Enchasing MBD with Product Performance Information (PPI)

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Digital Thread and Digital Twin

- The concepts of the ***Digital thread*** and ***Digital twin*** have been spearheaded by the military aircraft industry in their desire to improve the performance of future programs
- These concepts are expanding to other industries and converging with the digital manufacturing and system goals of Industrie 4.0 and Smart Manufacturing
- In the **Industrie 4.0** roadmap, a Digital-physical system is the digital representation of a physical system used to communicate properties and live status to other Digital-physical systems and applications in future smart factories
- **Smart Manufacturing** strives to orchestrate and optimize business, digital and physical processes across smart factories and the entire product value chain
- Successful organizations realize that Model Base Definition (**MBD**) enables the digital thread

Why MBD? Better, Faster, Cheaper

- US Defense Logistics Agency (DLA) estimates that moving to MBD Data Packages will **reduce procurement costs by 27%,** scrap and rework costs by 19% (were attributable to poor quality of the design specification)
- US Dept of Defense estimates that **60%** of the supplier data received has **errors** between models and drawings despite the fact that 30% of the total product development budget was spent on creating and maintaining drawings
- Many manufacturing systems can utilize information directly from the 3D models without having to be explicitly programmed
  - Inspection software
  - 3D Printing for prototyping
  - CAM Software for machining the parts
- Complete 3D models can feed directly into engineering analysis programs **CAE** to verify the performance of the design (**PPI** such as Tolerance, Structural, Thermal, CFD, etc.)
- United States Army Research, Development and Engineering Command: MRAP Egress Trainer Metrics using MBE. Bid without MBE **26,000** hrs, with MBE **1,500** hrs

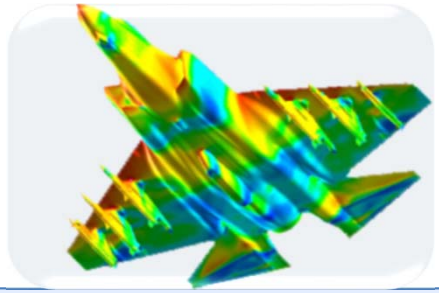
Model Based Enterprise - Approach

1 Design Intent frontloaded

Models are official Design Definition.
Drawings generated on demand

Model Based Definition

2 CAE - Design Optimization



PIDO with Multi-Physics CAE Models
CAD Models are Optimized

Model Based Definition

3 3D Models drive Manufacturing

Models are official Design Definition.
Inspection driven from model

Model Based Manufacturing

4 3D models drive Enterprise

3D for All - “Personalized” Technical
Data packages delivered

Model Based Enterprise

Evolutionary Steps in Design Specification

The Journey

Drawing Based
Master 2D Drawing

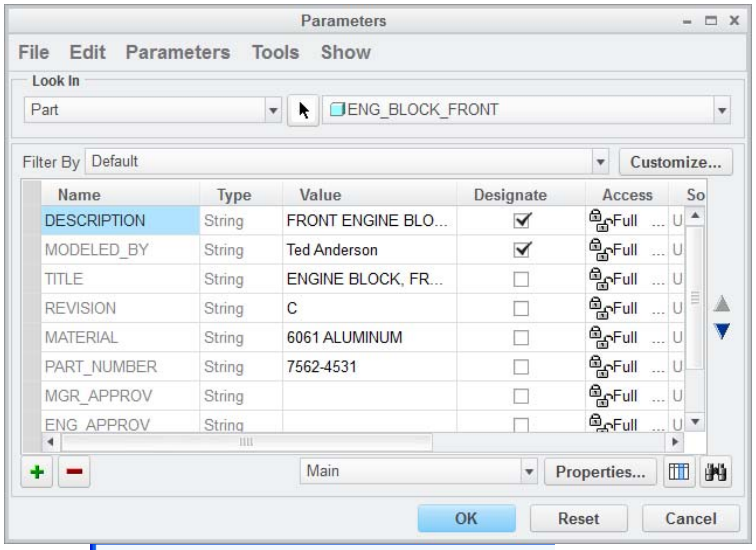
Model Centric
3D CAD Model with Master 2D Drawing

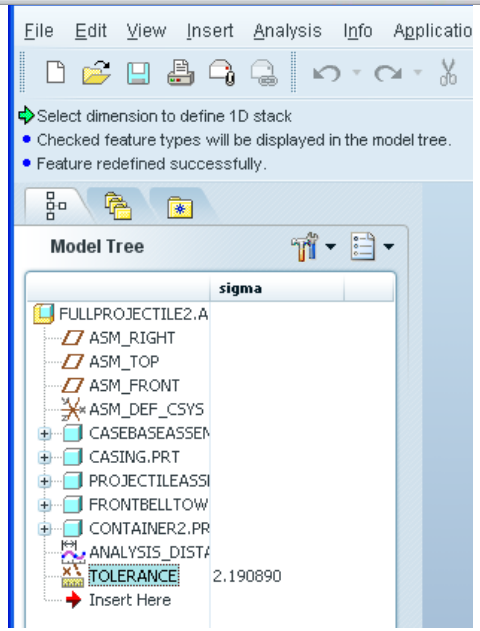
Model Based Definition
Master 3D CAD Model with 3D Annotated Models, 2D Drawings by exception

