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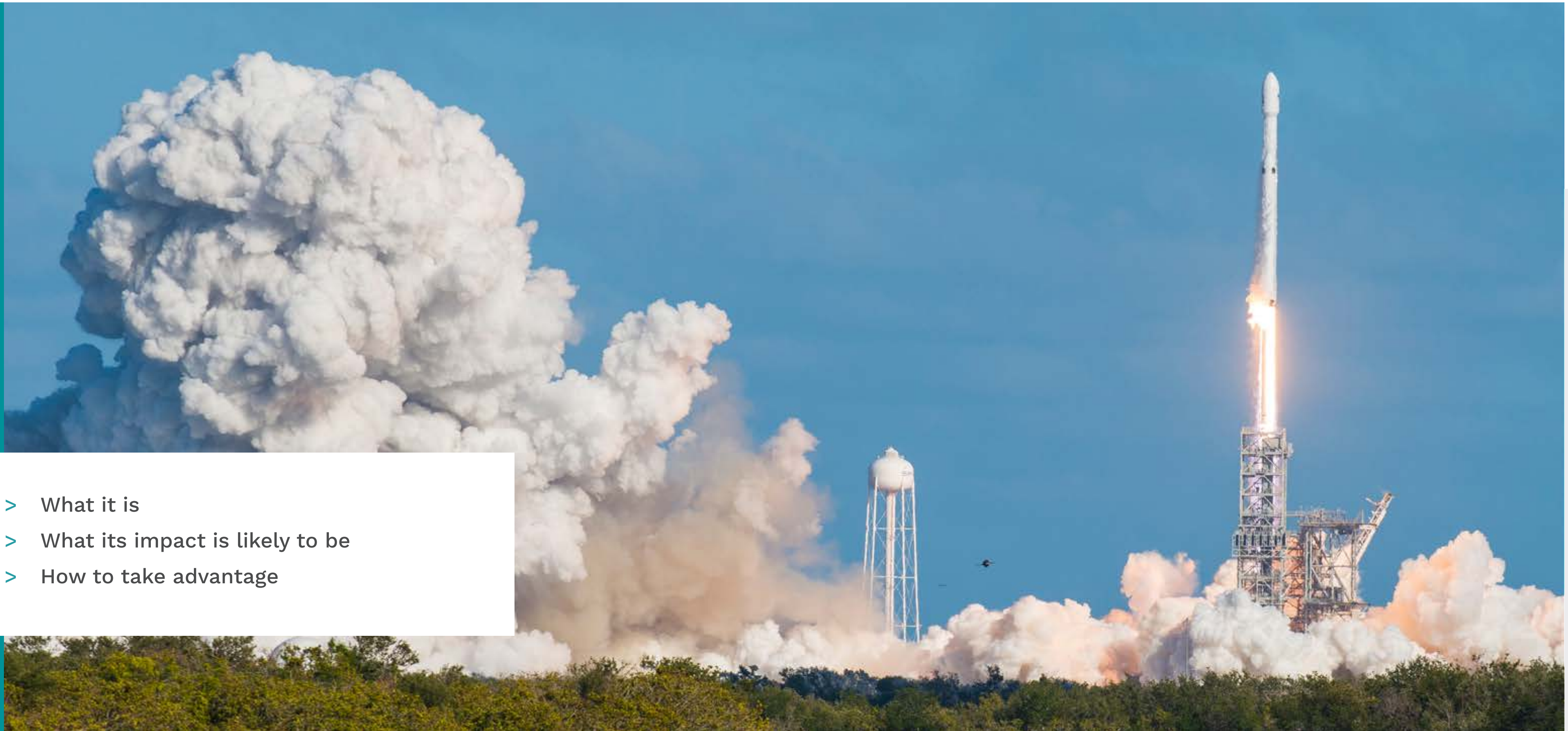
Automated Inspection for Aerospace via CT

2020



- What it is
- What its impact is likely to be
- How to take advantage

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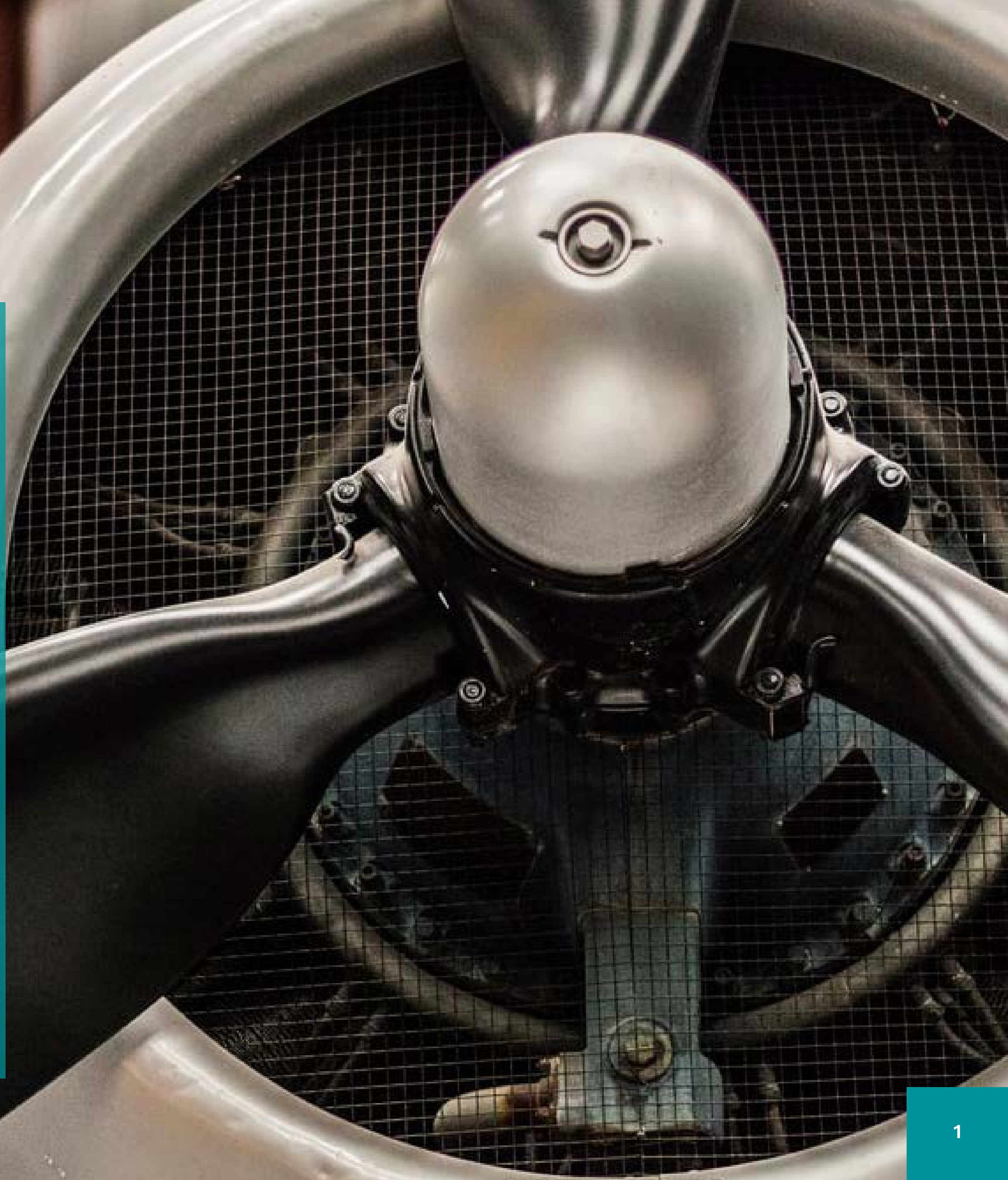
What you will learn from this paper

