

SPACEKEYS

Latest Evolution of RAIM Prediction Systems

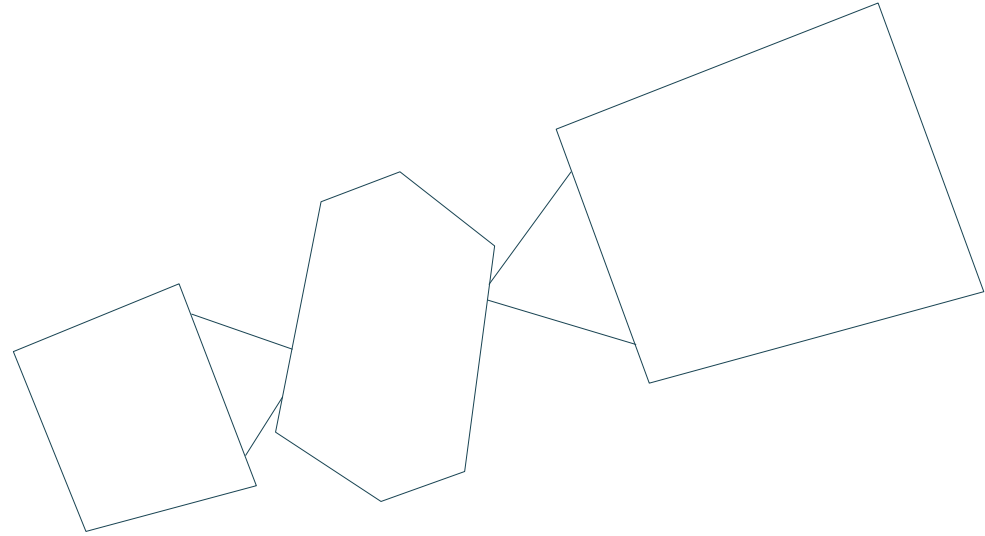
SPACEKEYS is a project funded by the European Space Agency



Topics

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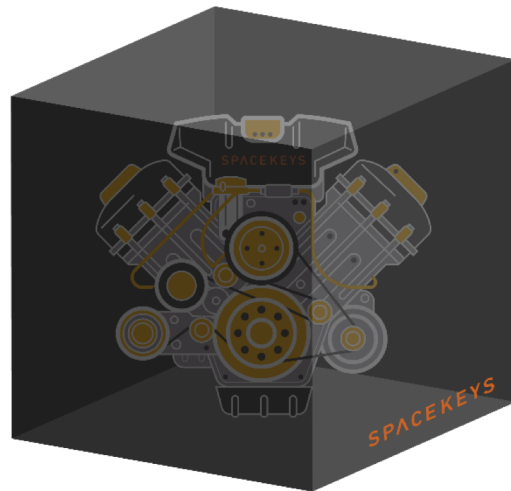
- Rationale
- Requirements
- Objectives
- Results
- Achievements
- Relevant case study
- Roadmap way forward



SPACEKEYS Rationale

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As the GPS satellites themselves have evolved over the years, so have the systems that allow operators to take the benefit of satellite navigation. SPACEKEYS presents the ultimate evolution of GNSS RAIM prediction solution for aviation. It provides for worldwide RAIM predictions for all aircraft types and for all navigation and surveillance specifications. SPACEKEYS is a project partly funded by European Space Agency (ESA) under the NAVISP programme ([NAVISP EL2-007](#)).



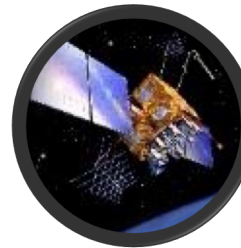
Black Box Design



- Airlines
- CAA/ANSPs
- Flight Planning
- Flight Following
- Weather
- Business Jets
- General Aviation



Create competition



Requirements (GNSS Receivers)

The RAIM solution performs predictions for all currently known receiver types in commercial aviation. This includes receivers compliant with TSO-C129, TSO-C196 and TSO-C145/146. The system is Future Ready For Multi-Constellation Receivers and Advanced Horizontal RAIM.

The following GNSS receiver parameters are supported:

Parameter	Options	Details
Algorithm	FD or FDE	
Barometric Aiding	ON, OFF or ON only on Failure	The option „On only on Failure“ provides the user the possibility to apply BA only in case the RAIM prediction resulted in an outage excluding BA. This is only available in the Spacekeys RAIM prediction solution.
Selective Availability	ON or OFF	
Mask Angle	-25° to 30°	
HAL Multiplier	Any certified value	Some aircraft are certified to apply a horizontal alert limit bias during RAIM predictions.

Requirements (Navigation)

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The RAIM solution performs predictions in compliance with the following navigation specifications. Terrain screening is performed as required for RNP AR predictions.

	RNAV 10 RNP 10	RNAV 5 Basic-RNAV	RNAV 2 US RNAV Type A	RNAV 1 Precision-RNAV US RNAV Type B	RNP 4	RNP1	RNP Approach	RNP AR Approach	MNPS
FAA (U.S.A.)	AC 90-105A (replaces Order 8400.12C)	AC 90-96A	AC90-100A	AC90-100A	AC 90-105A (repl. order 8400.33)	AC 90-105A	AC 90-105A (LNAV, LNAV/VNAV) AC90-107 (LP, LPV)	AC 90-101A AC20-138D	N8110.60
EASA (EU, EFTA and other countries)	AMC 20-12	AMC 20-4 JAA TGL 2	AMC 20-16 JAA TGL 10	AMC 20-16 JAA TGL 10		AMC 20-16 JAA TGL 10	AMC 20-27 (LNAV, LNAV/VNAV) AMC 20-28 (LP, LPV)	AMC 20-26	
CASA (Australia)	AC 91U-2(0)	CAAP B-RNAV-1	AC 91U-II-3-B	AC 91U-II-3-B	AC 91U-3(0)	AC 91U-II-C-3(0)	AC 91U-II-C-5 (LNAV) AC 91U-II- Attachment (LNAV/VNAV)	AC 91U-II-C-5 (RNP AR) AC 91-U-II-C-6	
SVRSOP (Latin America)	AC 91-001	AC 91-002	AC 91-003	AC 91-003	AC 91-004	AC 91-006	AC 91-008 (LNAV) AC 91-010 (LNAV/VNAV)	AC 91-009	
Transport Canada		AC 700-015							

