Dedicated to innovation in aerospace

Space R&D for society

Royal NLR - Netherlands Aerospace Centre

NLR can support you in the following areas

SPACE APPLICATIONS

- Satellite navigation
- Earth observation
- Cyber security assessment
- Space Situational Awareness

SATELLITES & LAUNCHERS

- Concept development
- Space avionics
- Antennas
- Thermal control
- Structures and materials

SERVICES

- AR / VR expertise
- Electromagnetic compatibility expertise
- Prototyping
- Low gravity flights
- Testing & qualification

Developing applicable space innovations for society

Royal NLR works closely with both industry and government on developing satellite, payloads an launchers systems and subsystems, such as thermal control systems, electronics and antennas. We also offer unique capabilities in the area of aerospace qualified light-weight composite structures and multi-metal additive manufacturing, and on the effective use of earth observation and satellite navigation data for both **civil** and **military** use.

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 environmental and structural testing and also wind tunnel testing, up to (zero- and low-gravity) flight testing.

This booklet gives an overview of the broad spectrum of the knowledge, capabilities and facilities that Royal NLR is applying in the research projects and programs in the Netherlands and worldwide. We hope you will enjoy reading about our research and welcome you to contact us for more information.

Michel Peters, CEO
Royal Netherlands Aerospace Centre

NLR supports developments on the **effective use of space data and on solutions** to generate reliable and robust systems that use these data. We develop methods to automatically convert earth observation data into information products and services for example to detect events, like ship movements. In the area of satellite navigation NLR focuses on the development of **robust positioning, navigation and timing (PNT) solutions** including mitigation methods for interference for mobility applications such as drones.

NLR has the ambition to **support small satellites integrators and government** to design safe and secure space systems. For this we do research on (automated) **cyber security solutions for small space systems.**

As space gets more and more congested the need for a **traffic management system for space (STM)** is growing and also systems to accurately monitor the space domain and alarm systems to prevent collisions. NLR wants contribute to these solutions as safe use of the space domain is essential for the future. NLR is working on concepts for a SSA tool with an automated alarm system and exploring options for future STM concepts.

Space applications

Satellite navigation
Earth observation
Cyber security assessment
Space Situation Awareness

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.

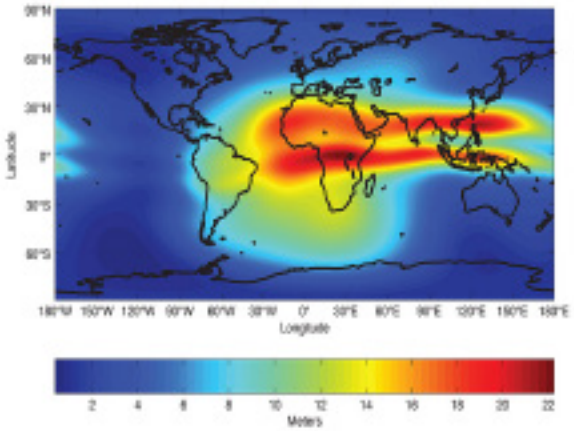
WHAT WE DO

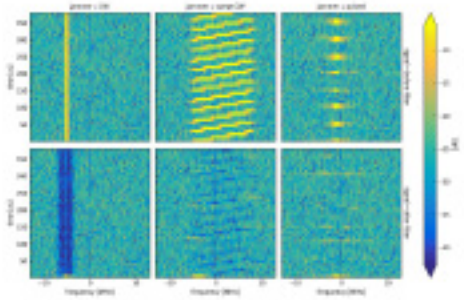
- Design and implementation of RF Interference Detection and Mitigation (IDM) module (interference filtering in time and frequency domain)
- Design and implementation of an anti-jamming antenna (interference filtering in the spatial domain)
- Design and implementation of a ionospheric correction module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

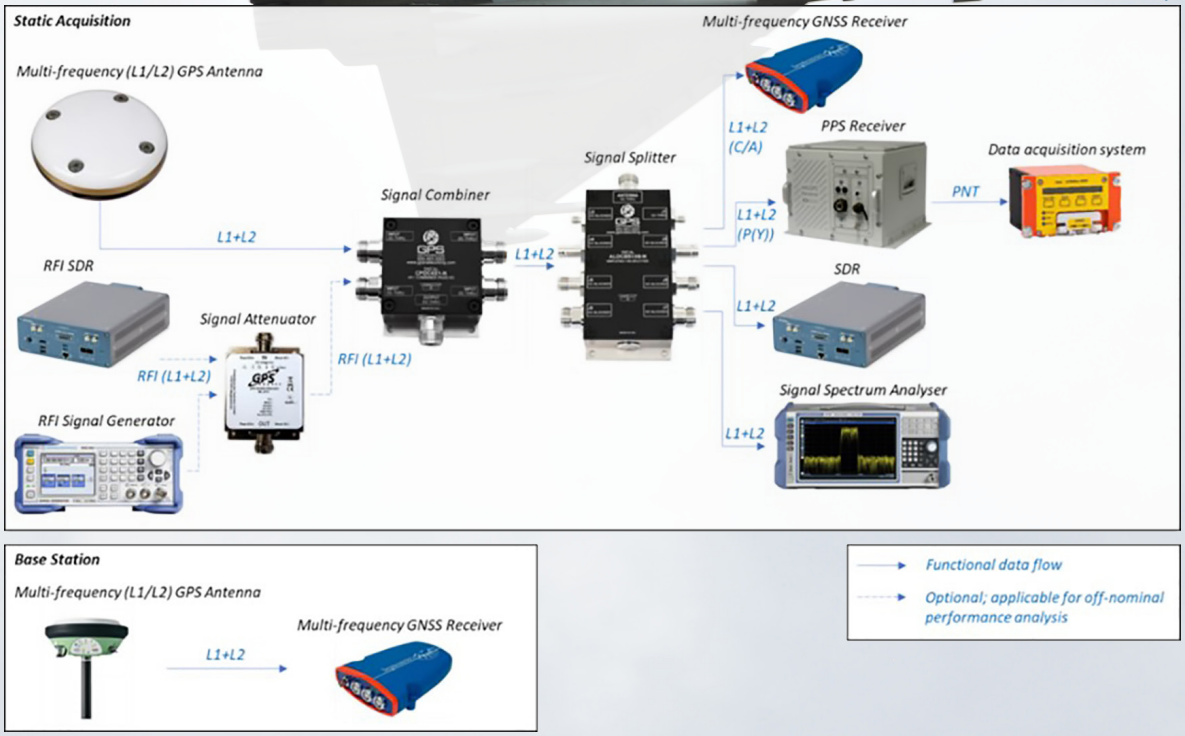
Client: DEFIS (Directorate-General for Defence Industry and Space)
Partners: GMV, VVA and NLR

Start: July 2021
Duration: 1 year

Project 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.

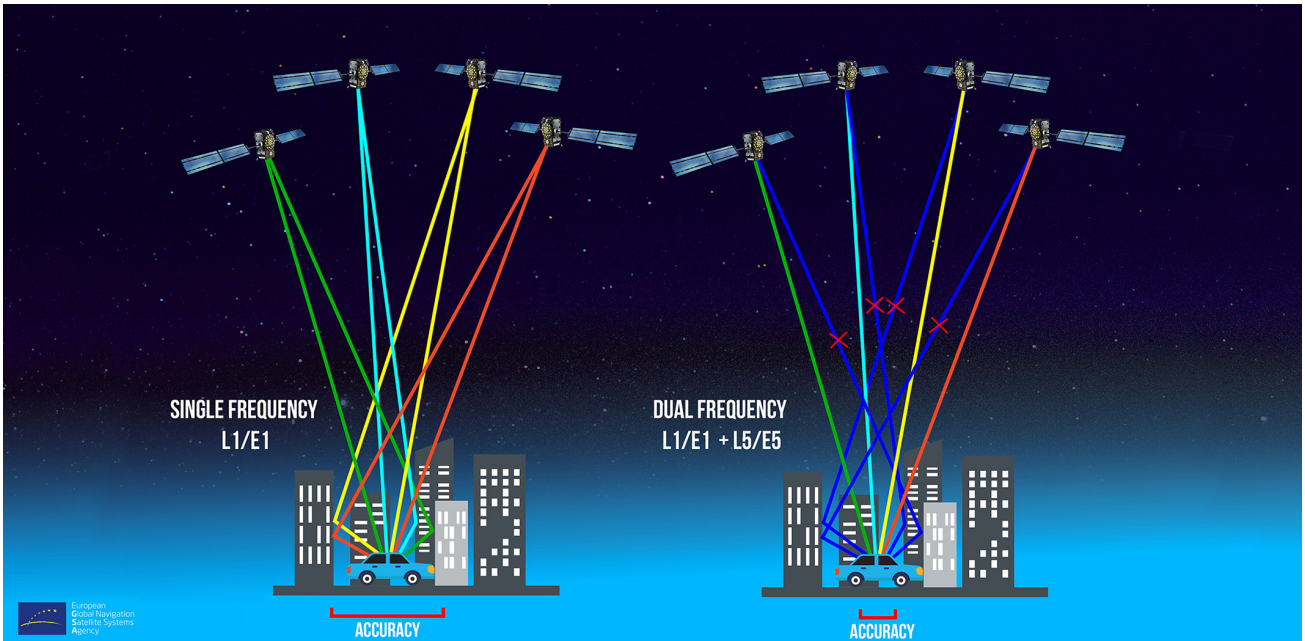
THE SOLUTION

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.

