SIMULIA

3DEXPERIENCE®

ACCELERATING INNOVATION IN AEROSPACE

Improve integration of simulation across the aircraft development process

DASSAULT SYSTEMES

THE CHALLENGE OF CHARTING NEW COURSES IN AIRCRAFT DESIGN

Aerospace & Defense (A&D) is an industry built on innovation, from the first powered flight more than a century ago to the novel aircraft designs emerging today. New forms of air transport, such as eVTOL (electric vertical take-off and landing) air taxis, are changing the mobility landscape. At the same time, A&D manufacturers are striving to meet growing demand for low-emission, low-noise aircraft concepts. Complexity is increasing as aircraft design moves into uncharted territory, where design teams can no longer rely on experience gained from previous programs.

In keeping with this spirit of innovation, A&D has pioneered the use of simulation in its development processes. This was the first industry to make productive use of finite element methods and computational fluid dynamics. In recent decades, those capabilities have expanded to include non-linear structural analysis, unsteady aerodynamics, aeroacoustics, vibroacoustics, multi-body dynamics and electromagnetic simulations. And as aircraft development becomes more complex, the need for an efficient, agile, simulation-driven development cycle grows.

This presents a challenge for A&D companies because in many cases, simulation has not yet fully delivered on its promise. Siloed systems and knowledge are one of the main reasons. Design and engineering teams work in separate environments, communication between teams may still depend on emails, phone calls and files-based data exchange, and usage of simulation tools still typically depends on subject matter experts whose knowledge is not widely documented or accessible to a broader user community. As a result, inconsistencies and inefficiencies occur, contributing to late-stage failures and delays that cost billions of dollars.

And yet simulation is the only efficient way to assess every aspect of how those new aircraft will perform. There is also huge potential for A&D firms to reduce flight testing by using simulation data in the certification process. So, how can these organizations make sure that simulation delivers the speed, flexibility and traceability they need?

The answer is better integration of simulation data and processes. By creating a digital thread throughout the development cycle, A&D firms can move towards a seamless modeling and simulation (MODSIM) approach and improve collaboration, governance and management of data and processes.

THE PROMISE OF MODSIM

MODSIM begins with unifying modeling and simulation data on a single platform. But this is only the start of the journey. On Dassault Systèmes' **3DEXPERIENCE**® platform, this harmonization of tools and processes is supported by automation, design space exploration and knowledge capture capabilities that dramatically accelerate the efficiency of simulation-driven design. Crucially for A&D companies, this integration includes both virtual and physical test data—making it possible to connect these processes in a way that is fully traceable with optimal governance.

A MODSIM approach brings together people, processes and best-in-class tools to automate design and simulation process and data management, geometry clean-up and simulation model building, from individual parts to entire aircraft models. Designers, simulation analysts and test engineers work together on the same data model, providing a single source of truth throughout the entire development process, and ensuring that every insight contributes towards the quality of the final product. As a result, it is easier to manage and reuse product data, increasing its value across the organization. In addition, every decision, part and process is traceable, so A&D companies can optimize governance at every step.

This level of integration effectively left-shifts the simulation process so that designers can explore and validate their ideas early in the development cycle. Automated processes and templates remove the dependence on siloed simulation experts and allow designers to quickly build models and create realistic, multi-physics simulation set-ups so they can identify and resolve issues early on. As a result, A&D organizations can accelerate innovation and reduce late-stage risks, cutting development time from months to weeks, and from weeks to days.

But one key challenge remains. Achieving the MODSIM vision requires a complete, enterprise-wide digital transformation. Doing it all at once just doesn't work for aircraft manufacturers who cannot afford to completely disrupt proven development processes built on decades of company experience.

For many A&D organizations, a better approach is to break that transformation down into manageable steps that create a customized path towards MODSIM. The **3D**EXPERIENCE platform empowers A&D firms to do that by putting in place the key enablers for MODSIM in a way that best suits their business needs. By beginning to incorporate MODSIM into their development processes now, organizations can realize immediate value while plotting a smooth, manageable path towards fully connected aircraft design and simulation.

KEY ENABLERS FOR MODSIM IN A&D

Let's look at those key enablers in more detail, and how A&D organizations can put them into place.

