Lucht- en Ruimtevaart Nederland

ROADMAP AERONAUTICS MANUFACTURING AND MAINTENANCE 2014 – 2020

TOPSECTOR HTSM

Topsector HTSM

Roadmap Aeronautics Manufacturing and Maintenance 2014 - 2020

September 2014

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INTRODUCTION

The primary function of civil aviation is to serve the societal demand for global and regional mobility. Millions of passengers and goods are moved around the world each year and global air travel remains a growth market: air traffic will double in size from 2014 to 2029. This growing demand for mobility shows that the worldwide market for air transport will be a promising growth market in the future. As a consequence aeronautics manufacturing and aircraft maintenance will also remain growth markets as foreseen in global market forecasts by leading aircraft manufacturing companies.

To enable the growth of mobility in a sustainable way, the challenges for the future are to develop greener and safer aircraft. The European aeronautics industry is world leader in developing sustainable aviation products. Innovative, leading-edge technology is the major competitive differentiator for green and more efficient products and processes in the light of the fierce and increasing competition from especially the emerging economies (BRIC).

Significant and sustained investment in research and technology is required to maintain this global leadership position of the European industry in aeronautics technologies. As the sixth largest country in aeronautics manufacturing and maintenance in Europe, the Dutch sector is an important player as exporter of integrated solutions. The sector employs around 15,000 people and has a yearly turnover of € 2.5 billion (Ref. 2). The aeronautics sector is a sector with potentially high return on investments because aircraft manufacturing programmes run for a very long period of time (around 30 years). These long business cycles (business for generations) lead to a need for the sector for specific credit facilities (revolving, long payback time), demonstration projects and dedicated “Top consortium for Knowledge and Innovation” (TKI) programmes.
Technology and innovations developed by the aeronautics sector have shown to have huge spin off and significant spill over effects towards other sectors, for example the wind energy sector.

The top sector High Tech Systems and Materials is one of the sectors in which the Netherlands excels globally and is a government priority. The top sector approach is geared towards providing a solid exchange between businesses, knowledge institutes and the government ('triple helix' of ‘golden triange’) in order to convert knowledge into new innovative products and services faster.
The competitive differentiators of the Dutch aeronautics manufacturing and maintenance sector are knowledge intensive and technological niches in the fields of the following five technology innovation themes:

- Aerostructures
- Engine subsystems and components
- Maintenance Repair and Overhaul (MRO)
- Aircraft systems
- Future concepts

1. SOCIETAL AND ECONOMIC RELEVANCE

Aviation plays a crucial role in serving the mobility needs of the global citizen. Air traffic is forecast to double in size from 2014 to 2029. This growth of mobility has to be accommodated in a sustainable way. Therefore the challenges for the future are to develop greener and safer aircraft. Aeronautics can contribute to formulate answers to these challenges by addressing key societal themes:

- **Climate/Environment:** The international nature of aviation leads to target setting on a European level for 2050. The Advisory Council for Aviation Research and Innovation in Europe (ACARE) has set the European targets in its ‘Flightpath 2050’. The aim is to reduce: CO_2 by 75%, NO_x by 90% and noise by 65%. Lighter aircraft systems, new propulsion concepts and more efficient engines are needed. Recycling and minimising the use of chemical substances will also contribute to achieving the targets set and will contribute to REACH. REACH is the Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals and streamlines and improves the former legislative framework on chemicals of the European Union.
- **Energy/material:** Lightweight aerostructures based on new materials, more efficient engines and rotorcraft concepts and improved new propulsion concepts with engine/airframe integration, will diminish the consumption of fuels. Focus is on the development of green technologies and products such as smart fixed wing aircraft and novel materials.
- **Safety:** While aircraft safety depends to a large extent on the further minimisation of human errors, new aircraft systems and materials will further improve the safety of air transport, strengthening European efforts.
- **Security:** The primary function of military aviation is to play a role in the security of the population, locally and globally. Research into the integration of sensors in aircraft will improve peace keeping operations.
- **Competitiveness:** Target setting by ACARE is not only done to meet the societal challenges mentioned above, but also to strengthen industrial competitiveness.

Global market size addressed (2013-2032)
In line with the growing demand for air transport, the global demand for new civil aircraft will grow at an average yearly rate of 4.7% (20 year world annual traffic growth). In September 2013 Airbus released its Global Market Forecast for the period 2013-2032. This report shows a global market demand for 28,355 new aircraft (large civil aircraft with 100 passengers and more, excluding freighters) over the next twenty years (2013-2032). The global turnover represented by these new civil aircraft represents a value of € 3 trillion. The global military aircraft market is forecasted to grow to USD 85 billion. The, for the Netherlands crucial, Maintenance Repair and Overhaul (MRO) market grows slower, but promising at 3.3% (per annum, Ref. 8). New market opportunities will arise in composite MRO with a forecasted growth of over 10%. Entry barriers are high due to certifications and safety legislation. New competitors come mainly from the BRIC countries.

