

# **Satellite Based Augmentation System Review**

## **1. Executive Summary**

In its December 2009 Aviation Policy White Paper, *Flight Path to the Future*, the Government asked Infrastructure portfolio agencies, in consultation with other portfolios, to review Satellite Based Augmentation Systems (SBAS) in more detail.

The review has examined the justification, practicality, cost and timing issues associated with the establishment of an SBAS capability in Australia, as well as other available options, for completing Approach with Vertical Guidance (APV) coverage in Australia. Terms of Reference for the Review are at **Attachment A**.

Overseas experience of implementing SBAS systems and the future deployment of SBAS worldwide was also examined, in order to understand the possible benefits, costs and challenges of implementing SBAS in Australia.

The main finding of the review is that at this time, on the basis of information currently available, it is difficult to justify the significant investment involved in establishing SBAS in Australia to cover aviation operations at smaller aerodromes.

The review notes a number of new satellites and augmentation systems will be launched in the future, which are predicted to increase satellite coverage over Australia. These advances will have implications for future requirements and costs of SBAS in Australia and may provide access to other alternative systems.

Consideration of any future investment in SBAS would need to be a part of a whole of Government approach with the significant cost considered against potential benefits across a range of industries. Indications are that so far those other industries (such as land and maritime transport, and agriculture) are using other technologies to meet their needs (e.g. using ground based augmentation systems for horizontal guidance) rather than expressing strong support for the adoption of SBAS. There is also as yet no demonstrated willingness from these industries to fund or invest in SBAS.

Further detailed work would be needed if the Government wished to consider further advice on an SBAS capability in Australia. This could include a detailed cost benefit analysis, undertaking a comprehensive SBAS industry demand survey; examining different funding options including private investment; the impact of increased satellite coverage and new technologies in the coming years from other countries and the implications of entering into an agreement or partnership with other countries in the region for satellite access.

Finally any further work on SBAS would need to link in with the Government's national space policy being coordinated by the Department of Innovation, Industry, Science and Research (DIISR) and involving the Department of Foreign Affairs and Trade (DFAT) and other relevant agencies, in terms of possible engagement with other countries in the region on their APV and SBAS plans where they exist.

A driving force for the possible adoption of SBAS has been the International Civil Aviation Organization (ICAO) resolution timeframes for implementing APV coverage at all instrument runway ends (30% by 2010, 70% by 2014 and 100% by 2016).

However in October 2010 ICAO superseded its initial resolution on APV to urge member states to introduce straight-in approaches to mitigate against controlled flight into terrain (CFIT) risk if they do not have the capability to implement Baro-VNAV or augmented GNSS in the first instance. Australian has straight-in approaches for at least one runway at around 260 aerodromes.

Nevertheless the review supports the increased adoption of APV at Australian aerodromes.

The review supports the development of a Baro-VNAV implementation plan, a more affordable and currently available technology which can provide APV coverage for over 97 percent of Instrument Flight Rules (IFR) passengers in Australia if implemented across all aerodromes serviced by Baro-VNAV capable aircraft. Use of Baro-VNAV could provide APV coverage at nearly 200 aerodromes throughout Australia.

The widespread adoption of Baro-VNAV has a range of resourcing and cost implications that need to be progressed further by Government agencies including Airservices Australia, the Civil Aviation Safety Authority (CASA) and the Bureau of Meteorology. There will need to be consultation with the aviation industry particularly with regional airline and airport operators in the finalisation of the Baro-VNAV implementation plan.

The review keeps open future consideration of establishing an SBAS capability in Australia. If strong multi-sectoral demand for such a capability were to emerge and SBAS coverage provided by other administrations were expanded significantly in the region then the efficacy of establishing an SBAS capability in Australia could be further examined.

## 2. Reducing CFIT in Aviation – Background

### 2.1 CFIT

Controlled Flight into Terrain (CFIT) is a leading cause of airplane accidents involving the loss of life. There have been over 9,000 deaths due to CFIT since the introduction of commercial jets<sup>1</sup>. Between 2000 and 2009 approximately 961 people died worldwide as a result of CFIT, the second largest cause of aircraft accident fatalities<sup>2</sup>.

CFIT occurs when:

- the aircraft is under the control of the pilot(s);
- there is no defect or unserviceability that would prevent normal operation of the aircraft;
- there is an in-flight collision with terrain, water, or obstacles; and
- the pilot(s) have little or no awareness of the impending collision.

In essence, the pilots are generally unaware of the danger until it is too late<sup>3</sup>.

*“For CFIT, the greatest concern is a loss of ‘place information’. Once a pilot’s mental picture of where they are at present, and where they will be in the future diminishes, safety becomes compromised. This is particularly crucial during those phases of flight when terrain clearance is unavoidably reduced (e.g. initial climb and approach). Reportedly, more than two-thirds of all CFIT accidents result from a loss of vertical situational awareness or an altitude error”<sup>4</sup>.*

### 2.2 Addressing CFIT – ICAO Resolution

In 2007 the International Civil Aviation Organization (ICAO) passed Resolution A36-23 which amongst other things required member States to put in place measures aimed at mitigating against the threat of CFIT and approach and landing type accidents for Instrument Flight Rules (IFR) aircraft.

ICAO Resolution A36-23 urged member States to complete a performance based navigation implementation plan by 2009 for implementation of APV (by barometric vertical navigation (Baro-VNAV) and/or augmented Global Navigation Satellite System (GNSS) – such as SBAS) for all instrument runway ends that serve aircraft with a mass of 5,700kg or more, either as the primary approach or as a back-up for precision approaches by 2016, with intermediate milestones of 30% by 2010 and 70% by 2014.

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<sup>1</sup> [http://www.faa.gov/training\\_testing/training/media/cfit/volume1/1Sec.pdf](http://www.faa.gov/training_testing/training/media/cfit/volume1/1Sec.pdf)

<sup>2</sup> Boeing 2009 Statistical Summary - <http://www.boeing.com/news/techissues/pdf/statsum.pdf>

<sup>3</sup> CFIT: Australia in Context 1996 – 2005, ATSB - <http://www.atsb.gov.au/publications/2007/b20060352.aspx>

<sup>4</sup> Ibid

At the 37th ICAO Assembly in October 2010 Resolution A36-23 was superseded by Resolution 37/11 which stated, inter alia:

*States complete a PBN implementation plan as a matter of urgency to achieve:*

*1) implementation of RNAV and RNP operations (where required) for en route and terminal areas according to established timelines and intermediate milestones; and*

*2) implementation of approach procedures with vertical guidance (APV) (Baro-VNAV and/or augmented GNSS), including LNAV only minima, for all instrument runway ends, either as the primary approach or as a back-up for precision approaches by 2016 with intermediate milestones as follows: 30 per cent by 2010, 70 per cent by 2014; and*

*3) implementation of straight-in LNAV only procedures, as an exception to 2) above, for instrument runways at aerodromes where there is no local altimeter setting available and where there are no aircraft suitably equipped for APV operations with a maximum certificated take-off mass of 5 700 kg or more;;*

### 2.3 Context of the Review

The Civil Aviation Safety Authority (CASA) has assessed that there are approximately 300 Registered and Certified Aerodromes in Australia with published Instrument Approach and Landing Procedures that are subject to the original ICAO resolution.

An earlier Australian APV study - commissioned and led by CASA and co-funded by the then Department of Transport and Regional Services – was finalised in 2009 and recommended that barometric vertical navigation (Baro-VNAV) be implemented as soon as practicable.

Baro-VNAV was seen as providing an immediate safety benefit to most of the travelling public as a majority of domestic and regional regular public transport (RPT) aircraft are already fitted with the necessary avionics for Baro-VNAV approaches<sup>5</sup>. CASA has identified 198 aerodromes that are utilised by aircraft that are or will be Baro-VNAV capable.

However, Baro-VNAV does not cover all RPT aircraft, as many aircraft in Australia's general aviation fleet which carry the remaining passenger traffic are not capable of conducting Baro-VNAV approaches because they are not fitted with the necessary equipment, nor capable of fitment.

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<sup>5</sup> CASA, 2009, GNSS Augmentation for APV – Technical Options and Cost Benefits

Consequently the 2009 Study identified SBAS as a technological solution that would enable more comprehensive APV coverage, particularly at smaller regional airports. The Study recommended that a determination regarding the establishment of an SBAS capability for Australia be made based on further investigation including a cost-benefit assessment.

### **3. Current Options to Mitigate against CFIT**

There are a number of options which can assist in the mitigation of CFIT in Australia.

