



# ***Template for GNSS Service Performance Commitments***

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# ***Purpose and Overall Approach***

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- This briefing introduces draft example sections of the GNSS Providers' Template for Performance Commitments
- Overall approach
  - Adopt new ICG Principle at ICG4 (Sep 2009)
    - *“Every GNSS provider should establish documented civil performance commitments to inform users about minimum levels of service”*
  - In parallel, continue to develop a GNSS Providers' Template for Performance Commitments
    - Supported by a common set of key terminology



# Context

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- This briefing progresses an on-going theme
  - First introduced in “*US WG-A Presentation on Compatibility and Interoperability*”, 3<sup>rd</sup> ICG meeting, December 2008 (LtCol Harrington)
  - Further developed in “*GNSS Service Performance Commitments ...initial thoughts for consideration*”, ICG Workshop on GNSS Interoperability, March 2009 (Mr. Steare)
  - Terminology introduced in “*Key Definitions for GNSS Service Performance Commitments*”, ICG WG-A meeting, July 2009 (Mr. Steare)
- The presenter of this briefing was the lead author on the GPS Standard Positioning Service Performance Standard (SPS PS), September 2008



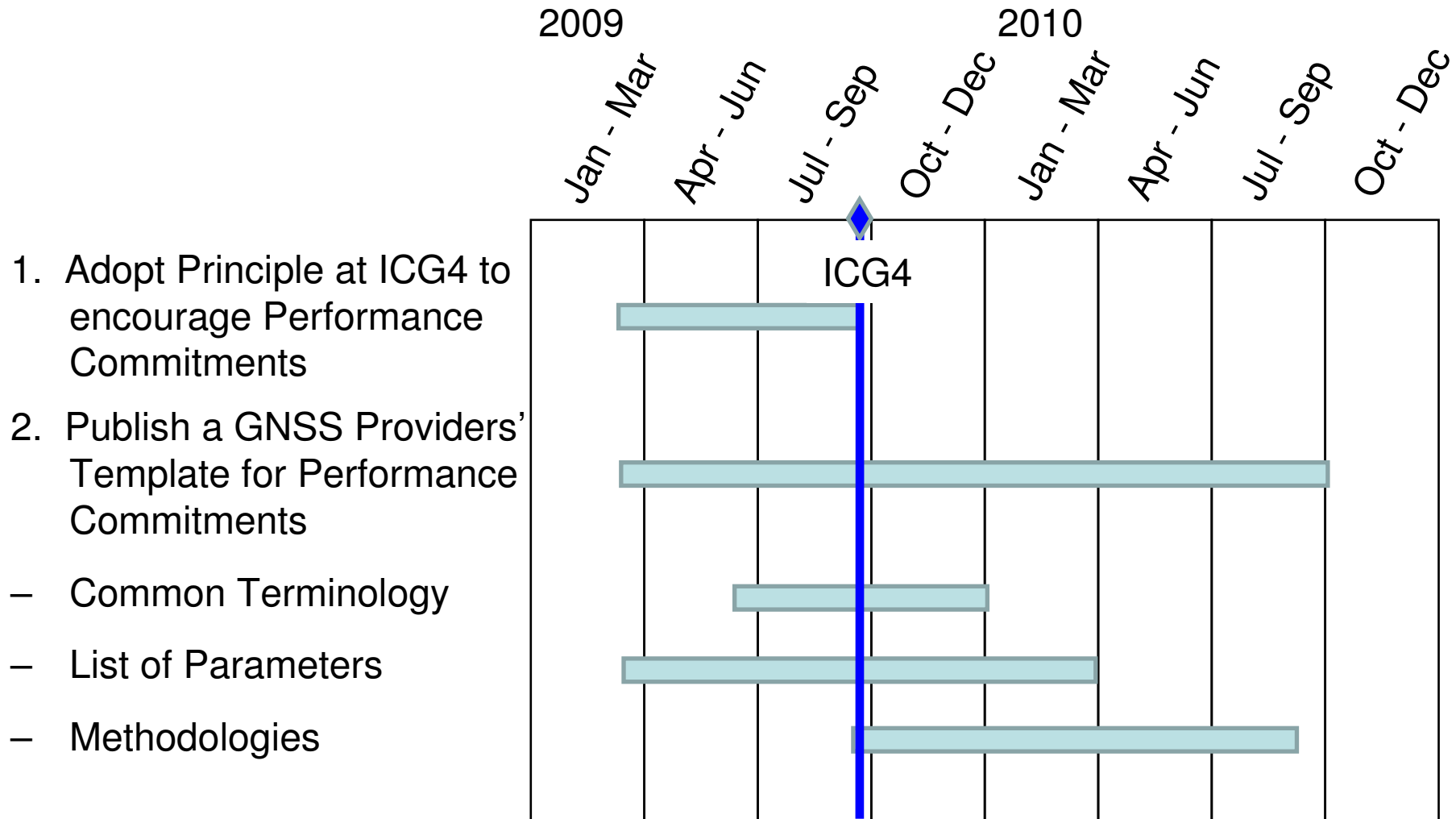
# *Template Plan*

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1. Develop common terminology
2. Develop list of parameters to be included in template
  - Continue review and refinement of existing list presented to ICG WG workshop in March 2009
  - Distinguish between *essential* and *desired* parameters
3. Develop methodology for each parameter
  - Document the components to be addressed for each parameter (i.e., those conceptual contributions necessary to define the parameter)
  - Allocation of contributing errors (i.e. resolve potential discrepancies between space & control versus user segments)
  - Determine whether to use a preferred convention



# Notional Timeline





# *Proposed New ICG Principle*

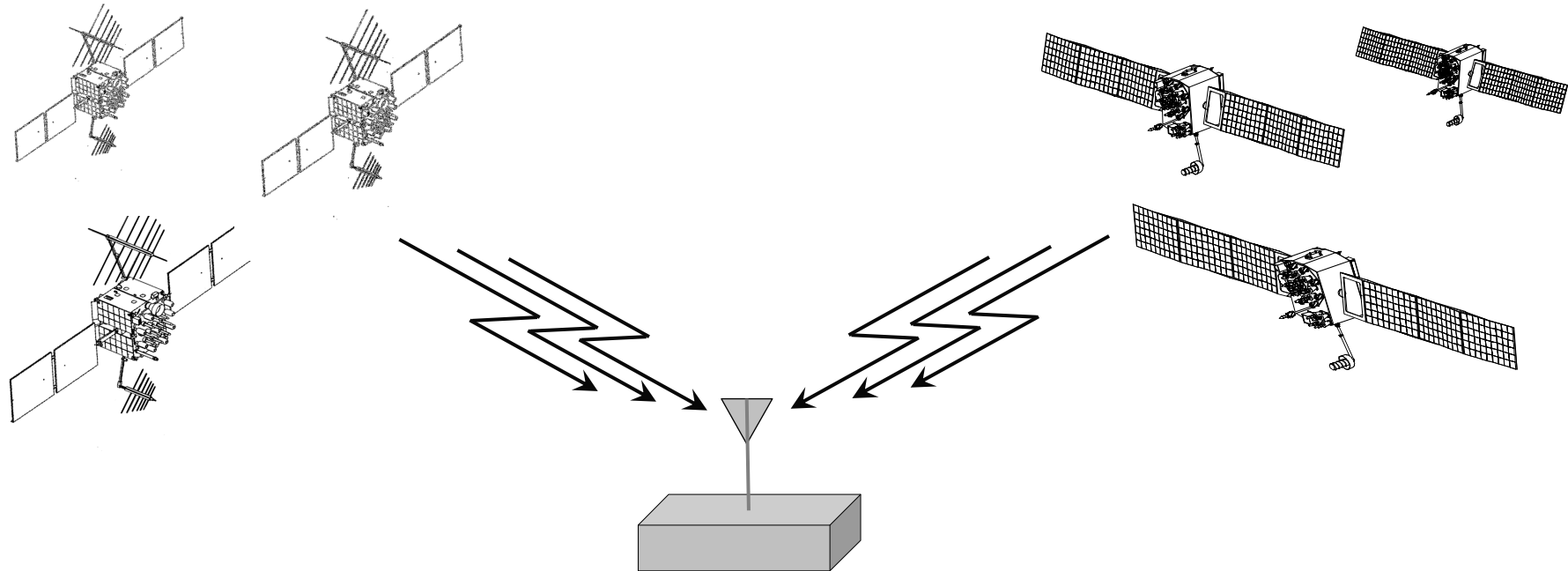
## Proposed New ICG Principle

**Every GNSS provider should establish documented civil performance commitments to inform users about minimum levels of service**