Space ISR

Focus and Impact

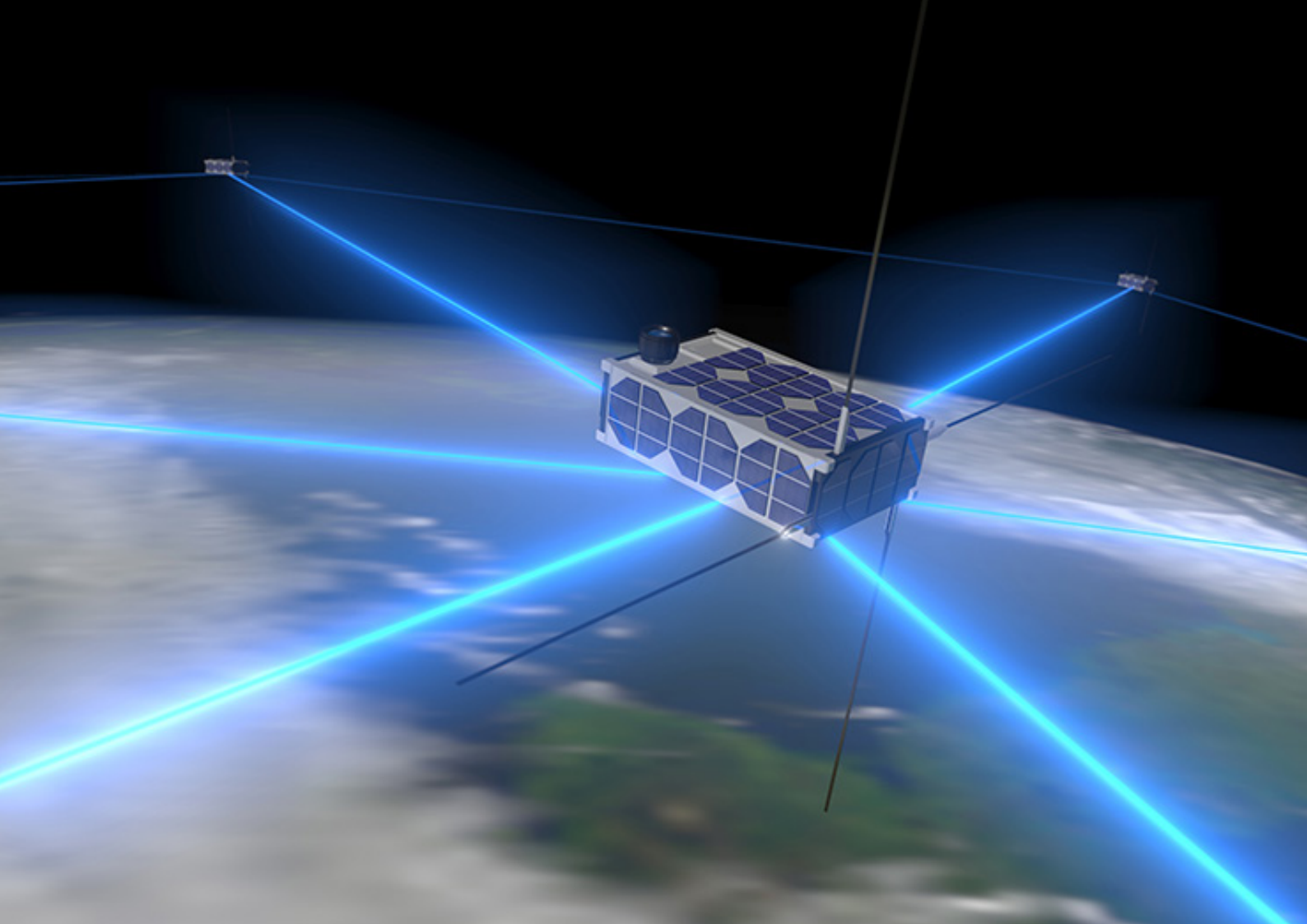
NATO already underlined the importance of the usage of Space at the end of 2019 in declaring Space as an operational domain. The Dutch Ministry of Defense recognizes the usage of space as an indispensable link within an information-driven Armed Forces. NLR has supported the RNLAF in the design and development of the nanosatellite 'BRIK-II'. This nanosatellite will provide the RNLAF with intelligence regarding navigation, communication and earth observation.

Applications and Capabilities

- Supporting military exercises using small, easy-to-launch space infrastructure
- Autonomous translation of operational satellite data to triggers for intel operations
- Thermal control systems
- Low to zero gravity flight testing
- Payload miniaturization

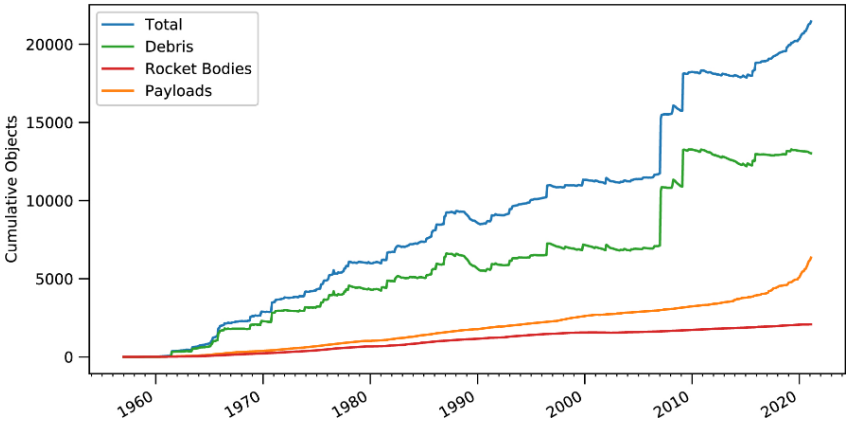
Projects and Partnerships

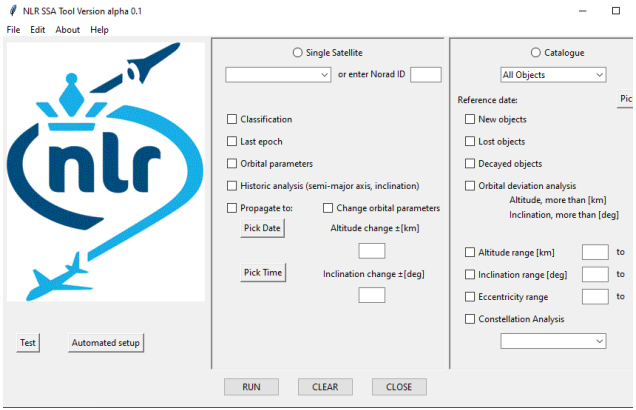
- BRIK-II (MoD, ISIS Space, TU Delft)
- Responsive Space Capabilities (MoU Netherlands & Norway)

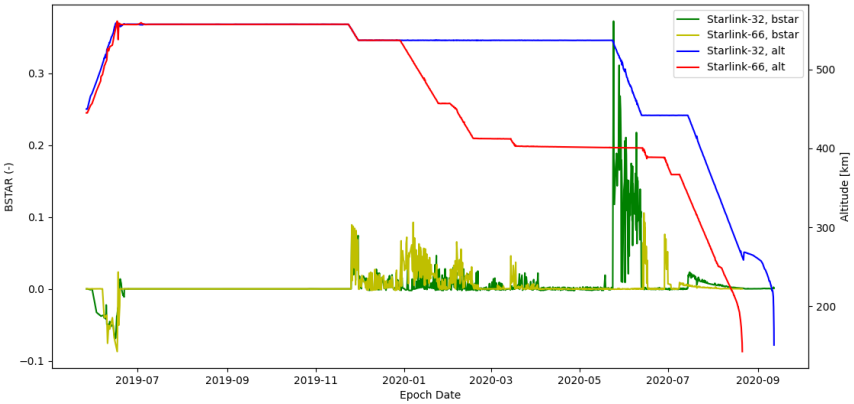


Project partners
Dutch Ministry of Defense - Space Contour 2019

Start: 2019
Duration: 4 years







Space Situational Awareness for safe and sustainable use of space

Currently, approximately 27,000 objects are being tracked to allow predictions to avoid collisions between satellites and debris. Forecasts indicate this number will increase exponentially over the next few years. To ensure a safe and sustainable space environment, it is vital to understand the orbital mechanics and growth in space usage and orbit selections to facilitate continued operations. In this way, by performing characterisations and trend analyses, it is possible to continue space exploration and utilise space as a nation.

THE CHALLENGE

To get an overview of the space objects orbiting the Earth and their characteristics and behaviour, the following questions need to be answered:

1. Which sources of data are available for this overview?
2. What kind of data is available in these sources?
3. What kind of characteristics can be deduced from this data?
4. Is it possible to identify capabilities?
5. Is there a trend analysis possible to obtain more insight?

WHAT DID WE DO

To address these questions, NLR is developing a Space Situational Awareness (SSA) tool. This tool is set up in such a way that databases and other sources of information can be combined and verified. With this data, details concerning the space objects such as last observation and number of new or decayed objects will be available. With this tool, a user is able to specify the required information and monitor specific space objects either on request or scheduled. This allows a more detailed insight in satellite (recurring) activities and influences on the orbital tracks, which could have an operational impact. This information can be included in future Space Traffic Management developments as well, with SSA being an essential enabler.

THE SOLUTION

By combining databases and reviewing the available information, it is possible to gather the required parameters to be able to perform the analysis. Furthermore, the gained insight can be used to look into space objects behavior such as orbit corrections and functional applications. By adding various data sources, a verification can also be performed. This will help in obtaining a better understanding of the situation and the potential threats to Dutch space assets and possible mitigation actions available.

NLR supports developments that **help bring small satellites easier, faster and affordable to orbit.** We can play a role from the very beginning of a rough idea up to the production of a prototype of a launcher structure or a satellite component or sensor.

In the field of structures we focus on the **development of light-weight structures based on composites and additive metal printing (AM)**. For composites NLR focuses on optimal design and use of composites in combination with automatisation of production processes to realise space structures for attractive costs. NLR has extensive knowledge of Metal-AM design rules, build preparations, production process and post-treatments, as well as certification and qualification processes.