- The ever-expanding aerospace sector and its significance
- Automated Inspection for aerospace using Non-Destructive Testing (NDT)
- Addressing the challenges faced by users of automated Computed Tomography (CT)
- The impacts and benefits of Automated Defect Recognition (ADR) for aerospace via CT
- How you can take advantage of Automated Inspection



Abstract

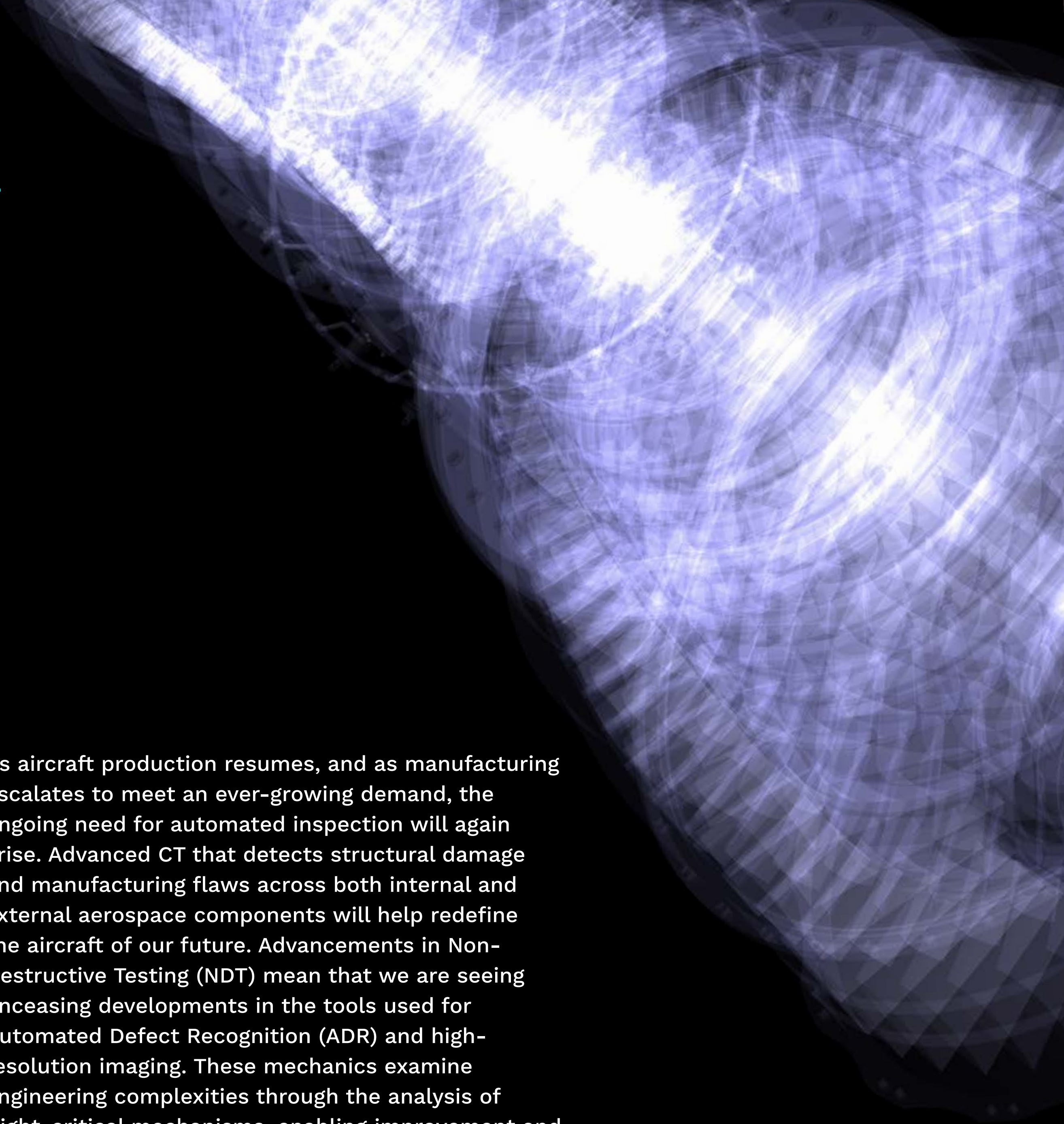
Cast your mind back to the beginning of 2020, when the aerospace industry was manufacturing aircraft at exceptional rates. Airlines were questioning whether they could continue to satisfy what seemed like an unappeasable appetite for air travel, with enough pilots and technicians.

Today, amidst the COVID-19 pandemic, nearly 75% of the world's aviation fleet is grounded. This means that fewer than 7,500 aircraft remain airborne, and most estimates are that it will take a minimum of two-and-a-half years post the peak of the Coronavirus for the grounded 75% to take to the skies once more. As the virus spread is controlled, aviation's globally essential nature means that the sector will continue its pre-COVID-19 growth, and realize a fleet of more than 35,000 by 2030. Passengers will again take vacations, the demand for freight will resume, and the number of aircraft produced for military and research purposes will scale back up. It is likely that the industry will still represent a decade of growth, despite a worldwide catastrophe.

Amidst upheaval, arises opportunity. As the initial impacts of the pandemic begin to subside, the aerospace industry will turn its attention towards the increased usage of next-generation technologies to increase efficiency amid the ‘new normal’.

One such technology is Inline Computed Tomography (CT): revolutionary scanning which will empower increased capability in the next generation of aviation manufacturing. We will likely see businesses investing in transformative high-end technologies, in readiness for subsequent decades and changing markets. It is, however, unlikely that there will be a one method fits all approach to post-pandemic recovery – with each organization being unique in terms of its revenue model, some will be less economically impacted than others. A snapshot analysis of aerospace, rocket manufacturers, and governments tell us that profits from frontrunners in these sectors are not always consumer-driven.

In the case of the rocket industry, a vast proportion of wealth is funded by private industry and billionaires. As for government sectors, whether it be rocket systems, munitions, or propellant equipment, we are noticing world governments upfronting large sums of money for their future development.



As aircraft production resumes, and as manufacturing escalates to meet an ever-growing demand, the ongoing need for automated inspection will again arise. Advanced CT that detects structural damage and manufacturing flaws across both internal and external aerospace components will help redefine the aircraft of our future. Advancements in Non-Destructive Testing (NDT) mean that we are seeing unceasing developments in the tools used for Automated Defect Recognition (ADR) and high-resolution imaging. These mechanics examine engineering complexities through the analysis of flight-critical mechanisms, enabling improvement and aeronautical safety.

Maturities in NDT equipment have addressed some of the most significant challenges faced by handlers of CT for aerospace – from scanning speed to image accuracy, and from labor intensity to operational efficiency. As users of revolutionary scanning equipment, we can feel confident that the technology of the last decade has evolved at a pace that has enabled automated CT to secure its place in the market, with consumers at its hub.

Where technological development is concerned, the fourth industrial revolution, more commonly referred to as Industry 4.0, teases the 'consumer at its core' approach for all scientific improvement. The tactic uses forward-thinking innovations to combine conventional manufacturing and industrial platforms with state-of-the-art technology. This helps organizations and professionals to reformulate the design, engineering, and manufacturing of not just CT Imaging, but across a variety of products and services.

