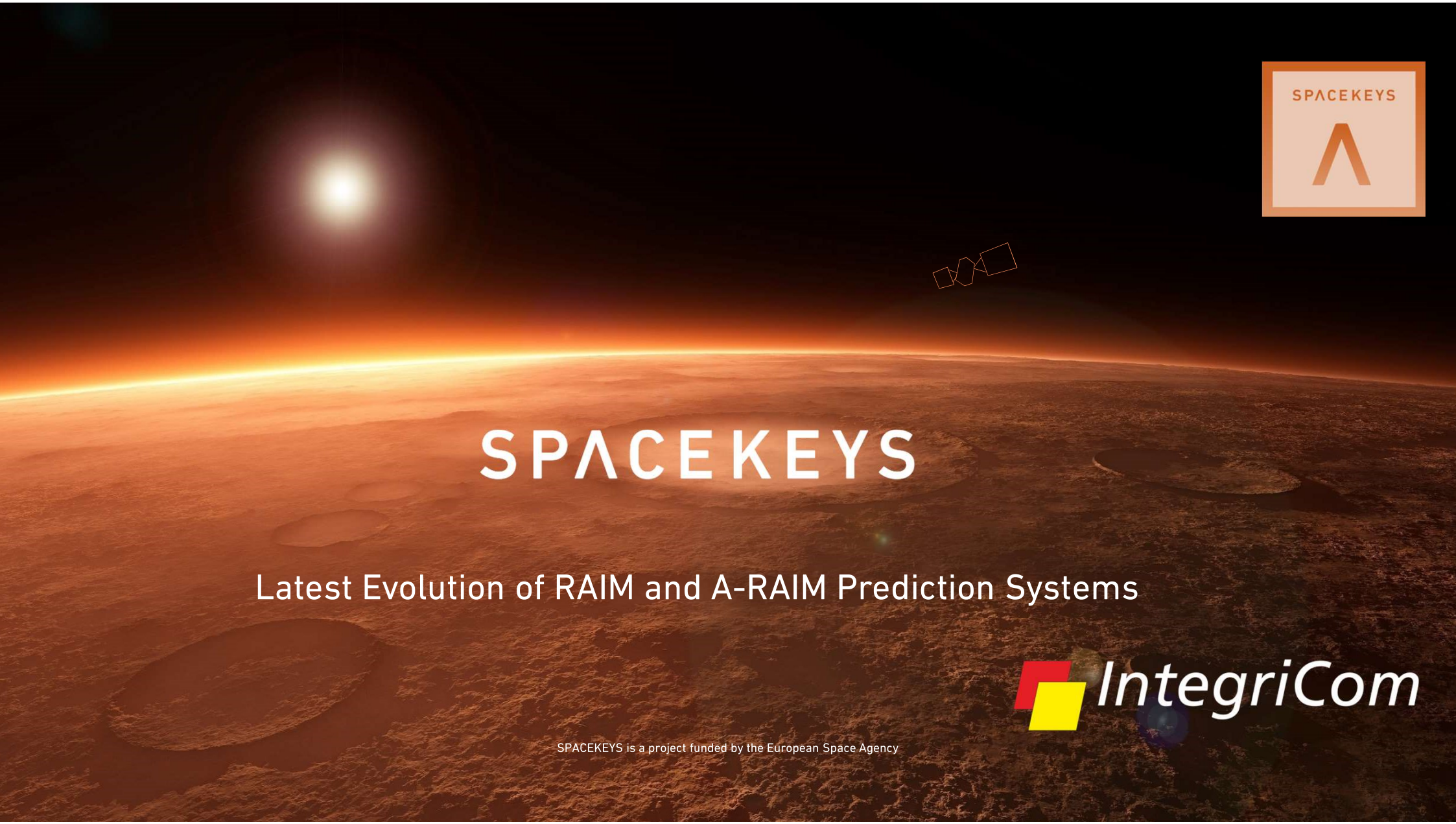
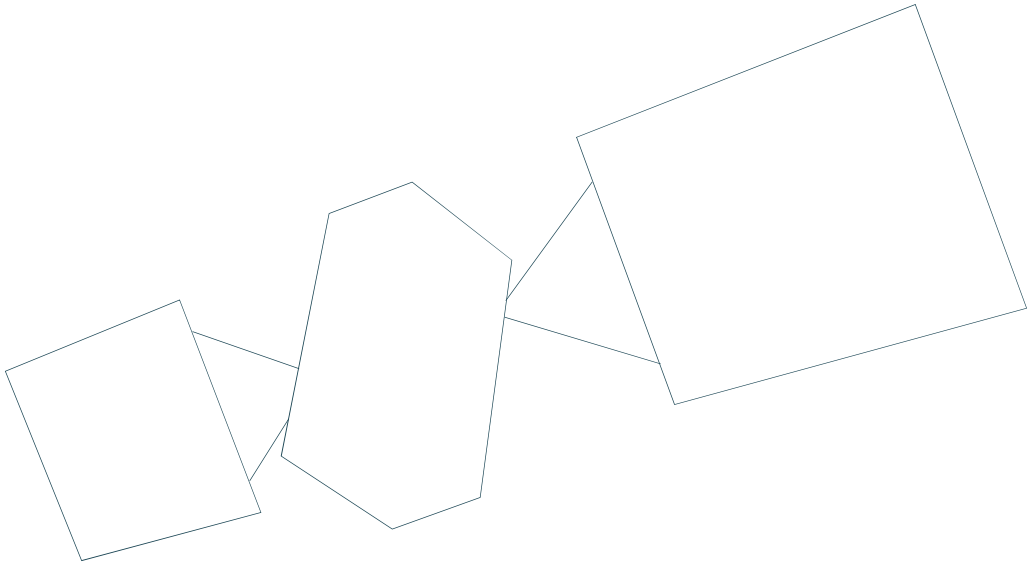

SPACEKEYS
SPACEKEYS
Latest Evolution of RAIM and A-RAIM Prediction Systems
IntegriCom
SPACEKEYS is a project funded by the European Space Agency

Topics

SPACEKEYS

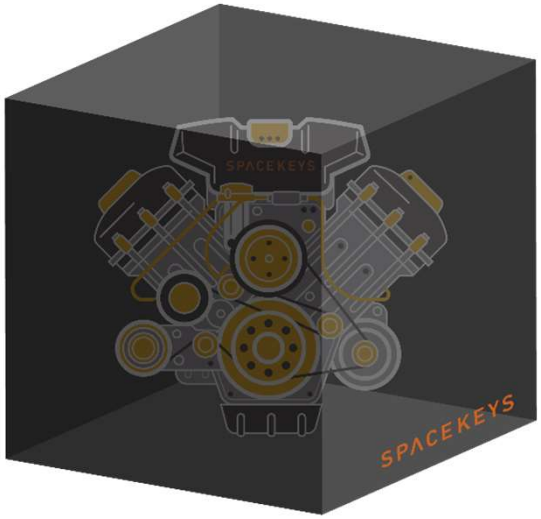
- Rationale
- Requirements
- Objectives
- Results
- Achievements



