

# GNSS Integrity

RAIM PREDICTION FOR PBN OPERATIONS

-

JOHN WILDE, GLOBAL STRATEGIC SALES

16.08.2016



AN AIRBUS COMPANY

o4 Future Developments

o3 Regional Solutions

o2 SATDIS

o1 What is GPS?



AN AIRBUS COMPANY

# What is GPS?

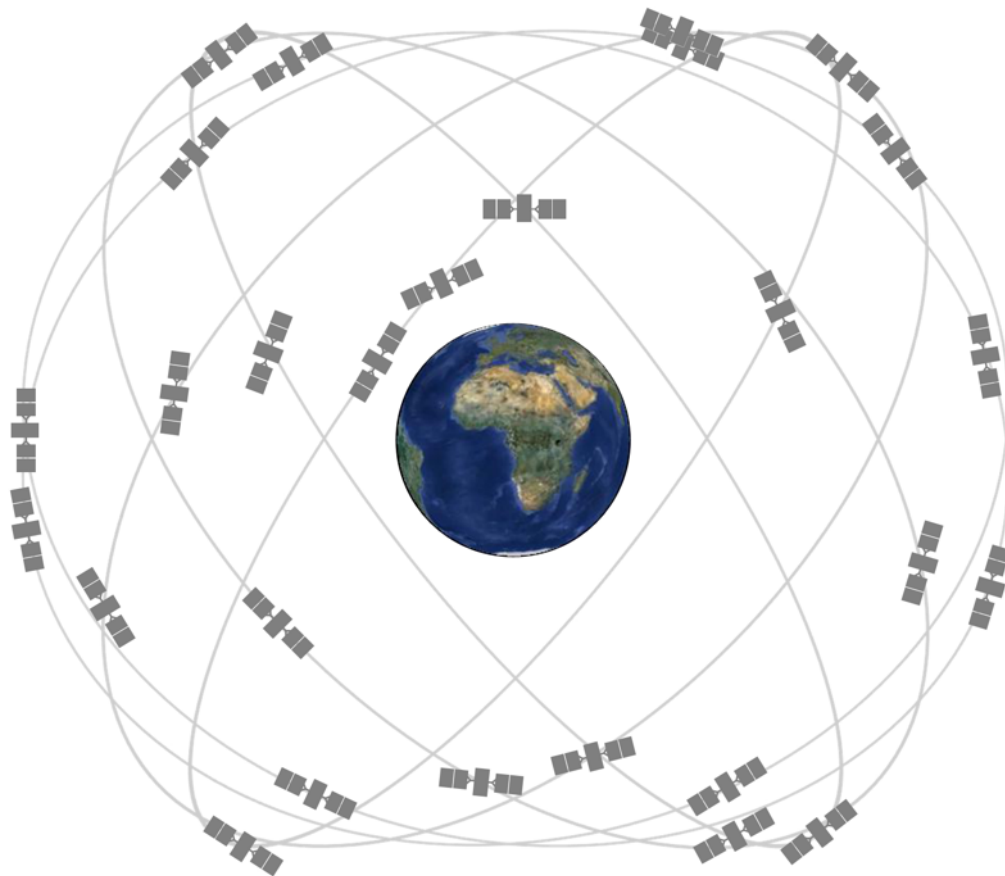
CHAPTER 01



AN AIRBUS COMPANY

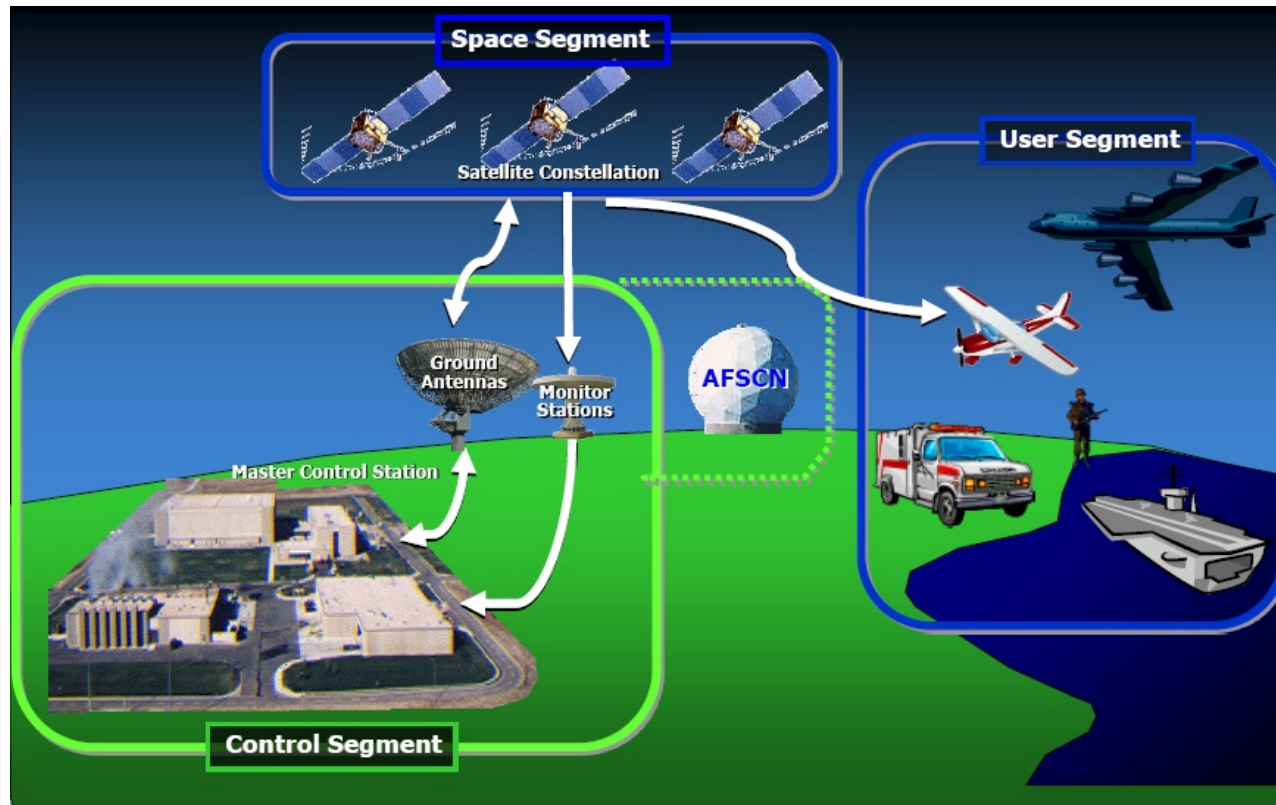
# Basic GNSS Principles

- NAVSTAR = Navigation System using Timing and Ranging
- GPS = Global Positioning System
- Initiated by Department of Defence
- Project was started in 1973
- First satellites launched in the late 1970's
- Declared fully operational in 1995
- System has been improving ever since



# Basic GNSS Principles

- 3 Component Segments of GPS
  - Space
  - Control
  - User



# GPS

## Space Segment

- Constellation of 32 satellites move in six orbital planes approximately 20,200 km above Earth
- Base constellation of 24 satellites in designated primary slots
- Increased to 27 operational satellites (June 2011) to improve availability, "The Expandable-24"
- GPS constellation has 31 operational satellites
- Zero Block IIA
- 12 Block IIR