Industry 4.0 plays a critical role in fueling operational effectiveness and worldwide growth, with research from Accenture suggesting that the optimum fusion of technologies could save business giants up to $16 billion.

It quickly becomes apparent that the advantages of automated inspection are vast, and the utilization of ADR-led, repeatable, dependable CT precision scanning, may well be the evolution catalyst for aerospace.

Introduction

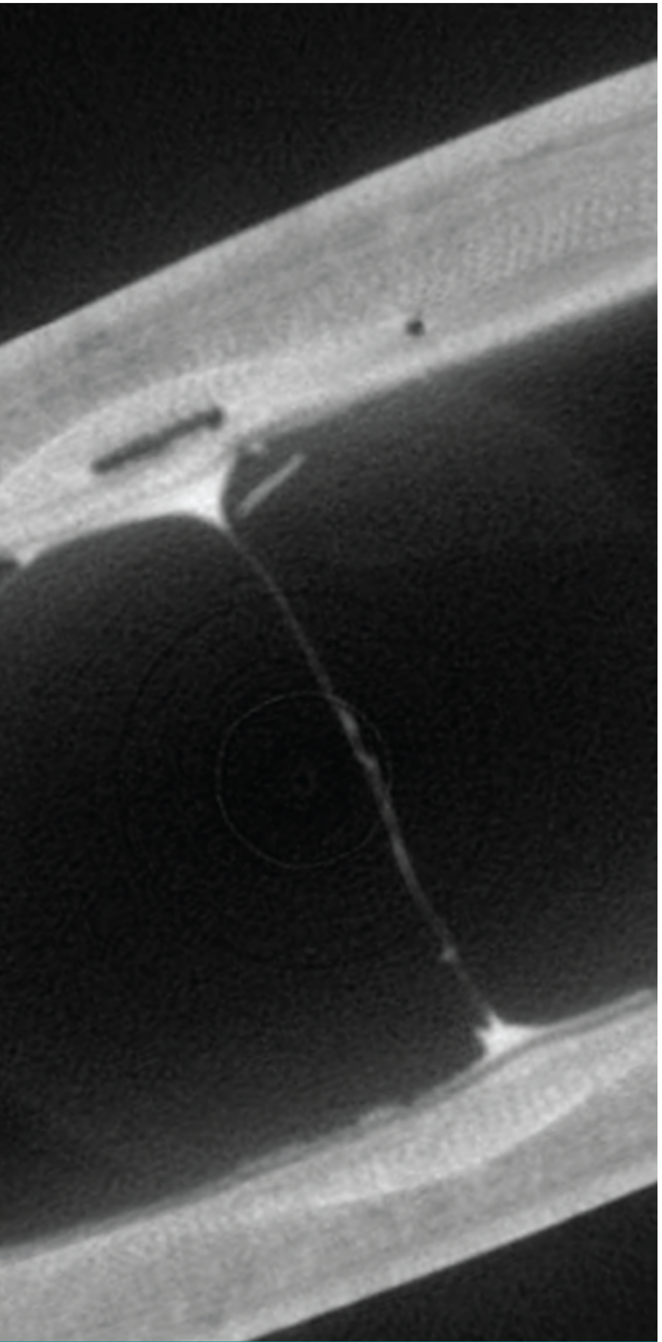
The US aerospace industry, across civil and military hardware, is judged to be the largest in the world. Its focus on pioneering revolutionary technologies has helped to expand and transform commercial and military aviation. This has enabled technology-led capabilities to speed up manufacturing processes and lower operating costs.

The aerospace industry has clear importance in providing the nation with safe, fast means of transportation and exploration, However, aerospace is more than just an industry – it's a robust mechanism for developing technologies that enable the growth of other sectors.

Industry 4.0 is critical to aerospace development. The 4.0 methodology within aerospace fundamentally emphasizes new-fangled digital technologies. These new technologies are penetrating the electronics manufacturing industry, and applying them to aerospace is what is driving the observable revolution in the sector.

These technologies include the Internet of Things (IoT), Artificial Intelligence (AI, often referred to as Machine Learning) Big Data, Additive Manufacturing (3D printing), Augmented Reality (AR), and mobile edge computing.

Aimed to assist engineers, manufacturers, operators, and specialists in quality control, this White Paper explores Automated Inspection for Aerospace via CT: What it is, its impacts, and how you can take advantage.



What is Automated Inspection for Aerospace via CT?

Put simply, automated inspection for aerospace is a process that eliminates manual activities from a user. Hardware and software work in harmony to automate the execution of an inspection. Together, they collect and analyze image data, determining whether the inspected product is good or bad, and, ultimately, whether it passes or fails the inspection.

An inspected product might be die-cast-made or produced using additive manufacturing. Additive manufacturing for aerospace is an innovative way of producing components – it could be considered as a transformative method of industrial engineering. It facilitates the instantaneous building of machine parts, comprising minute particles of internal detail. This makes it a high-class approach to component construction compared to that of traditional die-casting methods, which can force design limitations due to the pouring of hot metal and reliance on molds. It empowers consumers to design and build components with a high degree of internal complexity like never before.

Quality standards and safety regulations govern the aerospace industry, and so with design intricacy comes a necessity for 3D CT inspection. This is one of the only scanning tool methods that allows high-resolution scans of both internal and external surfaces.

Machine parts are internally inspected for imperfections, enabling improvement of the defective segment and ensuring design safety. New technologies mean that 3D Printing is no longer thwarted by mass production limitations, and consequently, the shift towards using additive manufacturing as a solution to producing machine parts at scale is driving the need for NDT via CT.

We'll refer to the relationship between additive manufacturing and NDT via CT, as *companionable machines.*

Global leaders in automated inspection will have participated in the standard committee development of 2D ADR inspection technologies. However, in support of additive manufacturing at scale, what consumers want now is for suppliers to leverage their expertise and develop a similar set of automated software algorithms that analyze defects using 3D instead of 2D data. There is demand for 2D technologies to grow into the 3D CT space – and who better to set new expectations for inspection, than users of additive manufacturing and consumers of NDT CT themselves.

What Challenges are Users of Automated CT Facing?

CT systems are complex, scientific instruments. CT imaging typically requires well educated, highly trained specialists to correctly operate, maintain, modify and troubleshoot the machines.

