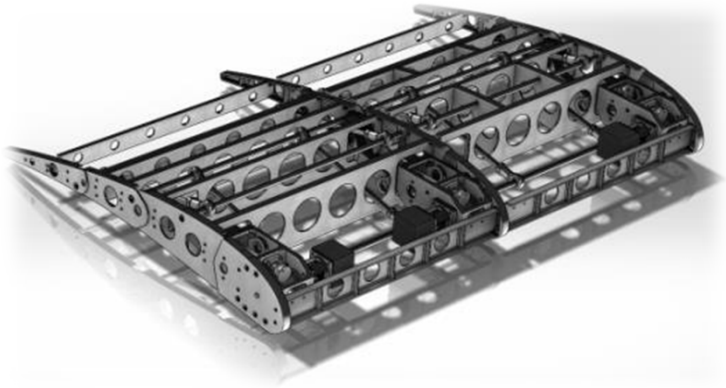
# LE TECNOLOGIE INNOVATIVE PER I VELIVOLI DI NUOVA GENERAZIONE

## Morphing Structures: 7 years of research at UniNA



R. Pecora

3° Incontro - Napoli, 25 Ottobre 2014

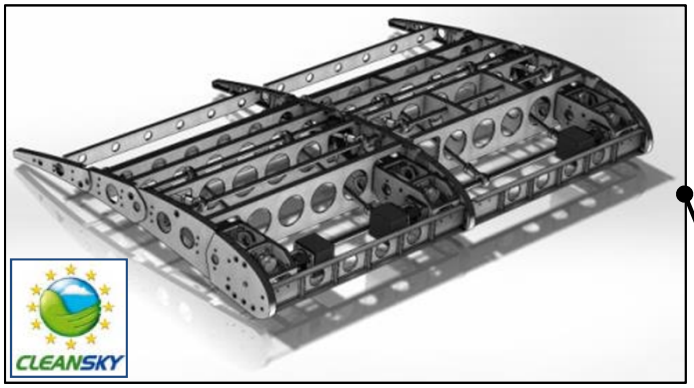
**Scuola Politecnica e delle Scienze di Base**
Piazzale V. Tecchio 80, 80125 Napoli

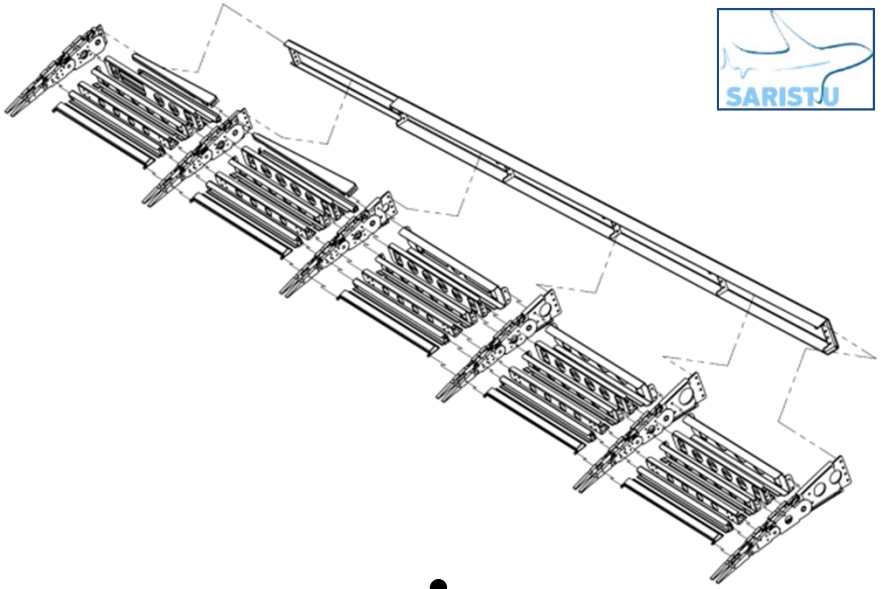
# 7 years of partnership

## IF YOU WANT TO GO FAR, GO TOGETHER

# Overview of research contracts

JTI-GRA: High TRL morphing structures enabling wing flap camber variation.



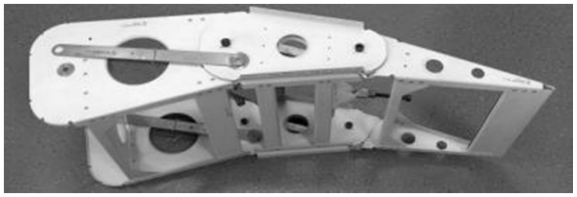



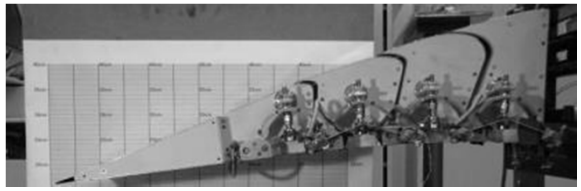

SARISTU: High TRL morphing structures enabling wing trailing edge camber morphing (CS-25 category A/C).

SEVENTH FRAMEWORK PROGRAMME

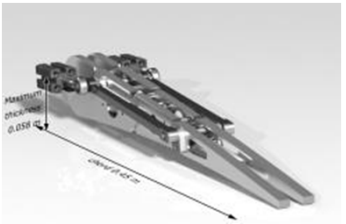
2007 — 2010 — 2011 — 2012

ALA-Smart TE: development of new technologies enabling (ATR42) wing trailing edge camber-morphing through SMA-based actuators.



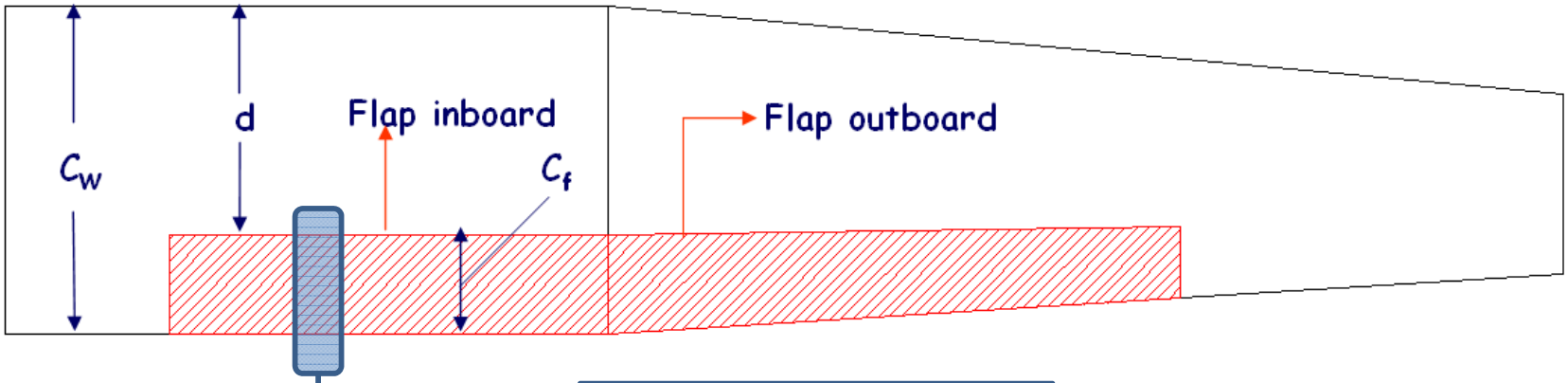


CRIAQ MDO505: development of an adaptive wing box (CS25 A/C) equipped with active skin bumps and morph-ing aileron for drag reduction.



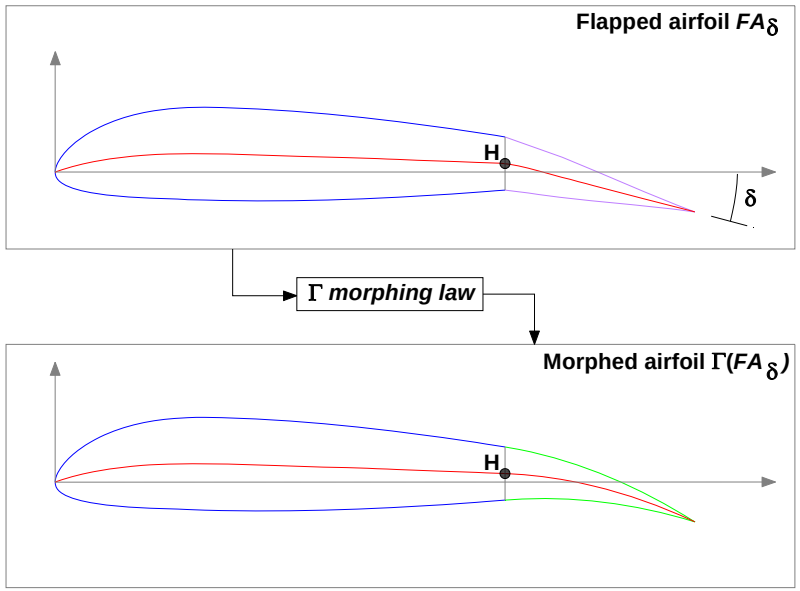
# ALA-Smart Flap (2007-2008)

**Research objective**: development of new technologies enabling (ATR42) wing trailing edge camber-morphing through SMA-based actuators.




$C_w = 2.574m$
$C_f = 0.772m$
$d = 1.802m$

Investigation domain




**Common features of the investigated architectures:**

- Rib structure as compromise between rigidity and flexibility
- SMA beams: acting as actuators and primary structural elements
- Different actuation modalities due to multiple SMA elements suitably distributed

# ALA-Smart Flap (2007-2008)

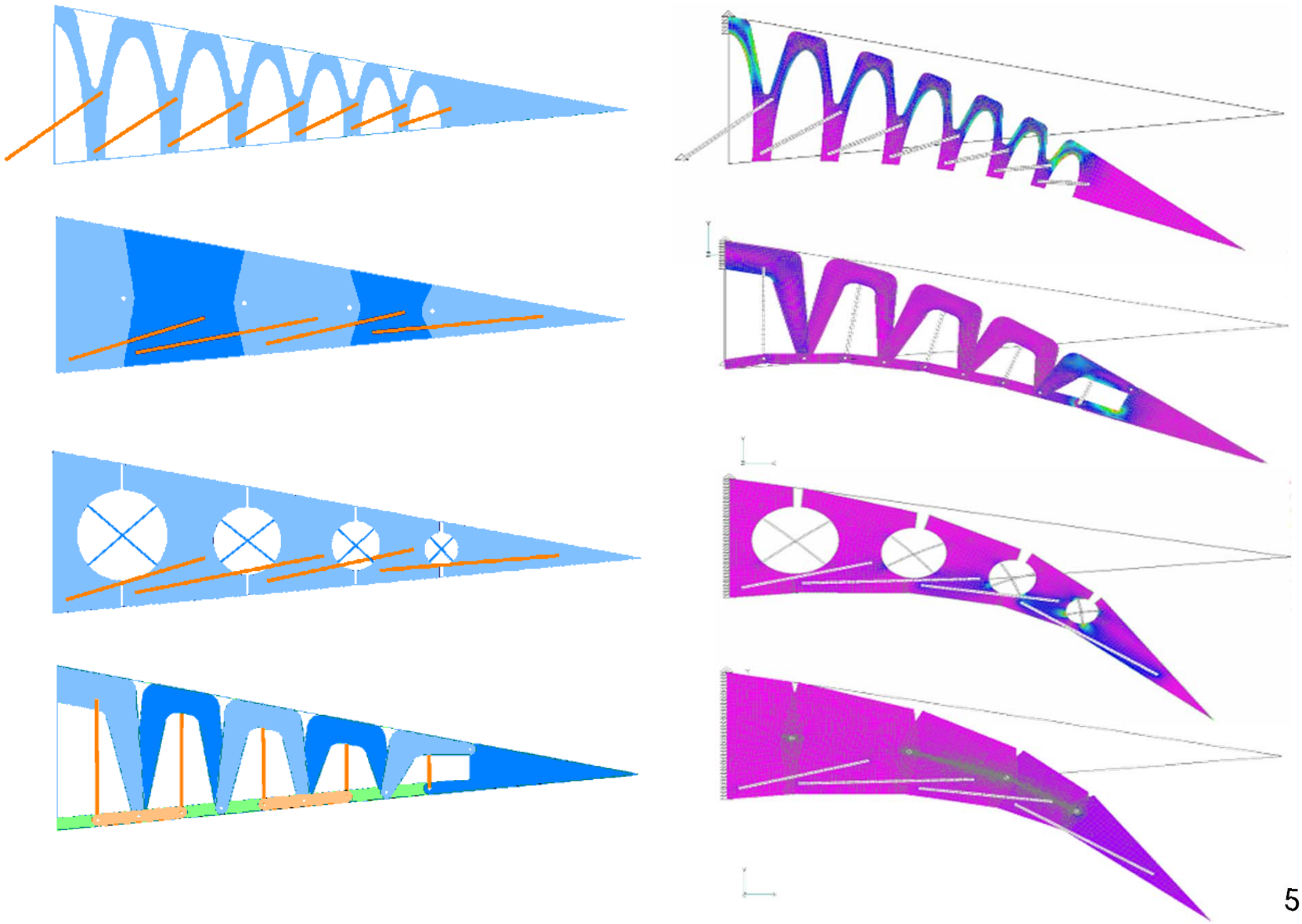
**Morphing rib architecture**: *thinking out of the boxes …*

