**LOCOMACHS Period 2: Publishable summary**

LOCOMACHS (LOW COst Manufacturing and Assembly of Composite and Hybrid Structures), is a collaborative research and development project coordinated by SAAB AB, gathering 31 partners including European key players in the aircraft industry. The project, supported by the EC and with a project budget of 33M €, has an objective to create cost efficient part manufacturing and assembly of composite, metal and hybrid airframe structures.

The benefits of using composites in aircraft design are numerous: important weight and fuel savings, a decrease in the number of individual parts through the design of more integrated and larger singular parts enabled by composite technology, as well as reduced life cycle costs (such as maintenance and inspection costs). However, the assembly of composite parts is more challenging than the relatively easy assembly of traditional machined metal parts.

Within the LOCOMACHS project, the step change will be to develop missing emerging technologies and integrate them with existing ones to create cost efficient part manufacturing and assembly of composite, metal and hybrid airframe structures.

The different RTD activities of the project will address simultaneously different areas of the product development cycle, from product design through to assembly of the structural parts.

**Project Objectives**

**More accurate parts and less structural joints**

A set of design and manufacturing rules will be defined and validated, taking into account architectural, time and cost constraints to reach more cost effective assembly, to be used in the design phase of product development.
Less shimming

The recurring costs of non-added value shimming operations in structural joints will be reduced by:

- Better knowledge of the manufacturing process (i.e. spring-in process simulation, statistical process control (SPC), tool design), which will lead to production of more accurate parts
- Innovative part assembly architecture and novel design of structural joints
- Use of materials and methods requiring less curing time for more efficient shimming

Optimized integrated geometrical tolerance and variation management

The geometrical tolerance and variation management will be optimized and fully integrated in a representative airframe assembled wingbox structure.

Optimized assembly

- Use of one-way assembly to avoid temporary assembly operations
- Development of more cost efficient measurement and verification methodology
- The use of flexible assembly tooling to handle geometrical variations in airframe parts

Increased level of automation

- Development of fully integrated automated assembly processes
- Development of safe solutions for human-robot co-working operations

Innovative NDI/NDT technologies

- More integration of the NDI/NDT operations on the in situ components
- More flexible, compact and faster processing of inspection
- More automation in the handling of NDI/NDT sensors

Demonstrators

LOCOMACHS will assess all developments through advanced physical and virtual demonstrators. Physical demonstrations will be performed on:

- The Lean Assembly Wingbox (LAWiB), an assembled structure with low level of part integration. It consists of a section of a front and rear spar, four ribs, upper and lower cover and connecting parts. It will be a mix of metal and composite parts
- The More Integrated Wingbox (MIWiB), based on the same part design as LAWiB but with a much higher level of integration. It consists of a section of a wingbox with integrated front and rear spar, two ribs, lower cover and an assembled upper cover
Virtual demonstrations, based on extrapolation of the technology feasibility test results to representative complex larger aircraft assembly units, will be performed on:

- The **Reference Wingbox** (REWiB), a complete wingbox airframe structure where the focus is on demonstrating a virtual lean production flow including both manufacturing and assembly processes in a lead time and physical handling perspective
- The **Reference Fuselage** (ReFus), to focus on design of individual design features included in typical interfaces in a fuselage structure

**Results**

After 2 years of design work to improve the original designs, the new and detailed definition of the design architecture for the physical demonstrators LAWiB and MIWiB has been frozen. The detailed designs of the LOCOMACHS virtual demonstrators REWiB and REFUS are also well matured and near completion. The Build Philosophy for LAWiB and MIWiB has also been defined.

Partners in all domains, from industry and academia alike, have proposed more than 80 technical solutions in total and >50% will be integrated on these demonstrators, such as:

**Flexible Tolerancing of composite structure**

The objective is to develop new Computer Aided Tolerancing (CAT) capability to enable flexible tolerancing for composite structure with material detailed properties (thickness, fibre orientation and layer). This is achieved through Finite Element Modelling (FEM) Model preparation adapted to composite assembly and tolerance analysis with accurate precision and high computation performance and solvers integration between variation propagation and mechanical solver.

The partners have worked with the specification and implementation of Anatoleflex, which will extend the capabilities of the CATIA V5 tolerance software Anatole in the flexible assembly domain by using Samcef solver capabilities.

**Drilling end-effector**

A compact end effector\(^1\) solution is being developed, for integration into a robotic work-cell. This will allow automated one-shot drilling of hybrid stacks. A detailed solution has been defined by the LOCOMACHS partners, it is integrating and automating the clamp drill with the crow foot drill. Preliminary trials with stereo vision and 3D matching have been performed. Drilling conditions using hybrid stacks have also been tested to determine the optimum working conditions for the end-effector.

\(^1\)In robotics, an end effector is the device at the end of a robotic arm, designed to interact with the environment.
**Integrated Co-cured Upper Cover**

For the LAWIB demonstrator, a wing box cover with integrated stringers and rib feet has been developed. The integration of rib feet by co-bonding will reduce the need to shim on assembly by rotating the interface 90°, utilising a common interface plane attachment to the ribs vs. traditional complex rib feet to the cover. This integrated component approach reduces the need to drill, strip and deburr which in turn, simplifies the assembly methodology.

**Laser Ultrasonics**

Quality operations are essentials in the CFRP manufacturing process. Non-Destructive Testing (NDT) using Laser Ultrasonics is one of the most advanced NDT techniques. It uses lasers to generate and detect ultrasounds and can be integrated in an automation process. The LOCOMACHS project is focused on the full mastering of this technology including better understanding of the phenomena through physic modelling, adaptation of the technology to industrial lean manufacturing and improvement of the capabilities to get a more robust diagnosis. Dedicated software modules for modelling, 3D shape recognition and 3D data representation, trajectory simulations in a robotic system and signal processing have been developed.

**Physical robot-human collaboration tasks**

The aim is to develop a layout design of a production cell adapted for man-robot-collaboration in an identified assembly task. Two tasks have been identified. In the first task the operator is performing assembly operations on a work piece while a robot is keeping the work piece in position. In the other task the operator and the robot is performing separate operations in a sequence on the same work piece. The challenge is to assure safe operations that fulfil future applicable machine directives and, as a back-up solution for the project demonstration, also safe operations that fulfil existing machine directives. Operative and secure solutions have been defined theoretically. A test vision system, for first trials, has been created using Microsoft Kinect and a physical mock-up for these trials has been constructed at LIU.
**Expected impact**

The specific expected impact of the LOCOMACHS project will be:

- 50% reduction of the recurring costs of non-added value shimming operations
- 30% reduction of the recurring costs of non-added value dismantling operations
- 30% reduction of the recurring costs related to part assembly by increasing the level of automation
- 30% reduction of the NDI/NDT lead time

LOCOMACHS directly addresses one of the challenges of the ACARE SRA2 High Level Target Concept (HLTC) “Highly Cost Efficient Air Transport System” and will be an important enabler to enhancing the supply chain competitiveness and reduce time to market of future products.

The European supply chain deliver airframe structures to aircraft manufacturers worldwide. LOCOMACHS’ approach is to reduce the non-added value operations, which are time and labour intensive, by developing new processes and technologies. This will allow the European supply chain to improve its competitiveness on the world market. LOCOMACHS’ integrated approach will enhance collaborations and technology development at a research level and, for exploitation, at an industrial level.

LOCOMACHS results will be deployed on the next generation of short range aircraft family, and will also be used to upgrade and improve the manufacturing and assembly of new aircraft currently starting production to help airframers to meet their very ambitious production goals.

*For more information, please visit:* [www.locomachs.eu](http://www.locomachs.eu)