Aerospace Testing with ARAMIS

Quality assurance at all altitudes

ZEISS

Seeing beyond

Embracing safety

Elevating performance

The mandatory nature of aerospace testing is evident throughout the prototype and development phase and during the certification process for new aircraft and associated products.

A multi-tiered testing framework, often called the test pyramid, is employed to effectively conduct various tests while adhering to the stringent requirements of aerospace components and structural designs.

The aerospace testing pyramid

This framework encompasses mechanical and virtual evaluations across materials (coupons), components, and structural elements and culminates with full-scale testing (refer to Figure 1).

The testing framework is structured as a multi-level pyramid encompassing a comprehensive range of evaluations. This includes testing materials and elements through standard tests such as tensile, compression, and shear tests, and conducting structural assessments of components, including airframes, wings, rotor blades, and landing gears. Customized test rigs facilitate static and fatigue testing, enabling a detailed evaluation of components within a controlled environment.

The ARAMIS digital image correlation (DIC) system provides optical three-dimensional full-field measurements of strain, deformation, and displacement for all tests aligned with this testing pyramid. Subsequently, the datasets generated from these mechanical tests are compared to simulation data, thereby contributing to the refinement of numerical models for new aircraft and their components.

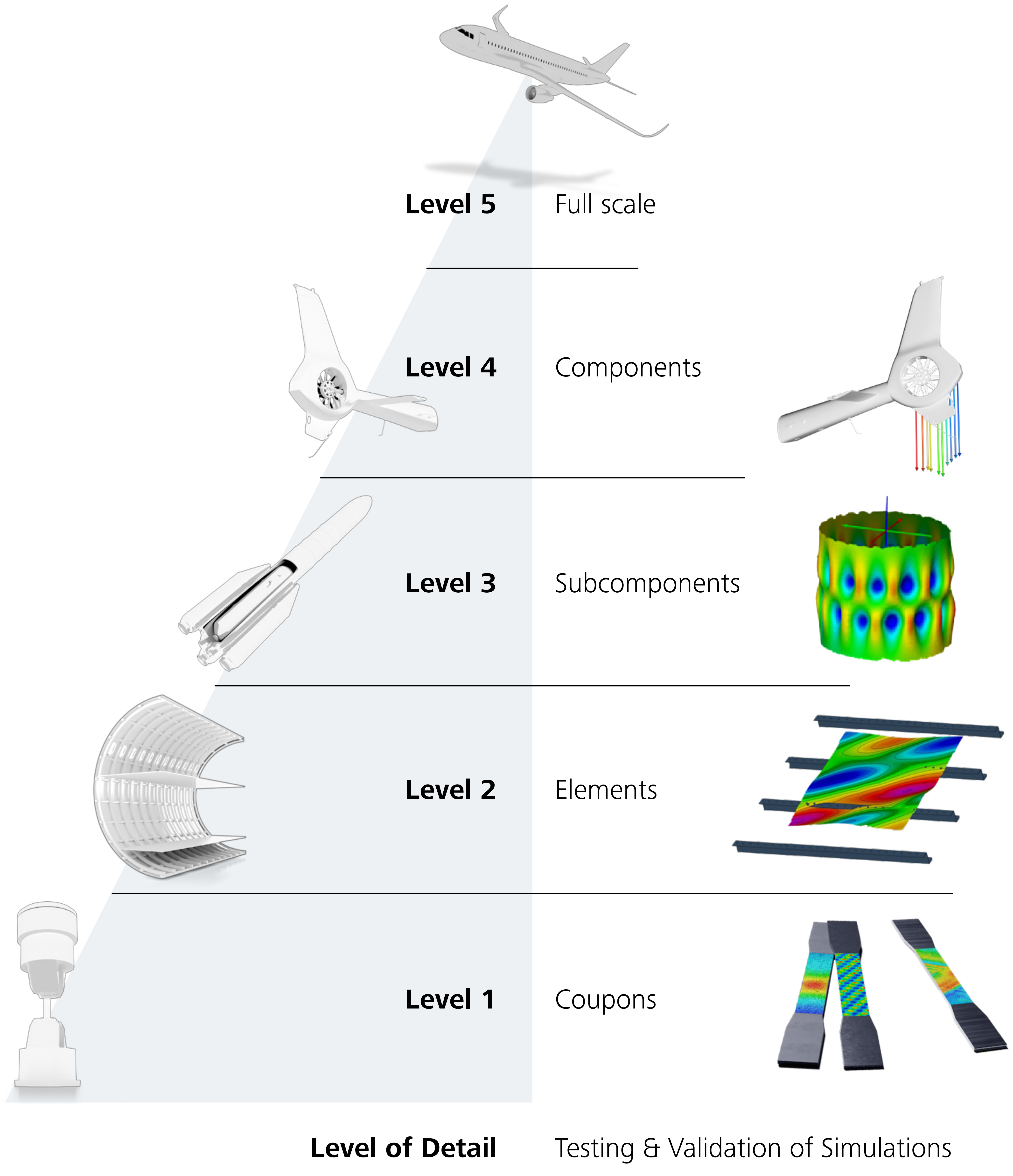

Figure 1: Aerospace test and certification pyramid

Photogrammetry and Digital Image Correlation

Optical systems offer a significant advantage by facilitating non-contact measurements while acquiring many data points without compromising the integrity of surfaces and specimens. ARAMIS delivers precise three-dimensional data through point-based photogrammetry analysis and full-field measurements through digital image correlation (DIC).

Optical 3D measurement technology

A calibrated stereo camera configuration is essential for assessing three-dimensional points and surfaces using the principles of triangulation and digital image correlation (see Figure 2).

Point-based measurements yield three-dimensional coordinates and displacements for each load step within a designated test. Six degrees of freedom (6DoF) analysis allows for the evaluation of complex trajectories in the analysis of component motion, such as with landing gears. Derived parameters, including three-dimensional velocity and acceleration, contribute to a comprehensive understanding of dynamic processes.

Full-field surface measurements, utilizing a stochastic pattern, facilitate the analysis of three-dimensional strain and displacement across specimens and components of various shapes, dimensions, and materials.

ARAMIS delivers three-dimensional data applicable to objects ranging from small to large and accommodates static and highly dynamic tests. It enables seamless communication with the test rig control system through analog and digital signals. While ARAMIS is an image-based measurement system, it supports live data streaming for both measurements and monitoring of the test rig.

