Integrating Cost into Model-Based Engineering Environments

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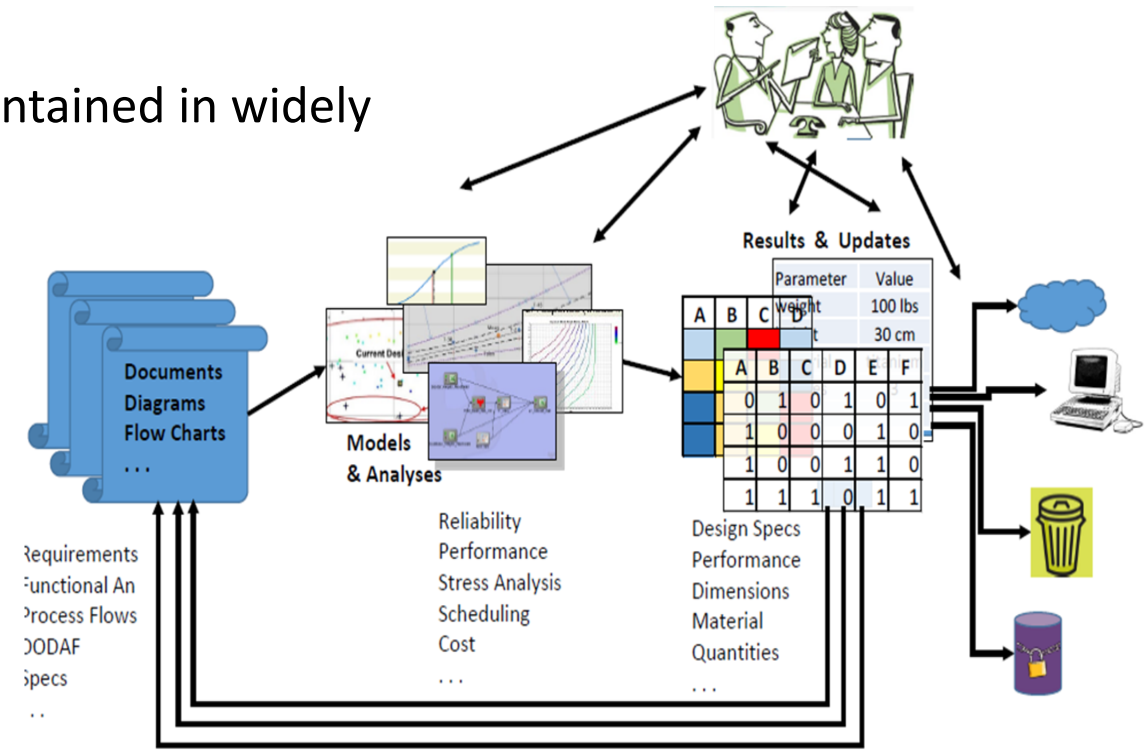
Abstract

- Model-based Engineering (MBE) incorporates digital models to represent system-level physical attributes and operational behavior throughout the system life-cycle.
- To date, many MBE efforts have focused on technical requirements with little emphasis on cost.
- Integrating cost models into MBE enables rapid exploration of design trades and associated cost impacts, traceability between requirements, cost targets and early identification of affordability issues.
- Here, we present the latest results from several ongoing efforts as a continuation of our 2019 presentation.

Historical Engineering Process

Document based actions:

- some model-based
- some connectivity
- artifacts (data) are maintained in widely dispersed locations
- cost is typically siloed



Activities are sequential and siloed. Cost is often a tertiary consideration.

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Current Evolution

Recent improvements in managing lifecycle change of products

- "Digital Thread" Integrated MBE
  - Engineering Design and Analysis
  - Driven by a multitude of factors:
    - Safety
    - Improvement (Quality)
    - Cost

Cost

- Cost is often NOT addressed concurrently in the change cycle
  - It's often a tertiary element AFTER the change is designed

Challenge:

- Make cost an element EARLY in the design phase and concurrent with other change activity

