Dedicated to innovation in aerospace

# R&D for Responsive Space

NLR - Royal Netherlands Aerospace Centre

# Royal NLR

## R&D for Responsive Space

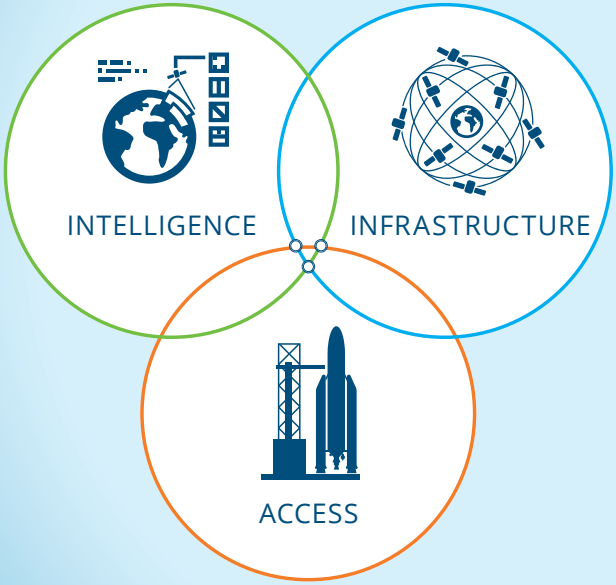
Royal NLR has a long heritage as a systems expertise centre, where system engineers make use of the inter-disciplinary knowledge base to assist in the development of space systems like satellites, payloads and launchers and subsystems like thermal control systems, electronics or antennas. It also offers unique capabilities in the area of aerospace qualified light-weight composite structures and multi-metal additive manufacturing.

NLR has available a wide range of test facilities with which we can test, verify and validate products. This includes environmental and structural testing, wind tunnel testing and (zero-gravity) flight testing. On the application side NLR has a long heritage in earth observation and satellite navigation. It is primarily focussed on applications in air traffic and defence, but also serves application domains like smart farming, critical infrastructures, and public safety & security.

We have selected some of the projects, research and capabilities that we have developed ourselves and together with partners, for you to get to know more about NLR and our activities.

We hope you enjoy reading and discovering more about NLR.

# R&D for Responsive Space




Big Data Analytics & AI

Collaborative Satellite Technologies

Micro RF Instruments

Smart Antennas

Electromagnetic compatibility

Space electronics

Thermal management

Structures & Materials

(Micro) Launchers

Testing & Qualification

# Beamforming antennas

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 specializes 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.

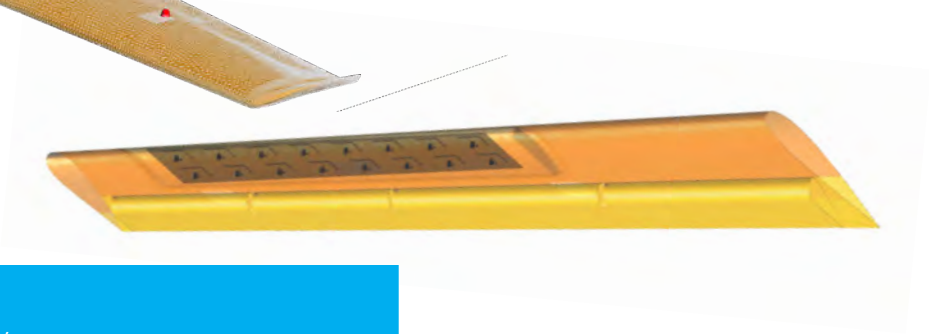
NLR carries out multidisciplinary research in a variety of cooperative groups:

## 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 will be investigating 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: Netherlands Aerospace Centre (NL)

**Start:** March 2018
**Duration:** 1.5 years

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

## WHY?

Unmanned Aerial Vehicles (UAVs) are used for applications such as infrastructure survey, pipeline inspection, surveying of crops, maritime surveillance and communication relay. A recurring obstacle is the accommodation of satellite antennas into small sized UAVs.

## HOW?

Available surfaces such as the wing and tail can be used to integrate antenna arrays. The objective of the ISABELLE project is 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.

## WHAT?

The main R&D activities of the project are:

- Development of a structurally integrated L-band phased array antenna in the wings of a mid-size UAVs
- Development of an electronic beam steering unit, to be placed in the fuselage or wing of the UAV.
- Development and manufacturing of breadboards in L-band for testing in laboratory and flight;
- Breadboards for critical hardware are L-band antenna tile, wing structures for structural embedding of the L-band antenna tile, beam steering unit and tracking/pointing system unit.
- Demonstration in flight of wing integrated L-and antenna tiles, with beam forming and tracking-and-pointing system, communication with Inmarsat BGAN satellites.

