Availability of GPS and MSAS with Standard and Degraded Constellations

Presentation for GIT/10

Tom Hsiao
S.V. Massimini
October 2006
• US government has committed to support worldwide peaceful use of GPS navigation without direct user fees for civil, commercial and scientific uses
  – Including GPS augmentations operated by the US (e.g., WAAS and NDGPS)

• Support for the nominal 24 satellite constellation has been excellent
  – Since Initial Operating Capability the system has operated with at least 24 satellites, and often significantly more
Receiver Autonomous Integrity Monitoring (RAIM)/Aircraft-Based Augmentation System (ABAS)

- Civil aviation aircraft flying under instrument flight rules must monitor integrity
  - Includes use of GPS position for ADS-A/C and ADS-B

- GPS navigation solution requires at least 4 satellites
  - Aircraft use additional satellites to verify integrity (RAIM/ABAS)
    - Some aircraft installations allow the use of the barometric altimeter to assist in RAIM/ABAS calculations

- RAIM/ABAS is not used with GPS augmentations such as SBAS, GBAS, and GRAS
  - Except as a backup in case of the loss of the augmentation signal
Although the USG has operated GPS with 24 or more satellites, the USG commitment for GPS is:

“In support of the service availability standard, 24 operational satellites must be available on orbit with 0.95 probability (averaged over any day). At least 21 satellites in the 24 nominal plane/slot positions must be set healthy and transmitting a navigation signal with 0.98 probability (yearly averaged).”

Many current GPS satellites have operated beyond their design lifetimes

– Excellent reliability

– A number satellites are “single string,” e.g., currently using their last bus or atomic clock

New IIR-M satellite just launched

– A number of new satellites are awaiting launch
Future GPS

• Although the US will maintain GPS at high levels of performance, the numbers of operating GPS satellites may not continue at the level experienced in the last few years

• Civil users and navigation service providers should plan conservatively with respect to performance of GPS

• What performance levels can be expected if the number of operating satellites drop to 24 or fewer?
  – Following slides show estimates of performance
Assumptions

• 24 GPS standard constellation
• Single-frequency receiver (URA=6m)
• 5° mask angle (2° for RNP results)
• Average availability of n-satellite failure (n = 0→3)
  – No failures on remaining 24 - n satellites
• MTSATs located at 140ºE and 145ºE
  – 8 GMS/MRS
  – No MTSAT failures
  – No MSAS ground equipment failures
• 24 hours with samples at 5 minute intervals
Predicted En Route Availability (HAL = 2 NM) for Standard and Degraded GPS Constellations

24 of 24

23 of 24

22 of 24

21 of 24

GPS

SBAS

Availability Scale
Predicted Terminal Availability (HAL = 1 NM) for Standard and Degraded GPS Constellations

Availability Scale

MITRE
Predicted NPA-BARO/VNAV Availability (HAL = 0.3 NM) for Standard and Degraded GPS Constellations

Availability Scale

GPS

SBAS
Predicted Availability of RNP 0.1 (29 Satellite GPS Constellation)

100% availability over 100% of the service area

Without SBAS

RNP .1/HAL=333m/No Inertial

With SBAS
Predicted Availability of RNP 0.1 (24 Satellite GPS Constellation)

100% availability over 100% of the service area

Without SBAS

RNP .1/HAL=333m/No Inertial

With SBAS

Availability Scale
Predicted Availability of RNP 0.1
(22 Satellite GPS Constellation)

Without SBAS

With SBAS

RNP .1/HAL=333m/No Inertial
Observations and Additional Thoughts

• Service availability tends to degrade with reduced numbers of GPS satellites without SBAS

• Service availability using SBAS is generally robust with reduced numbers of GPS satellites

• Possible launch of the Indian GAGAN system may further improve SBAS performance in Asia-Pacific

• Modernization of GPS, the development of Galileo, and effort with GLONASS should offer further improvements
Recommendations

• Economies should plan to approve the use of SBAS in their airspace
  – Low cost to the Economy
  – Similar to the recommendations of Asia-Pacific Regional Navigation Feasibility Study

• Economies should monitor the development and modernization of GPS, Galileo, GLONASS and augmentations to these systems
  – GAGAN
  – GBAS
  – GRAS