Lucht- en Ruimtevaart Nederland

ROADMAP AERONAUTICS MANUFACTURING AND MAINTENANCE 2013 – 2020

TOP SECTOR HTSM

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Roadmap Aeronautics Manufacturing and Maintenance 2013 - 2020

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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 2012 to 2027. 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. The aeronautics sector is a sector with potentially high return on investments because aircraft manufacturing programmes run over a very long period of time (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 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 e.g. wind turbine technology.

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 and innovation themes:

- Aerostructures
- Engine subsystems and components
- Maintenance Repair and Overhaul
- 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 2012 to 2027. 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) did set the European targets in its 'Flightpath 2050'. The aim is to reduce: CO2 by 75%, NOx by 90% and noise by 65%. Lighter aircraft systems, new propulsion concepts and more efficient engines are needed. Recycling and minimization of the use of chemical substances will also contribute to achieving the targets set.

- **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 (2012-2031)

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 October 2012 Airbus released its Global Market Forecast for the period 2012-2031. This report shows a global market demand for 28,200 new aircraft (large civil aircraft with 100 passengers and more, excluding freighters) over the next twenty years (2012-2031). The global turnover represented by these new civil aircraft represents a value of € 3 billion. The global military aircraft market is forecasted to grow to € 1.9 billion. The, for the Netherlands crucial, Maintenance Repair and Overhaul (MRO) market grows slower, but promising at 3.3%. 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.

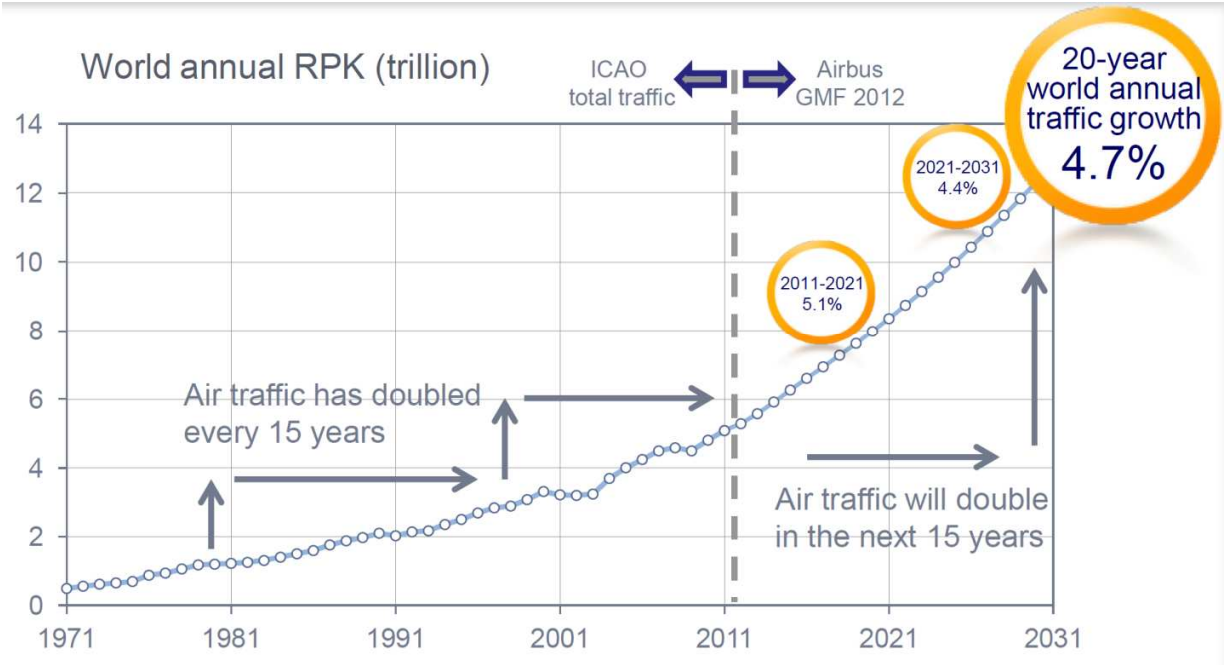

Figure: World air travel remains a growth market (Ref 3; RPK = Revenue Passenger Kilometres)

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). R&D investments are around 8% including product development. Around 90 companies, large ones 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. 2008) by: (i) Achieving global market leadership in aerospace materials, (ii) Participating in new aircraft platforms, with special attention to the BRIC countries, (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 and innovation themes described in the next chapter. The aeronautics sector is a sector with potentially high return on investments because aircraft manufacturing programmes run over 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 and 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: a 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: a strong position 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 the 2nd in the world in terms of turnover).
Aircraft systems: The sector has a strong position on aircraft wiring systems. Fokker ELMO is 2nd in the world, Aircraft Interiors systems (Zodiac Driessen) is one of the 2 global players.
Future concepts: New generation materials (self-healing, multifunctional) and new aircraft integration and certification (thanks to Fokker heritage as aircraft manufacturer and the presence of the NLR and DNW).