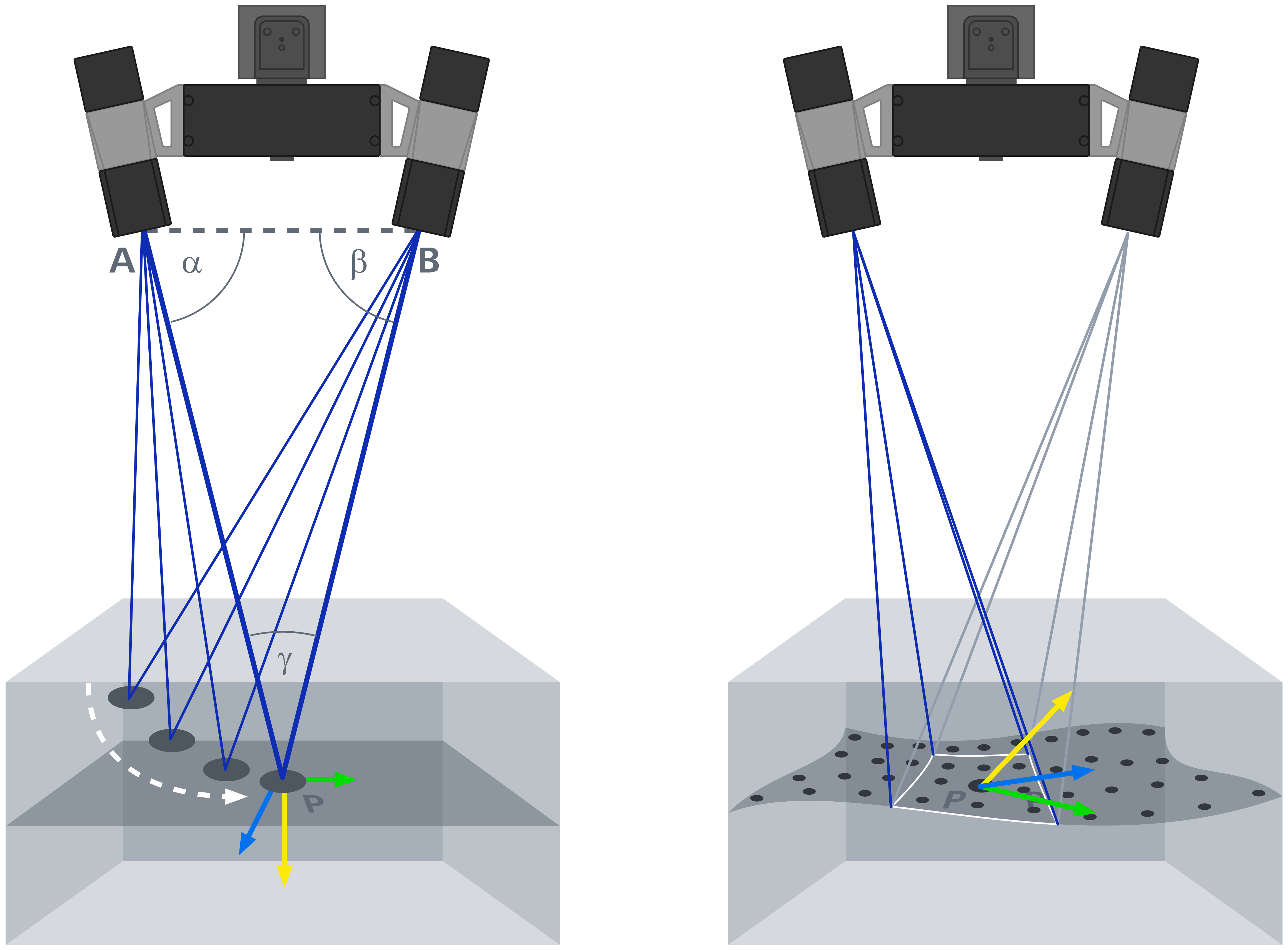

Figure 2: Principle of triangulation of three-dimensional coordinates and tracking over time (left) and digital image correlation (DIC) as full-field non-contact optical measurement technique (right)

Aerospace Testing

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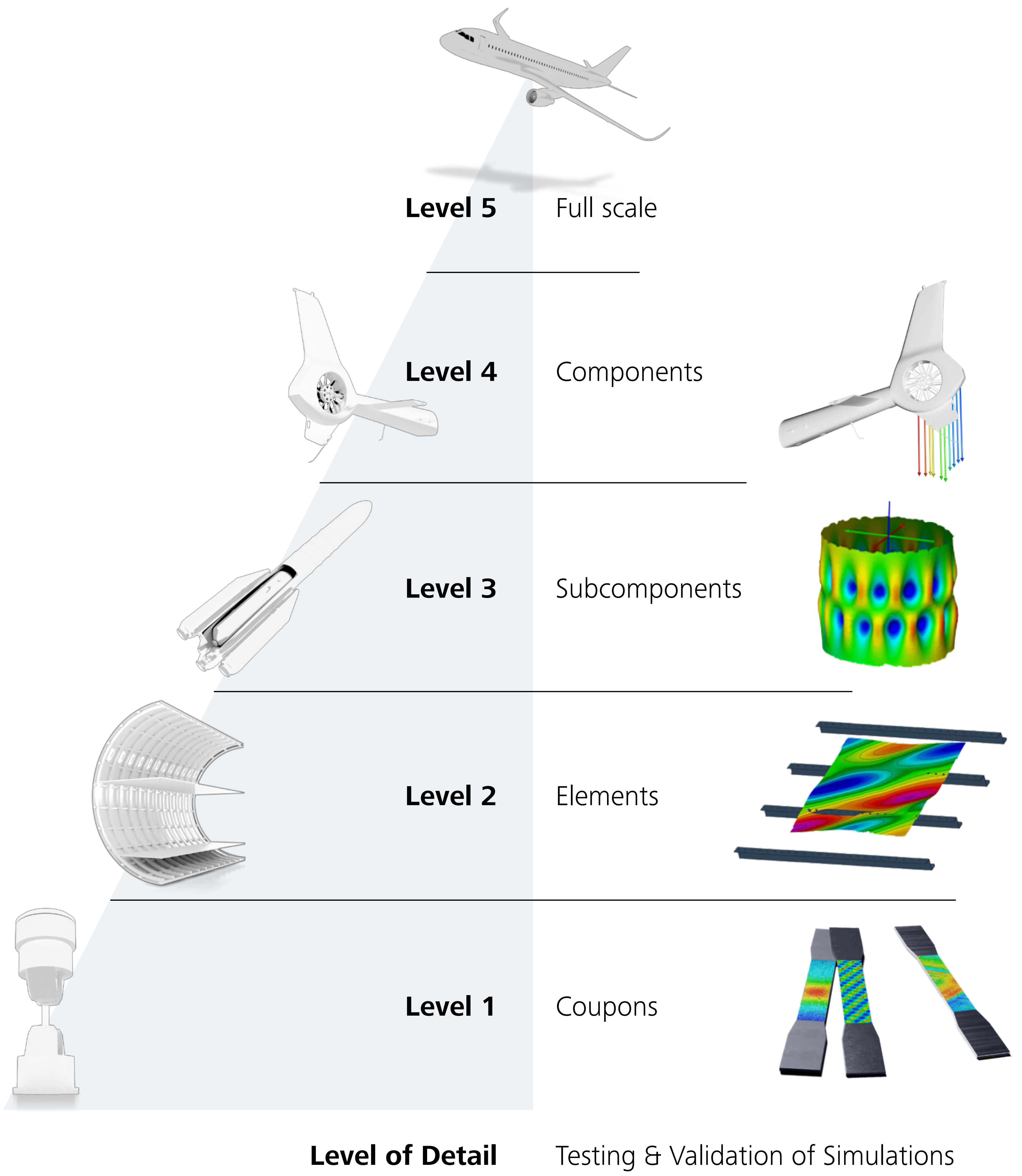
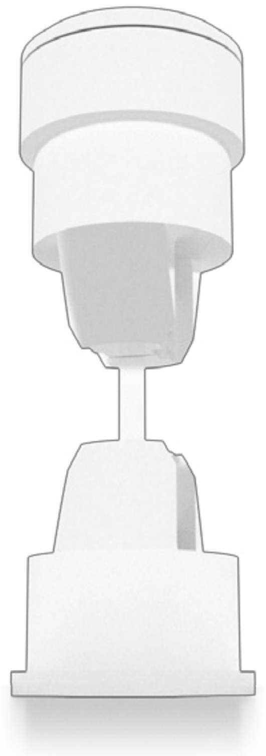


Level 1

Coupon testing

The characterization of material properties is the foundation of the test pyramid. ARAMIS offers full-field strain data for standardized tests, such as tensile, compression, and shear tests, particularly for composite materials. With this data, evaluating optical strain gauges, extensometers, and section-based data points becomes straightforward.