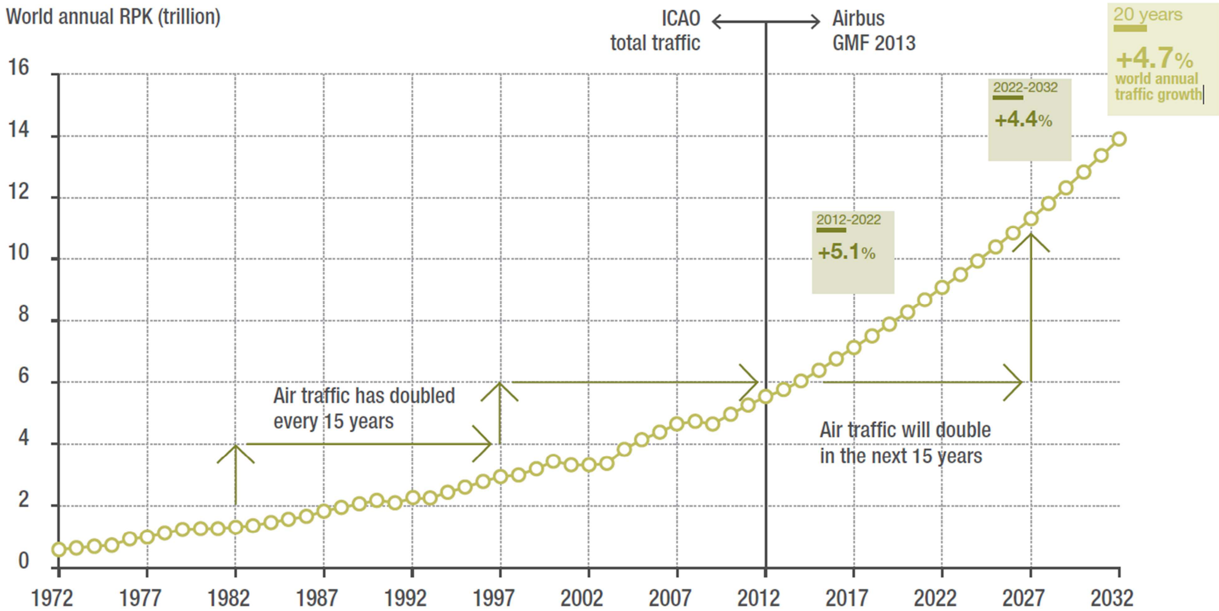

Figure: World air travel remains a growth market (Ref. 3; RPK = Revenue Passenger Kilometers)

Competitive position of Dutch industry, total R&D investments

The Dutch aeronautics sector occupies the sixth position in Europe (around 15,000 employees of which almost 60% in MRO and a yearly turnover of € 2.5 billion (Ref. 2)). R&D investments are around 8% including product development. Around 90 companies, large-scale industry and SMEs, are involved. They are part of the supply chain of almost all aircraft manufacturers (OEMs) worldwide. OEMs are increasing the percentage of outsourcing on a higher system-level with more engineering tasks, but are at the same time decreasing the number of suppliers. Dutch manufacturing activities are mostly focussed on design, engineering, manufacturing of high-end innovative components & subsystems and on materials & coatings. The Dutch MRO sector focusses on a variety of civil and military aircrafts, aero-engines and helicopters. The aeronautics sector is moving from component supplier to integrated component or systems supplier. Focusing on more complex and technology intensive products is essential to remain competitive.

The Dutch sector aims to double its market share in 2020 (Ref. 1) by: (i) achieving global market leadership in aerospace materials, (ii) participating in new aircraft platforms, with special attention to the BRIC-countries (plus South-Korea, Turkey and UAE), (iii) delivering complete systems and integrated products, and (iv) reaching an international leading position in the worldwide maintenance market through revolutionary maintenance concepts. To meet this ambition the sector needs to be competitive at a global level. This can only be reached through research, the development of new technologies and application of the achievements of R&D in new products and processes. Investments are therefore in five key technology & innovation themes described in the next chapter. The aeronautics sector is a sector with potentially high return on investments because aircraft manufacturing programmes run for a very long period of time (30 years). These long business cycles (business for generations) lead to a need for the sector of credit facilities (revolving, long payback time), demonstration projects and a dedicated aeronautics programming.

2. APPLICATION AND TECHNOLOGY CHALLENGES

State of the art for industry and science

The Dutch sector operates in market niches and its competitive position is based on advanced knowledge and innovative technology development. Niche positions lead to five well defined technology & innovation themes:

- **Aerostructures**: The Dutch aeronautics sector has a strong position on tail sections, wing boxes, movable wing parts, landing gears and accompanied materials technology (coatings, thermoplastic composites, Fibre Metal Laminates). Also NLR is highly involved in this area.
- **Engine subsystems and components**: Strong position on subassemblies for high pressure compressors, Auxiliary Power Units and parts: blisks, impellers, casings, seals, shrouds, turbine blades, and engine starters.
- **Maintenance Repair and Overhaul**: Well positioned as well: Dutch MRO activities are ranging from overhaul of aero engines, composite repair, new concepts for life cycle costs, corrosion, (prognostic) health monitoring from components and systems up to complete aircraft (Air France Industries – KLM Engineering & Maintenance is second in the world in terms of turnover).
- **Aircraft systems**: The sector has an excellent position on aircraft wiring systems. Fokker ELMO is second in the world, aircraft interior systems (Zodiac Driessen) is one of the two global players.
- **Future concepts**: New generation materials (self-healing, multifunctional) and new aircraft integration and certification (thanks to Fokker heritage of aircraft manufacturer and the presence of the NLR and DNW) and Remotely Piloted Aircraft Systems (with Dutch companies selling and operating RPAS worldwide).