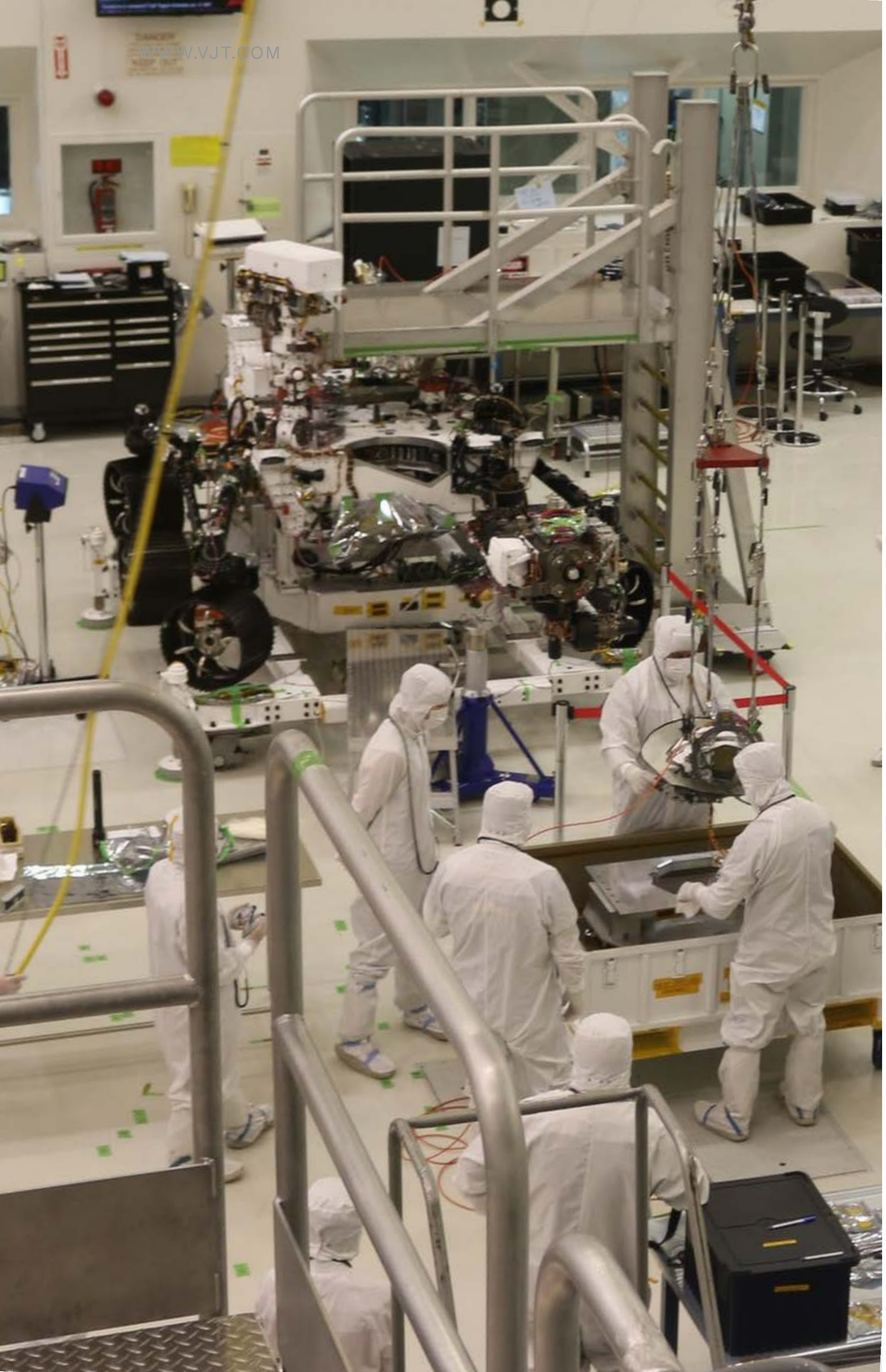
One of the biggest challenges with automated CT today is the need to simplify the operation so that less specialist users can operate machines effectively for mechanical inspection.

Non-Destructive Testing at the speed of production remains one of the most significant blockages in 3D CT scanning today. This is mainly because CT analysis itself comprises sets of complex software algorithms that process large amounts of data collected by X-ray detectors. CT systems link directly to software that supports the need to inspect machine parts in real-time, at the same time as the production line is producing the machine part. This is often referred to as Inline CT. This Inline production and inspection process means that critical components with complex material structures or internal geometries are inspected at the same rate they are being produced. No time-lag occurs, maximizing production and product sign-off efficiency. So, if a production line is making a part every 30 seconds, maximum efficiency would require an automated inspection to take place within that same 30 seconds. Further technologies that enhance both speed and function at that the development of automated inspection is, in some ways, still in its infancy.

As we hanker for fused, speed-of-light production and inspection processes, let us not forget how far automated inspection for aerospace has come.

Just five years ago, it could have taken hours, even days for detectors to run software algorithms, create 3D images and analyze the data. Now computers have improved, and the software is more refined. The days have become hours and hours have become minutes. Industry leaders are developing ever more efficient technologies and algorithms, which combined, tackle the speed challenges associated with automated inspection.

There is no escaping the time-gap between understanding what is needed to advance automated inspection further, and having that technology at our fingertips. A solid understanding of our existing equipment and the sophistication of 2D scanning operating in the 3D space is a manufacturer's ideal – as long as solutions to speed-based challenges are realized. This would enable the examination of more products, in real-time, and with exceptional resolution results. That is the end goal, and one that everybody who is anybody within the industry is trying to achieve ahead of its competitors. While cutting-edge technology that solves these challenges is in the throes of development, it will be some time before this intelligence is manufactured and, therefore, commercially available.



Three-dimensional imaging via CT is, at present, predominantly used for Research and Development (R&D) of machine parts. Sometimes referred to as First Article Inspection (FAI), 3D CT imaging identifies manufacturing process flaws, which aids manufacturers in the production of machine parts that conform to build specifications and requirements around quality and safety.

X-ray inspection facilitates quality control and aids in the adherence to safety requirements. However, to put consumers at the core of the manufacturing process means offering Non-Destructive Inspection through CT solutions that speed up processes, reduce costs, and ensure consumer confidence in their internal production rate requirements.

Repeatedly, we observe *traditional* consumers of CT performing production inspection using 2D technologies, and then utilizing 3D CT scan technologies for product development and validation, mainly for the supplementary information that 3D CT provides. Consumers who complete their end process via additive manufacturing are emerging, with a requirement for every manufactured part to be 3D CT inspected. The overriding development priority will be how providers of NDT via 3D CT can offer real-time, cost-effective automated inspection.

What’s interesting, is that while the capabilities of 3D CT automated defect recognition denote accuracy, this precision means that users are presented with reports that evidence more component-based anomalies than they are accustomed to. These variances were not known before being able to look at the internal structure of machine parts with 3D precision scanning, and highlight how those defects affect the performance of the machine part in question. Consumers can find this challenging, as, by nature of the equipment’s sophistication, they become obligated to further define internal quality and acceptance criteria, for areas of the part they were not even looking at prior.

Randy Shepard, from VJ Technologies, recalls that there have been instances where, post-machine-part analysis, the customer has returned with their imaging, asking questions such as ‘What is it we can see inside this part?’, and ‘What is this void that I can see?’. What is happening here is that 3D CT intelligence has scanned internal areas of machine-parts that manufacturers might have considered non-critical. 3D CT has captured an image of space, known as porosity, and caused by gas or shrinkage. It might be that the strength and structure of the scanned component has previously been validated by other scientific means. Still, we can begin to see how images from precision scanning technologies both answer and pose questions around the design and manufacturing of machine parts. As well as this, it becomes clear how producing at scale via additive manufacturing can reduce component ambiguity.

What are the Likely Impacts and Benefits of Automated Inspection for Aerospace via CT?

Amid the industries that NDT serves, aerospace is likely the most stringent in terms of its quality requirements and stipulations of accuracy.

The automotive industry, uses NDT for inspecting operationally critical machine parts that include rotors and control arms, but the risk of automotive part failure is relatively small compared to a component failure on an airplane at 35,000 feet. There is a distinct set of requirements in the aerospace industry geared at improving quality and ensuring safety.

