



INTERNATIONAL

CONFERENCE ON NDE 4.0

24 – 27 October 2022 in Berlin, Germany

PROGRAMME & ABSTRACTS



DEUTSCHE
GESELLSCHAFT FÜR
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Co-Sponsors:
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European Federation for
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NDE 4.0 – Enabling your journey!

Industry 4.0 is the ongoing fourth industrial revolution, based on digitisation, cross-linking and networks and lives on data for its feedback loops and one of its biggest and most valuable data sources is NDE. Industry 4.0 leads to an improved production and design by analysing the data stored in digital twins and provided by the industrial internet of things. Measures like artificial intelligence, big data processing, or augmented reality allow to evaluate and visualise the data. Blockchains allow ensuring modification-proof storage and traceability and 5G the wireless connections needed by Industry 4.0.

This will lead to big changes in NDE. First, the Industry 4.0 emerging technologies can be used to enhance NDE technologies and NDE data processing. Second, a statistical analysis of NDE data provides insight into reliability, inspection performance, training status, consistency, and value of the inspections. Finally, NDE is the ideal data source for Industry 4.0.

Listen to the presentations on most important NDE 4.0 topics and the keynote speeches by international experts!

In addition to the main technical programme the NDE 4.0 short courses and an excursion to the Berlin Center for Digital Transformation are offered.

We look forward to a successful conference.

Dr. Johannes Vrana
Conference Chair

Dr. Thomas Wenzel
DGZfP, Germany



Conference Venue

Hotel Dorint Kurfürstendamm Berlin
Augsburger Str. 41 | 10789 Berlin, Germany

Conference Secretariat

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Programme

The updated programme please find on the conference website
<https://conference.nde40.com>

Get-together

Monday, 24 October 2022 | 18:00 – 19:30 h, Conference Hotel

Conference Dinner

Tuesday, 25 October 2022 | 17:30 – 22:00 h at restaurant „Lemke am Schloss“
bus shuttle from hotel; return individual

In addition to the main technical programme:

► Short Courses

The World of NDE 4.0: Let the Journey Begin I + II

Monday, 24 October 2022 | 09:00 – 12:00 h, Registration fee: 290 Euro
Dr. Ripi Singh and Dr. Johannes Vrana

NDE for Additive Manufacturing

Monday, 24 October 2022 | 09:00 – 10:30 h, Registration fee: 150 Euro
Prof. Anton du Plessis

AI for Computed Tomography NDE

Monday, 24 October 2022 | 10:30 – 12:00 h, Registration fee: 150 Euro
Dr. Nicolas Piché

► Excursion

Excursion to the Berlin Center for Digital Transformation

Thursday, 27 October 2022 | 1/2 day – Information on website

PROGRAMME OVERVIEW

Monday, 24 October

Room: Concord A		Room: Concord B	
09:00	SHORT COURSE The World of NDE 4.0: Let the Journey Begin I Dr. Ripi Singh and Dr. Johannes Vrana	SHORT COURSE NDE for Additive Manufacturing Prof. Anton du Plessis	
10:30	SHORT COURSE The World of NDE 4.0: Let the Journey Begin II Dr. Ripi Singh and Dr. Johannes Vrana	SHORT COURSE AI for Computed Tomography NDE Dr. Nicolas Piché	
12:00	Break		
13:00	OPENING		
13:15	Mo.1.A Keynote Session		
14:30	Panel Discussion – Keynotes		
15:10	Break		
15:45	Mo.2.A Purpose and Value Proposition of NDE 4.0		
18:00	Get-together		

Tuesday, 25 October

08:30	Tu.1.A Artificial Intelligence I	Tu.1.B Artificial Intelligence in RT/CT
10:20	Break	
11:40	Tu.2.A Digital Twin	Tu.2.B Human Considerations
12:10	Lunch break	
13:15	Tu.3.A Artificial Intelligence II	Tu.3.B Additive Manufacturing
14:45	Break	
15:10	Tu.4.A Artificial Intelligence III	Tu.4.B Extended Reality (VR/AR)
17:30	Start to Conference Dinner	

Room: Concord A		Room: Concord B	
09:00	We.1.A	We.1.B	
	Management and Leadership 4.0	Reliability	
10:00	Panel Discussion	Panel Discussion	
10:30	Break		
11:00	We.2.A	We.2.B	
	Revision-Safe Data Formats and Storage	Enhanced Robotics/Drones	
12:30	Panel Discussion	Panel Discussion	
13:00	Lunch break		
14:00	We.3.A	We.3.B	
	Industrial Applications	Predictive and Prescriptive Maintenance	
15:40	Break		
16:00	Final discussion and closing remarks		

EXCURSION TO THE BERLIN CENTER FOR DIGITAL TRANSFORMATION

The four Fraunhofer Institutes FOKUS, HHI, IPK and IZM bundle their expertise in the fields of information and communication technologies (ICT), data processing, production and microelectronics in the Berlin Centre for Digital Transformation. In this Centre engineers and research fellows develop technologies and solutions that take into account the increasing digitization and networking of all areas of life. It conducts research on basic and cross-sectional technologies.

During our excursion to the Berlin Centre for Digital Transformation, you will be able to get a hands-on experience of the current research results from the fields of

- Sensors & Cyberphysical Systems
- Internet of Things & Blockchain
- 5G Infrastructure & Communication
- Industry 4.0 with collaborative robots
- Digital twins for processes, factories, and products

Further information on website

PROGRAMME | Monday, 24 October

	Room: Concord A	Room: Concord B
09:00	SHORT COURSE The World of NDE 4.0: Let the Journey Begin I Dr. Ripi Singh and Dr. Johannes Vrana	SHORT COURSE NDE for Additive Manufacturing Prof. Anton du Plessis
10:30	SHORT COURSE The World of NDE 4.0: Let the Journey Begin II Dr. Ripi Singh and Dr. Johannes Vrana	SHORT COURSE AI for Computed Tomography NDE Dr. Nicolas Piché
12:00	Break	
13:00	OPENING Mo.1.A Keynote Session	
13:15	Mo.1.A.1 Lets get to the point! – Face-off between Ripi Singh and Johannes Vrana J. Vrana, Vrana GmbH, Rimsting, Germany; R. Singh, Inspiring Next, Cromwell, USA	
13:45	Mo.1.A.2 Over-viewing the role of TIC companies in Industry 4.0 H. Taidi, TIC Council, Brussels, Belgium	
14:00	Mo.1.A.3 Data spaces: Maintaining data sovereignty in industry 4.0 ecosystems S. Steinbuss, International Data Spaces Association, Dortmund, Germany	
14:15	Mo.1.A.4 More data with Industry 4.0 –e digital sovereignty or the next dependency for SMEs? E. Stoeckl-Pukall, BMWK, Berlin, Germany	
14:30	Panel Discussion Summary discussion with all keynote speakers	
15:10	Break	

Mo.2.A

Purpose and Value Proposition of NDE 4.0

15:45

Mo.2.A.1

KEYNOTE: Industrie 4.0 and NDE – How to mutually benefit from each other
T. Usländer, Fraunhofer IOSB, Karlsruhe, Germany

16:15

Mo.2.A.2

NDE 4.0 Roadmap Guide – Your GPS for massive change.
R.S. Fernandez Orozco, Fercon Group, Zapopan, Mexico

16:35

Mo.2.A.3

NDE 4.0 for the Electric Power Industry Low Carbon Energy Future (LCEF)
T. Massey, Electric Power Research Institute, Charlotte, USA

16:55

Mo.2.A.4

NDE 4.0 Success Stories
J. Vrana, Vrana GmbH, Rimsting, Germany

17:15

Mo.2.A.5

NDE 4.0 concept and application for power plant O&M
M. Ochiai, Toshiba Energy Systems and Solutions Corporation, Yokohama, Japan

18:00

Get-together

Short presentations of the sponsors are presented during the sessions:

News and latest trends in nondestructive inspection and digitally supported process optimization

Volume Graphics (GOLD Sponsor)

Inspection Starts Here, Waygate Technologies - Baker Hughes

Baker Hughes (GOLD Sponsor)

Room: Concord A		Room: Concord B	
Tu.1.A Artificial Intelligence I		Tu.1.B Artificial Intelligence in RT/CT	
08:30	Tu.1.A.1 Synthetic training data generation for deep learning based billet detection in rolling mills M. Luschkova, German Research Center for Artificial Intelligence, Saarbrücken, Germany	Tu.1.B.1 Information Extraction from Industrial CT Scans using 3D Deep Learning P. Fuchs, Volume Graphics GmbH, Heidelberg, Germany	
08:50	Tu.1.A.2 Artificial Intelligence – A Solution for Inline Characterization of Li-Ion Batteries L. Chen, Fraunhofer IKTS, Dresden, Germany	Tu.1.B.2 Deploying machine learning for radiography T. Tyystjärvi, Trueflaw Ltd., Espoo, Finland	
09:10	Tu.1.A.3 Perspectives of NDE 4.0 Applications in Automotive Manufacturing Y. Oberdörfer, Tessonics Europe GmbH, Frechen, Germany	Tu.1.B.3 Automated RT interpretation through Artificial Intelligence (AI) L. Schulenburg, VisiConsult X-ray Systems & Solutions GmbH, Stockelsdorf, Germany	
09:30	Tu.1.A.4 Deep learning architecture for the detection, labeling and online measurement of surface treatment defects by laser B. Martin, IRT Saint Exupery, Talence, France	Tu.1.B.4 Object Identification on CT Data via 3D Optical Character Recognition C. Schmidt, Volume Graphics GmbH, Heidelberg, Germany	
09:50	Tu.1.A.5 Improved U-Net methods for CFRP defect recognition with pulsed thermography Z. Wei, Fraunhofer IZFP, Saarbrücken, Germany	Tu.1.B.5 Introducing ProSLAM: Production through Self-Learning Additive Manufacturing N. Brierley, diondo GmbH, Hattingen, Germany	
10:20	Break		

Short presentations of the sponsors are presented during the sessions:

News and latest trends in nondestructive inspection and digitally supported process optimization

Volume Graphics (GOLD Sponsor)

DIMATE – Fully Digital NDT Processes

DIMATE (SILVER Sponsor)

Digitization of the NDT workflow management with DRIVE NDTvolume

Dürr NDT (SILVER Sponsor)

Room: Concord A**Tu.2.A****Digital Twin**

10:40

Tu.2.A.1

Social and cognitive digital twins. A metaverse approach
D. Galar, Lulea University of Technology, Lulea, Sweden

11:00

Tu.2.A.2

Soft real-time framework for Structural Health Monitoring of wind turbine supporting structures
J. Rupfle, Technische Universität München, Germany

11:20

Tu.2.A.3

Ultrasonic Guided Waves Simulation in SHM Design – Finite Element Modeling and Model Data Handling
J. Lefèvre, Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR) / German Aerospace Center, Braunschweig, Germany

11:40

Tu.2.A.4

GigaFactory Digital Twins optimising for improved yields
P. Perera, Baker Hughes Waygate Technologies, Bristol, United Kingdom

12:10

Lunch break

Room: Concord B**Tu.2.B****Human Considerations****Tu.2.B.1**

Seminar concept and NDE 4.0 training programs for Applied AI and their practical use for data evaluation and decision-making
A. Osman, Fraunhofer IZFP, Germany

Tu.2.B.2

NDE 4.0 Requirements in Penetrant and Magnetic Particle Inspection
R. Link, Unternehmensberatung Dr. Rainer Link, Kerpen, Germany

Tu.2.B.3

Building quality into nondestructive evaluation through effective personnel qualification systems
R. Petrova, ASNT, Columbus, USA

Tu.2.B.4

Future of Training, Certification, and Qualification in NDE and in Times of NDE 4.0
J. Vrana, Vrana GmbH, Rimsting, Germany

Short presentations of the sponsors are presented during the sessions:**Fraunhofer IZFP – Sensor and Data Systems for Safety, Sustainability, and Efficiency**

Fraunhofer IZFP (BRONZE Sponsor)

Endity – Bringing NDT into a new era

endity Solutions (BRONZE Sponsor)

Room: Concord A		Room: Concord B	
Tu.3.A Artificial Intelligence II		Tu.3.B Additive Manufacturing	
13:15	Tu.3.A.1 DPAI: A Data-driven simulation-assisted-Physics learned AI for Modeling Ultrasonic Wave Propagation in the 2D domain T. Gantala, Centre for Nondestructive Evaluation, Indian Institute of Technology Madras, Chennai, India		Tu.3.B.1 Statistical analysis and automation through machine learning of resonant ultrasound spectroscopy data from tests performed on complex additively manufactured parts A.-F. Obaton, Laboratoire National de Métrologie et d'Essais (LNE), Paris, France
13:35	Tu.3.A.2 Data-Driven modeling of rail damage - data sources for building models T. Hartmann, Technische Universität Berlin, Germany		Tu.3.B.2 Deep learning based segmentation and quantification of porosity in additive manufacturing A. du Plessis, Object Research Systems Inc, Stellenbosch, South Africa
13:55	Tu.3.A.3 Challenges and Approaches when Realizing Online Surface Inspection Systems with Deep Learning Algorithms H. Stephani, Fraunhofer ITWM, Kaiserslautern, Germany		Tu.3.B.3 Frontloading GD&T into Simulation J. Mann, Hexagon, Heidelberg, Germany
14:15	Tu.3.A.4 Machine Learning Applied to Corrosion Degradation Prediction W. Silva, Petrobras, Rio de Janeiro, Brazil		Tu.3.B.4 Machine Learning based defect detection in Laser Powder Bed Fusion utilizing thermographic feature data S. Oster, Bundesanstalt für Materialforschung und -prüfung, Berlin, Germany
14:45	Break		

