Precise positioning services in the aviation sector

An estimate of the economic and social benefits of the use of augmented GNSS in the aviation sector

Prepared for the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education

June 2013

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GNSS is playing an increasing role in navigation in regional airlines and general aviation augmented by terrestrial navigation aids to provide a degree of redundancy in the navigation systems pilots rely on. Commercial aircraft generally operate with more comprehensive navigation instruments including Instrument Landing Systems (ILS), barometric systems (Baro-VNAV) as well as augmented GNSS.

Non precision approaches rely on GNSS for lateral guidance. All aviation certified GNSS receivers must have Receiver Autonomous Integrity Monitoring (RAIM) which is augmented with signals from static monitors to confirm the integrity of the GNSS for use by aircraft.

Navigation with RAIM enabled GNSS has delivered some benefits in terms of the ability for aircraft to fly user preferred routes which reduces fuel use and costs. In Australia it could allow the number of terrestrial navigation aids to be reduced. There is potential to reduce the number of terrestrial aides on regional routes after 2016 by not replacing them at the end of their operating life. The capital costs avoided would be around $119 million.

Further augmentation is possible from Ground Based Augmentation Systems (GBAS) and Space Based Augmentation Systems (GBAS). GBAS could theoretically replace existing ILS infrastructure at major airports for precision approaches. Precision approaches increase the safety and utilisation of airports in bad weather and thereby increase their operating capacity. They also reduce costs of lost time and fuel from diversions and delays caused by bad weather.

GBAS, along with other navigation systems that provide vertical guidance, reduce the fuel used in airport approaches. This is estimated to be of the order of $36 million per year if savings at all major airports are be included. GBAS also has cost advantages over Instrument Landing Systems (ILS) for precision approaches. The infrastructure it requires is less restrictive on runways and lower cost.

A GBAS has been installed at Sydney Airport and one is to be installed at Melbourne Airport in 2016. However the ILS systems will not be retired because not all commercial aircraft are GBAS equipped. The cost advantage of GBAS will not be realised until the ILS systems are retired.

SBAS is a wide area augmentation system where augmentation is delivered by satellite signal. Earlier economic studies and calculations undertaken by ACIL Allen show that it is unlikely that the net benefits to the aviation sector alone would exceed the cost of an SBAS.

There are currently no plans to develop an SBAS in Australia. Any consideration of this matter would need to be considered in the context of national positioning infrastructure and not in the context of the aviation sector alone.

Key findings

- Global Navigational Satellite Systems (GNSS) are increasingly being used in all sectors of the aviation industry as an aid to navigation. The regulatory authorities have acknowledged this trend and incorporated GNSS in regulatory policy and procedures.
- Aircraft navigation does not generally require high horizontal position accuracy.
  - The accuracy available from stand-alone GNSS is sufficient for most situations.
  - Integrity is more important with around 4 nautical miles over ocean, 2 nautical miles over land and 0. 3 nautical miles required for non-precision approaches.
  - Precision approaches require integrity of around 40 metres.
- Higher levels of vertical positional accuracy are however required for precision approaches and landings.
- There are two navigation technologies that provide precision approaches
  - instrument Landing Systems (ILS) that broadcast a flight path from radio beacons on the airstrip that are received by an ILS receiver in the cockpit
  - Ground Based Augmentation Systems that provide augmented GNSS at airports.
  - While GBAS would deliver savings in fuel costs if installed at all 9 major airports compared to approaches with vertical guidance, ILS delivers similar savings and is already installed.
  - GBAS would also deliver cost savings for infrastructure compared to ILS. However ILS is to be maintained for the time being as not all aircraft are GBAS equipped.
- Savings in capital costs to replace terrestrial navigation aids of around $119 spread are possible with RAIMS capable GNSS.
- Space Based Augmentation Systems (SBAS) provide augmented GNSS over a wide area, however, the net benefits of an SBAS to the aviation sector alone do not appear to be sufficient to justify the cost.

1 Introduction

ACIL Allen Consulting, in partnership with SKM and Lester Franks Surveyors and Planners, has been commissioned by the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education to assess the value of augmented positioning services in Australia. This report addresses the aviation sector.

The purpose of this report is to provide an understanding of the economic and social benefits of precise positioning information within the aviation sector. This information is to allow better informed decision-making and assist in identifying areas for growth and investment from both the private sector and government. It will also provide context to the National Positioning Infrastructure Plan being developed by Geoscience Australia.