- Civil signal interoperability benefits users and receiver manufacturers
  - Better performance for receivers that use GPS and other signals together
  - More rapid and extensive adoption of highly interoperable signals
- Interoperable signal-in-space (SIS) performance commitments allow a multi-GNSS receiver to manage contributions from each satellite SIS used to compute the positioning, navigation, and timing solution
  - Interoperable signals need interoperable SIS performance commitments
    - Consider interoperable signals from 3 GNSS-A satellites and 3 GNSS-B satellites
    - Without interoperable SIS performance commitments, the solution is just a guess



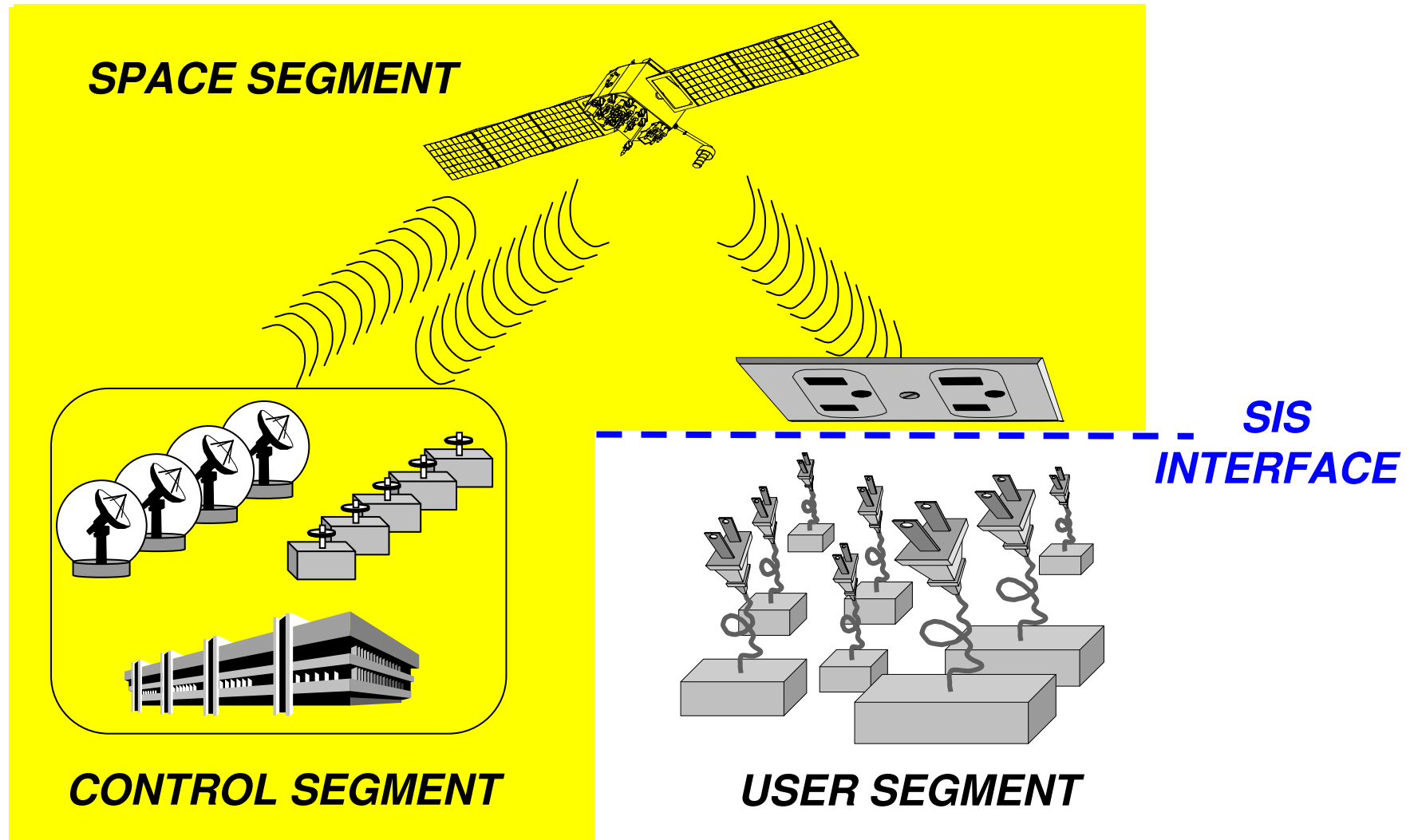
# 3 GNSS-A & 3 GNSS-B



- Weighted Least Squares Position Solution
  - Measurement weights come from pseudorange domain accuracy
  - Need performance commitment for pseudorange domain accuracy from SIS
- Receiver Autonomous Integrity Monitor (RAIM)
  - Probability of undetected faults comes from pseudorange domain integrity
  - Need performance commitment for pseudorange domain integrity from SIS



