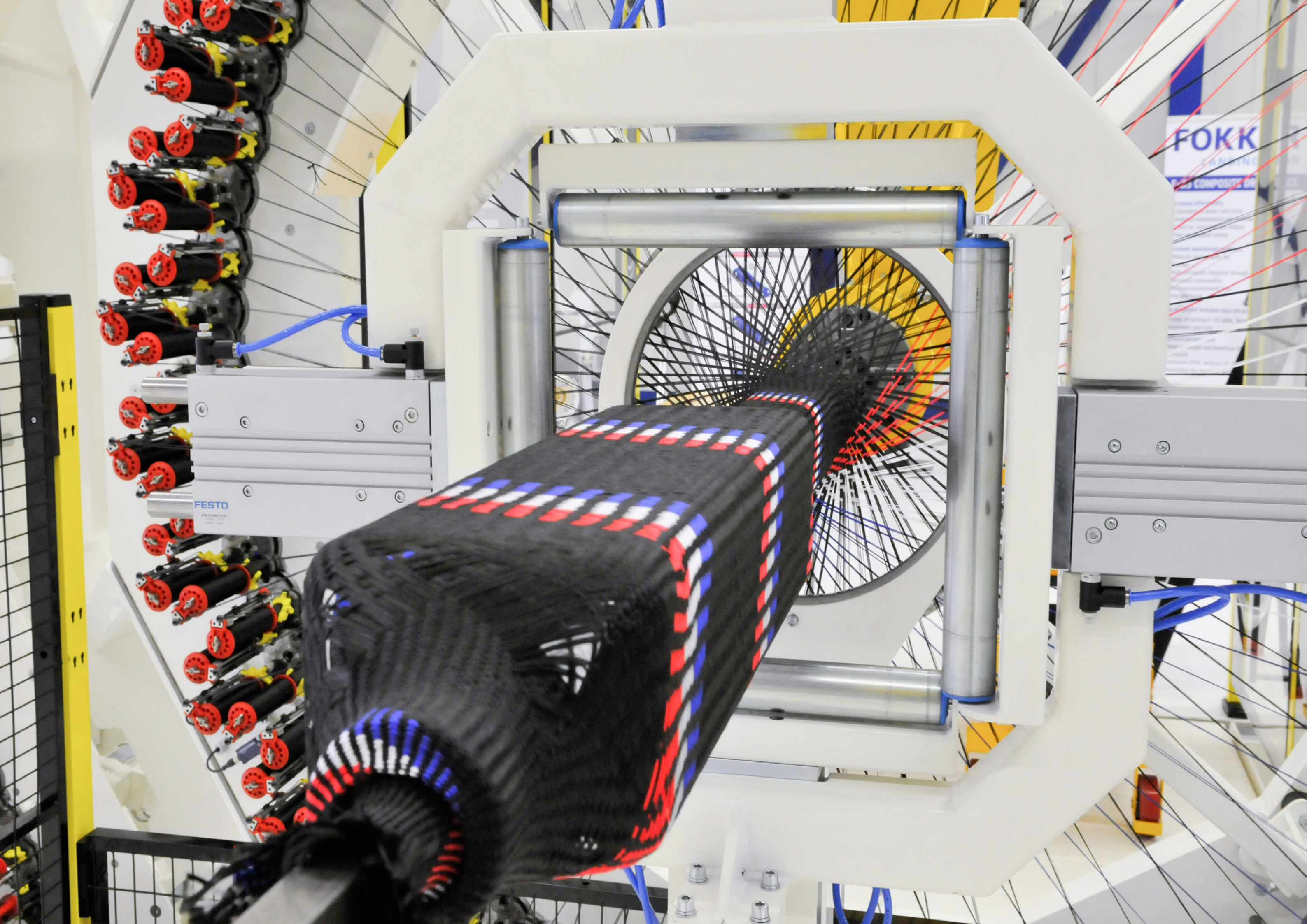
Dedicated to innovation in aerospace

Composites R&D

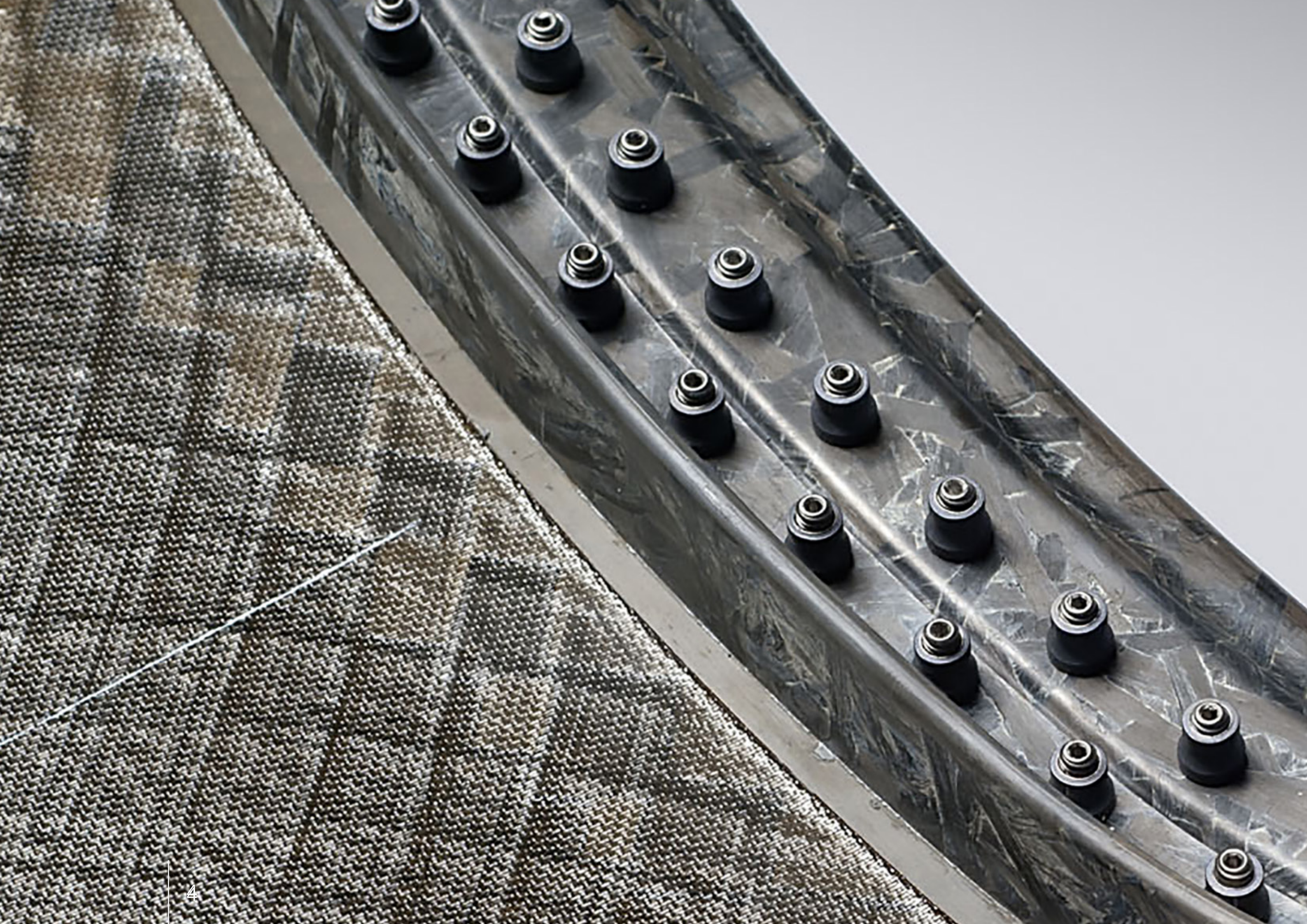
Netherlands Aerospace Centre


FESTO
FOKK

From process optimisation to industrialisation

Efficient, durable and automated

A key objective for more efficient and sustainable aircraft is to make lightweight, durable and affordable parts which are designed for ease of maintenance. To be allowed to use parts made of new materials like composite and metal additive printed components in an industry like aviation, all of the materials must be accompanied by the right certification. NLR takes care of the entire process, from calculation and design all the way through to manufacturing and certification. NLR assesses material properties, develops structural concepts and manufacturing technologies, designs components and builds parts up to the level of full scale prototypes. Spanning the entire spectrum of product development is what makes NLR unique.



NLR composites

Automated Composite Manufacturing Technology Centre (ACM Technology Centre)

It starts at the ACM Technology Centre, a facility that addresses research questions at the low to medium Technology Readiness Level (TRL) or levels 3 to 6. In close collaboration with industry, NLR elaborates ideas that are not yet viable or for which the business case is not yet clear, but which have the potential to become really big. NLR does this in a research environment where we sometimes develop the hardware ourselves.

Automated Composite Manufacturing Pilot Plant (ACM Pilot Plant)

After the ACM Technology Centre phase, it continues to the ACM Pilot Plant for the development of TRL 6 to 8. Within the ACM Pilot Plant NLR uses state-of-the-art equipment . The end-user must be able to do a copy-paste, so to speak, and start up production in their own facility.

Automated manufacturing

With the increasing penetration of robots in the production process, NLR also meets the demand for automation. The ACM Technology Centre develops a robot-based process for producing composite components. The actual robots are always ‘off-the-shelf’ models to which various end effectors can be fitted. If necessary, NLR develops its own end effector, frequently in cooperation with the robot manufacturer. NLR knows the requirements a certain robot end effector must meet, such as the pressure that must be exerted, it’s flexibility and so on. This is an important element in the cooperation with SMEs. NLR possesses the fundamental knowledge and understanding of materials, the manufacturing process and the final products.