2 Aviation use of precise positioning

2.1 Background

The aviation sector is an international industry with demanding safety of navigation standards and procedures for a wide range of aviation operations. The International Civil Aviation Organisation (ICAO) provides the forum for setting standards and procedures. Member states of ICAO have determined that aeronautical navigation services for the 21st century will increasingly be based on global navigational satellite systems (GNSS).

The Aviation White Paper released in 2009 supported the wider application of satellite navigation technology along with the use of other satellite surveillance technologies, such as Automatic Dependent Surveillance-Broadcast (ADSB) and ground-based surveillance capability, including radar to protect against vulnerabilities from over-reliance on one system (DITRDLG, December 2009).

Commercial aircraft now rely on integrated Flight Management Systems (FMS) involving a range of technologies including GNSS, inertial position sensing, terrestrial navigation aids and barometric height measurement.

2.2 Aviation positioning requirements

Aviation operations depend on pilots and air traffic controllers for the save execution of take-offs and landings, flight en-route and for the management of aircraft on the ground. Pilots and air traffic controllers in turn rely on a range of aids-to-navigation to augment visual cues for safety of operation and navigation.

Aids-to-navigation range from paper maps and compasses to sophisticated electronic navigation systems. In the cockpit they include altimeters, radio receiver, instrument landing systems and radar to provide the pilot (and the auto pilot in certain circumstances) with horizontal and vertical position information. For air traffic control, they include radar, electronic charts and aircraft reporting systems. For air search and rescue they include satellite based distress beacons and electronic mapping and charting.

GNSS is playing an increasing role in navigation in regional airlines and general aviation augmented by terrestrial navigation aids to provide a degree of redundancy in the navigation systems pilots rely on. Commercial aircraft generally operate with more comprehensive navigation instruments including Instrument Landing Systems (ILS), barometric systems (Baro-VNAV) as well as stand-alone and augmented GNSS.

Over the past 10 years or so, aircraft navigation systems have been improved to provide pilots with more accurate location information and the position of other aircraft. Developments include Required Navigation Performance (RNP-AR) procedures[1], user preferred routings and Automatic Dependence Surveillance Broadcast (ADSB). These processes have improved the management of aircraft both en-route and for airport approaches and departures (for more details see Box 1).

GNSS has become an important aid to navigation for aircraft. However its use in aviation requires additional augmentation to meet aviation standards. All aviation certified GPS[2] receivers are required to have Receiver Autonomous Monitoring (RAIM) which is a form of GNSS augmentation.

Further augmentation is possible through Ground Based Augmentation Systems (GBAS) and Space Based Augmentation Signals (GBAS). GBAS has been installed at Sydney Airport and is scheduled to be installed at Melbourne airport in 2016.

Examples of government run SBAS systems overseas include the Wide Area Augmentation System (WAAS) operating in the United States and the EGNOS system in Europe.

[1] RNP AR refers to Required Navigation Performance Authorisation Required refers to a range of aircraft operational procedures including approach procedures but it can also apply to missed approaches, standard instrument procedures.

[2] GPS stands for the Navstar Global Positioning System operated by the United States and made available free for use in Australia.

Box 1 Examples of improved on-board navigation

Horizontal accuracy: RNP-AR

RNP-AR (Required Navigation Performance – Authorisation Required) was developed by ICAO as a set of procedures and performance requirements to facilitate change in airspace operation in recognition of changes in global satellite systems, navigational infrastructure, operations and aircraft systems. Receiver Autonomous Instrument Monitoring (RAIM) is form of GNSS based navigation that has supports RNP-AR provides accuracy to 0.1 miles or better. This technology has been developed from better on-board assessment of data from satellite constellations location information for example), lateral thinking about the design of airport approaches, and rethinking the monitoring of airport positions. While not high resolution, it has produced substantial operational benefits for airlines.

Use of RNP instead of the traditional instrument landing system (ILS) at Brisbane allowed the straight-line approach to the airport to be reduced from up to 17 miles to approximately 2 miles, implying a reduction of 4% if applied to both ends of a typical 500 mile (800km) flight such as Sydney-Brisbane or Sydney-Melbourne (there are also noise and emission benefits). Several years ago Airservices reported that it was found that 3200 flights saved 700 tonnes of fuel. RNP-AR technology also allows a smooth rather than stepped descent, saving power.

The approach also allows higher take-off weights at constrained airports, in turn allowing more passengers and freight, and/or more fuel. For example, in Queenstown, NZ, with mountainous terrain and variable weather, the technology allows the airport to be used for a greater number of days and, by facilitating a better climb-out route, allows direct flights to Australia which previously had to refuel in Christchurch. Although Australia does not have airports with such dramatic constraints, it has economic benefits at airports with relatively minor terrain challenges. RNP departure allows Canberra – Perth to be unconstrained; conventional departure is payload limited. RNP departure at Cairns and Hobart also allows higher weights (payload).