Room: Concord A		Room: Concord B	
Tu.4.A Artificial Intelligence III		Tu.4.B Extended Reality (VR/AR)	
15:10	Tu.4.A.1 Spatial and Temporal Deep Learning in Air-coupled Ultrasonic Testing for enabling NDE 4.0 S. Schmid, Technical University of Munich, Germany	Tu.4.B.1	Capture of the operator gesture and augmented reality for improved UT manual operations F. Cartier, CEA List, Paris Saclay, France
15:30	Tu.4.A.2 Towards machine learning segmented porosity in ultrasonic tests for composite materials J.I. Caballero Garzón, Universidad Politecnica de Madrid, Spain	Tu.4.B.2	NDE 4.0 to Support Aircraft Structural Integrity Programs D. Forsyth, TRI Austin, USA
15:50	Tu.4.A.3 Usage of Acoustic Emission and Artificial Intelligence for structural health monitoring purposes S. Haas, TÜV AUSTRIA, Vienna, Austria	Tu.4.B.3	3D-Visualization of ultrasonic NDT data using mixed reality J. Rehbein, WIWeB Erding, Germany
16:10	Tu.4.A.4 AI in NDT – Implementation and qualification D. Grollmisch, VisiConsult X-ray Systems & Solutions GmbH, Stockelsdorf, Germany		
16:30	Tu.4.A.5 Artificial Intelligence Based Automated Analysis System for Industrial NDE Applications E. Anagnostopoulos, Intercontrôle Framatome, Chalon-sur-Saone, France		
17:30	Start to Conference Dinner at restaurant „Lemke am Schloss“ by bus shuttle; return individual		

Room: Concord A		Room: Concord B	
We.1.1.A Management and Leadership 4.0		We.1.1.B Reliability	
09:00	We.1.1.A.1 Digital Transformation Roadmap – A case study R. Singh, Inspiring Next, Cromwell, USA	09:00	We.1.1.B.1 Theoretical POD assessment of a NDE 4.0 application under the context of Aero-Engine Lifting V.K. Rentala, Applied Validation of NDT (AV-NDT), Berlin, Germany
09:15	We.1.1.A.2 Simulation and AI, two complementary tools for NDE4.0 P. Calmon, CEA List, Paris Saclay, France	09:15	We.1.1.B.2 Model Assisted Probability of Detection for NASA Space Missions E. Gregory, NASA Langley Research Center, Hampton, USA
09:30	We.1.1.A.3 NDE 4.0 – What is hype and what is the future? Decide for yourself! D. Kanzler, Vrana GmbH, Rimsting, Germany	09:30	We.1.1.B.3 The benefits of inspection qualification, from NDE to NDE 4.0 R. Martínez-Oña, Asociación Española de Ensayos No Destructivos, Madrid, Spain
09:45	We.1.1.A.4 Enhancing NDE Workflows through Cloud-Based Solutions A. Lamarre, Olympus Scientific Solutions Americas, Quebec City, Canada	09:45	We.1.1.B.4 POD Curves for Natural Frequency Testing A. Mendler, TU Munich, Germany
10:00	Panel Discussion Summary discussion with all speakers of the session	10:00	Panel Discussion Summary discussion with all speakers of the session
10:30	Break		

Short presentations of the sponsors are presented during the sessions:

- News and latest trends in nondestructive inspection and digitally supported process optimization**
Volume Graphics (GOLD Sponsor)
- DIMATE – Fully Digital NDT Processes**
DIMATE (SILVER Sponsor)
- Digitization of the NDT workflow management with DRIVE NDTvolume**
Dürr NDT (SILVER Sponsor)

Room: Concord A		Room: Concord B	
We.2.A		We.2.B	
Revision-Safe Data Formats and Storage		Enhanced Robotics/Drones	
11:00	We.2.A.1	11:00	We.2.B.1
A Proposed Common File Format for NDE Data D. Forsyth, TRI Austin, USA		IoT enhanced robot for autonomous ultrasonic inspection J. Mendikute, IDEKO, Elqoibar, Spain	
11:15	We.2.A.2	11:15	We.2.B.2
Development of a universal interface solution for proprietary non-destructive test systems based on the OPC UA standard D. Hofmann, Dresden University of Technology, Dresden, Germany		Innovation in robotics for inspection and maintenance – The RIMA project P. Trampus, EFNDT, Brussels, Belgium	
11:30	We.2.A.3	11:30	We.2.B.3
The positive effect on compliance, security, and efficiency by the use of state-of-the-art NDT management software A. Hansen, AAP-NDT GmbH, Dortmund, Germany		Towards unattended ultrasonic inspection process of rectilinear machined components of Jet-engines M. Bron, SCANMASTER SYSTEMS(IRT) LTD, Kfar Saba, Israel	
11:45	We.2.A.4	11:45	We.2.B.4
NDE 4.0 Success Story: Fully digital end-2-end dataflow in plant inspection at BP Rotterdam J. Martin, DIMATE GmbH, Bochum, Germany		ITER thermonuclear reactor: automatic control of the penetration depth of end welds on steel plates of resistive elements A. Polacek, NDT1 KRAFT s.r.o., Prague, Czech Republic	
12:00	We.2.A.5		
Secure and Scalable Data Lakes for Unified Asset Management in the Industry 4.0 J.M. Ferrão, EQS Global, Porto, Portugal			
12:30	Panel Discussion	12:30	Panel Discussion
Summary discussion with all speakers of the session		Summary discussion with all speakers of the session	
13:00	Lunch break		

PROGRAMME | Wednesday, 26 October

Room: Concord A		Room: Concord B	
We.3.A Industrial Applications		We.3.B Predictive and Prescriptive Maintenance	
14:00	We.3.A.1 The AIFRI project – NDE data processing and AI techniques for Rail Inspection M. Selch, German Centre for Rail Traffic Research at the Federal Railway Authority, Dresden, Germany		We.3.B.1 Digitalization of on-site data capture P. Stenov, Screening Eagle Technologies AG, Schwerzenbach, Zurich, Switzerland
14:20	We.3.A.2 Digitalization for railway-NDT T. Würsching, Waygate Technologies, Hürth, Germany		We.3.B.2 Industry trends driving the need to minimize unplanned downtime – concepts for X-Ray sources of the future P. Corbat, Comet AG, Flamatt, Switzerland
14:40	We.3.A.3 FANTOM, a flexible and automated NDE 4.0 platform for manufacturing N. Colin, IRT Jules Verne, Nantes, France		We.3.B.3 Embedded non-destructive testing ultrasound solution for damage detection and localisation A. Aubry, PYTHEAS Technology, Meyreuil, France
15:00	We.3.A.4 Magneto-Optic Technology for Integrity Monitoring of Pipelines C. Gouveia, EQS Global, Maia, Portugal		We.3.B.4 Numerical modeling of the Lamb waves propagation in containment liner plates A. Kakhramon ugli Malikov, Graduate School, School of Mechanical Engineering, Pusan National University, Busan, South Korea
15:20	We.3.A.5 Authenticity Verification: An Independent and Markless Method for the Authenticity Verification of Electronic Components L. Chen, Fraunhofer IKTS, Dresden, Germany		
15:40	Break		
16:00	Final discussion and closing remarks		

Thursday, 27 October:

Excursion to the Berlin Center for Digital Transformation

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Lets get to the point! – Face-off between Ripi Singh and Johannes Vrana

J. Vrana¹, R. Singh²

¹ Vrana GmbH, Rimsting, Germany; ² InspiringNext, Cromwell, USA

One of the important aspects of any successful transformations is a healthy conflict, resolved through candid conversation, with a purpose. Digital transformation of NDE, or NDE 4.0 as it is known, is no different. Even after so many years, this emerging field is full of unanswered questions with multiple equally plausible answers.

Ripi Singh and Johannes Vrana met for the first time in Fall 2018. Since then, they have been debating, discussing, arguing, and eventually converging on several aspects. These discussions cover technical, business process, business models, and human aspects of NDE 4.0. Since they have such diverse background and experiences, they often start off with exactly opposite perspectives. Sometimes it takes them months to agree upon, while they both do their independent research. This healthy conversation without losing mutual respect, has been the story behind the curtain, that has led to so many publications and joint workshops, on the topic.

During this live on-stage face-off, Ripi and Johannes will give you a sneak peek at how they address the topic of NDE 4.0, using three to four specific topics of relevance today. Our intent is to inspire more such conversations to build an even healthier eco-system.

So Lets get to the point.

These discussions can be tricky requiring delicate handling of diverse valid arguments. However, they are the basis for our journey towards a yet unknown digital eco-system. They are the basis for successful collaboration to build the necessary digital infrastructure, and we have to start them now.

Over-viewing the role of TIC companies in Industry 4.0

H. Taidi¹

¹ TIC Council, Brussels, Belgium

Over-viewing TIC Council, an international association representing the global independent testing, inspection and certification (TIC) industry, the work of their Industrial Life Cycle Services Committee and the role of TIC companies in the ongoing fourth industrial revolution and NDE.

Data spaces: Maintaining data sovereignty in industry 4.0 ecosystems[S. Steinbuss](#)¹¹ International Data Spaces Association, Dortmund, Germany

Increasing digitization of the manufacturing industry produces a broad variety of data and digital twins. Here non-destructive testing is one important data provider, but also depending on the availability of data. So, this data needs to be findable, accessible, interoperable and reusable in the global manufacturing networks, but under controlled conditions. This is the idea of data spaces that maintain data sovereignty for all participants in such ecosystems. This presentation will introduce the core concepts of data spaces including the Gaia-X Soft Data Infrastructure, the IDS Connectors and the rise of manufacturing data spaces.

More data with Industry 4.0 – digital sovereignty or the next dependency for SMEs?[E. Stoeckl-Pukall](#)¹¹ BMWK, Berlin, Germany

KEYNOTE:**Industrie 4.0 and NDE – How to mutually benefit from each other**T. Usländer¹¹ Fraunhofer IOSB, Karlsruhe, Germany

In its Vision 2030 the Platform Industrie 4.0 defined interoperability, autonomy and sustainability as core objectives to be achieved for a global digital ecosystem. One of the current core concepts specified by Industrie 4.0 is the Asset Administration Shell (AAS) for which several independent implementations exist on the market. Non-destructive examination (NDE) refers to the examination of components or workpieces for their quality and structure that does not damage or impair them. On the one hand, the talk addresses the question how NDE may benefit from the Asset Administration Shell (AAS), or in general, how an Industrie 4.0 Dataspace may be beneficial for NDE developments. On the other hand, it makes proposals how NDE initiatives and projects may feed back their results to the Platform Industrie 4.0 such that a mutual benefit occurs. The talk puts these ideas in context of the Industrie 4.0 Vision 2030, but also considers recent advances in Digital Twins, International Data Spaces and AI Systems Engineering. Furthermore, it takes a multi-step/multi-method quality inspection system as demonstration example.

NDE 4.0 Roadmap Guide – Your GPS for massive change.

R.S. Fernandez Orozco¹, R. Singh²

¹ Fercon Group, Zapopan, Mexico; ² Inspiring Next, Cromwell, CT, USA

Digital transformation, in any sector, constitutes a massive change. NDE is no different. Over the years, Ramon and Ripi have independently helped a number of clients in a diverse set of industries and geographical locations to create forward-looking roadmaps to manage large-scale transformations and create substantial value. As a part of ICNDT SIG on NDE 4.0, they volunteered to work together and create an NDE 4.0 Roadmap Guide, a document intended to help others create their roadmaps for NDE 4.0 implementation. This is now ready for broad dissemination.

The Guide is written in ISO style, covering (i) Context such as Internal, external, and prospective, (ii) Leadership items - purpose, vision, principles, policy, governance, and ethics, (iii) Planning items scope, dashboard, organization, and technology process (iv) Resources General, and human, (v) Operational items development validation, and execution, (vi) Performance analysis and review, and (vii) improvements options. Supporting details such as use cases, KPIs, and technology portfolios are handled as annexures. For those who may not have done a similar exercise ever before, there is also an annexure, which provides a step-by-step kick-off recipe for following the guidance.

This presentation will provide an overview of this Guide, and how to interpret it. The Guide is available to the community for free to use, and even adapt to their specific context and requirements.

PS: The document is guidance, intended to help plan and manage change, and it is not intended as a standard to comply with.

NDE 4.0 for the Electric Power Industry Low Carbon Energy Future (LCEF)

J. Lindberg¹, T. Massey¹

¹ Electric Power Research Institute, Charlotte, USA

The energy and electric power industry is decarbonizing; progressing through a transformative change called the Low Carbon Energy Future (LCEF). Globally, electric power production is evolving; increasing power generation with lower to no carbon energy resources, i. e., wind, solar, hydropower and advanced nuclear. Hydrogen, carbon capture utilization and storage (CCUS), advanced nuclear, and novel power cycles will be the catalysts to extend beyond 50% reduction by 2030 to achieving net-zero carbon energy by 2050. NDE 4.0 will redefine how nondestructive examination (NDE) technology and processes will transition to meet the changing demands for the LCEF electric power industry. Increased power production from low to no-carbon energy resources offers new and diverse asset management challenges. Utilization of different materials, i. e., composites for wind power, piping, and concrete repairs; higher thermal operating ranges for advanced power sources; and operating generation sources in more flexible operating schemes pose unique challenges for implementation of NDE. Integrating structural health monitoring and advanced NDE 4.0 technology must become an essential part of the power system design and asset management plan for these low carbon energy assets. Additionally, performance of NDE needs to factor the future workforce; taking the human out of harms way; harmonizing their skills and expertise in symbiosis with machines as automation and artificial intelligence becomes the norm.