#### **3.1 Non Precision Approach – Straight-in Approaches (RNAV GNSS)**

RNAV (GNSS) or otherwise known as LNAV (Lateral Navigation) utilises GPS for lateral navigation to provide straight-in approaches. Most Australian Registered and Certified aerodromes have at least one runway with an LNAV approach. These procedures are designed to be flown by aircraft equipped with appropriately certified self-contained GPS receivers<sup>6</sup>.

ICAO CFIT studies have shown that straight-in approaches are some 25 times safer than circling approaches and that once some form of vertical guidance is added to these, then the safety margin is increased again by some 8 times.

The ICAO resolution A36-23 was recently superseded to reflect the safety value of straight-in LNAV approaches in mitigating CFIT and in Australia 79% of instrument runway ends receiving RPT traffic have LNAV approaches. Airservices Australia is working towards implementing 100% coverage by the end of 2014.

#### **3.2 Terrain Awareness & Warning Systems (TAWS)**

A TAWS system provides a warning of higher terrain in the vicinity of the aircraft. The TAWS is a computer-based system that provides visual and acoustic alerts about the unintended approach to the terrain, taking into account the flight stage, flight crew response time, and aircraft speed.

In Australia, turbine engine aeroplanes operating under the instrument flight rules engaged in regular public transport or charter operations with a maximum take-off weight greater than 15,000kg or carrying more than nine passengers must have TAWS Class A fitted. Aircraft carrying more than nine passengers but having not more than 5,700kg maximum take-off weight must have fitted TAWS Class B plus a terrain display (TAWS-B+). This only provides coverage for approximately 40 aircraft that meet the criteria.

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<sup>6</sup> CASA Instrument 18/11

TAWS-A installation requires a terrain display and a radar altimeter. A TAWS-B + installation requires a terrain display. TAWS-B provides visual and aural alerts only but must be capable of allowing an optional terrain display.

CASA currently have a draft requirement incorporated in the proposed Civil Aviation Safety Regulation Part 135 that all aircraft that operate under IFR when carrying 6 or more passengers be equipped with a Class B TAWS (TAWS-B).

International advice indicates that no aircraft fitted with properly enabled TAWS has ever suffered a CFIT accident<sup>7</sup> and that more than 90 per cent of the aircraft in the commercial jet fleet worldwide had TAWS equipment installed<sup>8</sup>. However most general aviation aircraft do not have TAWS installed and this aircraft category has the highest CFIT accident rate worldwide.

According to the Flight Safety Foundation fitting TAWS to all commercial aircraft is one intervention strategy that would eliminate most serious airline accidents that are occurring worldwide today<sup>9</sup>.

Furthermore, the Australian Transport Safety Bureau investigation into the 2005 Lockhart River CFIT accident, which resulted in 15 fatalities, concluded that if the accident aircraft had been fitted with TAWS, it is probable that the accident would have been avoided<sup>10</sup>.

Therefore, increasing TAWS coverage, while not providing APV coverage, should reduce the risk of CFIT accidents, especially amongst general aviation aircraft and small RPT aircraft.

### 3.3 Precision Approach – Instrument Landing Systems

The Instrument Landing System (ILS) is an instrument presented, pilot interpreted, precision approach aid. 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<sup>11</sup>.

Currently 16 major Australian airports are fitted with an ILS. ILS is an appropriate option at major airports, given large traffic volumes, but is not cost feasible to install at every aerodrome with an instrument runway, with installation costing around \$1.5 million per unit and maintenance and flight checks costing about \$120,000<sup>12</sup>. There are also aircraft equipment and maintenance costs associated with ILS.

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<sup>7</sup> <http://www.flightglobal.com/articles/2009/01/13/320871/forecasts-2009-safety-and-security-are-in-the-doldrums.html>

<sup>8</sup> Flight Safety Organisation Journal, 2009 - [http://flightsafety.org/asw/dec09-jan10/asw\\_dec09-jan10.pdf](http://flightsafety.org/asw/dec09-jan10/asw_dec09-jan10.pdf)

<sup>9</sup> <http://www.flightglobal.com/articles/2011/01/18/351782/global-airline-accident-and-safety-review-for-2010.html>

<sup>10</sup> CFIT: Australia in Context 1996 – 2005, ATSB - <http://www.atsb.gov.au/publications/2007/b20060352.aspx>

<sup>11</sup> CASA website

<sup>12</sup> CASA Discussion Paper DP 1006AS

### 3.4 Approach with Vertical Guidance

#### (a) APV 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 RNAV systems capable of constantly computing barometric VNAV paths and displaying the relevant deviations on the instrument display.

APV Baro-VNAV require accurate aerodrome QNH<sup>13</sup> to conduct the approach procedure. In order to have a QNH broadcast an Automatic Weather Station needs to be first installed at the aerodrome by the Bureau of Meteorology.

Of the 300 Registered and Certified aerodromes in Australia, CASA has advised that around 198 have been assessed as being utilised by aircraft capable of Baro-VNAV operations, leaving approximately one third with no APV capability. Of these remaining 102 airports, four have no LNAV approach, which would provide some mitigation against CFIT.

APV Baro-VNAV is a vital step in expanding the adoption of APV and will provide coverage for over 97 percent of IFR passengers in Australia if implemented across all aerodromes serviced by Baro-VNAV capable aircraft.

Accordingly, APG Agencies should develop an implementation plan for the adoption of Baro-VNAV approaches. The widespread adoption of Baro-VNAV has a range of resourcing and cost implications that need to be progressed further by Government agencies including Airservices Australia, CASA and the Bureau of Meteorology. There will need to be consultation with the aviation industry particularly with regional airline and airport operators in the finalisation of the plan.

#### (b) Augmented Global Navigation Satellite Systems

##### *Ground Based Augmentation Systems (GBAS)*

GBAS is a satellite-based precision approach and landing system that is established at an airport. As shown in Figure 1, a ground station at the airport transmits locally-relevant corrections, integrity and approach data to aircraft in the terminal area via a VHF (radio) band. GBAS provides aircraft with very precise positioning guidance, both horizontal and vertical, which is especially critical during the approach and landing phase of flight. This allows for a safer, more efficient descent and landing.

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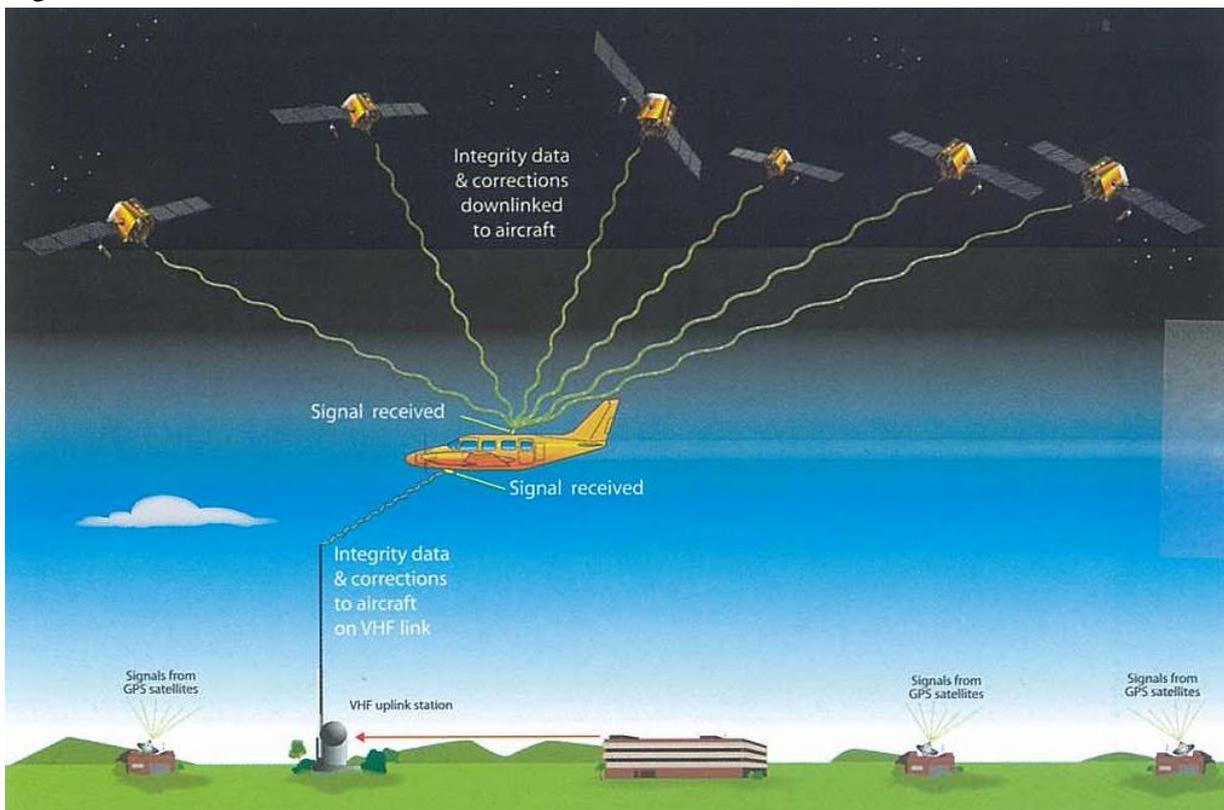
<sup>13</sup> QNH: Altimeter subscale setting to obtain elevation or altitude.