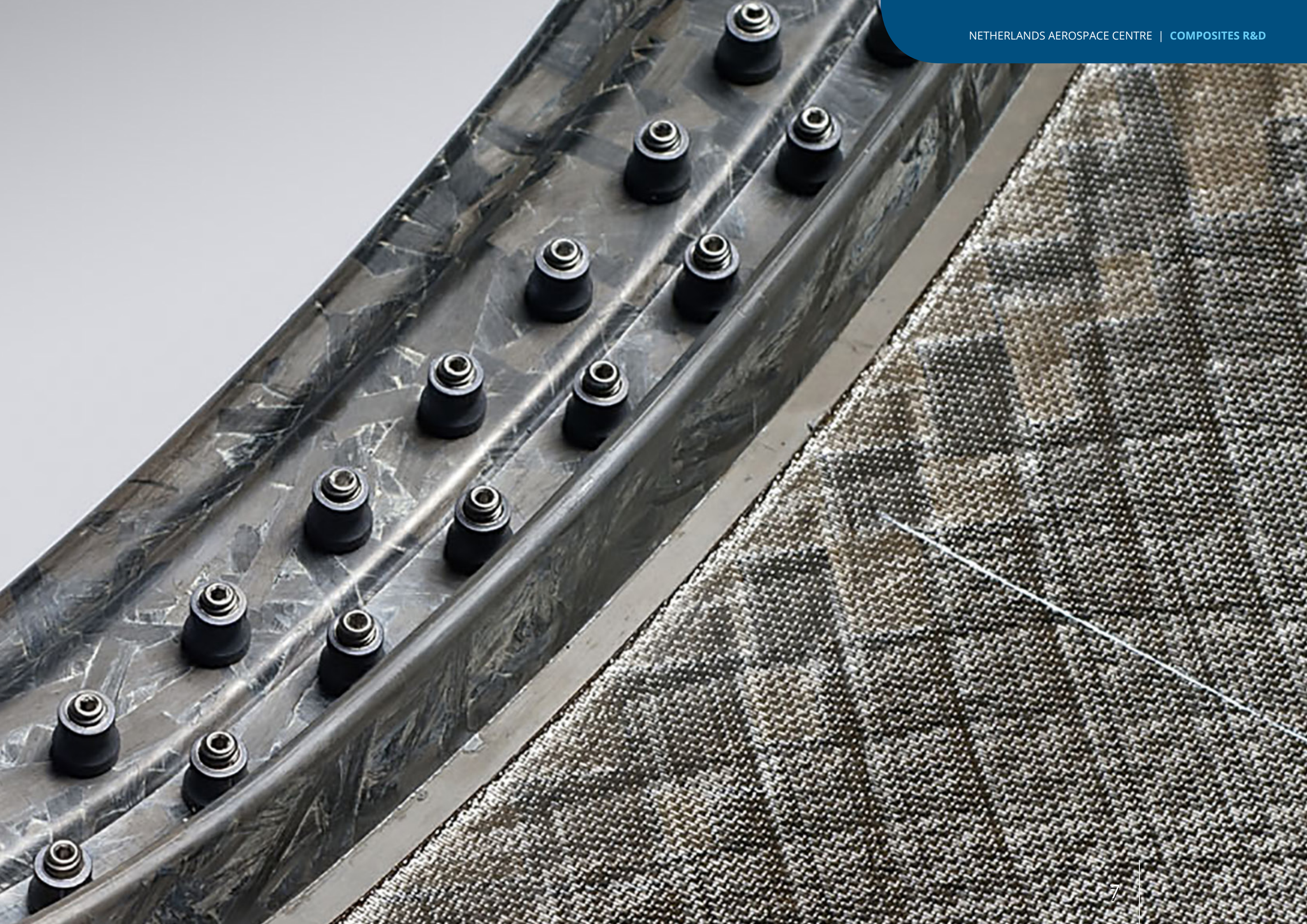
Detecting and repairing damage of composite parts

Besides the manufacturing industry, NLR is also active for MRO (Maintenance, Repair and Overhaul). There is a lot of MRO work that has to be done because, compared with metals, composites behave differently in the event of damage and maintenance. Knowledge of ageing and repair is becoming increasingly important, particularly with the growing number of composite aircraft parts.

The most important question in the aerospace industry is whether it is possible to continue flying after damage has occurred. With an aircraft made of metal there will be a dent, but in composite material you probably won’t see anything, although there is probably damage all the same. NLR has the equipment and the know-how to inspect such an aircraft and to determine whether the damage has to be repaired immediately or whether it is possible to continue flying.

Certification

When developing a new composite part, certification immediately has to be factored in. NLR is deeply involved in materials research so as to gain a better understanding of what happens to various materials, such as composites and printed parts. NLR ranks among the leaders when it comes to knowledge and certification.



Automated Composite Manufacturing Pilot Plant

NLR has renamed and repositioned its automated composites pilot plant into ACM3Field Lab ('ACM Cubic') with the aim of attracting more Small- and Medium-sized Enterprises (SMEs). This well-equipped, state-of-the-art field laboratory makes high-tech equipment available for the development of light-weight products.

The purpose of ACM3 (Field Lab for Automated Composites, Metal Manufacturing and Maintenance) is to support companies in the development of light-weight systems made of composite materials and/or metal. This support can be provided in nearly all phases of product development: from concept studies and material screening to preparing detailed designs and creating concepts. Repairs and full-scale prototyping are also carried out in the centre. ACM3 is optimizing accessibility in various ways. For instance, a 'menu' of the available equipment has been prepared to provide quick insight into the facilities and their operation. This allows companies to discover at a glance what they can do at ACM3. Users can receive training or hire an NLR operator if the equipment is too complex for unassisted operation. During the production of a pilot run, for instance, users can receive training to ensure that properly qualified personnel is available when actual serial production starts at the customer site.

Affordable prototypes

The centre particularly offers benefits for SMEs. Without any requirement for major investments, they can join forces with NLR and use the equipment available at ACM3 to work on the development of new light-weight products and the required manufacturing technologies. This process can start with 'proof of concepts' that are eventually developed into full-scale prototypes.

Another benefit is the ability to postpone capital investments until there is more certainty about the commercial potential of the product. The facilities at ACM3 enable companies to delay the ordering of production equipment until there is greater certainty of a successful market introduction. In order to bridge the intervening period and maintain market momentum, companies can use ACM3 equipment to produce the initial pilot runs.

This enables costly capital investments to be postponed until there are sufficient prospects of product sales, so that the much-feared 'Valley of Death' that affects many companies (particularly SMEs) can be avoided. One recent achievement illustrating the potential of ACM3 is the successful development of PAL-V: the world's first flying car production model, equipped with unique collapsible rotor blades. Designs for the composite rotor blades and propeller were developed and tested in the NLR Field Lab. The required manufacturing method was also developed here.