Requirements (Surveillance)

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The RAIM solution performs predictions in compliance with the FAA ADS-B 2020 specification AC90-114A Change 1. As other Worldwide surveillance requirements are developed the system will ensure all requirements are complied with.



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

Advisory Circular

Subject: Automatic Dependent
Surveillance-Broadcast Operations

Date: 3/7/16

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 ADS-B 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).

AC90-114A Change 1 – Prediction methods:

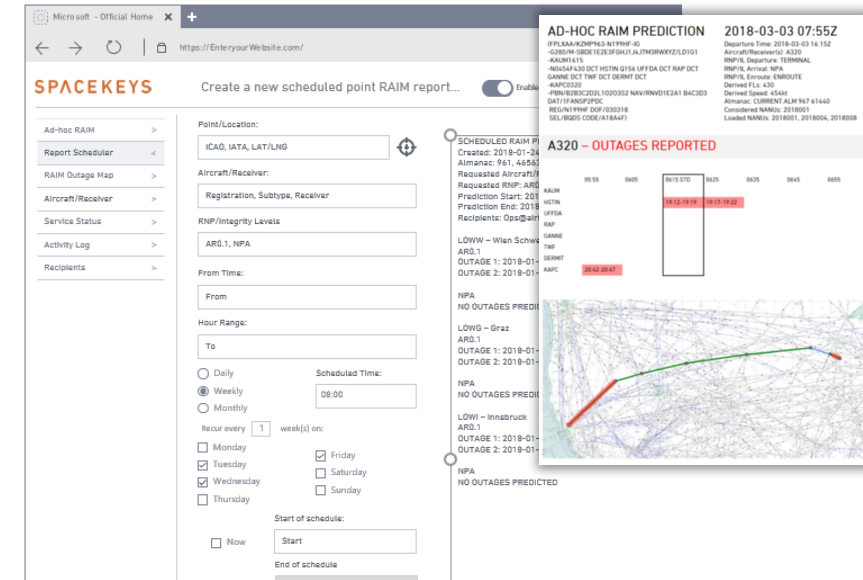
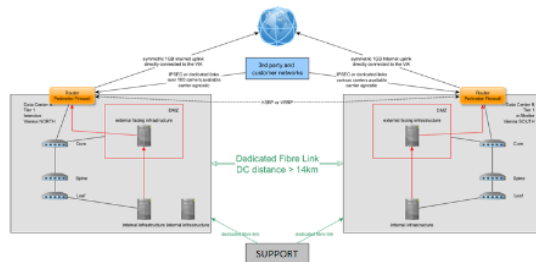
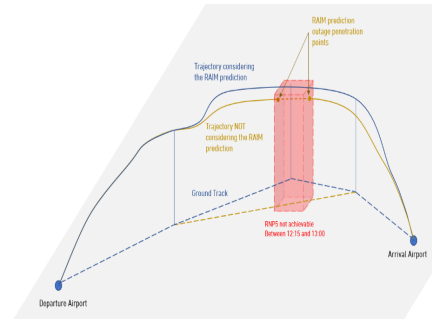
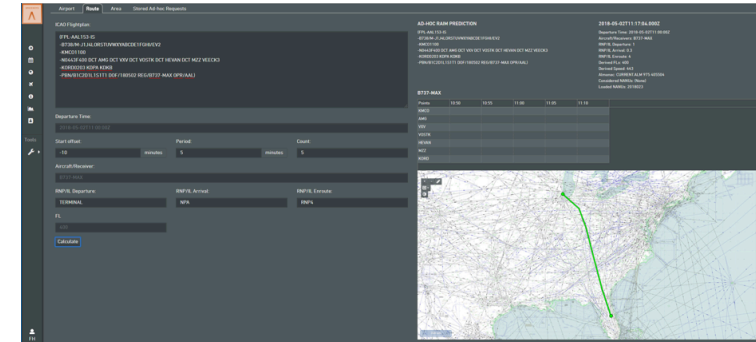
“Operators of large fleets of aircraft or users of flight planning programs may wish to use their own preflight availability verification tool. The operator is responsible for selecting a tool that accurately predicts the performance for their aircraft. The tool needs to account for the GPS satellites that are in service at the time of the prediction, and may take into account unique characteristics of the GNSS receiver, aircraft integration or installation; including performance better than required in FAA standards or use of inertial information integrated into the ADS-B Out position source. The FAA does not evaluate or approve a particular tool, but may evaluate the basis of the operator's determination that the tool is appropriate to their aircraft, particularly if its use results in noncompliant flights in airspace where ADS-B Out is required.”

