider states under Article 28 of the Chicago Convention are nevertheless subject to controversy[191].

First, a non-provider state has regulatory and supervisory duties according to which it must ensure that the GNSS signals provided by foreign entities and used for air navigation services over its territory, as well as its own implementation facilities and the equipment and procedures of the operators, comply with the relevant Standards And Recommended Practices (SARPs) of the International Civil Aviation Organization. Compliance with the SARPs has to be monitored on a permanent basis[192]. Non-provider states therefore have to take appropriate measures to monitor the availability, reliability and accuracy of Global Navigation Satellite Systems signals and give proper warnings in case of a disruption. In this regard, non-provider states should assume liability only when they have failed to fulfil their regulatory and supervisory duties[193].

A different view is that non-provider states remain ultimately liable. Arguably, when states delegate the provision of air navigation services to another entity, they still bear

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[190] Francis P. Schubert, "An International Convention on GNSS liability: *When Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1; Ruwantissa I. R. Abeyratne, "State responsibility in classical jurisprudence : reflections on the Global Navigation Satellite System" (1998) XXIII Annals of Air and Space Law 1; Roderick D.Van Dam , "GNSS and Aviation: Eurocontrol's perspective" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1.

[191] Francis P. Schubert, "An International Convention on GNSS liability: *When Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1.

[192] ICAO, *Final Report on the Work of the Secretariat Study Group on Legal Aspects of CNS/ATM Systems*, ICAO Doc. A35-WP/75 Appendix (2004).

[193] Francis P. Schubert, "An International Convention on GNSS liability: *When Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1; Roderick D. van Dam , "GNSS and Aviation: Eurocontrol's perspective" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1.

ultimate liability, while reserving all rights to engage in recourse actions against the perpetrators of the damage. If the doctrine of ultimate liability was applied to Global Navigation Satellite Systems related accidents, non provider States would have to compensate the victims for damages caused by a foreign signal provider, regardless of their negligence in fulfilling their regulatory and supervisory duties. The doctrine of ultimate liability is notably opposed by authors who argue that since non-provider states are not involved in the provision of the signals they should not be held liable[194]. Finally, it has been proposed that non-provider states should assume liability only when they have approved the use of Global Navigation Satellite Systems signals and services for air navigation purposes[195].

Responsibility under Article 28 is not the same as liability. Article 28 regulates relations between states only and does not give a cause of action to private persons to claim compensation for damages[196]. The liability regime of non-provider states will be the same as that of states for air navigation services. Since there is no applicable international regime, this issue will be governed by domestic laws.[197]. The provisions governing state liability for the performance of public services will often apply. This is usually a fault-based liability regime with unlimited liability. Claimants would have to take action against the relevant country in front of its own domestic jurisdictions, as most states refuse to submit to the jurisdiction of a foreign court[198].

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194 *Ibid.*

195 *Ibid.*

196 ICAO, *Final Report on the Work of the Secretariat Study Group on Legal Aspects of CNS/ATM Systems*, ICAO Doc. A35-WP/75 Appendix (2004).

197 Ruwantissa I. R. Abeyratne, "State responsibility in classical jurisprudence : reflections on the Global Navigation Satellite System" (1998) XXIII Annals of Air and Space Law 1; Francis P. Schubert, "An International Convention on GNSS liability: W*hen Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1.

198 Francis P. Schubert, "An International Convention on GNSS liability: W*hen Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1.

Air Traffic Control providers

Air Traffic Control Agencies can also be held liable under certain conditions in the case of an accident caused by a Global Navigation Satellite Systems failure or malfunction. Indeed, air traffic controllers have the duty to detect Global Navigation Satellite Systems malfunctions, warn users, and take corrective measures[199]. If the negligence of the agents of the Air Traffic Control agencies can be established, they will be held liable unless they prove that in the circumstances of the accident it was either impossible or not required for them to detect the failure or malfunction[200].