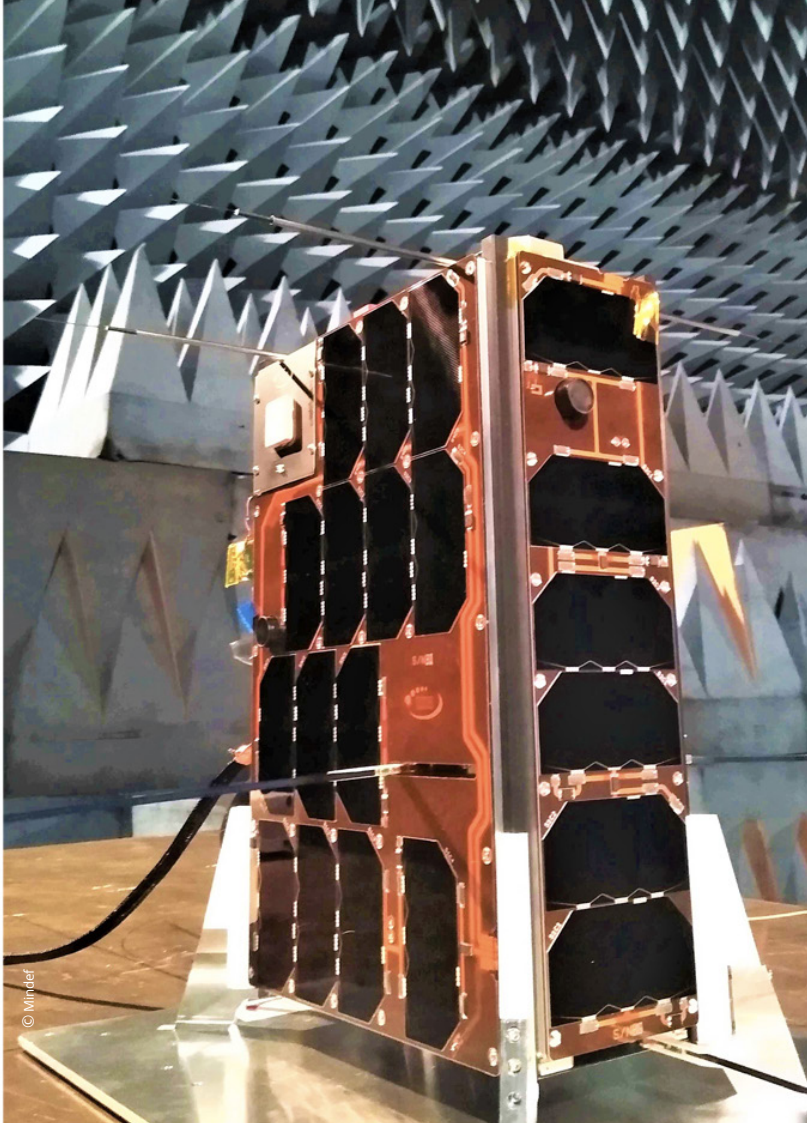
With our experience and overall system knowledge of space avionics we invest in **small and medium size high end satellites**. As more and more processing diverts from ground-processing to on-board processing we also work on onboard AI solutions.

NLR develops **phased array antennas or beamsteering antennas for satellite communication and smart satellite navigation antenna's.** Phased array antenna's utilise a series of elements that allow the antenna bundle to be controlled electronically instead of mechanically. This makes them less vulnerable and more flexible.

NLR has very broad expertise in developing **thermal management systems** for space applications and specifically pumped systems. Such systems are interesting in satellites with payloads that generate a lot of heat and need to be cooled in order to function properly.

Satellites and Launchers

Concept development
Space avionics
Antennas
Thermal control
Structures and materials


© Minder

BRIK II, the first Dutch military satellite

The first Dutch military satellite was successfully launched in June 2021. The BRIK II nanosatellite is an experimental project of the Royal Netherlands Air Force. On 30 June, the Virgin Orbit company launched the "LauncherOne" rocket, with BRIK II as one of its payloads from Mojave in the United States.

The launch is a first test for Defence to demonstrate the potential of nanosatellites for military and civil use. The Dutch Defence Vision 2035 states that space has become a necessary link for information-driven action by the armed forces. Defence is highly dependent on satellites. For example, consider the use of navigation and communication systems. In order to keep the development scalable and affordable, Defence works together with Dutch industry and knowledge institutes. BRIK II emerged from this.

COOPERATION

The construction of BRIK-II underlines the innovative abilities the Dutch industry and knowledge institutes are capable of in developing relevant military and/or dual use capacities. Innovative Solutions in Space (ISISPACE) located in Delft is the designer and integrator of the nanosatellite. Royal NLR has developed new technologies that will be put into practice on the BRIK-II: with a miniaturized payload, in the field of signal intelligence, the satellite can detect radio signals from space and locate the location of the source on the earth's surface. Furthermore there is a collaboration with the Delft University of Technology (TU Delft) and an international collaboration with the University of Oslo.

The name of the satellite is a reference to the first aircraft for the Aviation Department in Soesterberg. This aircraft from 1913 was called 'De Brik' and was used by the Dutch armed forces to discover the aviation domain.

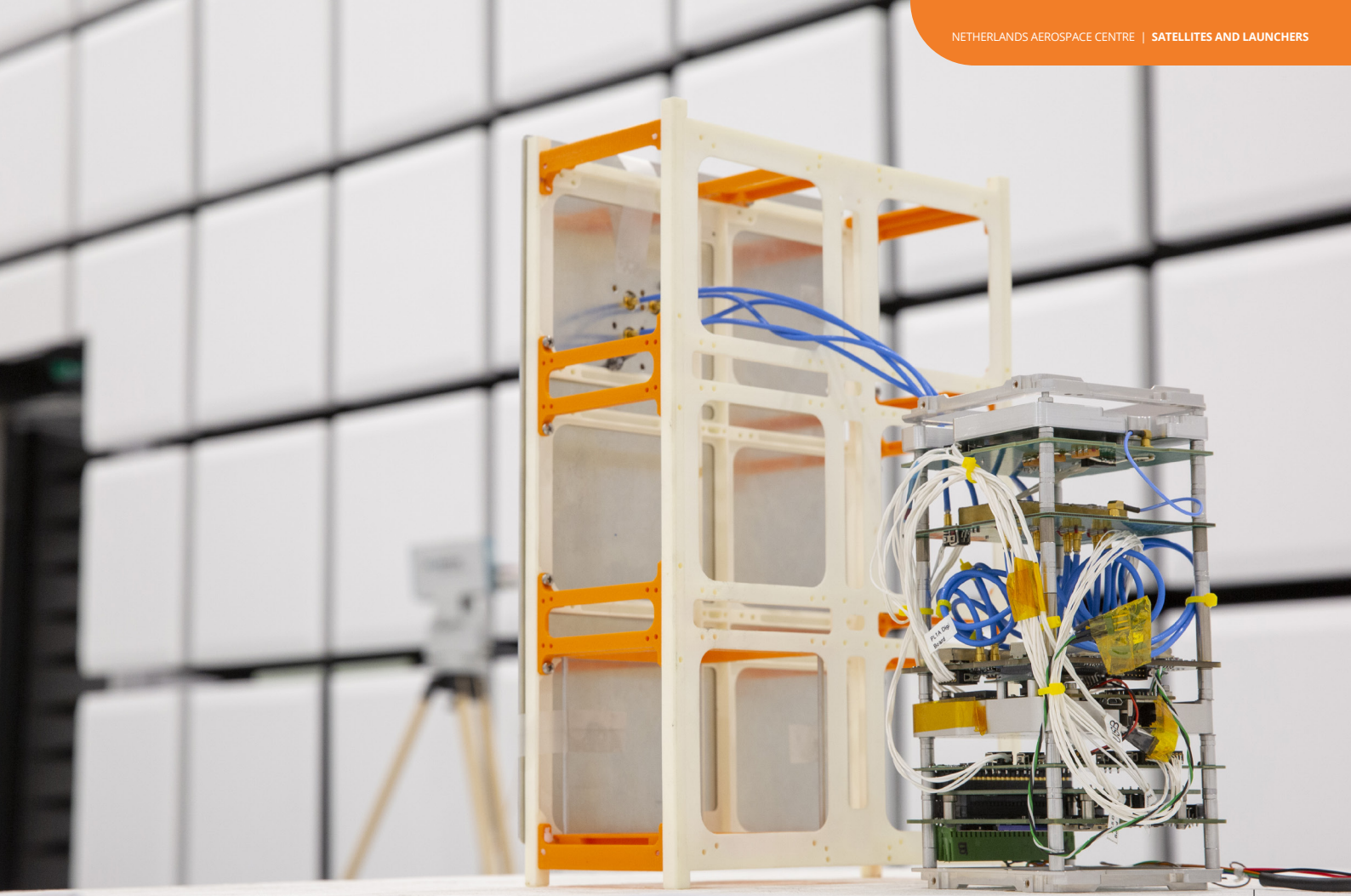
RF Sensor for CubeSats

With a more and more crowded RF spectrum, especially in the satellite communication domain, collection of information on the usage of the RF Spectrum becomes more and more important. NLR has developed a RF sensor for cubesats, called Phino. It detects and analyzes RF signals on-board of a cubeSats, it selects and filters these signals and sends the relevant information to the ground for further processing.

In Phino, the detection of signals is based on in-house developed innovative algorithms with an optimal trade-off between accuracy on one hand and low power consumption on the other hand.

KEY PARAMETERS PHINO

Mass: ca. 2.0 kg (depending on configuration)
Volume: ca. 1½ U (10x10x15 cm)
Power consumption : ca. 15 Watt (depending on the mode)
Operational modes: Raw mode or processed mode
Operating frequency: currently designed for X-band, but the design can be tuned to different bands according custom needs
Temperature range: -30 to +60 degC



On-board Advanced Payload Data Processing

Satellites become more and more complex. Sensors have a growing demand in bandwidth, resolution, sensitivity and accuracy. This results in higher data volumes generated by these sensors. The downlink capabilities also increase, but not in the same pace which makes the downlink often the bottleneck for the mission utilisation and yield.

THE CHALLENGE

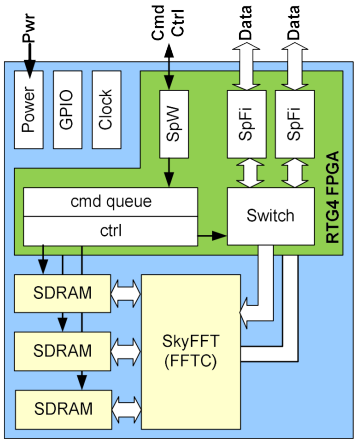
The challenge is to realise data compression or other advanced on-board data processing with the objective of downlinking less data or allowing more observations per orbit. This will optimise the utilisation and yield from space assets, and be an enabler for new mission capabilities.