RNP-AR uses ABAS and GPS with RAIM for lateral guidance and Baro-VNAV for vertical guidance.

User-preferred routings

Information from the world wind model is input into aircraft navigation planning, so an airline can determine a route that minimises experience of headwinds and maximises use of tail winds. Use of RNP navigation and Controller-Pilot Data-Link allowed initial implementation across the Pacific Ocean followed by the Indian Ocean and more recently on distant domestic airport pairs – Perth-Cairns, Perth-Brisbane.

An Airservices study several years ago found an average of 13 minutes is saved on each 14 hour flight between Los Angeles and Sydney. Los Angeles-Melbourne flights only became economic once user-preferred routings had been introduced; previous use of sub-optimal routes meant that an intermediate stop (e.g. Sydney or Auckland) was needed or that payloads so restricted that the operation was uneconomic.

Automatic Dependent Surveillance Broadcast

Automatic Dependant Surveillance Broadcast (ADSB) is a system that gives aircraft the capacity to automatically broadcast aircraft position, altitude, velocity and other data continuously. Other aircraft and ATC can access the data on display screens without the need for radar. ADSB systems have been defined and standardised by ICAO and other standards organisations worldwide.

Aircraft position is derived from the GNSS or internal navigation systems on board the aircraft. The ground unit is simply a receiver for the data, which is then integrated into the Air Traffic Control (ATC) System. ADSB units are currently being deployed to provide surveillance of airspace above 30,000 feet over the entire continent, including areas not currently provided with radar coverage. 30 ADS-B ground stations are in use across Australia with coverage above 29,000ft. 95% of international flights and 86% of domestic flights above 29,000ft are ADSB equipped and receive surveillance based services[3].

Source: Sydney Airport Master Plan 2009; Airservices; ACIL Allen.

[3] http://www.airservicesaustralia.com/projects/ads-b/upper-airspace-mandate-2013/

2.2.1 Horizontal accuracy

Integrity is a critical performance criterion for GNSS used by aircraft. Integrity is the limit of error for which an aircraft will be warned that the GNSS position information is not correct. Aircraft do not generally require high position integrity in the horizontal plane. In broad terms integrity of around 4 nautical miles is sufficient when flying over ocean and 2 nautical miles is sufficient for flying over land. Non-precision airport approaches, where pilots align their planes for landing visually, require integrities of around 0.3 nautical miles horizontal accuracy. Lateral guidance for precision approaches is more demanding but varies depending on the terrain. In general precision approaches require integrity of around 40 metres.

2.2.2 Vertical accuracy

While high horizontal accuracy is less important, aviation requires higher vertical accuracy. The level of accuracy required depends on the landing decision height or how close to the ground the vertical guidance system is used.

Non precision approaches

Non-precision approaches rely on visual guidance by the pilot for which the minimum required height for visual identification of an airstrip (decision height) is around 500 feet to 600 feet depending on terrain. The altimeter is sufficient for navigation at this height. An altimeter has a vertical accuracy of around 75 feet. Non-precision approaches are not considered adequate for high density regular public transport (RPT). CASA reports a significant number of near misses in RPT aircraft (Mallet, 6 December 2012).

Approach with vertical guidance (APV) is the highest capability in non-precision approach systems. APV can support multiple glide paths and touchdown zones, does not require runway specific infrastructure and is not subject to path aberration or periodic flight calibration (Scott, 2012).

APV uses RIAM augmented GNSS for horizontal position and altimeter readings and (Baro-VNAV) for vertical position.

Precision approaches

Precision approaches (CAT-I[4]) require minimum decision height of around 200 feet. Guidance can be provided by an Instrument Landing System (ILS) or by GBAS.

[4] There are three Categories of instrument landing systems for aircraft. Category 1 (CAT 1) applies to landing decision heights of 200 feet, CAT 2 applies for decision heights of 100 feet and CAT 3 allows decision heights ranging between 0 and 100 feet. Australian airports operate on CAT 1.

Precision approaches are superior to APV because they provide guidance to a lower decision height.

2.3 Navigation technologies

2.3.1 RAIM

RAIM uses inertial systems in GNSS receivers to validate signals from GNSS satellites. However, inertia is insufficient to evaluate GNSS performance on its own. For air navigation RAIM is augmented through the use of static monitors at known (surveyed) locations which transmit integrity data to the receiver. The combination of the use of RAIM and monitoring from ground stations is a form of augmentation to the GNSS signal.

