Dedicated to innovation in aerospace

NLR Strategy Plan 2022-2025

Royal NLR – Netherlands Aerospace Centre

Cover image: the electrically powered research aircraft PH-NLX. This Pipistrel Velis Electro is how NLR is taking an important step in strengthening knowledge and experience of electrically powered flight in the Netherlands.

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Our society is always demanding mobility and products

Summary

During the strategy period through to 2025, we are laying important foundations for achieving the climate targets set by the European Green Deal and ACARE, we are supporting the Ministry of Defence in the Netherlands in the initial implementation steps of its vision for 2035, and we are standing shoulder to shoulder with the aerospace sector to come out of the coronavirus pandemic in a stronger position. In this report, we analyse how society is expected to develop, what technology will be on the rise and what that means for aerospace. Additionally, we reflect on our own performance during the previous period.

The world population is growing and average life expectancy is increasing. As a society, we are increasingly aware of the risks of climate change and – thanks to worries about scarce natural raw materials – of the environment we live in and nature in general. The balance of power in the world is shifting and the threats are becoming hybrid in nature to an ever-increasing extent. That is putting the squeeze on our security, which is a precondition for our freedom and democracy. Hand in hand with that go changes in global trade, affecting the economic position of the Netherlands. The growing middle class in our society is always demanding mobility and products. The demand this creates for transport and cargo movements is being met at both the national and regional levels by a balanced mix of transport modalities. Population growth and accelerating urbanisation are imposing higher demands on safe infrastructure in and around the cities.

Technological development is proceeding apace and is making all kinds of things possible using smarter machines, robotics, automation, artificial intelligence (AI), advanced sensors, miniaturisation, AR/VR, digital twin techniques and human-machine integration. The development of explainable AI (XAI) is relevant for specific applications where you want to know how the AI reached its answer. In the case of autonomous systems in particular, this helps determine the consequences of the actions. That is certainly true for military applications in which unmanned and autonomous systems are playing an ever more important role. NATO [24] refers to Big Data, and advanced analytics, artificial intelligence, aerospace and hypersonic technology as 'disruptive technologies' that are expected to have a major impact on defence and security.Technological breakthroughs are also badly needed if aviation is to be climate-neutral, for production and for recycling. New concepts for power trains, energy storage, aerodynamic properties, materials, ultra-lightweight structures and propulsion integration are being studied so that emissions can be significantly reduced or even eliminated; attention for alternative propulsion methods is also growing strongly.

The European Commission is encouraging the digitalisation of the European economy and society; the Netherlands also has a strategy for digitalisation. Industry in the Netherlands is digitalizing and automating. Optimisation for 'right first time' production and products by using ICT, simulation tools and new manufacturing techniques such as 3D printing is making both the production process and the products created more efficient, cheaper and more sustainable, as well as improving the quality. Digitalisation is also making inroads in predictive maintenance: doing the work at just the right moment instead of preventively or in response to problems. Europe is attempting to achieve a single Digital European Sky by 2040. Digitalisation and automation of the infrastructure for air traffic control will lower emissions further.

National and international stakeholders are highly appreciative of the research carried out by NLR and the services it provides. We have also shown that we are able to cope during times of global crisis, although there are also points where we can improve

and become more robust for the future. In 2020, an independent committee assessed our quality, impact and vitality using the Evaluation and Monitoring Framework for Applied Research protocol (EMTO in Dutch). The committee assessed the quality of the research as being very good and in some areas even world-class. The impact of the work we do is also good and customer satisfaction levels are always high. NLR could however be more proactively involved with its stakeholders and the scientific impact could be improved.

As regards the vitality, the committee's conclusion was that the financial position is healthy. NLR is a financially robust organisation and must of course remain so in both the shorter and longer term. This does not have to be done for profit, but there must be sufficient scope for investment in knowledge and product development and technological infrastructure. Our state-of-the-art research infrastructure plays an essential role in accumulating knowledge and in technological development. For major upgrades of facilities or new investments, NLR depends on the government's funding regulations. Large research facilities are indispensable if we are to achieve our strategic objectives. The material scope for investments that this demands is not currently in place. On top of that, structural increases in the annual funding are needed if we are to maintain our current portfolio of research Infrastructure and adapt it to the future needs of government and the commercial sector in the Netherlands. The EMTO committee has underlined the importance of sufficient scope in the investments for the research infrastructure in a plea made not only to us but also directly to the government. It has also been noted that there is room for improvement in aspects of the HR policy such as diversity and inclusivity. NLR is happy to take the committee's recommendations on board.

This strategy plan explains what we are aiming to do and how we are going to make a success of it. NLR has a pioneering role in the Netherlands as the link between science, the commercial sector, society and governmental bodies. In our vision, we are focusing on 2035 and, where possible, on horizons beyond that. NLR is concentrating on three long-term themes in which we want to make an impact:

1. Sustainable aviation
2. Competitive aerospace
3. A safe and secure society

We are setting ourselves concrete and ambitious goals for each of these for the coming strategy period. The cornerstone that we are going to keep strengthening further is our knowledge base. On top of the single-discipline fields of knowledge, there are nine multidisciplinary programmes that NLR is using to put the strategy into practice:

1. Climate-neutral aviation
2. The impact on people and society
3. Safe and competitive operations
4. Aerospace vehicle development
5. Operational availability
6. Information-driven operations
7. Future air & space power
8. Unmanned and autonomous
9. Emerging technologies

NLR is aware that success in these areas relies on our own people and our clients. We want to be an inspirational organisation for them that responds to changing surroundings and makes the most of them. We believe firmly in improving performance through broadly-based teams. A diverse workforce makes us better able to have an impact for our customers and stakeholders, as well as for our own people and for society, of course. Everyone must feel that they are welcome, safe, valued and respected.

The market approach remains concentrated in five solid and recognizable market segments:

1. The civil aviation industry, focusing on the manufacturing sector and MRO operations.
2. Civil aviation operations, focusing on aerospace companies, air traffic control, airports, regulatory bodies and governmental authorities
3. Defence and security (governmental), concentrating on the long-term strategic relationship with the Ministry of Defence and the relatively new relationship with JenV (the Ministry of Justice and Security).
4. Defence and security (industrial), focusing on the defence industry in the Netherlands in the supply chain and on international OEMs (original equipment manufacturers).
5. Space, focusing primarily on strengthening the Dutch ecosystem of aerospace companies and on reliable access to vital space infrastructure.

NLR responds to the latest developments in the market and we retain a powerful focus on our vision, themes and programmes as described here. NLR has access to a wide range of stakeholders. The ministries of Infrastructure and Water Management (IenW), Economic Affairs and Climate Policy (EZK) and Defence are long-term strategic partners for us. We also want to strengthen our many cooperative activities involving the commercial sector. Both domestically and abroad, NLR cooperates actively with research institutions – something we are aiming to get even more out of during the coming strategy period. What we do at NLR is important for society, which means that we have to be both visible and accessible.

State-of-the-art facilities for acquiring knowledge and developing technology

The sector is aiming to beat the coronavirus crisis by accelerating innovation

1. Introduction

The world looks very different now than we envisaged when the 2018-2021 strategy plan was being drawn up. The coronavirus pandemic has had a huge impact worldwide and has hit the aviation sector particularly hard. On top of that, it is expected that the measures for keeping the virus under control will continue for some time yet. The generalised economic recovery that is anticipated after the pandemic will not happen immediately for the aviation sector: it may well be feeling the pinch until 2025 [20]. On the other hand, the crisis is also giving a positive impetus to making aviation more sustainable, and governments are freeing up resources to implement that. Which makes it all the more important for NLR to set out clearly for the coming strategy period how it wants to help the Dutch aerospace sector in its efforts to accelerate innovation and emerge from the crisis, to achieve the greatest possible societal impact and so to help create a sustainable aviation sector and add to the Netherlands' future earning power.

1.1 Review

THE STRATEGY PERIOD 2018–2021

The future never pans out quite as you predicted. Our strategy plan tries to respond to that uncertainty. Looking back at the previous strategy plan and the current strategy period, we can see that things have indeed sometimes gone differently. We can see that more scope has appeared for tackling new, strategic developments such as electrically powered flight, which had not been envisaged when the previous plan was being written. The previous strategy plan presented a menu of strategic options, but this time we are explicitly focusing on the period ahead and have adopted a programme-based approach. The focus of the previous strategy plan was on the market demand in our investment policy.

In the new plan, we want to build on that and bring the market strategy even more closely into line with the strategy for our knowledge development and facility development by linking them together in the three central themes. Moreover, we believe that we have found a balance in the new plan, more so than in the previous one, between the existing and continuing knowledge base within the organisation on the one hand and the new goals for the coming period on the other.

1.2 Looking ahead

THE 2022–2025 STRATEGY PERIOD AND BEYOND

During the strategy period through to 2025, we are laying important foundations for achieving the climate targets set by the European Green Deal and ACARE (Advisory Council for Aviation Research and Innovation in Europe), we are supporting the Ministry of Defence in the Netherlands in the initial implementation steps of its vision for 2035, we are helping resolve issues within society through the Mission-Driven Top Sectors and Innovation Policy (MTIB) and we are taking steps towards putting the implementation agenda of the Aerospace Memorandum into practice.

We are standing shoulder to shoulder with the aerospace sector to come out of the coronavirus pandemic in a stronger position.

Aviation also has its part to play in Europe's climate goals. The aim is to achieve sustainable and climate-neutral aviation by 2050. This applies to both operations and production. Aviation cannot become sustainable unless its relationship with the environment is in equilibrium, which includes recognizing the principles of a circular economy. Climate-neutral aviation means not only eliminating CO2 emissions but also counteracting the effects of other gases that affect the climate. Aviation's impact on global warming overall is three times higher than the contribution from CO2 alone [7]. The Dutch government wants the country to be in the vanguard if hybrid-electric flight by 2030 and is aiming to make all the ground-based operations climate-neutral. In the Destination 2050 report [8], NLR and SEO Economic Research have examined the CO2 objectives and shown them to be feasible, given the right preconditions and support from the governmental authorities. The ultimate dot on the horizon is that NLR is aiming for emission-free aviation to be possible by 2070, with zero emissions of greenhouse gases, nitrogen oxides and no deposition of fine or ultra-fine particulates. A memorandum of understanding (MoU) has been signed by the Dutch aerospace sector – represented by the Netherlands Aerospace Group (NAG) – and Airbus, signifying a major step on the road to the future of sustainable aviation. The purpose of the MoU is to establish a long-term strategic relationship for sustainability in aerospace research and innovation and to create a good competitive position for the Dutch sector.

Security is an important precondition for guaranteeing the freedoms, prosperity and democracy we have acquired. That security is feeling the pressure. The armed forces of potential adversaries are becoming more powerful and relations between the superpowers are becoming more entrenched. And we're not only talking about conventional threats. There is also unrest at Europe's outer borders, extremism and terrorism around Europe are worrying, we are having to face up to natural phenomena increasingly often and our strong and vital infrastructure is being seen as a target. On top of that, attacks are taking place more and more often in new domains, with cyberattacks on a daily basis, online influencing and a new space race developing.

There are good reasons why the Ministry of Defence entitled its vision for 2035, in which it recognises these threats, "Fighting for a Safe Future". Its strategic relationship with the Ministry of Defence lets NLR meet these challenges in both innovative and operational areas.

Space is increasingly a key enabler *inter alia* for security and mobility through applications based on data that is made available through satellite systems for communication, earth observation and navigation. This means that space plays a crucial and critical role for society and governmental authorities. New services, partly based on commercial space sector parties, seem to be really taking off, with large constellations of satellites. That offers opportunities for Dutch companies that have an interest in developing small satellite systems and the services they can offer. NLR helps them to do this. On the other hand, this growth also poses a threat in the form of space debris, junk created by the multitude of launches and dysfunctional satellites, for which there are no internationally accepted regulations. NLR advises the government about this.

1.3 Reader's guide

Chapter 2 gives an internal analysis of NLR's strategic position and an external analysis of its surrounding environment. A description is then given in Chapter 3 of the research topics and market segments that NLR focuses on and the targets that NLR is aiming to achieve, not only in the coming strategy period but also in the subsequent one. Finally, Chapter 4 explains how NLR wants to achieve those long-term objectives, how we and the rest of the Dutch aerospace ecosystem can innovate our way out of the crisis and achieve as large a social impact as possible. The implementation of the strategy will follow in an implementation agenda (yet to be drawn up), which will be adjusted annually after an evaluation of the strategy plan.

