DMDII Project 15-16-02: Automatic Generation of Optimized CMM Programs on the DMDII Digital Manufacturing Commons

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NIST MBE Summit 2017

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CAPVIDIA

Origin

UNC CHARLOTTE

DMC
DIGITAL MANUFACTURING COMMONS

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Project participants:

- Metrosage (lead)
- Capvidia
- Naval Air Systems Command (NAVAIR)
- UNC Charlotte

Goal:

Automatically generate optimized CMM programs from MBD models—deployed on the DMC

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Interoperability in academia

- One view of academic research in metrology and precision engineering is that we:
  - implement fundamental mathematics and basic physical principals in prototype systems to explore new limits of precision,
  - establish better estimates of measurement uncertainty, and
  - support standards that govern the specification of equipment

  for <u>both</u> manufacturing and metrology.

- This (especially the first bullet) sounds like a lot of custom work – why is interoperability important?

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Prototype systems

- Focus is on the system design
- Would like control strategies to be separate from the details of the hardware
- Do not want each project to require a student to develop a new translator for each flavor of solid model
- Interoperability allows us to reuse components of our designs, and more efficiently focus on what's novel.

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Optimization

- By nature, academic projects are quite narrow, and optimization within the project tends to occur over a very narrow domain
  - Interoperability allows the optimization of various use-cases over a broader range of manufacturing and measuring equipment, workpiece geometry, and optimization criteria.

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Research in interoperability

- We have worked with the DMSC to build a more comprehensive classification of metrology resources.
  - Hierarchical
  - Covers a broad range of instruments & instrument components
  - Covers instrument properties (calibration status, specifications, test results)

  - Still needs refinement
    - Operators as resources (?)
    - Details of calibration

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Model Based Enterprise – Industry View

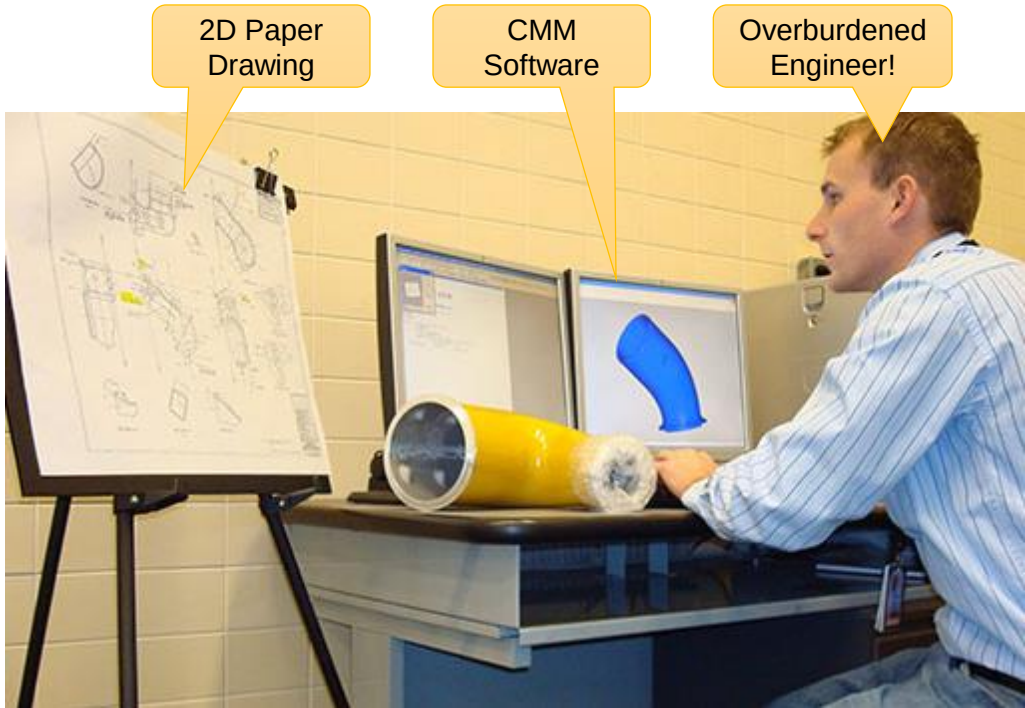
> Currently, due to the **enormous amount of cost** required when doing CMM programming manually, engineers have avoided using a significant amount of GD&T in their designs. **Leveraging the MBD** technology in this project would permit engineers to tolerance their designs **more efficiently**.
>
> —John Schmelzle, NAVAIR

This is currently a labor-intensive, manual process requiring a highly skilled CMM technician.

1. Import CAD model into CMM software
   - CAD translation issues can occur
2. Manually transcribe GD&T from 2D drawing into CMM software
   - GD&T interpretation errors
   - Erroneous or incomplete transcription
3. Create sampling strategies for measurement
   - Heuristic process based on knowledge and experience of CMM technician

Problems:

- Can take weeks to program a single part
- Requires a skilled CMM technician with expert knowledge of GD&T, CAD and measurement
- High risk of transcription or interpretation errors with GD&T



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Quality Information Framework (QIF)

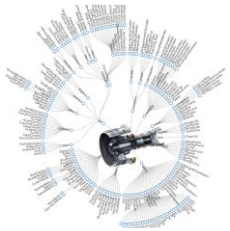
ANSI Standard (Fast-Track ISO Organization)

Feature-Based Ontology of Manufacturing Quality Metadata

</>

XML Technology: Simple Implementation and Built-In Code Validation

Data semantically linked to Model for full data traceability to CAD



QIF

QIF enables **advanced metrology workflows** with a **standards-based approach**, robust data models and **semantics**, and full **data traceability** to authority CAD data

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DIKW Pyramid & QIF

Application of Knowledge towards a specific goal

Applied Information

Data with context

Wisdom

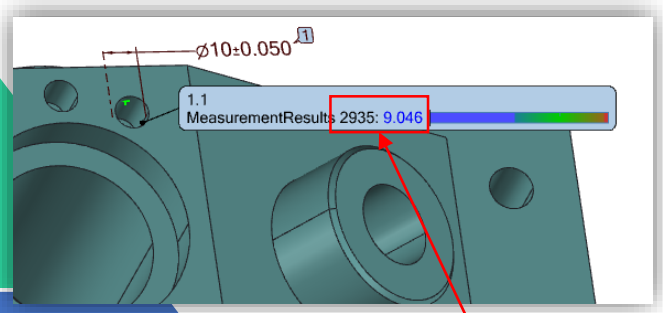
Knowledge

Information

Data

"Remove more material"

"This hole size is out of tolerance; the mating pin will not fit into this hole during assembly"



