ADVANS - A Strategic Collaboration for Airbus to Develop Advanced Numerical Simulation Capabilities

M. Marro, A. R. Ibbotson and J.-M. Delahaye

Airbus Operations S.A.S & Ltd.

Abstract: *Advanced non-linear and vulnerability analyses are used today to support all phases of Airbus aircraft structures, especially the design and certification phases, by providing an understanding and an ever better prediction level of structural behavior. On the A350XWB program, numerical predictions have become key to ensuring a risk free major static test campaign. In the coming years, with the increased number of flying aircraft, the use of numerical capabilities will also grow to help resolve or prevent potential in-service issues. The activity of Virtual Testing and the opportunity to deploy it massively within the Business rely on continuously improving prediction capabilities, e.g. in order to capture the complex failure mechanisms observed in the composite structures, and a reduced lead-time to build and exploit increasingly large finite element models. The "Advanced Vulnerability And Non-linear Solutions" (ADVANS) initiative is a collaboration between Airbus and Dassault Systèmes that targets a real step change in Airbus advanced numerical prediction capabilities by the adoption of the 3DExperience Platform, in end-to-end simulation process integration and aims to provide improved capabilities to handle very large finite element models. From the CAD to CAE process, via the solver and post-processing performance, to the traceability of analysis chain and management of simulation data, several crucial development axes are being investigated in parallel. This initiative strongly supports the Airbus Virtual Testing strategy and the ambition to massively disseminate simulation-based design. This paper presents an overview of selected ADVANS achievements reached so far and perspectives of the future.*

Keywords: *ADVANS, Aircraft, Finite Element Analyses, Non-Linear, Vulnerability, Impact, End-to-End Process.*

1. Introduction

Advanced non-linear and vulnerability analyses are used today to support all development phases of Airbus aircraft structures, especially the design and certification phases (as shown in Figure 1), by providing an understanding and continuously improving prediction of physical structural behavior. Numerical predictions have become key to de-risking major static test campaigns, as demonstrated during the recent A350XWB program.

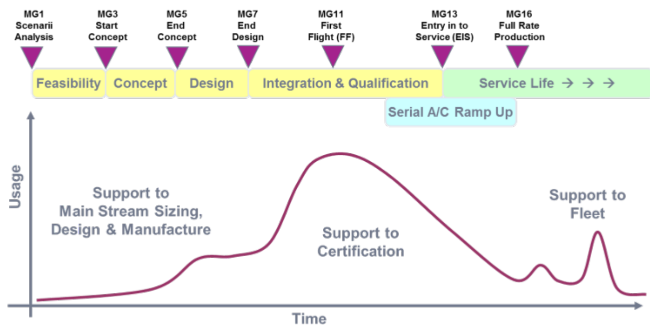

Figure 1: Aircraft lifecycle and usage of NLFEA

In the coming years, the use of advanced numerical capabilities will increase in order to support early aircraft development phases and to assist in the support of the in-service fleet. The development of Virtual Testing and Prototyping relies on continuously improving prediction capabilities, e.g. in order to capture the complex failure mechanisms observed in the composite structures, and a reduced lead-time to build and exploit increasingly large and complex physically based finite element (FE) models.

The “Advanced Vulnerability And Non-linear Solutions” (ADVANS) initiative was developed as a multi-year strategic collaboration between Airbus and Dassault Systèmes to deliver a step change in Airbus numerical prediction capabilities, in end-to-end simulation process integration and to provide improved capabilities to handle very large finite element models.

The foundation of this proposal was the alignment of the development road map for the SIMULIA multi-physics simulation environment with the needs and requirements of large scale non-linear Abaqus simulations within Airbus.

The objective of this paper is to give a perspective of selected ADVANS achievements reached so far and an overview of further challenges.