Monolithic plate

Multi-body with conventional hinges

Multi-body with elastic hinges

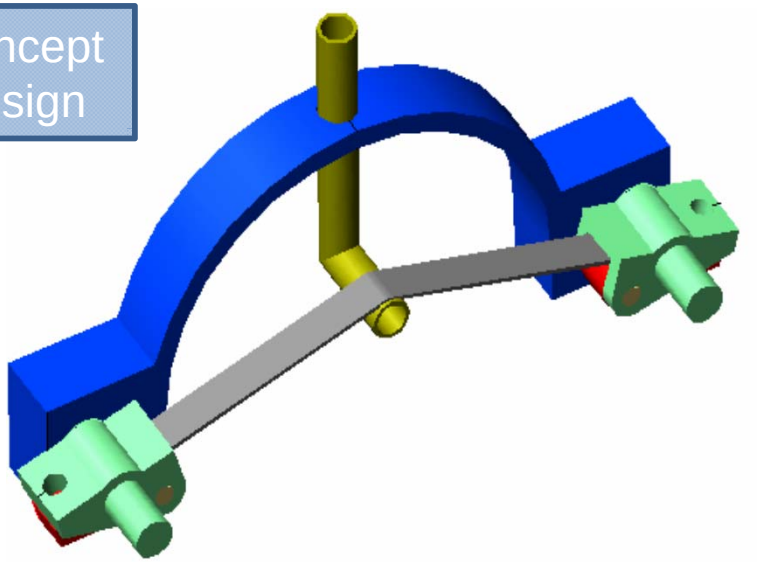
Multi-body with mechanic chains



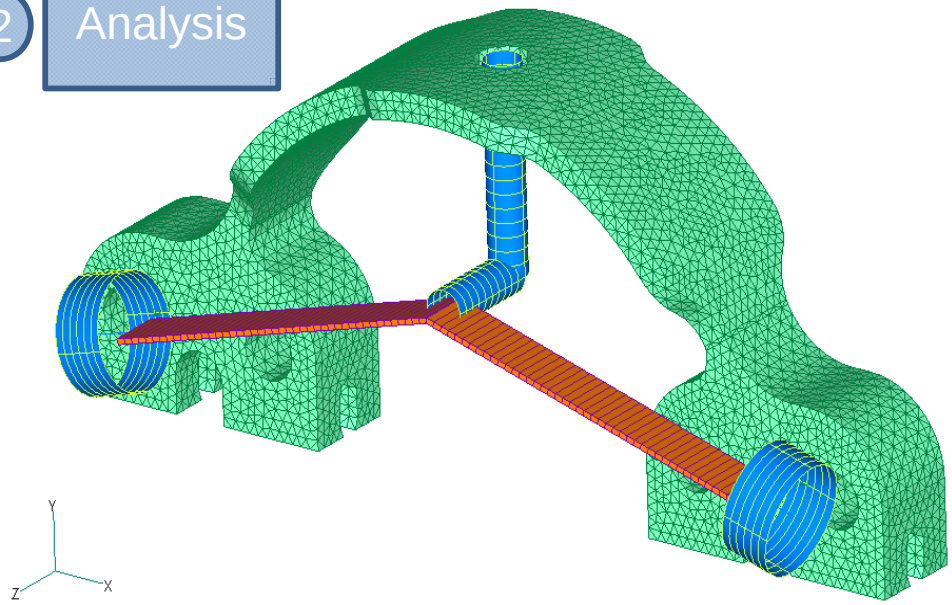
# ALA-Smart Flap (2007-2008)

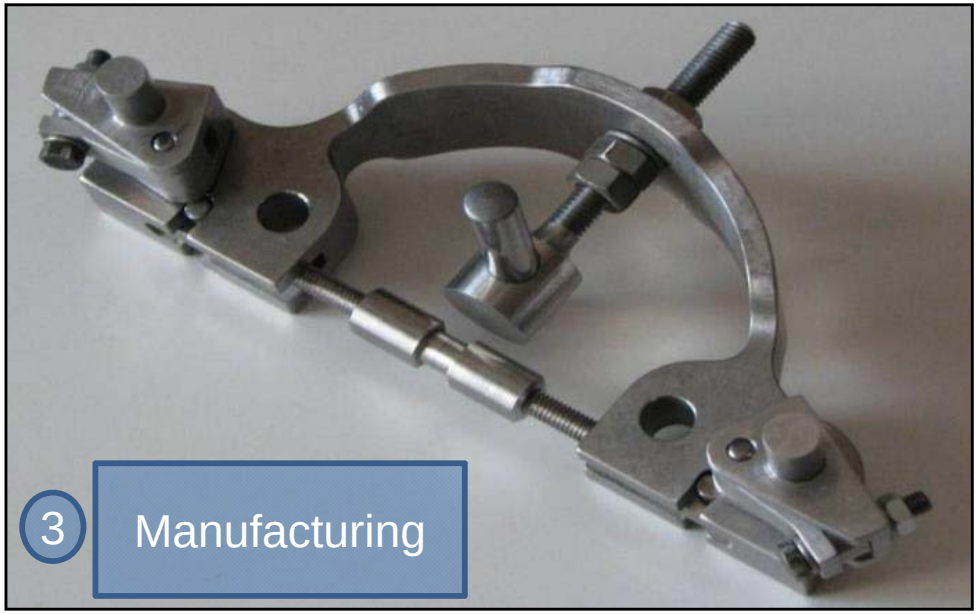
**The inspiration**: *the arch shaped actuator*

