INFLIGHT SAFETY EXPERIENCE

Aerospace Electromagnetic Compatibility Analysis

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At Dassault Systèmes SIMULIA we offer the necessary solutions for aerospace electromagnetic compatibility analysis in a collaborative environment. Our Virtual Twin Experience could even pave the way towards virtual certification.

EXECUTIVE SUMMARY

Electromagnetic hazards pose a serious threat to aircrafts and their safe operation, requiring OEMs to engage in a long, complex and challenging process to protect them. Electromagnetic simulation analysis, enabled by Dassault Systèmes SIMULIA, offers a path towards saving costs and time in aircraft design while maintaining the necessary high standards of safety required by international authorities. Using the **3D**EXPERIENCE EMC workflow, OEMs can utilize virtual twin experiences that reliably predict aircraft performance while promoting collaboration throughout their organization.

THE CHALLENGE OF ELECTROMAGNETIC HAZARDS

Safety is the priority when designing any aircraft. From commercial airliners to eVTOL to military aircraft, the consequences of any fault can be disastrous. As a result, regulators, crews and passengers rightly demand the highest standards from manufacturers to ensure confidence in their aircraft's performance. However, meeting those standards can be a time-consuming, expensive process, with any errors driving up costs significantly.

Figure 1: Aircraft in a lightning event.

Among the many factors that must be considered are electromagnetic (EM) hazards as lightning in Figure 1, which can degrade aircraft's electrical systems functioning and endanger their safe operation, with potentially catastrophic results. International authorities such as the FAA and EASA therefore require aircraft OEMs to protect aircraft against lightning [1] and the High Intensity Radiated Fields (HIRF) of strong radio transmitters near airports [2]. For military aircraft, even additional hardening against EM Pulses (EMP) is required [3].

Protecting aircraft against EM hazards is a complex, challenging and time-consuming task. The use of lightweight materials such as Carbon Fiber Reinforced Polymer (CFRP) together with the trend towards all-electric aircraft adds an additional layer of complexity. CFRP structures offer significantly less shielding than aluminum and require additional protection against EM hazards without sacrificing the lightweight benefit.

TOWARDS VIRTUAL AIRCRAFT CERTIFICATION

Aircraft certification for EM hazards can be accomplished by testing, analysis and similarity [1, 2, 3]. Currently, aircraft testing is usually the preferred method to demonstrate compliance with international standards. Still, this requires a real aircraft or a full-scale mockup of a part if it is being tested individually. This restricts aircraft testing to the final development stage, the "certification" of an aircraft program. Solving any issue at this late stage can be extremely expensive, given that major design changes could be required. On the contrary, EM simulation analysis, as in Figure 2 can be deployed over an entire aircraft development program from concept to certification. Still, it requires building confidence in EM simulation analysis among OEMs and international authorities.

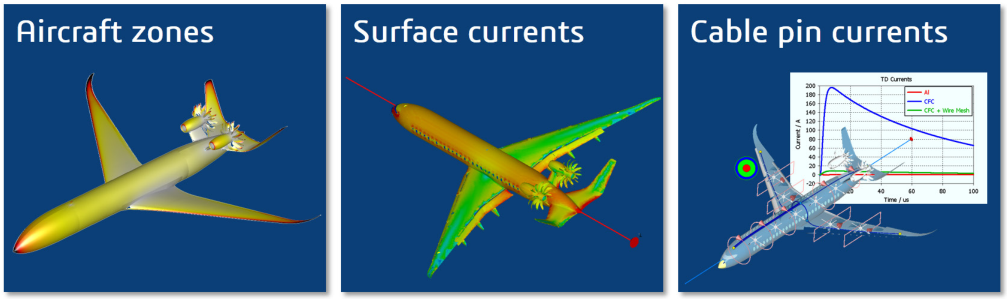

Figure 2: Simulated aircraft lightning responses.

While there is still a long way to go, aircraft OEMs have already started investigating electromagnetic (EM) simulation for certification [4, 5]. A first step towards simulation for certification is the combination of physical testing and EM simulation, as described in [5]. Ground testing is combined with EM simulation of in-flight scenarios in that approach to pass from on-ground to in-flight conditions. The link is established by measured and simulated surface currents on external aircraft, which are assumed to be linearly related to aircraft cable currents and internal fields. This approach avoids the need to deploy complex test set-ups to mimic in-flight conditions and reduces simulation uncertainties due to the complexity of real aircraft, which are made of many parts and a diversity of materials with often insufficient electrical characterization. In contrast, surface currents on external aircraft can be simulated with limited effort and sufficient accuracy.

The ultimate goal for EM simulation analysis is, of course, to replace necessary certification tests, to save cost and time. To achieve this, validated aircraft models are required to predict aircraft performance when exposed to EM hazards reliably. Physical testing will still be deployed, but more for model validation than certification. Once an aircraft model is fully validated, it could be used in the certification process similar to its physical counterpart.

In the author's opinion, the solution for virtual certification could be Dassault Systèmes' virtual twin experience [6, 7]. The continuous flow of information between the virtual and the real and vice versa allows well-controlled and validated models to predict aircraft performance virtually.

THE ELECTROMAGNETIC COMPATIBILITY WORKFLOW

At Dassault Systèmes, we offer solutions for aerospace electromagnetic compatibility (EMC) analysis in a collaborative environment, the **3D**EXPERIENCE® platform. This includes ENOVIA Product Life Cycle Management, CATIA Modeling and SIMULIA EM simulation. Our virtual twin experience, paired with modeling & simulation (MODSIM) could be the catalyst for virtual certification in aerospace and defense.