2. ADVANS scope

ADVANS spans not only the end-to-end non-linear simulation process (as presented in Figure 2), but also the link with the design and physical test environments, as shown in Figure 3:

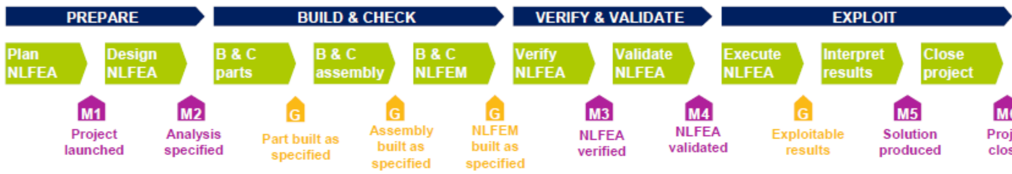

Figure 2: Generic non-linear Abaqus analysis workflow

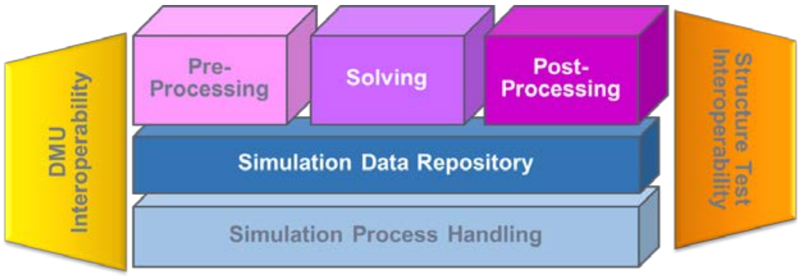

Figure 3: ADVANS scope

Division of the overall non-linear analysis workflow is made in order to allow distribution of development effort into a number of local teams formed between members of the Airbus Non-linear / Vulnerability technical centers and Dassault Systèmes. The efforts of each task team are then integrated into successive releases of the 3DExperience platform.

3. Field of Vulnerability analyses

The role of Airbus Vulnerability team is to analyze, using transient dynamic simulations performed with Abaqus/Explicit, the vulnerability of aircraft structures subjected to crash and high velocity / energy impacts, to provide damage assessment after impact for residual stress analysis, with the final objective to demonstrate the aircraft compliance with safety requirements.

Vulnerability analyses are typically used to cover the following applications:

- Impacts: bird strike, tire debris impact, rim release, hard debris impact, military threats, hail impact
- Crashworthiness
- Specific studies, such as advanced analysis involving complex physics (e.g. fluid / structure interactions): fuel tank sloshing, hydraulic ram effect

Vulnerability analyses support the design and the certification of many airframe structures, as shown in Figure 4.

It should be noted that the Vulnerability team is one of a number of teams making use of advanced numerical analysis to perform simulation of aircraft structures.

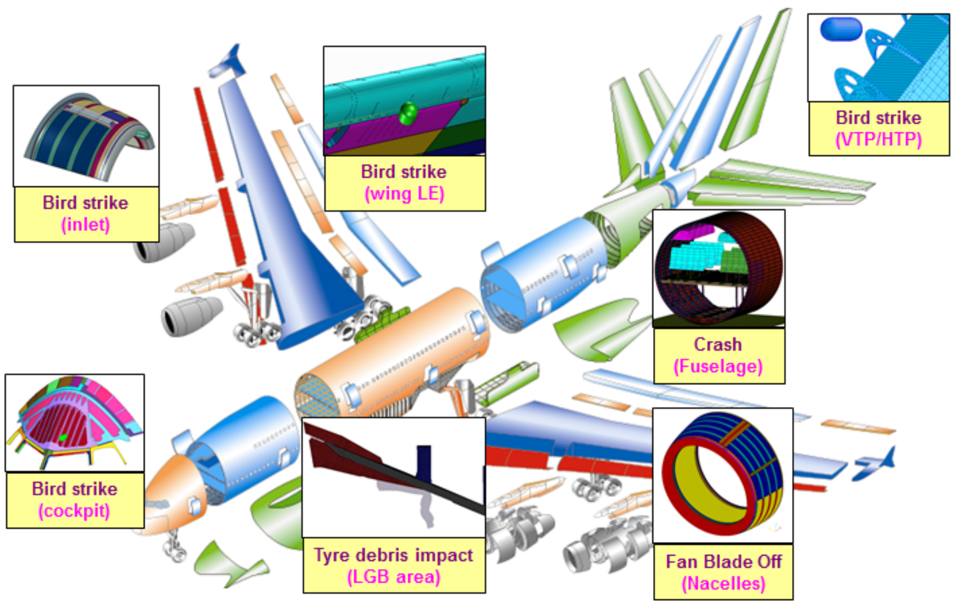

Figure 4: Typical Vulnerability applications

4. Selected ADVANS achievements

The following sub-sections provide an overview of technical achievements reached in the framework of ADVANS. It is important to emphasize that the ADVANS initiative also represents an achievement in terms of cross-organizational collaboration, transnational working.

