Template for GNSS Service Performance Commitments

5th ICG Meeting, Torino, Italy

18-22 October 2010

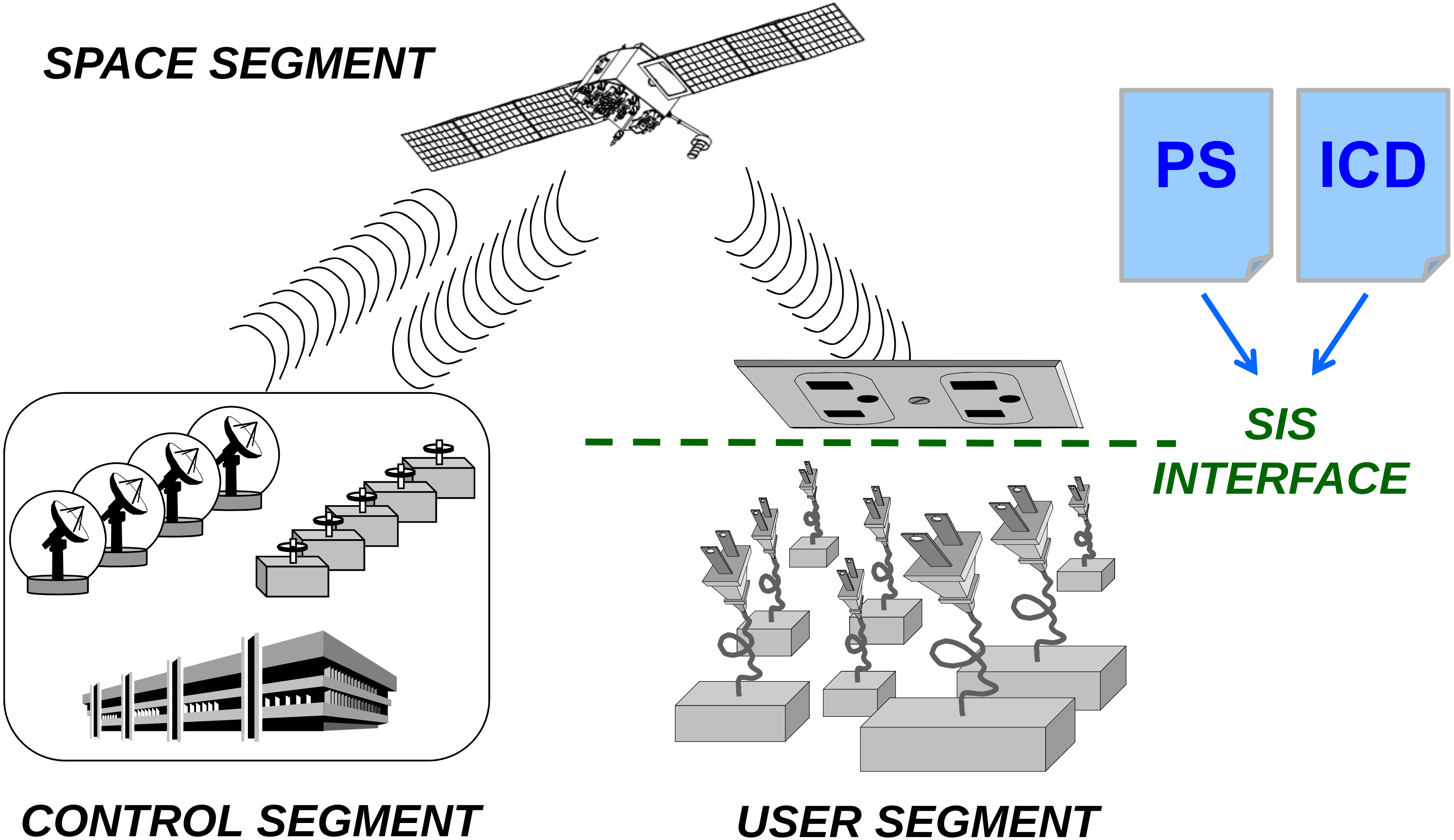
Mr. Karl Kovach

Rationale

Interoperable/transparent civil signal PSs simplify:

- National planning for GNSS usage
  - Rely on GNSS as specified in the civil signal(s) PS
- Augmentation planning
  - Augmentations depends on performance commitments in civil signal(s) PS
- Industrial planning for combined constellation
  - Design methods and algorithms for combining constellations
  - Marketing strategies and decisions by region/country/sector

PS (and ICD) Defines the Service



U.S. Offered the SPS Service

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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JUL 16 2008

The Honorable Efthimios Mitropoulos
Secretary-General
International Maritime Organization
4 Albert Embankment
London SE1 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

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

- U.S. offer of SPS service to ICAO generally similar

IMO Resolution A.953(23) 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.