NLR is retaining its current organisational structure with one exception: that our work must be more oriented to the programmes. That same structure is reflected in the layout of this document: three long-term themes, which we will be complementing from our knowledge base with nine programmes and continuing to acquire our orders from the familiar five market segments.

Space is becoming increasingly important for the Ministry of Defence

NLR has a central position in the national knowledge ecosystem

2. Strategic position and situation

Internal and external analyses have been carried out to determine NLR's strategic position at the national and international levels. Those analyses are described in this chapter.

2.1 Internal analysis

Who we are

Royal NLR – the Netherlands Aerospace Centre – is a pioneering research centre that has been operating independently for over a hundred years, working on creating a better world for tomorrow. To that end, we offer specific, innovative solutions and technical expertise – and we're proud of that!

OUR MISSION

Royal NLR is an applied research organisation that is making aerospace more sustainable, safer, more efficient and more effective. Our innovative and practical solutions reinforce the commercial sector's competitiveness and help find solutions for social issues. We work objectively and independently both for and with national and international companies and governmental bodies.

Our position in knowledge and technology

NLR has a central position in the national aerospace knowledge ecosystem. Internationally, we are also a respected knowledge partner and we work closely with our sister organisations in Europe within the Association of European Research Establishments in Aeronautics (EREA) and the Association of European Space Research Establishments (ESRE). At the global level, NLR looks for links through the International Forum for Aviation Research (IFAR).

We are the connection between scientific research, policy-based support and industrial development. There are various areas where our knowledge and technology are at a world-class level. We use our state-of-the-art research infrastructure, which was given new accommodation during the past period, to experimentally assess the effects of new technology and check the feasibility of new concepts. Using the funding opportunities that are available e.g. through government funds lets us make use of our knowledge and facilities to respond to new technological and social developments.

Our central position in terms of knowledge and technology strengthens the relationships with numerous other research institutions, both domestically and abroad. Every year, NLR offers a large group of trainees and graduates the opportunity to learn about the world of aerospace and helps PhD students to carry out scientific research.

The position of our research infrastructure

NLR's research infrastructure, both physical and digital, plays an essential role in acquiring knowledge and in technological development for aerospace, as well as in implementing the innovations that will be needed if we are to innovate our way out of the crisis. Knowledge development and experimental verification are deeply intertwined. The research infrastructure helps avoid risks by testing the technological feasibility of new concepts, utilizing the limits of the domains where aeroplanes, helicopters, drones or satellites can be used, and shortening the time to market for new systems and products. Applied research organisations (TO2) develop and manage strategic research facilities because they have the optimum position in the innovation system. That is one of the key roles that the government has tasked TO2 with.

NLR manages and commercially operates large research facilities that are unique in the Netherlands, and in some cases internationally. Large-scale research infrastructure does not generally cover its own costs, so commercial companies do not set up and run such facilities. It is therefore essential that the government provides funding arrangements to meet the shortfall in commercial returns and that these funds are updated regularly. This will let NLR retain the ability to validate new technology and to make new products and services possible that utilise these techniques.

Together with its German counterpart DLR, NLR set up the German-Dutch Wind Tunnel Foundation (DNW) in 1976. DNW is both socially and economically significant for the Netherlands.

Urban air mobility (UAM) focuses on mobility in cities using flying vehicles in their airspace. UAM covers the transport of passengers and freight by air within the city and in its suburbs, using vehicles ranging from small drones and personal air vehicles (PAV) to passenger aeroplanes.

Environmental targets in terms of emissions and noise nuisance are high on the political agendas. DNW has facilities for developing the next generations of aircraft with advanced electric propulsion systems, as well as drones and urban air mobility (UAM). DNW and NLR work in close cooperation as the national knowledge network that can implement the Dutch policy of having an active international and European role in the environmental field by contributing to aircraft construction. Participating in DNW lets the Dutch aviation sector anticipate global developments, both civil and military, at an early stage. DNW has a decisive influence on technological development in a variety of fields, from revolutionary propulsion techniques and innovation procedures for more efficient air traffic handling through to space travel and automotive applications.

NLR's annual investment budget for renewing and maintaining the research infrastructure is €2 million (excluding contributions to DNW), which is about 4% of the replacement value. NLR assesses the entire research infrastructure annually. Infrastructure that is no longer fulfilling a need of either the governmental bodies or the commercial sector in the Netherlands is divested. Over recent years, for instance, the research flight simulator GRACE and the burner rig test facility for testing gas turbine components in high-temperature gas flows have been disposed of.

For major upgrades of facilities or new investments, NLR also has a framework for assessing how to prioritise investments. For such investments, NLR depends in part on the government's funding regulations. Based on current developments and future requirements, we see a need to set up new facilities in areas such as flight testing (including both electric and unmanned), automated manufacturing and tactical simulation – an investment of more than €25 million – for which no funding is currently available.

On top of that, structural increases in the annual funding are needed if we are to maintain our current portfolio of research Infrastructure and adapt it to the future needs of government and the commercial sector in the Netherlands.

How we perform

National and international stakeholders are highly appreciative of the research carried out by NLR and the services it provides. This is shown by a customer satisfaction score of 4.33 in 2020 (on a scale from one to five), a knowledge uptake percentage[1] by the customers of 85% and our stable customer base.

NLR's financial policy is robust. We have also shown that we are able to cope during times of global crisis. NLR has also been able to absorb fluctuations in the state's contributions and in those from national and international funding instruments.

An overall assessment of all TO2 institutes was carried out in 2020 on instructions from the Ministry of Economic Affairs and Climate Policy (EZK). Independent committees assessed the TO2 institutes against the guidelines of the Evaluation and Monitoring Framework for Applied Research (EMTO) protocol developed by the Rathenau Institute. The assessment of the institutions' performance is based on three main criteria, namely quality, impact and vitality. This is reported directly to the minister of EZK in his capacity as the coordinating figure who is also responsible for the system on behalf of the TO2 institutes.

The committee[2] evaluating NLR assessed the quality of the research as being very good [21] and in some areas even as world-class; the customers have stated how much they appreciate it. The impact of the work we do is also good. Customer satisfaction levels are always high and the customers apply the projects' results broadly. NLR could however be more proactively involved with its stakeholders. Another point for attention is improving the scientific impact by publishing more about NLR's research, and also by strengthening the relationships with universities. As regards vitality, the committee's conclusion was that the financial position is healthy.

Improvement is needed in aspects of the HR policy such as diversity and inclusivity. In addition, the funding for maintaining NLR's infrastructure is a point that needs attention. NLR is happy to take the committee's recommendations on board. How they will be addressed is described in this strategy plan.

[1] *The extent to which the research results are utilised by the stakeholders.*
[2] *Prof. Hester Bijl (chair), Prof. Rolf Henke, Tineke Bakker-van der Veen MSc, Lt. Gen. Dennis Luyt*

2.2 External analysis

Social developments

Keeping up a desired standard of living is obviously not without consequences for society, the environment and the climate. According to predictions by Statistics Netherlands [9], the Dutch population is going to grow over the coming decades to almost 19.6 million inhabitants by 2060. The number of inhabitants is expected to hit 18 million in 2024 and 19 million by 2039. We are also ageing: it is expected that there will be twice as many people aged 80 plus by 2040 as there were in 2019. The population of the Netherlands is not only growing but also becoming more diverse. According to Statistics Netherlands [10], the number of residents with migrant backgrounds will grow from 4.2 million in 2020 to between 5.3 and 8.4 million in 2050. The rest of the world is also seeing growing populations and rising average life expectancies. There will be an additional billion people by 2025 [11]. The number of people in the middle classes worldwide is increasing, people with a standard of living that demands luxury, high-quality products and more flexible mobility.

Half the world's population currently lives in urban areas and that urbanisation can also be seen to be accelerating. There are one and a half million new city residents every week. That means that sixty per cent of the world's population will be living in urban regions by 2030 [12], with a demographic shift towards Asia.

These social developments are leading to new ways of consuming, in which sharing models are becoming more important than ownership, and a greater value is placed on personalised experiences and sustainable consumption.

As a society, we are increasingly aware of the risks of climate change and – thanks to worries about scarce natural raw materials – of the environment we live in and nature in general. The collective consciousness is now fully aware that climate change is real. People now genuinely want to tackle it. Over recent years, concreate and highly collective targets have been set that we will all be working on during the coming decades. Legally enforceable climate measures have been incorporated into legislation to help achieve the first climate targets by 2035. Sustainability goes far beyond just reducing CO_2 emissions. Climate adaptation and the effects of climate gases other than CO_2 are becoming increasingly important.

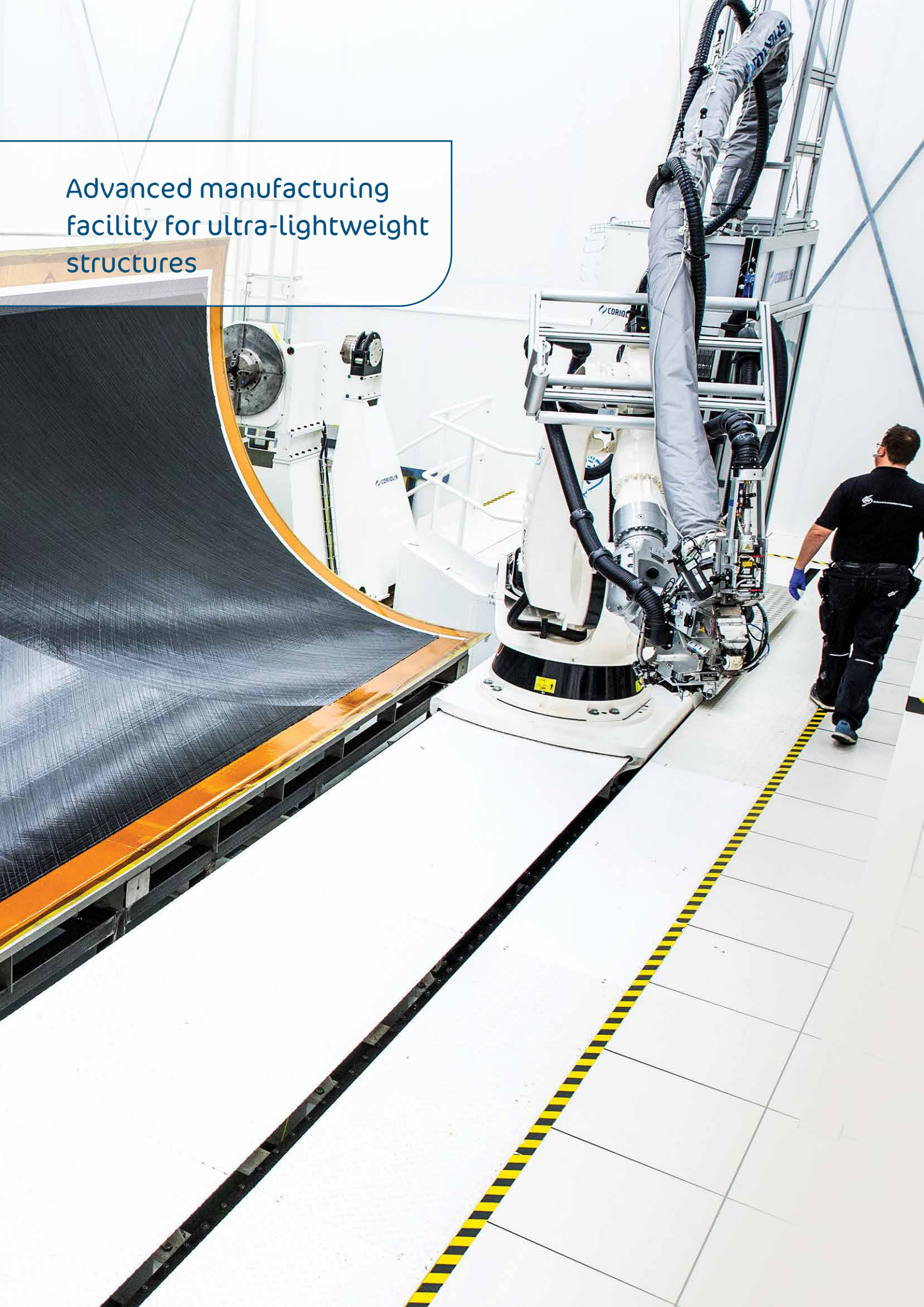
In the security arena, the Western world's technological superiority is decreasing. Every day we face cyberattacks and influencing on top of further increases in kinetic threats as a result of regional and geopolitical tensions. The financial and commodities markets are uneasy, potential opponents are becoming stronger thanks to higher levels of investment in defence and we are seeing extremism and terrorism. Poor living conditions around Europe's periphery are putting more and more pressure on its outer borders. Critical parts of our infrastructure are under threat and we are increasingly facing unpredictable natural threats, for instance from climate change [13]. In short, that is putting the squeeze on our security, which is a precondition for our freedom and democracy.