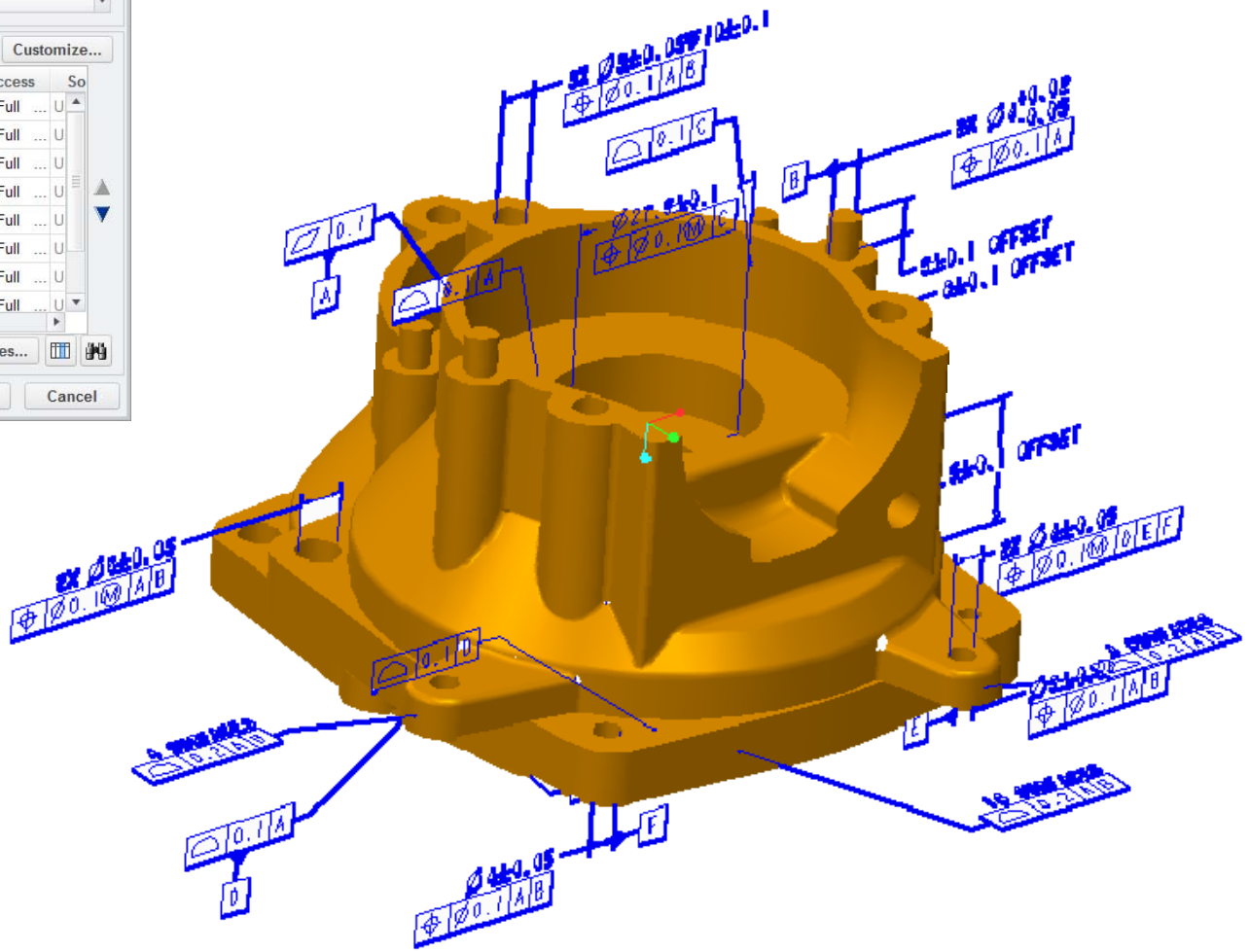
Model Based Environment
Master 3D CAD Model with 3D Annotated Models fully leveraged by the Enterprise

From MIL-STD-31000A

What is a Model?