APPLICATION EXAMPLE

Tensile test carbon fiber reinforced polymer (CFRP)

Coupon or material testing is essential for understanding the behavior of materials under specific mechanical loads, particularly during standardized assessments such as tensile, compression, and shear tests. The resultant properties indicate a material's characteristics, facilitating comparisons among various materials. This is particularly pertinent in the aerospace industry, which frequently utilizes reinforced materials.

The following example demonstrates the tensile testing of a CFRP specimen oriented at 90° fiber orientation. The stochastic pattern provides a three-dimensional surface for high-resolution strain analysis using optical extensometers.

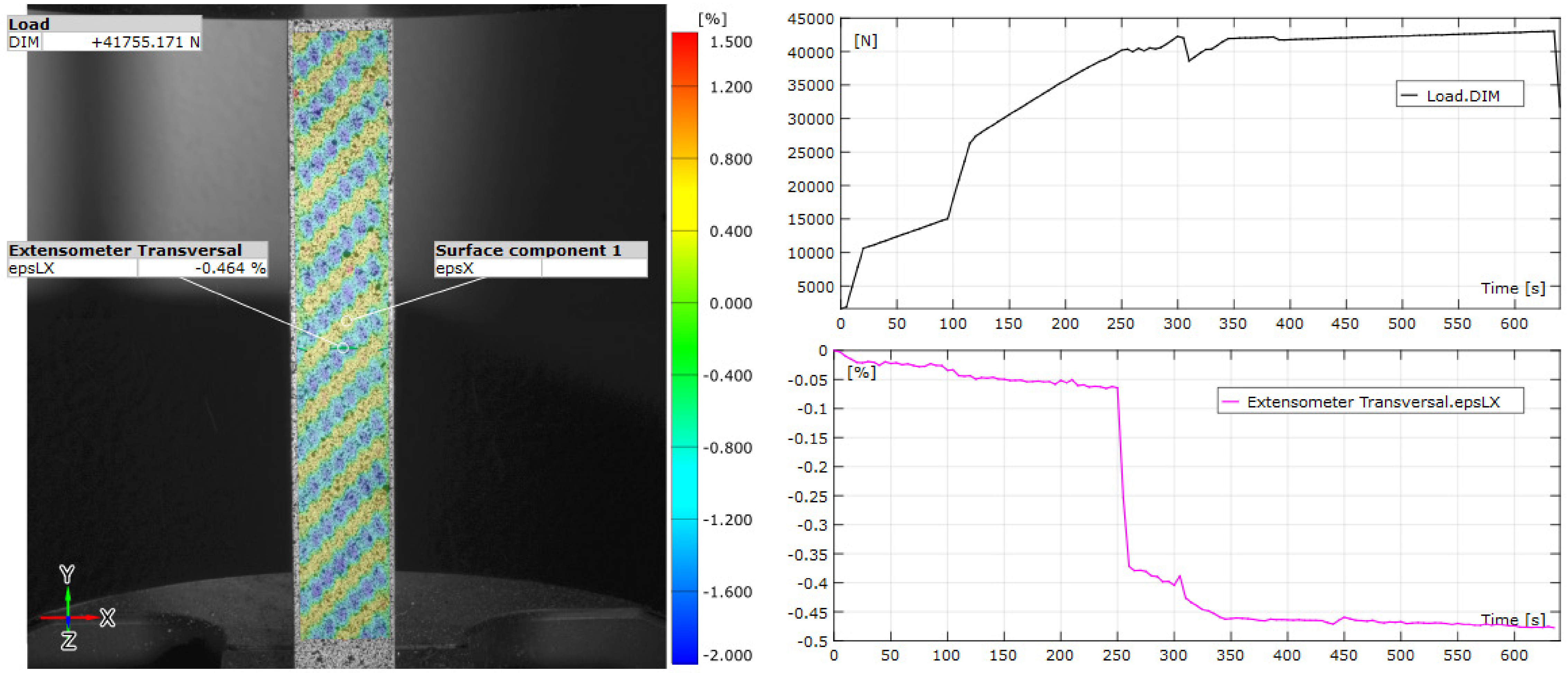
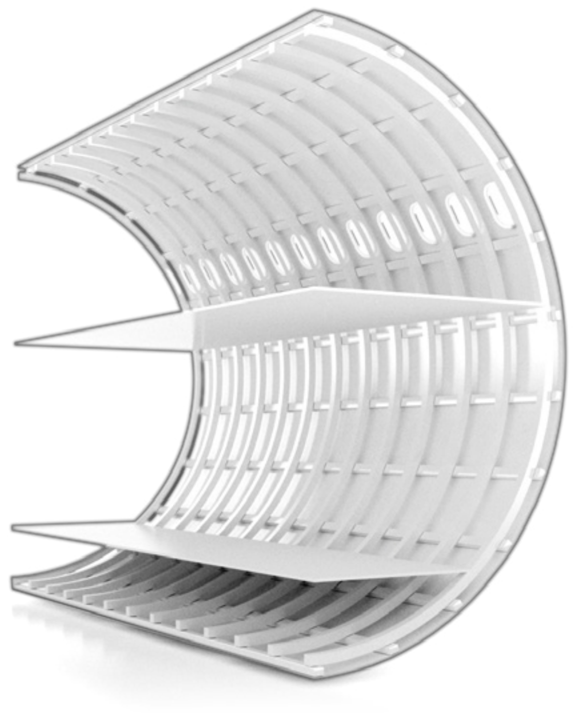


Figure 3 illustrates a strain analysis conducted with ARAMIS on a carbon fiber-reinforced polymer coupon exhibiting a 90-degree fiber orientation. A stochastic high-contrast pattern has been employed to obtain full-field three-dimensional surface information, with strain distribution visualized through color-coded maps. Red, orange, and yellow areas indicate positive technical strain values (tension), whereas blue areas depict negative technical strain values (compression). Additionally, the force signal generated by the testing machine is recorded synchronously with the image data, as shown in the upper right diagram.

Level 2

Element testing

Testing construction elements and their subcomponents under specific loads and conditions is essential to meet damage tolerance requirements. A standard procedure employed is the compression test following the impact on panels. The ARAMIS system offers full-field displacement measurements, which effectively illustrate the buckling dynamics between the panel skin and the stiffening elements, such as stringers, and enables the assessment of simulation data.



APPLICATION EXAMPLE

Compression test on panel with buckling analysis

New aircraft structures require the development and testing of fuselage or wing panels. Modern panels made of carbon fiber reinforced polymer (CFRP) must undergo testing to compare different designs and validate the corresponding simulation data. Standard tests for panels are compression and shear tests under static and cyclic loads to show the fatigue and damage tolerance behavior. This application example demonstrates a compression test and the buckling of a CFRP panel (Figure 5).

The ARAMIS measurement uses a stochastic pattern to provide a three-dimensional surface and three-dimensional displacements. The measurement data is aligned with CAD data, allowing for the analysis of displacements in specific coordinate directions. Figure 5 illustrates the displacement at maximum load in the Z direction (out-of-plane). With a high point density, the full-field analysis reveals the buckling effects at this load.