1 Concept design

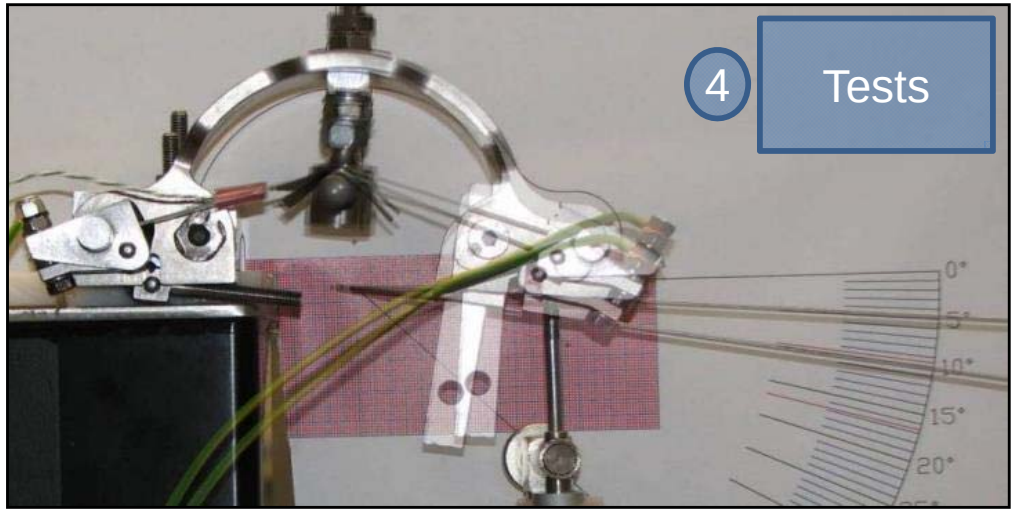


2 Analysis



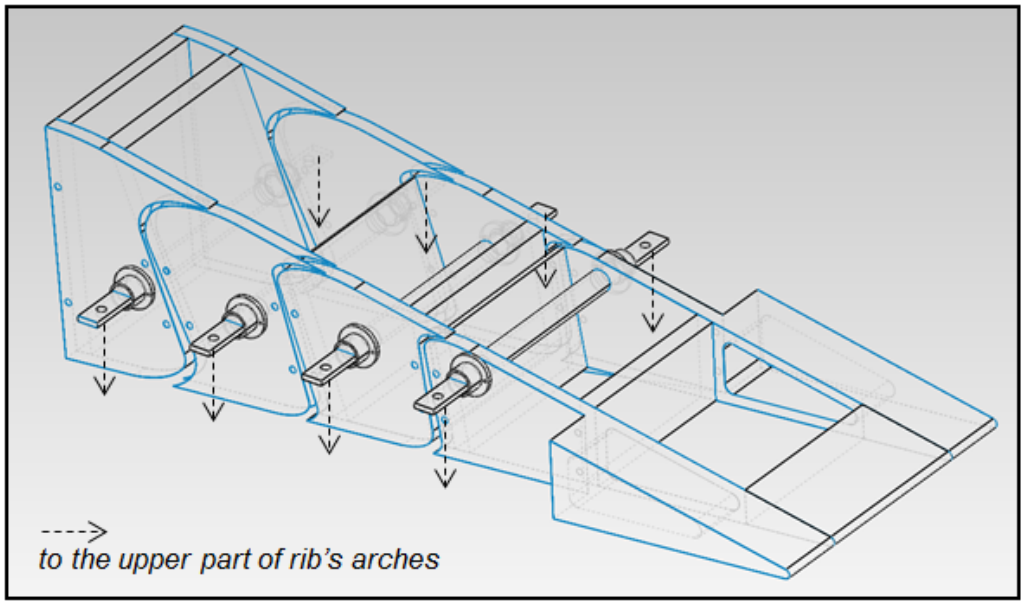
3 Manufacturing

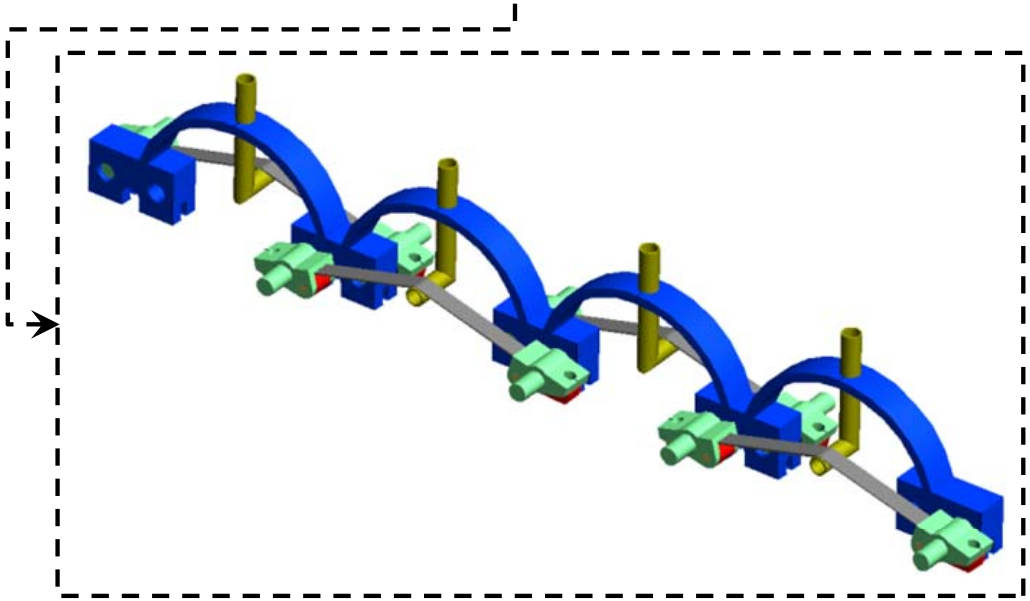


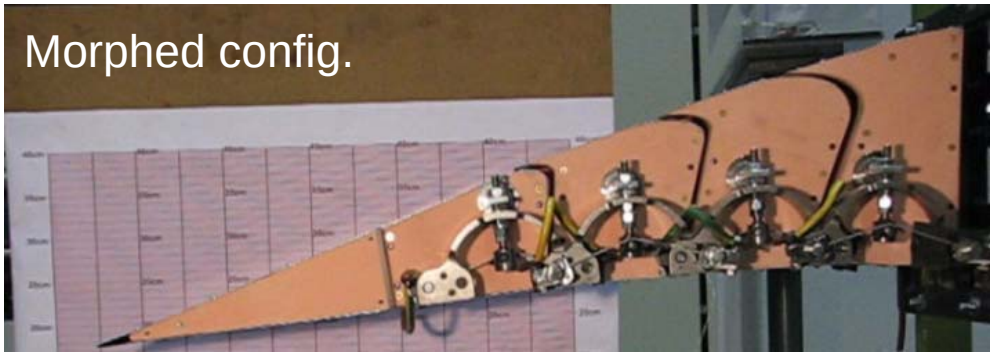

4 Tests

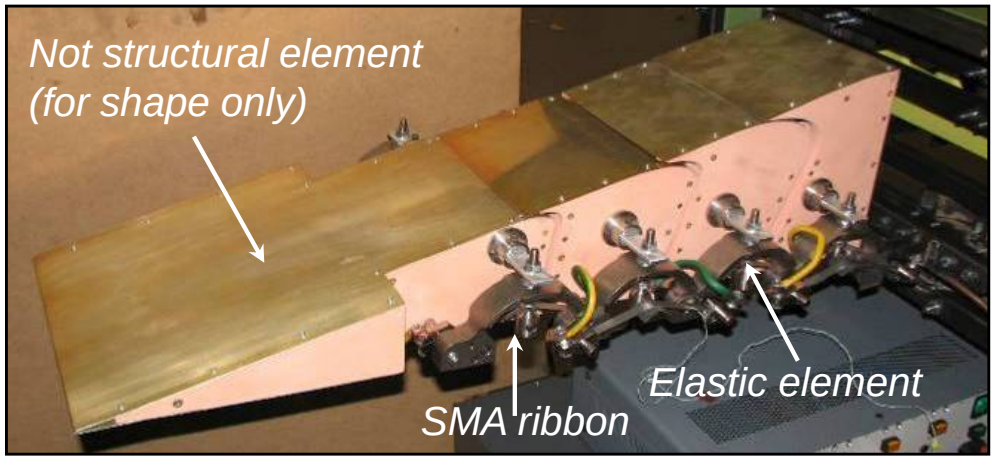
# ALA-Smart Flap (2007-2008)

**Actuator integration within the structure**: rib concept characterized by a *high level of integration*



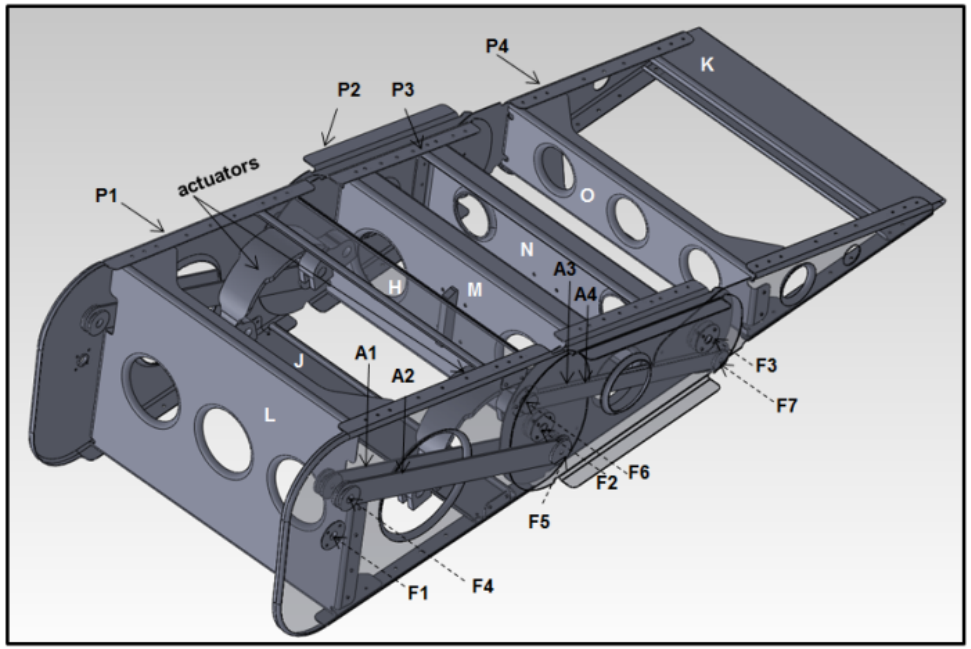



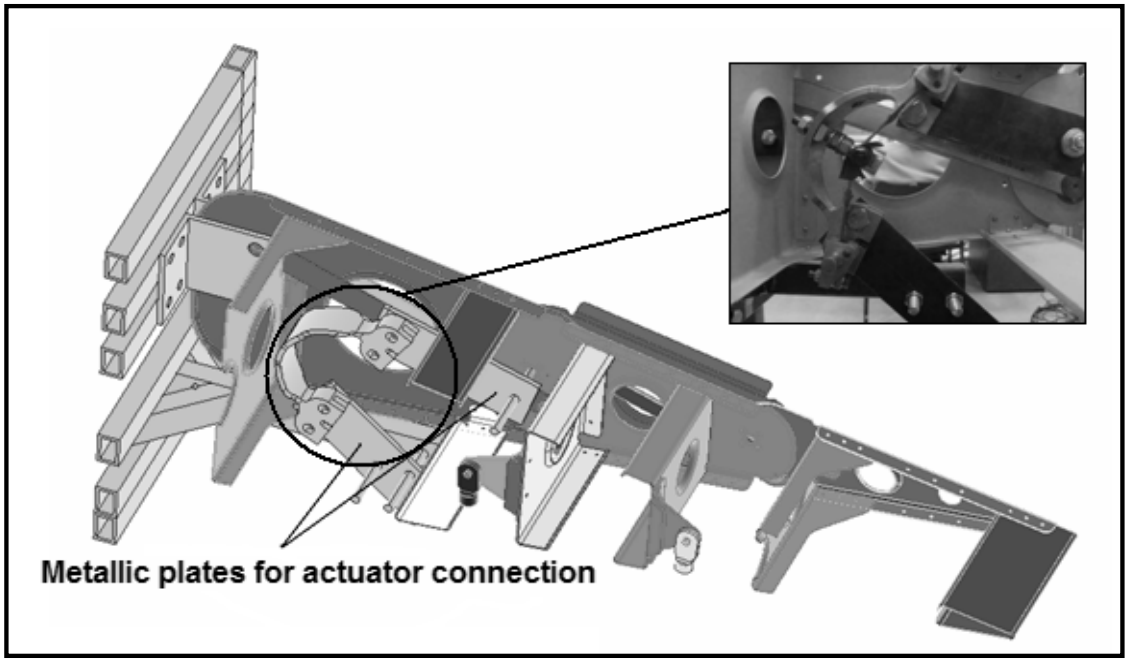



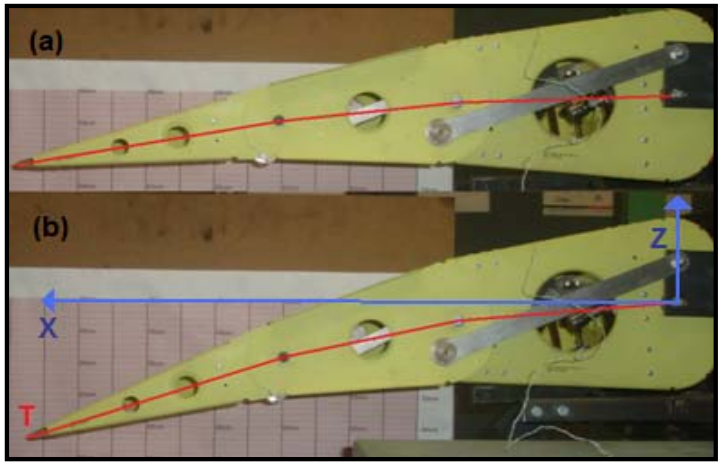



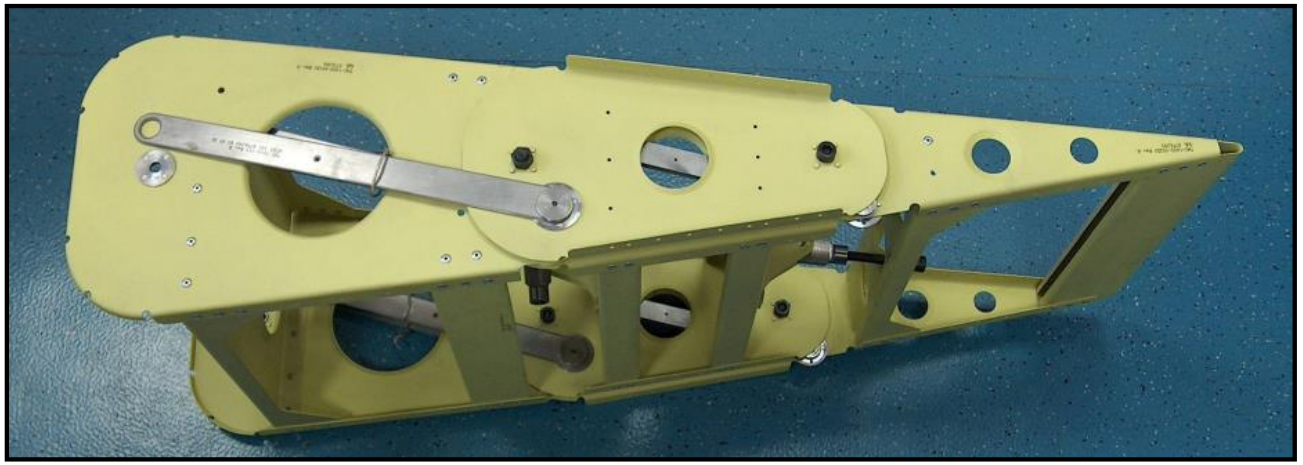
# ALA-Smart Flap (2007-2008)

**Actuator integration within the structure**: rib concept characterized by a *low level of integration*



# ALA-Smart Flap (2007-2008)

**Main achievements of the project:** actuation device and wing flap assembly successfully patented

(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) **EP 2 147 856 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
**12.10.2011 Bulletin 2011/41**

(51) Int Cl.:
***B64C 3/48*** *(2006.01)* ***B64C 9/02*** *(2006.01)*
***B64C 9/04*** *(2006.01)*

(21) Application number: **09165941.7**

(22) Date of filing: **21.07.2009**

(54) **An actuator device based on a shape memory alloy, and a wing flap assembly fitted with such an actuator device**

Stellantrieb aus Formgedächtnislegierung und Flügel- und Klappenanordnung mit solchem Stellantrieb

Vérin de commande basé sur un alliage à mémoire de forme et ensemble aile volet avec un tel verin

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR**

(30) Priority: **23.07.2008 IT TO20080566**

(43) Date of publication of application:
**27.01.2010 Bulletin 2010/04**

(73) Proprietor: **Alenia Aeronautica S.p.A.**
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  **83100 Avellino (IT)**
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- **Concilio, Antonio**
  **81020 San Nicola la Strada (Caserta) (IT)**
- **Ameduri, Salvatore**
  **80131 Napoli (IT)**

(74) Representative: **Fioravanti, Corrado et al**
**Jacobacci & Partners S.p.A.**
**Corso Emilia 8**
**10152 Torino (IT)**

(56) References cited:

US008348201B2

(12) **United States Patent**
**Pecora et al.**

(10) **Patent No.: US 8,348,201 B2**
(45) **Date of Patent: Jan. 8, 2013**

(54) **ACTUATOR DEVICE BASED ON A SHAPE MEMORY ALLOY, AND A WING FLAP ASSEMBLY FITTED WITH SUCH AN ACTUATOR DEVICE**

(75) Inventors: **Rosario Pecora**, Giugliano (IT); **Generoso Iannuzzo**, Avellino (IT); **Massimo Riccio**, Caserta (IT); **Salvatore Russo**, Quarto (IT); **Erika Calvi**, Montoro Superiore (IT); **Leonardo Lecce**, Naples (IT); **Silvestro Barbarino**, Cicciano (IT); **Antonio Concilio**, San Nicola La Strada (IT); **Salvatore Ameduri**, Naples (IT)

(73) Assignee: **Alenia Aeronautica S.p.A.**, Pomigliano D'Arco, Napoli (IT)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 227 days.

