A digital thread connecting engineering and manufacturing at the feature level to improve lead time and part quality

Daniel Hayek, Pratt & Whitney
Samuel Yang, RTX Technology Research Center

GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2023

Agenda

- **Presenters**
- **Challenges in aerospace manufacturing**
- **Value of connected data and the Model Based Digital Thread**
- **Feature Level Digital Thread Concept**
- **Traceability gaps in industrial standards**
- **Developed approach and demonstrated capability**
- **Conclusion**

Presenters Bio

Daniel Hayek

Daniel Hayek is the Product Owner of the Model-Based Manufacturing vertical with the Model Based Digital Thread Process Capability Center (MBDT PCC) at RTX. He has 10 years of Engineering experience and an additional 3 years of software implementation project management experience.
Prior to joining the MBDT PCC in 2019, he was a consultant and project manager at a SaaS software company in Toronto, Canada where he managed enterprise level solution implementations.
Before that he was a Combustion Mechanical Design Engineer at Pratt & Whitney Canada where he designed components for fuel manifolds, fuel nozzles, combustion liners, heat shields, cases, and bearing housings.
He has a Masters of Applied Science and a Bachelor of Engineering in Aerospace from Ryerson University in Toronto, Canada. He is also a licensed Professional Engineer of Ontario.
Daniel is also an Assistant Coach on the Canadian National Dragon Boat Team where he has both coached and competed internationally since 2013.

