Introduction to DW International

John Wilde
CEO/Director, DW International

Introduction

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

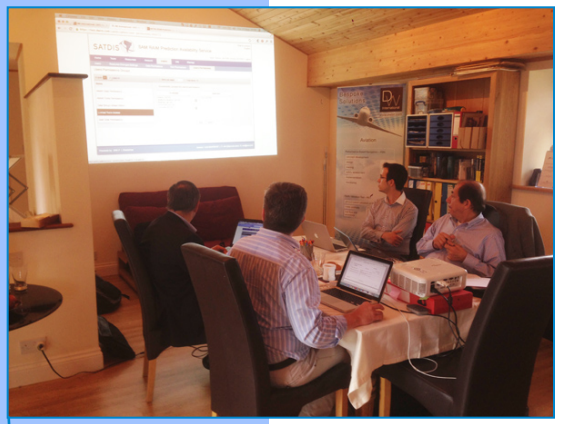
DW International

- 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

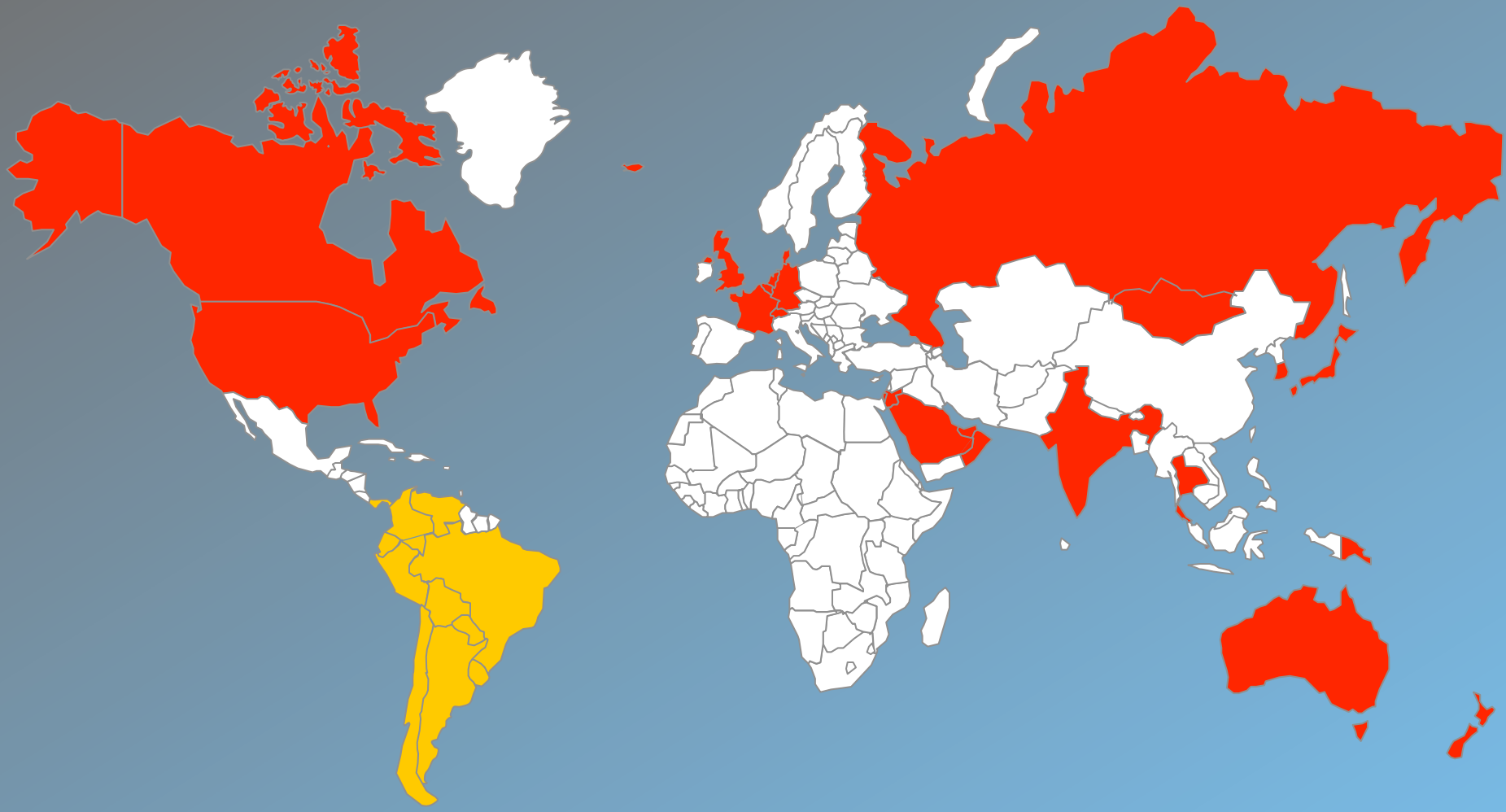
Clients – Americas

Clients – Asia-Pacific



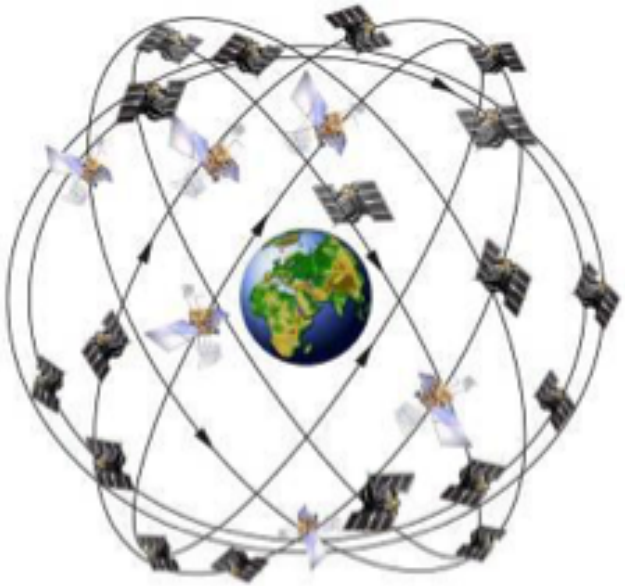
Clients – Europe-Middle East

Global Coverage

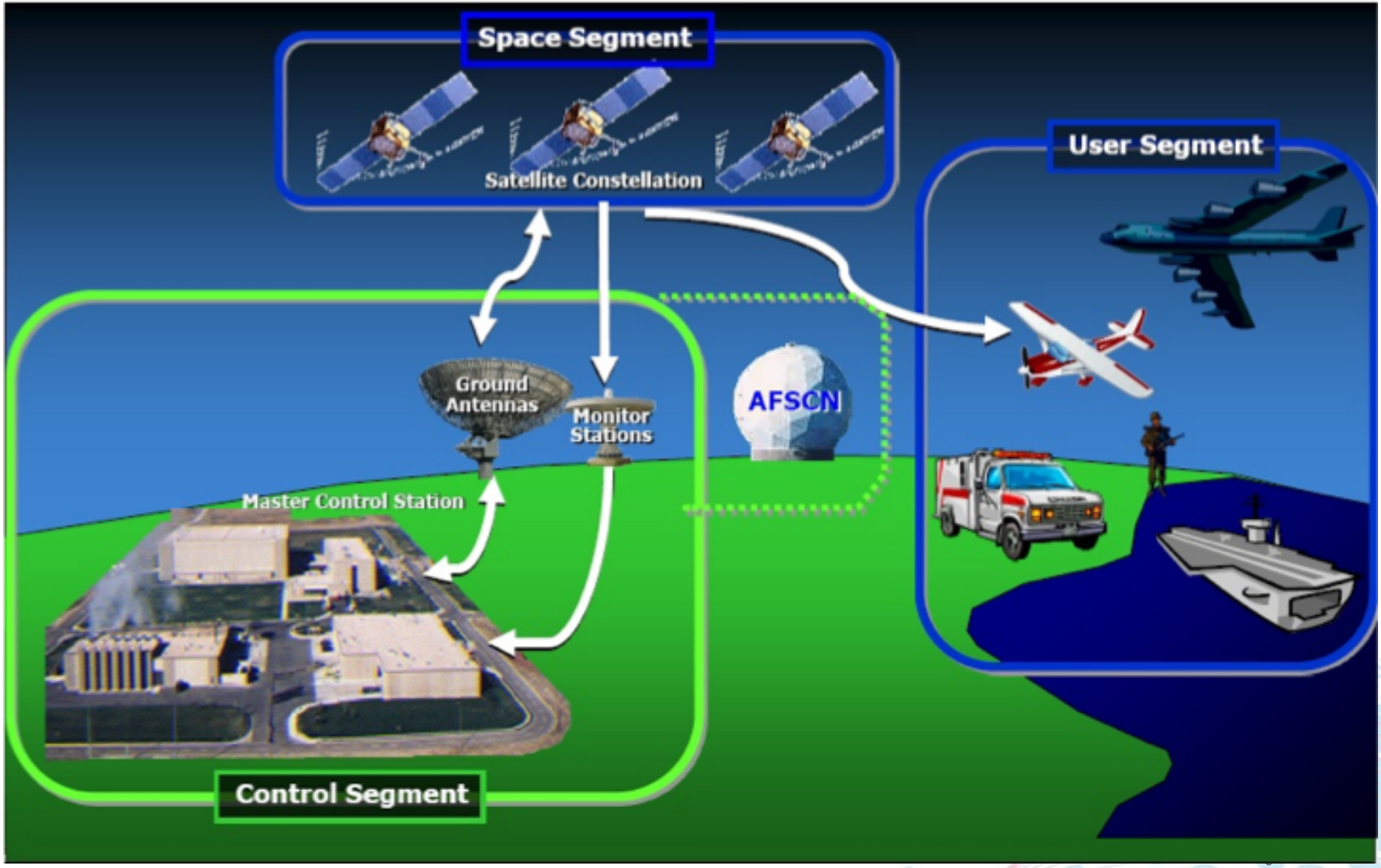


Basic GNSS Principles: What is GPS?

