Perspectives on Global Navigation Satellite Systems as an enabler for future ATM Environment

M. Kudo

*CNS Department
Electronic Navigation Research Institute (ENRI)
Tokyo, Japan
m-kudou@enri.go.jp

Abstract: This paper describes the future perspectives on Global Navigation Satellite Systems to realize future ATM environment and discusses a possible scenario to achieve the goal. Some other aspects which may affect the future scenario other than technical matters are also addressed. In addition, the paper discuss the role and directions of research and development to support ATM and aviation industries under the expected future GNSS environment.

Keywords: GNSS, GPS, Galileo, SBAS, GBAS, MTSAT, MSAS, INS/IRS, Air Navigation

1. INTRODUCTION

Global Navigation Satellite Systems have been contributing various areas of our lives other than military purposes, for which GPS/GLONASS were originally developed by the United States of America and Russian Federation. In aviation, too, GPS is now playing an important role for safe and efficient flight operations during various flight phases. It is believed that GNSS will be still served in the future and even higher performances will be offered to users. On the other hand, space and satellite technologies will be still kept within few capable states due to financial and technical reasons. When considering possible future GNSS environment for aviation, it is necessary to pay attention to such institutional matters as well as technical ones As GNSS is playing a vital role of navigation method in various field. The paper will discuss to what extent Japan has achieved in terms of GNSS technologies so far and, based on the observation, will also discuss perspectives on GNSS technologies to support future ATM environment.

2. HISTORY OF AIR NAVIGATION TECHNOLOGIES

The history of radio navigation could easily trace back to early 20th century.

By using characteristics of electro-magnetic waves which propagates straightly regardless weather conditions, aircraft could fly safely at night and even at non visible conditions. There is no doubt that the prosperity of aviation is dependent on the development of radio navigation technologies.

The first global navigation services were provided by OMEGA system, which was in operation during 1983-1997. Most of applications provided by OMEGA were surface mobile vessels such as maritime services. While OMEGA was not actually used for air navigation in worldwide basis, however as a predecessor of satellite-based navigation, OMEGA is regarded as the first radio navigation system that had a global service capability.

Table 1 transition of global navigation technologies

Year	Technologies
-1960's	Celestial Navigation
1960's -	Inertial Navigation System
1960's – 1970's (?)	Doppler radar
1980's – 1990's	(OMEGA)
1990's -	GPS, (+ ABAS, SBAS)

Current available technologies in aviation for global navigation coverage are INS/IRS and GPS. In fact, these two technologies are used, complementing each other because of the existence of some drawbacks originated by the natures of the two technologies. GLONASS is also recognized as an internationally standardized satellite navigation system. However, in reality, the system has not been much used for aeronautical flight operations so far.

3. CURRENT SITUATION OF GNSS TECHNOLOGIES FOR AVIATION IN JAPAN

Japan has been actively involved with worldwide effort to realize GNSS as a means of aeronautical navigation. Japan launched two Multi-functional Transport Satellite (MTSAT) in 2005 and 2006 respectively and is operating these two satellites for providing GPS wide area augmentation services in Japan.

3.1 Core Satellite constellations

As of today, available satellite constellations are GPS and GLONASS. Whereas looking at user communities, GPS virtually dominates the user market. This is because the firm commitment of GPS policy by the U.S. government and its faithful implementation, which has brewed a confident among sat-nav users to GPS.

Other satellite networks intend to take part in the satellite navigation services certainly need to have exquisite strategies to compete GPS.

Some core satellite networks announced evolutional plan of their satellite constellations. GALILEO, a European new navigation satellite constellation will have a plan to be operational in mid of the next decade. The new constellation will also have excellent capabilities such as dual frequency provisions, enabling more accurate and more robust measurement for users.

GLONASS also has a vital plan to modernize its constellations. The plan might include the modernized GLONASS satellites to consider CDMA signal format, which is identical to those of the other two systems. The direction of the modernization is encouraging and is welcome for users.

GPS will be also improved with dual frequency capability in sometime during the next decade. However ,interestingly superior lifetime of the existing satellites may delay the replacement. The existing satellites in orbit have marked an excellent longer operational lifetime than designed lifetime. It is ironic that an excellent longer operation time is likely to delay launches of the brand-new satellites. As a result, higher performance based on the advanced satellite constellations tends to take longer period than originally anticipated.

3.2 Satellite Based Augmentation System

Since 2007, a Japanese satellite based augmentation system – MSAS- is operational in Fukuoka FIR, providing augmentation services to aircraft enabling to conduct up to non-precision approaches. The limited performance compared with the U.S. WAAS, of which performance could reach up to LPV200 in almost CONUS, is mainly due to regionally unique ionospheric behaviors. After struggling to challenge the issue, ENRI invented a new algorithm to mitigate the ionospheric effects over Japan. Simulated results conducted by ENRI shows with the algorithm along with additional installations of ground monitor stations (GMS) the MSAS performance could reach LPV200 in most of all Japanese territory. Feasibility of application of the promising method to the MSAS is now under investigation.