Scientific challenges towards 2020

The Dutch position in aeronautics is often a direct result of intense collaboration between the Dutch knowledge infrastructure (universities (of technology), research institutes (NLR), Ref. 7) that generates creative concepts, mathematical modelling and experimental testing of key behavioural aspects and Dutch industrial companies taking validated technologies to industrial production. Such an intensive collaboration is unique in the world.

With the prior experience in the development of Glare, the Dutch network has unique experience in building the certification procedures crucial for the actual application in parallel to the actual development work.

For the future, also the newly defined key research topics under the above mentioned five technology & innovation themes offer many opportunities for successful academic research (fundamental and applied) leading to new application and industrial productivity. Key opportunities are new approaches to future aircraft concepts with more efficient propulsion, morphing structures, Structural Health Monitoring (SHM) in monolithic, laminated and fibrous materials, new Thermal Barrier Coatings (TBC), novel joining techniques, noise reducing structures, local repair/inspection methods for composite structures, damage prediction, enabling the expansion of the operational envelope for RPAS and more. Our knowledge of aerodynamics and aero-elastic effects in the creation of loading conditions and the generation of noise should be increased. The following table shows the link the societal challenges and the technology & innovation themes mentioned below:

Themes	Targets (properties and products)	Technology & innovation themes	NL strenghts 2014-2021
Mobility	Payload effictivity and efficiency	Future concepts	Flapless wings New wiring concepts
Energy	Less energy consumption/lighter	Aerostructures	Materials (composites, FML, new resins)
			Smart multifunctional materials
			Virtual testing
			Interior/airframe integration
	More efficient	Engine subsystems and components	Blisks & seals
			High temperature components
		Systems	All electric aircraft
		Future concepts	New propulsion concepts
Climate/ Environment	Reduction of CO_2, NO_x and noise	Engine subsystems and components	Geared turbofan In-flight in-situ acoustic absorption
		Aerostructures	Morphing wing
	Toxity	Aerostructures	Cr-free (research-sunset roadmap)
Safety	Passenger safety	Aerostructures	Structural Health Monitoring (SHM) Certification and qualification
		Systems	Sensoring and sensors
Security	Social security	Systems	Remotely Piloted Aircraft Systems (RPAS)
			Military transport systems
Life cycle	Longer life	MRO	Design for maintenance
			Self-healing materials
			Coatings
			Composite repairs
			NDI
			Avionics software
	End-of-life	Aerostructures	Design for reuse or recycling
	Reduction of life cycle costs	Aerostructures	PMA parts
		Systems	

To develop the Dutch strengths, needed in the near future, the intensive cooperation between the industry (also SMEs), the knowledge institutes and universities , needs to be fostered, valorisation cooperation models and knowledge flows needs to be tailored such that it follows the rapid changes in market and societal demand The strength of the Dutch aerospace industry is heavily based on the strong interaction between industry and academia, with all the networks for the applied and conceptual research in place. With the prior experience in the development of Glare the Dutch network has a unique experience in building the certification procedures crucial for the actual application in parallel to the actual development work.

Future outlook, in present and emerging markets

The following dynamics are forecasted:

- **Large commercial aircraft**: Largest part of the market for new civil aircraft: global market demand for 28,355 new large commercial aircraft over the next twenty years (2013-2032).
- **Regional jets**: Smaller market but steadily growing by 10% per year especially in China/India due to big home markets, long distance.
- **Business Jets**: Fastest emerging market with growth of 20% per year, especially BRIC.
- **Fighters**: Few new programmes (F35) expected and possible demand for sustaining older programmes.
- **Transport & tankers & surveillance**: increasing market due to upgrades of existing airframes and growing surveillance needs (military & civil).
- **Helicopters**: Emerging market due to new programmes and (peacekeeping) missions and European buying power.
- **Remotely Piloted Aircraft Systems (RPAS)**: Emerging market, still small with many start-ups and some well-established manufacturers and operators offering high tech and sensor-rich applications, both military and civil.

New competitors in the markets / BRIC countries

The coming decades, a large part of the worldwide growth in demand, but also in the supply for aircraft, will come from the emerging markets, mainly in the BRIC/Middle Eastern countries. Consistent growth and rising wealth levels in BRIC countries lead to double digit growth levels in the demand for aircraft. At the same time, these countries want to increase their own share in the design and development of aircraft and often place development of their national aerospace industry at the forefront of their industrial policies. This will also lead to an expected growth in the need for MRO. The coming years the demand will mainly be focused on qualified personnel, repair knowledge, training and tooling.