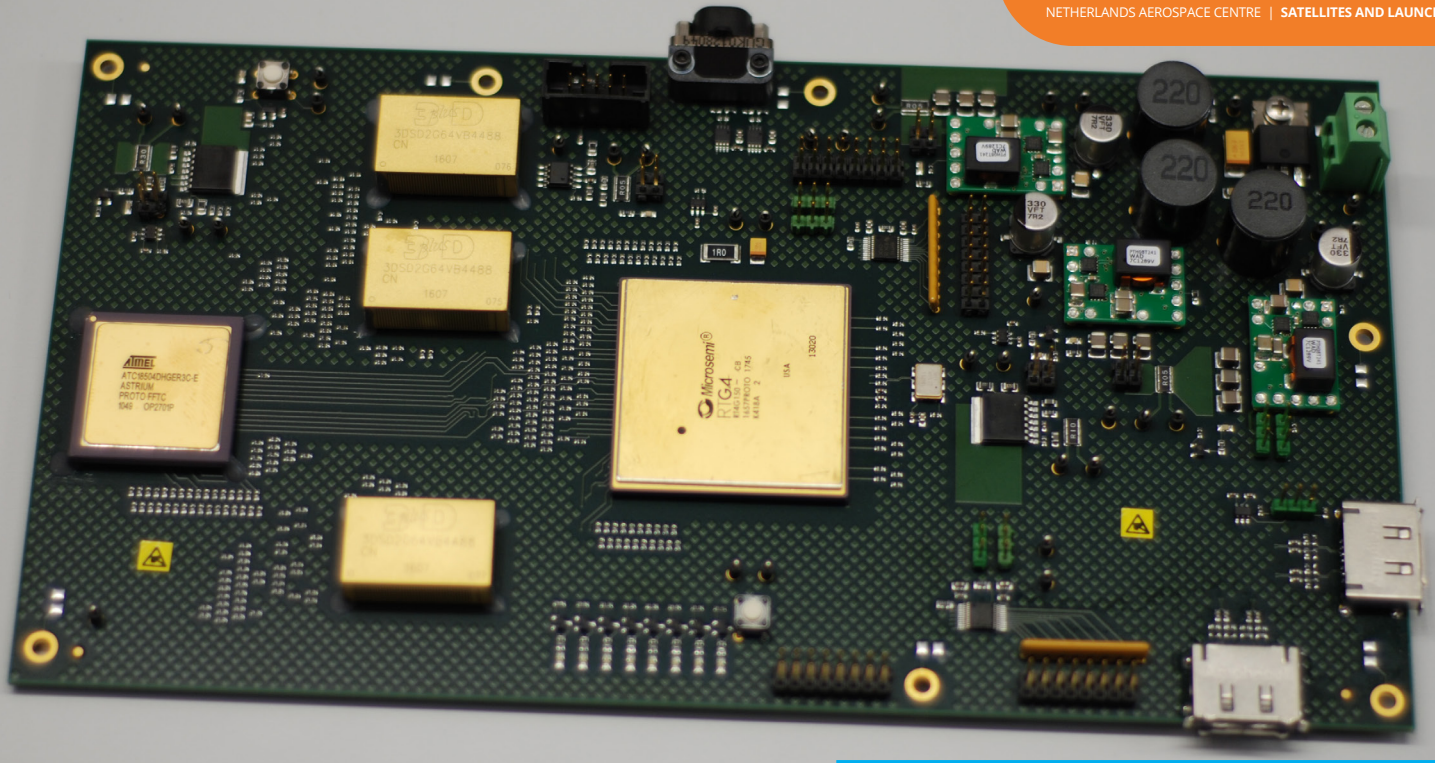
WHAT DID WE DO

NLR applied it's broad experience with dedicated processors for processing of artificial intelligence algorithms and Fast Fourier Transform operations. In this project the SkyFFT (Fast Fourier Transform Co-processor – FFTC), a space qualified ASIC that can perform all kinds of FFT operations, is applied. An RTG4 FPGA is used as core controller and included SpaceFibre interfaces capable to transfer payload data up to 2 Gbit/s net. A SpaceWire interface with a data rate up to 200 Mbit/s is implemented for TM/TC. The overall result is a hi-end and hi-reliable payload data processor board with a competitive form factor.

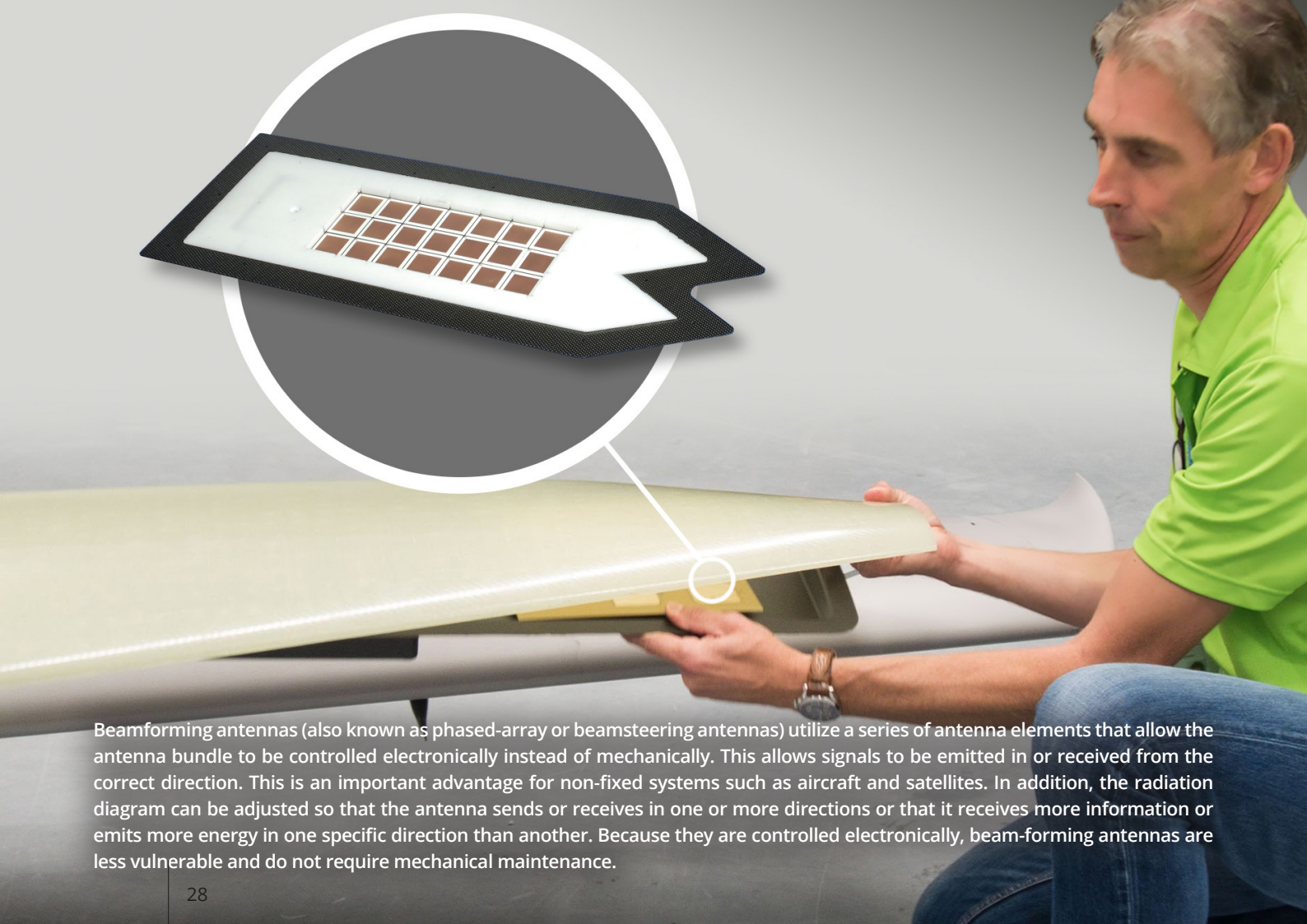
THE SOLUTION

Small and lower cost missions allow the use novel and high performance COTS components, but for larger missions (radar, SigInt and ComInt). the quality aspect becomes increasingly important. With the SkyFTT we developed a compact solution for efficient onboard data processing using Fast Fourier Transform operations. The overall result is a hi-end and hi-reliable payload data processor board with a competitive form factor.





Partners
ESA GSTP Project executed by NLR and SSBV (now C-STS)
Project: finalised in 2018



Beamforming antennas (also known as phased-array or beamsteering antennas) utilize a series of antenna elements that allow the antenna bundle to be controlled electronically instead of mechanically. This allows signals to be emitted in or received from the correct direction. This is an important advantage for non-fixed systems such as aircraft and satellites. In addition, the radiation diagram can be adjusted so that the antenna sends or receives in one or more directions or that it receives more information or emits more energy in one specific direction than another. Because they are controlled electronically, beam-forming antennas are less vulnerable and do not require mechanical maintenance.

NLR specialises in developing phased-array antennas, their individual antenna elements and the beam former that controls the array. For various aerospace applications, NLR develops the antennas or the antenna system and the system architecture. In addition, NLR has drawn up requirements for the antenna. For the technology in specific applications such as satellites and aircraft, and for the environment that the system is used in. In these jobs, NLR looks at aspects such as environmental factors like the vibrations, pressure and temperature levels that a satellite or aircraft has to cope with, as well as the propagation of signals – how they progress and move. Atmospheric damping or reflection by buildings can then occur. NLR can run through the entire process, from design to field testing and qualification.

DEVELOPMENTS

The most important application of beam forming is the aviation market, but it also plays an important role for ground stations that have to follow satellites. Electronic control is also going to play an important role in constellations of satellites that communicate with each other: intersatellite links. Internet signals are currently sent via the transmission masts for mobile communications, but with the advent of constellations of satellites in which beam forming may play an important role, everyone will be given direct access to the Internet from anywhere in the world. Even at the least accessible places on Earth. NLR carries out multidisciplinary research in a variety of cooperative groups:

OPTICAL BEAM FORMING

The beam former used for transmitting the signal can be controlled with RF electronics or alternatively using optical chips: the Optical Beam Forming Network (OBFN). In the field of optics, using beam forming is innovative and efficient because a large amount of processing can be done with a small chip. To do this, NLR is working with Lionix International, a supplier and designer of customized optical microsystem solutions. Using optical components will ensure that beam forming will be cheaper and less complex in the future. For the European SANDRA project, working with a number of partners, NLR developed a Ku-band antenna with optical beam forming: an antenna on an aeroplane that communicates with a satellite to improve the communications from on board an aircraft. The follow-up – integrating the antenna into the fuselage of an aircraft – will be tackled in the ACASIAS project.

INTEGRATION INTO AIRCRAFT

The European ACASIAS project will be reducing the energy consumption of aeroplanes in the future by improving their aerodynamic performance. As part of that, working together with GKN Fokker, NLR investigated smarter ways of using parts of the fuselage by adding functions to them, such as building in a beam-forming antenna. NLR already has the requisite knowledge in-house about the structural design and about composite structures in aircraft, aerodynamics and thermomechanics. The knowledge that NLR has about developing cooling systems for satellites will also be used for cooling antenna systems, as well as for analysis and modelling.