4.1 Speed-up of FE models creation

Today the creation of finite element models represents an important part of the lead time in our non-linear simulation workflow. One of the main objectives of ADVANS is to provide a framework that will allow replacing laborious manual processes by automated tools. As we exploit increasingly large finite element models, the aim is to speed-up the CAD to CAE process by developing tools allowing automatic extraction of properties from the geometry and mapping them onto the mesh.

For instance ADVANS fosters the development of new tools allowing the automated creation of section property definitions for metallic and composite shell meshed components.

Figure 5 illustrates, for a metallic part, the extraction process of thicknesses from a CATIA geometry and the result of the mapping onto the associated shell mesh.

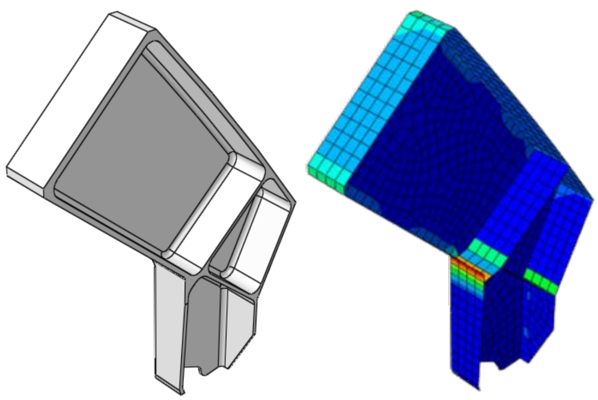

Figure 5: Mapping of metallic section property data to conventional shell meshes

The simulation process lead time is also driven by mesh creation tasks; therefore ADVANS is also focusing on enhancements of meshing capabilities.

The different steps involved in producing a part mesh are:

- De-featuring of the solid geometry by removing fillets and unwanted holes
- Producing surfaces at the mid-solid location
- Meshing the mid-solid surfaces

The objective is to speed up the production of part meshes, starting from a manual process to the ultimate goal of batch meshing with a reduced manual intervention. Preliminary results presented in the framework of ADVANS shows very encouraging results, but further effort is still needed to reach the target of 100% automatic creation of meshes for structural parts.

In the same spirit, the activities performed within ADVANS focus upon replacing the current laborious and long process of fasteners creation for large scale analyses by semi-automated tools that efficiently link the design and simulation environments. As large models can contain several thousand of mechanical fasteners, these tools will drastically reduce the time needed for the creation of fasteners.

Key features are that these tools directly link CATIA V5 geometry with the large scale simulation and the fastener behavior calibration process. The use of such prototypes allows the communication of needs and requirements to the development of the 3DExperience Platform.

Figure 6 illustrates the integration of the plugin into the Abaqus/CAE “Plug-ins” tab and the visualization of the fastener locations prior to the actual instantiation.

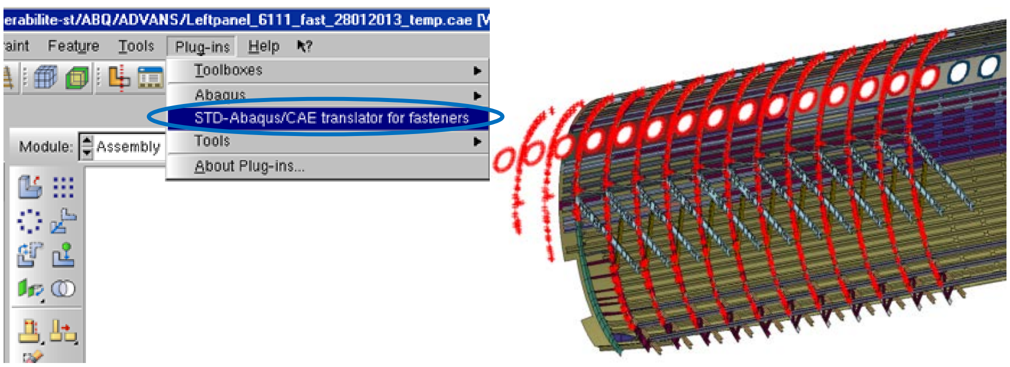

Figure 6: Abaqus/CAE plugin for fastener creation

The objective of ADVANS is to take benefit of the new 3DExperience platform and combine all these new technologies into a single server based and application driven framework.

