# *GNSS Open Service Performance Standards Template*

*7th ICG Meeting, Beijing, China*

*4-9 November 2012*

*Tom Powell*

*The Aerospace Corporation*

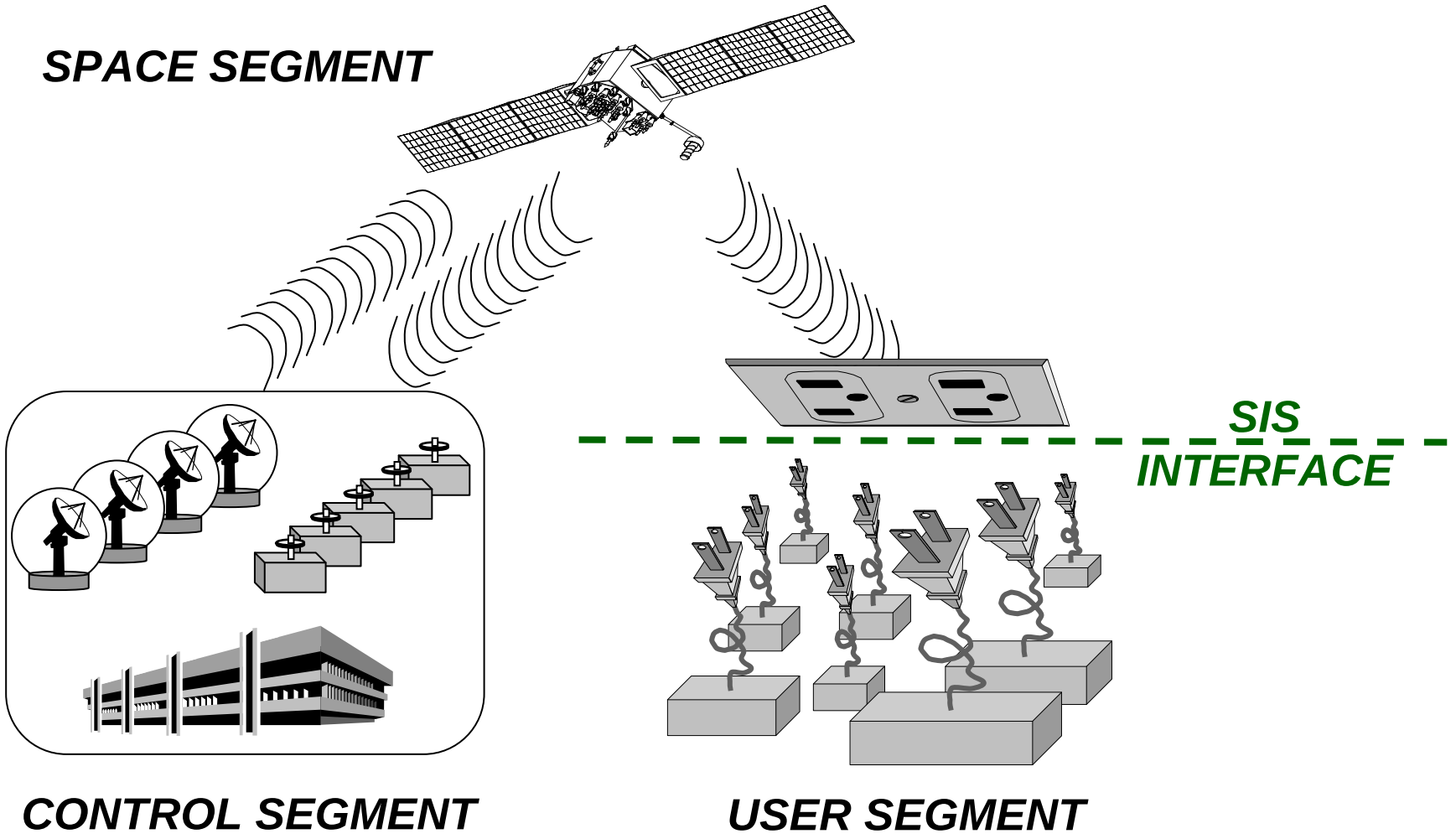