(21) Appl. No.: **12/507,677**

(22) Filed: **Jul. 22, 2009**

(65) **Prior Publication Data**

US 2010/0019096 A1 Jan. 28, 2010

(30) **Foreign Application Priority Data**

Jul. 23, 2008 (IT) ..... TO2008A0566

(51) **Int. Cl.**
***B64C 3/58*** (2006.01)

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| | | |
|---|---|---|
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Matthew Stubbs, Kinematic Design and Analysis of a Morphing Wing, Dec. 3 2003, Virginia Polytechnic Institute and State University, pp. 15-17.*

* cited by examiner

*Primary Examiner* — Christopher P Ellis
*Assistant Examiner* — Medhat Badawi
(74) *Attorney, Agent, or Firm* — Merchant & Gould P.C.

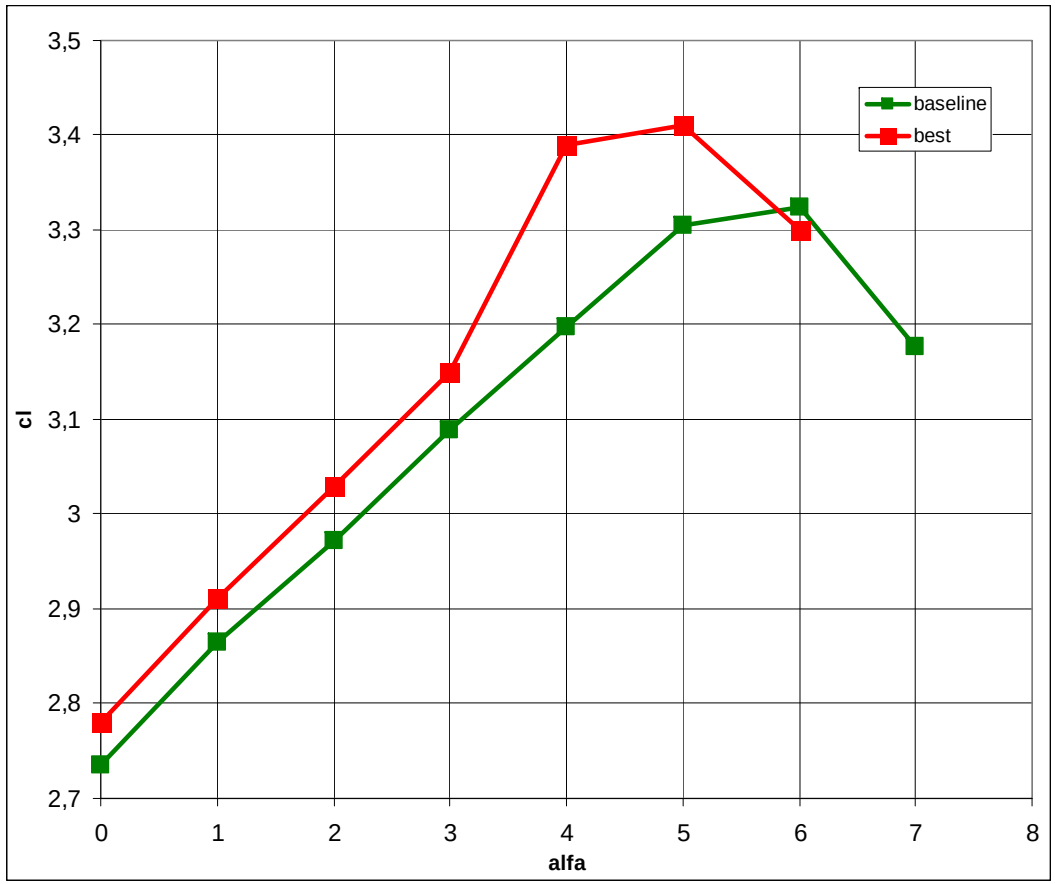
(57) **ABSTRACT**

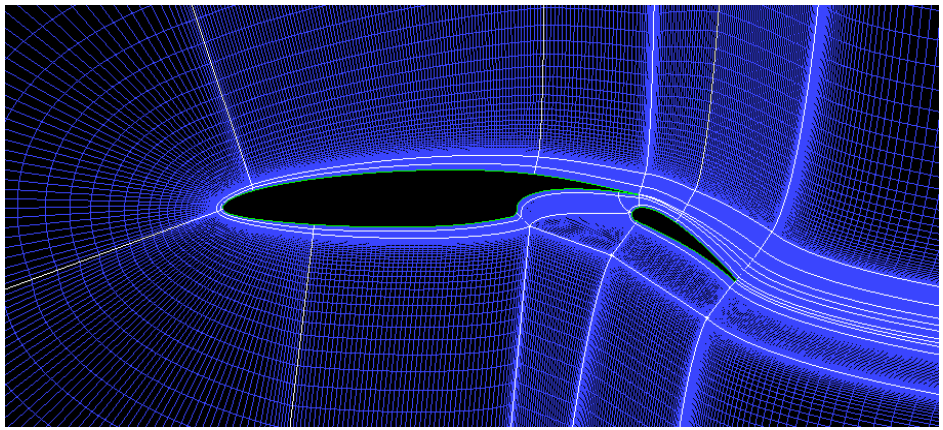
A wing-flap assembly includes a flap made up of a plurality of flap sections, in which each flap section is connected to the preceding one in a rotatable manner, and one or more actuator devices adapted to control the rotation of the flap sections. Each actuator device includes an extended element made of shape memory alloy and an arch-shaped framework made of elastic material, to which the extended element is fixedly connected under tension. Each end of the extended element is fixed to a respective end of the arch-shaped framework. At

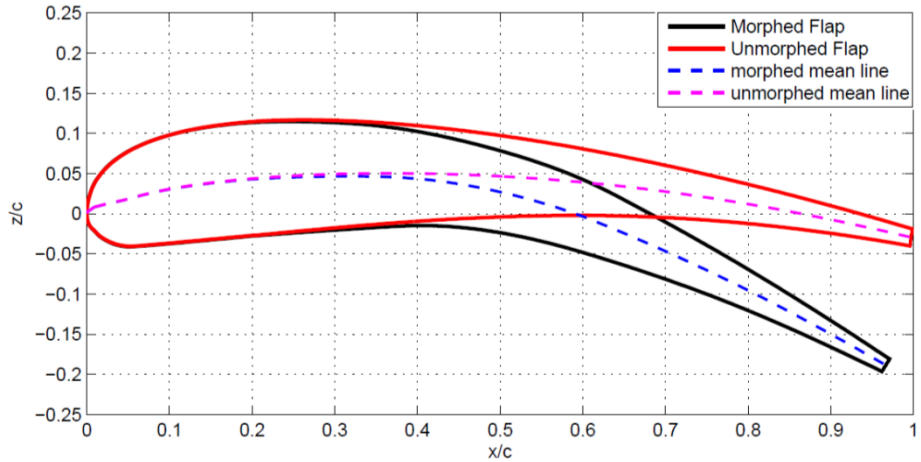
# Clean Sky – GRA (phase 1, 2010-2012)

**Research objective:** Design, manufacturing and validation of a morphing architecture enabling the controlled camber variation of a single flap element in compliance with target reference shapes.

The definition of the target (morphed) shape was carried out by CIRA through 2D CFD optimization analyses at M = 0.2 and based on in-house RANS flow solvers.



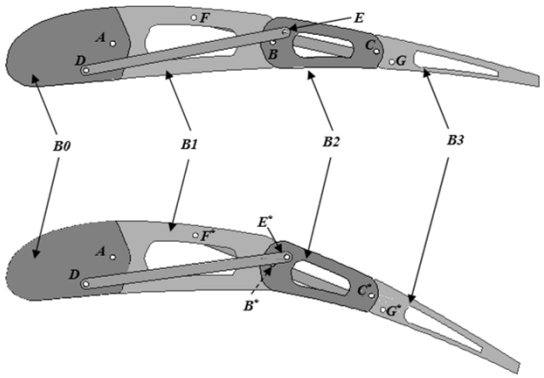





# Clean Sky – GRA (phase 1, 2010-2012)

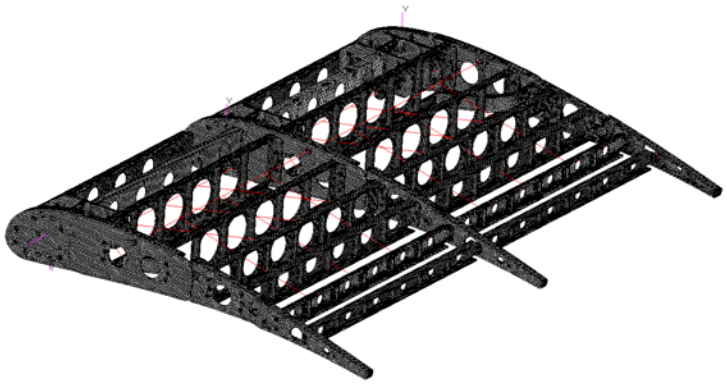
**Research objective:** Design, manufacturing and validation of a morphing architecture enabling the controlled camber variation of a single flap element in compliance with target reference shapes.

Concept identification → Preliminary design → Advanced design




- rib lay-out assessment
- spars lay-out assessment
- cross-links lay-out assessment
- actuator/control system assess.

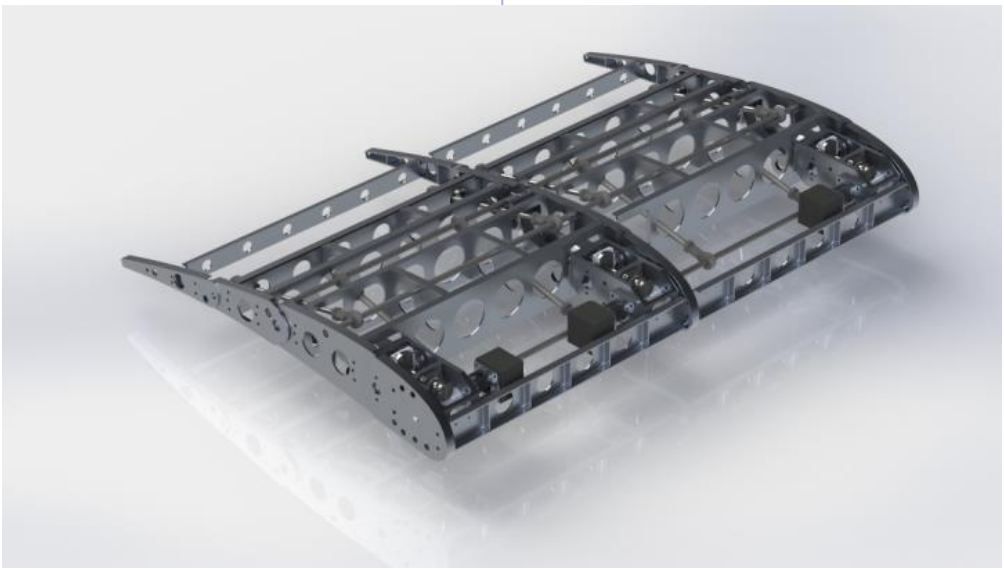
Advanced cinematic analysis → Refined FE model and analyses



