DMG MORI
Building a digital ecosystem for the machine tool industry

DMG MORI Company Limited
Executive Officer
Kentaro Blumenstengel

1. **Introduction of DMG MORI**
2. Connectivity at DMG MORI
3. Digital Twins for the Manufacturing of Safety-Critical Aerospace Parts

DMG MORI CO., LTD.

Representative	Dr. Masahiko Mori
Established	26 October **1948**
Stock Listings	Prime Market of Tokyo Stock Exchange Frankfurt Stock Exchange (SDAX index)
Business	**Provide total solutions consisting of machine tools** (5-axis machines, mill-turn centers, machining centers, turning centers, additive manufacturing machines, etc.), **software** (user interface, Technology Cycles, embedded software, etc.), **measurement equipment, service support, applications, and engineering**
Turnover	540.9 bn JPY / 3,298 mn EUR (Result: Jan.-Dec. 2024 / 1 EUR = 164.0JPY) **510.0 bn JPY** (Plan: Jan.-Dec. 2025)
No. of Employees	**13,500** people
Operation Bases	**Tokyo Global Headquarters** (Shiomi, Tokyo) **Nara Product Development Center** (Nara, Nara) Iga Campus (Iga, Mie) Nara Campus (Yamato-Koriyama, Nara) **Germany (Bielefeld, Pfronten, Seebach, Stipshausen)** Italy (Bergamo, Tortona) USA (Chicago Headquarters, Davis Factory and more) / China (Shanghai Headquarters, Tianjin Factory, Pinghu Factory) / Poland and more

HISTORY WITH GILDEMEISTER (GERMANY)

DMG MORI

2009

+ Capital & Business Commencement of Business Alliance

Shareholding ratio
> 5% (CO→AG)

2011

+ Expansion of cooperative areas

+ EMO Hannover Joint Exhibition

+ Product co-development

Shareholding ratio
> 20% (CO→AG)

2013

+ Cooperative agreement

+ Joint Committee

+ Unification of brands and company names

Shareholding ratio
> 24% (CO→AG)

2015

+ AG Shares Tender Offer Settlement & Becoming a consolidated subsidiary

+ Integrated management started

Shareholding ratio
> 50% (CO→AG)

2016

+ DPLTA (Domination Agreement) Completed

+ Complete business integration

Shareholding ratio
> 75% (CO→AG)

DMG MORI

GLOBAL ONE

"Our target: worldwide the number 1 for our customers!"

2024~

Shareholding ratio
> 88.2% (CO→AG)

R&D / MANUFACTURING

DMG MORI

7 countries
18 factories
8,000 machines per year

Japan

Iga Campus

One of the world's largest production sites for mill-turn machines, turning centers and machining centers

Nara Campus

Among the world's largest production sites for system solutions in the world

Germany

DMG MORI Pfronten Factory

DMG MORI's largest production site for 5-axis machines

DMU / DMC Series and others

DMG MORI Bielefeld Factory

DMG MORI Seebach Factory

DMG MORI Ultrasonic Lasertec Factory

Europe

DMG MORI Poland Factory (Poland)

DMG MORI Bergamo Factory (Italy)

DMG MORI Tortona Factory (Italy)

India

Lakshmi Machine Works Limited (Production consignment)

U.S.A.

Davis Factory

China

Tianjin Factory

Pinghu Factory

Group Companies (Japan)