*GPS Systems Engineering*

# *Rationale*

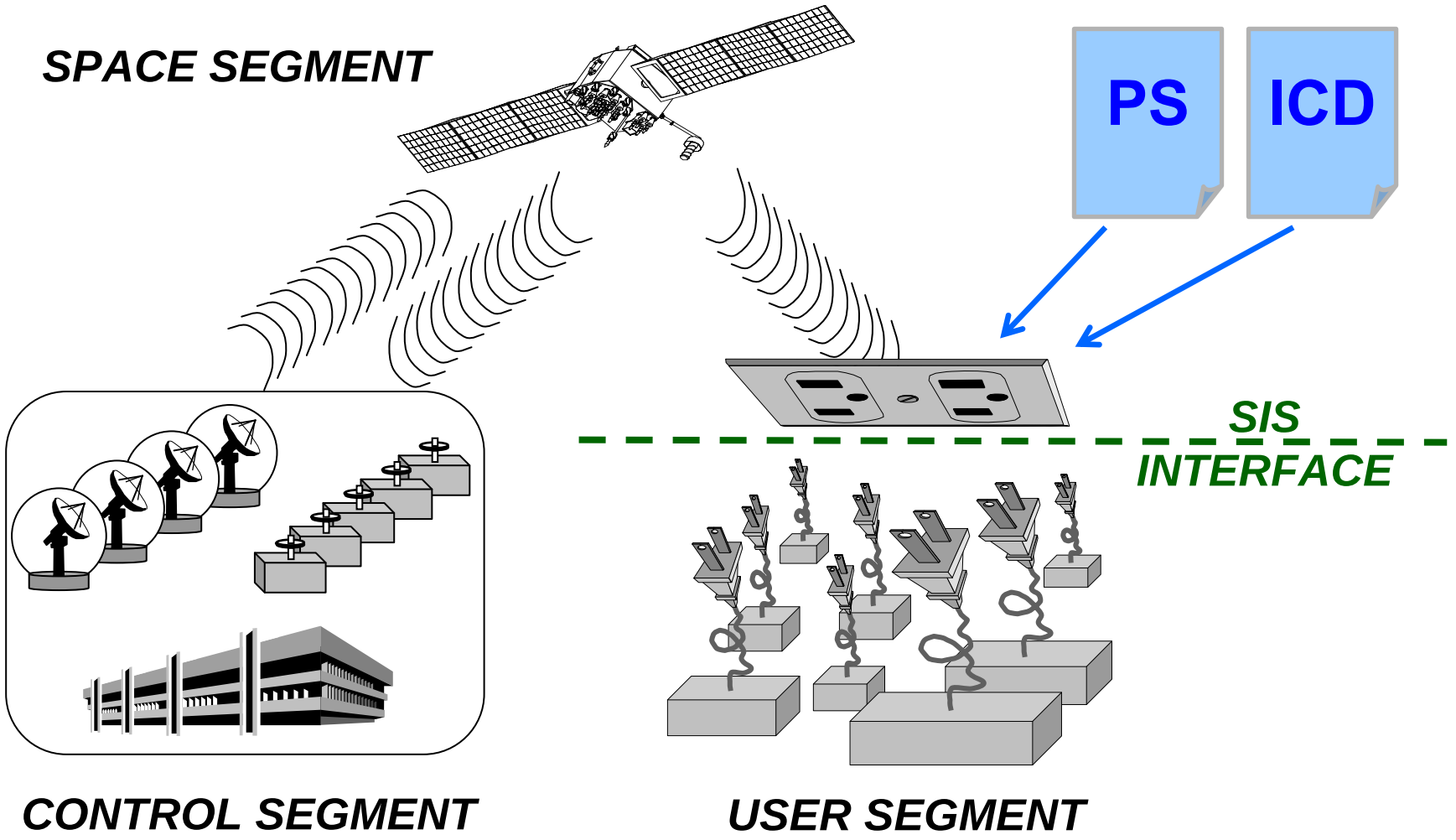
**Public open service civil signal Performance Standards (PS) simplify:**