Simulation Process and Data Management

By harmonizing modeling and simulation data in one place—the **3D**EXPERIENCE platform—A&D organizations can create a single source of truth across the development cycle. This approach, called Simulation Process and Data Management (SPDM), includes native and non-native data formats, so A&D companies can manage data from simulations and physical tests in a transparent and traceable way. In addition, established legacy simulation tools can be seamlessly integrated.

By exposing data relationships, SPDM makes it possible to improve the traceability, recovery and reuse of simulation data and boost the collaboration around it. Aircraft development teams can bring together multiple disciplines to configure, submit and monitor modeling and simulation jobs in one place. This means knowledge and experience can be captured, shared, exposed and stored for future reuse. This is made possible using flexible data attribution and contextualization, which support streamlined management of content across its lifecycle. As well as making its content more easily searchable and visualizing it in an optimal way for different stakeholders, the organization can create simulations that include instructions, how-to guides, lessons learned and workflow automation.

If data management is one side of the SPDM coin, process governance is the other. By closely integrating simulation activities with requirements, schedule and resource management, this approach creates a digital thread across the ecosystem. Planning simulation processes is made easier, with visibility of the data thread pedigree helping to reduce any uncertainty. Meanwhile, change management can be greatly enhanced by the ability to directly report issues and capture the routes of decisions, reviews and approvals. For validation and certification processes, a dashboard can be used to create and access simulation studies, including insights such as how the simulation is performed, how to include best practices and lessons learned, the reference data consumed, review status, input changes and whether reassessment is needed. At the product and program management level, dashboards can also be used to manage lifecycle and validation requests and approvals—providing a view of the who, when and why involved and the contexts of any changes.

Once their data and processes are connected, organizations can explore many ways to optimize and enhance their aircraft development using simulation. Crucially, this level of integration can be used to make traceability and governance an integral part of the process—enabling a better understanding of risks and uncertainties, and more confident decision-making.

ASKA has developed the world's first viable Drive & Fly electric vertical takeoff and landing (eVTOL) aircraft on the **3D**EXPERIENCE platform. Click here to watch a video about their journey

Cloud

Switching to the cloud for simulation is a key step for A&D companies to achieve the full promise of MODSIM. Without it, the collaborative, multi-discipline high-performance computing (HPC) needed for aircraft development is much harder to achieve and manage. However, a full move to the cloud is not the right approach for every organization—and even if it is, such a comprehensive overhaul can seem daunting. But that doesn't exclude those companies from the advantages of simulation in the cloud.

Dassault Systèmes empowers organizations to shift to the cloud gradually, in the way that suits them best—whether that entails a full shift or a hybrid approach alongside on-premise infrastructure investments. Its POWER'BY solution enables customers using on-premise HPC solutions to benefit from the **3D**EXPERIENCE platform with minimal investment. They can run

non-platform products in the **3DEXPERIENCE** environment and take advantage of its features, including collaboration, data management and on-demand cloud execution, which are essential for competitive aircraft development.

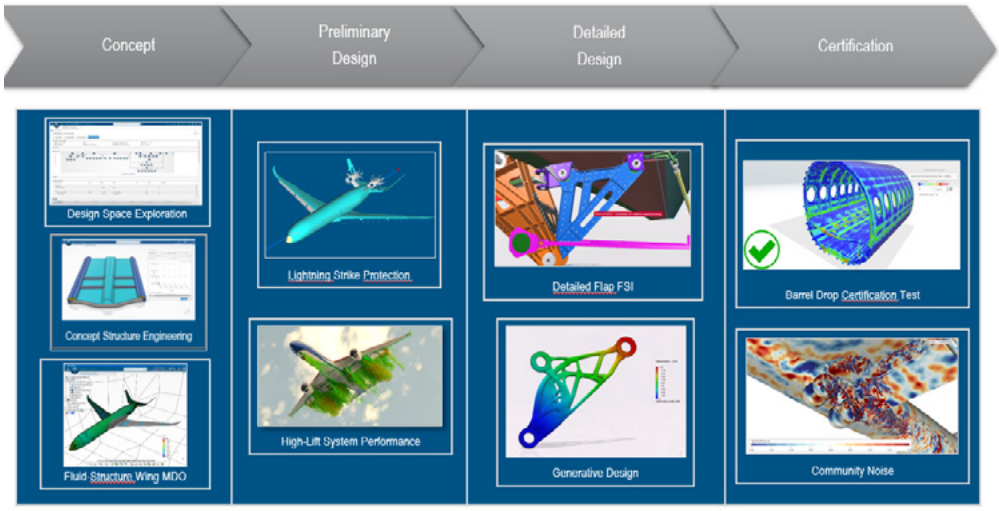
As a result, A&D firms can put in place an essential building block for MODSIM in their development processes. They can experience the cloud on their own terms and decide if and when they want to make a full switch.