Many emerging businesses in the aerospace sector will adopt additive manufacturing as their primary tool for engineering design, and will subsequently need to carry out NDT via 3D CT for the inspection of manufactured parts. Employing 3D-CT systems will be critical to the reputational success of these startups, and will encourage them to account for costs, labor, and manufacturing accuracy. For leaders in aerospace and the commercial rocket sector such as SpaceX, Blue Origin, and Virgin Orbits, additive manufacturing has become second nature. They are regular designers of large-scale machine parts using additive manufacturing that, post-production, leverage 3D CT Inspection.

We have observed too, how long-established organizations that use traditional manufacturing, methods such as die-casting, are seeking improved diagnostics that support quality build and enhanced performance of their components. We have witnessed how the revelation of NDT through 3D CT urges manufacturers – pre-NDT scrutiny – to analyze components and build them more prudently at the outset.

Reports derived from NDT analysis provide further opportunity to revise designs and to potentially increase the efficiency of machine parts through the construction of lighter-weight components that, for example, enhance air or fuel flow. Modern ADR equipment delivers supplementary data compared to that of 2D scanning, enabling the superior design of products for consumers that are faster, more cost-effective, and with increased capability.

Industry 4.0 facilitates the data connectivity of the 3D CT production and inspection process. Through the transformation of traditional manufacturing processes – such as the rise in additive manufacturing – and united with state-of-the-art technology such as NDT via 3D CT, Industry 4.0 enables the optimization of production processes. Th is can reduce manufacturing lead times, improve product quality, and heighten organizational performance. As corporations begin to develop CT inspection technologies and systems, they are doing so with industry 4.0 enabling tools, in such a way that software is providing information and data sets that can be fed into an industry 4.0 framework.

For instance, let us assume that automated software analysis finds 17 defects inside a machine part. Three-dimensional imaging will report quantitative information that categorizes those defects. It's then possible to position that data, configured in a way that can be filtered back into an industry-forum-connected-factory, enabling manufacturers to use that data as intelligence to their casting process, whether it be die-cast or additive manufacturing.

Additive manufacturing embraces multiple methods and technologies from laser-induced techniques to large-material welding methods.

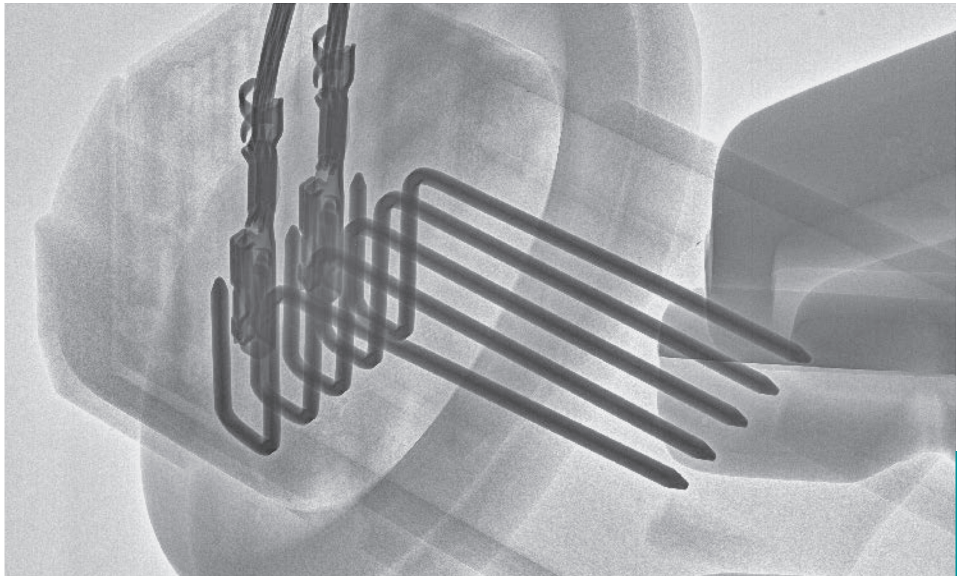
These escalating approaches to product fabrication via additive manufacturing give manufacturers of aerospace control over the materials they use, matched with the criteria of any given component. Twenty-first-century development of manufacturing materials is widespread; we can choose more sturdy, reliable materials that are lighter weight, ideal for the build of lighter cars and aircraft, making them more fuel-efficient, stronger, and safer. Dionysios E Mouzakis's (2018) paper titled, *'Advanced Technologies in Manufacturing 3D-Layered Structures for Defense and Aerospace'* offers a broad 'journey through the years' insight into advanced technologies used in additive manufacturing.

We already know that 2D scanning is widely used in the automotive sector today. Still, deprived of automation, the scanning process is much more labor-intensive. Let us take steering knuckles, (the safety components of any car) as an example. Every car has four steering knuckles. These machine parts are made for every vehicle in the world and must be inspected for defects after they are made to ensure compliance with safety regulations. Given the size of this component and its internal workings, we can image it today by taking five discrete impressions. The process sees the images presented to a technician who, just like a doctor, announces the scans as good or bad, pass or fail.

Without automated inspection, a technician must manually review each X-ray image and decide whether that image shows defective parts.

Like the steering knuckle, if a machine part's scan consists of five images, that means each of those five pictures must be analyzed before a decision can be made as to whether the part is flawed. In a production line that is producing 500 knuckles per hour, it is unfeasible for an operator to manually review every one of those images while also sustaining timely production. Let us take that same example and move it to 3D CT inspection. When we use 3D CT, we seek not four or five images, but instead rotate the machine part and take thousands of pictures at a variety of comprehensive angles. Software model algorithms then combine those images and create a 3D volume of the piece. It is next to impossible for an operator to review thousands of images, so software that enables 3D CT automated inspection becomes both a necessity and a blessing in the speeding up of processes.