- **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



# *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

# *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

# *Performance Commitment Categories*

I. SIS Constellation Definition
II. SIS Coverage

**Radionavigation Systems**

III. SIS Accuracy
IV. SIS Integrity
V. SIS Continuity
VI. SIS Availability

**Navigation Systems**

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

# *Performance Commitment Categories*

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

# *Performance Commitment Categories*

I. SIS Constellation Definition

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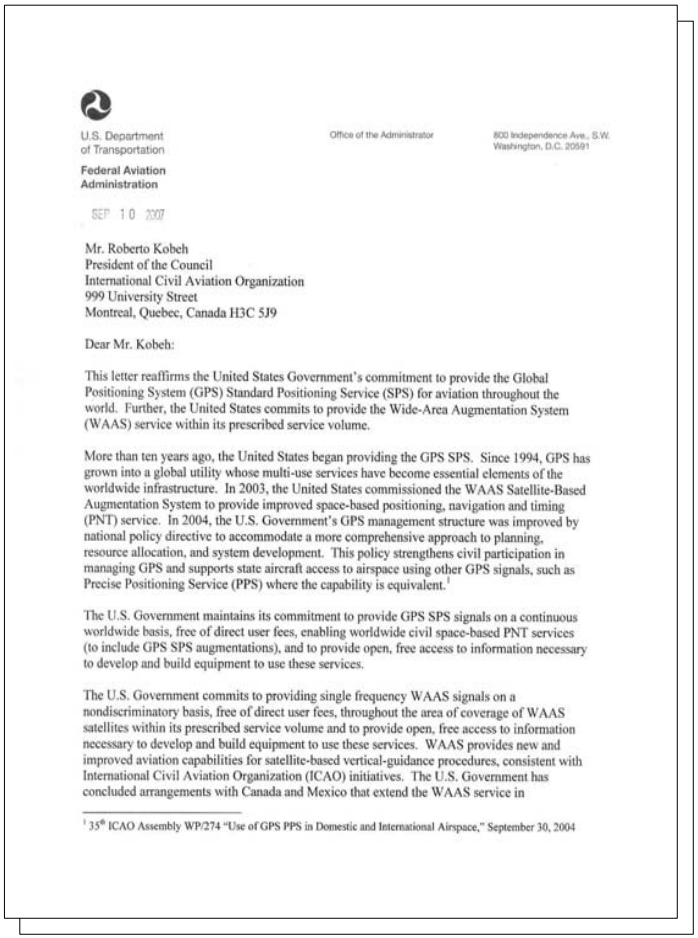
**International Maritime Organization (IMO) Example**

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

# U.S. SPS Service Offers to ICAO and IMO

## Offer to ICAO



U.S. Department of Transportation
Federal Aviation Administration

Office of the Administrator
800 Independence Ave., S.W.
Washington, D.C. 20591

SEP 10 2007

Mr. Roberto Kobeh
President of the Council
International Civil Aviation Organization
999 University Street
Montreal, Quebec, Canada H3C 5J9

Dear Mr. Kobeh:

This letter reaffirms the United States Government's commitment to provide the Global Positioning System (GPS) Standard Positioning Service (SPS) for aviation throughout the world. Further, the United States commits to provide the Wide-Area Augmentation System (WAAS) service within its prescribed service volume.

More than ten years ago, the United States began providing the GPS SPS. Since 1994, GPS has grown into a global utility whose multi-use services have become essential elements of the worldwide infrastructure. In 2003, the United States commissioned the WAAS Satellite-Based Augmentation System to provide improved space-based positioning, navigation and timing (PNT) service. In 2004, the U.S. Government's GPS management structure was improved by national policy directive to accommodate a more comprehensive approach to planning, resource allocation, and system development. This policy strengthens civil participation in managing GPS and supports state aircraft access to airspace using other GPS signals, such as Precise Positioning Service (PPS) where the capability is equivalent.[1]

The U.S. Government maintains its commitment to provide GPS SPS signals on a continuous worldwide basis, free of direct user fees, enabling worldwide civil space-based PNT services (to include GPS SPS augmentations), and to provide open, free access to information necessary to develop and build equipment to use these services.