Project partners
Customer: European Space Agency
SME (EU): Orange Aircraft (NL) and Barnard Microsystems Ltd. (UK)
Research organisations: Royal NLR - Netherlands Aerospace Centre (NL)

Start: March 2018
Duration: 3 years

Integrated Steerable Antenna for Beyond Line-of-sight L-band data Exchange-ISABELLE

The market for satellite communications for Unmanned Aerial Vehicles (UAV) is expected to grow considerably in the next years. The growth of the UAV sector follows from the diversity of potential applications. Among the earliest applications of UAVs for civil use are the so-called dull, dirty or dangerous tasks (e.g. performing oil and gas exploration surveys). In order to routinely operate a UAV Beyond Visual Line Of Sight (BVLOS), one needs a SATCOM link between the UAV and the Remote Pilot Station (RPS).

THE CHALLENGE

A recurring obstacle is the accommodation of any satellite antenna into small sized UAVs. Geometrical dimensions of a single antenna are an obvious consideration for interfacing with the UAV. In the project an integrated satcom array antenna has been developed.

WHAT DID WE DO

Available surfaces such as the wing and tail can be used to integrate antenna arrays. The objective of the ISABELLE project was to demonstrate by design, manufacture and testing the viability of an embedded antenna array with real time adaptive beam forming where the antenna is integrated in the wing structure of the UAV

THE SOLUTION

The work carried out in this project comprised:

- Providing an overview of the available satellite services and antennas for satellite communication.
- Selection of applications that benefit most of the use of the integration of antennas in the mechanical structure of the UAV.
- Defining an antenna concept, antenna architecture and antenna requirements.
- Making a preliminary design of an array antenna integrated in the wing of a UAV.
- Design, manufacturing and test of a number of critical components of the antenna system.
- Manufacturing of the antenna arrays (receive and transmit), the beamformers (receive and transmit) and the antenna control.
- Measurements to characterise the manufactured components.
- Ground and flight tests.
- Writing a detailed design, development and manufacturing plan to bring the UAV antenna to production level.

IMPACTA:

An innovative cooling system for satellite electronics

THE CHALLENGE

The Objective of IMPACTA is to create an innovative thermal control solution for Active Antennas that are a building block of next generation telecom satellites in Europe. This will as a consequence, solve the thermal control needs of future space missions of telecommunication. The developed technology will be transferrable other satellite payloads.

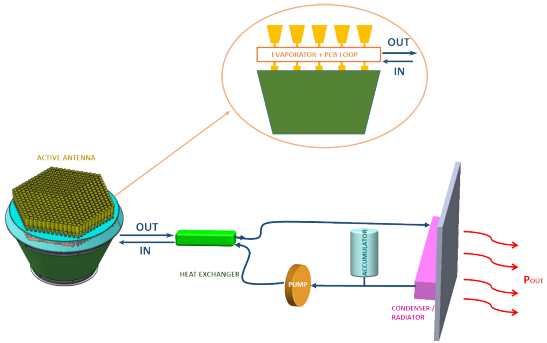
WHAT DID WE DO

A consortium of 6 leading partners in the space and thermal industry are collaborating on this project. At NLR-side the cooling system was modelled in NLR's in-house two-phase cooling system model. Therein, a quantitative analysis of applicable refrigerant fluids was done, to ultimately select the most optimal working fluid. With the fluid is selected, the entire design of the two-phase cooling system was determined. This involves the selection of a pump, heaters, compatible materials, and the design of the evaporator.

With the complete design, the necessary components were fabricated and assembled. This involved the usage of Additive Manufacturing for production of the evaporator section. The finalised system is currently tested to assess the correct working in various situations, including a test campaign in NLR's environmental test facilities.

THE SOLUTION

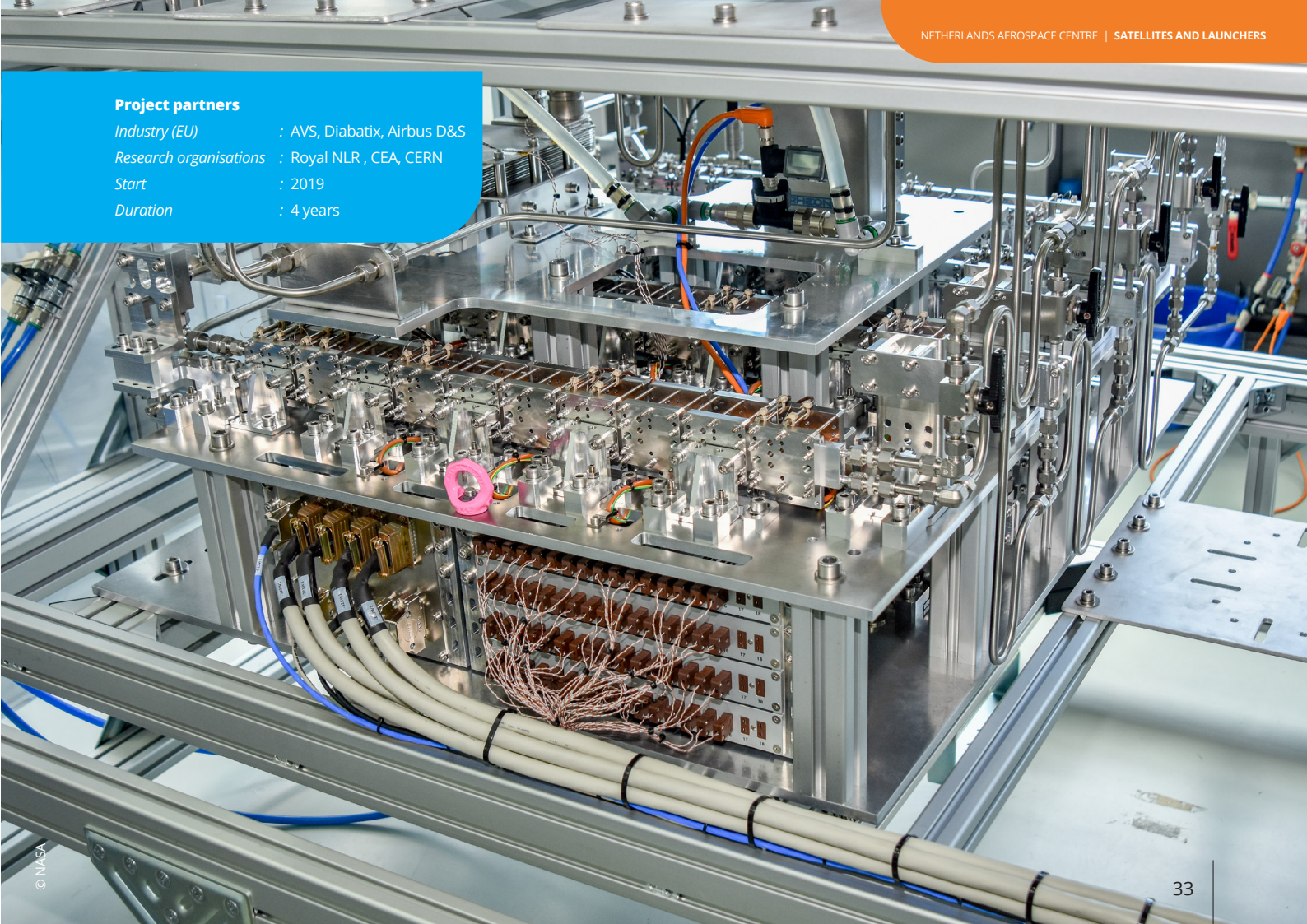
The expertise that has been developed during this EU-project, will be applicable in cooling needs for the next generation of satellites. This will enable the usage of electronics with a higher power density than currently used. Furthermore, the project has improved the TRL of two-phase cooling systems aboard satellites.



IMPACTA is co-funded by the European Union.
This message doesn't necessarily reflect the views of the EU

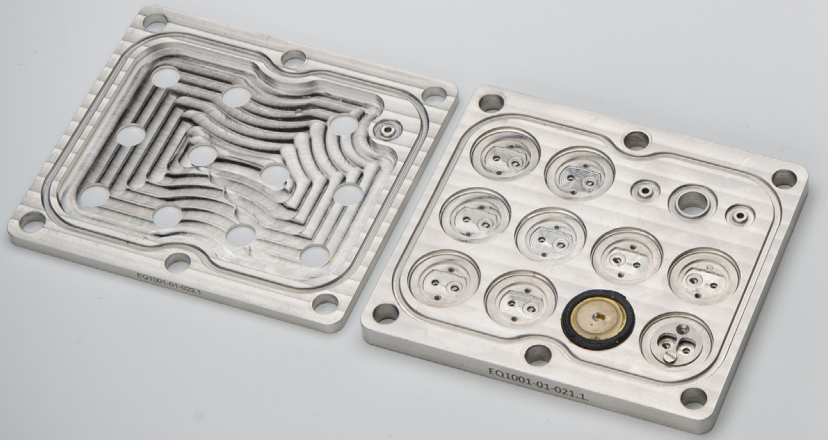
Project partners

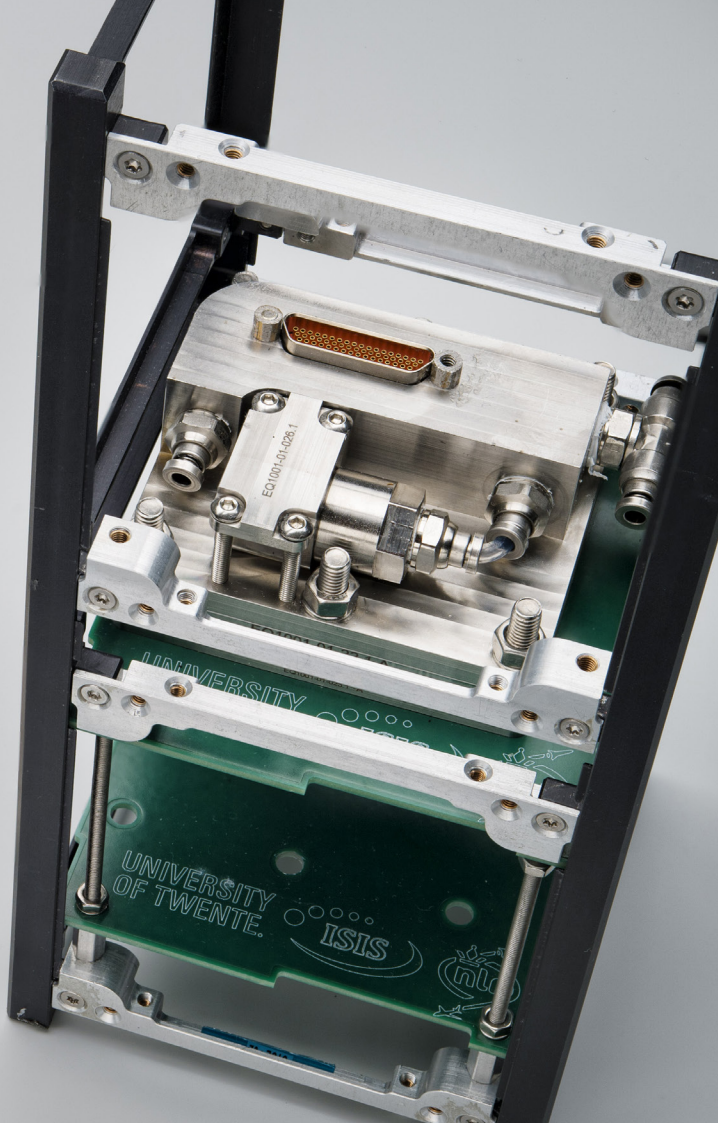
Industry (EU)	: AVS, Diabatix, Airbus D&S
Research organisations	: Royal NLR , CEA, CERN
Start	: 2019
Duration	: 4 years