Technological developments

The growing middle class in our society is always demanding mobility and products, particularly luxury items. The demand this creates for transport and cargo movements is being met at both the national and regional levels by a balanced mix of transport modalities. Population growth and accelerating urbanisation are imposing higher demands on safe infrastructure in and around the cities. Transport needs not only to be efficient and affordable but also clean and safe. Various niche solutions are also being developed. The development of UAM systems and drones should make unmanned and autonomously transportation of people and goods through the air possible to tackle congestion. Autonomous and unmanned systems are also being developed for military applications. The EU and NATO refer to Big

Climate-neutral: requires net-zero temperature increases due to all aviation exhaust gases together (CO_2 and non-CO_2) [8].
CO_2-neutral: net- zero carbon dioxide (CO_2) emissions are achieved when global anthropogenic CO_2 emissions are offset by CO_2 elimination over a specific period [8].
Zero-emission: no emissions of any greenhouse gases.

Advanced manufacturing facility for ultra-lightweight structures



Data, and advanced analytics, artificial intelligence (AI), aerospace and hypersonic technology as 'disruptive technologies' that are expected to have a major impact on defence and security. Emerging technologies that will mature within 20 years but for which the impact is still uncertain include quantum technology, bio-enhancement and human enhancement technology and new materials and manufacturing techniques.

Major technological breakthroughs are needed if aviation is to be climate-neutral. The energy density of kerosene is fifty times higher than that of a modern battery; this is what makes fully electric aviation such a huge challenge. New concepts for power trains, energy storage, aerodynamic properties, materials, ultra-lightweight structures and propulsion integration are being studied so that emissions can be significantly reduced or even eliminated. As well as electrification, alternative propulsion methods are also receiving a level of attention that is growing strongly. Sustainable aviation fuels and hydrogen as a fuel for aircraft seem to be highly promising options on the road to climate neutrality. The furrther electrification of the ground-based systems at airports will also be a significant help in making aviation more sustainable.

The European Commission is encouraging the digitalisation of the European economy and society. The Netherlands also launched a strategy for digitalisation in 2018 that was updated in 2020. Industry in the Netherlands is also digitalizing and automating. Optimisation for 'right first time' production and products by using ICT, simulation tools and new manufacturing techniques such as 3D printing is making both the production process and the products created more efficient, cheaper and more sustainable, as well as improving the quality. This is being driven inter alia by the use of smarter machines, robotics, automation, artificial intelligence, advanced sensors, miniaturisation, AR/VR, digital twin techniques and human-machine integration. The development of explainable AI (XAI) is relevant for specific applications where you want to know how the AI reached its answer.

In the case of autonomous systems in particular, this helps determine the consequences of the actions. There is optimisation not only within companies but also through cooperation between different companies in the value chain.

Digitalisation and automation of the manufacturing industry and MRO sector are increasing the productivity and added value of companies, as well as creating new jobs. On top of that, they are driving the consumption of raw materials and energy down. New manufacturing techniques and design methodologies enable the development of ultra-lightweight aircraft structures that help bring down fuel consumption and emissions.

Digitalisation is also finding its way into platform operations (including maintenance). The development of predictive maintenance driven by sensors and algorithms means the work can be done at just the right moment instead of preventively or in response to problems. This improves the availability – the uptime – of platforms. It also saves time and money, cutting the amount of waste and raising productivity. Europe is attempting to achieve a single Digital European Sky by 2040. Digitalisation and automation of the infrastructure for air traffic control will lower emissions further.

Finally, increasing digitalisation is driving the development of cybsersecurity technology. This applies to airborne platforms and satellites too, from the design to the certification and production and from operations to maintenance. The importance for society of cybersecurity measures for autonomous drones, for example, is clear.

Market developments

THE CIVIL AVIATION INDUSTRY

Taking part in new programmes and in the development of new platforms for aerospace has a lot of added value and spin-offs for the civil aviation industry in the Netherlands. Europe's civil aircraft builders are focusing (among other things) on radical new aircraft and propulsion techniques. The concepts under development range from aircraft with distributed electric propulsion, ultra-efficient aircraft for sustainable aviation fuel and hydrogen-fuelled propulsion through to entirely new blended-wing body designs.

In addition, traditional aircraft builders and newcomers worldwide are putting their effort into new concepts such as UAM and short-range electric vehicles (SREV). The first electrically powered commercial aircraft for up to 19 passengers are expected to come into service in 2035. Along with

various research organisations, the Dutch aviation industry is working closely with aircraft manufacturers to accelerate the development of these pioneering sustainable concepts. For the industry, the drive to cut costs and make the design and production processes more effective remains very important.
Major growth is envisaged in unmanned aviation and UAM systems and numerous new parties and OEMs are entering this market. In addition to UAM platforms at low altitudes, there are market parties working on high-altitude pseudo-satellite platforms (HAPS).

CIVIL AVIATION OPERATIONS

The coronavirus crisis has had an unprecedented effect on aviation. Travel restrictions brought air passenger transport to a virtual standstill in 2020 and airlines postponed purchases of new aircraft. Most forecasts assume a return to pre-crisis traffic volumes over a period of several years. Rearrangements of airspace are continuing in Europe and the Netherlands. On top of that, the Netherlands is making great strides towards implementing the agenda of the Aerospace Memorandum [1]. The measures taken in response to the coronavirus pandemic clearly show that passenger health is critical in the event of a pandemic and that the aviation sector must be resilient. Intruders (such as drones and hackers) also have to be considered, as does climate change. Airports must be very safe and healthy places, sustainable and climate-neutral and with sufficient attention paid to the quality of life of local residents.

The crisis has bankrupted some airlines and a lot of aircraft are being returned to the leasing companies. The scope for airlines, airports and air traffic control to invest will be very limited and cost-efficiency will be the order of the day. Governments are supporting airlines, airports and air traffic control financially on the condition that recovery is done sustainably. However, the crisis is also offering new opportunities, as national and European incentive programmes are letting the aviation sector develop sustainable products more quickly.

DEFENCE AND SECURITY – GOVERNMENTAL

NLR has a long-term strategic relationship with the Ministry of Defence, our largest customer. The vision on defence for 2035 [13], the strategic knowledge and innovation agenda for 2021-2025 (SKIA) [14], the defence industry strategy (DIS) [15] and the knowledge and innovation agenda for security [16] are the main cornerstones of that market. The development of our armed forces is geared towards technological excellence, being information-driven and being a reliable partner and protector.

The European Union (EU) is also aware of the urgency of a technologically strong and adaptive defence sector within Europe. That can be seen from the fact that a European Defence Fund (EDF) has been set up for joint research and innovation. A strong national knowledge technology and knowledge innovation programme is needed if we are going to matter at the European level. In addition to the above, the mission-driven innovation policy is also part of it. The Security Knowledge and Innovation Agenda (SKIA) looks at inter-departmental knowledge and innovation interests together with industry and research organisations. Sustainability and energy independence are also playing an ever-larger role in the various branches of the armed forces. Cooperation with other governments, many of which are also NATO members, is on a bilateral basis.

The Ministry of Justice and Security (JenV) has also published an SKIA that is relevant for NLR [17]. The section of that entitled "The smart challenge: Using modern technology to connect to the self-organizing society" in particular is relevant for our market position, above all because JenV has recently joined the NLR task group, which focuses on smart handling of Big Data. JenV and NLR have been formalizing their cooperation since 2019 on the basis of the Security KIA with the Ministry of Defence, market parties and other departments and governmental services that work together in that ecosystem.

DEFENCE AND SECURITY – INDUSTRY

The Netherlands has a well-functioning ecosystem in which the Defence ministry cooperates with industrial parties and centres of expertise. The defence and security industrial sector does not seem to have been hit particularly hard by COVID-19. Existing geopolitical tensions are increasing the need to keep defence budgets growing. The defence vision for 2035 [13], the SKIA for 2021-2025 [14], the DIS [15], the Security KIA [16] and the EDF also determine the direction taken by the Dutch defence and security industry. In addition to the *Defensie Materieel Programma* (Defence Equipment Programme), there are large international military programmes in future that offer opportunities for the Dutch defence industry.

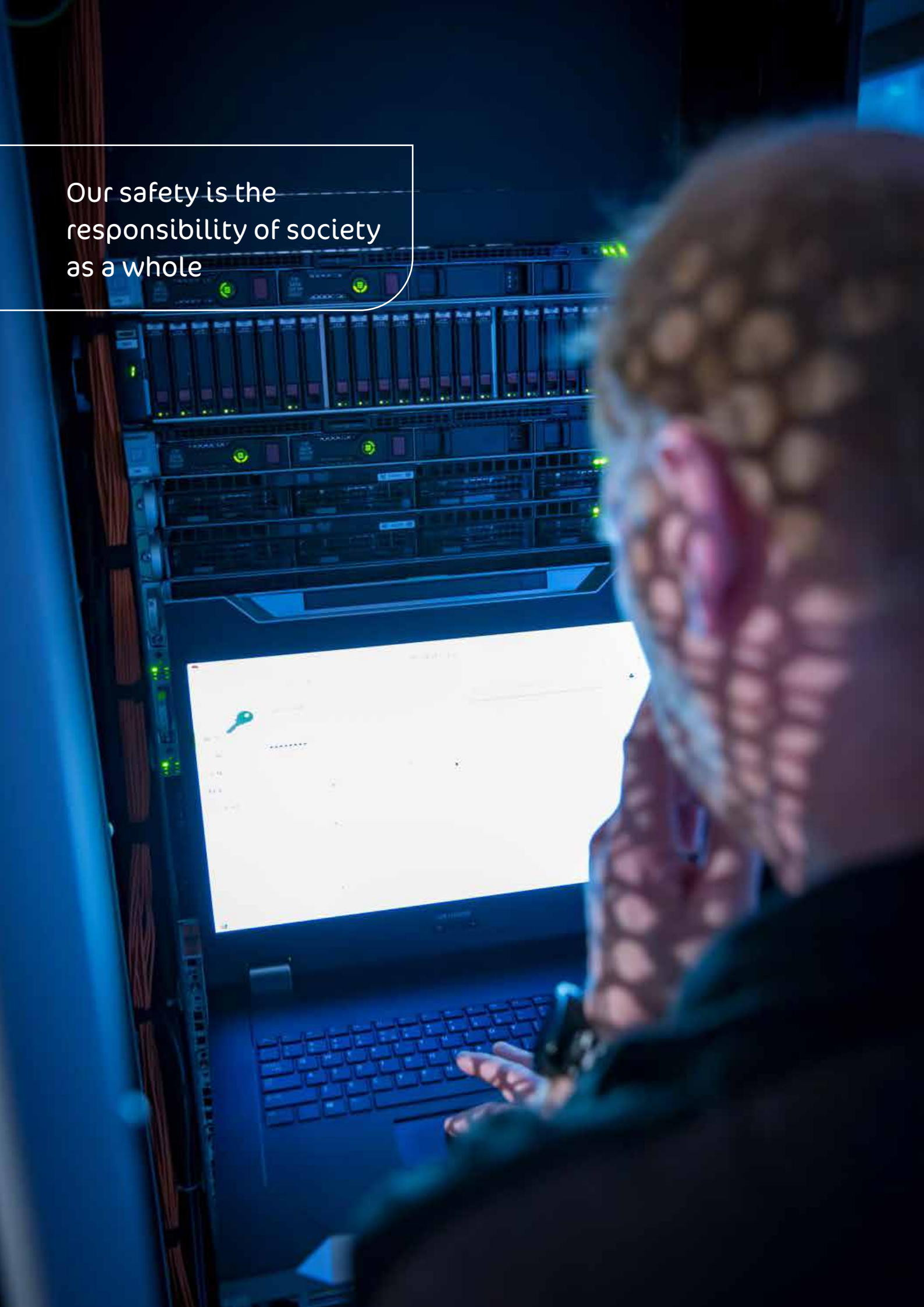
In the medium term, developments in the next generation of helicopters and unmanned concepts

are going to be important. Work is being done in both Europe and the United States on the military helicopter of the future. In the longer term, the next generation of fighter aircraft or a future combat air system (FCAS) will play a role. These European programmes will partly be financed by the EDF. Space flight is also being given a higher priority in national and international defence and security policy. The defence and security sector and the space sector are coming closer with new opportunities for both.