Air Traffic Control agencies in most countries are still state-run organizations, even though an increasing number of countries are privatizing this activity. Domestic laws governing the liability of government's civil servants apply. In most cases, this is a fault-based regime with unlimited liability, but rules may vary from state to state. In the United States, under the Federal Tort Claims Act, it must be demonstrated that the Air Traffic Controller was negligent, and that this negligence was the proximate cause of the damage, in order to hold the Government liable. However, an Australian court held in *Austrian National Airlines v The Commonwealth of Australia and Canadian Pacific Airlines* (1971) that both airlines involved in the accident were liable for 30 percent of the damages respectively, while the Air Traffic Control agency was liable for 40 percent of the total costs since the avoidance of collisions is a primary task of an Air Traffic Control agency[201].

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199 *Ibid.*
200 *Ibid.*
201 Prachee Kulkarni & Pablo Mendes de Leon, "Liability for damage in civil aviation within the context of GNSS" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1.

The air carrier

In the case of a Global Navigation Satellite Systems-related accident, the air carrier can be both a claimant and a defendant. With respect to the liability of the air carrier, several air law instruments exist, including: the Warsaw Convention of 1929[202], the Warsaw Convention as amended by the Hague Protocol of 1955[203] and the Montreal Protocols of 1975[204], intercarrier agreements[205] and the European Community Regulation 2027/97 (applicable to Community carriers)[206]. On 4 November 2003, the Montreal Convention entered into force[207]. These instruments govern the contractual liability of the air carrier towards its passengers, but do not contain specific rules for Global Navigation Satellite Systems[208]. However, can they be applied to deal with the liability of the air carrier in case of a plane crash caused by a failure or malfunction of Global Navigation Satellite Systems?

The Warsaw Convention is based on the presumed fault of the carrier. This is favourable to the victim, since it can be difficult to demonstrate actual negligence on the part of the carrier in practise. The carrier will be held liable unless it proves that it has taken "all necessary measures to avoid the damage, or it was impossible [...] to take such measures" (Article 20). In case of an accident caused by malfunction of a Global Navigation Satellite System, the carrier will be exonerated fully or partially if

202 *Warsaw Convention for the Unification of Certain Rules Relating to International Carriage by Air*, 12 October 1929, 137 LNTS 11, ICAO Doc. 7838.

203 *Protocol to Amend the Convention for the Unification of Certain Rules Relating to International Carriage by Air*, 28 October 1955, ICAO Doc. 7632.

204 *Additional Protocols No.1, 2, 3, 4 to Amend the Convention for the Unification of Certain Rules Relating to International Carriage by Air*, 25 September 1975, ICAO Doc. 9145, 9146, 9147, 9148

205 IATA Montreal Agreement of 1966, Private International Air Law casebook vol.1 (McGill University, 2004) at 405; IATA Intercarrier Agreement on Passenger Liability of 1995-1996, Private International Air Law casebook vol.1 (McGill University, 2004) at 407.

206 EC, *Council Regulation 2027/97 of 9 October 1997 on air carrier liability in the event of accidents* [1997] O.J.L. 285 at 1.

207 *Convention for the Unification of Certain Rules for International Carriage by Air*, 28 May 1999, ICAO Doc. 9740.

208 Ingrid Lagarrigue, "Are Existing Navigation Satellite Liability Provisions Adequate to Govern a Navigation Satellite Malfunction?" (February 2000) Outer Space Committee Newsletter.

it proves that the malfunction was not detectable and that there were no available means to avoid the accident[209]. The presumption of fault is balanced by the fact that .the liability of the carrier is very limited. The only means for a passenger to escape from this limitation and obtain full compensation for the damage suffered is to establish the wilful misconduct of the carrier (Article 25 Warsaw Convention): for instance, that the aircrew deliberately ignored warnings of a Global Navigation Satellite Systems malfunction. The Warsaw system provide four competent jurisdictions: the court of the carrier's domicile, the court of the carrier's principal place of business, the court where there is an establishment by which the contract has been made, or the court that has jurisdiction over the place of the accident (Article 28 Warsaw Convention).

