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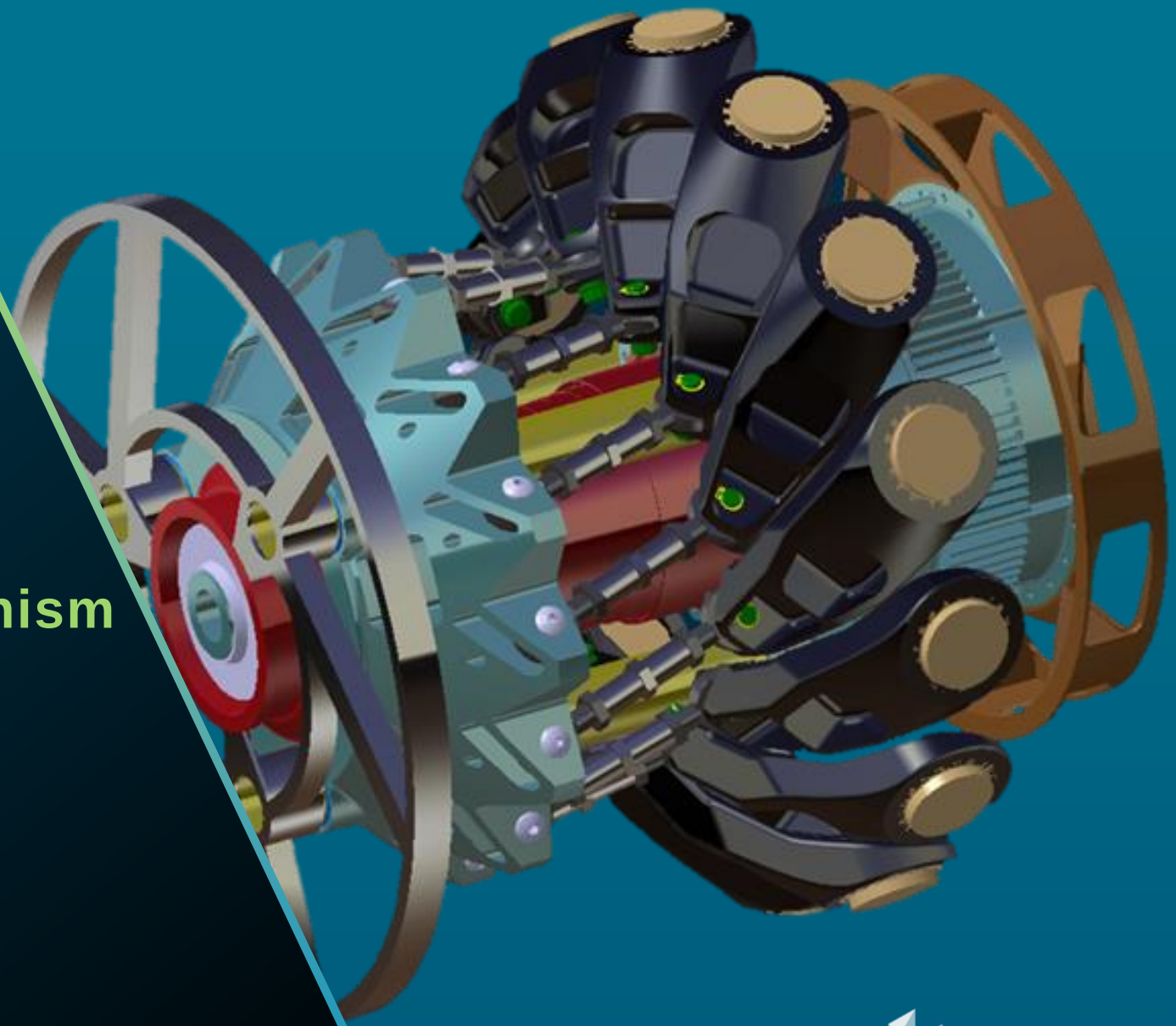
An end-to-end approach to additive manufacturing quality

ROTATOR pitch control mechanism

Applied Solutions Group, Manufacturing Intelligence Division

3D METROLOGY CONFERENCE

3DMC 2024 - Loughborough



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Tom Callow

Solutions Architect, Hexagon Manufacturing Intelligence division

Tom is a Solutions Architect within Hexagon's Applied Solutions group, which transform customer's new product introduction process by providing turnkey engineering services in electro-mechanical drive systems, enabling customers to release products to market quicker with leading innovation.
Tom received a Masters in Aerospace Engineering (Hons.) from the University of Leicester in 2019. He joined Romax into the Aerospace team in early 2020 where he worked on exploring synergies in rotor dynamics between Romax and Nastran as well as initiating a case study for urban air mobility. He joined the Applied Solutions team in 2021 where he now works as a Solutions Architect supporting project opportunities across the UK, Korea and Japan, covering all industries, with a greater focus on Aerospace and Renewables.

