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NDT 4.0 | *Non-Destructive Testing technologies revolutionizing the fourth industrial landscape*

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After the third industrial ***revolution,*** *marked by the advent of digital systems* **and robotics, Industry 4.0** *is the present-day trend that* ***automates*** *conventional* ***manufacturing*** *and* ***industrial*** *practices using innovative technologies.*

Introduction

To make the production quicker, more efficient and highly flexible, this new sector is intended to support future production in plants. It manages entire networks within industrial processes, from raw materials to finished products, including design, while taking into account the Non-Destructive Testing (NDT) technologies such as, inspection, production, central quality control, and Structural Health Monitoring (SHM). NDT aims to evaluate the properties of a material, component, structure, or system for characteristic differences or welding defects and discontinuities, without causing damage to the original part. It is also known as non-destructive inspection (NDI) and non-destructive evaluation (NDE). Its application has enormous potential in managing industrial equipment and critical structures in multi-sector plants and its processing lines. [1]

The available network possibilities in industrial processes will soon be a promising field. However, NDT 4.0 networking, which includes all aspects of the industrial process, requires more comprehensive information on the automation of NDT test procedures to be applied, while also distributing data to all interested parties. Intelligent sensors guide the component through the manufacturing process. Relevant information could be provided online to quality, the production department, and the customer.

Obviously, this will place additional demands on the performance of NDT systems.

1. Einav, I. (2005). Non-destructive testing for plant life assessment. International Atomic Energy Agency.

By taking a value and customer-oriented view of operations and processes, it has been observed that contemporary NDT technology is already gradually enabling two of Industry 4.0's four design principles:

(a) interoperability and ***(b) technical assistance.*** This is achieved by utilizing more and more NDT data collected by wireless sensors, exchanged over the Internet of Things (IoT), and analyzed by AI to generate insights around the object at hand, be it an artifact traced along a production line, or an entire building monitored and recorded along its entire life cycle, respectively.

In the near future, it is also expected this technology will progressively apply the rest of the two Industry 4.0 principles:

(c) information transparency and ultimately, ***(d) decentralized decisions.***

This could be achieved by helping users shift the burden of deriving actionable insights from fused heterogeneous data onto automated algorithms, thereby increasing the level of object's predictive and reactive self-monitoring and self-management. [2]

Rapid prototyping and additive manufacturing techniques can produce unique parts tailored to the specific needs of customs. Today's parts made with this technique are typically not safe. However, as technology advances, this may change. A complete turbine engine could theoretically be printed in the near future. The quality and maintainability of these sometimes unusual structures and components are also important considerations. Demand-driven manufacturing will lead to a paradigm shift in industrial quality management and non-destructive examination (NDE). Classical quality concepts are founded on optimized process chains, statistical process control, and statistical quality planning (Six Sigma).

2. Meyer, J., Tsalicoglou, I., Mennicke, R. (2017). The future of NDT with wireless sensors, A.I. and IoT. 15th Asia Pacific Conference for Non-Destructive Testing (APCNDT2017), Singapore.

Process monitoring with integrated intelligence, as well as self-teaching or involving external experts in decision-making, will be critical for safety-related components. Implementing new technologies to enable 'tele-presence' has the potential to improve the inspection process. With today's technology, it is possible to control NDE inspections remotely, even from another continent. This has the added benefit of incorporating the expertise of the world's most experienced inspectors into decision-making.

Improved NDT capabilities are critical for improving the quality of engineering materials and ensuring the safety of engineering structures. Defects in materials processing and manufacture can occur in manufacturing industries. NDT is used at virtually every stage of the development process for critical structures, including airplanes and engines, nuclear power plants, ships, and satellites, to ensure the final product is free of any harmful defects. The techniques employed must be appropriate for the level of detection required to confirm integrity. Increased product reliability can be achieved by designing with the duty cycle, material properties, and inspection capability in mind. [3]

Non-destructive testing can be used in all stages of production, fabrication and service in almost all heavy industries, including engineering, aerospace, automotive, rail, construction and power, the construction of a power plant, refinery, an offshore platform, or in the production line of a jet engine turbine or railway. Various methods of NDT, from the conventional methods of visual testing, penetrant testing, magnetic particle testing, radiographic inspection and eddy current testing (ET), to advanced methods of ultrasonic testing, such as phased array ultrasonic testing (PAUT) and time of flight diffraction (ToFD), are utilized to ensure the safety, security and reliability of items throughout their life.

