Economic impact of LOCOMACHS results

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LOCOMACHS M42 Internal Review
15-16th June 2016, MTC (Coventry, UK)
• Introduction to LOCOMACHS High Level Objectives
• Assessing cost benefits
• LOCOMACHS use-case results
• Conclusions
The Context of LOCOMACHS

Flightpath 2050 vision for tomorrow’s aviation (ACARE + EU)

HLO’s justified the need and funding of the project

LOCOMACHS HLO’s are coherent with this vision

LOCOMACHS High level objectives

Activities performed in coherence with HLO’s

Partners

Results

+ Other stakeholders

Results
Global Goals of FP7

- Involving SMEs based on cutting-edge research and education
- Cost effective transport chains
- No negative effects on the environment
- Maximising the aviation sector’s economic contribution and creating value: directly from aviation manufacturing
- Protecting the environment and enabling the use of sustainable energy
- Maintaining and extending industrial leadership: very cost effective and energy efficient products
Reminder – LOCOMACHS HLOs

Based on Flightpath 2050:
1. Maximising the aviation sector’s economic contribution and creating value
2. Maintaining and extending industrial leadership: very cost effective and energy efficient products

The LOCOMACHS High Level Objectives were defined

LOCOMACHS HLOs

- Define and validate a set of design and manufacturing rules for more complex structural parts
- Fully integrate geometrical tolerance and variation management in a representative airframe assembled wingbox structure
- Reduce by 50% the recurring costs of non-added value shimming operations in structural joints
- Reduce by 30% the recurring costs of non-added value dismantling operations
- Increase level of automation to reduce recurring cost during part joining by 30%
- Reduction of NDI / NDT lead time by 30%
Framework of Cost sensitivity analyses:

<table>
<thead>
<tr>
<th>Activity within a Unit Process</th>
<th>LOCOMACHS Innovative Technology</th>
<th>No Innovative Technology (Reference Process)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assembly</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

D42.3 Sensitivity Analysis

Reference Process

<table>
<thead>
<tr>
<th>Unit Process</th>
<th>Unit Process</th>
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</tr>
</thead>
</table>

LOCOMACHS Process

<table>
<thead>
<tr>
<th>Unit Process</th>
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</tr>
</thead>
</table>

Cost sensitivity analyses of LOCOMACHS innovations
Cost sensitivity analyses of LOCOMACHS innovations

LOCOMACHS Demonstrators:

- Case Studies of MIWiB
- Case Studies of LAWiB
- Case Studies of ReWiB

ReWiB
• **MIWiB Case study**
  – Co-bonded Upper Cover
## MIWiB Case study

**Co-bonded Upper Cover**

<table>
<thead>
<tr>
<th>Technology strand</th>
<th>Cost saving</th>
<th>Targeted components and processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-cured/Co-bonded part (Integration vs. Separate details)</td>
<td>-10%</td>
<td>Integrated CFC structures (lower assembly costs)</td>
</tr>
<tr>
<td>Possible dry fiber placement vs. handlay</td>
<td>-15%</td>
<td>Automated CFRP deposition (to reduce material deposition time)</td>
</tr>
<tr>
<td>Automated drill and fastening vs. Manual assembly</td>
<td>-5%</td>
<td>Automated drill, fasten, seal (lower sub-assembly costs)</td>
</tr>
</tbody>
</table>
LAWiB Cost sensitivity analyses

- Case studies of LAWiB
  - Rear Spar
  - Upper cover production
  - Rapid curing of liquid shimming
  - Laser surface treatment
  - RTM composite spar and wing box
  - Ultra-Sonic laminate thickness control
  - Countersink scan
  - Hexapod-assisted positioning
  - Improved drilling
  - Improved NDT/NDE: AUT
LAWiB Case studies

Rear Spar

Cost sensitivity analyses for different production scenarios

- Normalised Total Costs (based on baseline grand total)
- Normalised Assy Costs (based on baseline grand total)
- Normalised Manufacturing Costs (based on baseline grand total)
# Upper cover production

## Cost sensitivity analyses for wing skins/structures

<table>
<thead>
<tr>
<th>Technology Strand</th>
<th>Cost saving at TRL3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-cured/ Co bonded part integration</td>
<td>-5%</td>
</tr>
<tr>
<td>Automated deposition of composite material (prepreg)</td>
<td>-15%</td>
</tr>
<tr>
<td>Automated drilling and fastening</td>
<td>-4%</td>
</tr>
</tbody>
</table>
Rapid curing of liquid shimming