# Clean Sky – GRA (phase 1, 2010-2012)

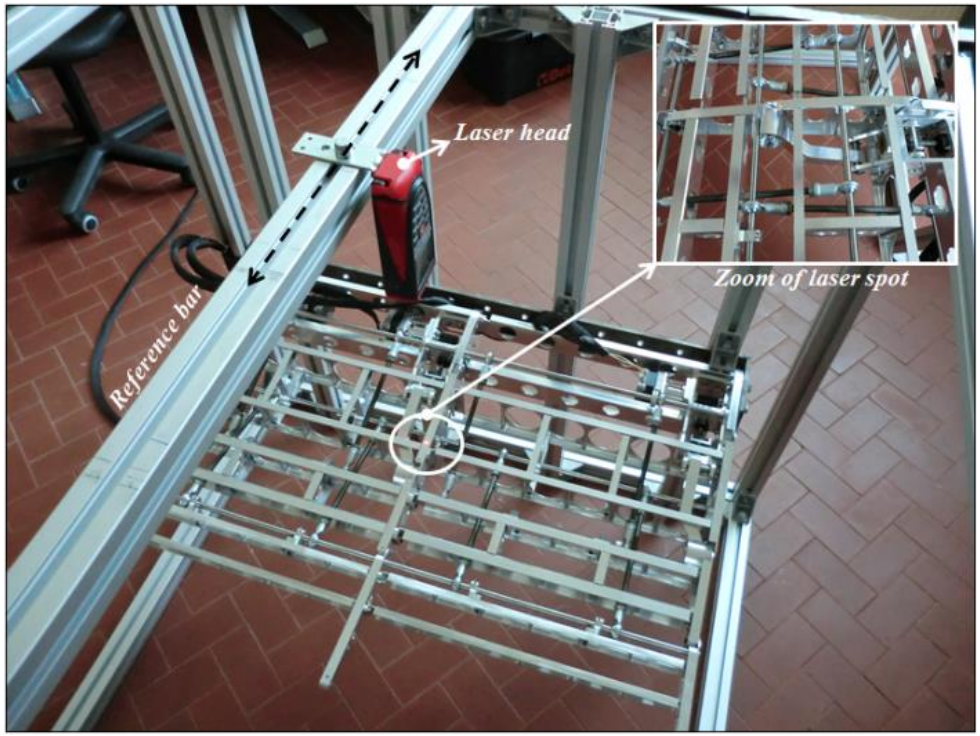
**Research objective:** Design, manufacturing and validation of a morphing architecture enabling the controlled camber variation of a single flap element in compliance with target reference shapes.

Prototype manufacturing



Experimental tests

- Func. tests
- Static tests
- GVT



# Clean Sky – GRA (phase 1, 2010-2012)

**Research objective:** Design, manufacturing and validation of a morphing architecture enabling the controlled camber variation of a single flap element in compliance with target reference shapes.

# SARISTU (2011-2015)

## OBJECTIVES

SARISTU (Smart Intelligent Aircraft Structures) focuses on the **cost reduction of air travel** through a variety of individual applications as well as their combination. For the first time ever in smart material concepts, SARISTU offers the opportunity to virtually and physically assess the interaction of different technological solutions and their combined effects at aircraft level.

Specifically, the joint integration of different conformal morphing concepts in a laminar wing is intended to improve aircraft performance through a **6% drag reduction**, with a positive effect on fuel consumption and required take-off fuel load. A side effect will be a decrease of up to 6dB(A) of the **airframe generated noise**, thus reducing the impact of air traffic noise in the vicinity of airports.

Another important objective is to **limit the integration cost of Structural Health Monitoring (SHM) systems** by moving the system integration as far forward in the manufacturing chain as possible. In this manner, SHM integration becomes a feasible concept to enable **in-service inspection cost reductions of up to 1%**.

Finally, the incorporation of Carbon Nanotubes into aeronautical resins is expected to enable **weight savings of up to 3%** when compared to the unmodified skin/stringer/frame system, while a combination of technologies is expected to **decrease Electrical Structure Network installation costs by up to 15%**.

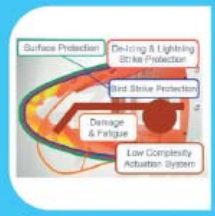
## PROJECT STRUCTURE

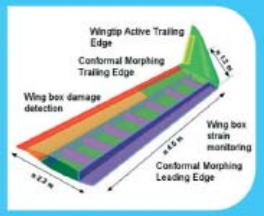
### Technology stream: Morphing

**AS01** Enhanced adaptive droop nose for a morphing wing

**AS02** Adaptive Structural Tailoring of Trailing Edge for Enhanced Aircraft Performance

**AS03** Wingtip Morphing Trailing Edge




### Integration and Validation

**IS12** Wing assembly integration and testing

**IS13** Fuselage assembly integration and testing

### Technology stream: Integrated Sensing

**AS04** Fibre optic based monitoring system

**AS05** Wing damage detection employing guided waves techniques

**AS06** Impact damage assessment by self-sensing structures using integrated ultrasonic sensors

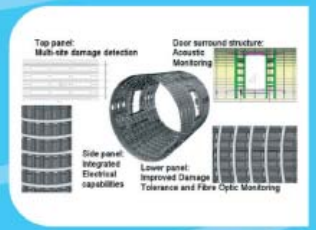
**AS07** Multi-site damage assessment of CFRP structures

**AS08** Sensitive Coating for Impact Detection

### Technology stream: Multifunction materials

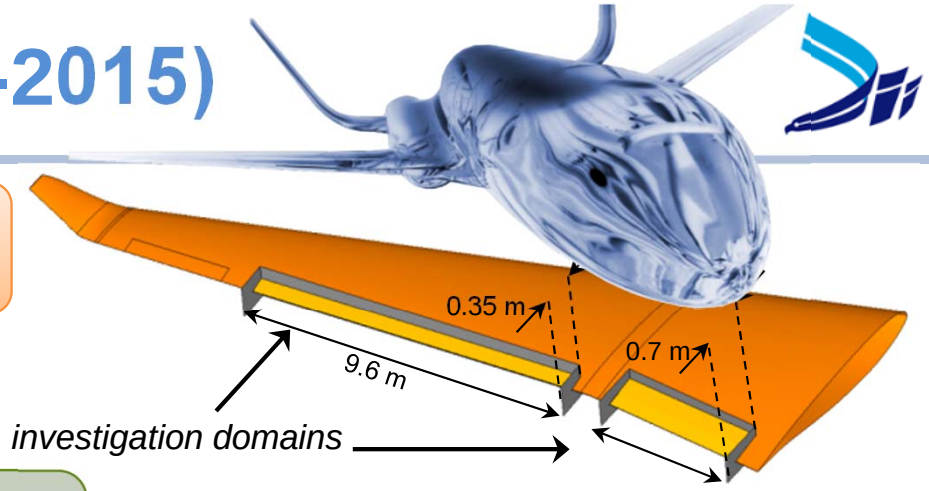
**AS09** Enhancement of primary structure robustness by improved damage tolerance

**AS10** Improvement of the electrical isotropy of composite structures




SARISTU
SMART INTELLIGENT AIRCRAFT STRUCTURES

# SARISTU (2011-2015)




**Application scenario 2, adaptive TE:** *key partners ..*

Preliminary design path

Alenia Aermacchi
A Finmeccanica Company

Definition of Requirements & Specifications

AIRBUS

Aerodynamic design

Design of the morph. structure

Design of systems

POLITECNICO MILANO

ONERA
THE FRENCH AEROSPACE LAB

TE box

CIRA

Actuation & control

Fraunhofer

Skin

INASCO
INTEGRATED AEROSPACE SCIENCES CORPORATION

Sensing

V&V path

Stressed layout emission / Aeroelastic assessment

Executive drawings and manufacturing of prototypes

Experimental tests

mare engineering
engineering & consulting

INNOWATTECH
ENERGY HARVESTING SYSTEMS

AERnnova engineering

ATARD
Defence and Aerospace Industry
Advanced Technology Applications
Research and Development Inc.