> "For me, the cloud platform concept makes it easy to add new tools and packages as we require them depending on the projects we take on. That flexibility is really impressive."
>
> Florian Bucher, Head of Design and Production, HeliAir

Click here to learn about HeliAir, an Austrian company that transforms standard helicopters into medical emergency centers using the self-developed interior concept KOKON, designed on the **3DEXPERIENCE** platform on the cloud. HeliAir plans to extend its use of the **3DEXPERIENCE** platform and is evaluating how it might take advantage of SIMULIA's simulation capabilities.

MODSIM THROUGHOUT THE AIRCRAFT DEVELOPMENT PROCESS

Established manufacturers and startups alike are focused on developing new aircraft architectures to meet emissions and efficiency goals. Their projects range from alternatives to the traditional tube-and-wing construction of large commercial aircraft, to new concepts like the eVTOL air taxi. These novel concepts are completely untested, so there's no institutional knowledge available to predict their performance. But it's increasingly important to understand that performance, and capture the complex, non-linear effects that drive aircraft behavior, as early as possible in the design cycle.



MODSIM on the **3DEXPERIENCE** platform enables increased use of simulations in all development phases with consistent modeling approaches and clearly defined hand-offs of models from one phase to the next.

MULTI-DISCIPLINARY OPTIMIZATION IN THE CONCEPT DESIGN PHASE

Traditionally, the aircraft concept design phase lacks the scope for the high-fidelity structural, aerodynamic and other analysis that make this early-stage understanding possible. But A&D companies that can bring these processes into the concept phase are able to explore a much broader design space early on, with confidence that they're going to make the right decisions.

This phase is a good starting point for A&D companies to use integrated simulations on the **3DEXPERIENCE** platform. It brings unique simulation capabilities with appropriate levels of fidelity and fast turnaround times needed to explore a wide range of design alternatives.

Structure and Aerodynamics

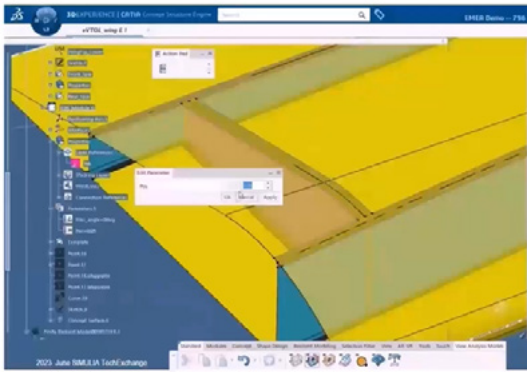
For example, by adding the capabilities of the Concept Aircraft Aerodynamics app, **3DEXPERIENCE** platform users can optimize the aerodynamic performance of their aircraft concept designs.

Different parameters, including relevant structural aspects and aerodynamic targets like drag and lift, can be used alongside other inputs and outputs to build a design study. Users can then evaluate the results against defined objectives, look at the contributing factors and select the best alternatives to meet their overall requirements.

The designer can see how each alternative will behave aerodynamically, alongside the associated weight requirements to support that aerodynamic shape. This allows them to trade off the different requirements and move quickly and confidently towards an optimal shape for their aircraft concept.