Maritime Performance Extracted from A.953(23) Appendix

Typical operation	Accuracy horizontal 95% (Notes 1 and 3)	Update Rate of Displayed Position Data (Notes 1 and 3)	Integrity (Note 2)	Time-to-alert (Notes 1 and 3)	Continuity (Note 1)	Availability (Note 4)
Ocean Waters	100 m	10 s (Note 5)	N/A	ASAP	N/A	0.998 over 30 dy
Harbor Entrances, Harbor Approaches, and Coastal Waters with Low Volume of Traffic and/or a Less Significant Risk	10 m	10 s (Note 5)	N/A	10 s	$1–1.5\times10^{-3}$ per 3 h	0.998 over 2 yr
Harbor Entrances, Harbor Approaches, and Coastal Waters with High Volume of Traffic and/or Significant Risk	10 m	10 s (Note 5)	N/A	10 s	$1–0.3\times10^{-3}$ per 3 h	0.995 over 2 yr

NOTES.—

1. Coverage of the system should be adequate to provide position fixing throughout this phase of navigation.
2. No system-level specification given for the integrity.
3. For ships with operating speeds above 30 knots more stringent requirements may be necessary.
4. Calculated in accordance with guidance in IALA Recommendation R-121.
5. If the computed position data is used for AIS, graphical display, or for direct control of the ship, then the update rate should be greater than once every 2 s.

Reference: 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).

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.953(23) 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;

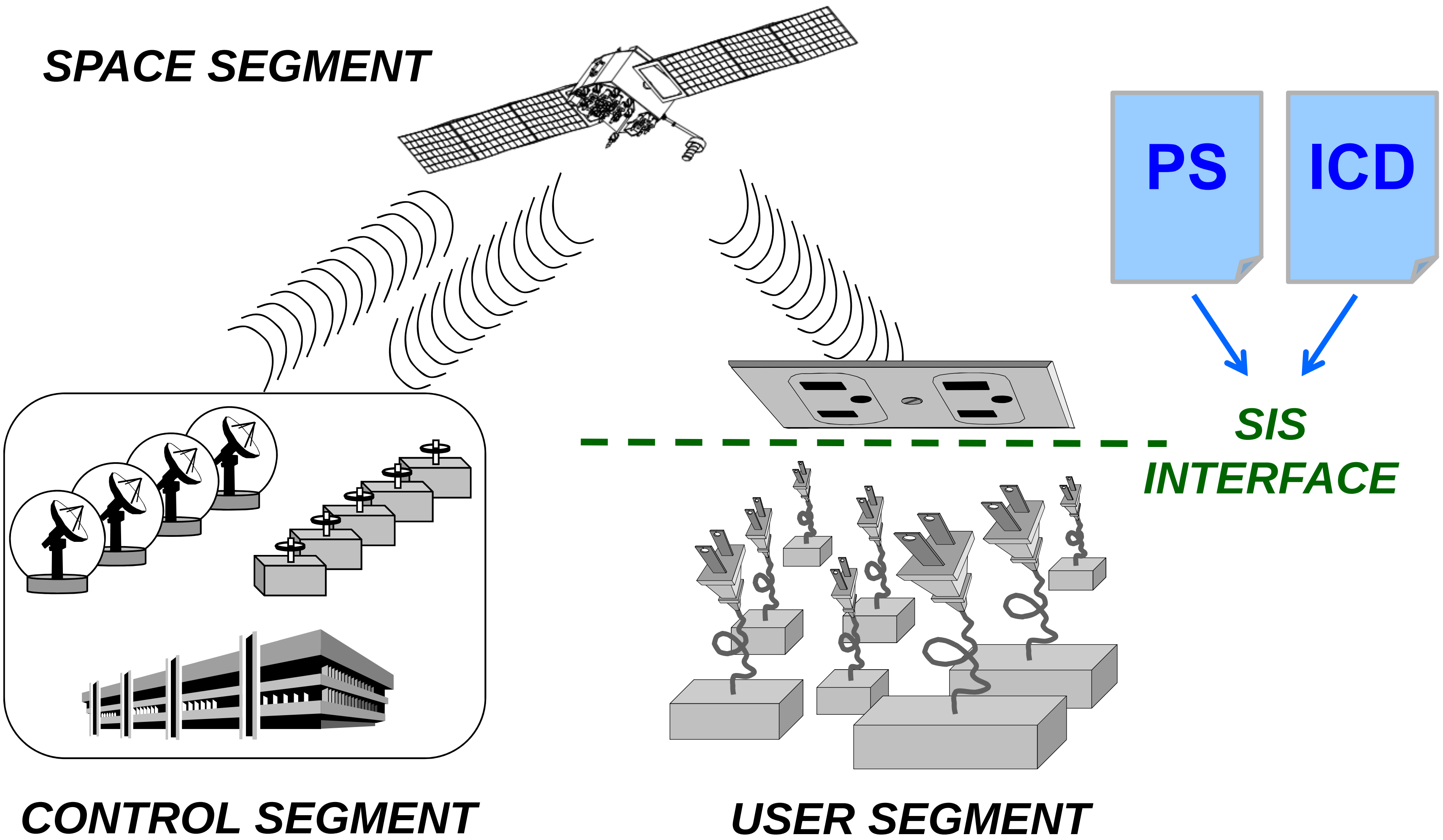
Letter → • its continued provision is assured;