Highlights

High temperatures, high performance, low costs

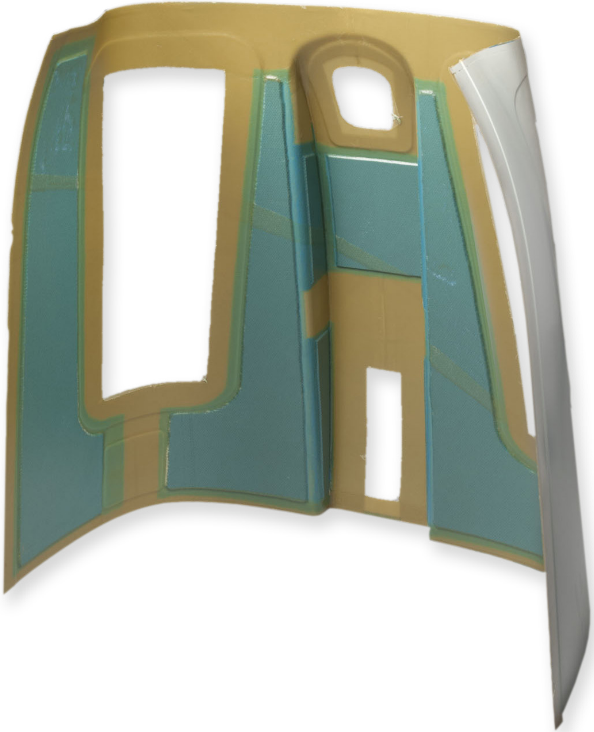
Work Programme 6.5 (WP 6.5) in ESPOSA (Efficient Systems and Propulsion for Small Aircraft) is an EU- funded project for the development of new and innovative design methods. The aim is to create advanced, higher-temperature capability composite nacelle structures for small aircraft. This will allow a cost-effective manufacturing solution suitable for this class of aircraft. To achieve this goal, several composite technologies were examined in order to leverage the potential of the most promising emerging materials and processes, such as Liquid Moulding (infusion) and Out-of-autoclave prepregs.

For the Piaggio P180 nacelle, the operating temperatures were very high. Original measurements performed on the metal version recorded temperatures of 200°C, so the prototype carbon-epoxy nacelles were inadequate. A high-temperature resin was obviously required. The type of aircraft, the required performance and the market resulted in the use of carbon fibre. However, a low-cost, high- performance approach was preferred and was achievable by means of a novel BMI resin and vacuum infusion. Based on the trade-off, it was decided to opt for the BMI-2 resin and vacuum infusion for onward development in ESPOSA. The results were very promising and confirmed the potential for a significant lowering of manufacturing cost and weight.

BMI composites

NLR in association with resin supplier Raptor Resins successfully employed a new vacuum resin injection method in 2013 using the Bismaleimide (BMI) resin system. This method enables the manufacture of composite structures that can withstand high temperatures. The resin system, called BMI -2, was developed in the United States by Raptor Resins, initially for use in USAF research for repair of BMI composites. BMI composites are used to a significant extent in the F22 and F35 fighters.

The resin has unique properties compared with the standard BMI resin systems currently available. This paves the way for the further use of composites in high-temperature applications such as gas turbines. The processing method, requiring only vacuum and heating, also makes it highly suitable for repairs of high-temperature composites.



An analysis of the manufactured product showed that the material properties will meet the requirements of the aerospace industry and other high-performance composite applications.

Work Program 6.5 (ESPOSA)
NLR - WP leader and main responsible partner for the design of the composite tooling required for the nacelles and actual manufacture of the composite nacelle components.
CIRA - Materials & Processes for BMI infusion and OOA prepregs.
P180 Carbon-BMI nacelle: Piaggio - design responsible partner.
ELEMENT - structural analysis.
VZLU - mechanical and fire resistance test (AC20-135) on the Carbon-BMI.
Grob - tooling manufacture.