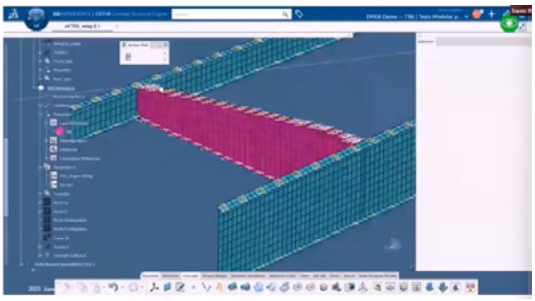
This combined way of looking at aerodynamic and structural aspects is of particular interest to organizations like eVTOL companies, which are looking at big variations in aircraft shapes.

Next, the designer uses the Concept Structure Engineering application to build up the modules of the wing and parameterize them according to geometric and material constraints.

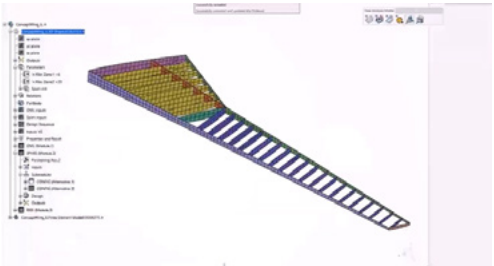


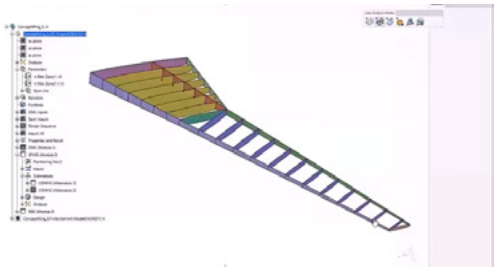
In this example, the rib is connected directly to the outside surface of the wing, to the spar and so on. The connections between the modules have been defined, and the model maintains these connections as the rib is moved back and forth to find the best position.

Once the full wing is constructed, the designer can quickly change the parameters or topology of the wing—in this example, the number of ribs in the outer section is altered. Automatically, this new wing is immediately constructed and meshed, ready for simulation.



A finite element mesh is automatically generated, ready to simulate.





"We created very large simulation models based on the CATIA design information and performed full-scale, nonlinear structural simulations."

"With SIMULIA, we transitioned from an approximate, linear analysis approach to a more accurate, nonlinear analysis, which gives us a deeper understanding of how the structure really performs in a given situation."

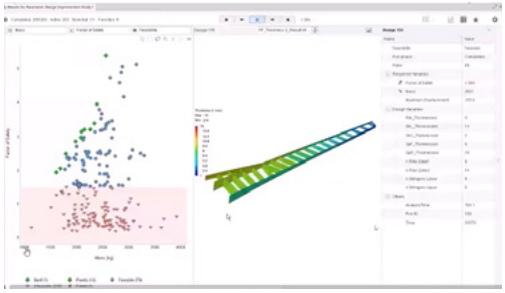
Antoine Scotto, head of the Product Lifecycle Management (PLM) program for the A350 XWB at Airbus from 2007 to 2011

Click here to learn how Airbus used SIMULIA very early in the design process, to predict the strength and behavior of the aircraft's structure.

Exploring the Design Space

Combining Concept Structure Engineering with the **3D**EXPERIENCE platform's Design of Experiment (DoE) capabilities makes it possible to conduct design studies using the parameterized model. This allows the designer to fully evaluate and explore the design space by varying the model's parameters, from the thickness of structural components to the number of ribs and stringers.

A graph is generated based on the optimization targets. In this example, the wing's mass is being optimized and we've set a safety factor of 1.5 tons. Every design variant that falls below that factor (in the red zone of the diagram) is discarded. Designers can then explore the remaining options and identify the best trade-offs to achieve safety with optimized mass.



PRELIMINARY AND DETAILED DESIGN

During the preliminary and detailed design phases, the focus is on optimizing and refining the aircraft to make sure it meets program targets and complies with regulations. Everything, from structural and control components to the dynamics of flight, is verified and validated during this phase as the aircraft is prepared for certification and launch. Siloed simulation processes can significantly slow down this process and cause gaps in information that result in late-stage failures.

By planning and executing their Validation and Verification (V&V) strategy on the **3D**EXPERIENCE platform, A&D companies can connect all their simulation data to requirements and streamline review and approval processes. This comprehensive overview of V&V allows them to organize virtual simulations and physical tests in one place and achieve full traceability, from requirements to compliance evidence.