The Montreal Convention of 1999 incorporates provisions adopted by the Montreal Agreement of 1966, the IATA agreement of 1995/1996 and the European Community Regulation 2027/97 and attempts to modernize the Warsaw System. A two-tier liability regime is established with strict liability for damages to passengers up to 100, 000 SDRs[210] and unlimited liability based on presumed fault of the carrier for claims exceeding that limit. A fifth jurisdiction is added: the court "in the territory of a State in which at the time of the accident the passenger has his or her principal and permanent residence and to or from which the carrier operates services for the carrier of passengers..." (Article 32(2)). In the first tier, the carrier cannot use the "all necessary measures" to be exonerated from its liability and in principle should be held liable regardless of the source of the damage[211].

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209 Prachee Kulkarni & Pablo Mendes de Leon, "Liability for damage in civil aviation within the context of GNSS" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1; Francis P. Schubert, "An International Convention on GNSS liability: W*hen Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1.

210 Special Drawing Rights.

211 Prachee Kulkarni & Pablo Mendes de Leon, "Liability for damage in civil aviation within the

The aircraft operator

The air carrier and the aircraft operator can be distinct entities. An aircraft operator is "the person who was making use of the aircraft at the time the damage was caused, provided that if control of the navigation of the aircraft was retained by the person from whom the right to make use of the aircraft was derived, whether directly or indirectly, that person shall be considered as the operator"[212] .

Third parties on the ground who suffer damage in the event of an accident can sue the aircraft operator under the *Convention on Damage caused by Foreign Aircraft to Third Parties on the Surface* (the Rome Convention)[213]. Nevertheless, the use of the Rome Convention for accidents caused by a Global Navigation Satellite Systems failure or malfunction seems to be limited[214]. First, the Convention only applies in cases of damage to third parties in the territory of a contracting state by an aircraft registered in another contracting state (Article 23). Moreover, only 42 states have ratified the Convention. (the liability limits are very low). On the other hand, the Convention establishes a regime of strict liability (Article 2) so there is no need to prove the negligence of the aircraft operator. The claimant must simply establish the damage and a proximate cause of the accident, without having to refer to the source of the accident (which could be a Global Navigation Satellite System malfunction). However, the monetary liability of the aircraft operator is very limited, depending on the weight of the aircraft (Article 11). If victims want to obtain full compensation for

context of GNSS" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1.

212 *Convention on Damage Caused by Foreign Aircraft to Third Parties on the Surface*, 7 October 1952, 310 UNTS 181, article 2(a).

213 *Convention on Damage Caused by Foreign Aircraft to Third Parties on the Surface*, 7 October 1952, 310 UNTS 181.

214 Francis P. Schubert, "An International Convention on GNSS liability: *When Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1; Prachee Kulkarni & Pablo Mendes de Leon, "Liability for damage in civil aviation within the context of GNSS" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1;

damages exceeding the limit, they must demonstrate a "deliberate act or omission of the operator [...] done with intent to cause damage" (Article 12).

The equipment manufacturer

Victims of a GNSS accident may also seek compensation from the aircraft or the equipment manufacturer. The manufacturer of a deficient navigation satellite or receiver can be held liable under the applicable product liability rules. The United States as well as the European product liability laws will be examined in this part.

If a product is manufactured in the United States, the Restatement Second of Torts Act, s402A[215] is applicable. The manufacturer will be held liable if the product is in "defective condition unreasonably dangerous" to users: that is, if the product is dangerous beyond the expectation of the ordinary consumer or if a less dangerous alternative or modification was economically feasible. American product liability law has already been applied in cases dealing with misuse of GPS technology, use of uncertified hand-held GPS receivers by general aviation pilots and failure of receiver equipment[216].

The Product Liability Directive 85/374/EEC[217] applies to products manufactured within the European Union. The producer assumes liability for the damage caused by a defect in his product (Article 1). Article 2 gives the definition of a "product", which includes all movables even when the products are incorporated into another immovable. Electricity is considered as a "product" (Article 2). Thus, both Galileo satellites and its receivers can be categorized as products under the Directive.