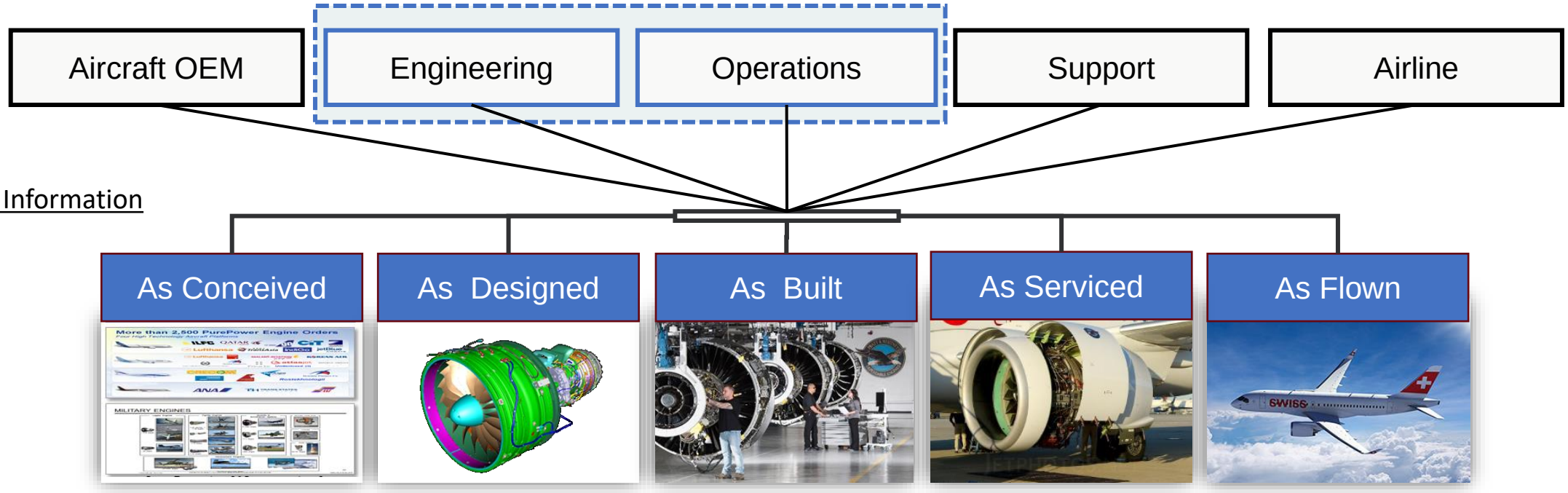
Samuel Yang

Samuel Yang is a senior principal engineer in modeling and methods group with the Model Based Digital Thread (MBDT) Process Capability Center (PCC) at RTX Technology Research Center specialized in 3D product design model. He has 12 years of mechanical design engineering and 6 years of test engineering experience. He is currently involved in developing digital thread capability to link and aggregate production data to model manufacturing capability as knowledge feedback in design evaluation to improve producibility for the Model-Based Manufacturing project, as well as developing eCreate solution for model exchange with IP protection to sustain detail design phase of the product lifecycle. Prior to joining the MBDT PCC in 2019, he was a mechanical engineer in the engine systems design group at Rocketdyne in Canoga Park, CA. Some of the key work includes managing a design team of ancillary system on RS-25 engine, engine integration and assembly on AR-22 engine, and service module maneuvering system for Boeing's Starliner capsule. He received his Master degree in System Engineering in 2002 from University of Pennsylvania, and Bachelor degree in Mechanical Engineering in 1998 from University of California, Riverside.

Model-Based Digital Thread PCC Mission

Methods, standards, and tools to deliver the next generation of products

Product Life-Cycle Stakeholders



The application of ***models*** to consistently flow ***product information*** to ***stakeholders*** throughout the ***life-cycle*** to drive quality & accelerate development, production, and service delivery for integrated systems

PCC: Process Capability Center

Challenges in Aerospace Manufacturing

- **More complex geometry**, more stringent requirements for material properties and geometrical tolerances, and more advanced (and automated) manufacturing methods

- **Drive for faster time to production** and change implementation – competitiveness
  - *"Delays in getting new products into service are the most critical issue affecting the A&D sector, and they carry significant costs"**

- Information needed for decision making is embedded deeper in vast, and **fast-growing manufacturing data sets**
  - Challenge for data collection, storage, retrieval, linking, analyses, etc.

Need solutions for data connectivity and correlation to support faster and more accurate planning and decision making.

Timelines for Defense Programs Have Grown Significantly

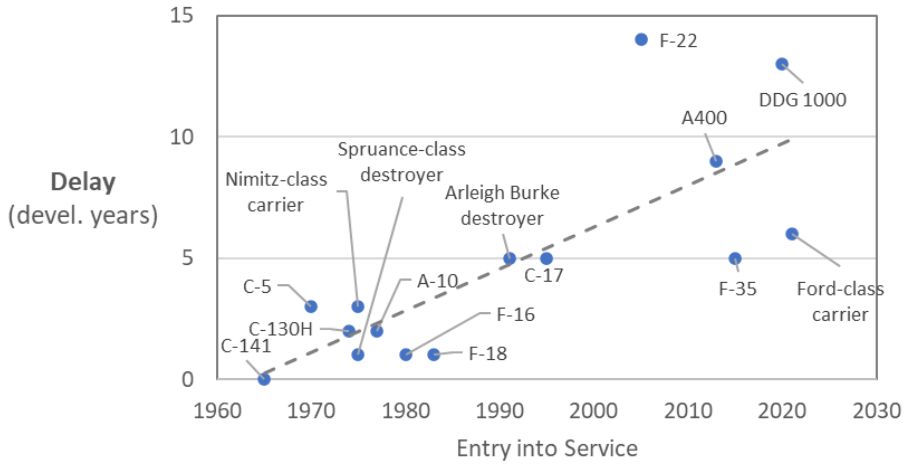
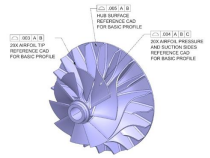


*Chart adapted from BCG analysis report

*A Need for Speed in Aerospace and Defense, BCG, 2022

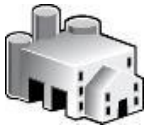
Moving towards Model Based and Data Driven Manufacturing