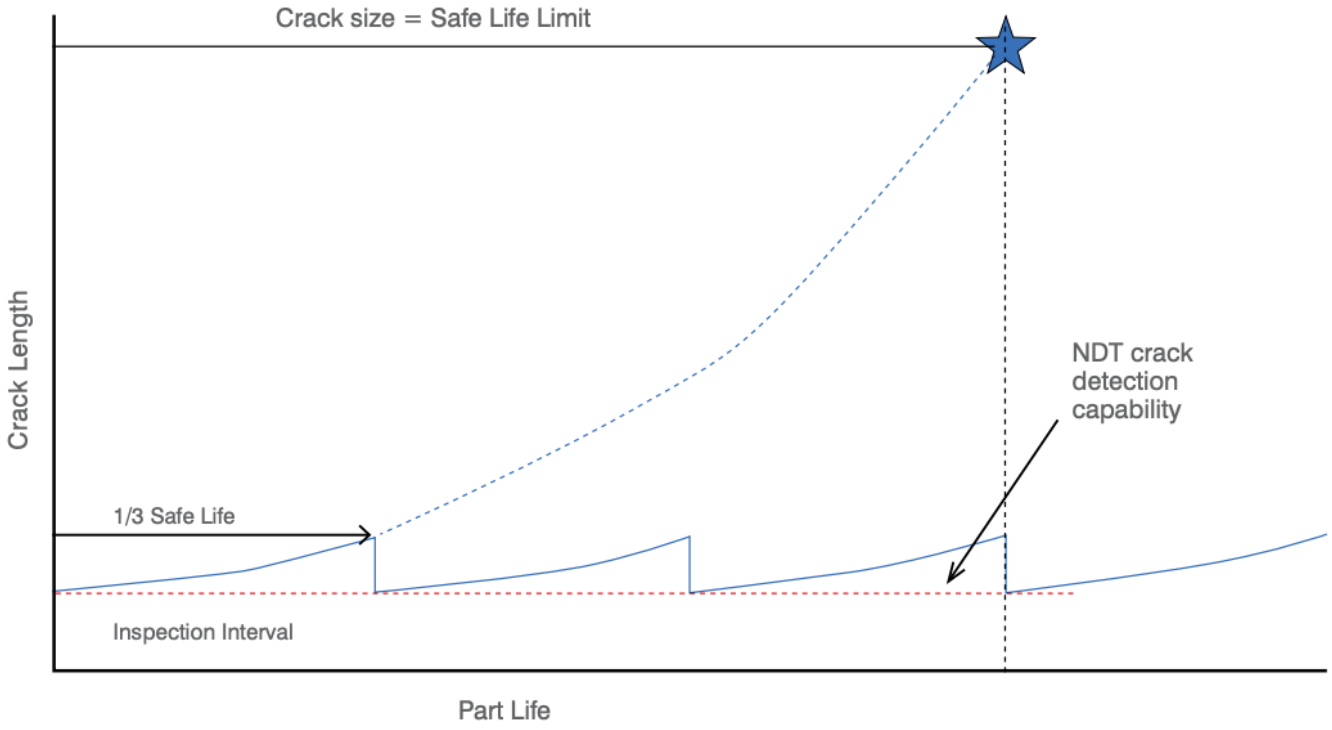
3. Meyendorf, N. G., Bond, L. J., Curtis-Beard, J., Heilmann, S., Pal, S., Schallert, R., Wunderlich, C. et al. (2017, November). NDE 4.0 for the 21st century: The internet of things and cyber physical systems will revolutionize NDR. In 15th Asia Pacific Conference for Non-Destructive Testing (APCNDT2017), Singapore.

