*Publishable summary*

## Project details

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| Project title | Self-healing Polymers for Concepts on Self-repaired Aeronautical Composites |
| Project Logo | Coordinator´s details |
|  | Mrs. Sonia Flórez<br>Tecnalia Research & Innovation<br>Parque Tecnológico<br>E-20009 DONOSTIA-SAN SEBASTIAN<br>Tel: +34 667115998<br>Fax: +34 943003800 |
| Project website | www.hipocrates-project.eu |

## Description of the project context and the main objectives

Lightweight, high-strength, high-stiffness fibre-reinforced polymer composite materials are leading candidates as component materials to improve the efficiency and sustainability of many forms of transport. Justifying this, advanced structural polymeric composite materials (e.g. CFRPs) are currently integrated and well in use in modern commercial aircrafts, as the examples of Airbus A380, Boeing 787 and forthcoming Airbus 350, even for primary structures. In addition, it is further expected that future aircrafts will have an increased use of composites. For these types of structures, the durability and damage tolerance design of composites is always an emerging need since polymeric matrix systems are generally susceptible to micro-damage induced by a number of events during in-service loading, which can cause macro-damage initiation and structural degradation. From this point of view it is logical to consider that new approaches are required in operations and maintenance due to the different nature of the plastics as compared to aluminium. In addition to this, meeting the targets set for 2020 and further towards the achievement of, e.g. the reduction of operational costs by 50%, is a major challenge. To make these different directions meet, the intense utilization and incorporation of smart designs and innovative concepts is required.

Engineering research and design has focused traditionally on either developing new materials with improved properties or developing non-destructive evaluation methods for material inspection, yet all engineering materials eventually fail. Degradation, damage, and failure are natural consequences in all material applications. In contrast to man-made advanced materials, biological systems approach this same phenomenon in a more elegant fashion - through self-healing. Self-healing materials offer a new route toward safer, longer-lasting products and components.

Investing effort in this direction, the HIPOCRATES project proposes the development of novel technologies that will enable future aero-structures to decrease (or even

reverse) the damage formation rate by enhancing them with the self-healing functionality. This process will deliver polymeric composite systems capable of self-repair addressing successfully the challenges described earlier.

The aim of HIPOCRATES project is to serve as a platform for developing the required knowledge, technologies, procedures and strategies to deliver self-repairing composite aero-structures, while defining the roadmap to achieve the vision of self-repairing composite structures.

In order to achieve this aim, the objectives of HIPOCRATES research and development activities are set to give answers in certain directions:

1. To provide experimental evidence to meet the State-of–the-Art shortcomings and broaden the understanding of the self-healing mechanisms
2. To develop strategies and respective procedures for enabling self-repairing of composite materials by critically analyzing the established techniques
3. To establish novel routes and technologies for utilizing the self-healing functionalities in aero-structures.
4. To develop new protocols and testing methods in order to specifically quantify the healing magnitude

Within this project, several critical issues for making the step change and achieving the aim stated above will be addressed. Among the major issues are:

- Durability and service life assessment of healing technologies
- Dynamic performance of healing mechanisms
- Manufacturing related aspects for producing self-repairing composites
- Characterization of the healing mechanisms and performance under aeronautical loading conditions (Fracture, Fatigue, Impact, Compression After Impact etc.)
- Novel chemistry for capsules, fibres and reversible polymers for epoxies
- Targeted/controllable activation of healing mechanisms
- Synergy and facilitation with Nanotechnology
- Self-healing process modelling

**Project duration**

From 01 November 2013 to 30 October 2016

**Description of the expected final results and their potential impacts and use**

Having within the consortium the leaders of self-healing in Europe, experienced chemical formulators, major composite and nano-composite developers, recognized testing and characterization partners, and key industrial partners, it is a unique opportunity to push forward for the step change in self-healing and up-scaling of the technologies for applications in the aeronautics sector.

In more detail, HIPOCRATES main technical objective is to develop self-repaired composite materials by transforming widely used resins within aeronautical industry to self-healing materials thus facilitating the consequent certification and its related cost. Taking into account the current technological maturity of self-repair, secondary structural composites shall be targeted. The transformation will be done through the epoxy enrichment with appropriate chemical agents, following current state of the art polymer self-healing technologies (*encapsulation, hollow fibers, remediable polymers*). Moreover the current progress of nanocomposites technology will be utilized towards either better facilitation of self-healing process (e.g. nano carriers) or enhancement of the self-healing performance or integration of other functionalities (e.g. monitoring the self-healing performance, activation of DA reaction). For each of the self-healing approaches, critical parameters will be experimentally studied towards optimum self-healing properties. The study will continue on the effect of the composites self-repair concept with respect to the composite materials properties that will offer durability and prolong the use of advanced aerospace structures (*reduction of operational cost*) such as mechanical properties (*impact resistance, fracture toughness, micro-cracking resistance, and fatigue*). Furthermore, feasibility and challenges that arise from incorporating such self-healing thermosetting systems into fibrous composites will be closely investigated at these early stages of development to ensure effective transfer of the properties to large scales required by the industry. A small scale technology platform will be manufactured and tested at final stages to validate and assess the concept.

Moreover the main HIPOCRATES outputs are expected to have essential societal impact. A successful implementation of self-healing composites will lead to the life extension of structural components with the subsequent reduction in scrap. This will make a significant impact by reducing waste, raw material consumption and power consumption in the service life of parts from manufacturing up to recycling or disposal.

In addition, shorting of maintenance periods and downtimes will support passenger friendly airliner operation (reduction of flight delays due to unscheduled aircraft maintenance) and the maximization of airport operating capacity for facing the increasing traffic and will contribute to a more flexible and efficient use of European air-fleet in an expected time scale of 5 years.

The self-healing technologies that will result from this proposal will also lead to an increased role of synergistic industries in the areas of nano-technology, chemicals etc and offer opportunities for the employment of highly skilled professionals. This would contribute in solving rising societal problems interconnected with the high unemployment in Europe in a critical period.

Thus, the strengthening of the competitiveness of European transport industry is expected to be benefited from the implementation of advanced self-healing technologies as described in the HIPOCRATES project will give the European aerospace industry the

opportunity to provide better solutions (operational, environmental and technological) than their competitors, to reduce the direct operating costs and thus to increase their market share. Self-healing materials are innovative products that will strengthen the position of European aerospace manufacturers, material providers and end-users (airliners) in the global market.