SPACE

Programming by ESA (the European Space Agency) underpins the European space flight market. Dutch space policy [18] focuses largely on ESA. In addition, space policy includes a national programme that encourages applications and technological development. The EU is also investing heavily in space; traditionally with the Earth observation system Copernicus, the EGNOS and Galileo satellite navigation systems and with resources for general research. Satellite communication (GOVSATCOM) and space situational awareness (SSA) are being added to that. NLR has options to link in with this, in the ESRE context and elsewhere. The EU countries have widened the scope of the European research programme further to include the defence domain, which offers new opportunities for us.

Increasing numbers of commercial companies and innovative startups, covered by large investors, are building up an interest in space. This is creating a growing commercially-driven component in the space market. Commercial initiatives in particular are making the booming exploitation of space bring a sustainability problem to the fore: space debris. Space junk is a growing issue of concern and it needs international agreements and measures, as well as offering new market perspectives.


Our safety is the
responsibility of society
as a whole

3. Strategic choices

The exploration of social, technological and market developments in the previous chapter has been used in this chapter to make choices.

3.1 Vision

What will our society look like in 2035?

Society is imposing ever higher demands on safety and we – society at large – are painfully aware of the consequences our actions can have for the climate. People are becoming ever more involved in technological developments that are becoming increasingly complex and that have a major influence on the surroundings we live in and on organisations. The internet and social media are making the world smaller and bringing things closer to us. More and more people are getting involved in the public debate, calling scientific findings and the way they are reported in the mainstream media into question. This shift also means that society – the general public – is becoming an important stakeholder for NLR.

Countries, companies and people are becoming increasingly interconnected. We want to be able to use the internet anywhere in the world. The world as we perceive it feels smaller. At the same time, its setup is becoming more sustainable and the economy is becoming more locally oriented.

The message is clear: "What you see is what you get" is a principle we will no longer be able to take for granted by 2035. It is becoming increasingly difficult to distinguish disinformation from factually based content. Digital security will therefore also play a crucial role and artificial intelligence will dominate our lives more and more, as well as making things easier. The most suitable moment to get down to work and the best way of wending our way through the traffic with autonomous vehicles is changing. Air traffic is changing too: air travel is being used less over shorter distances in particular and people are switching to alternatives.

By 2035, the Netherlands will be in the vanguard of hybrid-electric flight, a new generation of CO2-neutral aircraft will be flying and there will be practical applications of drones and UAM.

We also expect that the Netherlands and the EU will be free and democratic in 2035. The security needed to guarantee that is not a *fait accompli* and will probably be more under pressure than ever in 2035. Cyberattacks and digital influencing are going to increase. Furthermore, new kinetic threats will play a role in the field of defence. It is a challenge for every individual, every organisation and society as a whole to defend themselves against this. The Dutch armed forces will have developed as part of this to become flexible and scalable, capable of responding proactively to threats: a military that can take small-scale, specialist actions or can if necessary work with other parties in larger operations. Defence bodies must be able to operate even more effectively in the various domains (land, air, sea, space, cyber and information), and must be able to do so simultaneously (multi-domain) and to work with constantly changing civilian and military partners (integrated action). It is not only our armed forces that will be arming themselves against new threats to our freedom and democracy. Our security is a responsibility of society as a whole: not only will all departments of government and the EU have to take responsibility for it but so will the general public and organisations.

It will be busy in space by 2035, much busier than now. Space is increasingly becoming an environment for supplying commercial services, demanding associated space infrastructure for launches, Earth observation (such as asset management) and

communication (such as internet in the sky and the Internet of Things (IoT)).The space domain is also increasingly being seen as a domain of power for the superpowers. They will defend those interests. Collisions between satellites or with space junk will occur more often. The effect of that will be clearly felt by 2035, given that society will be even more dependent on space-based services than it is now. It is anticipated that setting up the treaties needed to regulate that will be a slow and cumbersome process. The EU will probably present itself as a single power bloc, a proponent of sustainable space flight and the treaties needed to regulate it.

What will our role be?

NLR has a pioneering role in aerospace in the Netherlands as the link between science, the commercial sector, society and governmental bodies. We are an applied research organisation, which means that we have a central position in the process of converting knowledge into value. Our aim is for the results of our research to find their way into applications in society and the economy, thereby making an impact.

We make this possible by running our business sustainably, by developing our knowledge of clean solutions and safety both in and from the air and space, and by making that knowledge accessible to the aerospace sector. This is how we and the Dutch aviation industry are making a meaningful contribution to maintaining a prosperous society and helping build a clean, safe and better world for the future. In addition, our knowledge and research infrastructure is part of a European network, presaging further integration of European aerospace research organisations. In the defence domain, we provide close links to the knowledge and research infrastructure of our NATO partners.

3.2 Impact through a strategic focus

NLR has chosen three themes where we want to make a long-term impact. We are setting ourselves concrete and ambitious goals for each of them for the coming strategy period .

Theme 1 – Sustainable aviation

In Europe, we are aiming for a climate-neutral society by 2050. Aviation will have its part to play in that; the targets for the sector have been defined in the Aerospace Memorandum [1] and in Destination 2050 [8].

To make climate-neutral aviation possible, the focus needs to be on radical innovations, both technological and social. In terms of the technology, new propulsion techniques, aircraft designs and alternative fuels are important. To make the new technologies socially relevant, the current infrastructure needs to be modified. This means, for example, that there must be a sufficient supply of climate-neutral fuels at airports. From the social point of view, we will also need to consider climate-friendly flight paths, regulatory aspects and economic conditions and consequences, as well as social acceptance. Together with the leading Dutch aviation companies, research organisations and the government, NLR aims to be one of the global aviation sector's smartest and most sustainable players [4].

NLR's aim is to make it possible for aviation to be climate-neutral by 2050.

Showcase: we will be making the first manned flight powered by liquid hydrogen in 2025.
NLR's first steps in this new technology will involve a hydrogen-powered flight with our electrically driven research aircraft. This means that we will be using the Pipistrel PH-NLX in 2025 to demonstrate steps taken in tackling the social challenge of making aviation greener. In addition to the activities mentioned above, the development of new operational concepts is important for enabling the transition to sustainable aviation.

Theme 2 – Competitive aerospace

The global impact of the COVID-19 virus on aviation has been huge. The scale of the long-term effects for the aviation sector will depend on passenger confidence and on how quickly the domestic and global economies recover. Eurocontrol expects that air traffic will take until 2024 to reach the same levels again as in 2019 [6]. An integrated approach to challenges for the living environment, accessibility and sustainable air transport will encourage the creation of new products and markets that strengthen the Dutch competitive position. However, a lot of applied research is still needed if a new type of passenger aircraft is to be put into production by 2035 [1] with the airport infrastructure adapted accordingly. This also applies to UAM and future military platforms.

NLR wants to make it possible for the Dutch aviation industry to acquire a share in existing UAM supply chains as well as in developing and producing the next generation, low-emission aircraft and in programmes for the next generation of helicopters by 2035.

Showcase: we will be delivering a technology demonstrator in 2025 showing the way towards the future positioning of the Dutch aviation sector. This is a deforming wing flap with integrated state and condition monitoring that increases the efficiency of a new platform and avoids unnecessary maintenance.

NLR aims to work with the aviation sector and governmental bodies to implement solutions that will significantly improve the efficiency and resilience of the aviation system. Optimum-performance Airport Operations Control and a redesign of airspace are needed for handling air traffic at lower operational costs and with higher efficiency (including in thee event of disruptions). Essential steps need to be taken for this in the period through to 2025.

Showcase: NLR is delivering the building blocks in 2025 for a new operational concept that will enable fixed approach routes, integration of manned and unmanned aviation and fully functional airport operations control.

NLR is aiming to strengthen the Dutch ecosystem of space companies, both those focusing on the space infrastructure and those focusing on reliable access to and utilisation of space services. Our focus is on the rapidly growing market for small satellites, launchers, robust PNT services (position, navigation and timing) and Earth observation applications. Technological innovations can be developed and brought to market in cooperation with these companies within the national, ESA and EU frameworks.

NLR's goal is to help build up the good position of the Dutch space industry further in small satellites, launchers and space applications by developing distinctive technologically advanced capabilities.

Showcase: in 2025, in co-creation with universities and market parties, we will be demonstrating the development of a high-resolution miniaturised instrument with on-board AI-based payload data processing and an autonomous data processing chain. This showcase item is driven by application in Theme 3, while assisting Theme 2, and puts the objectives of the interdepartmental mission 'Security in and from space' under the Security KIA into effect.

Theme 3 - A safe and secure society

The Netherlands must remain a safe country for its people – for their housing, their work and their recreation. Countering threats is therefore a key security task in both Dutch and European society [14]. Digitalisation is transforming our society at lightning pace. Cooperation in the aerospace domain at the national and European levels and within the context of NATO is therefore needed in order to stay one step ahead of (potential) threats at all times. By 2035, our technologically advanced armed forces and their well-trained personnel will be operating in an information-driven, adaptive and more effective way. Our armed forces will be able to take action that is integrated and covers multiple domains.

NLR supports the Dutch Defence and Security governmental department in the acquisition, operational deployment and implementation of its vision and strategy. We achieve this through an advanced knowledge position regarding the aerospace domain and about embedding aerospace capabilities in information-driven, multi-domain and integrated operations. NLR is also collaborating with industry to develop high-quality technology to that end.

Showcase: we develop concepts that focus on accelerating and improving decision-making processes in a properly secure environment. In 2025, we will be demonstrating our Future Air & Space Power battle lab concepts as part of a multi-domain, information-driven organisation.

To create a safe and secure society, a safe and healthy living environment must also be ensured and the risks that transport systems pose for the public must be minimal. Confidence in the government and certainty about the legitimacy of the services and products provided are the cornerstone of that sense of security. NLR supports the Dutch aviation sector and the government in this task. It is essential that new developments such as the electrification of aviation, the introduction of AI, and drones in the built-up environment are operationalised safely. This will involve recognizing and mitigating the risks.

English makes a natural distinction between safety and security, but other languages (such as Dutch) tend to use a single word for both concepts. For non-natives, then: Safety is about unintentional and non-deliberate risks to humans and the environment that have a clear natural or technological cause, such as flooding or a flu pandemic or an accident in the chemicals industry. Security is about hazards that someone is attempting to create deliberately. [25]

NLR supports the Dutch Defence and Security governmental department

Drone experiments to make safe unmanned aviation possible

4. Strategic agenda

Following the exploration of the strategic position in Chapter 2 and the elaboration of the strategic choices in Chapter 3, this chapter looks at how those goals can be achieved.

4.1 People & organisation

We want to be an inspirational organisation for everyone at NLR and for our customers – an organisation that responds to changing surroundings and makes the most of them. The organisation's capacity to learn is a determining factor for its agility. In the concept of the 'learning organisation', we focus not just on corporate culture and leadership development but also on the development of talent, plus the enhancement of diversity in the various teams. Employees educated in different fields, with different backgrounds and ambitions bring different kinds of knowledge, experience and ways of thinking. This will help us utilise talent and nurture creativity and innovation. At the same time, it is important that our employees feel a connection with one another. That is why we are developing our diversity and inclusiveness policy further, for instance by embracing role models within the organisation.
In the coming strategic period, NLR will continue its training programme aimed at developing talent and will also work on leadership development. In addition, NLR will draw up a new HR policy for feedback, performance and development.

