LOW COST MANUFACTURING AND ASSEMBLY OF COMPOSITE AND HYBRIDE STRUCTURES.

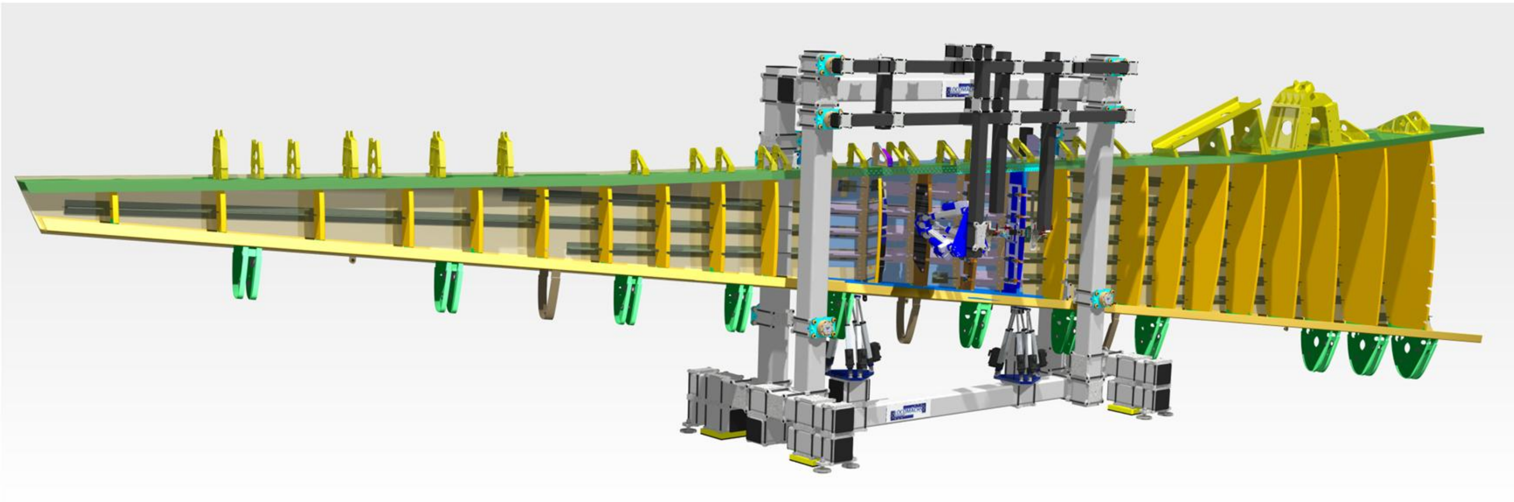
LOCOMACHS

EC-FUNDED RESEARCH PROJECT IN 7TH FP

Magnus Engström, magnus.engstrom@saabgroup.com

PRESENTATION OUTLINE

- Global presentation of the LOCOMACHS Project
- Demonstrations and demonstrators
- Example of technology developments
- High Level Achievements



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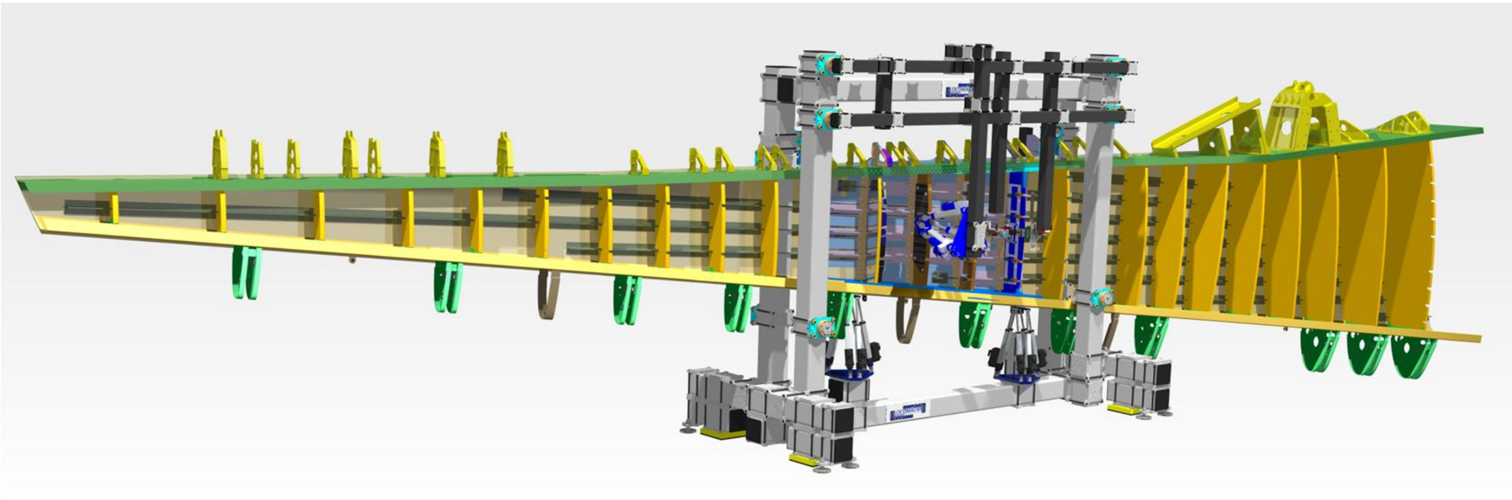

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PROJECT IDENTITY CARD

LOw COst Manufacturing and Assembly of Composite and Hybrid Structures – LOCOMACHS

• Start:	1 September 2012
• Duration:	48 Months (4 years)
• Number of Partners:	31
• Overall budget:	32 757 k€
• Overall financing by EC:	19 600 k€

