Dedicated to innovation in aerospace

R&D satellite navigation

Royal NLR - Netherlands Aerospace Centre

Developing applicable space innovations for society

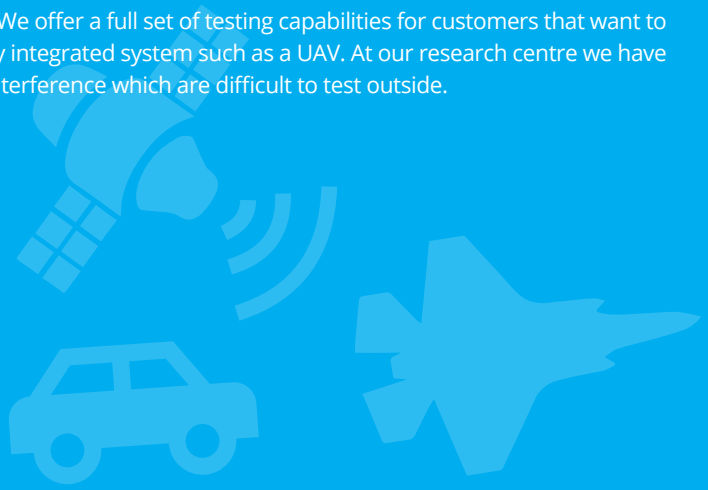
Royal NLR works closely with both industry and government on the effective use of earth observation and satellite navigation data for both civil and military use. We also offer unique capabilities to develop satellite, payload and launcher systems and subsystems, such as thermal control systems, electronics and antennas. We also support organizations in the area of aerospace qualified light-weight composite structures and multi-metal additive manufacturing.
As an independent R&D centre for aerospace we are known for our practical approach and innovative solutions. Based on our expertise combined with facilities we can support companies and government in the whole development chain from concept development to prototype and small series production. We develop hardware from sensors to launcher components, up to software and information products derived from multiple source data. For these developments NLR has a wide range of test facilities available with which we can test, verify and validate products. This includes a satellite navigation laboratory, (zero- and low-gravity) flight testing, environmental and structural testing and also wind tunnel testing,

We have selected a number of satellite navigation projects to give you an impression of our research and activities related to satellite navigation. We hope you will enjoy reading about our research and invite you to contact us for more information.

Michel Peters, CEO
Royal Netherlands Aerospace Centre

Satellite navigation

In the area of satellite navigation NLR focuses on the development and testing of robust positioning, navigation and timing (PNT) solutions. Our research ranges from detection and mitigation of GNSS interference, to testing of robust positioning solutions for mobility applications such as drones. Besides downstream applications, we also perform direct measurements of the GNSS signals coming directly from the satellites, to assess their quality and performance. Through our research and developments we help organisations to detect and protect against vulnerabilities of GNSS systems. We support the development of more reliable and robust GNSS antenna's and receivers and develop methods to set up more reliable GNSS end- to -end systems. We offer a full set of testing capabilities for customers that want to test the performance of a GNSS receiver, a navigation system or a fully integrated system such as a UAV. At our research centre we have the capability to simulate all kinds of signals, including spoofing and interference which are difficult to test outside.



GalilEo Authenticated Robust timing System - GEARS

Precise time is crucial to a great variety of economic activities around the world. Communication systems, electric power grids, and financial networks all rely on accurate and reliable timing for synchronisation and operational efficiency. The timing services supplied by GNSS (Global Navigation Satellite System) are an increasingly important part of modern infrastructure. The EU strives to improve and increase the robustness of critical infrastructures by increasing the resistance and resilience of timing and synchronisation (T&S) services. In particular, Galileo is the first GNSS that will provide an authentication function to civil users through the Open Service Navigation Message Authentication (OS-NMA) that will come into operation soon. The GEARS project aims at providing a Galileo-based timing receiver with increased robustness for Critical Infrastructures.

THE CHALLENGE

- The key objectives of the GEARS project:
- Improve performance and resilience of a Galileo and GNSS timing receiver
- Develop and demonstrate the effectiveness of unique Galileo services to operators
- Strengthen market adoption through standardisation activities.