- 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

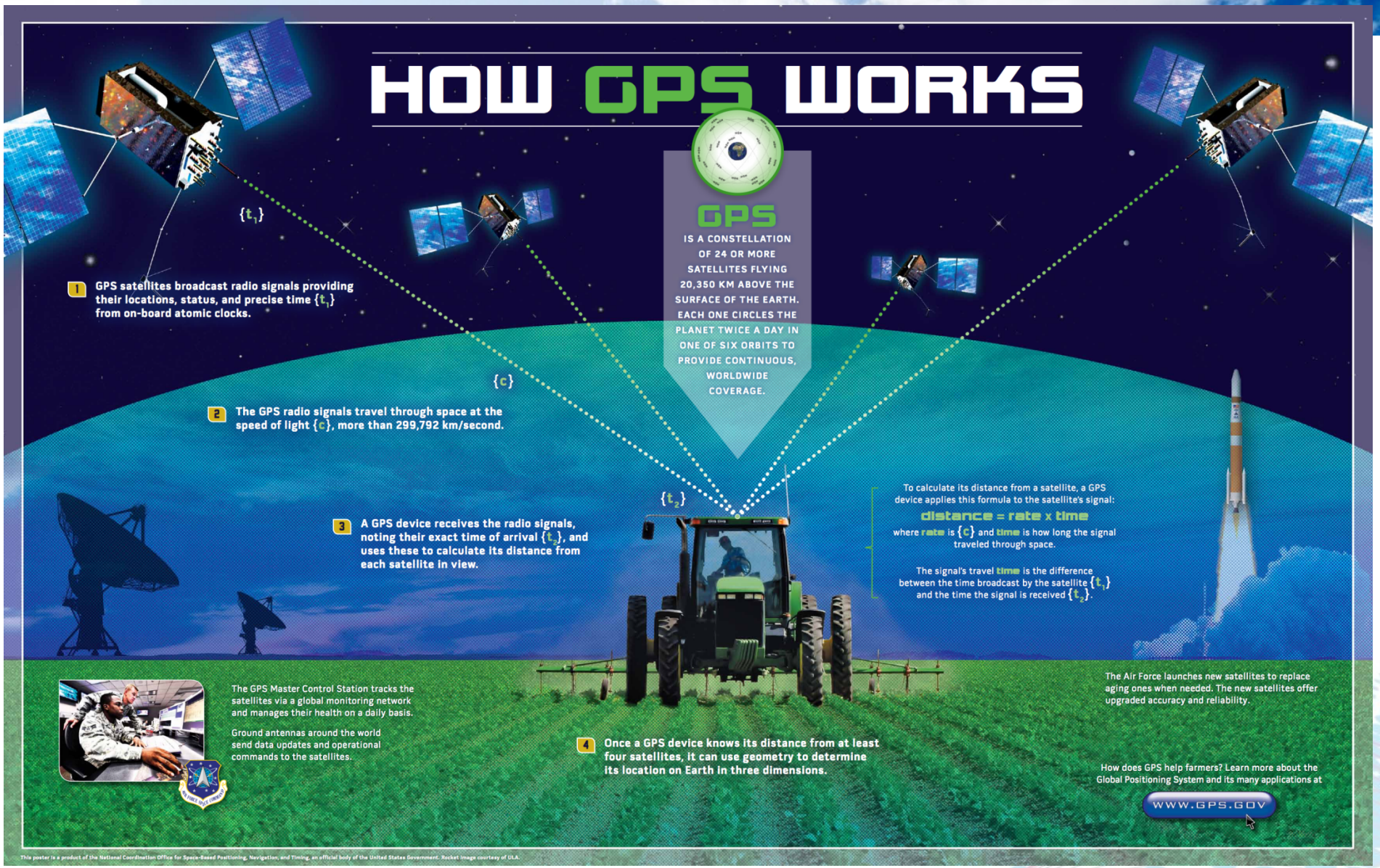
Basic GNSS Principles: Ground Segment

- 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

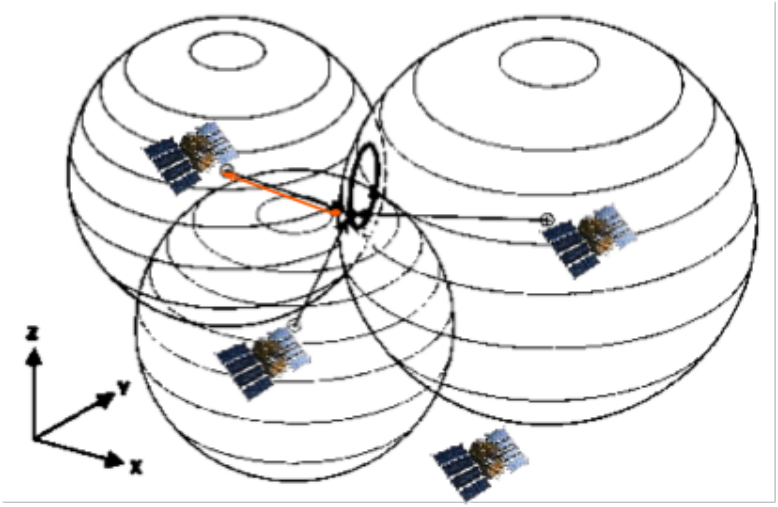


Basic GNSS Principles: Satellite Position Almanac & Ephemeris

- 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



$$\sqrt{(x_1 - x)^2 + (y_1 - y)^2 + (z_1 - z)^2} + c \cdot \Delta t = PR_1$$

$$\sqrt{(x_2 - x)^2 + (y_2 - y)^2 + (z_2 - z)^2} + c \cdot \Delta t = PR_2$$

$$\sqrt{(x_3 - x)^2 + (y_3 - y)^2 + (z_3 - z)^2} + c \cdot \Delta t = PR_3$$

$$\sqrt{(x_4 - x)^2 + (y_4 - y)^2 + (z_4 - z)^2} + c \cdot \Delta t = PR_4$$

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

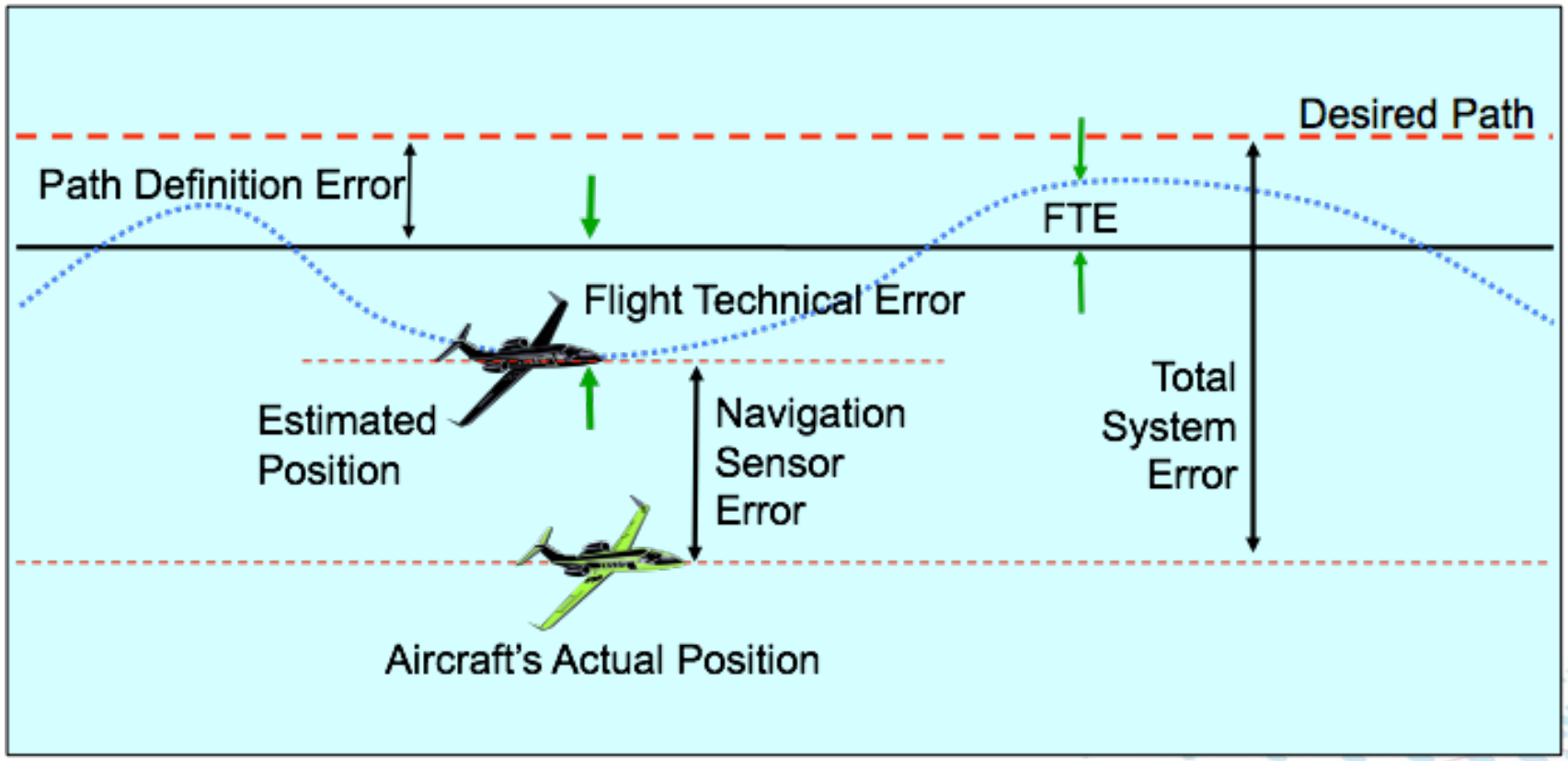
Typical Operation	Accuracy Horizontal 95%	Accuracy Vertical 95%	Integrity	Continuity	Availability	Horizontal Alert Limit HAL	Vertical Alert Limit VAL
En-Route (Oceanic)	7.4 km (4.0 NM)	n/a	1 - 1×10^{-7} /h	1 - 1×10^{-4} /h to 1 - 1×10^{-8} /h	0.99 to 0.99999	7.4 km (4.0 NM)	n/a
En-Route (Continental)	3.7 km (2.0 NM)	n/a	1 - 1×10^{-7} /h	1 - 1×10^{-4} /h to 1 - 1×10^{-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 - 1×10^{-7} /h	1 - 1×10^{-4} /h to 1 - 1×10^{-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 - 1×10^{-7} /h	1 - 1×10^{-4} /h to 1 - 1×10^{-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 - 2×10^{-7} In Any Approach	1 - 8×10^{-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 - 2×10^{-7} In Any Approach	1 - 8×10^{-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 - 2×10^{-7} In Any Approach	1 - 8×10^{-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