4.2 Solver improvements

Prior to the formation of ADVANS, solver development has been a topic for collaborative exchanges. ADVANS has accelerated these developments by allowing closer team working and detailed sharing of needs and requirements.

4.2.1 Improvement of Abaqus pre-processor performance

The need to increase the pre-processor performance was key to support the build phase of very large implicit and explicit A350XWB FE models, as shown in Figure 7.

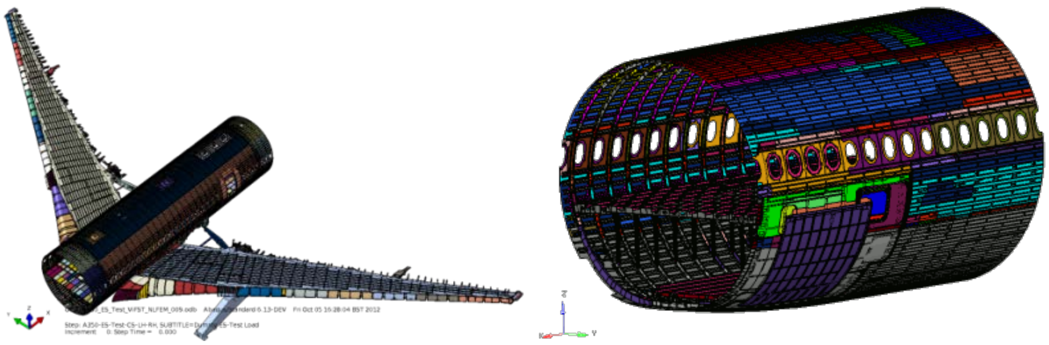

Figure 7: A350XWB Non-linear and Vulnerability FE models

The iterative approach developed between Airbus and Dassault Systèmes to understanding and resolving bottlenecks in the pre-processing task led to a significant improvement in the overall performance of the pre-processor spanning across a number of **general releases** of the solver.

Figure 8 presents the pre-processor performance increase from Abaqus version 6.10 to version 6.13 based on a simplistic, variable-sized model, using performance characteristics representative of airframe models:

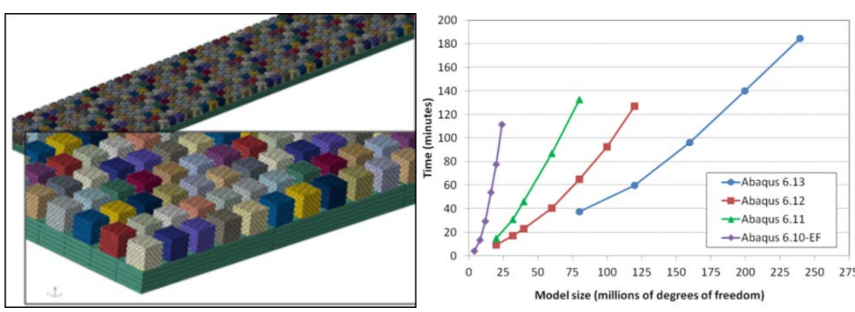

Figure 8: Improvement of pre-processor performance for Abaqus releases

The effort to enhance the capabilities of the pre-processor was vital for the success of Virtual Testing strategy implemented in A350XWB development. Further pre-processor improvements are currently investigated to extend previous benefits to the whole simulation process.

4.2.2 Smooth Particle Hydrodynamics (SPH) feature for bird modeling

With the traditional Lagrangian bird modeling approach, it is usually difficult to accurately simulate the spread of the bird after impact, especially when the bird is split into several pieces. This can lead to the use of conservative assumptions when considering secondary impacts on the structure. This conservatism becomes a real obstacle when searching for the lightest structural solution; therefore it is important to be able to capture the complete sequence of events during a bird impact.