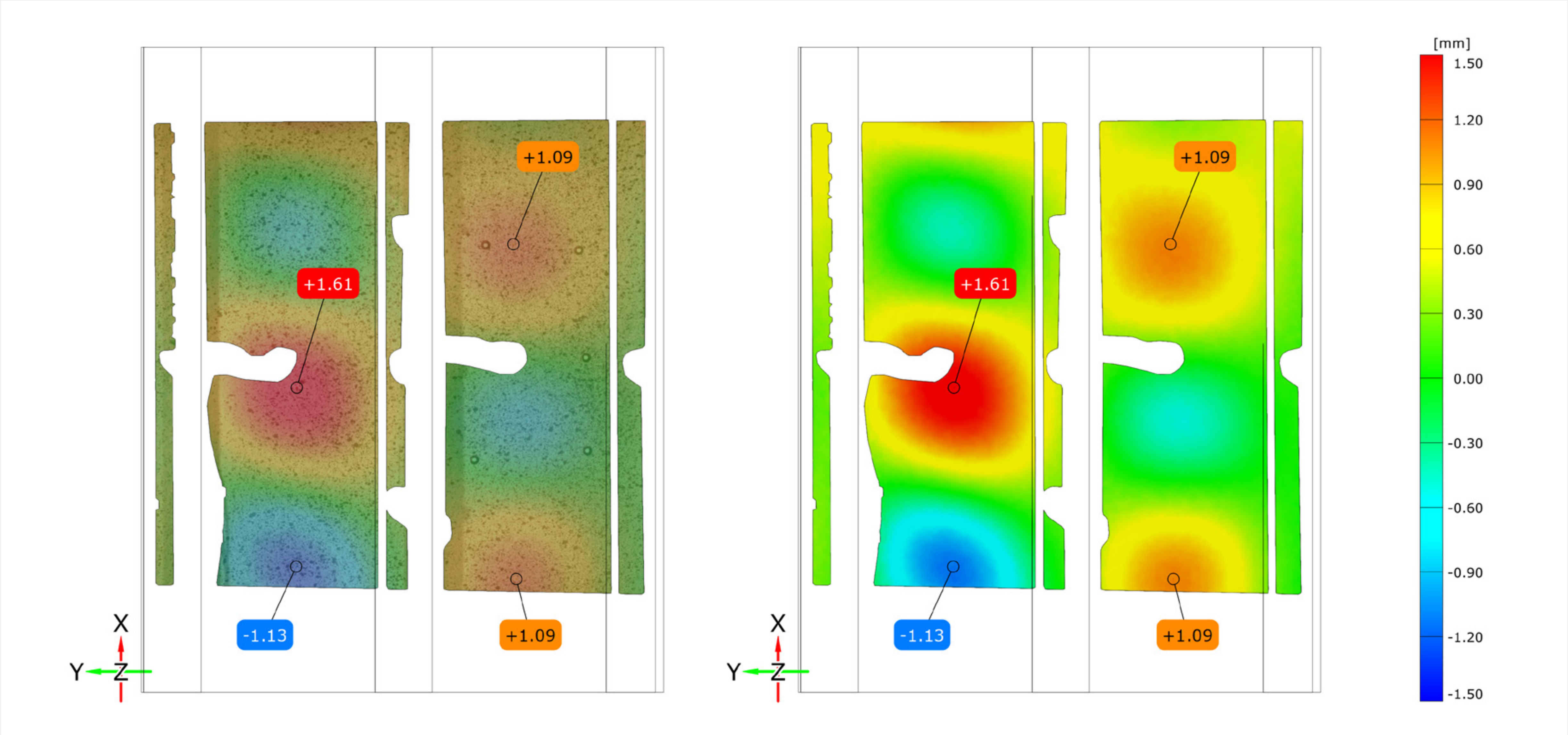
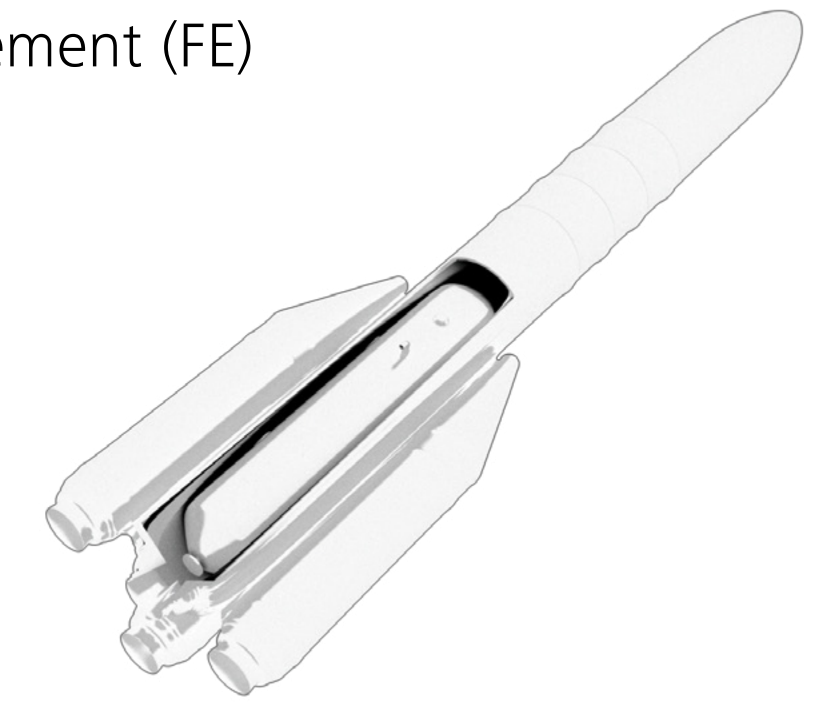


Figure 5: Buckling analysis with ARAMIS. The three-dimensional displacements in the Z-direction (out-of-plane) are visualized with the help of color-coded maps. Red areas indicate a bump and blue areas indicate a dent.

Level 3

Sub-component testing

Structural sub-components for the fuselage, wings, and tanks are qualified after different static and dynamic tests, such as fatigue testing. Replacing traditional tactile sensors, like strain gauges, the full-field ARAMIS measurement shows buckling effects and hot spots for strain analysis on important component areas. ARAMIS data is used to evaluate finite element (FE) simulation data.



APPLICATION EXAMPLE

Compression test on thin-walled CFRP cylinder panel with buckling analysis

The thin-walled cylindrical sub-component from carbon-fiber reinforced polymer is subjected to an axial compression load and torsion. At the same time, internal pressure is applied to the interior of the cylinder.

The combination of the optical three-dimensional measurement system ARAMIS and the photogrammetry system TRITOP allows for the generation of a full-field 360° data set of the cylinder surface and its response to the load scenarios. Four individual ARAMIS sensors are used for the synchronous measurement of the complete cylinder. Each sensor covers roughly 100 degrees of the cylinder surface.

A cloud of reference coordinates helps transform all four ARAMIS measurement data sets into one common coordinate system for the evaluation, which is defined by the cylindrical geometry.