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.

Line of Demarcation



At the Line of Demarcation

- 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

II. SIS Coverage

III. SIS Accuracy

IV. SIS Integrity

V. SIS Continuity

VI. SIS Availability

See IMO A.953(23) for example

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

Example: Maritime Performance Extracted from A.953(23) Appendix

Typical operation	Accuracy horizontal 95% (Notes 1 and 3)	Update Rate of Displayed Position Data (Notes 1 and 3)	Integrity (Note 2)	Time-to-alert (Notes 1 and 3)	Continuity (Note 1)	Availability (Note 4)
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NOTES.—

1. Coverage of the system should be adequate to provide position fixing throughout this phase of navigation.
2. No system-level specification given for the integrity.
3. For ships with operating speeds above 30 knots more stringent requirements may be necessary.
4. Calculated in accordance with guidance in IALA Recommendation R-121.
5. If the computed position data is used for AIS, graphical display, or for direct control of the ship, then the update rate should be greater than once every 2 s.

Performance Commitment Categories

I. SIS Constellation Definition

II. SIS Coverage

III. SIS Accuracy — **Some detail**

IV. SIS Integrity

V. SIS Continuity

VI. SIS Availability

More appropriate for a subgroup

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

Performance Commitment: Pseudorange Accuracy Example

Table III-x. SIS URE Accuracy Commitment

SIS Accuracy Standard	Conditions and Constraints
Single-Frequency Civil Signal “A”: • ≤ *x.x* m 95% Global Average URE during Normal Operations over all AODs • ≤ *y.y* m 95% Global Average URE during Normal Operations at Zero AOD • ≤ *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”: • ≤ *rr.r* m $Prob_1$% Global Average URE during Normal Operations • ≤ *rr.r* m $Prob_2$% 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* $Prob_1$*% and* $Prob_2$*%, if any>*
Single-Frequency Civil Signal “A”: • ≤ *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
  - Not protected by copyright
  - Source file (MS Word) available on request
  - FAA did exactly this to develop the WAAS PS
- GPS SPS PS is being updated (once again a starting point)
  - Incorporating the second civil signal (L2C)
  - Potential tightening of some performance commitments
  - Potential addition of one or two performance commitments
- Thoughts?

