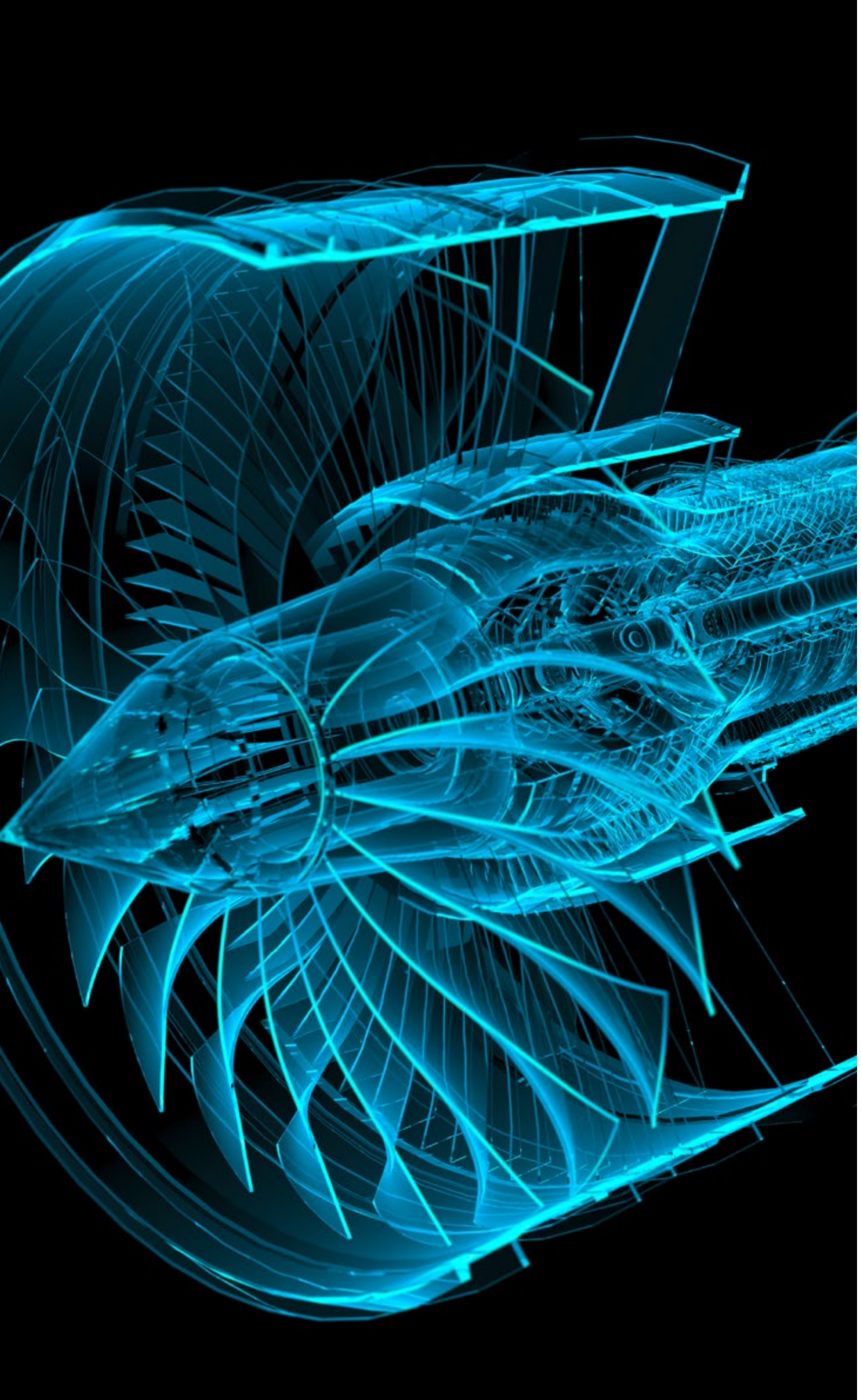
Seeing beyond

WHITE PAPER

It’s Time to Switch

Efficient validation techniques for aerospace first article inspections



Content

It’s time to switch

The COVID-19 pandemic has reshaped aviation supply chains. The number of source and method changes is increasing, which has led to a spike in new first article and last article inspection reports. These reports are fundamental in determining the airworthiness of flying products. But producing them is tedious, time-consuming and costly. Fortunately, there’s a way to drastically streamline the process – with modern 3D metrology.

A decade of cost-cutting has left its mark

While pictures of empty airport halls have captured the public imagination, COVID-19 has also dealt a heavy blow to the tens of thousands of suppliers that serve the aviation and aerospace industry.

The aviation supply chain is complex and diverse, ranging from internationally active multinationals to small mom-and-pop operations. In Germany alone, where ZEISS is headquartered, more than 2,300 companies supply the aviation / aerospace industry, the vast majority of them with fewer than 250 employees[1].

Prior to the pandemic, lower-tier players were already in a challenging position as OEMs and Tier-1 companies reduced the number of their direct suppliers. The companies that survived often had to meet increasingly demanding productivity and efficiency targets. As Alton Aviation Consultancy observed in 2020[2], “A decade of OEMs pressuring sub-tier manufacturers to make investments and tool up for production rate increases – coupled with relentless cost cutting through Boeing’s Partnership for Success and Airbus’s internal efficiency SCOPe/SCOPe+[3] programmes – has left the aerospace supply chain capital-starved.”

1 “Supply Chain Excellence in the German Aerospace Industry”, 2017, prepared for German federal ministry of economic affairs and energy.
2 https://altonaviation.com/wp-content/uploads/2020/06/Alton-2020-Covid-19-Implications-for-the-Commercial-Aviation-Industry.pdf, June 2020.
3 SCOPe = Single-aisle cost optimization

Engineering drawings have thousands of characteristics.

COVID-19 added insult to injury as many suppliers were forced into a more fragile financial state. As a result, OEMs and Tier-1 companies are once again reassessing their supplier relationships to mitigate their own financial and operational risks. This reassessment has taken the form of giving more business to financially robust suppliers, switching suppliers, and even insourcing production.