RAIM monitoring for aircraft reduces the need for terrestrial navigation aids which in the long run will reduce costs of replacing and maintaining them. Terrestrial navigation aids are supported by Airservices Australia. With the use of signal monitoring GNSS and RAM it will be possible to reduce the terrestrial navigation aid for en route flying. Airservices Australia advised that this not likely to occur until after 2016 when some of the existing aids need to be replaced. The cost of replacement of all the terrestrial aids is estimated to be around $119 million.

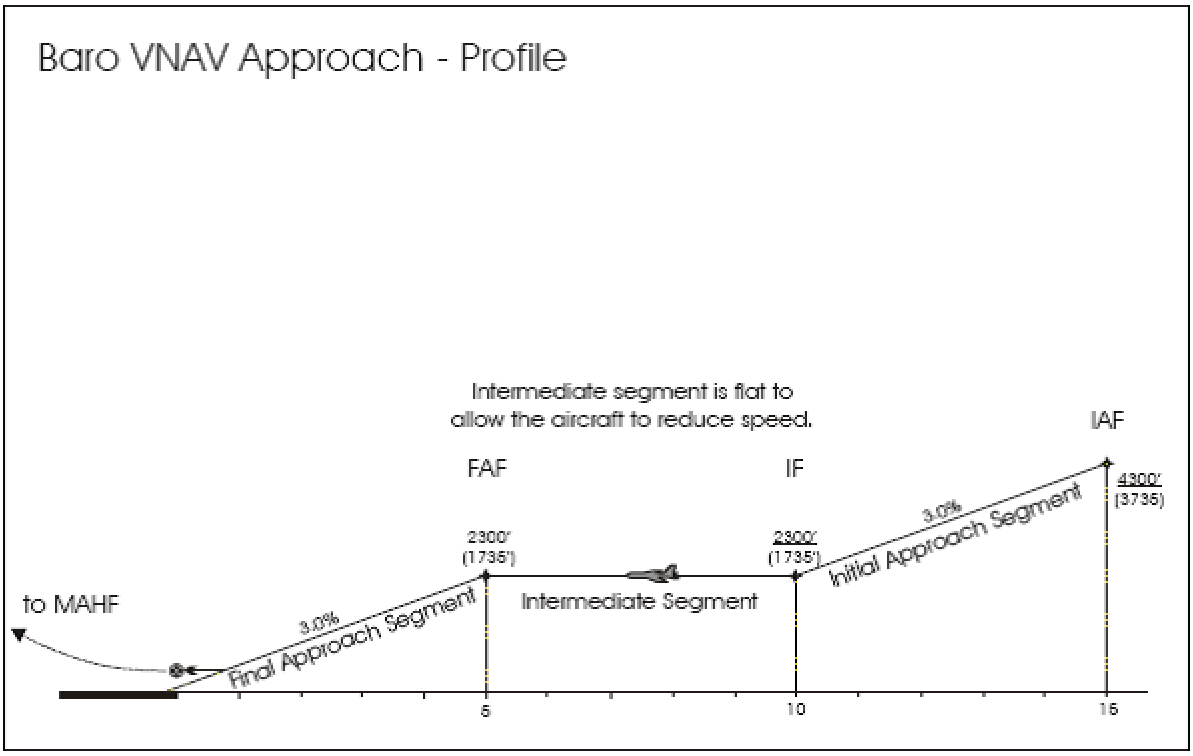
GNSS/RAIM also permits user preferred routes to be flown by international and regional airlines. This reduced the travel distance and travel time and saves fuel and emissions of CO_2.

2.3.2 Baro VNAV

APV Baro-VNAV utilises GNSS for lateral navigation and barometrically derived data for vertical navigation. APV Baro-VNAV procedures are intended for use by aircraft equipped with a flight management system or other area navigation systems capable of constantly computing barometric paths and displaying the relevant deviations on the instrument display.

The minimum vertical accuracy required under APV is 75 feet. This allows the minimum height for visual identification of the airstrip to be reduced from 166 metres to 260 feet. For this level of accuracy barometric measurement is sufficient. A typical approach path under Baro-VNAV is shown in Figure 1.

Figure 1 **Baro VNAV approach profile**



Data source: (ATNS, 2012)

While Baro VNAV provides a significant improvement in safety (8 times safer than visual straight in approaches according to CASA[5]) it also requires a straight in approach which limits flexibility of air traffic management at busy airports. It is also important to note that most general aviation aircraft do not have Baro-VNAV instrument capability.