Clean Sky 2

Magnomatics

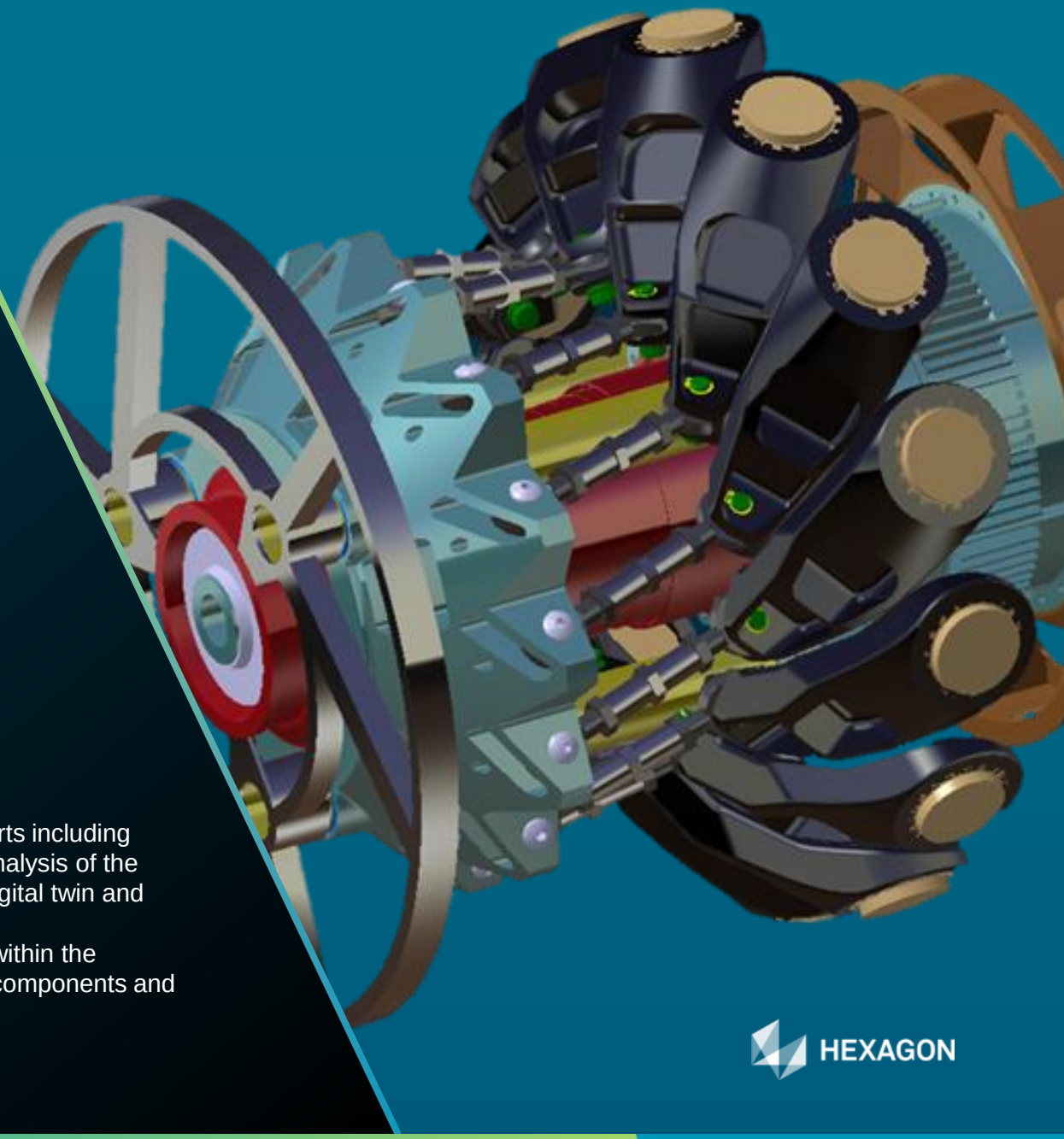
SAFRAN

ADVANCED ELECTROMAGNETICS GROUP

University of Sheffield AMRC Advanced Manufacturing Research Centre

ROTATOR

Electro-mechanical magnetic blade pitch control



Customer background

Safran is the second largest aircraft equipment manufacturer globally, and under Clean Sky 2, is developing a PCM for their open-rotor engine

Customer Challenge

To develop an advanced and fault tolerant electro-mechanical actuation system for open rotor aeroengines.

How Hexagon is helping

Hexagon contributed to the design and analysis of mechanical parts including analyse the many rolling element bearings, investigating modal analysis of the system, static loads, stiffness analysis, validation values for the digital twin and calculating the failure rate of roller/ball screw units.
In addition, Hexagon was responsible for specifying COTS parts within the mechanical elements, providing extensive input on the design of components and detailed drawings for all components

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The Consortium

Member	Responsibility
Safran	Customer
Hexagon	Actuator mechanical system design
Magnomatics	Pseudo direct drive (PDD) motor concept design
Advanced Electromagnetics	Permanent magnet direct drive motor concept design
University of Sheffield	Electric drive system sizing
AMRC	Lightweighting opportunities and assessments

Hexagon's contribution:

- The development of the concept and detailed prototype designs for the mechanical elements of the PCM and development of a multi-physics simulation for use in a digital twin.
  - Romax was used extensively to design and validate the bearings within the PDD.
  - Adams was used to validate the complete electro-mechanical performance and develop the digital twin.