Opportunities Dutch aeronautics sector

Being part of the supply chain of the existing world leading aircraft manufacturers, the Dutch aeronautics industry will profit from these rising demand levels through the delivery of its products and services at increased levels. Also the MRO market in these countries offers great opportunities to the Dutch industry, including the training of maintenance personnel. On a strategic level it is essential for the Dutch sector to start doing business with and become part of the supply chain of emerging aircraft manufacturers. Note that the forecast is that the 3rd aircraft manufacturer in the world will be Chinese. Positioning the Dutch aeronautics industry in these emerging markets and supply chains, is vital. Governmental support through economic diplomacy and the support to come to new MoUs are key to achieve an industrial position in these countries.

3. PRIORITIES AND PROGRAMMES

Selected items from roadmap

To realize the ambitions of the Dutch aeronautics manufacturing and maintenance sector towards 2020, an ambitious Strategic Research and Innovation Agenda 2020 (SRIA 2020) has been proposed by ACARE (Ref. 6). This includes already on-going programmes and projects which continue in 2012-2013 and for which funding is ensured, as well as new ones. This includes already on-going programmes and projects which continue in 2014-2015 and for which funding is ensured, as well as new ones. Under each technology & innovation theme, short term priorities for 2014-2017 are set. These priorities are an extention of LOIs of individual commitments by the stakeholders involved that have been signed at the end of 2012. The five key technology & innovation themes are:

1. Aerostructures 2014-2017

Subthemes	Research topics	2014 - 2017
Materials	Composites	New composite materials / effect of manufacturing processes on mechanical performance of composites
	Coatings	Environmently friendly materials / next generation coatings for high tech materials
	FML	Next generation Glare
	Metals, ceramics	Additive Manufacturing
Product development	Design methods & tools	Knowledge Based Engineering (KBE) / new certification and qualification philosophy (smart building block)
	Virtual testing	Mechanical testing process simulation
	Structures design, smart structures and systems	Integration of structures and wiring / cost modelling / aircraft loads estimation and composites allowables
System engineering	(Embedded) sensoring	Structural health monitoring / Landing gear noise (flaps)
Manufacturing	Robotizing	Automated composite manufacturing technologies / faster & cheaper Resin Transfer Moulding
	Bonding technologies	New assembly technologies
	NDI	Next generation NDT technologies / smart and automated quality assurance for manufacturing
	Fibre Placement Technology	Next generation fibre placement technologies
	Smart factory	Virtual manufacturing / innovative metal forming manufacturing technology

2. Engine subsystems and components 2014-2017

Subthemes	Research topics	2014 - 2017
Materials	High Temperature Materials	Environmental impact on high temperature materials / advanced high temperature resistant materials and coatings
Product development	Engine subsystems	Gas turbine combustion systems
	Design methods & tools	Design for manufacturing technology / design and development of engine assemblies / design knowledge for improved gas turbine cycles
System engineering	(Embedded) sensoring	Prognostics and health management of gas turbine components (incl. life assessment, sensors)
Manufacturing	Composites	Manufacturing of composite parts / Coating application methods
	New manufacturing technologies	Application technologies / additive manufacturing / advanced manufacturing technologies for complex parts

3. MRO 2014-2017

Subthemes	Research topics	2014 - 2017
Product and proces development	Re-engineering, PMA parts, retrofitting	Improved product & proces development
	(Prognostic) health monitoring	Further automation NDI inspection methods / In-service damage assessment, SHM
Manufacturing	Repair	Composite repair, determination design airworthiness strategy, damage tolerance / 3D printing and repair (3D printing for repair and repair for 3D printing)
	Corrosion	Anti-corrosion, surface treatments, mobile diagnostic equipment

4. Aircraft systems 2014-2017

Subthemes	Research Topics	2014-2017
Product development	Systems for green aircraft	Modular systems (avionics, electro-mechanic actuators, electric driven subsystems) / integrated wiring systems / antenna systems / control systems / training systems
	Systems for safe aircraft	Communication, navigation and surveillance (CNS) systems / sensor systems (radar, optic, acoustic) / display systems / protection systems
System engineering	System design methods and tools	Airworthiness rule making / smart system certification / instrumentation systems / model based design, software and simulation technologies