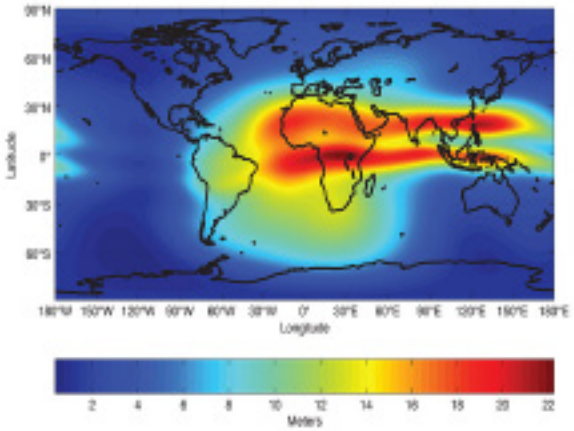
WHAT WE DO

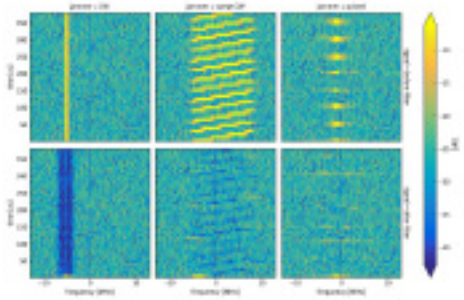
- Design and implementation of RF Interference Detection and Mitigation (IDM) module (interference filtering in time and frequency domain)
- Design and implementation of an anti-jamming antenna (interference filtering in the spatial domain)
- Design and implementation of a ionospheric correction module (including NeQuick G algorithm)

THE SOLUTION

The main focus of the project was the on the implementation of a range of technologies (Multi-Frequency, Multi-Constellation, OS-NMA, RF interference detection and mitigation, T-RAIM, etc.) for improving the accuracy, reliability and robustness of the GEARS timing receiver.

The GEARS project is funded by the European Union Agency for the Space Programme (EUSPA).





Research organisations : Royal NLR, NLS-FGI (Finland) Industry/SME: Orolia (France) (lead), FDC (France), NavCert (Germany) .

Start: July 2019
Duration: 2.5 years

Advanced Receiver Autonomous Integrity Monitoring - ARAIMTOO

Advanced Receiver Autonomous Integrity Monitoring (ARAIM) is a recent evolution of the currently used aviation focussed GNSS integrity algorithm, Receiver Autonomous Integrity Monitoring (RAIM). Both the RAIM and the ARAIM concepts were designed to serve the aviation community and civil aviation authorities. Within this project the possibility and advantages of using the ARAIM concept for other sectors was investigated. Royal NLR focused on the UAV application.

THE CHALLENGE

For many applications the use of standalone GNSS does not give high enough integrity values to perform all operations. Within this research it was investigated to understand if ARAIM can be evolved to ensure operation that cannot be performed with a standalone GNSS device, such as in the case of unmanned urban mobility by UAV's.

WHAT DID WE DO

To analyse the applicability of the current ARAIM algorithm for the other sectors and to understand the evolution to be made to the algorithm multiple steps have been taken

Analysis of the user sector needs in terms of GNSS key performance indicator Identification and prioritisation of technologies which could give an added value to ARAIM and could be combined to design a suitable Position Navigation and Time (PNT) concept for the sector Gap analysis to identify areas of improvement of ARAIM for the adaptation of this concept to the UAV sector Definition of a suitable PNT concept containing ARAIM evolutions and the other technologies. Analysing the proposed PNT concept by a dedicated experimentation using software implementations. Verification of the integrity provided with the ARAIM evolution with flight trials in urban environment.

THE SOLUTION

ARAIM is a promising integrity technique which could provide an added value and meet the stringent user requirements of the UAV sector. In this research it is shown that a combination of Precise Point Positioning (PPP) techniques with an adaption of ARAIM plus the hybridisation with IMU could allow to cope with environments typical of urban areas and the stringent accuracy and integrity requirements of UAVs in urban environments. The new Galileo High Accuracy Service (HAS) could be used to provide the user with such PPP corrections.