Conventional Process:
- Time: 10 h
- Cost: 10 h

LOCOMACHS Process:
- Time: 1.5 h
- Cost: -58%

Boing 787 Cargo Door – 290 parts until 2024
Laser surface treatment

Cost

-25%

Conventional Process
LAWiB Case studies

RTM composite spar and wing box

<table>
<thead>
<tr>
<th>Conventional Process</th>
<th>Composite solutions (after re-engineering)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Machined aluminum spar</td>
<td>- Dry-fibre placement spar + RTM injection</td>
</tr>
<tr>
<td>- Direct Assembly</td>
<td>- Direct assembly (liquid shimming)</td>
</tr>
<tr>
<td>30%</td>
<td>16%</td>
</tr>
<tr>
<td>25%</td>
<td>41%</td>
</tr>
<tr>
<td>15%</td>
<td>33%</td>
</tr>
<tr>
<td>30%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Overall cost evolution

<table>
<thead>
<tr>
<th>Overall cost evolution</th>
<th>Reference</th>
<th>+46%</th>
<th>+52%</th>
<th>-8%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary part manufacturing</td>
<td>- Machined aluminum spar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spar full assembly (inboard/outboard)</td>
<td>34%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepreg spar</td>
<td>26%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assembly (liquid/solid shims)</td>
<td>14%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepreg spar</td>
<td>26%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machining</td>
<td>13%</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Direct assembly (liquid shimming)</td>
<td>20%</td>
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<tr>
<td>Dry-fibre placement spar + RTM injection</td>
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<td>Direct assembly (liquid shimming)</td>
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<td>Spar integration in the wing box</td>
<td>41%</td>
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</tbody>
</table>
Ultra-Sonic laminate thickness control

Infusion

Conventional Process

Cost

-10%

Curing

Conventional Process

Cost

-7%
Stiffened Panel Structure

Main landing gear door (1 skin + 3 stiffeners)

Reference process

- Skin
  - Hand lay-up
  - Curing in OML tool
  - Secondary bonding in OML tool

Locomach process

- Skin
  - Hand lay-up
  - AFP on OML tool
  - Cocuring in IML tool

Cost

-9%
### Conventional Process

<table>
<thead>
<tr>
<th>Process</th>
<th>Time</th>
</tr>
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<tbody>
<tr>
<td>Mount part(s)</td>
<td>5 min/part</td>
</tr>
<tr>
<td>Shim</td>
<td></td>
</tr>
<tr>
<td>Measure shim</td>
<td>5 min/m²</td>
</tr>
<tr>
<td>Manufacture shim</td>
<td>20 min/m²</td>
</tr>
<tr>
<td>Unmount part(s)</td>
<td>5 min/part</td>
</tr>
<tr>
<td>Mount shim</td>
<td>5 min</td>
</tr>
<tr>
<td>Mount part(s)</td>
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<tr>
<td>Tack</td>
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<tr>
<td>Unmount part(s)</td>
<td>5 min/part</td>
</tr>
<tr>
<td>Drill</td>
<td>1.5 holes/min</td>
</tr>
<tr>
<td>Deburr</td>
<td>6 sec/hole</td>
</tr>
<tr>
<td>Clean</td>
<td>15 min/m²</td>
</tr>
<tr>
<td>Mount part(s)</td>
<td>5 min/part</td>
</tr>
<tr>
<td>Fasten</td>
<td>1 min</td>
</tr>
<tr>
<td>NDT</td>
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</table>

### Process Time

- Mount part(s): 5 min/part
- Shim: 5 min/m², 20 min/m², 5 min/part, 5 min
- Tack: 33%
- Unmount part(s): 5 min/part
- Drill: 1.5 holes/min
- Deburr: 6 sec/hole
- Clean: 15 min/m²
- Mount part(s): 5 min/part
- Fasten: 1 min
- NDT: 31%

### Cost

- n=50: 43600€/structure, 240€/kg
- n=600: 14400€/structure, 80€/kg

### Materials

- Mould: 31%
- Part bagging: 9%
- Fastening: 9%
- Demoulding & cleaning: 9%
- Milling: 5%
- Shimming: 5%
- Fastening: 4%
- Positioning: 4%
- Deburring: 3%
- Autoclave: 3%
- Drilling: 2%
- Assembly jig: 2%
- NDT: 11%
- Demoulding & cleaning: 10%
- Drilling: 7%
- Positioning: 7%
- Deburring: 7%
- Autoclave: 6%
- Assembly jig: 6%
- Fastening: 3%
Hexapod-assisted positioning