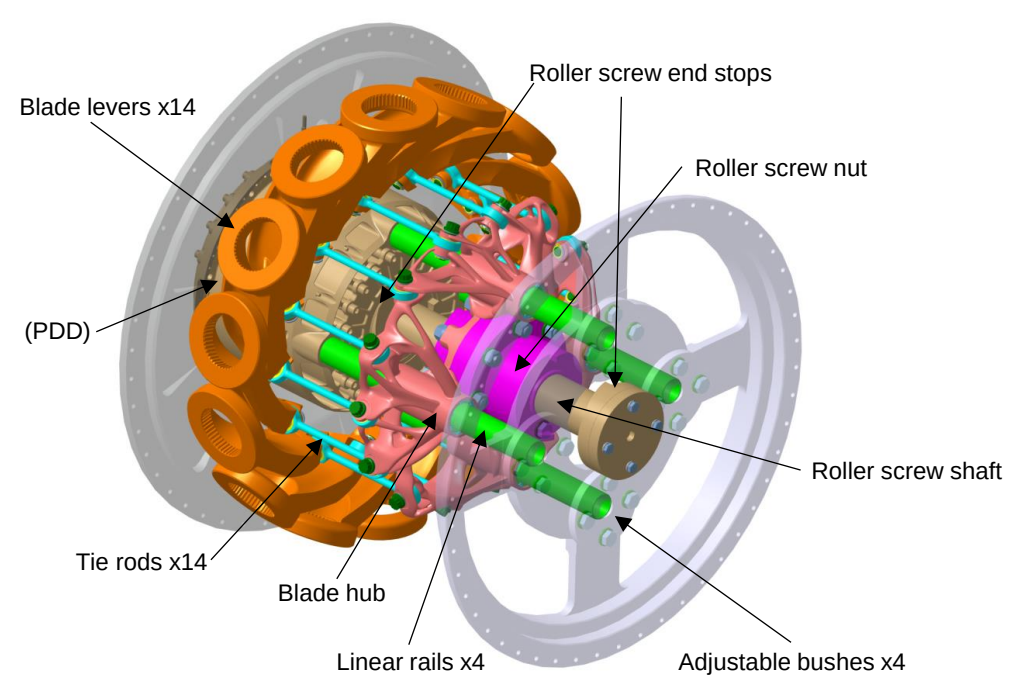
Project Objective

The high-level objective of the “More Electric Aircraft” is to replace existing hydraulic systems with electrical systems as far as possible

- Hydraulic systems present maintenance and servicing challenges, the goal being to completely remove hydraulic systems from future aircraft.

The major areas of focus for ROTATOR have been lightweighting, reliability, rotating power transfer, and fault tolerance.

The main parts Hexagon was responsible for or,
as in the case of the blade hub and blade lever, were heavily involved in their design.



Multi-body Dynamic Analysis

Digital twin

Collaborative engineering

Benefits

- Multi-Body Dynamic Analysis tool used to create a digital twin of the Pitch Control Mechanism (PCM)
- Digital twin used to predict dynamic loads and verify test controls across mission profiles
- Analysis enables prediction of loading in components not easily instrumented
- Load data then can be used in fatigue analysis for life prediction

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Lightweighting

Generative design

Collaborative engineering

Benefits

- Structural lightweighting and reduction in material cost achieved utilising generative design tools
- Boundary conditions determined by structural and multi-body dynamic analysis performed on original geometry
- Final prototype was cast whilst retaining organic design