This technology is critical for developing new manufacturing methods, materials, and designs. Defect mechanisms must be identified and understood during the development process, to improve these developments and reduce defects in the final products. This exercise also allows the development of NDT processes to meet the challenges of these new materials, shapes, and structures, while also entailing inspection practices to identify errors and harmful changes in any structure. However, many physics-oriented methods are also used, like radiography, ultrasound, magnetic, dye penetrating, eddy-current, thermal and visual. Most objects have cracks, corrosion, and damage that worsen over time. The evolution of such flaws depends on the structure's duty cycle, in relation to material, stress, integrity, with NDT engineers being involved in defining each inspection phase.

Energy extraction, transportation, power generation (conventional and nuclear), and aerospace are the major markets, with emerging but significant contributions from new markets, such as renewable energy. All this is underpinned by the R&D, equipment and service, vocational training and certification market. In general, the NDT industry has a few internationally consolidated players with opportunistic access to niche technology, product and service providers. This situation is generally stable, unless a specific industry develops a new technology, in which case a new business may be formed. Such opportunities are emerging, particularly in the renewable energy and aerospace sectors, due to the need for material and scale innovation. Brazil, the United States, and the Far East are among the potential growth markets. [4]

4. Young, R., Newton, K., Dunhill, T., Huggins, C. (2014). A landscape for the future of NDT in the UK economy. Brochure, Materials KTN, Knowledge Transfer Networks, Materials KTN, NPL Product Verification Programme, Materials Knowledge Transfer Network

Figure 1 | Indicative effect of NDT process on cracks in a structure. Young, R., Newton, K., Dunhill, T., Huggins, C. (2014). A landscape for the future of NDT in the UK economy. Brochure, Materials KTN, K



NDT 4.0 comprises all aspects within Industry 4.0 for the inspection of the material from raw to machined, inspected and classified until delivery to the customer and during its operational lifetime. Relevant information through the whole process of production, quality assurance to customers is provided. The material from the beginning of the process might be equipped with a sensor, which keeps all information about its future, choosing its way through manufacturing and inspection.

Quality can make or break a purchase decision. It is not merely about a vehicle's integrity, but also reflective of an automaker's commitment to customers and the industry. While quality has many aspects, Frost & Sullivan has restricted the focus of this paper to dimensional quality. A consumer's perception of dimensional quality affects an automaker's brand image: a car with poor fit and finish or malfunctioning internal components will leave a lasting impression. In the production process, suboptimal dimensional quality can lengthen lead times and cause cost overruns related to the reworking of non-compliant parts or forced downstream production adjustments. Manual dimensional inspection processes are time-consuming and costly, but they have remained largely unchanged for decades. It is imperative that dimensional inspection keeps pace with disruptive Industry 4.0 forces in the design engineering and production automation spaces. To move forward, there is a fundamental need to reimagine the purpose of dimensional quality control and the process of dimensional inspection in the production environment.