31 PARTNERS IN 10 COUNTRIES

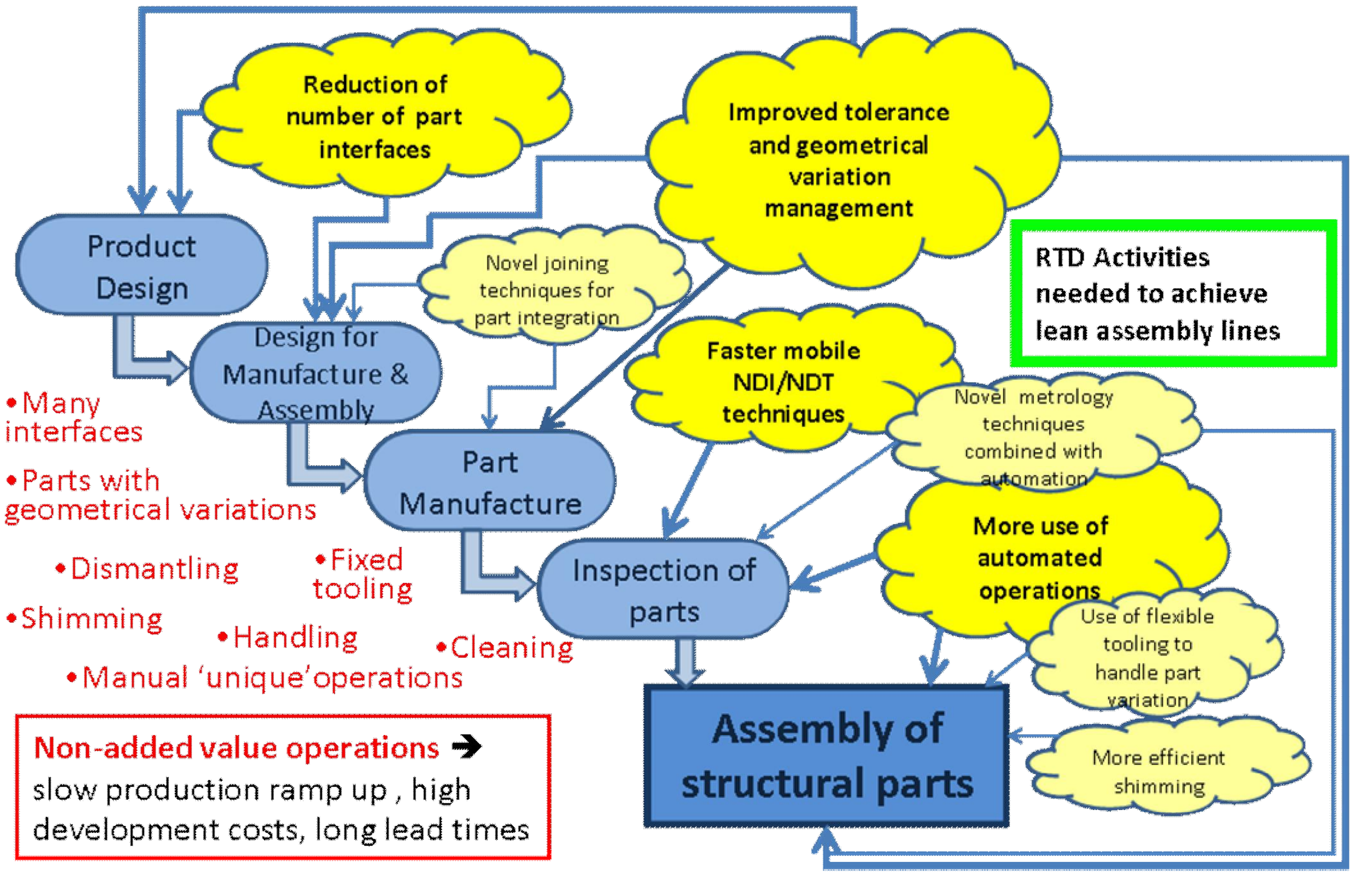
Co-funded by the European Union

HIGH LEVEL OBJECTIVES - HLO

LOCOMACHS will provide the necessary step changes for cost efficient high rate production paving the way to production rates for composite based aircraft of 50+ aircraft /month.

- 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 the level of automation related to part joining operations
- Reduce the NDI/NDT lead time by 30%

HOW TO ACHIEVE THE HLO



72 TECHNOLOGY TARGETS

	W	Ta	Target name	Target respon	LAWiB	MIWiB	Virt	Oth
12 Design	11	11-1	Fast Spring-In numerical method (SW)		x			
	11	11-2	Spring-back compensated moulds (SW)		x			
	11	11-3	SPC-based process analysis (SW)		x			
	12	12-1	Flexible Tolerancing of composite structure (SW)	LSM Samtech, CTH	x		x	
	12	12-2	Statistical modelling from SPC data (SW)	EADS, LMS	x		x	
	13	13-1	Intergrated Co-cured Upper Cover	GKN	x			
	13	13-2	Optimised Integrated Stiffener Design	GKN	x			x
	14	14-1	Spar-Hinge-Rib Integration	BAB	x			
	14	14-2	Integration/Coupling of CFRP frame at MCA	AI-D				x
	14	14-3	Adaptable assembly jig for ribs	DLR				x
	14	14-4	Allowance of increased pull-up load	ALA				x
	14	14-5	Determinate assembly hole capability	ALA				x
	14	14-6	front spar technological design	ALA	x			
	14	14-7	Local hole reinforcement for improved joint performan	SAAB				x
11 Joining tech	21	21-1	Cocuring of complex stiffened fuselage panel with int	SONACA				x
	21	21-2	Rib feet integration	GKN	x			
	21	21-3	Integrated Manufacturing Process	IAI		x		
	21	21-4	Manufacturing of integrated structure by OOA LRI	DAV				x
	21	21-5	Stiffened carbon panels with metallic inserts	DAV				x
	21	21-6	Integration of metallic fitting in thermoplastic structur	Cobham				x
	21	21-7	Co-cure with flexible tooling	Cobham				x
	21	21-8	Improved part positioning	NLR				x
	21	21-9	3D-reinforcements	EADS IW				x
	21	21-10	Hinge 2 alternatives	GKN				x
	21	21-11	Laser surface treatment for increased bond strength	TAI				x
	21	21-12	Through Thickness Reinforcement	GKN	x			
10 Manuf.	22	22-1	Spar-Hinge-Rib Post Integration	BAB	x			
	22	22-2	Infusion for Thickness Adaption	DLR	x	x		
	22	22-3	US Laminate Thickness Control	DLR	x	x		
	22	22-4	Increased Heat-up & Cool-down Rates	NLR				x
	22	22-5	Near Netshape Manufacturing	BAB	x			
	22	22-6	Rapid Preforming	BAB	x	x		
	22	22-7	Fan Stand Assembly Philosophy	GKN AES				x
	22	22-8	Automated Dry Fibre Placement	DAV				x
	22	22-9	Hybrid Design Features - Holes	SAAB				x
	~~22~~	~~22-10~~	~~Hybrid Design Features - Edges~~	~~SAAB~~				~~x~~
	22	22-11	Prepreg Forming of Spar	ALA	x	x		
8 NDI	23	23-1	Harmonization of requirements and test parts procur	IAI				x
	23	23-2	Laser Ultrasonics (LTU) developments (Nantes)	EADS				x
	23	23-21	Laser Ultrasonics (LTU) modelling	CEA				x
	23	23-22	Laser Ultrasonics (LUT) developments	TECNATOM				x
	23	23-23	Laser Ultrasonics (LUT) developments	EADS				x
	23	23-24	Laser Ultrasoncis (LUT) developments	EADS				x
	23	23-3	Air Coupled Ultrasonics (ACUT) developments	SONAXIS				x
	23	23-41	Acoustic emission (AE) developments	CREO				x
	23	23-42	Acousto Ultrasonics (AUT) developments	CREO				x
	23	23-5	Phased array Ultrasonics (PAUT) developments	SONAXIS				x

	W	Ta	Target name	Target respon	LAWiB	MIWiB	Virt	Oth
9 Geom. Comp.	31	31-1	Metrology solutions	DAV	x	Optional		
	31	31-2	Adaptive Machining	BCT				x
	31	31-3	Predictive gaps simulation for robotic additive manufa	EADS	x			
	31	31-4	Testing and modelling of new shim materials	Swerea KIMAB				x
	31	31-5	Force curing of liquid shimming material	SAAB	x			
	31	31-6	Shimming process	DAV	~~No~~			x
	31	31-7	Removal of sacrificial material	DAV				x
	31	31-8	Sacrificial Material Removal	BCT				x
	31	31-9	KTH - Image metrology	KTH	x			
11 Auto assembly	32	32-1	Drilling process optimization & monitoring	TECNALIA	x	Optional		
	32	32-2	Drilling End-Effector	TECNALIA	x	Optional		
	32	32-3	Robotized Drilling	UNISA				
	32	32-4	Fastening End-Effector	BAB	x			
	32	32-5	One Way Assembly of Covers to Structure	MTC	x	Optional		
	32	32-6	Automation of fillet and butt joint sealing	BAB				
	32	32-7	Automated Sealing	DAV				
	32	32-8	Automated Painting	DAV				
	32	32-9	Countersink scan to manufacturng riveting	SONACA	x	Optional		
	32	32-10	End Effector for the quality control of the swaging an	BAB	x			
	32	32-11	Hole inspection techniques for delamination and gap	DAV	x	Optional		
	32	32-12	Interferometer method based inspection system for h	ALA	x	Optional		
	32	32-13	Hole inspection	KTH	x	Optional		
3 Man/ mach.	33	33-1	Physical robot-human collaboration tasks	LIU	x			
	33	33-2	Virtual robot-human collaboration tasks	ALA			x	
	33	33-3	Vision as enabler in Robot-Human collaboration	TECNALIA			x	
	33	33-4	AR in assembly and inspection (SW)	TECNALIA				
8 Ass tooling.	34	34-1	Electric driven Pick-up for best fit positioning	PRODTEX	x			
	34	34-2	Manual driven pick-up for best fit positioning	LIU	x	x		
	34	34-3	Best fit supporting system (SW)	MTC	x			
	34	34-4	Robotic positioning of parts	TECNALIA	x			
	34	34-5	Reconfigurable tooling	PRODTEX	x	x		
	34	34-6	Thermally stable and lightweight fixtures	GKN	x			
	34	34-7	Self & rapid locating tooling	GKN	x			
	34	34-8	Tooling design tools & methodology (SW)	SAAB	x			