The Electric Power Research Institute (EPRI) is developing a strategic research plan to assimilate NDE 4.0 to meet the asset management challenges for the LCEF. The NDE 4.0 plan will address the integration of the diverse technological and digital transformations needed to design, implement, and process diverse NDE data streams for solving future LCEF inspection and asset management challenges. This presentation will provide an overview and update of EPRI's methodology to transition and execute a NDE 4.0 program for a decarbonized electric power industry.

NDE 4.0 Success Stories

J. Vrana¹, D. Kanzler¹, C. Amann², K. Kadau³

¹ Vrana GmbH, Rimsting, Germany; ² Siemens Energy, Mülheim, Germany;

³ Siemens Energy, Charlotte, USA

The term NDE 4.0 was coined in 2017 and defined as the cyber-physical confluence between NDE and the technologies associated with Industry 4.0. Its value is either created by improving NDE with those technologies or by implementing NDE as one of the most successful data sources for Industry 4.0 applications. In any case we the humans should be the focus of all those activities. Since 2017, substantial fundamental research has been conducted and published mostly regarding the big picture. In the meantime, first success stories are breaking free. This paper is focusing on some of those success stories from various sectors like infrastructure, power generation, circular economy, and civil engineering. Among others, the following two success stories will be presented: AIFRI is a project focusing on the use of artificial intelligence for the analysis of rail inspection data for optimized maintenance planning. Key within this project is the proof of the reliability of the AI implementation.

Within a probabilistic fracture mechanics program, we established NDE as one of the key data sources. The additional knowledge gained by statistically analyzing the NDE results led to a fundamental optimization of the lifetime of the components within the power generation equipment.

NDE 4.0 concept and application for power plant O&M

M. Ochiai¹, T. Hoshi¹, K. Takahashi¹, H. Nakajima¹

¹ Toshiba Energy Systems and Solutions Corporation, Yokohama, Japan

One of the important scopes of Toshiba Energy Systems and Solutions Corporation is design and manufacturing of power generation systems. Our experiences of operation and maintenance of power generation systems accumulate amount of data including Non-destructive Testing (NDT) data acquired by our advanced NDT techniques and tools, such as phased array ultrasonic testing, laser ultrasonic testing and so on. We are working on construction of Cyber Physical System (CPS), Non-destructive Testing where data collected in the physical world is assessed and analysed with digital technology, which embraces concept of digital data platform with AI digital solutions. This platform is based on the concept of NDE 4.0, where NDT data is acquired, digitalized and analysed using AI technology. In addition, NDT data can be associated with other data, for example, design data, material properties, operation data and so on. We will show NDE 4.0 concept and application for power plant O&M, and especially explain an example of AI application for ultrasonic testing data.

Synthetic training data generation for deep learning based billet detection in rolling mills

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AI-powered quality assurance solutions are gaining momentum in the steel industry under the Industry 4.0 paradigm. In rolling mills, knowing the real-time location of billets, i.e. fast moving bars of hot steel, is important in order to guarantee a safe process and defect-free end products. To achieve this aim, we present a deep learning-based detection of these billets in rolling mills using synthetically generated training data. A core practical challenge for many deep learning projects is the limited availability of appropriate, annotated training data. We propose a method for simulating images employing a partial digital twin of the rolling process. Partial models governing the shape and location of the billets, the layout of the rolling mill floor, the camera settings, and the lighting situation changing over time are combined into a scenario model. Choosing different parametrizations of this scenario model facilitates synthesizing a broad range of images for training. The resulting deep learning model is utilised to detect billets in real-world images from an actual rolling mill. We describe the creation of the partial models using aerial photogrammetry, expert knowledge, and 3D modelling, as well as the choice of the deep learning model. An evaluation of the model's performance on real-world images shows the applicability of our synthetic training data approach.

Artificial Intelligence – A Solution for Inline Characterization of Li-Ion Batteries

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Motivation: High-performance and cost-effective energy storage systems are a key component for the energy transition. For the broad mass market and the future spread of lithium-ion batteries for mobile or stationary energy storage, the manufacturing costs for battery cells must be further reduced. An important contribution is the reduction of production defects and the resulting high reject rates. To ensure the highest possible quality in battery production with minimal rejects, defects must be detected early in the manufacturing process and even before further processing. In addition, the porosity of the electrode also affects the electrochemical performance, for example, the energy density, power density and rate capability of the battery. Therefore, it is also important to monitor the porosity of the electrode during the manufacturing process to ensure a good quality state of the battery that meets the requirements of the desired applications. Method: Laser Speckle Photometry (LSP) is an inline optical method based on the evaluation of speckle patterns which contains morphological information of an optically rough surface. With the help of a deep learning model based on the Convolutional Neural Network (CNN), defects can be detected and classified in the speckle images during the manufacturing process of electrodes. In addition, by using an external thermal excitation source, tiny deformations are generated on the electrode surface due to thermal expansions. The deformations are analyzed with the corresponding dynamic speckle patterns, which can be further correlated to the local porosity of electrode numerically. Result: Preliminary results of the investigation show that the defects such as agglomerate can be detected by LSP with an accuracy over 80 %. In addition, a correlation between the local porosity of electrode and the speckle parameter is also observed. Therefore, it is promising to develop a LSP characterization system for the quality control of electrode manufacturing.

Perspectives of NDE 4.0 Applications in Automotive Manufacturing

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The automotive manufacturing industry stands to greatly benefit from Industry 4.0, but its implementation presents many challenges that must be overcome. Industry 4.0 requires NDE 4.0, which often requires the integration of various innovative solutions, including implementation of artificial intelligence (AI) into the process of NDE data interpretation. In this talk, I will discuss the benefits and challenges of Industry/NDE 4.0 in the context of automotive manufacturing, including signal/image processing and AI, and elaborate on the roles of AI in Industry/NDE 4.0.

I will also present an intriguing case study which highlights the considerations and challenges of transforming a pre-existing NDE system for an automotive application real-time integrated resistance spot weld analysis for NDE 4.0, through the integration of AI and, in particular, deep learning algorithms. This case study involves discussion of the original automated NDE system, the development of a deep learning component for NDE data interpretation, the considerations for the development of a feedback system including further development of an adaptive control algorithm for resistance spot welding. These elements (automated NDE data acquisition and big data storage, fast AI-based interpretation, super high speed feedback, and adaptive control) are essential to NDE 4.0, and the concept of zero-defect manufacturing in the automotive industry. Finally, we will discuss further horizons of this technology development and what kind of impact we expect in the near future.

Deep learning architecture for the detection, labeling and online measurement of surface treatment defects by laser

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The detection and measurement of laser treatment singularities by deep learning is part of the field of non-destructive testing of surfaces. Texturing metal surfaces by laser is a step prior to bonding. The real-time control of the quality of the treatment is an essential step for the validation of the conformity of the surface treatment. The imagined assembly, coupling image acquisition and processing by deep learning artificial intelligence, makes it possible to carry out this validation, and in the event of singularities to be able to detect, classify and measure them.

The principle of the proposed solution combines several elements: an image acquisition device and a deep learning architecture for the analysis. The acquisition means consist of a CMOS-type camera with a lens allowing zooming on the substrate. A lighting box completes the device between the camera and the substrate.

The analysis part uses software with a deep learning type architecture, inspired by Mask-RCNN type models, and adapted to images of metallic materials treated by laser.

The advantage of the proposed solution is that it potentially allows the quality of the entire treated surface analyzed. The analysis is done in „on-line“ mode (during laser treatment), based on three images analyzed per second. It is possible to identify several types of singularities constituting deviations from the nominal. One of the application cases has been to train an architecture to detect, classify and measure areas without treatment or areas with multi-treatment (covering) on Aluminum and Titanium materials.

Improved U-Net methods for CFRP defect recognition with pulsed thermography

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Autoencoder based deep learning methods have become standard approaches for image segmentation task, these methods can generate two-dimensional image map, which facilitate the pixel wise segmentation. However, the encoder-decoder methods have not yet been well investigated in the defect segmentation in the analysis on pulsed thermographic data.

Carbon Fiber Reinforced Thermoplastic (CFRP) plays an important role in the aircraft industry and therefore its quality assurance is also crucial out of safety reason. Pulsed thermography (PT) is an established nondestructive testing method for subsurface damage detection in CFRP components. After each PT experiment, the generated infrared video can be evaluated either automatically by machine learning methods or manually using human expertise. The defect regions in the CFRP specimens are often so scarce, many conventional machine learning methods do not work well because of the data imbalance. In this work, Deep Learning architectures are used to detect the defects within the CFRP specimens used in the aerospace industry. Specifically, U-Net and U-Net++ methods, with different network as encoders such as: Resnet and VGG net, are experimented. The U-Net++ with VGG 16 net as encoder has reached the best performance with F1-Score around 92%, comparing to the result generated by a simple U-Net with F1Score of 87%. This indicates that with well-designed encoding neural network, the performance of the model can be further improved comparing to simple U-Net architecture.

Information Extraction from Industrial CT Scans using 3D Deep Learning

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Data is at the heart of the fourth industrial revolution and with the spread of automated non-destructive evaluation we have an excellent driver of data generation at hand. However, the acquired information needs to be parsed to make it machine-readable. Especially, imaging data like 3D CT scans offer plenty of useful information. Yet, the impeding influence of image artifacts complicates the interpretation of this data.

Modern 3D deep learning with its processing speed and accuracy is a promising tool to efficiently automate the information distillation from imaging data. It allows us to solve high-level classification tasks, e. g. OK/NOK-decisions, as well as low-level semantic segmentation tasks which build the foundation for the extraction of more detailed information.

Unfortunately, as helpful machine learning is, as many risks it poses. We present the implementation of a machine-learning-based in-line inspection system for light metal cast parts in terms of a detailed case study which explains the typical machine learning project life cycle, unveils the potential pitfalls on the way to a solution, and explores the vast number of possibilities:

First, we examine the creation of a proper data set pointing out the importance of a consistent labeling. Here, we go in more detail about how the digital twin of the imaging system provides a shortcut to an accurately labeled training set via simulations. Then, we discuss the need for a proper validation set for the project to be successful and to build the necessary trust in machine learning systems. Finally, we share our considerations of model deployment and how to monitor the inspection system dealing with concept drift.

Deploying machine learning for radiography

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Solutions using artificial intelligence to analyse image data are rapidly developing and providing new possibilities in non-destructive evaluation using radiography, and the capability of such systems to both improve inspections and make better use of the data in industrial processes is a key component in the vision of non-destructive evaluation 4.0. As capabilities evolve, there is need for knowledge concerning how to deploy these technologies in practice and benefit from the new automatically generated information. In this study, automatic defect recognition based on machine learning was deployed as an aiding tool in industrial radiography of laser welds in an aerospace component, and utilized to study the flaw distribution over time to produce statistics for improved quality control. A multi-model approach with an added weld segmentation step improved inference speed and decreased false calls to improve field use. A user interface with visualization options was developed to display evaluation results. Using the automatic defect recognition, a dataset of 451 radiographs was analysed, yielding 10037 indications with size and location information. This provided material for statistical analysis beyond what would be feasible to carry out manually. Information gathered from the findings of the system showed significant potential for process monitoring and improvement. The distribution of indications was modeled as a product of the probability of detection and an exponentially decreasing underlying flaw distribution, opening the possibility for model reliability assessment and predictive capabilities on weld defects. An analysis of indications over time revealed trends and individual anomalous events in flaw formation, which could be focused to specific welds and sections in the components. This serves as a step towards smarter utilization of non-destructive evaluation data in manufacturing.

Automated RT interpretation through Artificial Intelligence (AI)

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Artificial Intelligence (AI) is a hype in every industry. From self-driving cars to intelligent social media algorithms, this technology is disrupting every aspect of our life. Also in the field of NDT, we see AI becoming a viable tool to increase the probability of detection of defects, while at the same time offering a potential to drive down inspection costs and stay competitive in a globalized world. This session will introduce the technology to NDT technicians and managers with practical background and will highlight some opportunities and challenges that are coming with it. Afterwards there will be a live demonstration of the latest algorithms coming straight out of the research lab. This will provide a feeling for the practical implications and maturity of the technology. The presentation will cover practical examples and comprehensive statistics about the performance (POD) of AI systems in comparisons to traditional manual evaluation. It will also explain the process and common pitfalls in detail.

Object Identification on CT Data via 3D Optical Character Recognition

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Industrial computed tomography (CT) has become a widely applied technology in the field of in-line production quality management. Decoupling the acquisition of a CT scan from its analysis allows for an improved utilization of expensive hardware but poses the problem of matching the results to the real counterpart. This can be solved using a serial number embossed on the part, which then can be automatically identified with optical character recognition (OCR).