GBAS is recognised by ICAO as a replacement for current ILS. It is a critical component of Australia's next-generation air traffic management infrastructure, particularly as a local solution in the vicinity of capital city airports and will help reduce fuel burn, aircraft noise and airport delays.

Airservices is implementing the Honeywell Smartpath™ SLS-4000 GBAS into the National Airways System<sup>14</sup>. Sydney Airport is the first Australian airport to install the system. Further assessments will be undertaken to consider expanding the GBAS service to other airports in Australia<sup>15</sup>.

However GBAS represents a local, rather than a regional solution to providing APV. Due to its high establishment (estimated \$1.5 million per aerodrome<sup>16</sup>) and maintenance costs and the fact that GBAS avionics are not presently feasible or available for regional and smaller aircraft, it is unlikely to present a practical solution for lower traffic/passenger volume regional aerodromes.

Figure 1<sup>17</sup>



<sup>14</sup> Airservices Website

<sup>15</sup> Ibid

<sup>16</sup> CASA Discussion Paper DP 1006AS

<sup>17</sup> CASA, GNSS Overview, 2010

*Satellite Based Augmentation Systems*

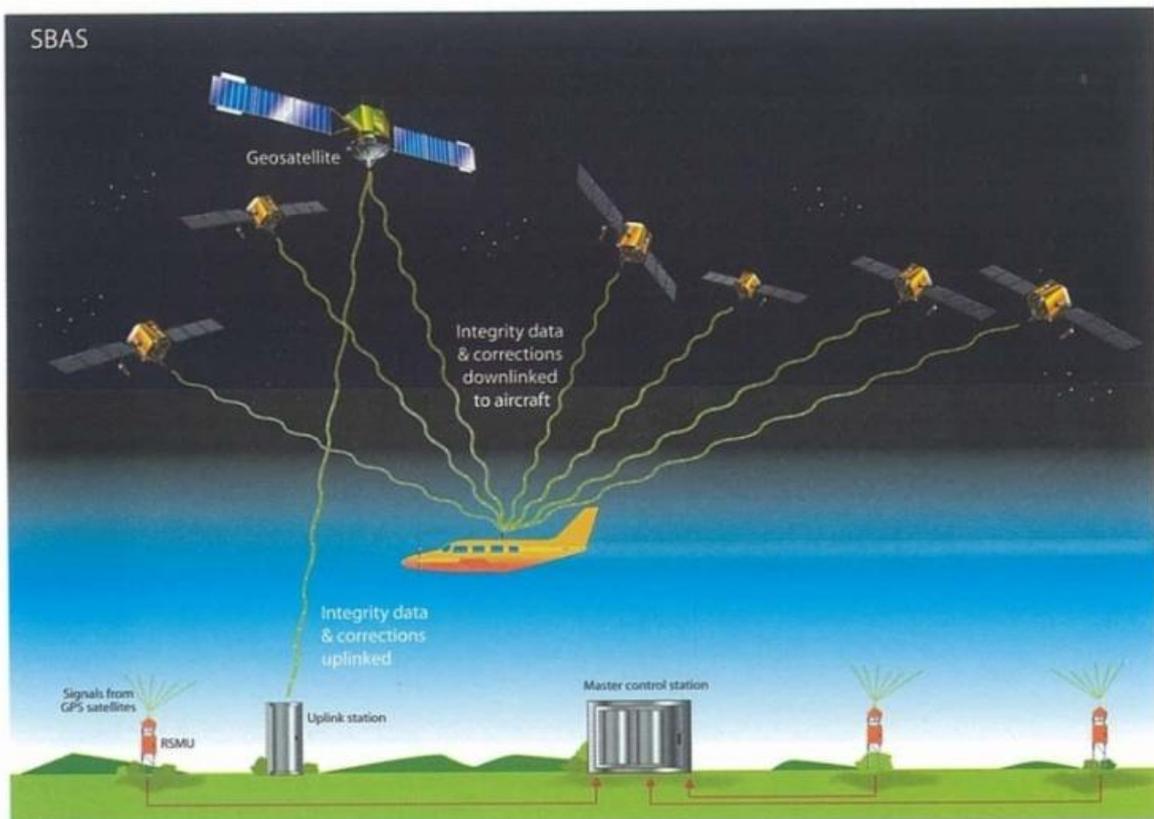
Satellite Based Augmentation Systems (SBAS) deliver error corrections, extra ranging signals (from the geostationary satellite) and integrity information for each GPS satellite being monitored. Like GBAS it also augments GPS signals to provide aircraft with very precise positioning guidance, both horizontal and vertical.

However SBAS differs from GBAS in that it provides GPS integrity monitoring via satellites, rather than from the ground and potentially provides coverage for a wider geographical area.

As shown in Figure 2, in addition to onboard GPS navigation equipment, SBAS comprise:

- a network of ground reference stations to monitor GPS signals;
- master stations that collect and process reference station data and generate SBAS messages;
- uplink stations that send the messages to the geostationary satellites; and
- transponders in the geostationary satellites that broadcast the SBAS messages to the aircraft.

Figure 2<sup>18</sup>



<sup>18</sup> CASA, GNSS Overview, 2010

#### 4. APV, SBAS and Aviation - Overseas Experience

##### 4.1 Background

Currently there are two SBAS systems in operation that are certified for APV approaches - the US WAAS and the European EGNOS. Others that are currently being implemented include Japan's MSAS, India's GAGAN, Russia's SDCM and China's COMPASS.

It is important to examine the experiences of overseas administrations with SBAS implementation, in order to fully consider the costs, benefits and challenges that Australia might experience if it were to pursue establishing an SBAS capability.

Overseas administrations have cited the following benefits and reasons for adopting SBAS for the aviation sector:

- Increased accuracy and integrity;
- Reducing delays, diversions and cancellations of flights;
- Reducing the occurrence of Controlled Flight into Terrain by as much as 75%;
- Acting as a backup system for existing precision approaches;
- Allowing the design of more flexible and safer approach procedures for rotorcraft;
- Enable curved approaches and continuous descent paths, reducing both noise and emissions;
- Improve approaches for helicopters in densely populated areas; and
- Reduces air traffic infrastructure costs - cost effective alternative to instrument landing systems, offering similar performance yet without the need for infrastructure installation and maintenance.

However, many overseas administrations have and are experiencing lengthy implementation delays and cost overruns. For example, the cost of the USA WAAS, was originally forecast at \$509 million in 1994 and has now cost over \$3 billion dollars. Furthermore, the initial operating capability was estimated to commence in June 1997, but did not eventuate until July 2003<sup>19</sup>.

Also the EGNOS Safety of Life (SOL) certification was expected in 2008, however this occurred only recently, i.e. within the second half of 2010. The EGNOS SOL service has only been available since early March 2011. EGNOS has also experienced significant additional establishment and maintenance costs<sup>20</sup>.

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<sup>19</sup> <http://www.gao.gov/new.items/d0511.pdf>

<sup>20</sup> <http://www.insidegnss.com/node/2448>

#### 4.2 United States of America – Wide Area Augmentation System (WAAS)

Since 2003, the USA has used WAAS for APV approaches. The Federal Aviation Administration (FAA) has published approximately 2000 precision-like approaches enabled by WAAS at more than 800 airports. These Localizer Performance with Vertical Guidance (LPV) procedures improve access to airports in lower visibility conditions and where obstacles are present. They are particularly valuable for smaller airports used by general aviation.

The FAA in its NextGen Implementation Plan 2010 is aiming to maintain the goal of at least 300 new LPV approaches per year, and is working with the aviation community to prioritise the schedule of runway ends slated to receive LPV procedures.

LPV capability is currently available on more than 30,000 general aviation and business/regional aircraft equipped with GPS receivers capable of processing WAAS signals and the USA expects that the WAAS capable equipage will continue to grow into the future.

WAAS is funded by the US Government and managed and regulated by the FAA.

#### 4.3 Canada -WAAS

Canada currently uses the American WAAS for APV. Telesat Canada provides the WAAS coverage from its Anik F1R satellite. NavCanada built and maintains four reference stations in Canada that, together with existing USA stations, provide signal coverage throughout much of Canada.

Twenty-four LPV approaches, supported by WAAS have been published to date. Additional sites are planned but are dependent upon provision of necessary airport survey data.