- 7 Block IIR-M
- 12 Block IIF
- 3-5 residual satellites in a stand-by mode

**NAVBLUE**

AN AIRBUS COMPANY



# GPS

## Space Segment

- 1 additional satellite set unhealthy (SVN49/PRN27 used for tests)
- “Residual” satellites are kept in a stand-by mode and can be set “healthy” if needed to replace a failed satellite
- The expanded constellation uses the additional satellites (24+3) to increase worldwide availability
- There are three expanded slots (one in the B, D and F planes)
- A "non-primary" satellite is typically located to back-up an older satellite and is not located in a primary or expanded slot

**NAVBLUE**

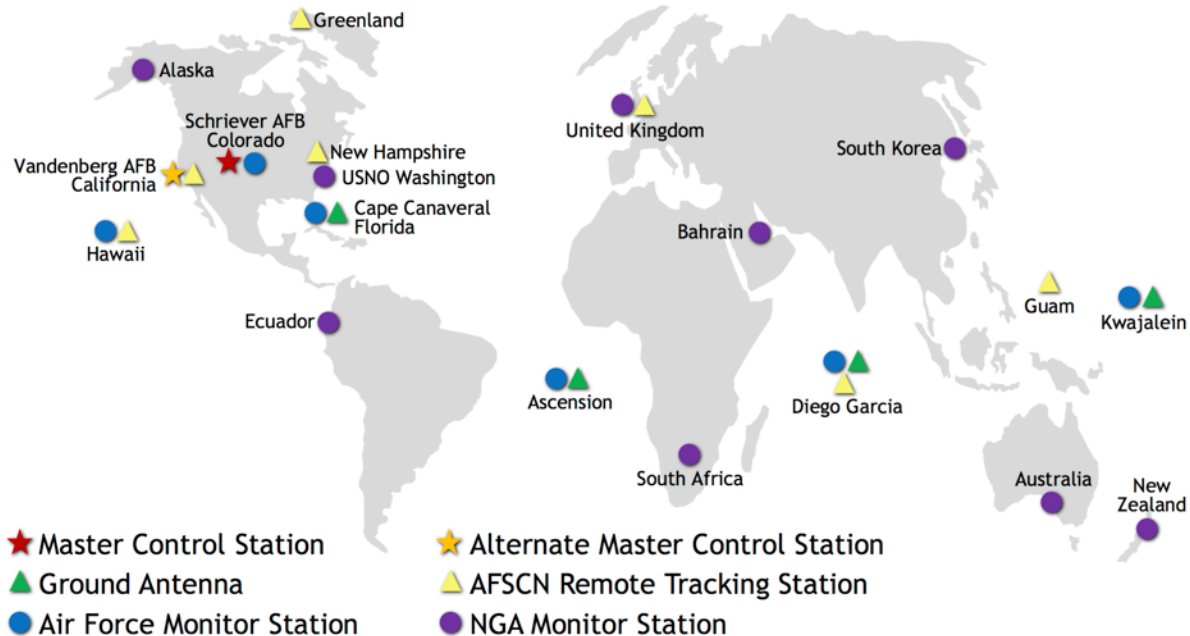
AN AIRBUS COMPANY



# GPS Control Segment

- Ground Control Segment is comprised of monitor stations and ground antennas with uplink capabilities. Monitor stations track all satellites in view
- Information from monitor stations is processed at Master Control Station (MCS) to determine satellite clock and orbit states and to update navigation message of each satellite. This updated information is transmitted to satellites via ground antennas