SPACEKEYS Rationale

SPACEKEYS

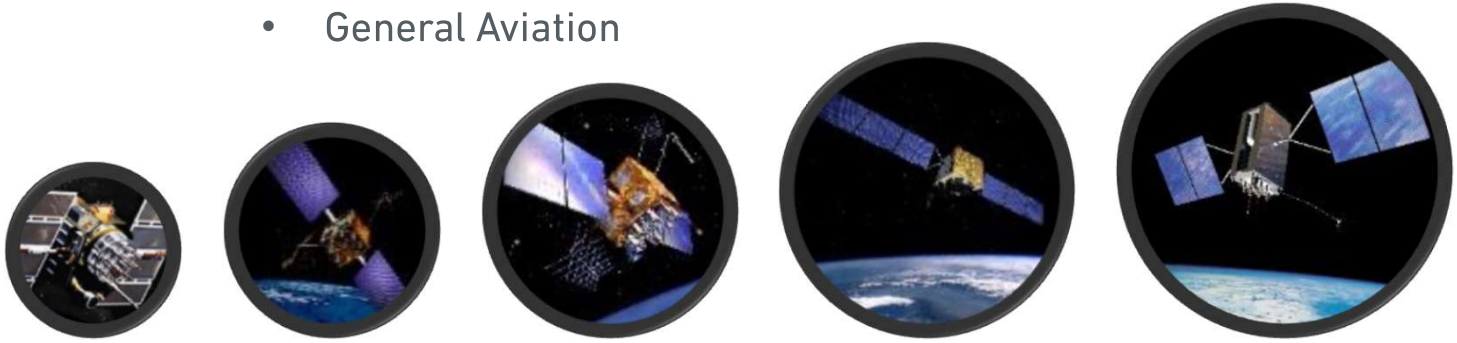
As the GPS satellites themselves have evolved over the years, so have the systems that allow operators to take the benefit of satellite navigation. SPACEKEYS presents the ultimate evolution of GNSS RAIM prediction solution for aviation. It provides for worldwide RAIM predictions for all aircraft types 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 and add multi-constellation



SPACEKEYS NAVISP Project Context

SPACEKEYS

- **Phase 1** - All Worldwide traditional RAIM prediction requirements met, including ADS-B.

- **Phase 2** – Addition of multi-GNSS (Galileo) and A-RAIM as an R&D project. Built on a solid Phase 1.

- Major emphasis on requirements capture from users (Airlines, Integration Companies).
- Agile software development process, development, verification and validation are significantly overlapping. Quick iterations minimize the refactoring efforts at the end of the development task.
- Rigorous Validation and Verification with **ESA unrivalled expertise in subject matter and external Quality Assurance review**.

SPACEKEYS NAVISP Phase 1 Project Activities

SPACEKEYS

- **Phase 1** - All Worldwide traditional RAIM prediction requirements met, including ADS-B.
    - Requirements gathering.
        - Major problem for Flight Planning re RAIM hole detection.
        - Partly user-driven
            - User Workshops held through 2018.
            - User Group Meeting 1-3 October 2019, Vienna.
    - System design.
    - Implementation.
    - Validation/Verification. FAA Volpe SAPT, Independent MATLAB implementation.
    - Deployment.
    - Maintenance.
        - Already significant user base.
        - Number of bespoke ‘per-user’ adaptations made.

RAIM Requirements (standards)

SPACEKEYS

Large variety of receiver and operational standards:

- RTCA Minimum Operational Performance Standards (MOPS).
- US: FAA ACs , TSOs, orders and notifications.
- Europe: EASA's AMCs.
- JAA's TGLs.
- ICAO.
- ... other third-country documents.

- In total over 50 standardization documents were analyzed...
- ... but none of them standardizes the RAIM algorithm as such.

RAIM Requirements (GNSS Receivers)

SPACEKEYS

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 horizonal alert limit bias during RAIM predictions.

RAIM Requirements (Navigation)

SPACEKEYS

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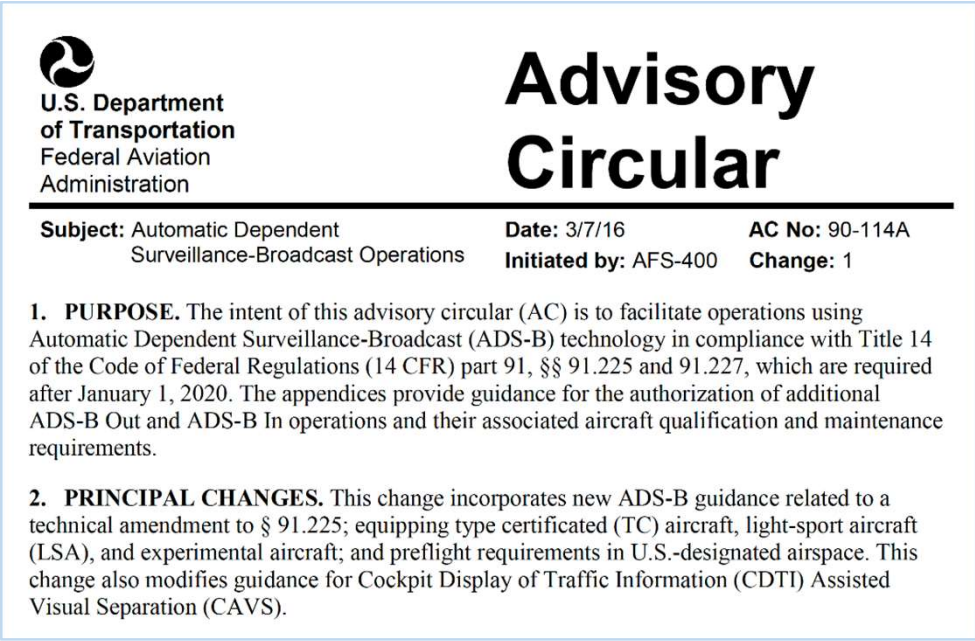
The RAIM solution performs predictions in compliance with the FAA ADS-B 2020 specification AC90-114A Change 1. As other Worldwide surveillance requirements are developed the system will ensure all requirements are complied with.



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

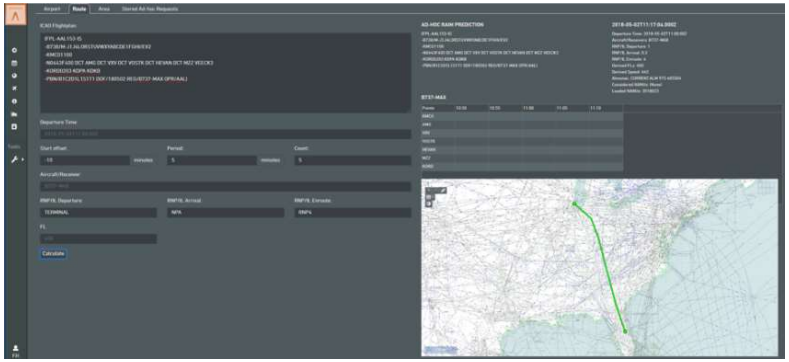
1. PURPOSE. The intent of this advisory circular (AC) is to facilitate operations using Automatic Dependent Surveillance-Broadcast (ADS-B) technology in compliance with Title 14 of the Code of Federal Regulations (14 CFR) part 91, §§ 91.225 and 91.227, which are required after January 1, 2020. The appendices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

