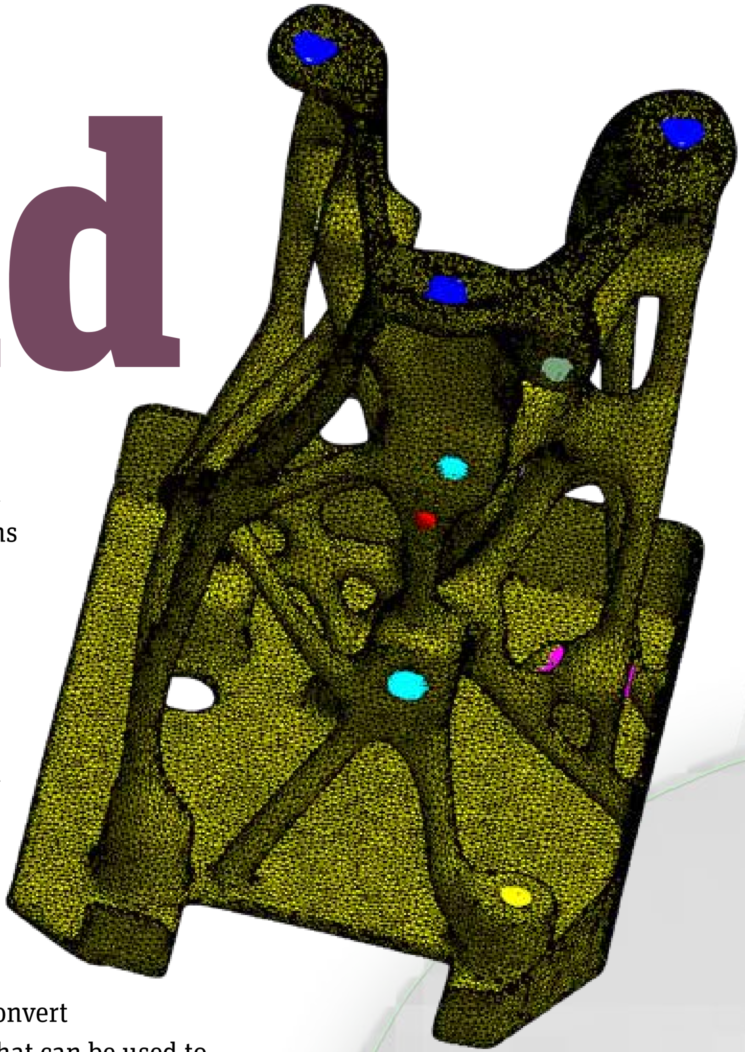
Filling a Void



Metal additive manufacturing enables production of complex metal parts that meet mechanical property specifications without the need for costly tooling. In addition, parts can be made in small batches or even manufactured on a "one-off" basis. Computed tomography (CT) scanning can be used to identify defects such as voids or inclusions that can occur in parts created through metal additive manufacturing, but in the past there was no way to determine how these manufacturing byproducts might affect performance. A new process has been developed to convert CT images into finite element models that can be used to predict the mechanical properties of as-manufactured parts.

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Materials and processes used to produce critical components for aerospace and defense applications must first be formally qualified to demonstrate that these components will function as expected. The increasing use of metal additive manufacturing creates validation challenges because the incremental process through which parts are built up stepwise, one layer at a time, creates the potential for inconsistencies not seen in traditional manufacturing methods. Tiny defects are often detected with CT scanning, which raises the question — what is their impact on the performance of the part? A new method for simulating the performance of an as-manufactured part based on CT scan data is being used to validate the sun assembly sensor (SAS) support in the TARANIS spacecraft.

More than two thousand storms are permanently active in the Earth's atmosphere at altitudes between 20 and 100 kilometers. These transient luminous events, each of which produces 50 to 100 lightning bolts per second, were discovered relatively recently, so current knowledge is limited to observations of light emissions from the ground. The

“A new method for *simulating the performance* of an as-manufactured part based on *CT scan data* is being used to validate a support in the *TARANIS spacecraft*.”

TARANIS microsatellite from Centre National d’Etudes Spatiales (CNES) — the government agency responsible for shaping and implementing France’s space policy — will observe these stormy regions from an altitude of 700 kilometers to better understand their effect on the earth’s atmosphere, ionosphere and magnetosphere.

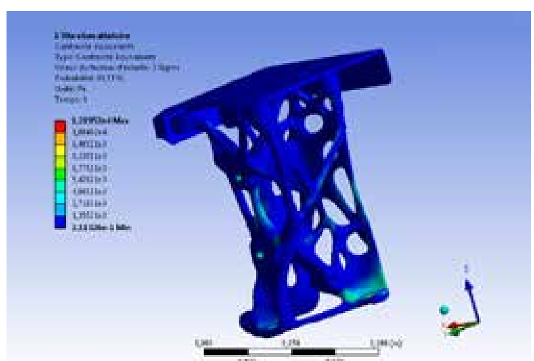
The attitude and orbital control system (AOCS) of the TARANIS microsatellite will precisely determine and control the orientation of the satellite. The AOCS uses the SAS to detect the position of the sun. The SAS support provides the sensor with 180-degree clear views. It is mounted to a device that swivels the sensor to maintain a view of the sun regardless of the satellite’s orientation. The position of the sensor in the payload, coupled with the lever effect of the support, makes the sensor very sensitive to the dynamic environment generated by the rocket during the launch phase. Thus, the most important structural requirement of the support is that it be stiff enough to maintain primary modal frequencies greater than 350 Hz. Modal frequencies below that value could potentially interact with the launcher and spacecraft main modes and damage the sensor.