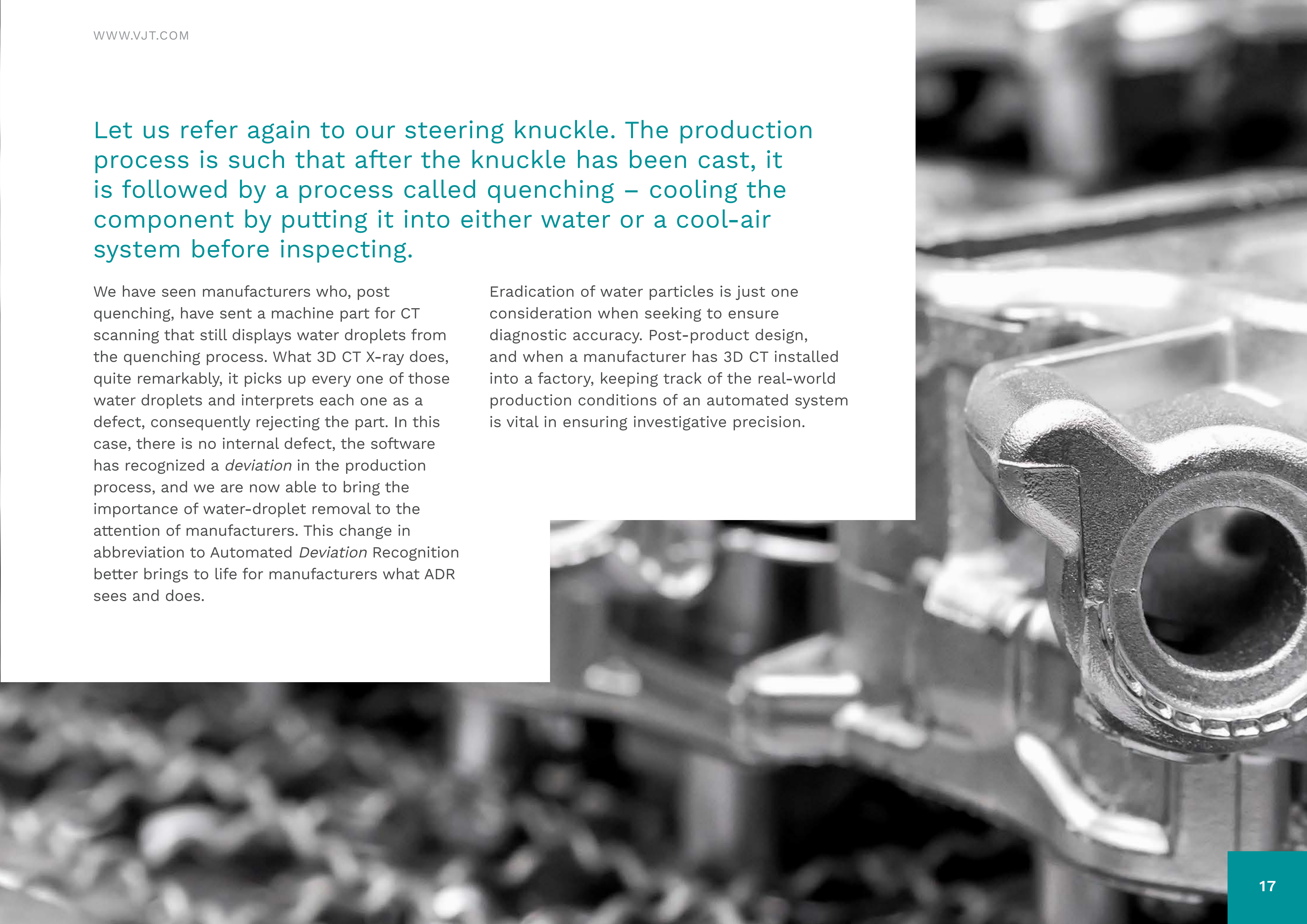
Post-production, every hour, minute, and second that a machine-part continues to live in a factory is a cost to any business. Process optimizations are imperative to cost-saving: the faster manufacturers can produce a machine part, inspect it, determine that it meets requirements and get it to the shipping dock, the more money we save our consumers.



Pioneering software not only detects defects in a machine part, but will also register non-regular changes in the manufacturing processes

In terms of scanning specifics, manufacturers and industry regulation set the criteria for what requires inspection, and the accuracy at which it should be checked. What the operational experts of CT scanners do is define which tools and software they use for ADR, which are each industry-governed in terms of how accurate scanning devices need to be and then designed to meet that exactness. In the 3D-CT space, the growth of inspection technologies means that consumers want to look more frequently at precise artifacts within their components. Twenty years ago, when we switched on an X-ray system and looked at a machine part, we might have been looking at a resolution of that X-ray image measured in millimeters. Today, the industry boasts systems and X-ray tube technologies that empower resolution precision down to the nanometer.

While the industry references ADR as Automated Defect Recognition, we explain it to our consumers as Automated Deviation Recognition. This is because pioneering software not only detects defects in a machine part, but will also register non-regular changes in the manufacturing processes which, during imaging, can also flag as a potential defect, and can be analyzed and understood as a result.



Let us refer again to our steering knuckle. The production process is such that after the knuckle has been cast, it is followed by a process called quenching – cooling the component by putting it into either water or a cool-air system before inspecting.

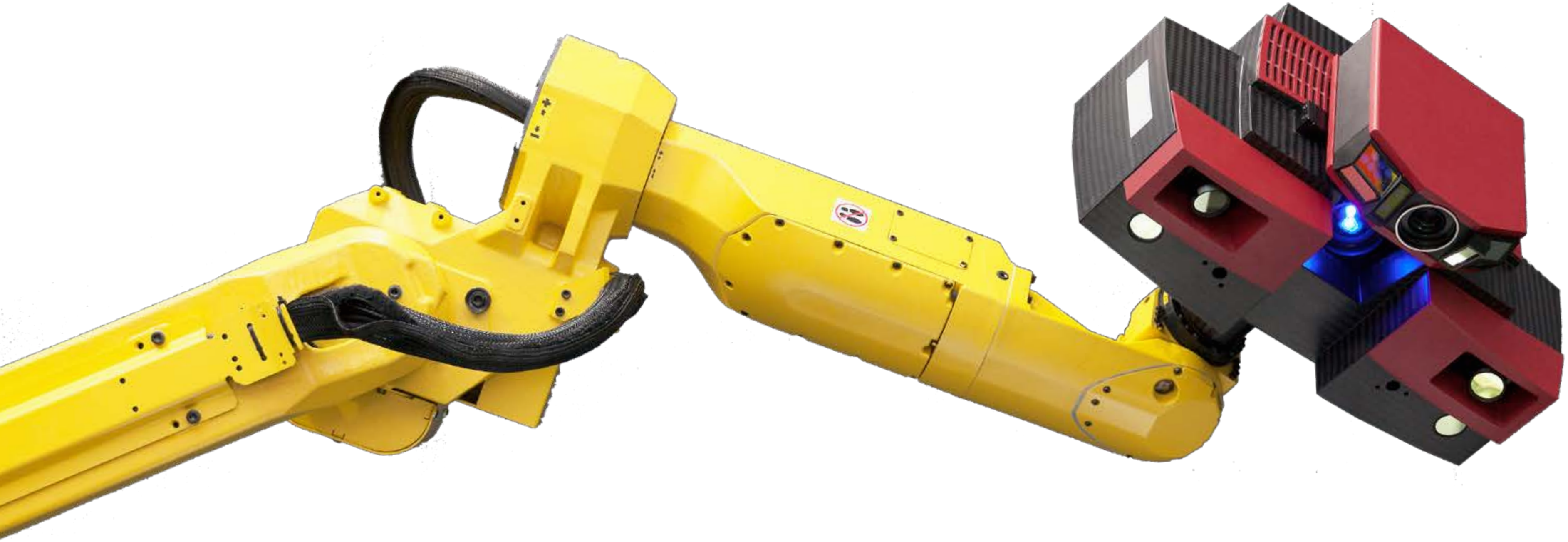
We have seen manufacturers who, post quenching, have sent a machine part for CT scanning that still displays water droplets from the quenching process. What 3D CT X-ray does, quite remarkably, it picks up every one of those water droplets and interprets each one as a defect, consequently rejecting the part. In this case, there is no internal defect, the software has recognized a *deviation* in the production process, and we are now able to bring the importance of water-droplet removal to the attention of manufacturers. This change in abbreviation to Automated *Deviation* Recognition better brings to life for manufacturers what ADR sees and does.

Eradication of water particles is just one consideration when seeking to ensure diagnostic accuracy. Post-product design, and when a manufacturer has 3D CT installed into a factory, keeping track of the real-world production conditions of an automated system is vital in ensuring investigative precision.

Every day, CT robotic arms experience wear and tear, and molds that hold machine-parts suffer erosion. Over time, the scanning apparatus that began in position X will shift. As gradual movement becomes more significant, automated software will start to reject machine-parts because it sees things that are different from how they were. What a manufacturer or any consumer of 3D CT must comprehend, is their obligation to routinely monitor their CT machine, keeping on top of correction, alteration, and modification, and preventing unnecessary product rejection.

We recommend that organizations that have in-house 3D CT assign designated ADR champions. Most providers of NDT will offer operational support as services, but a skilled person should be directly accountable for system monitoring and maintenance.

