GNSS Open Service Performance Standards Template

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Tom Powell
The Aerospace Corporation
GPS Systems Engineering
Rationale

Public open service civil signal Performance Standards (PS) simplify:

- **National planning for GNSS usage**
  - Rely on GNSS as specified in the civil signal(s) PS

- **Augmentation planning**
  - Augmentations depends on the performance commitments in civil signal(s) PS

- **Industry planning for combined constellation**
  - Design methods and algorithms for combining constellations
  - Marketing strategies and decisions by region/country/sector
Signal in Space (SIS) Interface between GNSS Provider and Users
PS (and ICD) Defines the Service

SPACE SEGMENT

CONTROL SEGMENT

SIS INTERFACE

USER SEGMENT

PS

ICD
SIS Interface

- SIS interface is line of demarcation where GNSS service provider responsibilities end and receiver manufacturer/user responsibilities begin

- A GNSS service provider can only commit to the level of performance that its SIS interface will provide, and then operate the GNSS service to fulfill that commitment
  - Just as electricity service provider can only commit to the level of performance its interface will provide (voltage, frequency, etcetera)
  - Toaster manufacturer will decide how to toast the bread
I. SIS Constellation Definition
II. SIS Coverage
III. SIS Accuracy
IV. SIS Integrity
V. SIS Continuity
VI. SIS Availability

Combinations of “essential parameters” and/or user equipment assumptions allow for derived standards
Performance Commitment Categories

I. SIS Constellation Definition
II. SIS Coverage
III. SIS Accuracy
IV. SIS Integrity
V. SIS Continuity
VI. SIS Availability

Combinations of “essential parameters” and/or user equipment assumptions allow for derived standards
I. SIS Constellation Definition ~ Transmitter locations

II. SIS Coverage ~ Region(s) of SIS compliance

III. SIS Accuracy

IV. SIS Integrity

V. SIS Continuity

VI. SIS Availability

Combinations of “essential parameters” and/or user equipment assumptions allow for derived standards
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Combinations of “essential parameters” and/or user equipment assumptions allow for derived standards

International Maritime Organization (IMO) Example
U.S. SPS Service Offers to ICAO and IMO

Offer to ICAO

...service will be available on a nondiscriminatory basis to all users at the performance levels specified in the SPS Performance Standard...

Offer to IMO

...provide open, free access to information necessary to develop and build equipment to use these services...
Consider U.S. offer of SPS service to IMO as example
  – U.S. offer of SPS service to ICAO generally similar

IMO Resolution A.1046(27) lists five responsibilities
  – In deciding whether or not to recognize a radionavigation system, IMO should consider whether:
    • the Government or organization providing and operating the system has stated formally that the system is operational and available for use by merchant shipping;
    • its continued provision is assured;
    • it is capable of providing position information within the coverage area declared by the Government or organization operating and providing the system with a performance not less than that given in the appendix;
    • adequate arrangements have been made for publication of the characteristics and parameters of the system and of its status, including amendments, as necessary; and
    • adequate arrangements have been made to protect the safety of navigation should it be necessary to introduce changes in the characteristics or parameters of the system that could adversely affect the performance of shipborne receiving equipment.

Resolution A.1046(27) superseded Resolution A.953(23) as of 30 Nov 11
Consider U.S. offer of SPS service to IMO as example
– U.S. offer of SPS service to ICAO generally similar

IMO Resolution A.1046(27) lists five responsibilities
– In deciding whether or not to recognize a radionavigation system, IMO should consider whether:

- Letter → • the Government or organization providing and operating the system has stated formally that the system is operational and available for use by merchant shipping;
- Letter → • its continued provision is assured;
- PS → • it is capable of providing position information within the coverage area declared by the Government or organization operating and providing the system with a performance not less than that given in the appendix;
- PS & ICD → • adequate arrangements have been made for publication of the characteristics and parameters of the system and of its status, including amendments, as necessary; and
- Letter → • adequate arrangements have been made to protect the safety of navigation should it be necessary to introduce changes in the characteristics or parameters of the system that could adversely affect the performance of shipborne receiving equipment.
## Example IMO Operational Requirements