Design Exploration

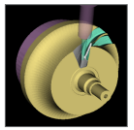


Model-based Product Definition

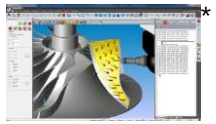
Manufacturing Planning



Process Plan



NC programs



CMM programs

Operations: mfg., quality, sourcing

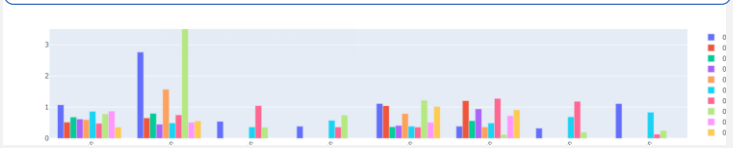
Process & Probing Data

Inspection data

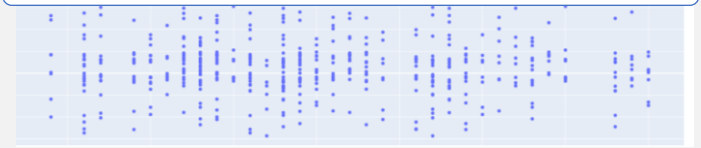
Cost & performance data

Process capability (Cpk) by product feature

Process capability (Cpk) vs. machines for product feature



Inspection result vs. Process data exploration for correlations



Feature Level Digital Thread enabling advanced capabilities

- Evaluate tolerancing for producibility
- Reduced design iteration
- Enable DFx: design for manufacturing, assembly, and cost

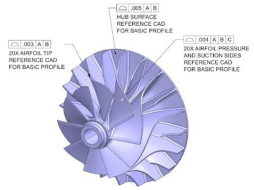
- Automation of manufacturing planning & programming
- Faster and more precise manufacturing process optimization

- Process correlation exploration to evaluate relationships
- Connected process monitoring data to predict and correct errors in the manufacturing process

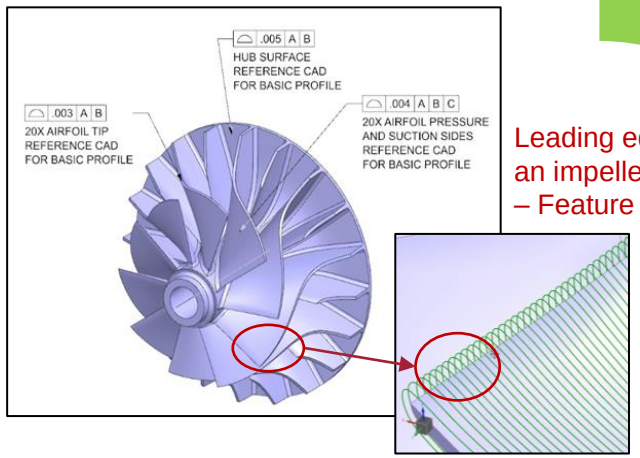
*Image: https://www.automationmag.com/2316-cmm-programming-software/

Feature Level Digital Thread Concept

Design Exploration



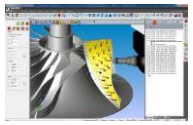
Model-based product definition with common feature identification. Faster time to final design with use of feature level data feedback from Operations.



Leading edge of an impeller airfoil – Feature ID

Manufacturing Planning





Process, CNC, and CMM plans created automatically using feature ID to load previous/pre-defined plans from libraries, significantly reducing planning lead time.

Operations: As-Inspected


Inspection data against feature ID creates traceability back to the design definition, manufacturing plan, and manufacturing process.

Data connected through geometry with standardized feature IDs, common across part numbers within a part family