Project partners

Industry (EU)	:	Demcon Kryoz, ISISpace
Research organisations	:	Royal NLR, ESA
Start	:	2021
Duration	:	2 years





Mini Multi Parallel Micro Pump development

THE CHALLENGE

Development, production and launch costs for CubeSats are very low compared to conventional satellites. This has sparked interests from industry to develop their own CubeSats. The drive for volume and mass optimisation from the industry has led to miniaturisation of electronics in CubeSats. To keep costs down, commercially available electronics (COTS) are used which are very cost effective but have a small operational temperature range. The relatively high power density of CubeSats means that more power is being transferred into heat in the same volume, causing a faster warm-up of components. The thermal problems are aggravated by the introduction of propulsion modules for CubeSats which themselves produce a large amount of heat. Without adequate heat removal the CubeSat components can quickly overheat.

WHAT DID WE DO

Conventional methods like heat pipes to remove this heat are no longer suitable, and mechanically pumped loops are a feasible solution to remove this heat as they are more efficient. However, these loops are usually expensive and need much smaller mass flows compared to the larger satellites. To create a smaller mechanically pumped loop, a smaller, flexible pump is needed which is the goal of the MPMP. A consortium of Demcon Kryoz, ISISpace and Royal NLR, with support of the European Space Agency (ESA) aims to develop the MPMP for use in small satellites.

THE SOLUTION

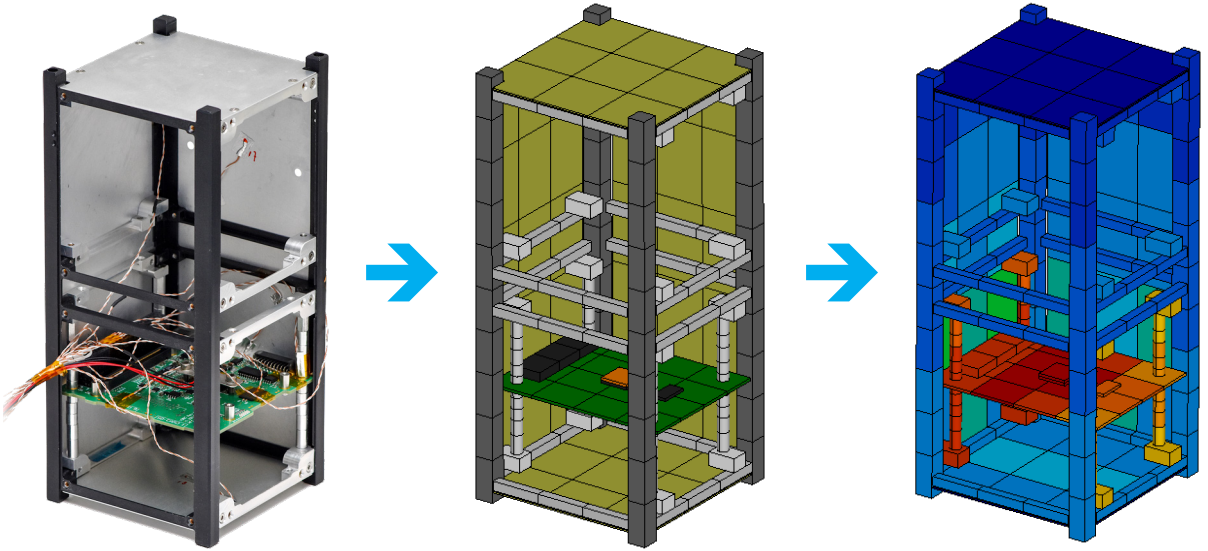
The Multi Parallel Micro Pump consists of a stack of several micro pumps, which consists each of a piezo membrane and a valve to direct the flow. The prime functionality lies in the flexibility the current solution offers: if a higher flow is needed, more pumps can be added to be able to deliver that flow; which also helps in the robustness. For typical space applications expensive pumps are used, and due to redundancy reasons, added with a second back up. With for instance 20 micropumps placed in one stack, the loss of one single pump will not result in loss of functionality of the loop, but will lower the flow with 5%.

We currently have a full scale MPMP prototype which has demonstrated a mass flow of 500 mg/s which is sufficient to transport at least 20 watts of heat. The consortium aims to improve upon the design to transport at least 100 watts of heat away from a heat source, such as a CubeSat propulsion module, to a heat sink elsewhere in the satellite.

This project was funded by ESA.

Project partners

Industry (EU)	:	ISIS
Research organisations	:	Royal NLR
Start	:	2019
Duration	:	no end date



CubeSat Thermal Modelling:

Applying ESATAN-TMS for the CubeSat industry

THE CHALLENGE

With the increase in power density, thermal control measures are needed for CubeSats. This requires low-cost hardware and software solutions, which are currently hardly available. Miniaturisation and application of thermal control systems is being worked on, however evaluating design iterations is hindered by the lack of thermal analysis imposing large uncertainties in the thermal design of CubeSats. ISIS - Innovative Solutions in Space and Royal NLR have worked together on an innovative modular approach for CubeSat thermal analyses in ESATAN-TMS. Key of this approach is the interchangeability and scalability of validated thermal submodels allowing for fast and more accurate analysis for LEO missions.

WHAT DID WE DO

NLR's expertise with ESATAN-TMS is applied in this project to set up a modular approach of thermal modelling of CubeSats. Thermally relevant submodels are built for commercially available subblocks, like the ISIS TXS-module, and general building blocks of a CubeSat frame. This is built in such a way, that it can be easily adapted and assembled into an entire CubeSat system. The correct modelling of interfaces between sub-models is herein critical for the thermal maturity of the model. Hence a lot of attention is given to this minor detail in the assembly. In the next stage of the project, the thermal submodules were correlated with the results of thermal vacuum tests. This correlation will ultimately result in a verified thermal model of the submodules.

THE SOLUTION

A library of validated thermal sub-models will be created in ESATAN-TMS, allowing for fast and accurate orbital analysis, which results in improved thermal designs of CubeSats. CubeSat manufacturers and integrators can use the thermally verified submodels in ESATAN-TMS and decrease their development time of the design of a CubeSat by implementing the thermal modelling in an early stage of the design cycle.

Project partners

Industry (NL)	:	ArianeGroup
Research organisations	:	NLR, DNW, ONERA
Start	:	2014
Duration	:	6 years

ARIANE 6:

Europe's development of the sixth generation launcher

THE CHALLENGE

The overall objective of the development of the Ariane 6 launcher is to create a reliable, flexible and competitive European launch system.
Flexibility comes in the form of a launch configuration adjustable for smaller or larger payload or lower or higher delivery orbits. The competitiveness comes from the fact that Ariane 6, compared to Ariane 5, can be launched more often per year and cheaper.

WHAT DID WE DO

In the entire development of the Ariane 6 launcher, NLR plays various roles. Most effort of NLR up to now has been devoted to providing ArianeGroup with wind tunnel models for various stages in the development:

- Aerodynamic characteristics of basic lay-out
- Buffeting and acoustic characteristics of detailed aerodynamic shape
- Aerodynamic characteristics of detailed aerodynamic shape

THE SOLUTION

Results from wind tunnel tests performed on the models provided by NLR have delivered the design teams of ArianeGroup valuable data to be able to advance the design. This contributes to realizing the goals of the Ariane 6 project: a reliable, flexible and competitive launcher.

NLR has used its expertise to equip the three models with a significant amount of sensors, be it static or reference dynamic pressure sensors. The available space in the models was minimal which forced the design and instrumentation of the models to be optimized. Modularity of instrumented boosters added complexity but surely also functionality for ArianeGroup.

CFRP Vinci Thrust Frame

Optimising the engine thrust frame of the Ariane 6 launcher

The Ariane 6 Launcher will enter a very competitive commercial launcher market. New entrants to this market have reduced the launch price per unit mass payload by half (50%). Compared to Ariane 5 the production costs of the Ariane 6 launcher should be reduced by at least 50%.