Magnescale

TAIYO KOKI*1

DMG MORI CASTECH

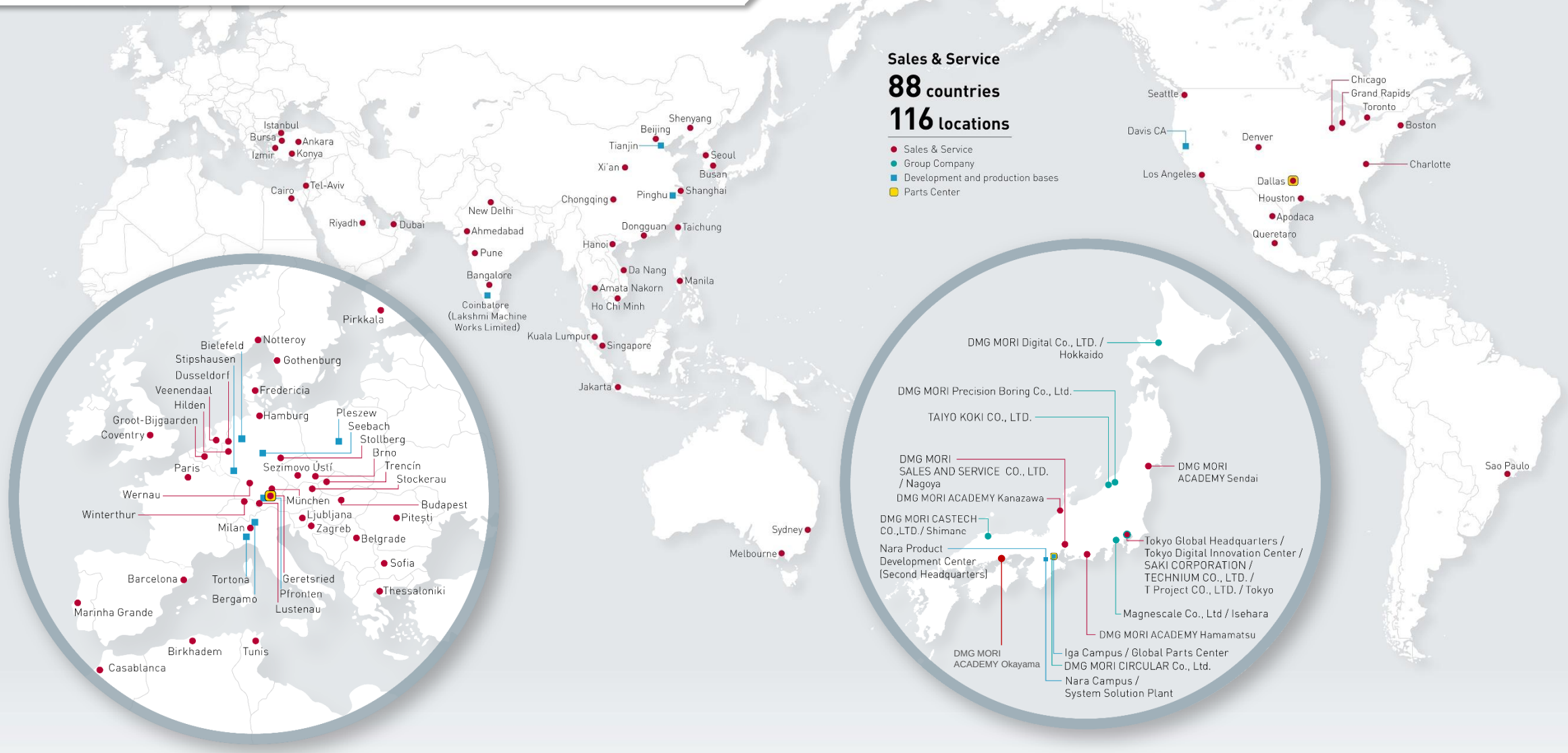
DMG MORI Precision Boring (KURAKI)*2

Saki Corporation

*1 Global brand: DMG MORI Precision Grinding *2 Joined DMG MORI Group in January 2024

SALES / ENGINEERING / SERVICE

DMG MORI



PRODUCT LINEUP

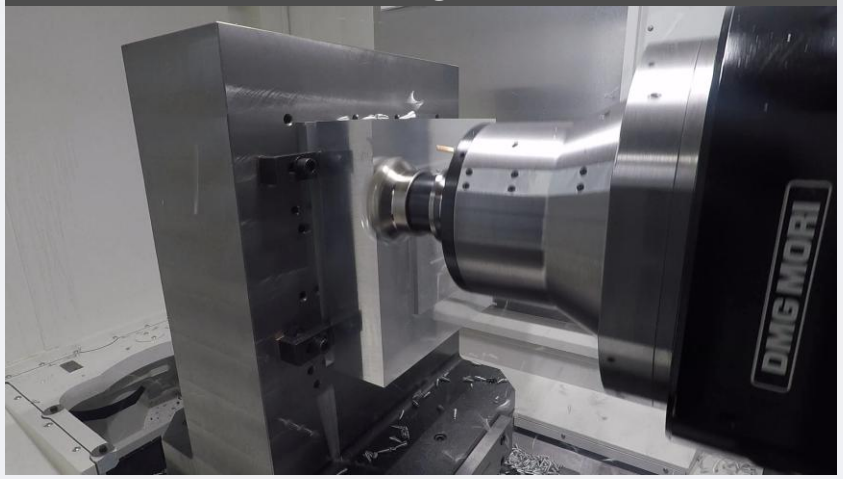
DMG MORI

5-axis Machining Center

Mill Turn Center

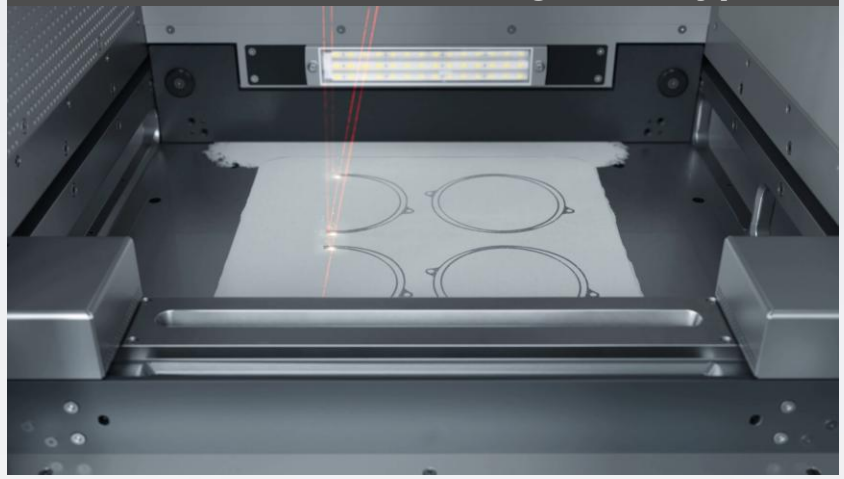
Additive Manufacturing: DED type

Machining Center



Turning Center

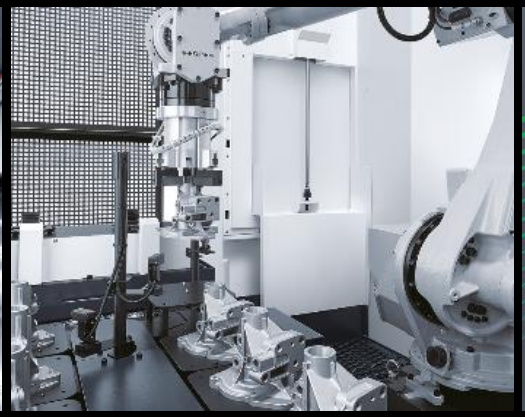
Additive Manufacturing: SLM type



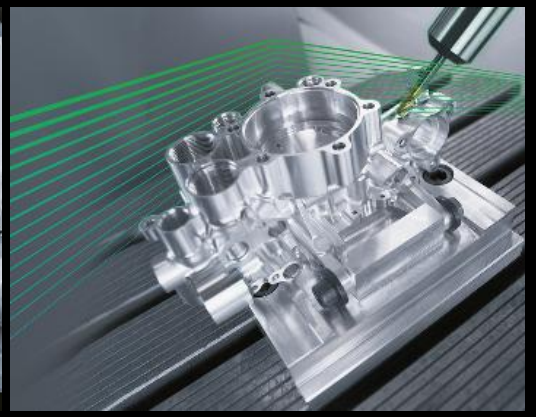
MX – MACHINING TRANSFORMATION

DMG MORI

PROCESS INTEGRATION



AUTOMATION



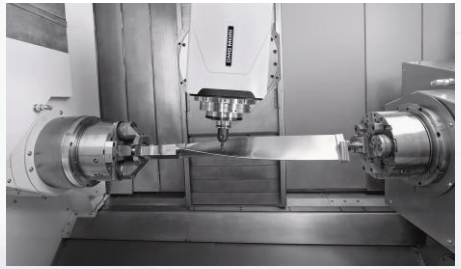
GX – GREEN TRANSFORMATION

DX – DIGITAL TRANSFORMATION

FOCUS: PROCESS INTEGRATION

Higher usage of a universal machining center, instead of partial usage of several simple, single purpose machines.