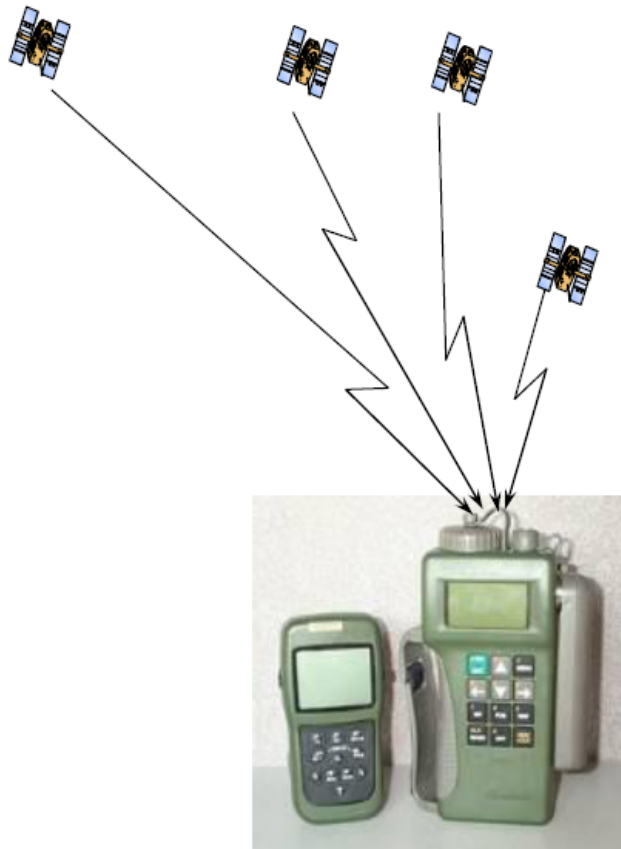
## GPS Control Segment



# GPS

## User Segment

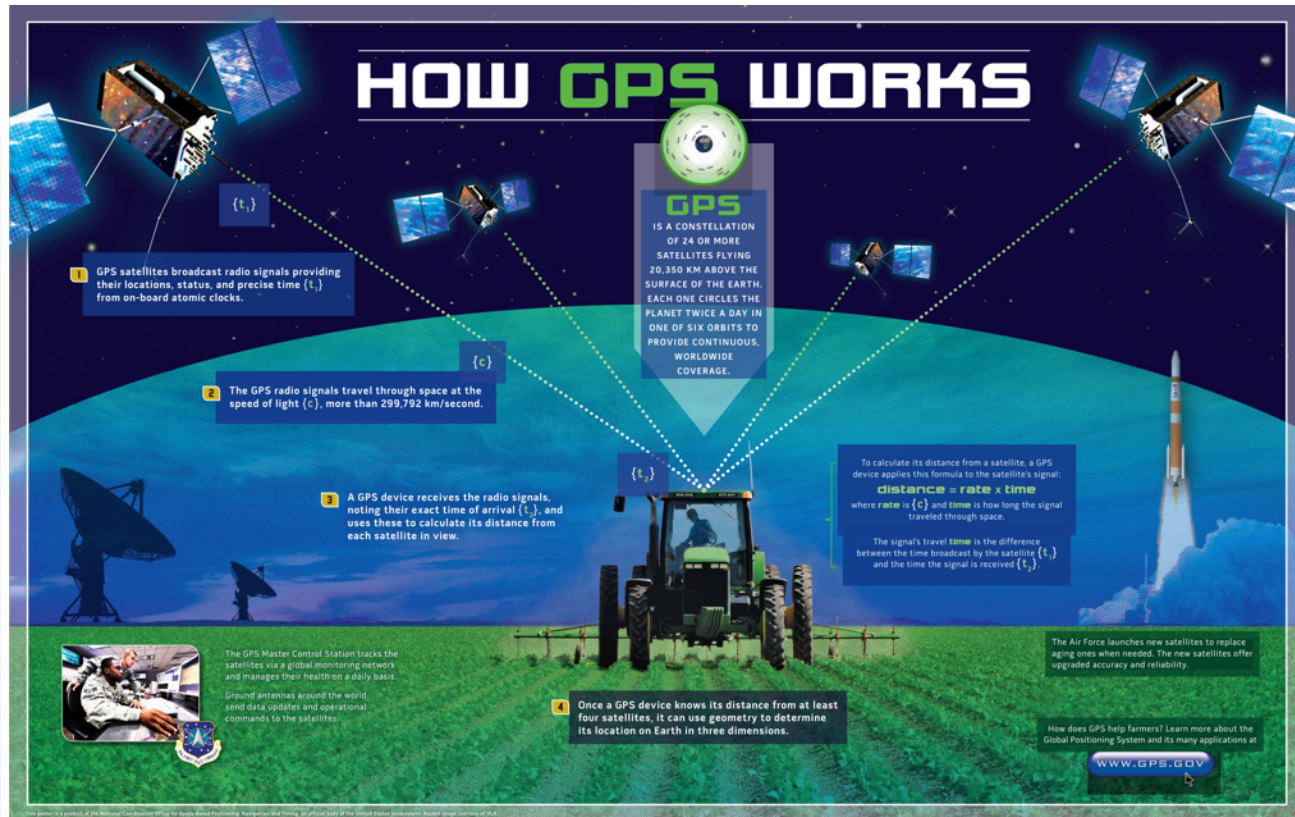
- Each satellite transmits its position and a time signal
- Signals travel to receiver delayed by distance travelled
- Differences in distance travelled make each satellite appear to have a different time
- Receiver calculates distance to each satellite and can then calculate its own position