In line with the importance we attach to a diverse organisation, we also greatly value having an inclusive organisation in which everyone feels welcome, valued and respected. For years, we have prioritised open and transparent communication as one of our internal values. We therefore act accordingly, embracing alternative perspectives and holding one another to account if we fail to treat someone with respect.

Our employees, who often have unique expertise and experience, are our most important form of capital. They know the customers, share ideas with each other and turn those ideas into practical solutions for our clients. Innovations are nurtured best in an inspiring working environment, with an open culture and through dialogue within the team in collaboration with knowledge partners in the Netherlands and abroad.

At the organisational level, we are continuing to work to optimise the exchange of knowledge, within programmes, across programmes and in single-discipline development of expertise. This involves systematic support for permanent learning and development for everyone at NLR, where possible and worthwhile. Because having an impact has become more important, we discuss the effects of our research in terms of its impact when we talk and write about it internally and in our external communication. This will ensure we do not lose sight of the intended impact. An evaluation of the organisational structure will be carried out in 2024, after the new programmes and associated working methods have been used for two years. In addition to making aviation more sustainable, we also want to make NLR itself more sustainable. NLR should be setting an example to others. What is more, this is a prerequisite if NLR is to be an innovative and attractive employer. Over the past few years, NLR has invested in making the accommodation and energy consumption more sustainable. In the coming years, we will shift our focus to alternative forms of travel with the aim of reducing CO_2 emissions due to commuting and business travel.

The living lab is an example of an inspiring working environment, separate from the regular research and development channels within NLR. The aim of this living lab is to develop skills for innovation and to give everyone the chance to learn and build up experience. It gives people the space – both literally and figuratively – to experiment and explore a broader, more risky and less predictable range of technical, methodological and leadership concepts.

4.2 Knowledge base

The NLR knowledge base is organised into knowledge areas (NLR's fields of knowledge, page 46) to allow a focus on building up knowledge, straightforward exchange of knowledge, minimisation of fragmentation and validation of research results by colleagues.

Knowledge is accumulated in response to requests and also at NLR's own initiative, in order to maintain and develop the knowledge required to answer future questions from industry, as well as policy questions. Projects are carried out by multidisciplinary teams whose members have knowledge in relevant areas, contributing the expertise necessary to achieve the project objectives.

NLR will keep knowledge up to date in the standard technical aerospace disciplines. This knowledge is a *sine qua non* for NLR. In addition, NLR will build up knowledge in areas beyond the technical aerospace disciplines, for example in data science, computer science, AI, quantum technology and hydrogen technology. The knowledge in these disciplines and technological fields is geared primarily to applications in aerospace. NLR already has knowledge in non-technological areas such as psychology and education science, and this knowledge will be bolstered in the coming period as a complement to our technological base. Work on this knowledge acquisition started in the previous strategy period and will be continued in the coming period.

The multidisciplinary research will largely be done as programmes in which the knowledge will be accumulated as described in Section 4.4, with various disciplines cooperating.

4.3 Research infrastructure

As explained in Subsection 2.1.3, NLR's research infrastructure plays a crucial role in the accumulation of knowledge and development of technology for the aerospace industry. This research infrastructure needs to remain relevant for the future. When technological limits are exceeded or new areas explored, new questions arise that cannot be dealt with satisfactorily using the existing research infrastructure. In such situations, NLR first investigates whether the required capacity is available at its knowledge partners or whether it can be created by extending, combining or modifying the existing facilities.

The developments in unmanned and autonomous systems for the transport of people and goods in urban areas, as described in Chapter 2, and NLR's focus on sustainable aviation, as one of the three themes elaborated on in Chapter 3, have led to the decision to develop a Mobility and Infrastructure Test Centre (MITC) on NLR's site in Marknesse. Increasing digitalisation combined with the need to improve sustainability has led to major challenges in mobility.

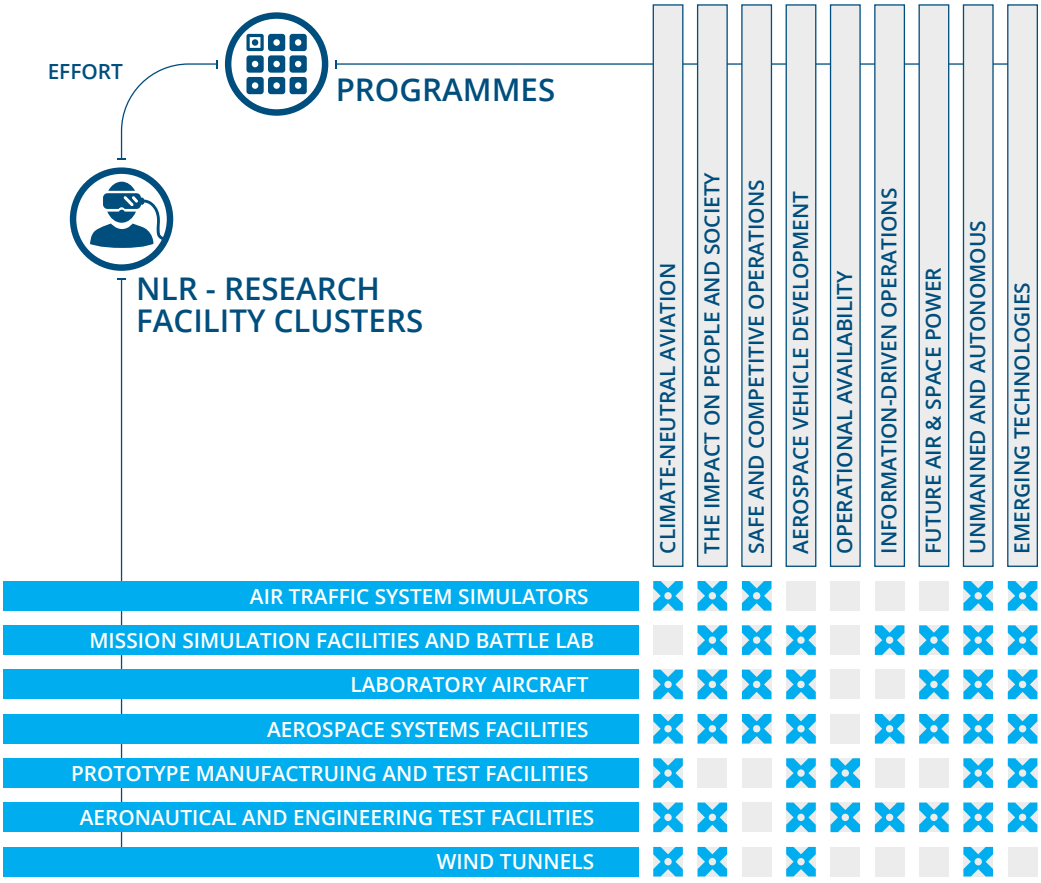


TABLE 1 DEPLOYMENT OF NLR'S RESEARCH FACILITY AND CLUSTERS IN THE PROGRAMMES

Building up knowledge from other domains offers new opportunities

The MITC facilitates the transition from testing and experimentation to application and utilisation, thereby contributing to the government's policy objectives and goal of maintaining the Netherlands' position as a leader for testing and extending this to the use of smart mobility. In the coming strategy period, we will develop the MITC together with DNW and the Netherlands Vehicle Authority (RDW), creating an innovative and unique cluster operating across the full spectrum of testing, certification and validation in the field of mobility and infrastructure. The combination of high-quality test facilities offered by NLR, DNW and RDW will consolidate the Netherlands' leading position in digitalisation and smart mobility and makes the MITC cluster stand out.

The development of hydrogen as a fuel for aircraft seems a promising option in the transition to climate neutrality. In September 2019, NLR flew a hydrogen-powered drone (the HYDRA) at the NLR drone centre in Marknesse. This was a first in Dutch airspace. The drone was powered by gaseous hydrogen. In the hydrogen lab, NLR is developing a facility to enable flight fuelled by liquid hydrogen.

NLR is working on the Cerebro battle lab, which will let it support the Ministry of Defence in its aim to have information-driven operations by 2035, adopting modern training concepts and introducing new tactical operational concepts. Cerebro will be available as a permanent physical location at NLR's site in Amsterdam. Cerebro will allow concepts, doctrines, tactics, procedures and technologies for aerospace operations and information-driven operations to be tested and evaluated in a virtual world. Cerebro can be connected up to systems in the real world and to other battle labs run by government bodies, TO2 institutes or industry players. This allows joint multi-domain studies to be carried out on a larger scale. An F-35 and MQ-9 research simulation is being built for Cerebro.

Given society's extensive dependency on satellite navigation services for positioning, navigation and timing (PNT), the associated space infrastructure (GPS and Galileo) can justifiably be seen as a utility. Like all infrastructure, this system has weak spots and disruption or outages of these services can have far-reaching consequences for society at large.

The Celeste – Position Navigation & Time RDT&E suite lets NLR introduce and test innovations for robust PNT services for aviation, drones, the military and security.

In addition to the new infrastructure mentioned above, NLR will consider any requirements that arise during the strategic period for new large-scale research infrastructure, weighing up the degree of urgency and the availability of funding. NLR will also investigate whether collaborating with our European partner organisations could be a way of meeting our infrastructure requirements more efficiently.

4.4 Working in programmes

To implement and achieve the strategic themes and objectives described in Chapter 3, NLR will be opting for a programmatic approach in the coming strategic period. In this, we will focus on the objectives that really matter in the three themes, that help realise NLR's strategy, and that our staff want to engage with. A great deal of new knowledge will be acquired over the next few years, and current knowledge will be consolidated. On the one hand, we will continue as before to do this in the existing fields of knowledge as set out in Section 4.2. This is where the knowledge base is created. On the other hand, knowledge will be developed further in projects in nine programmes, with cross-disciplinary collaboration. These nine programmes were determined following careful consideration and based on the Dutch public and private stakeholder roadmaps and visions. The knowledge base and each of the multidisciplinary and cross-division programmes help achieve the objectives for the three themes of sustainable aviation, competitive aerospace and a safe and secure society. The programme objectives, which are agreed with our stakeholders, set the direction for the knowledge projects that we will be carrying out.

The programme management is structured by setting up a coordination group for each programme. The programme management is responsible for aligning the development of knowledge and technology using an ecosystem approach. All stakeholders are part of this. Roadmaps will be developed for the programmes, aimed at achieving the envisaged societal impact. The roadmaps will guide the research activities and their timing. This will reveal the connections between the research and development activities throughout the entire TRL range. The targeted development of such an ecosystem of knowledge partners for each individual programme will create a solid foundation for collaboration and mutual trust, thereby giving access to the knowledge available outside NLR. Market orientation and knowledge orientation are both crucial for the development of the roadmaps and they will bolster one another. The roadmaps will

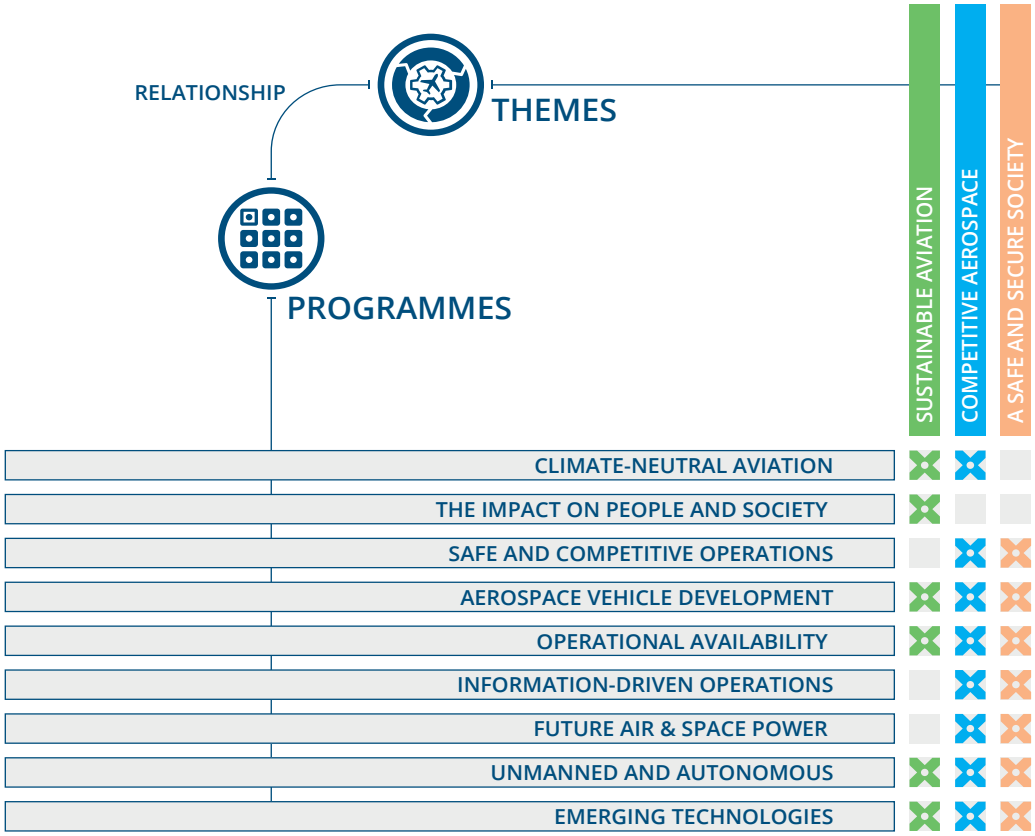


TABLE 2 RELATIONSHIP BETWEEN PROGRAMMES AND THEMES

be included in the implementation agenda. The programmes are briefly described below:

CLIMATE-NEUTRAL AVIATION

We will help the aviation industry become climate neutral by 2050. To achieve this, we will analyse the effects of changes both in the design and propulsion technology of aircraft and in the operation of and around the aircraft. Climate-neutral means that we need to consider the entire chain from manufacture and use to recycling, using a lifecycle assessment. Moreover, the production and operation of the aircraft must be part of a circular economy. We also want to give the aviation sector a better understanding of which factors have the biggest effect on climate change, what impact climate change has on the sector and how it can prepare for this. Important aspects are greenhouse gases (both CO2 and non-CO2), support in setting climate targets, and monitoring and adjusting them through policies and regulations.