The following examples give an idea of how this process works.

High-Lift Aerodynamics Simulation

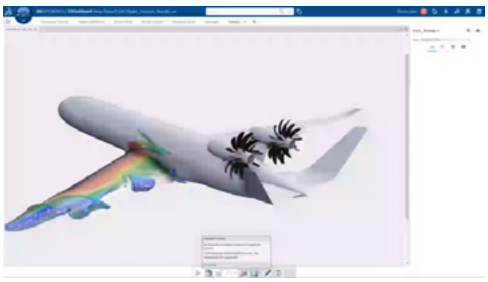
Aerospace organizations have led the way in using computational fluid dynamics (CFD) simulation to ensure safe and efficient aerodynamic performance. In the past, these simulations have been limited to flight configuration at the center of the flight envelope where airflows are fairly steady and geometries are smooth. Physical wind tunnel tests have been the only way to assess the envelope's edges, where geometries are more detailed and flows are separated and unsteady—for example to assess the aerodynamic behavior of the aircraft in high-lift configuration, and in particular to determine maximum lift and stall characteristics.

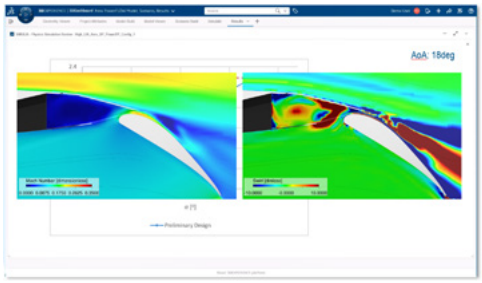
SIMULIA Lattice-Boltzmann based simulation technologies allow organizations to explore the entire flight envelope. This method, which provides a view of fluids as a distribution of particles, brings several key advantages:

- Robust and streamlined meshing cuts preparation time from weeks to days on fully detailed geometries
- Complex, unsteady flows can be predicted with proven accuracy
- Fast solvers provide accurate responses 10 times faster than large eddy simulation solvers
- Low numerical dissipation provides accurate predictions of near-field direct aeroacoustics
- By running these simulations in parallel, on multiple cores or in the cloud, A&D organizations can dramatically reduce their turnaround time so that simulation results can impact decisions earlier in the design process

In the preliminary design phase, the process starts with importing and characterizing the CAD model of the aircraft wing. At this stage the model typically does not yet include details such as flap brackets. A mesh is then automatically created and the simulation scenario— in this example, high-lift aerodynamics—is set up.

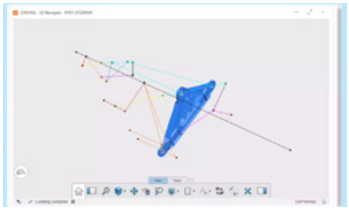
The CFD simulation results are analyzed and visualized on the **3D**EXPERIENCE platform, providing an accurate picture of where and how performance is compromised so designers can act quickly to prevent any problems.

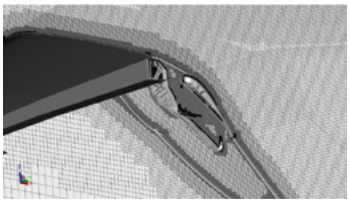




Detailed Structural Simulations at the Component Level

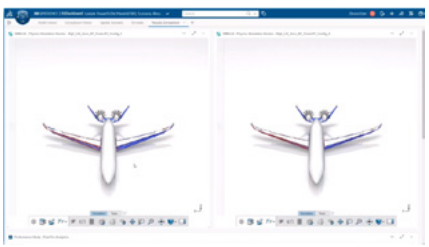
As the development proceeds to the Detail Design phase, the geometry gets progressively more refined— by adding a detailed wing flap bracket, for instance. Easy access to the engineering bill of materials on the **3D**EXPERIENCE platform provides the designer with the full engineering definition of the product on a web-based dashboard as the design of aircraft components matures throughout the development process.

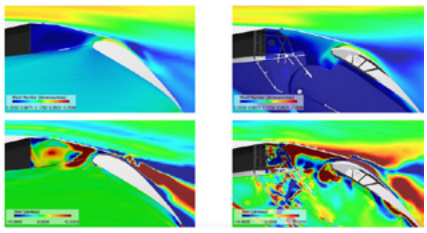




Every design change is automatically captured in the CFD mesh by adding refinements around the flap bracket geometry to the simulation set-up.