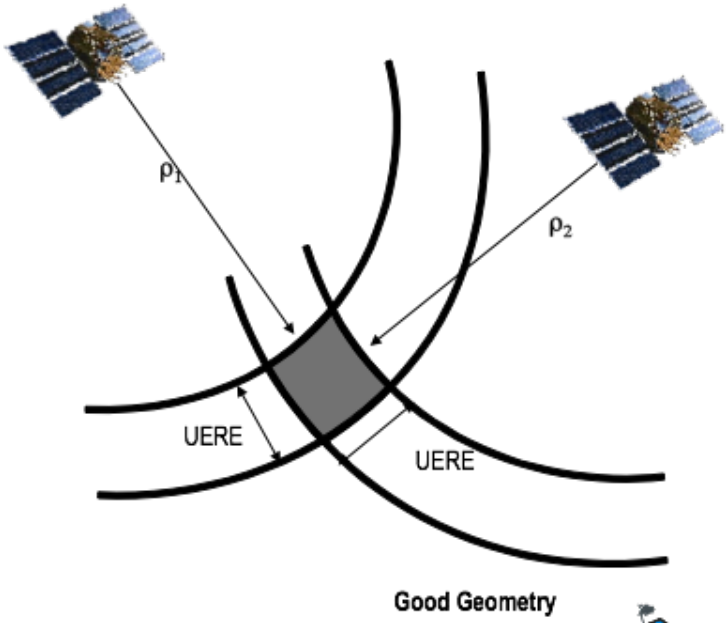
Navigation System Performance - RNP

- 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

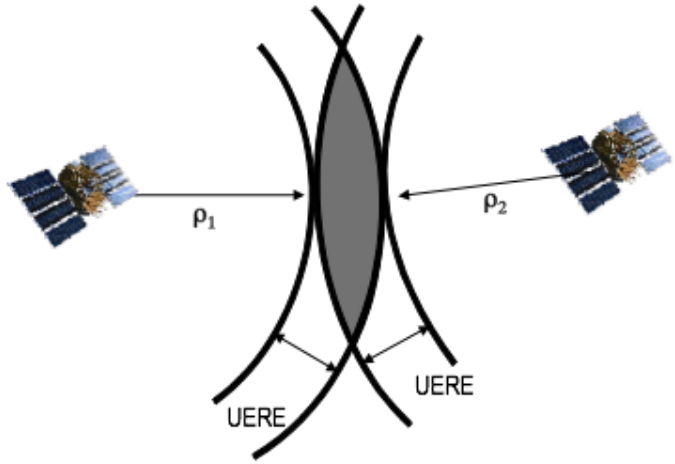
Navigation System Performance - Accuracy: Lateral



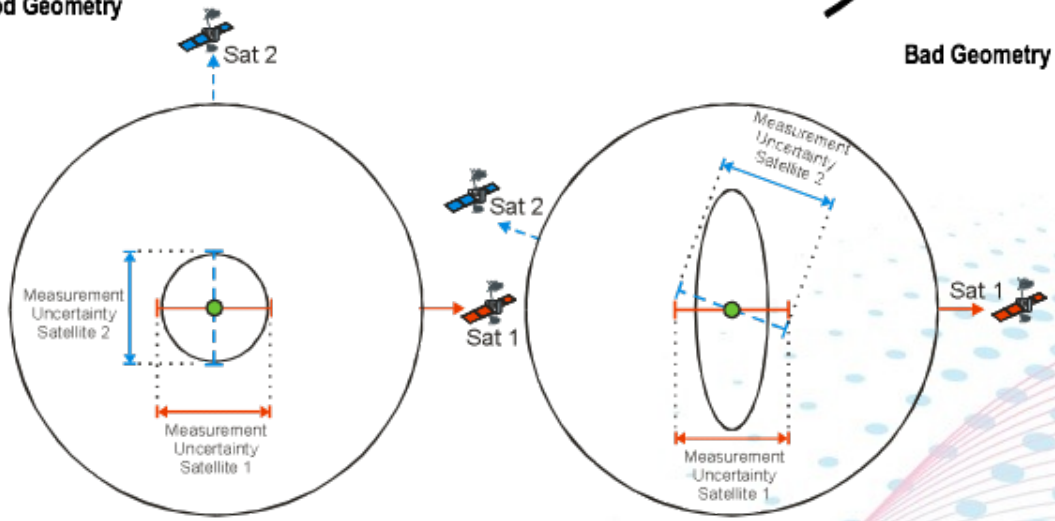
Navigation System Performance - Accuracy: Geometry