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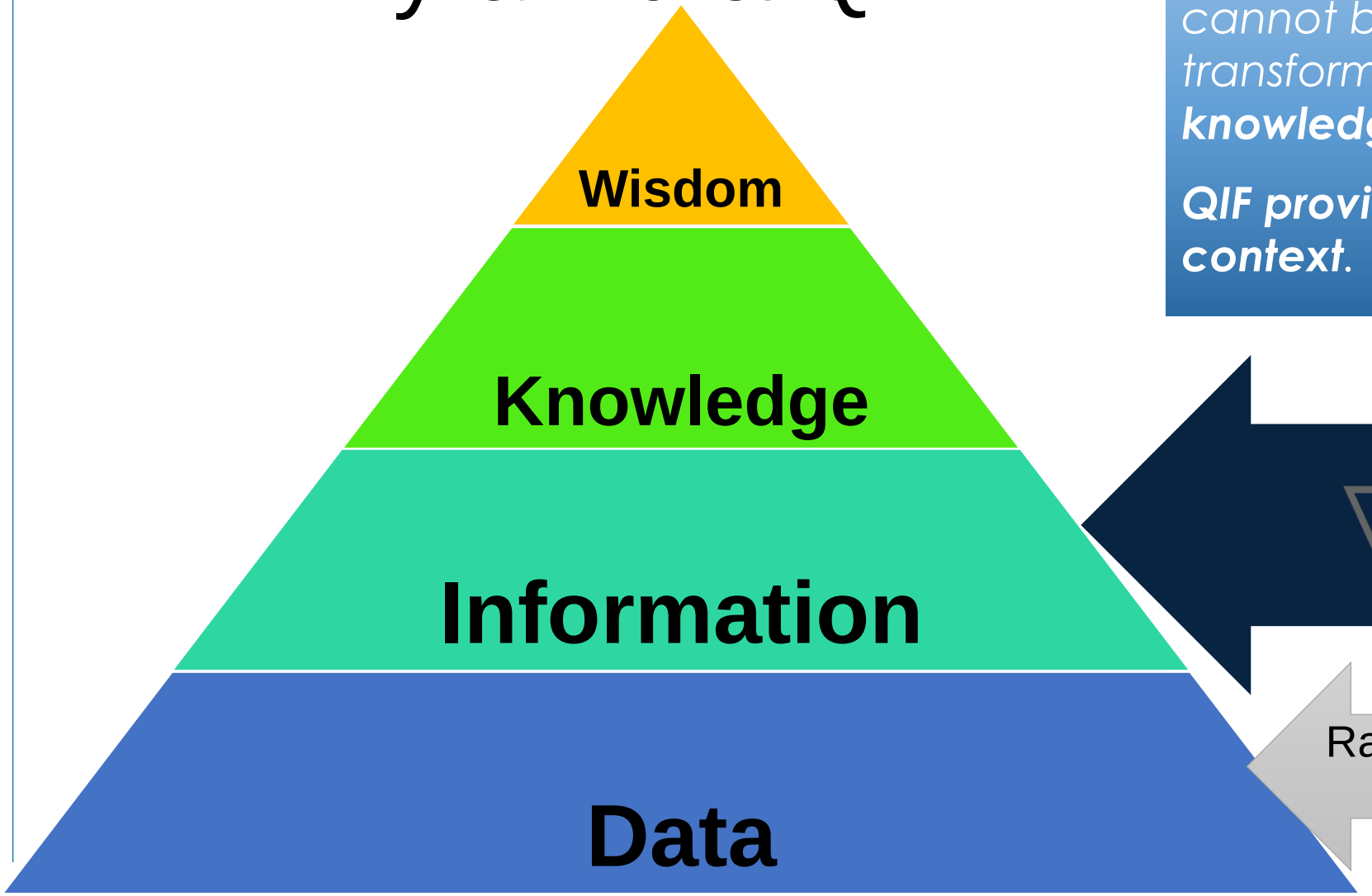

*Without **context**, **data** cannot be transformed into **knowledge**.*

QIF provides this context.

QIF

Raw Measurement Data

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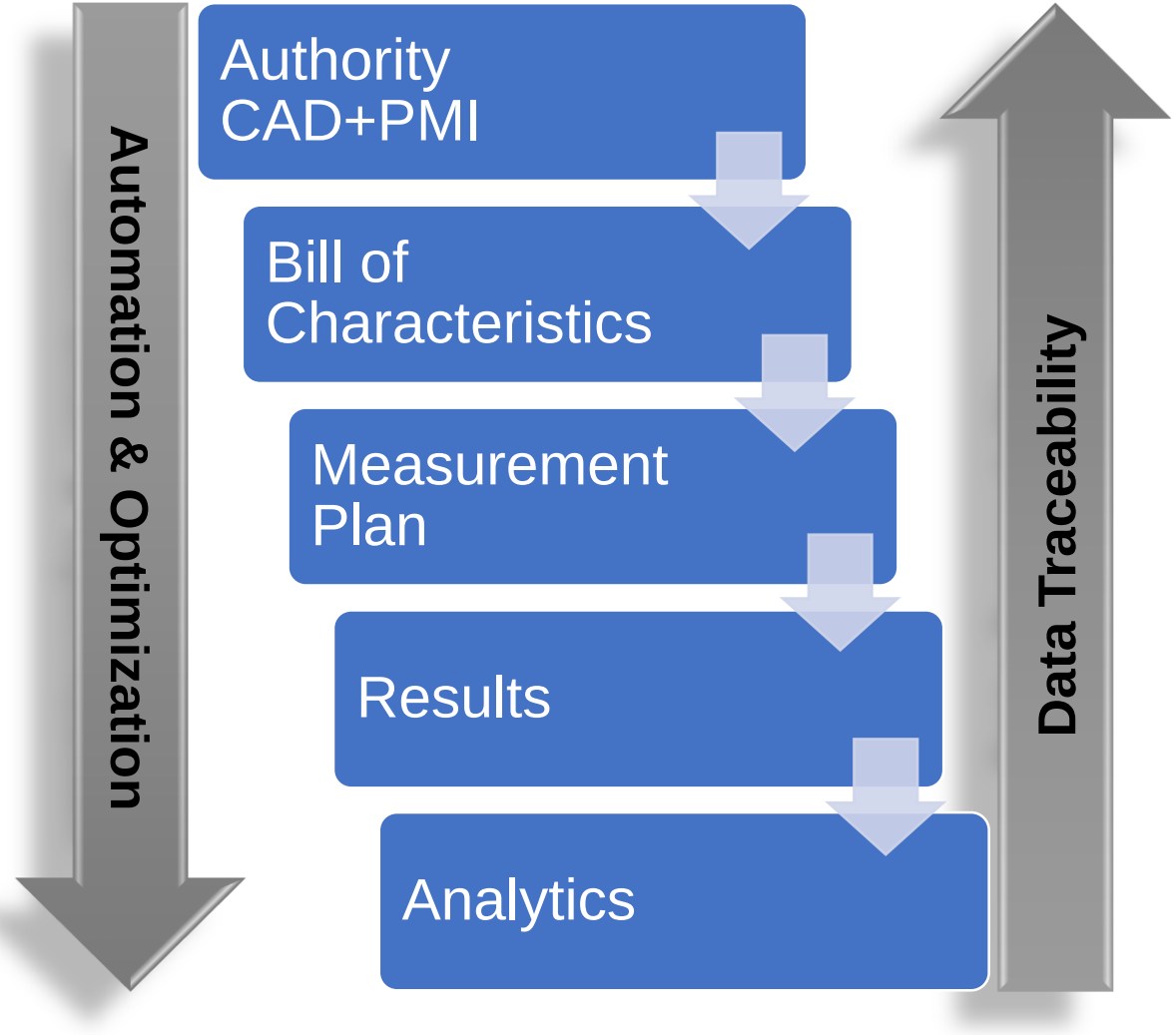
QIF & Measurement Data as MBD



- Identifiers are put in place to track all QIF measurement data and map it to authority CAD
- When results are collected in QIF format, they become an integral part of the Model Based Definition
- Data traceability + semantics **enables analytics**

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Software Components: Capvidia

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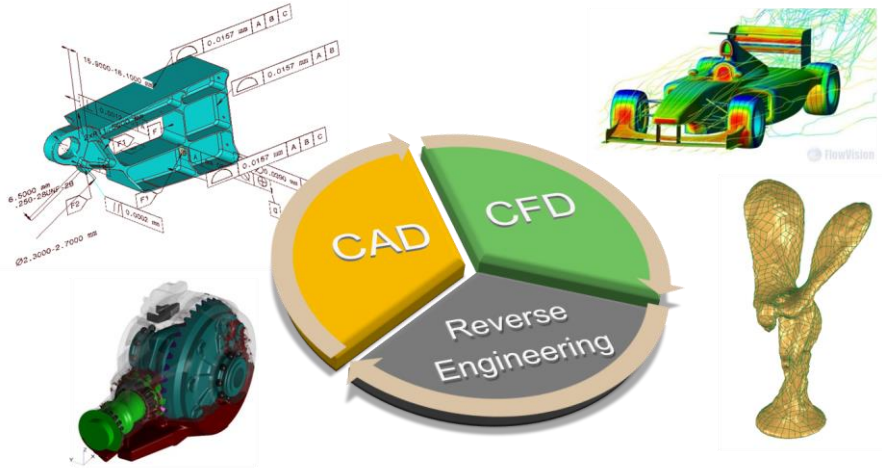