<table>
<thead>
<tr>
<th>Typical Operation</th>
<th>Accuracy Horizontal 95% (Note 1)</th>
<th>Update Rate of Displayed Position Data (Note 2)</th>
<th>Integrity (Note 3)</th>
<th>Time-to-alert (Note 3)</th>
<th>Continuity (Note 1)</th>
<th>Availability (Note 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean Waters</td>
<td>100 m</td>
<td>2 s</td>
<td>N/A</td>
<td>ASAP</td>
<td>N/A</td>
<td>0.998</td>
</tr>
<tr>
<td>Harbor Entrances, Harbor Approaches,</td>
<td>10 m</td>
<td>2 s (Note 5)</td>
<td>N/A</td>
<td>10 s</td>
<td>1–0.3×10⁻³ per 15 min</td>
<td>0.998</td>
</tr>
<tr>
<td>and Coastal Waters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>

**NOTES.—**
1. Coverage of the system should be adequate to provide position fixing throughout this phase of navigation.
2. Applies to computed and displayed position data, but not to the update rate of any correction data which may remain valid for 30 s or more.
3. No system-level specification given for the integrity.

**Ref:** IMO Resolution A.1046(27)
I. SIS Constellation Definition
II. SIS Coverage
III. SIS Accuracy
IV. SIS Integrity
V. SIS Continuity
VI. SIS Availability

Combinations of “essential parameters” and/or user equipment assumptions allow for derived standards
Instantaneous User Range Error (URE) and “Age of Data” (AOD)
Example Accuracy Requirements versus Age of Data

- **a.** 95% over all AODs (i.e., over all time)
- **b.** 95% at zero AOD (i.e., at time of predict for upload)
- **c.** 95% at any AOD (e.g., at max AOD in this example)
## Performance Commitment: Pseudorange Accuracy Example

### Table III-x. SIS URE Accuracy Commitment

<table>
<thead>
<tr>
<th>SIS Accuracy Standard</th>
<th>Conditions and Constraints</th>
</tr>
</thead>
</table>
| **Single-Frequency Civil Signal “A”:**  
  - $\leq x.x$ m 95% Global Average URE during Normal Operations over all AODs  
  - $\leq y.y$ m 95% Global Average URE during Normal Operations at Zero AOD  
  - $\leq z.z$ m 95% Global Average URE during Normal Operations at Any AOD  |  
  - For any healthy Civil Signal “A” SIS  
  - Neglecting <list of particular neglected errors, if any> errors  
  - Including <list of particular included errors, if any> errors |
| **Single-Frequency Civil Signal “A”:**  
  - $\leq rr.r$ m $\text{Prob}_1\%$ Global Average URE during Normal Operations  
  - $\leq rr.r$ m $\text{Prob}_2\%$ Worst Case Single Point Average URE during Normal Operations  |  
  - For any healthy Civil Signal “A” SIS  
  - Neglecting <list of particular neglected errors, if any> errors  
  - Including <list of particular included errors, if any> errors  
  - <caveats relative to rare normal URE limit value of rr.r and relative to probability values of $\text{Prob}_1\%$ and $\text{Prob}_2\%$, if any> |
| **Single-Frequency Civil Signal “A”:**  
  - $\leq cc.c$ m 95% Global Average URE during Extended Operations after $dd$ Days without Upload  |  
  - For any healthy Civil Signal “A” SIS  
  - Neglecting <list of particular neglected errors, if any> errors  
  - Including <list of particular included errors, if any> errors  
  - <caveats relative to maximum coasting URE value of cc.c and maximum coasting duration of dd, if any> |
Recommended Way Forward

- Use GPS SPS PS as template starting point
  - Template created from most recent version of GPS SPS PS
  - Not protected by copyright
  - Source file (MS Word) available to all providers
  - Free to modify as desired
  - FAA used GPS SPS PS to develop the WAAS PS

- GPS SPS PS is being updated (once again a starting point)
  - Incorporating the new civil signals (L2C, L5, L1C)
  - Potential tightening of some performance commitments
  - Potential addition of one or two performance commitments
Contact Information

Send feedback & suggestions to:
Karl Kovach
The Aerospace Corporation
Karl.L.Kovach@aero.org