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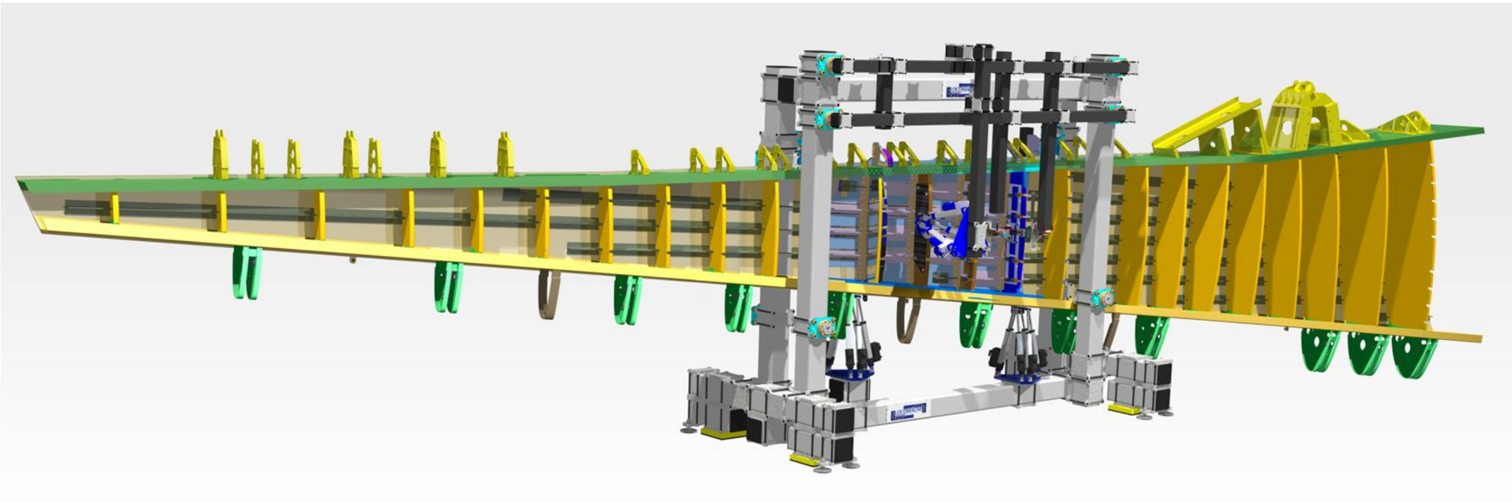

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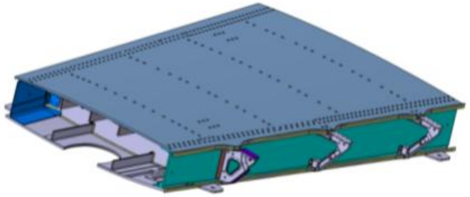
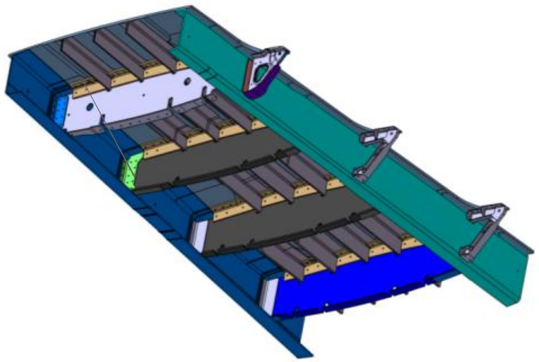
PHYSICAL WING BOX DEMONSTRATORS

LaWiB demonstrator
Lean **A**ssembly **Wi**ng **B**ox

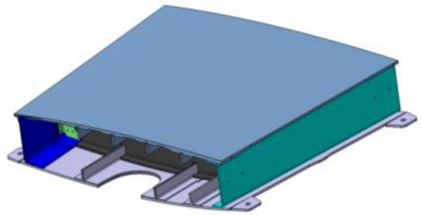


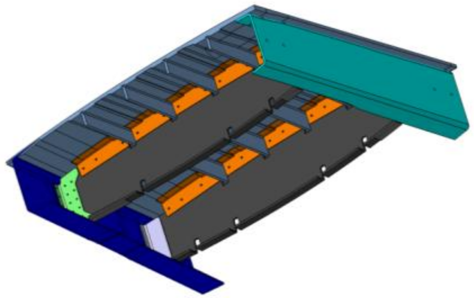


These architectures meet:

- product requirements (surface waviness, leakage risks, weight),
- production requirements (reduced shimming)
- Innovation in design architecture
- challenges in assembly technologies (requires flexible tooling, collaboration operator/robot,….)

MiWiB
More **I**ntegrated **Wi**ng **B**ox



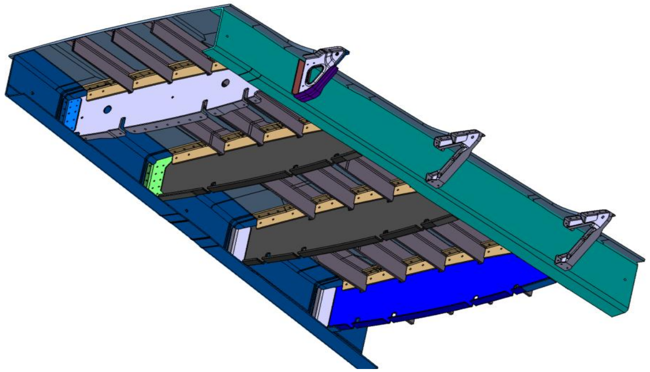


Co-cured and Co-bonded Upper Cover with rear and front spar and 2 ribs

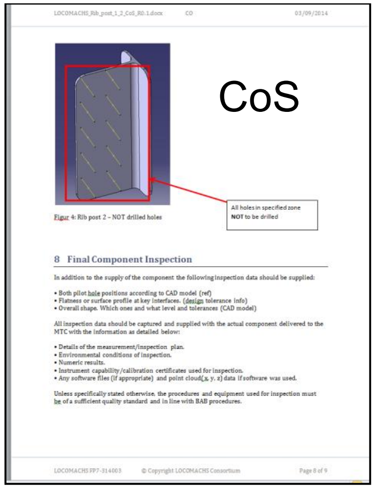
PHYSICAL WING BOX DEMONSTRATORS

TRL5/6 = traceability required

DMU



CoS



LOCOMACHS_Rib_post_1_2_CoS_R0.1.docx CO 03/09/2014

Figur 4: Rib post 2 – NOT drilled holes

8 Final Component Inspection

In addition to the supply of the component the following inspection data should be supplied:

- Both pilot hole positions according to CAD model (ref)
- Flatness or surface profile at key interfaces. (design tolerance info)
- Overall shape. Which ones and what level and tolerances (CAD model)

All inspection data should be captured and supplied with the actual component delivered to the MTC with the information as detailed below:

- Details of the measurement/inspection plan.
- Environmental conditions of inspection.
- Numeric results.
- Instrument capability/calibration certificates used for inspection.
- Any software files (if appropriate) and point cloud(x, y, z) data if software was used.

Unless specifically stated otherwise, the procedures and equipment used for inspection must be of a sufficient quality standard and in line with BAB procedures.