# GPS

## One-Way Ranging

- GPS satellites broadcast radio signals providing their locations, status, and precise time from on-board atomic clocks.
- The GPS radio signals travel through space at the speed of light, more than 299,792 km/second.
- A GPS device receives the radio signals, noting their exact time of arrival ( $t_r$ ), and uses these to calculate its distance from each satellite in view.
- Once a GPS device knows its distance from at least four satellites, it can use geometry to determine its location on Earth in three dimensions.



**NAVBLUE**

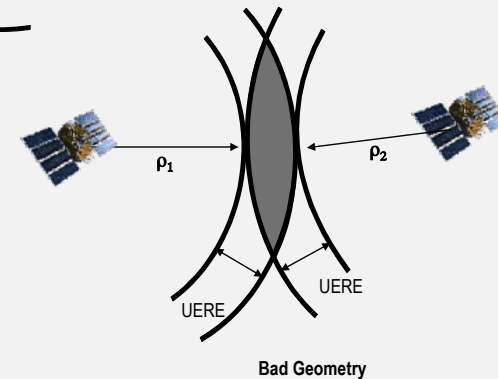
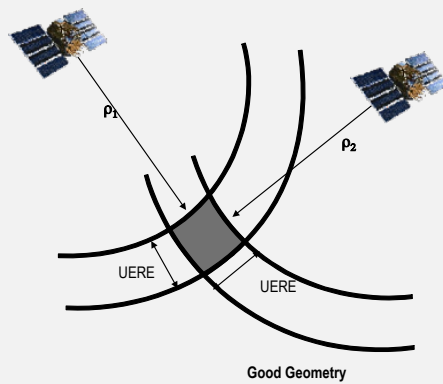
AN AIRBUS COMPANY

# Satellite Position: Almanac and Ephemeris

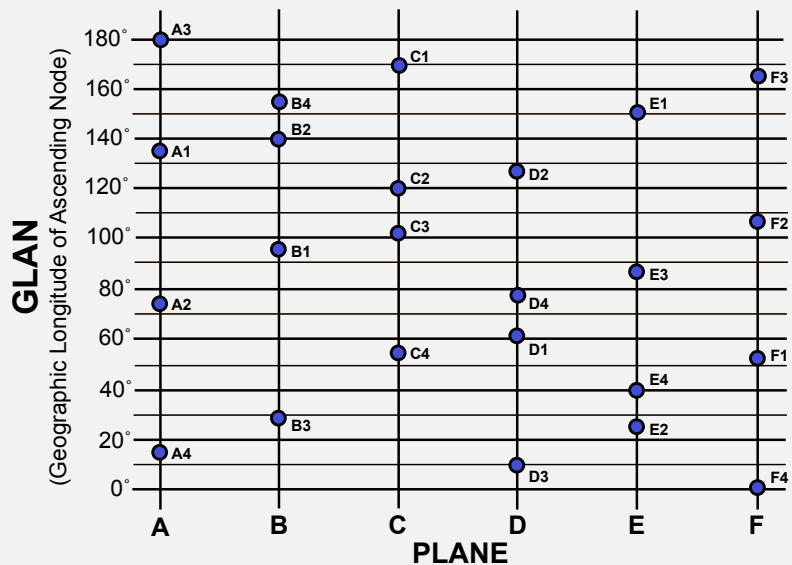
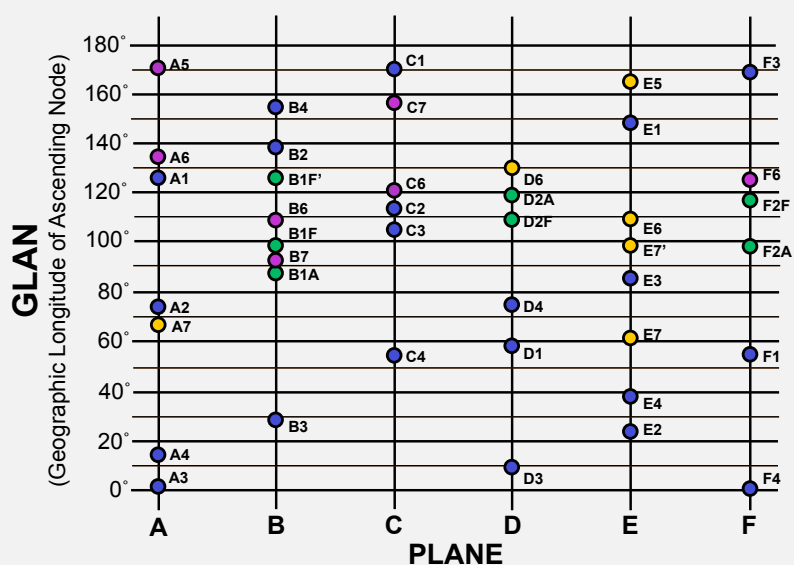
- GPS Navigation Message
  - Time
  - Almanac data
  - Ephemeris data
- Almanac data
  - Coarse orbital position of whole constellation
  - Valid for a long time
- Ephemeris data
  - Coarse orbital position for whole constellation
  - Valid for a few hours
  - Updated regularly