Active engagement with VOLPE on validation

SPACEKEYS Objectives

- All Worldwide prediction requirements met, including ADS-B
- Modern System To System APIs
- Sophisticated Web User Interface – including flight plan cut/paste
- Daily Reports – Users Customisable
- File2RAIM – file the ICAO flight plan to us and get a RAIM report
- Dynamic “Just In Time” Terrain Screening for RNP-AR
- RAIM Outage Avoidance During Flight Planning
- Pro-Active Alerting

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EUROCONTROL AUGUR - A SPACEKEYS Achievement

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augur.spacekeys.aero



- Service Status
- Terminal/Approach Tool
- Help

Disclaimer

TERMINAL/APPROACH TOOL

Airports

egll,loww

Mask Angle

5.0°

Algorithm

FD

Selective Availability

Aware

Integrity Level

APPROACH (RNP 0.3)

Barometric Aiding

Off

Predict RAIM



SCENARIO

Begin 2018-05-29T00:00:00Z
End 2018-06-01T00:00:00Z
Created 2018-05-29T09:19:55.784Z
Almanac CURRENT.ALM 979 405504
NANUs (None)

CONFIGURATION

Mask Angle 5.0
Algorithm FD
Integrity Level APPROACH (RNP 0.3)
Selective Availability Aware
Barometric Aiding Off

EGLL LONDON/HEATHROW - 51.48 / -0.46 / 25

NO PREDICTED OUTAGES

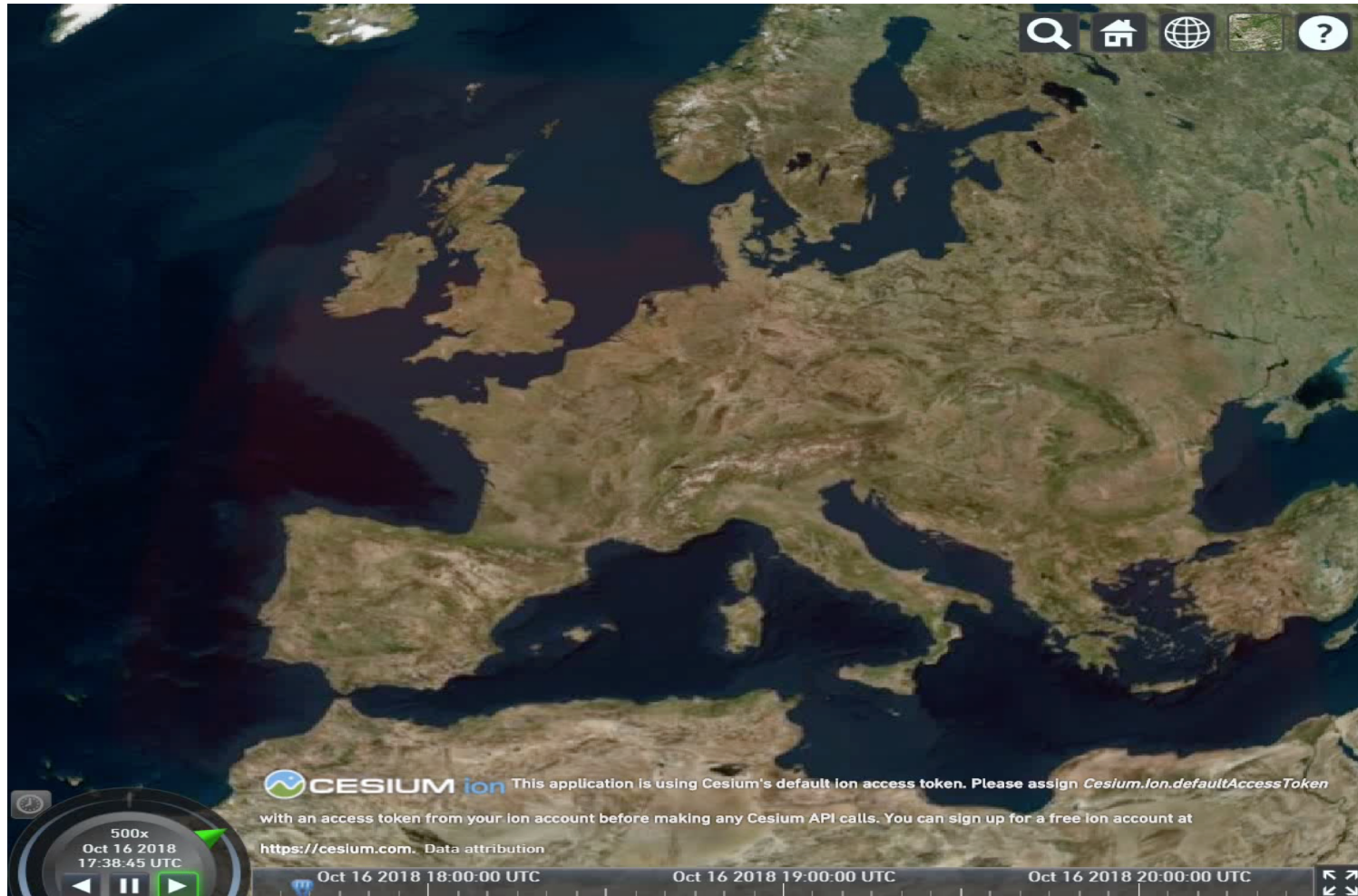
LOWW VIENNA/SCHWECHAT - 48.11 / 16.57 / 183

NO PREDICTED OUTAGES

Download Report

- NAVISP
 - Design, implementation and validation/verification – MTR.
- SPACEKEYS
 - EUROCONTROL Augur.
 - Airlines in Europe, US and Asia.
 - SPACEKEYS sit on US Congressional ADS-B review committee.
- A **case study** – Europe on October 16th 2018.....a major aviation GPS event never seen in 20 years.

