Cost Engineering Enabled by PLM Standards

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Outline

- Issues and Requirements for Cost Modeling
- Standards Driving Cost Models Across the Lifecycle
- Cost Process and Data Governance

Costing Guidance

- Methods and Models for Lifecycle Costing
  - NATO TR-SAS-054 in 2007
  - Cost data collection is critical
  - Separately calls for use of
    - ISO STEP AP 239 PLCS and OASIS DEX implementations
    - US DoD Earned Value Management (EVM) reports from contractors
- US Government Accountability Office (GAO) Cost Guide
  - Best practices in cost estimating and earned value management
  - Standard Work Breakdown Structures

Major Cost Estimating Methods

- Analogy
  - To **existing** item with **actual** cost
  - **Subjectively** evaluate & add/subtract or modify
- Parametric
  - Statistically **infer** Cost Estimating Relationships (CERs) from **actual** costs
- Engineering Detailed
  - Activity based costing **with** resource constraints
- Actual
  - Cost output of **an** accounting system

MRL Matrix Cost Sub-Threads

MRL Working Group with input by CAM-I Target Costing group

*** MRL = DoD Manufacturing Readiness Levels**

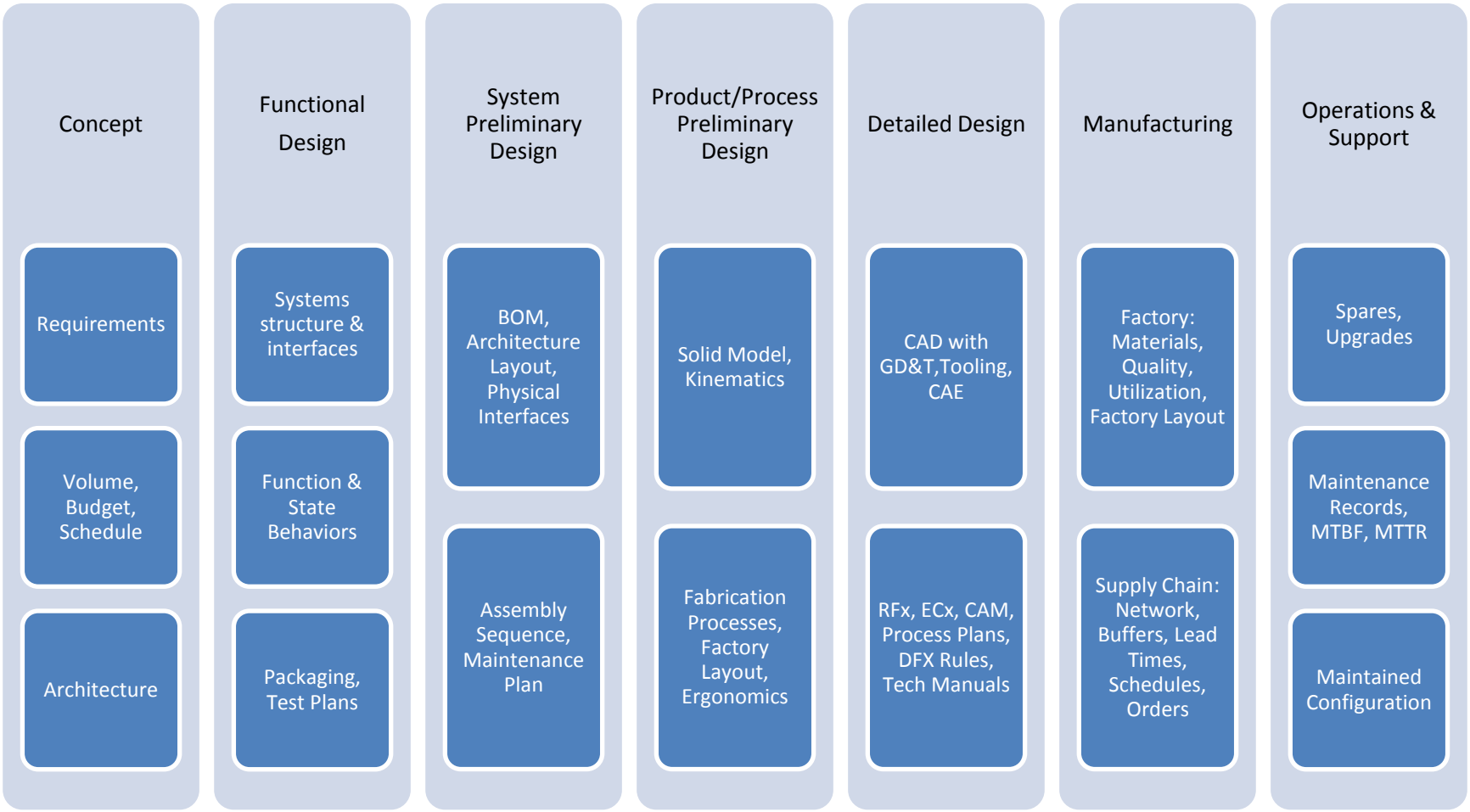
Sub-Thread	MRL 3	MRL 4	MRL 5	MRL 6
Production Cost Knowledge (Cost modeling)	•Technology cost models developed for new process steps and materials based on engineering details. •High-level process chart cost models with major production steps identified . •Cost driver uncertainty ranges assigned. •Target Cost goals and risks identified	•Detailed process chart cost models driven by process variables. •Manufacturing, material and specialized reqt. cost drivers identified. •Cost risk assessment begun.	•Detailed end-to-end cost model for major system components includes Materials, Labor, Equipment, Tooling/STE, setup, yield/scrap/rework, WIP, and capability/capacity constraints. •Component simulations drive cost models.	•Cost model inputs include design requirements, material specifications, tolerances, integrated master schedule, results of system/subsystem simulations and production relevant demonstrations. •Cost risk assessment complete.
Cost Analysis	•Sensitivity, Pareto analysis to find cost drivers and production representative scenario analysis to focus S&T initiatives and address scale-up issues. •Cost estimates include uncertainty.	•Material, manufacturing, and specialized reqt. costs identified for design concepts. •Producibility cost risks assessed and manufacturing technology initiatives identified to reduce costs.	•Current state analysis of cost of design choices, make/buy, capacity, process capability, sources, quality, key characteristics, yield/rate, and variability.	•Cost analysis of mfg future states, design trades, supply chain/yield/rate/SDD/technology insertion plans. •Allocate cost targets. •Cost reduction and avoidance contract incentives identified.

