Project n° **516115**

Project Acronym: **MUSCA**

Project title: **Non-linear Static Multi-Scale Analysis of Large Aero-structures**

Instrument type: Specific Targeted Research Project
Thematic priority: 4, aeronautics and space

Final Publishable Activity Report

Start date of project: 05/09/2006 Duration: 42 months

Stéphane Guinard EADS IW

1. Publishable Executive Summary

1.1 Project summary

Structural testing of major aircraft components is a very expensive and time-consuming process that adds significantly to the overall cost of designing and certifying a new aircraft product. If testing can be reduced, based on validated and safe numerical analysis methods, then this will provide the European Aircraft industry with a significant business and technological advantage. A structural certification based on a Virtual Testing process appears as a promising way to achieve in a medium term (5 to 7 years) the following global goals:

- 30% to 40 % reduction of component tests and consequently certification costs
- 20 % to 30% reduction of structural certification duration

The main innovation in MUSCA is to address built-up structures with a high degree of complexity where the modelling is fine enough to capture local effects or non-linear behaviour that are necessary to predict both failure initiation and collapse. The scientific tools to reach these objectives require novel advances in computational mechanics and statistics that are addressed in MUSCA in parallel with large scale computing. Based on the state of the art, the consortium identified three key research areas to address:

- **Techniques for large scale Non Linear analysis**: domain decomposition techniques coupled with advanced parallel processing Non Linear solvers, error estimator for quality assessment
- **Multi-criteria failure analysis**: critical review, selection and validation of the most efficient engineering procedures for multi-mode failure analysis of structural details
- **Sensitivity and reliability techniques**: assessment of input uncertainties (material properties, geometry and load scattering) on the structural performance using stochastic simulations, sensitivity surface response methods

Based on existing experimental data comparison, MUSCA output will be the ability of the new developed analysis techniques to predict accurately **static failure of large aircraft components**

1.2 Work strategy

The three major research topics identified above will constitute the core R&D activity of MUSCA, but special attention will be made to **focus partnership activities** on actual analysis needs. The MUSCA consortium has therefore adopted the following work strategy:

a) WP1 analysed the **certification process** for some representative large aircraft components. These have been provided by industrial partners in order to demonstrate how testing and analysis are currently used to provide structural certification. Main analysis difficulties have been identified and classified for those MUSCA industrial large component **benchmarks** (WP1). Costs and duration have been evaluated to **establish a baseline for future gains**.

b) N**umerical benchmark cases** with associated existing structural tests have then been identified representing main analysis problems derived from large-scale industrial benchmarks (WP2.0, WP3.0 and WP4.0). The **partnership** activities have been **exclusively** focused on these numerical test cases for evaluation and development of methodologies in each of the three key research areas previously defined.

c) Based on the most promising methodologies available, the actual **validation** of the **overall multi-scale analysis process** will be made on three **selected industrial benchmarks** (WP5), with an original **collaborative work organisation** between partners. The validation of MUSCA developments will be made using **existing experimental test data** provided by industrial partners for large-scale benchmark tests.

d) Potential cost savings and cycle reduction will be assessed compared to base line established in WP1. Finally, with the experience gained in WP5, **recommendations** will be provided for an **evolution of the structure justification process** (WP6) that integrates the methodologies developed in MUSCA. **To reach this goal, a senior expert in airworthiness requirements will be associated with MUSCA in** WP1 and WP6, in order to obtain information and advice on issues like analysis methods, processes, quality control and associated responsibilities.

At this stage of the program, section a) is over (WP1, process analysis and use cases preparation), technical developments within WP2-3-4 are still in progress and will end in 6 months (March 2008), and the effective demonstrations of the progresses performed (WP5) began in September 2007.