#### 4.4 Europe – EGNOS

The European GNSS Navigation Overlay Service (EGNOS) has been developed through a tripartite agreement between the European Space Agency (ESA), the European Commission (EC) and Eurocontrol (the European Organisation for the Safety of Air Navigation). The European Commission now has full ownership of EGNOS. ESA contributed €200 million (from its Member States and European institutions related to civil aviation and cartography) and the European Commission €100 million to establish EGNOS<sup>21</sup>. Ongoing funding is provided through the Seventh Framework Programme for Research and Technological Development.

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<sup>21</sup> [http://www.esa.int/export/esaNA/SEMNGFX5WRD\\_index\\_0.html](http://www.esa.int/export/esaNA/SEMNGFX5WRD_index_0.html)

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The European Satellite Services Provider (ESSP) was established in 2001 to operate EGNOS. In 2007 the GNSS Supervisory Authority was established to manage all public interests related to European GNSS programmes.

The official start of operations was announced by the European Commission on 1 October 2009. According to the Single European Sky (SES) regulations, the EGNOS Service Provider (ESSP) has been certified for the provision of the EGNOS safety of life (SOL) service as of 12 July 2010. The European Commission (EC) authorised the entry into service of the full SOL service, including vertical guidance application for aviation, in early March 2011.

Eurocontrol has launched projects in France, the UK and Poland aimed at the operational implementation of Approach Procedures with Vertical Guidance (APV) using EGNOS.

Other European countries have plans in place for both the use of Baro-VNAV and SBAS. They have been awaiting certification of EGNOS for vertical navigation before proceeding with adoption of SBAS to support APV. Europe plans to remove all non-precision approaches using terrestrial navigation aids by 2016 by adopting satellite based technology.

### 4.5 Japan - MSAS

MSAS is in its initial operating phase. There are six ground reference stations on the Japanese Islands, one in Canberra and one in Hawaii. There are two master control stations and two multifunction transport satellites (MTSAT).

Because of the limited network coverage, MSAS is only certified for lateral guidance at present. Japan is undertaking a MSAS performance enhancement program which will add ten additional ground reference stations and a new algorithm developed by its Electronic Navigation Research Institute (ENRI) to enable vertical guidance by 2014.

Japan is also investing in GBAS at Kansai International Airport and has already adopted Baro-VNAV enabled APV at selected airports.

### 4.6 India - GAGAN

Indian Space Research Organization (ISRO) in association with the Airports Authority of India (AAI) is developing an SBAS, known as GAGAN. GAGAN has a capability to provide the augmentation service within its footprint, which covers a large portion of the airspace beyond Asia-Pacific Region, Africa to Australia.

The final operational phase of GAGAN is proposed to provide APV coverage by June 2013. GAGAN will comprise three geostationary satellites. However, GAGAN's first satellite launch in April 2010 was unsuccessful.

GAGAN will comply with ICAO safety-of-life operations and support APV coverage. The implemented GAGAN shall be compatible and interoperable with other SBAS systems and provide seamless air navigation services within the Indian region.

In the interim, India is in the process of implementing Ground-Based Augmentation System (GBAS) approach operations to improve access in low-visibility conditions. This will allow Category I, II and III precision approaches to non-ILS runways at Mumbai and Delhi.

India is also implementing Baro-VNAV procedures at the maximum possible number of airports, primarily international airports.

#### 4.7 Russia – System of Differential Correction and Monitoring (SDCM)

SDCM is based on the Russian GLONASS satellite constellation. The baseline 24-satellite constellation is planned to be deployed in 2011, after which time it will be maintained at that level by means of group or single-profile launch events. The next generation of “Glonass-K” spacecraft was launched at the end of February 2011 and aims to provide 99.9% availability worldwide.

In order to improve SDCM coverage, Russia plans to launch three geostationary satellites between 2011 and 2013. The ground control augmentation segment is expected to be extended and modernized by increasing the number of SDCM stations to nine in Russia and five overseas, including one in Australia.

GLONASS satellites broadcast two types of navigation signals in L1 and L2 frequency bands: the standard positioning signal and the high accuracy positioning signal<sup>22</sup>.

#### 4.8 China - COMPASS

On 14 April 2007, the first Medium Earth Orbit satellite, named Compass-M1, was launched. On 15 April 2009, the first geostationary satellite, named Compass-G2, was launched. According to the construction schedule, the Compass/BeiDou Navigation Satellite System will, as a first step, cover China and the nearby area, in 2011, but the full deployment of the System is scheduled to be completed between 2015 and 2020.

However, Compass will not be compatible with current GPS receivers, or other SBAS systems. China does not intend for Compass to broadcast L1-band GPS or WAAS signals, so SBAS receivers won't be able to use the Compass system without upgrades<sup>23</sup>.

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<sup>22</sup> United Nations, 2010, Current and Planned Global and Regional Navigation Satellite Systems and Satellite-based Augmentations System

<sup>23</sup> [http://www.aviationweek.com/aw/jsp\\_includes/articlePrint.jsp?storyID=news/nextgen0710p05.xml&headline=null](http://www.aviationweek.com/aw/jsp_includes/articlePrint.jsp?storyID=news/nextgen0710p05.xml&headline=null)

#### 4.9 Asia Pacific Region

Most other countries, particularly in the Asia Pacific region are facing difficulty in meeting ICAO's timelines for implementing APV. In a number of cases member states have not implemented straight-in approaches, which is a key first step in safety improvement before considering APV approach coverage. Most Asia Pacific countries have difficulty in adopting SBAS due to interoperability issues and the lack of access to suitable GNSS augmentation system capability within the southern hemisphere, in addition to cost considerations and competing safety priorities.

For example, New Zealand indicated in its Performance Based Navigation (PBN) Plan that PBN approaches with vertical guidance will be based on Baro-VNAV specifications for the foreseeable future. Early adoption of SBAS is considered unlikely due to interoperability issues and the lack of suitable GNSS augmentation systems within New Zealand's airspace.

Consequently, most countries within the Asia Pacific region will adopt Baro-VNAV as the preferred method for APV approaches for the short to medium term, with SBAS being considered for adoption well beyond 2016.

### **5. SBAS – Operational, Structural and Financial Issues**

#### 5.1 Overview

As outlined in Section 3, there are a number of options which can be used to reduce CFIT and enhance APV coverage in Australia. Depending on the final scope of coverage envisioned, the vast majority of airports may be covered using one or a suite of technology solutions.

In pursuing an SBAS capability in Australia, indicative costs and benefits were outlined in the 2009 APV study. These broad indicative costs and benefits, even with any subsequent variations, and potentially different public/private funding approaches, make it difficult to justify the significant investment involved in establishing SBAS in Australia to cover aviation operations at smaller aerodromes at this time.

It is important to note that a greater body of work would need to be undertaken to deliver high accuracy costings and economic benefits against each of these options – for inclusion in any submission to the Government to support a final informed decision on whether to consider progressing an SBAS capability, including whether there were quantifiable benefits and interest from other industry sectors.

5.2 The required roles and responsibilities of industry, government agencies and other stakeholders for successful implementation.

There are a number of possible ownership and operational structures Australia could consider. It ultimately depends on the level of interest and adoption of SBAS by industries other than aviation, and the type of SBAS adopted e.g. Australian owned, participation in MSAS, another regional SBAS model or commercial arrangement, etc.

Under an “aviation only” SBAS model, it is highly unlikely that the aviation industry would seek ownership of SBAS infrastructure, particularly given the main potential beneficiaries of SBAS, the smaller regional airlines, have the least capacity to fund such a major investment. The major airlines and airports in Australia already have access to ILS or other systems or can utilise Baro-VNAV technology without requiring SBAS and hence have no incentive to invest in SBAS.

Government aviation portfolio agencies are also not likely to take on an ownership role. Airservices Australia, which provides most civil air traffic services in Australia, is funded by industry, which as indicated above, would have only a partial interest in funding investment in SBAS. Airservices already has a major role in resourcing and undertaking approach design work for vertical guidance procedures over the next four years for the nearly 200 aerodromes where Baro-VNAV capable aircraft are operating public transport services.

CASA is a safety regulatory body not an air traffic service provider, and their role in SBAS would centre on establishment of regulatory requirements and compliance.

In terms of use beyond aviation and in fact beyond transport, if there was a demand and willingness to pay which extended to other industries such as agriculture, forestry and mining, broader consideration would need to be given to which current government agency or private sector interest would be best placed to manage the development, establishment, operation and maintenance of such a SBAS capability.

If other industries wish to use SBAS, then SBAS would become a whole of Government issue, involving a number of Departments and agencies in its development, operation and final regulatory oversight. This scenario may also necessitate the need to establish a new entity to manage SBAS issues in Australia.