A key benefit offered by the new SPH feature (available in Abaqus v6.12 and on onwards) is the ability to better simulate bird / structure interactions involving very large mesh deformations. Typical examples of such events are bird slicing during the primary impact event and the prediction of damage resulting from secondary impacts.

Development of the SPH feature during ADVANS involved significant effort within Dassault Systèmes SIMULIA to mature the SPH capability to the point at which predictions of structural behavior could be compared to a series of physical benchmarks tests, as presented in Figure 9 to Figure 12:

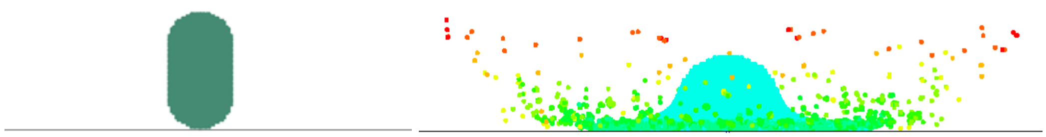

Figure 9: Bird strike on a rigid flat plate

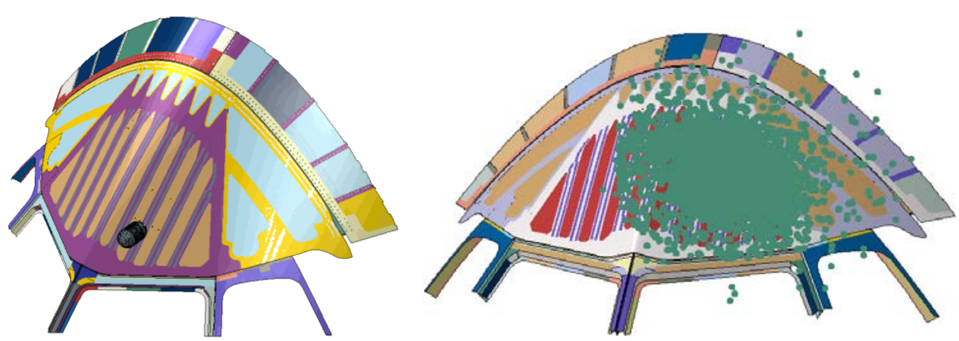

Figure 10: Bird strike on a cockpit frame structure

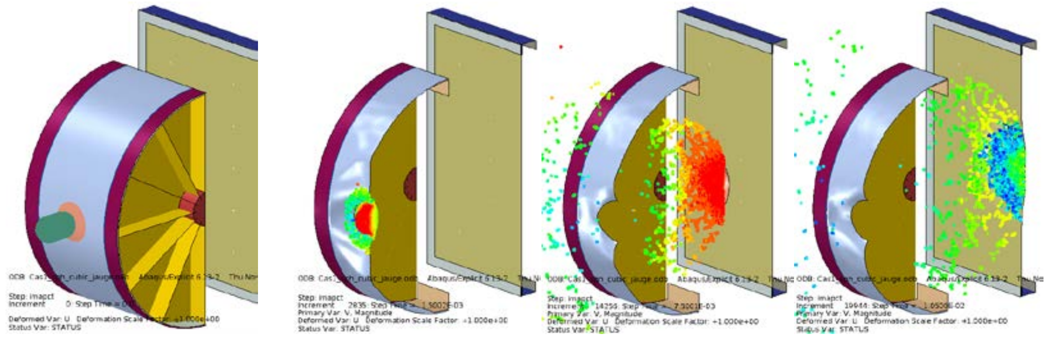

Figure 11: Bird strike on a weakened curved panel followed by secondary impact

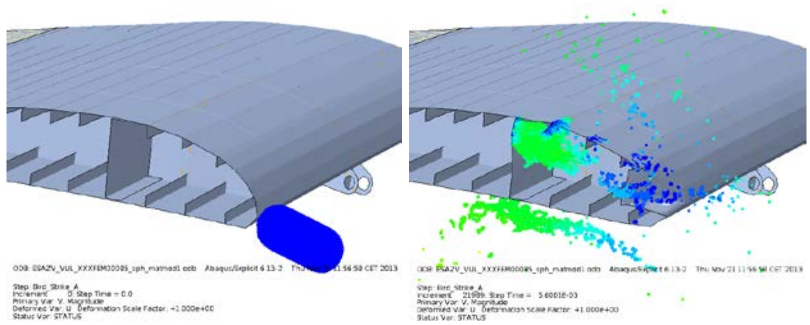

Figure 12: Leading edge impact involving complex failure mechanisms

As presented above, first simulations performed with the SPH feature gave very promising results, but further investigations are still on-going within the framework of ADVANS to industrialize this feature.