What 16th October Should Have Been...Non Precision Approach **SPACEKEYS**



Notice Advisory to Navstar Users (NANU) No. **2018046**:

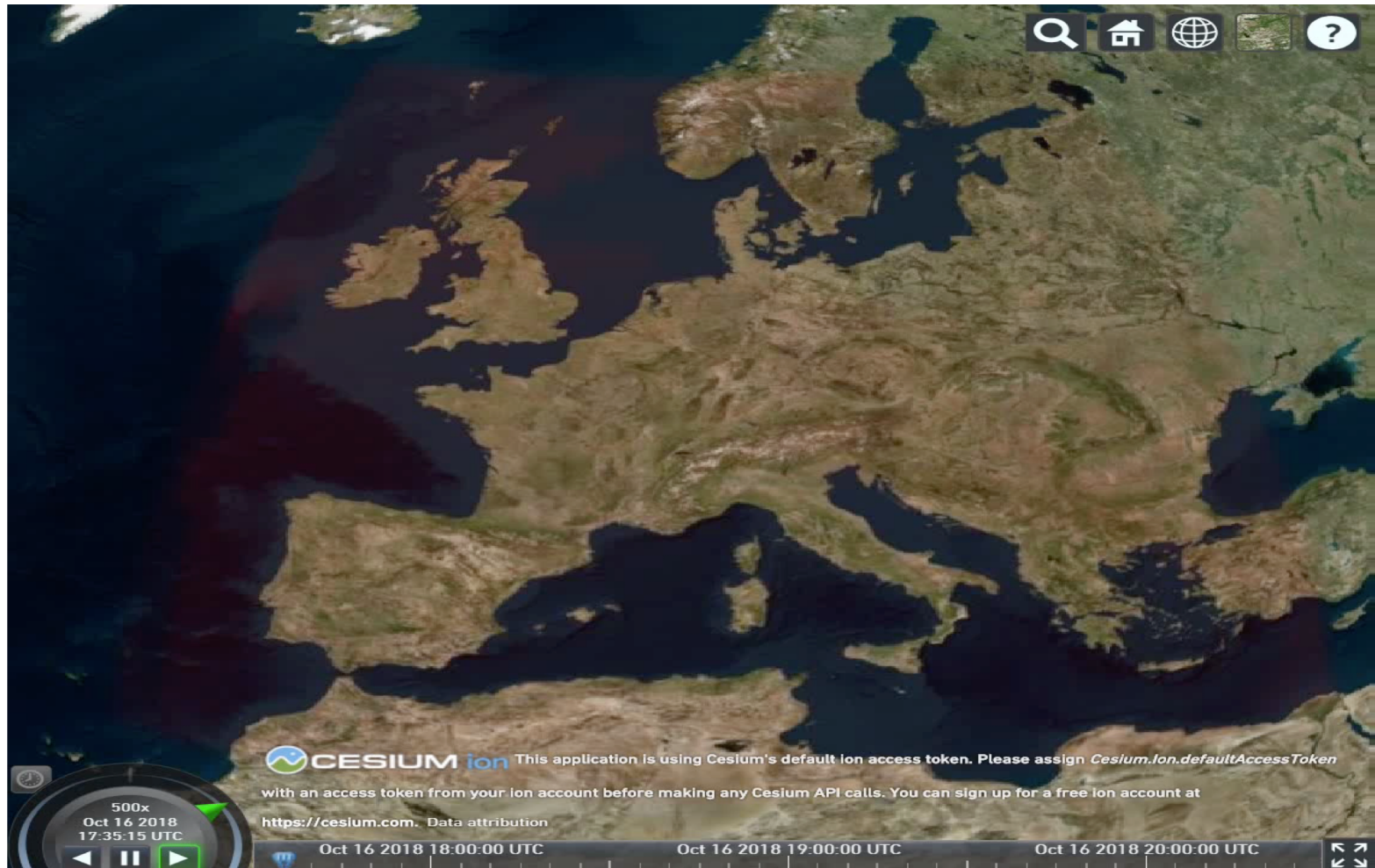
- Satellite **PRN 5** 'out of service' from **1305 for 12 hours**

SVN50 (PRN05) FORECAST OUTAGE JDAY 289/1305 - JDAY 290/0105 NOTICE ADVISORY TO NAVSTAR USERS (NANU) 2018046 SUBJ: SVN50 (PRN05) FORECAST OUTAGE JDAY 289/1305 - JDAY 290/0105

1. NANU TYPE: FCSTDV NANU NUMBER: 2018046 NANU DTG: 101502Z OCT 2018 REFERENCE NANU: N/A REF NANU DTG: N/A SVN: 50 PRN: 05 START JDAY: 289 START TIME ZULU: 1305 START CALENDAR DATE: 16 OCT 2018 STOP JDAY: 290 STOP TIME ZULU: 0105 STOP CALENDAR DATE: 17 OCT 2018
2. 2. CONDITION: GPS SATELLITE SVN50 (PRN05) WILL BE UNUSABLE ON JDAY 289 (16 OCT 2018) BEGINNING 1305 ZULU UNTIL JDAY 290 (17 OCT 2018) ENDING 0105 ZULU.
3. 3. POC: CIVILIAN - NAVCEN AT 703-313-5900, [HTTPS://WWW.NAVCEN.USCG.GOV](https://www.navcen.uscg.gov) MILITARY - GPS OPERATIONS CENTER AT [HTTPS://GPS.AFSPC.AF.MIL/GPSOC](https://gps.afspc.af.mil/gpsoc), DSN 560-2541, COMM 719-567-2541, GPSOPERATIONSCENTER@US.AF.MIL, [HTTPS://GPS.AFSPC.AF.MIL](https://gps.afspc.af.mil) MILITARY ALTERNATE - JOINT SPACE OPERATIONS CENTER, DSN 276-3514, COMM 805-606-3514, JSPOCCOMBATOPS@VANDENBERG.AF.MIL