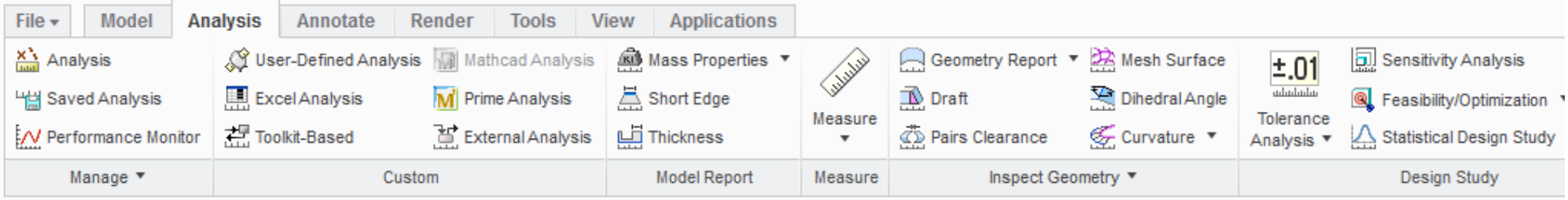






Model = Geometry + Attributes + GD&T Annotations + PMI+PPI

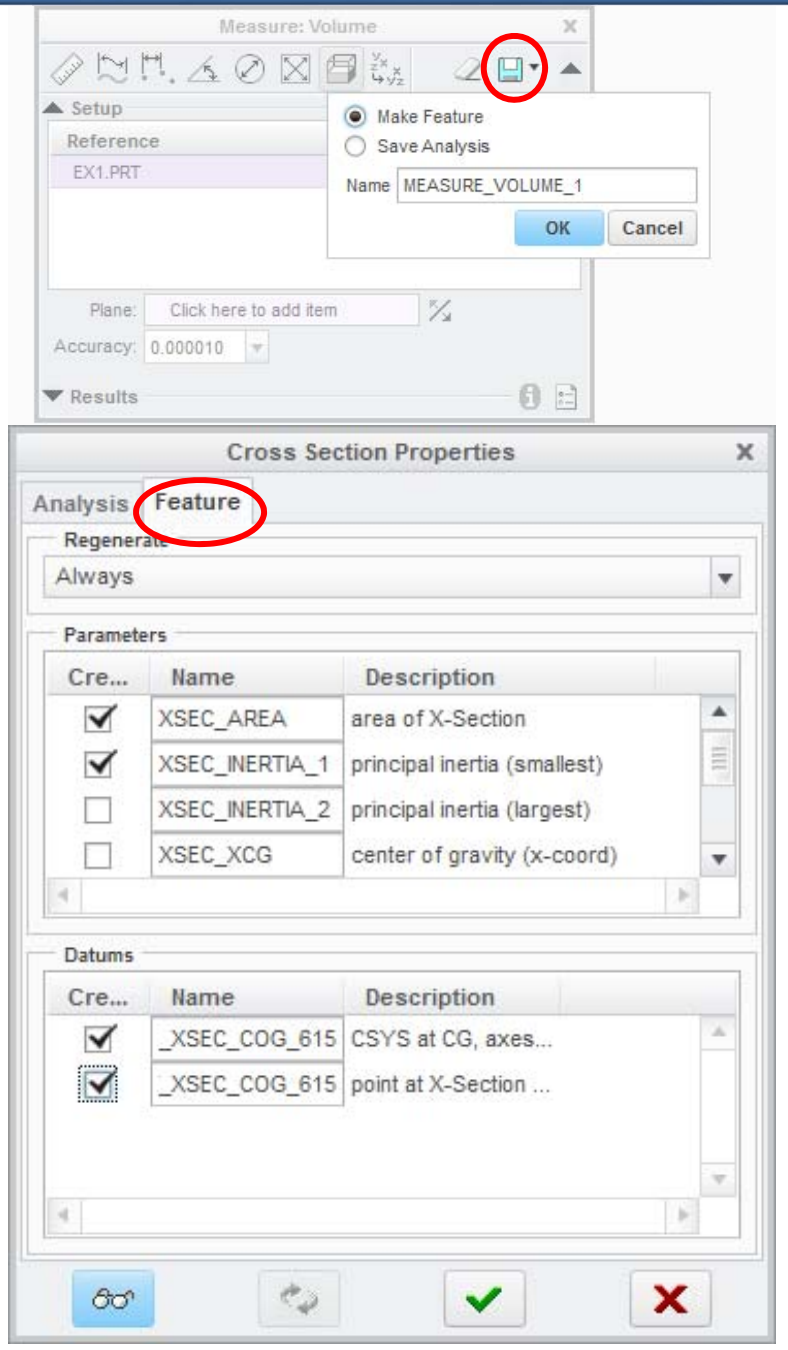
Product Performance Information (PPI)



- Part and Assembly Characteristics can be featurized:
  - Analysis features and Field points
  - User-Defined Analysis (UDA) - Persistent Display
  - External Analysis, Excel, MATLAB, Toolkit-based
  - MATHCAD Prime Analyses
  - Sensitivity, Feasibility, Optimization and Studies Statistical Design Study
  - Design Exploration / Multi-Objective Design studies
  - Simulation Analysis (Tolerance, Motion, CAE, Electrical)

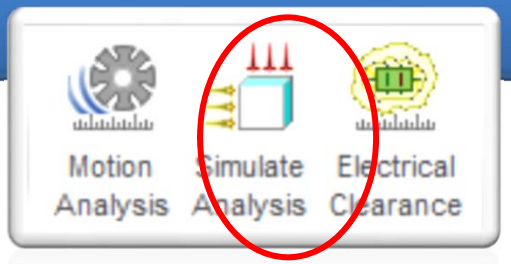
Measurement Features

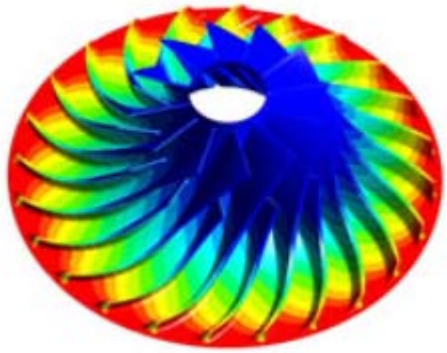
- Any measurement can become a feature
- These features are displayed in the **model tree** and can be selected as parameters and datums for a variety of analysis tools in Creo Parametric.
- Several measurement can be combined and compared to performance requirements (**performance monitor**)
- Where appropriate points (CG) and coordinate systems (principal at section CG) can be generated

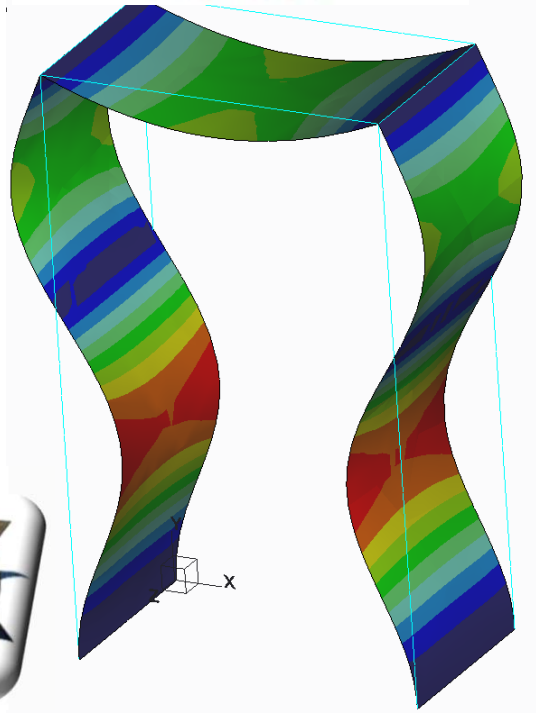


PPI - Simulation Features

- Safety factors, Critical Buckling values or Natural frequencies, drag coefficients, HIC are characteristics of the part/assemblies and its supports
- They can be associative to the part and update as dimensions or materials change
- They can appear in the model tree and part of MBD
- They can be used in the performance monitor for requirements management
- Mesh Controls, Load cases, Boundary conditions
- Surface and Volume Regions
- Mid-surfaces and welds