TURN-MILL

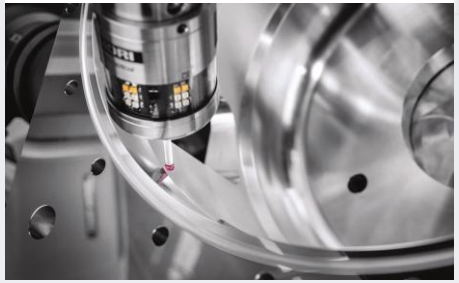


MILL-TURN

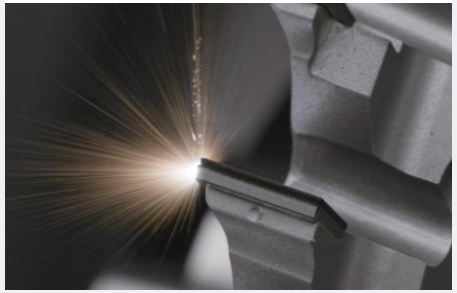
GRINDING

GEAR CUTTING

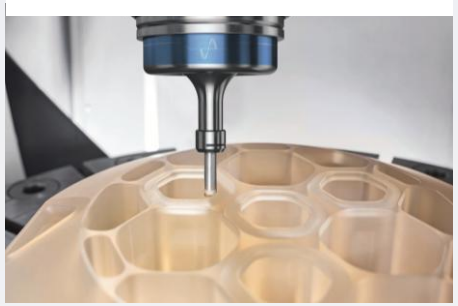
MEASURING



LASERTEC



ULTRASONIC



ADDITIVE MANUFACTURING

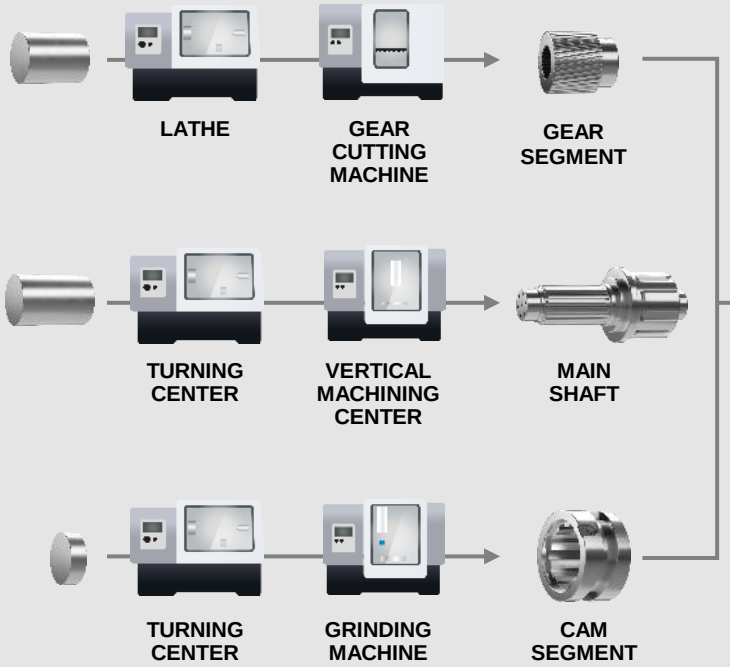
BENEFIT OF PROCESS INTEGRATION

1 INSTEAD OF 6 MACHINES – EXAMPLE

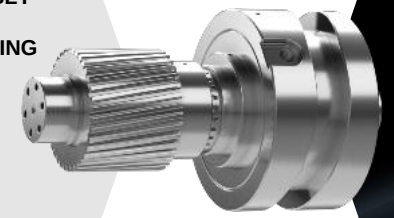
DMG MORI

CONVENTIONAL PROCESS

6× machines 6× machine operators 1× assembly worker



ASSEMBLY INCL. MEASURING



CAMSHAFT

MX MACHINING TRANSFORMATION

INTEGRATED TURN MILL CENTER

1 × machine 1 × machine operator

PROCESS INTEGRATION +

- **Turning**
- **Milling**
- **Gear cutting**
- **Measuring**
- **...**

AUTOMATION +

All from one source: machine, automation and process design

DX – DIGITAL TRANSFORMATION

- **CAD-CAM solutions**
- **Post-processors**
- **Simulation with Digital Twin**

= GX – GREEN TRANSFORMATION

FOCUS: AUTOMATION

DMG MORI

WORKPIECE HANDLING

Gantry Loader

Robot

PALLET HANDLING

Round Storage System

Linear Storage System

CENTRAL TOOL STORAGE

CTS – Wheel Type

CTS – Rack Type

14 MODELS
52 ITEMS

TURNING

MILLING

TURNING & MILLING

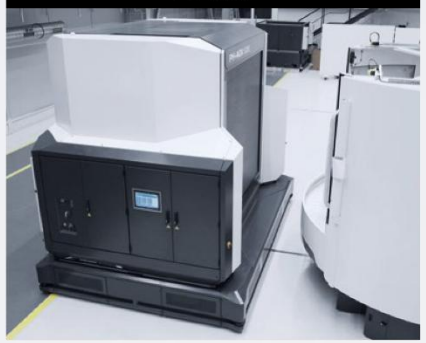
MILLING

WH-AMR

AMR for Material Handling

AMR for Chip Handling

PH-AMR



AMR for Tool Handling

AMR – AUTONOMOUS MOBILE ROBOTS (WORKPIECE, MATERIAL, CHIP, PALLET & TOOL HANDLING)

LPS 4th Generation
Control software
for DMG MORI
Automation Systems

DMG MORI'S MISSION

Collecting disposal machines

High value-added machine models

2055 **1** million machines

Now **5** million machines

Replacement with cutting-edge technologies is essential for innovation

Number of operators

Power consumption

Goods in Progress

Number of machine tools in the world (million machines)

	Now	2035	2045	2055
<20years	**1.5**	**2.0**	**1.5**	**0.3**
10-20years	2.0	1.5	0.3	0.4
10years<	1.5	**0.3**	**0.4**	**0.3**
Total	**5.0**	3.8	2.2	**1.0**