Revalidation activities are growing

These developments, coupled with the regulatory requirements of AS9100, are causing numerous changes in the sources and methods of aero products. The result has been a sharp rise in revalidation activities through so-called first article (FAIR) and last article inspection reports (LAIR). The entire supply chain is affected as FAIRs and LAIRs are required at every tier.

An additional challenge is that FAIRs and LAIRs need to be prepared by highly skilled metrologists and quality engineers. Their number is finite and there's a war everywhere for technical talent.

Millions of characteristics

Every FAIR and LAIR consists of three parts, or Forms. As every metrologist knows, Form 3 (Characteristic Accountability) is the most time-consuming and tedious part of the whole process as it involves the inspection of literally millions of characteristics across an entire engine. Every characteristic on the drawing needs to be verified. A turbine blade can easily have anywhere from 1,000 to 1,500 characteristics; an engine casing will have several thousand.

Though the process is time-consuming, the rigor associated with these activities is good and necessary in order to guarantee the quality of the final product and therefore flying safety.

The problem of equivalence

In addition to these 'standard' dimensional validation activities, it is common for the design authority at the OEM to request additional analysis between the LAIR and FAIR parts in order to prove 'equivalence'.

The purpose of 'equivalence' is to ascertain whether there are any significant differences that could have an adverse effect on the function and/or performance of the aero product, and ultimately the engine, by changing the origin of the manufacture.

Equivalence is difficult to prove. While the two parts may well meet all the requirements of the engineering drawing, they may still differ in subtle but important ways. Take the trailing edge of a turbine blade. Depending on where within the tolerance range the blade has been manufactured, it might end up being thinner or thicker than if it had been manufactured at another point in the tolerance range defined by the OEM. Even within the same supplier, factory A might make the blade slightly differently than factory B.

Hence, satisfying pre-defined tolerances isn't enough. Both parts may be good, but different. The impact of certain characteristics – even if they fall within the required tolerances – could end up permanently changing engine performance (thrust), fuel efficiency and even the weight of the aircraft. Everything hinges on the aggregate effect of seemingly small changes on the originally-certified engine.

Doubts about equivalence raise questions at the design authority like:

Why is this feature material-on the FAIR part and material-off on the LAIR?

This part seems to have more twist on the LAIR. How did you measure it on the FAIR?

The stakes are high with equivalence. Though not a formal part of AS9102, it is still a common requirement by OEMs. The ability to prove equivalence is a critical consideration when making source or method changes, and often the decisive factor in whether an OEM grants a work order or not. Any sign of lower engine performance later due to lack of equivalence can also result in financial penalties for the manufacturer.

Equivalence

The condition of being equal or equivalent in value, worth or function.

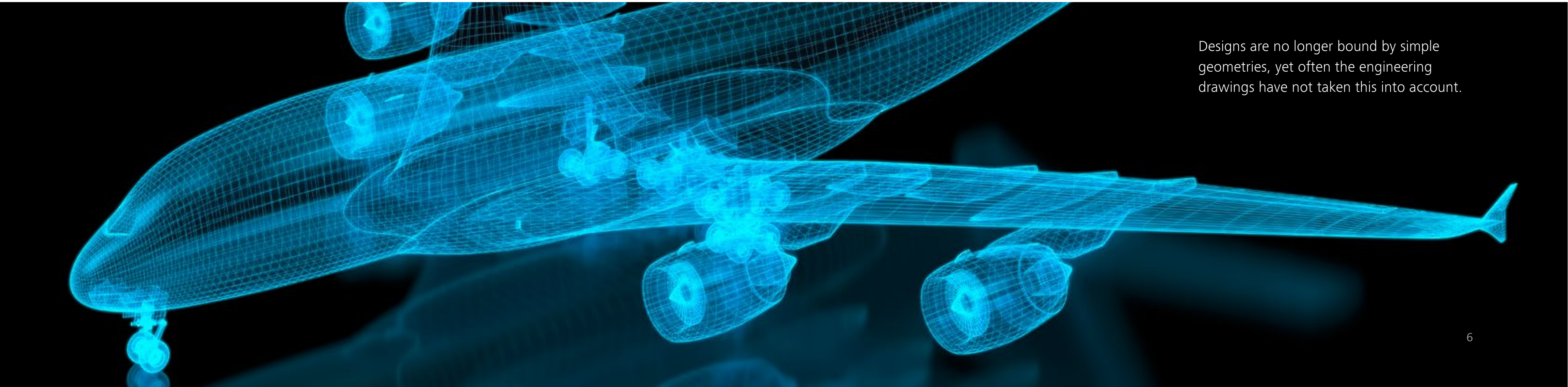
Aviation design has moved on, engineering drawings have not

Another notorious problem during the FAIR and LAIR process is how to deal with measurement uncertainties between the pre-defined inspection lines, points or sections.

For decades, the drawing, or blueprint, has been the glue between FAIR and LAIR activities. Hours, even weeks, of work go into not only validating the individual parts against the drawing, but also looking for values of significant difference between FAIR and LAIR parts. Much of the analysis is manual and requires a meticulous level of detailed scrutiny.

This is largely because aero engineering drawings reflect conventional manufacturing and inspection techniques. Engineering drawings today are still created in the manner of lines, points and sections in order to suit tactile inspection techniques like coordinate measurement machines (CMMs), fixtures and gauging. Yet this continues to increase the number of features that must be measured today because the boundaries of design have been extended in the last few decades.

Indeed, the geometries used in aero parts 30 years ago are different than those found today. Thanks to modern analysis software, designers of aircraft systems and engines are no longer limited by prismatic shapes; they have a much larger ‘toolbox’ of shapes at their disposal. There is more complexity and greater use of freeform surfaces.