# GNSS Principles: Error Sources

Error Source	GPS Error (m)
Almanac / Ephemeris	1 to 3
Ionosphere	1 to 7
Troposphere	0.1 to 0.5
Multi-path	0.5 to 1.5
Satellite Clock vs Receiver Clock	1 to 2
Receiver Noise	0.2 to 0.3



# GNSS Principles: Navigation System Performance: Geometry

1<sup>st</sup> July 19933<sup>rd</sup> April 2015

Slot	SV	Slot	SV
A1	SVN-65	D1	SVN-61
A2	SVN-52	D2A	SVN-63
A3	SVN-64	D2F	SVN-46
A4	SVN-48	D3	SVN-45
A5	SVN-39	D4	SVN-67
A6	SVN-27	D6	SVN-34
A7	SVN-38	E1	SVN-69
B1A	SVN-56	E2	SVN-47
B1F	SVN-71	E3	SVN-50
B2	SVN-62	E4	SVN-54
B3	SVN-44	E5	SVN-23
B4	SVN-58	E6	SVN-40
B6	SVN-49	E7	SVN-51
B7	SVN-35	F1	SVN-41
C1	SVN-57	F2A	SVN-55
C2	SVN-66	F2F	SVN-43
C3	SVN-59	F3	SVN-68
C4	SVN-53	F4	SVN-60
C6	SVN-36	F6	SVN-32
C7	SVN-37		

- Primary Slot SV
- Expandable-24 SV
- Non-primary Slot SV
- LADO / Auxiliary SV

# Navigation System Performance - RNP

- Traditionally “box-based”
  - Mandatory Equipment
  - Performance not specified explicitly
- Move towards Required Navigation Performance or Performance-Based Navigation
  - Operator can meet requirements in ‘anyway he pleases’
  - e.g. with GPS
- Goal: Target Level of Safety
- Risk of leaving containment area distributed amongst:
  - Accuracy
  - Integrity
  - Continuity
  - Availability



# Introduction to RAIM+

## OVERVIEW

- RAIM+ supports all RNAV and RNP operations supported by ICAO PBN
- Supports all PBN Navigation Specifications and regional / state AMCs and ACs
- From RNAV 10 to RNP AR down to 0.1 NM
- Since DWI (now NAVBLUE) started to supply the RAIM+ to commercial customers (Scheduled 2007, On-Demand 2008, Web UI 2012) there has been zero downtime of the service
- Updated for
  - New Navigation Specifications
  - New Constellations (Galileo, Compass etc)