Make Cost Data Available EARLY to Decision Makers

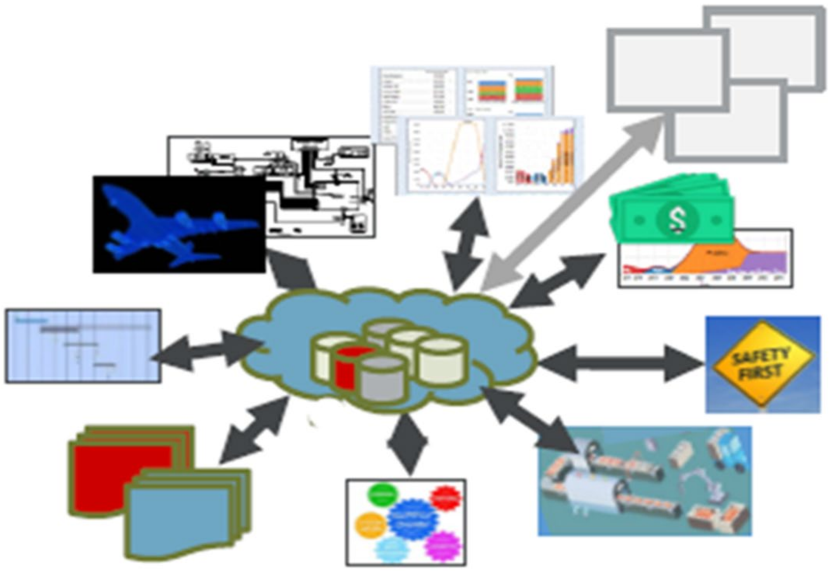
Integrated Model Based Engineering

Integrated MBE

- Central source of “Truth”
- Information is updated and made available in “real time”

MBE Data

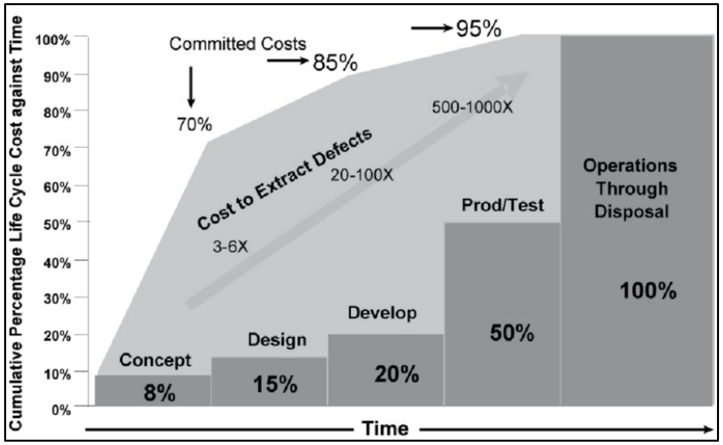
- Design parameters
  (ex. CAD Data, FEA, CFD)
- Logical/functional models
- Requirements (Specifications)
- Requirement verifications
  (Documentation)
- Notifications of changes
- Production Planning
- Cost ? Dated ☹



Activities are concurrent and results shared among stakeholders

Product Change

- Building on our previous work of integrating cost analysis for **production engineering***, our current effort looked to expand the use of cost analysis at the **product change** level, integrated into an MBE environment.
- PLM and change control elements used within the MBE environment are the means to communicate requested or required changes.
- Identifying the cost impact of the proposed change provides valuable insight into the viability of the change.
- Better to address change EARLY in life cycle rather than LATER due to increase in cost (as shown here).



Reference: INCOSE System Engineering Handbook v4

*presented at 2019 ICEAA Annual Workshop

Change is expensive, recognize the cost early

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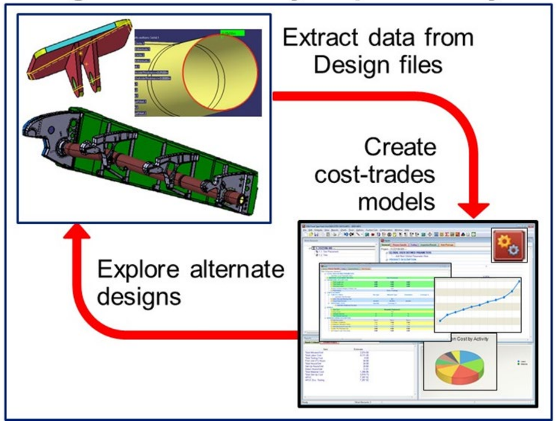
Current Effort

For this effort, we analyzed the cost impacts of changes to a major structural assembly of an airplane