# 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
  - Take example of 3 GNSS-A satellites and 3 GNSS-B satellites
    - Multi-GNSS receiver manufacturer will decide how to integrate (interoperate with) this set of GNSS-A and GNSS-B satellites
      - Not under control of GNSS-A service provider or GNSS-B service provider
- 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



# *Per Satellite SIS Basis*

- A “per satellite SIS” basis for performance commitments allows a GNSS receiver to manage contributions from each satellite SIS used to compute the positioning, navigation, and timing solution
  - True for a single-GNSS receiver faced with multiple blocks of satellites
  - True for a multi-GNSS receiver faced with different types of satellites
- If service provider only publishes constellation-level commitments, then contributions from individual GNSS satellites are unclear
  - Does not support example of 3 GNSS-A satellites and 3 GNSS-B satellites

**GPS Lesson Learned #1:** Using “per satellite SIS” as basis for performance commitments enables interoperability among multiple blocks of satellites

**GPS Lesson Learned #2:** Using “per satellite SIS” establishes the least common denominator as minimum threshold for backwards compatibility



# ***Performance Commitment Categories\****

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- 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
- Radionavigation Systems**
- Navigation Systems**

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

\*Chart from “GNSS Service Performance Commitments...initial thoughts for consideration”, March 2009



# ***Performance Commitment Categories\****

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- 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 ICAO SARPs for example**

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

\*Chart from “GNSS Service Performance Commitments...initial thoughts for consideration”, March 2009



# Example: 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	$1-1 \times 10^{-7}/h$	5 min	$1-1 \times 10^{-4}/h$ to $1-1 \times 10^{-8}/h$	0.99 to 0.99999
Enroute, Terminal	0.74 km (0.4 NM)	N/A	$1-1 \times 10^{-7}/h$	15 s	$1-1 \times 10^{-4}/h$ to $1-1 \times 10^{-8}/h$	0.99 to 0.99999
Initial approach, Intermediate approach, Nonprecision approach (NPA), Departure	220 m (720 ft)	N/A	$1-1 \times 10^{-7}/h$	10 s	$1-1 \times 10^{-4}/h$ to $1-1 \times 10^{-8}/h$	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).



# 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

\*Chart from “GNSS Service Performance Commitments...initial thoughts for consideration”, March 2009





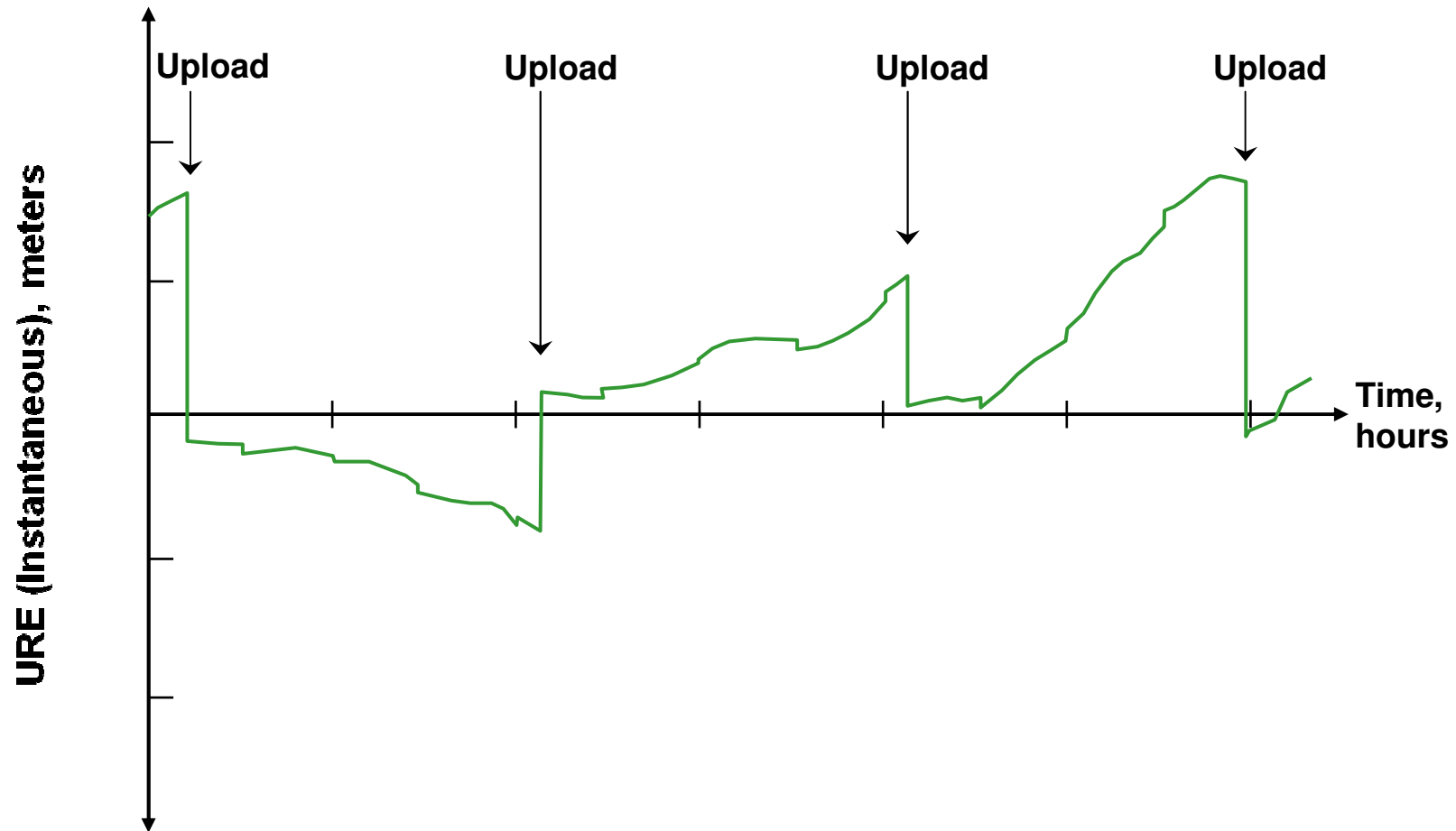
# Performance Commitment: Pseudorange Accuracy Example

