Large scale models for A350

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Abstract*: In order to secure the A350 structural test campaign, the Virtual Full Scale Test project (ViFST) was launched to predict more accurately the behaviour of the aircraft, especially to better handle nonlinear effects (large displacements, plasticity, contact ...). The project covers most of the aircraft structure and brings together teams from 5 countries (Germany, England, Spain, India and France). The presentation will focus on the central model, which is composed of the central fuselage and the two wings. This is the largest model of the project (68 millions of variables). The presentation will detail the particular challenges overcome by Airbus and Simulia teams: - CAD data management - Model build - Model verification - Model runs and calculations management - Methods and tools development to deal with large scale model analysis and secure test campaign*

Keywords*: Aircraft, Assembly Deformation, Composites, Experimental Verification, Postprocessing, Shell Structures, Visualization.*

1. Introduction

For aircrafts, the structural test campaign is necessary prior to major milestones of a development program. It is an essential element of aircraft validation because the results are key to the flight test campaign and aircraft certification. The main objective of a static test campaign is to assess the structural quality of the aircraft by ensuring that the product can withstand all types of loads, stress and impacts.
In order to secure the A350 XWB static test campaign, non linear numerical simulation has been used in the frame of the Virtual Full Scale Test (ViFST) project.

To achieve this goal, non linear simulations of the static load cases have been done with the ViFST models prior to their performance on the real test cell. The results of the simulations were analyzed in order to anticipate any unpredicted issue and to put in place necessary actions to prevent the test planning to be significantly impacted.

In a first section, the ViFST models will be presented, insisting on central model (ES2) mainly. Then, the challenges encountered during the model build and exploitation will be detailed. Finally, an example will illustrate how the ViFST models have succeeded in securing the A350 test campaign.

2. ViFST finite element models presentation

2.1 Introduction

In order to support and to secure the A350 major tests campaign, a set of finite element models has been defined. In total, five finite elements models have been built to represent the major tests (Figure 1).

In these models the test cells themselves as well as the loading devices have been modelled with some simplification in order to allow the simulation of the real load cases.

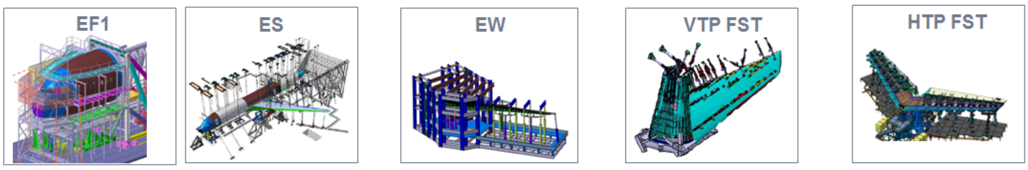

Figure 1: Major tests illustration

In the following sections, focus will be put on the “ES2 model” which is devoted to represent ES test.

2.2 Model extent

The ViFST ES2 model contains (see Figure 2):

- The Centre Fuselage ViFST model, i.e. from frame 38 to frame 74
- The two Outer Wing Box ViFST models
- Other fuselage areas (before fr38 and after fr74) are modelled through condensation of a global model

Figure 2: ViFST ES2 model illustration

2.3 Model general presentation

The overall architecture of the model is consisting in a set of folders containing different model characteristics.
In terms of geometry, an initial clean up has been done. Fillets have been removed in most of the parts, edge corner removed, small holes filled.
The general meshing rules can be summed up as follows (see Figure 2 for illustration):

- Classical shell elements for fuselage area at neutral fibre
- Continuum shell elements in CWB area to cope with wing box modelling principles
- Continuum shell elements in OWB area. 3D elements have been used for some OWB fittings.
- Typical mesh size is about 15-20mm.
- Typical numbers of elements have been given in specific areas/parts to allow for satisfactory representation at level 1 model of basic physical phenomena