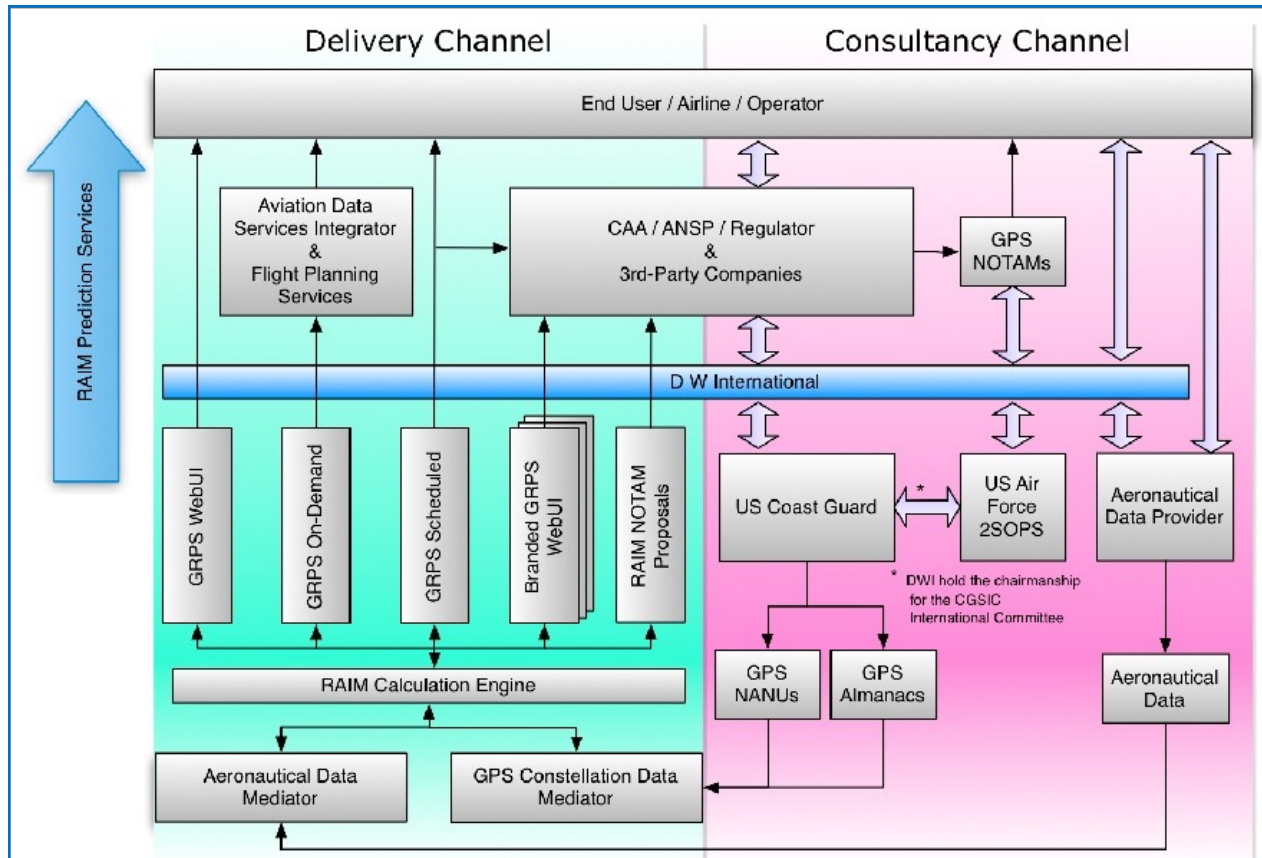
## THREE MAIN DELIVERY CHANNELS

- RAIM+ Web User Interface
- RAIM+ On-Demand
- RAIM+ Scheduled



## RAIM+ Delivery Channels

- Interfaces with USCG/USAF – official distributors of GPS Almanacs and NANUs
- NAVBLUE aeronautical data
- Same core engine for all services



# Standards Compliance

- Meets ICAO PBN guidance, FAA ACs and EASA AMCs

- Local variations on the above

	USA FAA	Europe EASA	Australia CASA	South America SVRSOP
<b>RNAV</b>				
<b>RNAV 10 (aka RNP 10)</b>	Order 8400.12	AMC 20-12	AC 91U-2(0)	AC 91-001
<b>RNAV 5 (aka B-RNAV)</b>	AC 90-96	AMC 20-4 (JAA TGL 2)	CAAP B-RNAV-1	AC 91-002
<b>RNAV 2 (aka US RNAV Type A)</b>	AC 90-100	JAA TGL 10 (AMC 20-16)	AC 91U-II-3-B	AC 91-003
<b>RNAV 1 (aka US RNAV Type B; P-RNAV)</b>	AC 90-100	JAA TGL 10 (AMC 20-16)	AC 91U-II-3-B	AC 91-003
<b>RNP</b>				
<b>RNP 4</b>	Order 8400.33		AC 91U-3(0)	AC 91-004
<b>RNP 1</b>	AC 90-105	JAA TGL 10 AMC 20-16)	AC 91U-II-C-3(0)	AC 91-006
<b>RNP Approach</b>	AC 90-105() (LNAV, LNAV/VNAV) AC 90-107() (LP, LPV)	AMC 20-27 (LNAV, LNAV/VNAV) AMC 20-28 (LP, LPV)	AC 91U- AC 91U-II-Attachment (LNAV/VNAV) II-C-5 (LNAV)	AC 91-008 (LNAV) AC 91-010 (LNAV/VNAV)
<b>RNP AR (Authorisation Required) Approach</b>	AC 90-101	AMC 20-26	AC 91U-II-C-5 (RNP AR) AC 91U-II-C-6	AC 91-009

# SATDIS

CHAPTER 02



AN AIRBUS COMPANY

# SATDIS for South America

- Argentina
- Bolivia
- Brasil
- Chile
- Colombia
- Ecuador
- Panama
- Paraguay
- Peru
- Uruguay
- Venezuela



## SAM RAIM Prediction Availability Service

Skip to content  
English

Login

Home

Tools

Account

Info

Sitemap

### SAM RAIM PREDICTION AVAILABILITY SERVICE

SAM RAIM Prediction Availability Service (SATDIS) has support for the following PBN/RNAV /RNP operations:

#### En route

Oceanic and remote continental area: RNP 10, RNP 4 RNP 2, Advanced RNP Continental area: RNAV 5, RNAV 2, RNAV 1, RNP 2, Advanced RNP, RNP 0.3

#### Terminal

RNAV 5, RNAV 2, RNAV 1, RNP 1, Advanced RNP, RNP 0.3

#### Approach

RNAV 1 (Initial, intermediate, missed approach segments)

RNP 1 (Initial, intermediate, missed approach segments)

RNP 0.3 (Initial, intermediate, missed approach segments)

Advanced RNP (all segments)

RNP APCH (all segments)

#### Departure

RNAV 2, RNAV 1, RNP 1, Advanced RNP, RNP 0.3

SATDIS meets the Requirements for RNAV/RNP operation as outlined in the SAM Circular Advice. See here. <http://www1.lima.icao.int/srvsop/circular>



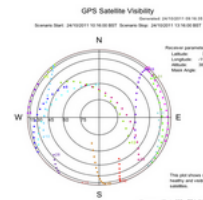
Aerodromes Tool



Route Tool




Status Tool



Visibility Tool

# SATDIS for South America

- In operation since 2014
- Aerodrome Tool
- Route Tool
- Status Tool
- Visibility Tool



[Skip to content](#)  
[English](#)

[Login](#)

Home
Tools
Account
Info
Sitemap

Status
Aerodromes
Route
Visibility
Standards
Contact
Disclaimer

### Aerodrome Prediction

The Aerodrome Prediction tool calculates the predicted RAIM availability for periods of 24, 48 or 72 hours for a list of user-selected aerodromes.