1.3 Work Performed

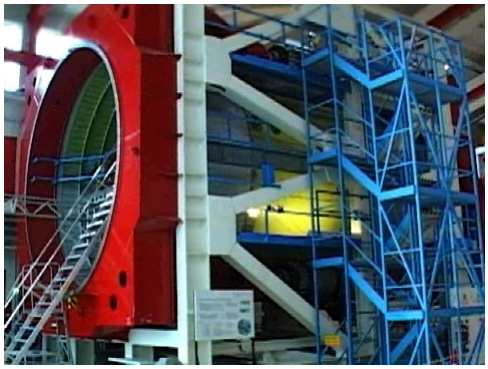
WP1 – analysis of structural certification of large components

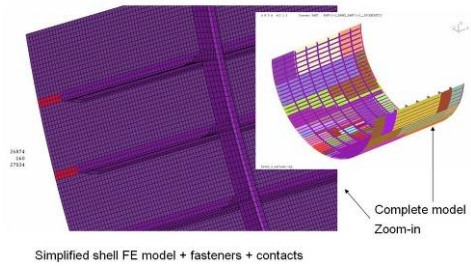
Four large component structural tests were identified and documented by the industrial partners, with a special focus on the following items:

- description of the role of the test with regards to the overall process
- description of the main analysis difficulties
- process analysis, with a recommended way towards a more “simulation assisted” process
- delivery of CAD, FEM to the partners (still in progress: see §3.2.4, 3.3.4 and 3.4.4)

These test-cases are illustrated hereunder:

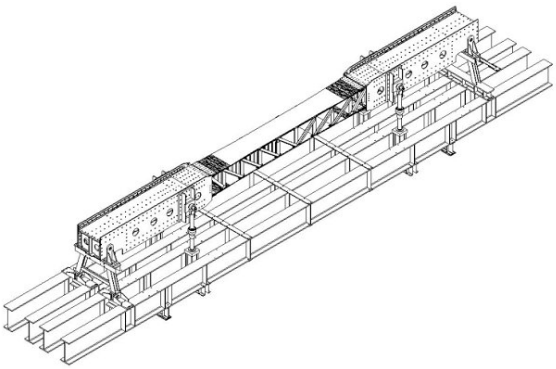
AI-F&G A340 section 16 fuselage section

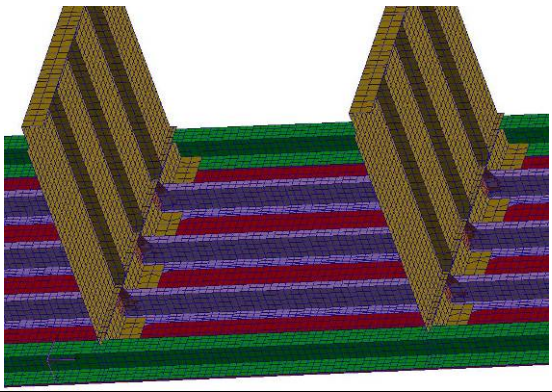




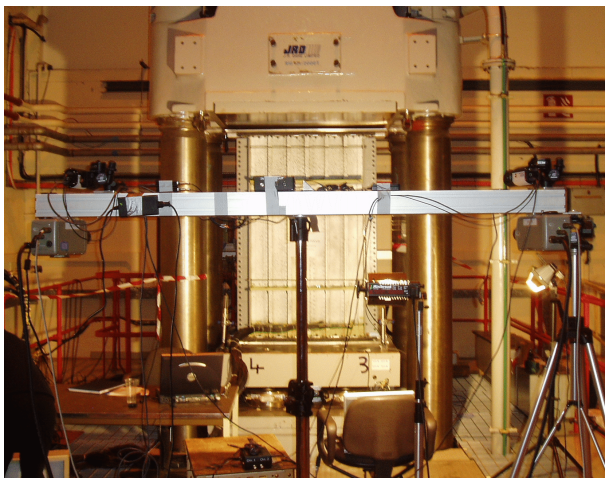
Simplified shell FE model + fasteners + contacts