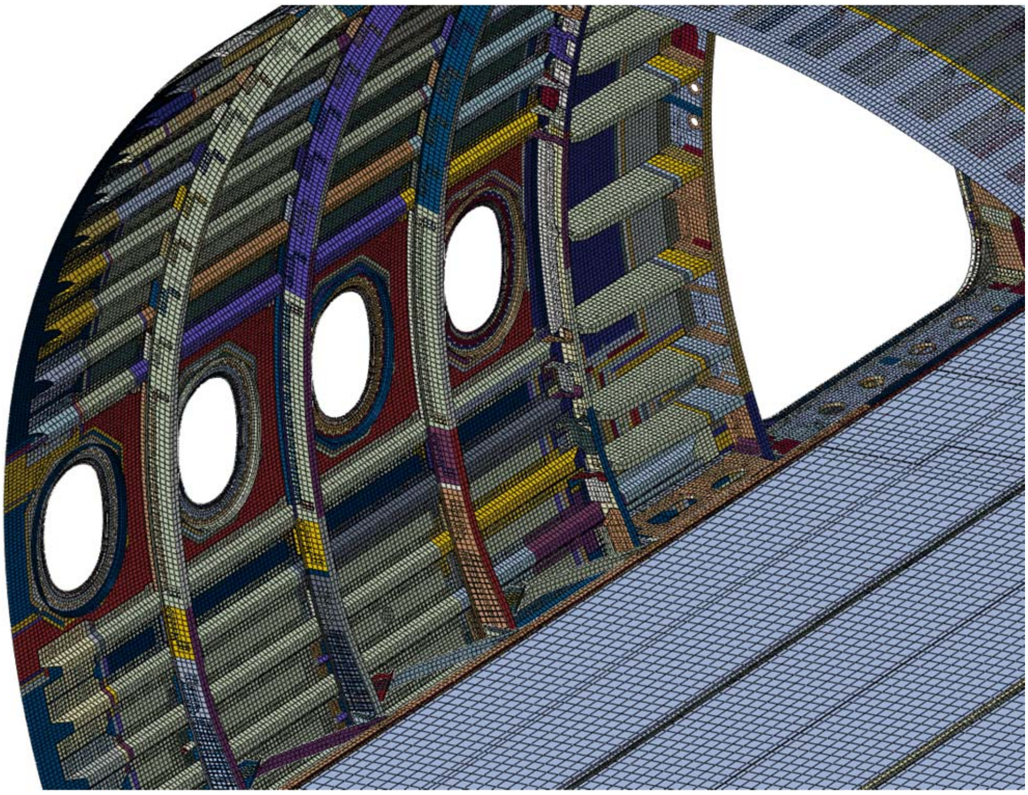

Figure 3: ViFST model mesh illustration

The materials are represented with linear elastic properties.
The interactions between the different parts are tie conditions, except for the window frames that are linked to the fuselage through fasteners without contact.

2.4 Model size

This results in a model with following dimensions (Figure 4):

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                    P R O B L E M   S I Z E

NUMBER OF ELEMENTS IS                                  10852853
NUMBER OF ELEMENTS DEFINED BY THE USER AND *TIE        10852547
NUMBER OF INTERNAL ELEMENTS GENERATED FOR CONTACT           274
NUMBER OF NODES IS                                     14180567
NUMBER OF NODES DEFINED BY THE USER                    14143782
NUMBER OF INTERNAL NODES GENERATED BY THE PROGRAM         36785
TOTAL NUMBER OF VARIABLES IN THE MODEL                 68758158
(DEGREES OF FREEDOM PLUS MAX NO. OF ANY LAGRANGE MULTIPLIER
 VARIABLES. INCLUDE *PRINT,SOLVE=YES TO GET THE ACTUAL NUMBER.)
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Figure 4: ES2 model size summary

3. Challenges associated to the project

3.1 CAD-CAE link and model configuration management

For the model build and follow-up, new processes and tools have been defined.

First, the CAD data has been extracted and tracked robustly before being transferred to the mesh teams: products, parts, materials, maturity…

Then, a first “manual” selection has been done in order to keep in the future model only parts that have significant impact on structural predictions. The data has then been sent to the mesh teams.

Geometry has been prepared, meshed and assigned properties. Each part mesh has been checked individually and as a result, one input file has been created per part. The link with the cad data has been done through an appropriate naming of the model part.

Then interactions have been defined, subcomponent by subcomponent, and checked. The final assembly between the different subcomponents led to the overall model.

A specific architecture, harmonized across the different sites, has been used for the model build. The different input files have been sorted in specific folders in order to ease both the update of the models and their final integration. For ES2, the global architecture is depicted in Figure 5.