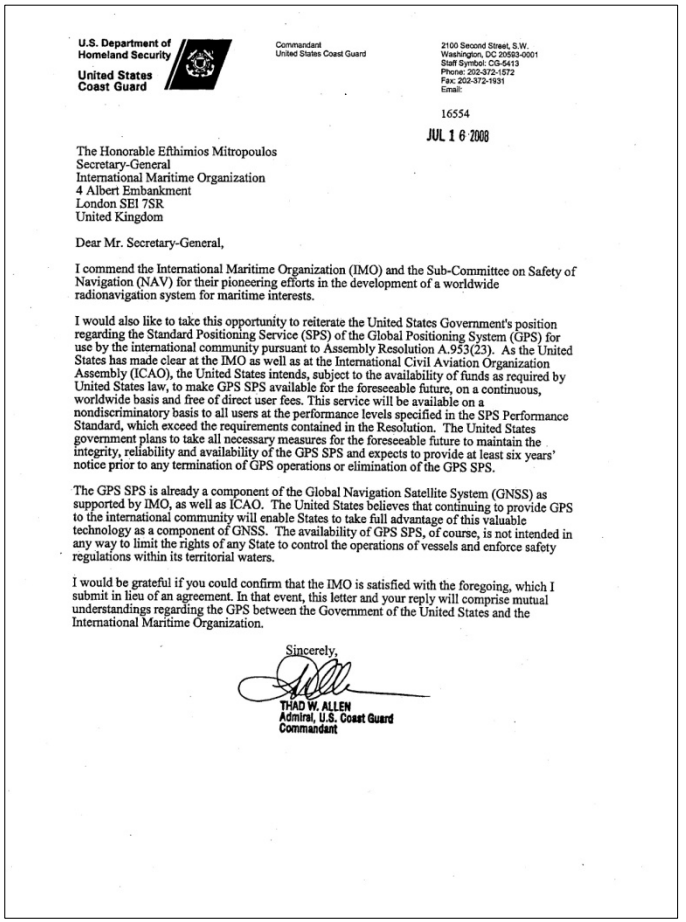
The U.S. Government commits to providing single frequency WAAS signals on a nondiscriminatory basis, free of direct user fees, throughout the area of coverage of WAAS satellites within its prescribed service volume and to provide open, free access to information necessary to develop and build equipment to use these services. WAAS provides new and improved aviation capabilities for satellite-based vertical-guidance procedures, consistent with International Civil Aviation Organization (ICAO) initiatives. The U.S. Government has concluded arrangements with Canada and Mexico that extend the WAAS service in

[1] 35th ICAO Assembly WP/274 "Use of GPS PPS in Domestic and International Airspace," September 30, 2004

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

**…provide open, free access to information necessary to develop and build equipment to use these services…**

## Offer to IMO



U.S. Department of Homeland Security
United States Coast Guard

Commandant
United States Coast Guard

2100 Second Street, S.W.
Washington, DC 20593-0001
Staff Symbol: CG-5413
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16554

JUL 16 2008

The Honorable Efthimios Mitropoulos
Secretary-General
International Maritime Organization
4 Albert Embankment
London SEI 7SR
United Kingdom

Dear Mr. Secretary-General,

I commend the International Maritime Organization (IMO) and the Sub-Committee on Safety of Navigation (NAV) for their pioneering efforts in the development of a worldwide radionavigation system for maritime interests.

I would also like to take this opportunity to reiterate the United States Government's position regarding the Standard Positioning Service (SPS) of the Global Positioning System (GPS) for use by the international community pursuant to Assembly Resolution A.953(23). As the United States has made clear at the IMO as well as at the International Civil Aviation Organization Assembly (ICAO), the United States intends, subject to the availability of funds as required by United States law, to make GPS SPS available for the foreseeable future, on a continuous, worldwide basis and free of direct user fees. This service will be available on a nondiscriminatory basis to all users at the performance levels specified in the SPS Performance Standard, which exceed the requirements contained in the Resolution. The United States government plans to take all necessary measures for the foreseeable future to maintain the integrity, reliability and availability of the GPS SPS and expects to provide at least six years' notice prior to any termination of GPS operations or elimination of the GPS SPS.

The GPS SPS is already a component of the Global Navigation Satellite System (GNSS) as supported by IMO, as well as ICAO. The United States believes that continuing to provide GPS to the international community will enable States to take full advantage of this valuable technology as a component of GNSS. The availability of GPS SPS, of course, is not intended in any way to limit the rights of any State to control the operations of vessels and enforce safety regulations within its territorial waters.