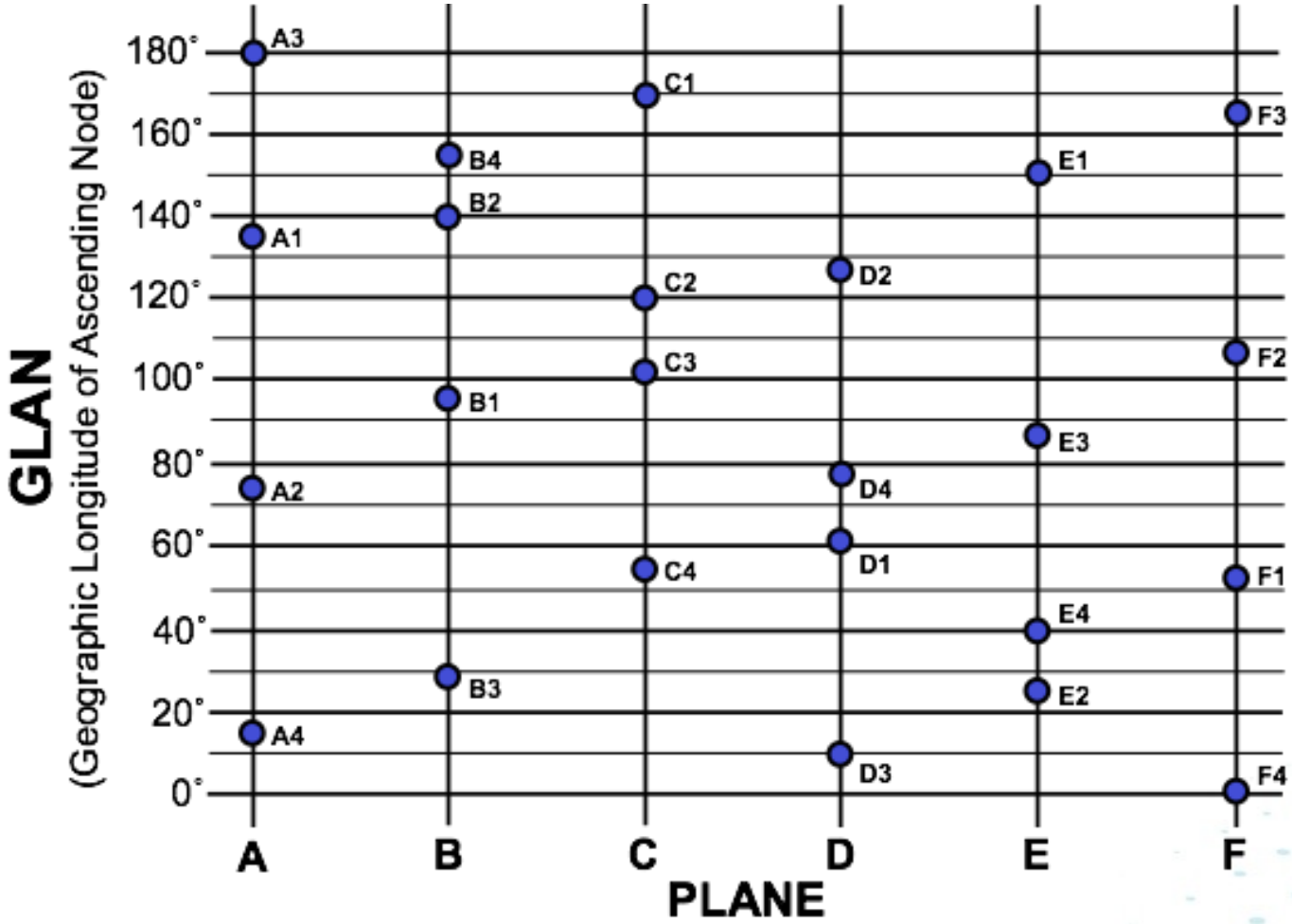
Good Geometry



Bad Geometry

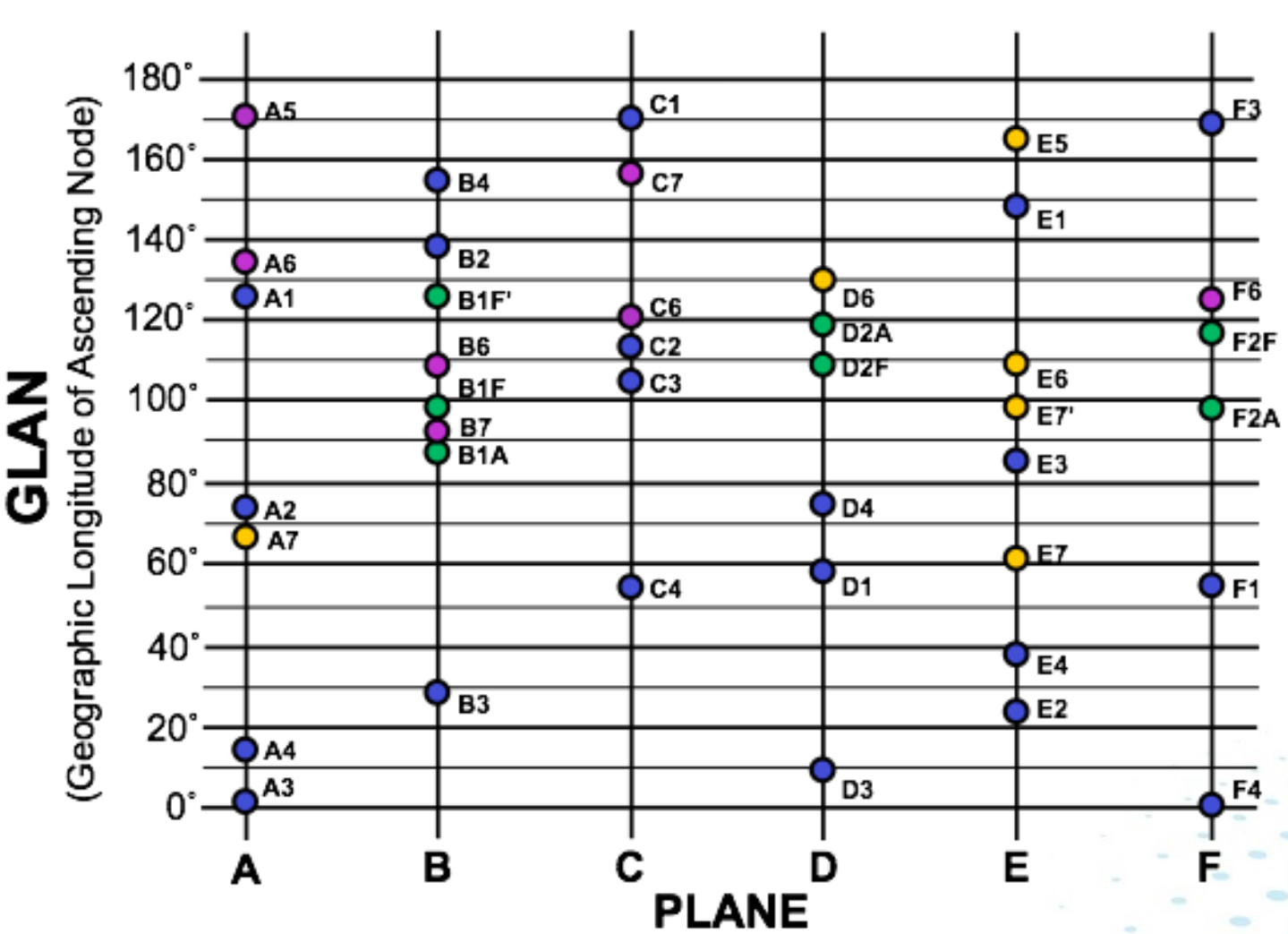


Navigation System Performance - Accuracy: Geometry



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

Navigation System Performance - Accuracy: Geometry

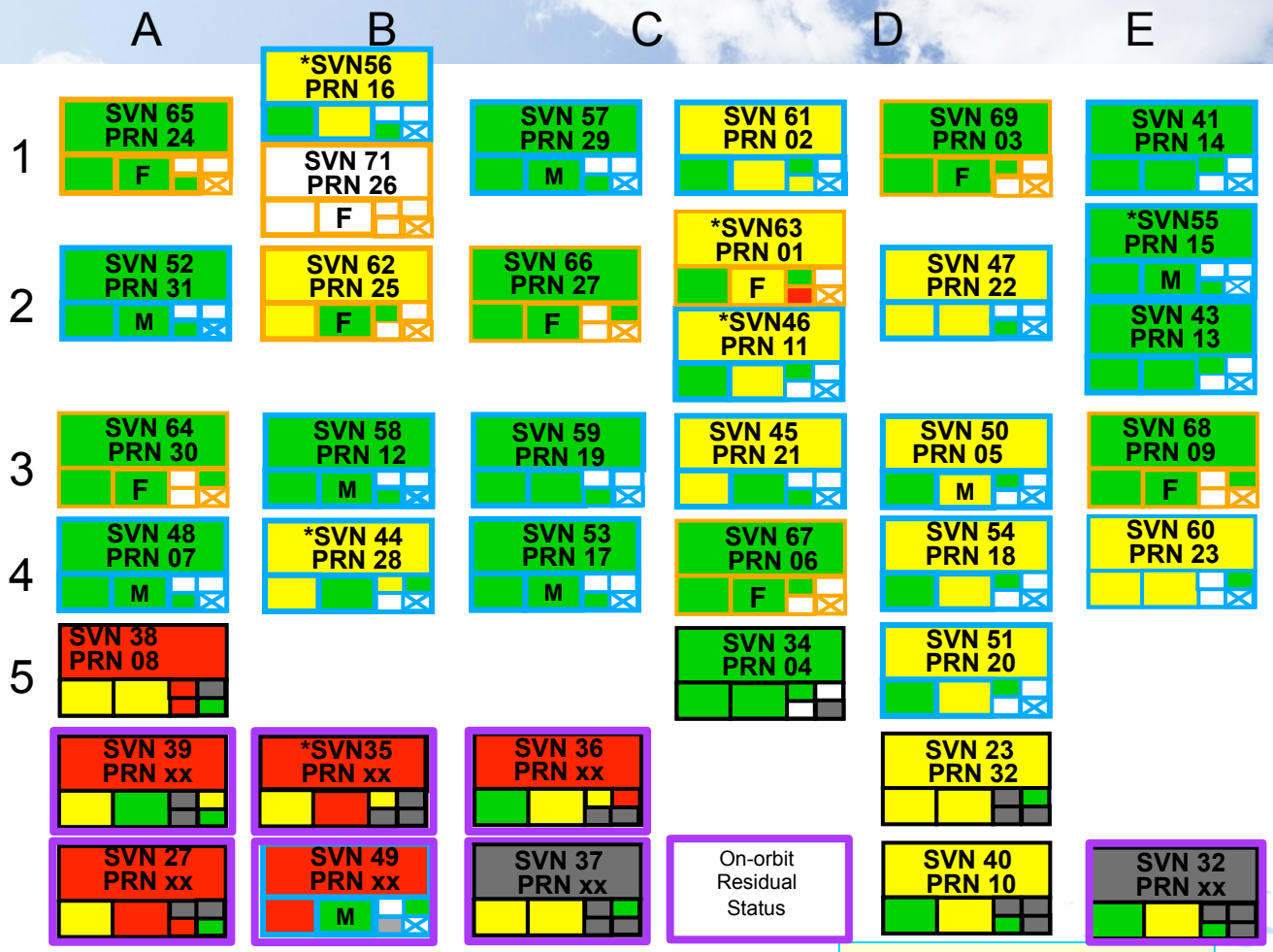


Slot	SV	Slot	SV
A1	SVN-65	D1	SVN-61
A2	SVN-52	D2A	SVN-63
A3	SVN-64	D2F	SVN-46
A4	SVN-48	D3	SVN-45
A5	SVN-33	D4	SVN-67
A6	SVN-27	D6	SVN-34
A7	SVN-38	E1	SVN-69
B1A	SVN-56	E2	SVN-47
B1F'	SVN-71	E3	SVN-50
B2	SVN-62	E4	SVN-54
B3	SVN-44	E5	SVN-23
B4	SVN-58	E6	SVN-40
B6	SVN-49	E7'	SVN-51
B7	SVN-35	F1	SVN-41
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

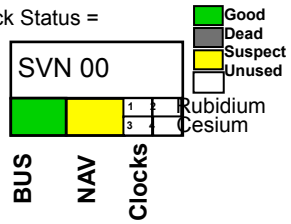
Epoch: 3rd April 2015

GPS Constellation Status



Design Life:(avg 11.8)
IIA - 7.5 yrs
IIR - 7.5 yrs
IIF - 12 yrs

Clock Status =



*SVN= shared slot

IRs : 3 Rb clocks
IIFs: 2 Rb /1 Cs Clocks

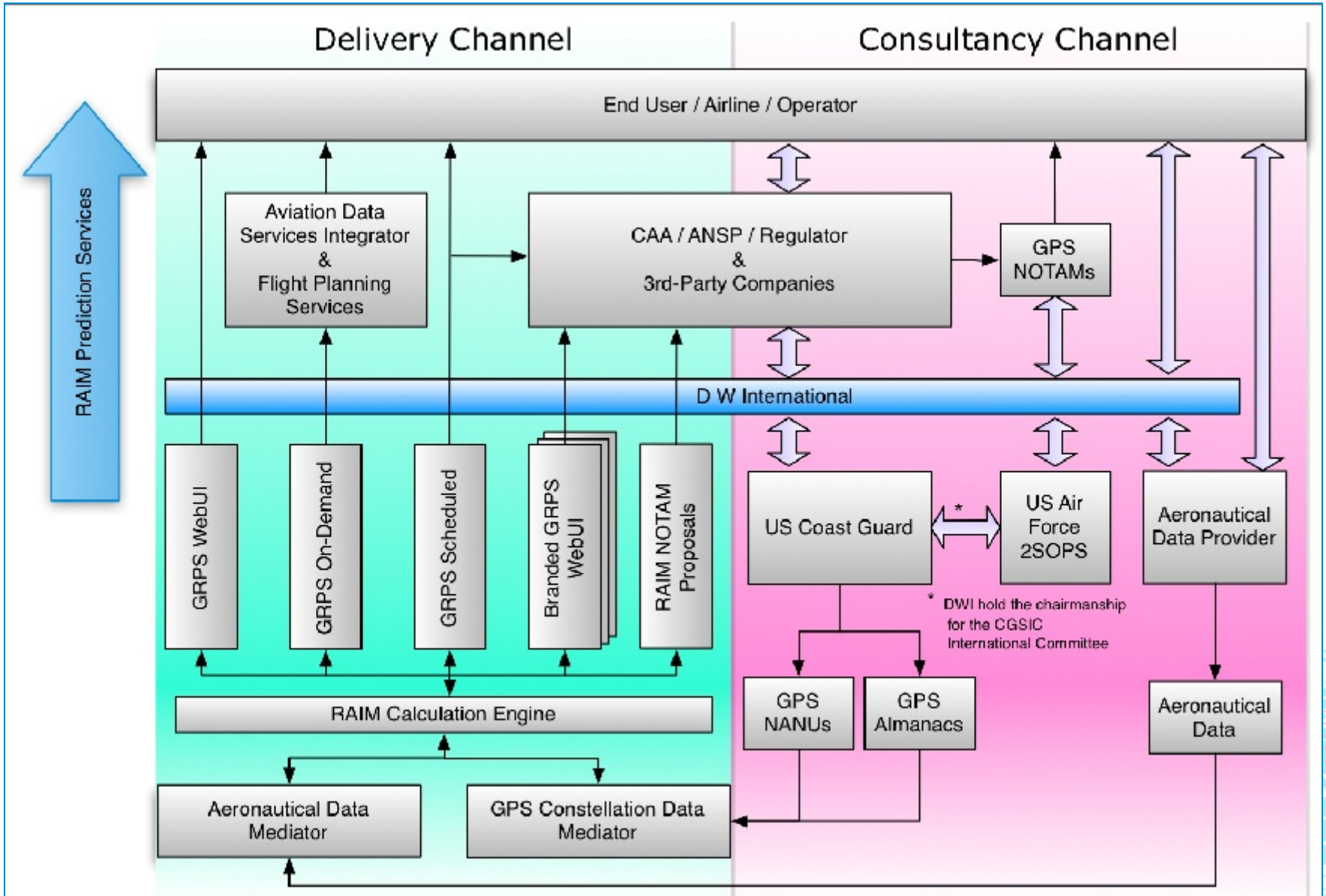
Veh count: 30 healthy
Resid:(27/32/38/35/37/49/36/39
3 IIAs
19 IIRs (includes 7 IIR-Ms)
8 IIFs

As of 9th March 2015

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)