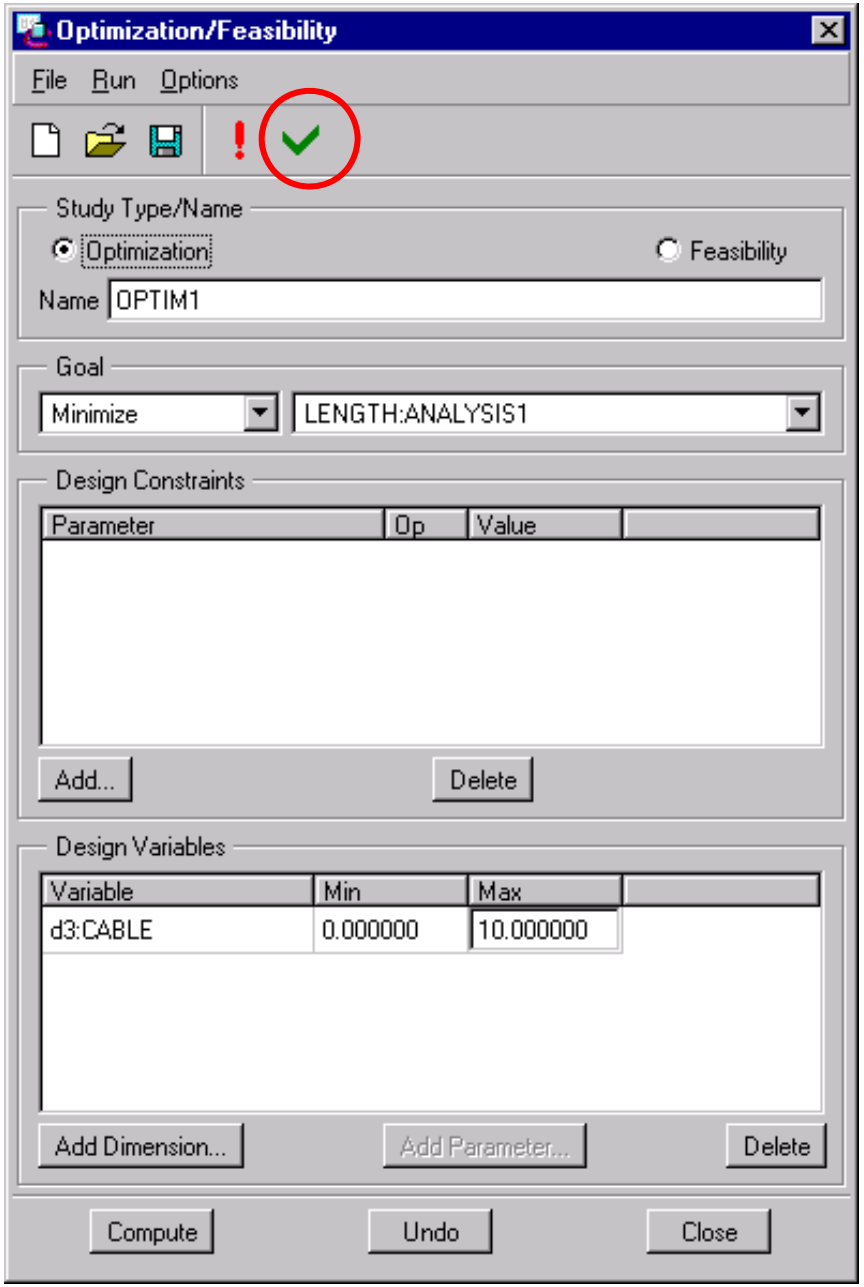






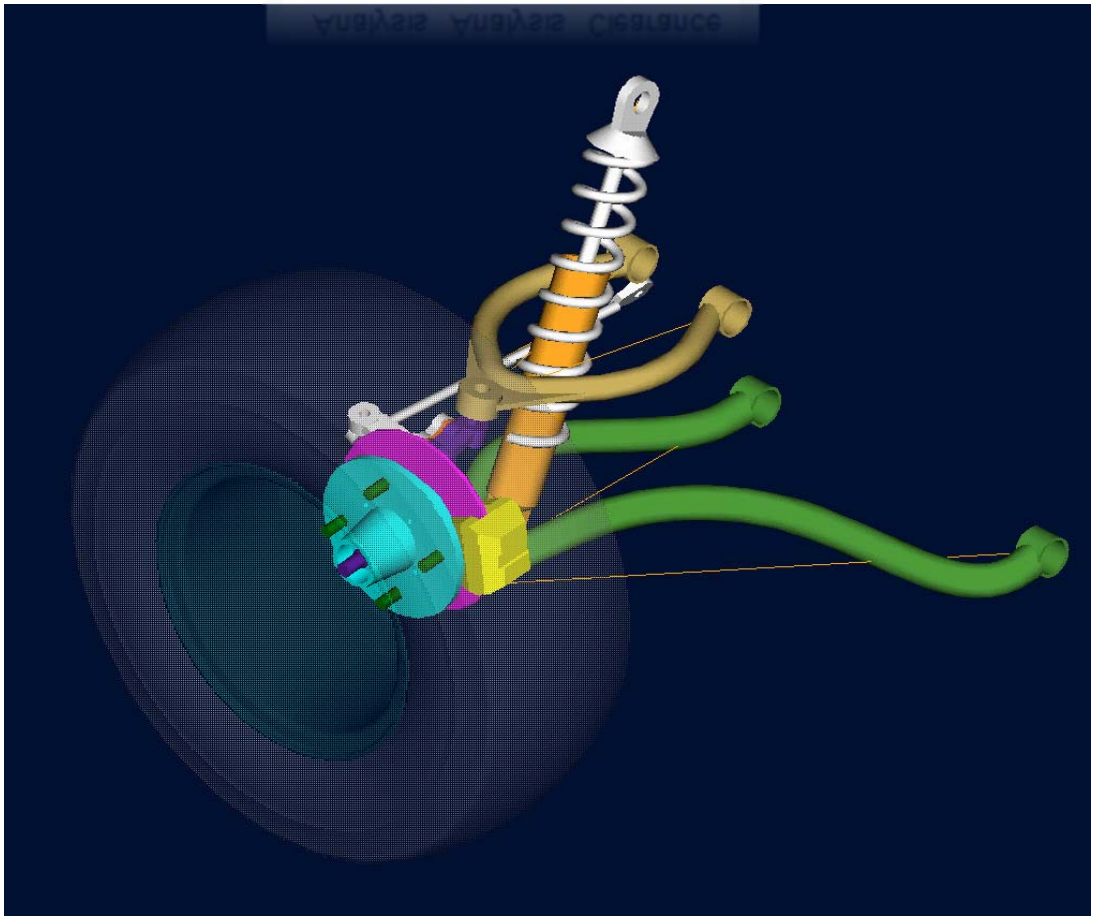
Optimization Features – Smart Parts

- Optimization / Feasibility studies setup:
  - Design Variables
  - Constraints
  - Objective Function
- Optimization Study can be executed one time
- Optimization Study can be saved as a feature
- If dimension or parameters change, the part or assembly can be optimized automatically and design variables are selected by optimizer
- Balancing, CG location, Inertia values, harness lengths & locations, packaging opt., buoyancy studies



