SPACE BASED NAVIGATION AUGMENTATION SYSTEMS WORLDWIDE - CURRENT STATUS AND FUTURE OUTLOOK

Norbert Frischau, STP  
Manfred Wittig, STP  
Otto Koudelka, TUG  
Charles Villié, EC/GSA  
Suresh V. Kibe, Consultant (ex-ISRO)

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Pilots using this chart must refer to the notes on page 16-9A.

**MISSING APOCH:** Climb on LOC crd (255°) with max gradient to D1.0 OEV, then turn LEFT (max radius 0.9 NM, e.g., 155 KT IAS, 25° bank) onto 060° to AB Lctr, rejoin LOC overhead AB Lctr and continue climb on 073° with max gradient. At D1.4 OEV, turn LEFT to RTT NDB and hold at 9500'.

**WARNING:** Be aware of back course indication on reciprocal track.

Alt Set: NFA
Rev Elev: 67 NFA
Trans level: By ATC
Trans alt: 11000' (3300')

**MAX RADIUS 0.9 NM**
(e.g. 155 KT IAS, 25° BANK)

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Due to mountains, the coverage of LOC OEV and DME OEV is restricted to 7 NM within +/– 10° of the nominal inbound track. Caution advised outside this area.

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Profile flight path and terrain contours are depicted to scale.
To satisfy its high safety requirements, the aviation sector has developed and rolled out a plethora of air navigation systems...

RNAV… Area NAVigation: Routing via waypoints - navigation beacons like VOR, DME and NDB provide geographical reference
Current Air Navigation Systems: PA and the non-liked NPA

... and several approach procedures, of which NPAs are to be replaced due to ‘loss of situational awareness’ safety issues.

![Diagram of a VOR/DME approach]

**FIGURE 1 — EXAMPLE OF A VOR/DME APPROACH**

The procedure starts at the Initial Approach Fix (IAF), which is at 10 DME on the ABC 095° radial. The aircraft may not descend below 2000 ft until passing 7 DME, after which it descends on the 095° radial. Due to high terrain, the aircraft may not descend below 1200 ft until it passes 4.4 DME, when it continues descent to the MDH. If the required visual references have not been established before 2 DME the aircraft must commence a missed approach.

RNP... Required Navigation Performance
B-RNAV... Basic Area Navigation (±5 NM)
P-RNAV... Precision Area Navigation (±1 NM)
FAF... Final Approach Fix
MDA/MDH... Minimum Descent Altitude/Height
DA/DH... Decision Altitude/Height

High Risk for Controlled Flight into Terrain (CFIT) Accidents
The ILS has established itself as PA reference, even allowing for landings in all weather, but due to high costs and limited approach characteristics, PA alternatives need to be found...

**Current Air Navigation Systems: The great but expensive ILS**

<table>
<thead>
<tr>
<th>Approach category (CAT)</th>
<th>Decision height or alert height (minimum above runway threshold or touchdown zone)</th>
<th>Runway visual range (RVR)</th>
<th>Visibility minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>200 feet (61 m)</td>
<td>550 m or 2400 ft (1200 ft is approved at some airports), increased to 800 m for single crew operations</td>
<td>800 m (1600 ft or 1200 ft in Canada)</td>
</tr>
<tr>
<td>II</td>
<td>100 feet (30 m)</td>
<td>300 m or 1000 ft</td>
<td>N/A</td>
</tr>
<tr>
<td>IIIa</td>
<td>50 ft &lt; DH &lt; 100 feet (30 m)</td>
<td>200 meters (660 ft)</td>
<td>N/A</td>
</tr>
<tr>
<td>IIIb</td>
<td>0 &lt; DH &lt; 50 feet (15 m)</td>
<td>75 meters (246 ft) (JAA) &lt; RVR &lt; 200 meters (660 ft)</td>
<td>N/A</td>
</tr>
<tr>
<td>IIIc</td>
<td>No DH</td>
<td>No RVR</td>
<td>N/A</td>
</tr>
</tbody>
</table>
On the Search for a low-cost Alternative to ILS

... for smaller airfields and the GA community that cannot afford costly IFR systems and which are already ‘happy’ with a CAT I PA

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System minima

<table>
<thead>
<tr>
<th>Facility</th>
<th>Lowest MDH</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILS (no glide path - LLZ)</td>
<td>250 ft</td>
</tr>
<tr>
<td>VOR</td>
<td>300 ft</td>
</tr>
<tr>
<td>VOR/DME</td>
<td>250 ft</td>
</tr>
<tr>
<td>NDB</td>
<td>300 ft</td>
</tr>
</tbody>
</table>

Note: MDH... Minimum Descent Height

All NPA!
The advent of GPS in 1995 has given the aviation community a cost-efficient en-route navigation tool, still it requires SBAS to enable GNSS based precision approaches and landings.