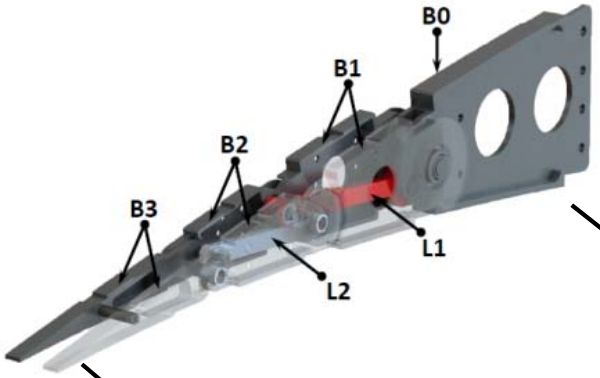
CIRA

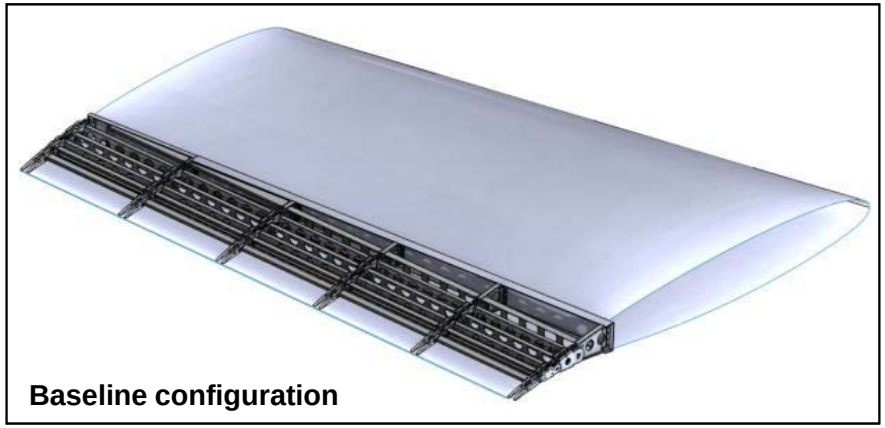
Fraunhofer

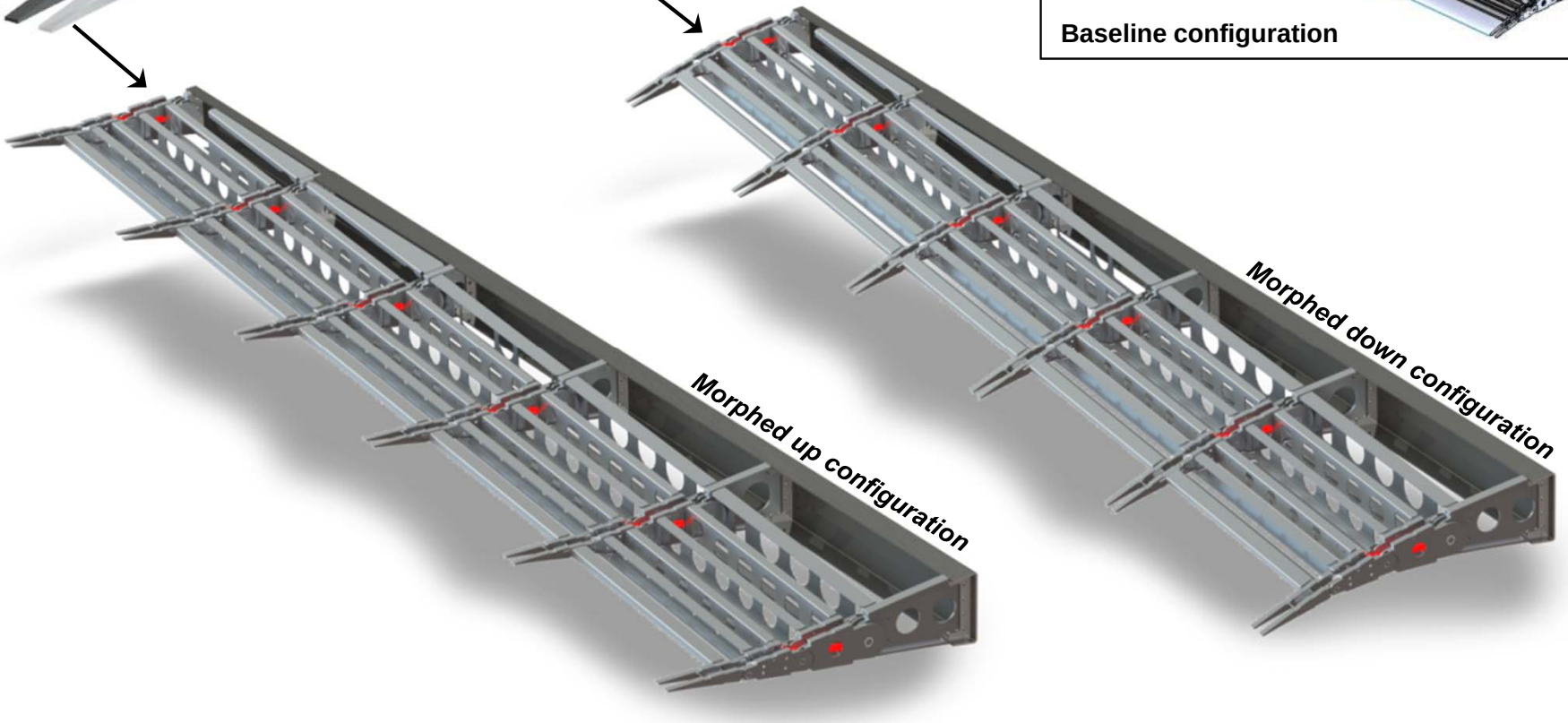
AERnnova engineering

# SARISTU (2011-2015)

**Application scenario 2, adaptive TE:** *the inner structure …*



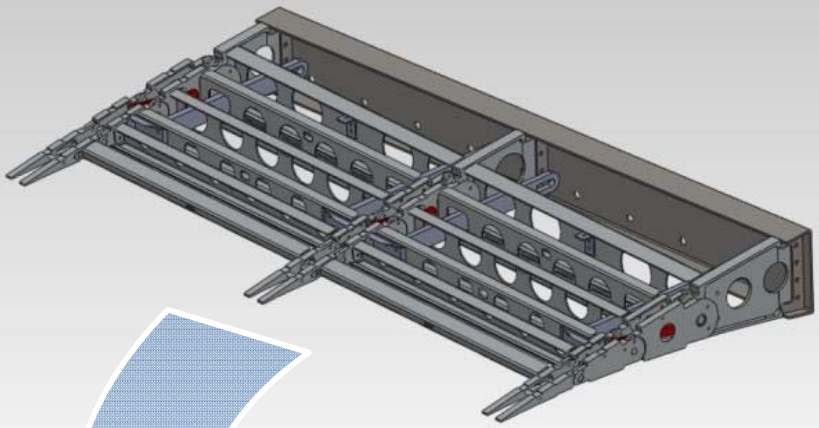


Baseline configuration



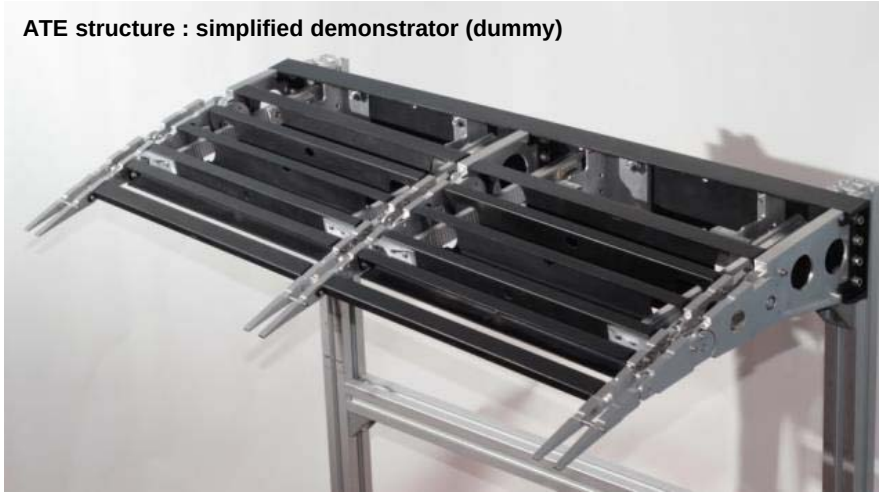
# SARISTU (2011-2015)

## Application scenario 2, adaptive TE: *the dummy demonstrators*

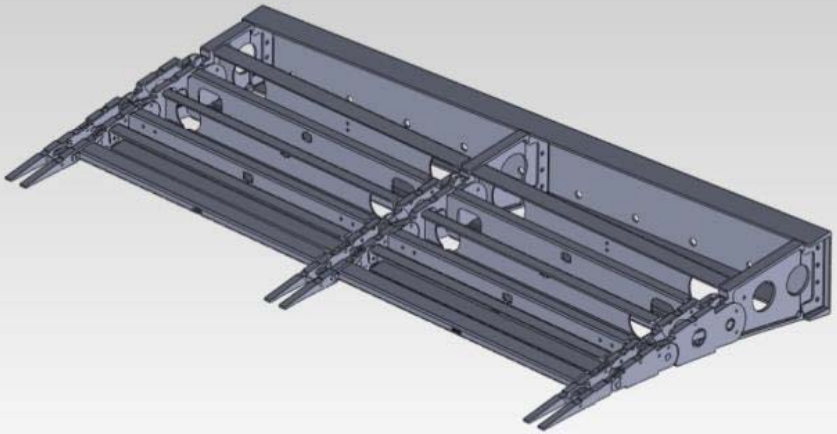
ATE structure : executive layout



ATE structure : simplified demonstrator (dummy)



ATE structure : simplified layout



**Application scenario 2, adaptive TE:** *AS02 demonstrator and qualification tests*

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**Application scenario 2, adaptive TE:** *AS02 demonstrator and qualification tests*

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**Application scenario 2, adaptive TE:** *AS02 demonstrator and qualification tests*

# SARISTU (2011-2015)

**From AS02 to IS12:** 5-bay demonstrator

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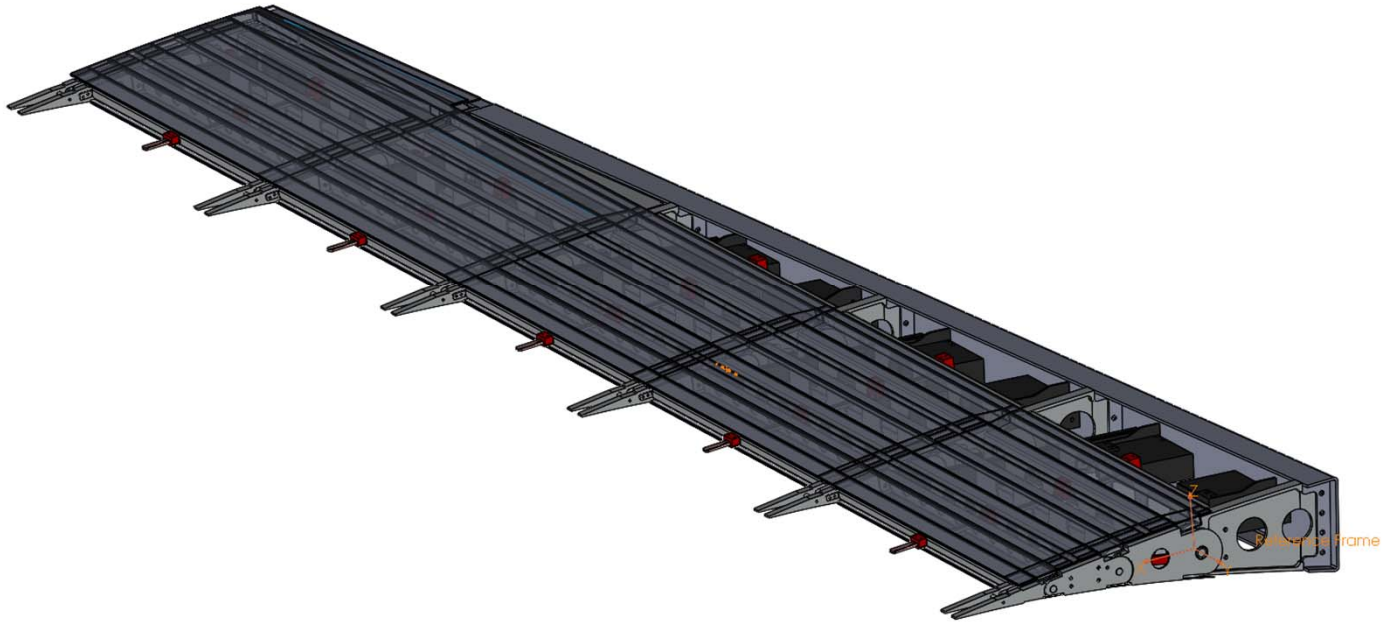
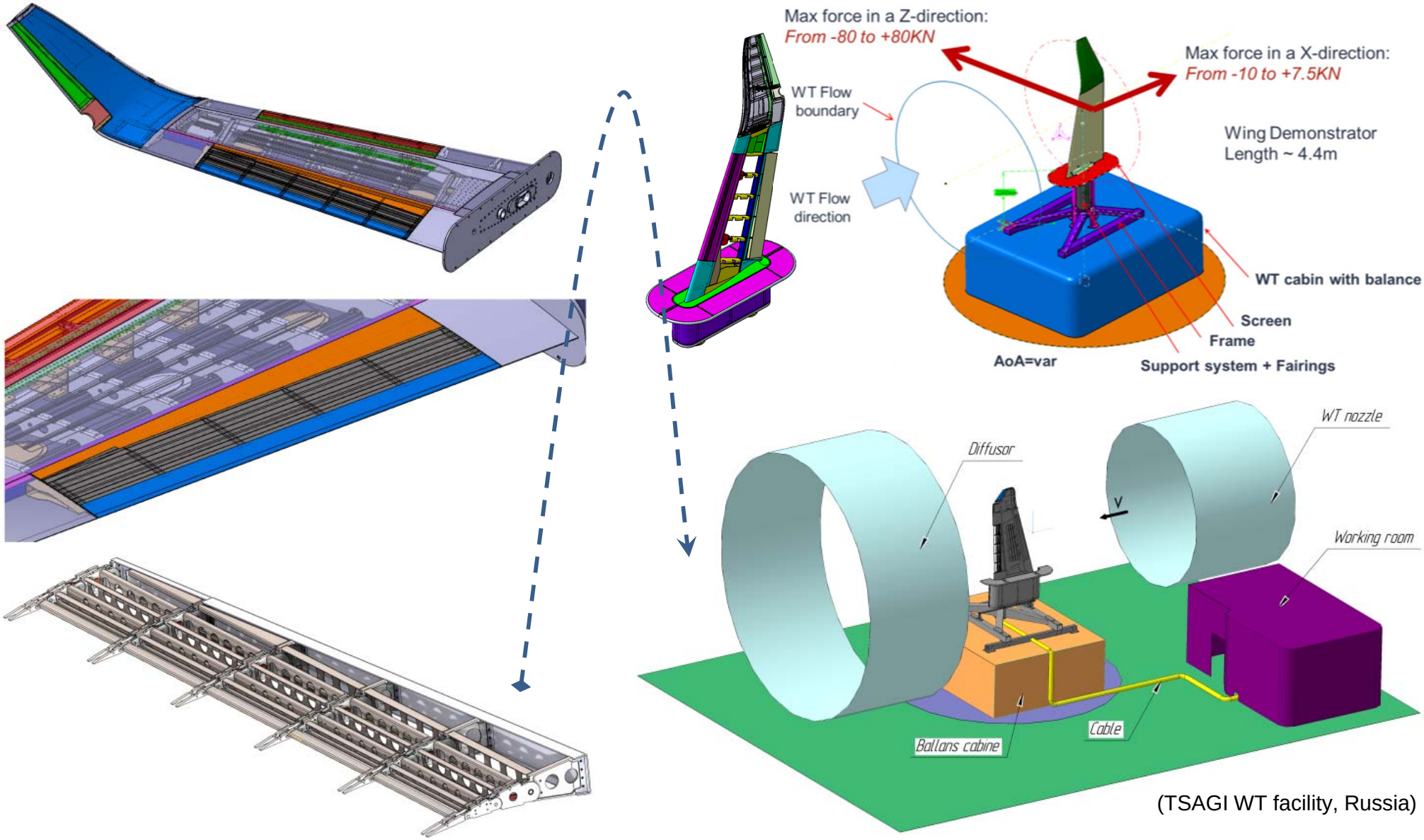


# SARISTU (2011-2015)

**From AS02 to IS12:** for the firs time ever, a true scale wing segment equipped with 3 fully functional morphing devices will be tested in one of the largest WT of the world !