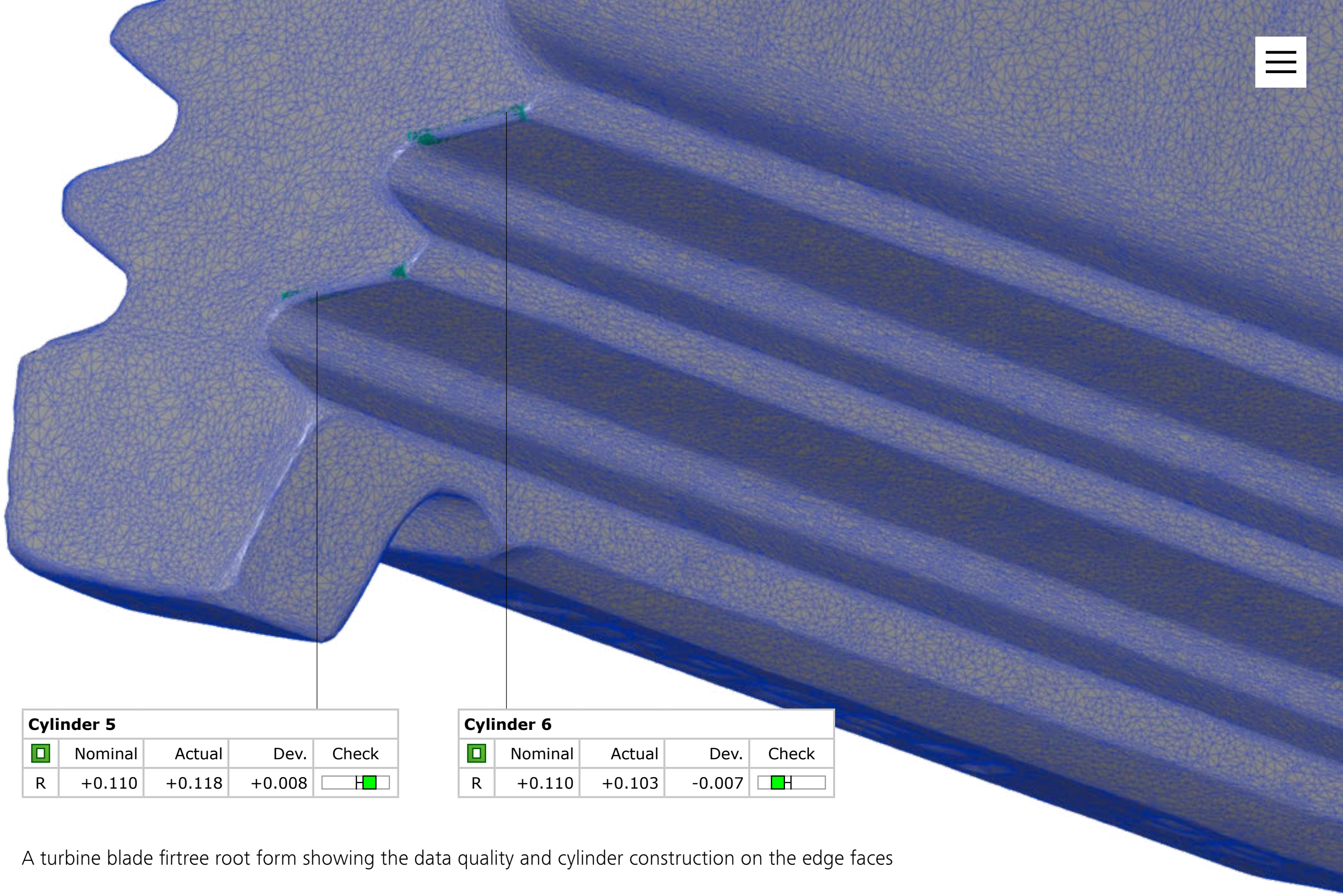
Designs are no longer bound by simple geometries, yet often the engineering drawings have not taken this into account.

FAIR/LAIR measurements: always a compromise

That said, many design authorities are still stuck in the past (or forced down this path) and typically ask a part manufacturer to check a small selection of inspection points or discrete line scans based on the engineering drawing. (Typical are 3 sections for a turbine blade and 15–20 sections along the length of the airfoil for a fan blade.)

Ultimately, however, the pre-determined sections, lines or sections are a compromise between what the designer really wants – namely, to know everything about the part – and what's feasible for the manufacturer. Obtaining a complete picture of the turbine blade would mean inspecting not 3 but perhaps 30–40 surface sections, lines or points. The pre-defined inspection points only convey the designer's intent about how the part will perform.

The design authority's goal is always to minimize safety risks and maximize performance, so information from traditional inspection techniques can inevitably lead to questions at the OEM such as:



Cylinder 5				
	Nominal	Actual	Dev.	Check
R	+0.110	+0.118	+0.008	

Cylinder 6				
	Nominal	Actual	Dev.	Check
R	+0.110	+0.103	-0.007	

A turbine blade firtree root form showing the data quality and cylinder construction on the edge faces

- If radius X is too thin, we need to check the thickness of feature Y or the part could fail.
- If this feature is malformed, could it adversely affect performance?
- Does the position of this runout create a stress point on the disc?

A further problem can arise in the FAIR/LAIR process when historic parts are moved to a new supplier that uses new measurement methods, and the supplier discovers more than was previously known about the part.

How to boost the efficiency of FAIR/LAIR activities

Fortunately, there's a way to eliminate these age-old problems while at the same time streamlining the entire FAIR/LAIR inspection process. The solution is optical 3D metrology, which offers three transformational benefits:

1. A drastic reduction in the time needed to do the dimensional validation for Form 3
2. A complete view of the part – which is what design authorities really want
3. An archived, digital copy – totally independent of the production-measurement system – of the actual product which was certified to serve as a baseline for future reference

What is optical 3D metrology?

Optical 3D metrology is ZEISS's range of high resolution 3D optical digitizing devices, commonly known as ATOS sensors, which precisely deliver 3D data quickly.

The positioning of the ATOS sensors can be manual, semi-automated or fully automated. Every ATOS sensor produces accurate and repeatable 3D measuring data at high speeds with highly detailed resolution.

Parts that previously required 30–40 hours to be characterized for Form 3 can in many cases be done in 20–30 minutes with optical technology.