TARANIS satellite will study high-altitude storms.

CAD model of sun assembly sensor support

ADDITIVE MANUFACTURING SAVES WEIGHT

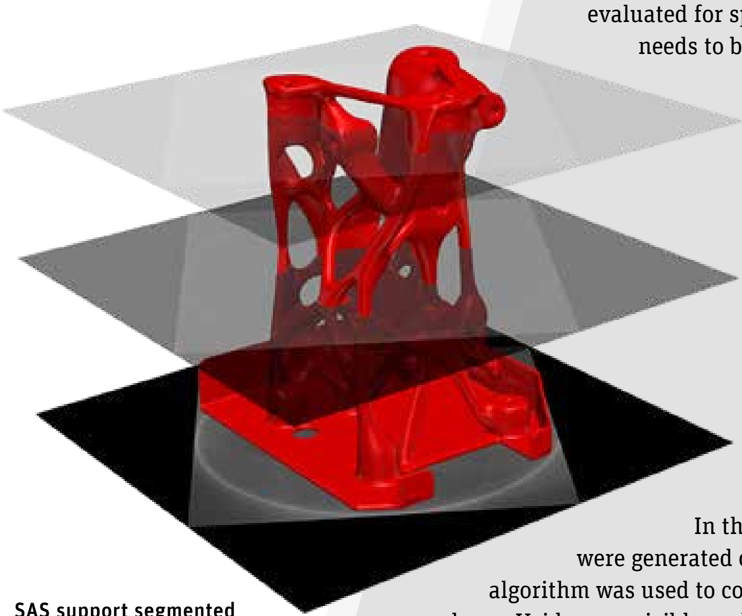
Additive manufacturing is expected to be the manufacturing method to produce the SAS support because it eliminates the design-for-manufacturability constraints of conventional subtractive manufacturing processes. Engineers used topology optimization to fully exploit the design freedom provided by additive manufacturing by starting from blank space and iterating to an optimized design while changing both the basic shape and the dimensions of the part. The result is a design that reduces manufacturing and assembly costs by reducing the number of components within the support from 11 to one. At the same time, the weight of the support was decreased by 30 percent to allow for an equivalent increase in the spacecraft payload.



Von Mises stress plot created by finite element analysis of model based on CT scanning of physical part in ANSYS software

The ANSYS Vision for Simulation-Driven Product Development in Additive Manufacturing
ansys.com/am-vision

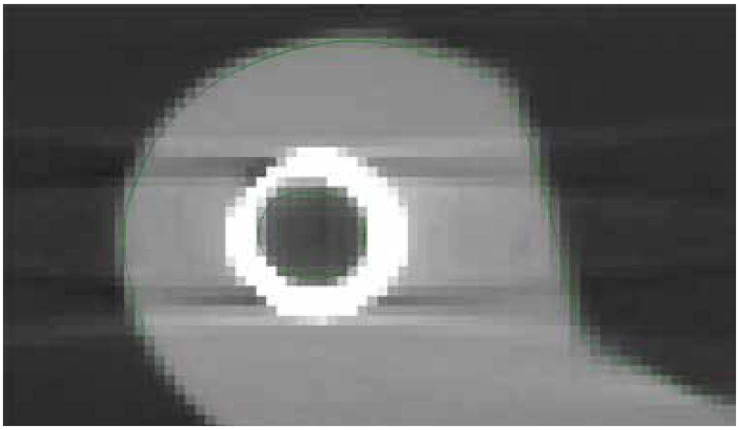
It cannot be assumed that parts made from additive manufacturing are free of internal defects. Three-dimensional (3D) printed parts are just beginning to be evaluated for spacecraft applications, so their reliability needs to be proven beyond a shadow of a doubt since there will be no way to perform repairs in space. Today, CT scanning is the most common way to assess the compliance of parts produced by additive manufacturing because it can detect internal flaws without destroying the part. Until recently, engineers could only detect flaws with CT scanning; they were unable to quantify the impact of these flaws on the properties of the as-manufactured part.