15 min or
greater
0.3Nm
approach

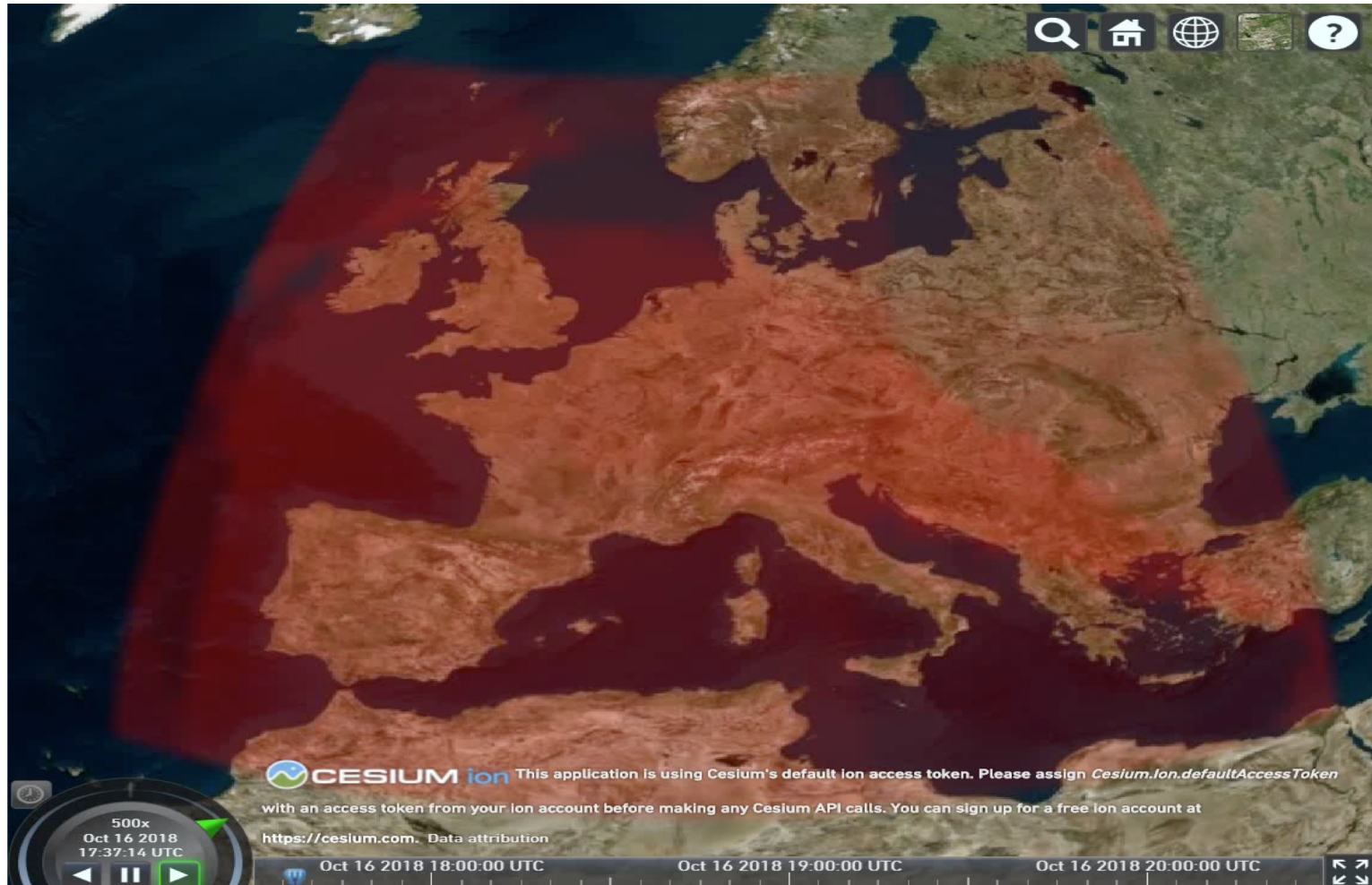


16th October With NANU – SA Unaware

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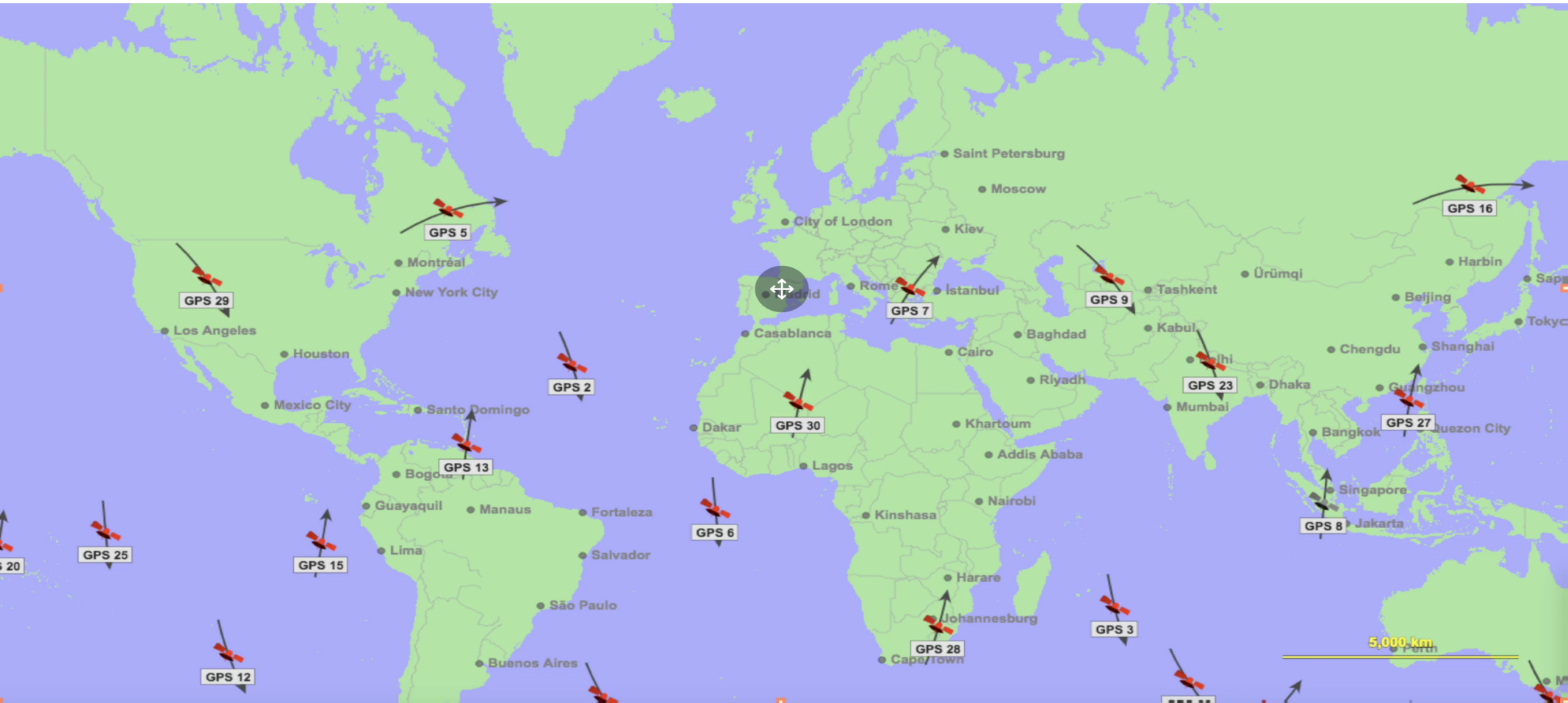


15 min or
greater
0.3Nm
approach



So Why? – Satellite Movements and GEOMETRY!