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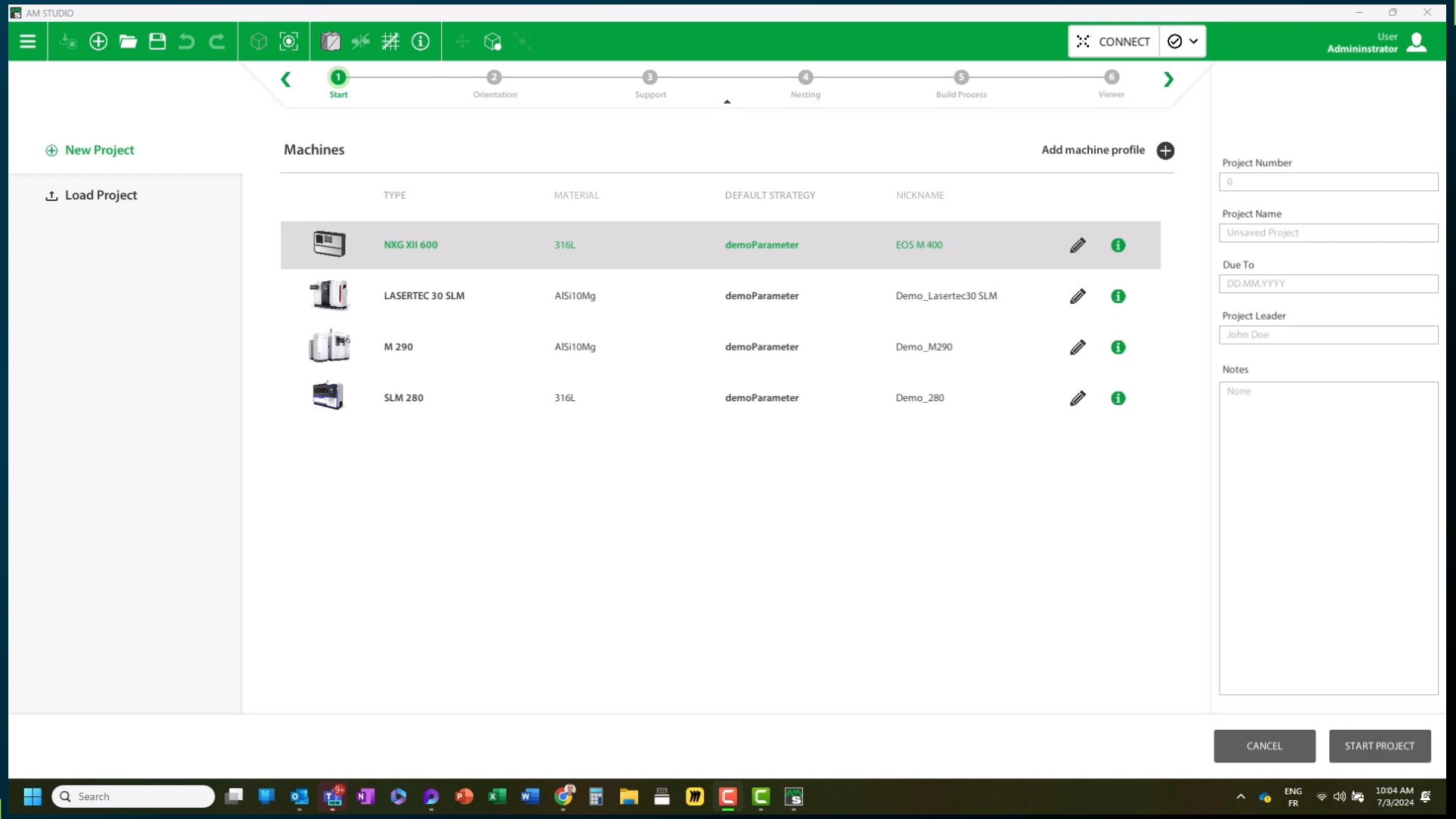
Manufacturing preparation

Additive manufacturing build preparation



Collaborative engineering

Benefits

- Optimising orientation based on printing time, material usage and risk of distortion
- A large choice of supporting structure types and options to meet the most advanced requirements
- Advanced capabilities in nesting as well as print job preparation (hatching strategy)