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


**Project partners**

| | |
|---|---|
| *Industry (NL)* | : GKN Fokker Elmo |
| *Research organisations* | : NLR |
| *Start* | : June 2018 |
| *Duration* | : 2 years |

# Electromagnetic Compatibility (EMC)

## Crosstalk

### WHY?

Crosstalk between cables in aircraft causes electromagnetic interference. Therefore, appropriate electromagnetic models need to be developed which predict the crosstalk between wires in cable bundles and between cable bundles. Shielding and twisting are usually applied to reduce crosstalk. Therefore, the electromagnetic models need to able to predict crosstalk between unshielded untwisted wires but also between twisted and shielded wires. The position of the wires in a cable bundle is in most cases not fixed. This causes uncertainty in the amount of crosstalk in practical cable bundles.

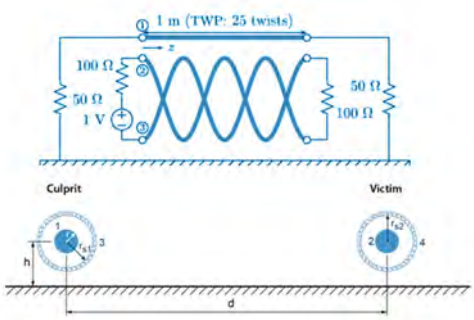
### HOW?

The effects of cable shielding are taken into account by means of the transfer impedance of the shield. The transfer impedance can be measured or calculated from analytical models. The effects of twisting are taken into account by dividing the helix forms into many small, uniform segments. The total crosstalk can then be calculated by cascading all those small segments of the entire transmission line.

For the statistic analysis of crosstalk in cable bundles, first a prediction is made of the potential position of the wire in the bundle. The crosstalk is then computed very efficiently by using the Stochastic Reduced Order Models (SROM) method.

### WHAT?

Both deterministic and stochastic models have been derived for crosstalk in cable bundles and between cable bundles. These models will be implemented in the design software for cable harnesses.



# ISR: Lead by Information with Innovation

Superior information position calls for the right information in the right place at the right time. Increasing complexity and hybrid nature of current conflicts call upon a proper intel position within the military context. Data is gathered from a variety of sources and contains varying types of information. These different types of data are fused in order to increase the situational awareness.

### WHAT YOU NEED

- Right information in the right place at the right time to support the right decision making of commanders and operational units in the field in order to generate the right military effects
- Looping through the Observe-Oriënt-Decide-Act OODA cycle faster than the adversary in order to achieve and maintain a lead with respect to the adversary

### WHAT WE DELIVER

- NLR is a one-stop-shop for end-to-end complete chain-based ISR solutions by means of innovative sensor, processing, analytics and presentation techniques
- NLR supports, analyses and advises for ISR procurement, exercises and operations for the continuous improvement of Information Governed Operations (IGO)

### OUR CAPABILITIES

- NLRs capabilities comprise of
- Innovative sensors for Air- & Spaceborne platforms for i.e. geolocation & identification
- Federated Processing Exploitation and Dissemination (FPED) processes
- ISR information analytics by Artificial Intelligence and Big Data techniques
- Effective decision support for operators
- Presentation of ISR information for operators using Virtual and Augmented Reality
- Protection against cyberattacks
- Support Information Governed Operations by Concept Development & Experimentation
- Provide tactical and operational support for Information Governed Operations
- Provide products and services to enhance Situational Awareness and Understanding
- Enhance Processing Exploitation & Dissemination cycle
- Expertise in reconnaissance pods
- Real-time Access to Airborne ISR (RAAISR)
- Apache Data Video Intelligence SystEm (ADVISE)

# Small satellites: track record

**SloshSat FLEVO**

2005

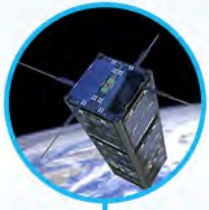
**Delfi C3**

2008

**Delfi-N3xt**

2013

**Triton-1**



2013

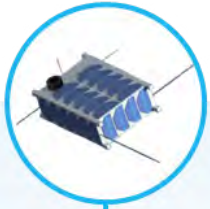
**AIRA**

2014

**Space-based Sensor Network**

2014

**Brik-II / Phino**



2019

**MilSpace**

2021


© Andøya Space Centre

# SMILE:

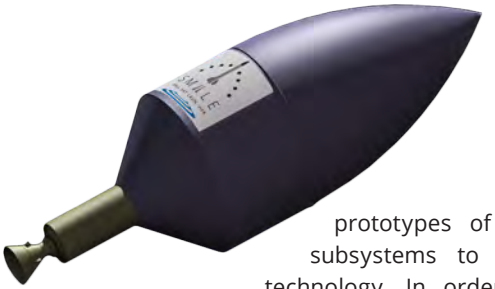
## SMall Innovative Launcher for Europe

**WHY?**

Today's market for small satellites is expanding rapidly, but there are few affordable or dedicated launch opportunities. Many of the small satellites are to operate in large constellations and will deliver new commercial services to the global markets. The Small Sat Launcher is needed to provide more launch opportunities, higher flexibility and rapid response capabilities to deliver the small satellites in their dedicated Low Earth Orbit. The launcher also provides Europe with an independent access to space. Innovative small launcher solutions are needed to be competitive in the global space economy.