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DIGITAL TRANSFORMATION (DX) SERVING MACHINING TRANSFORMATION (MX)

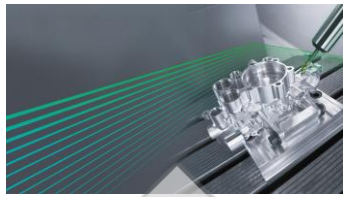
MX – Machining Transformation

Process Integration & Accuracy

Automation

DX – Digital Transformation

GX – Green Transformation



DMG MORI Platform

CELOS X, Connectivity & Digital Twin

Joint Platform based development
End-to-End Process Integration
Focus on Machine & Shopfloor

Machine & Automation

Ultra-high Precision
Improving productivity
Reducing CO_2 emissions

ROLE OF CONNECTIVITY

DMG MORI

“You can only manage what you can measure.”

MACHINE SIGNALS VIA OPC-UA, MTCONNECT AND MQTT

- MACHINE DATA (3)
- MACHINE STATUS (5)
- PRODUCTIVITY (4)
- PROCESS DATA (5)
- ADDITIONAL MACHINE SIGNALS

Maximum efficiency on the shopfloor

1. Increase Machine Availability
2. Increase Planning Reliability
3. Reduction of Work Steps

AS A STANDARD SINCE 2013

- All DMG MORI machines are equipped with the IoT*connector* as a standard
- The IoT*connector* is compatible with open protocols including MTConnect, **OPC UA** and MQTT

umati
OPC UA
MQTT
MTConnect

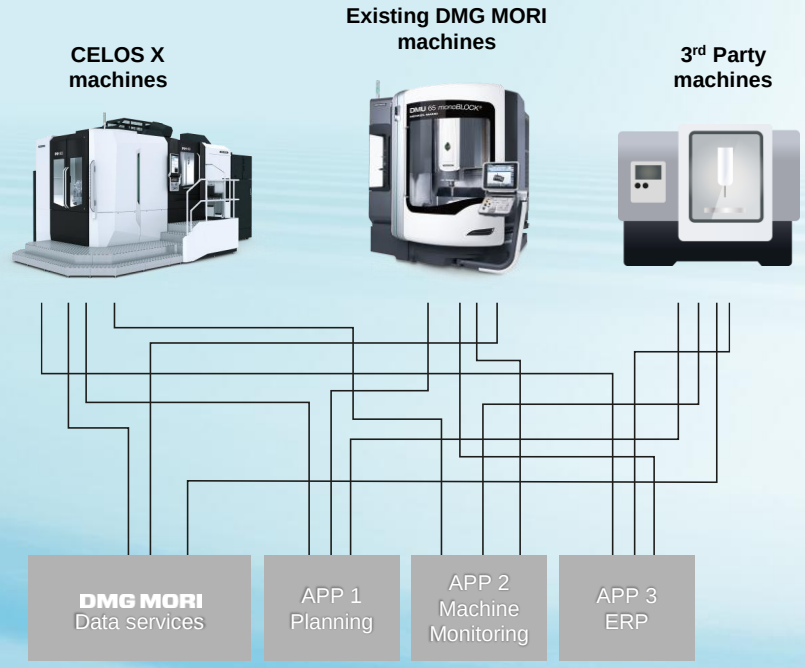
CELOS X – PLATFORM BASED END-TO-END SHOPFLOOR SOLUTION

DMG MORI

CELOS XCHANGE – SCALABILITY MADE EASY

DMG MORI

WITHOUT CELOS Xchange

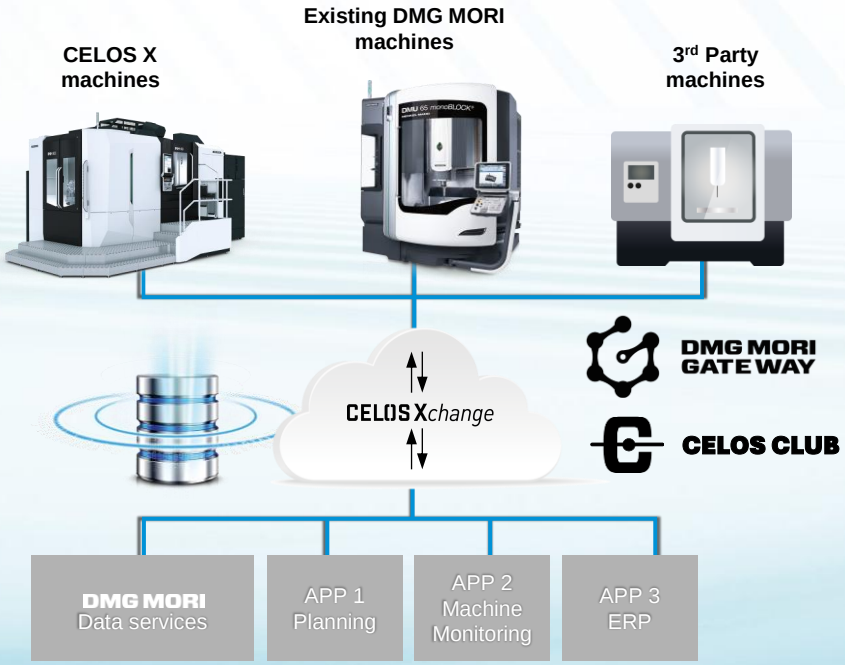


5 Apps – 20 machines

100 INDIVIDUAL CONNNECTIONS

VS.