2.3.3 Instrument Landing Systems (ILS)

ILS broadcasts a flight path from radio beacons on the airstrip that are received by an ILS receiver in the cockpit. The system provides the pilot with instrument indications which, when utilised in conjunction with the normal flight instruments, enables the aircraft to be manoeuvred along a precise, predetermined, final approach path[6].

Currently 16 major Australian airports have ILS capability. ILS is an economic option at major airports, given large traffic volumes. An ILS installation costs around $1.5 million per unit and maintenance and flight checks costing about $120,000 per annum[7]. There are also aircraft equipment and maintenance costs associated with ILS.

[5] (Mallet, 6 December 2012)

[6] CASA website

[7] CASA Discussion Paper DP 1006AS

An ILS approach must be a straight runway aligned 3 degree descent path that cannot be varied from aircraft to aircraft. This can be an issue for busy metropolitan airports where greater flexibility in flight paths is an increasing imperative.

2.3.4 GBAS

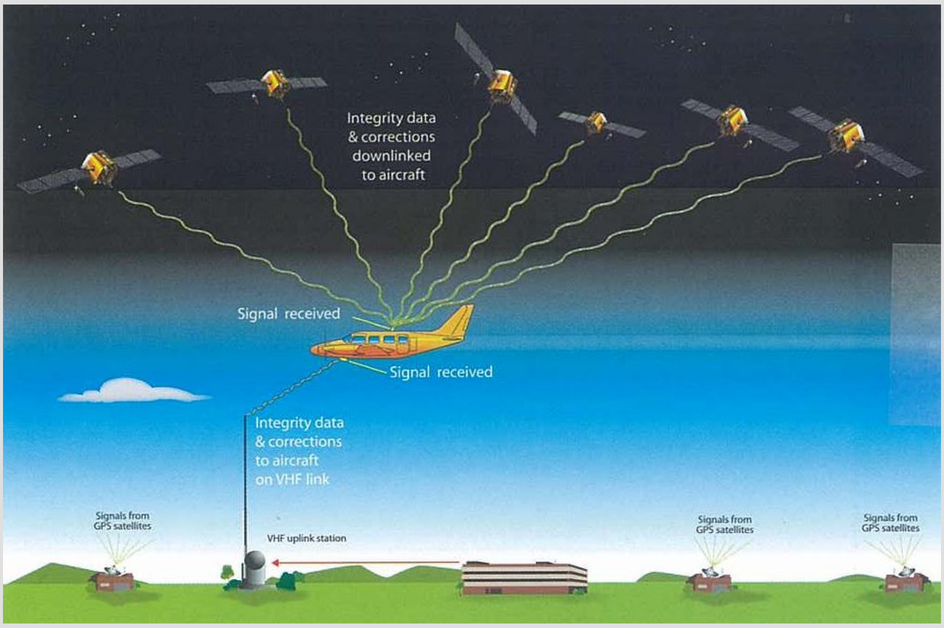
GBAS is a system that uses ground based reference stations at Airports to provide augmentation signals to the GNSS receiver on the flight deck. Its working arrangements are outlined in Box 2. GBAS is designed from an aircraft perspective to look like a traditional instrument landing system (ILS). It is used in conjunction with other instruments to report vertical position during the descent.

GBAS can provide vertical accuracy of 1 metre and transmit this 5 times per second with a probability of not detecting a corrupt GNSS signal of less than 2 in 10,000,000 (Williams, 6 December 2012). This is far higher than the accuracy that Baro-VNAV.

Airservices Australia has deployed a GBAS at Sydney Airport and has plans to install a GBAS system at Melbourne Airport in 2013. The nine other larger airports are expected to also have GBAS landing systems installed in subsequent years.

Box 2 GBAS

GBAS is a satellite-based precision approach and landing system that is established at an airport. A ground station at an airport transmits locally-relevant corrections, integrity and approach data to aircraft in the terminal area via VHF radio. GBAS is recognised by ICAO as a replacement for current ILS. It is a component of Australia's next-generation air traffic management infrastructure, particularly in the vicinity of capital city airports and will help reduce fuel burn, aircraft noise and airport delays.



Source: Sydney Airport Master Plan 2009; Airservices, CASA

Besides providing vertical accuracy, the system allows greater effective airport capacity than the traditional instrument landing systems (ILS), for example reducing waiting times before take-off after another flight has landed, and less reduction of capacity in bad weather (Scott, 2012).

GBAS supports multiple flight paths to the runway. The descent angle and touchdown point can be varied. While curved paths are possible they are not likely to be supported under the current arrangements.

Safety is increased through increased signal stability and system design. GBAS supports multiple straight in paths to the runway. The decent angle and touch down points can be varied. Curved paths are possible although not supported at Australian airports at the present time.