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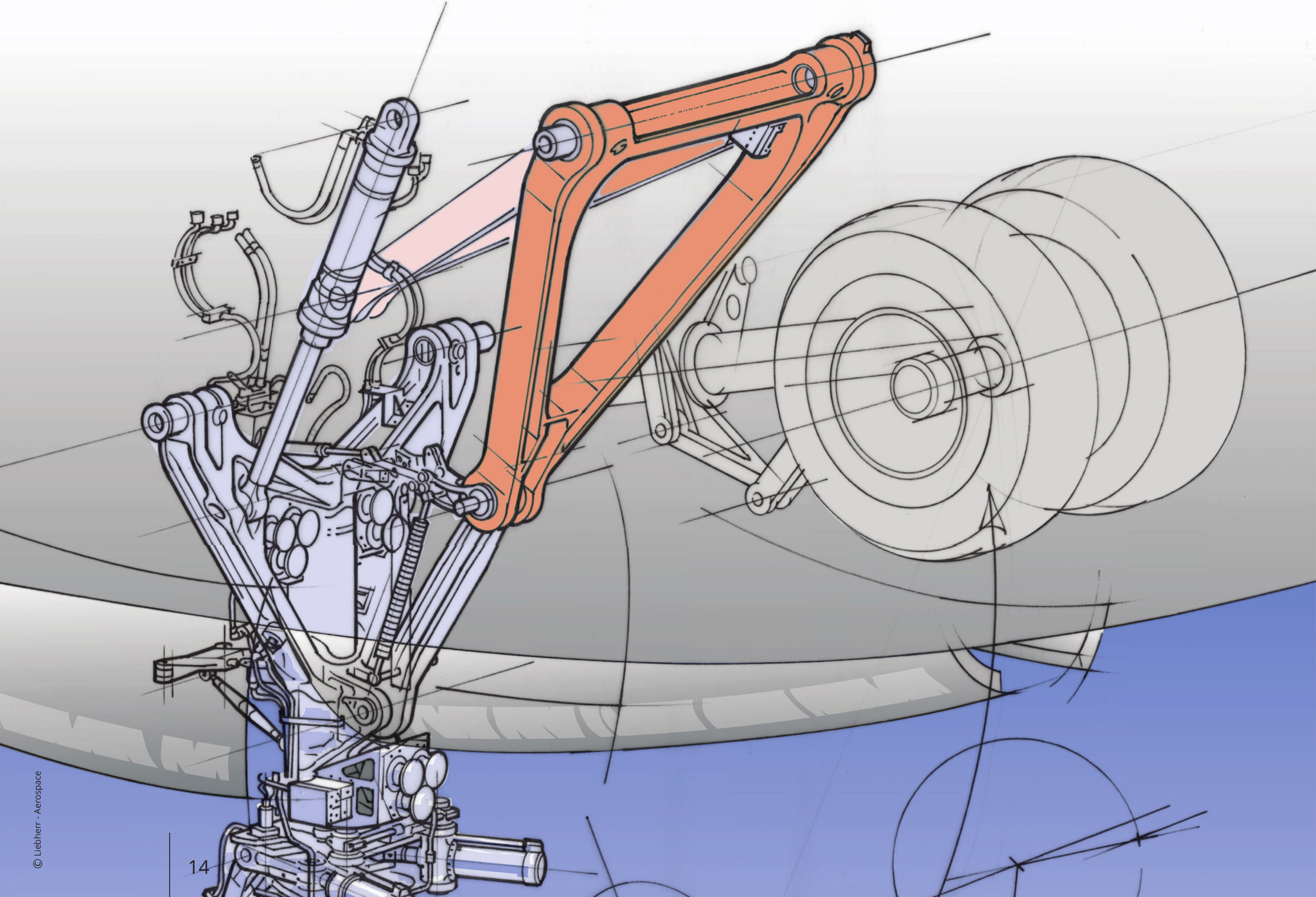
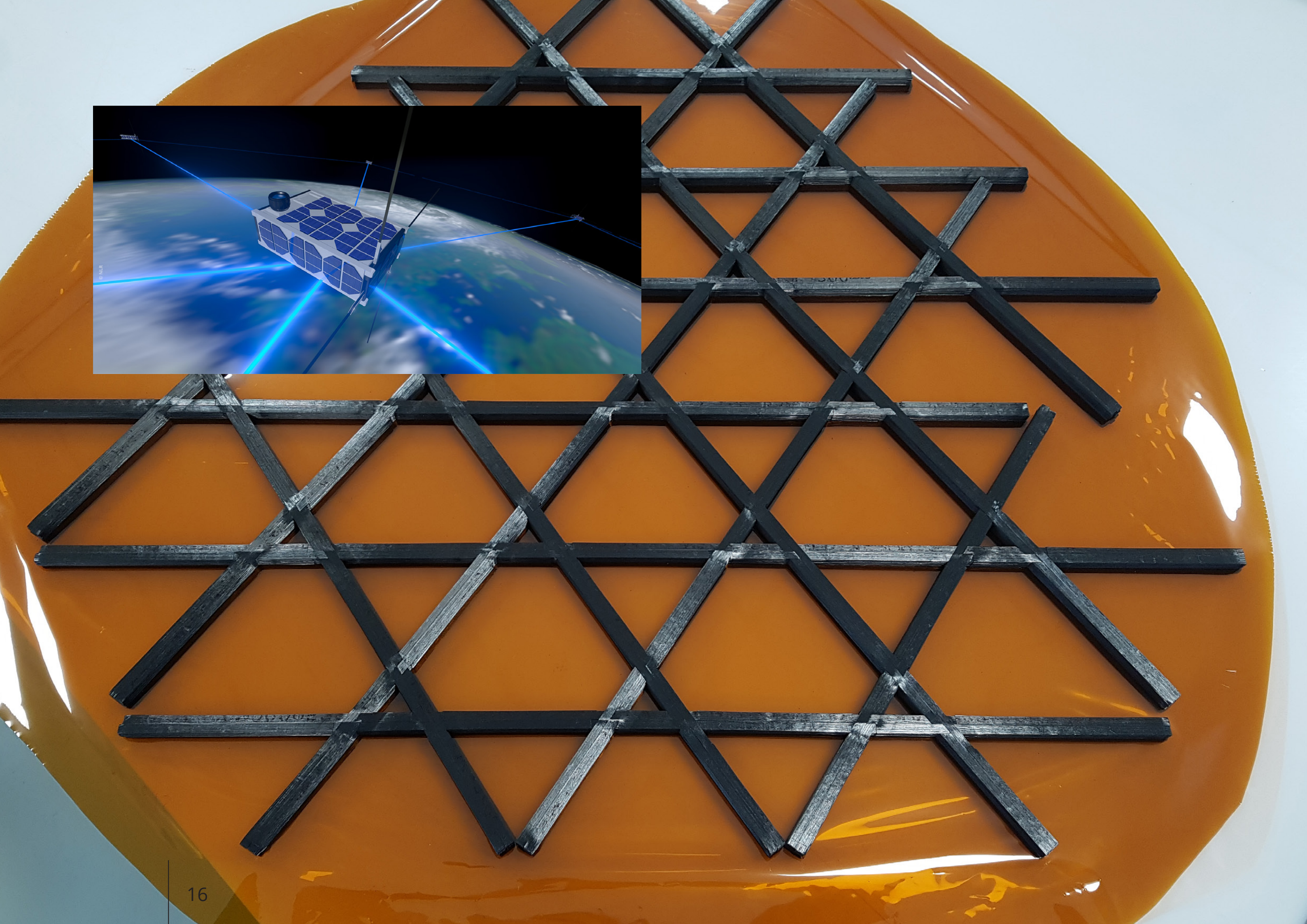