Simulations are then re-run to evaluate the impact of the design changes on the aircraft's aerodynamic behavior.





"With MODSIM, we can draw a 2D diagram of a tank or pipe, for example, connect it to the 3D model, test how it fits and functions, and then any design changes automatically update in the simulation. That seamless integration is saving significant time as we don't have to go back and forth checking and duplicating changes. This also removes some of the constraints we'd might otherwise face if we tested everything in the real world."

Jacques-Alexis Verrecchia, Head of Product, Beyond Aero

Beyond Aero wants to use a MODSIM approach to iterate and validate new designs fast. Click here for the full story.

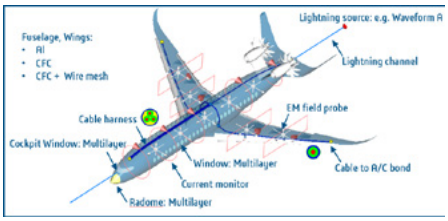
Aircraft Lightning Simulation

Every aircraft design must include lightning protection to make sure all the installed electronic components are safe during adverse weather conditions. If a thundercloud-to-ground lighting strike hits the nose of an approaching aircraft, for instance, the discharge can cause streamers that connect the plane to the to the downward ladder of the lightning and to an upward ladder from the ground. The aircraft becomes part of this ground-to-cloud conducting channel, which then conducts a return stroke of lightning.

In the following example, the **3D**EXPERIENCE platform is used to simulate and analyze how this lightning attachment phenomenon affects the aircraft.

Step 1: 3D CAD modeling

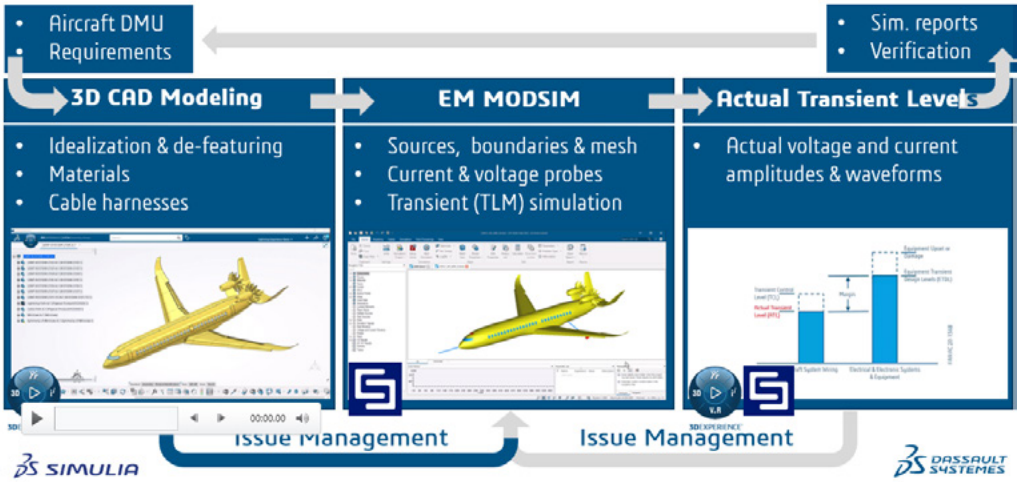
First, the designer accesses the aircraft **3D**EXPERIENCE CAD model from the same single source of truth used for other simulation disciplines. Electromagnetic simulations do not require all the details included in the CAD model, so this mock-up is further idealized, with any unnecessary features removed. At this stage, the outer shape of the aircraft is used. A cable path is set up and materials are assigned to the aircraft skin and windows.



Step 2: Electromagnetic MODSIM

An aircraft electromagnetic simulation model is prepared using the **3D**EXPERIENCE CAD model in CST Studio Suite, with defined sources, boundaries and mesh. Wires are used to create lightning current paths and a port is attached to one of these wires to inject the lightning waveform. Finally, a cable harness with cross-section and cable ports is attached to the cable path that was defined in the modeling step.