215 Ingrid Lagarrigue, "Are Existing Navigation Satellite Liability Provisions Adequate to Govern a Navigation Satellite Malfunction?" (February 2000) Outer Space Committee Newsletter.

216 *Ibid.*

217 EC, *Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products [1985] O.J.L.210/29.*

However, how about a Galileo signal? Is it a product or a service? The Directive does not provide an answer. Radio electric waves have been qualified as a "product" by French jurisdictions[218]. The courts in other jurisdictions may have the opportunity to resolve the question once Galileo is in operation.

There are many liability regimes potentially applicable to Global Navigation Satellite Systems. Some experts are in favour of the adoption of an international convention, others do not see the need for a new instrument. A third group supports a contractual framework as an alternative solution. The debate dates from the creation of the Legal and Technical Experts Panel on Global Navigation Satellite Systems (LTEP).

B/ Is an international convention necessary?

A first group, essentially represented by provider states and centered around the United States, opposes the creation of an international convention on liability for Global Navigation Satellite Systems. They argue that existing liability regimes are adequate to address all aspects of Global Navigation Satellite Systems. Moreover, GPS has been in operation for a number of years under the current regimes and no difficulties have been encountered. Further, it is argued that an international convention is not a necessary prerequisite for the implementation of navigation satellite systems[219].

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[218] Cass.crim, 3 August 1912, DP 1913.I.439.

[219] Francis P. Schubert, "An International Convention on GNSS liability: W*hen Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1; memorandum from Francis P. Schubert on Global Navigation Satellite Systems (2004); ICAO, *Report on the establishment of a legal framework with regard to CNS/ATM system including GNSS*, ICAO Doc. A35-WP/75 (2004).

The second group is represented by non-provider states in the developing world (Latin America and Africa) and European countries. They argue that an international convention is necessary. First, the fact that GPS has been working for years without any difficulty with respect to liability does not prove that the existing regime is adequate. This is particularly the case given that there have not been any major GPS failures since its inception.

This group points out that the current system is fragmented into numerous and uncoordinated liability regimes. While mechanisms for compensation do exist, there is no coordination between the various applicable regimes. It is impossible to bring all parties before the same court. Moreover, claims against foreign states and their agencies may be impossible because of the principle of sovereign immunity. Such a complex system results in endless series of legal proceedings with a risk of partial or total denial of compensation. Finally, most national laws place the burden of proof on victims to establish negligence. By contrast, an international convention could adopt a victim-oriented approach to overcome the deficiencies of the existing regime and establish a comprehensive and fair legal framework. A convention would also guarantee the predictable allocation of liability between the various actors[220].

Non-provider states, including a great number of developing countries, also stress the need for an international convention to increase confidence in Global Navigation Satellite Systems. Because these countries will have to authorize the use of Global Navigation Satellite Systems over which they have no control, they are eager to commit both providers and users to certain rights and obligations in the form of a binding international legal instrument[221]. The existing *Charter on the Rights and*

[220] Roderick D. van Dam , "GNSS and Aviation: Eurocontrol's perspective" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1; Francis P. Schubert, "An International Convention on GNSS liability: *When Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1; memorandum from Francis P. Schubert on Global Navigation Satellite Systems (2004).

[221] ICAO, *Eleventh Air Navigation Conference* (Montreal, 22 September to 3 October 2003) Agenda

Obligations of the States Relating to GNSS Services cannot assure legal certainty since it is not binding[222]. The Honorable K.O. Rattray, Solicitor of Jamaica, stated at the World-wide CNS/ATM Conference of 1998:

> All these issues relating to liability must be resolved in order to inspire confidence, give credibility to the system and establish the foundations for universal acceptability on a sustainable basis. An international convention which established the legal obligations and liabilities of States and services providers is necessary in order to provide the necessary guarantees[223].