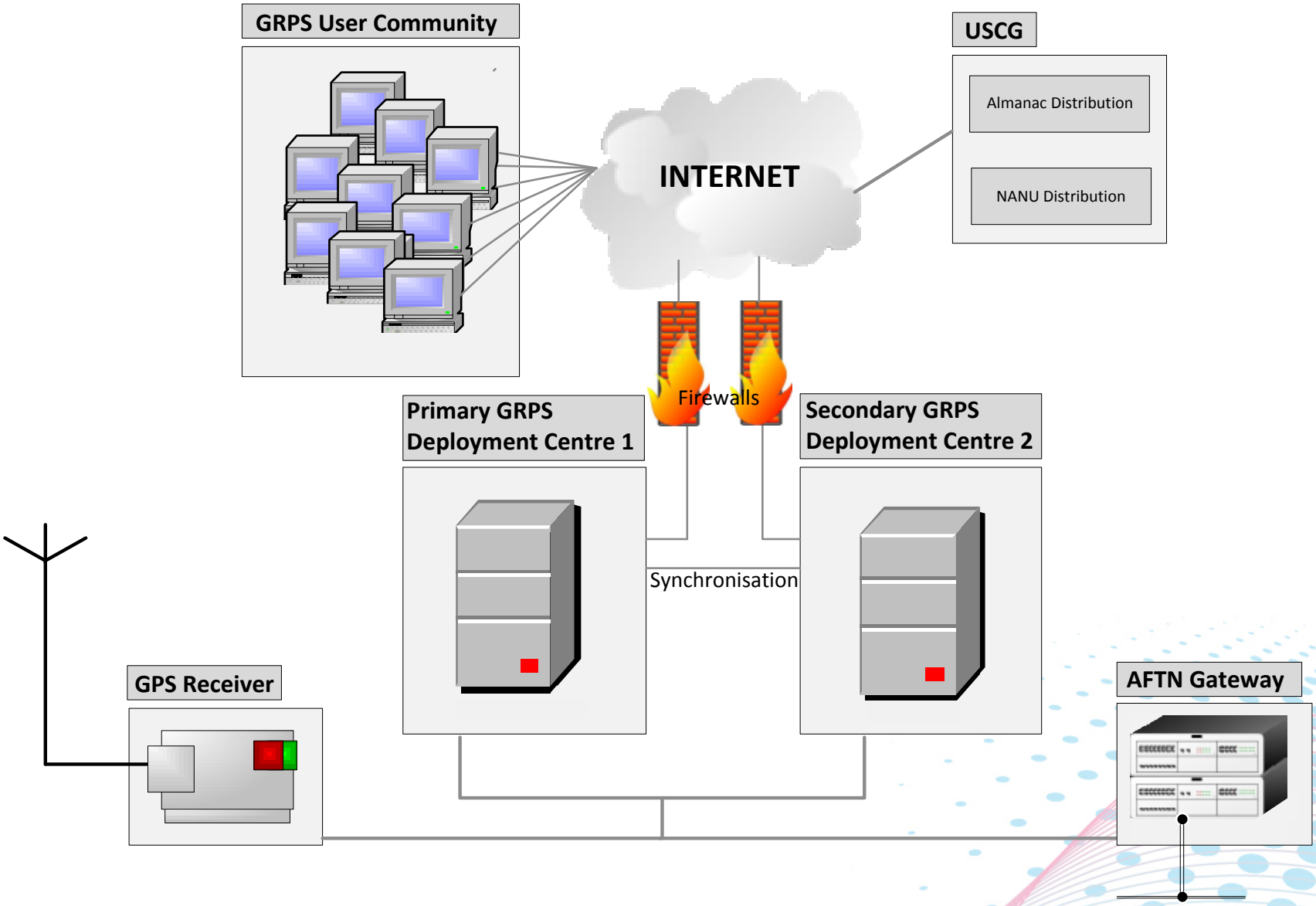
GRPS Delivery Channels



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

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GNSS RAIM/RNP Prediction System (GRPS)

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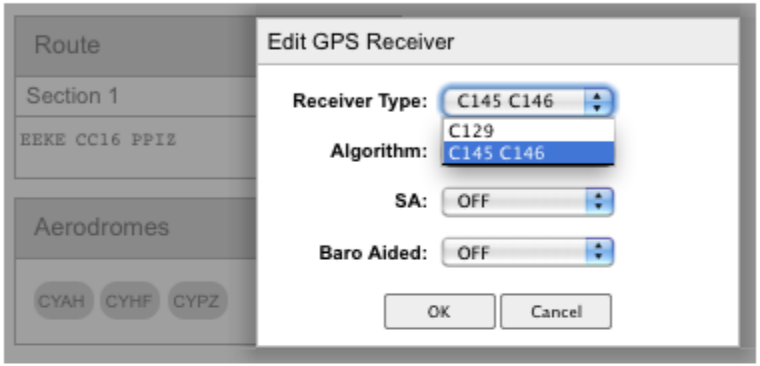
GNSS RAIM/RNP Prediction System

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**.

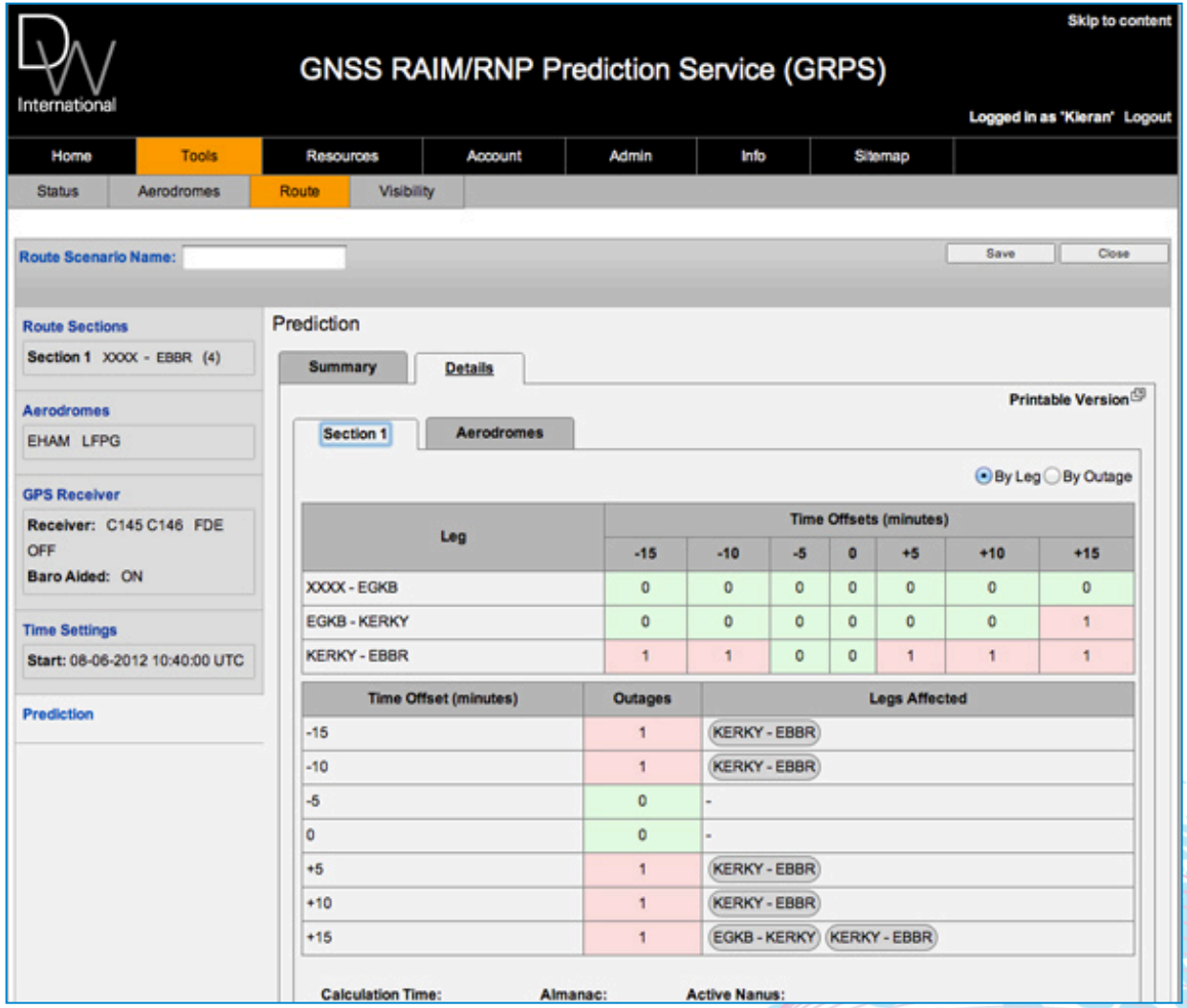
GRPS has been designated for predictions relating to NAVSTAR GPS system. However, it will be expanded in the future to include Galileo, GLONASS (Global Orbiting Navigation Satellite System), COMPASS and INRSS (Indian Regional Navigational Satellite System).

GRPS provides access to four tools:

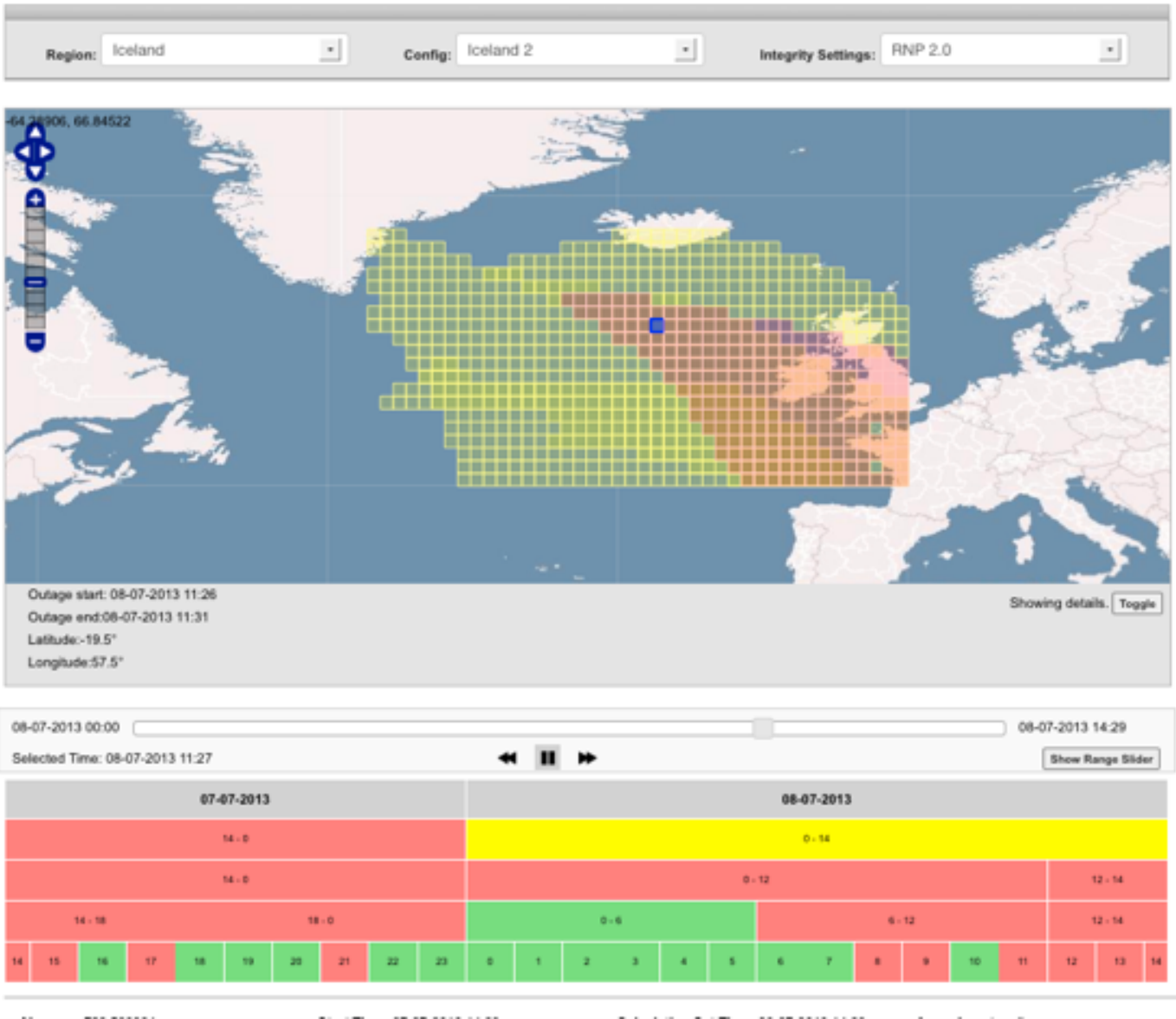
Route Prediction | Aerodrome Prediction | Satellite Visibility | Constellation Status