Capvidia provides software solutions for 3D CAD/CAM/CMM data interoperability and CFD simulation to simplify processes, increase quality and reduce costs

MBD/MBE Applications:
- Translation
- Validation
- Quality assessment
- QIF, STEP AP242, 3D PDF
- SDK for software

Commitment to Standards:
- QIF
- STEP AP 242
- 3D PDF

Proud to cooperate with the following organizations:

SIEMENS

DASSAULT SYSTEMES

SIMULIA

SPATIAL

SOLIDWORKS

CATIA

ptc

QIF

NIST National Institute of Standards and Technology U.S. Department of Commerce

PDES, Inc.® Connecting the Digital Enterprise

ANSI

LOTAR LONG TERM ARCHIVING AND RETRIEVAL

Dimensional Metrology Standards Consortium DMSC

3DPDF CONSORTIUM

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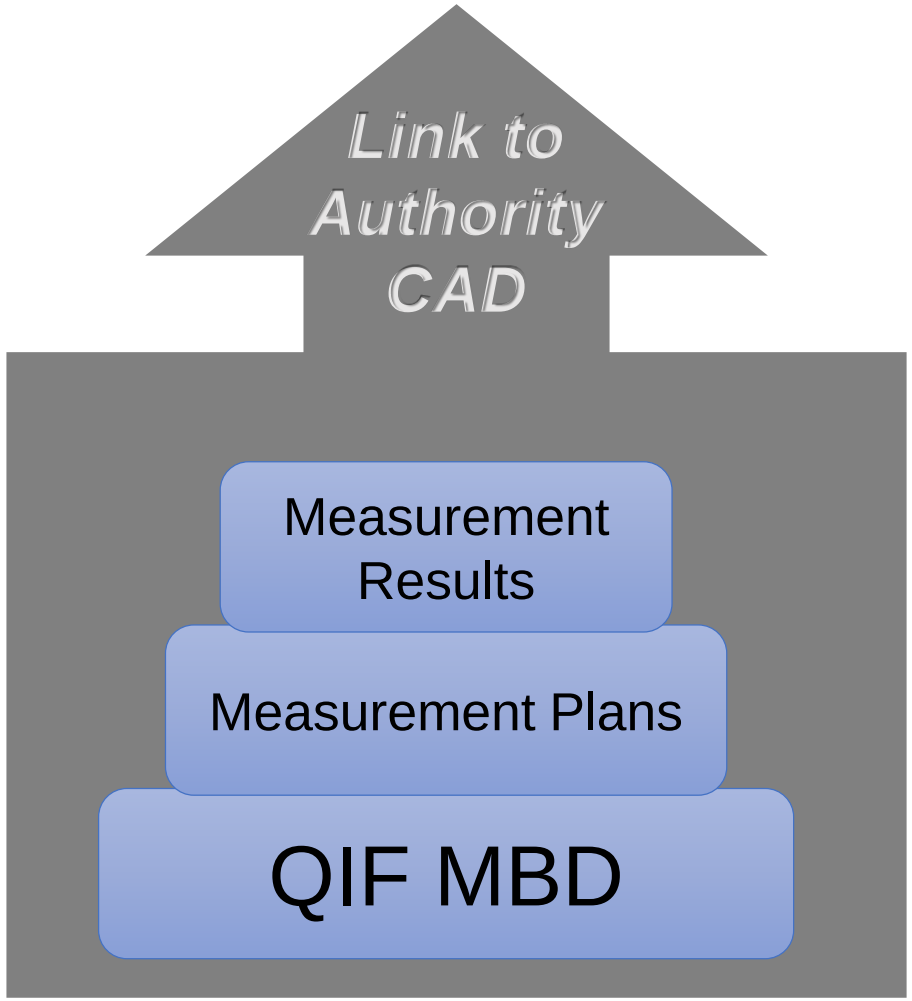
Software Components: MBDVidia



MBDVidia

- Translation from authority CAD data to ANSI-standard QIF, including semantic PMI
- Links to authority CAD data are maintained to create full data traceability of all measurement data to CAD—the “single source of truth”

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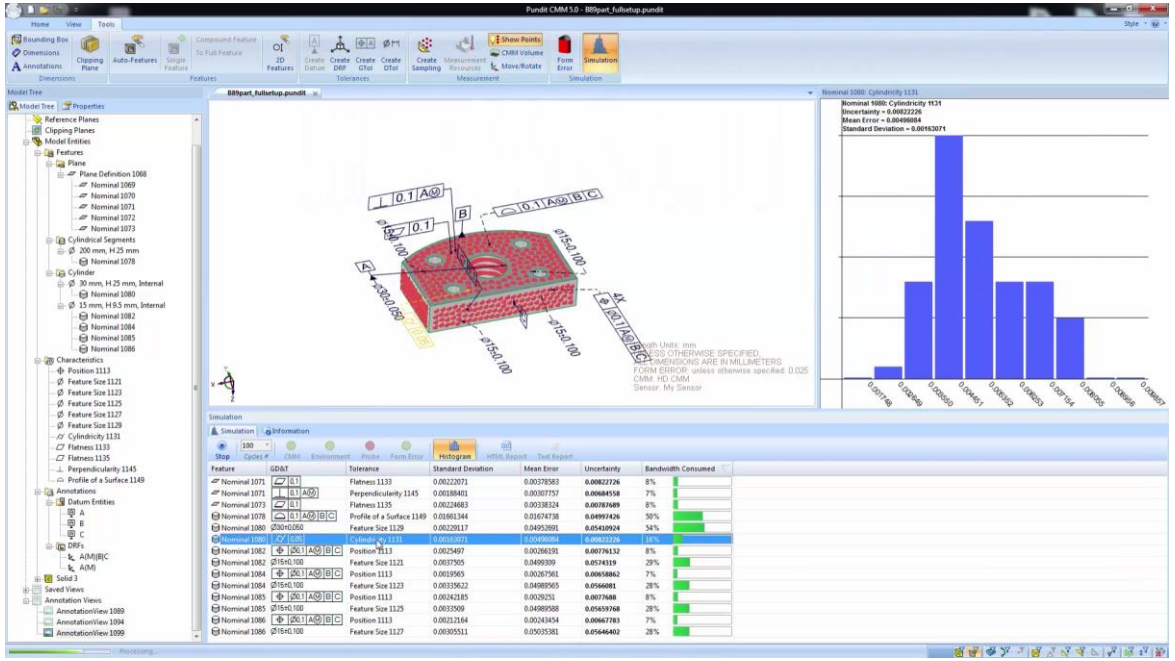
Software Components: Metrosage

Software and services in the domain of dimensional inspection, measurement uncertainty, and MBD for measurement

Flagship software:
Pundit CMM

PUNDITCMM



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Software Components: Metrosage & Capvidia

Recent News: Metrosage technology becomes part of Capvidia toolset

- Capvidia NA acquires Pundit CMM—leader in CMM measurement uncertainty simulation
- Extends Capvidia's growth in the digital metrology market
- Pundit CMM customers benefit from Capvidia's global sales & support presence and best-in-class competence in solutions for MBD and Digital Enterprise

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NEWS – Capvidia & Metrosage

Over the past several years Metrosage LLC and Capvidia have developed a close working relationship, collaborating on several projects to the mutual benefit of both organizations. Both companies have deep interests in dimensional measurement and robust expression and communication of model-based PMI, being member companies of the Dimensional Metrology Standards Consortium, the Digital Design and Manufacturing Innovation Institute, and the Manufacturing Technology Centre.