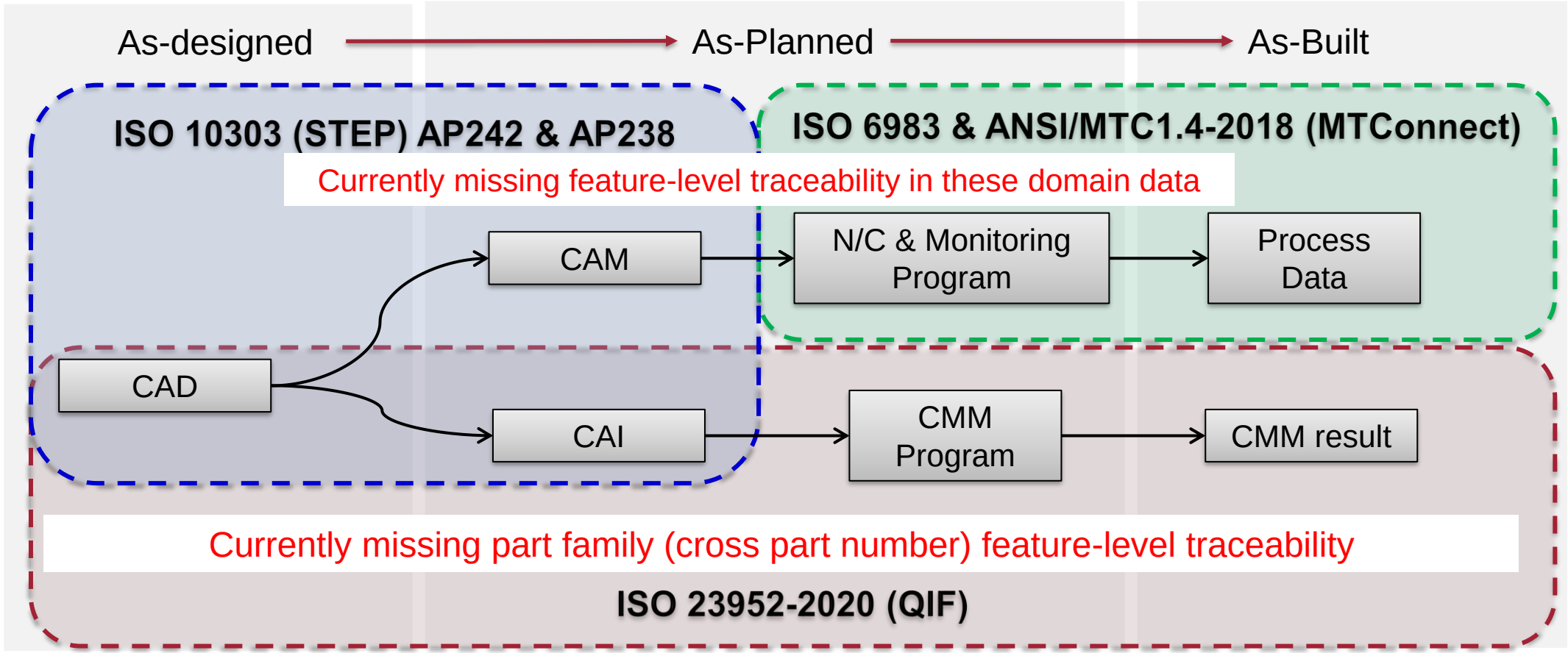
- Reusable & traceable
- Enables automation
- Reduces iteration
- Larger datasets for evaluation

Operations: As-Built

Manufacturing process monitoring connected to the feature IDs for quick error identification and supporting resolution. Capture of process data to update plan libraries.