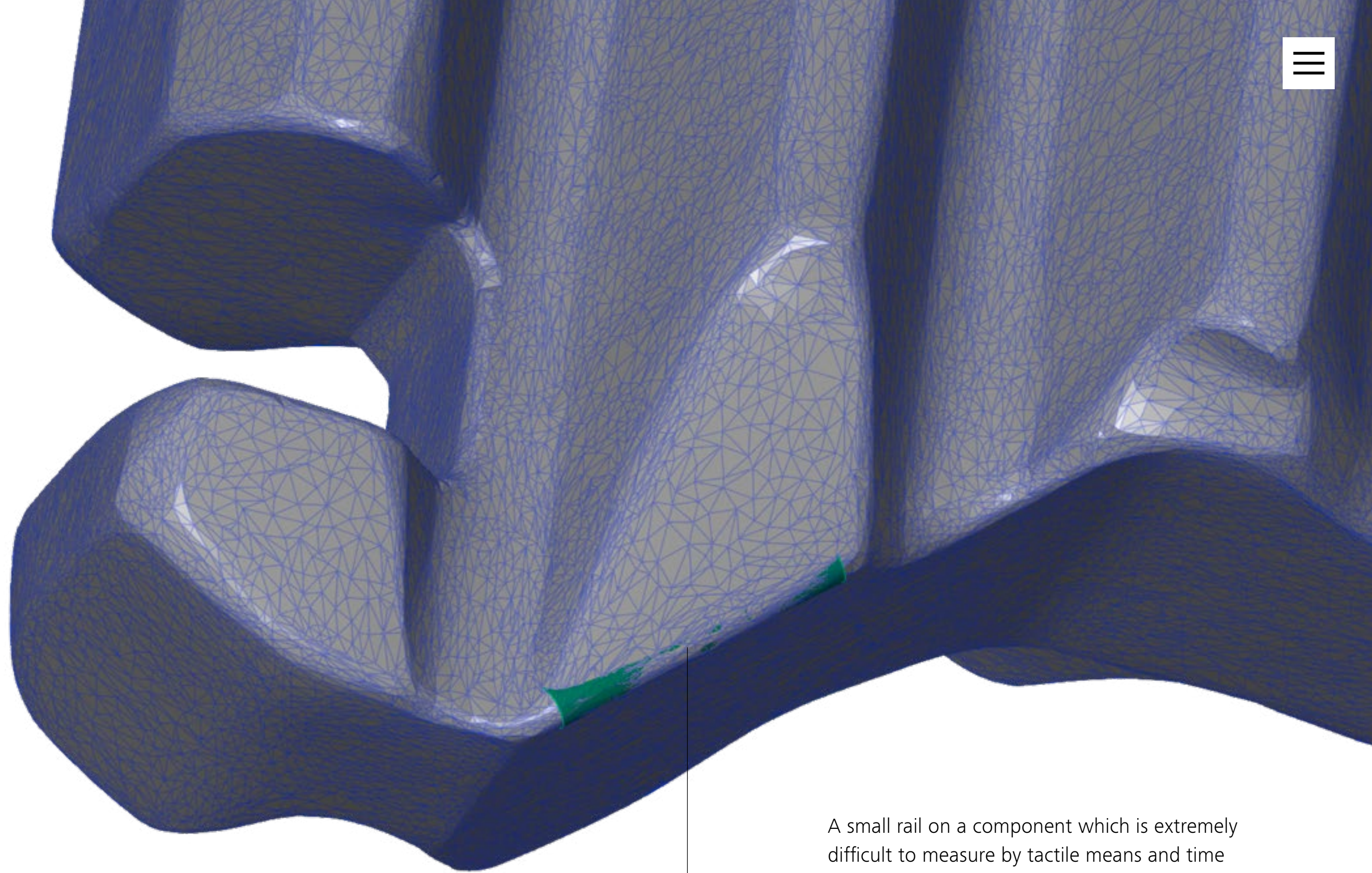
How is that possible?

ATOS: a one-stop solution for Form 3

Whereas mechanical measuring systems capture data in a point-based or linear manner, ATOS optical metrology provides full-field data. Everything the ATOS sensor sees in a single observation or viewpoint is captured in thousands of points. Each measurement takes less than a second. The combination of the multiple viewpoints builds the 3D representation, or digital twin – a process that is done in minutes, not days.

Optical technology 'breaks free' of the limitations of a traditional drawing by measuring between every line and / or additional points and capturing the whole product is captured in 3D. Now a design authority can receive data on 3 or 30 inspection point / lines or sections, or as many as he or she needs.