Scientific challenges towards 2020

The strong Dutch position in aeronautics is often a direct result of intense collaboration between the Dutch knowledge infrastructure (technical universities, research institutes (NLR)) 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 and innovation themes offer many opportunities for successful academic research 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 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 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 and Innovation themes mentioned below:

Themes	Targets (properties and products)	Technology & innovation themes	NL strenghts 2013-2020
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, composites
			HT components
		Systems	All electric aircraft
		Future concepts	New propulsion concepts
Climate/ Environment	Reduction of CO_2, NOx and noise	Engine subsystems and components	Geared turbofan, In flight acoustic absorption
		Aerostructures	Morphing wing
	Toxity	Aerostructures	Cr free (Research-sunset roadmap)
Safety	Passenger safety	Aerostructures	Structural Health Monitoring
		Systems	Sensoring and sensors
Security	Public safety	Systems	UAV
			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 as was done in the past, needs to be continued. Again, 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 28,200 new large commercial aircraft over the next twenty years (2012-2031).
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 (JSF) 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.
UAV/Unmanned Aerial Vehicles: Emerging market, still small, but offering high tech and sensor-rich applications, mainly military.

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 and 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 MoU's 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) is proposed. This includes already on-going programmes and projects which continue in 2012-2013 and for which funding is ensured, as well as new ones. Under each technology & innovation theme, short term priorities for 2013-2016 are set. These priorities are part of LOIs of individual commitments by the stakeholders involved that have been signed at the end of 2012. The five key technology and innovation themes are:

1. Aerostructures 2013-2016

Subthemes	Research topics	2013-2016
Materials	Composites / coatings / FML	New resins, thermoplastics, 3D & preforms / enhanced coatings for composites / (Green) Glare
Product development	Design methods & tools / Virtual testing / structures design	Knowledge Based Engineering (KBE) / design tools / mechanical testing process simulation / several subassemblies
System engineering	(Embedded) sensoring	Structural health monitoring
Manufacturing	Robotizing / Bonding technologies / faster & cheaper Resin Transfer Moulding, NDI, Fibre Placement Technology, Smart Factory	New layup technologies / welding & adhesive bonding / out-of autoclave processing / medium loaded parts, faster NDI, fibre steering, smart monitoring and control technology /selective laser melting

2. Engine subsystems and components 2013-2016

Subthemes	Research topics	2013-2016
Materials	High Temperature materials	New materials, TBC's
Product development	Engine subsystems/ Design methods & tools	Blisks, seals, advanced blades, variable vanes and valves / KBE / integrated design tools / design for manufacturing
System engineering	(Embedded) sensoring	Prognostic health monitoring
Manufacturing	Composites / new manufacturing technologies	Medium temperature composite parts / complex parts / (additive) manufacturing / ECM & ECD

3. MRO 2013-2016

Subthemes	Research topics	2013-2016
Product and process development	Re-engineering/PMA parts/ retrofitting/ (prognostic) health monitoring	Improved product & process development / further automation NDI inspection methods
Manufacturing	Composite repair/ corrosion	Determination design airworthiness strategy / damage tolerance / anti-corrosion / surface treatments / mobile diagnostic equipment

4. Aircraft systems 2013-2016

Subthemes	Research topics	2013-2016
Product development	All electric aircraft / wiring systems / sensors & antennas /design methods and tools	Modular systems / integrated wiring concepts / sensors for safety / KBE / system certification

5. Future concepts 2013-2016

Subthemes	Research topics	2013-2016
Materials	Self-healing/ multifunctional materials	Self-healing / multifunctional materials / next generation FML / smart materials
Product development	Future structure / design methods / smart wind tunnel testing / sensor technology / unmanned aircraft systems	New design method / actuators / smart wind tunnel model manufacturing / smart sensors / unmanned aircraft systems
New aircraft	Development new aircraft, propulsion integration, and demonstrators	Future propulsion systems, Integration & certification, validation

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, developments in aeronautics often lead to spin off and spill overs for other industries and markets.