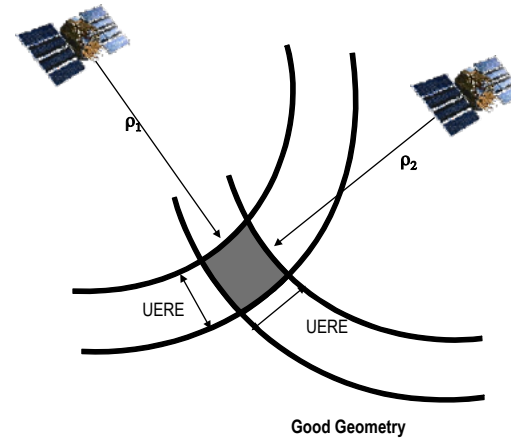
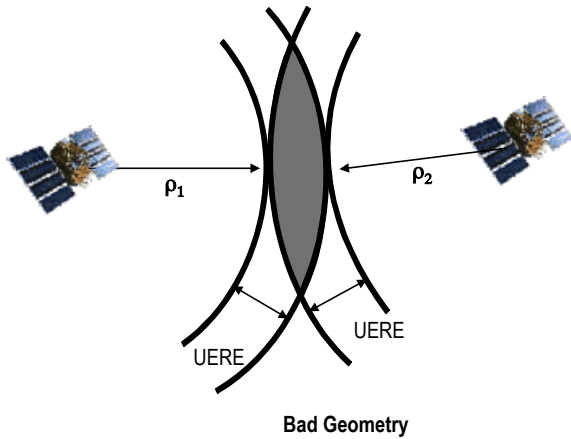
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What Makes RAIM Outages?

We want good GEOMETRY!

- Different angles between us and the satellites. NOT the same angles.