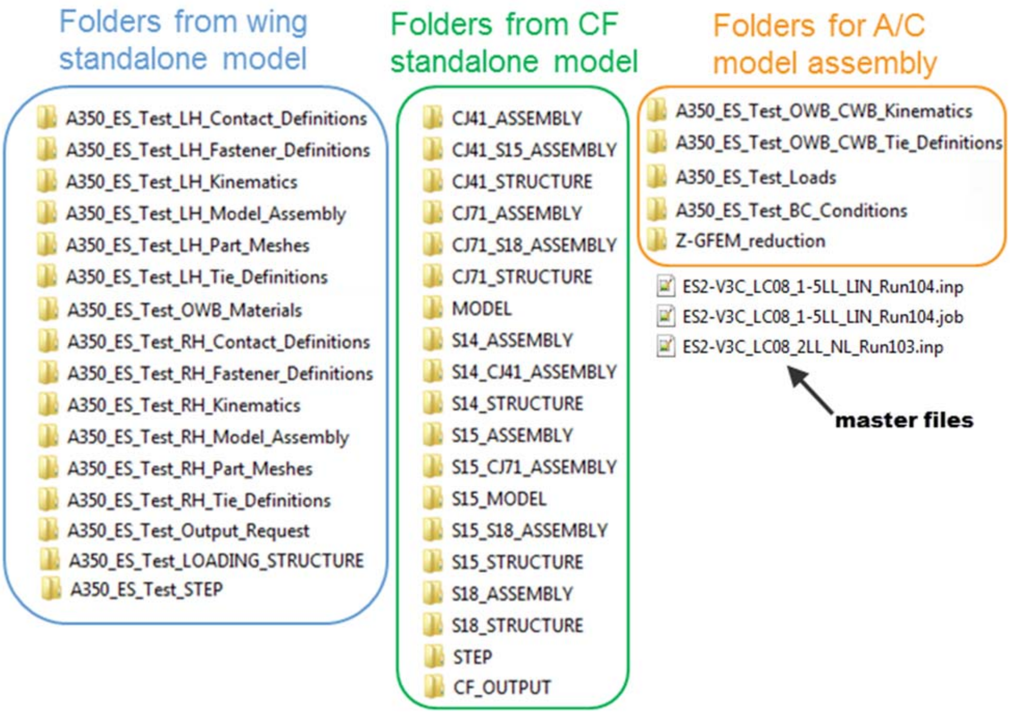

Figure 5: ES2 model constitutive folders (Root folder content)

3.2 Pushing software & IT resources limitations

Due to the total size of the model, some limitations have been encountered (and overcome!) with software and IT resources.

First of all, Simulia provided a specific patch for Abaqus Standard 6.12 in order to deal with the large number of orientations defined in the model. Moreover, through a strong collaboration between Airbus and Simulia, a lot of improvements have been done. In terms of preprocessing the memory consumption has been notably decreased compared to previous versions. Relevant parameters for memory allocation during the runs have been set in order to prevent the computing nodes from crashing.

Inside Airbus, new standards for IT resources have been used: High Performance Computing platform has been put in place as well as high-hand graphical interface tools.

3.3 Developing new methods and tools for model post-processing

The model presented above led to very large output files not manageable with Abaqus Viewer in reasonable times. For example, storing only displacement field at fifteen time points led to a 50Gb odb file. As other data were necessary to allow a complete post-processing (strains, stresses, shell forces, etc…) new solutions had to be defined.

Among them, according to Airbus need, Simulia developed a script that “broke” a big odb file in a set of smaller ones (Figure 6). It allowed to select specific areas (by choosing instances) and selected output data at chosen time points. This provided output files far more manageable and offered the possibility to work efficiently in parallel.