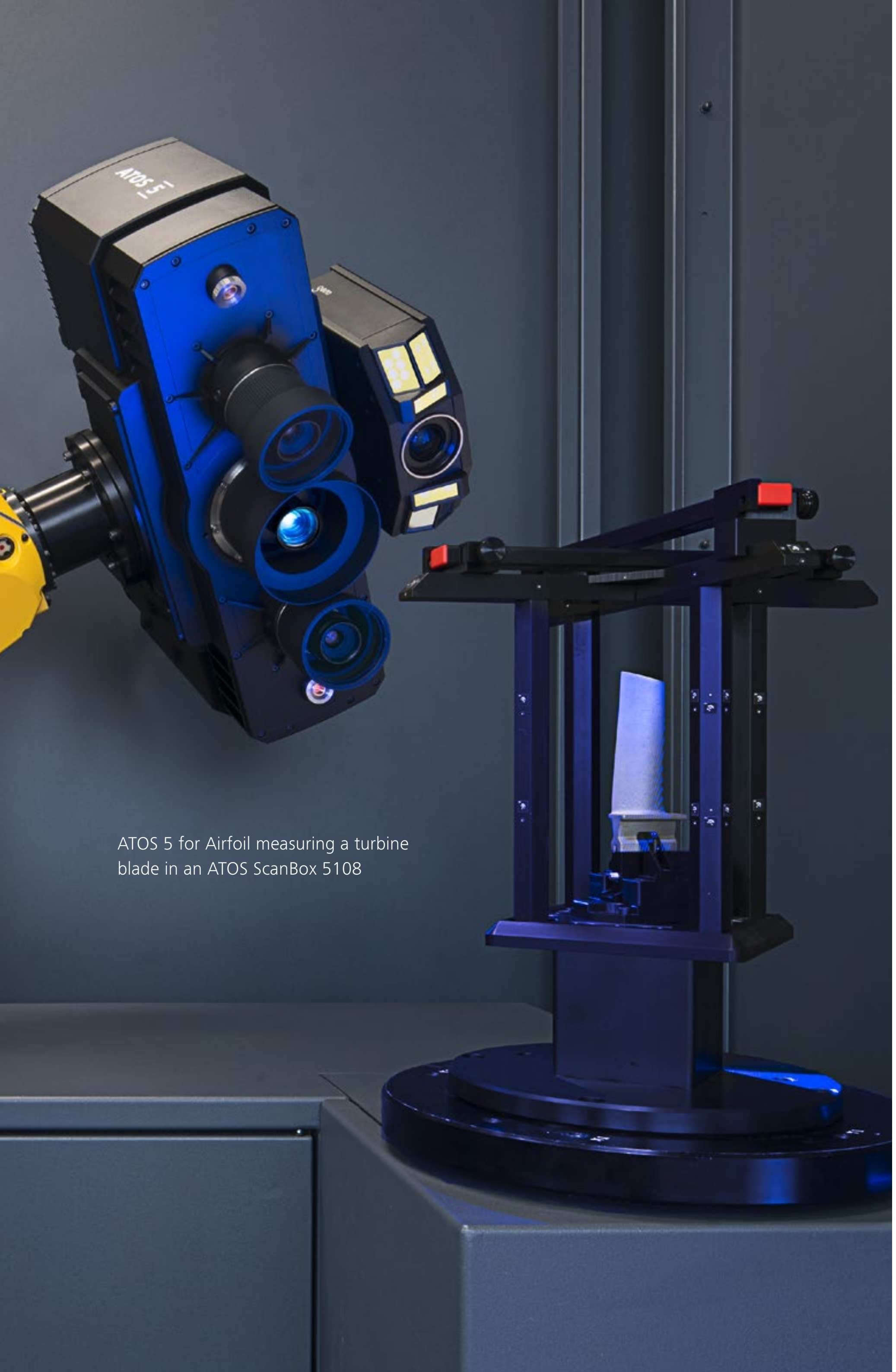
Optical technology is therefore a one-stop solution for FAIR / LAIR because it enables metrologists to do the vast majority of what is required for Form 3 (depending on the part size) in a fraction of the time compared to conventional methods.



Cylinder 7

	Nominal	Actual	Dev.	Check
R	+0.110	+0.100	-0.010	

A small rail on a component which is extremely difficult to measure by tactile means and time consuming by alternative methods.



ATOS 5 for Airfoil measuring a turbine blade in an ATOS ScanBox 5108

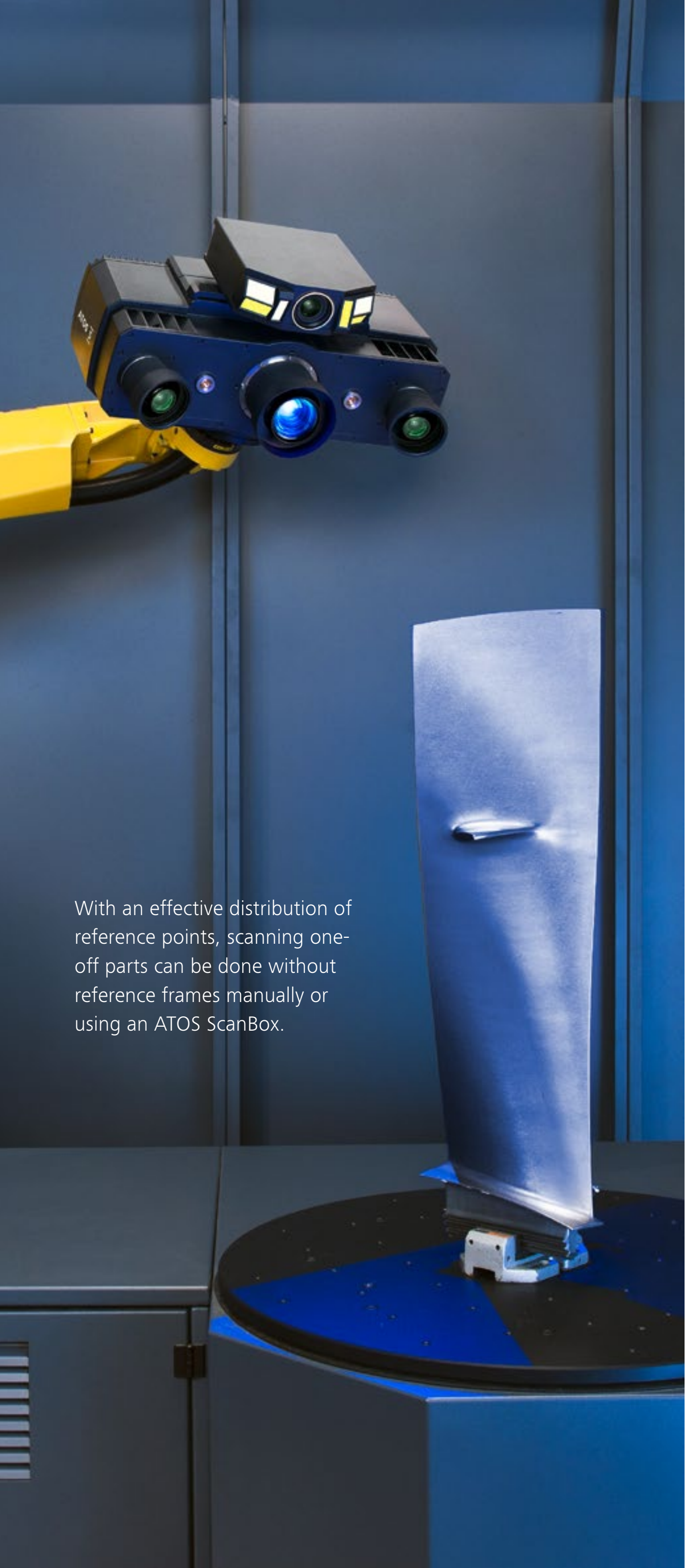
The simplicity of one-time scans

For good reasons, measurement processes for aerospace parts require fast cycle times, high repeatability standards and common fixturing. However, for First and last article inspections, a one-time scan of the part is sufficient to gather all necessary dimensional information.