Even though it is not an absolute prerequisite for the implementation of Global Navigation Satellite Systems, an international convention may be necessary to ensure non-provider state confidence in the system. This, in turn, would greatly facilitate the successful implementation of Global Navigation Satellite Systems.[224]

Some members of the Secretariat Study Group on Legal Aspects of CNS/ATM Systems presented a list of the main elements to be included in an international convention. The *Proposal by Certain Members of the Study Group relating to Main Elements of an International Convention*[225] covers elements notably derived from the *Charter on the Rights and Obligations of States Relating to GNSS services,* such as acknowledgement of the paramount importance of safety of international civil

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item 6.2, ICAO Doc. AN-Conf/11-WP/143 (2003); ICAO, *Report on the establishment of a legal framework with regard to CNS/ATM system including GNSS*, ICAO Doc. A35-WP/75 (2004); ICAO, *Report of the World-wide CNS/ATM Systems Implementation Conference* (15 May 1998), online: ICAO <.http://www.icao.int/icao/en/ro/rio/finrep.html#ag1> (date accessed: 10/10/2005); Francis P. Schubert, "An International Convention on GNSS liability: *When Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1.

222 Memorandum from Francis P. Schubert on Global Navigation Satellite Systems (2004); ICAO, *Eleventh Air Navigation Conference* (Montreal, 22 September to 3 October 2003) Agenda item 6.2, ICAO Doc. AN-Conf/11-WP/143 (2003).

223 The Hon. K.O. Rattray, QC, "legal and Institutional Challenges for GNSS, the Need for Fundamental Obligatory Norms" (paper presented to the World-wide CNS/ATM Conference in Rio de Janeiro, May 1998), online: Air Safety Week <http://www.findarticles.com/p/articles/mi_m0UBT/is_23_12/ai_50058817/print> (date accessed: 21/11/2005).

224 Francis P. Schubert, "An International Convention on GNSS liability: *When Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1.

225 ICAO, *Proposal by Certain Members of the Study Group relating to Main Elements of an International Convention*, ICAO Doc. A35-WP/75 Appendix Attachment H (2004).

aviation, unlimited access to Global Navigation Satellite Systems services on a non-discretionary basis, the sovereign right of every state to control operations of aircraft and enforce safety of regulations within its airspace, the obligation of providers to ensure continuity, availability, accuracy, transparency and uniformity in the provision and operation of services, and certification.

With respect to liability for loss or damage caused by the failure, malfunction or improper use of Global Navigation Satellite Systems or services, two solutions are proposed: a two-tier liability regime in line with the Montreal Convention of 1999 with a strict liability up to a determined limit and a fault-based liability for claims exceeding that limit, or alternatively, a fault-based liability regime with a reversed burden of proof. Providers would be held jointly and severally liable to the extent to which they are at fault in case of damage caused by more than one system.

Further provisions could establish the conditions under which sovereignty immunity could not be invoked "to avoid situations where parties would be unable to seek redress due to this rule"[226].

To avoid the possibility of multiplicity of actions in different jurisdictions, the Proposal would allow victims of a Global Navigation Satellite Systems related accident to bring all claims in a single jurisdiction. Recourse to arbitration mechanisms could also be considered, since it would resolve the issue of foreign jurisdiction immunity and the reluctance of states to appear in front of a foreign national jurisdiction. The competent jurisdiction or arbitration tribunal could apply "the liability regime applicable in accordance with existing international and internal rules[227]". Finally, system operators and service providers could be required to provide adequate risk coverage[228]. Note, however, that this Proposal does not represent the

226 *Ibid.*
227 *Ibid.*
228 *Ibid.*

view of the majority of the Study Group. A third group proposed a contractual framework as an alternative solution between the status quo and the long-term elaboration of an international convention[229].

C/ A contractual framework as an interim solution?

The notion of a contractual framework was proposed by the member states of the European Civil Aviation Conference. It is supported by the European Commission and has been discussed within the Secretariat Study Group on Legal Aspects of CNS/ATM systems[230]. The proposal covers the contractual relationships between the parties involved in the implementation, operation, provision and use of Global Navigation Satellite Systems services; including primary signal providers, augmentation signal providers and states with jurisdiction under Article 28 of the Chicago Convention.