We are always tuning our CT systems to realize the *sweet spot*, optimizing them to catch minute detail – albeit that analysis takes longer compared to simplified criteria checks that maximize throughput. The sweet spot is to optimize the CT system for the best possible performance.



How to Take Advantage of Automated Inspection

When looking at 3D CT performance, CT machine frameworks made of granite offer superior temperature and vibration stability, compared to that of metal structures.

Metal fares well in a typical lab environment where the temperature is relatively controlled, and where there is no large-scale equipment that generates vibration. But 3D CT scans can take hours or days to run depending on the component that is being inspected, with extended machine-operating lengths causing temperature gradients or vibrational impacts during the acquisition that can affect data quality. Granite and steel are similar in price, and most vendors of 3D CT provide both.

As we look a little deeper into achieving the *best possible performance*, it is crucial to recognize that without automation, manual loading becomes the bottleneck of the inspection process. In some parts of the world, where labor is still relatively cheap, it is more financially viable to use manual labor over Artificial Intelligence (AI) – we have seen instances where some organizations choose to assign ten people to a problem instead of designating AI. Still, regardless of who or what fulfills this role, there will always be a requirement for machine-parts to be loaded and unloaded at a relatively high volume.

In time, 3D CT inspection for aerospace will operate with 2D inspection sophistication. However, to maximize opportunity for the continuous evolution of automated CT inspection and align the speed of CT scanning analysis with production rates, the industry must continue to see improvements in the sophistication of 3D automated software analysis technologies. These are supplemented with faster computing know-how – advancements that will enable experts in 2D scanning equipment to move their solutions into the 3D arena.

We foresee 2D imaging disappearing over the next 5-to-15 years.

There is little reason to only look at a machine part in 2D when 3D provides more data. The future of X-ray inspection will be in the 3D space, and the only things holding it back are cost and speed.

Ahead of 3D CT, there is – albeit conceptual – a mathematical extension of the 3D space, enabling objects that could not exist in their current form without the use of additional space, sometimes referred to as 4D. We prefer to call it Cinema-graphic CT. Imagine a real-time CT inspection that has been recorded. Consider an electromechanically operated valve such as a solenoid as it passes through CT imaging and then envisage the activation of the solenoid during imaging, providing a visual of how it works during operation. This scan would record, and capture each mechanical detail, and this will form the future of CT scanning. We will see trucks that are 3D CT scanned as they drive through border security, obtaining almost instantaneous results as they collect their scan report from a booth just 30-seconds down the road. It might sound futuristic, but it is to become our reality.

A manufacturer of a machine part that requires 3D CT automated testing ultimately wants to know if their sensitivity requirements can be met in line with their production rates.

VJT CT-scan sample parts for our customers and provide diagnostic reports. We emulate the imaging we believe necessary to meet a manufacturer's image sensitivity requirements and then calculate how fast that imaging can occur.

We pride ourselves in offering an education to our consumers of automated inspection. If a vendor is not asking to see a machine part, we suggest that manufacturers ask why. Without part analysis, how can vendors provide answers to questions? There is no one formula; every machine part can be different based on how it is made, what its geometry is, what the component requirement is, and how fast the machine part needs to be manufactured.

Before the release of any order to VJT, we comprehensively characterize how quickly and how well we can image and report on a machine part. Consumers that embrace automated inspection for aerospace quickly celebrate enhanced product quality. This is derived from increased scanning accuracy, production-cost savings as a direct consequence of increased output, and labor savings through process automation. NDT via 3D CT enables the production of complex machine parts swiftly, economically, and competitively.

Various industry sectors will use an array of NDT methods that include visual, fluorescent penetrant magnetic particle laserography, shareography X-ray, ultrasound, and guided-wave ultrasound. There are upwards of 15 different technology inspection modalities that one can apply based on the construction of a machine part. For example, ultrasound works well on a bare-metal product by placing a sensor on either side and injecting an electrical wave through the surface of the metal. Any deformation of the signal usually means there is a defect in the material, but ultrasound does not provide quantitative information; it bestows only knowledge that something is wrong. A CT X-ray can provide quantitative data of a specific defect that includes its size and location.

When we look at additive manufacturing and consider the internal complexities of the components that it prints, it becomes clear why many scanning modalities – such as optical measurement tools –fail. They inspect the surface of the product only, excluding multiple aspects and crucial internal elements. There is no solution quite like 3D CT – a companionable machine for additively manufactured machine-parts.

COMPARISON CHART

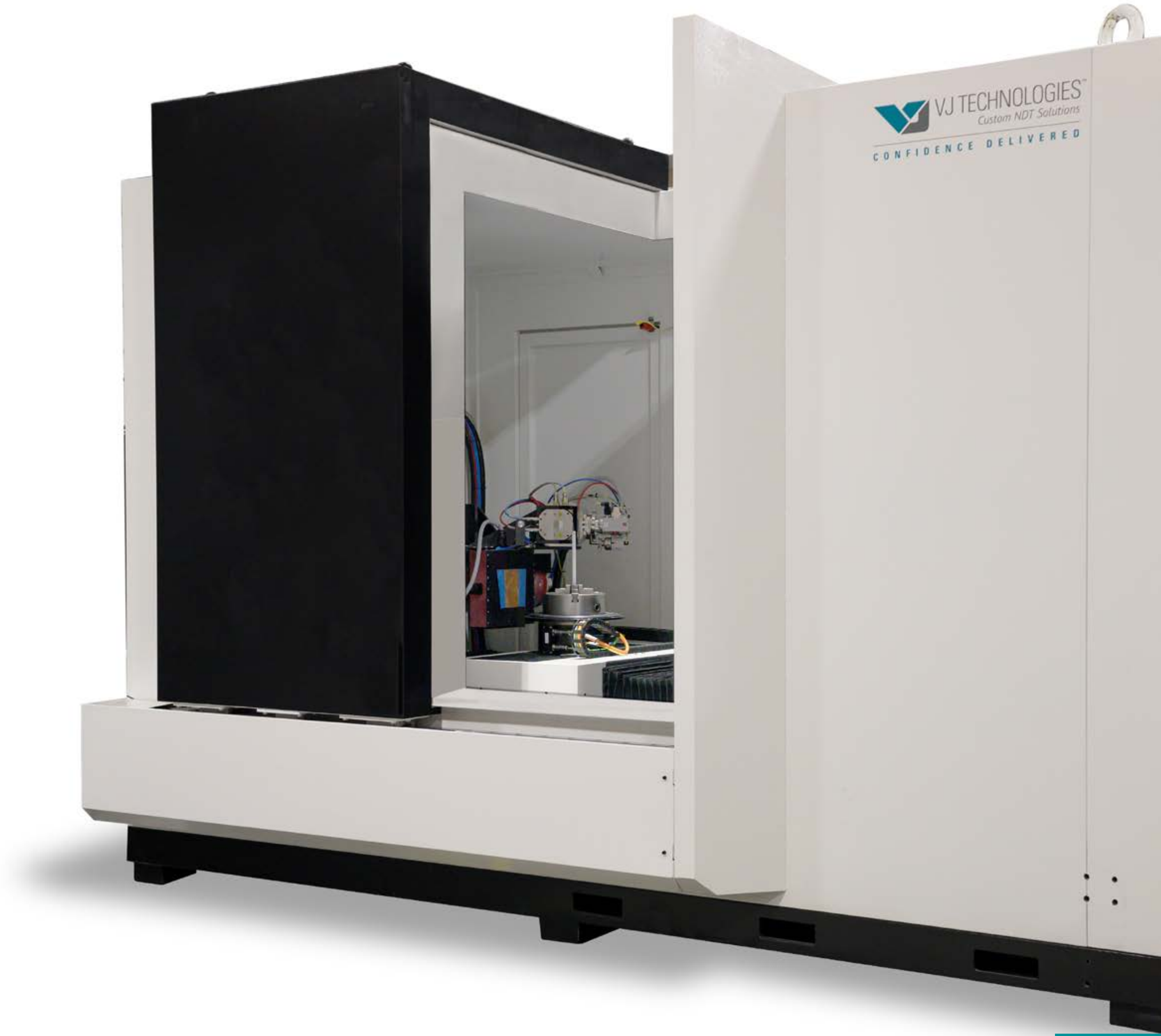
A longtime customer of VJ Technologies, Associate Quality Manager at Tesla's Casting & CNC facility in Lathrop recently spoke to us. 'We currently have two robotic in-line systems from VJ Technologies at our facility, which we use for production quality assurance of nine different high-pressure die-casting part types for the Model S and X along with engineering investigations. Over the years, we have had multiple engineering and process changes that have required support from the sales, engineering, and services department of the VJ Technologies team. I have always found them very prompt, supportive, and professional.'