GRPS Route Mode

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

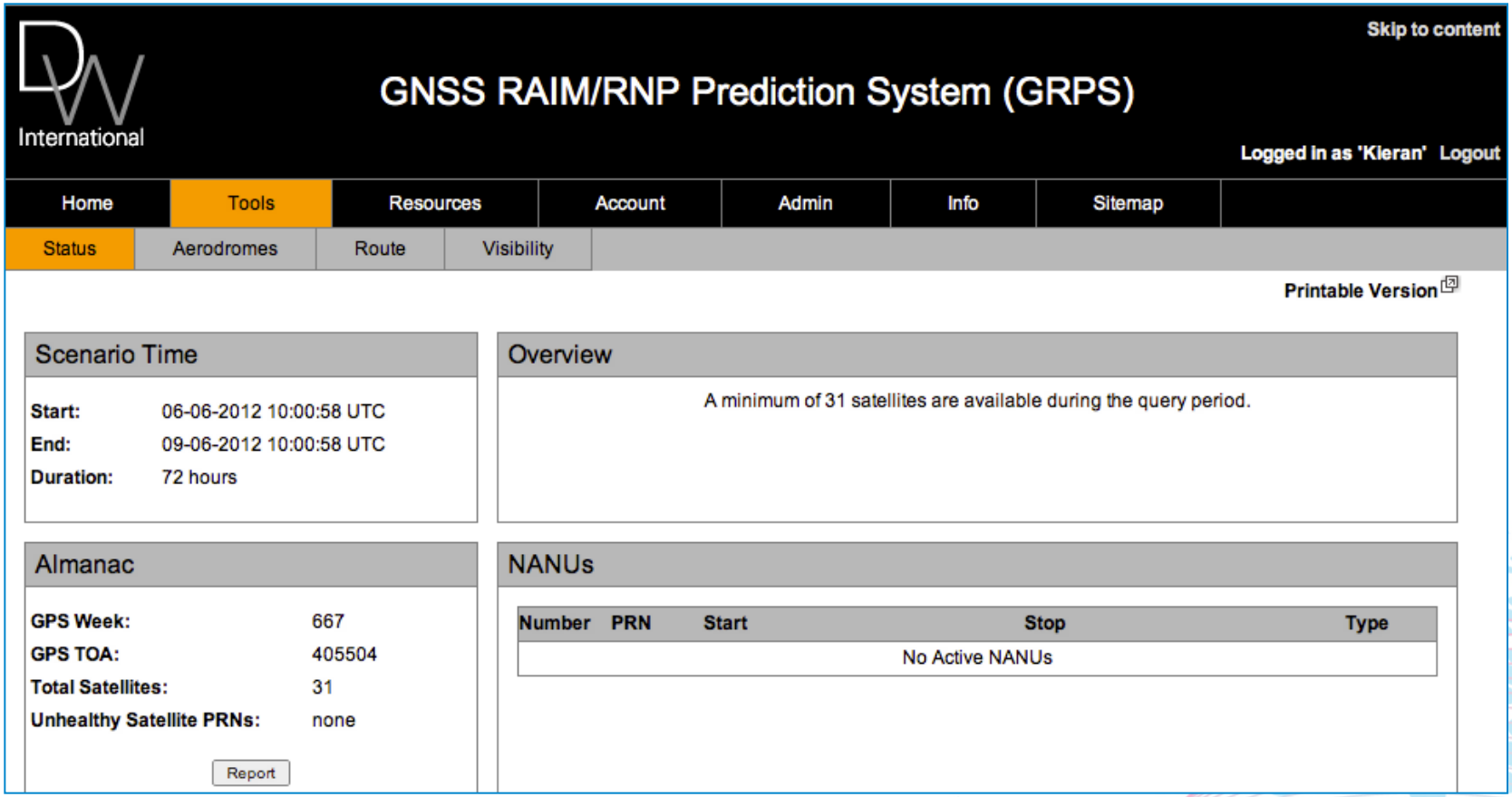


GRPS Region Mode



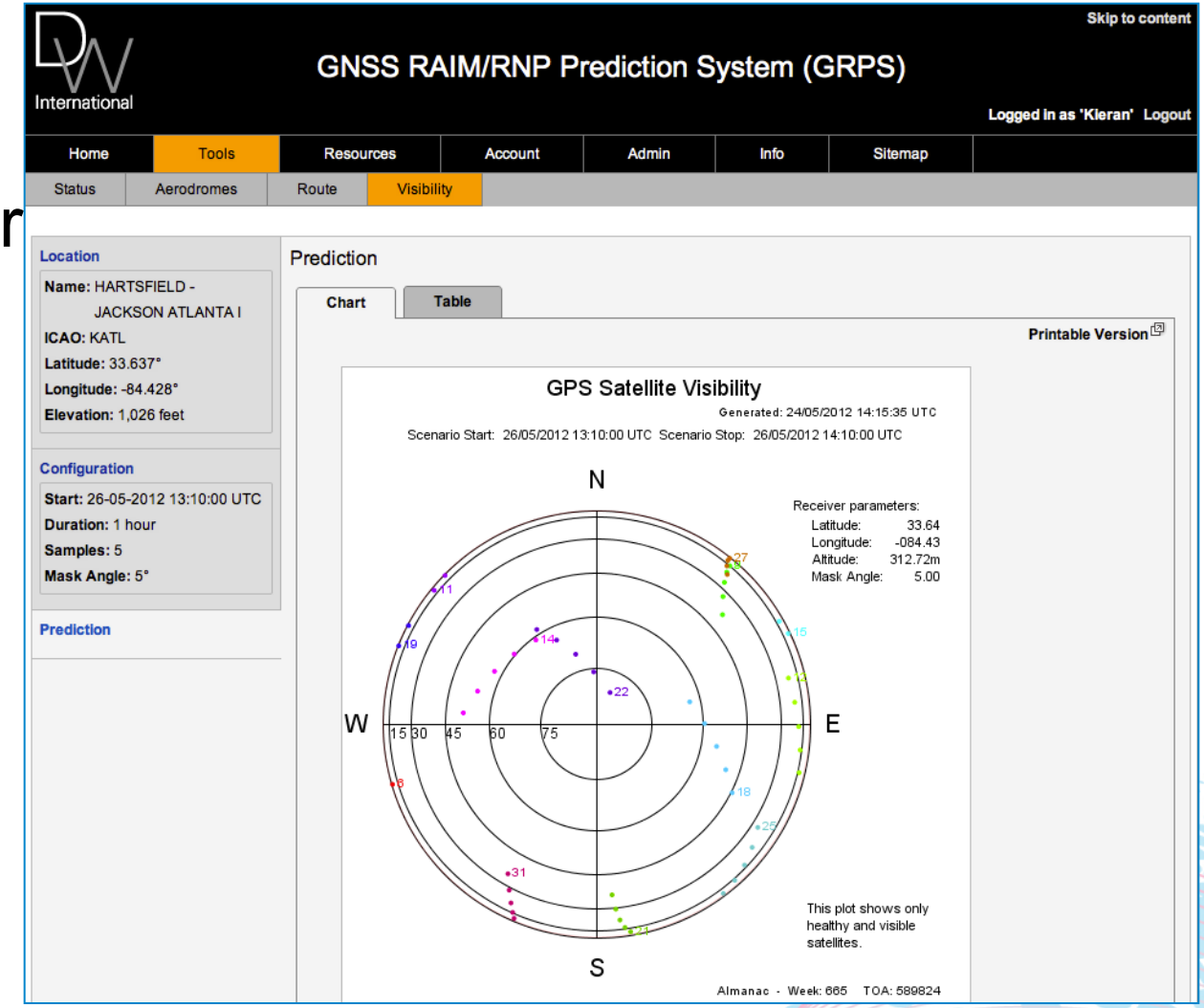
GRPS Constellation Status Tool

- Status Tool
  - Shows latest NANU and Almanac



GRPS Visibility Tool

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

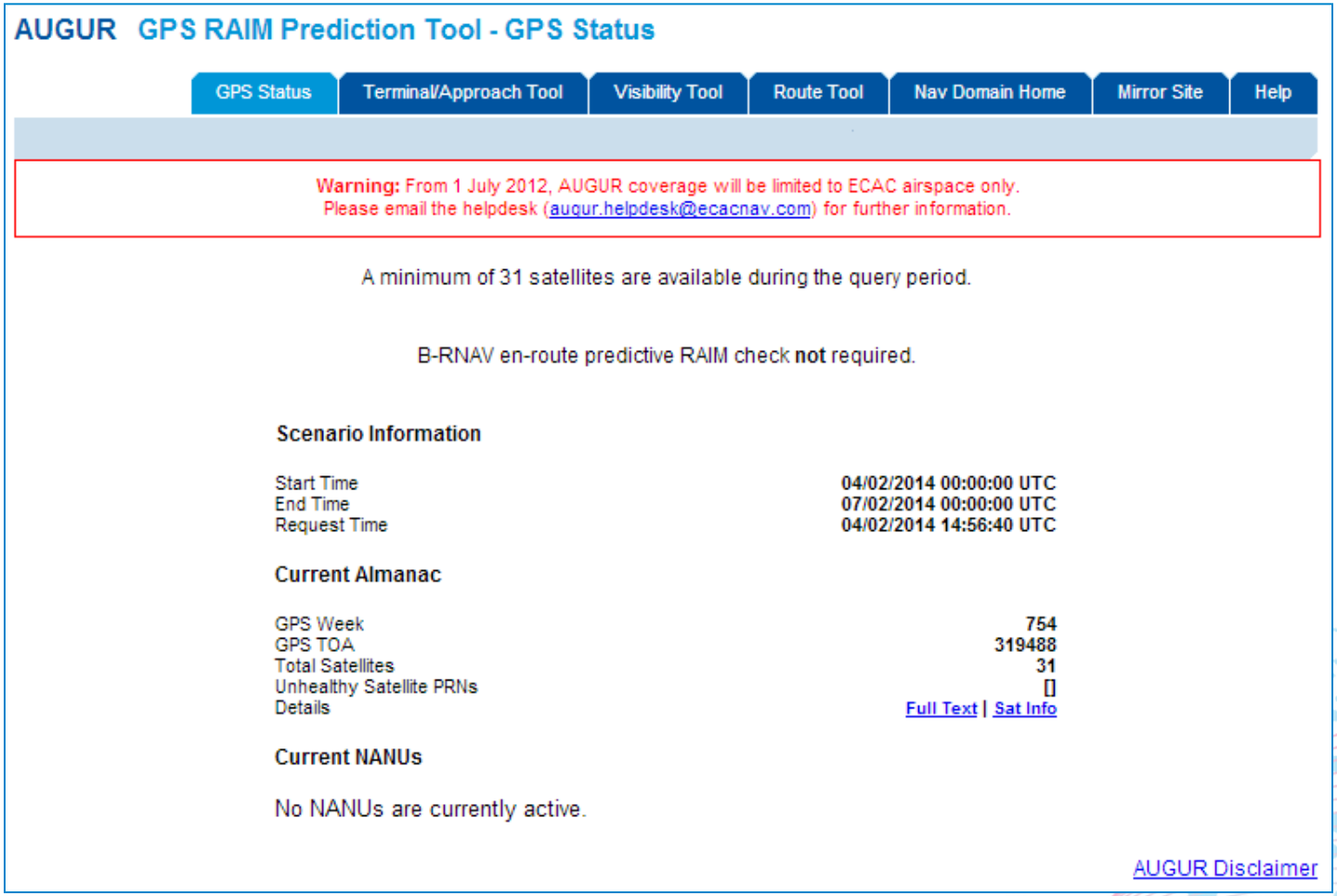


GRPS Training

- ½ Day Training
- Online or classroom

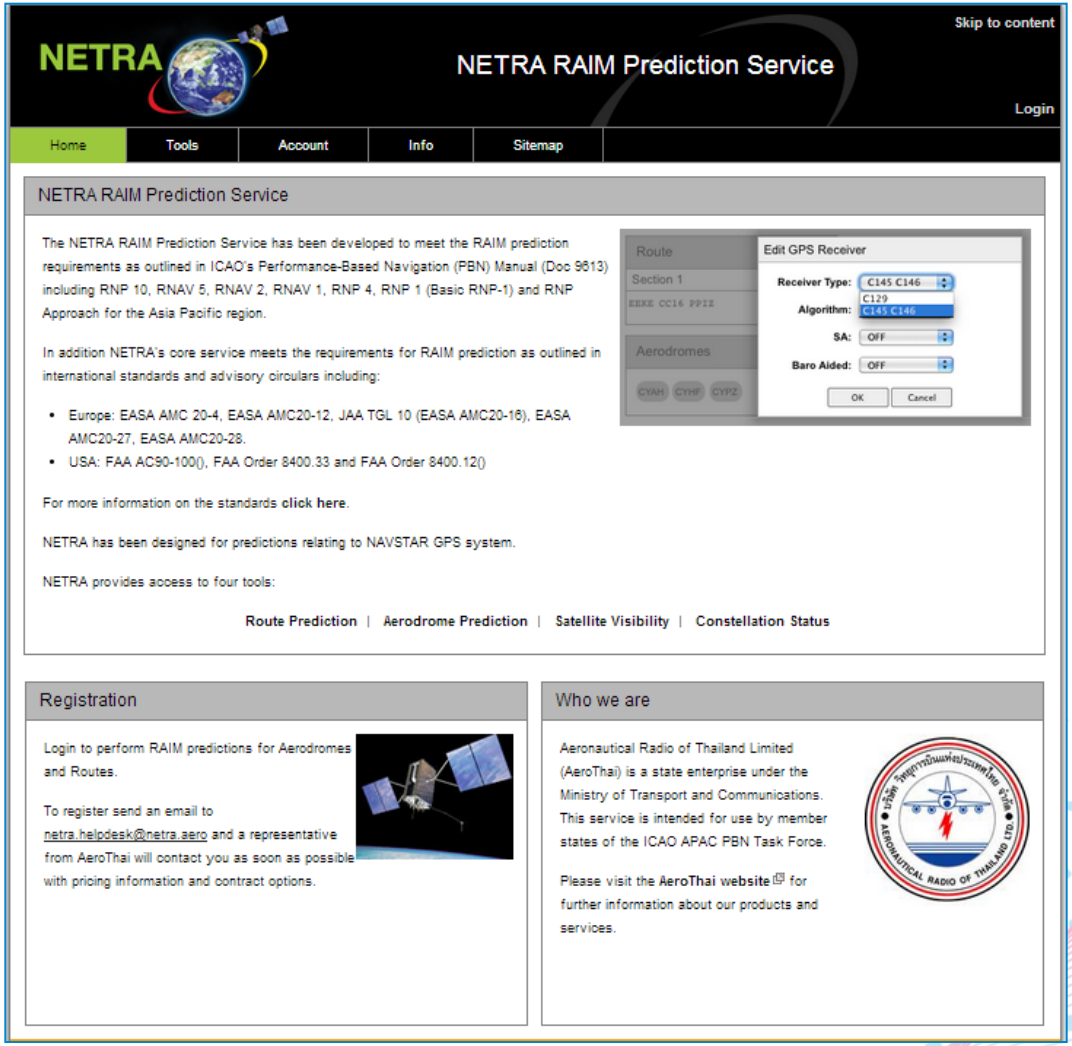
GRPS Branded Deployments

- Augur – EUROCONTROL