ARAIMTOO is a European Commission funded project

Client: DEFIS (Directorate-General for Defence Industry and Space)
Partners: GMV, VVA and NLR

Start: July 2021
Duration: 1 year

Project research infra:
GMV, NLR, FGI, Axentec, GMV NSL, Enaire

Aviation resilience to GNSS frequency jamming and cyber threats - AIRING

The AIRING project has investigated the increased risk of interference and spoofing for aviation, and the technical ways it can be detected or mitigated. A concept was proposed to combine technology and operational procedures, in such a way that GNSS interference can be detected and dealt with in an effective and safe way.

THE CHALLENGE

The increasing use of GNSS in civil aviation (Performance Based Navigation) also increases the risk of flights being affected by GNSS interference. When moving toward GNSS-based navigation solutions, detection and mitigation of such interference becomes critical. The project aims to present a set of technologies to be applied, as well as a roadmap how to integrate them into current rules and operational standards.

WHAT DID WE DO

NLR has investigated the use of a controlled radiation pattern antenna for civil aviation. The complex, multi-element antenna enables both detection and mitigation of GNSS interference and spoofing. The impact of AIRING technologies on ATC operations was investigated in an operational demo with the tower (NARSIM) and cockpit (APERO) simulators, to show that the concept can reduce the operator workload and increase safety

