

Introduction to DW International

John Wilde

CEO/Director, DW International



Introduction

- About DWI
- GNSS RAIM Prediction System (GRPS)
- Training

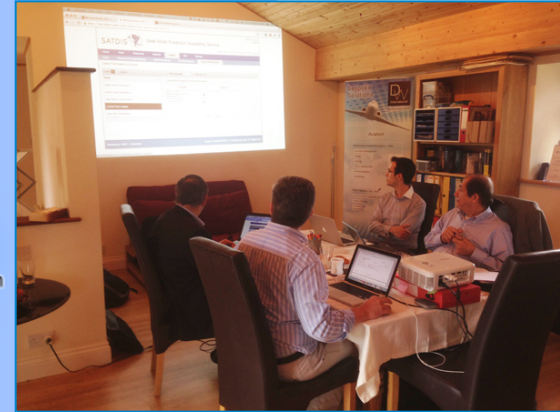
- Formed in 2005
- Consultancy for:
 - Air Navigation
 - Civil Air Communications
 - Air Traffic Management
- In-house Expertise in Aviation
- Array of External Consultants
- International Presence
- ISO 9001: 2008 Certified



DW International Locations



Cardiff
Software Office



Windsor
Admin/BD



Winchfield
HQ

Clients – Americas



Clients – Asia-Pacific



AIR MAURITIUS



AIR NEW ZEALAND



ANA



CATHAY PACIFIC



CIVIL AVIATION AUTHORITY OF MONGOLIA

CAAS

Civil Aviation Authority of Singapore



JAPAN AIRLINES

JEJU AIR

JET AIRWAYS

Jetstar



NTT DATA



Vanilla Air

Virgin australia

Clients – Europe-Middle East

AeroLogic

AirEuropa

AIR FRANCE

香港華民航空
air Hongkong

AIR SUPPORT
- flexibility makes the difference.

Avitech

DRAGONAIR

EL AL
הכי בבית בעולם

Fly Emirates

EUROCONTROL

flydubai

الهيئة العامة للطيران المدني
General Authority of Civil Aviation

Isavia

KLM

Lufthansa Cargo

Lufthansa Systems

Martinair

NATS

novair

الطيران العماني
OMAN AIR

الملكية الأردنية
ROYAL JORDANIAN

S7 AIRLINES

SITA

SMARTAVIATION

SWISS

virgin atlantic

Global Coverage

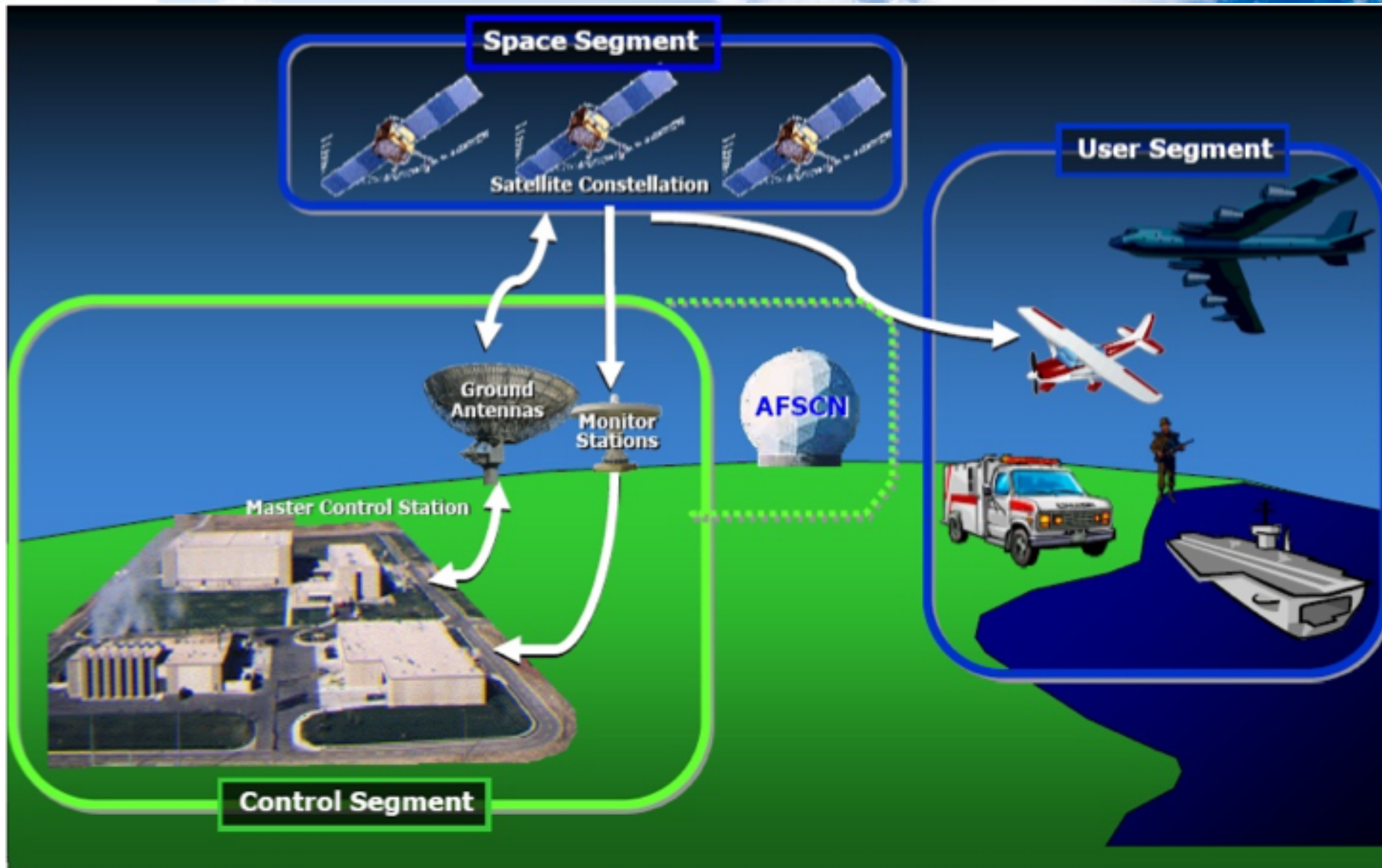


Basic GNSS Principles: What is GPS?

- 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



Basic GNSS Principles: 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 30 operational satellites
 - 3 Block IIA
 - 12 Block IIR
 - 7 Block IIR-M
 - 8 Block IIF
- 3-5 residual satellites in a stand-by mode



Basic GNSS Principles: Space Segment (cont'd)

- 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



Basic GNSS Principles: Ground Segment



- Ground Control Segment is comprised of 6 dedicated monitor stations and 4 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

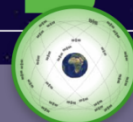
Basic GNSS Principles: User Segment



- 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

Basic GNSS Principles: One-way Ranging

HOW GPS WORKS



GPS

IS A CONSTELLATION OF 24 OR MORE SATELLITES FLYING 20,350 KM ABOVE THE SURFACE OF THE EARTH. EACH ONE CIRCLES THE PLANET TWICE A DAY IN ONE OF SIX ORBITS TO PROVIDE CONTINUOUS, WORLDWIDE COVERAGE.

1 GPS satellites broadcast radio signals providing their locations, status, and precise time $\{t_1\}$ from on-board atomic clocks.

2 The GPS radio signals travel through space at the speed of light $\{c\}$, more than 299,792 km/second.

3 A GPS device receives the radio signals, noting their exact time of arrival $\{t_2\}$, and uses these to calculate its distance from each satellite in view.

To calculate its distance from a satellite, a GPS device applies this formula to the satellite's signal:

$$\text{distance} = \text{rate} \times \text{time}$$

where **rate** is $\{c\}$ and **time** is how long the signal traveled through space.

The signal's travel **time** is the difference between the time broadcast by the satellite $\{t_1\}$ and the time the signal is received $\{t_2\}$.

4 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.

The GPS Master Control Station tracks the satellites via a global monitoring network and manages their health on a daily basis.

Ground antennas around the world send data updates and operational commands to the satellites.



The Air Force launches new satellites to replace aging ones when needed. The new satellites offer upgraded accuracy and reliability.