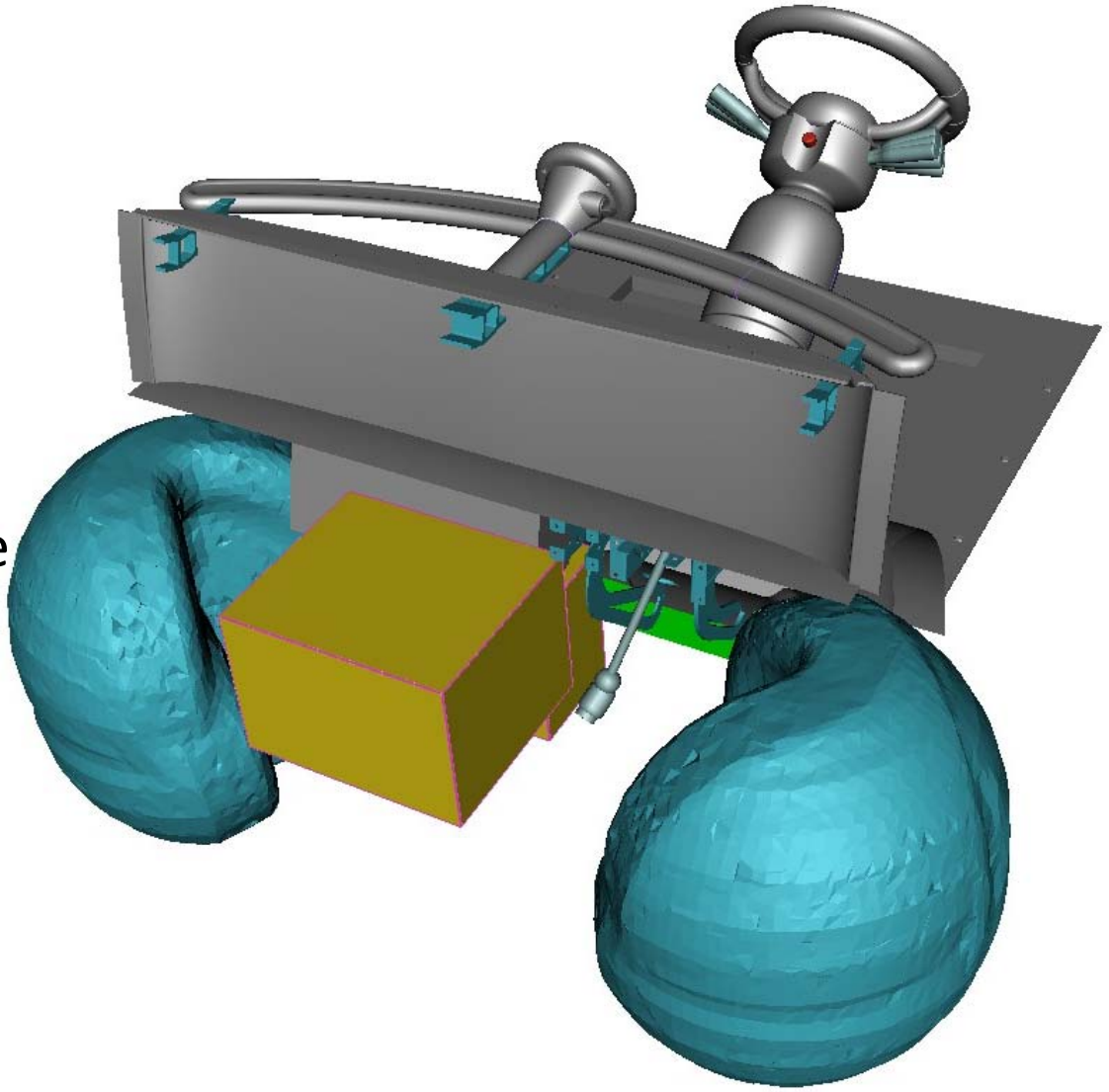
Mechanism Features Connections

- Definition of Mechanism Connections (insert –> pin)
- Connection motion limits
- Driver functions (left-right ±15 mm, up-down ±20°
- Snapshots of extreme positions
- Motion Analysis Features can capture:
  - Max velocities
  - Max Accelerations
  - Max Joint / Reaction forces
  - Min Clearence