Over the past several months Capvidia and Metrosage have been exploring ways of further strengthening our relationship. Today we are pleased to announce that, effective March 1, 2017, Capvidia NA LLC, with headquarters in New Ulm, Minnesota, has acquired various product lines of Metrosage and a variety of intellectual property assets, merging the unique strengths of our two companies and bringing to bear on MetroSage's dimensional measurement uncertainty product line Capvidia's considerable resources in software development and international sales and marketing.

As part of this transition, Mr. Daniel Campbell, a Metrosage principal, joins Capvidia NA LLC as Director of Business Development, with responsibility for the Digital Metrology market. Metrosage LLC continues as an active player in dimensional metrology, concentrating its operation on consulting and R&D contracting to assist manufacturing companies in improving and advance their dimensional metrology capabilities.

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Software Component: Pundit CMM

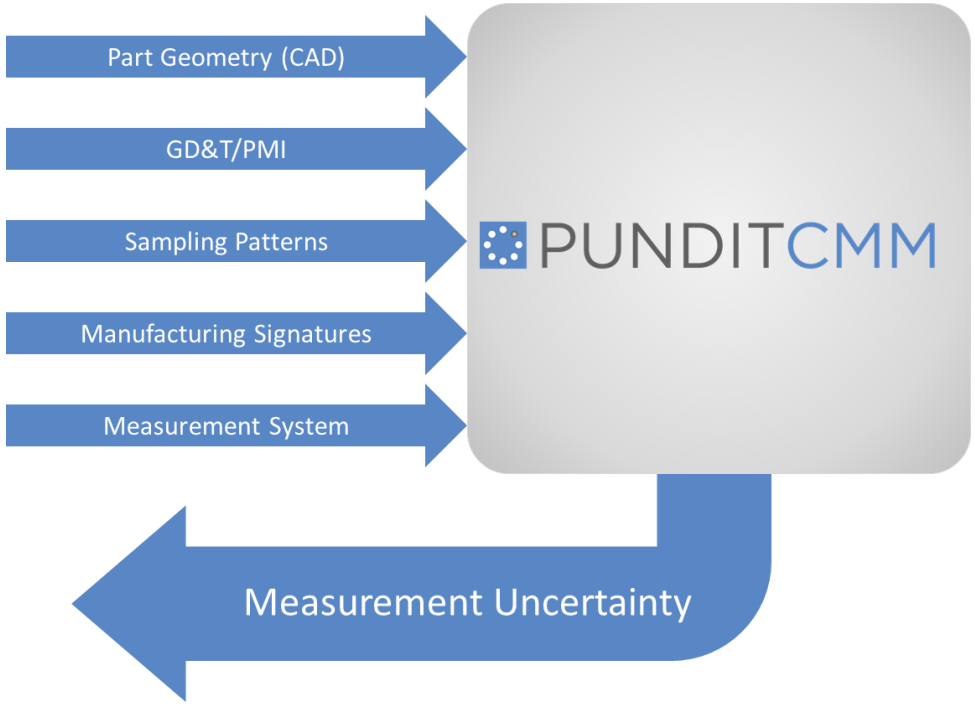
Using the following information supplied by the user:

- MBD model with PMI
- Available CMMs
- Known manufacturing signatures on workpiece

Pundit CMM will automatically generate an optimized high-level CMM plan:

- Which measurement system to use
- Sampling strategies for all features

Measurement uncertainty values for each tolerance will also be reported.



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Software Components: Origin International Inc.

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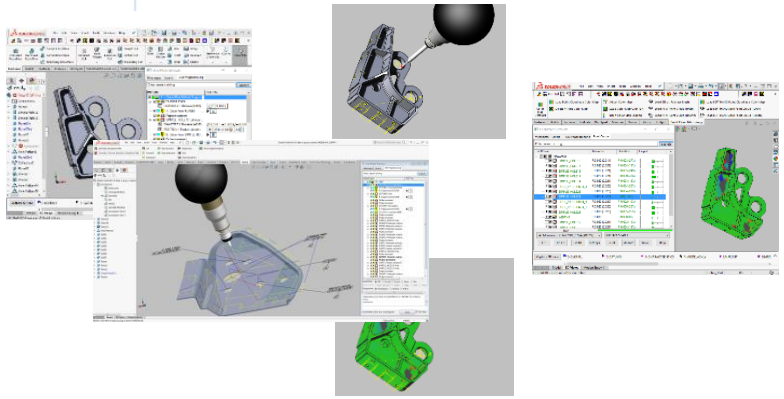

Origin provides CAD-based and standalone software applications to increase measurement process and equipment productivity and to reduce scrap by increasing part quality and eliminating false part rejections.

CheckMate for SOLIDWORKS

- Off-line CMM programming with MBD (DMIS, QIF, and native language)
- CAD-based results display, fitting and statistical analysis
- Point cloud metrology

CMEngine (CheckMate run-time)

- Runs CheckMate authored scripts for complex analysis
- CMM report conversion (native to DMIS and QIF)
- Part program translation

Commitment to Standards:

- *DMIS 3.0 through 5.3*
- *QIF 1.0 through 2.1*

QIF

sme

CERTIFIED Solution Partner SOLIDWORKS

Dimensional Metrology Standards Consortium DMSC

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Software Components: Origin International Inc.

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- Target measurement points generated using hierarchy:
  1. Target points already in QIF document are preserved
  2. CAD surfaces used for auto point creation (when CAD is present)
  3. QIF feature extents and boundaries used
- Features/characteristics re-ordered based on dependencies
- Datums created from datum targets as necessary
- Coordinate systems created from 6 degree of freedom datum reference frames (e.g., ABC as opposed to A)
- Measurement feature order optimized (within dependency based constraints) with probe clearance moves and probe tip changes/ rotations using prequalified sensor definitions
- Collision detection and avoidance using facet model in QIF document
- Output in DMIS flavored for target CMM system
- (In development: accessibility analysis to limit measurement point set and to establish minimum required list for probe rotations.)

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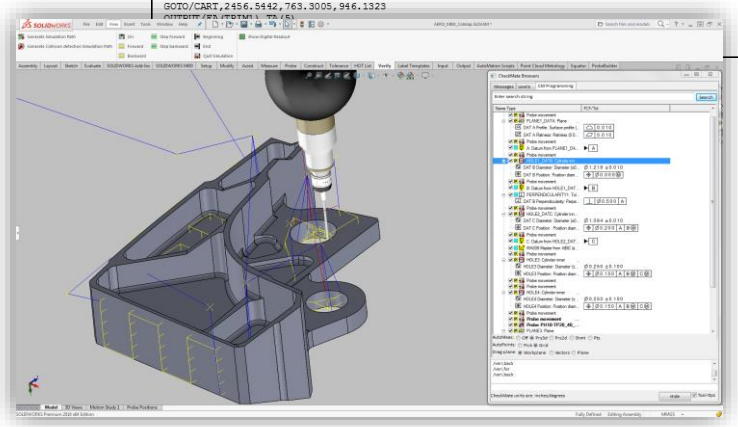

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Automatically Generated, Optimized CMM Programs

What is needed:

1. Automatic generation of CMM programs from MBD
2. Optimized to satisfy measurement needs while reducing inspection time & cost
3. *A priori* knowledge of measurement uncertainty to ensure control of measurement process

This technology is here!