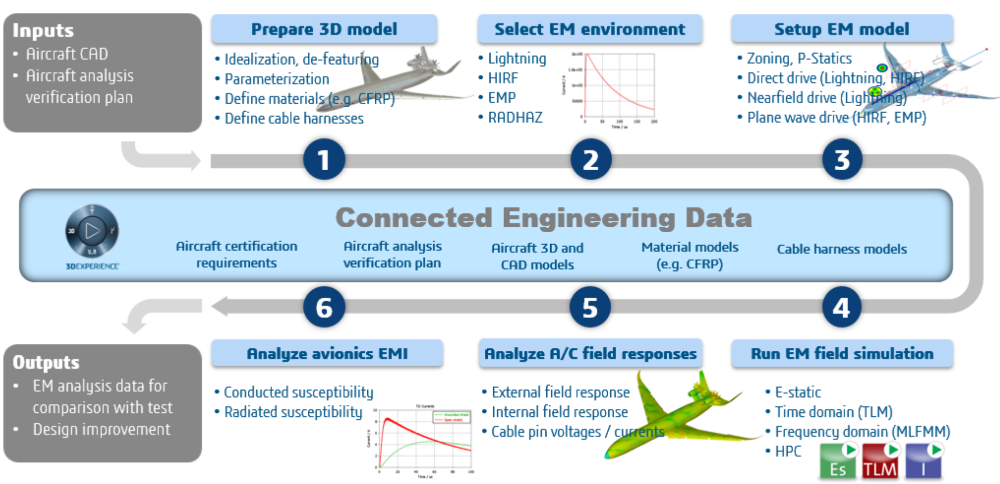

Figure 3: **3D**EXPERIENCE EMC workflow.

The **3D**EXPERIENCE EMC workflow [8] in Figure 3 goes beyond the established workflow of pre-processing, electromagnetic simulation, and post-processing in the SIMULIA CST Studio Suite [9], a high-performance 3D electromagnetic analysis software package for designing, analyzing, and optimizing electromagnetic components and systems. With **3D**EXPERIENCE analysis, OEMs will benefit from the ability of virtual twin experiences to reliably predict aircraft performance in SIMULIA CST Studio Suite and the capacity to share results among peers and even with certification authorities such as the FAA and the EASA.

The EMC workflow for EM hazard analysis in Figure 3 has six steps. The workflow starts and ends with input and output data in **3D**EXPERIENCE that the digital thread has established. All project data is stored in a collaborative space that defines a single source of truth and is accessible everywhere and at all times by project members. For the initial step, "Prepare 3D model", native platforms are deployed for model idealization and de-featuring, material assignment and cable harness topology definition.

In the second step, "Select EM environment", an EM environment of the EM hazard under consideration is selected. Standardized EM environments are specified for lightning in SAE ARP 5412B [10], for HIRF in SAE ARP5583A [11], and for EMP in MIL-STD-464D [3]. These specifications should, of course, be accessible in the previously mentioned collaborative space.

A simulation model is set up in the third, "Setup EM model" step. The CAD model prepared in the initial step is imported into SIMULA CST Studio Suite and the cable harness topology is populated with cable cross sections. Different simulation scenarios for zoning, lightning, HIRF and EMP are prepared. For instance, a direct drive could be required for a lightning simulation, while for HIRF and EMP, a plane wave drive is necessary. In addition, field, current and voltage monitors, boundary conditions and the mesh are defined in this step. In step four, "Run EM field Simulation," electromagnetic solvers are used calculating field responses to EM hazards. For zoning analysis, the electrostatic solver is chosen [12], while for lightning, HIRF and EMP analysis SIMULIAs Transmission Line Matrix (TLM) time domain is recommended [9]. Also, the frequency domain MLFMM solver might be of interest for some cases, especially for HIRF analysis. In general, large-scale problems with millions of unknowns need to be solved, which may benefit from high-performance computing capabilities to reduce simulation time. For that purpose, Dassault Systèmes even offers the **3D**EXPERIENCE cloud for sustained and burst compute.

In the fifth step, "Analyze A/C field responses", external and internal aircraft field responses and cable pin voltages and currents are analyzed. As explained in [13], the EM threads to aircraft electronics strongly depend on frequency. In the frequency band from 10kHz to 50MHz, cable pin voltages and currents are mostly affected by EM hazards, while in the high-frequency band from 100MHz to 18/40 GHz the EM threat comes from strong field amplitudes inside of aircraft. In the medium frequency band from 30MHz to 400MHz, the EM threat is a mixture of both. Lightning is a threat located in the low-frequency band, therefore, the related analysis mostly targets cable currents.

Finally, step 6, "Analyze avionics EMI", concerns the conducted and radiated susceptibility analysis of aircraft electronics. To the author's knowledge, comparing the electronics' EMC specification and the level of EM threats they might be exposed achieves this. The field and cable current levels calculated in the previous step are EM threats. In case of failure, relocation of electronic equipment or further shielding might be necessary.

CONCLUSION

There remains a long way to go to reach the goal of EMC analysis fully replacing certification tests. However, by using the solutions offered by Dassault Systèmes SIMULIA, the considerable costs of physical testing can start to be reduced. The **3D**EXPERIENCE EMC workflow provides all the tools necessary for aircraft OEMs to begin exploring simulation as an effective tool within their design processes. With the reliable results and demonstrable savings this will produce, confidence can start to be built among OEMs and international authorities regarding the efficacy and efficiency of EM simulation, paving the way to increase adoption in aircraft design processes across industries.

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