NLR also carries out studies into the development of aircraft that are propelled by batteries, hydrogen and sustainable aviation fuel (SAF). The programme makes a contribution to the challenge society is facing to maximise resilience to climate change, and to sustainable aviation and a more competitive Dutch aviation industry.

THE IMPACT ON PEOPLE AND SOCIETY

We support airports, aviation companies and government bodies in the societal acceptance of new technological developments. Social innovations are becoming more and more important. The aim is to enhance the positive impact of technology on professionals, organisations and people in society more broadly. This will help organisations and society at large deal better with technological developments. We will investigate new ways of measuring air quality and noise nuisance, determining the influence that flight routes have on sound pollution and identifying potential measures for mitigating that pollution. The programme will make a positive contribution to the quality of life of people living in the vicinity of airports and will help government bodies give better advice.
By giving a better understanding of the parameters for quality of life, improving the predictability of pollution and enhancing the engagement of local residents – through participation and consultation setups – the programme will help increase societal acceptance of drones, UAM and sustainable aviation

at the national and international levels in line with Theme 1 (Sustainable aviation).

SAFE AND COMPETITIVE OPERATIONS

We will give government bodies, the aerospace sector and society at large a better understanding of the consequences of changes and the introduction of new technology, for example for safety, operational concepts, organisation, rules and supervision of safety in aerospace. In doing so, we will be helping the civil and military aviation sectors become increasingly safe, thereby creating a safe society. We will provide solutions for aviation operations that help reduce the costs of flight movements, increase airspace capacity and maximise the reliability and resilience of aviation operations, within socially acceptable limits. For the space ecosystem of Clean Space and Space Traffic Management (STM), we will investigate issues that are fast becoming a priority in national and international policy. This is how NLR will improve the competitive position of the Dutch aviation industry both domestically and internationally (Theme 2) and help create a safe and secure society (Theme 3).

AEROSPACE VEHICLE DEVELOPMENT

In aerospace, we help manufacturing industry, suppliers, the government and the authorities with the development of innovative and advanced avionics, systems, materials and structures and the associated manufacturing processes, modelling, simulation, data analytics and AI methods. The aim is a short 'time to market' or 'time to battlefield' at optimum costs and smart, reconfigurable systems. We develop knowledge and technology that will make Dutch companies attractive suppliers for aviation and space OEMs – and keep them that way. The programme brings innovations – which are often linked to national and international sustainability targets – to the government and companies, thereby creating more business and employment in aerospace in the Netherlands. This lets NLR contribute to sustainable aviation (Theme 1) and a stronger competitive position for Dutch industry (Theme 2) in the domestic and international contexts, as well as to the government's implementation of its policy.

OPERATIONAL AVAILABILITY

We support the Ministry of Defence, aviation companies, maintenance companies and the MRO sector in developing and applying innovative solutions that will allow the maintenance, inspection and repair of flying platforms to be planned and executed effectively, efficiently and sustainably. We are working on achieving official recognition as an expertise centre for aircraft maintenance and fleet replacement and for sustainable materials and coatings used in aircraft maintenance. We are working on accepted techniques and procedures for composite repairs, inspection techniques, maintenance concepts for electric flight, maintenance optimisation based on AI, and autonomous visual inspection of aircraft. This will let NLR help increase the sustainability of aviation (Theme 1), improve the competitive position of the Dutch aviation industry both domestically and internationally (Theme 2) and contribute to a safe and secure society (Theme 3).

INFORMATION-DRIVEN OPERATIONS

We propose solutions for the ministries of Defence, of Infrastructure & Water Management and of Justice & Security that put them in prime position to operate in an information-driven way. We do this mainly from our focus on the aviation and space domains. We support the Ministry of Defence, and in particular the Royal Netherlands Air Force Command (CLSK), with the further implementation of the information-driven organisation that it is aiming for. Having information-driven operations requires an authoritative information position and a multi-domain, integrated approach, which in turn demands multi-domain, integrated collaboration with partners aimed at accumulating knowledge and developing concepts, techniques and applications. At an interdepartmental level, that is put into practice through the Security Knowledge and Innovation Agenda (KIA), where the ministries of Justice & Security, Defence, and Foreign Affairs jointly present their requirements. We also continue to draw on our knowledge to support the Ministry of Infrastructure & Water Management with its agenda for alternative ways of dealing with data. In this way, NLR will contribute to a safe and secure society (Theme 3) and improve the competitive position of the Dutch aviation industry both domestically and internationally (Theme 2).

FUTURE AIR & SPACE POWER

We propose solutions for the Ministries of Defence and Justice & Security that allow them to carry out their tasks effectively and increase the preparedness of their troops and forces for deployment and their resilience to new threats in the aerospace domains This will improve the agility and clout of the military, security services and police, and make society safer. In addition to knowledge of their own systems and operations, the focus is on knowledge of the systems and technologies behind threats, the associated

Improvements to MRO for a safe and competitive aviation industry

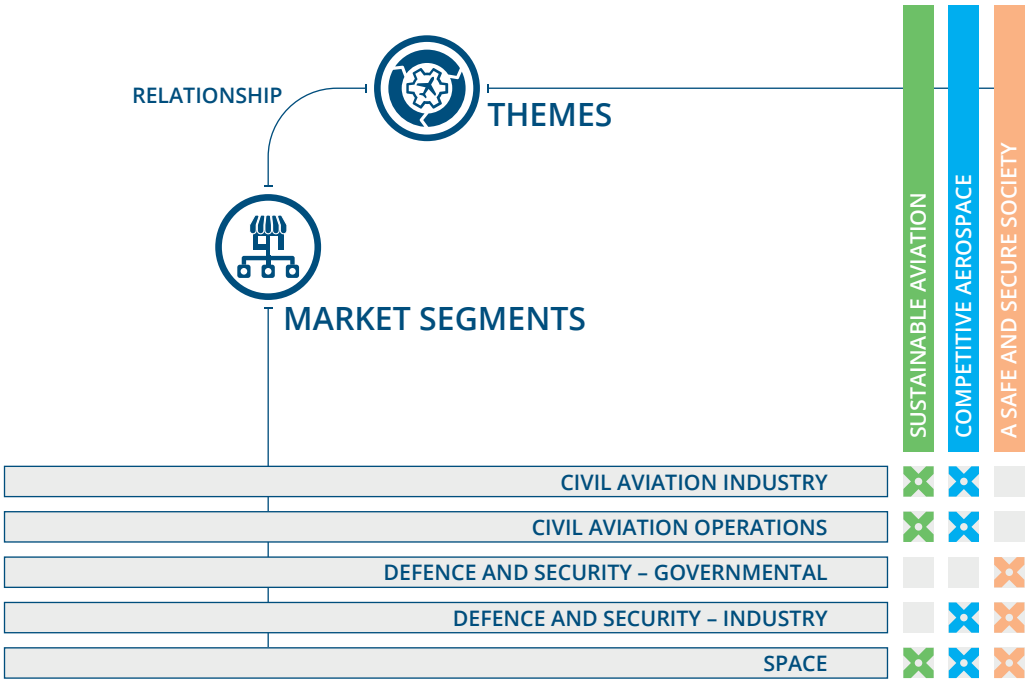


TABLE 3 RELATIONSHIP BETWEEN MARKET SEGMENTS AND THEMES

mitigating measures, and education and training. A workforce that has received optimum training will let the governmental authorities anticipate and prepare for changes in the outside world. In this way, NLR will be contributing to a safe and secure society (Theme 3).

UNMANNED AND AUTONOMOUS

We offer support in the development, implementation and social acceptance of unmanned and/or autonomous aviation. NLR focuses on the societal challenges of smart, sustainable unmanned and autonomous mobility, while taking into account safety and the need to minimise nuisance. We help Dutch and European stakeholders to implement unmanned aviation safely and with broad public support, and to exploit commercial opportunities. We are also assisting the rise of Dutch manufacturers of drones and UAM. This lets NLR help meet the social challenges in strengthening the competitive position (Theme 2), ensuring safety (Theme 3) and minimizing nuisance (Theme 1).

EMERGING TECHNOLOGIES

NLR invests in technologies for the future that are applicable across the board in NLR, within the three themes and the programmes described above, and that can potentially have a big impact on the way we live, learn, work and produce. We explore, select and implement strategic options for knowledge development for the aerospace sector. That knowledge is increasingly often from new domains, which we aim to investigate largely in collaboration with partners in those domains. We are looking at virtualisation, digitisation, automation, AR/VR, AI and explainable AI (including machine learning and deep learning), distributed ledger technology such as blockchain and advanced data analytics. Emerging technologies are monitored continually via Technology Watch and assessed as to their applicability within the aerospace sector.

4.5 The approach to the market

It is crucially important for us to carry out assignments for government bodies and industry players, both in the Netherlands and internationally, because that lets us maintain and strengthen our knowledge position. Over 75% of our turnover comes from contract research that is paid for entirely by customers. We focus on five market segments. Like the programmes, they help us achieve the objectives in the three themes. Table 3 gives a brief explanation of the market segments.

THE CIVIL AVIATION INDUSTRY

The main target groups in the aviation industry are manufacturers and the MRO sector. Sustainable, more effective and more flexible operations are important for both groups. The main issues for the

industry – and for NLR in Theme 2 (Competitive aerospace) – are reducing production costs and thereby product costs too, increasing adaptability, and increasing sustainability throughout the lifecycle. Cost reductions can be achieved by:

1. reducing the costs of design and production, certification and testing;
2. making business processes more flexible;
3. automating the production and maintenance process.

In all three of these cost reduction approaches, it is important to retain sustainability and circularity as essential components of the process. The aim of making aviation climate-neutral, as described in Theme 1 (Sustainable aviation), can act as an incentive encouraging the use of new materials, new production methods, different kinds of propulsion and operation, and revolutionary aircraft designs.
This is relevant not just for traditional aircraft manufacturers but also for new players working with UAM concepts, both in Europe and beyond.

The aircraft manufacturing industry is essentially the first step in the supply chain for making aviation more sustainable. It has that role because it is responsible for designing and building aircraft that will incorporate new sustainable elements. NLR is responding to these requirements by remaining in dialogues with market players about all the relevant research topics.
To keep fully abreast of the manufacturing and MRO sectors, NLR will continue to play a proactive role in collaborative ventures and major projects in the domestic and international civil aviation industry. Dutch SMEs are an important focus for NLR in this domain.