5. Future concepts 2014-2017

Subtheme	Research topics	2014-2017
Materials	Future materials	Multifunctional/3D printed/high performance/hybrid materials, next generation FML, high temperature composites
	Bio-inspired materials	Bio inspired, self-growing, self healing materials
	Materials life cycle	State-of-the-art and future material development, production, testing, qualification, certification, sustainment, recycling
Product Development	Future aircraft structure	Patchwork aircraft structure, bionic design, optimized load paths, sound-fire-impact resistant structure, integrated structures for fast rotorcraft (compound helicopter, tilt rotor), morphing structures
	Design methods	Future intuitive analysis & design methods, certification requirements and interpretations, future production and assembly technologies, short turn around time and low cost, multiscale simulation techniques
	Smart wind tunnel testing and sensor technology	Miniaturized remote controls of wind tunnel (WT) models, smart WT correction methods, aero-elastically scaled WT models, cost-reduction WT models, rapid prototyping of wind tunnel models with embedded sensors (3D printing), accurate balances with temperature compensation, sensors and HUMS validity for maintenance optimization
	Future aircraft systems	Remotely piloted aircraft systems (RPAS), impact more electric on systems, integrated systems for fast rotorcraft, cheap aircraft weight and balance system
New Aircraft	Development new aircraft, propulsion integration, and demonstrators	Future aircraft concepts, propulsion concepts, multi-disciplinary engine-airframe integration, future aircraft design - certification - validation methods, multidisciplinary optimisation of aspect ratio 10-15 wing, future concepts for passenger cabin, (active) noise reduction technologies
	Integral life-cycle cost	Technology development constrained by life-cycle cost
	Future cockpit	Integral safety assessment of cockpit and ATM in integrated air-ground-space system-human machine interface, future cockpit and control concepts, human factors & resilience of future complex systems (incl. cockpits)
Aircraft in a new environment	Development of new ground systems, procedures and concepts	Remote Tower, ATC systems, Flight procedures

While some of the research topics may be addressed in other roadmaps as well, they form the core business of the *Aeronautics Manufacturing and Maintenance* domain. As in the past, desired cross-overs often lead to spin off and spill overs for other industries and markets.

Proposed implementation (NLR, NWO, international R&D, regional, other)

The realization of the roadmap *Aeronautics Manufacturing and Maintenance* depends on the implementation mechanisms available for the so-called "golden triangle". Each development phase in the innovation cycle (from knowledge via technology to product development) requires different approaches. The Dutch aeronautics sector also looks beyond national borders and is heavily involved in international cooperation at five levels: (i) strategic alliances, (ii) international sharing of facilities, (iii) transnational and international institutional cooperation, (iv) joint industry participation in international collaborative R&D programmes, and (v) participation in and through international professional societies. Various implementation forms are described below.

Collective R&D with / without public private partnerships within NL

Knowledge institutes TUDelft and NLR are prime suppliers of knowledge to the aerospace sector. However, the other universities of technology also contribute to the development of the Dutch aerospace expertise. Technology Foundation STW has played and will play an important role in the academic research relevant to aerospace key sectors as identified in this roadmap. Their involvement is particularly strong in the fields of aero elasticity, high performance polymers and composites, multiscale simulation techniques, self-healing anti-corrosion coatings and structural health monitoring. Various aeronautics programmes have made important contributions to the field (mainly technology development).

Collective R&D within EU Programmes

The Dutch aeronautics sector participates widely in FP7 under the *Collaborative Research Programme, Transport Theme, Aeronautics and Air Transport* (AAT). The main value of participating in EU-projects is to develop excellent scientific knowledge for the benefit of Dutch society, cooperation with (European) OEMs, a large network and new commercial opportunities. The EU supports R&D in the AAT theme through the following lines:

- *Joint Technology Initiative (JTI) Clean Sky*: Public-private partnership (PPP) between EU and industry, 2008-2014, budget € 1.6 billion, 50/50 industry focused on greening of air transport system. R&D focusses on next generation smart fixed wing aircraft, aero-engines, new propulsion and eco-friendly design. The yearly value of the Dutch activities in Clean Sky amounts to around € 8 million. The Dutch clusters will continue this line of research for the coming years in Clean Sky 2, but co-funding of their activities has to be ensured.
- *Collaborative research*: Covers research projects from knowledge development to technology development. As this kind of research is usually more distant to the market, the main actors stem from the knowledge institutes (TUDelft/NLR). The total value of activities for NL-parties is around 11 M€/year. The sector expects to continue this line of research the coming years.
- The sector is participating in several smaller projects in European programmes: ERA-NET, EUREKA, INTERREG, ITEA, FP7 and ERC.

Horizon 2020: The follow-up of FP7, Horizon 2020 will focus heavily on ‘societal challenges’. Aeronautics will be addressed under the heading of ‘smart, green and integrated transport’. To be able to realize its ambitions in the future, the aeronautics sector needs the Dutch government to actively pursue a ring fenced/dedicated budget for aviation under Horizon 2020 due to the specificities of the sector, as well as governmental support for continuation of a best practice PPPs such as JTI Clean Sky.

MoUs: The Memorandum of Understanding (MoU) is an additional tool to promote international cooperation. Today, there are two international MoUs in the aeronautics sector, one with Airbus and one with SNECMA.
The Airbus MoU defines a joint research and technology programme of common interest with the objective to extend and increase the international business relations between parties involved. This airplane MoU has been agreed between Airbus, Fokker and the Netherlands Aerospace Group (NAG), consisting of 105 Dutch aerospace companies and representing the entire Dutch aerospace sector (production, maintenance, education, engineering, R&D and science).
The SNECMA MoU covers engine research and technology development with the objective to extend and increase the business relation between the international partners. This aero engine MoU has been agreed between SNECMA and the Dutch Aero Engine Cluster (DAEC). DAEC is a partnership between companies in the manufacturing industry (Sulzer Eldim and Dutch Aero), the engineering firm Atkins and the research institute NLR. DAEC was founded in 2001 with the objective to significantly improve the market position of the Dutch aero engine manufacturing industry.
Together with the Dutch government, the sector is also looking for new MoUs with newly emerging aircraft manufactures.