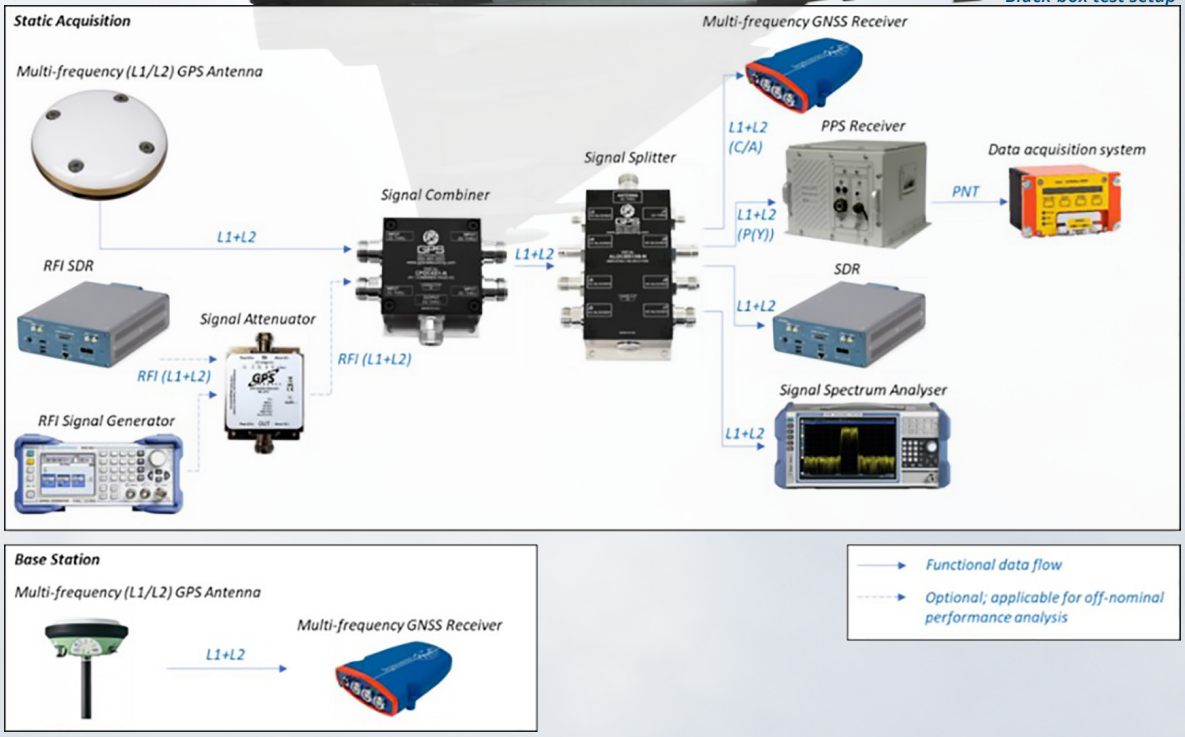
THE SOLUTION

A wide range of technological solutions for interference detection and mitigation was investigated, ranging from simple and readily available filtering techniques to complex, new antennas that cannot (yet) be applied on civil aircraft. The technologies are integrated in a detection and reporting concept. An operational concept is proposed to integrate the solution into current ATC practice.

Project partners
Eurocontrol

Start : 2021 - 2022

Black-box test setup



Compliance of GNSS receivers used in military aircraft - COMSTAC

Performance-based navigation (PBN) is being introduced in Europe. Military Aircraft must be compliant to be allowed to fly in civil PBN airspace. However, most military GPS-PPS receivers are not certified for this use. An methodology is defined to qualify and certify military GPS PPS receivers.

THE CHALLENGE

Define an alternative method to show that GPS-PPS receivers can provide navigation data compliant with PBN requirements.

The method must allow states to approve and certify military aircraft to comply with PBN requirements, safeguarding civil-military interoperability.

WHAT DID WE DO

The methodology was defined based on:

- Determination of technical requirements
- Gap analysis between requirements and GPS PPS receiver
- Definition of a new compliance method based on black box testing
- Example demonstration on the Eurofighter Typhoon aircraft

THE SOLUTION

A new methodology is demonstrated based on extreme value theory and black-box testing.

- Black box testing with only 3 month of data collection
- Changes to the aircraft under test are not required
- Technical performance requirements are derived from the PBN regulations
- The safety levels for compliance are equal to or better than the PBN safety requirements
- Alternative compliance allows optimal use of airspace, strategic de-confliction of flight paths and reduction of ATC intervention

Project partners
Research organisations: ESA, NLR, ASTRON

Start: December 2014
Duration: 1.5 years

The LOFAR 'superterp'. This is part of the core of the extended telescope located near Exloo, Netherlands. Photo credits: LOFAR / ASTRON

Measuring the ionosphere using the LOFAR radio-telescope and Galileo satellite navigation receivers

THE CHALLENGE

Europe is developing its own satellite navigation constellation Galileo. The European Space Agency (ESA) has asked industry and research organisations to come up with novel ways to improve satellite navigation technology, or to apply it in different fields of science.

The ionosphere disturbs radio signals, causing significant disturbances in satellite navigation as well as in astronomy. In this project we have investigated if the LOFAR radio telescope operated by ASTRON can measure the ionosphere accurately enough to improve satellite navigation. At the same time we investigate if satellite navigation receivers can measure the ionospheric disturbance, to help LOFAR creating sharper images of the radio sky.

WHAT DID WE DO

LOFAR is a huge distributed radio telescope, spread of several countries in Europe. NLR and ASTRON have installed a Galileo GNSS receiver at 2 LOFAR stations in the Netherlands to perform parallel observations. The GNSS receivers observed a passing Galileo satellite, while LOFAR at the same time observed known radio sources in the same direction.

By comparing the measurements, the quality of the ionosphere measurements from each instrument was determined.

To achieve this result, a new measurement approach had to be made for the LOFAR telescope, dynamically measuring several sources along the path of a passing Galileo satellite.