I would be grateful if you could confirm that the IMO is satisfied with the foregoing, which I submit in lieu of an agreement. In that event, this letter and your reply will comprise mutual understandings regarding the GPS between the Government of the United States and the International Maritime Organization.

Sincerely,

THAD W. ALLEN
Admiral, U.S. Coast Guard
Commandant

# SPS Service Offering Elements

## 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

# SPS Service Offering Elements

## Consider U.S. offer of SPS service to IMO as example

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## 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

| Typical Operation | Accuracy Horizontal 95% (Note 1) | Update Rate of Displayed Position Data (Note 2) | Integrity (Note 3) | Time-to-alert (Note 3) | Continuity (Note 1) | Availability (Note 1) |
|---|---|---|---|---|---|---|
| Ocean Waters | 100 m | 2 s | N/A | ASAP | N/A | 0.998 |
| Harbor Entrances, Harbor Approaches, and Coastal Waters | 10 m | 2 s (Note 5) | N/A | 10 s | $1–0.3\times10^{-3}$ per 15 min | 0.998 |

*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)**

# *Performance Commitment Categories*

I. SIS Constellation Definition

II. SIS Coverage

III. SIS Accuracy } **Example**

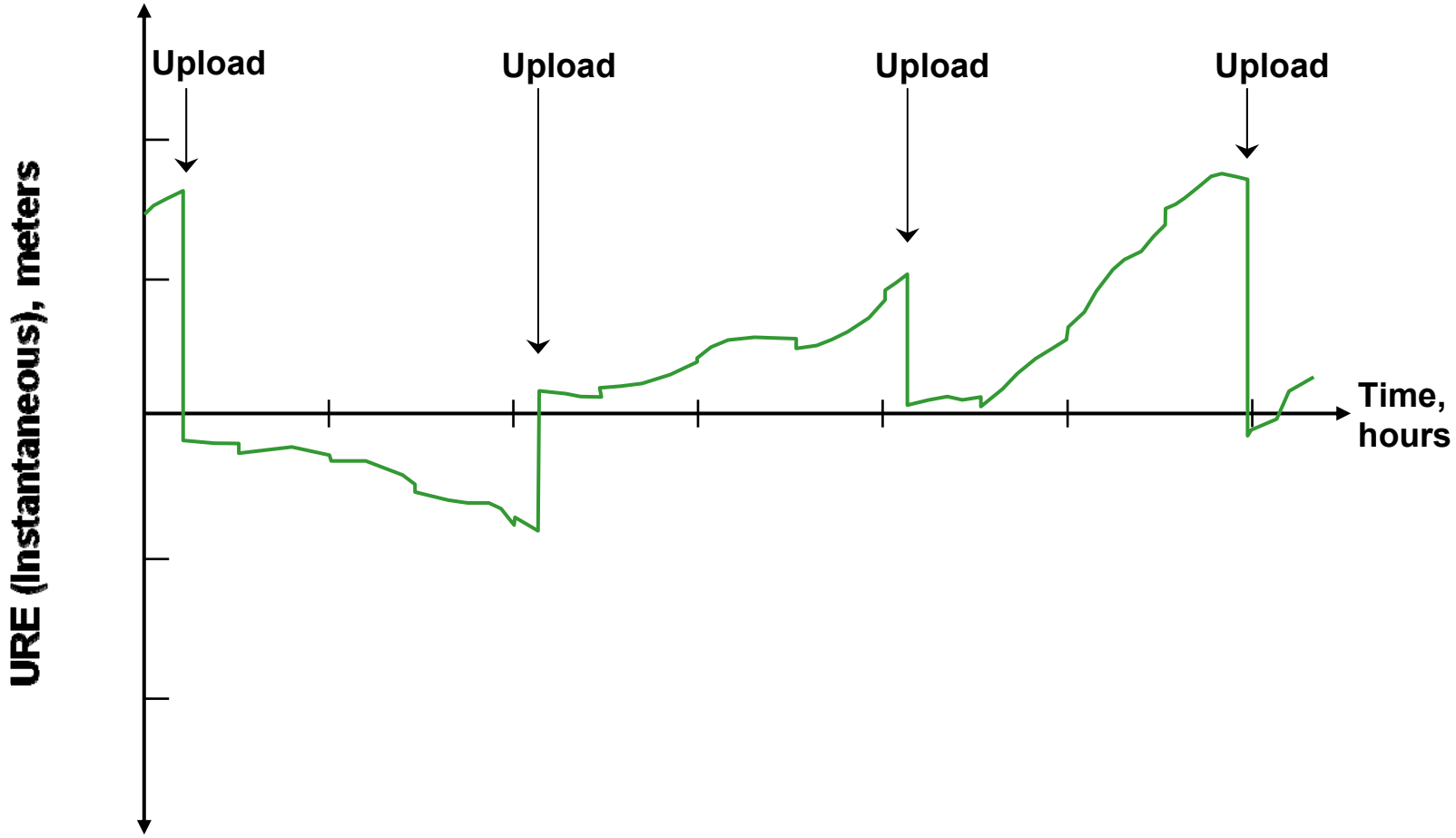
IV. SIS Integrity

V. SIS Continuity

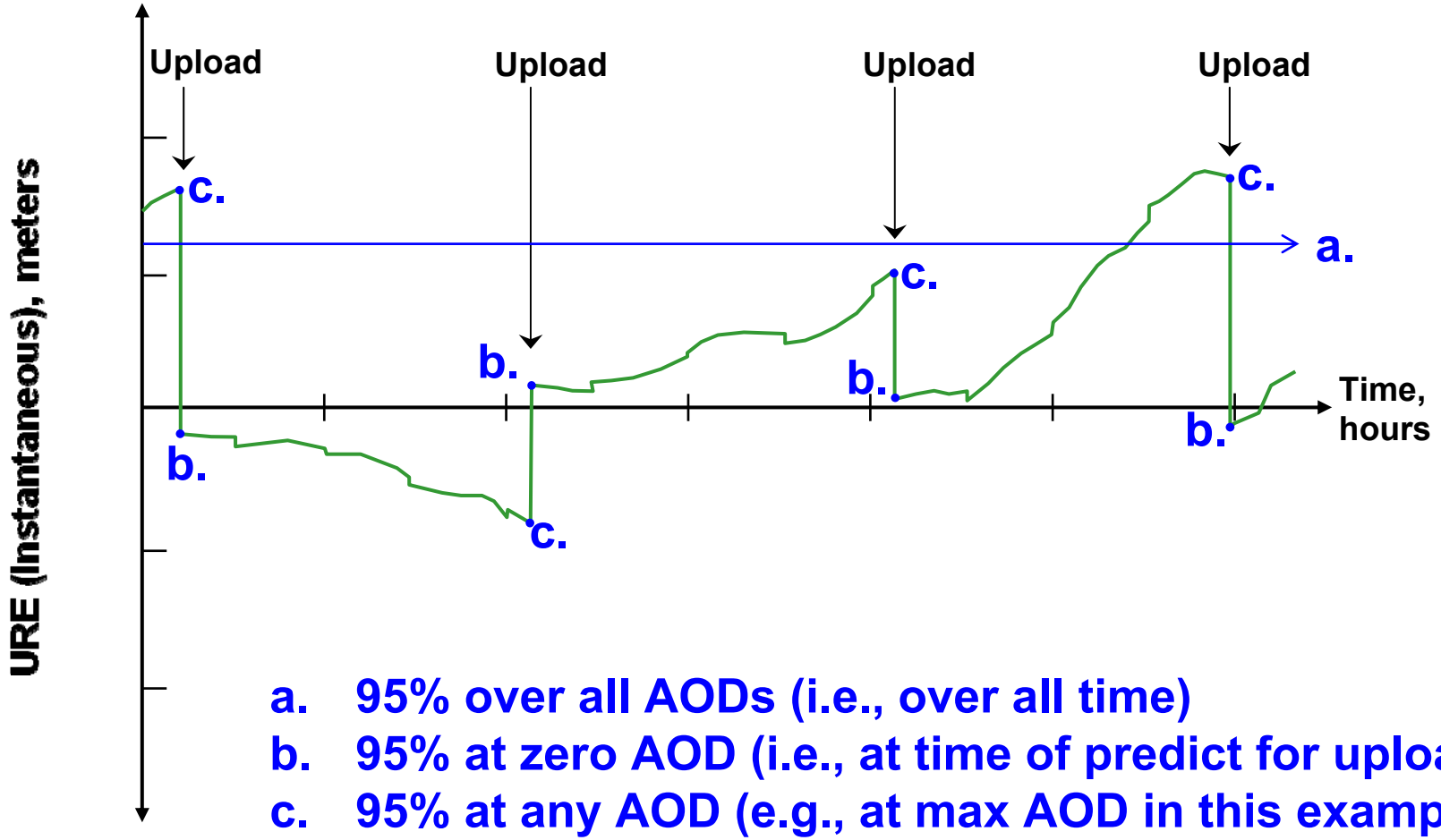
VI. SIS Availability

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**