THE CHALLENGE

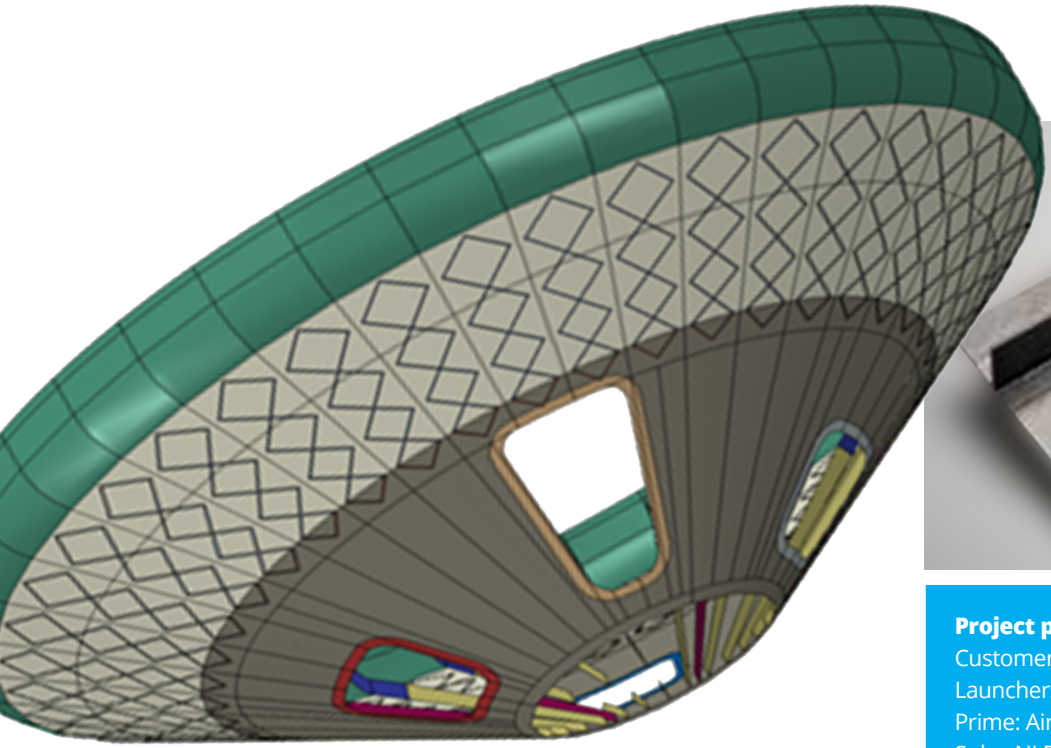
A key requirement for the development of the Ariane 6 is reduced recurring production costs and increased performance. Cost reductions and performance increase (both stiffness and mass) is to be realised in proposed materials, manufacturing technologies, processes, procedures and optimisation of the industrial organisation.

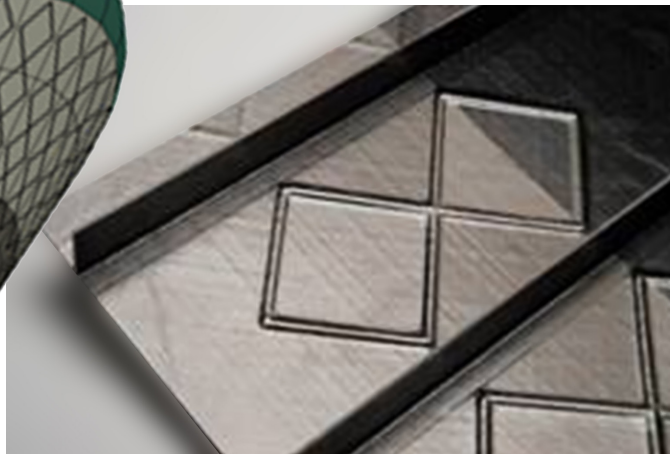
WHAT DID WE DO

Currently, engine thrust frames for launchers are made from metal. Previous programs showed that cost and weight can significantly be reduced by application of carbon fibre reinforced polymers (CFRP) in tailored ply architectures, processed by the automated fibre placement technology. Based on a reference finite element model provided by Airbus DS NL, NLR developed optimisation to reduce the amount of manufacturing steps and tooling and to create vector fields for the steered plies. This innovative design in combination with the automated fibre placement technology will lower knock-down factors, reduce weight and minimize scrap material, resulting in reduction of material and energy consumption, processing time and increased payload.

THE SOLUTION

NLR developed optimisation to reduce the amount of manufacturing steps and tooling and to create vector fields for the steered plies. Dedicated local reinforcements are composed by smart overlapping in order to improve the buckling behaviour between the reduced amount of blade stiffeners. This innovative optimisation method is combined with the automated fibre placement technology. In addition, fibre detection methods are integrated by Infactory Solutions into the automated fibre placement technology. Possible material defects like gaps, overlaps or twists are detected, analysed and written to a database. Corrections are applied in order to support first time right production for further cost reductions.





Project partners
Customer: European Space Agency – Future Launchers Preparatory Programme (FLPP)
Prime: Airbus Defence and Space Netherlands
Subs: NLR, Infactory Solutions

Start: 2018
Duration: 2 years

NLR has a **wide range of test facilities available for testing, verification and validation**. This includes environmental and structural testing and also wind tunnel testing, up to (zero- and low-gravity) flight testing.

NLR has extensive knowledge of **electromagnetic interference and compatibility (EMC)** and offers customers support to improve their designs for optimal performance and validate products in our EMC Facility.

We also offer facilities to support companies to optimize their products and production processes such as composite structures in our **Composites Field Lab** and metal printed products in our **Metal Additive Manufacturing Technolgy Centre (MAMTeC).** We can also develop avionics and sensor prototypes in house supported by our ESA-certified personnel. Besides NLR has extensive experience in **wind tunnel modelling** and production of high precision wind tunnel models.

Furthermore, in our NLR X-Lab we develop **applications with immersive technologies such as AR/ VR** for customers in order to improve communication on designs or missions, to support engineering processes or make remote handling possible.

Space Services

AR/VR expertise
Electromagnetic compatibility expertise
Prototyping
Low gravity flights
Testing & qualification

Flex-XR – Taking AR and VR to the moon

ESA and DLR are developing an analogue lunar facility to train astronauts for future lunar missions. Part of the facility is a simulated lunar base (FLEXHab) in which scientific experiments can be conducted. Utilisation of such a facility is expensive and the cost could be lower by reducing time spent in de FLEXHab, especially during the familiarisation phase and experiment preparation and design.

THE CHALLENGE

NLR developed a user-centered VR-concept that supports users to get familiar with the environment, design and review their experiment set-up before ever physically entering the facility. This saves time and money during the development phase of the experiment. For such an application to be useful several functionalities, like a database instrument model and their interaction with the environment, needed to be developed.

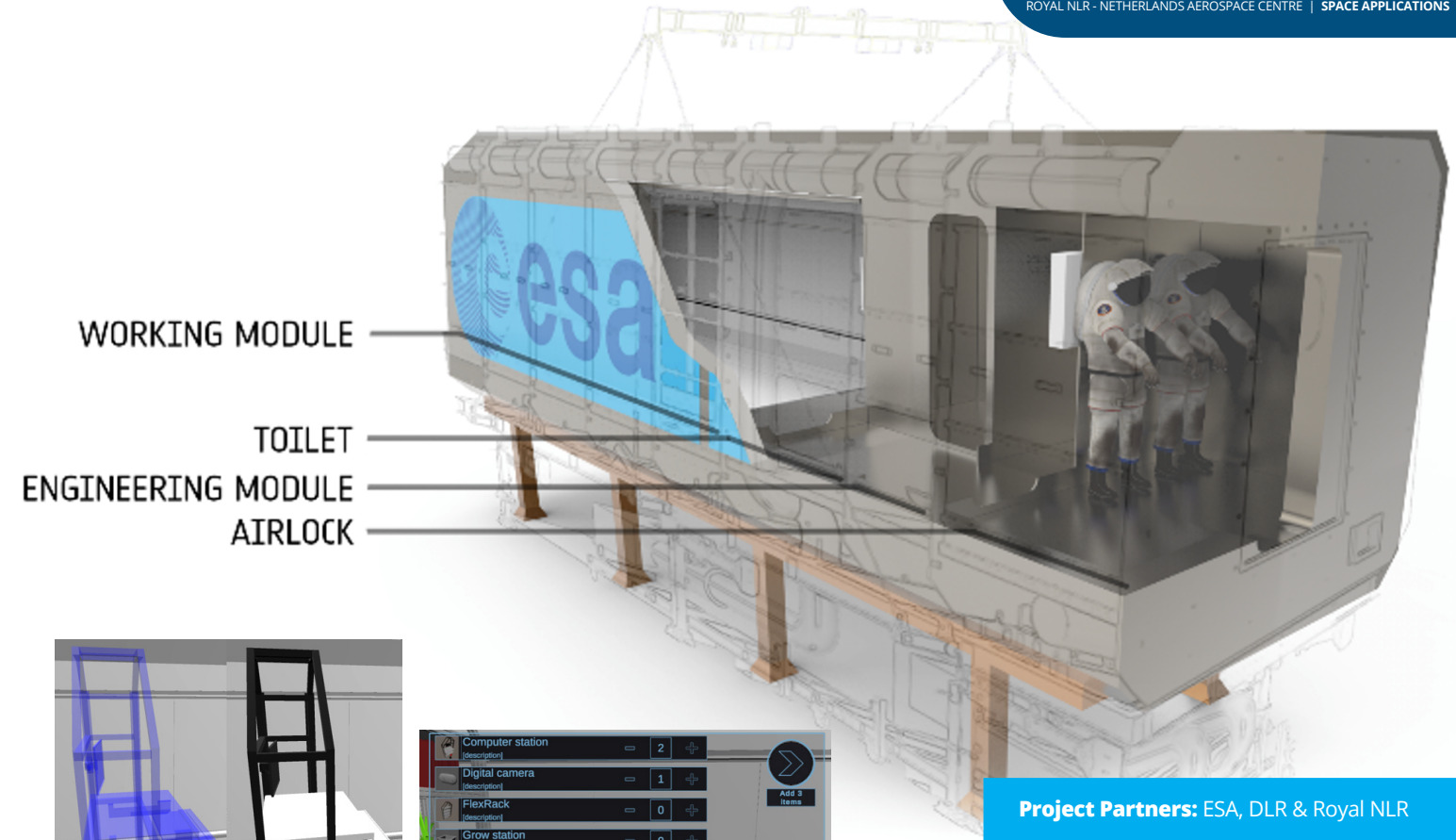
WHAT DID WE DO

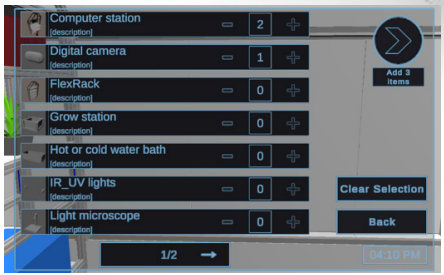
NLR developed a VR application that can recommend instrumentation based on the specific research domain that users are designing an experiment for. Moreover, it assists users to configure their experiment set-up as well as verify and validate constraints and assumptions concerning their experiment design. The application is promising to be a useful tool. User tests are now required to validate whether the developed VR application indeed results in more efficient experiment designs. The next steps would include complementing digital twin with AR technology, to seamlessly merge the virtual and real environments, enhancing collaboration between users and ground segment personnel in the actual FLEXHab and eventually soon on the moon.