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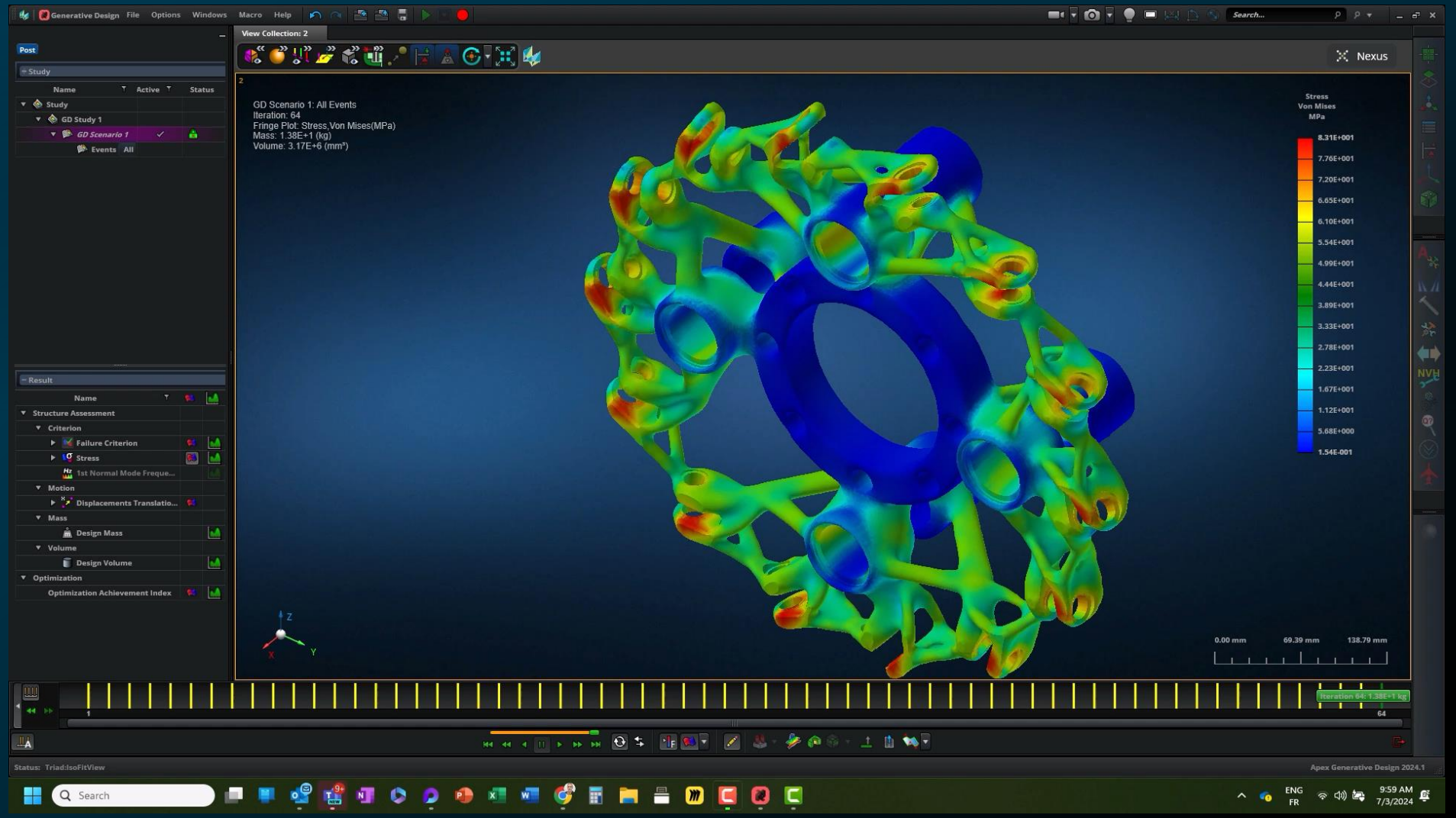
Process simulation

Build simulation



Collaborative engineering

Benefits

- Reduce physical try-out by virtually mitigating manufacturing issues and validating manufacturability
- Easy-to-use, intuitive additive manufacturing process simulation solution meant to be used by process experts (not FEA specialists)
- Covers all process steps including post-treatment operations (cutting, support removal & heat treatment)

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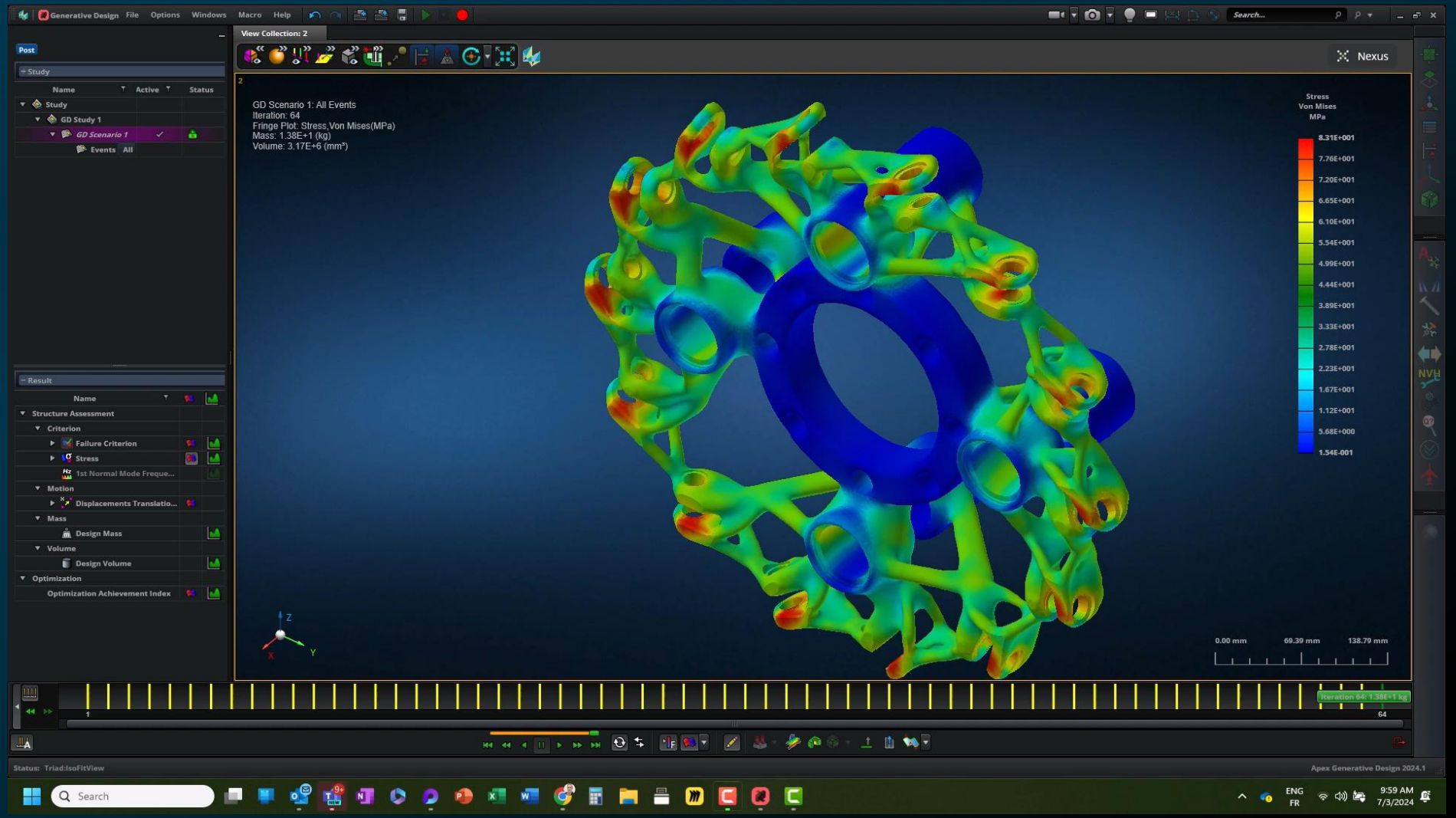
Process simulation