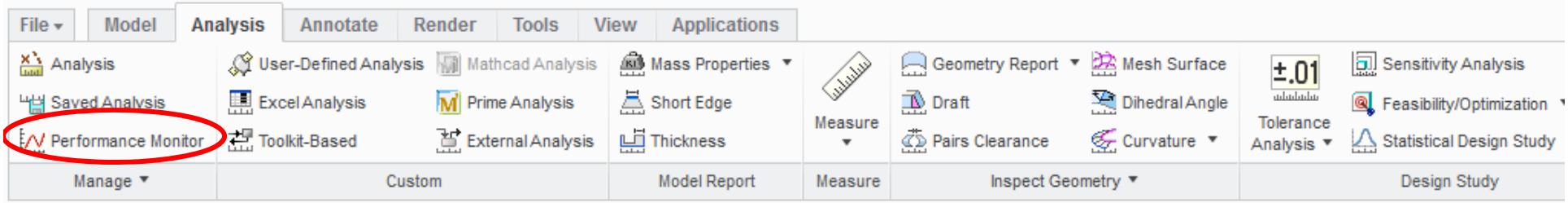
Space Claim Envelopes

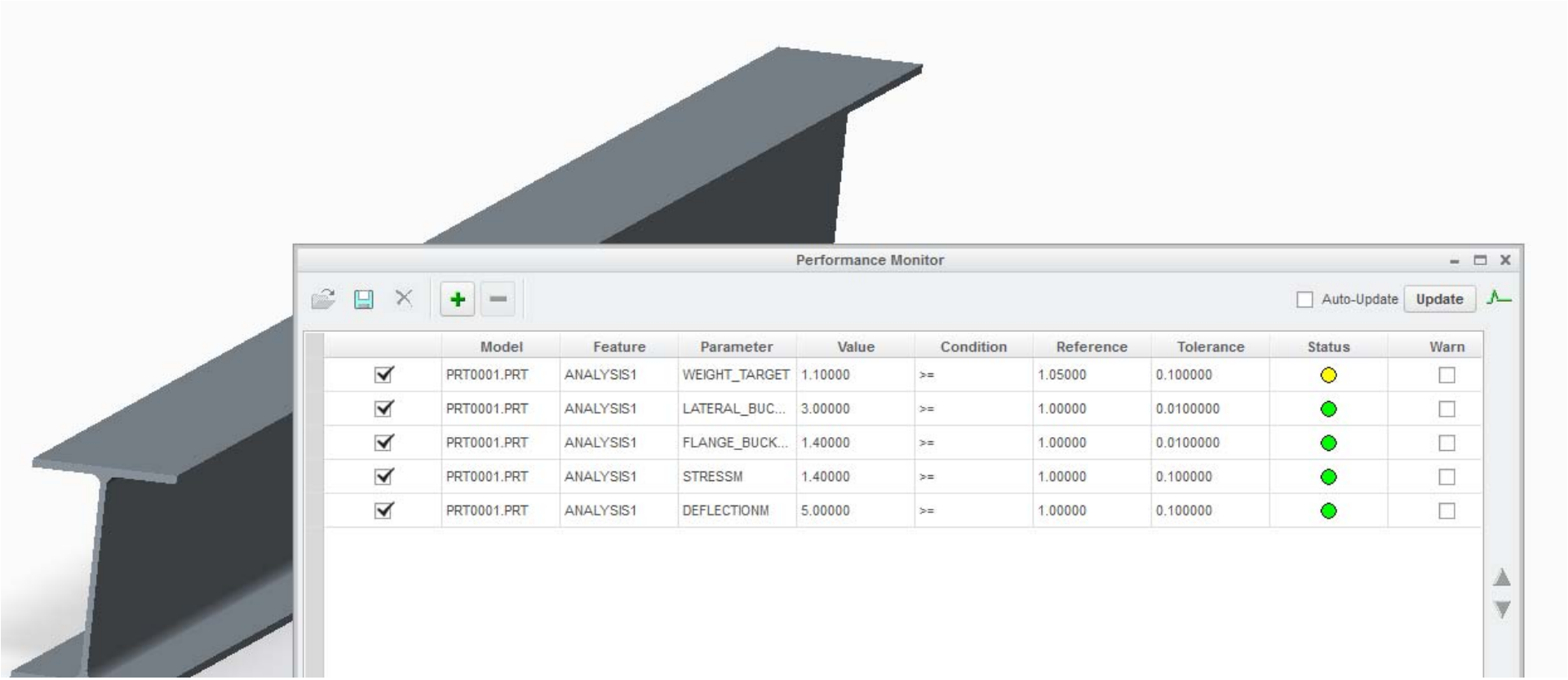
- Space claim envelop parts don’t exist in BOM
- Used by designers to avoid interference on the first iteration
- Space claim envelope is a characteristic of the assembly for a given range of motion
- Preserve associativity to moving parts
- Used for tolerance studies
- Communicates keep-out zones to other groups



Requirement Management with Performance Monitor

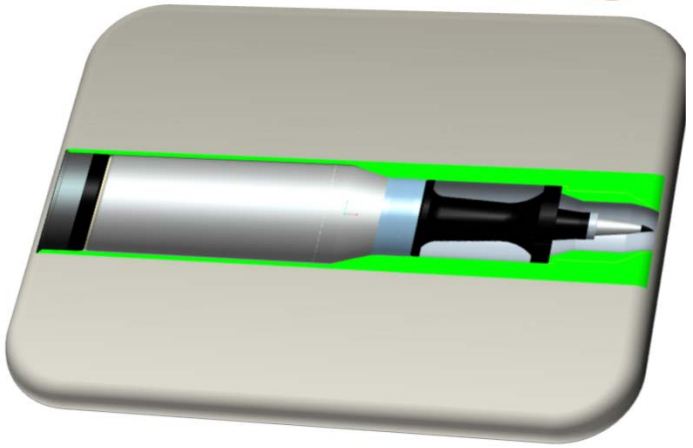
Performance Monitor provides a summary of the values of the analyses features for immediate performance requirement status