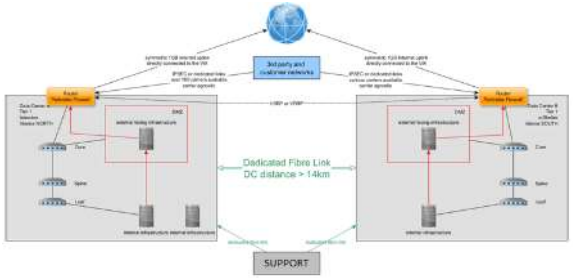
2. PRINCIPAL CHANGES. This change incorporates new ADS-B guidance related to a technical amendment to § 91.225; equipping type certificated (TC) aircraft, light-sport aircraft (LSA), and experimental aircraft; and preflight requirements in U.S.-designated airspace. This change also modifies guidance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

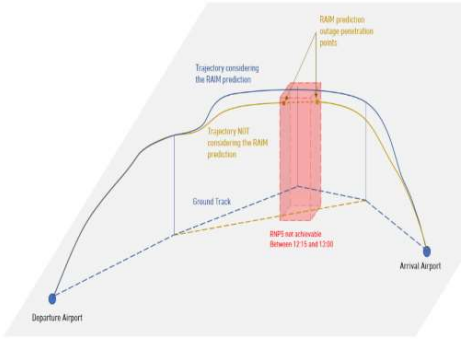
SPACEKEYS Objectives

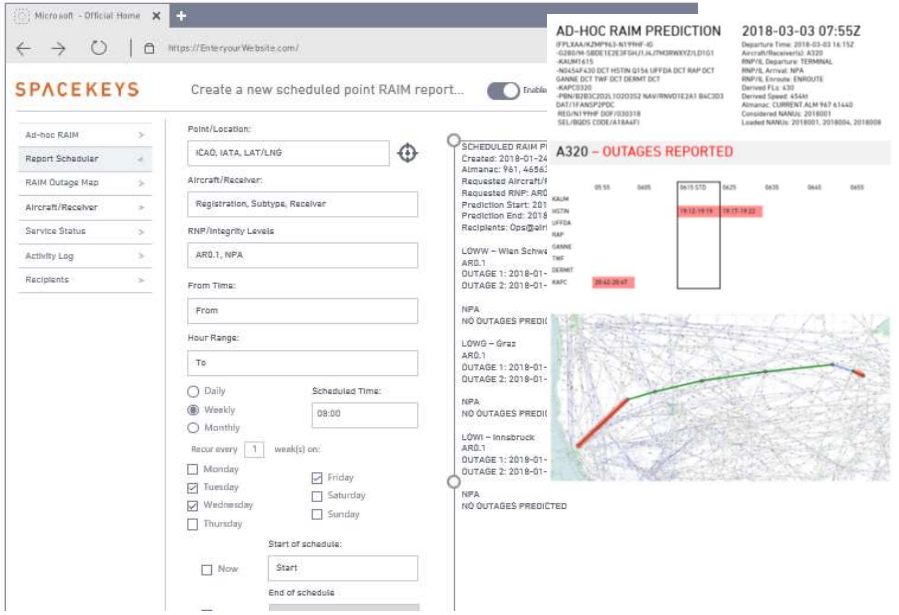
SPACEKEYS

- 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 .









System Integration / API

SPACEKEYS

Spacekeys RAIM supports real time integration with third party systems such as flight planning and flight following systems. Both SOAP and REST APIs are provided for system developers to develop integrated solutions. The APIs are load and stress tested and deliver outstanding performance.

The following integration options are possible:

- API to request a location RAIM prediction for any airport with specific RNP levels (departure, destination, destination alternates,...).
- API to request a trajectory RAIM prediction for any trajectory of a flight (main, alternates,...).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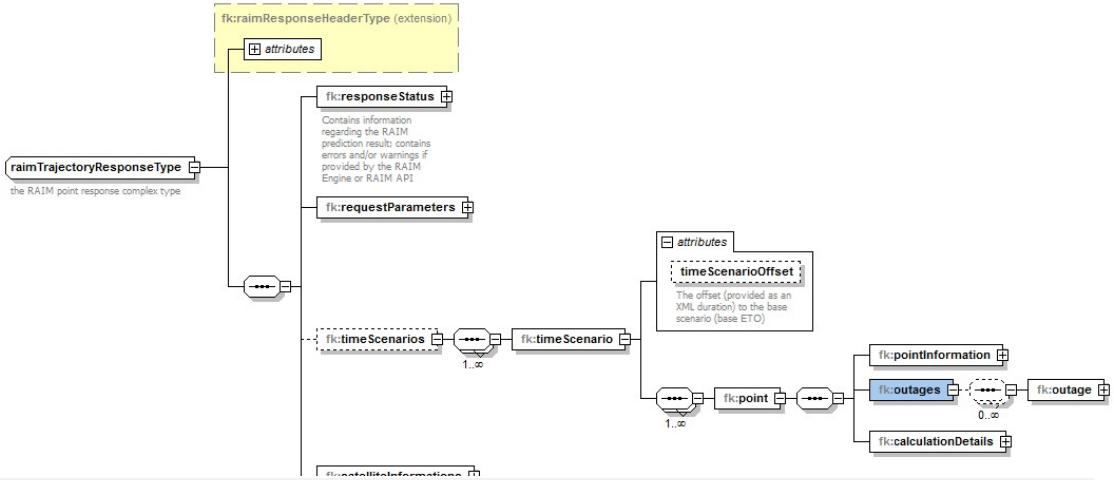
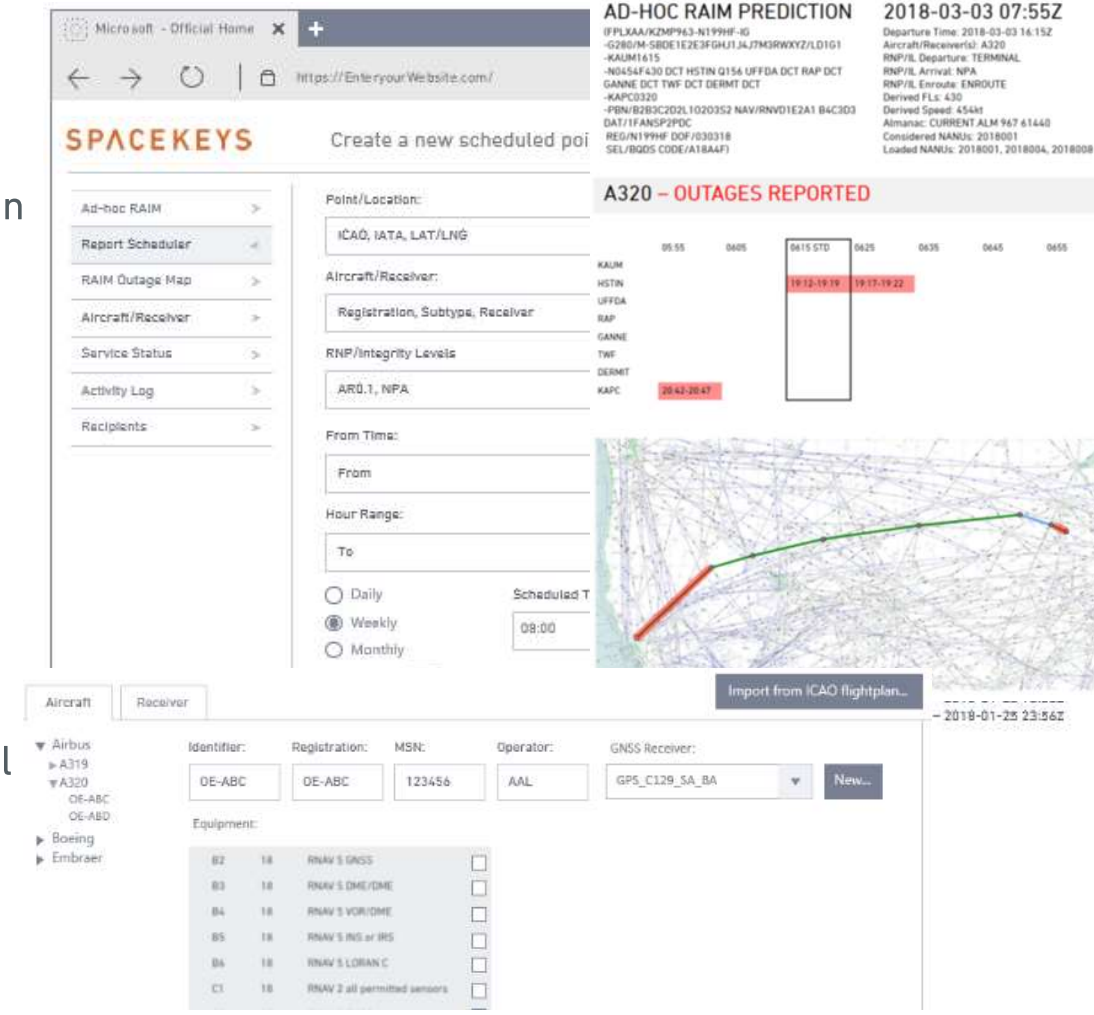