In order to connect cost modeling tools to PLM tools, we first identified a variety of metrics that drive cost into the assembly

- Materials of construction
- Tolerances of features
  - Holes
  - Interfaces
- Numbers of fasteners
- Assembly method

Design / Affordability Impact Analysis



We considered complexity of the design change and determined two paths of integrated cost analysis

- Automated analysis for simple (minor) changes
- Manual intervention for complex (major) changes

Connect Cost Modeling Tools to MBE Environment to inform design trades

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Automated Cost Analysis (Minor Trade)

Prior to executing trade study analyses

- MBE PLM system (CAMEO) contained baseline configuration data
- A baseline cost model was developed in SEER-MFG

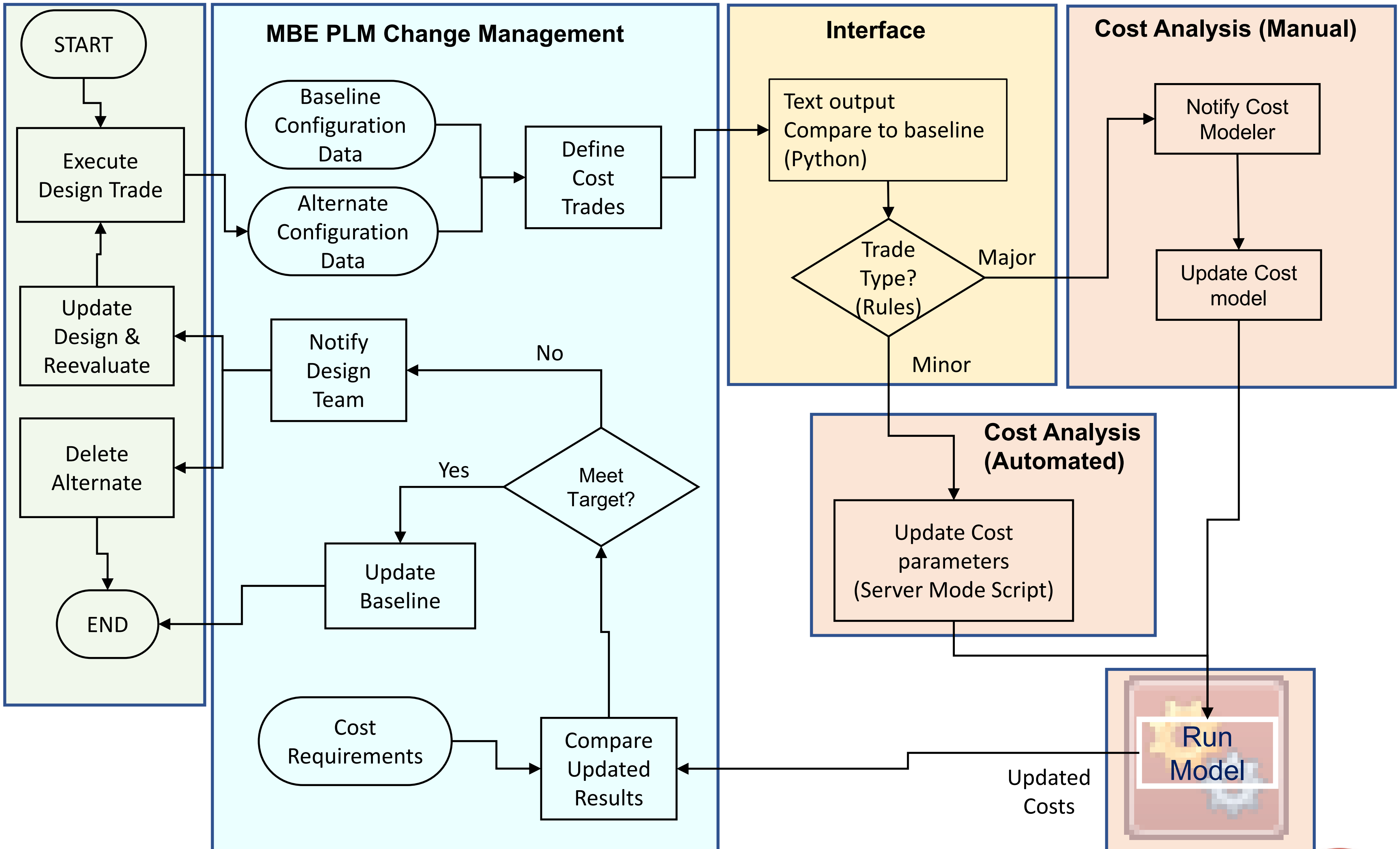
To analyze the proposed change

- PLM system was updated with alternate configurations

Automated:

- Data from the MBE PLM system passed to the Cost model
- Previously developed rules determined update method
- Cost model was updated ("reprogrammed") via text files passed from PLM system containing changes
- Cost model was re-run via a Server Script (i.e. no user interface required) with the new inputs to determine the new cost
- Updated cost passed back to PLM system for evaluation

Integrated Cost-Design Trade Study Process



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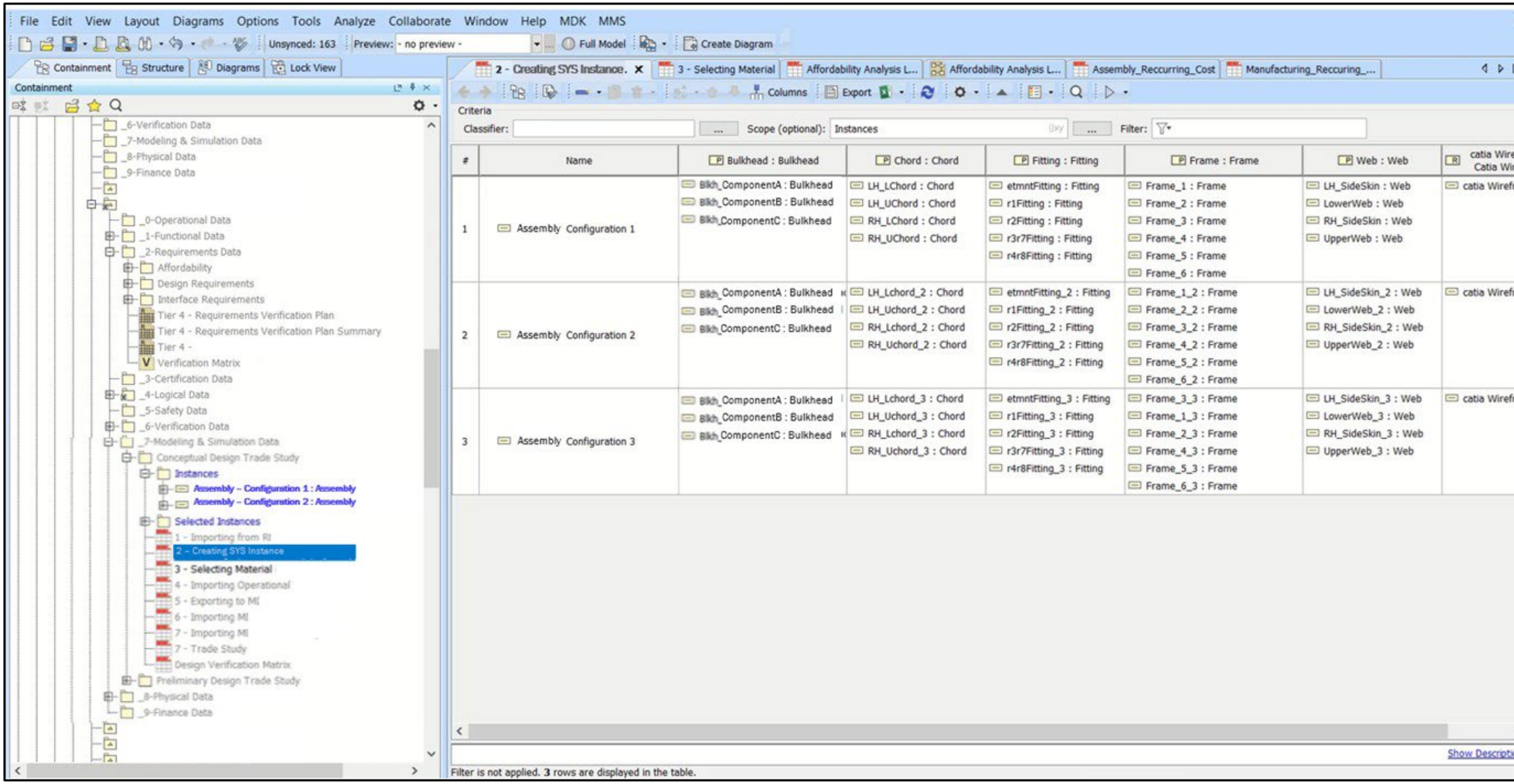
CAMEO Change Notification