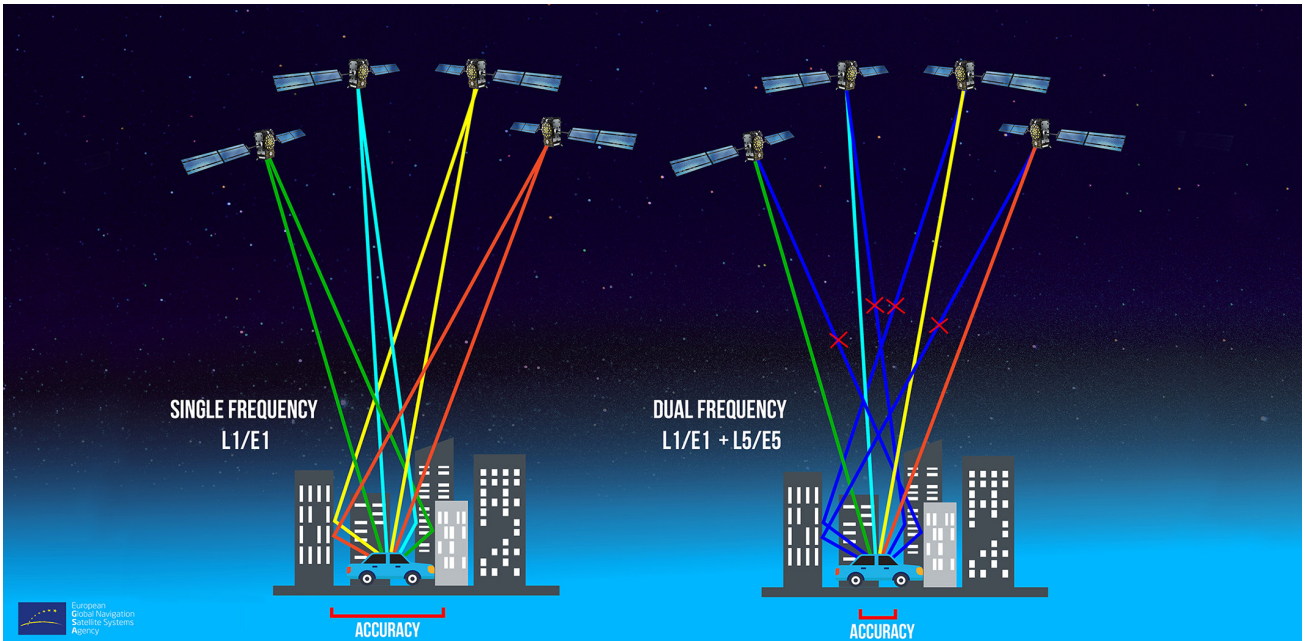
THE SOLUTION

The study has delivered several very interesting results:

- A new measurement mode for the LOFAR telescope
- Better understanding of the biases and relative measurements of Ionospheric TEC
- Calibration of LOFAR imagery using affordable GNSS receivers, which can be expanded to improve the LOFAR telescope
- A method to create (relative) ionospheric maps with high accuracy using LOFAR. These maps can be used for more accurate GNSS navigation.

Satellite navigation for vital infrastructure and business opportunities

NLR is closely involved in the research and activities relating to satellite navigation and Galileo, the European satellite navigation system. NLR has a rich history of accumulating knowledge relating to satellite navigation and has been involved in the development of GPS, EGNOS and Galileo. Now that the Galileo system is online, the focus is has shifted from development to testing, verification and monitoring. NLR is studying the risks, vulnerabilities and performance of receivers, as well as detecting interference. What are the properties of such interference and how can it be counteracted? What special antenna technology or what special algorithms must be used in the receivers for detecting and filtering out interference? NLR has an understanding of the Galileo system, the signals and navigation messages, the ground-based systems and the typical characteristics of interfering signals.



Source: GSA

NLR provides assistance and advice for the Ministry of Infrastructure and Water Management, the Ministry of Defence, the police, the Directorate-General for Public Works and Water Management, Air Traffic Control the Netherlands (LVNL) and others about the use of GPS, EGNOS and Galileo. The purpose of this advice is protecting the vital infrastructure, for example when integrating GPS or Galileo into existing applications. A multidisciplinary approach is used for gathering knowledge and combining it from the various activities of the NLR and the initiatives in which it takes part. A few examples:

JAMMING/SPOOFING

GNSS is being used in more and more daily and vital applications. Besides, users rely more on their (GNSS) technology and become more dependent on them. However, GNSS signals are very faint and therefore 'easily' to overrule (jamming) or to replicate (spoofing). The NLR is working on jamming/spoofing detection and different mitigation techniques. Techniques within the antenna, in the receiver or during processing in combination with other sensors are being assessed. As jamming/spoofing tests are not always possible (jamming and spoofing is illegal), the NLR owns a commercial GNSS simulator to simulate constellations, jamming and spoofing. In this way it is easy to perform jamming and spoofing tests.