Similarly, in relation to the Government participating in a joint venture/ capability with another country or through a commercial arrangement with the private sector, such an approach would require involvement of departments such as DBCDE, DIISR and DFAT as well as extensive negotiations with overseas administrations to test their willingness to cooperate/participate with Australia in such an arrangement.

### 5.3 Estimated Costs and Benefits Profile Over the Life of developing SBAS or other options to complete APV coverage in Australia

Indicative costs for establishing and implementing SBAS in Australia depend on the operational model adopted, leaving aside ongoing maintenance and operational costs. A range from over \$100 million to approaching \$1 billion could broadly be estimated acknowledging that over time and with different financial and infrastructure options this range may vary.

Further analysis would be needed to determine the benefits accrued purely from SBAS over and above those significantly less costly options such as adopting Baro-VNAV.

That is, if other non-aviation users could not demonstrate the need (and therefore benefits) for SBAS in their industries the additional benefits of the more expensive SBAS options would only be related to reduced risk to operations at small regional aerodromes which would not be covered by using Baro-VNAV. Even at the smaller aerodromes the initial focus from a cost-benefit point of view would likely be on ensuring, wherever possible, all runway ends do have a straight-in approach.

Care also needs to be taken in making any comparisons with overseas non-aviation benefits of SBAS if state government and industry have already found (and are funding) alternative effective ways of using satellite-based technology without the need for the vertical precision of SBAS.

### 5.4 An examination of feasible timelines for introduction of a SBAS or other capability and risk management.

In 2007 the original ICAO Resolution A36-23, required all member states need to implement APV at all instrument runway ends that serve aircraft with a mass of 5,700kg or more in line with the following deadlines:

- 30% by 2010;
- 70% by 2014; and
- 100% by 2016.

However at the 37<sup>th</sup> ICAO assembly meeting in October 2010, a new Resolution was passed which represents an acknowledgement that few member states will be able to implement APV coverage within the given ICAO timeframes. The change also recognises the primary safety importance of having straight-in approaches at a wider range of smaller aerodromes.

The resolution now allows for:

- *implementation of approach procedures with vertical guidance (APV) (Baro-VNAV and/or augmented GNSS), including LNAV only minima, for all instrument runway ends, either as the primary approach or as a back-up for precision approaches by 2016 with intermediate milestones as follows: 30 per cent by 2010, 70 per cent by 2014; and*
- *implementation of **straight in** LNAV only procedures, as an exception to 2) above, for instrument runways at aerodromes where there is no local altimeter setting available and where there are no aircraft with a maximum certificated take-off mass of 5 700 kg or more suitably equipped for APV operations.*

It should be noted that Australia has already implemented straight-in approaches for at least one runway end, where possible, at most airports serviced by RPT aircraft.

Given the lead times involved in establishing an SBAS capability and noting industry training and equipment requirements to adopt APV approaches, it is not realistic for Australia to meet the ICAO full coverage requirements, nor is there an apparent compelling cost benefit case to do so. Australia's position is likely to be shared with the majority of countries which have significant numbers of small aerodromes and by those countries looking to adopt Baro-VNAV as the primary means of adopting APV approaches.

Australia will need to provide advice to ICAO outlining its position and include its proposed course of action in terms of the implementation plan for the wider adoption of Baro-VNAV to provide expanded APV approaches in Australia.

If Australia is to consider SBAS, a realistic implementation plan and timetable would need to consider a number of issues such as:

- the necessity or otherwise of regulatory mandates;
- aircraft equipment fitment requirements and adoption rates and training requirements;
- regulatory amendment and approval processes;
- approach design and approval;
- potential negotiations with other countries and/or private operators on access to their satellite facilities, including talks with neighbouring countries over the possibility of a regional SBAS; and
- responsibility and funding for building and maintaining necessary infrastructure such as ground reference stations.

In terms of risk management, Australia had 27 CFIT accidents and incidents from 1996-2005, with most occurring in the general aviation sector. The main commonalities in CFIT incidents were:

- approach to the aerodrome with instrument flight rules;
- reduced visibility;

- hilly/mountainous terrain;
- visual flight rules with visual meteorological conditions; and
- pilots tracking off-course<sup>24</sup>.

However, since 2006, Australia has only had one fatal CFIT accident (in 2007), which occurred under visual flight rules. There have been no fatal CFIT accidents operating under instrument flight rules since 2006<sup>25</sup>.

Australia has straight-in approaches at around 260 aerodromes, which significantly reduces the risk of a CFIT accident. As indicated in Section 3.1, ICAO CFIT studies have shown that straight-in approaches are some 25 times safer than circling approaches.

Added to the proposed adoption of Baro-VNAV to achieve APV approaches covering most passenger traffic in Australia, there is already a significant commitment to risk mitigation for CFIT without the need for SBAS at this time.

## 5.5 Possible Funding Options

Indicative costs for establishing and implementing SBAS in Australia depend on the operational model adopted, leaving aside ongoing maintenance and operational costs. A range from over \$100 million to approaching \$1 billion could broadly be estimated acknowledging that over time and with different financial and infrastructure options this range may vary.

The current aviation funding model for air traffic facilities involves industry funding through Airservices Australia's enroute and terminal navigation charges. Even spread out over the five year long term pricing model used by Airservices, the cost of SBAS would represent a dramatic increase in charging for regional aviation.

This funding model presumes Airservices would become the service provider of SBAS infrastructure – an assumption which currently has no basis given the already extensive Airservices infrastructure program including the replacement of critical safety assets.

In addition, Airservices would need to do a funding case for supporting such investment without a regulatory mandate from CASA. As large sectors of the aviation industry are unlikely to support such investment, the aviation funding case would be difficult to sustain.

If a private or other entity became the provider of SBAS to aviation, then another charging mechanism would be needed to fund the initial investment and ongoing cost of SBAS infrastructure. Again, if it was only to be funded by aviation users, a sustainable funding mechanism is unlikely to be established.

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<sup>24</sup> CFIT: Australia in Context 1996 – 2005, ATSB - <http://www.atsb.gov.au/publications/2007/b20060352.aspx>

<sup>25</sup> ATSB data

If SBAS could attract other industries to support its establishment and operation, then either a new Government or private entity could seek to manage SBAS with a higher possible future funding stream from multiple users.

However the risk involved in establishment would be whether that entity could lock-in potential SBAS users to underwrite the significant establishment costs involved. It is ultimately up to private entities whether they wish to pursue this type of investment.

A detailed cross industry justification and cost benefit analysis for considering SBAS would need to be provided to the Government if it were to consider any form of investment in SBAS, including any negotiations with regional partners who might also be interested in SBAS. There would also need to be considerable work on examining what sort of Government agency would need to be established to pursue such an investment, including the issue of establishment and ongoing costs and the level of possible involvement of the private sector.

#### 5.6 Possible Future Alternatives

There are a number of other considerations that Australia should have regard to in the possible development of an SBAS capability. Recently, a new satellite was launched by the US Defence Force providing dual frequency SBAS, which improves signal accuracy and coverage.

There are also many new satellites and augmentation systems that will be launched in the future which are predicted to increase GNSS coverage in Australia. These advances may reduce infrastructure requirements and costs for the development of SBAS in Australia and could also reduce the need for SBAS in the future.

#### *Multi-GNSS*

It is estimated that by 2015, if the planned deployments go ahead, there will be up to three times the number of satellites and four to six times the number of individual signals on which measurements can be made. The more satellites and signals there are, the better the positioning performance is – in terms of accuracy, availability, reliability and integrity<sup>26</sup>.