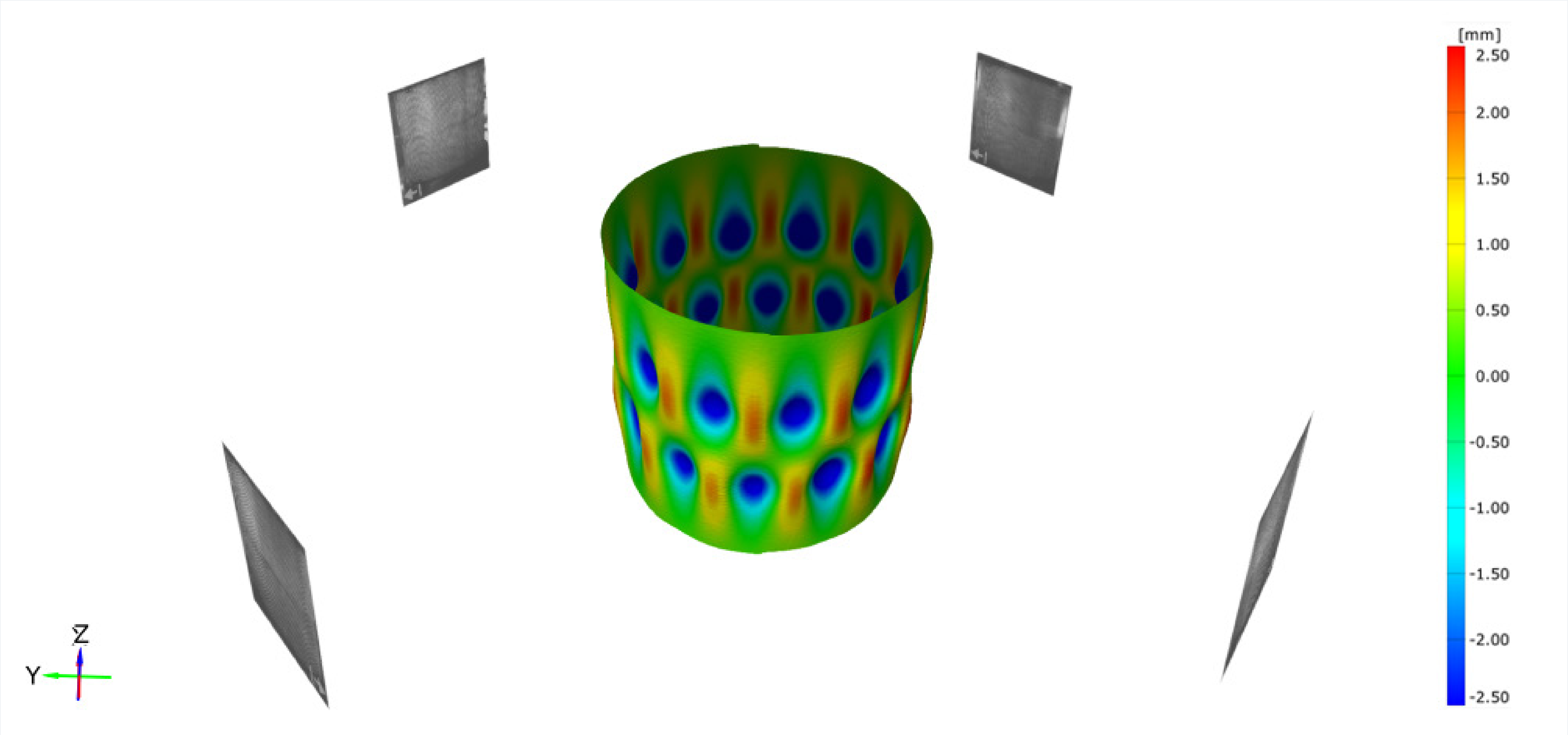
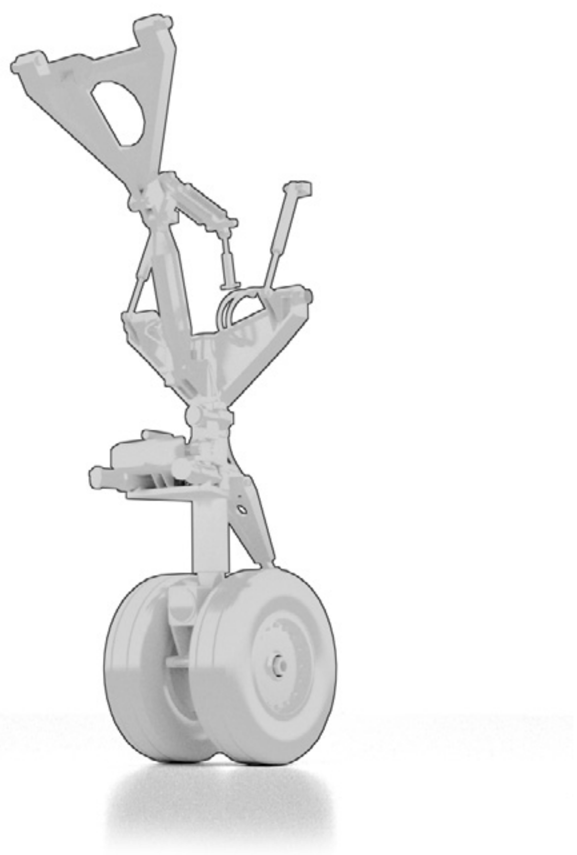


Figure 6: Buckling analysis with ARAMIS in a 360° measurement setup with four ARAMIS sensors. The radial displacements are visualized with the help of color-coded maps. Red areas indicate a bump, and blue areas indicate a dent.

Level 4

Component testing

One example of component or subsystem testing is the motion analysis of landing gears conducted under realistic conditions. ARAMIS provides three-dimensional points and displacements for both static and dynamic tests. It can analyze complex trajectories by utilizing 6 DoF analysis alongside live data streaming. Using reference point markers significantly reduces setup time compared to traditional LVDT sensors.



APPLICATION EXAMPLE

Ground-based tests on landing gears

Ground-based testing of landing gear systems encompasses various loading scenarios designed to simulate the stresses these components will encounter during operation, both before and after landing. Such scenarios include braking, turning, and towing maneuvers. These ground-based tests are integral to the certification process for aircraft. They are essential for establishing the limit strength (which confirms no detrimental plastic deformation), the ultimate strength (which ensures no structural failure occurs for three seconds), and the fatigue behavior (which guarantees the absence of detectable cracks) of the landing gear system. The ARAMIS system facilitates in-rig measurements of three-dimensional coordinates, three-dimensional displacements, and the evaluation of complex motions through trajectory analysis and six degrees of freedom (6 DoF) assessments.