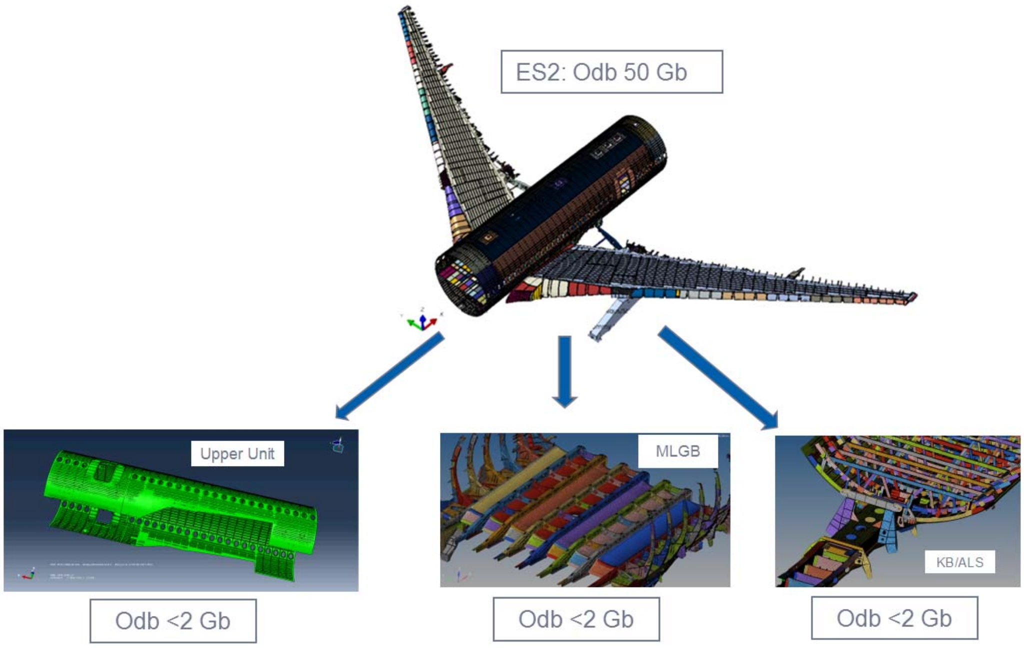

Figure 6: Illustration of the “breakup” tool

3.4 Analyzing results

Analyzing model results has been also a major challenge, particularly considering the time constraints (tight test campaign planning). Indeed, how to screen efficiently such a huge model, being sure not to miss any important thing?

For this purpose, specific features have been introduced in the model (for instance, virtual dummy strain gauges, see Figure 7). Python scripts have been developed in order to help choosing the areas to be deeply investigated first (high bending areas, high strains ones, high non linearity observed…).

Coupled with visual inspection and regular exchanges with specific design teams, this way of working allowed to secure the test campaign as next Section will tend to illustrate.

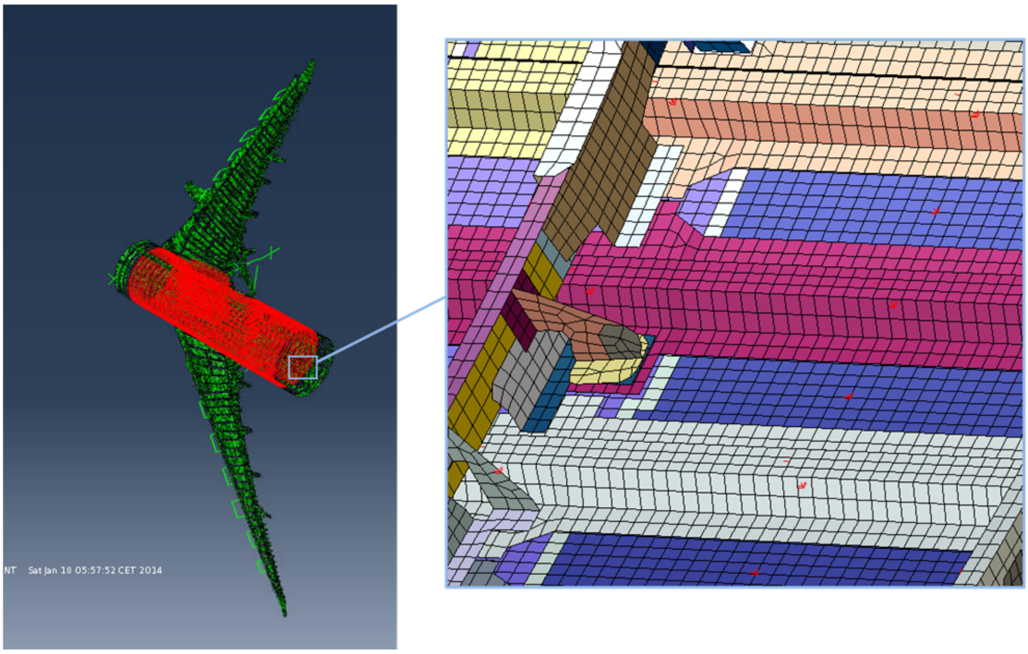

Figure 7: Virtual dummy strain gauges implemented in the model

4. How ViFST participated in securing the test campaign

4.1 Introduction

For confidentiality reasons, the full results given by ViFST model exploitation cannot be given here. However, this section will try to illustrate the benefit of the approach with regards to test securing.