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

SIS Accuracy Standard	Conditions and Constraints
Single-Frequency Civil Signal "A": <ul style="list-style-type: none"> <li>• <math>\leq x.x</math> m 95% Global Average URE during Normal Operations over all AODs</li> <li>• <math>\leq y.y</math> m 95% Global Average URE during Normal Operations at Zero AOD</li> <li>• <math>\leq z.z</math> m 95% Global Average URE during Normal Operations at Any AOD</li> </ul>	<ul style="list-style-type: none"> <li>• For any healthy Civil Signal "A" SIS</li> <li>• Neglecting <i>&lt;list of particular neglected errors, if any&gt;</i> errors</li> <li>• Including <i>&lt;list of particular included errors, if any&gt;</i> errors</li> </ul>
Single-Frequency Civil Signal "A": <ul style="list-style-type: none"> <li>• <math>\leq rr.r</math> m <math>Prob_1\%</math> Global Average URE during Normal Operations</li> <li>• <math>\leq rr.r</math> m <math>Prob_2\%</math> Worst Case Single Point Average URE during Normal Operations</li> </ul>	<ul style="list-style-type: none"> <li>• For any healthy Civil Signal "A" SIS</li> <li>• Neglecting <i>&lt;list of particular neglected errors, if any&gt;</i> errors</li> <li>• Including <i>&lt;list of particular included errors, if any&gt;</i> errors</li> <li>• <i>&lt;caveats relative to rare normal URE limit value of rr.r and relative to probability values of Prob<sub>1</sub>% and Prob<sub>2</sub>%, if any&gt;</i></li> </ul>
Single-Frequency Civil Signal "A": <ul style="list-style-type: none"> <li>• <math>\leq cc.c</math> m 95% Global Average URE during Extended Operations after <math>dd</math> Days without Upload</li> </ul>	<ul style="list-style-type: none"> <li>• For any healthy Civil Signal "A" SIS</li> <li>• Neglecting <i>&lt;list of particular neglected errors, if any&gt;</i> errors</li> <li>• Including <i>&lt;list of particular included errors, if any&gt;</i> errors</li> <li>• <i>&lt;caveats relative to maximum coasting URE value of cc.c and maximum coasting duration of dd, if any&gt;</i></li> </ul>