THE SOLUTION

A digital twin to:

- Enter and explore the FLEXHab environment
- Select a research domain for which they would like to design an experiment and configure instrumentation
- Access a catalogue with recommended instruments based on the selected research domain
- Place and configure the instrumentation in the FLEXHab and FLEXracks
- Work collaboratively in the virtual environment. Users do not have to be in the same physical location to cooperate





Project Partners: ESA, DLR & Royal NLR

Start: January 2021
Duration: 6 months

ace2space:

Zero-G Flight Testing Capability

THE CHALLENGE

- Test space equipment before launching it (free fall tower, sounding rocket, space station)
- Expose your application to in-flight zero- or low gravity conditions (e.g. moon or Mars)
- Save on your experiment cost by obtaining a favorable cost-per-parabola ratio
- To only perform a customer-required number of parabolic maneuvers. No implication to take more parabolic maneuvers and associated costs than really needed.
- Use of a low gravity flight test facility that is solely dedicated to your project, allowing for a customer oriented and confidential project environment
- To be able to return to base whenever your application is not properly functioning, thereby saving valuable flight test time

ace2space is the partnership between Royal NLR and Delft University of Technology for performing parabolic flights

HOW CAN WE SUPPORT YOU

- A modified and instrumented Cessna Citation II research aircraft capable of performing zero or partial gravity flight maneuvers
- A relatively small aircraft which allows for favorable cost, yet provides enough cabin space for many low gravity applications
- Multiple certified cabin configurations are available which can host almost all required experiments
- Part 21 based design organization to support installation of your application onboard our aircraft
- A flexible and affordable flight test facility representing more than one century of experience

Flight operations that are dedicated to a single customer or project, which allows for:

- performing of only those parabolic maneuvers that are required by the customer > saving time and cost
- aborting a flight whenever your application requires so > saving flight time
- confidentiality and protection of intellectual property rights

- Demonstrations, Training of Pilot Flying Skills and Instructions (Aerospace Engineering Curriculum)
- Fluid & fundamental physics
- Materials
- Sensors and systems
- Physiology
- Human
- Biology

NLR Metal Additive Manufacturing Centre - MAMTeC

MAMTeC is the Metal Additive Manufacturing Technology Centre in the Netherlands. More than 45 years of materials experience in aerospace applications is applied to define optimised process parameters and post-processing methods. We support development processes up to the certification qualification of the metal–AM products. The development of Metal-AM materials and components is supported by making use of advanced inspections, analysis techniques and testing facilities.

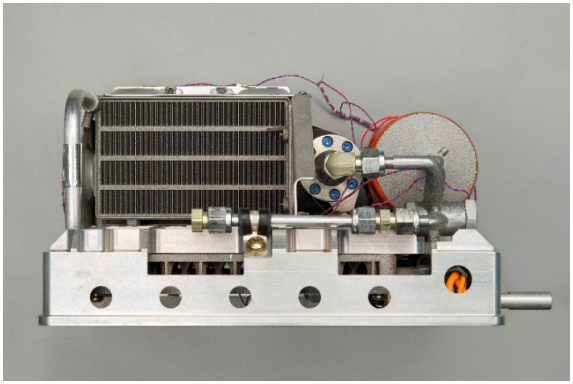
Technologies and Materials

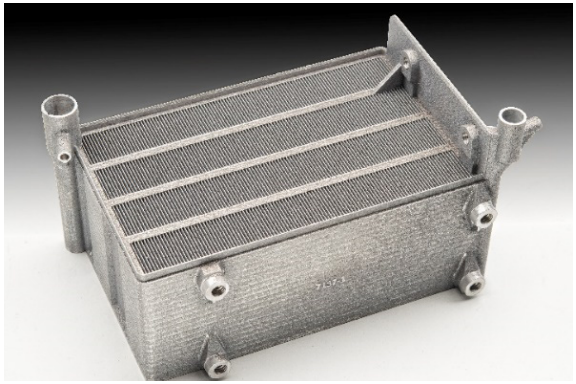
- Laser Powder Bed Fusion
- Blown Powder Directed Energy Deposition (manufacturing & repairs)
- Sinter-based Fused Filament Fabrication
- High Performance Alloys (e.g. aluminium, titanium, nickel based super alloys, magnesium)
- Multimaterial AM
- Materials laboratories and testing facilities

Space applications

NLR has developed and produced various heat-exchangers for space applications in cooperation with our thermal management experts. Complex internal geometries were realised for optimum performance, high efficiency and low weight. The combination of design optimisation capabilities, extensive AM material performance knowledge and qualification expertise enabled NLR to support with the development of structural and propulsion space applications.


TIMO





Environmental test facilities

With our wide range of test facilities we can simulate your environmental testing requirements for your spacecraft or aircraft equipment, meeting international, military, aircraft and commercial standards. Regardless of the environment that has to be simulated, NLR is the 'one stop shop' for all your testing needs.

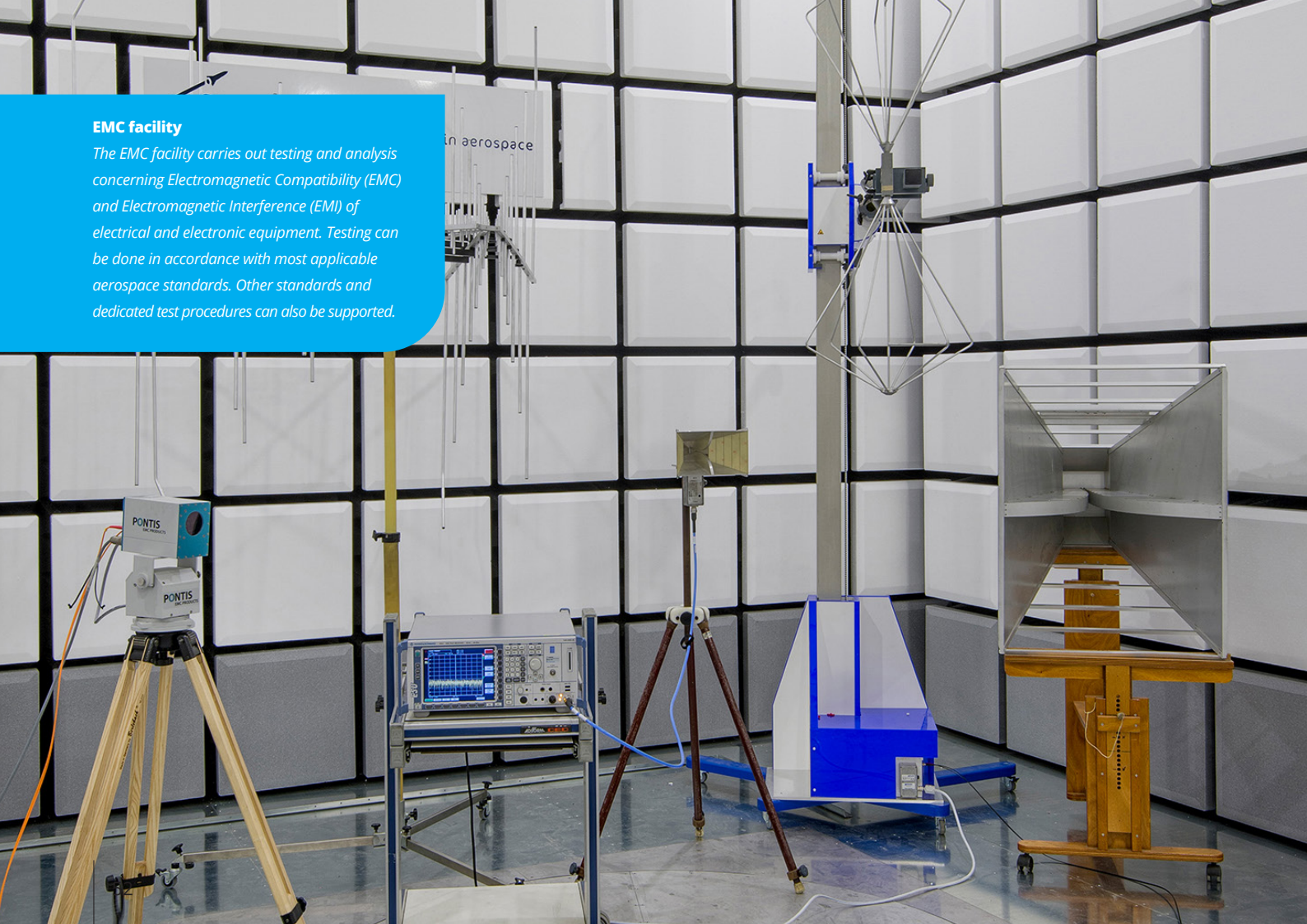
We conduct environmental tests for climatic, thermal vacuum, mechanical, electric, radiation and acoustics properties using our specialised knowledge, experience and over 20 different facilities for environmental testing.

We can advise and support you throughout the entire
testing process from establishing test requirements and test definition, to test set-up and execution. We can also assist you in validating your own models of your test subject.

NLR Environmental test facilities

- **Climatic**
  - Temperature
  - Humidity
  - Salt Spray
  - UV Light
  - Fluid Susceptibility
  - Altitude, Decompression & Overpressure
  - Waterproofness
  - Icing
  - Tear Down
  - Thermal Vacuum
  - Fungus
  - Sand & Dust
- **Mechanical**
  - Vibration
  - Shock
  - Acceleration
  - Static Load
  - Bending Resistibility
  - Pull Force
- **Electric**
  - EMI/EMC
  - ESD
  - HIRF
  - Lightning
- **Radiation**
  - Total Dose
  - Proton
  - Heavy Ion
  - Californium Cf-252
- **Acoustics**
  - Acoustic Noise
  - Transmission Loss

Tests performed externally under NLR responsibility



EMC facility

The EMC facility carries out testing and analysis concerning Electromagnetic Compatibility (EMC) and Electromagnetic Interference (EMI) of electrical and electronic equipment. Testing can be done in accordance with most applicable aerospace standards. Other standards and dedicated test procedures can also be supported.

Vibration and Shock Facility

The Vibration and Shock Testing (VST) facility subjects sensitive equipment used in the aerospace industry to shock and vibration tests. It fulfils an essential role in the certification process for precision instruments and electronic equipment on board aircraft and spacecraft. Vibration and shock testing is part of NLR's full range of solutions for Electromagnetic Characteristics (EMC) testing and environmental testing (e.g., temperature and altitude tests).

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

800+
staff

€ 110 M turnover

74% Dutch, 23% EU
and 3% worldwide

Active in 26 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

Peter Dieleman
peter.dieleman@nlr.nl

Rudy Veul
rudy.veul@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

February 2024