WITH CELOS Xchange



5 Apps – 20 machines

<5 INDIVIDUAL CONNNECTIONS

BUILDING A DIGITAL ECOSYSTEM FOR THE MACHINE TOOL INDUSTRY

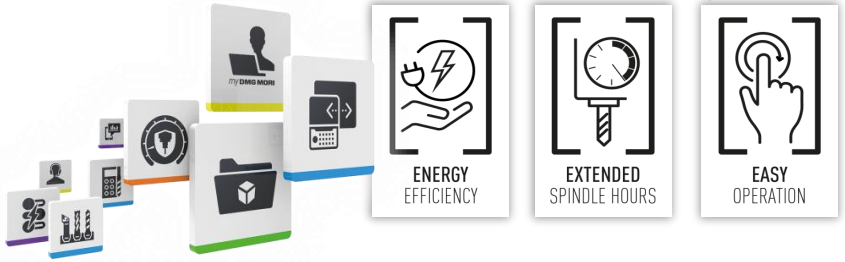
DMG MORI

Ecosystem Machines & Automation

DMG MORI Data Ecosystem

CELOS Xchange

DMG MORI and third-party Applications



CELOS Xperience

Industry Specific Data Ecosystems

MANUFACTURING-X

Factory-X
Machinery

Catena-X
Automotive

International Manufacturing-X
Smart & Connected Industries

EnergyData-X
Energy

Semiconductor-X

Aerospace-X
Aerospace

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MANUFACTURING-X
A Global Initiative

DMG MORI

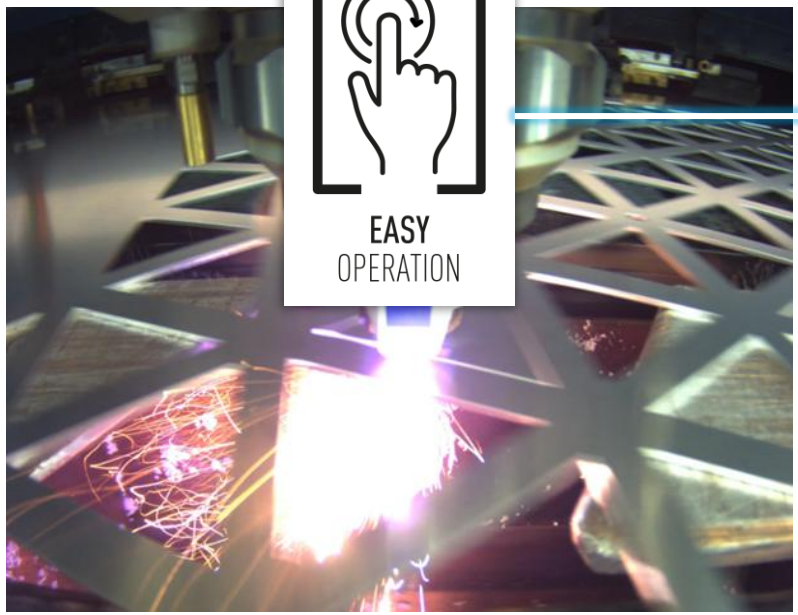
IM-X Meeting October 11th, 2024 at DMG MORI HQ in **Tokyo**

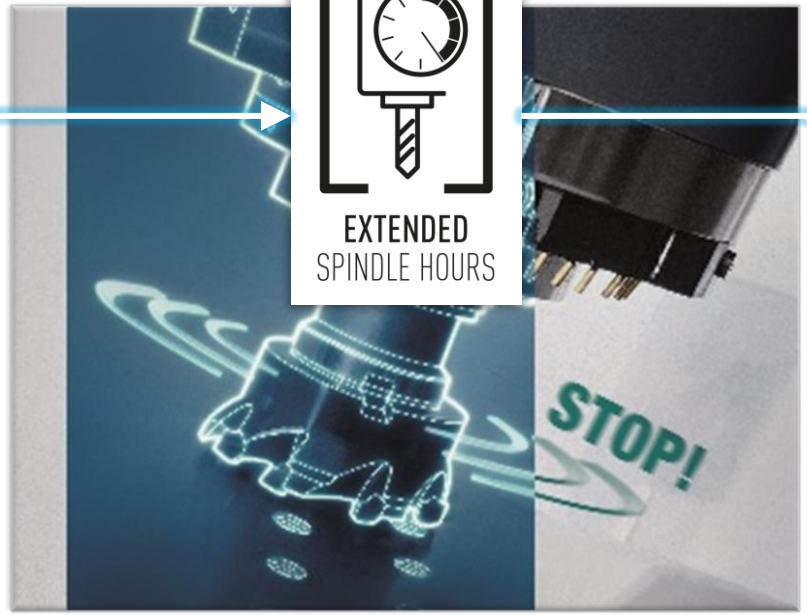
Manufacturing-X is a **global initiative**, supported by a worldwide network of industry associations!

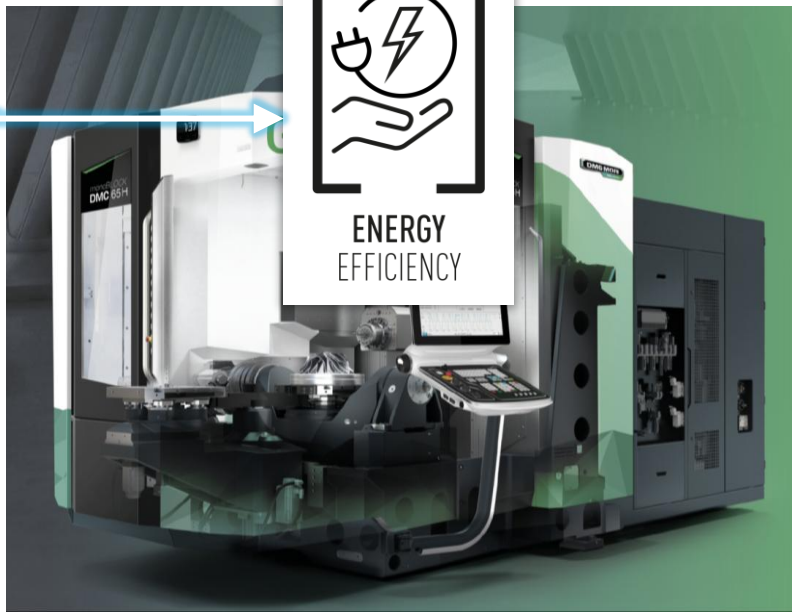
ICTM AACHEN
International Center for Turbomachinery Manufacturing
Fraunhofer IPT
DMG MORI
PLATTFORM INDUSTRIE 4.0
Robot Revolution & Industrial IoT Initiative
ロボット革命・産業IoTイニシアティブ協議会
FACTORY-X
AEROSPACE-X
Catena-X Automotive Network