**HOW?**

The SMILE project partners are designing a concept for an innovative, cost-effective European launcher for small satellites to be operated from a Europe-based ground facility, based on the sounding rocket launch site at Andøya Space Center. To achieve this, the partners are increasing Technology Readiness Level (TRL) of critical technologies and are developing



prototypes of components and subsystems to demonstrate said technology. In order to enhance the continuity of the project's objectives, a roadmap is set-up by assessing scenarios and critical future steps at technical, financial, and organisational levels. A market analysis runs in parallel with the project's execution to verify the validity of the initial market potential.

## WHAT?

The SMILE project aims at providing a European, ITAR-free, cost effective, commercially exploitable launch service. The project has chosen the well-proven path of a vertical orbital launcher for small satellites, whilst developing technology that can also be applied to other initiatives. Based on market conditions, a target price is set to be less than €50,000 per kg from the first launch, and decreasing as launch volumes rise. The proposed development of critical advanced European technology (including materials, structures, engines, and avionics) with affordability in mind is an essential step to achieve this goal and is combined with the application of series production at subsystem level, possible reuse of the first stage, and integrated low-cost avionics.

The SMILE project also provides a technology roadmap and a business development plan up until the realisation of an operational European small satellite launch service provider.

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

**Project partners**

| | | |
|---|---|---|
| *Industry (EU)* | : | Airborne Composites, BoesAdvies, ISIS, Andøya Space Centre, Heron Engineering, Nammo, PLD Space, Tecnalia, Terma, WEPA-Technologies, 3D Systems |
| *Research organisations* | : | DLR, INCAS, NLR (coordinator) |
| *Start* | : | December 2015 |
| *Duration* | : | 3 years |

# CFRP Vinci Thrust Frame

**WHY?**

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%). As a consequence a key requirement for the development of the Ariane 6 is reduced recurring production costs and increased performance. Compared to Ariane 5 the production costs should be reduced by at least 50%. Cost reductions and performance increase (both stiffness and mass) shall be realized in proposed materials, manufacturing technologies, processes, procedures and optimization of the industrial organization.

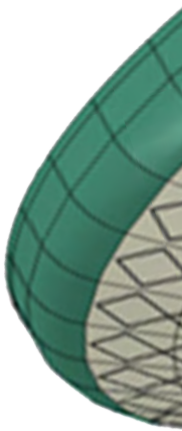
**HOW?**

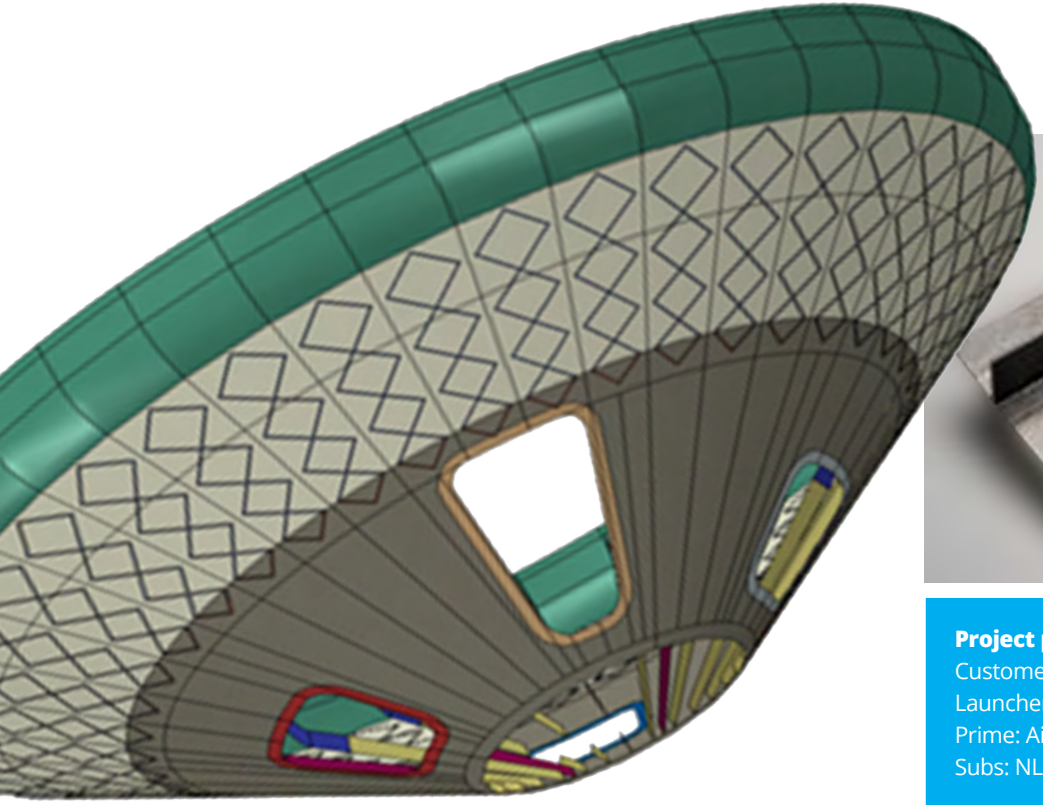
Currently, Engine Thrust Frames for launchers are made from metal. Previous programs showed that cost and weight can significantly be reduced by application of carbon fibre reinforced polymers in tailored ply architectures, processed by the automated fibre placement technology. Based on a reference finite 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.