While OCR is a well-established method for 2D images, the application of these 2D approaches to volumetric data comes with major challenges. As the text follows the surface geometry of the component, it can be arbitrarily distorted and is not necessarily located on a plane. Furthermore, a mapping of the 3D text to a 2D image with sufficient fidelity is required. In order to prevent the loss of information due to dimensional reduction and to improve overall performance, both object detection and character recognition can be implemented in 3D using deep learning algorithms. We present a novel approach based on modern neural network architectures, which combines existing techniques from 2D OCR and 3D object detection.

Introducing ProSLAM: Production through Self-Learning Additive Manufacturing

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The ProSLAM collaborative R&D programme, supported by the German federal government, brings together six partners (Fraunhofer ILT, Precitec, BCT, resolto, point8 & diondo) and three end-users (Airbus, Isar Aerospace & Mercedes-Benz) striving to achieve a step change in the capability of Laser Material Deposition (LMD) Additive Manufacturing (AM). The approach for achieving improved productivity and right first time efficiency of the (re-)manufacturing process features both NDE for Industry 4.0, as well as Industry 4.0 for NDE aspects. The former involves the online process monitoring (courtesy of Precitec, ILT and BCT) and at-/offline X-ray Computed Tomography (XCT) inspection (courtesy of diondo) being used for process control via edge and offline (courtesy of resolto and point8, respectively) artificial intelligence. The latter relates to enhancements of the XCT process flow through, for example, automated optimised positioning of samples, enabled by a digital twin of the inspection.

The talk will present an overview of the programme before focusing on the activities of diondo to date.

Social and cognitive digital twins. A metaverse approach

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A digital twin is not a static model but a responsive system connecting physical and digital systems, with numerous potential applications in industry and transport. Other terms for digital twin are digital shadow, digital mirror, digital model, and digital avatar.

A digital twin is a model of a real system that is coupled with the digital realisation of the abstracted model via data generated by and collected from the real system and this coupling yields the digital twin. The result is not a realistic digital representation of physical thing; it is an abstracted digital representation of an observed complex physical system.

However, this is a one-to-one digital twinning process, and industry demands a more attractive proposition i.e. the creation of a virtual scenario where virtual instances gather together with the twins of real ones. We call this scenario the metaverse, a digital replica of our reality where all physical assets are twinned along with entities that only exist in the digital dimension. The metaverse is the digital dimension where the digital entities interact. The metaverse is the expansion of DTs with more content and social meaning.

That is why maintainers have to keep an eye on the evolution of DTs and how they transfer those replicas to the metaverse, as degradation mechanisms, maintenance plans, and prognostics will seriously affect the DT once it starts interacting in the digital arena with its counterparts.

The immersive virtual reality universes will become the industrial playgrounds. This will transform our maintenance team, as team members will interact with digital entities every day. Immersive virtual worlds will command an increasing portion of their time. In these virtual sites, maintainers will take the form of avatars in the movies sense of the word digital representations of themselves (but not necessarily tall and blue).



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Soft real-time framework for Structural Health Monitoring of wind turbine supporting structures

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Real-time data analytics for advanced Structural Health Monitoring (SHM) and digital twin applications is a prerequisite for further real-time analysis as load estimation and displacement calculation of wind turbine supporting structures. A framework that provides the basis for near real-time analytics is developed as scope of this work. A large-scale onshore wind turbine has been equipped with a range of measurement technology. The main components are acceleration sensors, strain sensors, inclination sensors, and a real-time kinematics (RTK) module, which are further supplemented by other measurement technology. The measurement data is then preprocessed on-site by filtering and downsampling as well as coordinate transformations. Different real-time capable transmission protocols such as AMQP, MQTT, DDS, XMPP, OPC UA, and CoAP are analyzed in detail. MQTT is selected for developing the framework since it is a platform-independent protocol in a lightweight design for constrained devices. A distributed network is presented with the advantage of the speed of local networks and the computing power of cloud environments. Its scalability allows monitoring of several entire wind farms. An Instantaneous Packet Delay Variation (IPDV) and Packet Loss Ratio (PLR) analysis on the present low-bandwidth, high-latency network for a real-world data stream is performed to analyze performance and limitations. Results show that the use of a real-time MQTT environment is appropriate for SHM, however particular attention must be paid to transmission delay, packet loss, and establishment of local queues.

Ultrasonic Guided Waves Simulation in SHM Design – Finite Element Modeling and Model Data Handling

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Over the last years a lot of scientific work has been done regarding structural health monitoring (SHM) systems. Introducing SHM systems offer the possibility of saving weights going along with other advantages, e.g. an improved condition-based maintenance of the structure, decreasing fuel consumption. In case of thin-walled lightweight structures as they are used for aerospace applications SHM concepts based on ultrasonic guided waves are very promising.

The large experimental effort of designing such SHM systems can be significantly reduced by accompanying simulations. Simulation techniques to analyze the guided wave propagation have been developed using different numerical methods, e. g. conventional and higher order finite element methods (FEM), elastodynamic finite integration technique (EFIT), finite cell methods.

To investigate the static and dynamic behavior of thin-walled lightweight structures shell-type finite element models are widely used. For general purpose SHM simulations it is advantageous to employ these models also to analyze wave propagation phenomena without switching to a special tool. Only few modifications regarding mesh refinement are needed. Therefore, we present a strategy to simulate the guided wave propagation in layered composite structures by using finite shell elements of Reissner-Mindlin type. The results are benchmarked with experimental data coming from the Open Guided Waves project (<http://openguidedwaves.de>).

The usability of such simulations as well as the comparison with experimental data is simplified by easy access to the results in a standardized data format using open-source tools. Thus, we particularly focus on aspects of model and result data handling, post-processing and visualization. The implementations presented here are based on the recently introduced FE data standard VMAP (www.vmap.eu.com). The approach enables the combination of simulation data in a central data container coming from different analysis tools. It yields to an improved evaluation of the proposed SHM system and allows the direct comparison with experimental data.

GigaFactory Digital Twins optimising for improved yields

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Battery Inspection and quality data are becoming more exact and precise as inspection sensors and Industry Internet of Things (IIOT) services become more advanced. The ability to turn the growing amount of data provided by increasingly advanced sensors into actionable information is a challenge for quality inspections. To overcome this, they must seek solutions that help process their entire workflow using one single solution and bringing this together in a factory requires a digital twin to help optimise the results to make them actionable.

The prize for harnessing this data will be significant, a recent factory case study producing 20GWh per annum, with a 2% improvement on yield could achieve a saving of Euros 210 Million. There are solutions across the Battery Life-Cycle which could benefit from Automating defect inspection with AI and bring the cost of non-quality down, with less resources applied. This revolution in manufacturing and NDE4.0 will require collaboration, standards and developing open architectures.

The Battery GigaFactories appearing globally, have the potential to achieve a faster route to success than in many industries, as they are set up from the initial stages with more inspection feeds, and data than most process industries in the past. As there is a likely set of changes to the technology for batteries and product mix the needs for quality inspection are set to grow, and Quality inspectors must will need to constantly adapt to different quality requirements for different products, which often leads to inaccuracy and a lack of consistent quality.

In the future we will see more augmented digital inspection solutions which will feed into the simulations, and be able to analyse and act on the information developed through the 'Digital Twin' with this comes the opportunity to improve yields, and reduce scrap.

Seminar concept and NDE 4.0 training programs for Applied AI and their practical use for data evaluation and decision-making

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Deep Learning (DL) is currently the most important discipline of Artificial Intelligence (AI). It enables machines to process data, learn patterns, recognize and classify complex defects. By means of DL, problems can be processed automatically whose mathematical descriptions are difficult or impossible. In close combination with NDE sensors, process data and robotics, the application of DL opens up new possibilities that will define the next generation of NDE systems. The NDE community needs to be well prepared for the NDE 4.0 as AI and especially DL is a driver of the paradigm shift in this direction. Educative and training seminar in an applied form help to bring the AI into the NDE community. In a collaboration between Fraunhofer IZFP, the German Research Center for AI DFKI and the German society for NDE DGZFP, a first-time training for DL for NDE is offered. The training is primarily designed for researchers, developers and manufacturers of NDT equipment and systems. Within it, participants will learn how AI systems work, how they are designed, and learn the application potential of the state of the art DL-models. Using hands-on exercises from NDE, a first-hand experience about the mechanisms of neural networks and modern DL models is presented. Attendees will learn the important DL-terms and their influence, without superfluous technical overhead. By means of relevant exercises of multimodal NDE data sets (including X-ray, thermography and ultrasound), a practical understanding of the underlying principles is provided. For an ideal result, basic knowledge of mathematics at university level is required (e.g. to be familiar with the terms vector, non-linearity and matrix), additionally to initial programming experience in, for example, Python, Matlab, or another language. The Training will be offered one to two times this year and is expected to become a regular module in the DGZFP Training catalog.

NDE 4.0 Requirements in Penetrant and Magnetic Particle Inspection

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There are in principle two main areas which can be defined for equipment in NDE 4.0:

- a) Marking and measurement of relevant indications in digital presentation, decision and dokumentation by a human inspector,
- b) Complete automated evaluation, decision and documentation by computer integrated systems with image processing and even with sophisticated artificial intelligence.

In both cases, the digital information can automatically be transferred to the interested parties in production or incoming goods inspection.

- a) The testing equipment is set and the human inspector is guided by the implemented test instructions on the computer. Measurements of the indications are digitally carried out in a copy of the original image. If necessary, image processing can be used to facilitate the human operators decisions which he has to notify in the digitally presented form.
- b) In case of a completely automated system all steps of the testing procedure are carried out by the handling and computer system of the test equipment.

The completely automated system has the advantage of not depending on human errors in the decision, because of an inspectors physical or psychological state. One should bare in mind the environmental stress of the inspectors especially if there are only few defects to be observed.

For evaluation of the inspection capability in a) or b) it is necessary to refer to POD and ROC statistical concepts to obtain the required result with respect to the indications.

In this presentation we report on our experience, results and failures, with both areas a) and b) in non destructive surface crack detection with Penetrant and Magnetic Particle techniques.

Building quality into nondestructive evaluation through effective personnel qualification systems

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¹ ASNT, Columbus, USA

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- Cost Reduction – Save time and resources and reap potential cost reductions through fewer site visits to review NDT personnel certification

Future of Training, Certification, and Qualification in NDE and in Times of NDE 4.0

J. Vrana¹

¹ Vrana GmbH, Rimsting, Germany

The emerging technologies, digitalization, digital transformation, and NDE 4.0 are changing the industry. Inspectors have to operate equipment with intelligence augmentation; workflows are handled digitally; results are stored revision safely; remote inspections are becoming reality; NDE personnel has to interact more closely with engineers. All this needs to become part of the training, qualification, and certification in NDE to enable inspectors and inspection supervisors for the world they will have to operate in the future. But it is not only the content that will have to change. Also training, certification, and qualification itself. Training will get augmented by extended reality enabling off-site training and deeper immersion. Predictive, personalized training and certification offer huge advantages. And Qualification needs to become electronically accesable while maintaining data protection.



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DPAI: A Data-driven simulation-assisted-Physics learned AI for Modeling Ultrasonic Wave Propagation in the 2D domain.

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AI models such as the Data-driven simulation-assisted-Physics learned AI (DPAI) model shown here could simulate ultrasonic wave propagation in the 2-D domain by implementing a recurrent neural network (RNN) based algorithm. The DPAI model consists of convolutional long short-term memory (ConvLSTM) with an encoder-decoder structure. The DPAI used a data-driven approach to learn the underlying physics of elastodynamics from the spatio-temporal dataset by utilizing deep neural networks. The DPAI model is trained with the finite element (FE) time-domain simulation dataset of distributed multipoint sources excitation in the domain. The various case study is performed to show the capability of the trained DPAI model for generalizing to modeling wave propagation simulation in irregular domains, larger domains, different frequencies with the number of cycles, multipoint sources. The trained DPAI model and FE explicit dynamic solvers are compared for computational time and accuracy in generating wave propagation simulation. The DPAI is shown to be significantly faster in modeling simulations with reasonable accuracy.

Data-Driven modeling of rail damage - data sources for building models

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Developing preventive methods for maintaining railway infrastructure relies on meaningful prediction models. To build such models, machine learning methods are used that detect patterns in collected data for predicting future states. Data that can be used are measurement and test data, for example, provided by test trains that provide eddy-current and ultra-sound based measurements of the rail status. However, building widely applicable models from such measurement and test data is difficult as these models usually are too general and cannot account for the specifics of local conditions across an entire railway network. Complementing these measurement and test data, additional contextual data can be employed to further improve the predictive power of the machine learning models, such as data about the type of rail, data about local soil conditions, data about traffic on specific railway sections, data about past maintenance activities, or weather data. In this paper, we provide an overview about these available contextual data summarizing work conducted on the previous Shift to Rail EU project GoSafe Rail about general open data sources available for railway asset management. Based on this overview, the paper provides a first assessment of which data sources exist to support context sensitive model building fusing context data with measurement and test data collected on the German railway network. The paper will also present first results of machine learning experiments conducted within the German nationally funded AIFRI project.

Challenges and Approaches when Realizing Online Surface Inspection Systems with Deep Learning Algorithms

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Using deep learning in complex online surface inspection systems is challenging due to different framework conditions. First, time restrictions in production are usually fixed in terms of clock rate and response time. Furthermore, these methods need a lot of data, while typically the data situation is thin in the beginning as well as continuously unbalanced: defects occur rarely and thereby providing few example data for learning, while the desired detection rate is 100%.