The plan is to eventually have the following satellites in orbit between 2015 and 2020:

- GPS (the current 31 satellite constellation);
- Russia - Glonass (planned 24 satellite constellation);
- Europe - Galileo (planned 30 satellite constellation);
- China - Compass (possible 27 satellite constellation);
- India - RNSS (possible 7 satellite constellation); and

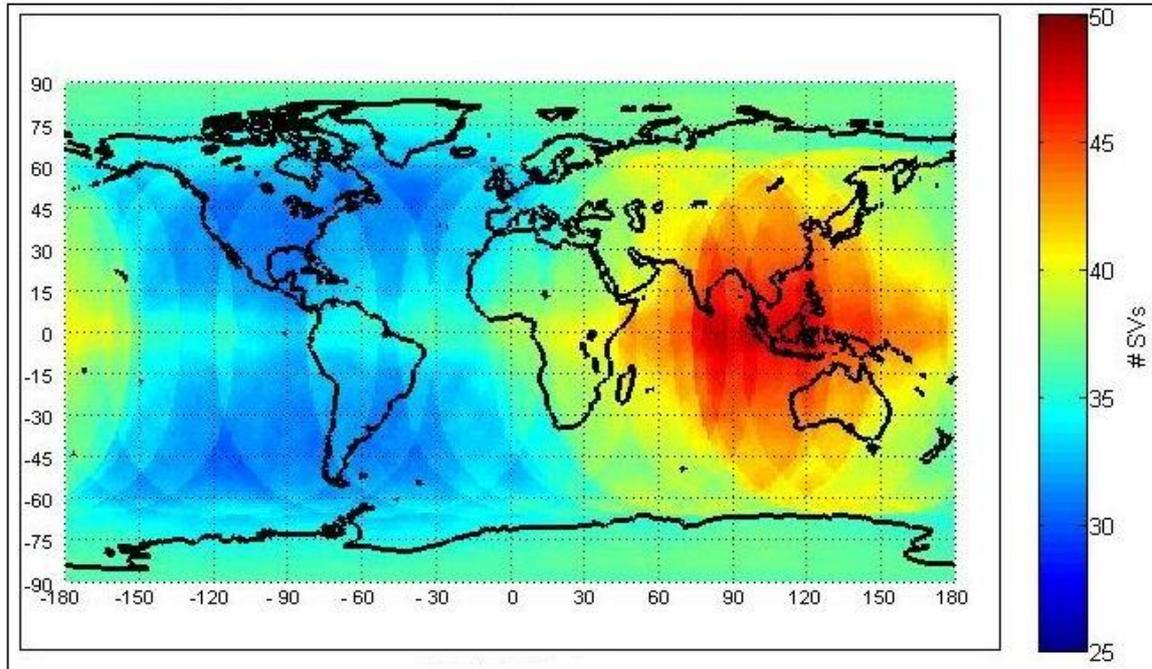
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<sup>26</sup> Dempster & Rizos, 2009, Multi-GNSS report

- Japan - QZSS (3 satellite constellation).<sup>27</sup>

As shown in Figure 3, the average number of satellites in the Australasian region will be over 40. The maximum number of visible satellites is close to 60<sup>28</sup>.

Figure 3<sup>29</sup>



Average number of visible satellites (15° elevation cutoff angle) of the GPS, Glonass, Galileo, Compass, WAAS, EGNOS, QZSS, MSAS, IRNSS and GAGAN constellations on a worldwide basis over a 24 hour period.

In addition to increased satellite coverage, on 27 May 2010 the US Air Force successfully launched a new satellite that contains a new third GPS signal known as L5. L5 is broadcast in a radio band reserved exclusively for aviation safety services and radio navigation satellite services. The L5 signal is designed to support safety-of-life transportation and other high-performance applications. Future aircraft will use L5 signals in combination with L1 C/A (also in a protected band) to improve signal accuracy<sup>30</sup>.

Both L1 and L5 will be used for basic GPS and SBAS in the coming years because a dual-frequency approach helps to compensate for ionospheric signal distortion, an atmospheric anomaly made particularly troublesome by the location of the earth's magnetic equator<sup>31</sup>. A recent study<sup>32</sup> conducted on dual frequency demonstrated that with increased satellite coverage and dual frequency, APV coverage can be established with comparatively sparse ground reference networks in Australia.

<sup>27</sup> Ibid

<sup>28</sup> Ibid

<sup>29</sup> Ibid

<sup>30</sup> United Nations, 2010, Current and Planned Global and Regional Navigation Satellite Systems and Satellite-based Augmentations System

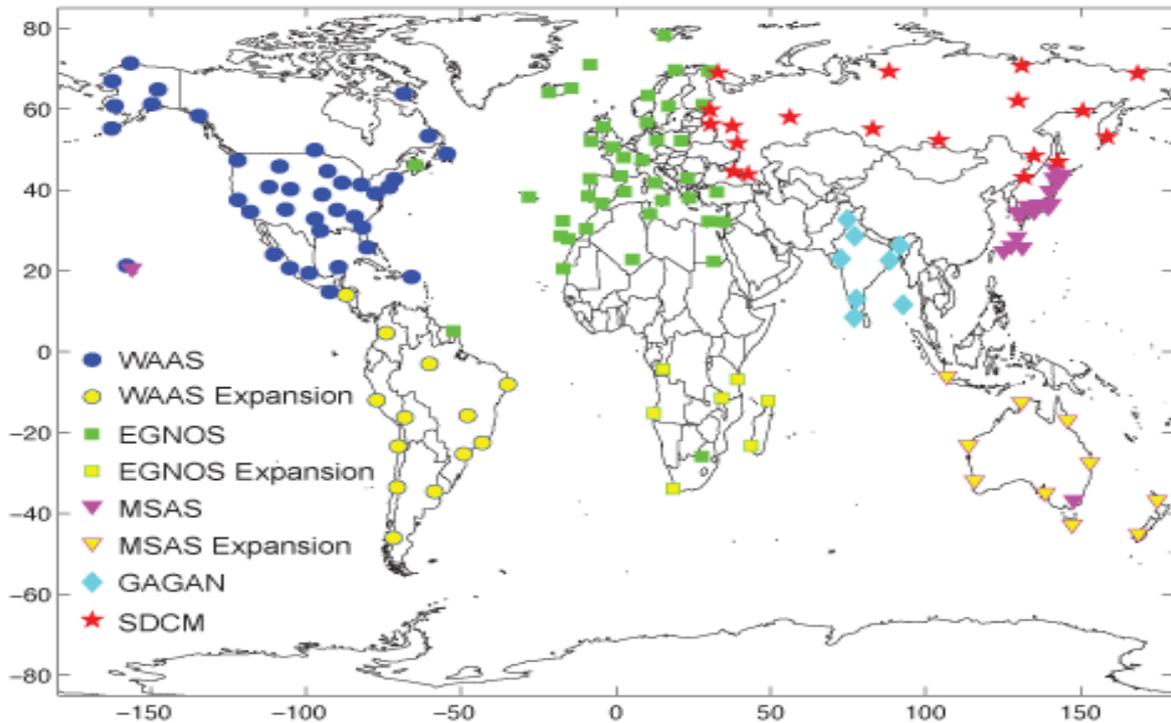
<sup>31</sup> [http://www.aviationweek.com/aw/jsp\\_includes/articlePrint.jsp?storyID=news/bca0609p2.xml&headline=null](http://www.aviationweek.com/aw/jsp_includes/articlePrint.jsp?storyID=news/bca0609p2.xml&headline=null)

<sup>32</sup> Walter, Enge and Blanch, 2010, Coverage Improvement for Dual-Frequency SBAS Article

Additional dual-frequency core constellations such as Galileo, Compass, or GLONASS could greatly expand coverage to well outside the original reference network regions. The expanded coverage can provide increased availability, accuracy and integrity of signals over Australia. As shown in the following diagrams, the advantages of dual frequency allow much less dense ground reference stations, which would reduce the cost of establishing SBAS in Australia.

Figure 4 shows the networks of the five SBAS systems, including hypothetical expansions into the southern hemisphere.