The proposal adopts a two-tier approach, involving a series of private law contracts between the various parties involved as well as a public law agreement between the participating states to ensure that these contracts are harmonized and contain common provisions on safety, certification, liability and jurisdictional matters[231].

After discussing in detail the concept of a contractual framework, the Study

[229] ICAO, *Report on the establishment of a legal framework with regard to CNS/ATM system including GNSS*, ICAO Doc. A35-WP/75 (2004).
[230] *Ibid.*
[231] Eurocontrol, "GNSS legal framework contractual framework for the implementation, provision, operation and use of the Global Navigation Satellite System for air navigation purposes" (presented to the Eleventh Air Navigation Conference in Montreal, 22 September-3 October 2003, Agenda item 6), ICAO Doc. AN-Conf/11-WP/153 (2003); ICAO, *Report on the establishment of a legal framework with regard to CNS/ATM system including GNSS*, ICAO Doc. A35-WP/75 (2004); ICAO, *Development of a contractual framework leading towards a long-term legal framework to govern the implementation of GNSS*, ICAO Assembly, 35[nd] session, ICAO Doc. A35-WP/125 (2004).

Group presented in its final report a *Draft Contractual Framework Relating to the provision of GNSS services*[232] (the Draft Contractual Framework). The framework delineates the rights and obligations of the Air Traffic Services Provider and the Global Navigation Satellite Systems Signal Provider with respect to "all services related to the GNSS signals for the purpose of air navigation" (Article 1).

Each contract is applicable to the airspace where the Air Traffic Services Provider is responsible for providing its services. This could be a State with jurisdiction under Article 28 of the Chicago Convention, a private entity charged by the state, or an international organization (Eurocontrol for instance). Both primary signal providers and augmentation signal providers are considered as Global Navigation Satellite Systems Signal Providers (Article 2). Like Air Traffic Services Providers, they may be states, private entities, or international organizations.

The obligations of the signal provider are set out in Article 3 and include the provision of signals with guarantees of continuity, availability, integrity, accuracy and reliability. If the signal provider is not a state entity, it must obtain a licence from the state in territory of which the signals are controlled. Moreover, it has to comply with the safety management provisions of the relevant Standards and Recommended Practices of the International Civil Aviation Organization and provide information on any modification of the signals which may affect the services provided by the Air Traffic Services Provider.

Under Article 4, the Air Traffic Services Provider must, if it is not a state entity, "obtain from the relevant State the necessary authorization for the use of GNSS signals". Its other obligations include coordination with the Global Navigation Satellite Systems Signal Provider with a view to facilitating the transmission of the

[232] ICAO, *Draft Contractual Framework Relating to the provision of GNSS services*, ICAO Doc. A35-WP/75 Appendix Attachment F (2004).

signals, compliance with the safety management provisions of the relevant standards and Recommended Practices and, if applicable, payment of the service charges to the signal provider.

The Global Navigation Satellite Systems signal provider is entitled to establish a cost recovery mechanism, in accordance with Article 15 of the Chicago Convention and Paragraph 6 of the *Charter on the Rights and Obligations of States relating to GNSS services*. Reasonable allocation of the costs between civil aviation and other users, as well as between civil aviation users themselves, is required, in line with the Eurocontrol's methodology and the position of the airlines[233].

Article 6 provides that "[t]he liability of each Party for failure to perform its obligations under this contract shall be governed by the liability regime applicable to its activity". The Draft Contractual Framework only focuses on contractual liability and does not address liability towards third parties.

The right to invoke sovereign immunity is waived (Article 8) and disputes related to the performance or interpretation of the contract are to be settled through negotiation, conciliation or arbitration mechanisms (Article 9).