Tom Powell
The Aerospace Corporation
Thomas.D.Powell@aero.org
BACKUP CHARTS
### Table 3.7.2.4-1 Signal-in-Space Performance Requirements

<table>
<thead>
<tr>
<th>Typical operation</th>
<th>Accuracy horizontal 95% (Notes 1 and 3)</th>
<th>Accuracy vertical 95% (Notes 1 and 3)</th>
<th>Integrity (Note 2)</th>
<th>Time-to-alert (Note 3)</th>
<th>Continuity (Note 4)</th>
<th>Availability (Note 5)</th>
</tr>
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<tbody>
<tr>
<td>Enroute</td>
<td>3.7 km (2.0 NM) (Note 6)</td>
<td>N/A</td>
<td>1–1×10⁻⁷/h</td>
<td>5 min</td>
<td>1–1×10⁻⁴/h to 1–1×10⁻⁸/h</td>
<td>0.99 to 0.999999</td>
</tr>
<tr>
<td>Enroute, Terminal</td>
<td>0.74 km (0.4 NM)</td>
<td>N/A</td>
<td>1–1×10⁻⁷/h</td>
<td>15 s</td>
<td>1–1×10⁻⁴/h to 1–1×10⁸/h</td>
<td>0.99 to 0.999999</td>
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<tr>
<td>Initial approach, Intermediate approach, Nonprecision approach (NPA), Departure</td>
<td>220 m (720 ft)</td>
<td>N/A</td>
<td>1–1×10⁻⁷/h</td>
<td>10 s</td>
<td>1–1×10⁻⁴/h to 1–1×10⁻⁸/h</td>
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### NOTES.

1. The 95th percentile values for GNSS position errors are those required for the intended operation at the lowest height above threshold (HAT), if applicable. Detailed requirements are specified in Appendix B and guidance material is given in Attachment D, 3.2.
2. The definition of the integrity requirement includes an alert limit against which the requirement can be assessed.
3. The accuracy and time-to-alert requirements include the nominal performance of a fault-free receiver.
4. Ranges of values are given for the continuity requirement for en-route, terminal, initial approach, NPA and departure operations, as this requirement is dependent upon several factors including the intended operation, traffic density, complexity of airspace and availability of alternative navigation aids. The lower value given is the minimum requirement for areas with low traffic density and airspace complexity. The higher value given is appropriate for areas with high traffic density and airspace complexity (see Attachment D, 3.4).
5. A range of values is given for the availability requirements as these requirements are dependent upon the operational need which is based upon several factors including the frequency of operations, weather environments, the size and duration of the outages, availability of alternate navigation aids, radar coverage, traffic density and reversionary operational procedures. The lower values given are the minimum availabilities for which a system is considered to be practical but are not adequate to replace non-GNSS navigation aids. For en-route navigation, the higher values given are adequate for GNSS to be the only navigation aid provided in an area. For approach and departure, the higher values given are based upon the availability requirements at airports with a large amount of traffic assuming that operations to or from multiple runways are affected but reversionary operational procedures ensure the safety of the operation (see Attachment D, 3.5).
## Example: Maritime Performance

Extracted from A.1046(27) Appendix

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Example of a GPS Derived/Desired Performance Commitment: Position Accuracy

• Position Accuracy depends on two factors:
  – Satellite-to-user geometry (i.e., the dilution of precision (DOPs))
  – User Equivalent Range Error (UERE)

• DOPs allocated between GPS SIS and Receivers
  – GPS SIS: constellation slots, number of healthy satellites
  – GPS Receivers: number of channels, mask angle, etc.

• UERE allocated between GPS SIS and Receivers
  – GPS SIS: User Range Error (URE)
  – GPS Receivers: User Equipment Error (UEE)

• GPS Performance Commitments cover GPS SIS performance allocations
Position Accuracy Allocation (Cont)

DOP Allocation:
- Constellation Slots
- Slot Occupancies

UERE Allocation:
- GPS SIS URE

Position Accuracy

DOP Variations:
- Number of Channels
- Satellite Selection
- Mask Angle
- Vertical Aiding

UEE Variations:
- Dual-/Single-Frequency
- Troposphere Algorithm
- Multipath Environment
- Receiver Technology