By comparison, ILS provides a beam to follow, which can mean one aircraft shades another, in turn requiring greater separation (e.g. waiting longer for take-off). The integrity, availability and continuity are an improvement on existing technology.

According to published papers[8] the benefits of GBAS are:

- For airlines it delivers:
  - improved safety
  - lower fuel costs
  - less flight disruptions and associated cost caused by ILS interference
  - minimal pilot training.
- Airports benefit from:
  - improved airport capacity from accurately guided, simultaneous operations to parallel runways and reduced runway exit times
  - flexibility in GBAS station location, unlock valuable airport land and alleviate traffic restrictions which are otherwise required to protect ILS signals from interference sources
  - improved airport access, especially where ILS cannot be installed for terrain or economic reasons.
- Air navigation service providers can obtain:
  - reduced traffic delays and congestion as a result of more efficient and predictable approaches
  - reduced capital investment cost and lower ongoing maintenance, as one GBAS covers all runways at an airport compared to one ILS installation required per one runway end
  - easier and less frequent flight inspections than ILS
  - continued operations even during routine flight inspection or airport works

[8] Information provided at Workshop on GBAS held on 13 December 2013 in Sydney (Scott, 2012), (Williams, 6 December 2012).

- greater ability to manage noise levels in built up areas through use of runway aligned straight in multiple flight paths.

There would also be economic benefits in improved safety at airports from more effective management of aircraft separation, benefits to airport operations through the ability to reduce wake induced separation and increase traffic volume and benefits to air traffic management at major airports in terms of greater flexibility in managing aircraft movements.

Both GBAS and ILS deliver similar benefit to aircraft. The principle difference is the greater freedom on touchdown on the runway that GBAS offers. An important benefit of GBAS compared to ILS systems relates to the fact that a GBAS would provide coverage for all runways at an airport while each ILS installation is runway specific. GBAS would have lower operating and capital costs than ILS.

2.3.5 SBAS

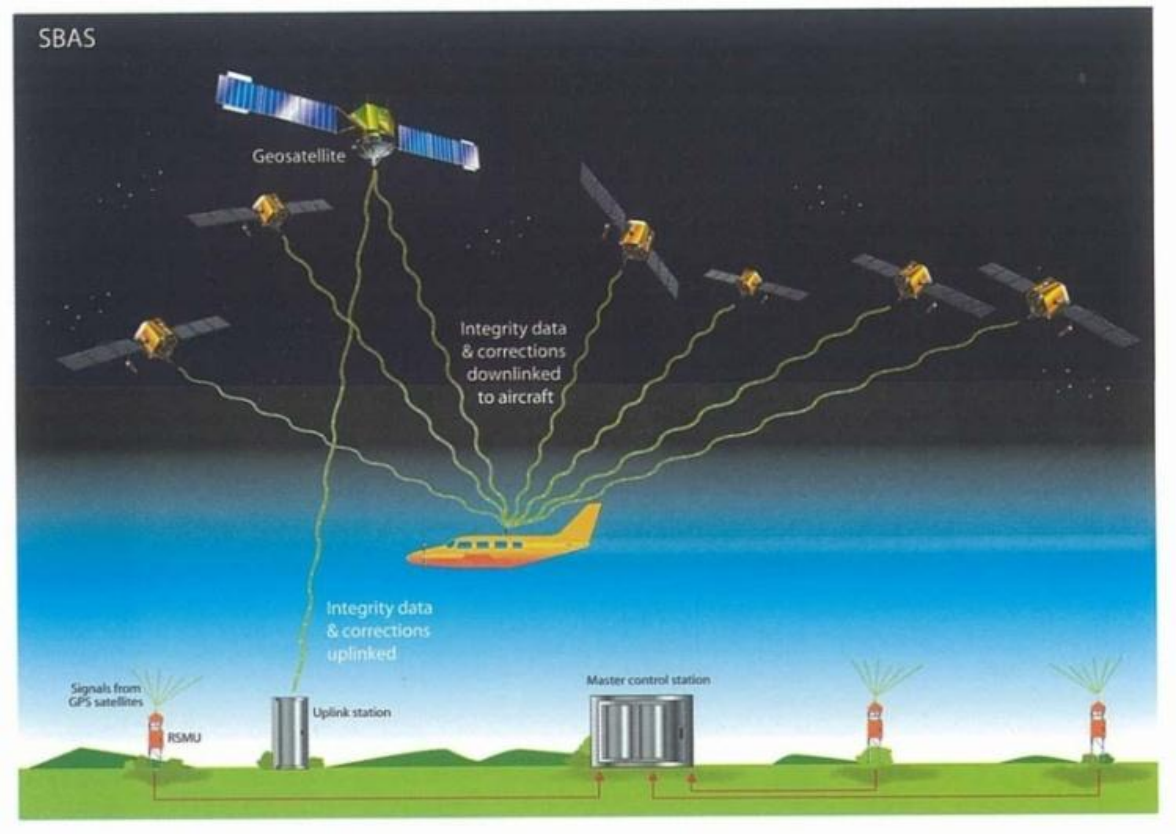
Space Based Augmentation System (SBAS) monitors the GPS satellites and broadcasts corrections and integrity information by satellite to aircraft (see Box 3). SBAS exists in the European Union, North America and Japan. China and India are well advanced in deploying a SBAS. These services are provided free of direct user charge. There are no SBAS services operating in Australia.