Compensate geometry



Collaborative engineering

Benefits

- Identify part distortion due to build process as well as post-treatment operations (such as heat-treatment, baseplate cutting, support removal, HIP) before printing any part
- Automatic, simulation-based iterative geometry distortion compensation process
- Take the costly guesswork out of manual geometry compensation, further reduce the need for physical try-out, and aim at "print first time right"

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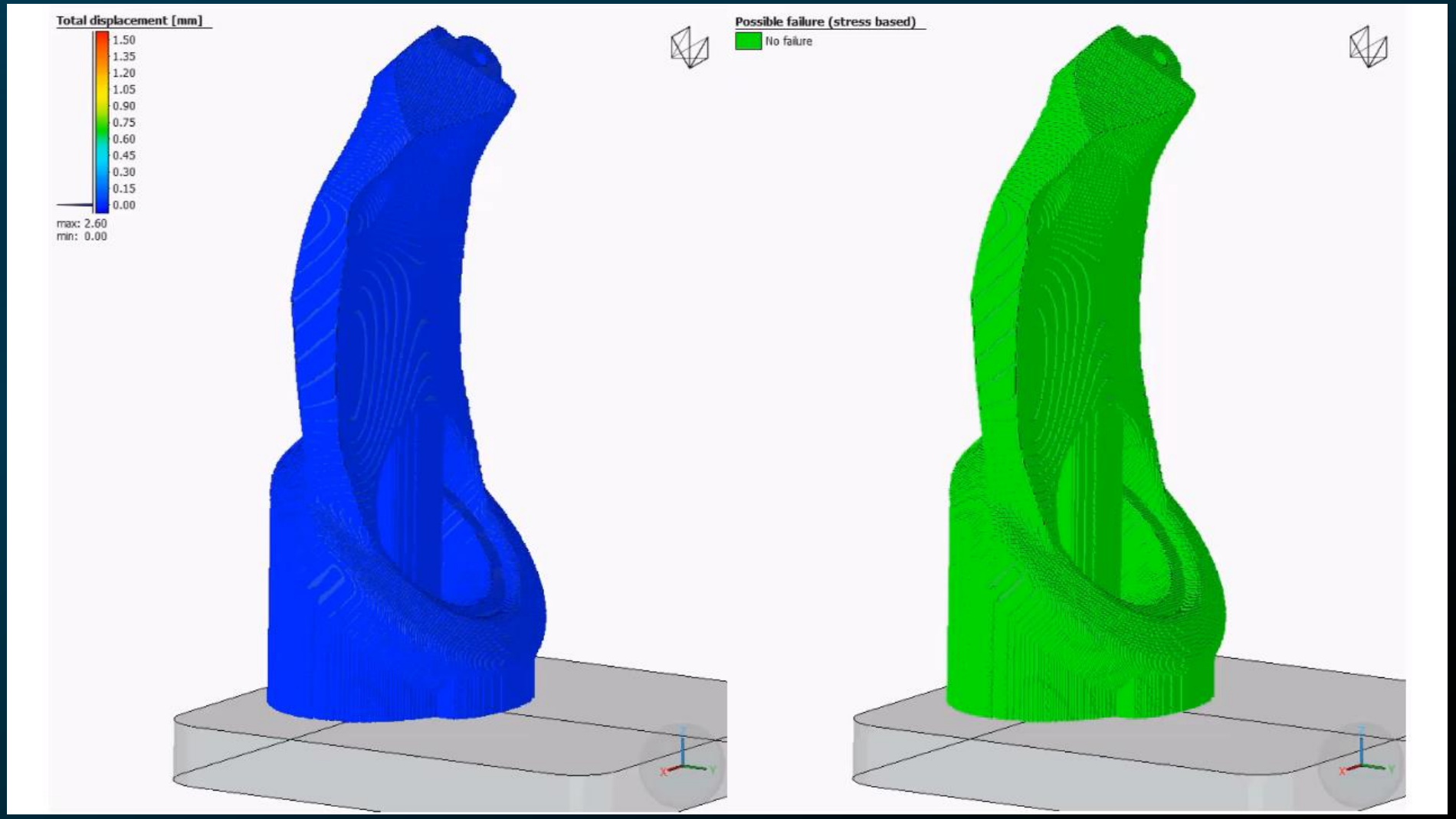
Print defect prediction