Another important issue is that although defect catalogues exist, they often change, especially when automatic inspection is applied for the first time. This is due to imaging systems usually being able to detect more defects than visual-manual inspection, therefore production, management, and quality assurance usually reiterate their prior defect catalogues. However, data driven methods depend heavily on consistent annotation. Therefore, respective parties must be made aware of this issue on the one hand, on the other hand, annotation and reannotation must be easy and useable by non-experts.

Related is the task of parametrization and traceability. Both are not inherent to neural networks but must be provided to some level to help building trust in machine learning methods.

In this paper, we present a quality inspection system that uses deep neural networks for defect detection under real production conditions in wood manufacturing. We will address how we systematically deal with the above issues both in terms of process and algorithm.

Machine Learning Applied to Corrosion Degradation Prediction

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Heat exchangers play a very important role in refineries. The maintenance cost of this equipment can reach 60-70% of the total cost of maintenance of these industrial facilities. Therefore, the increase in reliability of these assets is very important, both from a financial and environmental point of view. Depending on the number of tubes of a heat exchanger, a partial coverage inspection (PCI) is required using Non Destructive Testing (NDT). Modern statistical techniques are of great help to estimate tube wall minimum thicknesses. Additionally, the use of machine learning (ML) tools can be very promising for this purpose. ML is a subfield of Artificial Intelligence (AI) that includes complex statistical techniques, enabling machines to enhance the problem-solving experience, and excels at identifying underlying statistical patterns, resulting in greater accuracy in predictive models. For this work, a database with 1850 subsamples of NDT results were constructed, where each subsample is compound by 36 values of minimum thickness randomly choose of a big sample and the minimum value of the big sample to supervised training purpose. With this data, statistical parameters and AI tools were used to generate the features necessary to feed supervised training of several classic ML procedures. After training, validating and testing several models, the best metrics (RSME = 0.034 and R2 = 0.971) were obtained using K-Nearest Nearest Neighbors, having as features 8 outputs of the encoder model of an artificial neural network auto-encoder and quantity of tubes in the bundle. The minimum value of RMSE obtained with traditional statistics tools was 0.128, that is; 376% higher than the best ML result. It can be concluded that the use of AI techniques is fundamental for structural integrity analysis of heat exchanges bundles to attend the paradigms of planning and control maintenance in Industry 4.0.

Statistical analysis and automation through machine learning of resonant ultrasound spectroscopy data from tests performed on complex additively manufactured parts

[A.-F. Obaton](#)¹, N. Fallahi², A. Tanich¹, L.-F. Lafon¹, G. Weaver³

¹ Laboratoire National de Métrologie et d'Essais (LNE), Paris, France; ² Engineering Ingegneria Informatica, Torino, Italy; ³ Weaver NDT, LLC, Las Vegas, USA

To be able to rely on the integrity of parts additively manufactured (AM), their inspection is required prior to use. However, one of the main benefits of AM is to build very complex part geometries, such as cavities, internal channels, free forms, lattices, which do not facilitate ease of inspection. Besides being non-destructive, the quality method needs to be volumetric, and capable of complex shapes and rough surfaces. The challenge is high. X-ray computed tomography (XCT) sometimes meets these requirements, however the method is limited by the size and density of the parts. Among investigated methods on complex AM parts, resonant ultrasound spectroscopy (RUS) methods have shown particularly promising results. Their principle is based on the analysis of the positions, in frequency, of the freely resonant vibrational modes of the part under test as a result of an impulse excitation. Shifts in frequency of the positions of the resonant peaks is synonymous of a change in the integrity of the part. These methods are global and comparative to parts from the same family or simulations, they have the advantage to be faster, easier to use and cheaper than XCT, but also suitable to large and dense parts. We have already demonstrated the benefit of the methods to sort parts with planned defects from reference parts supposedly flawless, we have also shown that the parts can be classified accordingly to their AM process parameters. We propose here to present the statistical analysis, through Z-scores implementation, of a lot of parts supposedly identical and to automated the whole analysis implementing machine learning algorithms.

Deep learning based segmentation and quantification of porosity in additive manufacturing

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¹ Object Research Systems Inc, Stellenbosch, South Africa

Additive manufacturing is an enabling technology advancing rapidly, especially in the medical and space industries. It allows unique advantages to be leveraged including short lead times and optimized designs with complexity not possible by other manufacturing methods. With these advantages come manufacturing challenges, including defects (pores) that are often much smaller than those found in castings, but are more widespread and can lead to poor performance in some applications. X-ray computed tomography (CT) has been key in this field to identify these pores and improve defective processes, leading to higher quality manufacturing. Besides process optimization CT is also useful for non-destructive inspection of final parts for quality assurance. In both of these cases, image analysis of porosity in CT is needed and is mostly based on thresholding. This can be problematic for pores with small size relative to the voxel size used, and in the presence of image artifacts, leading to many pores that may be missed from the analysis. In this work, we demonstrate the use of deep learning for this application. A series of 25 cubes previously characterized using Archimedes method, gas pycnometry and traditional CT porosity segmentation using thresholding is used. The superior performance of deep learning for porosity quantification is demonstrated in this paper, showing better segmentation of small pores with no user influence. The potential to extend this model to general NDT application is discussed.

Frontloading GD&T into Simulation

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CT Technology was first used in advanced material labs for material analysis, and in many cases to inspect failed components. As time progressed, CT would be utilized not only in reaction to failures, but proactively as a tool critical to product development. As well as inspecting CT data of developmental prototypes, Volume Graphics software is now part of the process before products even exist. Process simulation departments utilize VG's metrology and geometry compensation capabilities to evaluate simulation results and fine tune geometries. It can then compensate machine, tool and production effects. As a result, geometric product specification can be applied and respected from design to simulation, production, and quality control, in one software solution – no matter if the data is acquired as a point cloud, mesh or voxels. Ultimately this enables a seamless and uniform specific quality description across the whole product development cycle, and dramatically increases the effectiveness of communication within the company, as well as towards the customers and suppliers.

Machine Learning based defect detection in Laser Powder Bed Fusion utilizing thermographic feature data

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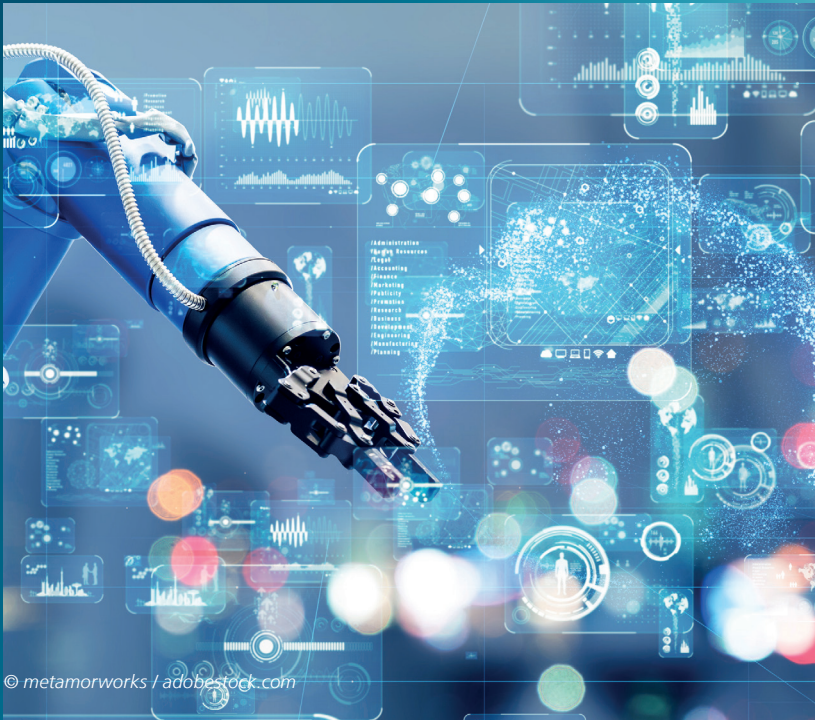
The formation of irregularities such as keyhole porosity pose a major challenge to the manufacturing of metal parts by laser powder bed fusion (PBF-LB/M). In-situ thermography as a process monitoring technique shows promising potential in this manner since it is able to extract the thermal history of the part which is closely related to the formation of irregularities. In this study, we investigate the utilization of machine learning algorithms to detect keyhole porosity on the base of thermographic features. Here, as a referential technique, x-ray micro computed tomography is utilized to determine the part's porosity. An enhanced preprocessing workflow inspired by the physics of the keyhole irregularity formation is presented in combination with a customized model architecture. Furthermore, experiments were performed to clarify the role of important parameters of the preprocessing workflow for the task of defect detection. Based on the results, future demands on irregularity prediction in PBF-LB/M are derived.

Spatial and Temporal Deep Learning in Air-coupled Ultrasonic Testing for enabling NDE 4.0

[S. Schmid](#)¹, F. Dürrmeier¹, C.U. Grosse¹

¹ Technical University of Munich, Germany

Air-coupled ultrasonic (ACU) testing has been used for several years to detect defects in plate-like structures. Especially, for automated testing procedures, ACU testing is advantageous in comparison to conventional testing. However, the evaluation of the measurement data is usually done in a manual manner, which is an obstruction to the application of ACU. The goal of this study is to automate and improve defect detection and NDE 4.0 accordingly with deep learning. In conventional ACU testing the measurement data contains temporal (A-scans) and spatial (C-scans) information. Both data types are investigated in this study. For the A-scans, which represent time series data, neural network architectures tailored for time series data are applied. Furthermore, it is evaluated if further adaptations of the training procedure (e.g. augmentation) increase the performance. The C-scans are segmented using different U-net-like architectures and training strategies. To compare the performance of all trained models and training strategies, we use the AUC_roc score. As specimens, artificial defects in plastic and CFRP plates are investigated.



NDE 4.0 – The Future of NDE of tomorrow!

Sensor and Data Systems for
Safety, Sustainability and Efficiency

Towards machine learning segmented porosity in ultrasonic tests for composite materials

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One of the most common manufacturing defects in composite materials is the presence of voids. Ultrasonic testing is the most widely used technique to assess porosity in service. However, morphological features, such as the shape, size, and distribution of the voids, affect mechanical properties, and there is no method to measure them by ultrasound. X-ray computed tomography (XCT) provides very high-resolution 3D reconstructions and is usually used to measure porosity features. The use of XCT volumes as ground truth could guide ultrasonic tests to determine morphology factors. One possible approach consists in obtaining the best resolution ultrasonic volume possible using a phased array and relating it to the XCT volume. Still, ultrasonic data are difficult to interpret in composite materials because of their inhomogeneous nature. The ultrasonic volume may contain porosity echos together with noise, resonance effects, matrix, and fiber echoes, or other defects. Its relation to XCT helps to establish what is void, and the use of image processing and/or machine learning could automate and improve this task. In this paper, we present a methodology for performing the segmentation of voids in ultrasonic data. The study includes the effect of different phased array equipment, the relation of XCT and ultrasound data, and the segmentation of voids with machine learning models for two carbon fiber reinforced materials with different porosity morphologies.

Usage of Acoustic Emission and Artificial Intelligence for structural health monitoring purposes

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Acoustic emission (AE) is a well-known phenomenon related to a number of irreversible processes, whereby transient elastic waves are released. For example, it is found in a broad variety of different materials, when mechanically loaded to a certain extent. Local overstress leads to the emission of sound wave packets into the surrounding material, where they can be detected by piezoelectric sensors mounted onto the surface. In this way the response of the material to the applied load is obtained immediately and in a rather straightforward way as a series of electrical AE signals in time measured on one or more channels. All state-of-the-art measuring systems deliver measuring data in a digital format with many options for further data processing. This allows integration into a 24/7 structural health monitoring system to assess the structural integrity of in-service equipment under operational conditions. In order to assess the stream of data against indications for potential degradation, powerful methods including artificial intelligence (AI) algorithms can be employed to unleash the full potential of this method.

AI in NDT – Implementation and qualification

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¹ VisiConsult X-ray Systems & Solutions GmbH, Stockelsdorf, Germany

Digital transformation and highly automated inspections systems allow manufacturers to significantly optimize their quality control and assurance processes. Due to the higher throughput of parts, the evaluation and interpretation of X-ray images is starting to become a costly bottleneck. Advanced technologies like Automated Defect Recognition (ADR) and Artificial Intelligence (AI) have the potential to significantly reduce the required time per part. Depending on the inspection standard and requirements the algorithms can be implemented in an as an assistance to the operator or fully automated.

Under the umbrella of the fourth industrial revolution, also coined NDE 4.0, new technologies like Artificial Intelligence (AI), cloud computing, IIOT, simulation and big data offer the next level of performance. Having low-maintenance and accurate Automated Defect Recognition (ADR) algorithms available helps operators to make better decisions in less time. Digitalization and smart data evaluation strategies have the potential to contribute to serious improvements for inspection processes. Learn more about how to unlock the value of these technologies.

This presentation will cover the basics of AI in the NDT sector and provide some insightful implementation examples. There will be a special focus on qualification and how to move from a lab prototype to a production environment.

Artificial Intelligence Based Automated Analysis System for Industrial NDE Applications

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In all industrial sectors the critical components are evaluated periodically to ensure their integrity and the highest level of security. While Non-Destructive Evaluation methods and procedures are subject to Norms and Qualification standards, several aspects could still be optimized and achieve on one hand the improvement of the overall quality of the inspection and on the other hand the reduction of equipment downtime: the long occupation of the components can be a real burden in terms of costs and productivity.