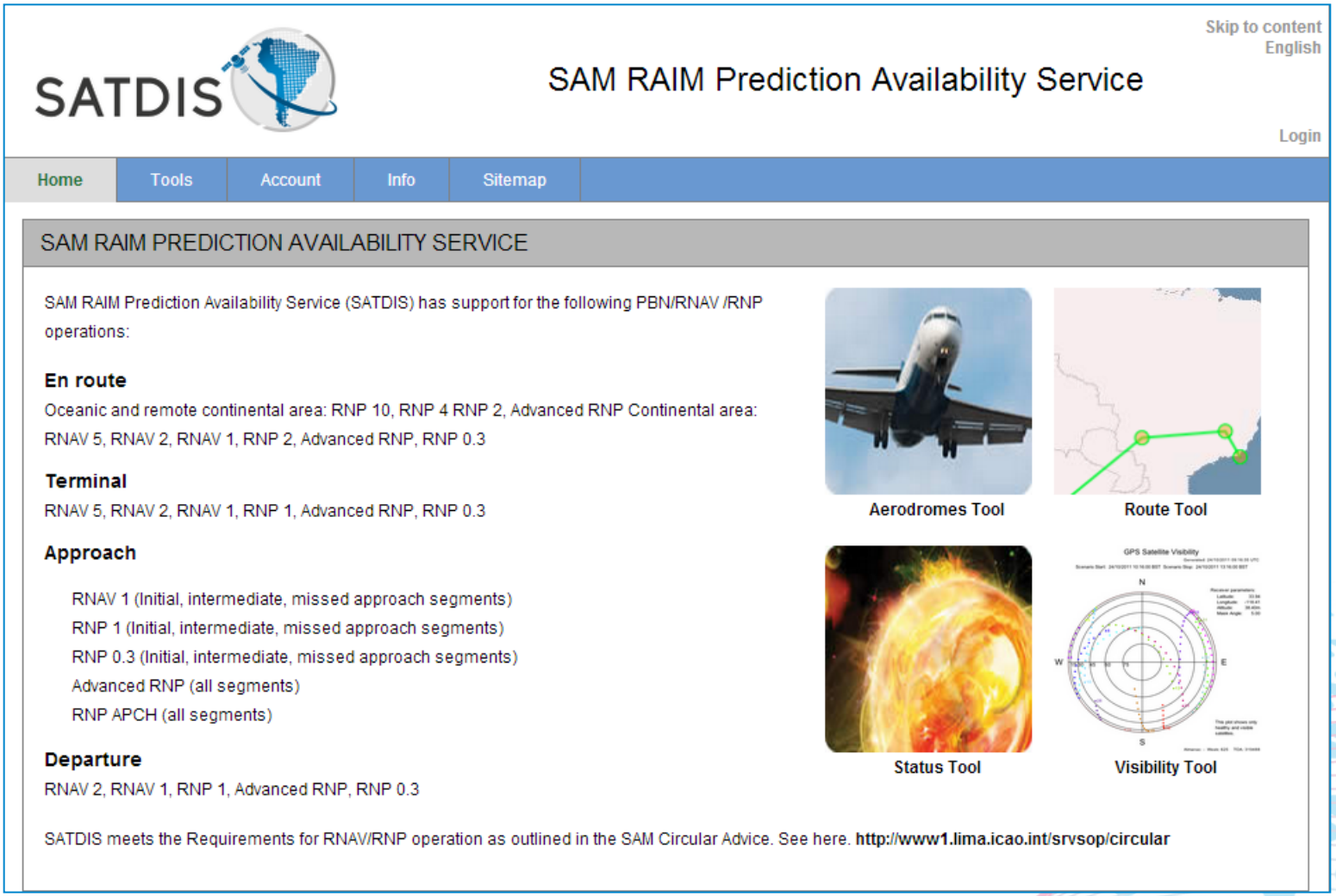
GRPS Branded Deployments

- NETRA – AEROTHAI



GRPS Branded Deployments

- SATDIS – ICAO South America Regional Office



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

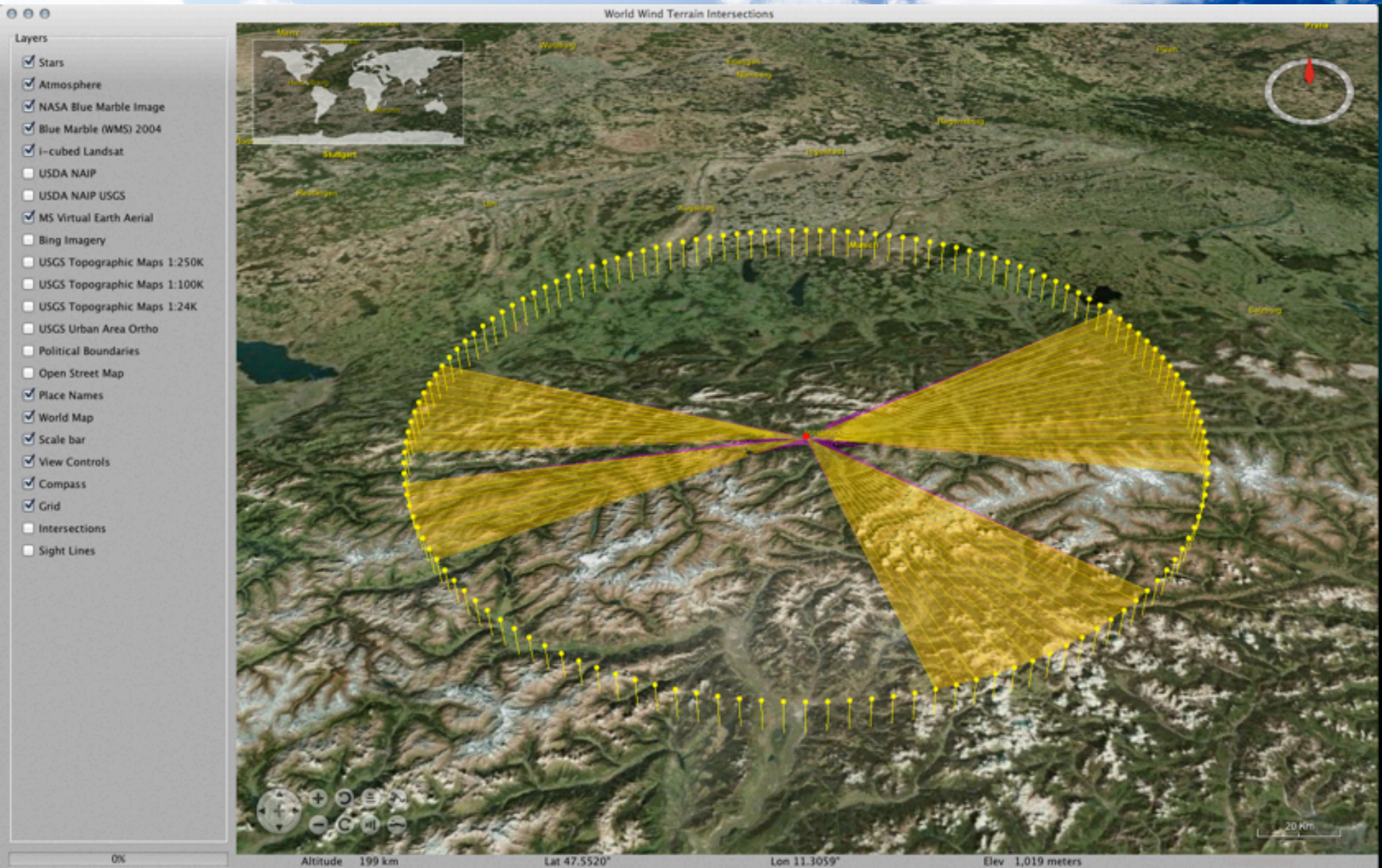
- GNSS RAIM Outages for Aerodromes
- NOTAM Proposals generated for State NOTAM Office
- Proposals issued in NOTAM format so no additional formatting required by NOTAM Office

NOTAM N example

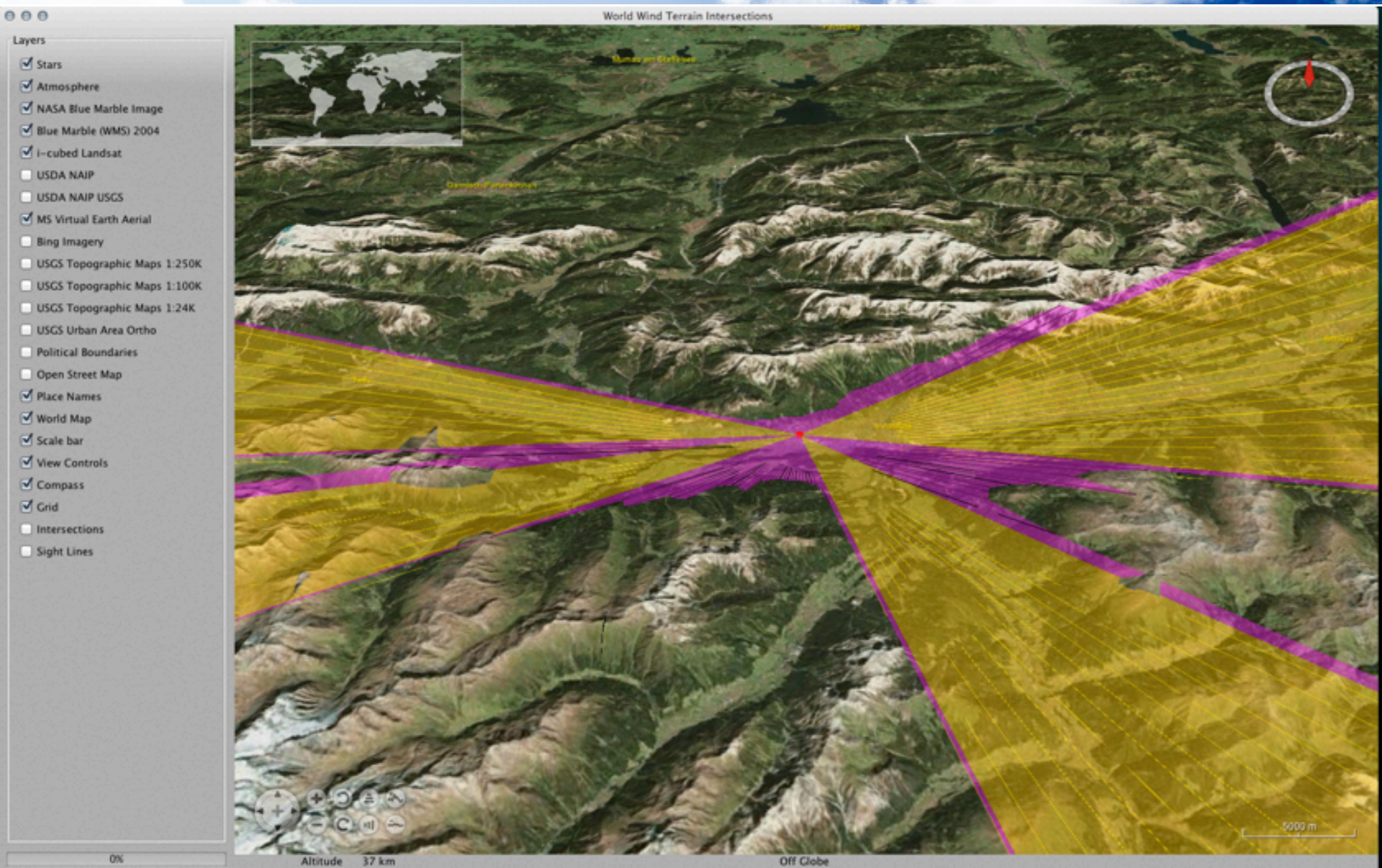
A1234/09 NOTAMN