(TSAGI WT facility, Russia)

# CRIAQ-MDO505 (2012-2015)

**Research objective:** Design, manufacturing and test of a morphing aileron as part of an integrated wing tip system devoted to increase aerodynamic efficiency in cruise.

Université du Québec
École de technologie supérieure

THALES

BOMBARDIER
AEROSPACE

*confidential contents removed*

NRC·CNRC

CIRA

AleniaAeronautica
A Finmeccanica Company

# CRIAQ-MDO505 (2012-2015)

**Coupled morphing device:** morphable skin box + aileron with morphing camber capabilities


Canadian team responsibility

Italian team responsibility

# CRIAQ-MDO505 (2012-2015)

**Morphing aileron:** *morphing box and actuation*

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# CRIAQ-MDO505 (2012-2015)

**Morphing aileron:** *the sliding skin concept (high TRL)*

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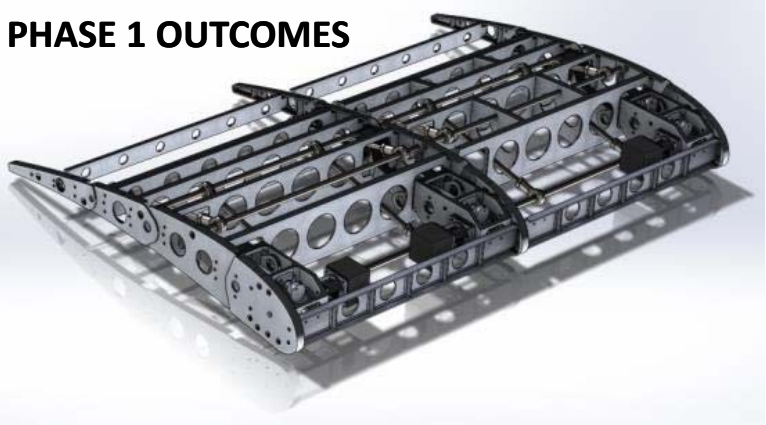
# Clean Sky – GRA (phase 2, 2013-2015)

Phase 1 architecture was selected for follow-on activities addressing the design and the mechanical demonstration of an advanced 3D prototype implementing similar but enhanced morphing solutions.
The new device, is applicable to the NLF wing of the 130-seats GRA with rear fuselage power plant.

**PHASE 1 OUTCOMES**



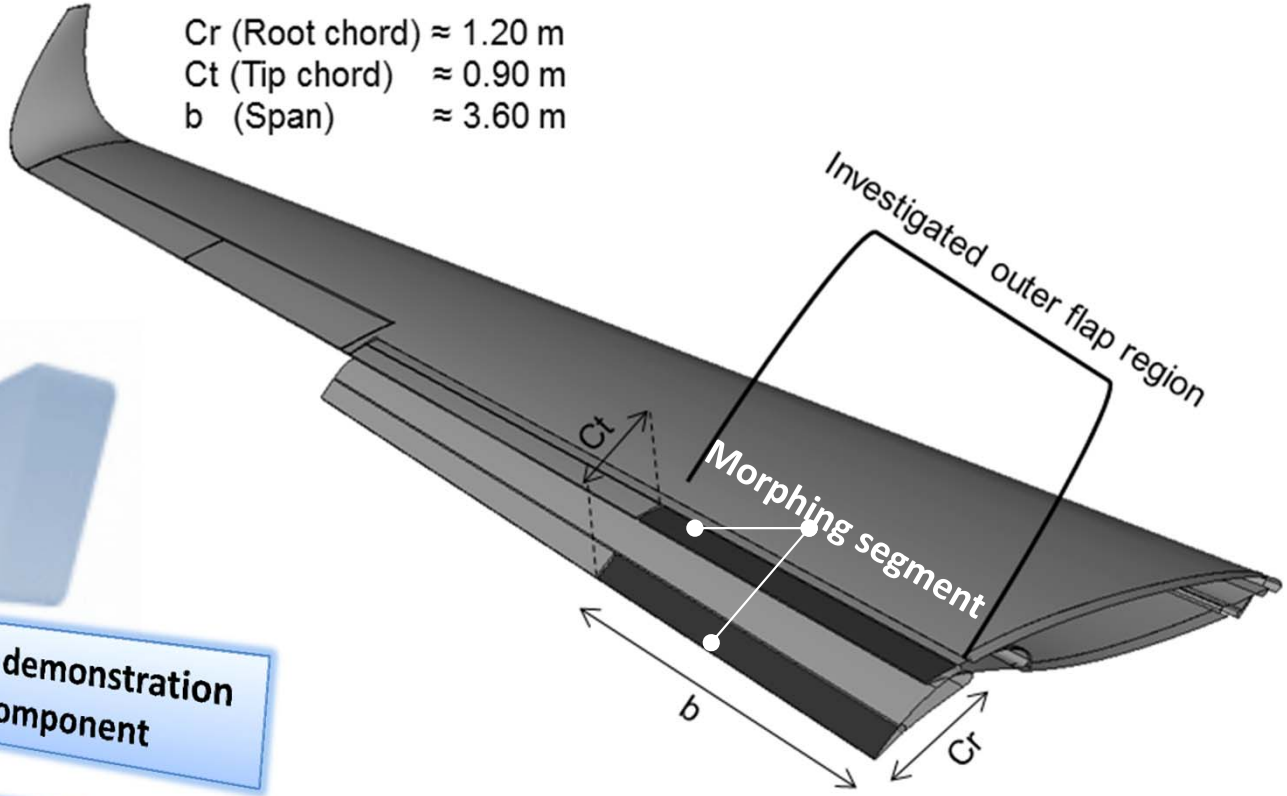
**TRL 3 (2012)**

**TRL 4/5 (2015)**

Large scale (ground) demonstration including skin component

Double functionality implemented (LC in cruise, HLD enhancement)

Scale up of the (phase 1) conceived architecture (larger span, var. chord)

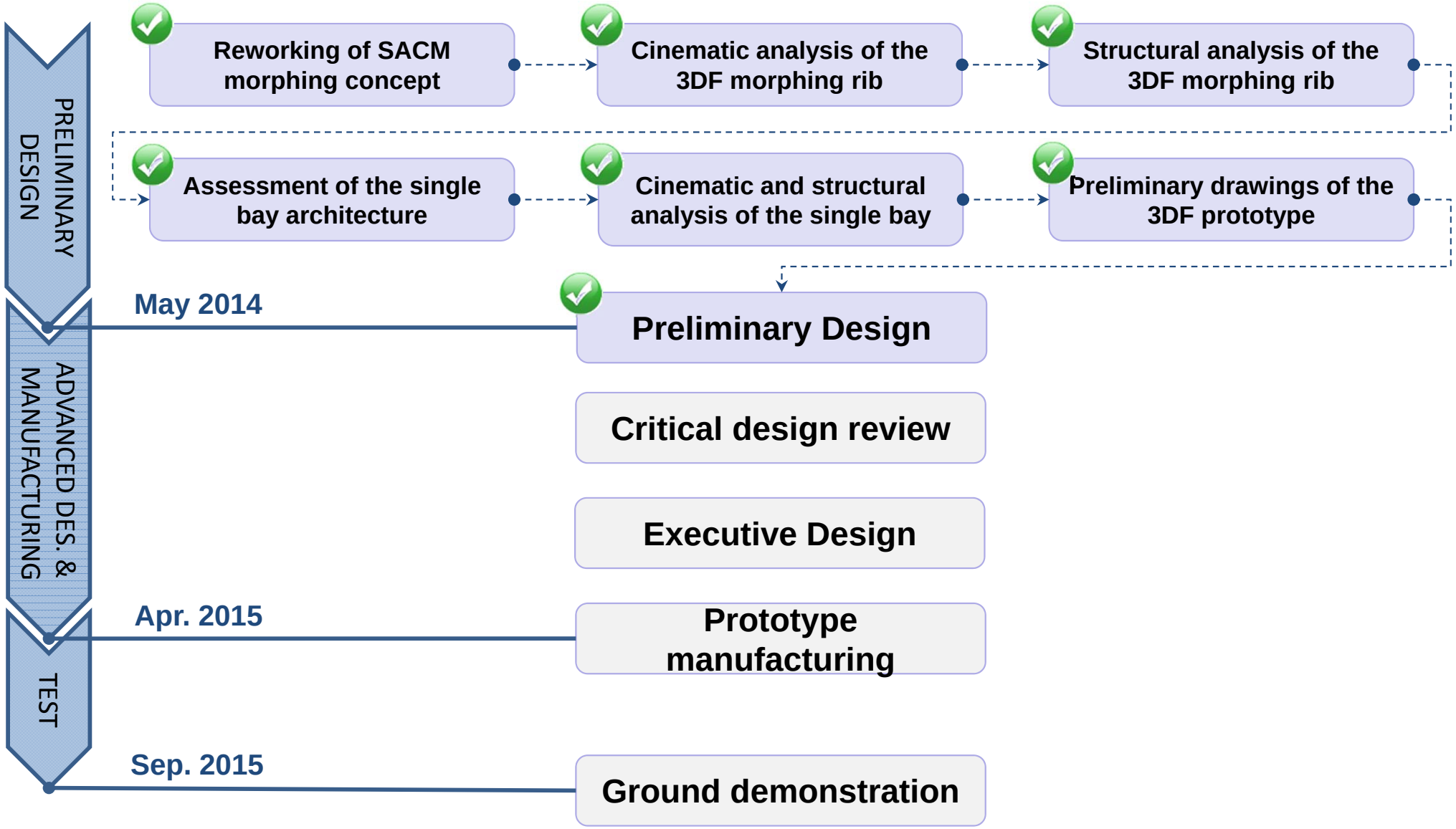



Clean Sky JOINT UNDERTAKING

GRA GreenRegionalAircraft

# Clean Sky – GRA (phase 2, 2013-2015)

## Overview of the work plan



# Clean Sky – GRA (phase 2, 2013-2015)

**Bi-modal morphing rib:** mode 1 actuation

# Clean Sky – GRA (phase 2, 2013-2015)

**Bi-modal morphing rib:** mode 2 actuation

**Bi-modal morphing rib:** *morphing mode 1*

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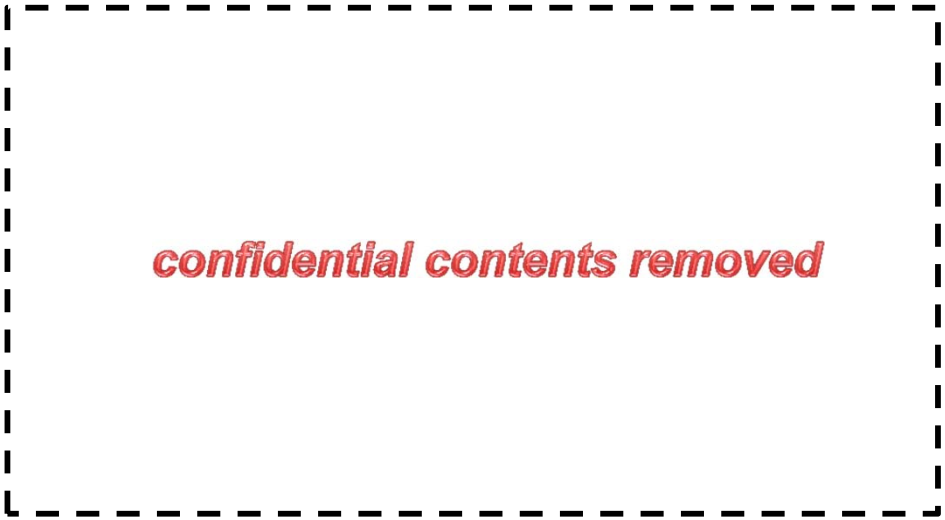
# Clean Sky – GRA (phase 2, 2013-2015)