Aerospace brings:

- New alloys, new coatings and new composites and manufacturing processes
- New sensors
- New imaging and massive data systems
- Bill of materials and traceability processes
- MRO and Product Lifecycle Management concepts

HTSM brings:

- Nanotechnology for actuators and other parts
- New sensors
- New imaging and massive data systems
- Automotive production concepts
- Multi-site and multidisciplinary collaborative engineering processes

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

The realization of the SRIA 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:

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

Knowledge institutes (TUD/NLR) are prime suppliers of knowledge to the aerospace sector. However, the other technical universities also contribute to the development of the Dutch aerospace expertise. 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, 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 rate of return under this theme is 5,4%. The main value of participating in EU-projects is to develop excellent scientific knowledge for the benefit of Dutch society, cooperation with (European) OEM's, a large network and new commercial opportunities. The EU supports R&D in the AAT theme through two main lines:

- **Joint Technology Initiative (JTI) Clean Sky**: 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.
- **EU**: As Clean Sky is rather close to the market, the programme is interesting for Dutch industry. The yearly value of the Dutch activities in Clean Sky amounts to around 8 M€. 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 (TUD / 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, FP7 and ERC.

Horizon 2020: The follow-up of FP7, Horizon 2020 will be focussed 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 JTI Clean Sky.

MoU's: The Memorandum of Understanding (MoU) is an additional tool to promote international cooperation. Today, there are two international MoU's 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 (Fr.) and the Dutch Aero Engine Cluster (DAEC). DAEC is a partnership between companies in the manufacturing industry (Aorborne 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 MoU's with newly emerging aircraft manufactures.

Summarized roles

NLR is one of the important centres for aerospace expertise in the Netherlands. NLR activities cover Air Transportation, Government Defence &d 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 top sector 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 SME's), and by questions defined by the Ministry of Defence, and the Ministry of Infrastructure and Environment. The NLR application programme on HTSM has an almost one-to-one correspondence with the five key technology and 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 TAPAS but also extensively used by Dutch industrial companies to support product development up to the highest Technology Readiness Levels. DNW wind tunnels are used by Clean Sky (incl. new propulsion concepts), by defence customers, by Fokker Services to test a derivative aircraft configuration, and by NG 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.

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. Multi scale 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 has a modest but first rate position in the aeronautics sector. 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 en 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 NL. 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).

3.1 Towards TKI programme for Aeronautics Manufacturing and Maintenance

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, will be part of the TKI programme according to the five technology and innovation themes. Under these themes, the different key technologies and their R&D&I needs, will be translated into collaborative research projects. In 2013 this TKI programme will take form as the present projects and future proposals need to evolve under the 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 are 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 M€ (for years). In 2012 the TAPAS consortium has been extended to eleven Dutch partners. This extended consortium has formulated the TAPAS-2 proposal that is needed for further development of TAPAS technology (total budget estimate TAPAS-2: 27M€).
- **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 2013. The IMPACT II proposal has been updated in January 2013; this restart is needed to achieve improved performance of advanced aero-engine compressors (total budget estimate IMPACT II: 9.5M€; 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, OEM's, 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 8M€ in the time frame 2009 – 2014.
- **FMLC- Fibre Metal Laminates Center of Competence**: FMLC is a dedicated research foundation, established by TU Delft, NLR and Fokker Aerostructures in 2001. Fibre Metal Laminates (FML's) 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 a Glass fiber reinforced aluminum sandwich. The mission of FMLC is to: i) Unite and grow the know-how on FML's to support the targets groups in the development, application and marketing of FML's, ii) become the internationally recognized center of competence for FML's, iii) to promote the application of FML's for all kinds of markets and applications.