CNC: Computer numerical control router
CMM: Co-ordinate measuring machine

Traceability Gaps in Industrial Standards

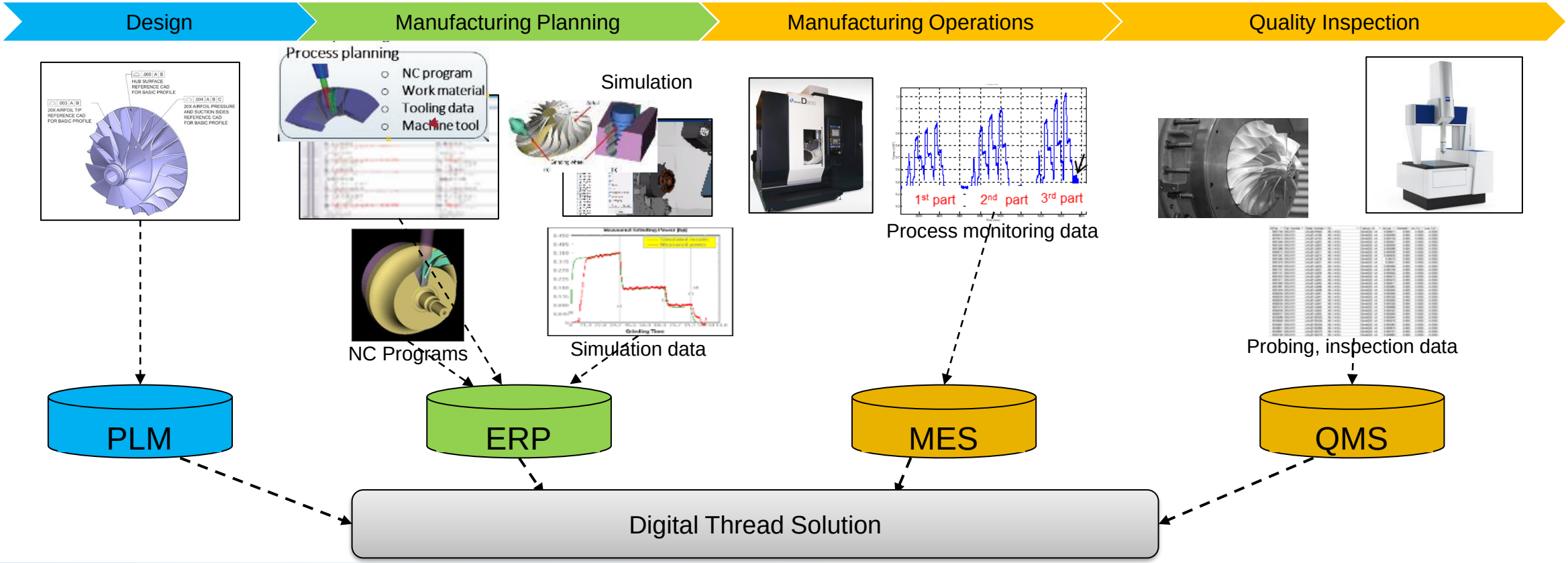


Need to enhance current standards or develop new interoperable data standards to ensure data connectivity through the product lifecycle digital thread

CAM: Computer aided manufacturing
CAI: Computer aided inspection

Implementing Traceability for a Feature Level Digital Thread

- Developed new methodology to embed feature-level traceability data for the entire DMI data stream
- Demonstrated feature-level traceability with **product feature nomenclature** for CNC G-code, probing, and process monitoring programs