4.2 An example of ViFST finding

For a specific load case where pax floors were highly loaded, ViFST model encountered convergence difficulties. After analysis, it has been found that this was due to floor structure instability under such a loading.

Presenting the problem to the appropriate design work team, new instrumentation has been defined and implemented in the real test cell as well as in the ViFST model in order to be able to monitor strains in the area during the loading. The objective was to see if ViFST prediction was realistic or if it was due to modelling assumptions.

It appeared that the issue highlighted by ViFST initiated during the first application of floor loading case (Figure 8).

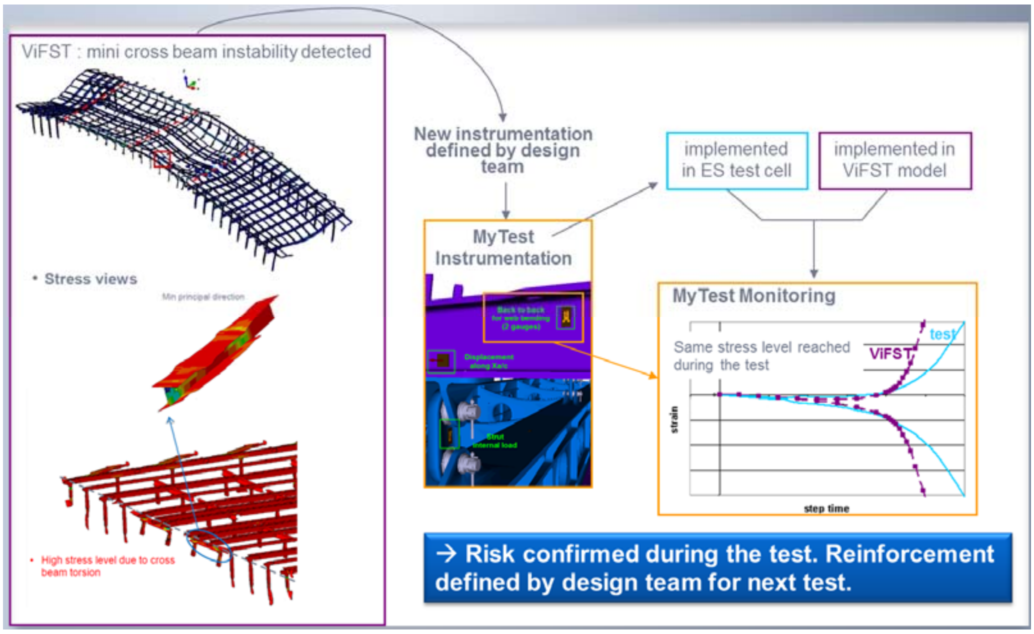

Figure 8: Illustration of ViFST use for securing the test

Then, the design team defined reinforcement for the area to be put in the test cell before the second performance of the case.

The reinforcement solution has been modelled in the ES2 model and a new computation has been launched. After analysis, the reinforcement solution has been proven to be efficient prior to test occurrence.

4.3 Conclusion

Thanks to ViFST finding, the test could be secured. The reinforcement solution has been anticipated so that the test cell has not been broken and the test campaign could follow its initial planning as expected.

A lot of time has been saved compared to the scenario where the problem had not been anticipated.

5. General conclusion

Thanks to IT resources improvement and efficient collaboration with simulation partners, virtual testing is taking a growing place in high-technology industries such as Airbus.

Presenting the Virtual Full Scale Test project, the potential of non linear numerical simulation has been shown. Such an approach is offering a lot of advantages in terms of prediction capabilities, understanding of physical phenomena (even the ones that cannot be physically monitored up to now), etc…

In addition, this project constitutes a great prototype for the definition of the tools of the future. As an example, ViFST experience is being largely considered for the development of next Simulia v6 platform.