Some members of the Study Group have argued in favour of expansion beyond the content of the Draft Contractual Framework. They call for the introduction of a set of mandatory elements, which would apply to all contracts, with the aim of maintaining a desired degree of uniformity. These mandatory elements would include: compliance with the Standards and Recommended Practices; compliance with the *Charter on the Rights and Obligations of the States Relating to GNSS Services* with respect to continuity, availability, integrity, accuracy and reliability; compulsory risk coverage; recognition that organizations of states are subject to the same rules as private parties;

[233] See Chapter III.1, above, for more on the cost allocation issue.

waiver of the right to invoke sovereign immunity; and mandatory recourse to arbitration. The role of the International Civil Aviation Organization in the implementation of the Global Navigation Satellite Systems is also recognized. Liability should be based on fault[234].

A contractual framework would cover the legal and institutional elements related to the Global Navigation Satellite Systems at the regional level with more flexibility than an international convention. It would also provide clarity and legal certainty by defining the roles, responsibilities, and liabilities of the parties involved and therefore harmonize their contractual relationships. It could also be used to provide experience, and would represent a first step towards the adoption of a binding international instrument in the long-term[235]. However, the contractual framework proposed by the Secretariat Study Group remains subject to controversies.

D/ Assessment of the situation: an international convention might be too premature

To date, there has been no consensus either on the need for new international arrangements (due to opposition between supporters of the status quo and supporters of an international convention); nor on the form of any new agreement (international convention, or a contractual framework with or without a set of mandatory elements);

[234] ICAO, *Final Report on the Work of the Secretariat Study Group on Legal Aspects of CNS/ATM Systems*, ICAO Doc. A35-WP/75 Appendix Attachment G (2004); Eurocontrol, "GNSS legal framework contractual framework for the implementation, provision, operation and use ot the Global Navigation Satellite System for air navigation purposes" (presented to the Eleventh Air Navigation Conference in Montreal, 22 September-3 October 2003, Agenda item 6), ICAO Doc. AN-Conf/11-WP/153 (2003).

[235] ICAO, *Development of a contractual framework leading towards a long-term legal framework to govern the implementation of GNSS*, ICAO Assembly, 35nd session, ICAO Doc. A35-WP/125 (2004); Eurocontrol, "GNSS legal framework contractual framework for the implementation, provision, operation and use ot the Global Navigation Satellite System for air navigation purposes" (presented to the Eleventh Air Navigation Conference in Montreal, 22 September-3 October 2003, Agenda item 6), ICAO Doc. AN-Conf/11-WP/153 (2003).

nor on the nature of the liability to be imposed (liability based on proven fault, on presumed fault or strict liability, limited or unlimited liability). Nevertheless, a significant number of states have called for the adoption of an international convention.

According to Professor Milde and the majority view within the Secretariat Study Group, it might be too early for the elaboration of an international convention.
Indeed, Law does not govern Technology but rather the resultant social relations. "A new technological invention does not require legal regulations unless and until it creates specifically new social regulations and conflicts of social interests"[236]. The implementation of Global Navigation Satellite Systems is still ongoing. Therefore, more practical experience is necessary to identify the conflicts of social interest connected with this new technology which will be balanced through legal regulation. To date, any attempt at discussing or drafting an international convention is too premature. The International Civil Aviation Organization should refrain from hypothetical and wasteful legal considerations on Global Navigation Satellite Systems-which so far have only resulted in resolutions which lack of binding force- and should encourage the implementation of Global Navigation Satellite Systems instead. "Law if necessary but not necessary law should be the axiom motivating further work in ICAO"[237]. The elaboration of an international convention can start only after substantial experience is gained, after conflicts of social interests connected with Global Navigation Satellite Systems in practise are analyzed, and after a consensus is reached on the need for an international convention as well as on the principles to be embodied in such instrument[238]. Until this time, domestic legal

[236]Michael Milde, "Solutions in search of a problem? Legal aspects of the GNSS" (1997) XXII-II Annals of Air and Space Law 196.
[237] *Ibid.*
[238] *Ibid.*

regimes will apply, according to the ordinary principles of conflict of laws[239].