Various configurations explored via Cameo model

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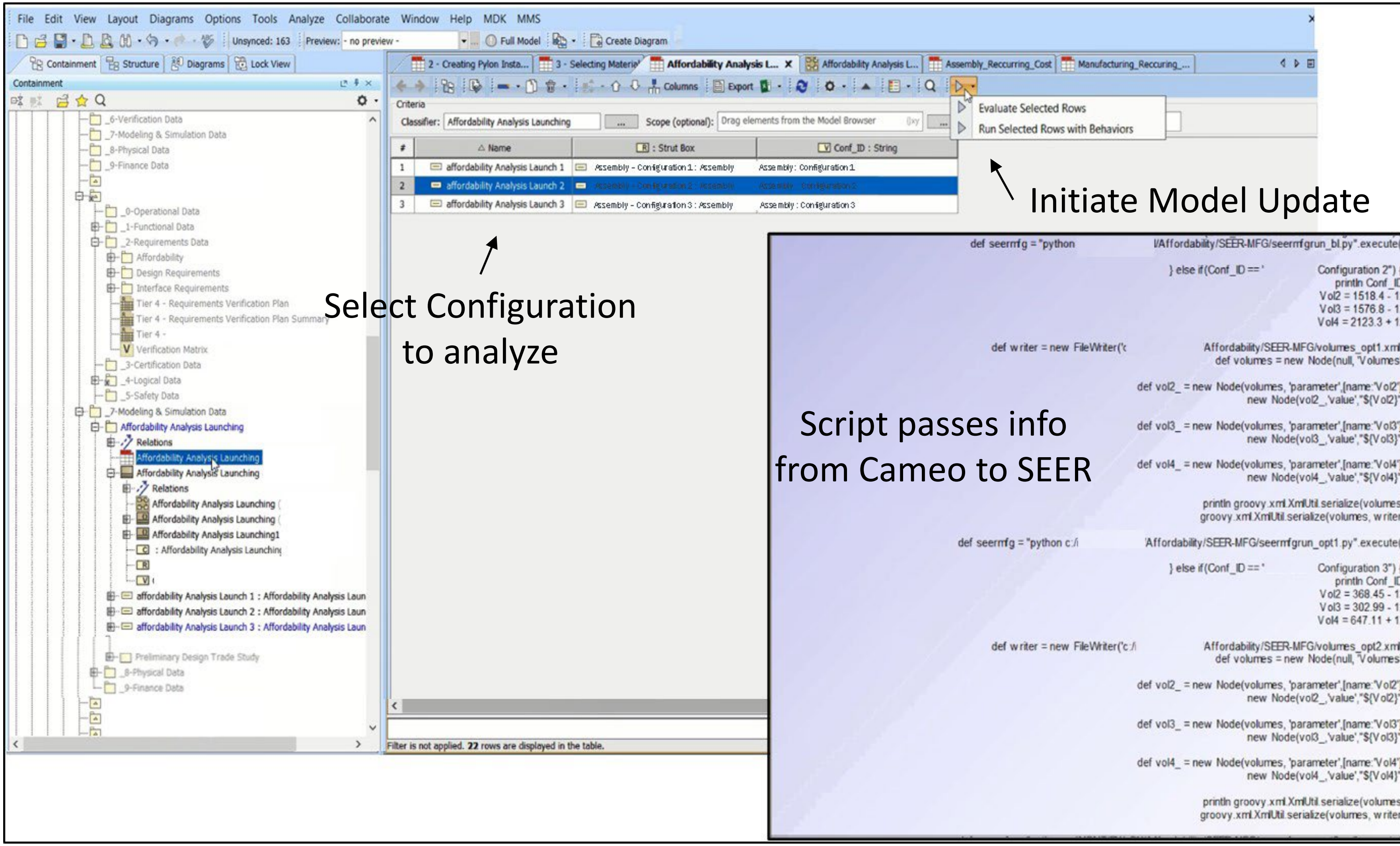
Launch Cost Analysis via Python