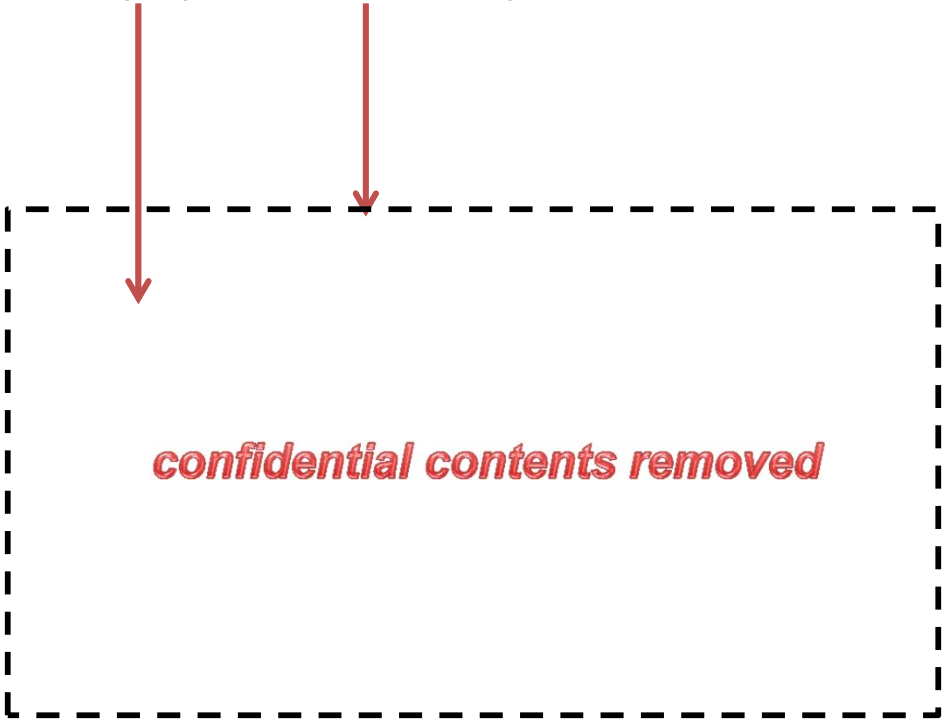
**Bi-modal morphing rib:** *morphing mode 2*

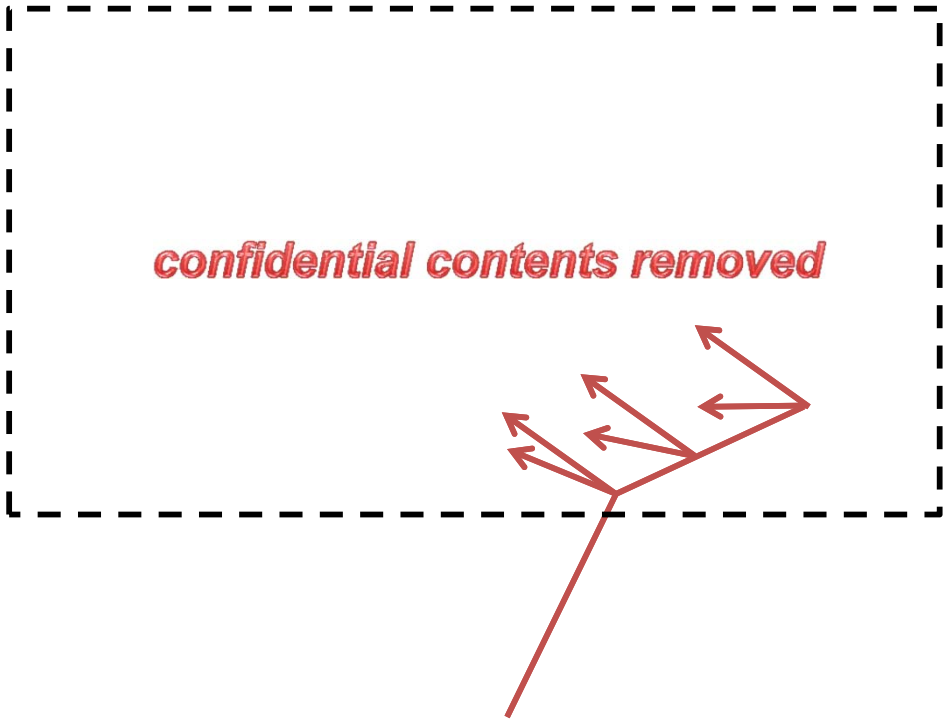


# Clean Sky – GRA (phase 2, 2013-2015)

**Key-issues:** *fitting mechanisms in a tapered structure, design of a (large) sliding skin*

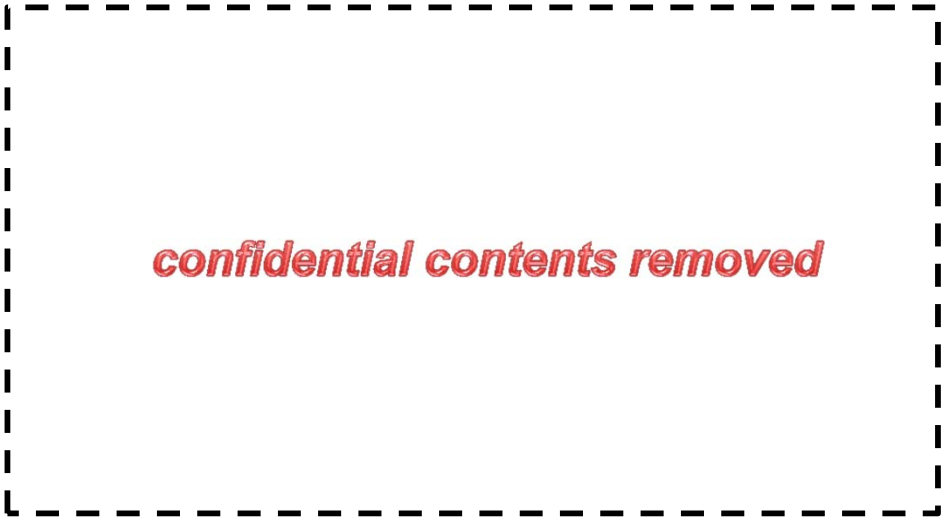
*(only) 1st and last chordwise segments tapered. Straight hinge lines perpendicular to rib's planes*



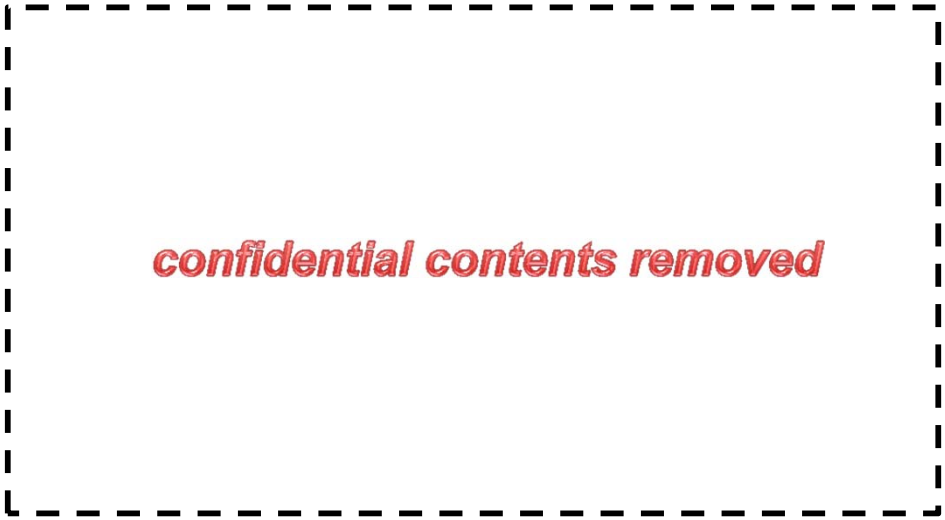

*Armadillo-like skin with syliconic seals*

**3DF architecture:** *morphing mode 1*



# Clean Sky – GRA (phase 2, 2013-2015)

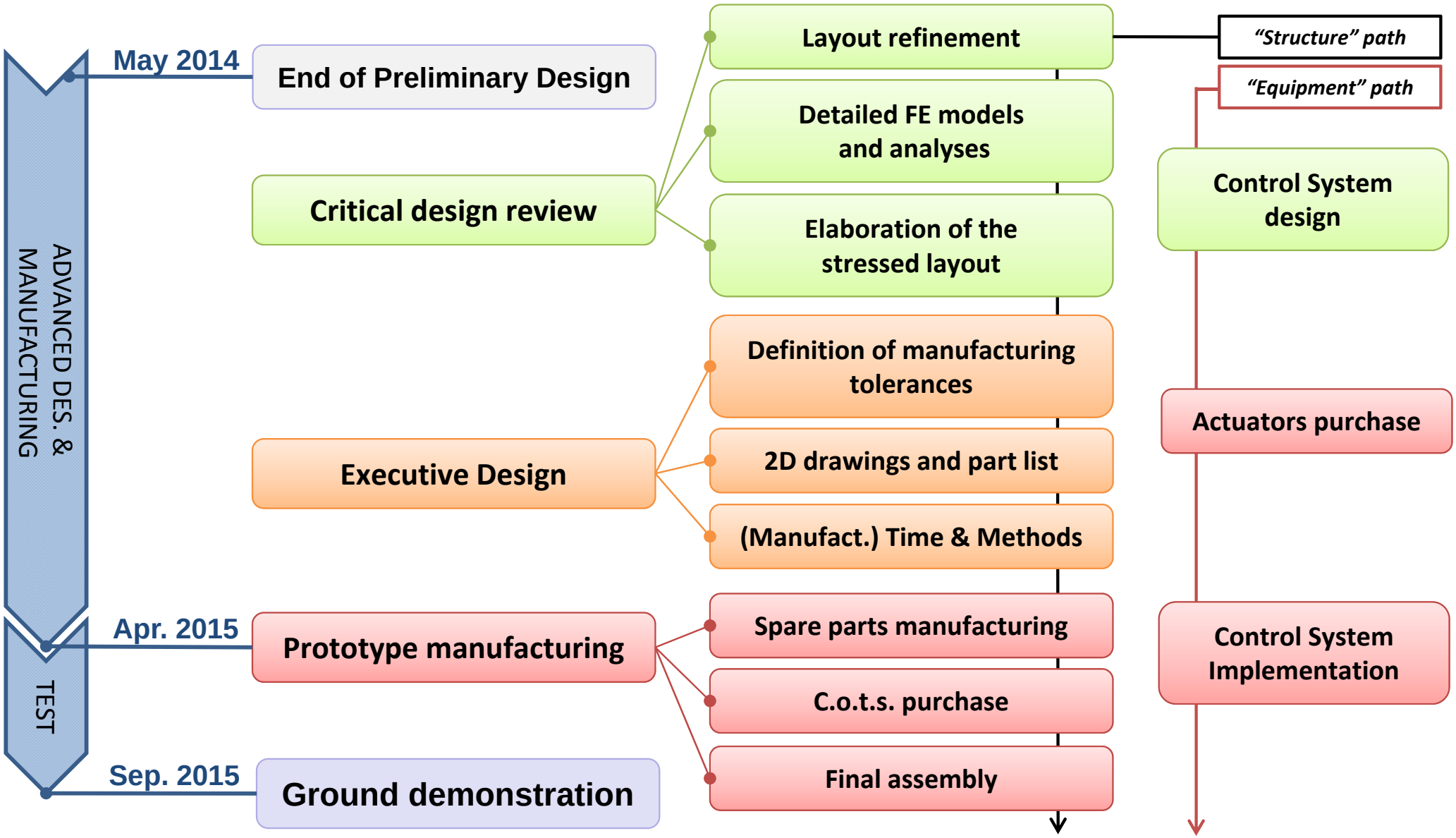
**3DF architecture:** *morphing mode 2*



# Clean Sky – GRA (phase 2, 2013-2015)

**3DF architecture:** *the armadillo-like skin during morphing*

# Clean Sky – GRA (phase 2, 2013-2015)




WHAT'S NEXT ?

# Waiting for Clean Sky 2 …

…The best is yet to come !