UNMANNED SYSTEMS IN AVIATION AND THE DRONE WORLD

For unmanned aerial system, the NLR focuses on obtaining a robust PNT solution. In several situation, the PNT solution obtained with GNSS is not accurate or reliable enough for unmanned air systems. For example this can happen in an urban environments (multipath, loss of line-of-sight) or when a GNSS constellation degrades due to interference or a system error. To improve the accuracy of GNSS PNT solutions, the NLR is conducting research into RTK and PPP processing.

The NLR is also investigating alternative navigation solutions and (software) systems which improve the robustness of the PNT solution. Such as sensor fusion and SLAM (Simultaneous Localization and Mapping). It is important to observe the integrity of the system in this regard.

TEST ACTIVITIES

In addition to the public signals, which anyone can receive, there are also secure signals. GPS includes military codes, a specific system for defence. These encrypted signals are difficult to replicate. Galileo Public Regulated Service (PRS), Galileo's encrypted navigation service, was developed in principle for the public sector or for civilian purposes: the police, emergency services such as fire brigades, and vital infrastructure items. Royal NLR is participating in different tests for both the military GPS codes and PRS.

EGNSS CENTRE OF EXCELLENCE

The EGNSS Centre of Excellence is a cooperation between NLR, CGI and S[&]T. Together the companies provide a one-stop shop for GNSS-related issues and services. The focus of the CoE is on the mobility sector and safety critical GNSS applications.

Royal NLR in brief

One-stop-shop	Global player with Dutch roots	100+ Since 1919	Amsterdam, Marknesse Rotterdam, Noordwijk, Brussel
Innovative, involved and practical	For industry and governmental	For civil and defence	725 staff
€ 100 M turnover	69% Dutch, 24% EU and 7% worldwide	Active in 29+ countries	Extremely high customer satisfaction

About NLR

NLR is a leading international research centre for aerospace. Its mission is to make air transport safer, more efficient, more effective and more sustainable. Bolstered by its multidisciplinary expertise and unrivalled research facilities, NLR provides innovative and comprehensive solutions to the complex challenges of the aerospace sector.

NLR's activities span the full spectrum of Research, Development, Testing & Evaluation (RDT & E). Given NLR's specialist knowledge and state-of-the-art facilities, companies turn to NLR for validation, verification, qualification, simulation and evaluation. They also turn to NLR because of its deep engagement with the challenges facing our clients. In this way, NLR bridges the gap between research and practical applications, while working for both government and industry at home and abroad.

NLR stands for practical and innovative solutions, technical expertise and a long-term design vision, regarding their fixed wing aircraft, helicopter, drones and space exploration projects. This allows NLR's cutting-edge technology to find its way also into successful aerospace programmes of OEMs like Airbus, Boeing and Embraer.

As an independent R&D centre for aerospace, NLR- Royal Netherlands Aerospace Centre is known for its practical approach and innovative solutions. NLR is the connecting link between science, industry and government. Based on our expertise combined with facilities we can support companies and government in the whole development chain from concept development to prototype and small series production.

Royal NLR makes aerospace more sustainable, safer, more efficient and more effective. The innovative solutions and practical advice strengthen the competitiveness of the business community and contribute to solutions for social issues. NLR works in an objective manner, for and with the (inter) national business community and government agencies.

For more information:
May Kerstens
may.kerstens@nlr.nl

Hein Zelle
hein.zelle@nlr.nl

Merle Snijders
merle.snijders@nlr.nl

NLR Amsterdam
Anthony Fokkerweg 2
1059 CM Amsterdam
The Netherlands
p) +31 88 511 3113
e) info@nlr.nl i) www.nlr.org

NLR Marknesse
Voorsterweg 31
8316 PR Marknesse
The Netherlands
p) +31 88 511 4444