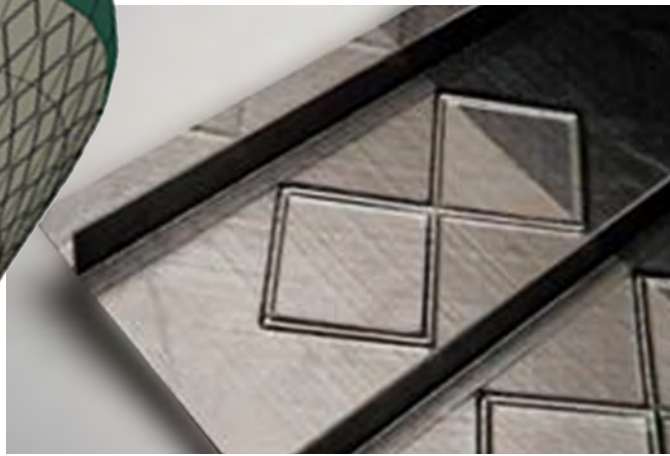
Dedicated local reinforcements are composed by smart overlapping in order to improve the buckling behaviour between the reduced amount of blade stiffeners. This innovative optimisation method in combination with the automated fibre placement technology will lower knock-down factors, reduce weight and minimize scrap material, resulting in reduction of material consumption and processing time in order to save manufacturing costs and increase the payload. 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.

**WHAT?**

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. Together with application of smart tooling, a snowball effect is created to reduce. A detailed track record of each component will be available in a manufacturing database, containing as-built information.







**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

**Project partners**

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


Artist impression : SkywalkerPL

# ARIANE 6:

## Europe's development of the sixth generation launcher

### WHY?

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.

### HOW?

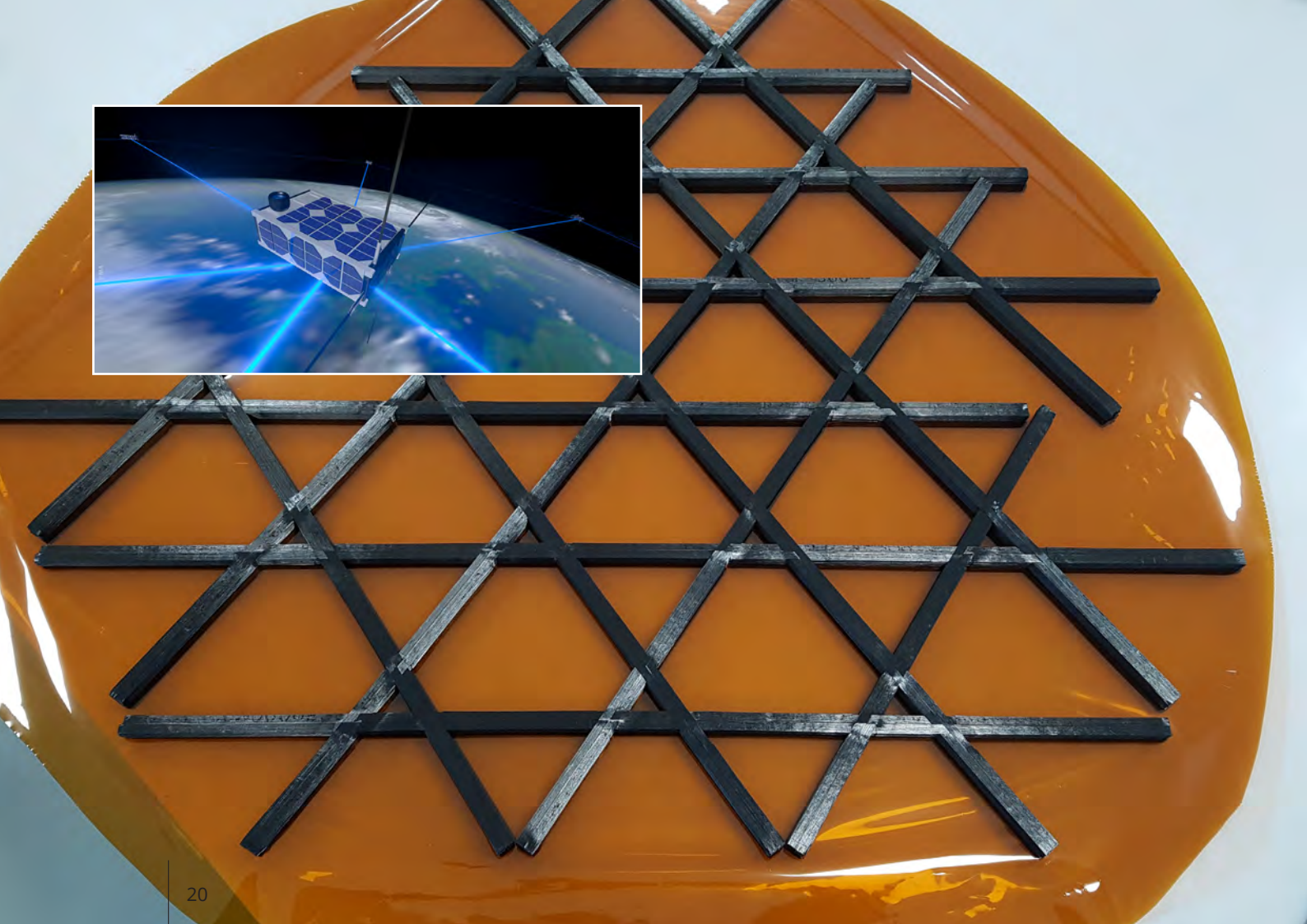
In the entire development of the Ariane 6 launcher, NLR plays various roles. Most effort of NLR up to now has been devoted to providing ArianeGroup with wind tunnel models for various stages in the development:

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

### WHAT?

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.



# Dimensionally Stable CFRP Grid Stiffened Structures for Space Applications

With the increasing maturity of composite materials and more automated production processes, grid structures are gaining more and more attention. Application examples are mainly cylindrical structures in space applications, manufactured in a filament winding process. The European Space Agency (ESA) has identified the composite grid as a suitable candidate for a dimensionally stable spacecraft structure, acknowledging it is now at Technology Readiness Level (TRL) 2 and wishing the technology to make a leap to TRL 4 by manufacturing and testing a technical demonstrator.

In an ESA funded project a Telescope Support Structure (TSS) for the Tropospheric Monitoring Instrument (TROPOMI) was selected as a suitable candidate for replacement by a dimensionally stable grid structure. A preliminary trade study was conducted to study grid patterns and individual materials that minimize deformations under thermomechanical loads at the same time being compatible with the fabrication methods under consideration. A high-modulus UD prepreg thermo-set tape in combination with advanced fibre placement was selected for manufacturing.

Several design iterations were performed to optimise the layout and thickness of the grid while still meeting all the requirements. The final design of the grid consists of an anisogrid structure with a thickness of 80 mm. Due to the use of two tapes and a special cutting sequence at the crossings no additional thickness build-up is generated while in each layer 50 percent of the tapes are continuous in both directions at the crossing.

To verify the design of the grid a test campaign was conducted and the results were compared to finite element analysis. An 80 mm thick grid structure was manufactured and tested at several loadcases to demonstrate its compliance with the requirements at TRL 4.

**Project partners**
Customer: European Space Agency
R&D: NLR

# Maintenance of NASGRO/ESACRACK and FRAMES-2

**WHY?**

The European Space Agency (ESA) has developed and distributed since the mid-eighties the software packages ESACRACK and FRAMES-2. These packages can be used to verify the damage tolerance of spacecraft structures. ESACRACK can be used for fatigue spectrum generation and fracture control analysis. FRAMES-2 is a database system for storage, processing and retrieval of material properties and associated mechanical test results, specimen geometry and testing conditions. To be able to continuously support the users of this software packages: maintenance, bug fixes, and improvements are an ongoing effort.


**HOW?**

NASGRO/ESACRACK comes with mainly load-controlled crack geometries. These have been extended in several ESA projects by a number of displacement-controlled solutions which are for example important for crack growth analyses of constraint components such as in space structures (launchers) and engine components.
In order to generate these solutions many thousands of 3D finite element models were generated and solved, requiring a highly automated procedure to make this feasible. Use was made of the finite element tool Abaqus, offering a CAD modeler and an extensive application program interface with which external code can be written to modify the FE model and process the results. In a previous project at NLR a generic framework was developed with which such stress intensity factor solutions can be generated much more efficiently for complex geometries and loads. That framework formed the basis of these analyses.