An Automated assistance based on Artificial Intelligence (A.I.) for analyzing the important number of acquired NDE data can importantly contribute.

INTERCONTROLE (France) and QUALICON (Germany) of Framatome Group, provide NDE services in Nuclear Plants for inspecting the full Primary Circuit of the Reactor. To deploy an A.I. based industrial solution INTERCONTROLE and QUALICON have developed the FAIA Software. This platform integrates Artificial Intelligence analysis algorithms for most used NDE methods such as Visual, Ultrasonic and Eddy Current Testing. The system is capable to process input signal (images, video, timeseries) and provide real-time alarms for potential existence of defects.

In this conference we present the FAIA Software, and we illustrate its performances for two use-cases from nuclear and railway industries: Visual Testing of Reactor Vessel components and Ultrasonic Phased Array inspection of train axles. The use of Object Detection backed by Convolutional Neural Networks (CNN) allows not only to detect relevant indications such as natural defects (cracks, scratches) and notches but also accurately localize and characterize them. The proposed CNN is combined with the Transfer Learning and Data Augmentation methods that reduce the necessary training time of the model and the size of the learning data set respectively. Therefore, the adaptability and versatility of A.I. in different environments with high noise level, varying illumination conditions, and geometric echoes is demonstrated.

Capture of the operator gesture and augmented reality for improved UT manual operations

M. Cardoso¹, F. Grassin¹, V. Saint-Martin¹, [E. Cartier](#)¹

¹ CEA List, Paris Saclay, France

Digital technologies can be used to assist NDT operators, facilitate data acquisition and analysis, improve the reliability and traceability of inspections. With this in mind, CEA List has developed a technology dedicated to manual inspections that combines operator gesture monitoring, augmented reality (AR) tools or other visualization tools. The technology is based on a platform that synchronizes probe position tracking, NDT data acquisition and visualization. It is compatible to Android tablet and remote viewing. It was first implemented and evaluated in the case of manual UTPA inspection. The system connects an ultrasonic acquisition system, optical position tracking cameras, a real-time data processing chain and augmented reality glasses. In this communication, we describe the technology and this first implementation. We show how this enables better real-time viewing of UTPA images through AR glasses while providing inspection metadata to assess the coverage of the inspected area. We also discuss the performances and perspectives offered by this technique.

NDE 4.0 to Support Aircraft Structural Integrity Programs

D. Forsyth¹, J. Aldrin², S. Rajaram¹, D. Motes¹

¹ TRI Austin, USA; ² Computational Tools, Guerneee, USA

Industry 4.0, the digital thread, the digital twin, attritable aircraft, unmanned systems, depot transformations are all modern concepts that support Aircraft Structural Integrity Programs (ASIP) with the tools and technology that are available to us. ASIP tasks in design, manufacturing, and maintenance are now implemented with digital tools and processes. However, nondestructive testing (NDT) in the factory and especially at maintenance depots and field units is often not digitally integrated into ASIP. Current practice may go as far as to digitally record results of inspections, or maybe even display bitmaps from inspection datasets mapped onto a CAD model.

Forward modeling of NDT can be used in the design tasks of ASIP to predict inspection capability on design control points. NDT results from Full-Scale Testing can support the model results and refine NDT techniques and capability predictions in support of maintenance. Inspectors can be supported in training and execution of their job with virtual or augmented reality (VR, AR), real time intelligence augmentation, and Assisted Defect Analysis (ADA). Spatial awareness and integration of NDT execution with CAD information can support the manufacturing review board (MRB) process and the disposition of damage in sustainment by registering the NDT data to CAD and reducing the NDT data to physical characteristics of defects. Results in CAD can be meshed and assigned properties for FEA, and can be integrated into maintenance databases and support data mining and fleet support decision making.

We will show examples of the critical technologies of forward modeling, spatial awareness, intelligence augmentation, and automated defect analysis with reference to their impact on ASIP and critical metrics of NDT performance: capability, time, and cost.

3D-Visualization of ultrasonic NDT data using mixed reality

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In this paper we present an approach where ultrasonic testing data (UT) is linked with its spatial coordinates and direction vector to the examined specimen. Doing so, the processed nondestructive testing (NDT) results can be visualized directly on the sample in real-time using augmented or virtual reality (AR/VR). To enable the link between NDT data and physical object, a 3D-tracking system is used. Spatial coordinates and NDT sensor data are stored together. For visualization, UV texture mapping was applied on a 3D model. The testing process consists of data recording, processing and visualization. All three steps are performed in real-time. The data is recorded by an UT-USB interface, processed on a PC workstation and displayed using a Mixed-Reality-System (MR). Our system allows real-time 3D visualization of ultrasonic NDT data, which is directly drawn into the virtual representation. Therefore, the possibility arises to assist the operator during the testing process. This new approach results in a much more intuitive testing process and a data set optimally prepared to be saved in a digital twin environment. The size of the samples is not limited to a laboratory scale, but also works for larger objects, e.g. a helicopter fuselage. Our approach is inspired by concepts of NDE 4.0 to create a new kind of smart inspection systems.

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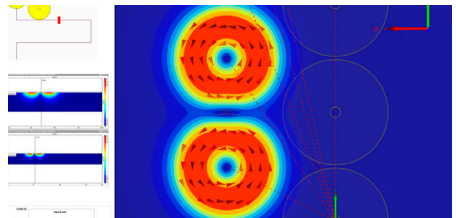
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Digital Transformation Roadmap – A case study

R. Singh¹

¹ Inspiring Next, Cromwell, USA

Digital transformation, in any sector, is a massive change. NDE is no different. Like any major change, It requires defining purpose, vision, strategy, success metrics, and a road-map. It requires leadership commitment, dedicated team, resources, and continuous review and adjustment. Ripi Singh is a freelance innovation coach and a professional change management advisor, who has helped several companies along the journey of digitalization and digital transformation.

This presentation will cover a two-year case study, and some lessons distilled from few other digital transformation engagements, facilitated by the presenter. The scope covers fully integrated value streams for market capture, product/service development, process digitalization, talent development, technology enhancement, and meeting compliance requirements.

Lessons learned will include what works and what does not work when implementing a roadmap for change.

These lessons and case study formed the basis for creating the NDE 4.0 Roadmap Guide which lays out the scope and recipe for a generic transformation roadmap.

Simulation and AI, two complementary tools for NDE4.0

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The rise of artificial intelligence techniques and machine learning promises tremendous advances in the field of NDE and SHM for both the assistance to the operator or for automated diagnostics. The potential benefits concern detection, characterization and sizing of defects. However, the development of efficient algorithms often face challenges due to the complexity of the NDE problem, the multiplicity and the variability of parameters impacting acquired signals or images, combined to a lack of fully representative data bases. It has already been pointed out that simulation can be a powerful mean to tackle these issues. Simulation which relies on physic-based models can be used to provide numerical data for training algorithms and can also be used to select the relevant features, to design and to evaluate ML based algorithms. With this belief, CEA List is working on a CIVA module allowing the NDE engineer to benefit of the potential of simulation to handle and implement data science tools. In this communication, we develop the complementarity between simulation and AI, with examples of recent achievements, applications and results.

NDE 4.0 – What is hype and what is the future? Decide for yourself!

D. Kanzler¹, V. Rentala²

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NDE 4.0 is the most recent, strongly discussed topic in the NDE field. There are no conference and no modern discussion about NDE without AI support, predictive and prescriptive maintenance as well as digital threads and digital twin. The potential is high for the technology of NDE 4.0. NDE 4.0 can be a new way to understand technical quality for a various number of industrial fields.

Where and when to go the steps in the direction NDE 4.0 depends on the testing situation itself. And the decision, if NDE 4.0 might end as an empty shell, is made by the experts in the field and the NDT management.

This presentation will provide the audience with all needed tools to be able to gain a mighty tool to enable the NDE 4.0 as the promising future, we hope for, for your specific case: The evaluation of reliability of the NDE application.

For example, in case of the project AIFRI, the evaluation of AI in the field of railway inspection, a specific real-world situation is simulated. It explains the use of the tools and mentions all the necessary steps which provide the audience with an answer for this question.

Enhancing NDE Workflows through Cloud-Based Solutions

A. Lamarre¹, G. Bauer², D. Park², G.-L. Zhang²

¹ Olympus Scientific Solutions Americas, Quebec City, Canada; ² Olympus Scientific Solutions Americas, Waltham, USA

Digital transformation is revolutionizing nearly all industries and professional areas, including the nondestructive evaluation (NDE) world, improving process efficiency and data integrity while reducing cost.

While the connectivity of NDE devices is a key element of digital transformation, the seamless integration of these devices into a data-management platform and related applications adds considerable value to asset owners (AOs), inspection service providers (ISPs), and other stakeholders. With this in mind, Olympus set out to develop a cloud platform for the NDE industry that not only improves data transfer between devices, but also offers value-adding digital applications based on customer needs.

In this paper, we will review the advantages of using connected instruments, such as the Vanta XRF analyzer, the 38DLP thickness gauge, the EPOCH 6LT flaw detector, OmniScan series flaw detectors, and the IPLEX NX videoscope. We will also present two recently developed cloud-based solutions: Inspection Project Manager, which is an application that optimizes ultrasonic and visual data acquisition, reporting, and inspection management to assist the maintenance industry, and ViSOL software, which is designed to improve the remote visual inspection (RVI) workflow, including online data storage, data sharing, inspection planning, report template design, report generation, stereo image remeasurement, as well as offline productivity.

Theoretical POD assessment of an NDE 4.0 application under the context of Aero-Engine Lifting

V.K. Rentala¹, D. Kanzler¹

¹ Applied Validation of NDT (AV-NDT), Berlin, Germany

Under the context of NDE 4.0, it is believed/predicted that the POD of NDE 4.0 systems is capable of obtaining beyond the intrinsic capability of the existing test systems. However, there is not even one study published in the literature that can clearly show the POD of NDE 4.0 systems under the realistic experimental conditions. This can be due to not obtaining the complete transformation of NDE 4.0 in the current industrial scenario as the 4th NDE revolution is still under the process of evolution.

Hence, in the current work, an attempt has been made to estimate the POD of NDE 4.0 systems by means of developing statistical POD models. These models are developed by obtaining the prior information from the experimental NDT data under the context of implementing damage tolerance life extension methodologies for aero-engines. These models aim to obtain the POD curves for intrinsic capability, POD curves under the human factors influence and the POD curves for NDE 4.0 systems.

This study results in providing the information on what percentage the existing systems has to be improved so as to obtain the POD of NDE 4.0 systems beyond their intrinsic capabilities. Under the aegis of NDE 4.0, several advanced and alternative approaches such as incorporation of AI/ML algorithms, data fusion, digital twins, etc., are proposed to enhance the reliability of NDT techniques. In addition, this study also results in identifying the safe inspection intervals such that only one or two inspections are possible for most economical ways of carrying out the damage tolerance lifting extension methodologies for aero-engines.

Model Assisted Probability of Detection for NASA Space Missions

E. Gregory¹, W. Schneck¹, P. Juarez¹

¹ NASA Langley Research Center, Hampton , USA

Model assisted probability of detection (MAPOD) uses data from simulations to improve a traditional probability of detection (POD) study. This could include extending the parameter space to reduce uncertainty or substituting experimental data with simulated data to reduce the time and cost of a POD study. In the past MAPOD was difficult due to limited computational resources, but recent innovations in simulation tools and high-performance computing have made this type of high-degree-of-freedom modelling possible, and complex structures have made it necessary.

This presentation will summarize the work done by the computational nondestructive evaluation (CNDE) group at NASA Langley Research Center (LaRC) to complete a MAPOD study for phased array ultrasound testing (PAUT) of a friction stir welding (FSW) method to be used on Space Launch System (SLS) structures. The three critical needs for a MAPOD study are a validated and verified model of the inspection technique for the structure being inspected, some experimental POD data, and an uncertainty model for both the model and the experimental data. PAUT was simulated using Extende CIVAs UT module. The model was validated using laboratory inspection data from NASA Marshall Space Flight Center (MSFC) for a Hit/Miss POD for FSW in 2219-T87 aluminum panels representative of those used in the SLS.

This model was then used to simulate flaw sizes that were originally omitted from the original POD study. The results of this new MAPOD study will be presented along with a discussion of the methods and processes used to analyze the original data, selected simulation parameters, and development of the uncertainty model used for the statistical analysis. The goal of this effort is not just to improve the POD study but to demonstrate the value of MAPOD and provide a roadmap for application of MAPOD on future projects.

The benefits of inspection qualification, from NDE to NDE 4.0

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Qualification of NDE inspection systems is an essential requirement to assure the performance level prescribed and as a mean to enhance its reliability. There are different inspection system qualification methodologies with long experience of application and associated advantages, one of these is the ENIQ Methodology widely used in the inspection of European Nuclear Power Plants.

One of the characteristics of ENIQ methodology, in order to increase its reliability, is to prepare a technical justification (TJ) of the NDE inspection system (IS) to be qualified, before any practical demonstration takes place. Among the main elements of the TJ, in this context, are: the definition of the essential variables, and a physical reasoning of their selection, value and range.

For developing a NDE 4.0 environment, semantic interoperability is an essential element to exchange data between computers systems with a proper meaning. It is recognised that ontological approaches help understand the semantics of data under study. The information contained in the TJ, which are the essential variables and their justification, could become the base for elaborating the ontology of the NDE inspection system. In doing this, the building up of the ontology is abbreviated and reliable, while guaranteeing the reliability of the applied IS.