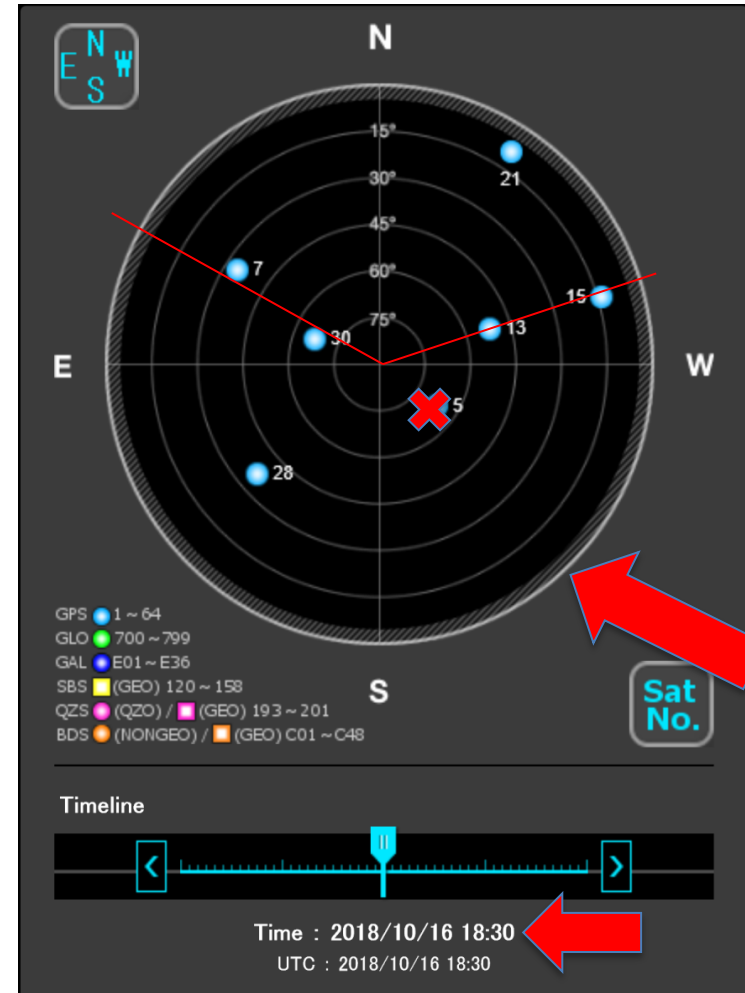
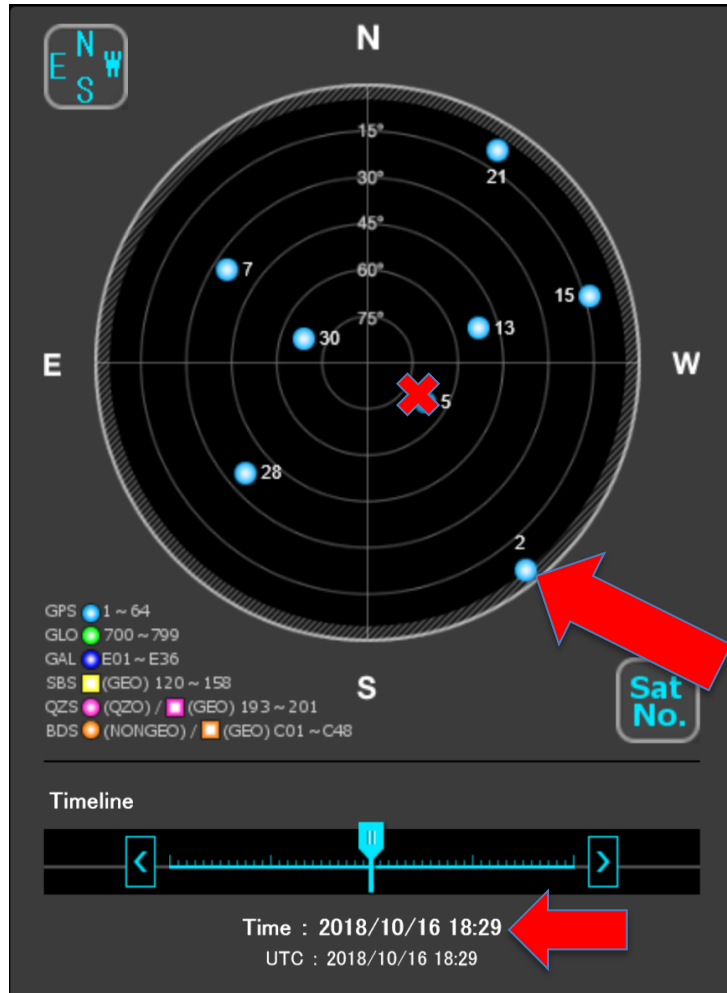


UERE: User Equivalent Range Error

- Ionosphere
- Clock errors
- Electronics noise
- Multipath
- Troposphere
- Almanac/Ephemeris