How does GPS help farmers? Learn more about the Global Positioning System and its many applications at

WWW.GPS.GOV

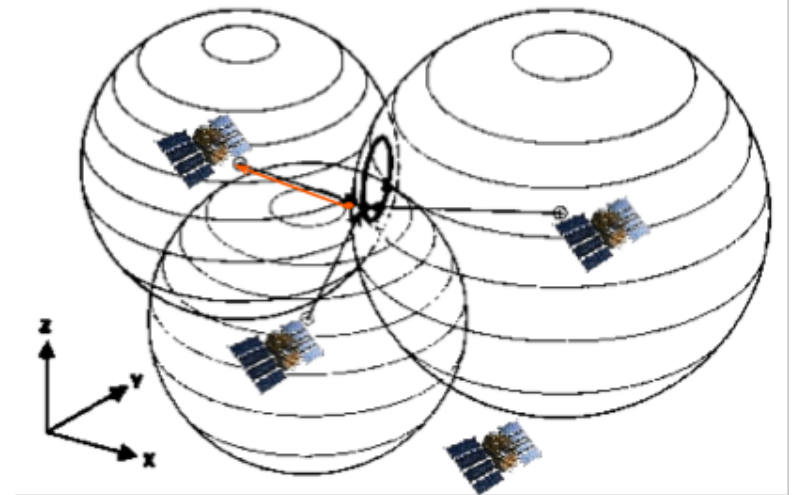
Basic GNSS Principles: Satellite Position Almanac & Ephemeris



- 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

Basic GNSS Principles: Positioning Principles

- 3-Dimensional Case
 - 4 satellites required
 - 3 co-ordinates of the receiver are unknown (x,y,z)
 - 1 time parameter unknown
- Determined position is at the intersection of all spheres



$$\begin{aligned} \sqrt{(x_1 - x)^2 + (y_1 - y)^2 + (z_1 - z)^2} + c \cdot \Delta t &= PR_1 \\ \sqrt{(x_2 - x)^2 + (y_2 - y)^2 + (z_2 - z)^2} + c \cdot \Delta t &= PR_2 \\ \sqrt{(x_3 - x)^2 + (y_3 - y)^2 + (z_3 - z)^2} + c \cdot \Delta t &= PR_3 \\ \sqrt{(x_4 - x)^2 + (y_4 - y)^2 + (z_4 - z)^2} + c \cdot \Delta t &= PR_4 \end{aligned}$$

Basic 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

RAIM in Aviation: ICAO RNP Requirements

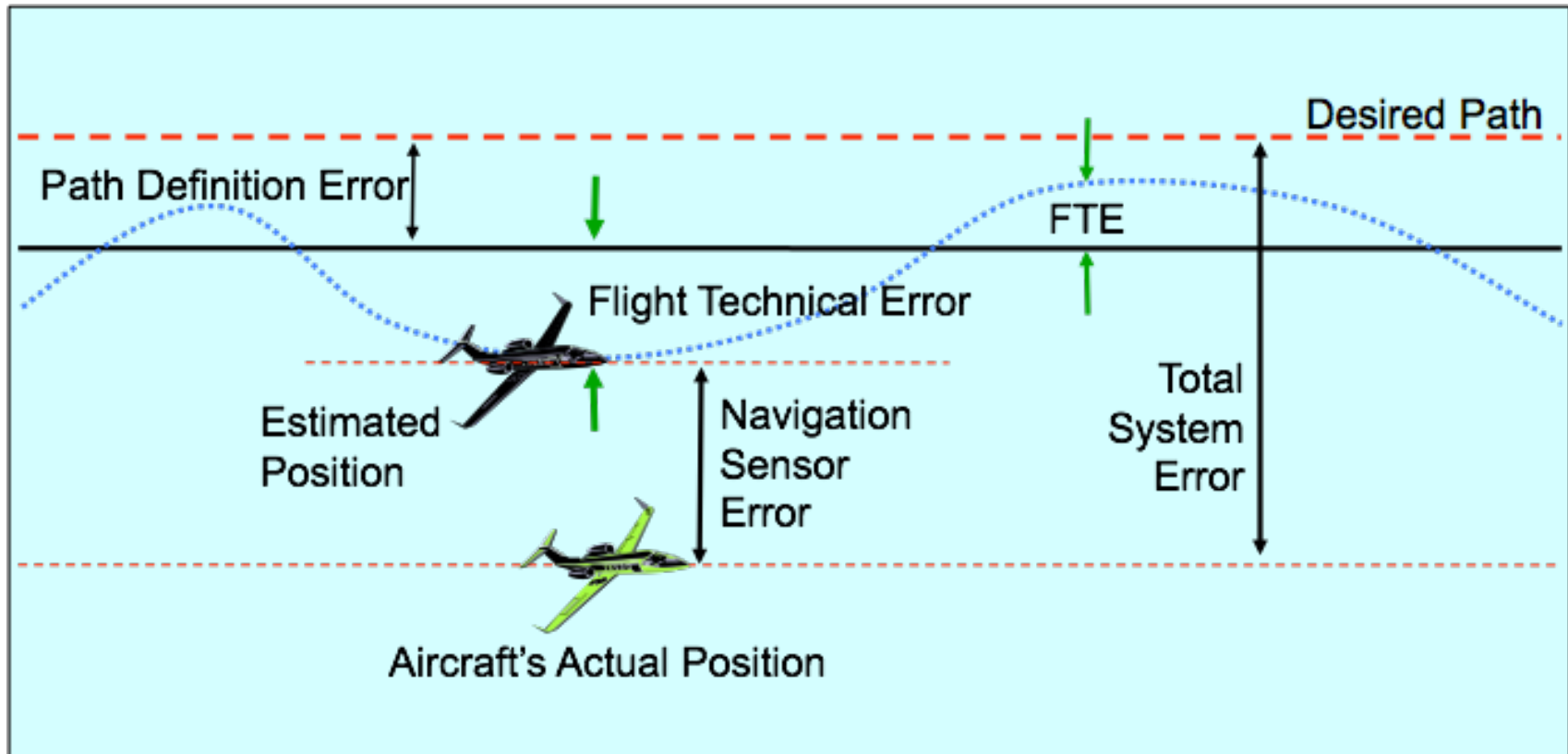
Typical Operation	Accuracy Horizontal 95%	Accuracy Vertical 95%	Integrity	Continuity	Availability	Horizontal Alert Limit HAL	Vertical Alert Limit VAL
En-Route (Oceanic)	7.4 km (4.0 NM)	n/a	$1 - 1 \times 10^{-7}$ /h	$1 - 1 \times 10^{-4}$ /h to $1 - 1 \times 10^{-8}$ /h	0.99 to 0.99999	7.4 km (4.0 NM)	n/a
En-Route (Continental)	3.7 km (2.0 NM)	n/a	$1 - 1 \times 10^{-7}$ /h	$1 - 1 \times 10^{-4}$ /h to $1 - 1 \times 10^{-8}$ /h	0.99 to 0.99999	3.7 km (2.0 NM)	n/a
En-Route (Terminal)	0.74 km (0.4 NM)	n/a	$1 - 1 \times 10^{-7}$ /h	$1 - 1 \times 10^{-4}$ /h to $1 - 1 \times 10^{-8}$ /h	0.99 to 0.99999	1.85 km (1 NM)	n/a
Initial Approach Intermediate Approach Non-Precision Approach (NPA) Departure	220 m (720 ft)	n/a	$1 - 1 \times 10^{-7}$ /h	$1 - 1 \times 10^{-4}$ /h to $1 - 1 \times 10^{-8}$ /h	0.99 to 0.99999	556 m (0.3 NM)	n/a
Approach Operations with Vertical Guidance (APV-I)	16 m (52 ft)	20 m (66 ft)	$1 - 2 \times 10^{-7}$ In Any Approach	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999	40m (130 ft)	50 m (164 ft)
Approach Operations with Vertical Guidance (APV-II)	16 m (52 ft)	8 m (26 ft)	$1 - 2 \times 10^{-7}$ In Any Approach	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999	40m (130 ft)	20 m (66 ft)
Category I Precision Approach	16 m (52 ft)	6 m to 4 m (20 ft to 13 ft)	$1 - 2 \times 10^{-7}$ In Any Approach	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999	40m (130 ft)	35 m to 10 m (115 ft to 33 ft)

Source: ICAO - Signal-in-Space Performance Requirements

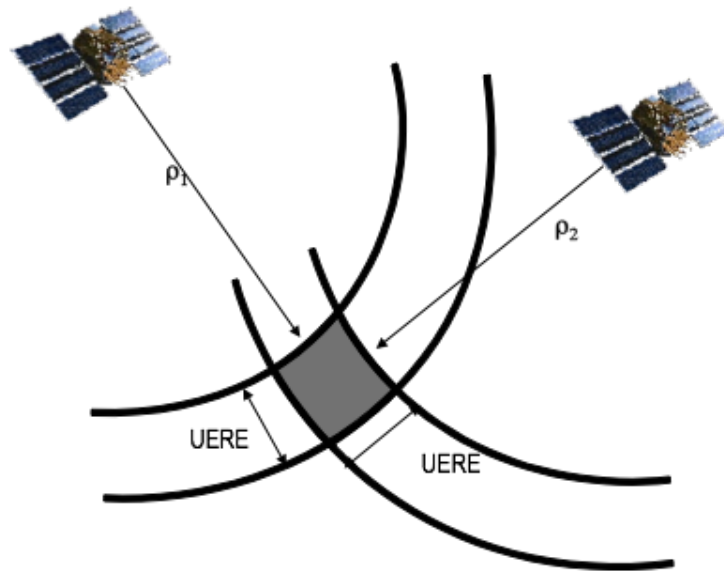
Navigation System Performance - RNP

- 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

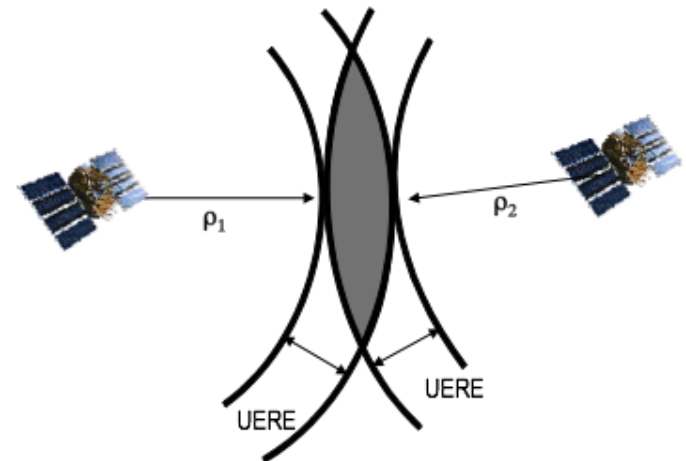
Navigation System Performance - Accuracy: Lateral