Summarized roles

NLR is one of the most important centres for aerospace expertise in the Netherlands. NLR activities cover Air Transportation, Government Defence & Security, Civil & Defence Industrial Companies, Transnational partnerships (German Dutch Wind tunnels (DNW), Space, Government programmes and Government contributions to aerospace facilities. Industrial and Space related NLR activities cover around 50% of NLR’s turnover implying that 50% of NLR activities is focussed on the aerospace manufacturing, maintenance and space ecosystem in the topsector HTSM. NLR role in this ecosystem is implemented through national and international collaboration, extensive international networking and partnerships. Government financed programmes at NLR are driven by the demands from Dutch industry (including SMEs), and by questions defined by the Ministry of Defence, and the Ministry of Infrastructure and Environment. The NLR application programme on HTSM has a one-to-one correspondence with the five key technology & innovation themes defined in this roadmap. NLR composite manufacturing facilities and NLR testing facilities are used extensively by Dutch industry. Material and structures test facilities are not only used for industrial research programmes like TAPAS2 but are also extensively used by Dutch industrial companies to support product development up to the highest Technology Readiness Levels. DNW wind tunnels are used by EU-projects, by defence customers, by Fokker Services to test a derivative aircraft configuration, and by Netherlands Aircraft Company (NAC) aircraft to validate new aircraft designs in the area of engine airframe integration. NLR receives a government contribution to improve and sustain key aerospace facilities.

Netherlands Organisation for Scientific Research (NWO): As pointed out, the academic research activities should focus on the one hand on predicting the behaviour of materials and compound structures closer to industrial implementation over very long periods of time under variable conditions and on the other hand on innovative research on the novel concepts for future concepts aimed at substantially reducing the environmental and societal impact. Multiscale and multilevel modelling of multifunctional materials and structures will be a key challenge for the years to come. The consistently large national and international student interest in obtaining a Dutch Aerospace Engineering degree guarantees a strong pool of newly trained scientists and engineers to push the field forward. For many years the academic work at the TUDelft has led to many new businesses, some of which have grown substantially in recent years.

TNO: Since no special aeronautics programmes exist within TNO, the strength of TNO for this sector is the application of a very broad technology base. Interesting focal points are Sensors & Large Area Electronics.

Ministry of Defense: Due to the dual-use capacity of several Defense innovations and technologies for the civil aeronautics market, spill-over effects are paramount and close cooperation with the Ministry of Defense is important.

Dutch government: The sector would like to emphasize the importance of an active engagement by Dutch governmental representatives abroad for realizing the SRIA 2020. The Dutch aeronautics sector relies on international customers, since all the big OEMs are located outside the Netherlands. Economic diplomacy by the Dutch government can open doors in countries that are more centrally organised and in which national governments play a big role in the industrial policy (mainly BRIC, but also France).

TKI programme for Aeronautics R&D&I

The *College Lucht- en Ruimtevaart Nederland* (LRN) plays a central role in the Dutch Aeronautics sector involving industrial companies, knowledge institutes and government. Different PPP initiatives, both national and international, are part of the TKI programme according to the five technology & innovation themes. Under these themes, the different key technologies and their R&D&I needs have been and will be translated into collaborative research projects. In 2014 this TKI programme takes form as the present projects and future proposals need to evolve in this new PPP umbrella. At this moment already several PPP programmes and projects relevant to the TKI programme are in place or new initiatives. Some are funded nationally, some regionally. Important examples of PPPs in the sector are:

- **TAPAS-2 (part of the Airbus MoU):** In TAPAS - the Thermoplastic Affordable Primary Aircraft Structure Consortium - eight Dutch partners were commercially active in the Dutch aerospace industry and work closely with Airbus in the field of material-, production- and connection technology and design. The technology is targeted for future Airbus-developed applications, including primary structural components as fuselage and wings. This technology can also be used for automotive or marine applications. Over the four year period 2009-2012 TAPAS received central government support for its industrial research amounting to 50% of the total cost of € 13.4 million.

Airbus' Executive Vice President Engineering Charles Champion signed the TAPAS-2 proposal during a Paris Air Show ceremony at Le Bourget Airport with Minister Kamp and other participants from the Dutch thermoplastic composite industry in June 2013. The TAPAS consortium has been extended to eleven Dutch partners (2 large scale companies, 6 SMEs and 3 research institutions). TAPAS-2 is a four year project. The total cost of the project is € 24,4 million.