- The reason why SBAS is needed is threefold:
  - Accuracy (better than 4/16 m)
  - Integrity (Alarm within 6.2 s)
  - Availability (> 99.999%)

- These features define the realm in which SBAS

**SBAS competitive space**

<table>
<thead>
<tr>
<th>GNSS</th>
<th>Vertical Spread</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
<td>400 – 600 ft DH</td>
</tr>
<tr>
<td>GPS/Inertial</td>
<td>350 – 400 ft DH</td>
</tr>
<tr>
<td>SBAS</td>
<td>250 – 300 ft DH</td>
</tr>
<tr>
<td>SBAS/GBAS</td>
<td>200 ft DH</td>
</tr>
<tr>
<td>GBAS</td>
<td>200 – 0 ft</td>
</tr>
</tbody>
</table>

**Note:** LNAV... Lateral NAVigation, VNAV... Vertical NAVigation, IAP... Instrument Approach Procedure.
SBAS will help to make the skies safer and aircraft routing more efficient, which ultimately saves time, fuel and money

- The main advantage of SBAS is its broadcast approach similar to Satellite Telecom with one satellite serving millions of users ⇒ enormous cost savings potential

- Cost Benefit Assessment for the US:
  - CAPEX
    - Publication of a WAAS approach: approx. US$ 50,000
    - Installation of an ILS: US$ 1m to 1.5m
  - OPEX
    - Provision of WAAS for all 5400 public use airports: < US$ 50m
    - OPEX of ILS installed at only 600 airports: US$ 82m

- Shifting from NPA to PA and introducing IFR like procedures at low cost into the GA community will significantly increase safety
  - Approximately 420,000 GA IFR flights took place in Europe in 2010
  - These 420,000 flights represent only 7% of total GA movements, thus the clear majority of GA flight falls into the VFR category

Note: IFR... Instrument Flight Rules, VFR... Visual Flight Rules
As aviation is truly a global business it requires a global approach in providing SBAS functionality - WAAS, EGNOS, MSAS and in future GAGAN and SDCM are the consequent answers.

Future Dual-GNSS based LPV-200 Coverage with L1 and L5 and expanded Networks provided by WAAS, EGNOS, MSAS, GAGAN and SDCM.
Once a second and/or third GNSS is fully operational the rebuilt of the air navigations systems will enter into its ‘final’ stage by phasing out VORs and NDBs and introducing RNP on grand scale

- Already today, the FAA is considering phasing out VORs, also because 80% of the 967 US VORs are working well beyond their service life, and repair parts are getting increasingly harder to find.

- The goal is therefore to start retiring these obsolescence plagued air navigation systems. The survivors will create the MON – the Minimum Operational Network - which will provide minimal navigation. If flying above 5,000 feet AGL, it will “enable aircraft anywhere in the continental United States to proceed safely to a destination with a GPS-independent approach within 100 NM”

- ILS are likely to be replaced step-wise by RNP approaches, allowing an aircraft to fly a specific path between two 3-dimensionally defined points in space ⇒ Key to curved approaches

Note: AGL.. Above Ground Level, RNP... Required Navigation Performance
Aviation is not the only sector in need of increased accuracy and integrity – EGNOS offers three services to address other markets.

Other Applications for SBAS?

**Mass Market**
- **Rail**
- **Logistics**
- **Road Adv. Appl. (Mainly RUC)**

**Aviation**

**Maritime**

**Public Benefits**
- Market size
- EGNOS Value added

**Shipment of GNSS Devices in the Aviation Sector (1000's)**

**eCall: Serving a 200 million vehicle market in Europe from 2015 onwards**

1. **Emergency Call**
   - A 112 emergency call (eCall) is made automatically by the car as soon as an onboard sensor (e.g. the airbag sensor) registers a serious accident. By pushing a dedicated button on the car, any car occupant can also make an eCall manually.

2. **Positioning**
   - For accurate positioning and mobile telephone call location, the accurate position of the accident scene is fed and then transmitted by the eCall to the nearest emergency call centre. More information is given in the eCall, e.g. the direction of travel and the vehicle type.

3. **Emergency Call centre (PSC)**
   - The PSC can instantly get the accident’s location can be seen on a screen. A trained operator tries to talk with the vehicle’s occupants to get more information. Where is no elec, emergency service are sent of without delay.

4. **Quick help**
   - Thanks to the automatic notification of the crash site, the emergency services can reach the accident area much quicker than. Time saved translate into lives saved.

Source: GSA Analysis, 2009
Conclusion: SBAS like WAAS, EGNOS, MSAS will make aviation safer and more cost efficient, other markets are likely to benefit from specific applications in the years to come

- The availability of Air Navigation Systems (ANS) is key for aviation
  - A plethora of ANS and approach procedures has been developed
  - Due to safety issues, ICAO aims to replace NPAs by PAs

- The ILS concept has become a very costly state-of-the-art PA
  - Only big airports can afford an ILS from a CAPEX and OPEX PoV
  - The GA community would be ‘happy’ with CAT I PA class

- GNSS and SBAS offer low cost alternatives to ILS
  - APV-I is a PA, LPV-200 is similar to ILS CAT I
  - Pilots, airport operators and the federal authorities benefit from SBAS
  - WAAS, EGNOS, MSAS, GAGAN and SDCM serve aviation globally

- With Aviation being the prime beneficiary of SBAS, WAAS, EGNOS et al share a big common functionality core, still differences exit and will help to identify new services and applications to address new markets
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