In this paper, the main characteristics of the ENIQ Methodology are described. Examples of essential variables, their explanation and justification, and the advantage of using them for developing ontologies in different NDE applications are also presented.

POD Curves for Natural Frequency Testing

A. Mendler¹, M. Döhler², C.U. Grosse¹

¹ TU Munich, Germany; ² Inria, Rennes, France

Evaluating natural frequencies for damage detection and localization is a standard procedure in non-destructive testing (NDT) and structural health monitoring (SHM). Examples of successful applications are resonant ultrasound spectroscopy and the evaluation of cables and prestressing tendons. Various methods are available to perform the analysis based on ambient vibration data measured during normal operating conditions, but uncertainties are introduced due to stochastic loads, measurement noise, and insufficient excitation of individual modes of vibration. This paper recaps a damage diagnosis approach that considers these types of uncertainties, the so-called asymptotic local approach, and applies it for the evaluation of natural frequency changes. The method is capable of detecting damages based on data and locating them using finite element models. Moreover, it can quantify the probability of detection (POD) and draw POD curves for damage detection and localization. A distinctive feature is that the POD curves can be created based on measurement data and a model from the undamaged state, with no empirical data from the damaged state. For proof of concept, a numerical case study is presented, where damage is defined as a change in cross-sectional values and axial forces.

A Proposed Common File Format for NDE Data

[D. Forsyth](#)¹, S. Holland²

¹ TRI Austin, USA; ² Iowa State University Center for Nondestructive Evaluation, Ames, USA

The NDE community has long been hampered by the difficulty of exchanging data due to a lack of standardization. Most vendors have their own proprietary file formats and the use of these formats limits interoperability. Analysis and inversion are hampered by difficulty of access to data. A proliferation of file formats is also problematic for digital thread/digital twin/NDE 4.0 systems that depend on data accessibility. Existing standardization efforts such as DICONDE, while well intentioned, have been hampered by the extreme overcomplexity of the underlying DICOM format as well as the distribution restrictions on the specification.

We propose a new format that has the flexibility to store all types of NDE data in a consistent fashion, is largely self-documenting, and can be specialized to each modality. The format is built on the HDF5 library and 15 years of academic experience using similar structures. It supports a hierarchy of tagged and annotated elements which can contain multidimensional arrays as well as metadata. We are also attempting to develop a simple but flexible and extensible notation for specifying spatial registration of the NDE data to a physical structure or CAD model.

We welcome input and feedback and are open to suggestions and changes from the community. We expect to have a prototype free and open source viewer that is compatible with the draft specification available by the time of the conference.

This presentation is based on work supported by TRI-Austin and the Air Force Research Laboratory; clearance #AFRL-2022-0381

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Today's requirements for manufacturers of individual test technology systems are diverse and multi-layered. Varying sensor technologies and software architectures as well as guideline-compliant designs determine everyday life. In addition, there are decentralized development departments, which per se preclude a uniform strategy.

The industrial and global development of non-destructive testing offers the opportunity to implement the urgently needed further development towards a uniform information model, as required for use in IIOT networks. With OPC UA Standard, an open standard already exists for manufacturer- and platform-independent communication across different levels and degrees of automation. In addition, already numerous, very different information models have already been developed based on this standard, which make a comprehensive application possible.

The article presents the challenges of developing a company's own OPC UA interface for different test process technologies and varying software. In addition to the development of a uniform concept, a first exemplary implementation is explained.

The positive effect on compliance, security, and efficiency by the use of state-of-the-art NDT management software

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The Digitalization and the associated networking of systems is progressing continuously in the NDT industry. In terms of workflow management, however, a combination of several tools such as Excel spreadsheets, Word documents, a wide variety of software and even paper documents are still often used. There is therefore enormous potential for improvement through digitalization. Recent NDT workflow management systems are the key, efficiently integrating all NDT test methods and associated processes into a single system. All information is available centrally and digitally for every stakeholder involved. This guarantees compliance and enables comprehensive transparency and control of the entire NDT workflow and real-time status overview of all inspections. Inspection personnel can be managed, as well as customers, equipment, test objects, inspection procedures and standards. All processes and test results are and will remain traceable at all times. This paper describes the application of such management software and it discusses the significant increases in compliance, security, and efficiency along the basic NDT workflow.

NDE 4.0 Success Story: Fully digital end-2-end dataflow in plant inspection at BP Rotterdam

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Plant operators typically use risk-based inspection (RBI) methodologies and software to increase plant availability, reduce maintenance costs, and perform repairs and shutdowns as efficiently as possible.

The project goal of BP Rotterdam was to eliminate errors in the transmission of measured values from inspection into the leading RBI system (Meridium APM), resulting from a manually processed inspection data and reports. Likewise, the communication processes were to be optimized by means of suitable interfaces with the inspection service providers commissioned by BP, and data formats were to be standardized.

The project implementation was done on the Azure Cloud platform. Since the inspection devices of the service providers write data in DICONDE format, the according network communication services of DICONDE for digital inspection order transmission (worklist) and for direct storage of inspection data, measurements and reports into a DICONDE of the company DIMATE were configured.

The PACS (Picture Archiving and Communication System) aggregates order data for routine inspections as well as for orders in the context of shutdown planning (TAR, turnaround) from another planning software (Roser). For unplanned ad-hoc inspections, the full list of all installed parts of the plant (isometry) can also be accessed, so that inspection results can be reliably assigned to the inspected component, even if fast action is required in the event of damage.

Measurements and annotations, typically wall thicknesses of safety-relevant piping, or markings of defects in weld seams are also stored and transferred using DICONDE. The PACS automatically retransmits measurements to the operator's RBI system.

After the pilot phase, the PACS has been in routine operation since Q1/2022. The BP Rotterdam QA team has full access to all data, can recheck each measurement and monitor the test progress in real time. Test data and results are assigned to the tested components, are reproducible and quality assured.

Secure and Scalable Data Lakes for Unified Asset Management in the Industry 4.0

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In the last few years, we observed a considerable growth in the adoption of informatic systems in the industrial 9 environment for monitoring and management of mission critical assets. The introduction of concepts such as the Internet of Things (IoT), Big Data and Artificial Intelligence paved the path for the creation of tightly integrated data lakes that store and process information convenient from vastly different data sources.

The amount of data acquired by information system is constantly growing and is shared across multiple stakeholders and processes. This imposes many challenges to ensure that: only authorized users can access data, performance of the system across different applications, scalability of the system in performance and accessibility.

In this paper we propose an industry ready cloud-based approach for asset data management focused on the unification of data across different operation areas, across multiple sites ensuring performance, safety, and accessibility. The system proposed integrates of different data sources and processed such as: Asset Documentation, Inspection Reports, Maintenance Reports, GIS (Geographic Information System), IoT Monitoring, 3D Computed Assisted Drawing (CAD), etc.

All data is integrated into an adaptable process targeting the optimization of the asset lifecycle using Artificial Intelligence with the objective of improving their availability while also helps to reducing operational losses, safety, and environmental protection issues due to unwanted failures. All data introduced has a set of security and accessibility policies associated that will ensure even after automated processing that only the entitled stakeholders can access the outputs.

IoT enhanced robot for autonomous ultrasonic inspection

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The paper will present the ENDITY IoT platform that allows to collect data from any commercial robot and any commercial ultrasonic acquisition hardware, run applications locally, store data, send the data to other devices and upload it to the cloud. Specific local software applications will be developed and installed in the ENDITY IoT platform for signal processing, event evaluation, data analytics and machine learning operations. The technology incorporated in the ENDITY IoT platform will allow the integration of other software applications developed by the client giving high autonomy for the management and integration of new applications. The solution will be demonstrated during the robotic inspection of complex wind blade components changing the actual go/no go inspection systems concepts. It will transform the actual robot solution in a holistic multi-functional robotic IoT flexible digital platform able to connect the system to the cloud, monitor the component and evaluate and detect defects autonomously.

Innovation in robotics for inspection and maintenance – The RIMA project

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Robotics for Inspection and Maintenance (RIMA) is a 4-year Horizon 2020 project aiming to reinforce the connection between Europe's rich technological offer, the market needs and high potential applications in the field of inspection and maintenance (I&M). There is a massive potential for robotic applications to increase productivity and improve safety. Thus, among project goals are the provision of education and training and connection of value chain (research, technology companies, service providers, end users and investors) to have an impact for accelerating economic growth and extending EU's leadership in this sector. RIMA concentrates on I&M including NDE in a large area spanning across multiple sectors such as energy, nuclear, oil and gas, water supply, transport and civil engineering infrastructure.

This success case, is key to understand best practices on how RIMA Network formed a network of 13 Digital Innovation Hubs (DIHs) on robotics offering services such as technology scouting (including digitalization, artificial intelligence, machine learning etc.), feasibility studies, project plans, identification of technological trends and innovations. The network is enriched with industrial organizations and associations like the European Federation for Non-Destructive Testing (EFNDT) that have the links and means to promote the innovations coming from the DIHs to their stakeholders. DIHs typical clients are the Small and Medium Enterprises (SMEs) who have the problems related to deployment of robotics in their industrial processes, i. e. in NDE or in overall in-service inspection. SMEs are beneficiaries of RIMA because 50% of project budget is distributed to them with cascade funding methodology to run experiments within the framework of two open calls. The presentation will illustrate RIMA network best practices of a few sophisticated NDE related robotics applications that could be replicated in other projects and sectors (e. g. drone-based contact NDE, phased-array ultrasonic testing of unstructured settings, underwater NDE in radiation environment).

Towards unattended ultrasonic inspection process of rectilinear machined components of Jet-engines

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The demand for component supply especially engine disk and related hardware, is forcing manufactures to find ways to address the bottle necks created at the Ultrasonic NDT stage of production and maintaining high standards of quality.

One of the approaches is to automate as much as possible the inspection process. Automation is not only allowing to increase the productivity of the inspection, but it also increases the quality of the inspection by minimizing and excluding up to the certain extent of human factor from the inspection process.

The nature of the ultrasonic inspection makes the task of unattended inspection very challenging due to ambiguous interpretation of the signals. This is relevant not only for evaluation, but also for calibration and inspection process.

Traditionally it is resolved by human-system interaction. Though it is working well for last few decades, in some cases the results of human mistakes or unfollowing to the inspection procedures can be dangerous.

Therefore, the proper approach is to exclude human intervention is most of routine tasks, such as material handling , transducer replacement and calibration, searching for suspicious indications. Beside that, human is required for inspection process programming as well as for validation of the final results.

Recent developments completed and integrated into ScanMaster Ultrasonic Inspection systems covers all aspects of such approach. These developments include the following:

- Automation of everyday procedures such as transducer normalization, sensitivity calibrations and material attenuation
- Automatic elimination potential false positives
- Sophisticated algorithms to auto evaluate captured data while working according to OEM procedures and specifications.
- Automated transducers exchange mechanisms for multi-zone type inspection.
- Solutions for automatic loading/unloading of the inspected parts
- Rapid Data exchange with factory's Enterprise Management Systems to allow deep learning and predictive maintenance

These developments provide a big step towards unattended human-machine cooperative inspection of critical jet-engines components.

ITER thermonuclear reactor: automatic control of the penetration depth of end welds on steel plates of resistive elements

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In the design of the elements of the switching equipment for power supply and protection of the superconducting magnetic system of the ITER thermonuclear reactor, powerful resistor assemblies are used. All welds must undergo mandatory automatic inspection after the manufacture of resistive assemblies.

In accordance with the requirements, one hundred percent testing of end joint involves automatic scanning with a non – contact measuring probe and determination of the penetration depth.

To solve this problem, it is optimal to use the eddy current phase-sensitive method. To reduce the magnetic permeability of the metal of the plates and the weld, in order to increase the penetration depth of eddy currents, magnetization is used to saturate the controlled zone using an electromagnet.

Based on research and modeling, an eddy current probe with an electromagnet was developed that magnetizes the weld with a constant magnetic field (induction of at least 2.2 T), which ensures control of the penetration depth of the weld up to 1.4 mm at an excitation current frequency of 100 kHz.

The dimensions and mass of the eddy-current probe are optimized in finite element modeling using automatic algorithms. To cool the electromagnet, liquid cooling and a special laying of wire turns are used.

Before starting the inspection, the 6-axis manipulator examines the welds with a laser scanner, determines their actual location and shape, after which a scanning map is built containing the actual required trajectory of the eddy current transducer. The neural network simulator is used to recognize characteristic areas of the weld.

The principles and results of modeling are described in detail, the main technical characteristics of the developed eddy current transducer, a robotic six-coordinate scanning system and an automatic processing and decision-making system, and the main technical characteristics are given.

The AIFRI project – NDE data processing and AI techniques for Rail Inspection

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Maintenance management for rail tracks at Deutsche Bahn is based on data coming from non-destructive measurement, namely from ultrasonic and eddy current testing systems mounted to rail inspection cars (SPZ). Collected data currently is being evaluated visually by humans with the help of a special viewer software, indications for typical rail defects like can be identified but must be validated on-site by inspectors.

AIFRI (AI-based techniques for rail inspection data) is a German national funded research project that first of all aims to automate this evaluation process by making use of advanced AI techniques. A Deep Machine Learning model will be developed and trained to automatically detect rail defects and provides assessments of defect severities. By taking into account both ultrasonic and eddy sensor data as input to the AI model it will be possible to enhance the range of detectable rail defects. Furthermore, the reliability of detection will be improved.