Additive manufacturing simulation



Collaborative engineering

Benefits

- Part was designed for additive manufacturing from the outset by the AMRC as part of a set of 14 identical parts
- Blade lever was manufactured from titanium using Selective Laser Sintering on a Renishaw AM500Q
- Initial manufactured part experienced cracking due to distortion
- Hexagon Applied Solutions Group simulated manufacturing process in Simufact and were able to predict cracking and adjust print setup to counter deviations.

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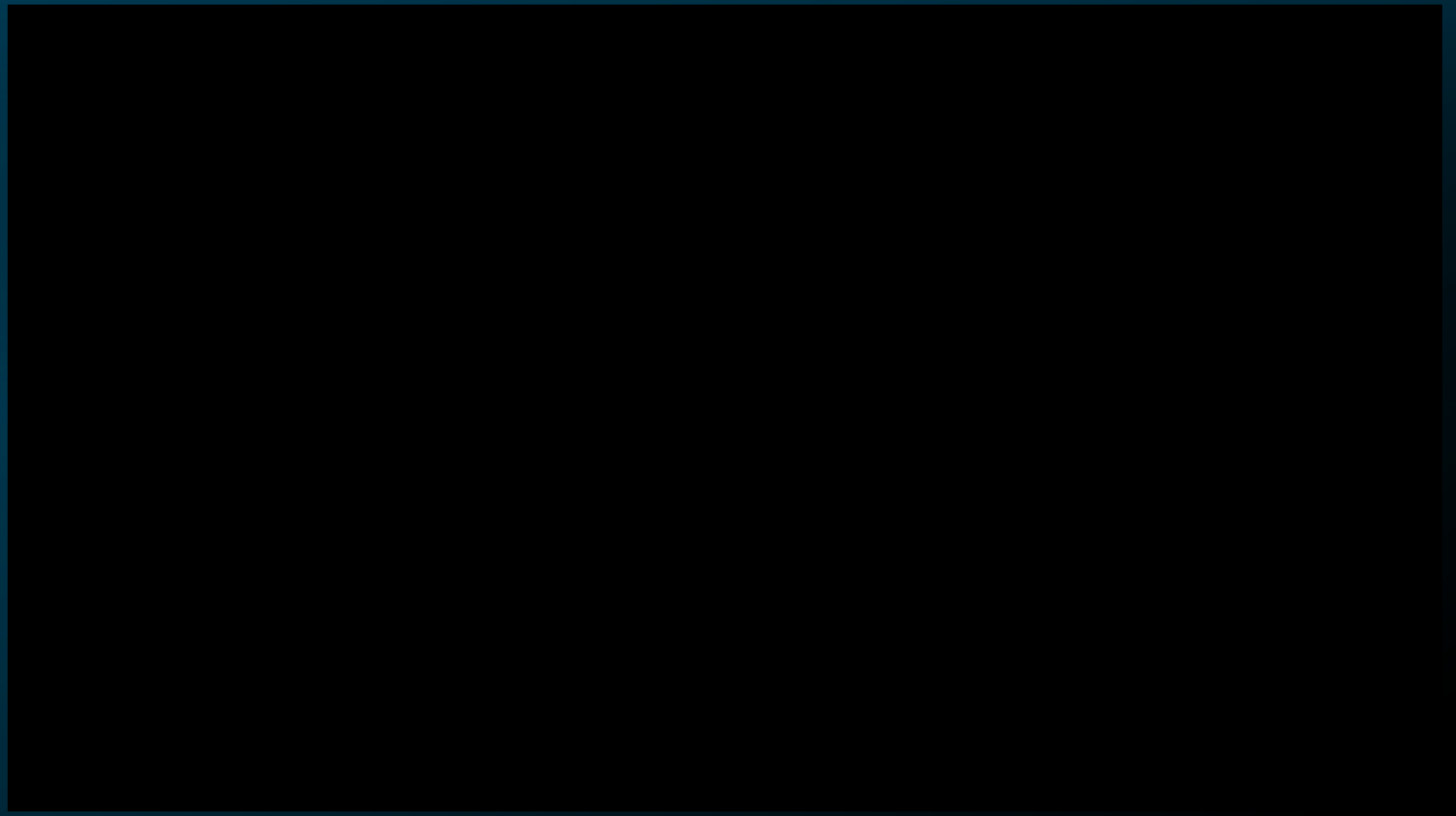
Inspection & validation