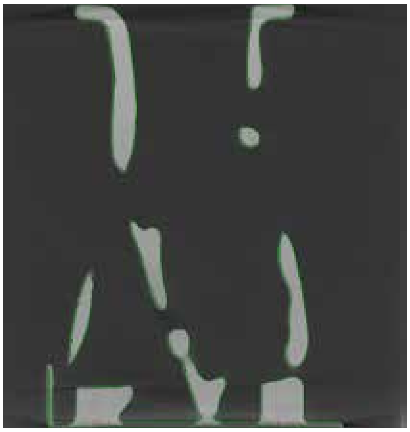


SAS support segmented from CT scan data in Simpleware software

SIMULATING THE AS-MANUFACTURED PART

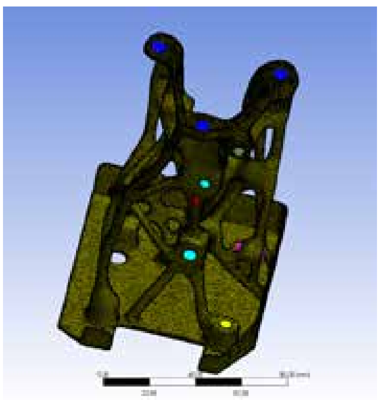
In this project, a total of 1,300 CT images were generated of the SAS support, and a mathematical algorithm was used to combine these images to reconstruct the part volume. Voids were visible as dark gray areas and inclusions as light gray areas in the 3D scan data. In addition, titanium screws in the part were visible as light-colored artifacts. Working with the scan data, Simpleware and ELEMCA engineers used Simpleware's ScanIP image processing platform to import the scan data. Employing ScanIP, they segmented the structure by detecting voxels (values on a grid in 3D space that are analogous to pixels in 2D space) by setting threshold values that differentiated the part from its surroundings and excluded the latter. Manual segmentation methods were used to further enhance the scan data by, for example, identifying the screw holes and removing the screws. The geometry was meshed using Simpleware's FE module to automatically produce a coarse mesh while enhancing details where gradients were expected to be high. The final model, which consisted of about 450,000 elements, was then exported as a native ANSYS model for finite element analysis. The boundary conditions set up in ANSYS Workbench were the same as the





Segmentation of the SAS support in Simpleware software

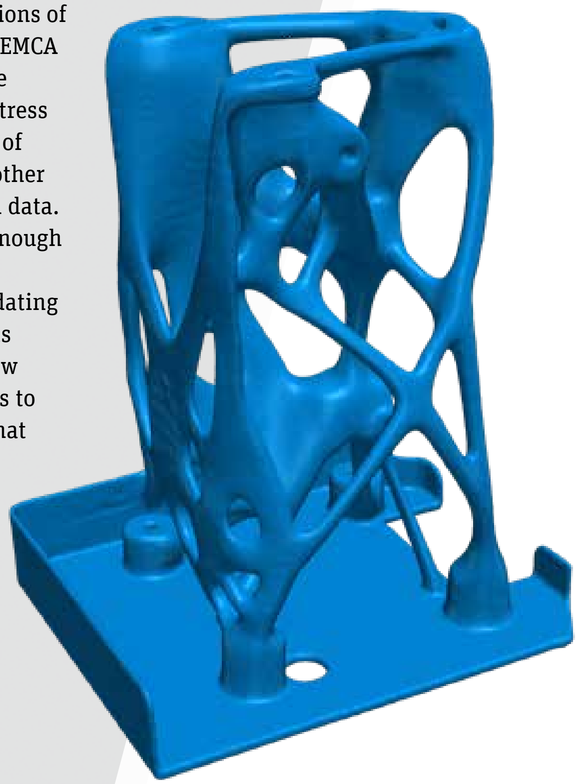
"CT scanning can be combined with *finite element analysis* to provide a structural simulation of the as-manufactured part that provides a more *realistic prediction* of part performance."



ANSYS model generated in Simpleware FE module

structural simulation that had been used to create the original design. They included a fixed support at the base, a point mass for the support and a point mass at the connectors representing the SAS. ANSYS Mechanical results showed that the design produced by additive manufacturing met the main flight requirement with modal frequencies well below the critical value. Von Mises stress values for the as-manufactured part were slightly less than the values that had been obtained in structural simulations of the CAD model. ELEMCA engineers attribute this reduction in stress to the elimination of screws and a few other minor components from the model produced from the CT scan data. Importantly, the inclusions and voids in the part were small enough to have an insignificant impact on performance.

Simulation played an important role in the process of validating this part, which is currently undergoing physical testing and is expected to be integrated into the mission. It demonstrates how CT scanning can be combined with finite element (FE) analysis to provide a structural simulation of the as-manufactured part that provides a more realistic prediction of part performance. This advancement should aid in the difficult task of qualifying parts produced by additive manufacturing for critical aerospace and defense applications. By using Simpleware software to develop the as-manufactured model and ANSYS software to perform virtual testing, ELEMCA achieved the potential of additive manufacturing to produce complex mechanical parts with less weight and superior mechanical properties while avoiding tooling expense.



SAS support segmented from CT scan data in Simpleware software

Reference

Uzanu, J.; Dhennin, J.; Nixon, M.; Harman, D.; Desmarres, J-M. Quality Control of a Metallic Additive Layer Manufacturing Part Thanks to X-ray Computerized Tomography and Finite Element Modeling, 14th European Conference on Spacecraft Structures, Materials and Environmental Testing, Toulouse, France, September 27–30, 2016.