3.3 Ground Based Augmentation System

GBAS is another promising technology designed to support precision approaches and landings up to Category-III weather conditions. The technology is also applied to support precise surface movements in all weather aerodrome operations. ENRI has been conducting research activities on GBAS since 1996. The institute is now engaged with an integrity-proof GBAS prototype. Through the current activities ENRI will soon perceive competence for safety analysis and possible mitigation techniques to assure integrity requirements, resulting in readiness of certification of actual implementation in near future.

Internationally, thanks to the worldwide effort, straight-in Cat-I capability by GBAS will be closely achieved in the U.S.A.

During the latest ICAO NSP meeting CAT-II, III capable GBAS development has a priority in its work plan.

In summary, the development of GNSS technologies in aviation has made a remarkable progress as a whole. However, there still needs to conduct research and development especially in the areas of approach and landing phases. Once CAT-III capability is achieved, GNSS technologies will be an alternative candidate of existing legacy navigation systems.

4. FUTURE SERVICES ON GNSS TECHNOLOGIES

4.1 Some other aspects for transition to GNSS environment

As discussed in paragraph 3, GNSS applications to aviation are gradually expanding. The target of the GNSS development settled by ICAO, i.e. ILS-like CAT-III capability, is quite reasonable at least technical point of view. Without this, there is no way to replace ILS with GNSS. However it seems that autonomous transition from existing terrestrial systems to GNSS (with appropriate augmentations) will not occur due to some other barriers.

The following discussions will address these non-technical aspects.

4.2 Necessity of carefully designed transition scenario

The other discussions may be raised is that how aviation industry move forward to the new GNSS based environment. It would be ideal if all stakeholders agreed a common transition scenario under consensus. However, it is usual that interests among stakeholders could sometimes be dispersive or even contradict each other. The experience of the history exactly shows that such discrepancy may slow or even cease market acceptance of new technologies.

For example, in case of GBAS, the current target under consensus among international experts is to standardize straight-in CAT-III capability. For airport operators, when realizes the GBAS CAT-III capability, they would be still reluctant to install a straight-in CAT-III GBAS. The airport operators have to keep ILS during sufficient long transition period (15-30years), waiting for replacement of aircraft by air operators. For airports who already have CAT-III capability by ILS, they certainly need to have business case for the additional investment of GBAS ground. If the benefit of the GBAS is the same as that of ILS, there must be many obstacles for the operators to justify the investment.

Therefore, it is quite important to develop and provide excellent applications on GNSS, giving the GNSS absolute superiority to existing technologies.

Successful transition scenario should address this aspect as well.

4.3 Future perspectives on core navigation satellite constellations

Another aspect which may affect further implementation of GNSS in aviation is when, how and why future constellations will provide aviation users with satellite navigation services.

Currently GPS and GLONASS are the core constellations offering global navigation services as of today. While original technologies were developed for military purposes, more and more civil applications are widely developed and many people are benefitted by its services. As so far any possible alternate global navigation technology has not been found, existence of GNSS constellations will not lose its commercial value in the considerable future (between 20-30years). The optimistic expectation of future availability of GNSS services is also justified through the following discussion.

Because maintaining GNSS constellations requires both huge budgetary expense and high-level competence of space technologies to the owner states, Core technologies of GNSS and space utilization will be likely to be still enclosed among very few capable states even in the future. Holding GNSS constellations will have fit the national political interests of the states despite the relatively huge obligations..

In conclusion, owner states will have a sufficient reason to keep the constellations with consent of their respective taxpayers.

There may be the “imbalance” between the owner states and the others. This situation will not be able to be neglected when considering future directions/perspectives.

As a result, future GNSS environment will be defined by the few “owner” states. The most of the other states will be forced to depend on the “given” GNSS environment.

For the other states, to contribute and intervene in GNSS development through international fora, it is necessary to conduct continuous R&D effort to build potential technical competence necessary to hold GNSS just in case they want to do so.

In summary, in the future GNSS environment, there is enough reason for users to believe GNSS services will continue and to be benefitted by the future advanced and useful navigation services. Nonetheless to say, at the same time the user communities should not forget the enclosure of critical satellite navigation technologies. For smooth and short transitions, the scenario has to accommodate consents of all stakeholders, considering tendency of marketing principle. To be competitive in the worldwide GNSS market, it is fundamentally necessary to conduct continuous effort in the GNSS research field.

5. DISCUSSION OF FUTURE GNSS AS AN ENABLER OF AIR TRAFFIC MANAGEMENT

In conclusion, there are some findings as shown below.

(1) GNSS will still play a vital role for aviation industry during the coming 15-30 years. Newly advanced navigation performances will be offered by improved new satellite constellations. Aviation industries could be confident to move to the fourth dimensional trajectory ATM environment assuming the advanced GNSS services.

(2) When examining future scenario based on GNSS, aviation industries will be, more or less, forced to depend on technical and institutional aspects on core satellite constellations.

(3) Critical knowledge to maintain core satellites may be apt to be enclosed among few capable states due to some technical, financial and political reasons.

(4) For successful transition to the new environment, it is required that possible scenario should be acceptable, feasible and reasonable for **all** stakeholders (air users, airport operators, ATS providers, regulators, airborne/ground manufacturers, national/local governments)

In summary, based on the above observation, research institutes should conduct research activities to develop and offer new applications to aviation industries so as to keep technical competitiveness of GNSS technologies and to offer user groups more attractive applications which will accelerate transition to the New ATM/CNS environment.

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