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<tr>
<td>Fasten</td>
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</tr>
<tr>
<td>NDT</td>
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Process Timetable:
- 5 min/part for Mount part(s)
- 33% for Tack
- 5 min/part for Unmount part(s)
- 1.5 holes/min for Drill
- 6 sec/hole for Deburr
- 15 min/m² for Clean
- 5 min/part for Mount part(s)
- 1 min for Fasten
- NDT

Costs:
- n=50: 28900€/structure, 160€/kg
- n=600: 11100€/structure, 60€/kg

- Mould: 28%
- Part bagging: 13%
- Fastening: 8%
- Autoclave: 4%
- Hexapod: 4%
- Positioning: 33%
- Deburring: 13%
- Drilling: 16%
- NDT: 5%
- Assembly jig: 11%
Improved drilling

<table>
<thead>
<tr>
<th>Activity</th>
<th>n=50</th>
<th></th>
<th>n=600</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40500€/structure</td>
<td>220€/kg</td>
<td>13500€/structure</td>
<td>70€/kg</td>
</tr>
</tbody>
</table>

- **Mould**: 10%
- **Part bagging**: 20%
- **Fastening**: 3%
- **Demoulding & cleaning**: 3%
- **Milling**: 34%
- **Shimming**: 6%
- **Autoclave**: 4%
- **Assembly jig**: 1%
- **Positioning**: 4%
- **Deburring**: 1%
- **Drilling**: 30%
- **NDT**: 12%

- **Mould**: 4%
- **Part bagging**: 5%
- **Fastening**: 10%
- **Demoulding & cleaning**: 1%
- **Milling**: 10%
- **Shimming**: 8%
- **Autoclave**: 13%
- **Assembly jig**: 1%
- **Positioning**: 4%
- **Deburring**: 7%
- **Drilling**: 11%
- **NDT**: 12%

- **Mould**: 4%
- **Part bagging**: 1%
- **Fastening**: 4%
- **Demoulding & cleaning**: 3%
- **Milling**: 34%
- **Shimming**: 8%
- **Autoclave**: 3%
- **Assembly jig**: 13%
- **Positioning**: 12%
- **Deburring**: 11%
- **Drilling**: 34%
- **NDT**: 12%
Improved NDT/NDE: AUT

<table>
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<th></th>
<th>n=50</th>
<th>n=600</th>
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<tr>
<td></td>
<td>39400€/structure</td>
<td>10500€/structure</td>
</tr>
<tr>
<td></td>
<td>220€/kg</td>
<td>60€/kg</td>
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</tbody>
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- Mould: 33%
- Milling: 16%
- Positioning: 11%
- Shimming: 13%
- Part bagging: 9%
- Fastening: 16%
- Deburring: 4%
- Autoclave: 11%
- Drilling: 7%
- Demoulding & cleaning: 5%
- Assembly jig: 1%
- Pulse Array NDT: 4%

LAWiB Case studies - KTH
ReWiB Case study

– Conventional build vs. ReWiB incl. LOCOMACHS technologies
ReWiB vs. conventional build

Recurring Cost

<table>
<thead>
<tr>
<th>Labour Fab. (h)</th>
<th>Labour Assy. (h)</th>
<th>Material (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-11%</td>
<td>-31%</td>
<td>+11%</td>
</tr>
</tbody>
</table>
Economic impact - conclusions

- Define and validate a set of **design and manufacturing rules** for more complex structural parts. Smart shifting of functionalities between parts of the LAWiB proves to save time in assembly. Design and manufacturing rules will be addressed in various deliverables to come.

- Fully integrate geometrical tolerance and variation management in a representative airframe assembled wingbox structure. → **Linked the tool design with geometrical assurances process**

- **Reduce** by 50% the recurring costs of **non-added value shimming operations** in structural joints. → no shimming on interface rib to UC, no shimming between LC and ribs due to new build philosophy, shimming should be further reduced.

- **Reduce** by 30% the recurring costs of **non-added value dismantling operations** → not fully verified...

- **Increase the level of automation** related to part joining operations. → **Yes**

- **Reduce the NDI/NDT lead time** by 30% → not fully verified...
“Finding new Friends in LOCOMACHS”