| SIS Accuracy Standard | Conditions and Constraints |
|---|---|
| Single-Frequency Civil Signal "A":<br>• ≤ *x.x* m 95% Global Average URE during Normal Operations over all AODs<br>• ≤ *y.y* m 95% Global Average URE during Normal Operations at Zero AOD<br>• ≤ *z.z* m 95% Global Average URE during Normal Operations at Any AOD | • For any healthy Civil Signal "A" SIS<br>• Neglecting *<list of particular neglected errors, if any>* errors<br>• Including *<list of particular included errors, if any>* errors |
| Single-Frequency Civil Signal "A":<br>• ≤ *rr.r* m $Prob_1$% Global Average URE during Normal Operations<br>• ≤ *rr.r* m $Prob_2$% Worst Case Single Point Average URE during Normal Operations | • For any healthy Civil Signal "A" SIS<br>• Neglecting *<list of particular neglected errors, if any>* errors<br>• Including *<list of particular included errors, if any>* errors<br>• *<caveats relative to rare normal URE limit value of rr.r and relative to probability values of $Prob_1$% and $Prob_2$%, if any>* |
| Single-Frequency Civil Signal "A":<br>• ≤ *cc.c* m 95% Global Average URE during Extended Operations after *dd* Days without Upload | • For any healthy Civil Signal "A" SIS<br>• Neglecting *<list of particular neglected errors, if any>* errors<br>• Including *<list of particular included errors, if any>*errors<br>• *<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:

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The Aerospace Corporation