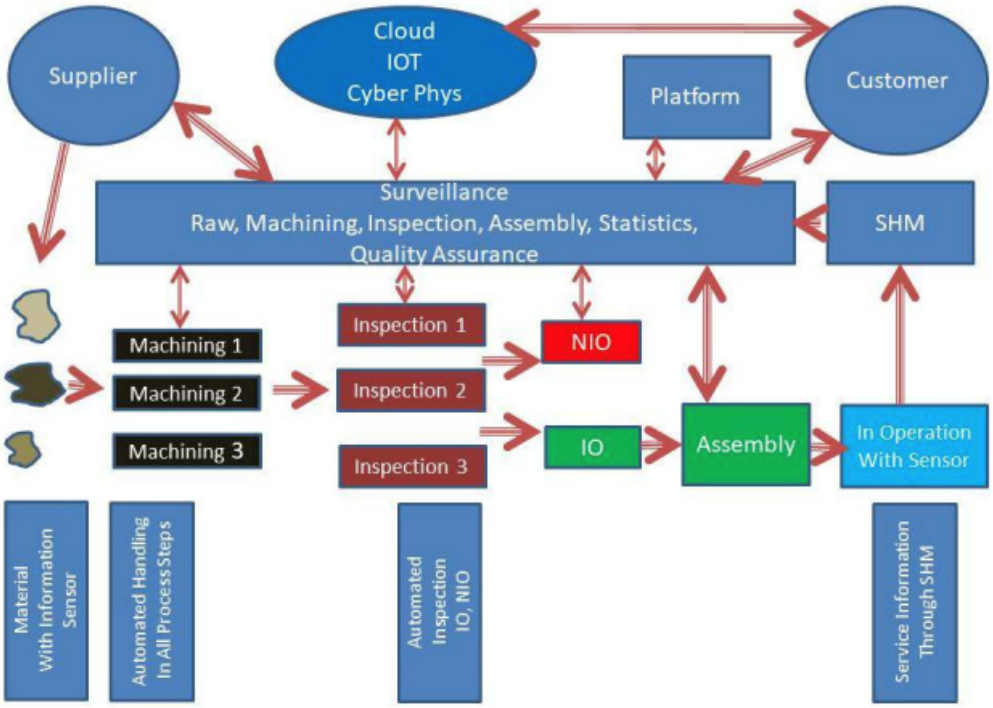
The global non-destructive testing (NDT) services market revenue in 2020 reached USD 8,865.9 million, and is expected to grow at a compound annual growth rate (CAGR) of 3.2 percent between 2020 and 2025. North America is the biggest market for NDT services, with 32.4 percent of the global revenue, while the Asia-Pacific region is predicted to witness the highest CAGR of 3.6 percent during the same forecast period. Nevertheless, the US is likely to continue to be the biggest revenue contributor by 2025, with 32.2 percent of the global revenue share.