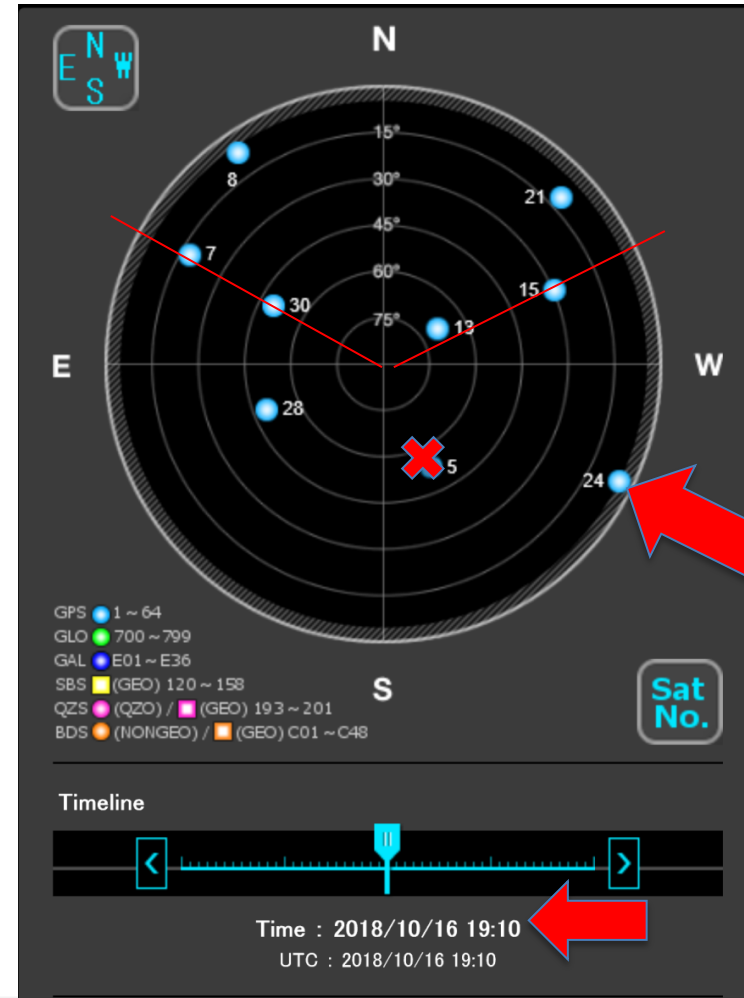
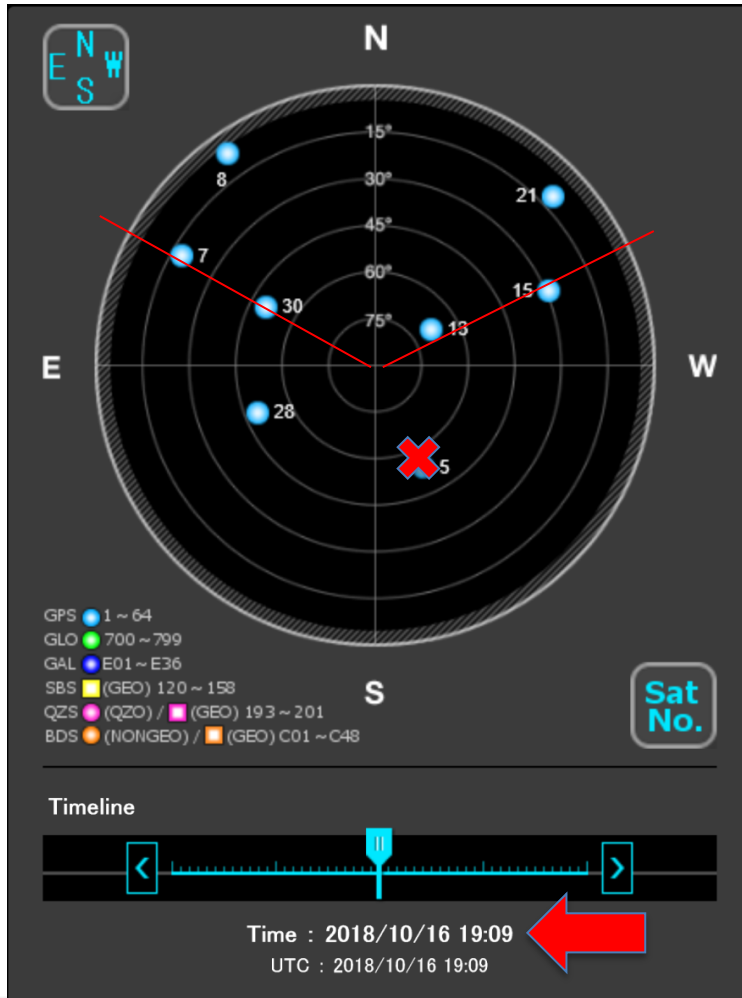
Start of 42 Minute RAIM Outage @ Paris CDG

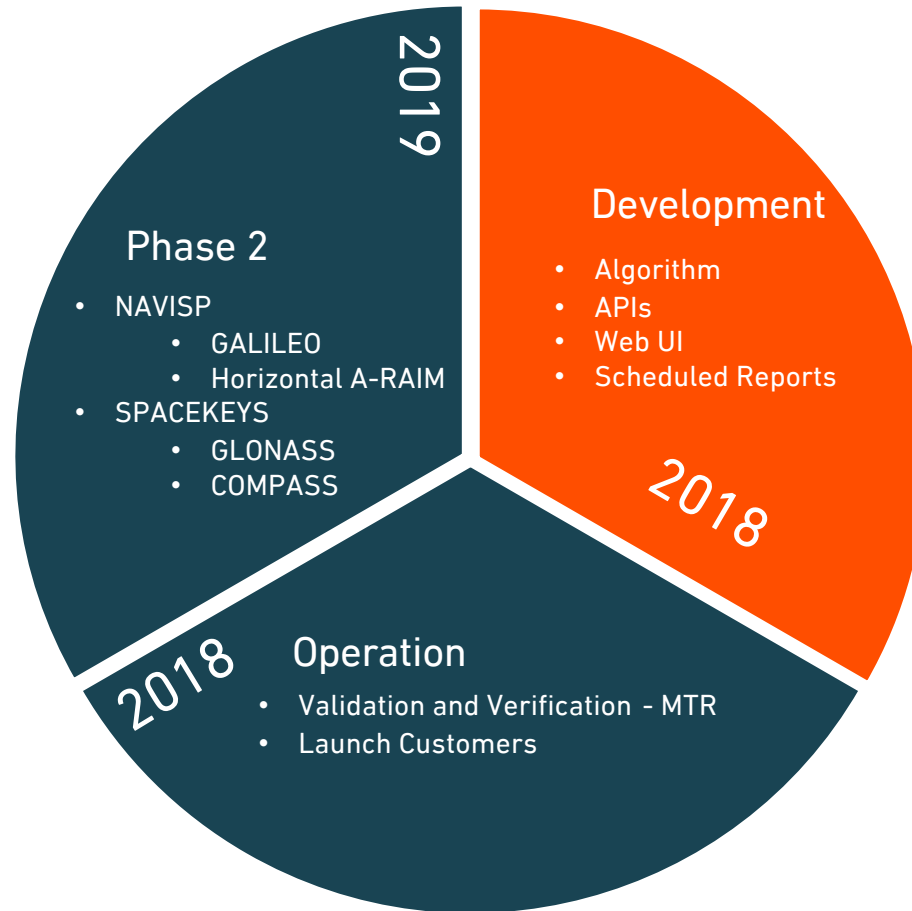
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End of 42 Minute RAIM Outage @ Paris CDG

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THANK YOU!

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