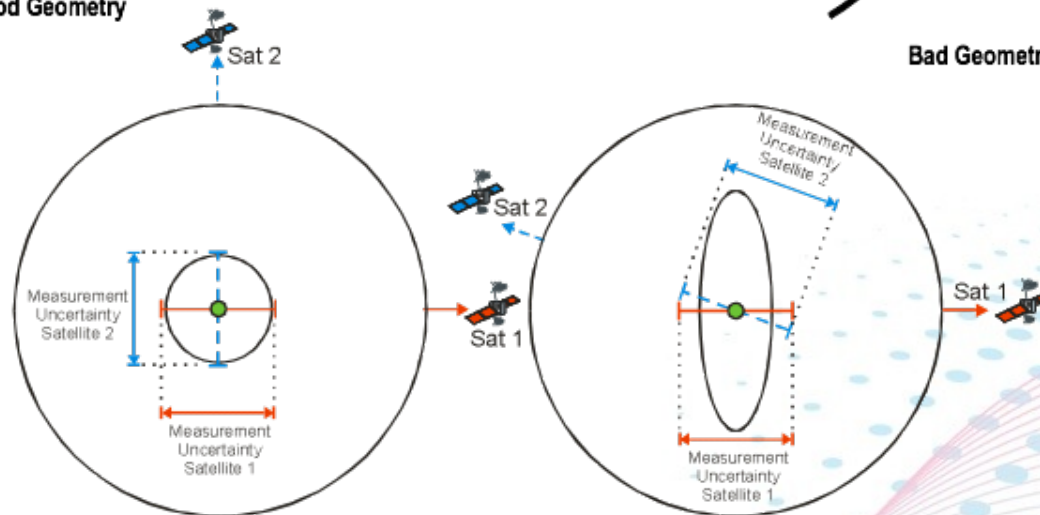
Navigation System Performance - Accuracy: Geometry