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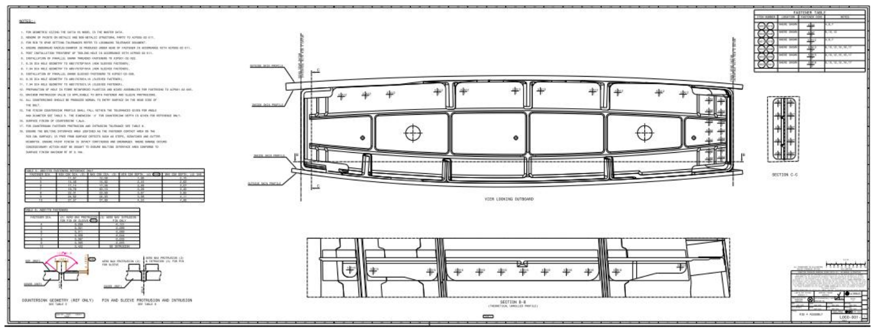
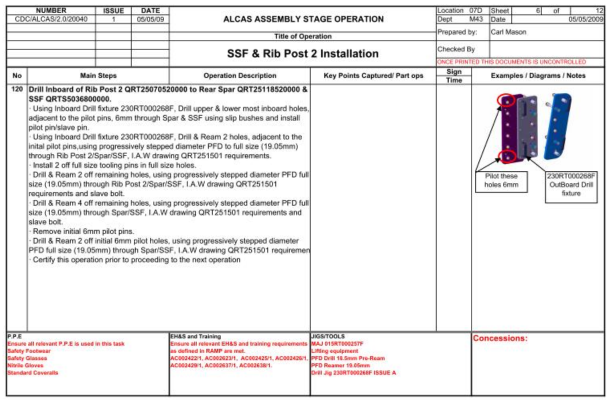
Assembly Drawings



SOI



NUMBER	ISSUE	DATE	ALCAS ASSEMBLY STAGE OPERATION	Location 07D	Sheet 6 of 12
CDC/ALCAS/2.0/20040	1	05/05/09		Dept M43	Date 05/05/2009
			Title of Operation	Prepared by:	Carl Mason
			SSF & Rib Post 2 Installation	Checked By	
				ONCE PRINTED THIS DOCUMENTS IS UNCONTROLLED	

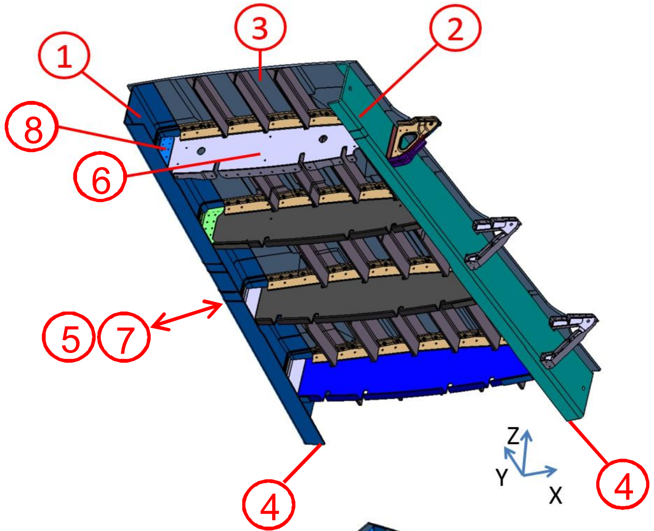
No	Main Steps / Operation Description	Key Points Captured/ Part ops	Sign / Time	Examples / Diagrams / Notes
120	**Drill Inboard of Rib Post 2 QRT25070520000 to Rear Spar QRT25118520000 & SSF QRTS5036800000.** · Using Inboard Drill fixture 230RT000268F, Drill upper & lower most inboard holes, adjacent to the pilot pins, 6mm through Spar & SSF using slip bushes and install pilot pin/slave pin. · Using Inboard Drill fixture 230RT000268F, Drill & Ream 2 holes, adjacent to the inital pilot pins,using progressively stepped diameter PFD to full size (19.05mm) through Rib Post 2/Spar/SSF, I.A.W drawing QRT251501 requirements. · Install 2 off full size tooling pins in full size holes. · Drill & Ream 2 off remaining holes, using progressively stepped diameter PFD full size (19.05mm) through Rib Post 2/Spar/SSF, I.A.W drawing QRT251501 requirements and slave bolt. · Drill & Ream 4 off remaining holes, using progressively stepped diameter PFD full size (19.05mm) through Spar/SSF, I.A.W drawing QRT251501 requirements and slave bolt. · Remove initial 6mm pilot pins. · Drill & Ream 2 off initial 6mm pilot holes, using progressively stepped diameter PFD full size (19.05mm) through Spar/SSF, I.A.W drawing QRT251501 requiremen · Certify this operation prior to proceeding to the next operation			Pilot these holes 6mm 230RT000268F OutBoard Drill fixture

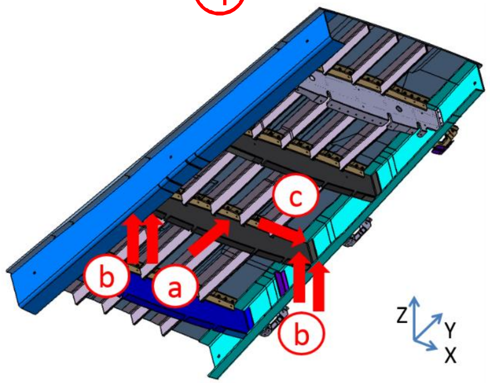
P.P.E	EH&S and Training	JIGS/TOOLS	Concessions:
Ensure all relevant P.P.E is used in this task Safety Footwear Safety Glasses Nitrile Gloves Standard Coveralls	Ensure all relevant EH&S and training requirements as defined in RAMP are met. AC002422/1, AC002623/1, AC002425/1, AC002426/1, AC002429/1, AC002637/1, AC002638/1.	MAJ 015RT000257F Lifting equipment PFD Drill 18.5mm Pre-Ream PFD Reamer 19.05mm Drill Jig 230RT000268F ISSUE A	

PHYSICAL WING BOX DEMONSTRATORS

LAWiB build philosophy:

1. Load Leading edge
2. Load Trailing edge
3. Load Upper cover, align to part contact in Z. Assemble to Rear spar
4. Measure position of spars lower flanges
5. Move out Front spar
6. Load ribs, align to part surfaces in Y(a) / Z(b) / X(c). Assemble to Rear Spar and Upper Cover
7. Move in Front spar. Assemble to Upper cover.
8. Load Rib posts, align to part surfaces/edges in Z / X / Y. Assemble to Rib and Front spar
9. Load Lower Cover (not visible), align to part contact in Z





PHYSICAL WING BOX DEMONSTRATORS

Status of LAWiB assembly June 2016, at
The Manufacturing Technology Centre – MTC, UK

WP	Target No.	Target name
31	31-3	Predictive gaps simulation
31	31-5	Forced curing of liquid shimming material
31	31-9	KTH - Image metrology
32	32-2	Drilling End-Effector
32	32-4	Fastening End-Effector
32	32-9	Countersink scan to manufacturing riveting
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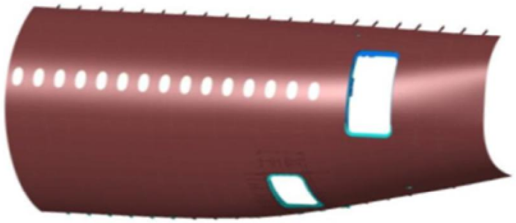
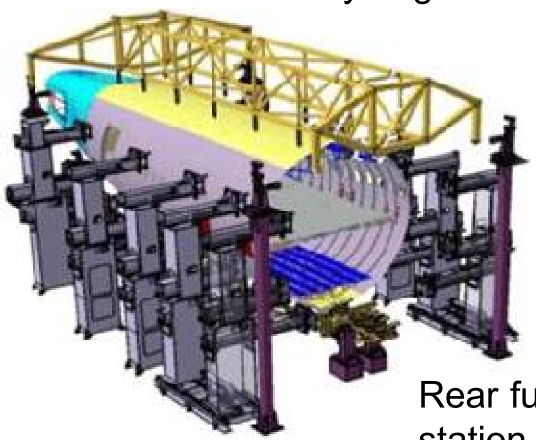
VIRTUAL DEMONSTRATORS