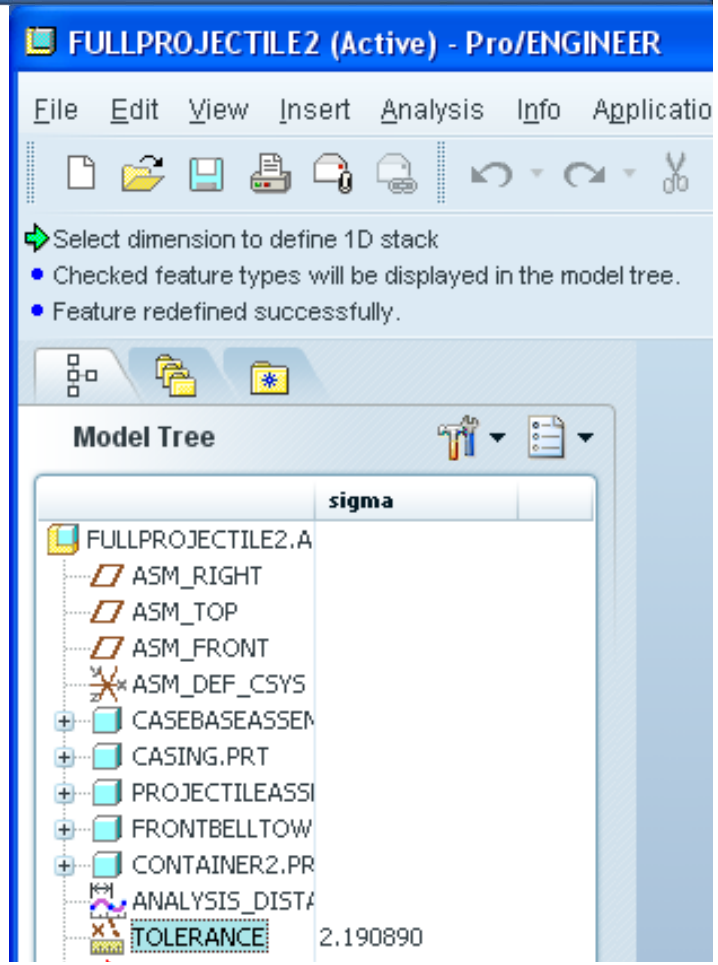
DOD Quality performance requirements

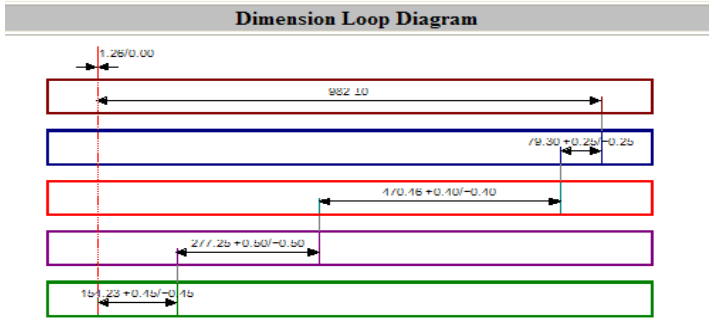
- DOD Quality performance requirements
- Reliability and Materiel availability metrics as KPP
- Demonstration of compliance with virtual prototypes
- Immediate feedback during development process
- Experimental Validation is required
- MBD (Geometry, GDT, PMI, PPI) as part of the TDP



Tolerance Analysis Feature

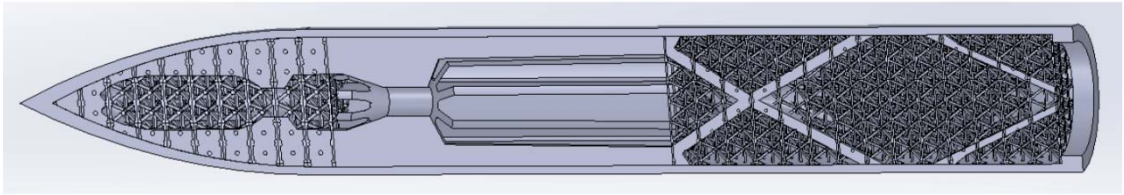
- The sigma quality level of a specific requirement is part of the model tree and MBD
- Demonstrates compliance with DOD's ICD
- Provides immediate feedback during development process on the sigma quality level
- Alerts if incorrect part tolerance is introduced
- Automatic report generation (Sensitivities & contributions of each dimension in stack up)
- Modify on the fly tolerance bounds to achieve desired quality level