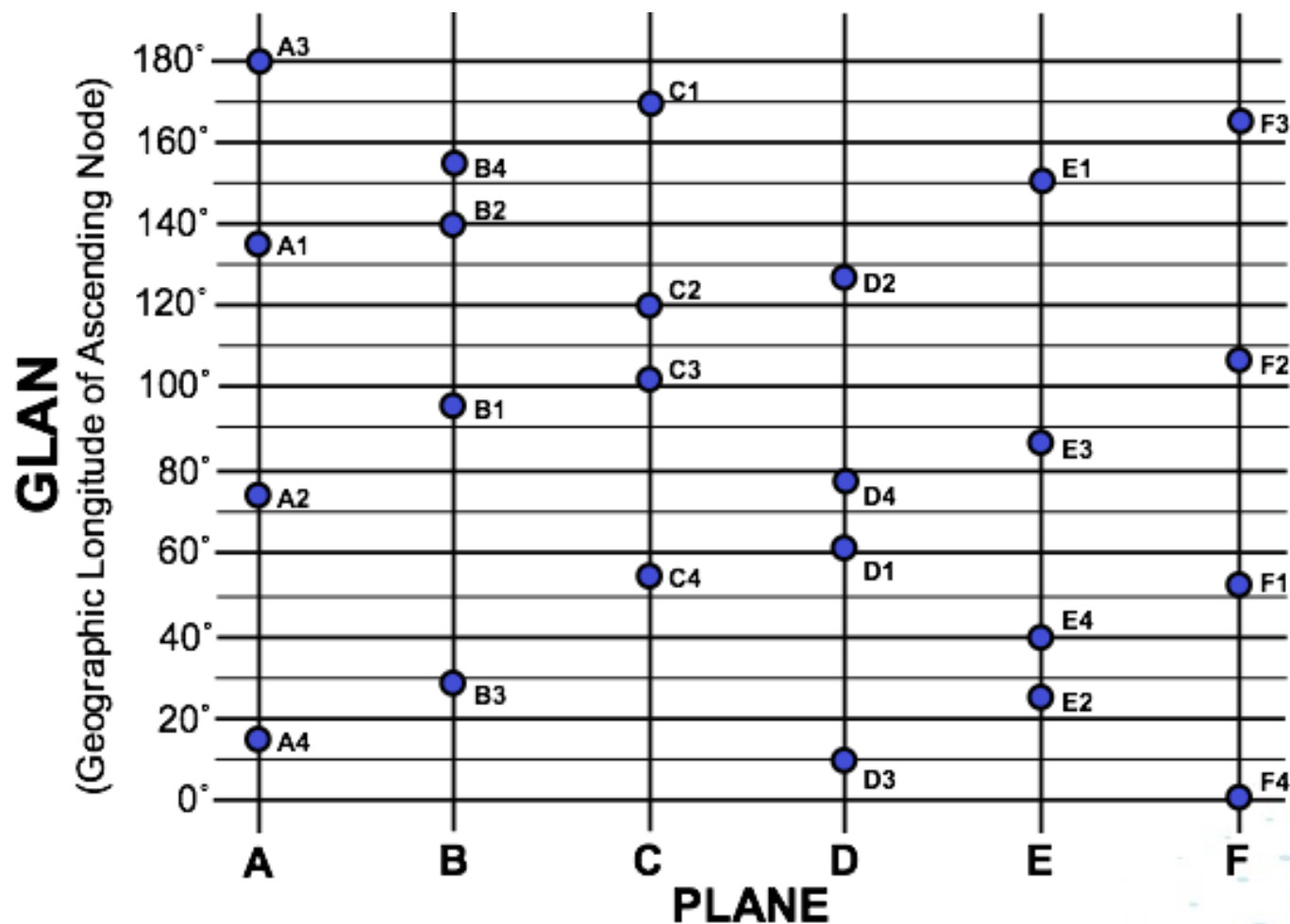
Good Geometry



Bad Geometry

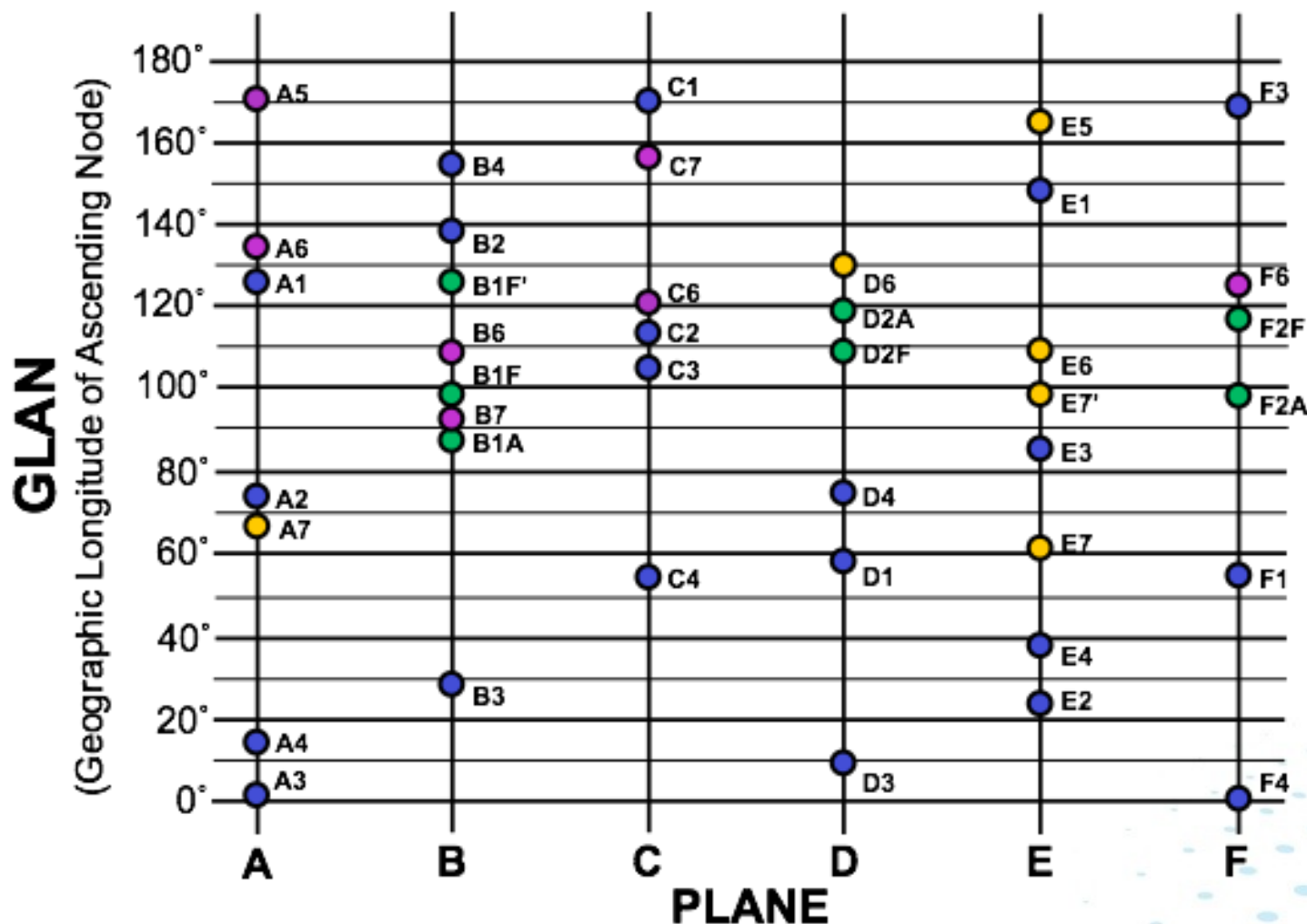


Navigation System Performance - Accuracy: Geometry



Reference: Standard Positioning Performance Standard 2008
Epoch: 1st July 1993

Navigation System Performance - Accuracy: Geometry

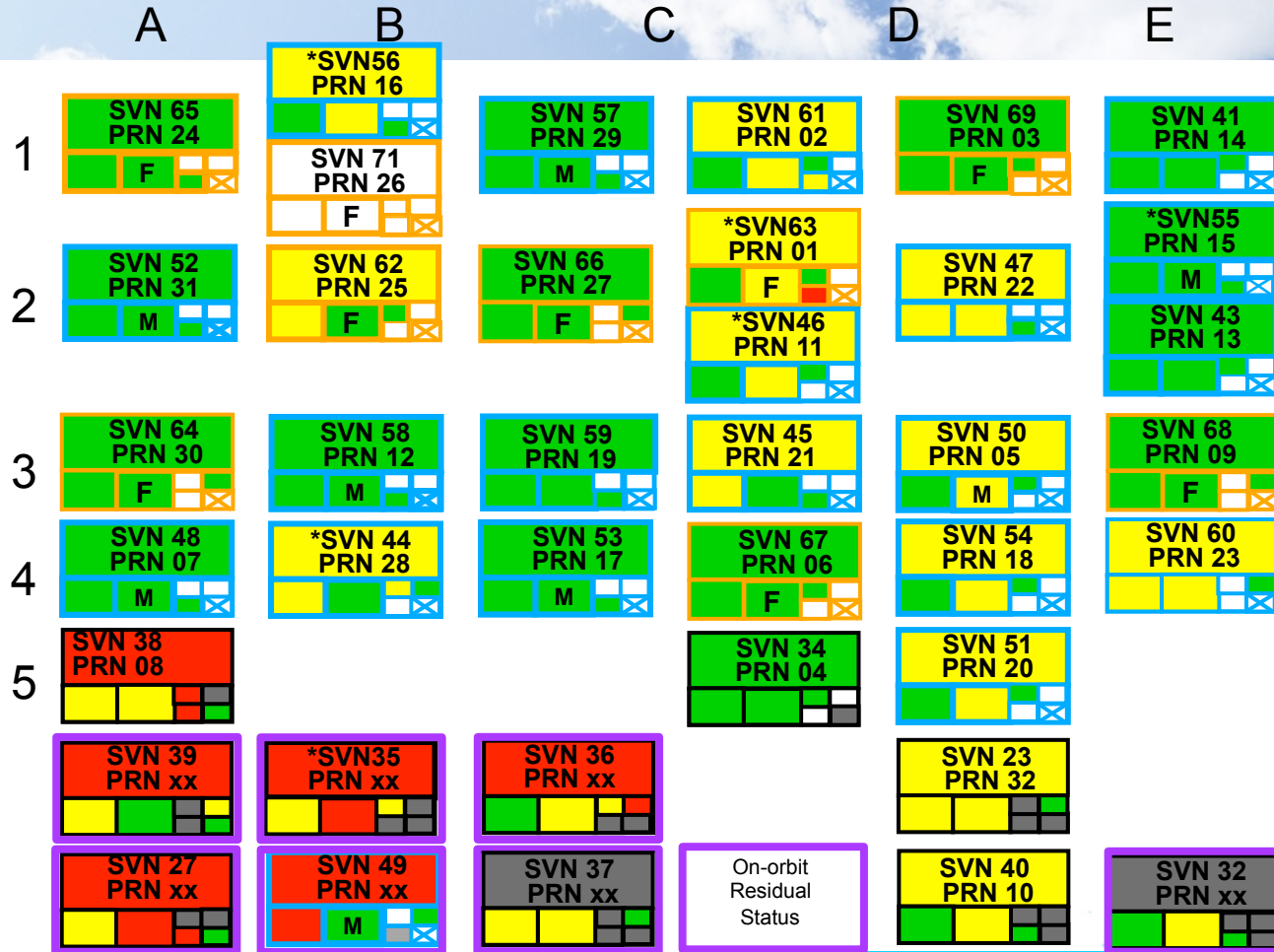


Slot	SV	Slot	SV
A1	SVN-65	D1	SVN-61
A2	SVN-52	D2A	SVN-63
A3	SVN-64	D2F	SVN-46
A4	SVN-48	D3	SVN-45
A5	SVN-39	D4	SVN-67
A6	SVN-27	D6	SVN-34
A7	SVN-38	E1	SVN-69
B1A	SVN-56	E2	SVN-47
B1F'	SVN-71	E3	SVN-50
B2	SVN-62	E4	SVN-54
B3	SVN-44	E5	SVN-23
B4	SVN-58	E6	SVN-40
B6	SVN-49	E7'	SVN-51
B7	SVN-35	F1	SVN-41
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

Epoch: 3rd April 2015

GPS Constellation Status



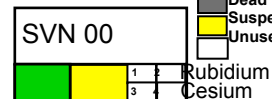
Design Life:(avg 11.8)

IIA - 7.5 yrs

IIR - 7.5 yrs

IIF - 12 yrs

Clock Status =



*SVN= shared slot

Rs : 3 Rb clocks
Fs: 2 Rb / 1 Cs Clocks

Veh count: 30 healthy

Resid:(27/32/38/35/37/49/36/39

3 IIAs

19 IIRs (includes 7 IIR-Ms)

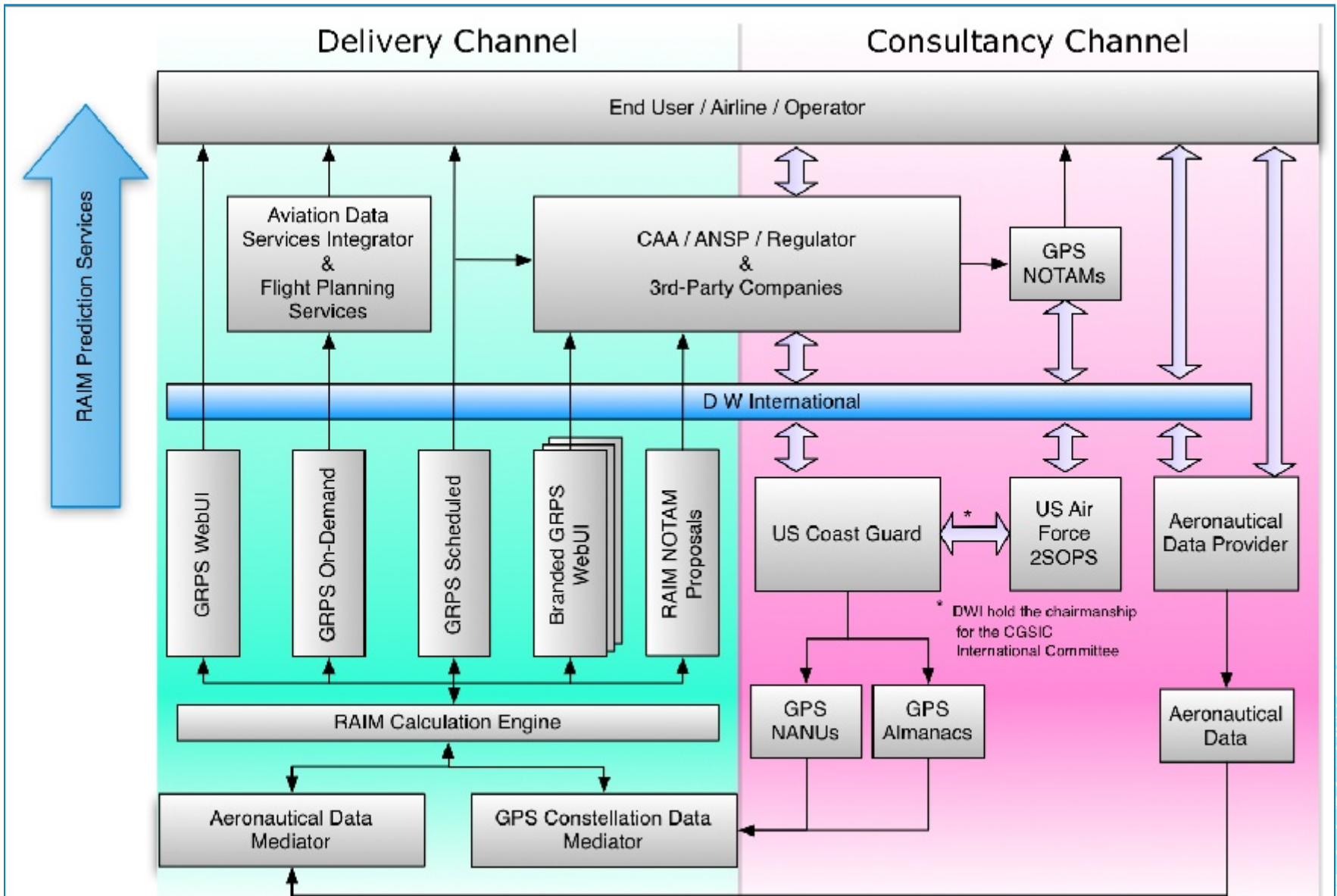
8 IIFs

GNSS RAIM / RNP Prediction Service (GRPS)