World leaders in CT technology, VJ Technologies have participated in the standard committee development of ADR technologies, equipment that has been recognized in summary reports as some of the best-in-class. With design safety at the core of inspection for aerospace, we believe that CT imaging should do more than just simplify and speed up processes – it should provide users with unrivaled confidence in first-rate technology.

VedaCT/450

VJT's VedaCT/450 - 450kV Option satisfies these requirements through its delivery of dependable customized NDT solutions – advanced CT that is set to transform automated inspection through its unwavering capabilities in speed and high-resolution imaging. Granite-based and well-known for its effective absorption of vibrations, the VedaCT meets all expected world standards and, utilizing industry-leading hardware, supports a wide range of applications, including Aerospace, Automotive, Electronics, Additive Manufacturing, and Research and Development.

A recent report from Precision Castparts Corporation (PCC) evidences VJT's True Positive Rate (TPR—the percentage of actual defects detected by ADR), as more than 50% higher than the average TPR score for leading competitors, a notable example of VJ Technologies ADR capability. ***Insert link to report?**



Over the coming decade, as the aerospace industry turns its attention to next-generation technologies, 3D CT for aerospace will remain competitive in a universal market, enabling the development and production of machine-parts quickly, cost-effectively, and of uncompromised quality.

Embracing modernistic digital tools within the Aerospace 4.0 arena will be paramount and will further support cost reduction, quality improvement, and enhanced output.

When investing in best-in-class 3D CT for automated inspection, the initial outlay may appear daunting and costly, but when we consider how technology assists manufacturers of aerospace equipment in making the right decisions quickly, the longer-term cost-savings become evident.

As design engineers and manufacturers embrace 3D CT technology along with Industry 4.0-related tools, they will gain insight into the significance of real-time analytics and supply chain efficiency. Visit **https://vedact.vjt.com**

Founded in 1987, VJT develops and manufactures a complete line of automated, manual, and turnkey X-ray inspection systems for a wide variety of industries. Our primary market sectors include aerospace, automotive, electronics, remediation, nuclear, oil & gas, and pipe & weld applications. VJT Inspection Services provides a full range of expert Inspection Services (IS) to meet your needs, In-house or in-the-field.

References:

‘Advanced Technologies in Manufacturing 3D-Layered Structures for defense and Aerospace’ Dionysios E Mouzakis. Published March 21st, 2018.

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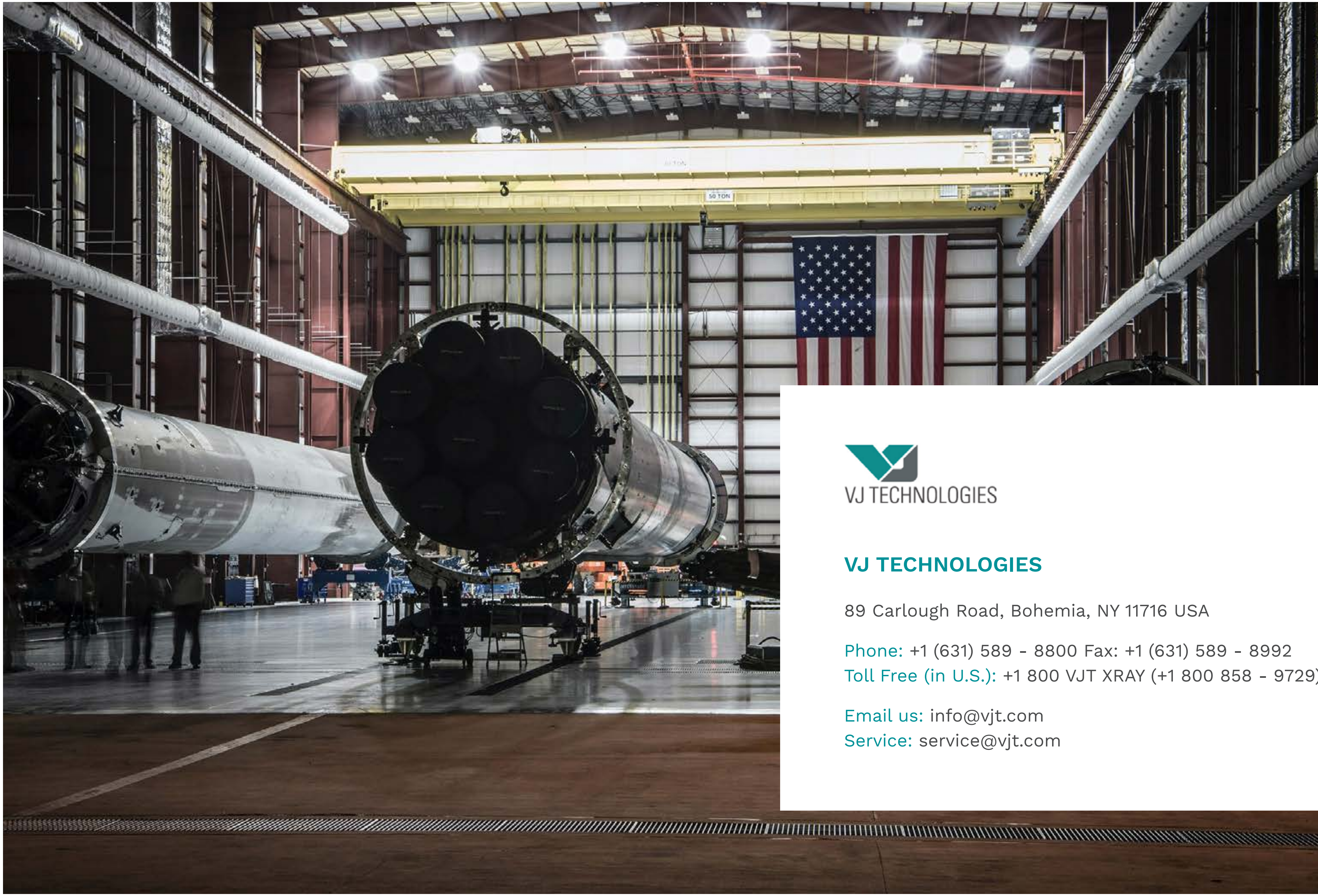

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