[Click here to watch this video online](https://vimeo.com/191977302)
https://vimeo.com/191977302

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Automatically Generated, Optimized CMM Programs

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Extract Bill of Characteristics from PMI

- Query semantic relationships of features & GD&T
- Convert to QIF MBD format

PUNDITCMM

Optimize Measurement Plan

- Generate optimized measurement plan from CAD + PMI and available measurement resources

Origin

Generate Inspection Program

- Analyze feature accessibility and choose workpiece orientation
- Generate CMM clearance paths

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A Public/Private Partnership Digitizing Manufacturing

DMDII
a UI LABS Collaboration

Established through a 5-year cooperative agreement with $70M in federal government funding and over $105M in matching funding from industry, academia, local government, and community partners.

ROLLS ROYCE
LOCKHEED MARTIN
SIEMENS
JOHN DEERE
DOW
Microsoft
CATERPILLAR
BOEING
P&G
ITW
faurecia

Applied Research & Development

Reduce cost and risk of commercializing new technology

Technology Integration & Commercialization

Develop innovative methods and practices for supply chain integration

Education, Technical Skills & Workforce Development

Engage with small & medium-sized manufacturing enterprises

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About DMDII

DMDII's Technology Roadmap

5 Technology Focus Areas

1 ADVANCED MANUFACTURING ENTERPRISE (AME)

- Information systems integration throughout the product lifecycle.
- Digital links between design and fabrication.
- Smart factory and supply chain management.

2 INTELLIGENT MACHINES (IM)

- Integration of smart sensors and controls to enable equipment to automatically sense and understand current production environment in order to conduct "self-aware manufacturing."

3 ADVANCED ANALYSIS (AA)

- Utilization of high performance computing to model materials, products and processes to enable "design with manufacturing in mind."

4 DIGITAL MANUFACTURING COMMONS (DMC)

- An open source software platform that enables data aggregation, analysis, and action.

5 CYBER PHYSICAL SECURITY

- Industry and national needs for security, trust and IP protection within the manufacturing environment.

The DMDII Digital Manufacturing Commons (DMC)

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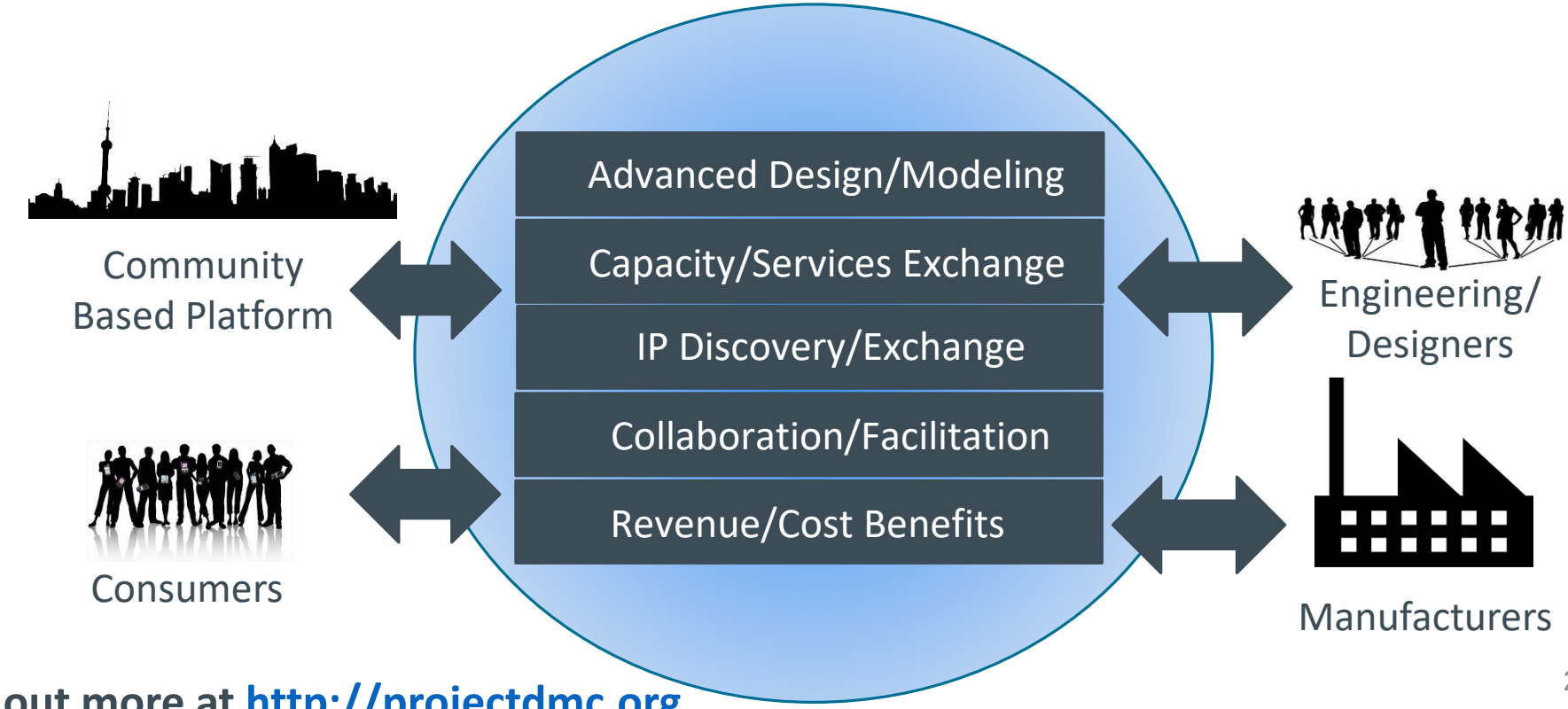
Open Source Software Platform, Initially created by GE Global Research, DARPA, MIT

a free and open-source software project to develop a collaboration and engineering platform, which will enable plug-and-play functionality across the entire digital thread from product development to manufacturing and services.



Find out more at http://projectdmc.org

DMC: Collaborative Platform for Systems Design

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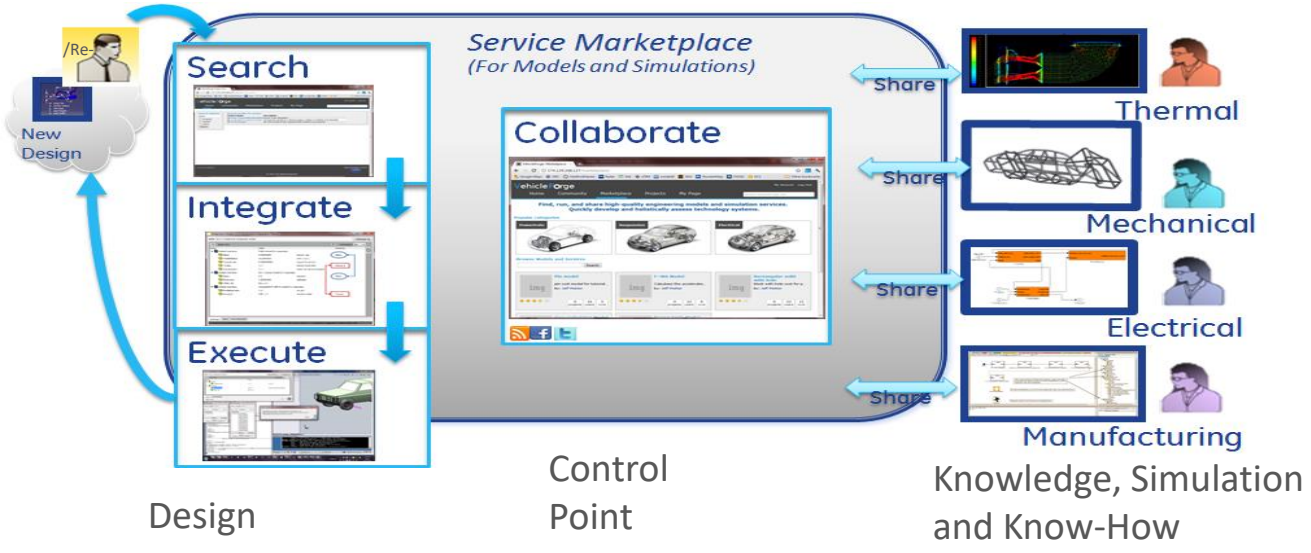