ATOS optical 3D scanners and automated measurement machines, ZEISS ScanBox, are ideal for high-resolution scanning in a one-time set-up environment and/or laboratory. The process is extremely simple and doesn't require a special-to-product fixture to secure the part.

The high-speed scanners gather data on the part's surface from multiple vantage points. Notoriously troublesome features like small radii, edge breaks and complex forms, which are extremely labour-intensive to validate, can be properly verified with 3D optical metrology.

Once the series of measurements is complete – having captured nearly 100 % of the visible surfaces – the ZEISS Quality Suite of software compiles the individual scans into a singular 3D object known as a digital twin scan, or STL file, which to the untrained eye looks like a CAD model. Repeating this process for the FAIR and LAIR product is typically done in minutes. From here on, all the digital-twin analysis happens in the ZEISS Quality Suite software.



With an effective distribution of reference points, scanning one-off parts can be done without reference frames manually or using an ATOS ScanBox.

Complete metrology toolbox

The metrologist doesn’t even need a CAD when using optical technology from ZEISS because the ZEISS Quality Suite software is a complete metrology toolbox that performs all the traditional drawing (blueprint) analysis, including detailed alignments, GD&T analysis and the evaluation of freeform surfaces.

Advantages of the GOM technique for FAIR at a glance

- no additional measurements on physical part needed
- no repeat measurements or rechecked values, as all information is contained in one scan
- no time wasted time with tricky traditional set ups
- reduced if not completely eliminated need for mold / replicast measurements
- minimal “on-machine” time for the FAIR activity – the majority being possible offline

The software contains standard GD&T and advanced evaluation tools that meet all ISO standards. For companies with more advanced requirements, it offers model-based definitions (MBD), also known as Product Manufacturing Information (PMI). The point cloud can be compared with the drawing or with data from previous measurements, and an easy-to-understand overview of the dimensional accuracy of the part that was just produced will be created.

GOM Blade Inspect is a software within GOM Suite and is the answer to the inspection of airfoil features with all the well known methods including camberline, edge points, chords, thicknesses, throat area, and much, much more.

For these one-off scans, it is not even necessary to use reference frames[4]. The set-up could be an ATOS sensor, a rotary table and some reference points on the part, table or holding device. Because of the way the software and hardware collect the information, the reference points will still allow for a detailed 3D point cloud and 100 % complete scan.

The one-time scans for FAIR and LAIR can even be done by trained and experienced technicians, or by one of the many service providers across the globe with the systems and experience to deliver high-quality scan data – freeing up your metrologists and quality engineers to apply their much-needed skills elsewhere.

4 Reference frames and fixtures are the optimal way of working for repeat measurements of the same products in the production environment, when standardization is needed.

The GOM ScanCobot with ATOS Q measuring a Nozzle Guide Vane (NGV). This mobile measuring station is a highly versatile set-up for doing FAIRs and LAIRs and one-off inspections in a measuring lab.

With digital twin, proving equivalence is easy

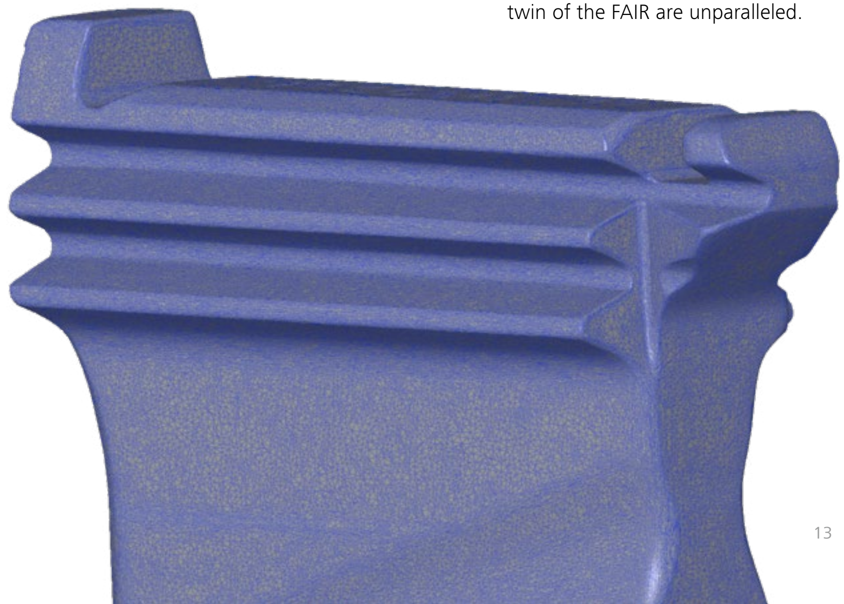
The digital twin can be used to compare a FAIR or LAIR part with the drawing, or to compare both parts. Parts made at different sources can be compared and the deltas between them color-mapped. Thousands of characteristics from two sources and two methods can be automatically tallied up in an easy-to-understand table and compared line by line.

A metrologist can also LAI the part against the nominal model and generate a surface deviation for everything scanned. Next, the user can do a FAI and perform the same comparison to the nominal model and the LAI part to determine any variations.

In this way, equivalence can be determined in a way never seen before – in a fraction of the normal time and with the ability to archive all the information for future reference.

In some cases, measurement uncertainties can be reduced to a minimum by using the exact same sensor and scanning set-up to capture the data from the two parts, regardless of the production technique.