BENEFIT MANUFACTURING-X USE CASES

DMG MORI







Autonomous Operation-as-a-Service
- Remote Operation with camera

Advantages customer
- ✓ Less downtime machine
- ✓ Less operators & personnel costs

Advantages machine tool builder
- ✓ Faster service
- ✓ Less effort for service

Condition Monitoring led services
- Reduce unplanned service operations

Advantages customer
- ✓ Less downtime machine
- ✓ Less service operations & costs

Advantages machine tool builder
- ✓ Better planning of service operations
- ✓ Less service operations (remote analysis)
- ✓ Reduced stock of spare parts

Energy & Load management
- Reduce energy consumption
- Optimize load management & costs

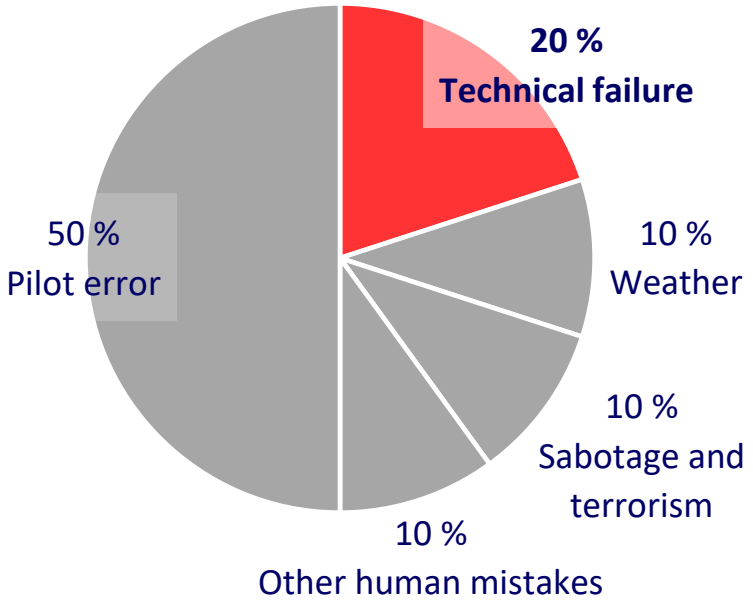
Advantages customer
- ✓ Reduce energy consumption
- ✓ Optimize machining process

Advantages energy supplier
- ✓ Better planning of energy demand
- ✓ Reduced energy costs

THE IMPORTANCE OF SAFETY IN THE AEROSPACE INDUSTRY

DMG MORI

Most Likely Causes of Airplane Crashes



ENG14IA028 (Long Beach, 18/09/2014)

"During a machining operation of the disc lug, a tool mark was introduced that set up the area for fatigue cracks to initiate."

DCA21FA085 (Broomfield, 20/02/2021)

"A discontinuity in a local tight radius in the internal blade geometry that had been introduced during the machining […] reducing the fatigue life by 50%."

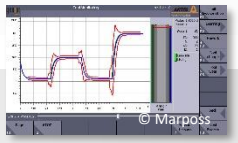
Picture: Lufthansa

Source: FOCUS article (20/05/2016), National Transportation Safety Board (NTSB)

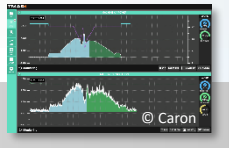
STATUS QUO IN TODAY'S MANUFACTURING

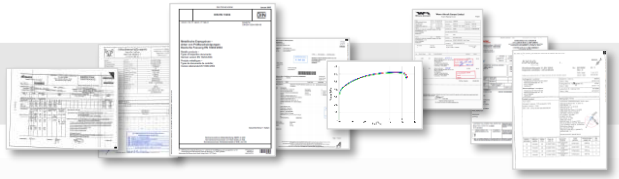
Process Monitoring solutions in manufacturing are nowadays characterized by:

- Monitoring of individual signals
- Pure envelope monitoring
- Complex learning phases
- Inadequate data labelling
- Distributed data storage
- Time-consuming data analysis

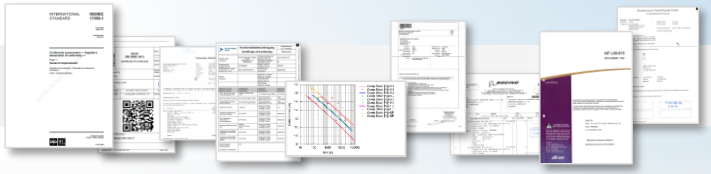


PREVENTIVE





REACTIVE



Traceability, **Root Cause Analysis**, and P**roblem Solving** are nowadays characterized by:

- Manuel processes
- Data fragmentation
- Lack of standardisation
- Limited depth of data
- Slow problem solving
- Low level of digitalisation