ReFus demonstrator
Reference **Fus**elage

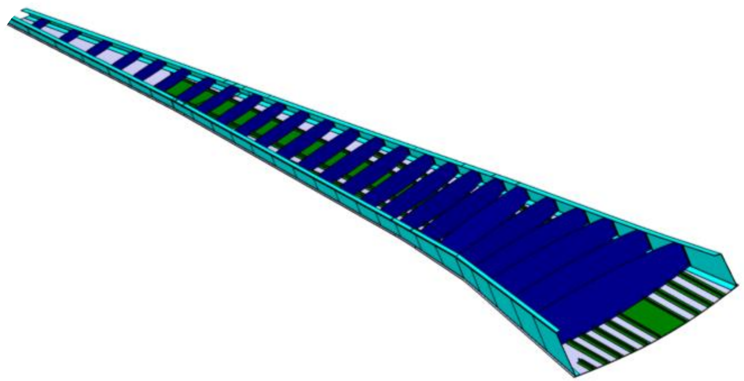


Very large composite side shell panel

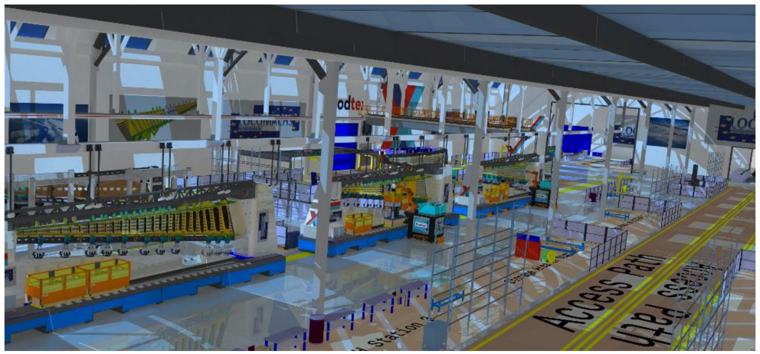


Rear fuselage assembly station with monitored sensors and actuators

ReWiB demonstrator
Reference **Wi**ng **B**ox

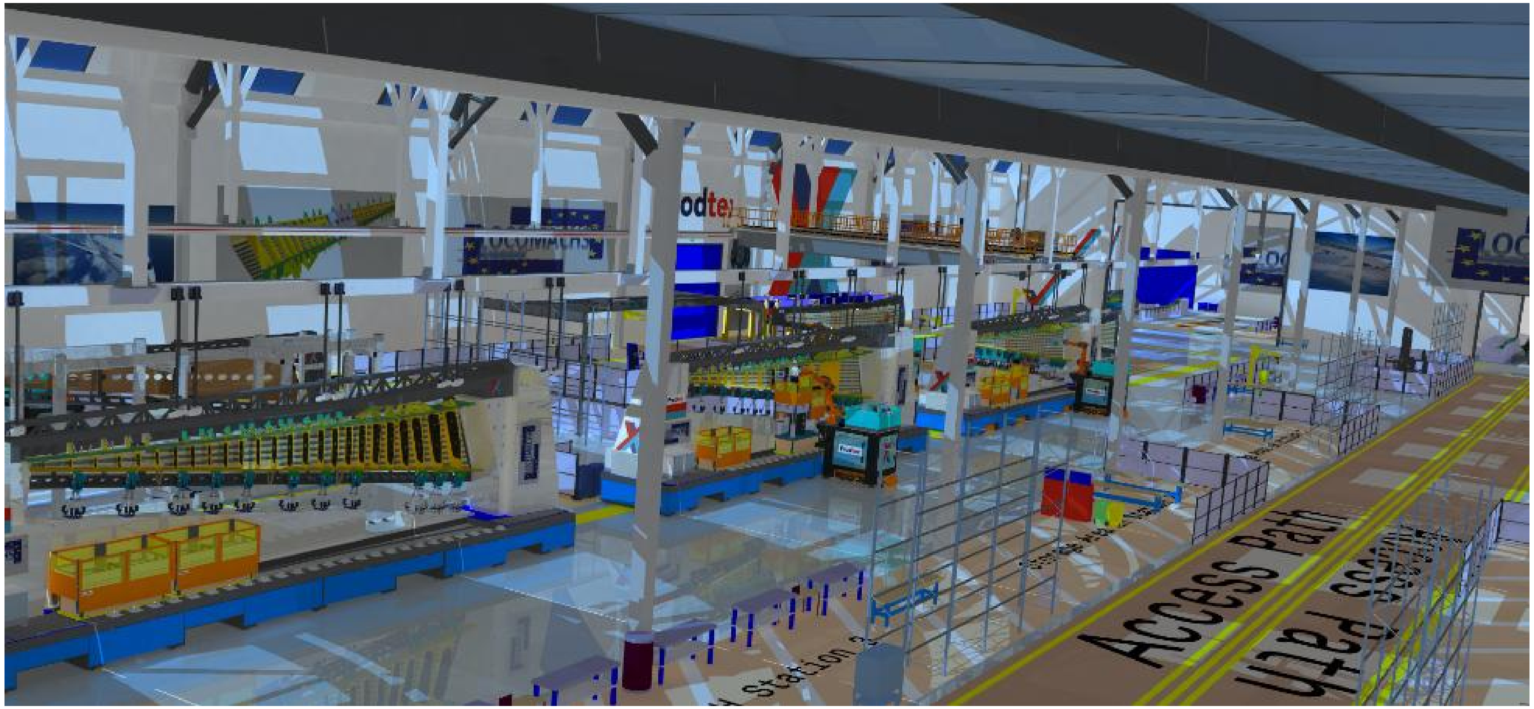


ReWiB Virtual Workshop



VIRTUAL DEMONSTRATORS

ReWiB Virtual Workshop



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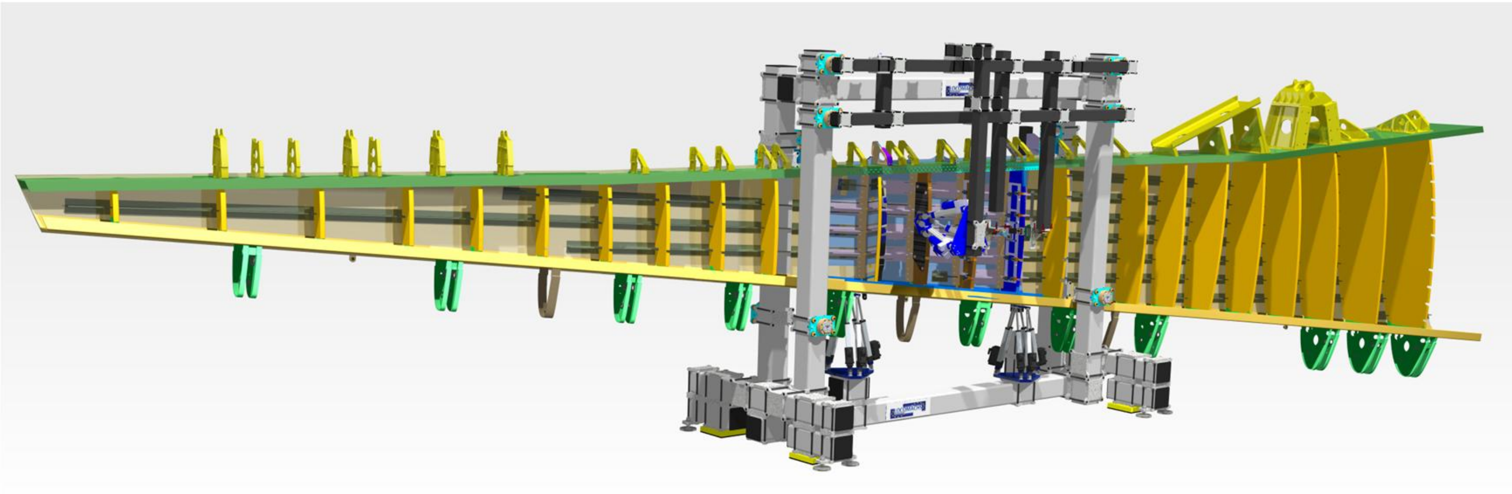
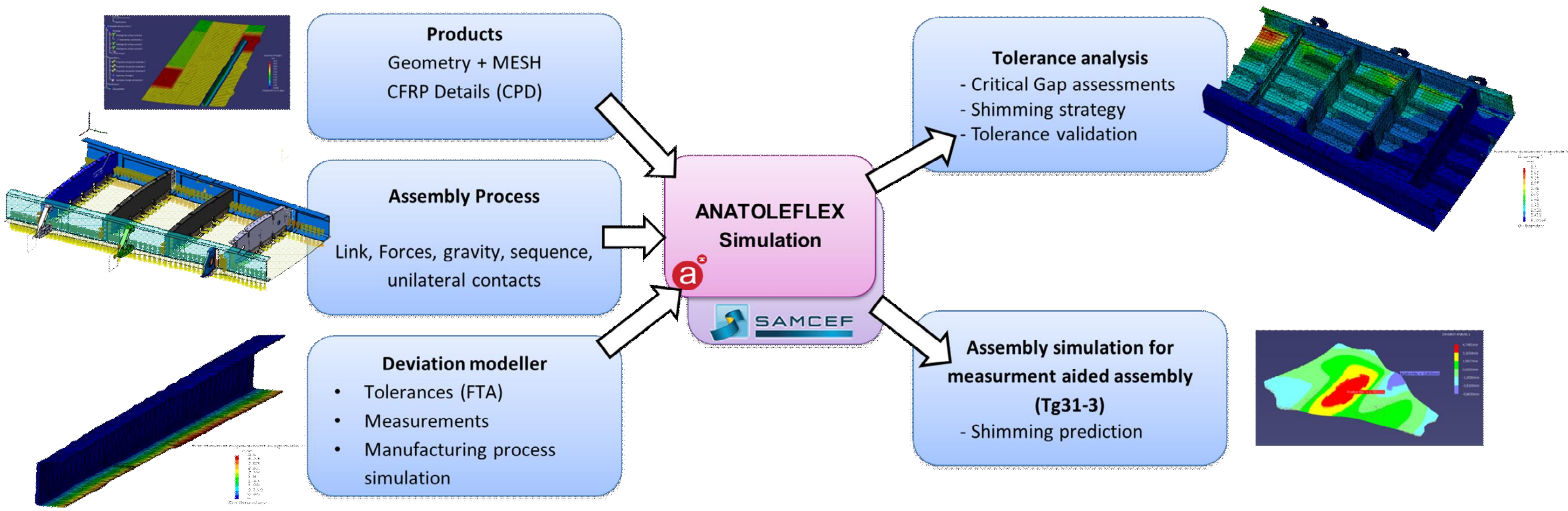