Web-Based User Interface

SPACEKEYS

A full suite of web tools to allow the user to perform RAIM predictions:

- Manual ad-hoc operations including ad-hoc location predictions or route predictions.
  - ICAO flightplan copy/paste.
  - Supported by an interactive map.
- Storing of ad-hoc predictions for future re-usage.
- Configure automated reports.
  - Providing the capability to set specific schedule parameters.
- Configure aircraft types, aircraft registrations and receivers.
- XML Flight Plan Import (e.g.: ARINC 633).
- Full Worldwide area map display (with navigational data overlay).
- Activity Log / RAIM Prediction History.
- Service Status Monitor.



[2] Utilizing the unique FLIGHTKEYS 5D dynamic aircraft parameter inheritance system

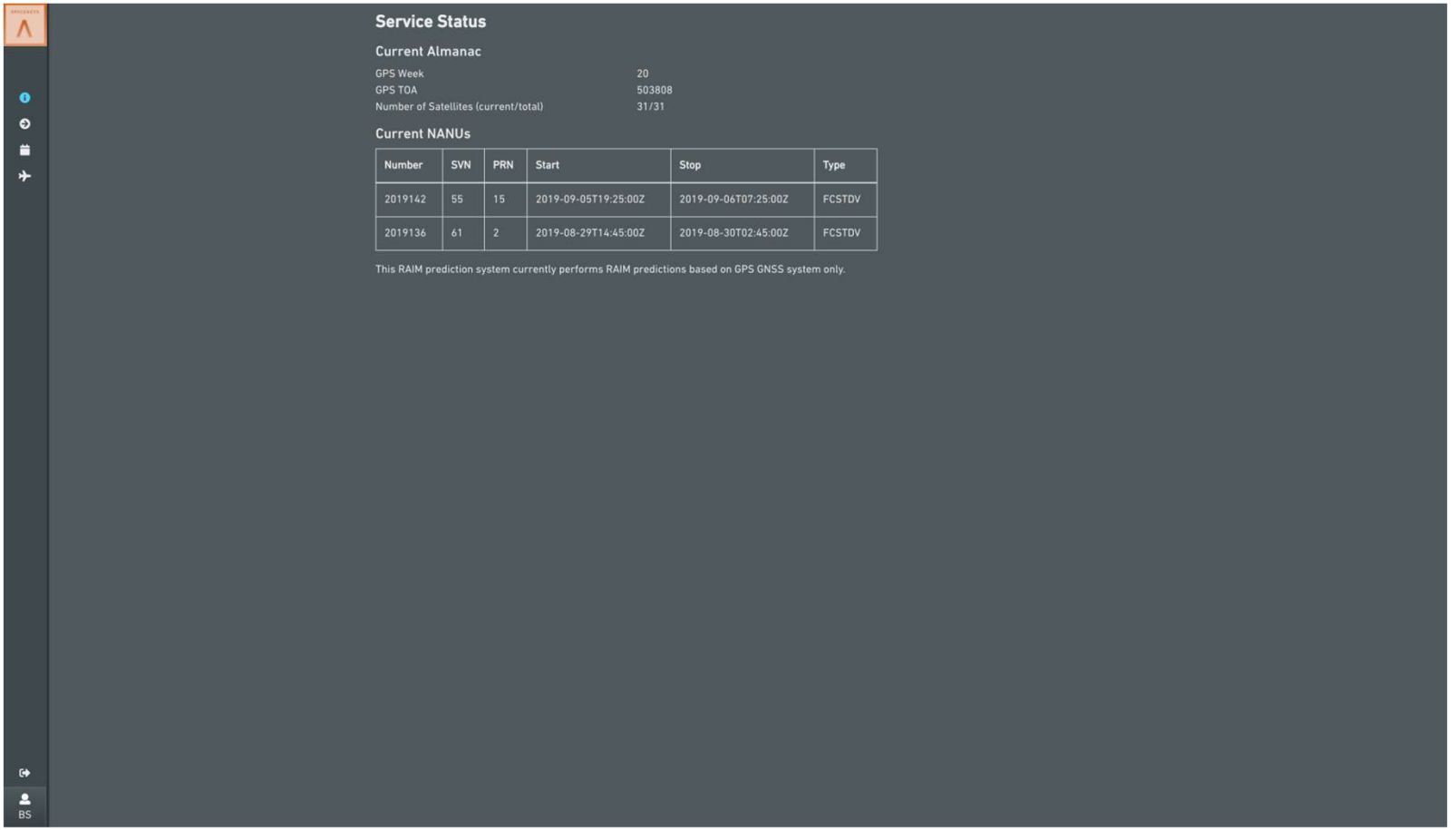
SPACEKEYS Tools

SPACEKEYS

- Constellation Service Status. 
- Ad-hoc Predictions. 
- Scheduled Predictions. 
- Receiver/Aircraft Settings. 