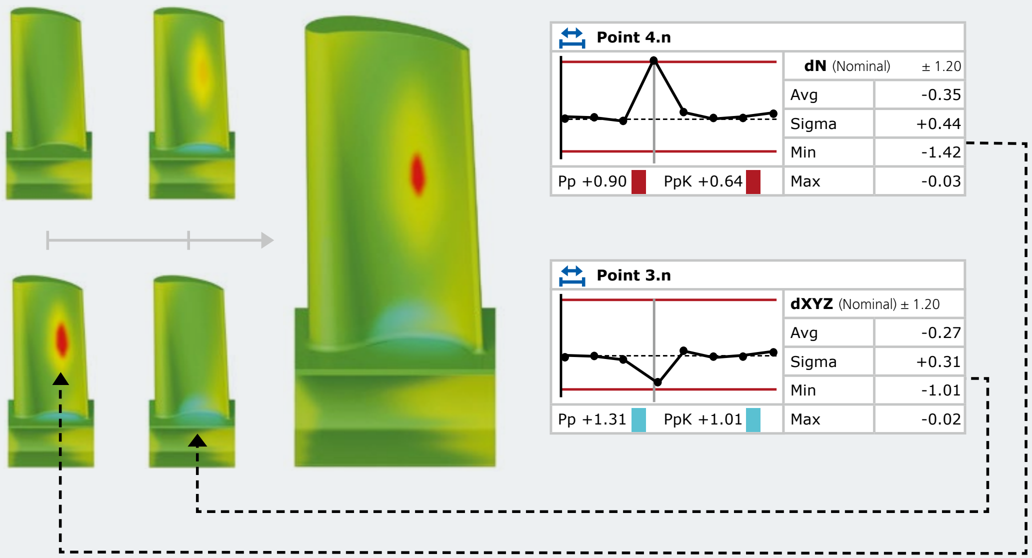
The advantages of having the digital twin of the FAIR are unparalleled.



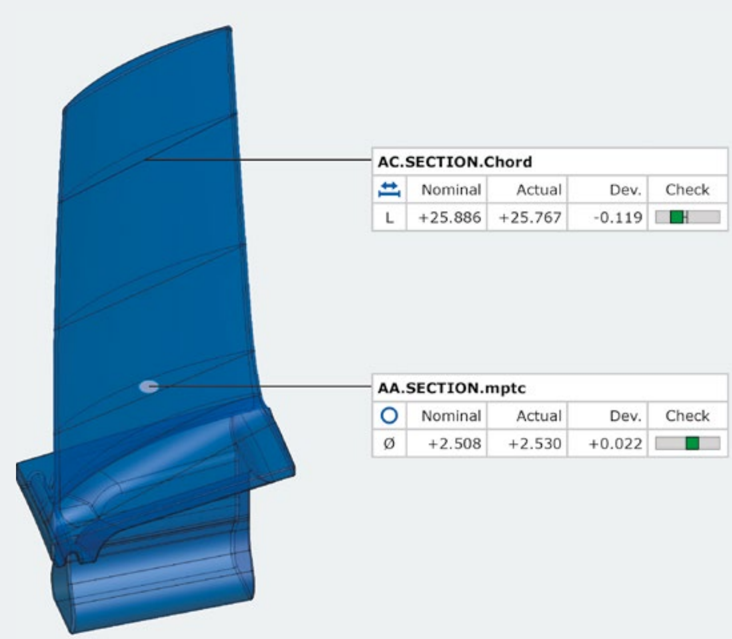
If both the FAIR and LAIR part are in the same project file, the analysis of the part only needs to be carried out once; it's then automatically applied to the other part. If an alignment is applied to the CAD, it's automatically applied to the FAIR and immediately on the LAIR. Insert a GD&T dimension, and it's applied to both parts in the project file.

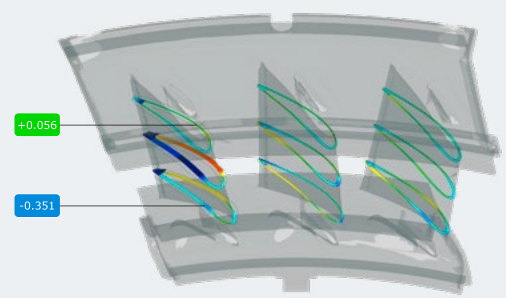
The graphical user interface allows all features and characteristics to be evaluated individually or both parts to be compared using tables. The software also allows point data, pictures and supporting information to be imported into inspection reports. Reports with pages can also be created.

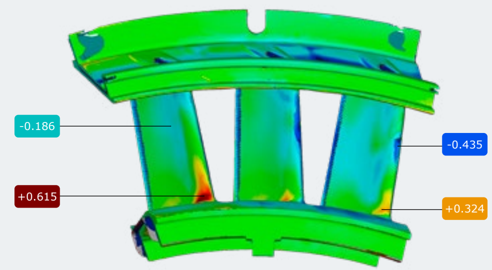
- CAD to Actual
- Actual to Actual – equivalence
- Local alignments
- Part/blade alignments
- Dimensional evaluations
- Trend project to show the difference



Putting measurement data side-by-side in ZEISS Quality Suite is an easy and effective way to review equivalence in 3D, tables, charts, etc.







Faster decisions, deeper discussions

Aside from these significant time savings and efficiency gains, obtaining a complete view of the part with the digital twin supports the core value that is at the heart of everything in aviation and aerospace: safety.

Full knowledge about a part can help designers model and simulate more from the real data. It could also break down barriers and even speed up and simplify decision-making, especially across geographic borders.

Being able to share the data, not as a PDF or a table, but as a real replica, is valuable too. With the digital twin, all stakeholders can see what happens through the lifetime of an aerospace part. The part can be rescanned on service and the data compared to understand more about the part. ZEISS Quality Suite is available as a FREE download for this reason, to enable the real evaluation of data across departments, companies and geographies.

Manufacturers can also use the 3D data to proactively highlight a problem that the manufacturer has perhaps always stated about the part, but which the designer didn't accept until now. The 3D data gives the manufacturer more 'ammunition' to prove its case in a debate with the OEM.

Now is the time to act

Now is the time to switch to 3D metrology. 2021 was a turning point for the aviation/aerospace industry: the switch to greener, sustainable aviation is building momentum. This will have a huge impact on the future FAIR/LAIR process.

The quest for lower emissions will usher in a new era of aircraft and engine design. New engines designed for a carbon-free world will increase the number of source and method changes, and hence the number of FAIRs and LAIRs.