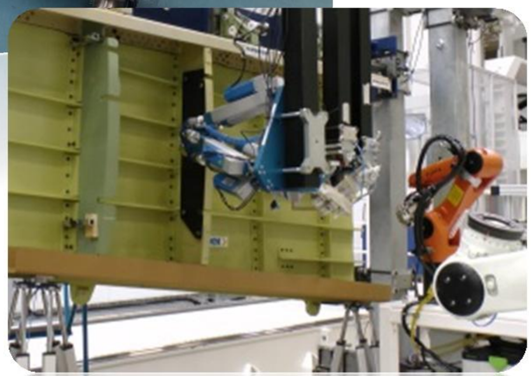
FLEXIBLE TOLERANCING OF COMPOSITE STRUCTURE



- Fruitful collaboration (Airbus Group, Airbus, Samtech, ENS de Cachan)
- New ANATOLEFLEX platform with some key features
  - Powerful integration: Catia V5 (FTA, CPD, Analysis) + ANATOLE + SAMCEF
  - Deviation modeller to define and analyse measurement data
  - CAD-CAE link for dedicated assembly modelling
- ANATOLEFLEX implemented on industrial use cases

LMS ENGINEERING INNOVATION
AIRBUS GROUP
ENS CACHAN

INTEGRATED CO-CURED WING COVER (LAWIB)



GKN AEROSPACE
DLR
IAI
TAI
NLR

1. **Integrated part design**
   - Part unitisation reducing part count and number of part interfaces.
     - Reduces Assy. lead-time
   - Use of spring-back analysis methods for composite part manufacturing.
     - Reduces need for rework, adjustment during assy.
   - Implementation of 3D tolerance analysis systems.
     - Reduces Assy. lead-time

2. **Innovative approach to part manufacture**
   - Inner Mould Line moulding of parts to control interfaces between Spars/Ribs and outer covers.
     - More accurate part interfaces leads to a reduction in Assy. Lead-times.

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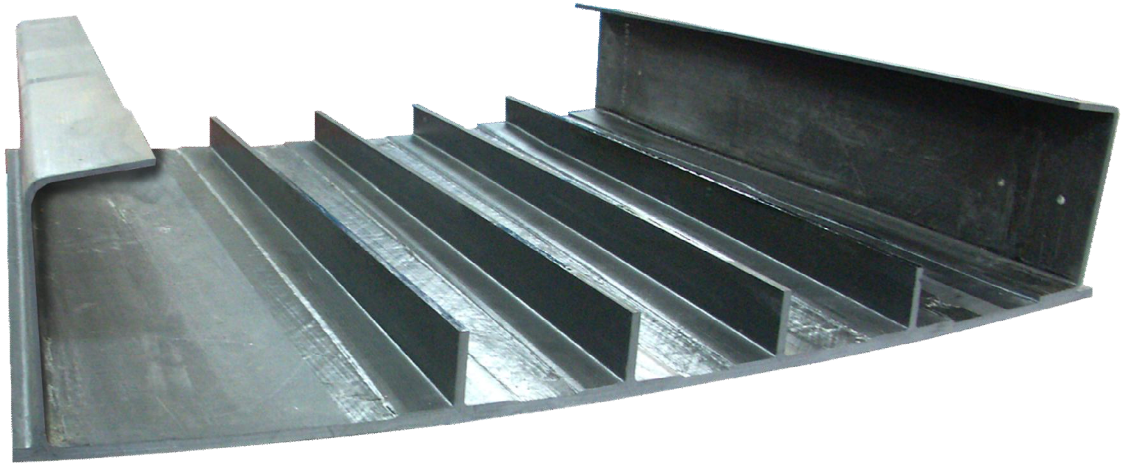
INTEGRATED CO-CURED WING COVER (MIWIB)



- Assembly effort reduced due to more integrated parts
- No shimming on upper skin-spar interface
- Possible interface control of lower skin/spar interface during infusion process
- Labour cost for assembly roughly 30% less due to less amount of fasteners and shimming
- MIWiB concept can be applied on other types of structures: Smaller business jet wings, tails for example.

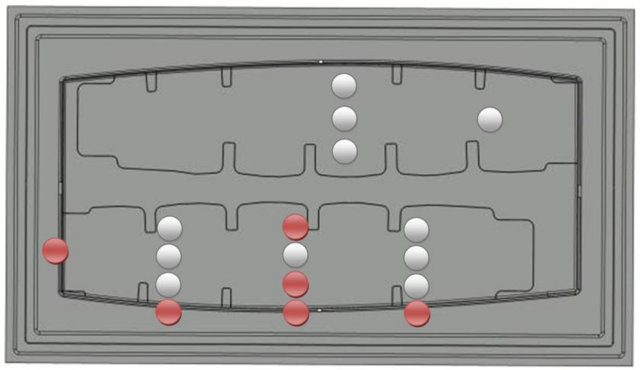
IAI NLR TAI DLR GKN AEROSPACE

INFUSION FOR THICKNESS ADAPTION & US LAMINATE THICKNESS CONTROL

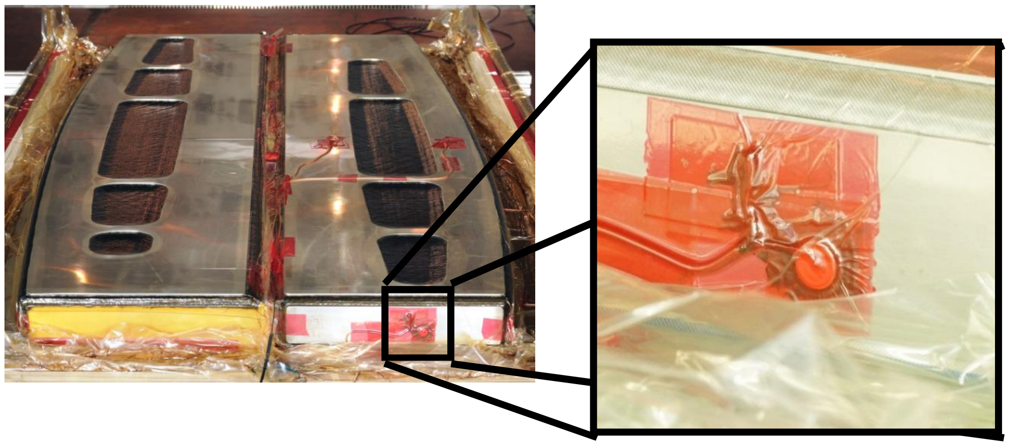
- Low cost aluminum tool
- Flange angles are Spring-In compensated
- 24 ultrasound sensors for process monitoring
- Transmission (separate transmitter and receiver) needed for thickness and cure monitoring, bag side sensors on top of caul plates
- Pulse-Echo (transmitter = receiver) sufficient for flow front monitoring
- Verification of reached thickness with GOM ATOS
- Thicknesses in tolerances, good agreement with sensor results