Picture: Lufthansa

THE NON-CONFORMITY DEMONSTRATOR

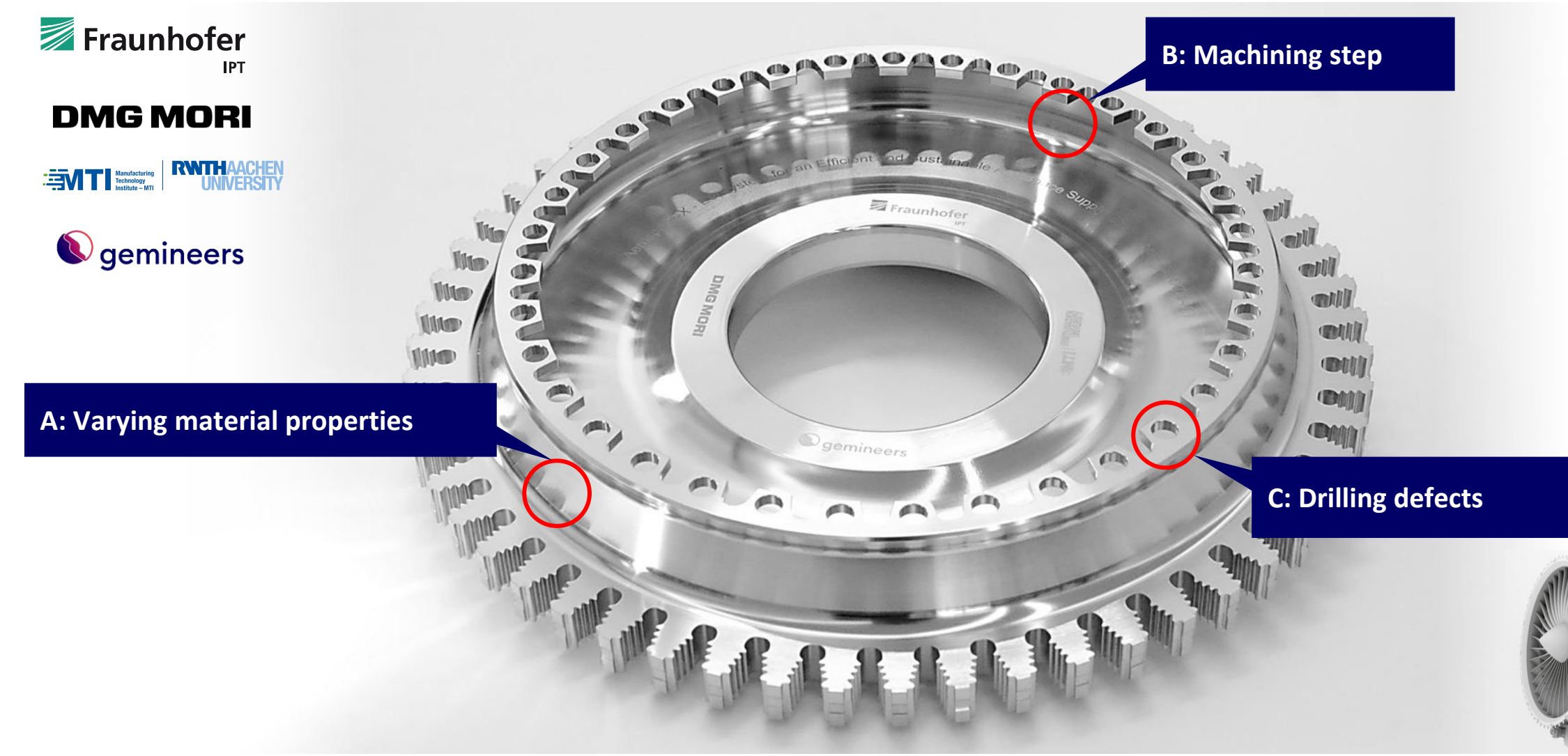
DMG MORI

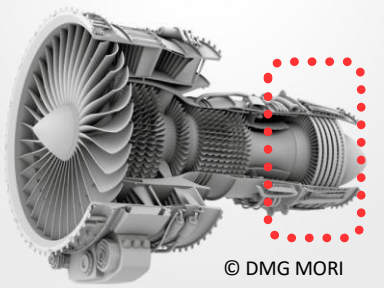
Fraunhofer IPT

DMG MORI

MTI Manufacturing Technology Institute – MTI | RWTH AACHEN UNIVERSITY

gemineers





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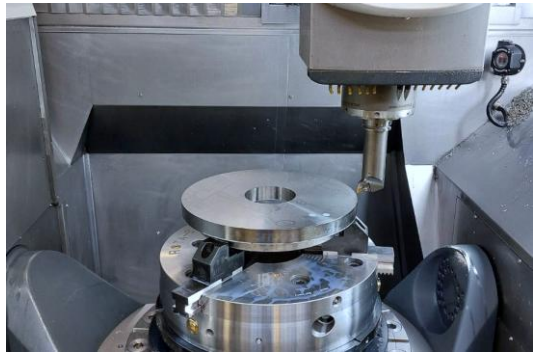
Collaborative research in partnership with DMG MORI, Manufacturing Technology Institute – MTI and Fraunhofer IPT (Aerospace-X)

THE PROCESS CHAIN

DMG MORI

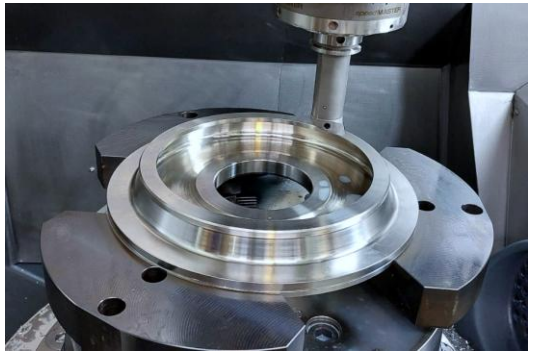
Setup 1 & 2: Pre-machining



Machine:
DMU 65 (FD) monoBLOCK

Operation:
Turning of forged raw part

Setup 3 & 4: Roughing right/left



Machine:
DMU 65 (FD) monoBLOCK

Operation:
Turning to 1 mm stock allowance

Setup 5 & 6: Finishing right / left

Machine:
DMU 65 (FD) monoBLOCK

Operation:
Turning/milling/ drilling finish part

Setup 7: Broaching

Machine:
Forst RASX

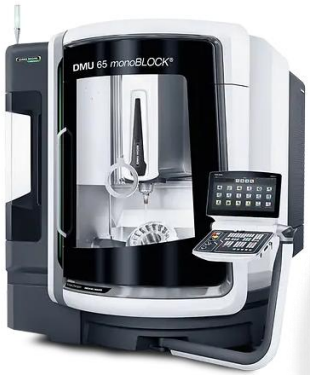
Operation:
Broaching of fir-tree slots

... PRE-TURNING ... ROUGH TURNING ... FINISH TURNING / MILLING / DRILLING ... BROACHING* ...