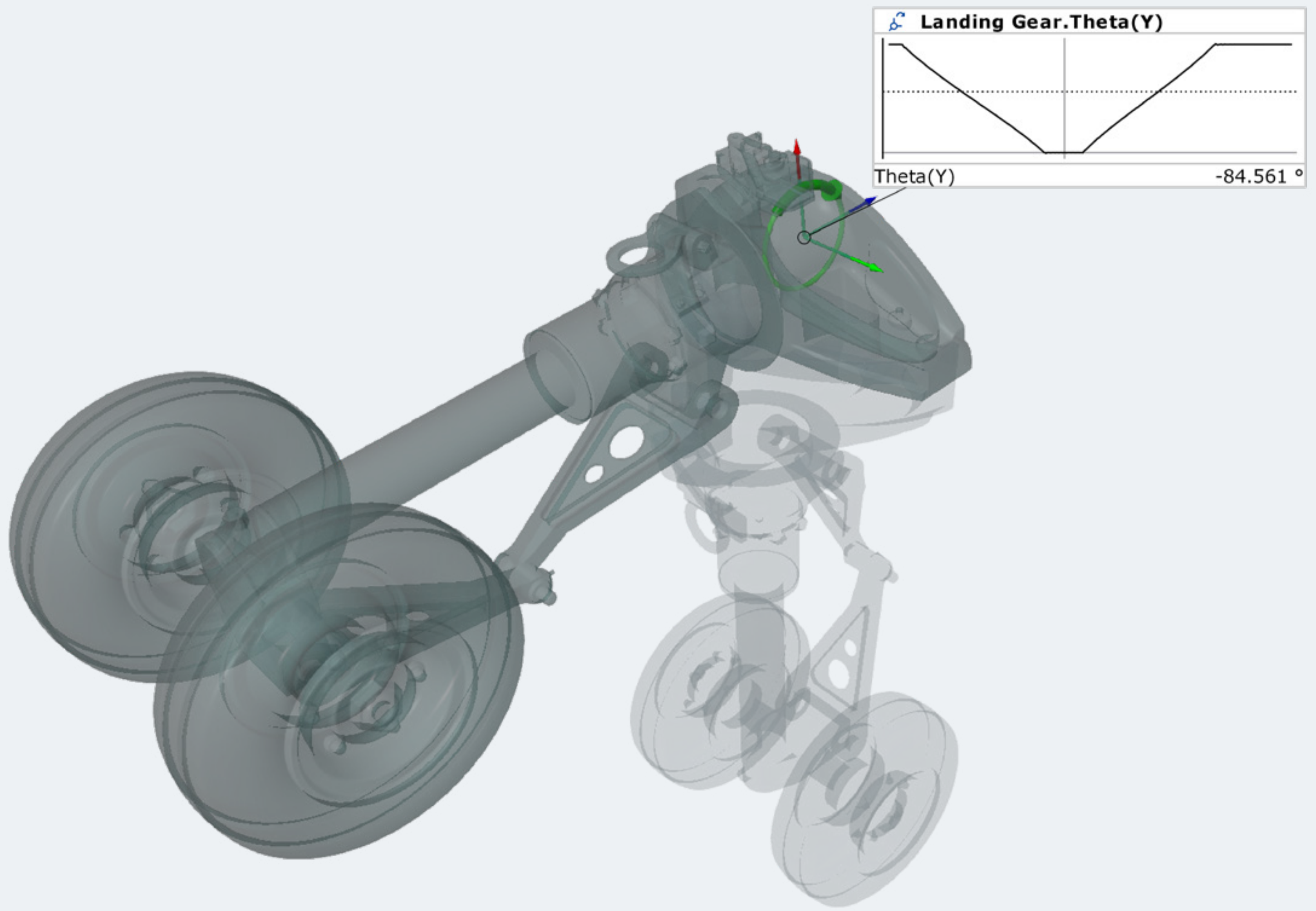


Figure 8: Rotation of the landing gear around the Y-axis during a retraction test.

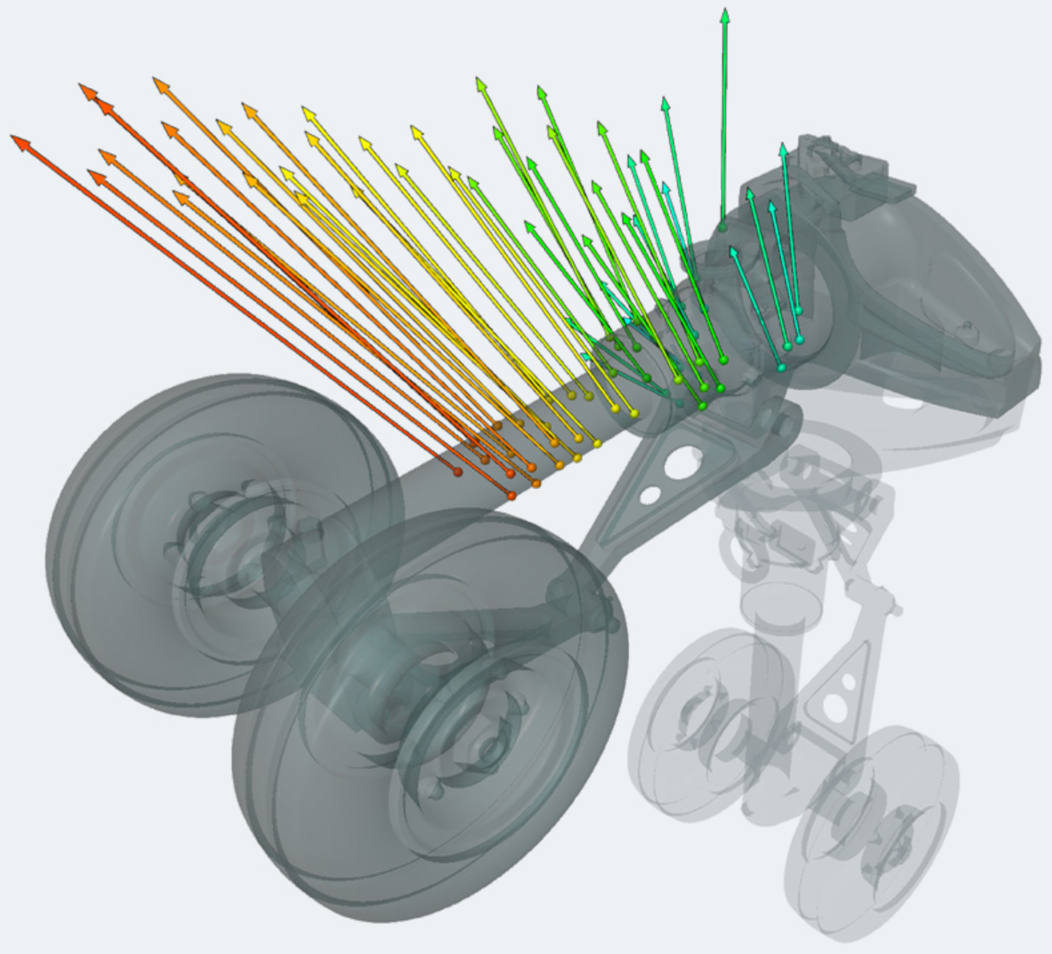
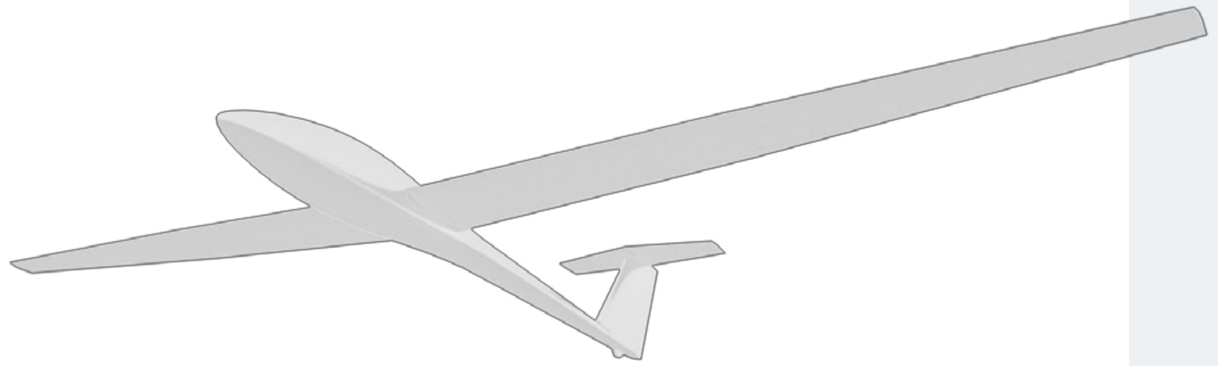


Figure 9: 3 Three-dimensional displacements of the landing gear during a test of the retraction function.



Level 5

Full-scale testing

Structural testing evaluates an aircraft's strength, durability, and reliability under operational stresses. ARAMIS provides full-field strain data as well as three-dimensional points and displacements from quasi-static and dynamic tests of airframes. Using reference point markers and stochastic high-contrast patterns on the surface of the object under test significantly shortens the setup time compared to linear variable differential transformers (LVDT) and strain gauge sensors.