- GRPS 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 started to supply the GRPS 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)

GRPS Delivery Channels

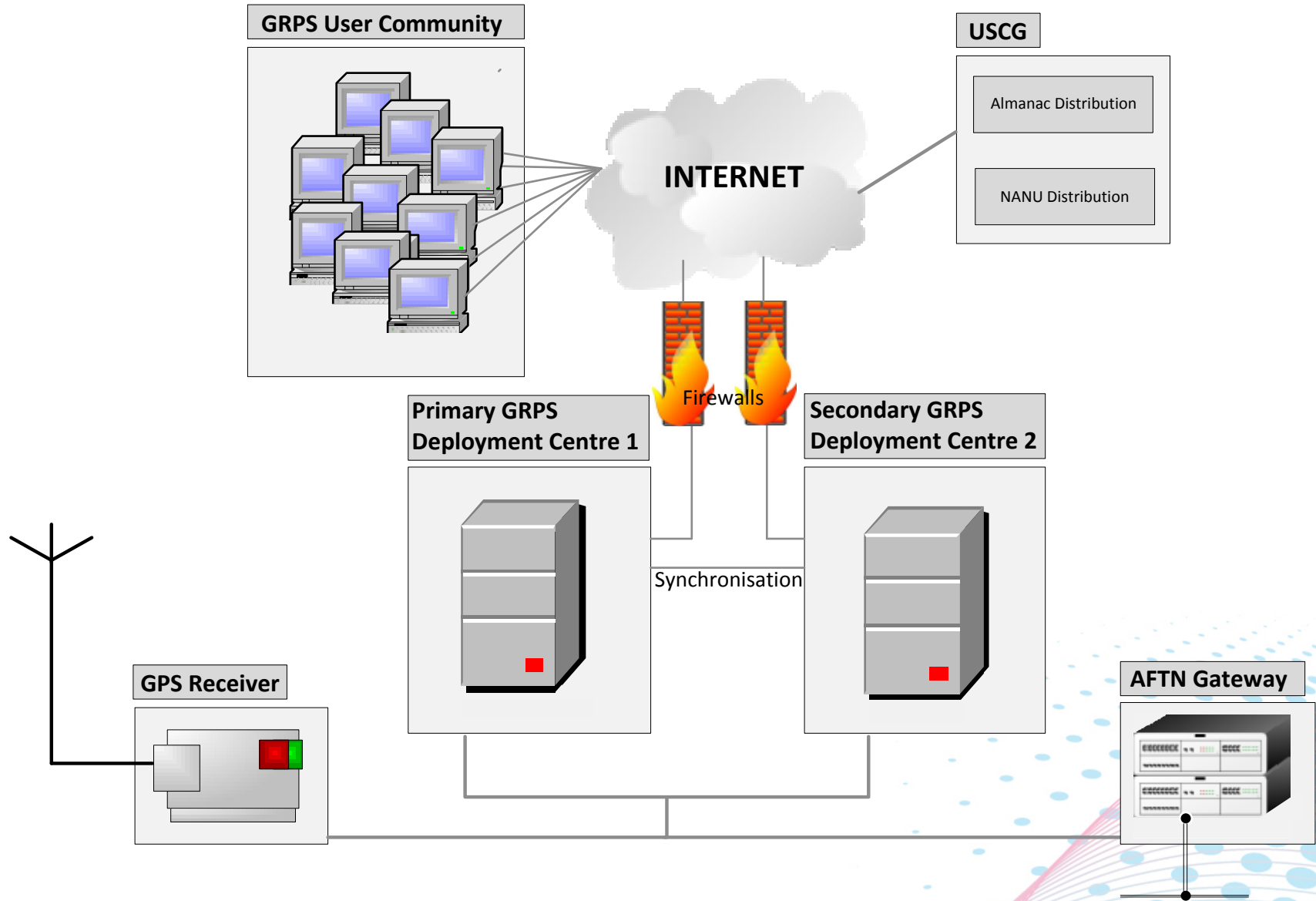


GRPS Criteria Compliance



	USA FAA	Europe EASA	Australia CASA	South America SVRSOP
RNAV				
RNAV 10 (aka RNP 10)	Order 8400.12	AMC 20-12	AC 91U-2(0)	AC 91-001
RNAV 5 (aka B-RNAV)	AC 90-96	AMC 20-4 (JAA TGL 2)	CAAP B-RNAV-1	AC 91-002
RNAV 2 (aka US RNAV Type A)	AC 90-100	JAA TGL 10 (AMC 20-16)	AC 91U-II-3-B	AC 91-003
RNAV 1 (aka US RNAV Type B; P-RNAV)	AC 90-100	JAA TGL 10 (AMC 20-16)	AC 91U-II-3-B	AC 91-003
RNP				
RNP 4	Order 8400.33		AC 91U-3(0)	AC 91-004
Basic-RNP 1	AC 90-105	JAA TGL 10 (AMC 20-16)	AC 91U-II-C-3(0)	AC 91-006
RNP Approach	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)
RNP AR (Authorisation Required) Approach	AC 90-101	AMC 20-26	AC 91U-II-C-5 (RNP AR) AC 91U-II-C-6	AC 91-009

GRPS Architecture – XML Interface



GRPS – Web User Interface



GNSS RAIM/RNP Prediction System (GRPS)

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GNSS RAIM/RNP Prediction System

The GNSS RAIM/RNP Prediction System (GRPS) has been developed to meet the RAIM/RNP prediction requirements as outlined in ICAO's Performance-Based Navigation (PBN) Manual (Doc 9613, Edition 3 - 2008) including RNP 10, RNAV 5, RNAV2, RNAV1, RNP4, Basic RNP-1, RNP Approach and RNP AR Approach down to 0.1NM.

In addition the GRPS core system meets the requirements for RAIM prediction as outlined in international standards and advisory circulars including:

- Europe: EASA AMC 20-4, EASA AMC20-12, EASA AMC20-16, EASA AMC20-26, EASA AMC20-28, EASA AMC20-28 as well as JAA TGL 10.
- USA: FAA AC90-100A, FAA AC 90-101, FAA Order 8400.33 and FAA Order 8400.12A.

For more information on the standards [click here](#).

GRPS has been designated for predictions relating to NAVSTAR GPS system. However, it will be expanded in the future to include Galileo, GLONASS (Global Orbiting Navigation Satellite System), COMPASS and INRSS (Indian Regional Navigational Satellite System).

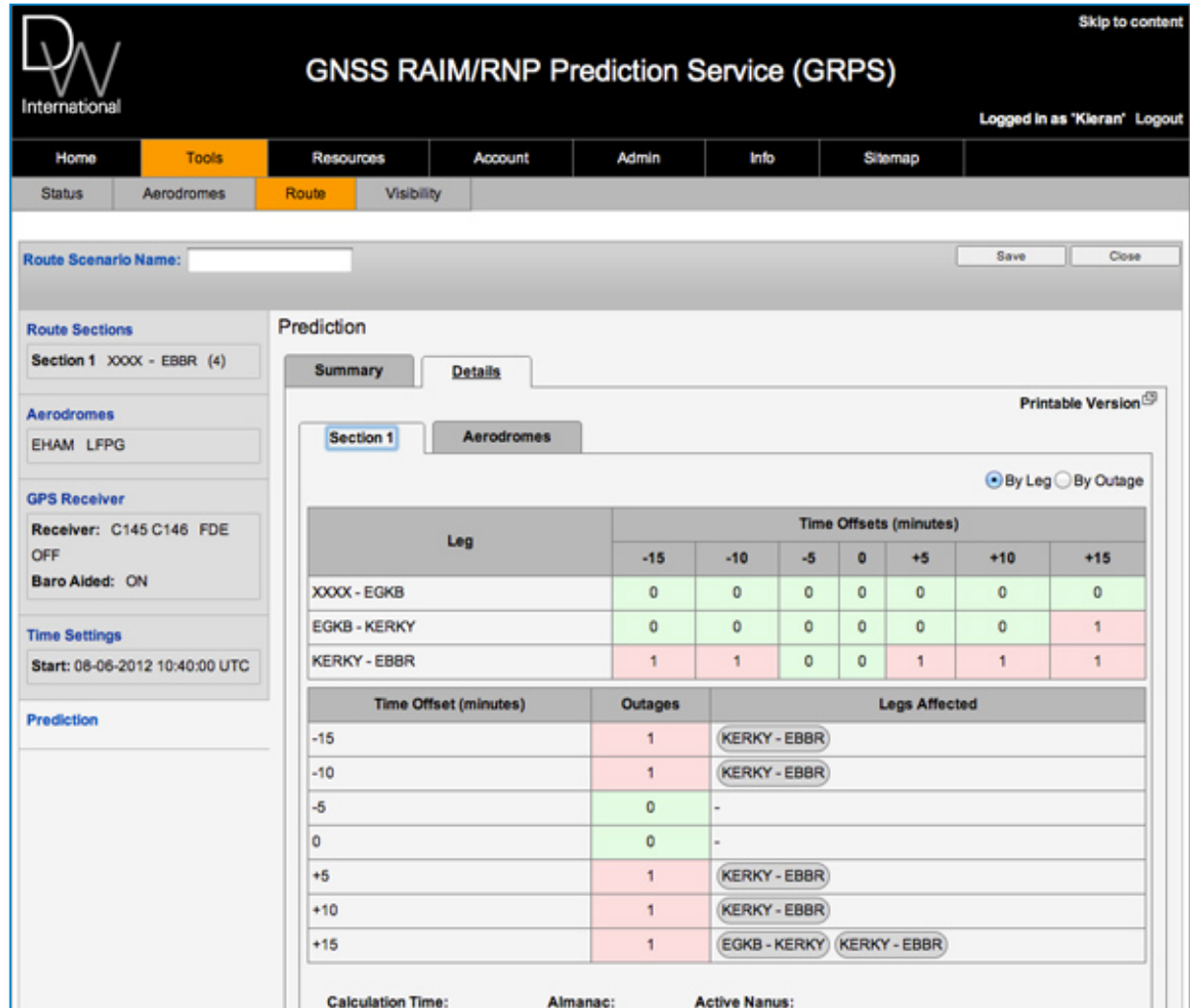
GRPS provides access to four tools:

[Route Prediction](#) | [Aerodrome Prediction](#) | [Satellite Visibility](#) | [Constellation Status](#)

Route	Edit GPS Receiver
Section 1	Receiver Type: C145 C146
EEKE CC16 PPIZ	C129
	Algorithm: C145 C146
Aerodromes	SA: OFF
CYAH CYHF CYPZ	Baro Aided: OFF
	OK Cancel

GRPS Route Mode

- Route Tool web interface
- User configurable
- All phases of flight
- Real-time calculations – i.e. not pre-calculated



GNSS RAIM/RNP Prediction Service (GRPS)

Logged In as "Kieran" Logout

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Status Aerodromes Route Visibility

Route Scenario Name: Save Close

Route Sections

Section 1 XXXX - EBBR (4)

Aerodromes

EHAM LFPG

GPS Receiver

Receiver: C145 C146 FDE
OFF
Baro Aided: ON

Time Settings

Start: 08-06-2012 10:40:00 UTC

Prediction

Summary **Details**

Printable Version 

Section 1 Aerodromes

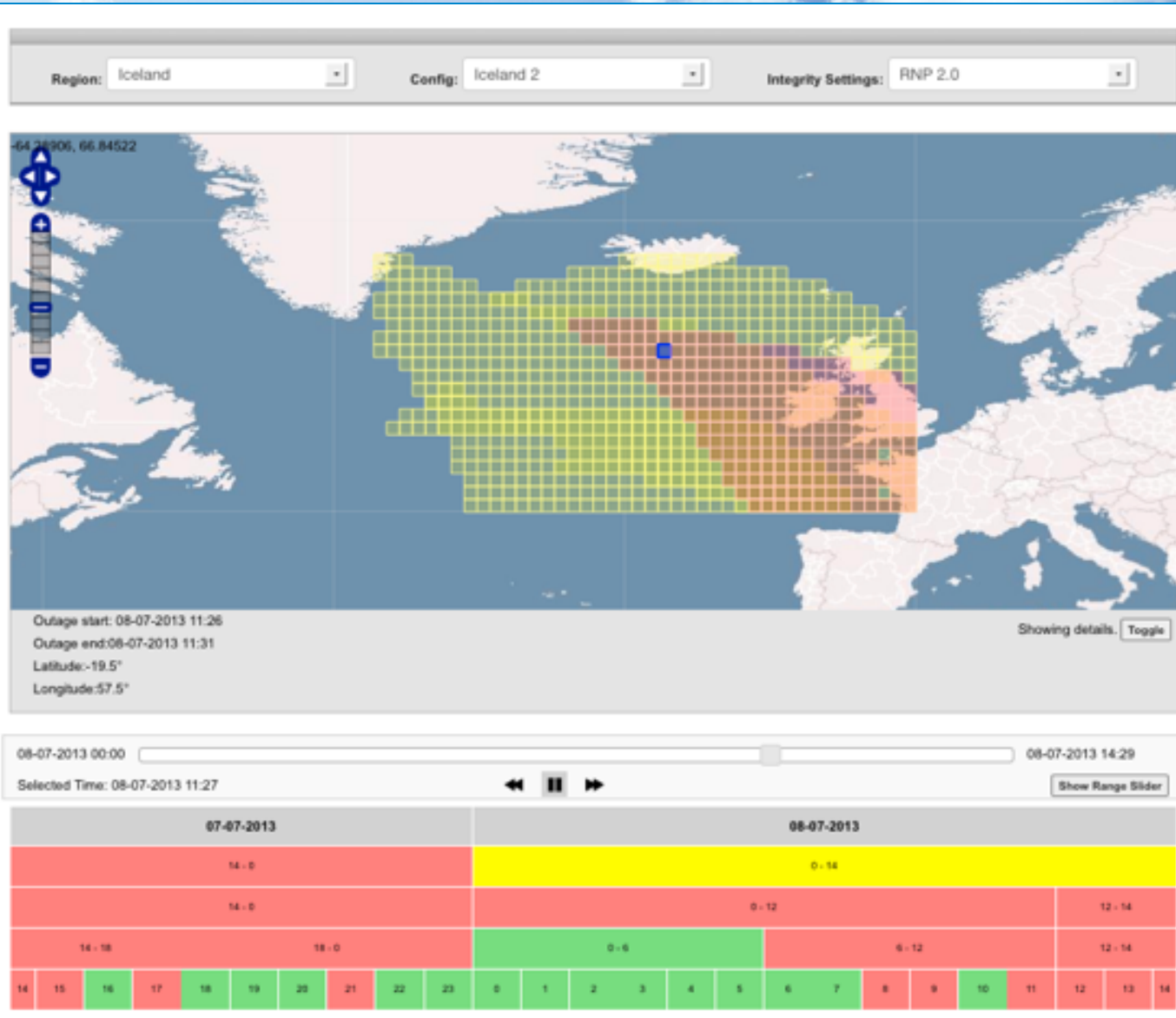
☒ By Leg ☐ By Outage

Leg	Time Offsets (minutes)						
	-15	-10	-5	0	+5	+10	+15
XXXX - EGKB	0	0	0	0	0	0	0
EGKB - KERKY	0	0	0	0	0	0	1
KERKY - EBBR	1	1	0	0	1	1	1

Time Offset (minutes)	Outages	Legs Affected
-15	1	KERKY - EBBR
-10	1	KERKY - EBBR
-5	0	-
0	0	-
+5	1	KERKY - EBBR
+10	1	KERKY - EBBR
+15	1	EGKB - KERKY KERKY - EBBR

Calculation Time: Almanac: Active Nanus:

GRPS Region Mode



GRPS Constellation Status Tool

- Status Tool
 - Shows latest NANU and Almanac



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GNSS RAIM/RNP Prediction System (GRPS)

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[Route](#)
[Visibility](#)

[Printable Version](#)

Scenario Time

Start: 06-06-2012 10:00:58 UTC
End: 09-06-2012 10:00:58 UTC
Duration: 72 hours

Overview

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

Almanac

GPS Week: 667
GPS TOA: 405504
Total Satellites: 31
Unhealthy Satellite PRNs: none