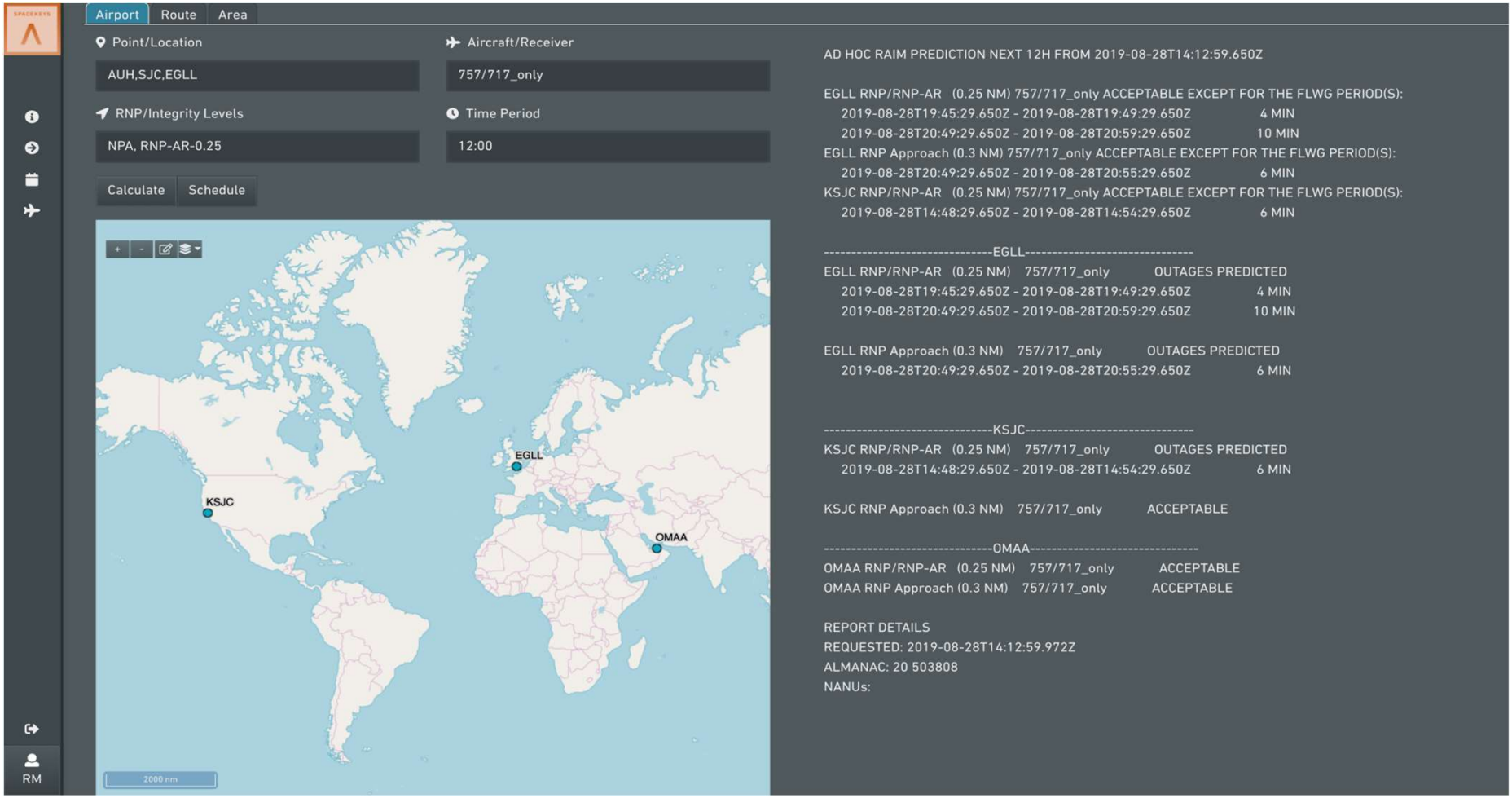
Constellation Service Status

SPACEKEYS



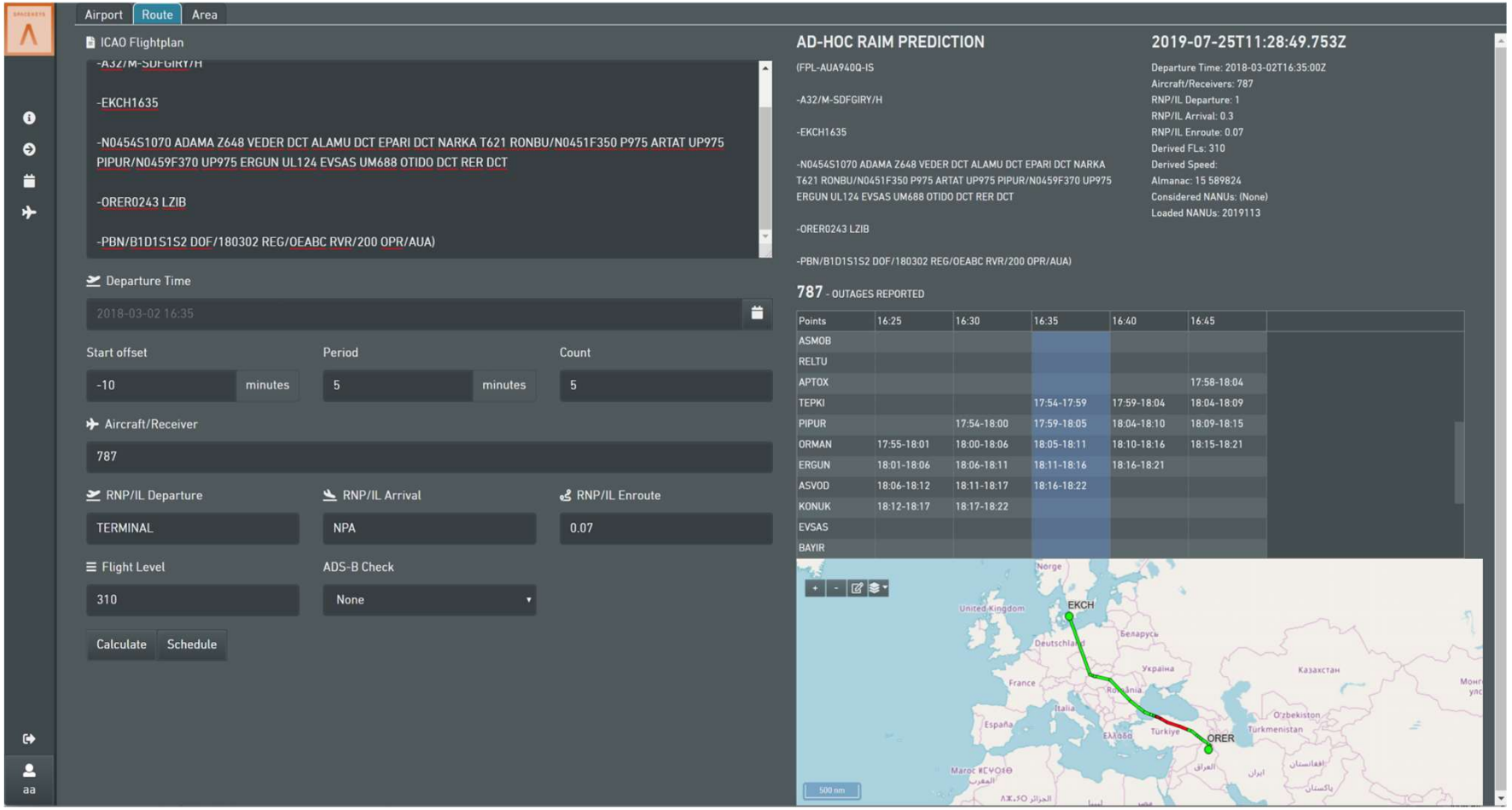
Ad-hoc Predictions - Airport

SPACEKEYS



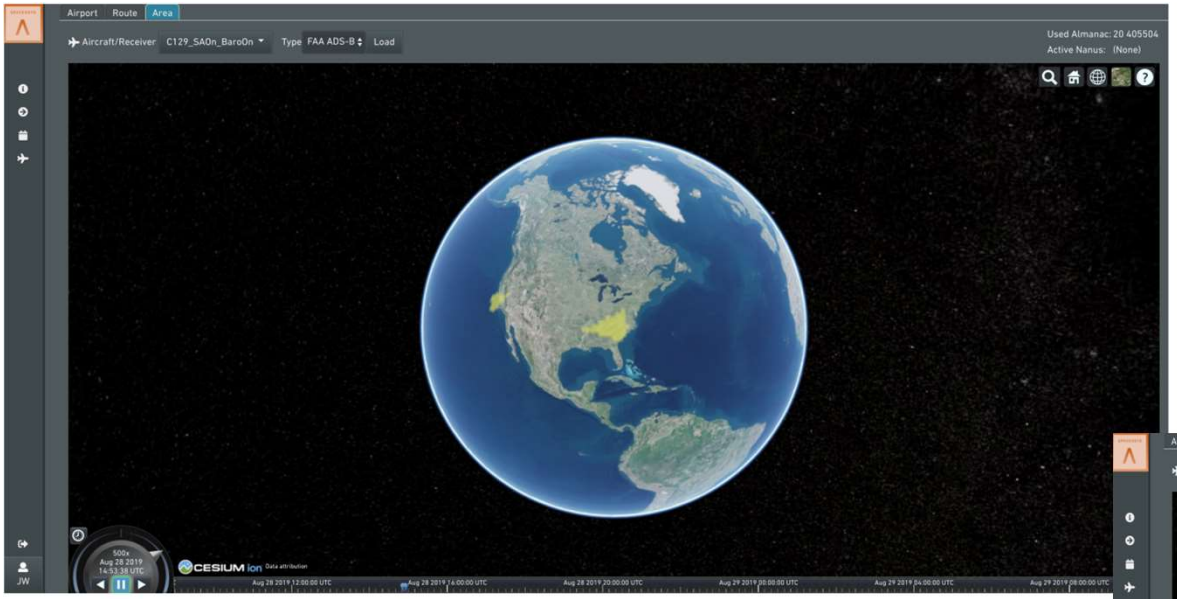
Ad-hoc Predictions - Route

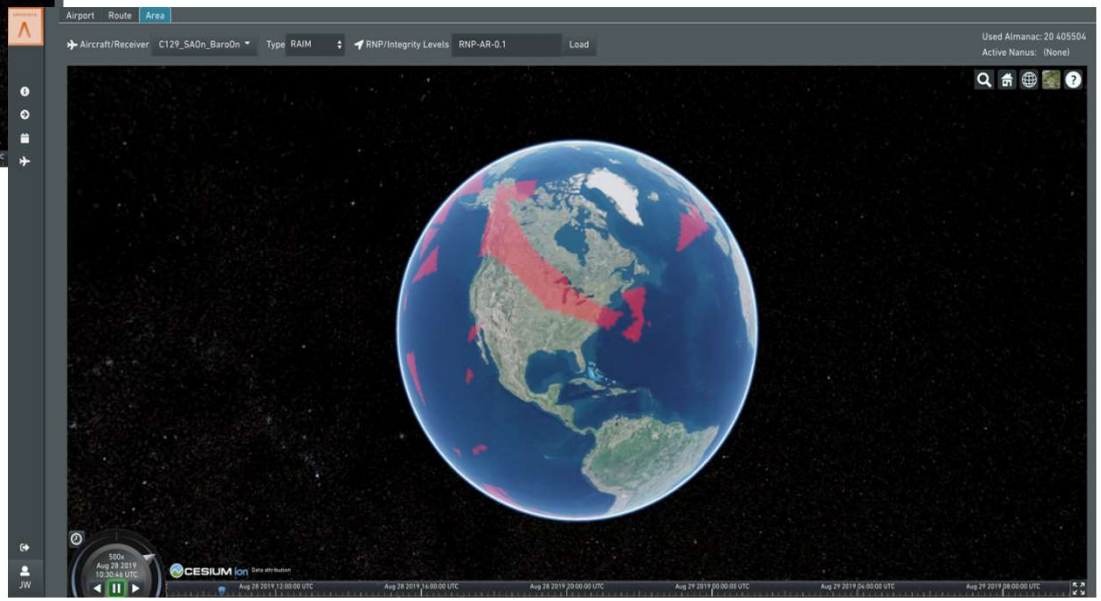
SPACEKEYS



Ad-hoc Predictions - Area

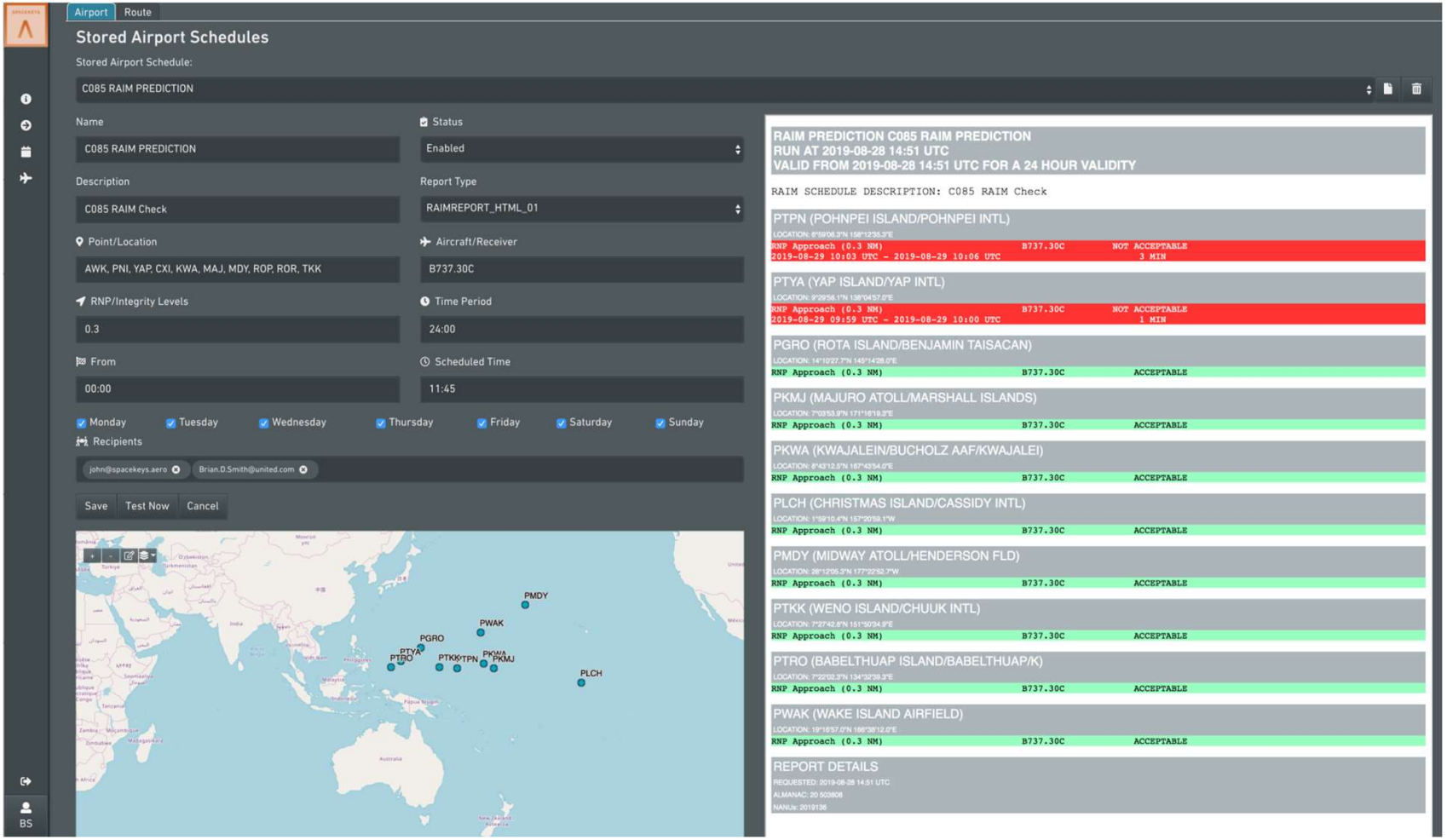
SPACEKEYS





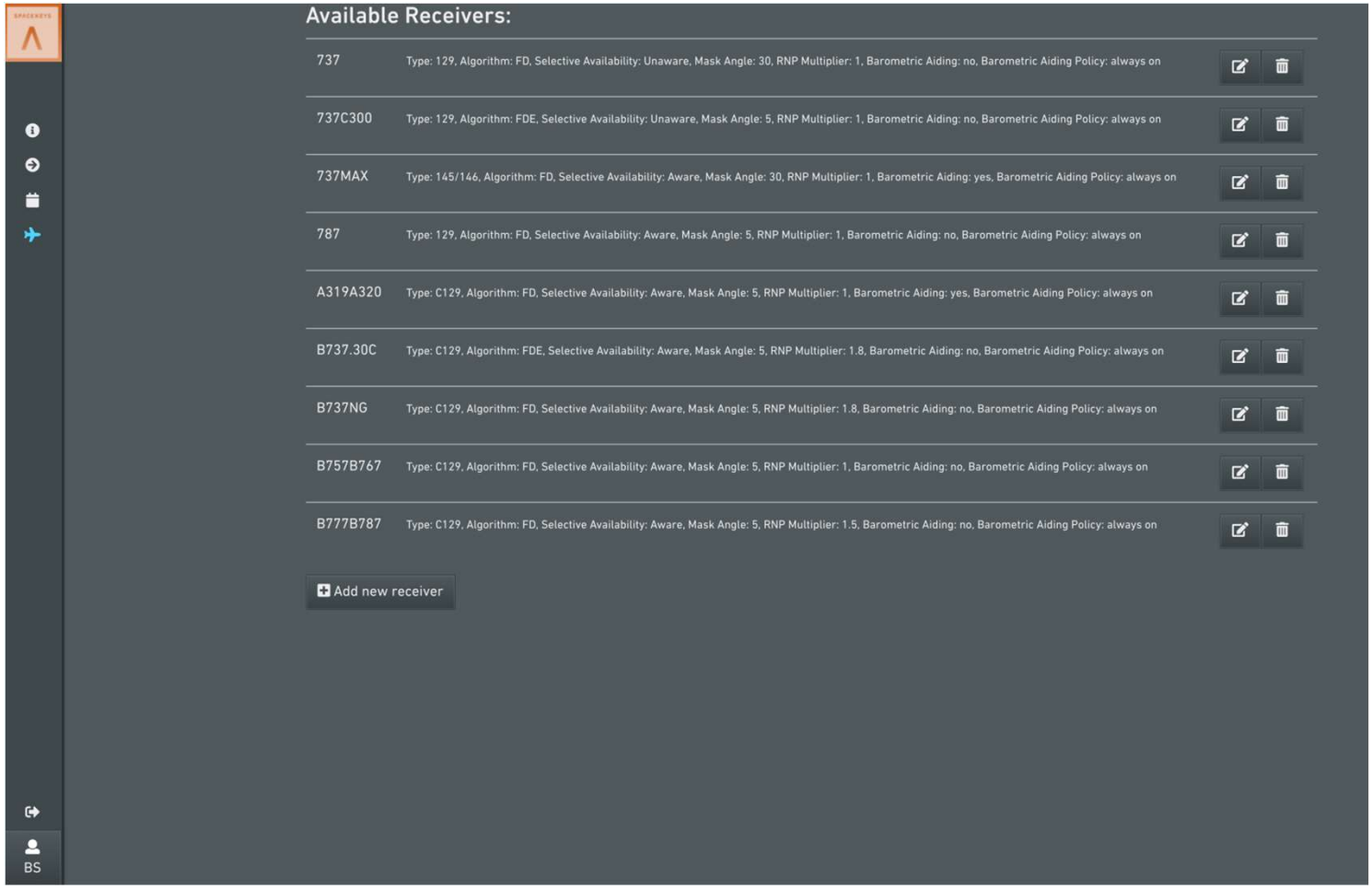
Scheduled Predictions

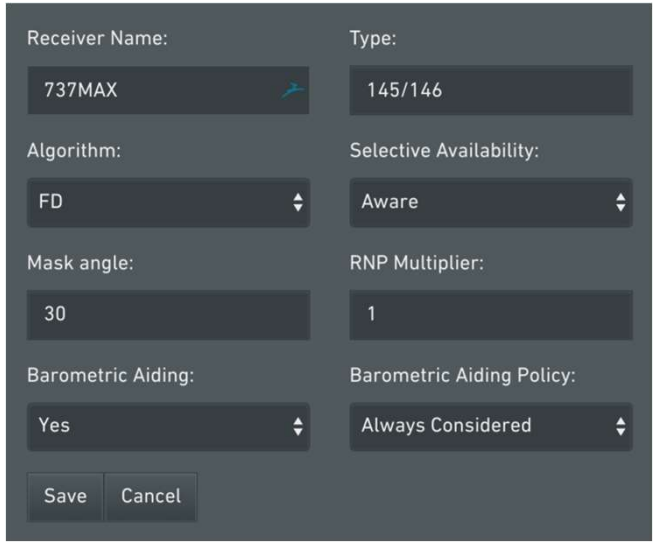
SPACEKEYS



Receiver/Aircraft Settings

SPACEKEYS





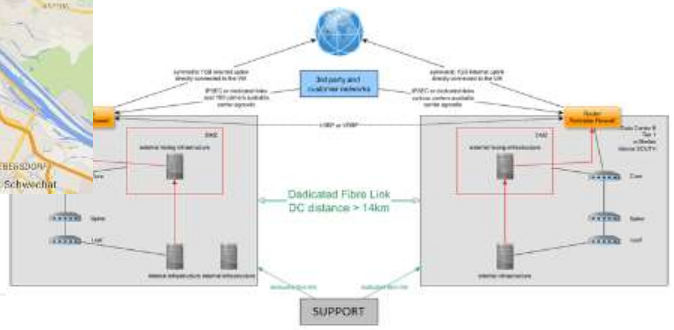
Architecture and SLA

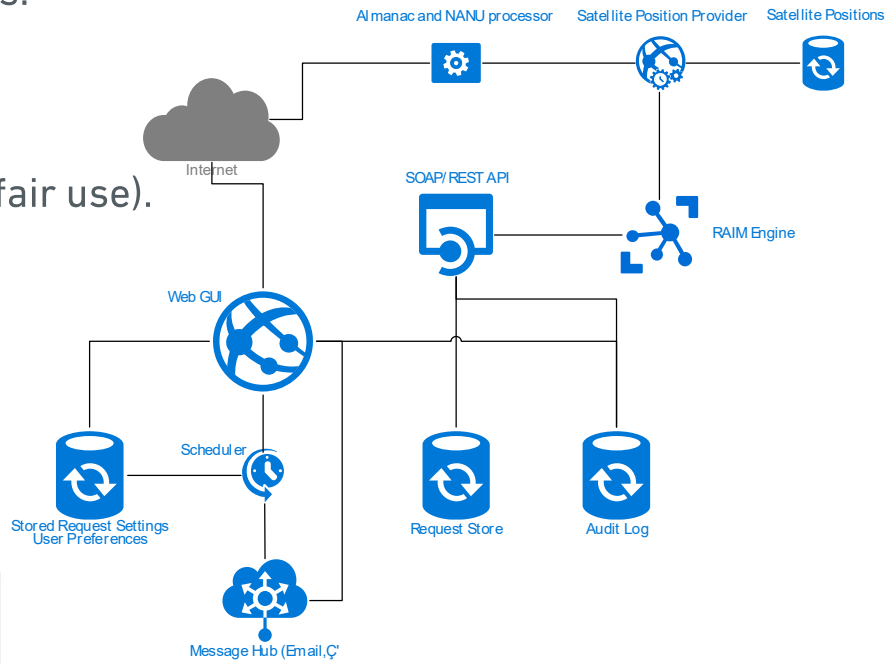
SPACEKEYS