## WHAT?

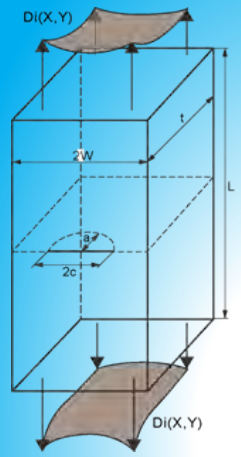
Added crack geometry stress intensity solutions are:

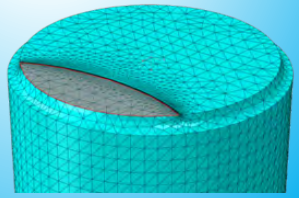
- Through crack at plate center with cubic displacement field (TC24)
- Through crack with offset and cubic displacement field (TC24 extension)
- Corner Crack with bi-quadratic displacement field (CC20)
- Surface Crack with bi-quadratic displacement field (SC33)
- Semi-elliptical surface crack in a round bar (under development)

The FRAMES-2 database has been extended with experimental crack growth test results of several materials, which required an extension of the software capabilities.

**Project partners**

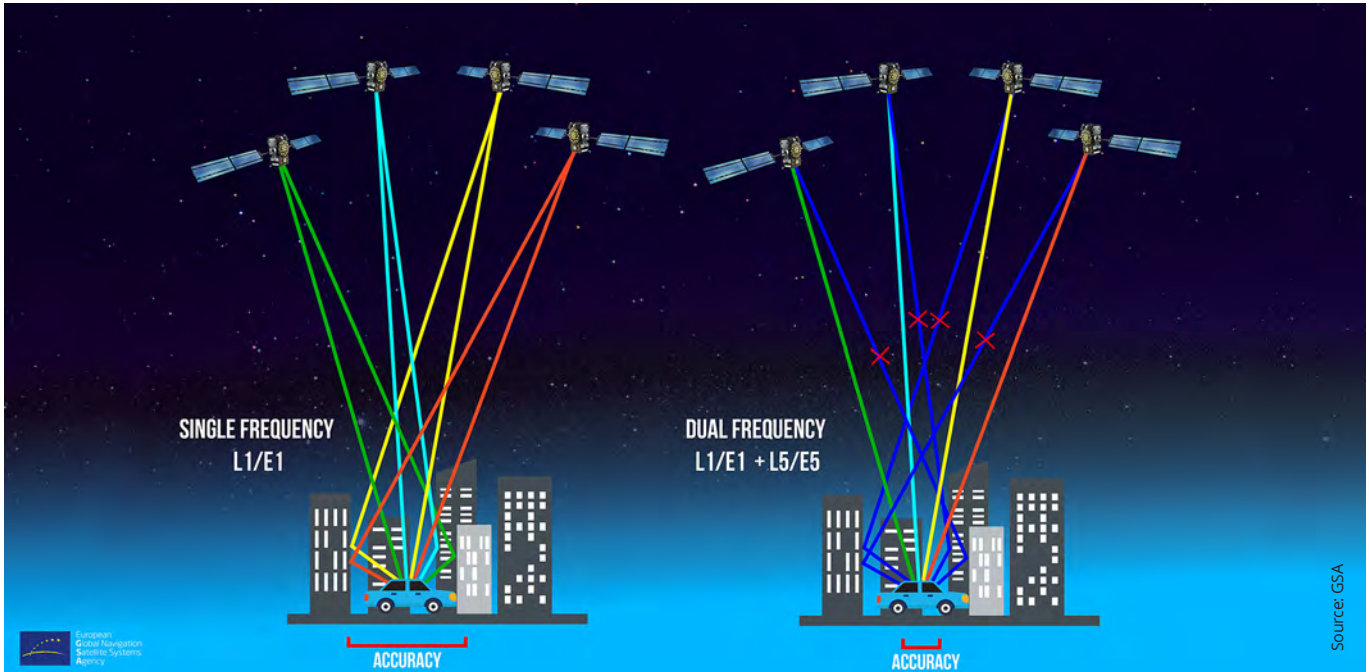
| | |
|---|---|
| *Industry (EU)* | : DOREA |
| *Research organisations* | : ESA, NLR |
| *Start* | : 2012 |
| *Duration* | : no end date yet |



# Satellite navigation for vital infrastructure and business opportunities

Royal 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 coming online, the focus is shifting 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:

## GALILEO PERFORMANCE MONITORING

The primary task of the Galileo Reference Centre (GRC) in the Netherlands is to monitor the performance of Galileo. Together with other parties in a consortium, Royal NLR supplies measurement data and performance calculations to the GRC. As part of the Netherlands' contribution, NLR requests data from the Land Registry and processes it. The Land Registry has its own network of satellite receivers in the Netherlands in order to improve the accuracy of its surveying. Measurements are also made using the NLR's Cessna Citation test aircraft.