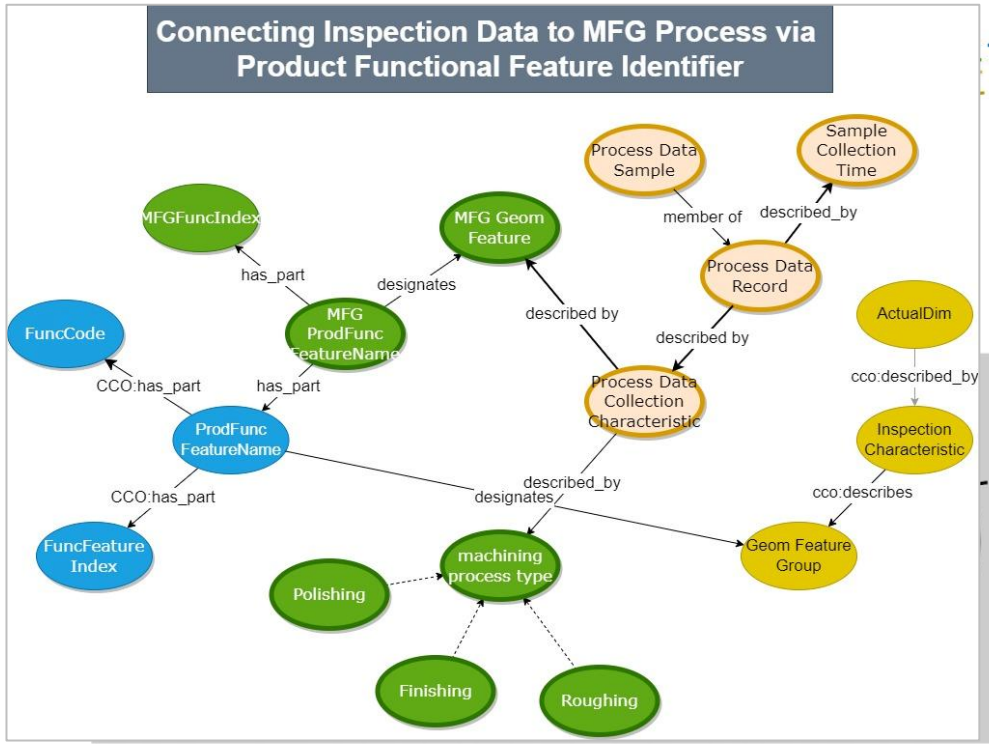


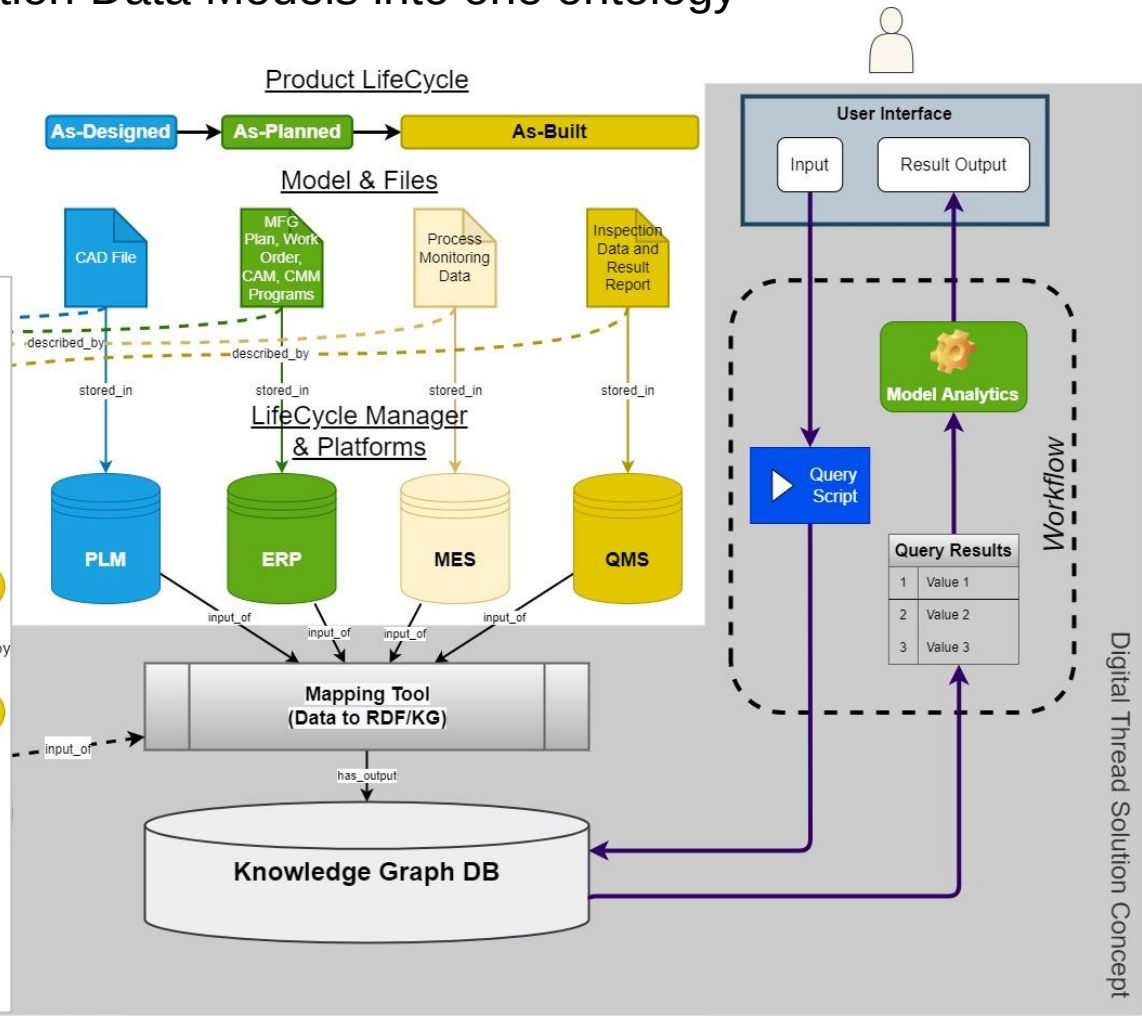
DMI: Definition, Manufacturing, and Inspection

Semantic Connectivity for Feature Level Digital Thread

Objective: Integrating Design-Manufacturing-Inspection Data Models into one ontology

Solution: Supplement existing datasets with common product functional feature identifiers, in addition to geometry feature identifiers, to enable cross-domain and cross P/N association.