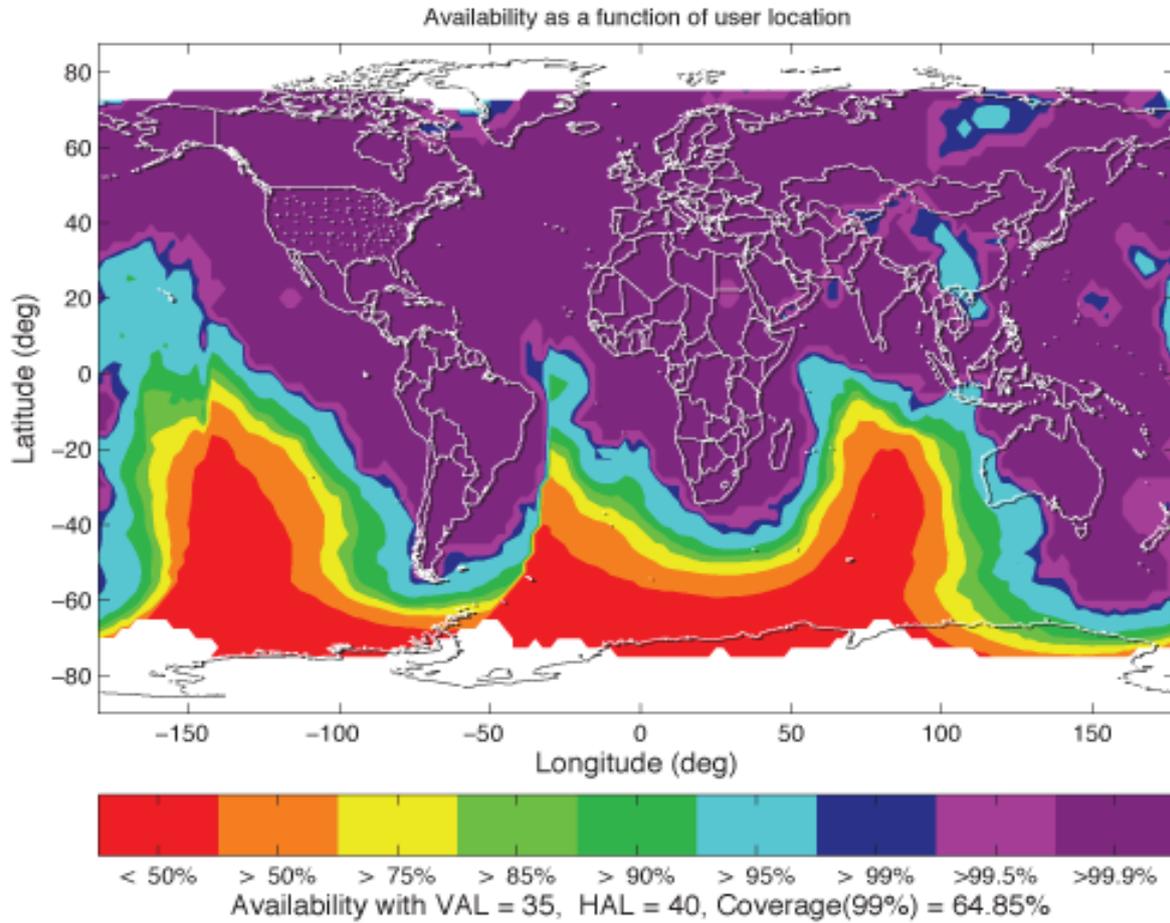
Figure 4<sup>33</sup>



<sup>33</sup> Walter, Enge and Blanch, 2010, Coverage Improvement for Dual-Frequency SBAS Article

Figure 5 shows the combined dual-frequency APV coverage for these SBASs with the expanded ground reference stations.

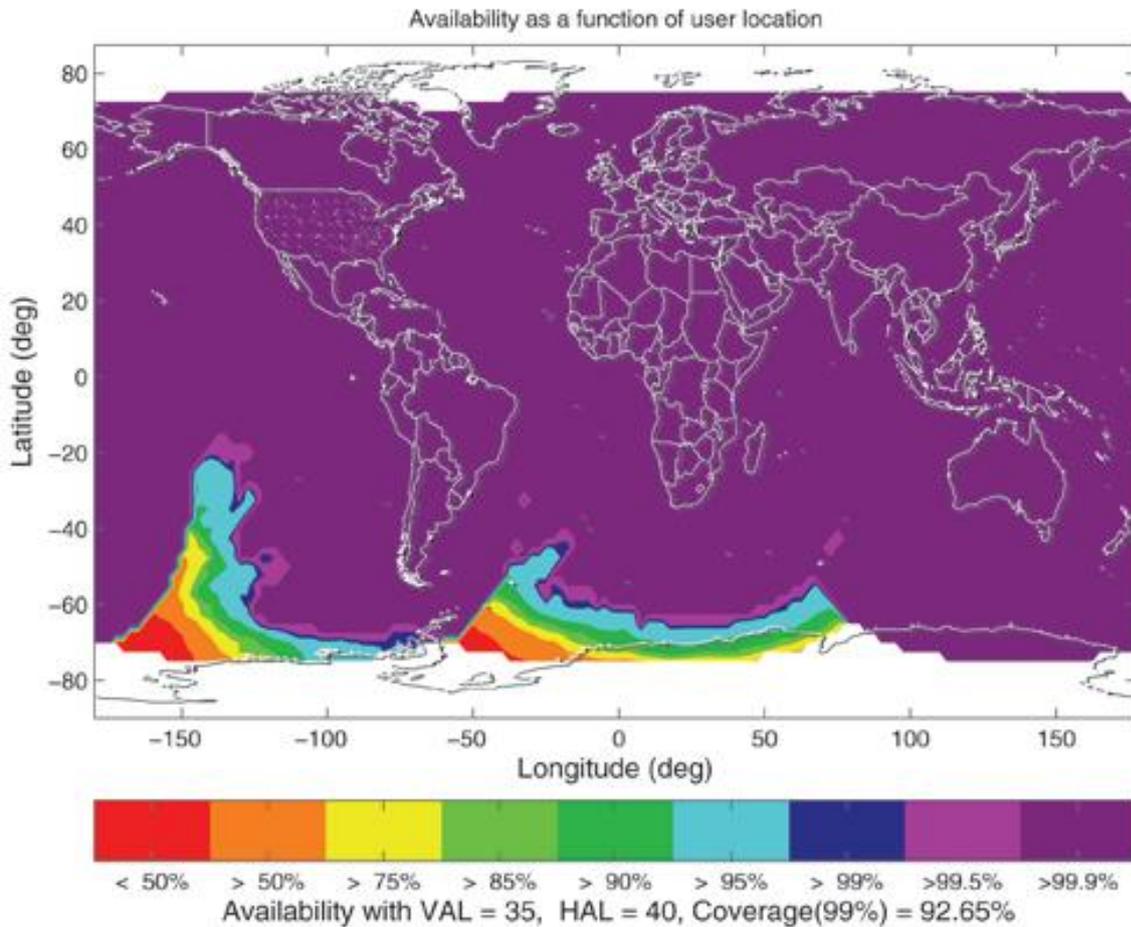
Figure 5<sup>34</sup>



<sup>34</sup> Walter, Enge and Blanch, 2010, Coverage Improvement for Dual-Frequency SBAS Article

Figure 6 shows the results when the expanded GNSS networks of Russia’s Glonass and Europe’s Galileo are incorporated. Compared to Figure 5, the southern hemisphere is much more reliably covered. Australia would have complete APV coverage.

Figure 6<sup>35</sup>



*Test SBAS*

Australia could conduct a test SBAS in order to determine the likely benefits of having an SBAS capability in Australia. CASA has held discussions with Inmarsat regarding a trial for the development of SBAS in Australia and advised that a real time SBAS test message could be broadcast over Australia with the provision of the following system components:

- Existing Australian ground reference stations;
- Magic SBAS software (GMV) on board aircraft;
- 4F1 satellite and LI/L5 transponder (Inmarsat); and
- Navigation Land Earth Station – NLES (uplink station) with associated receivers, amplifiers and control computers plus a 9m antenna.

<sup>35</sup> Walter, Enge and Blanch, 2010, Coverage Improvement for Dual-Frequency SBAS Article

Inmarsat has 4 NLES in the region with varying availability (Indonesia, Philippines, Australia and Auckland). The fully available antenna is 8.1m (transmission requirements TBC) and is located in Batam, Sekupang, Indonesia. The remaining three NLES could be available on a shared basis but excess capacity would need to be determined and such a solution could be technically challenging.

An alternative solution would be a purpose built NLES which is estimated at US\$1.5m, comprising a HDA - RFU system (computer racks that comprise the uplink station capability are estimated at US\$1.0 million) and 9m antenna is estimated at US\$500,000 (although if there was an appropriate antenna available for shared use elsewhere this could conceivably be used).

A purpose built NLES could be dedicated to research and development of an SBAS correction message tailored for Australian ionosphere conditions. The provision of a real time SBAS correction message would not only enable research, test and development of SBAS signals under Australian conditions but would permit the uses of the test message in trials for transport modes and industries. However, it is important to note that this test SBAS signal would not be suitable to test for aircraft APV approaches.

The trial would however, provide data and end user feedback that could inform future decisions regarding the value of a future SBAS capability acquisition, such as ground reference station locations.

This interim measure however does not resolve the ownership, management and funding of the eventual cost of an SBAS capability and whether such investment is justified.

## **6. SBAS – Non-Aviation Issues**

### **6.1 Australia's National Space Policy**

The Space Policy Unit within the Department of Industry, Innovation, Science and Research (DIISR) is developing a National Space Policy to provide a vision for Australia's use of space and space-related technologies including providing strategies to enable Australia to meet its National Priorities through space and to ensure Australia meets its future space-related education and innovation needs.

It will have a particular focus on the areas of earth observation, satellite communications, and position, navigation and timing applications which are key strengths for Australia.

The National Space Policy will also have a significant role in coordinating the space activities of government on the national, state and, importantly international stage. The policy will express that international collaboration is vital to Australia's space efforts, as Australia is reliant on the space systems of our international friends and partners. The challenge is assuring this access to these systems.

The Policy will consider mechanisms to assure access to these space systems that provide data that the remote sensing and wider Earth observation community requires. The Space Policy Unit is aiming to deliver the National Space Policy to Government later this year.