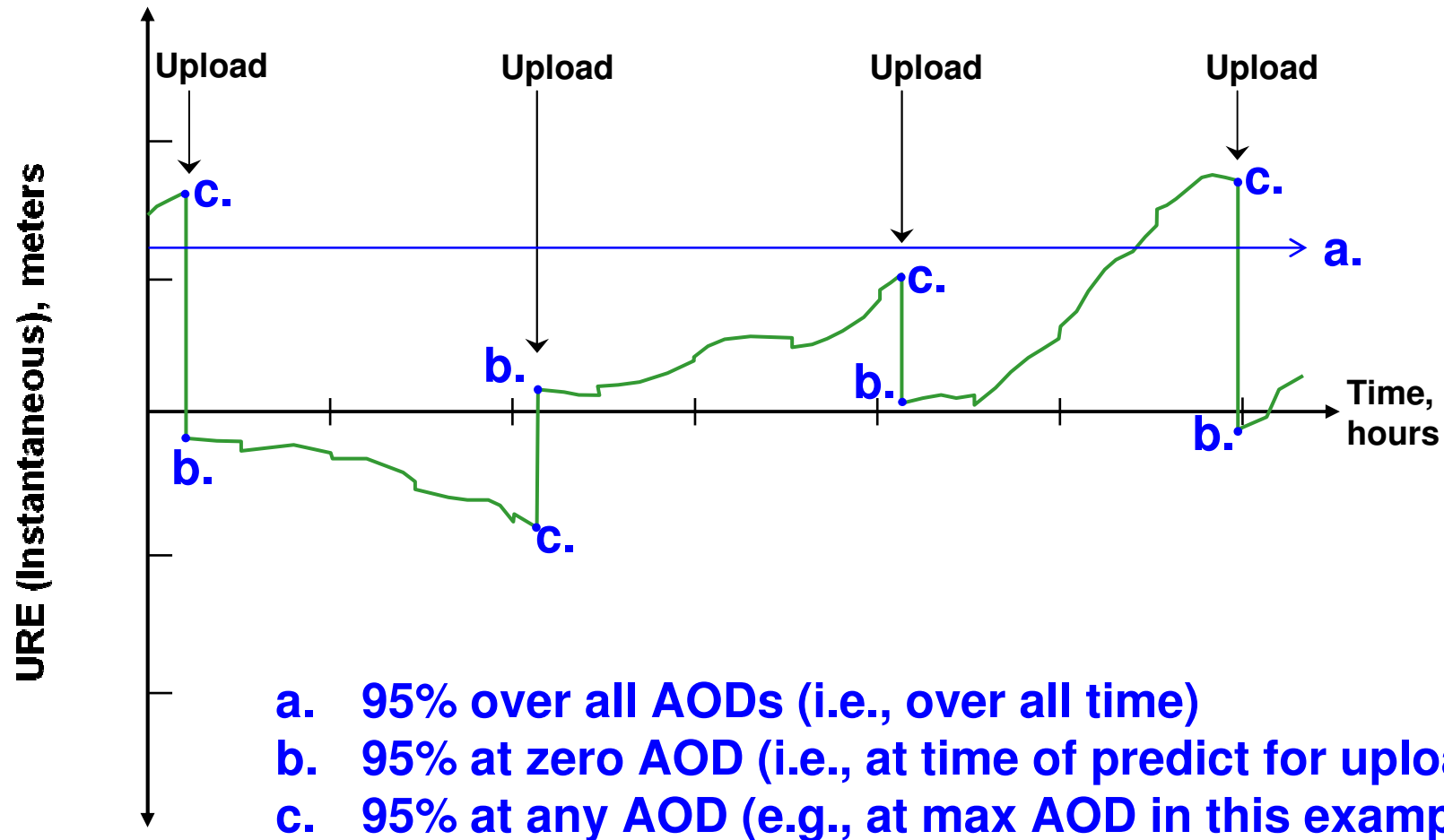


# ***Assumed Common Characteristic: “Age of Data” (AOD) Parameter***





# Assumed Common Characteristic: “Age of Data” (AOD) Methodology





# Performance Commitment: Pseudorange Accuracy Example

Table III-x. SIS URE Accuracy Commitment

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May want to omit, actually more appropriate as integrity

For GPS,  $dd$  is essentially the data senescence "time out" limit



# *Way Ahead*

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- Adopt the proposed ICG Principle
- Add the Template activity to the WG-A workplan
  - Complete Performance Commitment Template by next year's 5<sup>th</sup> ICG meeting
  - Identify POCs from each Provider
- Leverage WG-A meetings to status progress during next year
- Thoughts?



## *Way Ahead (Cont)*

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Send feedback & suggestions to:

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c/o GPS Wing (Aerospace)

[Karl.L.Kovach@aero.org](mailto:Karl.L.Kovach@aero.org)



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# BACKUP CHARTS



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

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- 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)