Feature Connectivity for WEDM Process Optimization

Use Case: Collecting and aligning process data for Wire EDM process parameter correlation exploration & optimization at Pratt & Whitney Canada

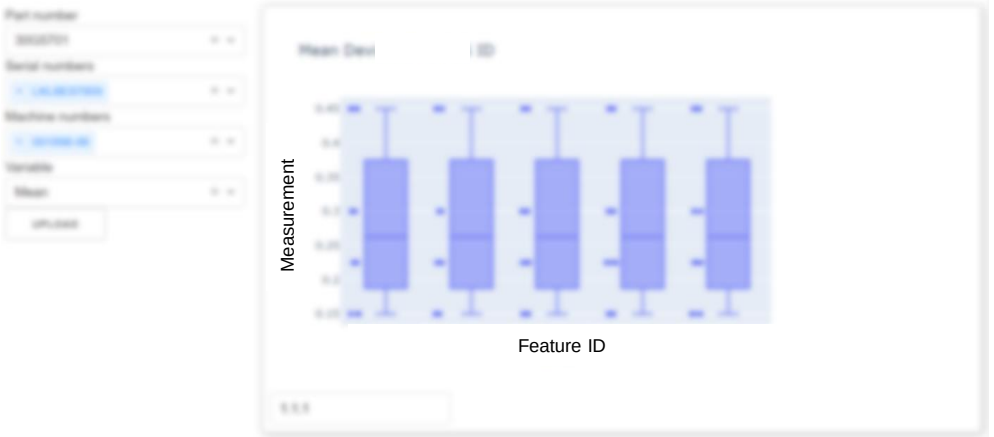
Business Value:

- Dashboards enabling the process engineer to explore potential correlations that exist within the WEDM process in order to make more informed adjustments
- Applied to a WEDM process optimization for a product family at P&WC

Realized Impact:

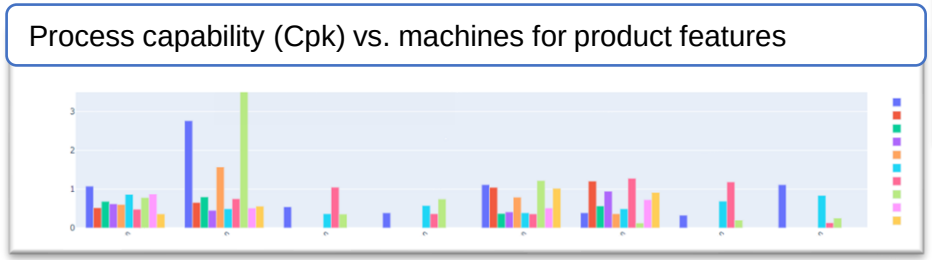
- Increased precision
- Reduced cycle time
- Reduced optimization iterations and reduced machine down-time

Simplified exploration of correlations between the process parameters and the geometry (Visualization & Data Mining)

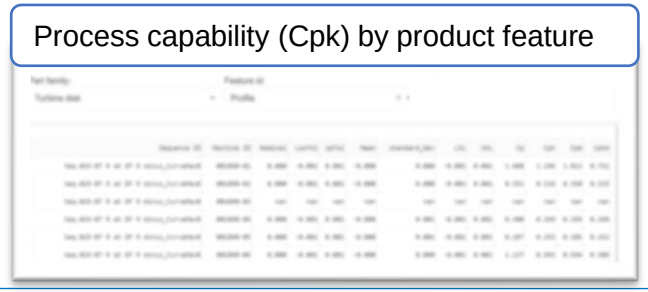


Inspection results vs. Process data exploration for correlations

Process capability (Cpk) vs. machines for product features



Process capability (Cpk) by product feature



Conclusions

- Demonstration shows realized value of the Feature Level Digital Thread
- The Feature Level Digital Thread is the backbone for manufacturing digital transformation - enables traceability and reusability of information through the product lifecycle
- Current industrial standards and tools lack capability to maintain digital traceability and interoperability across a part family
- Semantic connectivity enables the Feature Level Digital Thread solution

Acknowledgment

- The MBDT team acknowledges the valuable interactions and contributions from the Pratt & Whitney Canada team, and RTRC (Changsheng Guo) for providing subject matter expertise essential to the project's success and helping to highlight synergies across other ongoing digital thread efforts across RTX.