An instrument coordinating the existing regimes remains necessary to ensure prompt and fair compensation to victims of GNSS failure. The form of such an instrument is of secondary importance in practise. However, states may be less reluctant to adopt an international convention aimed only to coordinate various claims arising from a GNSS-related accident, without establishing a new liability regime.
A two-step approach could be adopted[240]. First, a single jurisdiction within the state where the accident occurred would have the task of collecting and evaluating all claims made by all plaintiffs against any defendant (preliminary assessment). This would result in the production of a single claim implicating all plaintiffs and defendants. No material decision would be rendered at this stage. The case would then move to another court, which would allocate liability between the various defendants. If there was no state involved, the competent court would be the court where the accident occurred (this could be the same court that made the preliminary assessment). However, the situation becomes more complicated if one or more states are defendants, since states are usually reluctant to appear before a foreign domestic jurisdiction. Thus, if the list of the defendants includes only one state, the court of that state would be the competent jurisdiction. If several states are involved, the determination of the competent court could be made by agreement. Recourse to traditional arbitration mechanisms is also envisaged in such case either to determine the competent court or to provide the material decision.

239 ICAO, *Final Report on the Work of the Secretariat Study Group on Legal Aspects of CNS/ATM Systems*, ICAO Doc. A35-WP/75 Appendix Attachment G (2004); Prachee Kulkarni & Pablo Mendes de Leon, "Liability for damage in civil aviation within the context of GNSS" (2000) International Bar Association Section on Business Law Committtee Z (Outer Space) v.3 n.1.

240 Francis P. Schubert, "An International Convention on GNSS liability: W*hen Does Desirable Become Necessary?*" (1999) XXIV Annals of Air and Space Law 1.

A more realistic solution could be to encourage and assess the development of the Galileo framework, which is likely to be implemented before any international arrangement is adopted within the International Civil Aviation Organization[241]. This framework would provide the necessary experience on which the elaboration of a future international instrument, if needed, could be based.

[241] Memorandum from Francis P. Schubert on Global Navigation Satellite Systems (2004).

CONCLUSION

Global Navigation Satellite Systems are a tremendous technology and the key element of the CNS/ATM systems. They will bring significant benefits in terms of safety, efficiency, capacity, and economy. The provision of vertical guidance on approach procedures where no guidance exists today, improved communications, navigation and surveillance allowing more autonomous operations of aircraft and reducing the controller workload, reduction in the separation between aircraft, increased airspace capacity and less congestion are just a few examples.

Nevertheless, Global Navigation Satellite Systems have limitations. They are extremely vulnerable to interference (unintentional and intentional) and a satellite failure is not unusual. Moreover, GPS accuracy and geographic reliability are questionable, and the United States has the prerogative to turn the system off or degrade the signal for national security reasons. The introduction of Galileo will be able to overcome or mitigate GPS vulnerabilities, and their combined used will offer great opportunities. However, the vulnerabilities identified above can be reduced but will never be fully eliminated. Depending solely on one system that can be disrupted is not acceptable for safety of life applications such as aviation. A mixed system, that is, a mix of satellite and terrestrial navigation aids seems to be the appropriate solution.

The implementation of Global Navigation Satellite Systems also raises several unique legal issues. As a result of the work of the International Civil Aviation Organization, a core set of legal principles has gradually emerged, addressing issues including universal access, continuity of services, respect of state sovereignty, liability, certification, and cost allocation. Liability in the event of a GNSS-related accident is the predominant issue, notably because of the co-existence of numerous, uncoordinated and sometimes inaccessible domestic legal regimes. Some experts have called for the adoption of an international convention, while others do not see the need for a new instrument. A third group supports the adoption of a contractual framework as an alternative solution. To date, no consensus has been reached but arguably the elaboration of an international convention may be too premature, given that the implementation of Global Navigation Satellite Systems is still ongoing and not enough experience has been gained. Hypothetical legal discussions should not be used as an excuse to slow down the implementation of Global Navigation Satellite Systems. These systems constitute a tremendously valuable technology which, when used in conjunction with terrestrial navigation aids, has the potential to revolutionize air navigation.

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