A hexahedral TLM mesh is created automatically, in alignment with the aircraft surface. The electromagnetic simulation then accurately captures the field energy behavior and calculates transient currents and voltages in a schematic, with cable loads and voltage and current probes clearly defined. The electromagnetic simulation model and its results can be saved in the **3D**EXPERIENCE platform.



Step 3: Actual Transient Levels (ATLs)

Voltage and current amplitudes and waveforms can now be extracted and compared with the defined requirements for equipment transient levels. In our example, a study of the differential voltage drop for different fuselage material confirms that aluminum provides the best shielding and carbon-fiber composites alone provide the poorest. Placing a wire mesh on top of these composite materials increases their lightning protection.

These simulation results can be shared with peers and authorities from the **3D**EXPERIENCE platform. ATLs of cable pin voltages and currents, which are used for certification, can be established through measurement or electromagnetic simulation.

STREAMLINING THE CERTIFICATION PROCESS

Certification of new aircraft typically takes years and costs around 20% of the total design program and the challenge is growing as new aircraft architectures continue to emerge.

Two major factors contribute to that picture:

- Most of today's certification activity involves physical tests, both on the ground and during thousands of flight hours.
- Late-stage design failures—which could be avoided by using simulation early on—are costing billions in delays and can even lead to entire program cancellations.

Some physical testing, such as flight tests, will always be necessary. However, by increasing the use of simulation in the certification process and optimizing the synergies between simulation and physical tests, the organization can decrease the number of flight tests needed and reduce late-stage risk.

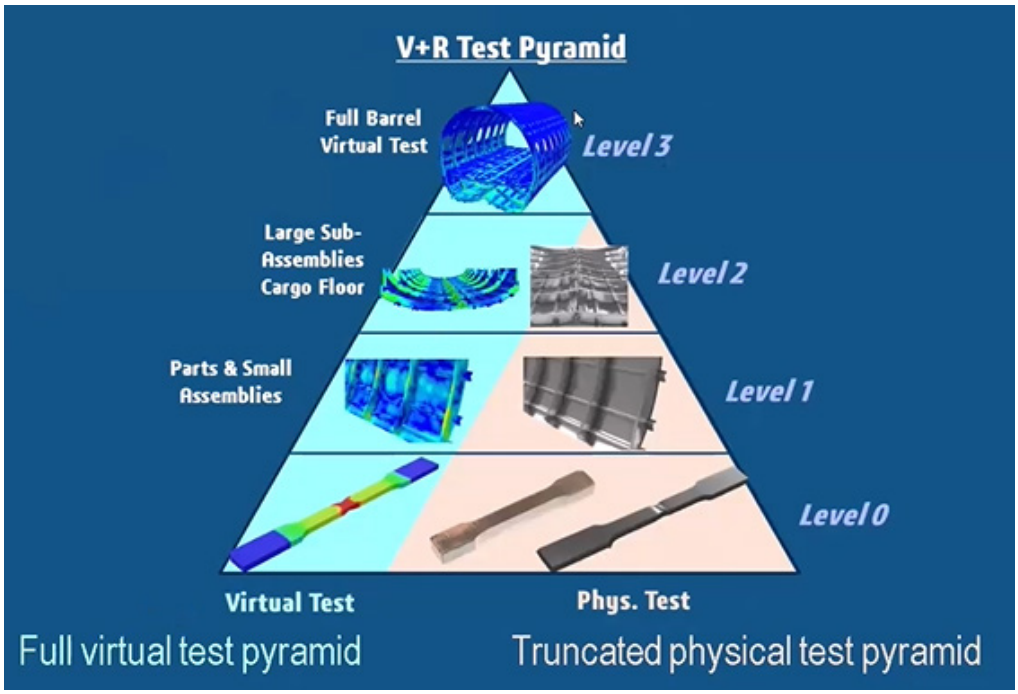
This simulation-based approach—called Certification by Analysis—is only possible when full cross-functional collaboration, traceability and governance exist throughout the development cycle. It is dependent on advanced, highly accurate simulation capabilities, coupled with well-managed validation and verification (V&V) processes. This end-to-end governance is enabled by the SPDM capabilities of the **3D**EXPERIENCE platform discussed earlier in this whitepaper. Two examples of how this approach to certification by analysis can be executed for specific certification requirements are described below.