- **IMPACT II (part of the SNECMA MoU)**: Aero-engine subassemblies will be developed by Dutch industrial partners and the NLR, together with SNECMA. This will lead to a more efficient and sustainable aero-engine. Period 2010-2014 stopped in 2011 due to changes in policy. Aim is to restart in 2015. The IMPACT II proposal has been updated in January 2013; the restart is needed to achieve improved performance of advanced aero-engine compressors (total budget estimate IMPACT II: € 9.5 million; 50% to be paid by IMPACT II partners).
- **Dutch Institute World Class Maintenance (DI-WCM)**: Cooperation between civil and military aircraft maintenance to create an efficient, high quality maintenance organization. Education, knowledge institutes, local governments and industries are involved. Numerous projects are aeronautics related such as: ACAST, Maintenance of Avionica & Electronics and Composites, OLCEP (Optimization Lifecycle Costs)
- **TPRC Thermoplastic Composites Research Center**: TPRC is a dedicated research foundation, open for the complete thermoplastic composites value chain, including material and equipment suppliers, (sub-) component manufacturers, OEMs, universities and research institutes. The members pay a yearly fee to fund TPRC. The Provinces of Gelderland and Overijssel and EFRO are co-funding TPRC. The TPRC budgets amounts to over € 8 million in the time frame 2009 – 2014.
- **FMLC - Fibre Metal Laminates Center of Competence**: FMLC is a dedicated research foundation, established by TUDelft, NLR and Fokker Aerostructures in 2001. Fibre Metal Laminates (FMLs) are hybrid materials that combine the typical good properties of metals, such as bearing strength with excellent composite properties such as fatigue and damage tolerance. One member of the FML family is Glare, consisting of glass fibers and aluminum. The mission of FMLC is: i) to unite and grow the know-how on FMLs to support the targets groups in the development, application and marketing of FMLs, ii) to become the internationally recognized center of competence for FMLs, iii) to promote the application of FMLs for all kinds of markets and applications.

- **PPP for military engine maintenance**: This PPP between the Ministry of Defense and Dutch Aero Services tries to use the best out of the two worlds to jointly develop a world class military engine maintenance center at the Logistical Centre in Woensdrecht. The goal is to become a multiple engine / multiple customer maintenance shop growing towards the maintenance base for the European F35 (JSF) engines which will provide high value business.

- **CompoWorld**: A 2012 regional initiative from the Province of Flevoland, local industries and the NLR centered on the NLR composites manufacturing facility in Marknesse. This PPP explores current knowledge levels of composite materials for aerospace and other industrial applications. It is therefore a truly cross-sectorial effort. Its core purpose is to bring composite knowledge to production maturity by using the NLR facility for the production of demonstrators and possible very short initial production runs. Period 2012-2016: industry € 5 million, local government 2/3 (*Zuiderzeelijn* funding).

- **IOP (Dutch: Innovatiegericht Onderzoeks Programma) self-healing materials**: Within the existing IOP-Self Healing Materials a substantial part of the research programme is devoted to self-healing materials for aerospace applications, in particular: self-healing Thermal Barrier Coatings, self-healing composites, self-healing paint systems and self-healing aluminum alloys. Period 8-10 years. Tender offers € 4 million, industry participation at around € 0.5 – 1.0 million (around 60 companies involved).

TKI programme High Tech Materials

The aeronautics sector supports the development of its cooperation on material knowledge and research within the TKI programme High Tech Materials (HTM). HTM comprises nine industrial sectors: Aerospace, Automotive, Maritime, Materials Production, Professional and Consumer Products, Energy, Security, Medical and Civil Engineering.

Aerospace is one of these nine sectors. The Dutch aerospace sector has established strong partnerships for material developments with leading industries as Airbus, Boeing, Lockheed Martin and Snecma. Leading materials are FMLs and thermoplastic composites where companies like Fokker and TenCate are increasingly successful in getting more materials and components used by the aerospace industry. Also for the production of thermoset composites, the Netherlands have a good infrastructure with large companies like DSM and Teijin producing resins and strong fibers. Various R&D centers are active to further develop those materials like NLR, TPRC and FMLC. The main driver is ultra-light but very strong materials with sophisticated functionalities.

4. PARTNERS AND PROPOSED IMPLEMENTATION

Industrial partners involved

Fokker Aerostructures, DSM, Fokker Services, Fokker Elmo, Fokker Landing Gear, Netherlands Aircraft Company, KLM E&M, TenCate, AkzoNobel Aerospace Coatings, Thales, Zodiac/Driessen, Hamilton, GE Energy. SMEs: Airborne, Aalbers, AELS, ALS, Nedaero, Aeronamic, ADSE, Dutchaero, Zodiac Aerospace, Sulzer Eldim, Atkins, Avio/Dutchaero Services, Epcor, Chromalloy, Buhl fijnmetaalbewerking bv, Microflown, KE works, LCW, AcQ Inducom, AMTS/WCAA, VTOC, Innogrind-Stresstech, NCLR, Sergem, Ansaldo Thomassen, Axxiflex Turbine Tools, Chromin Maastricht, Dutch Space, Dutch Thermoplastics Components, EECT, Eurocarbon, Geocopter, Kok & Van Engelen, GTM, Lionix MOOG, Nspyre, Philips Consumer Lifestyle, Recemat International, Technobis Fibre Technologies, Tri-O-Gen, Van Campen Industries B.V., CM Preform, Composite Tank Structures, Deen Polyester Constructies, Dutch Composite Solutions, Focal Meditech, Optimal Forming Solutions, Prince Fibre Tech, Promorfo. Samco, Nayak, Parker, KMWE, Tecnovia, NDF Special Light Products, MTT, Specto, 3D-Metal Forming, DTC, Delft Dynamics, Standardaero, Bosch Rexroth, Seco Tools, CHL Nederland, Teijin Aramid, Egmond Plastics, Opera Turbines.