CIVIL AVIATION OPERATIONS

In civil aviation operations, the key client segments are aviation companies, air traffic control, airports, regulatory bodies and governmental authorities. The recovery of profitability, reducing costs, sustainability and safety are important issues for this group of stakeholders.

That is why NLR will focus on innovations that deliver cost reductions or sustainability improvements in the short term, and on tools that put stakeholders in command of their current and future sustainability performance in line with Theme 1 (Sustainable aviation) and Theme 2 (Competitive aerospace).

NLR can offer support in the introduction of cost-saving technologies and new forms of service provision, knowledge, experience, products and services in the field of sustainability. We focus on innovations and advice that help make civil aviation operations more sustainable and enable climate targets to be achieved, reducing the burden on the environment and ensuring efficient, safe operations. If sustainability is to be improved, a transition will need to be made to hybrid/electric aircraft and to efficient and effective operation of flights with such aircraft. At the international level, we mainly make use of the Airport Council International (ACI) network and work with our partners to achieve this. In relation to the European climate targets, NLR has a great deal of knowledge and experience as well as products and services that can help the client segments in civil aviation operations.

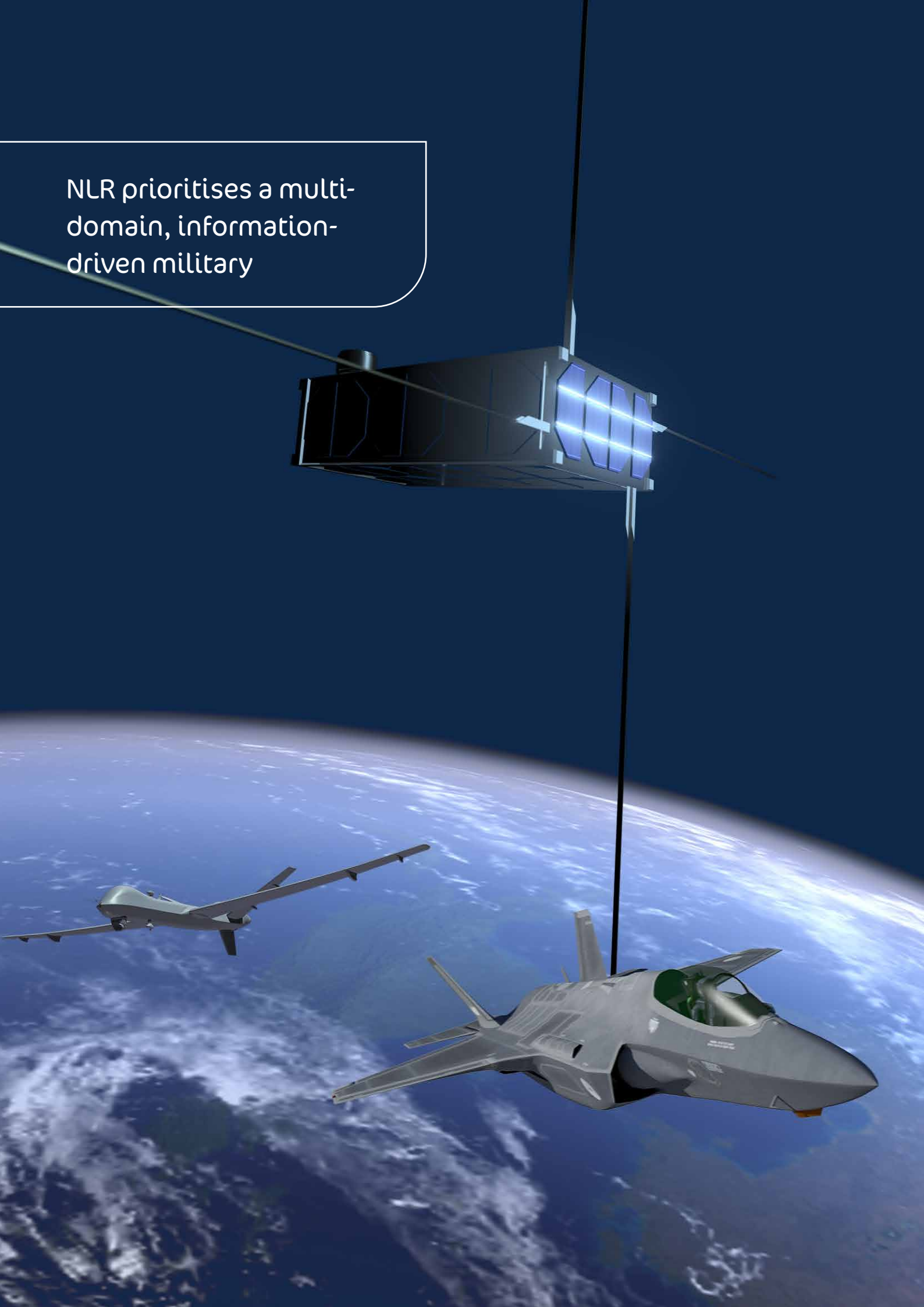
The market approach for regulatory authorities and government bodies focuses more on the relationship, through participation in working groups and committees and by playing an active role in the liaison between EASA and the European research institutes. In addition to EASA, we will focus on intensifying our interaction with national Civil Aviation Authorities (CAAs). In the first instance, that means the Human Environment and Transport Inspectorate in the Netherlands, but it also includes regulators in the USA, Singapore, South Korea and Switzerland, and other regulators dealing with the approval and supervision of new technology and training methods at the national level.

DEFENCE AND SECURITY – GOVERNMENTAL

In this market, NLR will further consolidate its long-term strategic relationship with the Ministry of Defence with the aim of helping the ministry put its vision and strategy into practice. In the coming period, the Ministry of Defence will start operating sophisticated new systems. In addition, it will be focusing on protecting our safety in the newly identified domains of cybersecurity and space. There will be a key role for technologically sophisticated and multi-domain, information-driven armed forces. NLR offers its knowledge, expertise and technology for the entire lifecycle of systems, whether this involves drawing up specifications, operational testing and evaluation, flight safety, operations, improvements or preparedness.

The Security KIA is an agenda that was drawn up by a group of ministries in conjunction with research organisations and market parties. The ministries of Defence and Justice & Security act as the client ministries while the Ministry of Foreign Affairs is also involved. This is leading to intensification of the relatively new relationship with the Ministry of Justice & Security, while NLR is also extending its relationship

NLR prioritises a multi-domain, information-driven military



with the Ministry of Foreign Affairs. New products and services are being developed with the market ecosystem in question in response to operational government requirements. Based on national defence and security needs, we develop the international market position together with the private-sector partners. That is also designed to make Europe self-sufficient, through participation in the European Defence Fund (EDF).

At the international level, NLR often operates through collaborative ventures between governments, frequently on a bilateral or multilateral basis with NATO and/or EU members. NLR regularly collaborates with research organisations and market parties in these other countries, or works directly with the governments in question.

DEFENCE AND SECURITY – INDUSTRY

Level playing fields are few and far between in the defence and security industry. National industry players and research organisations usually only have a realistic chance in programmes where the military is involved with the aim of meeting its equipment requirements. Given the absence of a self-sustaining aircraft industry, Dutch industry parties are dependent on the Netherlands' participation in international programmes.
NLR focuses on the defence industry in the Netherlands in the supply chain and on international OEMs. NLR will remain involved in relevant development programmes in order to maintain and extend the Dutch knowledge base. We will work closely with international OEMs, suppliers and users so that we can play a significant role in the entire lifecycles of platforms and systems. Areas we will concentrate on include capability development and technology aimed at cost reduction, as described in the section on the civil aviation industry. This position will enable NLR to retain essential knowledge in military technology, letting us support the Ministry of Defence, in partnership with Dutch industry, in implementing 'smart procurement' and 'joint development' in the acquisition of new equipment. This ties in with Theme 3 (A safe and secure society). NLR's work here not only benefits security but also the economy, given that Dutch industry is bolstered by the accumulated knowledge in the value chain for military platforms, in line with Theme 2 (Competitive aerospace).

SPACE

NLR focuses primarily on strengthening the Dutch ecosystem of aerospace companies and on reliable access to vital space infrastructure. In the coming strategic period, NLR will further extend its position in the civil space navigation market. To that end, NLR will invest in its portfolio and in relationships and networks in the Netherlands, both at the European Space Agency (ESA) and more broadly in Europe. NLR will also look to collaborate more with academic and applied universities with the aim of adding new innovations to its portfolio. The NLR product portfolio for space applications focuses on PNT services and Earth observation. The focus of the NLR portfolio for space infrastructure is on technology for launchers and small satellites. NLR will continue to build up its track record in the military space domain and use it to support space companies in the civil market.

Developments in the space ecosystem are increasingly geared to adding value for society at large. Dutch space policy is expected to follow this trend, based for example on the Dialogic report *Brede verkenning toegevoegde waarde ruimtevaart voor Nederland* (Broad exploratory study of the added value of the space industry for the Netherlands) [19] and the reorientation of SpaceNed, the space industry association. NLR has an extensive knowledge base in policy areas covered by the Ministry of Infrastructure & Water Management and the Ministry of Defence. The policy areas of the Ministry of Justice & Security are a more recent addition. That makes NLR a natural knowledge partner for the government and in the market cooperation between the government, private industry and research institutes. NLR can draw on its specific knowledge of application domains and space technology to give expert, objective advice.

With a solid national policy and with collaboration, the Netherlands could consolidate its international position, benefit more from European funds and achieve economic growth by expanding its market position. NLR is a keen proponent of this.

4.6 The approach to external stakeholders

GOVERNMENT

Our unique knowledge makes us a long-term strategic partner for the ministries of Infrastructure and Water Management, Economic Affairs and Climate Policy, and Defence. For each department, we develop specific technologies and facilities and we put flesh on the bones of the knowledge agendas Our three themes let us help solve social issues from the MTIB (Mission-Driven Top Sectors and Innovation Policy), especially the Security KIA, the Key

Technologies KIA and the Future-proof Mobility Systems sub-KIA. As a research organisation with an independent position, we consider it important to see society and its citizens as our stakeholders too.

We want to develop the strategic partnership with the Royal Netherlands Air Force further. With our in-depth knowledge of the entire aviation domain, we want to help the Ministry of Defence achieve its goals, and more specifically to assist the Air Force in the transition to a fifth-generation air force. The knowledge and experience we have been bringing to the Air Force have had spin-offs to the land and naval domains for many years already. We bring these opportunities emphatically to the attention of the other branches of the armed forces. Added value has arisen from the MTIB that is also letting us develop a strategic cooperation with the Ministry of Justice and Security (JenV). To that end, they have joined the NLR task force, advisory board and advisory committees. NLR aims to provide added value for JenV structurally and wants to expand its research portfolio with that in mind. NLR will continue to discuss this with JenV and the coordinating ministry, Economic Affairs. The Ministry of Foreign Affairs also recently introduced a space security policy and joined the relevant section of the MTIB. NLR will actively approach policy departments with a new interest in aerospace. Space needs extra attention to align it better with the formulation of national and other policy, NSO, ESA-ESTEC and the NL Space Campus in Noordwijk. We will strengthen our relationships with the ministries and operational departments, working closely with SpaceNed and the Dutch space ecosystem.

THE COMMERCIAL SECTOR

Extra attention is also being paid to intensifying our cooperation with the commercial sector (in particular with SMEs) and sector organisations through public-private partnerships (PPPs), field labs and knowledge transfer events. An annual call is made to SMEs, aiming to make our knowledge and large research facilities more accessible. The MTIB encourages the development of strategic aims within ecosystems consisting of governments with needs, companies with innovative solutions and research organisations that can connect them together with knowledge and technology.

Where necessary, we will also work together outside the aerospace ecosystems to accelerate the achievement of aerospace goals, for example within the composites ecosystem. NLR is actively engaged in setting out strong value propositions for support through economic stimulation instruments in the Netherlands, within Europe and beyond, based on the aims that have been jointly set out in the Knowledge and Innovation Agendas in the PPP context. Outside Europe, we are blazing the trail for the aerospace sector. Once the foundations have been laid, we will be able to operate in that market together. At the same time, orders worldwide will ensure that we maintain the knowledge position that lets us continue to support Dutch companies.