Democratized Platform Delivered Via a Networked System of Systems

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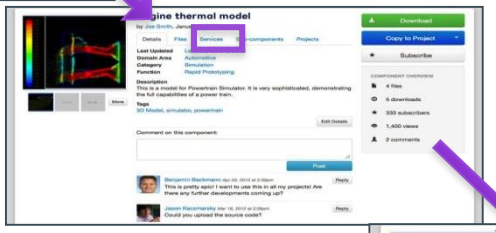
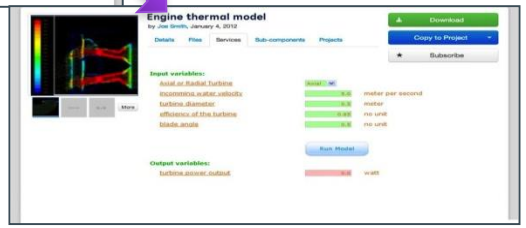
DMC: Service Interaction Via the Cloud

Finding & Exchanging Data and Models

Single Source of Model, Data & Services



Exposed Automated Tool to Authorized Users



- Transparent
- Auditable
- Automated

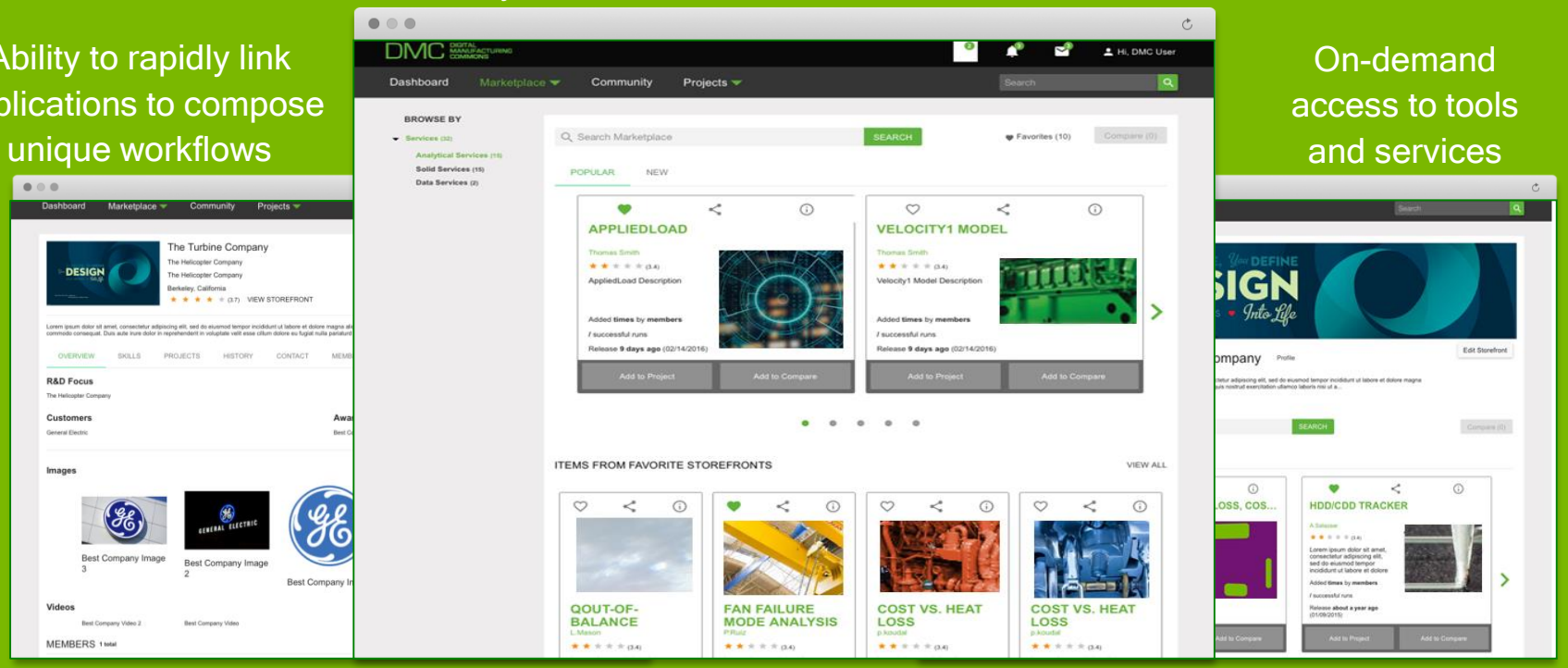
Expose Tools, Data and Compute in a Searchable Automation Platform “The Commons”

DIGITAL MANUFACTURING COMMONS

The Digital Manufacturing Commons (DMC) is a leading open-source platform for connecting communities and sharing solutions across the manufacturing product life cycle.

EASY ways to connect, collaborate and share solutions

Ability to rapidly link applications to compose unique workflows



On-demand access to tools and services

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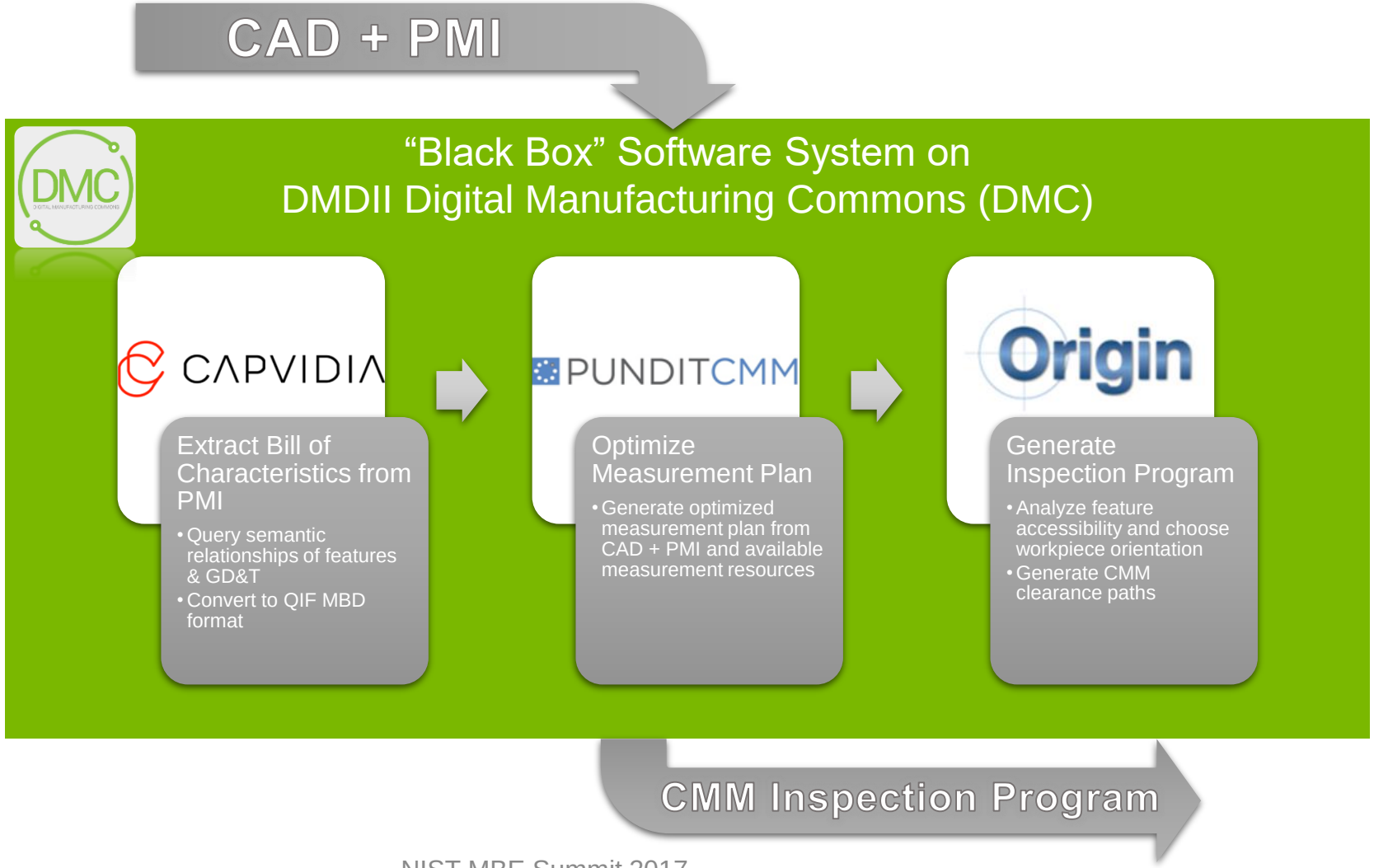