## AIRFIELD MONITORING

For the Dutch Air Traffic Control (LVNL), NLR measures the performance of GPS, EGNOS and Galileo at Dutch airfields. Based on these measurements, LVNL can introduce new approach routes and procedures based on GNSS; strict requirements have to be met for this. Approach routes based on GNSS provide major benefits such as more flexible routes, reduced fuel consumption and noise, and cost reductions for the infrastructure at the airfields.

## UNMANNED SYSTEMS IN AVIATION AND THE DRONE WORLD

Tracking of unmanned systems, unmanned aircraft, cars and ships is widely used throughout the world. During autonomous flying, driving and sailing, the position is sent to a central system and monitored. NLR is investigating the vulnerabilities of receivers and how they can be improved, including creating an overview of the kinds of problems that arise in practice and recognising their characteristics. The key aspect here is detection.

## JOINT TEST ACTIVITIES

In addition to the public signals, which anyone can receive, there are also secure signals. GPS includes the P(Y) code, 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 the Joint Test Activities, a European initiative for encouraging the introduction of the PRS signal. A monitoring network is being set up in various European countries to accumulate expertise for the users. Various forms of interference in the Galileo signals in the airwaves are being studied. NLR is investigating the measured data and helping make measurements for monitoring the Dutch part. The results from all countries will be published for the general public, such as the European commercial sector.

**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

## WHY?

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.

## HOW?

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.

## WHAT?

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.

# Zero-G Flight Testing Capability

**WHY?**

- 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

**Newly certified and operational in 2018-2019**

Executed by NLR

**HOW?**

- 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
- A flight test organization which offers flexible (re) scheduling of flights and a short time between project request and flight test execution
- Part 21 based design organization to support installation of your application onboard our aircraft
- A flexible and affordable flight test facility representing almost one century of experience

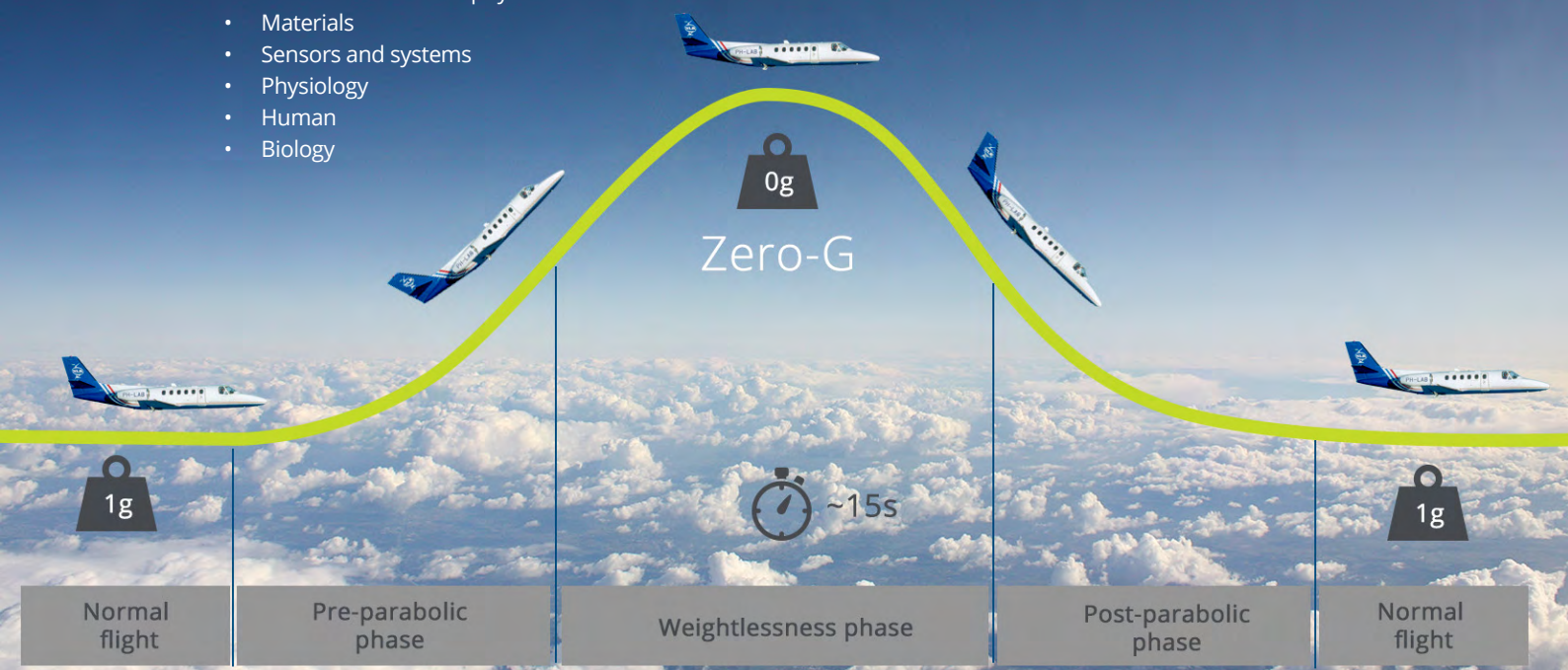
**WHAT?**

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

Low / 0-g gravity flight testing in the field of (among other):

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



# MPMP:

## Multi Parallel Micro Pump

### WHY?

As electronics gets smaller and smaller, interesting applications are starting to emerge to use these electronics for short / medium term usage in for instance cube sats and drones. The consequent heat generated by these electronics gets distributed over smaller areas, with large temperature gradients as a consequence. Convential 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.