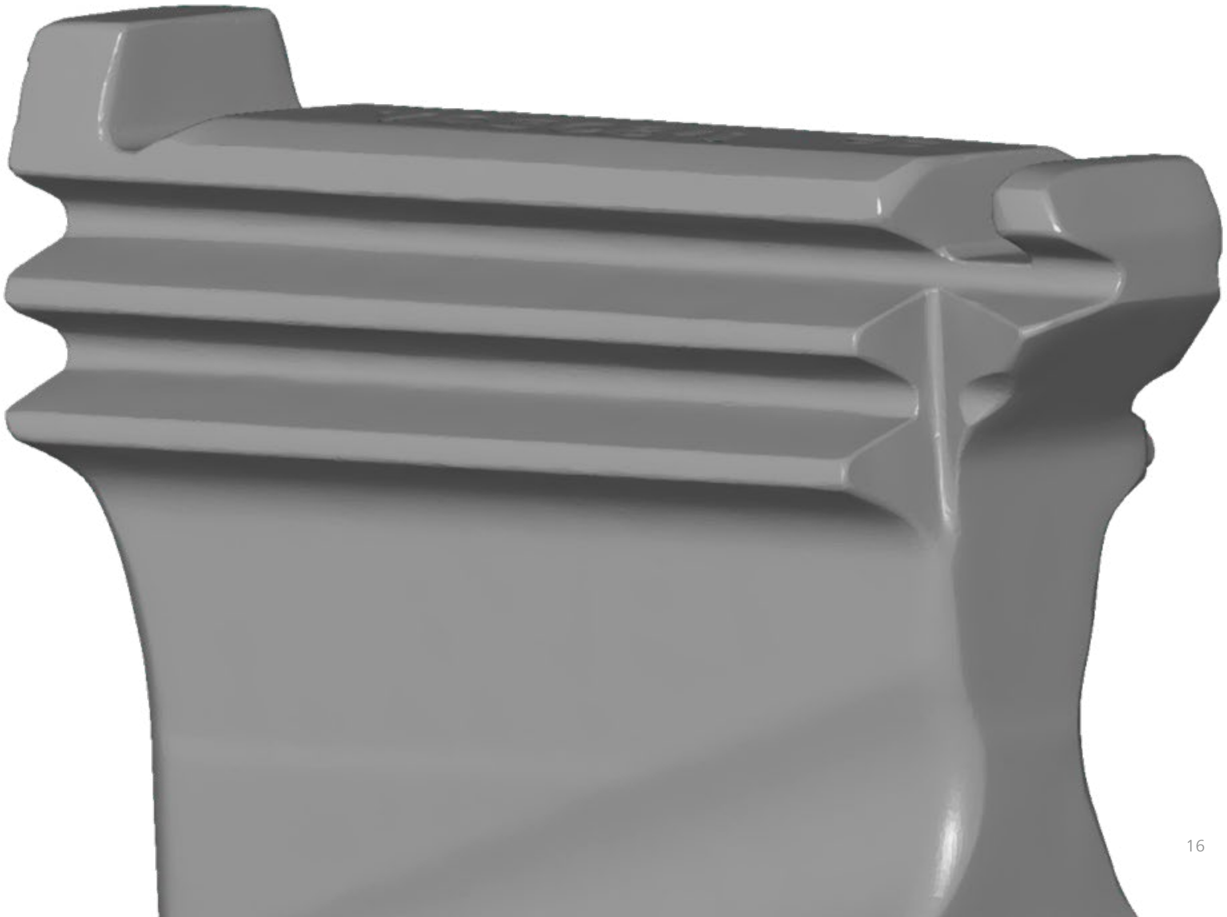
Therefore, increasing efficiency and productivity in the quality lab is more important than ever. By adopting modern inspection methods like 3D optical metrology now, manufacturers will be well equipped to cope with the extra FAIR/LAIR workload in the future. Suppliers who stick to their old ways of working will be uncompetitive.

The future of aero manufacturing is digital

As manufacturing gets smarter and more connected, digital-twin technology, will become the new norm. Digital twins are already widely used for engineering and aero design, and this will accelerate as airlines and OEMs aim to create a seamless digital thread of parts throughout the supply chain.

As digital-twin technology is applied to more and more areas of aerospace design and manufacturing, OEMs and Tier-1 companies will increasingly expect their suppliers to have this technology too.

Cost-cutting will continue at airlines and OEMs, and we believe the next wave of cost-cutting will be focused on increasing automation and introducing new Industry 4.0 technologies. This, too, will sharply increase the number of method changes, long after the pandemic ends. Suppliers that are slow to adapt may be locked out.



Digital twin – the 3D digital copy of the actual part prior to measurement analysis.

Conclusion

Suppliers have a choice: stick to the status quo or embrace modern inspection technologies. For ZEISS, it's clear which choice will position suppliers for lasting success in what is quickly becoming a greener and more digitally-enabled industry.

Now is the time to future-proof your organization by embracing time-saving, digitally-supported FAIR and LAIR inspection techniques.

ZEISS optical 3D metrology not only streamlines the entire FAIR/LAIR process. Armed with data that fully characterizes each part, you will be able to have better and more meaningful discussions about quality with the source- and method-change owners and design authorities at the OEMs.

Contact us to discuss your challenges.

Learn more

Best solutions from ZEISS for optical FAIR/LAIR inspections

GOM ScanCobot: This mobile measuring station is an extremely versatile set-up for doing FAIRs and LAIRs. GOM ScanCobot was designed for automating simple inspection tasks and doing one-off inspections in measuring labs. It delivers high-resolution detail thanks to the ATOS Q sensor. This scanner can fit parts with a diameter of up to 500 mm.

ZEISS ScanBox: For a more advanced solution, the ZEISS ScanBox is the ideal choice. This fast, compact measurement system comes in different versions depending on the size of the part to be inspected. The ATOS 5 for Airfoil sensor (which works in the ScanBox 5 and 6 series) was specially developed to meet the exacting requirements of the aviation industry.

Whether you do your FAIR/LAIR inspections with the GOM ScanCobot or ZEISS ScanBox, you don't need the CAD because the ZEISS Quality Suite software is a complete metrology toolbox that performs all the traditional drawing (blueprint) analysis, including detailed alignments, GD&T analysis and the evaluation of freeform surfaces.

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