The RAIM calculation can be configured to represent the receiver equipment, fault detection algorithm (Fault Detection (FD) or Fault Detection and Exclusion (FDE)) and awareness of SA (Selective Availability):

- C129 - FD/FDE - SA On/Off
- C145/146 - FDE - SA Off

For most aerodrome calculations the integrity levels will be Non-Precision Approach (NPA), Terminal or RNP


Summary
Report

Aerodromes		RAIM Outage Predictions	
ICAO	Name	Baro	Non-Baro
CYAH	La Grande-4	0	0
CYHF	Hearst Mun	0	1
CYPZ	Burns Lake	0	0

**Calculation Time:**  
21-10-2011 15:16:19 UTC

**Almanac:**  
635 61440

**3 Active Natus:**  
2011084, 2011083, 2011042



AN AIRBUS COMPANY

# Regional Solutions

CHAPTER 03



AN AIRBUS COMPANY

# Regional Solutions

## OVERVIEW

- Multiple regional solutions
- Different levels of SLA and functionality
- NAVBLUE supplies to multiple regional customers

## OPERATED BY NAVBLUE

- Europe: Augur
- Singapore: CAAS GPS RAIM Prediction Service
- South America: SATDIS
- Thailand & Vietnam: NETRA

## NOT OPERATED BY NAVBLUE

- Australia: NAIPS
- Japan: GPS RAIM Prediction Japan



# Augur for ECAC

- Operated by NAVBLUE
- In operation since 2006
- Aerodrome Tool
- Route Tool
- Status Tool
- Visibility Tool
- NOTAM Proposals

## AUGUR GPS RAIM Prediction Tool - GPS Status

[GPS Status](#)
[Terminal/Approach Tool](#)
[Visibility Tool](#)
[Route Tool](#)
[Nav Domain Home](#)
[Mirror Site](#)
[Help](#)

**Warning:** From 1 July 2012, AUGUR coverage will be limited to ECAC airspace only.  
Please email the helpdesk ([augur.helpdesk@ecacnav.com](mailto:augur.helpdesk@ecacnav.com)) for further information.

A minimum of 31 satellites are available during the query period.

B-RNAV en-route predictive RAIM check **not** required.

### Scenario Information

Start Time	04/02/2014 00:00:00 UTC
End Time	07/02/2014 00:00:00 UTC
Request Time	04/02/2014 14:56:40 UTC

### Current Almanac

GPS Week	754
GPS TOA	319488
Total Satellites	31
Unhealthy Satellite PRNs	0
Details	<a href="#">Full Text</a>   <a href="#">Sat Info</a>

### Current NANUs

No NANUs are currently active.

[AUGUR Disclaimer](#)

# NAVBLUE

AN AIRBUS COMPANY

# CAAS GPS RAIM Prediction Service

- Operated by NAVBLUE
- In operation since 2015
- Aerodrome Tool
- Route Tool
- Status Tool
- Visibility Tool
- Region Tool

Home Tools Account Info Sitemap

CAAS GPS RAIM Prediction Service

The CAAS GPS RAIM Prediction Service (CAAS GRPS) has been developed for the Civil

Route

1  
6 PPII  
omes  
CYPH CYPZ

**Edit GPS Receiver**

Receiver Type: C145 C146  
Algorithm: C129  
SA: OFF  
Baro Aided: OFF

OK Cancel

Constellation Status

Vietnam  
Thailand  
Cambodia  
Philippine  
SINGAPORE FIR  
Malaysia  
Singapore  
Indonesia  
Jakarta

# NETRA for Thailand

- Standard tool set
- NOTAM Proposals generated for State NOTAM Office
- Proposals issued in NOTAM format so no additional formatting required by NOTAM Office
- Expanded to cover Vietnam

**NETRA RAIM Prediction Service**

The NETRA RAIM Prediction Service has been developed to meet the RAIM prediction requirements as outlined in ICAO's Performance-Based Navigation (PBN) Manual (Doc 9613) including RNP 10, RNAV 5, RNAV 2, RNAV 1, RNP 4, RNP 1 (Basic RNP-1) and RNP Approach for the Asia Pacific region.

In addition NETRA's core service meets the requirements for RAIM prediction as outlined in international standards and advisory circulars including:

- Europe: EASA AMC 20-4, EASA AMC20-12, JAA TGL 10 (EASA AMC20-16), EASA AMC20-27, EASA AMC20-28.
- USA: FAA AC90-109B, FAA Order 8100.22 and FAA Order 8100.120.