In relation to SBAS, the National Space Policy may provide a broader context for Government in its consideration of whether there is merit in any further work on an SBAS capability for Australia, especially given that any viable SBAS proposal in Australia would require cross portfolio Government and industry support, in addition to potential bilateral and multilateral discussions with other countries in the Asia-Pacific region.

## 6.2 Other Users – Land and Maritime Transport and Other Industries

### *GNSS Ground Based Augmentation Systems in Australia*

Many other Australian industry sectors currently use Continuously Operating Reference Stations (CORS), which is a continuously operating survey quality GNSS Reference Station, also known as a ground based augmentation system.

CORS continuously record, distribute and archive GNSS satellite data and when used in conjunction with a second roving GNSS receiver enables the roving unit to accurately determine its position. Unlike SBAS which provides vertical navigation, it only provides horizontal navigation capability.

A 2010 Tasmanian Government CORS Feasibility Study<sup>36</sup> provides a useful summary of current activity in different industries in this area.

### *Agriculture*

Agriculture currently represents the fastest growing sector using GNSS. GNSS is currently used in agriculture for a number of applications described as “Precision Agriculture”. These include machine guidance, yield mapping, variable rate application of inputs (fertiliser, seed, water, etc.) and digital elevation mapping.

While machine guidance is the most widely adopted application, the technology is essential to the implementation of Controlled Traffic Farming (CTF), a technique that involves constraining the movement of tractors to permanent wheel tracks year after year by fitting tractors with GNSS steering guidance.

### *Construction and Civil Engineering*

The predominant use of GNSS in this sector is for machine guidance for the building of roads, highways, rail, bridges and water and electricity infrastructure. As with other sectors, there is an increasing uptake in the use of the technology, with most major suppliers experiencing growth in sales of precision machine control systems.

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<sup>36</sup> SKM, 2010, Feasibility Study- CORS Network Tasmania

*Mining*

The use of GNSS for accurate selective mining is well established. The application involves the fitting of GNSS equipment to excavators to allow precise positioning of equipment for dig operations.

*Surveying & Spatial Industry*

The surveying and spatial industry use GNSS in all areas of operation and are the most advanced users.

*Science & Research*

Real time and static GNSS data is critical to the execution of many current and future scientific research programs. GNSS data, combined with other forms of observations, contribute significantly to research into global climate change, sea level studies, modelling of the upper atmosphere in relation to storm and weather prediction, crustal strain and seismic deformation, and surface expression of hydrologic loading.

*Maritime*

The Australian Maritime Safety Authority (AMSA) operates 16 CORS which broadcast a GPS augmentation (DGPS) service for coastal shipping around Australia as part of their international commitments to the safety of marine navigation.

*Rail*

The Australian Rail Track Corporation, the Australian Government-owned national rail track manager, is trialling the Advanced Train Management System (ATMS) to increase the safety, capacity and efficiency of the national rail network. The ATMS is designed to use the existing Global Positioning System (GPS) and Broadband Data and Voice communication technology. If successful, the ATMS trial would replace ageing and disparate physical train control and signalling systems.

The trial of the system is taking place on a section of track between Crystal Brook and Port Augusta in South Australia. If the trial is successful it would provide opportunities for industry participants in the implementation phase.

*Road*

In regard to road transport, the Australian Government is examining the use of satellite technology in the following areas:

- progressing the Council of Australia Government's heavy vehicle pricing and regulatory reforms, which will potentially include the monitoring of heavy vehicle movements on national and state road networks.
- In-Vehicle and At-Roadside Technology and Intelligent Speed Assist as well as specific technology standards for future innovative products.

The Australian Government has initiated a Parliamentary inquiry into smart infrastructure, covering the transport, communications, energy, and water sectors. The committee is expected to reconvene in the first half of 2011 and is likely to cover the use of GNSS for road transport. Currently most road transport systems are based on standard GPS systems.

### 6.3 Future Demand from Land and Maritime Transport and Other Industries

Most State Governments are currently undertaking studies to consider further developing their CORS network or have already started investing in new CORS infrastructure.

AuScope, a National Collaborative Research Infrastructure Strategy funded project to enhance Australia's ability to monitor the Australian continent will build over 100 GNSS Continuously Operating Reference Stations (CORS) by collaboration between Geosciences Australia and state governments.

The Department of Agriculture, Fisheries and Forestry (DAFF) and the Australian Maritime Safety Authority (AMSA) have indicated that it is likely both the agriculture and maritime industry will continue to use CORS as their primary GNSS position navigation timing system. A strong interest in using or funding an SBAS capability has not been identified in these sectors. Furthermore, AMSA has advised that it is currently upgrading its ground based augmentation system network, based on differential GPS.

The road and rail areas within the Infrastructure and Transport portfolio have advised that there does not seem to be a strong desire within these industries to have satellite based augmentation systems.

Whilst SBAS would provide some benefits to these industries, it is clear that all these industries are continuing to invest in ground based augmentation systems for GNSS applications rather than considering satellite based augmentation systems. This is most likely because these industries, unlike the aviation industry, do not currently need the added benefit of vertical guidance provided by satellite based augmentation systems, nor the level of accuracy or high availability and integrity that SBAS offers.

### 6.4 Overseas Experience

There are a number of examples overseas where multiple users of SBAS have been established. For example, in Europe, EGNOS is being used by a number of industries, including, agriculture, maritime, aviation, rail and road.

It seems that EGNOS is mainly being adopted in the agriculture and road planning/monitoring (toll charges) industries. The European rail traffic management system uses GPS via a mobile communication service provider and radio communication. Despite a number of studies, there do not appear to be any plans to upgrade the system to EGNOS.

Furthermore there does not seem to be a significant adoption of the American WAAS by industries other than aviation. American agricultural machinery company "John Deere" has developed an SBAS system for precision farming known as the StarFire navigation system. StarFire is considerably more accurate than WAAS due to a number of techniques that improve its receiver-end processing, but is only used for horizontal navigation.

## 7. Conclusion

On the basis of information currently available, it is difficult to justify the significant investment involved in establishing SBAS in Australia to cover aviation operations at smaller aerodromes at this time.

The review notes a number of new satellites and augmentation systems will be launched in the future, which are predicted to increase satellite coverage over Australia. These advances will have implications for future requirements and costs of SBAS in Australia and may provide access to other alternative systems.

Consideration of any future investment in SBAS would need to be a part of a whole of Government approach with the significant cost considered against potential benefits across a range of industries.

Further detailed work would be needed if the Government wished to consider further advice on an SBAS capability in Australia. This could include a detailed cost benefit analysis, undertaking a comprehensive SBAS industry demand survey; examining different funding options including private investment; the impact of increased satellite coverage and new technologies in the coming years from other countries and the implications of entering into an agreement or partnership with other countries in the region for satellite access.

However, the review supports proceeding in the short-term with the development of a Baro-VNAV implementation plan, a more affordable and currently available technology which can provide APV coverage for over 97 percent of IFR passengers in Australia if implemented across all aerodromes serviced by Baro-VNAV capable aircraft. Potentially the use of Baro-VNAV could provide APV coverage at nearly 200 aerodromes throughout Australia.

There are a range of resourcing and cost implications that need to be progressed by Government agencies in consultation with industry to ensure the extension of APV coverage in Australia.

The possible future establishment of an SBAS capability in Australia in the long-term therefore remains open. If strong multi-sectoral demand were to emerge over the coming decades and SBAS coverage provided by other administrations were to expand significantly in the region then the efficacy of establishing an SBAS capability in Australia could be further examined.

**SBAS REVIEW – Terms of Reference**

Specifically, the review will need to critically examine and report on:

1. The justification and cost of the development of a SBAS capability, or other options, for completing APV coverage in Australia - in the context of a commitment to increased use of Baro-VNAV systems, and other current and future means of implementing safer flight approach paths particular at regional aerodromes
  - (a) having regard to ICAO's APV milestones and objectives, and to mitigate controlled flight into terrain (CFIT) events
2. The review will consider:
  - a. Australia's National Space Policy;
  - b. the demand and potential involvement of other transport modes and other portfolios for utilising a national SBAS capability, looking at any relevant experiences of overseas administrations; and
  - c. possible SBAS ownership, operational and regulatory oversight structures.
3. The review will examine:
  - a. the required roles and responsibilities of industry, government agencies and other stakeholders for successful implementation, e.g. infrastructure, equipment and personnel investment;
  - b. estimated costs and benefits profile over the life of developing SBAS or other options to complete APV coverage in Australia;
  - c. feasible timelines for the potential introduction of a SBAS or other capability, including any priority needs in relation to fleet fitment or airports procedures development;
  - d. likely risks and risk management requirements involved with developing a SBAS or other capability in Australia and the need for any interim or transitional arrangements;
  - e. possible funding options for establishing and operating a SBAS or other capability in Australia.