DLR

JEC GROUP WINNER OF 2015 INNOVATION AWARD



Pulse-Echo **Transmission**

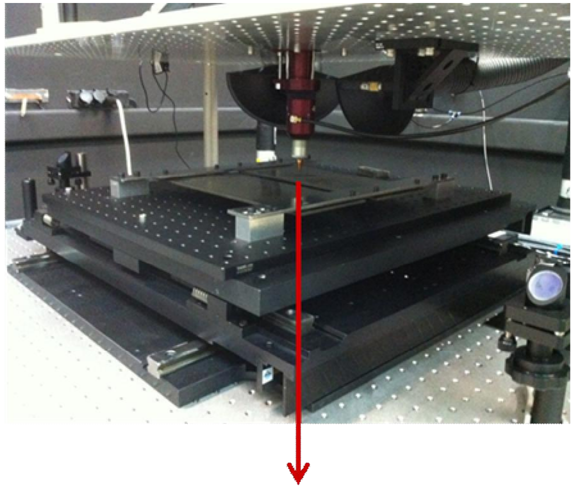


LASER SURFACE TREATMENT FOR INCREASED BOND STRENGTH

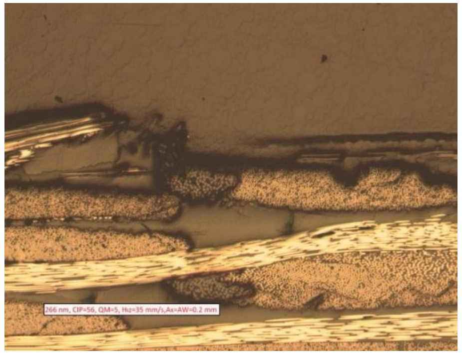
Laser treatment was carried out with lab scale, solid state, Q-switched Nd-YAG laser system. Scanning was done on Aerotech ALS3600 series x-y table

After successful integration of the system, 40 trials have been done with 266 nm and optimization of power, velocity of x-y table and distance between pulses.

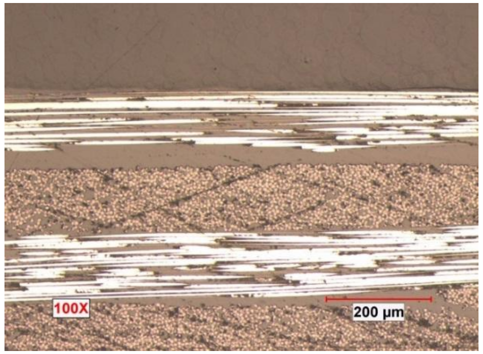
Single Lap Shear Tests were performed using Loctite (Hysol) EA 9394 showed average increase of strength with 38%

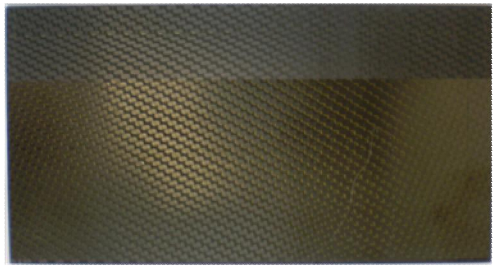


Initial tests



Final tests





TAI

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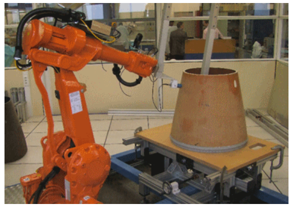
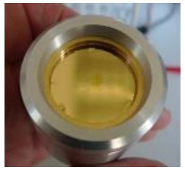
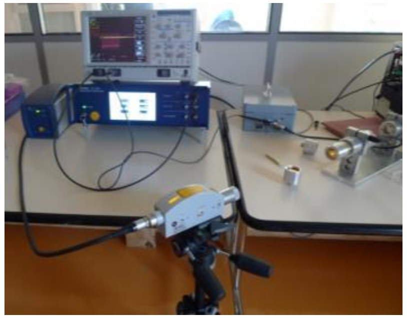
NDT; AIR COUPLED ULTRASONICS (ACUT) DEVELOPMENTS



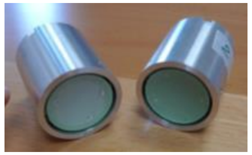
Capacitive micromachined transducer



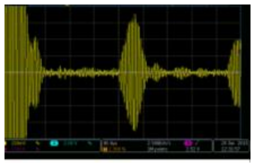


Multichannel electronic systems

Piezo-composite based focused transducers

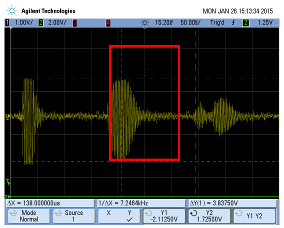


Benefits:
Improved sensitivity and detection of composite part that can not be inspected in immersion. Faster inspection. Easier automation and higher capabilities to improve aerospace composite and sandwich structures inspection

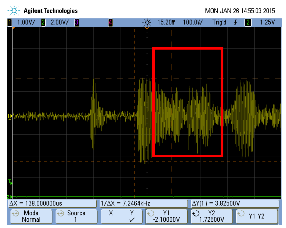


Conclusions : Two new air coupled transducers technologies have been developed with high capabilities as good or even better compared to the baselines as well as a novel multichannel electronics to drive them. Manufacturing and characterization procedures have been validated for new European products.

SONAXIS probe
3.84 Vpp

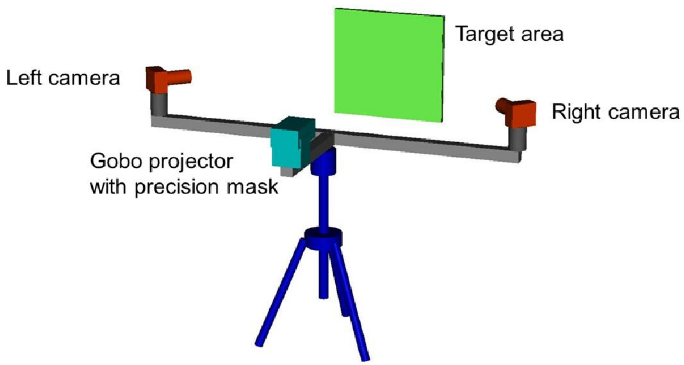


QMI probe
3.82 Vpp



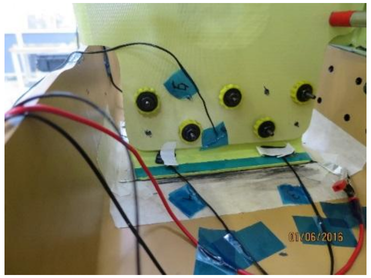
IAI · AIRBUS GROUP · DASSAULT AVIATION · tecnatom · SONAXIS

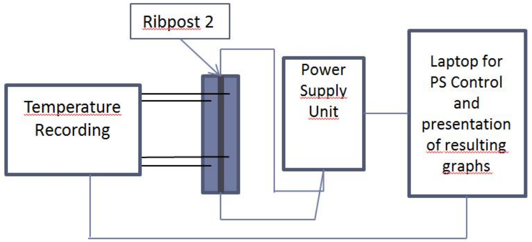
METROLOGY SYSTEM – KTH IMAGE METROLOGY SYSTEM (KIMS)