### HOW?

We started by using a commercial micropump used for medical applications, which uses piezo's to displace the liquid. Multiple pumps placed in parallel will increase the flow, while placing them serial will give a larger pressure head, when needed.

**Project partners**

| | |
|---|---|
| *Research organisations* | : NLR |
| *Start* | : 2011 |
| *Duration* | : 8 years |

Although flexible, the liquids typically used for thermal control applications were not suited for the commercial pump, so we had to develop this, based on the commercial version. After many hurdles, we have a functional lab scale. With a functional prototype, we took a major milestone in this project, but we are far from an 'off the shelf' part. To further mature the project, we are currently investigating for industrial partners for the space approval and production.

### WHAT?

The Multi Parallel MicroPump 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 even see possibilities to increase the flow of the remaining pumps slightly to compensate for that occassion. This would make the MPMP a flexible, low cost solution for thermal control projects for smaller Mechanically Pumped Loops.

# Introduction: overview NLR

**SYSTEMS**

- Collaborative Satellite Constellations
- Launchers

**SPACE APPLICATIONS**

- Satellite navigation
- ISR
- Earth observation
- Space situational awareness (SSA)

**SUBSYSTEMS**

- Thermal control
- Space qualified electronics
- Electromagnetic compatibility
- Antennas
- Structures and materials

**TESTING**

- Environmental testing
- Material and structural testing
- Security and safety analysis
- Low gravity flight testing

# NLR in brief

| | | | |
|---|---|---|---|
| One-stop-shop | Global player with Dutch roots | 100+ Since 1919 | Amsterdam, Schiphol, Marknesse, Noordwijk |
| Innovative, engaged and practical | For industry and government | For civil and defence | 632 employees |
| € 88 M turnover | 72% Dutch, 21% EU and 10% international | Active in 26 countries | Extremely high client satisfaction |

# About NLR

## Netherlands Aerospace Centre

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.


# Milestones

- **1919** **Establishment NLR**
- First air brakes **1921**
- **1923** Flutter research
- First Dutch helicopter **1926**
- **1955** New propulsion helicopter
- Flight data stored digitally **1962**
- **1966** Supercritical wing profiles
- New wing shapes **1970**
- **1980** Accurate position determination
- Safer & quieter flying **1982**
- **1983** First astronomical satellite
- Air Traffic Control Simulator **1987**
- **1987** Vegetation monitoring Africa
- Lynx service life extension **2001**
- **2006** Detect-and-avoid-system
- Fighter pilots training simulations **2006**
- **2009** Hover trial simulation
- Antimatter detector cooling **2011**
- **2012** Tiltrotor wind tunnel model
- Cleaner, quieter landing **2016**
- **2019** **NLR 100 years!**

# A century of knowledge and innovation in aerospace

Wanting to progress is human nature. We dream about the unknown. We're curious about what we may find beyond the horizon and want to get to the bottom of things we don't understand. NLR has been an ambitious, knowledge-based organization for a hundred years now, with a deep-seated desire to keep innovating. We are very proud that we have received the royal predicate and that we are now the **Royal Netherlands Aerospace Centre**. Our knowledge and expertise have made us one of the driving forces in the aerospace sector, both in our own country and abroad. Our staff search tirelessly for new technology and have the courage to think outside the box, translating trends and developments into actual solutions for the market. That drive is helping us make the world of transport safer, greener, more efficient and more effective.

Above all, we keep looking ahead – because we have to keep setting ourselves tougher challenges if aerospace is to become more sustainable in the long term. How can we make sure that the environmental impact is minimized? How can we guarantee aviation safety despite its exponential growth? In short, how can we use airspace more efficiently? How can we make the best possible use of satellites and satellite data? The future looks highly demanding yet fascinating and it will require even faster innovation and closer cooperation, with the right driving forces behind it. We are devoting our knowledge and expertise to that future, with an eye on the interests of the commercial sector, the general public and the environment at all times.

Together with our partners, we can help shape the fascinating world of tomorrow. We are on the threshold of innovations that will really break the mould. But plans and ideas only really get moving if they are nourished with the right kind of energy – and the amazing thing is that the source of that energy is still exactly the same as it was when we started a hundred years ago. That driving force is NLR's knowledge.

## Knowledge powers the future

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