Barrel-drop Certification

Survivability of the aircraft fuselage in a crash situation is a mandatory certification test for every aircraft. The so-call barrel-drop test to achieve this certification requirement—dropping a part of the fuselage from a defined height to ensure that it remains structurally intact—typically carried out very late in the development process, so a failure can cause long and costly delays as designers have to revisit fundamental aspects of the structural design.

By drawing a digital thread through virtual and physical testing activities, A&D companies can increase the use of simulation from early design to certification. This vision of smarter testing—built on strong governance of tools, data and processes—combines virtual and physical testing to optimal effects, to dramatically reduce development lead times and costs.

For example, when the European Union Aviation Safety Agency (EASA) and the Federal Aviation Administration (FAA) raised a special condition on crashworthiness to address a new fuselage concept, one Dassault Systèmes customer created a V+R (virtual plus reality) test pyramid. This strategy reduced physical tests, combining them with virtual ones at the coupon, parts and small assemblies, and large sub-assembly levels. At the final and most expensive stage, virtual testing was used exclusively to validate and certify the full fuselage section.



By using this approach to avoid late-stage failures, the company reduced its certification lead time by two years and cut the cost of physical testing by 40%.

Inflight Icing

Certifying that an aircraft can still operate in severe ice conditions is another very costly area of physical testing. To gain that certification, A&D firms must identify the most critical ice shapes that can form on the aircraft. Traditional wind-tunnel approaches to this involve building sub-scale models, creating the different ice shapes and then testing them in scale-model wind tunnels to prove that the aircraft can fly in those conditions. As well as taking a lot of time, this method also lacks fidelity because it is difficult to replicate the complex geometries involved.

In contrast, using PowerFLOW to simulate inflight icing on the **3D**EXPERIENCE platform enables accurate reproductions of the complex geometries of ice formations on a full-scale model of the aircraft, in a much shorter time. These simulations have been accepted by certification authorities, so A&D firms can use them to identify the most critical ice shape and focus their flight test on just that shape.

PLOTTING A PATH TOWARDS MODSIM

A MODSIM approach empowers A&D manufacturers to develop innovative aircraft concepts, minimize the risk of late-stage failures and get them to market faster—but it doesn't have to involve an enterprise-wide overhaul. The **3D**EXPERIENCE platform offers manageable steps towards a fully connected aircraft design and simulation process, so each organization can approach MODSIM in the way that suits their business best.

INTEGRATED DATA GETS NEW AIRCRAFT OFF THE GROUND

Innovate faster

Automated simulation set-up puts virtual testing tools in the hands of designers, so they can validate their ideas against key requirements early in the development cycle.

Collaborate better

A single source of truth for simulation means everybody can work together on the same model.

Optimize traceability and governance

Integrating data and processes provides a digital thread across the ecosystem, ensuring traceability and supporting optimized governance strategies.

Maximize the value of simulation data

Well managed simulation data provides contextualized, reusable resources to streamline design, V&V and certification processes.

Enhance change management

Direct issue reporting and visibility on the routes of decisions, reviews and approvals optimizes change management.

Integrate V + R

Seamless connection of virtual and physical testing empowers A&D firms to streamline certification processes.

The Future of Aircraft Development from Concept to Certification

To find out how the **3D**EXPERIENCE platform can help your organization from concept to certification, watch this webinar here.

Our **3D**EXPERIENCE® platform powers our brand applications, serving 12 industries, and provides a rich portfolio of industry solution experiences.

Dassault Systèmes, the **3D**EXPERIENCE Company, is a catalyst for human progress. We provide business and people with collaborative virtual environments to imagine sustainable innovations. By creating virtual twin experiences of the real world with our **3D**EXPERIENCE platform and applications, our customers can redefine the creation, production and life-cycle-management processes of their offer and thus have a meaningful impact to make the world more sustainable. The beauty of the Experience Economy is that it is a human-centered economy for the benefit of all—consumers, patients and citizens. Dassault Systèmes brings value to more than 300,000 customers of all sizes, in all industries, in more than 150 countries. For more information, visit **www.3ds.com**.

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