* Broaching performed here as last operation due to logistical reasons

Source: DMG MORI, Fraunhofer IPT, Manufacturing Technology Institute – MTI

THE DIGITAL TWIN APPROACH



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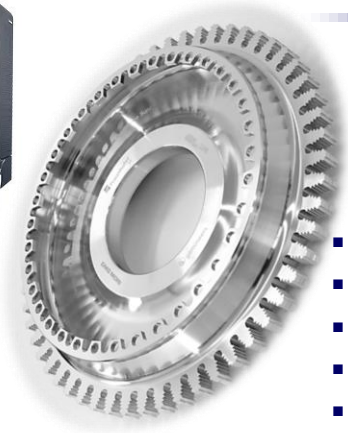
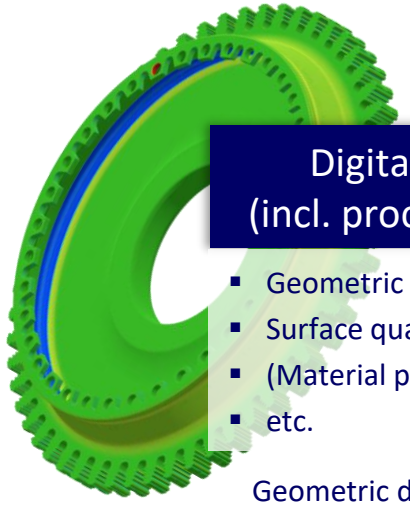


High-Frequency Data Acquisition

- Meta data & process parameter
- Positions & orientations
- Drive & spindle loads
- Bending moment and vibration
- etc.

Model-based Data Processing

- Position error
- Engagements & process forces
- Tool & workpiece deflection
- Tool wear & offsets
- etc.

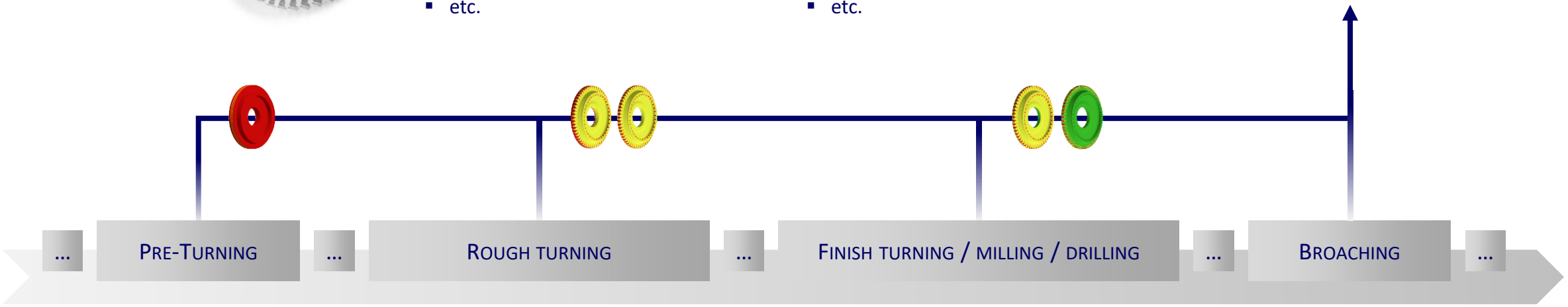


Digital Twin (incl. process data)

- Geometric deviations
- Surface quality
- (Material properties)
- etc.

Geometric deviation [mm]

-0.1 +0.1



THE DIGITAL TWIN ALONG THE PROCESS CHAIN

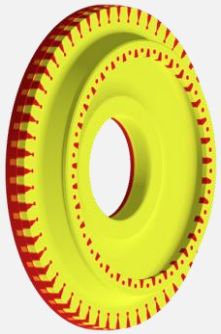
DMG MORI

Setup 1 & 2:
Pre-machining

Shape dev. [mm]

-3.0 +3.0

Setup 3:
Roughing right



Setup 4:
Roughing left

Shape deviation [mm]

-3.0 +3.0

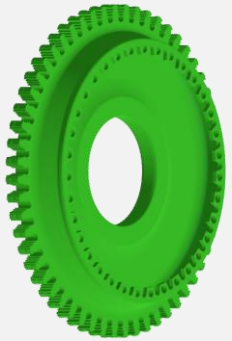
Setup 5:
Finishing right

Setup 6:
Finishing left

Shape deviation [mm]

-3.0 +3.0

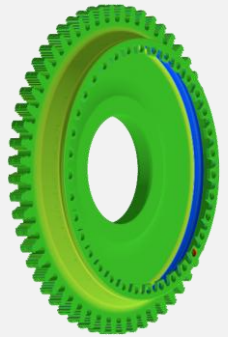
Setup 7:
Broaching



Shape dev. [mm]

-3.0 +3.0

Digital Twin
(adjusted scale)



Shape dev. [mm]

-0.1 +0.1

... PRE-TURNING ... ROUGH TURNING ... FINISH TURNING / MILLING / DRILLING ... BROACHING ...

TARGET PICTURE: END-TO-END QUALITY MANAGEMENT FOR SAFETY CRITICAL AERO ENGINE COMPONENTS

DMG MORI

3. Containment and Countermeasure

„Engines identified where worn tool was used…"

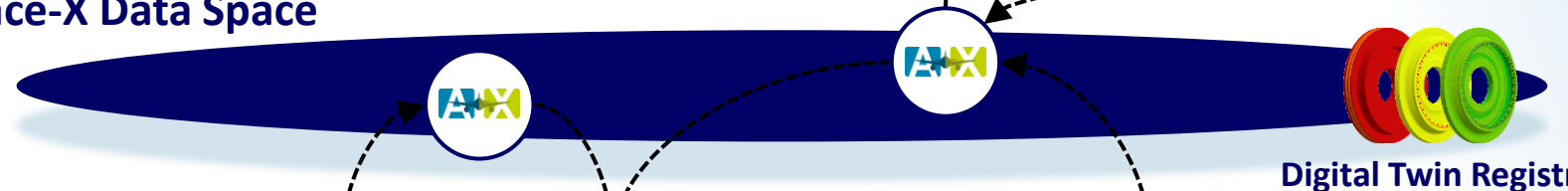
1. Production Monitoring and Early Warning

„Material batch shows difficult machinability…"

2. Traceability and Root Cause Analysis

„Cracks at drill holes detected during MRO…"

Aerospace-X Data Space



Digital Twin Registry
(ID only, no data)

Connector

Operation & MRO

Airline

Connector | Connector | Connector

Material extraction	Material processing	Component manufact.	Module assembly	Engine assembly	Aircraft assembly
…	Tier-n	Tier-2	Tier-1	Engine-OEM	Aircraft-OEM

Picture: Lufthansa

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AEROSPACE-X

DMG MORI

MACHINING
TRANSFORMATION

INH 63

DMU 75 *monoBLOCK* 2nd Gen.

NTX 500 +IMTR