Scientific partners involved

The major scientific partners of the aerospace sector are the Faculty Aerospace Engineering at the TU Delft and the Netherlands National Aerospace Laboratory (NLR) as the more applied research institute of the sector. Scientific cooperation in aeronautics is broad with the Boeing-UTwente centre on thermoplastic composites TPRC, with MESA+ /UTwente and all departments at the three universities of technology in the Netherlands in general. The Technological Top Institute for Materials, M2i, is another significant scientific partner in aeronautics. On the more applied research side, cooperation exists with TNO and its Holst Centre. Several parts of the roadmap are being studied after proposed and awarded in STW's Open Technology Programme and annual HTSM call. These are Public Private Partnerships in which multiple industrial partners are involved to enhance knowledge dissemination.

Proposed implementation

The highest level coordination of the implementation of this roadmap will be the responsibility of *College Lucht- en Ruimtevaart Nederland*, representing all parties involved.

The programmatic implementation of the *Aeronautics Manufacturing and Maintenance* roadmap will be realised by a combination of different programmatic, national and international partnerships as been exposed in chapter 3.

One of the key characteristics of this roadmap is that all OEMs are abroad. At European level the implementation of this roadmap will be realised through collective R&D activities within European Framework Programme 7 and its successor Horizon 2020, covering all topics related to ACARE's Flightpath 2050 targets (Ref. 5), and directed towards a programmatic approach as defined in the Strategic Research and Innovation Agenda, launched by ACARE at the Berlin Air Show on September 12, 2012 (Ref. 6). The topics mentioned in chapter 3 fit within the European R&D programme.

Therefore it is also essential that European and national (industry) policy are aligned as far as possible.

At the higher Technology Readiness Levels Dutch partners are cooperating in the Joint Technology Initiative (JTI) Clean Sky (Ref. 4), and are proposing to cooperate in its successor Clean Sky 2. The Clean Sky JTI consists of a number of Integrated Technology Demonstrator, one of which is Smart Fixed Wing Aircraft (SFWA). The SFWA consortium has a budget of € 393 million.

5. REFERENCES

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4. EU Joint Technology Initiative Clean Sky
5. ACARE Flightpath 2050: Europe's Vision for Aviation, maintaining Global Leadership and serving society's needs, presented at Aerodays Madrid, March 30, 2011
6. Strategic Research and Innovation Agenda by ACARE, launched at Berlin Airshow, September 12, 2012
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8. Aerostrategy 2011

6. ABBREVIATIONS

Acronym	Description
AAT	Aeronautics and Air Transport
ACARE	Advisory Council for Aviation Research and Innovation Europe
BRIC	Brazil Russia India China
CompoWorld	Foundation promoting application of composites (Flevoland)
CVO	Civil Airplane Development
DI-WCM	Dutch Institute World Class Maintenance
DNW	*Duits-Nederlandse Windtunnels*
DAEC	Dutch Aero Engine Cluster
ECM	Electro Chemical Manufacturing
ECD	Electro Chemical Drilling
EU	European Union
EUREKA	European Network for Industrial Innovation
FAA	Federal Aviation Authority (USA)
FML	Fibre Metal Laminates
FMLC	Fibre Metal Laminates Centre
FP7	European Framework Programme 7
ERC	European Research Council
Glare	Glass Fibre Reinforced Aluminum Sandwich
HTSM	High Tech Systems and Materials
INTERREG	Cross-border cooperation between regions
ITEA	Information Technology for European Advancement
JSF	Joint Strike Fighter
JTI	Joint Technology Initiative
KBE	Knowledge Base Engineering
LOI	Letter of Intent
LRN	*College Lucht- en Ruimtevaart Nederland*
MoU	Memorandum of Understanding
MRO	Maintenance Repair and Overhaul
NDI	Non Destructive Inspection
NLR	*Nationaal Lucht- en Ruimtevaartlaboratorium*
NWO	Netherlands Organisation for Scientific Research
OEM	Original Equipment Manufacturer
PMA	Parts Manufacturer Approval by FAA
PPP	Public Private Partnership
R&D	Research & Development
RPAS	Remotely Piloted Aircraft Systems
RTM	Resin Transfer Moulding
SBIR	Small Business Innovation Research
SHM	Structural Health Monitoring
SME	Small Medium Enterprise
SRIA 2020	Strategic Research and Innovation Agenda 2020
STW	*Stichting Technologie Wetenschappen*
TAPAS	Thermoplastic Affordable Primary Aircraft Structure
TBC	Thermal Barrier Coatings
TKI	*Topconsortium Kennis & Innovatie*
TPRC	Thermoplastic Composites Research Centre
TUD	*Technische Universiteit Delft*
WBSO	*Wet Bevordering Speur- en Ontwikkelingswerk*

Lucht- en Ruimtevaart Nederland