Karl.L.Kovach@aero.org

Tom Powell
The Aerospace Corporation
Thomas.D.Powell@aero.org

# BACKUP CHARTS

# Aviation Requirements Extracted from the ICAO SARPs

## Table 3.7.2.4-1 Signal-in-Space Performance Requirements

| Typical operation | Accuracy horizontal 95% (Notes 1 and 3) | Accuracy vertical 95% (Notes 1 and 3) | Integrity (Note 2) | Time-to-alert (Note 3) | Continuity (Note 4) | Availability (Note 5) |
|---|---|---|---|---|---|---|
| Enroute | 3.7 km (2.0 NM) (Note 6) | N/A | $1–1\times10^{-7}$/h | 5 min | $1–1\times10^{-4}$/h to $1–1\times10^{-8}$/h | 0.99 to 0.99999 |
| Enroute, Terminal | 0.74 km (0.4 NM) | N/A | $1–1\times10^{-7}$/h | 15 s | $1–1\times10^{-4}$/h to $1–1\times10^{8}$/h | 0.99 to 0.99999 |
| Initial approach, Intermediate approach, Nonprecision approach (NPA), Departure | 220 m (720 ft) | N/A | $1–1\times10^{-7}$/h | 10 s | $1–1\times10^{-4}$/h to $1–1\times10^{-8}$/h | 0.99 to 0.99999 |

*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

| Typical Operation | Accuracy Horizontal 95% (Note 1) | Update Rate of Displayed Position Data (Note 2) | Integrity (Note 3) | Time-to-alert (Note 3) | Continuity (Note 1) | Availability (Note 1) |
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| Ocean Waters | 100 m | 2 s | N/A | ASAP | N/A | 0.998 |
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3. No system-level specification given for the integrity.

# *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)