Q) LFBB/ QGAAU/ I/ NBO/ A/ 000/ 999/ 4100N00200E005
A) LFBO
B) 0908240145
C) 0908250225
D) 24 0145-0230 0630-0645 25 0155-0225
E) EGNOS NOT AVAILABLE FOR LPV

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

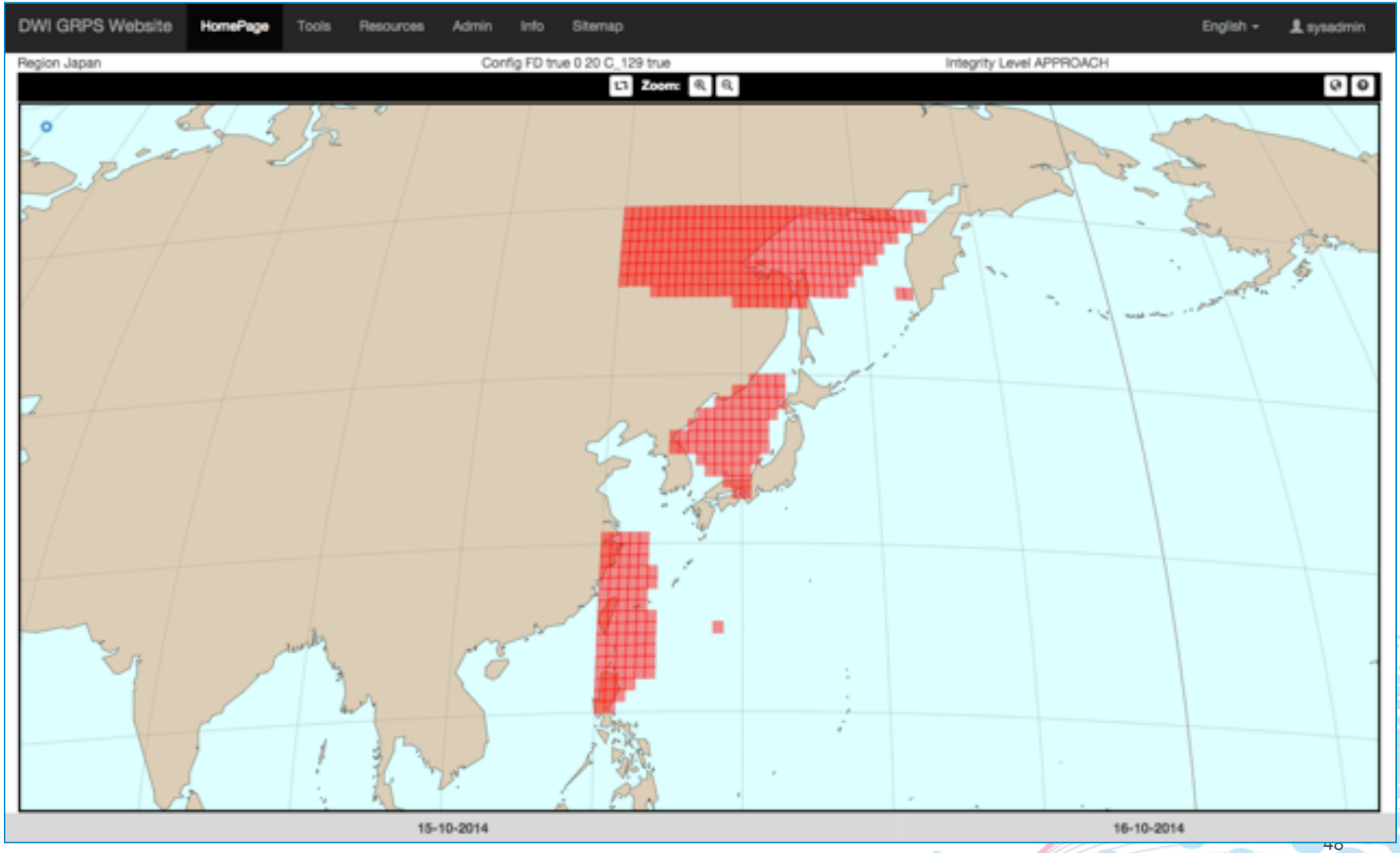
- Known users via 3rd party systems

- Many other users via flight / trip planning services

GRPS User Base

- Flight / Trip Planning

Coming Soon: GRPS Version 4



DWI & ICAO Together!

DW International

Thank you for listening - Any questions?

john.wilde@dwint.com

www.dwint.com