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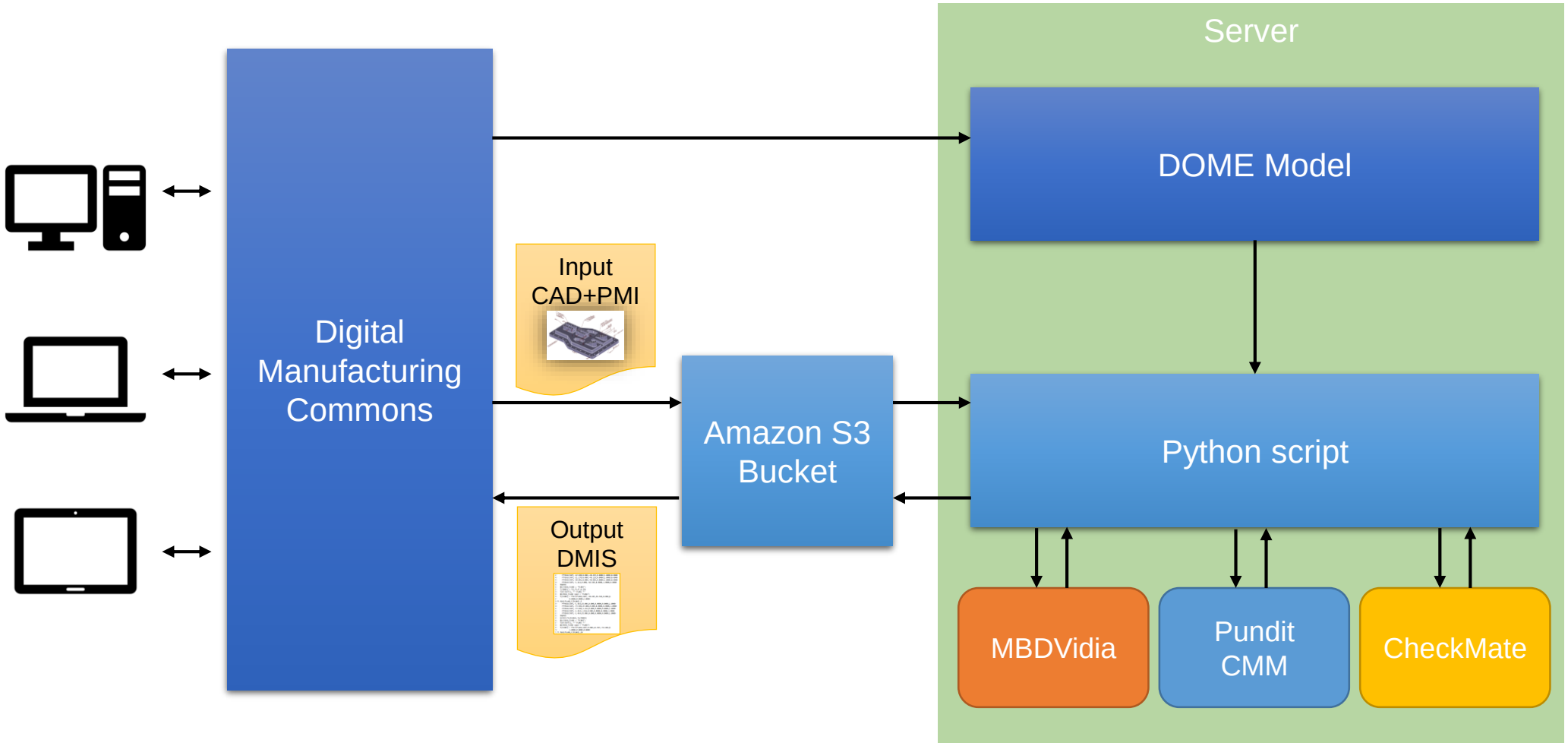
Deployment on DMC



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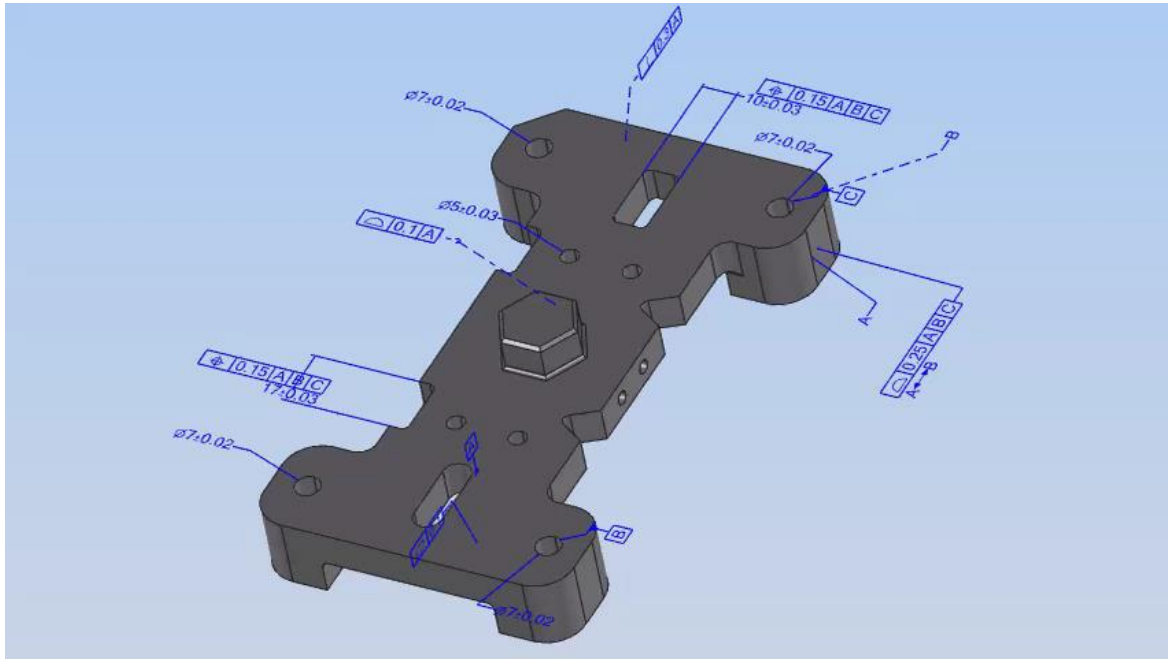
Prototype Demonstration