Contact Information

Send feedback & suggestions to:

Mr. Karl Kovach

c/o GPS Wing (Aerospace)

Karl.L.Kovach@aero.org

BACKUP CHARTS

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**

DOP Variations:

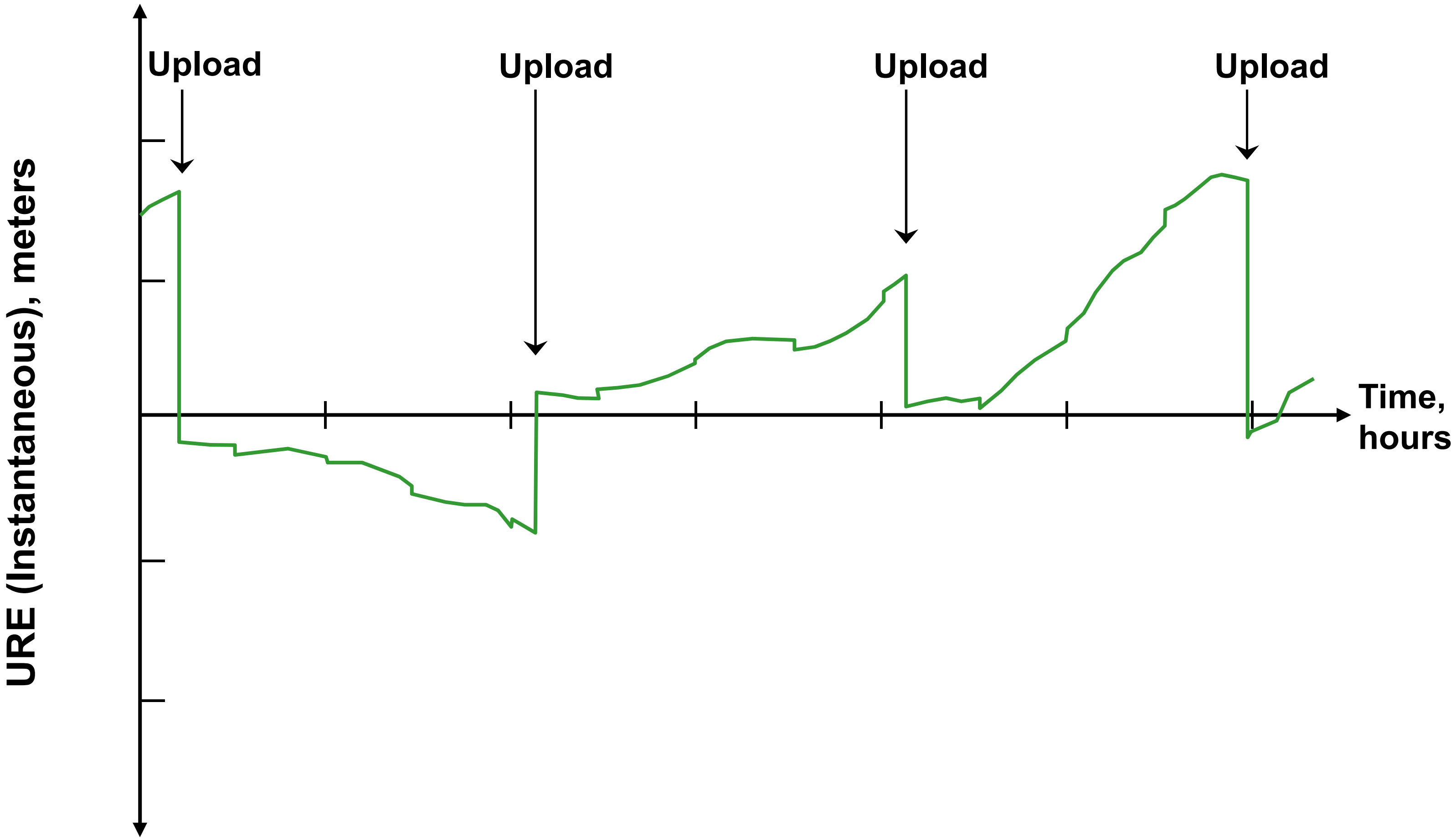
- **Number of Channels**
- **Satellite Selection**
- **Mask Angle**
- **Vertical Aiding**

UEE Variations:

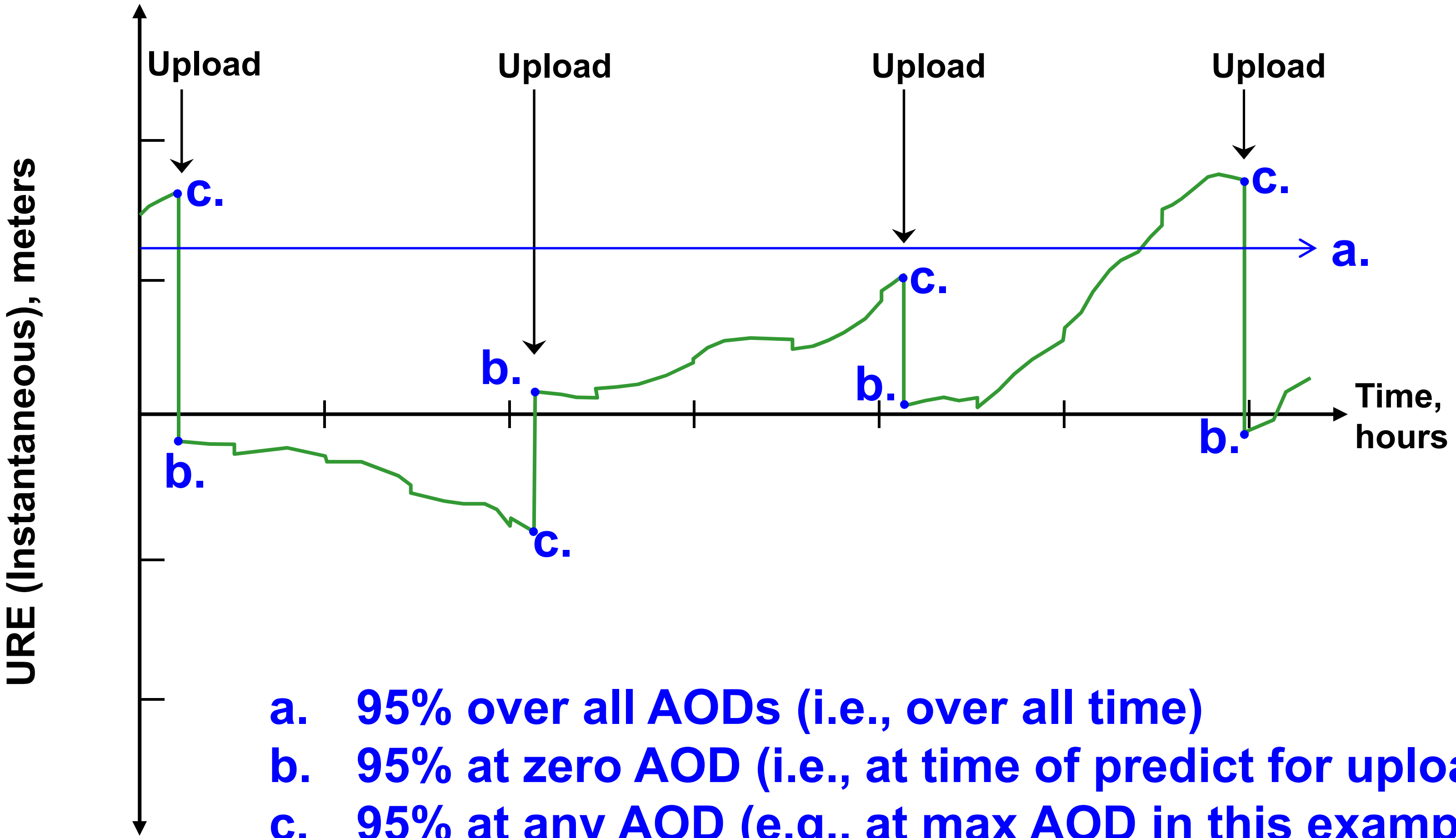
- **Dual-/Single-Frequency**
- **Troposphere Algorithm**
- **Multipath Environment**
- **Receiver Technology**

Position Accuracy

Assumed Common Characteristic: "Age of Data" (AOD) Parameter



Assumed Common Characteristic: "Age of Data" (AOD) Methodology



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)