Laser scanning

Collaborative engineering



Benefits

- Quality Inspection of Manufactured part with Measurement Arm and Laser Scanner
- Check Tolerances and Geometric Dimensions against Nominal Design
- Generation of FE mesh based on real geometry for further analysis in simulation tools
- Feedback to manufacturing areas and optimise process

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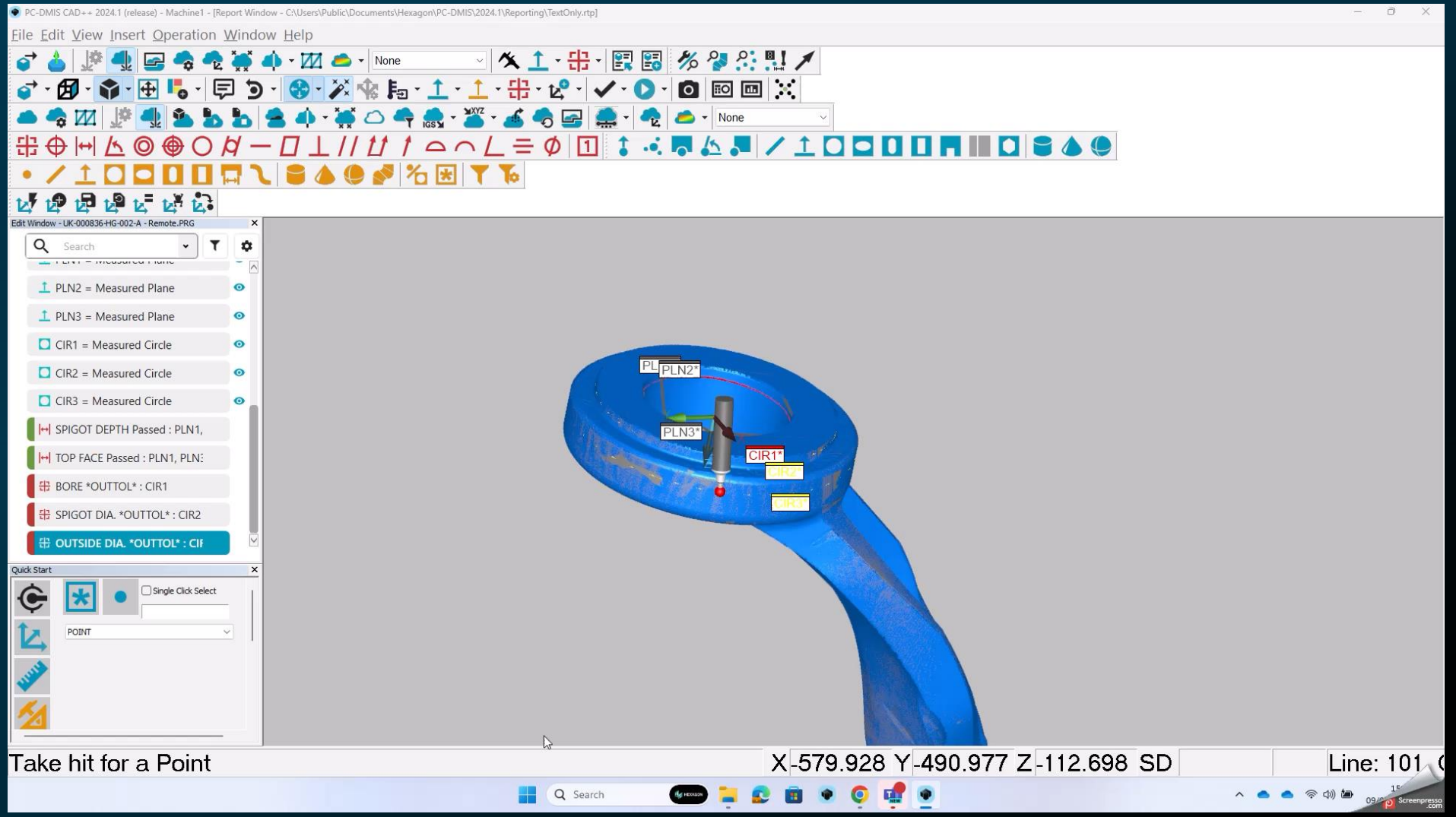
Optimise process

Collaborative engineering



Benefits

- Central location for all reporting data and functionality provides collaboration, error reduction and efficiency opportunity
- Faster and better decision making due to ease of access to reports, trends and statistics
- Secure, cloud-based access to data anytime, anywhere

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Thank you.

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empowering an autonomous future