4.2.3 Multi-scale approach for Vulnerability analyses

A fundamental requirement of dynamic explicit analyses within the Airbus Vulnerability team is the ability to make detailed predictions of localized damage and failure for large sections of aircraft structure, especially for composite materials.

The nature of the dynamic explicit analysis procedure is not conducive to the approach of multi-scale analysis by means of successively refined sub-models. Therefore, in order to perform explicit dynamic analyses of large sections of structure, a means must be found to embed detailed damage and failure simulations into a large numerical simulation.

One “brute force” approach is to construct a very large and detailed analysis and then solve this using a very large and powerful supercomputer. Clearly, this is inefficient and a more intelligent method can be proposed.

Research work funded by Airbus and performed in collaboration with LMT Cachan [1] seeks to address the above issue by coupling an adaptive meso-scale damage and failure model to a large macro-scale analysis, as shown schematically in Figure 13.

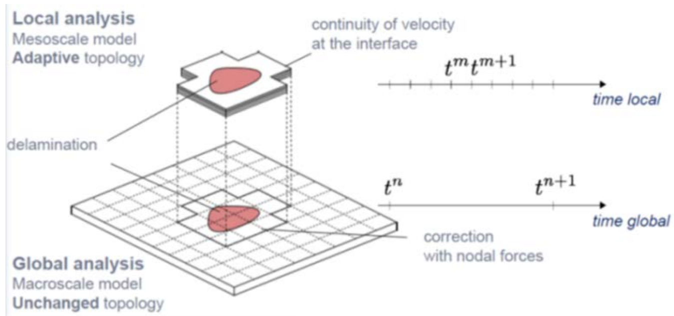

Figure 13: Schematic diagram presenting the concept of multi-scale analysis for Vulnerability applications

The effort within ADVANS is to bring together the research work performed previously with key developers within Dassault Systèmes [2] in order to access the viability of integration with core code features.

4.3 Post-processing enhancements for large models

The use of very large models and the need to analyze in detail complex structures made of numerous composite plies generates not only numerically heavy finite element models but also huge output files (10's – 100's Gb).

Enabling successful simulations and post-processing of aircraft-scale models allows analysts to avoid making boundary condition assumptions of portions of an assembly that are not part of the simulation, because all significant structural components and physical behaviors are included in the simulation. Furthermore, viewing simulation results in the context of full assemblies, allows engineers to better understand complex structural behavior involving complex interactions and load paths between subassemblies.

Manipulating and exploiting such result files was a real challenge for the A350XWB program and the need to fulfill the certification requirements, de-risk the static test campaign and allow for first flight clearance on time. To achieve this, a high-performance visualization tool was needed.

ADVANS enabled the installation and deployment of the V6R2013X Exsight Multiphysics Results Visualization tool within Airbus computing infrastructure.

The use of this new tool allowed finalizing the build of important A350XWB finite element models and saving time during post-processing phase.

Figure 14 to Figure 16 show some images of A350XWB Non-linear and Vulnerability FE analyses post-processed using the V6R2013X Results Visualization tool.