Script in Python to perform change detection of cost model inputs

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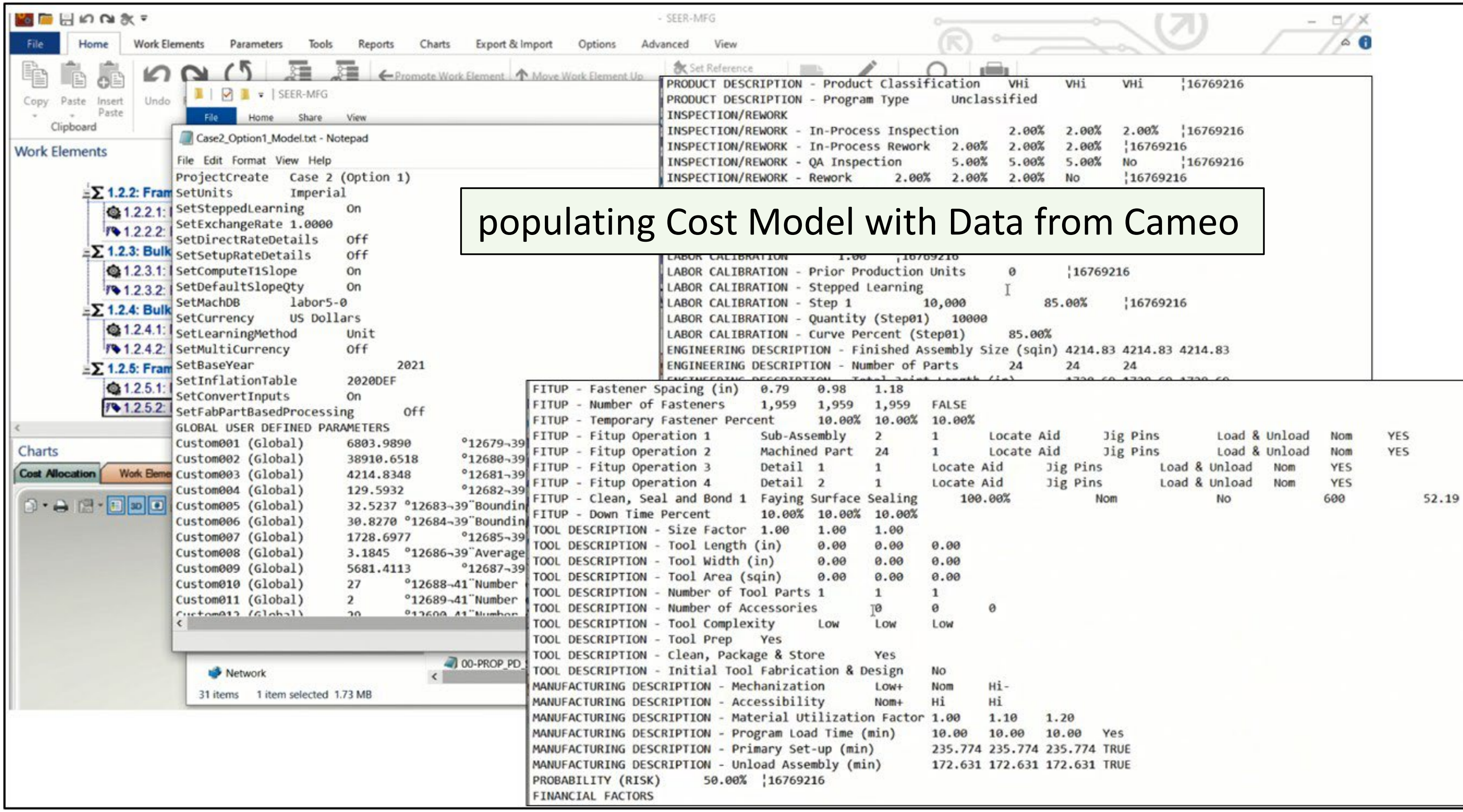
Server Mode Script