APPLICATION EXAMPLE

Emergency landing on a two-seater glider

In the certification process for a two-seater glider design, safety evaluations through simulated emergency landing tests are imperative. A critical requirement for completing these tests is that the safety cell for both pilots must ensure sufficient space for survival. The ARAMIS system utilizes optical three-dimensional measurements to detect deformations surrounding the canopy cut-out. The measurements reveal red regions that indicate a bulge of up to 16 millimeters under applied loads, while dark blue areas demonstrate no observable deformation. Furthermore, the CAD data of the airframe and associated rig components are imported into ZEISS CORRELATE software, which enhances the visualization of measurement results and facilitates the analysis of directional strains and displacements within the CAD coordinate system.

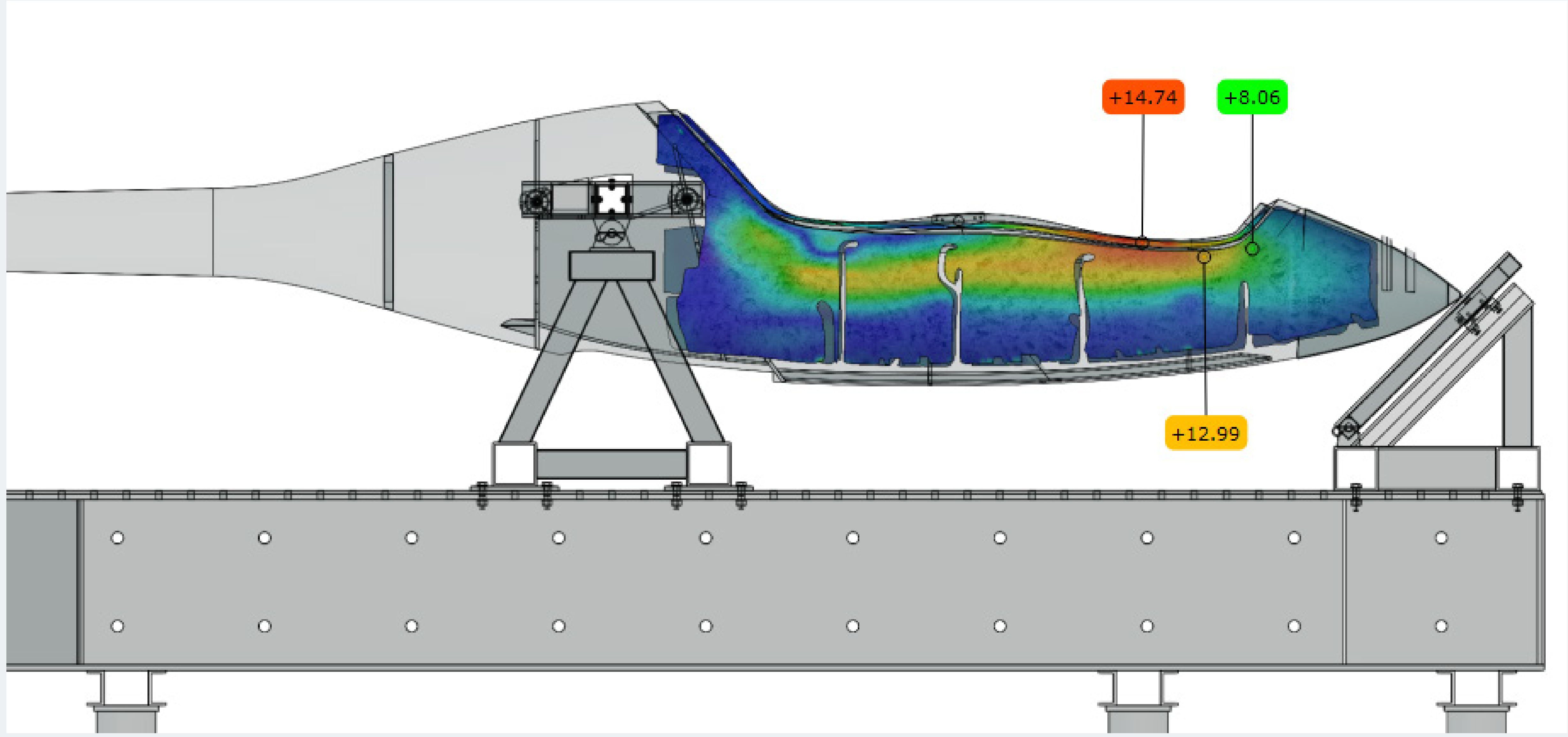


Figure 10: ARAMIS is used to detect the three-dimensional deformation around the area of the canopy cut-out.

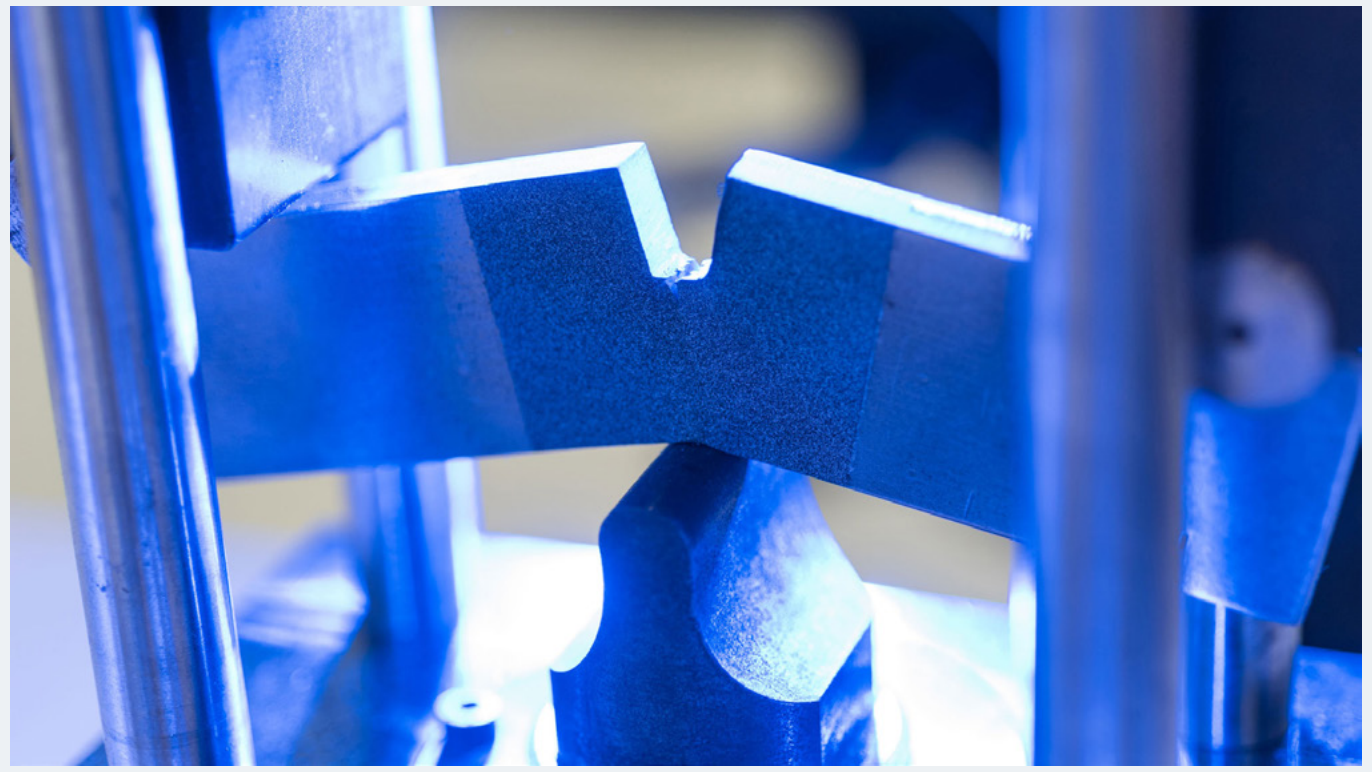
Summary

ARAMIS is an advanced optical 3D measurement system that utilizes digital image correlation (DIC) technology. It is designed to provide comprehensive full-field and point-specific measurements of displacements, deformations, and surface strains within industrial settings.