SBAS in Australia could be provided by a series of around 35 monitoring stations. The monitoring stations would have precise locations, map the ionosphere and broadcast corrections to aircraft via satellites. Their information would apply to all of Australia.

SBAS would enable augmentation services to be used on regional routes and by general aviation. A recent study by the Federal Aviation Authority in the United States suggested that one carrier had reduced regional cut as much as 25 per cent off its flight times for certain city-pairs by equipping GPS units with the wide area augmentation system (WAAS) in its Cessna fleet. Reduced flying times improved navigation at regional airports would be possible with an SBAS (Croft, 2013). However as discussed in section 3.3 the benefits to the airline sector alone are unlikely to exceed the costs.

Box 3 SBAS

SBAS delivers error corrections, extra ranging signals (from the geostationary satellite) and integrity information for each GNSS satellite being monitored. Like GBAS it also augments GNSS signals to provide aircraft with very precise positioning guidance, both horizontal and vertical. SBAS differs from GBAS in that it provides GPS integrity monitoring via satellites rather than VHF data link, rather than from the ground and potentially provides coverage for a wider geographical area.



Source: (DITRDLG, 2011)

Investment in an Australian SBAS carries with it a funding issue. Estimates of the cost of an SBAS for Australia range between $300 million and $1 billion (SBAS review, (CRCSI, 2011)).

While it is most likely that part of the cost of running SBAS would be recovered from the airline industry through landing and other charges, other users could free ride if the signal were not encrypted. Many other users in other industry sectors would benefit from an SBAS.

The Department of Infrastructure, Tourism, Regional Development and Local Government reviewed the advantages and disadvantages of an SBAS in 2011 (DITRDLG. (2011) and the CRC for Spatial Information undertook an economic assessment of an SBAS in 2011 in the context of a possible positioning component on the NBN satellite (CRCSI, 2011). The latter did not eventuate. At the present time there are no plans to develop an SBAS for Aviation in Australia although as discussed below, future developments in GNSS systems and technologies could make SBAS more feasible.

3 Economic and social impacts

3.1 Likely applications of augmentations to GNSS in the Australian Aviation Sector

The Aviation White Paper recognises the growing role of GNSS as an aid to navigation for the Australian aviation sector. This applies to the sophisticated integrated flight management systems of commercial aircraft and to the navigation systems used in general aviation.

The application of augmented GNSS systems in the foreseeable future is however most likely to be confined to its use in RAIM and GBAS systems. RAIM is already a requirement for GNSS receivers in aviation. GBAS systems are scheduled to be installed in major airports over the next decade or so.

With RAIM confirmation signals now in place, Airservices Australia will be able to retire en route terrestrial navigation aids from around 2016 realising total capital savings of around $119 million[9].

Not all aircraft will be fitted with GBAS capabilities and for the time being it will be necessary for major airports to retain their ILS infrastructure. While GBAS equipped aircraft will benefit from slightly more flexibility in approaches and landings, airports will not be able to realise the benefits of lower costs until they are able to retire their ILS infrastructure. There will be some benefits to airports in greater flexibility of aircraft management for those aircraft that can use GBAS enabled approaches the full benefits of greater flexibility are not likely to be fully realised until the majority of aircraft are GBAS capable.

There are no immediate plans to implement an Australian SBAS. While launches of new GNSS satellites such as the European Galileo or the Chinese Compass constellations may provide SBAS capability, their use in aviation is unlikely to be adopted in the short term. If they were, it may require local augmentation to address localised interference.

An SBAS would benefit regional airlines. However the major benefits of such systems are likely to be realised by other sectors such as agriculture, construction, transport and mining.