The aim of this presentation is to introduce the projects background, its scientific-technical objectives together with basic research questions, the intended solution approach and expected results.

Digitalization for railway-NDT

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WheelStar-UnterflurPrüfEinrichtung (underfloor testing machine) is a testing machine for wheels (flange and web) of high-speed trains used by a leading train operator in Germany. Due to its innovative testing procedure, high automatization level and user-friendly controlling and inspection tools, the testing machine is a good example of how to use Industry 4.0 ideas in non-destructive testing (NDT).

Testing machine supports user during inspection task with several visualization and inspection tools for specimen analyses. Thus, human factor can be reduced and inspection reproducibility increases. Documentation and management of inspection data can be saved central or decentral on servers or in the cloud. Thus, internal, or external experts such as a competence centre for NDT of highspeed train-wheel-inspection can support in case of difficult results. Solutions for connectivity and tools for stand-alone-evaluation increase flexibility and support evaluation process.

In case of any trouble OEM can support operator via remote connection, too. So, availability of testing machine increases.

To increase producibility WheelStar-inspection system allows inspection of a train wheel (flange and web) within less than 90 seconds.

Thus, WheelStar-inspection system is one of the key factors for quality assurance and maintenance of high-speed trains.

FANTOM, a flexible and automated NDE 4.0 platform for manufacturing

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The increase in production rates in the aerospace sector brings out the needs for flexibility, reduction of the human factor and development of digital functionalities in the field of NDT. The FANTOM project, presented here, is part of this approach and aims to address these three major needs. To do this, a fully cobotized inspection system for large CFRP structures or complex geometry requiring flexible systems will be developed, as well as the tools necessary for the relevant interpretation of inspection data. FANTOM will enable complete integration of flexible and mobile NDT systems closer to manufacturing processes in the aerospace industry. At the end of the three years of the project, we are aiming four main developments. First, a cobotic architecture fully optimized for NDT, an application that requires precise mapping of the entire surface of the part, whether flat, cylindrical, or truly complex. Particular attention will be paid to the automatic generation of inspection trajectories adapted to the real geometry of each part. Secondly, the adaptation and optimization of inspection tools to complex geometries (such as radii, holes, part edges, openings, variations in thickness) through simulation, adaptative piloting software, smart effector offering several inspection tools to improve the reliability of the diagnosis and reduce the time spent on rechecking for false positives (ultrasonic NDT with optimized coupling, visual inspection and dimensional control). Thirdly, combined analysis tools adapted to complex and very large geometries for diagnostic. Fourthly, develop data fusion tools in order to optimize the restitution to the operator through augmented reality.

The presentation will focus on the general objectives of the project in relation to NDE 4.0, the results of the first months of work and the challenges to come.

Magneto-Optic Technology for Integrity Monitoring of Pipelines

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Pipelines are omnipresent infrastructures in the industry, they are used for the transport of products and raw materials to and from factories, and in many cases to distribution points and end customers. Over time, due to structure ageing, corrosion and erosion the original wall thickness of these structures reduces to a point that compromises their safe & reliable operation. Thus, within the scope of protection and optimization of structural resilience of critical assets, it is fundamental to monitor the structural integrity condition.

In this context, EQS Global has developed a magneto-optic transducer (MOT) based on long-range ultrasonics, that combines magnetostriction-based wave generation with fibre optic detection. The MOT can be permanently installed on the pipeline and from a single installation point, monitors the integrity in a range of about 80 m (40 m in each direction) and 360°, providing a comprehensive overview of the pipeline integrity. The retrieved data is sent to the UNO Asset Management Platform, which does a semi-automatic analysis of the data. More data sources can be connected so that a more contextualized analysis can be arranged and use predictive algorithms to plan maintenance or replacement interventions.

UNO platform predictive algorithms produce real-time insights, promoting preventive and predictive asset management, and the management of the useful life of the asset by inferring the possible consequences on the long-term performance.

In this work it is demonstrated the ability of this system to detect the early appearance of small defects and follow its evolution in different situations. The results show a capacity to detect mass losses of 0.15%, and the possibility of detecting the appearance of small changes (less than 1.5%) in the vicinity or inside pipe construction elements was demonstrated.

Authenticity Verification: An Independent and Markless Method for the Authenticity Verification of Electronic Components

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Motivation: Counterfeiting and product piracy directly or indirectly affect almost all industries (electronics, pharmaceuticals, cosmetics, clothing, accessories, luxury goods, etc.) and increase sharply especially in times of supply shortages. Defective or counterfeit electronic components are problematic for several obvious reasons, including health risks in branches such as medicine, mobility and military, impaired product performance and significant costs and revenue losses for the industry. Previous methods of counterfeit protection or identification require either a continuous communication of the members within the supply chain from component manufacture to product finalization (e.g. RFID chips), are easy to check but insecure (e.g. surface markings), or are costly and in some cases destructive (e.g. X-ray inspection). **Method:** Each manufacturer of electronic components uses its own recipes for the composition and processing of the housing materials of its components. As a result, the surface properties and reflectivity of the components have their own „fingerprint“, which enables differentiation between different manufacturers and the detection of manipulations. Our proposed laser speckle photometry (LSP) method for material characterization provides a fast, non-contact, and robust technique to generate, identify, and track speckle patterns through multiple processes. The „fingerprint“ as an intrinsic material structure leads to a characteristic speckle pattern. These speckle patterns can be used to recognize components from the same manufacturing process without having to store a speckle pattern for each individual component in advance and make it available on a server for matching. **Result:** In the first investigations, the LSP was applied to distinguish memory chips from different manufacturers based on different LSP parameters. The results are promising to develop and establish the LSP as the method for the authenticity verification.

Digitalization of on-site data capture

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Traditional asset inspections and on-site data capture are often labor-intensive. They rely largely on paper-based processes and lag the use of technology. Data capture during inspections is often trapped on isolated hard drives and on paper records with no ability to collaborate internally and externally. This means that traditional asset inspections are often inefficient in execution, result in incomplete asset health records, and in a worst-case scenario end in devastating disasters.

Powered by data from intelligent and autonomous inspection, predictive healthcare can extend asset life and increase long-term value for asset owners. Inspection of new build and existing assets is essential to secure efficient usage as well as safety for the users and adequate long-term financial returns for the asset owners. By introducing a new intelligent software platform to create accurate data collections towards a complete health record of assets can change these massive shortcomings. Long-term access to this information will allow fast and concise decision-making for predictive maintenance and collaboration.

About Screening Eagle Screening Eagle Technologies provides a technology platform for intelligent inspection and on-site data capture of the built environment. The company was created through the merger of Dreamlab in Singapore and Proceq in Switzerland with a mission to protect the built world with software, sensors, and data. Screening Eagle's full-stack inspection solution combines intuitive software and powerful portable sensors to deliver reliable data for construction and asset maintenance decisions.

Powered by data from intelligent and autonomous inspection, Screening Eagle is on a steep growth path to realizing its vision of predictive healthcare that extends asset life and increases long-term value for asset owners.

Industry trends driving the need to minimize unplanned downtime – concepts for X-Ray sources of the future

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Traditional approaches to machine maintenance do not do much to eliminate unplanned downtime: with a reactive approach, technicians always step in too late, whilst a preventive approach will only do a better job of catching issues early if maintenance happens to be performed when a system begins showing clear signs of breaking down. An unplanned downtime of an X-ray system can easily take hours if not days fix, given the likely need to source replacement components, components that may well not be kept in stock locally given high costs and limited shelf life. Especially in a high-volume production environment, such an unplanned outage is quickly very expensive. A prescriptive maintenance approach is called for to preempt failure.

diondo GmbH, a leading manufacturer of industrial computed tomography systems, is Comets OEM partner on this subject. The maintenance challenges diondo faces are unusual in the market, given that diondo specialises in bespoke machines, so uses a greater range of components and in lower volumes than competitors, but many manufacturers will be familiar with the difficulties of maintaining systems internationally during the pandemic. Our journey already started some years ago by laying the foundations for prognostic maintenance by incorporating data acquisition capabilities in our generators. The next milestone is a human readable visualization of the data and system behavior. Partnering with a system OEM like diondo, mastering the entire image chain, opens the possibility of the inspection output quality to be used as a key input to the monitoring system of the X-ray source. It is our vision to improve data collection and processing algorithms towards accurate system health reports and hence prescriptive maintenance, and potentially even the provision of X-ray flux as a service.

Embedded non-destructive testing ultrasound solution for damage detection and localisation

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In line with the goal of reducing the cost of space launch, ESA and CNES (French national space agency) are engaged in a program aiming to develop the future European reusable space launchers. In this context, PYTHEAS Technology develops an embedded Non-Destructive Testing (eNDT) solution aiming to ensure that strategic parts of the launcher are free of damage before a new launch. A network of piezoelectric transmitters/receivers, embedded in the structure, allows to detect, localize and characterize potential structural damages by propagating guided waves. The technique is based on a comparison between the pristine ultrasound signature of the structure and the deviation of a new ultrasound cartography from this reference. The performances of the system were first demonstrated on a honeycomb sandwich structure, specifically on a section of a payload adaptor, and tested for different damage types: hole, recess and crack.

Numerical modeling of the Lamb waves propagation in containment liner plates

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The containment liner plate (CLP) is a cylindrical shell structure anchored with concrete. Corrosion of CLP is the main phenomenon leading to wall thinning and detachment of plate from concrete. Structural integrity of the CLP is a key factor in ensuring the long-term safety of nuclear power plants. Ultrasonic tomographic inspection of the CLP is one of the promising technique for structural health monitoring (SHM) of the nuclear power plant. The reconstruction algorithm for probabilistic inspection of damage (RAPID) is one ultrasonic tomography method, which is based on lamb waves propagation. The main limitation of the RAPID algorithm is that the tomographic reconstruction result depends on the value of the input parameter. Manual setting of the ultrasonic algorithm parameters requires experience and is prone to mistakes. On the other hand, implementation of the Neural Networks allows to automatically set ultrasonic tomography parameters depending on the waveform parameters. However, the Neural Networks required big data for the training, which was impossible to get by real case experiments. In this research, a numerical method was used to study the interaction of ultrasonic Lamb waves with defects. In the numerical model, S0 mode with 2.7 mmMHz was used as a Lamb wave and 16 sensors were equally distributed along the plate with 6 mm thickness. Also, the MATLAB based program was implemented to set the position and dimension of the defect by interacting with CAE software. Differently from real case experiments, the investigated numerical method allows to reconstruct the CLP damage and compare the reconstructed image with that of the original defect.

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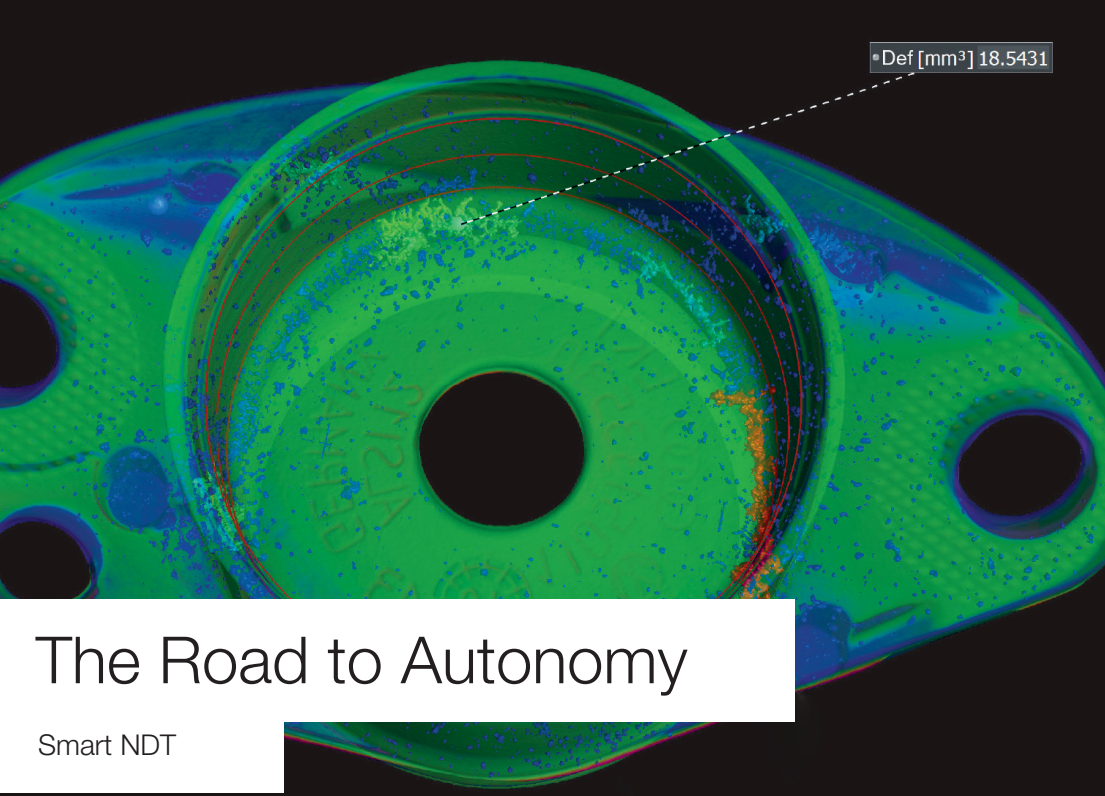
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