- **Thermal cycling behavior of Fibre Metal Laminates (FML's) with integrated heater elements**: This fundamental research project carried out at TU Delft aims at acquiring an understanding of FML's with embedded heater elements. STW call HTSM 2012, total cost 0.6M€.
- **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: Total budget 5M€, local government 1/3 (*Zuiderzeelijn* funding).
- **Aerospace Composites Roundtable** *(Composieten Tafel):* The M2I institute supports all sectors on a broad range of material related issues. Since the aerospace industry has its specific requirements with regards to composite material both in its applications as through its use during the life of a programme a dedicated platform is created under the wings of the M2I platform: *Composieten Tafel*. A broad range of the aeronautics sector both public and private will meet at this table and prioritize research efforts in the field of composites.
- **IOP 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 M€, industry participation at around 0.5 – 1.0M€ (around 60 companies involved).

3.2 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 FML's 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, NG aircraft, 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 National Aerospace Laboratory (NLR) as the more applied research institute of the sector. Scientific cooperation in aeronautics is broad with the Boeing-University of Twente centre on thermoplastic composites TPRC, with MESA+ /University of Twente and all departments at the three Technical Universities in the Netherlands in general. The Technology 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.

Proposed implementation

The highest level coordination of the implementation of this roadmap will be the responsibility of *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 has been exposed in section 3.1.

One of the key characteristics of this roadmap is that all OEM's are abroad. At European level the implementation of this roadmap will be realised through collective R&D activities within European projects like the EU 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).

At the higher Technology Readiness Levels Dutch partners are cooperating in the Joint Technology Initiative (JTI) Clean Sky, 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 393M€ and consists of 128 partners (NL cluster representing 6.2% of voting rights).

5. INVESTMENTS TABLES DECEMBER 2011

Year 2012 (all amounts in M€ per year)

Financing → / ↓ Execution	Companies	State TNO/NLR	State NWO	State other	University (matching)	EC Projects	Other and Foreign
Universities TKI	0,6	-	2,5	2,6	5,3	0,8	-
Universities non-TKI	0,3	-	0,5	1,3	2,2	0,4	-
TNO/NLR TKI *)	0,4	0,6					1,0
TNO/NLR non-TKI *)	4,7	12,1				6,0	1,0
Companies TKI	3,5			1,7			1,8
Companies non-TKI	11,5			0,2			
International R&D	2,8	p.m.	p.m.	-	p.m.	7,8	-
Total Million € per year	23,8	12,7	3,0	5,8	7,5	15,0	3,8

Year 2013 (all amounts in M€ per year)

Financing → / ↓ Execution	Companies	State TNO/NLR	State NWO	State other	University (matching)	EC Projects	Other and Foreign
Universities TKI	0,7	-	3,0	2,6	5,8	1,0	-
Universities non-TKI	0,3	-	1,0	1,3	2,4	0,5	-
TNO/NLR TKI *)	0,8	1,2					1,5
TNO/NLR non-TKI *)	3,4	11,1				7,0	1,5
Companies TKI	5,0			0,3			3,5
Companies non-TKI	11,5			0,2			
International R&D	3,1	p.m.	p.m.	-	p.m.	8,0	
Total Million € per year	24,8	12,3	4,0	4,4	8,2	16,5	6,5

2014-2016 (average M€ per year over 3 years)

Financing → / ↓ Execution	Companies	State TNO/NLR	State NWO	State other	University (matching)	EC Projects	Other and Foreign
Universities TKI	0,8	-	4,0	1,0	6,5	1,3	-
Universities non-TKI	0,4	-	2,0	1,0	2,8	0,7	-
TNO/NLR TKI *)	1,4	2,1					2,0
TNO/NLR non-TKI *)	3,0	9,0				8,0	2,0
Companies TKI	7,0			0,3			5,0
Companies non-TKI	12,0			0,2			
International R&D	4,0	p.m.	p.m.	-	p.m.	9,0	
Total Million € per year	28,6	11,1	6,0	2,5	9,3	19,0	9,0

*) NLR total R&D turnover is approx. 80 M€ covering Air Transportation, Defence and Security, Industrial Company Contracts, Contracts DNW, Government Programmes + Contribution to Large Facilities; NLR entries in Table represent roadmap relevant parts of NLR R&D turnover

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7. 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
IOP	*Innovatiegericht Onderzoeksprogramma*
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	Nederlandse Organisatie voor Wetenschappelijk Onderzoek
OEM	Original Equipment Manufacturer
PMA	Parts Manufacturer Approval by FAA
PPP	Public Private Partnership
R&D	Research & Development
RTM	Resin Transfer Moulding
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*
UAV	Unmanned Aerial Vehicles
WBSO	*Wet Bevordering Speur- en Ontwikkelingswerk*