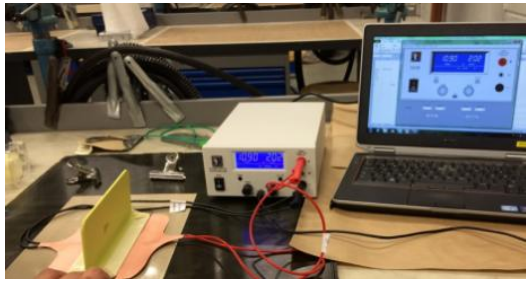


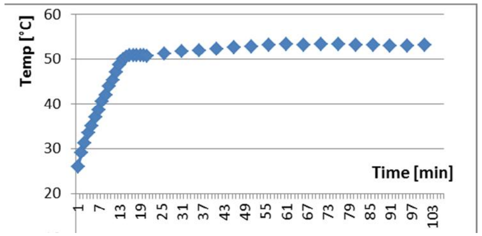
- Specs fulfilled by 10 times (10 µm rather than 100 µm)
- Measurement range can be doubled to 1000 x 1200 x 200 mm^3
- Hardware cost: 2% of a conventional Laser tracker
- Make use of the system also for other parts to be assembled
- TRL2 TRL4, Reduced dismantling cost and increased automation

FORCED CURING OF LIQUID SHIM MATERIAL

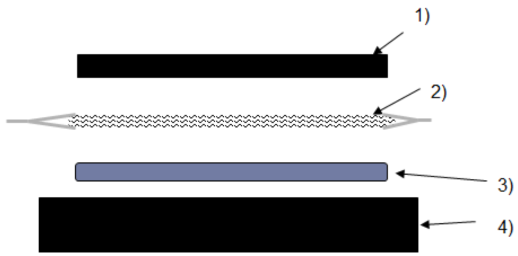








1. Ribpost
2. Combined release tape/ resistive tape with electrical connections
3. Liquid shimming material
4. Composite part/front spar



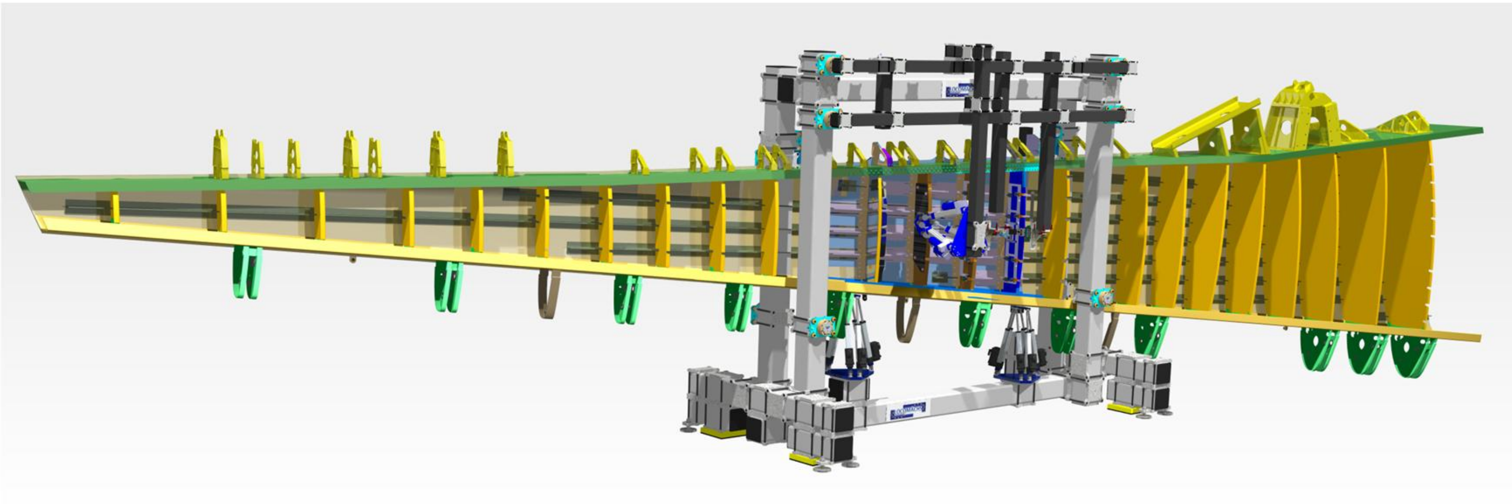
- Heating by using a resistive release tape in the shimming assembly will shorten the curing time from 9 to 1,5 hours.
- The temperature increase of the surrounding jigs and part is limited compared to heating lamps
- Resistive tape can be placed inside or outside the assembly

ELECTRICAL TOOLING FOR BEST-FIT POSITIONING OF RIB AND NOMINAL POSITIONING OF FRONT SPAR

- Selected the Hexapod as the best concept of all the electrical driven solutions. No Hexapod on the market today meet our demands.
- Bench marketing and talking with suppliers to find the right mechanical parts (low cost Hexapod can be achieved by using standard parts and open source software programming.
- Physical Hexapod robots build 2 Off Hexapod A and one Hexapod B
- Optimal design tools have been used for the design
- Open source software to be able to synchronize the Hexapod moves
- Development of force feedback integration
- Best-fit positioning of rib and nominal positioning of spar was demonstrated physically.

PRESENTATION OUTLINE

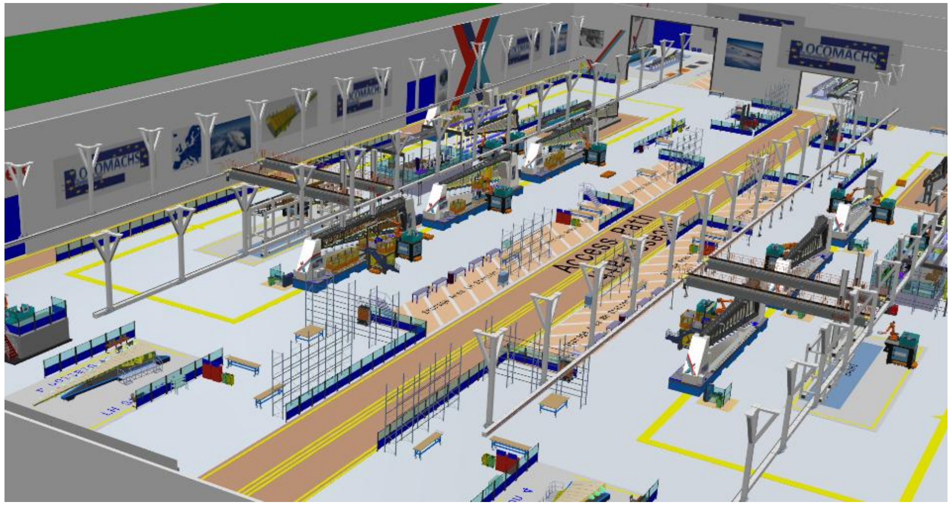
- Global presentation of the LOCOMACHS Project
- Demonstrations and demonstrators
- Example of technology developments
- High Level Achievements



HIGH LEVEL ACHIEVEMENTS
RECAP ON HLO

- Define and validate a set of **design and manufacturing rules** for more complex structural parts, ***→ 37 targets contributing***
- Fully **integrate geometrical tolerance and variation management** in a representative airframe assembled wingbox structure. ***→ 32 targets contributing***
- **Reduce** by **50%** the recurring costs of **non-added value shimming operations** in structural joints ***→ 38 targets contributing***
- **Reduce** by **30%** the recurring costs of **non-added value dismantling operations** ***→ 25 targets contributing***
- **Increase the level of automation** related to part joining operations ***→ 37 targets contributing***
- **Reduce the NDI/NDT lead time** by **30%** ***→ 13 targets contributing***

HIGH LEVEL ACHIEVEMENTS
REWIB VS. CONVENTIONAL BUILD



LEONARDO AIRCRAFT

Recurring Cost		
Labour Fab. (h)	Labour Assy. (h)	Material (€)
-11%	-31%	+11%

HIGH LEVEL ACHIEVEMENTS FINAL DEMONSTRATIONS

- NDI/NDT: Sept 29:th 2015 Technocampus, Nantes, France
- Assembly: June 16:th, 2016, MTC, Coventry, UK

HIGH LEVEL ACHIEVEMENTS
NEW GROUP OF ”FRIENDS”

QUESTIONS?

www.locomachs.eu

SAAB

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