Creo model used as input:
Variation on nist_ctc_01_asme1_cr2040_rd.prt.1

- User interaction in development: currently requires manual uploading of inputs to server
- Pundit optimization not included in prototype—default sampling patterns currently applied
- Output is a DMIS program which can be executed on a CMM

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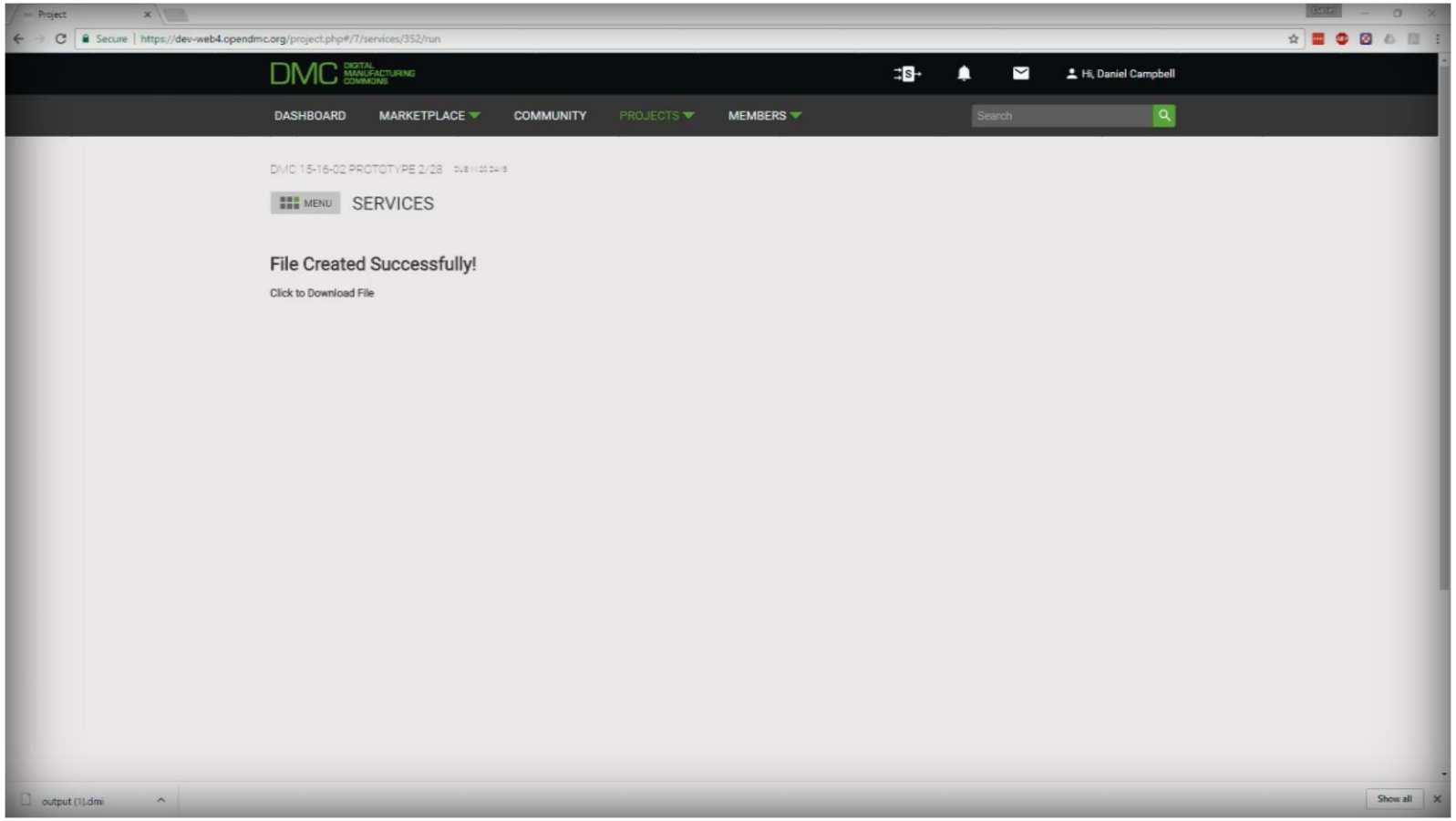
Origin

Demo



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15-16-02

METROSAGE

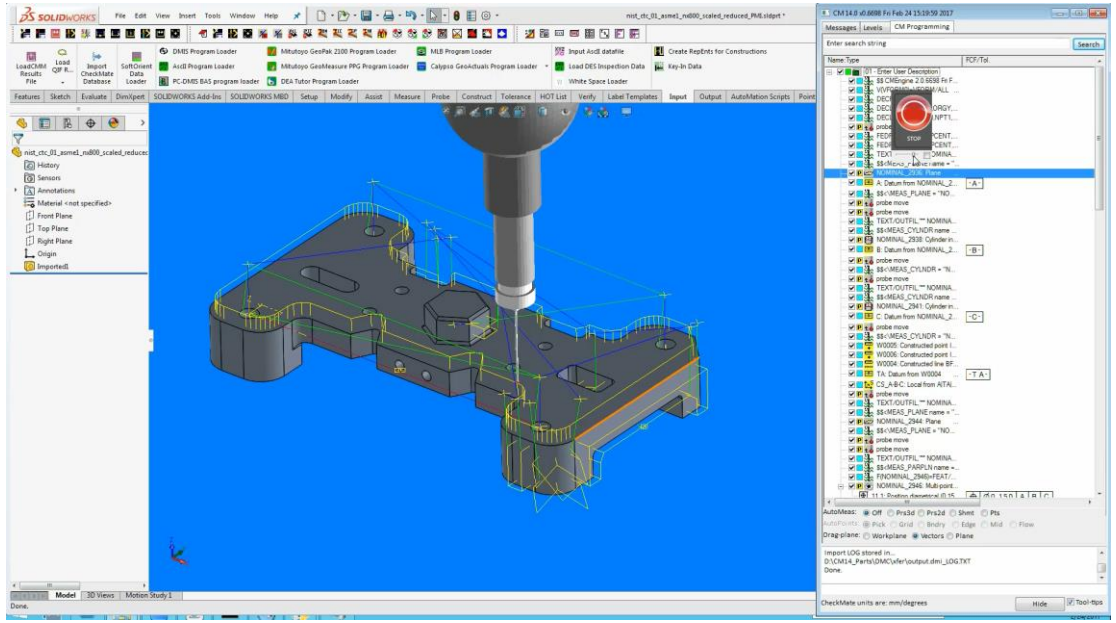
CAPVIDIA

NAVAL AIR SYSTEMS COMMAND

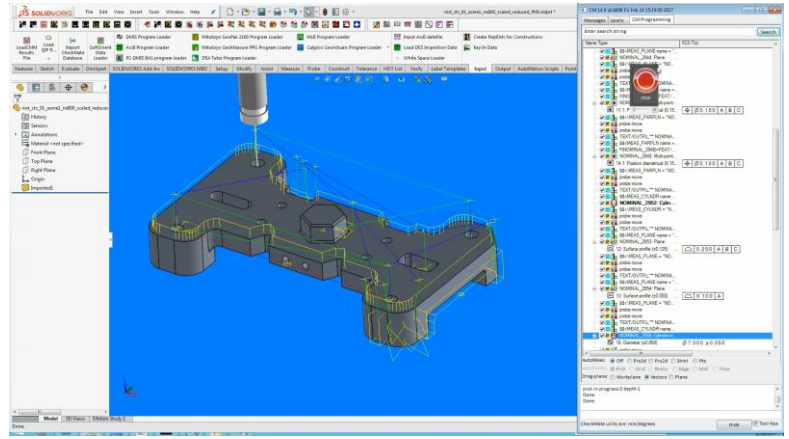
UNC CHARLOTTE

Origin

Let's See it Run!



Automatically generated DMIS program being run in the CheckMate software



Program is collision-free

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Origin

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