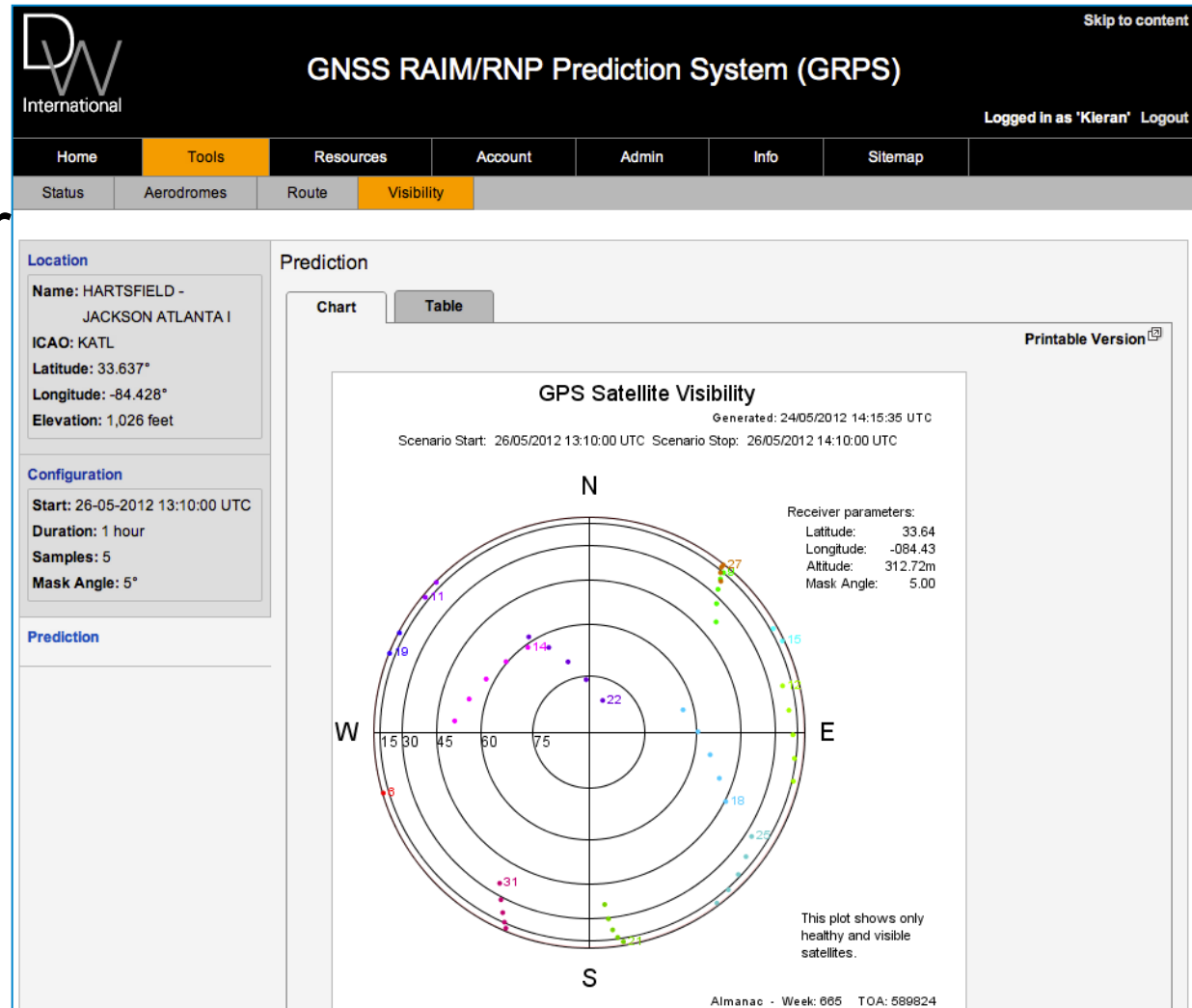
[Report](#)

NANUs

Number	PRN	Start	Stop	Type
No Active NANUs				

GRPS Visibility Tool

- Visibility Tool
- Like all tools parameters are user-configurable
 - Receiver Position
 - Mask Angle
 - Duration
 - Sample
 - Time



GRPS Training

- ½ Day Training
- Online or classroom



GRPS Branded Deployments

- Augur – EUROCONTROL

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) 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	Full Text Sat Info

Current NANUs

No NANUs are currently active.

[AUGUR Disclaimer](#)

GRPS Branded Deployments

- NETRA – AEROTHAI



NETRA RAIM Prediction Service

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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 AC90-100(), FAA Order 8400.33 and FAA Order 8400.12()

For more information on the standards [click here](#).

NETRA has been designed for predictions relating to NAVSTAR GPS system.

NETRA provides access to four tools:

[Route Prediction](#) | [Aerodrome Prediction](#) | [Satellite Visibility](#) | [Constellation Status](#)

Registration

Login to perform RAIM predictions for Aerodromes and Routes.

To register send an email to netra_helpdesk@netra.aero and a representative from AeroThai will contact you as soon as possible with pricing information and contract options.



Who we are

Aeronautical Radio of Thailand Limited (AeroThai) is a state enterprise under the Ministry of Transport and Communications. This service is intended for use by member states of the ICAO APAC PBN Task Force.

Please visit the [AeroThai website](#) for further information about our products and services.



Route

Section 1

EEEE CC16 PP12

Aerodromes

CYMS CYHP CYPZ

Edit GPS Receiver

Receiver Type: C145 C146

Algorithm: C129

SA: OFF

Baro Aided: OFF

[OK](#) [Cancel](#)

GRPS Branded Deployments

- SATDIS – ICAO South America Regional Office



SATDIS

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SAM RAIM Prediction Availability Service

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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>



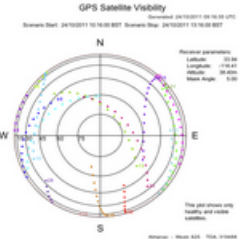
Aerodromes Tool



Route Tool



Status Tool



Visibility Tool

GRPS Bespoke Deployments

- Contracted, about to be deployed:
 - Civil Aviation Authority Singapore
- In advanced negotiation:
 - Vietnam Air Traffic Management Bureau
 - NAV CANADA

GRPS On-Demand

- Integrated with flight planning systems
- Calculates RAIM predictions automatically as part of routine flight planning

GRPS Scheduled Service

- Daily subscription service
- Emailed / AFTN or preferred delivery
- Aerodrome outages prioritised in message

Subject RAIM PREDICTION B772/B773 Cathay - New York
Date 2014-05-19 02:02:18 UTC
Message RAIM PREDICTION B772/B773 Cathay - New York
 RUN AT 02:01Z 19/May/2014
 VALID FROM 02:00Z 19/May/2014 FOR A 48 HOUR VALIDITY

B772/B773 KEWR RNP:0.3 RAIM Check
COVERAGE UNACCEPTABLE FOR OPERATION DURING GIVEN PERIOD
 FROM (Z) TO (Z)
 19/05/2014 17:39:30 - 19/05/2014 17:44:30

B772/B773 KEWR RNP:1.0 RAIM Check
 GPS COVERAGE ACCEPTABLE FOR THIS OPERATION OVER THE NEXT 48 HOURS

B772/B773 KJFK RNP:0.3 RAIM Check
 GPS COVERAGE ACCEPTABLE FOR THIS OPERATION OVER THE NEXT 48 HOURS

B772/B773 KJFK RNP:1.0 RAIM Check
 GPS COVERAGE ACCEPTABLE FOR THIS OPERATION OVER THE NEXT 48 HOURS

GRPS NOTAM Proposal

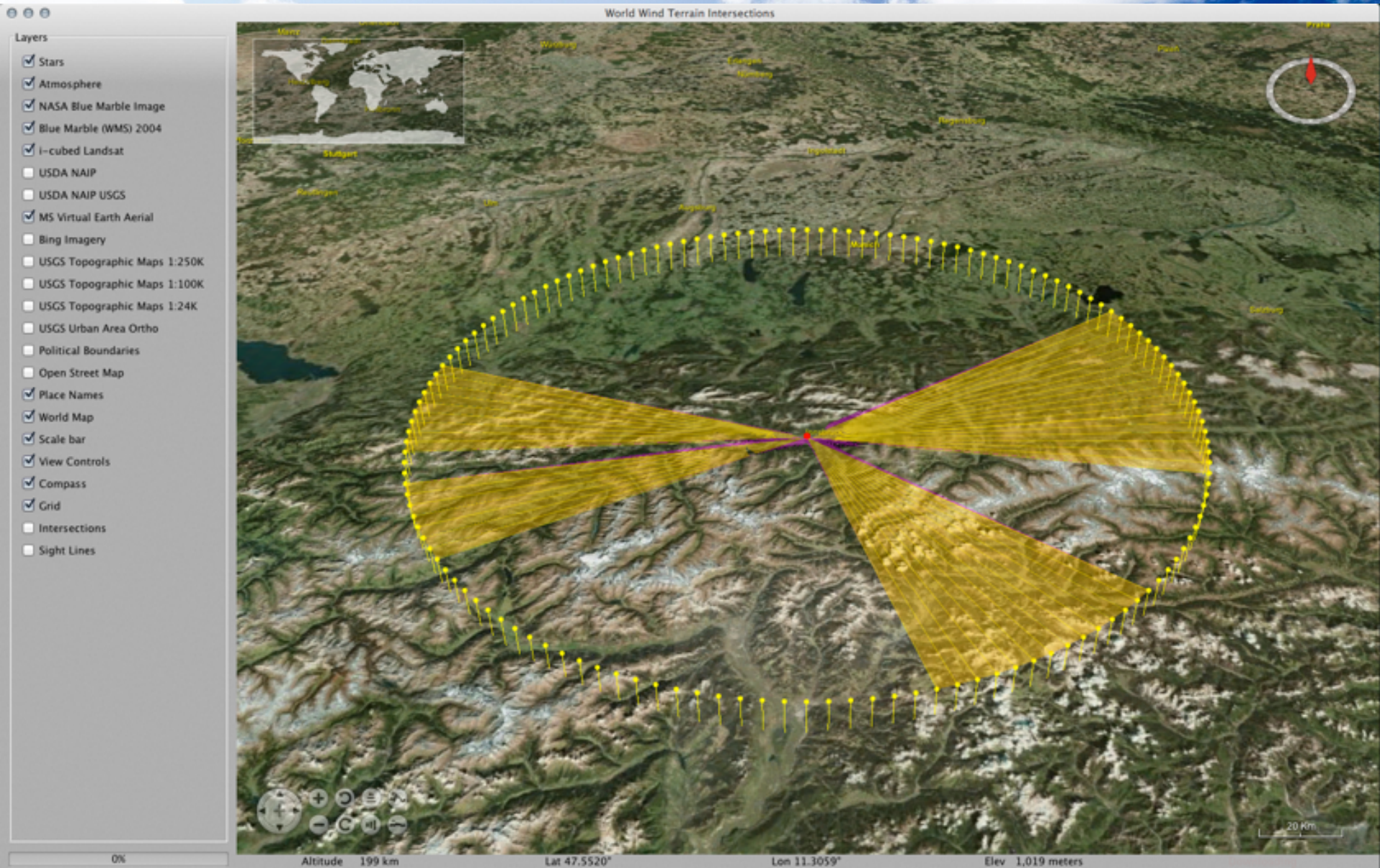
- GNSS RAIM Outages for Aerodromes
- NOTAM Proposals generated for State NOTAM Office
- Proposals issued in NOTAM format so no additional formatting required by NOTAM Office