Within the context of aerospace testing, ARAMIS caters to a diverse range of applications, accommodating small and large objects and static and high-dynamic tests while ensuring seamless integration into the testing environment.

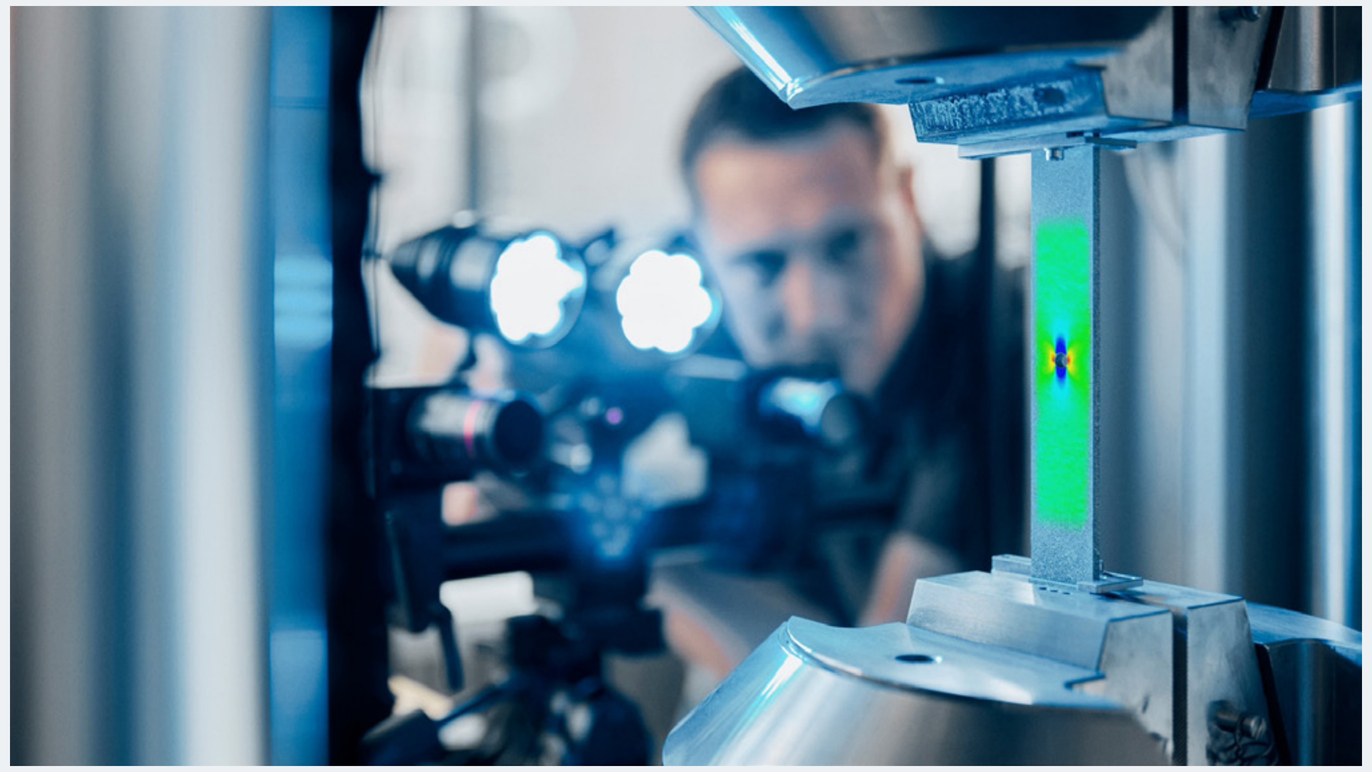
ARAMIS supersedes traditional measurement instruments in such testing scenarios, including linear variable differential transformers (LVDTs), strain gauges, and accelerometers, owing to its straightforward specimen preparation and measurement protocols.

For more information



Digital Image Correlation (DIC)

Learn more



ARAMIS and 3D testing

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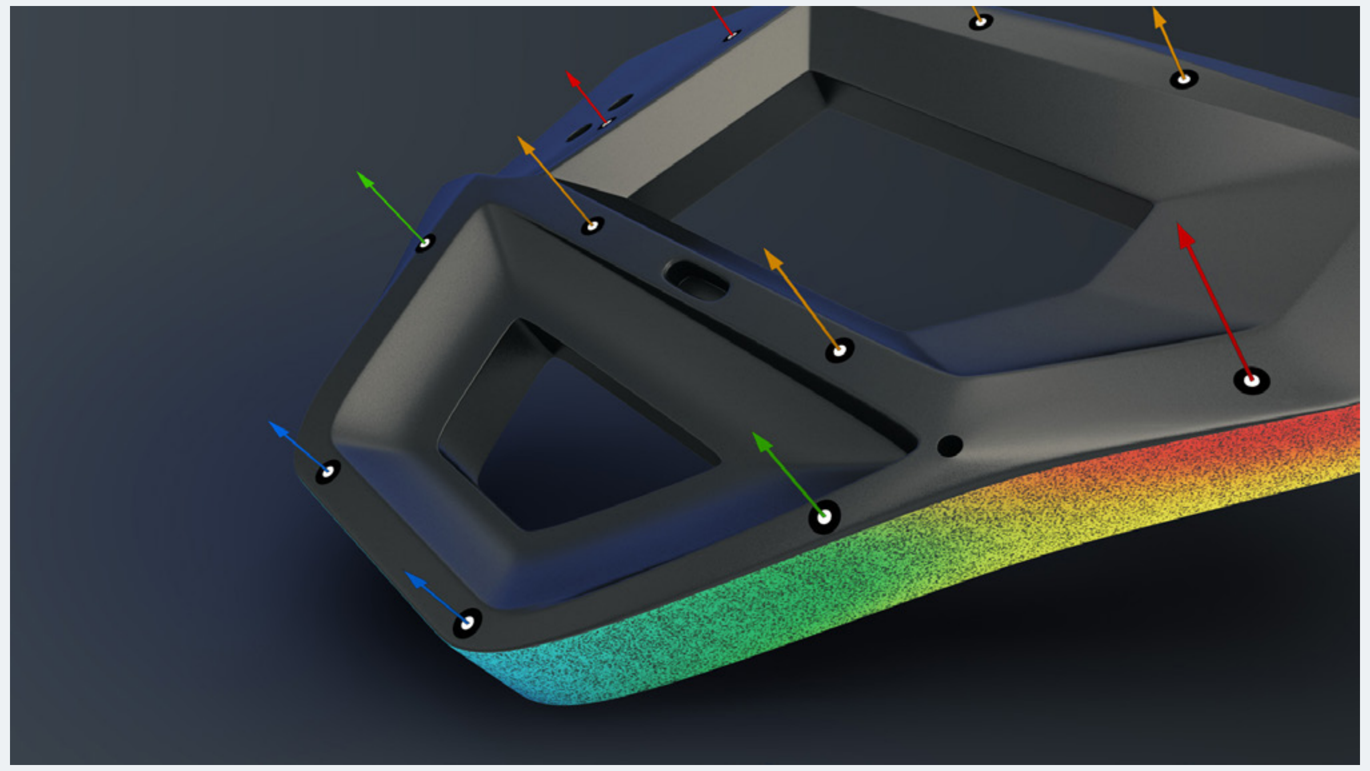

ZEISS CORRELATE software

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