Development of composite drag stay for Airbus A350-1000

IWithin the CS2 Systems ITD a CFRP drag stay for the A350-1000 is being developed in the Core-Partner project HECOLAG. The goals for the CFRP structure are a weight saving of over 30% at recurring cost similar to the current aluminium drag stay as manufactured by Liebherr-Aerospace. The CFRP drag stay is designed by Fokker Landing Gear (part of GKN Aerospace) in cooperation with NLR, to requirements set by Liebherr Aerospace. Within the project NLR has focused on automated manufacture of preforms for these types of complex geometries. The present design is optimized for automated preform manufacturing and offers a weight saving of approximately 40%. The tooling for prototype manufacturing is designed and built by Compose Tooling. Functional prototypes are being manufactured by NLR and will be tested in 2019 by Fokker Landing Gear.

Project:	**HECOLAG**
Customer:	**Liebherr Aerospace**
Partners R&D and testing:	**NLR, Fokker Landing Gear, Compose**

Horizon 2020
European Union Funding
for Research & Innovation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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 thermoset 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.

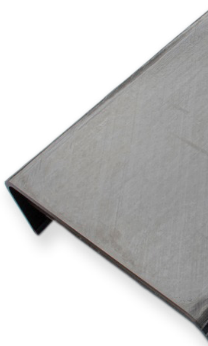
To verify the design of the grid a test campaign was conducted and the results were compared to finite element analysis. An 80 mm thick grid structure was manufactured and tested at several loadcases to demonstrate its compliance with the requirements at TRL 4.

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

Thermoplastic automated upper spar for an aircraft pylon by Fibre Placement

The challenge: to find out whether thermoplastic materials can be used for really thick and large components, for example in aircraft. Parts of the aircraft engine pylon become very hot during normal use of the aircraft. For that reason, the pylons currently used are commonly made of titanium. Most of the parts, such as ribs and spars in the pylon, are made by forging and milling. A reduction of costs might be achievable if the titanium parts can be replaced by composite materials.

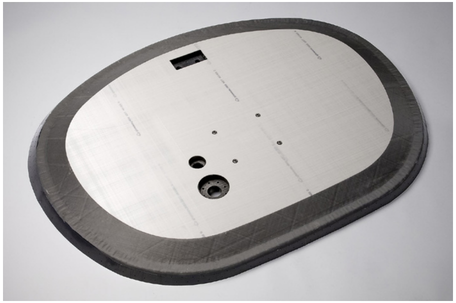
As part of a Dutch innovation programme TAPAS 2 (Thermoplastic Affordable Primary Aircraft Structure 2), NLR examined the manufacturing of a large and thick thermoplastic composite part using Advanced Fibre Placement and Cetex, TC1320 AS4D PEKK material of TenCate. Within this programme, a preliminary design was made for a pylon upper spar using finite element calculations. Mechanical tests were conducted with the material at higher temperatures and a first prototype was constructed. The prototype was made by fibre placement on a male mould and subsequently consolidated in an autoclave.



Based on developments in this programme, it was concluded that thick components can be made of thermoplastic materials with an automated manufacturing process, thus reducing weight and production costs. The material is usable at higher temperatures. This innovative process has great potential for thick U-shaped products in the aerospace sector. The technique is also usable as a replacement for a wide variety of products like wing spars, stabiliser spars and floor beams.

Customer:	**Netherlands Enterprise Agency - RVO**
R&D:	**NLR**
Partners:	**GKN Fokker Aerostructures, TenCate, Airbus**