The system architecture has been created using latest technologies with the main focus on stability, scalability and performance. Each component is resilient and deployed over multiple physical locations. Deployment in a commercial cloud provider's infrastructure (AWS, Azure,...) is supported out of the box.

Spacekeys guarantees the following Standard Service Levels:

- 99.95% system uptime.
- New Almanac Processing within 2 minutes.
- New NANU processing within 60 minutes.
- Average 500 requests per aircraft registration and day (fair use).
- 24/7 support.





Achievements – RAIM/ADS-B

SPACEKEYS

- NAVISP
  - Phase 1: RAIM - Design, implementation and validation/verification.
  - Phase 2: A-RAIM - Galileo and A-RAIM experimental test bed.

- SPACEKEYS Success
  - EUROCONTROL Augur. A cut down functional system to meet EUROCONTROL requirements. Created from Phase 1 success.

  - Airlines in Europe, US and Asia. British Airways, American Airlines, Virgin Atlantic, Delta Airlines, SouthWest Airlines, Volotea, ARINC Direct, SAS, Cathay Pacific, Brussels Airlines….
  - Two major Worldwide flight planning companies direct API integration.
  - Integration with two Flight Following systems.

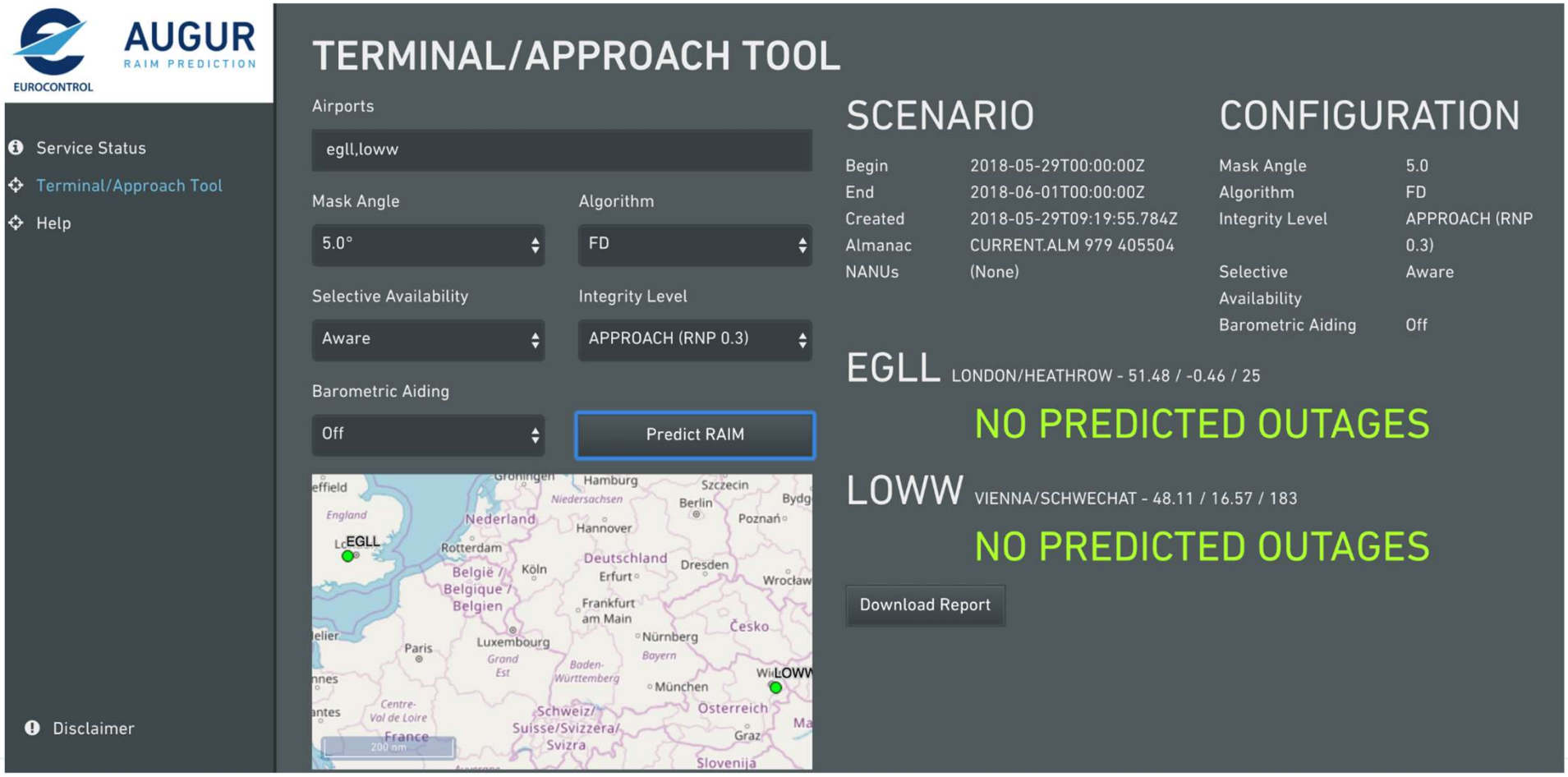
  - SPACEKEYS sit on US Congressional ADS-B review committee.

- A **case study** – Europe on October 16th 2018……..a major aviation GPS event never seen in 20 years.
  - One satellite out for maintenance.
  - Bad geometry – GPS outage for approach over most of Europe.

EUROCONTROL AUGUR - A SPACEKEYS Achievement

SPACEKEYS

augur.spacekeys.aero



SPACEKEYS NAVISP Phase 2 Project Activities

SPACEKEYS

- **Phase 2** – Addition of multi-GNSS (Galileo) and A-RAIM as an R&D project. Built on a solid Phase 1.
    - Requirements gathering (literature study).
    - System design.
        - Special care to be taken as phase 1 system went live during phase 2.
    - Implementation.
    - Algorithmic testing.
    - Integration.
    - Integration testing.


THANK YOU!
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john@spacekeys.aero