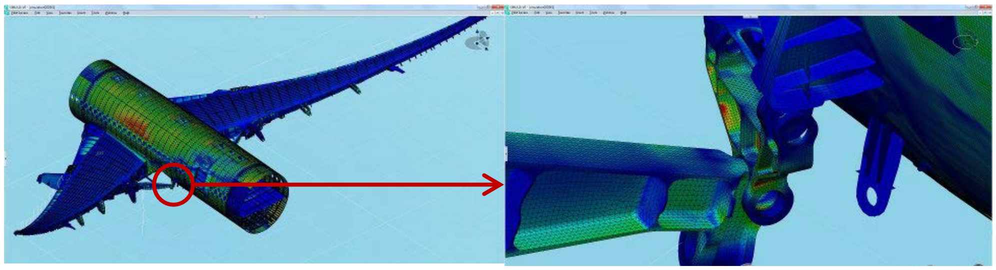

Figure 14: Display of very large A350XWB Non-linear FE analysis

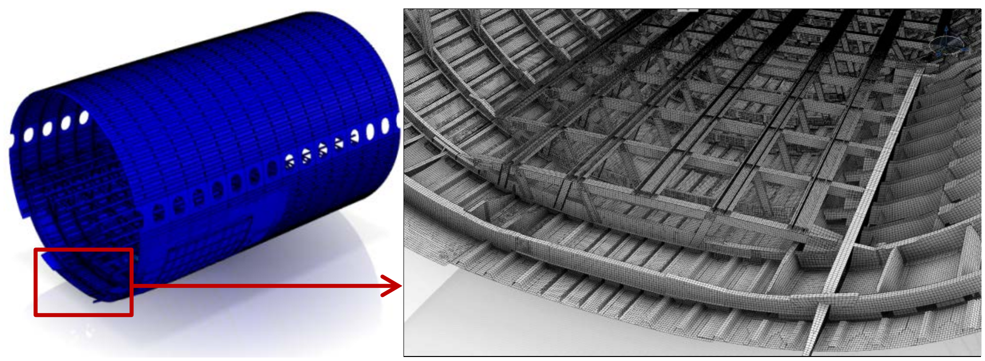

Figure 15: Display of large A350XWB Vulnerability FE model

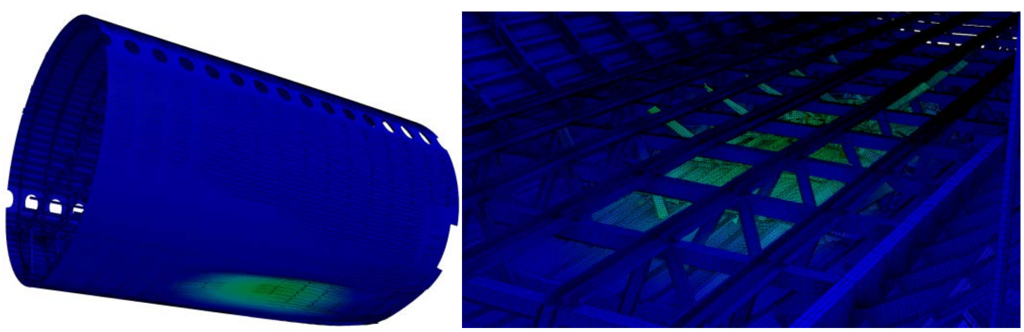

Figure 16: Display of large A350XWB Vulnerability FE analysis

5. Conclusion

For Airbus Non-linear and Vulnerability teams, the ADVANS initiative represents the start of a long term program of change.

ADVANS aims to deliver a real step change in Airbus advanced numerical prediction capabilities, in end-to-end simulation process integration and to provide improved capabilities to handle very large aircraft finite element models.

ADVANS strongly supports the Airbus Virtual Testing strategy and the ambition to massively disseminate simulation-based design.

Numerous achievements have been made up to now: new CAD to CAE functionalities, improved pre-processor and solver performances, very promising SPH feature and new high-performance visualization tool. From a human point of view these achievements were accompanied by efficient collaborative working and cross-organizational teams, representing a solid foundation for the future.

Further ADVANS challenges target all aspects of the non-linear finite element analysis, including the traceability of analysis chain and management of simulation data, as well as improved meshing capabilities, as proposed by the Dassault Systèmes 3DExperience Platform.

The advantage of the 3DExperience Platform is to combine well known technologies currently available to Airbus – CATIA, Abaqus non-linear finite element solvers, Isight, ENOVIA… – and new Apps into a single server based, application driven framework. This server based framework provides close association between design and simulation processes and offers the potential to expand and encompass the Airbus Non-linear and Vulnerability activities.

6. References

1. C. Dupleix-Couderc, « Vers une analyse multi-échelle des grands délaminages en dynamique transitoire », PhD Thesis - LMT Cachan
2. O. Bettinotti, O. Allix, B. Malherbe, V. Oancea, “Towards a weakly intrusive space-time multi-scale strategy for the prediction of delamination under impact”, CFRAC 2013

7. Acknowledgement

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