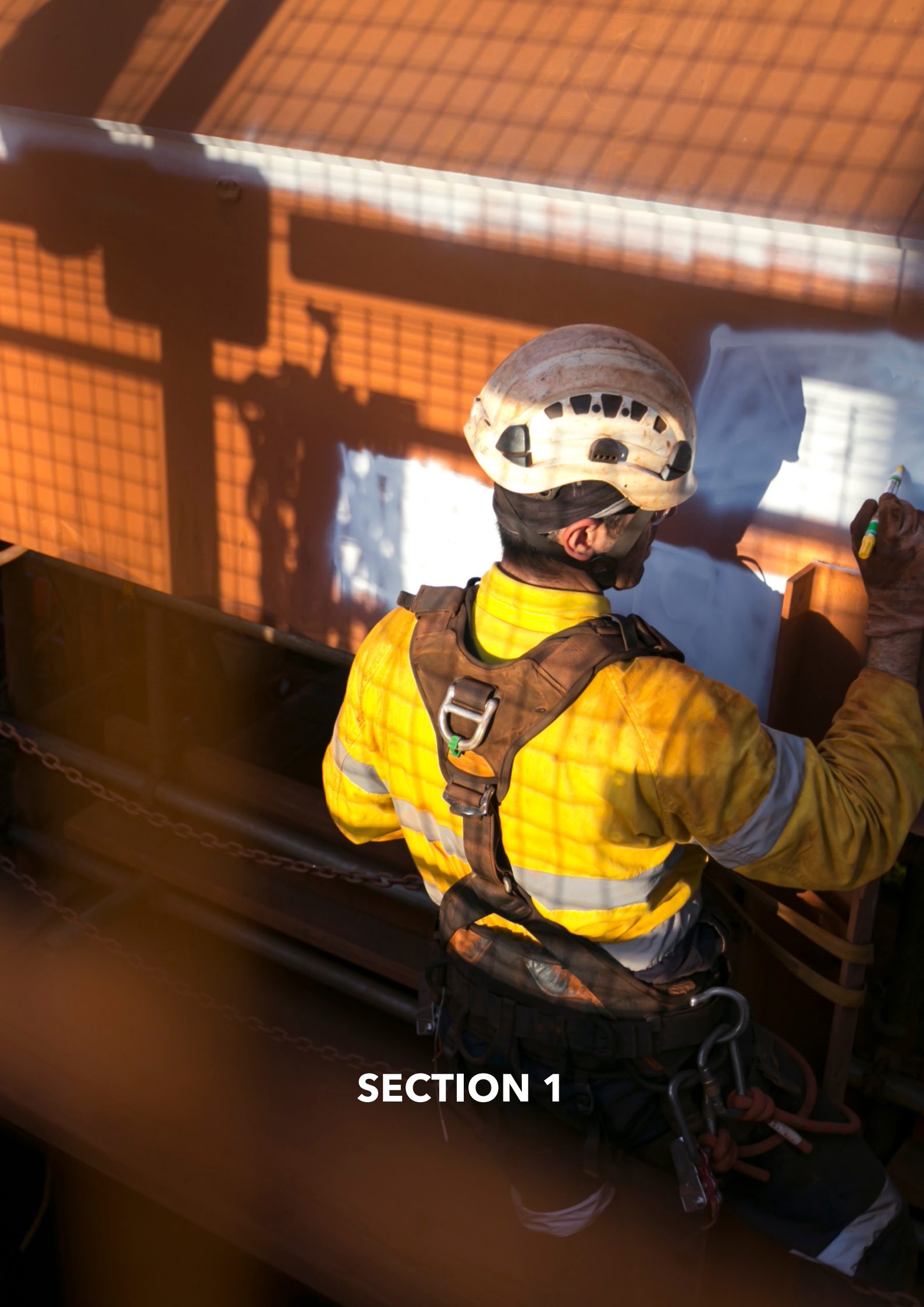
Particularly, the ultrasonic testing technology is the most used, achieving revenues of USD 3,874.4 million in 2020, whilst holding the majority revenue share during that time. Radiography is the other more popular technique, comprising 25.8 percent of the market share in 2020, and is set to record a 3.1 percent CAGR between 2020 and 2025. The oil and gas vertical market is the biggest revenue contributor, with a 47.6 percent revenue share, whereas the O&G downstream market is the smallest segment. Power is the second-biggest vertical, holding 17.4 percent of the global revenue in 2020. The automotive vertical is witnessing a sharp decline in 2020, but is projected to grow at a CAGR of 6.3 percent between 2020 and 2025. The railways vertical market is likely to reach a CAGR of 4.3 percent between 2020 and 2025.

The NDT services market is highly competitive, with about 900 participants, top 7 of which hold 44.1 percent of the market share globally. Services providers consistently come up with new technologies and high-quality solutions, with most of them offering ultrasonic and radiography testing technologies. Because of the increase in equipment cost and the requirement for highly skilled workforces, companies have begun outsourcing their NDT needs and developing new NDT services. Additionally, governments and industry regulatory bodies have strict mandates on industry safety norms that companies have to adhere to, and therefore encourage quicker adoption. As the market is highly competitive, leading participants, Tier-II companies, and start-ups compete on similar solutions offerings, demonstrating product innovation and staying ahead of their peers. Market leaders also focus on inorganic growth to expand their product portfolio and customer base. [5]

5. Link, R., Riess, N. (2018, June). NDT 4.0 - Significance and implications to NDT automated magnetic particle testing as an example. In 12th European Conference on Non-Destructive Testing (ECNDT 2018) (pp. 11-15).

Figure 2 | A typical NDT 4.0 process. Link, R., Riess, N. (2018, June). NDT 4.0 - Significance and implications to NDT automated magnetic particle testing as an example. In 12th European Conference on Non-Destructive Testing (ECNDT 2018) (pp. 11-15).





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