NOTAM N example

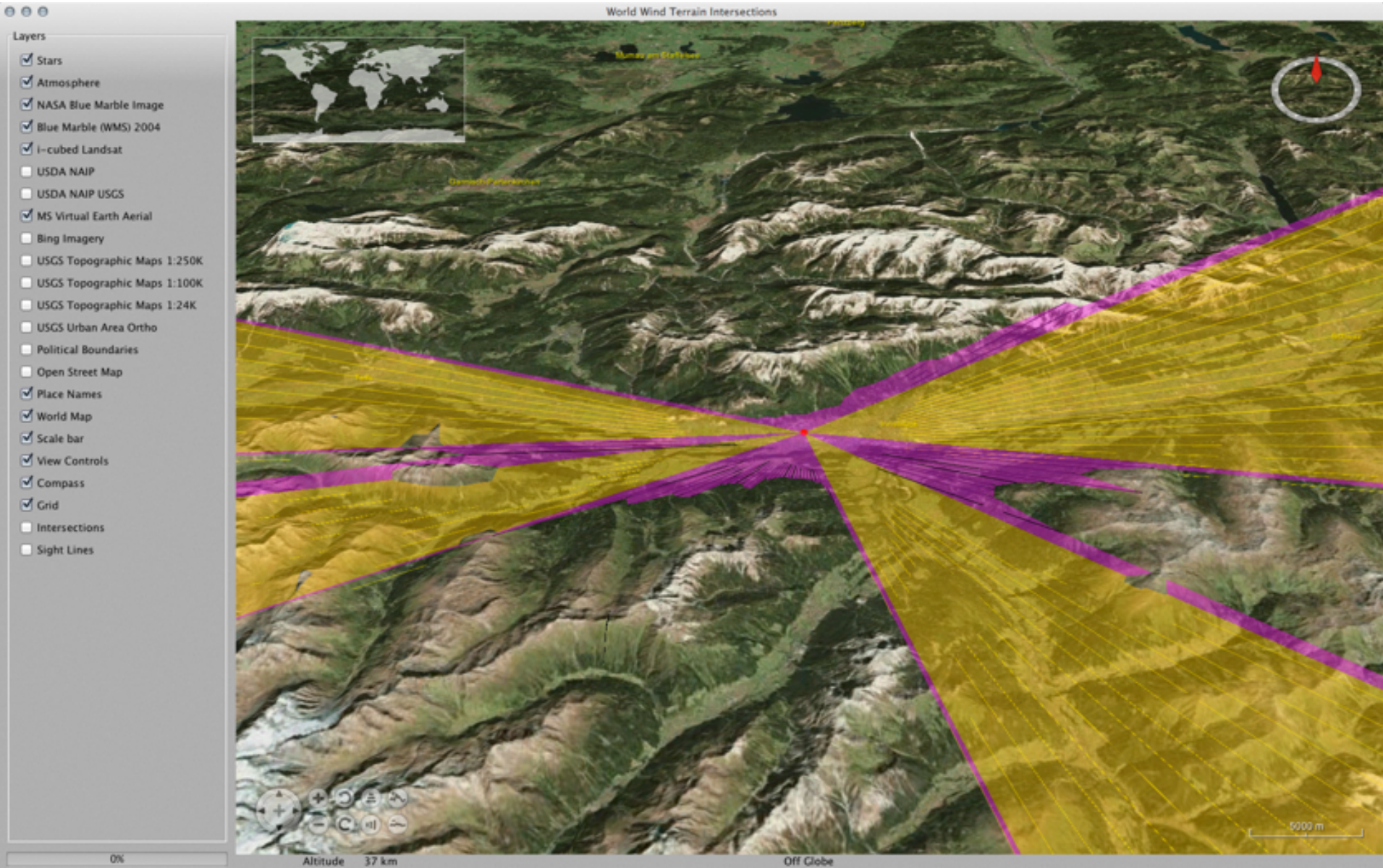
*A1234/09 NOTAMN
 Q) LFBB/ QGAAU/ I/ NBO/ A/ 000/ 999/ 4100N00200E005
 A) LFBO
 B) 0908240145
 C) 0908250225
 D) 24 0145-0230 0630-0645 25 0155-0225
 E) EGNOS NOT AVAILABLE FOR LPV*

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

GRPS Terrain Screening



GRPS Terrain Screening



GRPS User Base

- Direct Contracted Airlines



GRPS User Base

- Known users via 3rd party systems



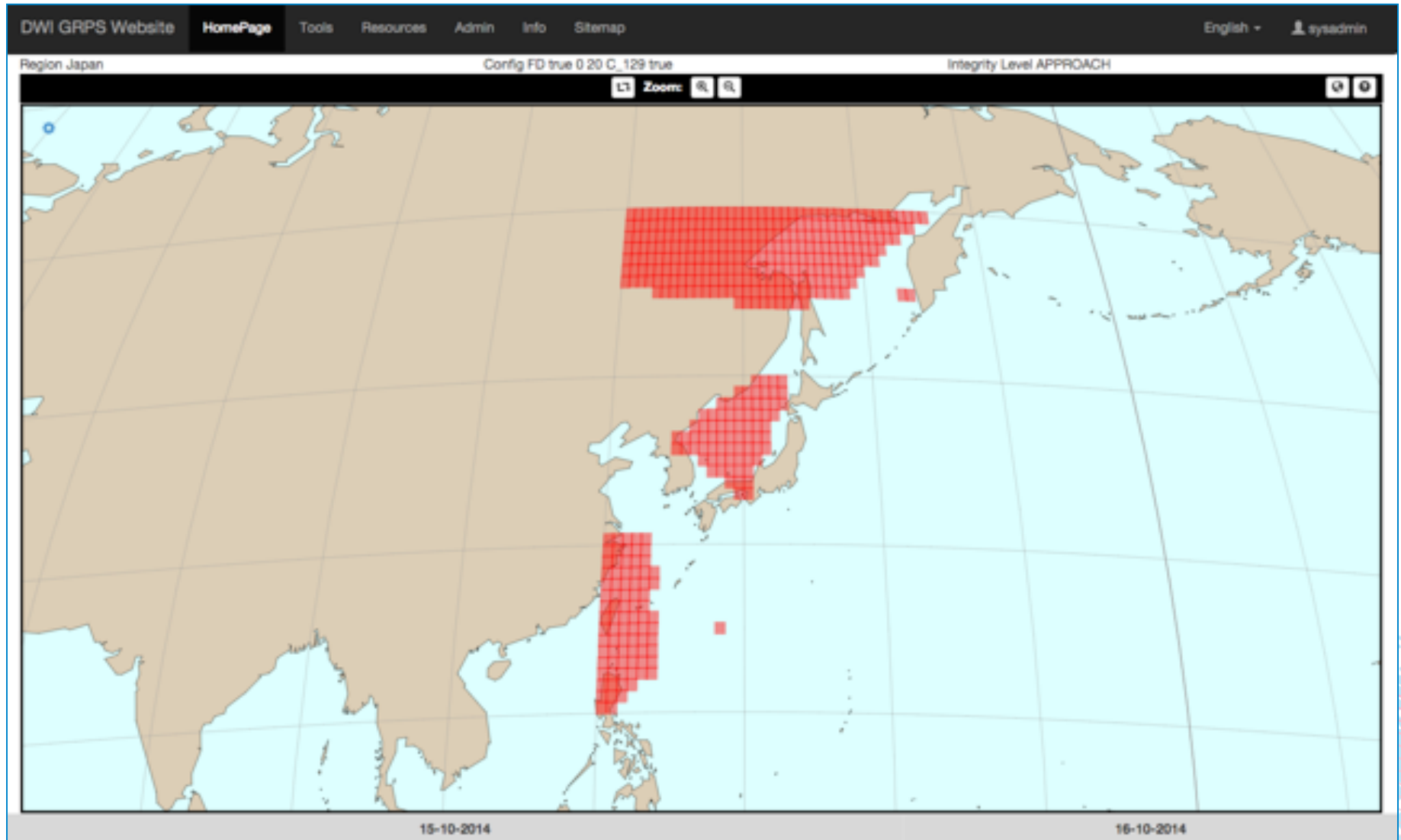
- Many other users via flight / trip planning services

GRPS User Base

- Flight / Trip Planning



Coming Soon: GRPS Version 4



DWI & ICAO Together!



Thank you for listening - Any questions?

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