Route  
Section 1  
BRRR CC16 PP12

Aerodromes  
CYAH CYHF CYPZ

Edit GPS Receiver  
Receiver Type: C145 C146  
Algorithm: C145 C146  
SA: OFF  
Baro Aided: OFF  
OK Cancel

## NOTAM N example

*A1234/09 NOTAMN  
Q) LFBB/ QGAUU/ I/ NBO/ A/ 000/ 999/ 4100N00200E005  
A) LFBO  
B) 0908240145  
C) 0908250225  
D) 24 0145-0230 0630-0645 25 0155-0225  
E) EGNOS NOT AVAILABLE FOR LPV*

This NOTAM is a new NOTAM (NOTAMN). Its reference is A1234/09

# Future Developments

CHAPTER 04

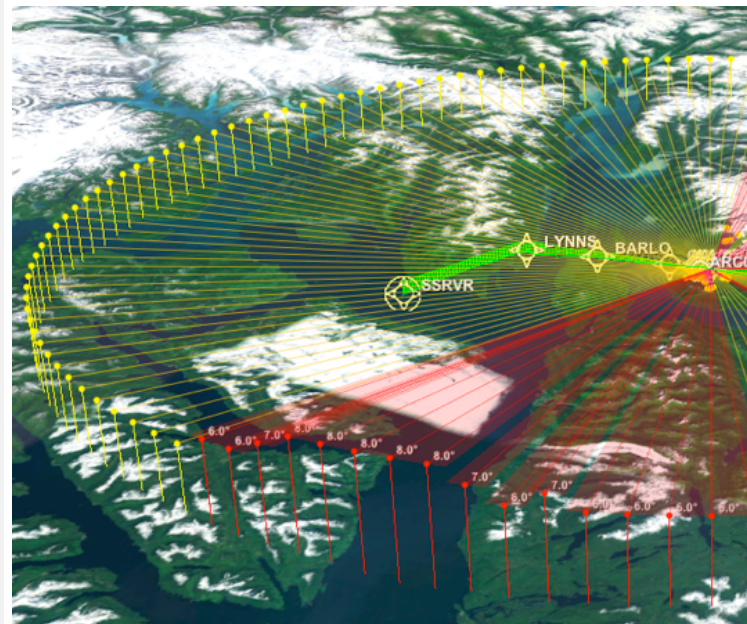


AN AIRBUS COMPANY

# Enhancements for SATDIS

## TWO POSSIBLE ENHANCEMENTS

- Region Tool – like CAAS GRPS. Gives a visual overview of RAIM outages over a country or region
- NOTAM Proposals – like NETRA. Sends NOTAM Proposals to state NOFs for distribution



# Future Possibilities

## ADS-B IN THE USA

- ADS-B Availability Predictions required for operations in USA from 2020
- If a similar mandate implemented in other ICAO regions this functionality will be available for SATDIS

“DRAFT”



**U.S. Department  
of Transportation**  
Federal Aviation  
Administration

# Advisory Circular

**Subject:** Automatic Dependent  
Surveillance-Broadcast Operations

**Date:** DRAFT

**AC No:** 90-114A

**Initiated by:** AFS-400

**Change:** 1

**1. PURPOSE.** The intent of this advisory circular (AC) is to facilitate operations using Automatic Dependent Surveillance-Broadcast (ADS-B) technology in compliance with Title 14 of the Code of Federal Regulations (14 CFR) part 91, §§ 91.225 and 91.227, which are required after January 1, 2020. The appendices provide guidance for the authorization of additional ADS-B Out and ADS-B In operations and their associated aircraft qualification and maintenance requirements.

**2. PRINCIPAL CHANGES.** This change incorporates new ADB-S guidance related to a technical amendment to § 91.225; equipping type certificated (TC) aircraft, light-sport aircraft (LSA), and experimental aircraft; and preflight requirements in U.S.-designated airspace. This change also modifies guidance for Cockpit Display of Traffic Information (CDTI) Assisted Visual Separation (CAVS).

## NAVBLUE and Worldwide RAIM Requirements



**NAVBLUE**

AN AIRBUS COMPANY

# Contact

—  
JOHN WILDE  
JOHN.WILDE@NAVBLUE.AERO

+44 (0) 118 324 0172



AN AIRBUS COMPANY

© AIRBUS S.A.S. ALL RIGHTS RESERVED. CONFIDENTIAL AND PROPRIETARY DOCUMENT. THIS DOCUMENT AND ALL INFORMATION CONTAINED HEREIN IS THE SOLE PROPERTY OF AIRBUS. NO INTELLECTUAL PROPERTY RIGHTS ARE GRANTED BY THE DELIVERY OF THIS DOCUMENT OR THE DISCLOSURE OF ITS CONTENT. THIS DOCUMENT SHALL NOT BE REPRODUCED OR DISCLOSED TO A THIRD PARTY WITHOUT THE EXPRESS WRITTEN CONSENT OF AIRBUS S.A.S. THIS DOCUMENT AND ITS CONTENT SHALL NOT BE USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT IS SUPPLIED. THE STATEMENTS MADE HEREIN DO NOT CONSTITUTE AN OFFER. THEY ARE BASED ON THE MENTIONED ASSUMPTIONS AND ARE EXPRESSED IN GOOD FAITH. WHERE THE SUPPORTING GROUNDS FOR THESE STATEMENTS ARE NOT SHOWN, AIRBUS S.A.S. WILL BE PLEASED TO EXPLAIN THE BASIS THEREOF. AIRBUS, ITS LOGO, A300, A310, A318, A319, A320, A321, A330, A340, A350, A380, A400M ARE REGISTERED TRADEMARKS.