Command Line to by-pass GUI interface and to automate cost analyses

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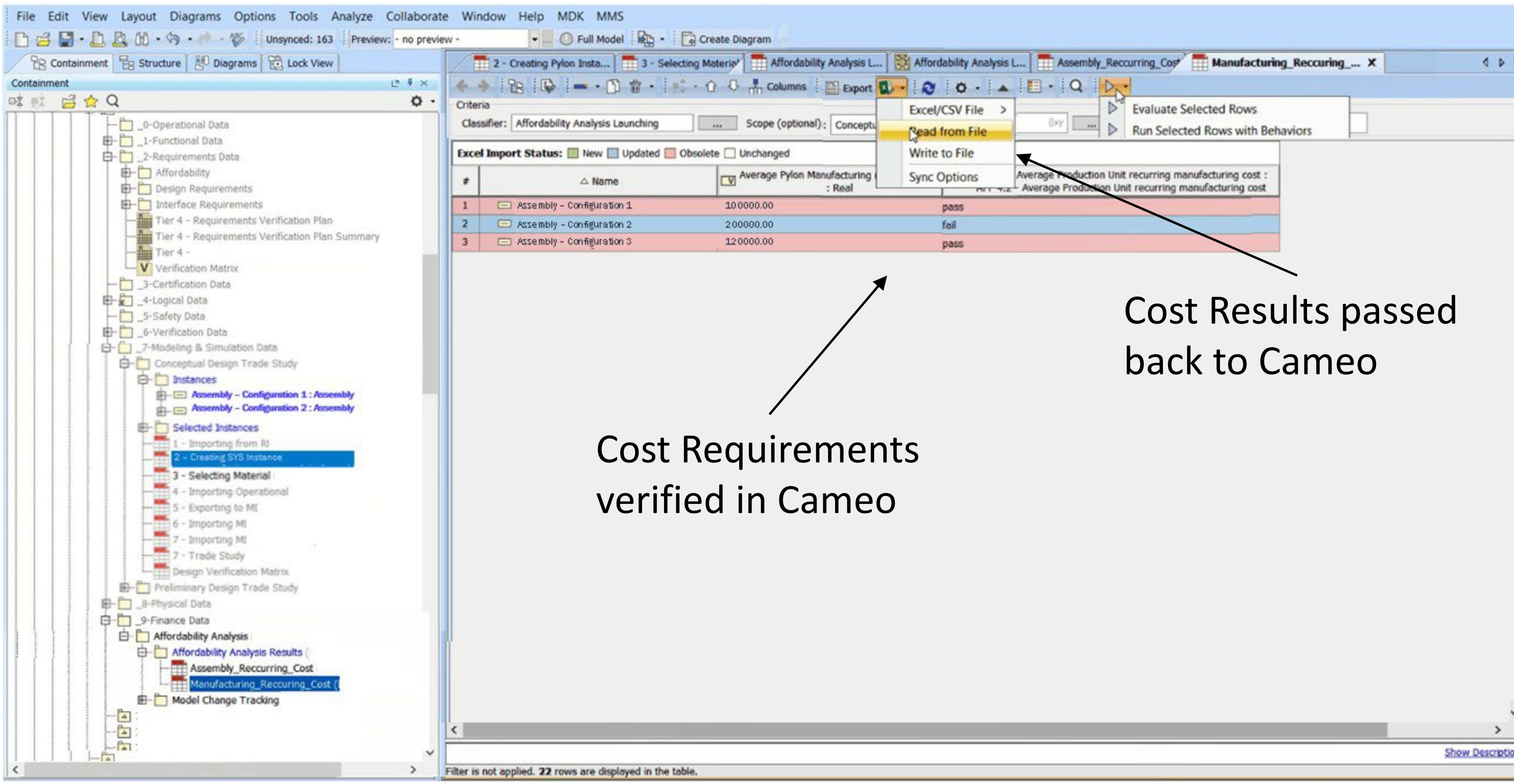
Verify Cost Requirements



Cost Results passed back to Cameo

Cost Requirements verified in Cameo

Notional results for presentation

Summary and Next Steps

Objective: Integrate cost models into MBE

- Enable rapid exploration of cost impacts of design trades, concurrent with other change activity

Progress to date

- Demonstrated a means to quickly, effectively and automatically determine cost impacts of proposed changes inside an MBE environment
- Focused on automated (minor) updates to cost models
  - Without manual intervention

Next Steps

- Integrate cost analysis of major design trades to provide timely feedback to design teams
- Evaluate integration of additional cost modeling methods and tools