10% weight reduction, high stiffness and cost effective manufacturing



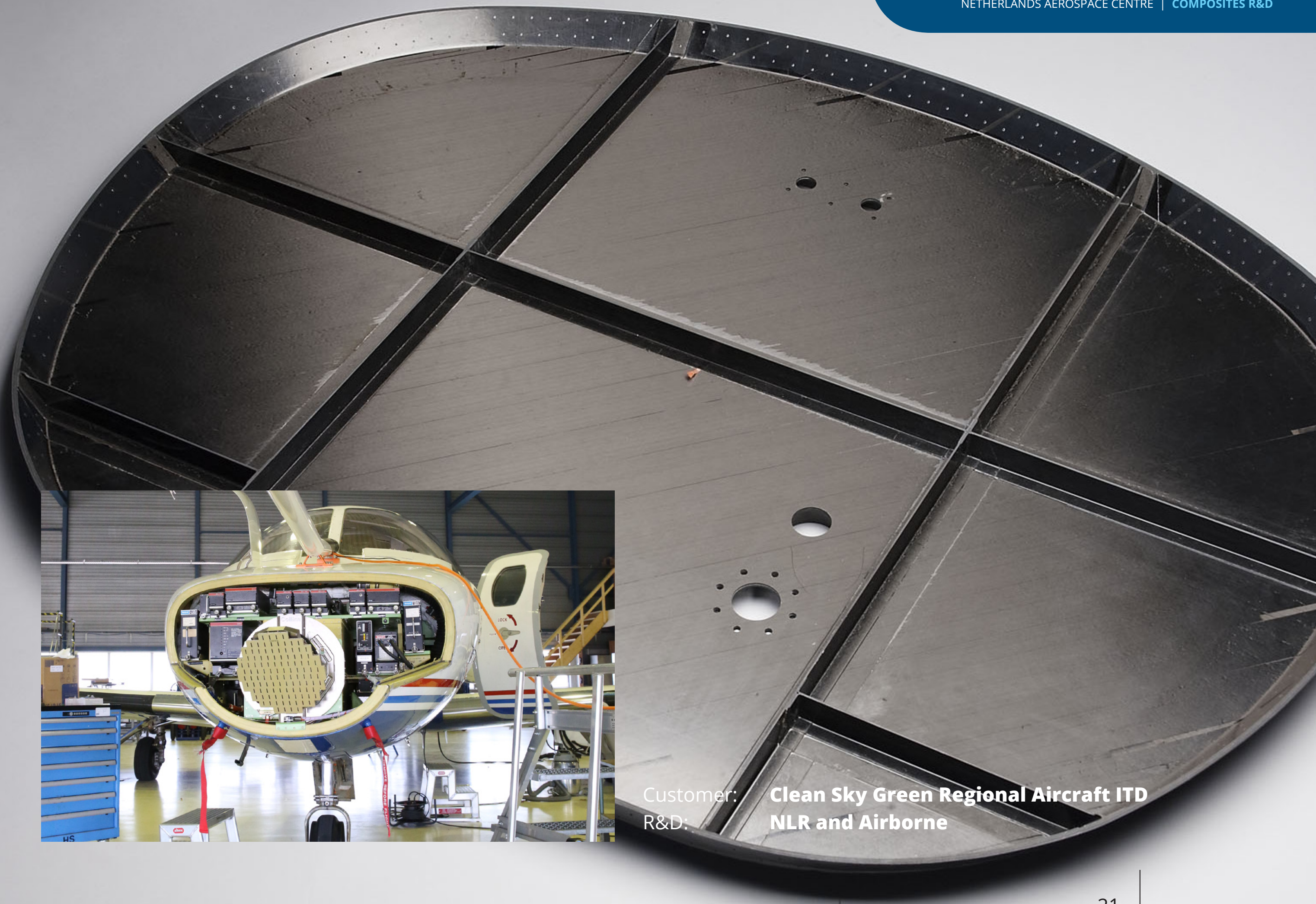
The challenge: to design and manufacture a composite forward pressure bulkhead that is 10% lighter than the original aluminium bulkhead, while still meeting bird impact and stiffness requirements. An obvious job for NLR and partner Airborne, commissioned for Clean Sky Green Regional Aircraft ITD.

Two concepts were evaluated: a stiffened solid panel and a sandwich concept.

Solid or sandwich composite panels
It was found that the solid panel did not meet the high stiffness requirements without compromising on weight. While the sandwich concept could easily meet the stiffness and strength requirements, the bird impact analysis revealed that the concept failed to meet the requirements. Therefore, a Dyneema plate was added on top of the sandwich to protect the bulkhead from bird impact damage.

Cost-effective manufacturing
Another project challenge was the use of a cost-effective manufacturing concept. The Liquid Resin Infusion process was selected, using a cost-effective tooling concept. A semi-flexible caul plate was used to achieve the required tolerance and surface roughness on the perimeter flange. The caul plate was be made of a non-silicone tooling rubber, locally stiffened with a CFRP prepreg.

The injection strategy included injecting the resin in the centre of the blade stiffeners and using runners on top of the blade stiffeners and the perimeter flange to distribute the resin, after which the resin flowed up the perimeter flange to end at a membrane on top of the product.