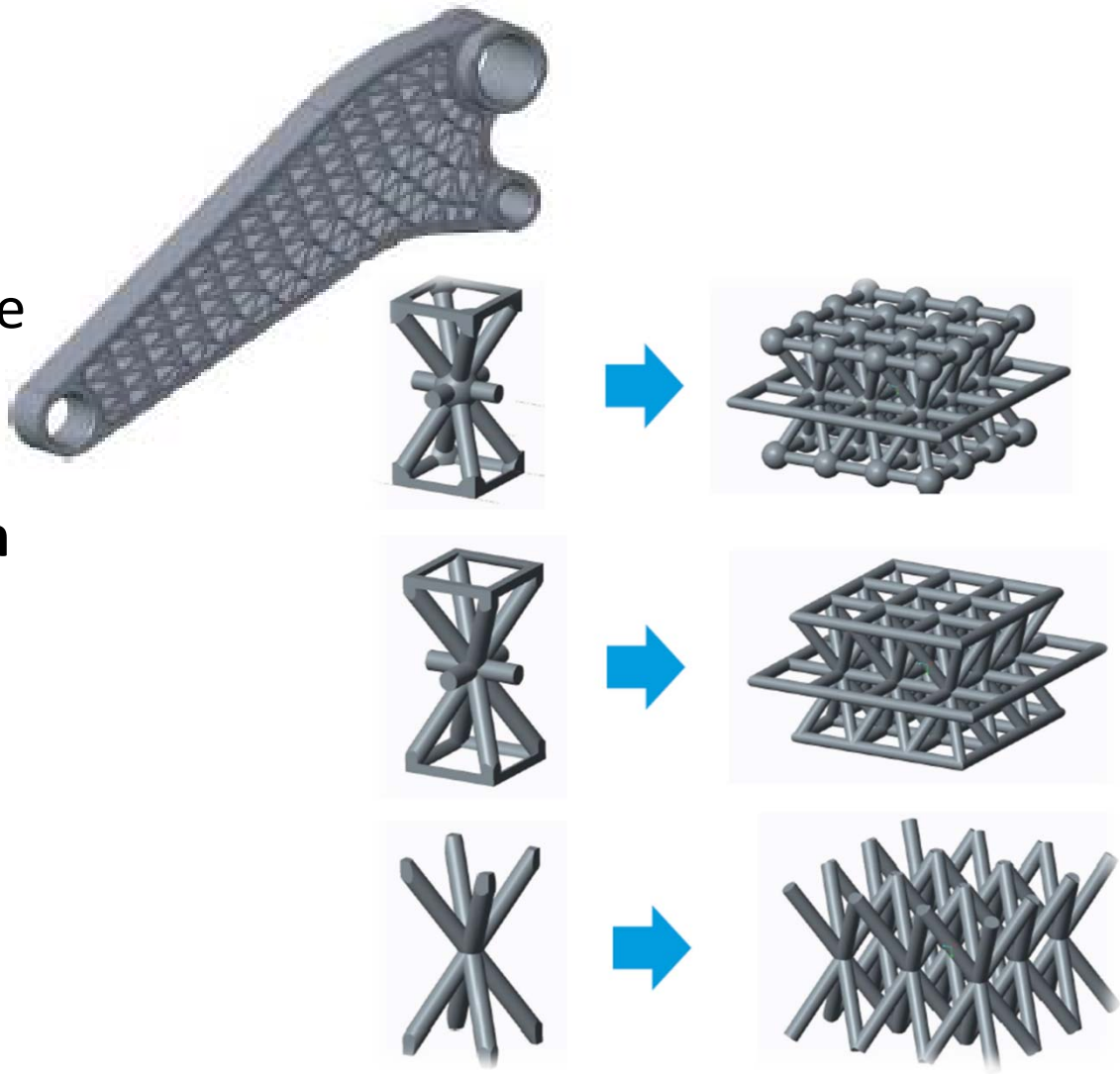




Lattice Structure Feature

- Automatic Lattice solid feature (NURBS) creations
- Library of lattices
- The cross section of the beams can be hollow, square or hexagonal
- The regeneration times are high for complex lattice structures
- **Simplified Representation** of Lattice Structures with datum curves is available and captured in the MBD
- 3D printers can accept Simplified Representation

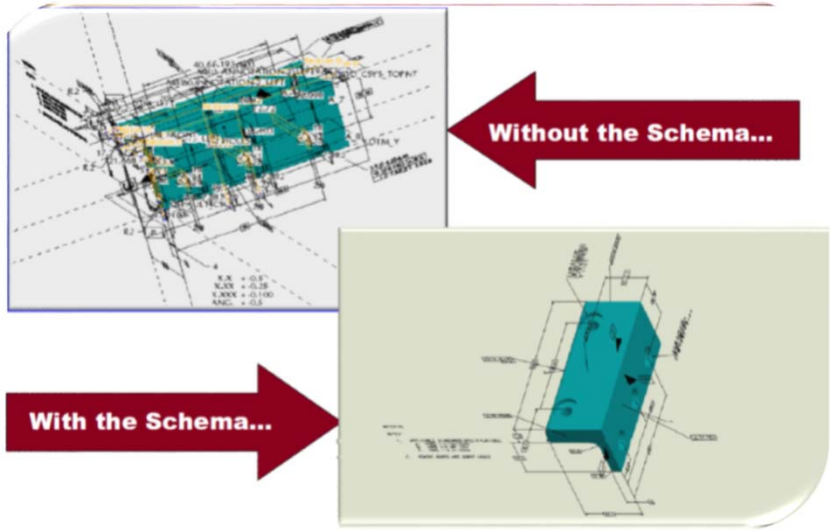


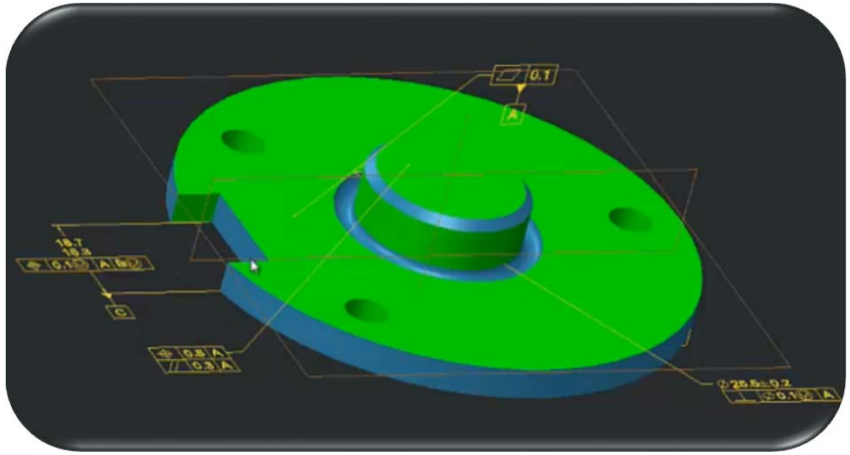


MBE Challenges

- Exchanging 3D geometry with metadata keeping semantic relations as they are defined in native CAD system is currently difficult (Step AP242, 3DPDF, JT, …)
- Lack of open/standard based data exchange mechanisms for mainstream and downstream applications, production processes and long term archiving

- Lack of designers knowledge for applying **Schema** (Overdoing GD&T Annotations)
- **GD&T advisor authoring tools** for complete and correct GD&T (GD&T Advisor)
- **Unbiased advise** on MBE implementations (Software vendors sometimes are bias)
- View of data is dependent on applications used to create data (Lack of universal viewers)
- Proprietary application file formats limit application choices
- **No accepted standards** for digital data storage and long term access
- Products may **outlive** software applications & computer hardware used to create them
- Current DoD acquisition specifications and guidelines are based on 2D drawings





Expected Benefits of MBE with PPI

- **Product Engineers working together with Manufacturing Engineers** create a 3D model with production process instructions
- ***Product characteristics PPI*** are linked to 3D models and extracted directly out of designs into conformance requirements
- Conformance requirements **(QIF)** are linked to **manufacturing process and inspection** instructions
- **As-built data** is delivered by Production along with product to customer and is made available for sustainment services to continue evolving the products' data during operation and maintenance services
- **Product design changes** follow the same data flow and automatically update downstream models, references and instructions.