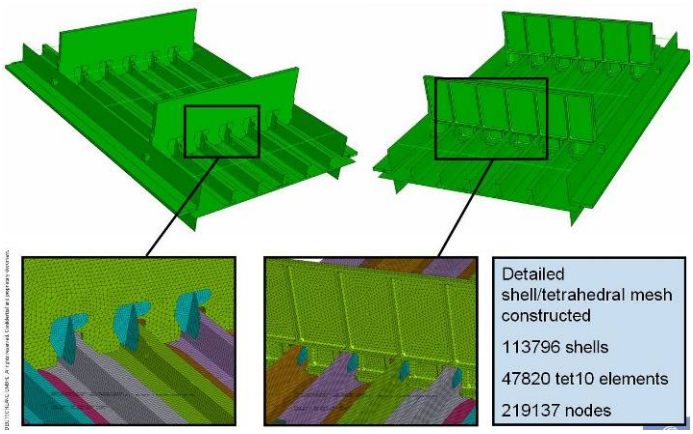
AI-UK A380 wing box-beam



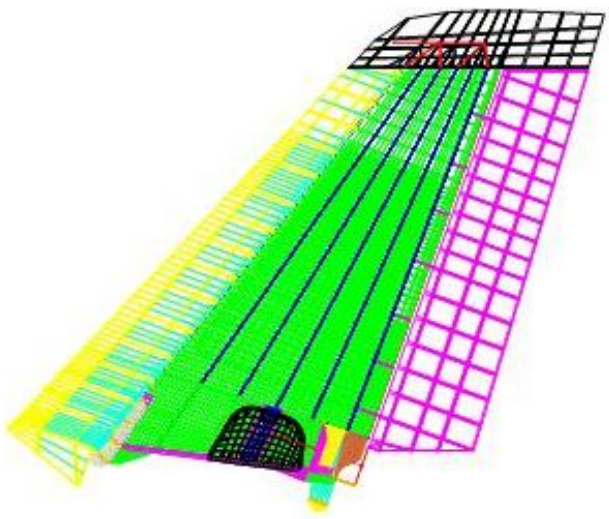


AI-UK A340 wing cover compression panel test

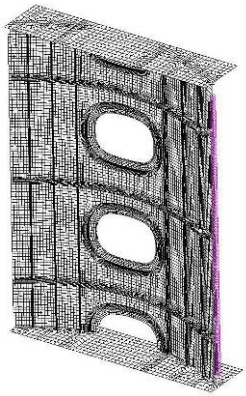




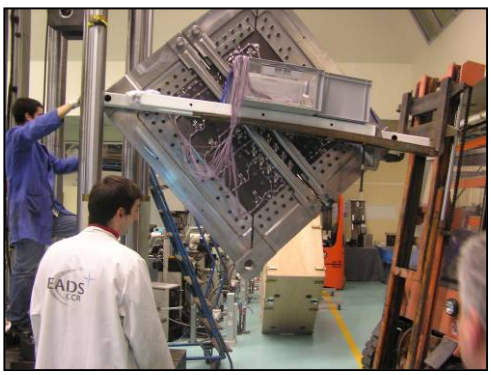
DAV F7X vertical tail

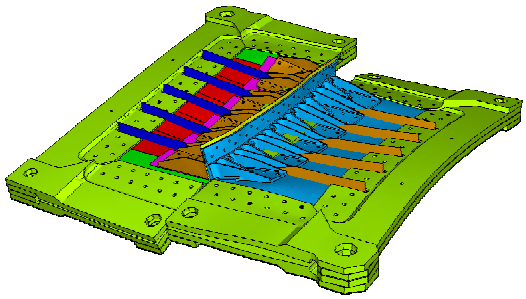


Saab panel test



CRC-F generic shear-joint





WP2 – Large modelling capabilities

The main objective of WP2 is to develop methods and computational schemes of such effectiveness that displacements, stresses and the maximum load carrying capacity of structural components of a size up to large aircraft sections can be accurately analysed with control of the error in the numerical solutions.

WP3 – Smart multi-criteria failure analysis

Within WP3 the multi-mode failure behaviour of large structures will be identified and structural details will be designed for each generic analysis difficulty of existent test data. Existing failure criteria will be reviewed or further developed and validated using the defined structural details to provide an integrated multi-criteria failure analysis that could be accepted by airworthiness authorities.

WP4 – Reliability & sensitivity methods

The objective of WP4 is to deliver numerical tools that will be able to predict the effect of uncertainties on component performance and validate the integration of various types of data necessary to generate an understanding of a given component's characteristics including the uncertainties in materials, loading in a probabilistic sense.