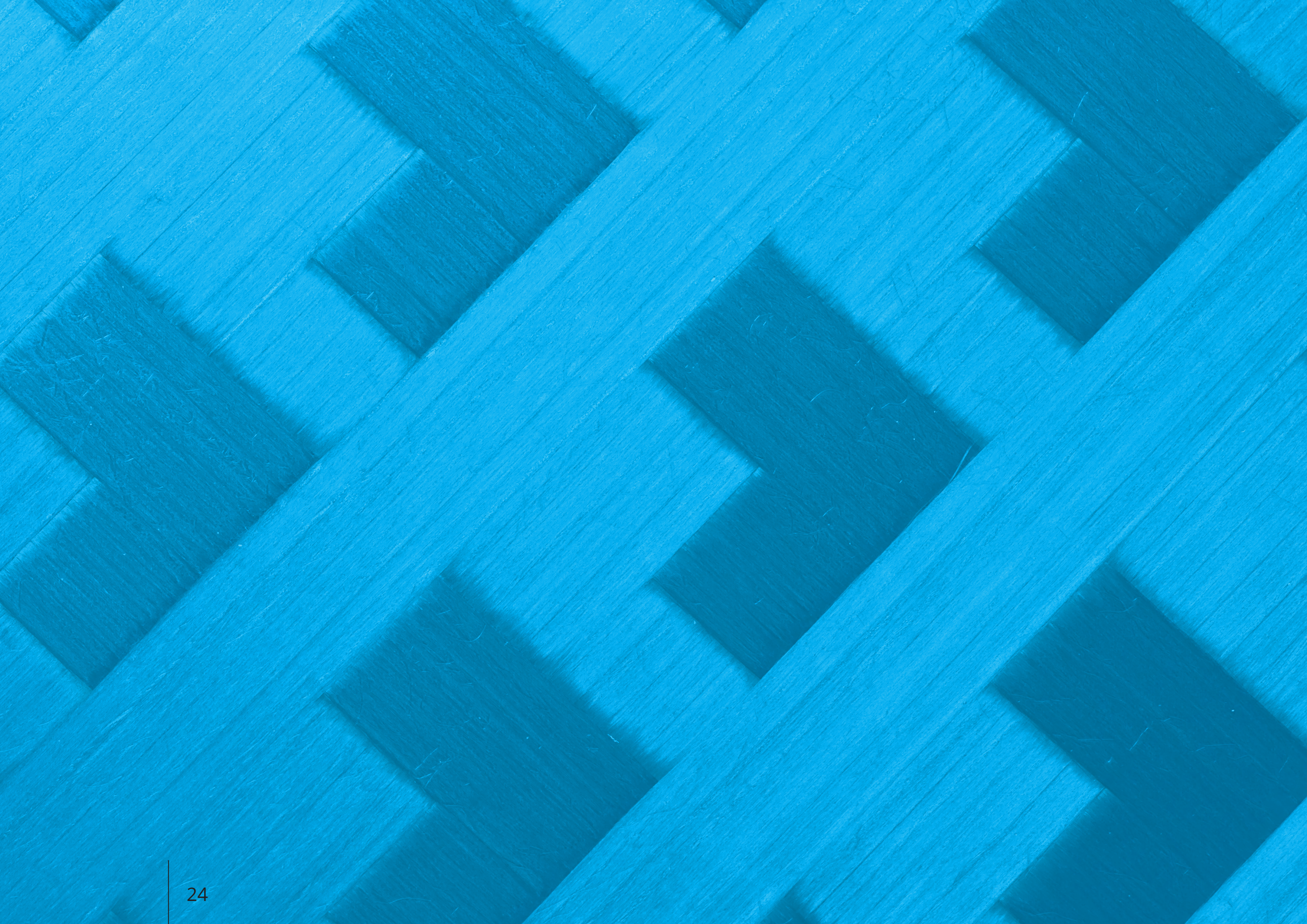
Customer: **Clean Sky Green Regional Aircraft ITD**
R&D: **NLR and Airborne**

Foldable rotor blades and foldable propeller for the PAL-V

The PAL-V Liberty is a true innovation. This new Personal Air and Land Vehicle is capable of driving on the road at 160 km/hour and of flying at up to 180 km/h. In flying mode, the gyrocopter principles are applied. In drive mode, the rotor and propeller are folded. The foldable rotor blades and foldable propeller have to comply with the EASA CS27 small rotorcraft design principles and airworthiness requirements.

PAL-V and NLR evaluated several conceptual solutions for the foldable rotor blades and propeller. The most promising concepts were developed into a mature design that can meet certification requirements. The main challenges were the reduction of the weight of the rotor system and the integration of a free flappable mid-hinge in the rotor blade. Low-cost manufacturing processes based on press moulding principles were developed. Fully functional prototype rotor blades and propellers have been manufactured and are being tested.

PAL-V Liberty was introduced at the Geneva International Motor Show (8-18 March 2018).



Technology Readiness Level, R&D and industry

In the field of construction technology, NLR develops at almost all TRL levels from 1 to sometimes 8. To be able to implement the processes properly elsewhere, the goal is to work towards generic, flexible systems. A significant portion of the research nowadays takes place virtually using simulations, which speeds up lead time and reduces costs.

TRL stands for Technology Readiness Level, a method of estimating technology maturity of Critical Technology Elements (CTE) of a program (hardware, components, peripherals, etc) to integrate this technology into an operational system or subsystem. TRL 1 is the lowest level, where scientific research begins to be translated into applied research and development (R&D). For NLR, TRL 8 is the highest level, where the actual system is completed and qualified through test and demonstration. TRL 9 is the highest TRL level.

NLR in brief

- One-stop-shop
- Global player with Dutch roots
- >100 — 100 years young
- Amsterdam, Marknesse, Schiphol
- Innovative, engaged and practical
- For industry and government
- For civil and defence
- 632 employees
- € 73 M revenue
- 75% Dutch, 21% EU and 4% international
- Active in 29 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.

NLR enjoys working in a challenging and fast-changing field of research every day, assisting a wide range of clients. All of this knowledge benefits companies that are suppliers of large corporations like Airbus and Boeing and SMEs. Much of the knowledge of these new materials is also widely usable in other fields, such as the automotive industry, the maritime sector and the infrastructure, creating numerous spin-offs outside the aerospace industry.

Some of our partners and clients: Airborne, Airbus, CIRA, Clean Sky Green Regional Aircraft ITD, Compoworld, Dutch Thermoplastic Composites (DTC), European Space Agency (ESA), Fokker Landing Gear, GKN Fokker Aerostructures, Grob, Gurit Ltd, ICO BV, Kuiken NV, Liebherr Aerospace, Pal-V, Piaggio, TenCate, Rijksdienst voor Ondernemend Nederland (Netherlands Enterprise Agency), Province of Flevoland, VABO Composites, VZLU.

Some of the programmes NLR is currently involved in: CleanSky (European Union),TAPAS 2 (Thermoplastic Affordable Primary Aircraft Structure 2).

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