The economic and social impacts of precise positioning over the coming decade are therefore likely to be related to ongoing RAIM confirmation signals and installation of GBAS systems at major airports and their adoption by the commercial airlines. Adoption is likely to be gradual. While some aircraft are equipped with GBAS capability it may take time for it to be taken up. Some older aircraft will not adopt it.

[9] Personal communication with Airservices Australia.

3.2 Economic impacts

3.2.1 2012

RNP-AR, user preferred routes and ABAS (described Box 1) have already delivered improvements and savings in aircraft operations, air traffic management and air safety. Baro-VNAV has already been rolled out at some airports to improve vertical guidance. The main augmentation system to stand-alone GNSS is the combination of RAIM and static monitoring of the GNSS signal.

RAIM monitoring is a part of the navigation support systems for RNP-AR. The latter has delivered benefits in reduced fuel costs for landing (see Box 4). The potential savings are of the order of $30 million per year.

Box 4 Economic benefits from RNP-AR

For the purpose of estimating the direct economic impacts of RAIM the savings in fuel for landings in 2020 for domestic commercial aircraft were estimated. The airline sector estimated that between 130 Kg and 200 Kg of fuel would be saved using landings based on RNP. In addition to these savings there would be reduced emissions of between 420 to 650 kg CO^2 per landing[10]. It was assumed that half of these savings could be attributed to the added accuracy of GBAS over Baro VNAV landings.

ACIL Allen estimated that this resulted in savings in fuel of around $30 million per year assuming RNP-AR approaches are used by all airlines at Australia's 9 major airports.

Source: ACILAllen based on data supplied by Qantas.

However while this is RAIM/ground monitored GNSS is a form of augmentation, ILS which is installed at these airports also delivers approximately the same benefits overall as far as fuel consumption is concerned[11]. Therefore no net benefit can be attributed to this technology for this report.

RAIM GNSS has delivered some benefits in enabling aircraft to fly user preferred routes domestically and internationally.

3.2.2 2020

While there are identifiable and quantifiable benefits that can be attributed to the installation of GBAS at Sydney and Melbourne Airports, and potentially other major airports, the fuel savings that could be attributed to more efficient approaches can also be delivered in general by ILS approaches and RNP – AR approaches. Therefore there is no net benefit that can be attributed to GBAS in terms of fuel efficiency on landings over alternative technologies at major airports.

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[10] Advice from Qantas.

[11] The differences in fuel consumption between RNP –AR and ILS approaches would vary between terrain and airport.

There are benefits in greater flexibility at airports potential benefits from the fact that GBAS covers all runways at an airport whereas ILS installations are runway specific. However for the time being both Sydney and Melbourne airports will continue to operate ILS systems as not all aircraft are fitted with GBAS capability at the present time. This situation is likely to apply in 2020.

Therefore no additional benefits have been attributed to the installation of GBAS at airports or the cost of infrastructure savings at this time.

It is likely however that with the requirement for the operation of RIAM GNSS in conjunction with static monitoring will enable the retirement of terrestrial navigation aids. This is likely to commence around 2016 saving capital expenditure of around $119 million spread over ten years. There would be some benefits that would also accrue from savings in aircraft flying user preferred routes.

3.3 Implications of SBAS

As discussed in this report earlier, there are currently no plans to develop an SBAS in Australia. Earlier economic studies and calculations undertaken by ACIL Allen show that it is unlikely that the net benefits to the aviation sector in fuel savings and improved navigation in regional areas would exceed the cost of an SBAS. For example ACIL Allen estimated the savings to regional and major airlines could be in the order of $10 million per year in fuel savings compared to capital costs estimates that have ranged between around $300 million to as high as $1 billion.

As the other reports in this series show, other sectors would also benefit from the development of an Australian SBAS. The overall net benefits may well exceed the costs of such an investment. Such developments however would need to be considered in the context of the National Positioning Infrastructure policy and not in the context of the aviation sector alone.

Appendix A Glossary of terms

Term	Meaning
GNSS	Global Navigational Satellite System
GPS	Global Positioning System – originally the term for the US Navstar GNSS
SBAS	Satellite Based Augmentation System
ABAS	Aircraft Based Augmentation System
GBAS	Ground Based Augmentation System
ADSB	Automatic Dependent Surveillance Broadcast
RNP AR	Required Navigation Performance Authorisation Required
AAIM	Aircraft Autonomous Integrity Monitoring
RAIM	Receiver Autonomous Integrity Monitoring
QZSS	The Japanese GNSS constellation of navigational positioning satellites.
Baro VNAV	Barometric height measurement – a component of APV
APV	Approach with vertical guidance

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