RESEARCH ORGANISATIONS

Like the other TO2 institutes, NLR acts as the link between knowledge and its application. Each institute has a dedicated portfolio and network and they work closely together in several areas, with active support from the Ministry of Economic Affairs and Climate Policy [23]. NLR values this cooperation highly. Best practices are shared in a TO2 context, for instance, and working methods are harmonised. Cross-sector applications are extremely important. On top of that, the TO2 institutes come together in the joint programming within the MTIB. One example of this is the common aim of NLR, TNO (the Netherlands Organisation for Applied Scientific Research) and the ministries of JenV and Defence to set up a long-term programme called Ground-Based Situational Awareness together with the space ecosystem within the Security mission, as part of and working from the Security KIA.

NLR wants to collaborate more actively and exchange knowledge with national and international knowledge partners to strengthen our linking role between academic knowledge with low TRLs and new market value or governmental requirements. We want to be connected with knowledge partners outside the aerospace domain so that we can learn how their knowledge can be applied within our own domain, as well as to share our knowledge with them. NLR's aim is to carry out more PhD research in collaboration with scientific institutes. NLR will also ask for support from the Ministry of Education, Culture and Science (OCW) and the Netherlands Organisation for Scientific Research (NWO) to make this PhD research possible. This will link academic science and low-TRL research even more strongly to market opportunities and governmental requirements.

Cooperation in the European context is becoming increasingly important. We foresee the possibility of a European aerospace research centre being created with national branches and specialist fields. NLR believes that this would be a positive development. Based on its long-standing cooperation with DLR in Germany, NLR will propose to DLR that they join forces in promoting this effort. NLR will also play a

Cooperation in the European context is becoming increasingly important

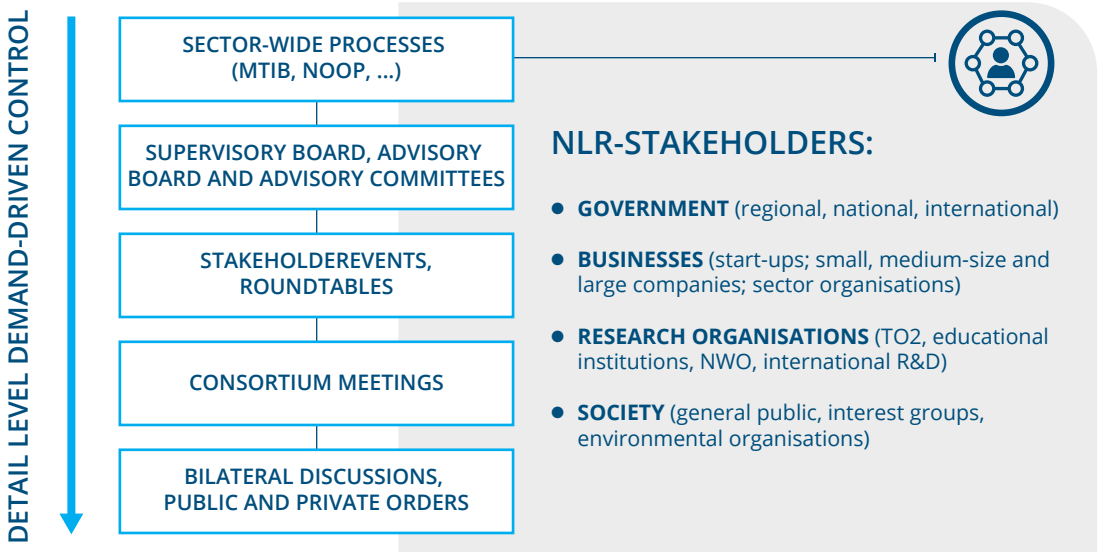


FIGURE 1 LEVELS OF DEMAND-DRIVEN CONTROL

major role in the European body ACARE, where sector-wide discussions are held about goals and research priorities. The update to the document FlightPath 2050 deserves special attention here. Additionally, NLR is continuing to strengthen strong transatlantic and NATO ties.

SOCIETY

As an independent research organisation with an independent position, we think seeing society and its citizens as our stakeholders is very important. Social media and discussion forums have given the people at large direct access to public and political debate and to journalism – as the representatives of the mainstream media, as a source of news and for background information. This gives us the opportunity to share the results of our research and its expected impact on society and the economy in even clearer terms. As an independent organisation (i.e. not steered by others in the design, implementation or reporting of our research), we will also play an active role in the debates on making aviation greener and on space policy development.

Our expertise and our knowledge position let us interpret the effects of new developments and put them in perspective. To do that, we need to increase our political and social presence further.

DEMAND-DRIVEN CONTROL OF RESEARCH

NLR is in daily contact with its stakeholders at all operational levels. These contacts are the basis of the demand-driven control and agreements about the research that NLR carries out. NLR distinguishes various levels at which that control is provided. The highest level involves sector-wide processes such as drawing up KIAs as part of the MITB and setting up a national research and development programme (NOOP) for which the entire sector provides input for the broad outlines. One level of detail below that are the NLR's supervisory board, advisory board and advisory committees, which include representatives from the government, industry, SMEs and universities; these define the direction for long-term research by NLR at all the TRLs at which NLR operates (typically TRL 3 to TRL 8). Stakeholder events and roundtables are used for getting into a dialogue with the stakeholders. Once projects are up and running, demand-driven control is provided through consortium meetings for projects and through bilateral discussions with project partners and customers. That is also the deepest level of demand-driven control.

Direct lines of communication and consultations with Dutch stakeholders are essential for demand-driven control of NLR's research.

In the Netherlands, NLR works with other TO2 institutes to find solutions for society's challenges such as security and climate change, and to reinforce the competitiveness of Dutch industry. In the international arena, NLR has strong ties with EREA, ESRE, IFAR, GARTEUR and others, because aerospace is a prime example of a field that demands international cooperation. There has been structural cooperation for many years with DLR in particular through DNW and the AT-One consortium.

Universities are essential collaboration partners for NLR. At the level of NLR's departments, there are regular contacts with a variety of faculties at numerous universities. During the coming strategy period, a business strategy will be worked out for this, given that there is a desire among the departments to strengthen relations with the universities further.

4.7 Finances

We need a robust financial organisation to let us achieve our short and long-term goals. We do not have to do this for profit, but there must be sufficient scope for investment in knowledge and product development and technological infrastructure.

FINANCIALLY ROBUST

The organisation's solvency must be in order if financial continuity is to be ensured. Turnover growth must at least keep pace with inflation. Additionally, we need to ensure that there is a good balance between the amount of work and the available capacity, so the order intake has to be kept at a good level. As an applied research organisation, we anticipate the market developments and questions from the ministries. We do that while keeping an eye open to make sure that the knowledge areas retain a minimum critical mass.

SUFFICIENT INVESTMENT SCOPE

To remain relevant in the future, there must also be sufficient financial scope to keep investing in facilities. Together with the governmental bodies, we are looking for ways of extending the resources for maintaining the infrastructure and of investing in necessary renewal (digitalisation in particular) in the medium term. The European and Dutch authorities have created various new funding instruments such as the EU's Recovery and Resilience Fund, the *Nationaal Groeifonds* (National Growth Fund) and the R&D scheme for the mobility sectors, all of which offer opportunities to fulfil wish-list items from our long-term investment agenda. Given the many opportunities presented by the new programmes and support packages, NLR is open to growth.

AN INCREASING NEED FOR MATCHING

Over 75% of our turnover comes from contract research that is paid for entirely by customers. We generate the remaining 25% through research that is paid for with government funding. In view of our role as an applied research institute, it is important that the funding for our knowledge base is kept at a good level, so that we will remain relevant and can have an impact in the future. However, we expect an increasing need for matching in the coming years to let us keep participating in new national and European programmes. We will be discussing that with our coordinating authority, the Ministry of Economic Affairs and Climate Policy.

We are working on a better world for tomorrow, with an eye on the future

Afterword

The NLR Strategic Plan 2022-2025 was drawn up with the utmost care, for which we thank our staff as well as the Supervisory Board, ministries, the Advisory Council and Advisory Committees for their close involvement. All their contributions have been extremely valuable to the development of this plan. Furthermore, the evaluation report by the EMTO committee has been important. We have been pleased to take their recommendations on board.

It is important that we continue to work well with governments, businesses and research organisations, while remaining fully cognizant of sentiment within our society. To that end, we are continuing to expand our network both nationally and internationally.

NLR's focus is on strengthening the Dutch aerospace sector. We envisage a major role for NLR in that ecosystem, helping to create solutions for the major societal, global challenges we face. It is a complex task, one that is too large and too urgent for us to tackle alone. However, armed with our strategy plan, we are confident that we and our partners can make it happen together – for a better world tomorrow.

List of (translated) abbreviations

ACARE	Advisory Council for Aviation Research and Innovation in Europe
ACI	Airport Council International
AI	Artificial Intelligence
AR	Augmented Reality
ATM	Air Traffic Management
BZ	Ministry of Foreign Affairs
CAA	Civil Aviation Authority
CO_2	carbon dioxide
DIS	Defence Industry Strategy
EDF	European Defence Fund
EMTO	Evaluation and Monitoring Framework for Applied Research
EREA	Association of European Research Establishments in Aeronautics
ESA	European Space Agency
ESRE	Association of the European Space Research Establishments
EU	European Union
EZK	Ministry of Economic Affairs and Climate Policy
FCAS	Future Combat Air System
GARTEUR	Group for Aeronautical Research and Technology in Europe
GOVSATCOM	Governmental satellite communications
HAPS	High Altitude Pseudo-Satellite
HR	Human Resource
ICT	Information and Communication Technology
IenW	Ministry of Infrastructure and Water Management
IFAR	International Forum for Aviation Research
JenV	Ministry of Justice and Security
IoT	Internet of Things
KIA	Knowledge and Innovation Agenda
MITC	Mobility and Infrastructure Test Centre

MoU	Memorandum of Understanding
MRO	Maintenance, Repair and Overhaul
MTIB	Mission-Driven Top Sectors and Innovation Policy
NATO	North Atlantic Treaty Organization
NOOP	National Research and Development Programme
NWO	Netherlands Organisation for Scientific Research
OEM	Original Equipment Manufacturer
OO	Research Organisation
PAV	Personal Air Vehicles
PNT	Positioning, Navigation and Timing
PPS	Public-Private Partnership
RDT&E	Research, Development, Testing and Engineering
R&D	Research and Development
SAF	Sustainable Aviation Fuel
SKIA	Strategic Knowledge and Innovation Agenda
SME	Small and Medium-sized Enterprises
SREV	Short-Range Electric Vehicle
SSA	Space Situational Awareness
STM	Space Traffic Management
TO2	Applied Research Organisations
TRL	Technology Readiness Level
UAM	Urban Air Mobility
USA	United States of America
VR	Virtual Reality
XAI	Explainable AI

NLR's fields of knowledge

CODE	FIELD OF KNOWLEDGE
AS.1.A	Electronics technology
AS.1.B	Qualification of Avionics
AS.1.D	Aircraft systems development
AS.1.E	Flight testing systems
AS.1.F	Weapons systems
AS.1.G	Electronic warfare
AS.1.H	Mission support
AS.1.I	Aerospace infrastructure
AS.1.J	Aerospace applications
AS.1.K	System maintenance and platform management
AO.1.A	Aviation safety
AO.1.C	Air traffic management (ATM) and airport simulation and validation
AO.1.D	Air traffic management (ATM) and airport operations
AO.1.E	Planning, advanced information processing and control (incl. of sensors)
AO.1.J	External Aviation Safety and Policy Support
AO.1.K	Aircraft acoustic effects on the surroundings
AO.1.L	Air pollution by aviation
AO.1.M	Software technology for aviation
AV.1.A	Aircraft lifecycle monitoring & maintenance
AV.1.B	Gas turbine technology
AV.1.C	Structure modelling and multidisciplinary analysis
AV.1.D	Collaborative engineering and data science
AV.1.E	Computational physics & theoretical aerodynamics
AV.1.F	Aeroelasticity, aeroservoelasticity and aircraft stresses
AV.1.G	Vertical flight technology
AV.1.H	Aeroacoustic & experimental aerodynamic research
AV.1.I	Construction and manufacturing techniques
AV.1.J	Aerospace materials
AV.1.K	Experimental mechanics and wind tunnel model design
AV.1.L	Materials technology and wind tunnel model construction
AV.1.M	Aerospace materials and damage investigation
AV.1.N	Aerospace structure testing

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Colophon

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