Producibility Cost Modeling and Simulation Needs

NDIA Joint Systems Engineering and Manufacturing Committee
Sub-committee on Modeling and Simulation

	requirements analysis	**functional analysis & allocation**	**system preliminary design (physical)**	**product/process preliminary design**
MRL	3 to 4	4 to 5	5 to 6	6 to 7
Cost Modeling	* cost driver identification * analysis of technology maturity impact on cost risk * cost estimates based on similar to complexity relationships, analogies, and assumptions * prediction of size and weight envelope constraint impact on producibility and cost * prediction of cost impact of emerging technology maturity * probabilistic analyses to define cost uncertainty for cost estimating relationships	* cost per function modeling and analysis * identification of architecture structure and interface complexity drivers * analysis of functional interaction impact on cost and risk * prediction of manufacturing learning curve assumption impact on cost * prediction of industrial base maturity (location, capacity, process maturity, etc.)	* identification of cost dependencies per component (density, complexity, material, assembly tolerances, etc.) * analysis of system integration costs (interconnects, yield losses, etc) due to assembly process * automated EBOM cost analysis	* prediction of cost per geometric features and key characteristic tolerance ranges * prediction of alternative material cost impact * prediction of tooling/fixturing costs * prediction of top down component assembly sequencing costs * analysis of labor and overhead rate impact * prediction of yield impact on component manufacturing cost, cycle time, and capacity constraints * automated MBOM cost analyses

Information Across the Life Cycle

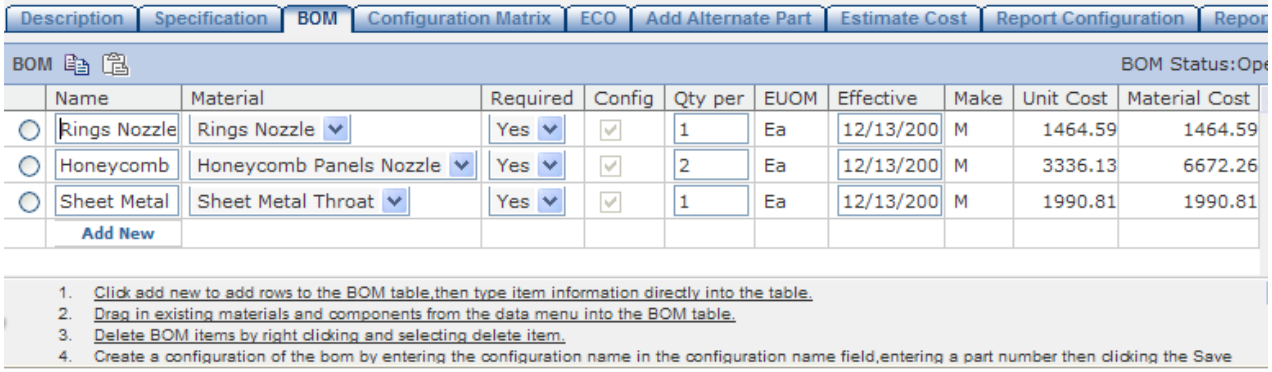


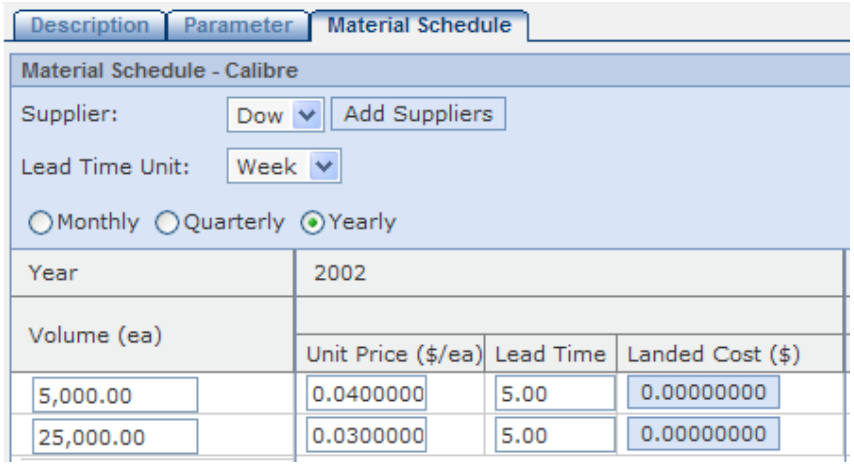
System Architecture Tools

- Architecture Frameworks
  - DoDAF and MoDAF
  - CADM mapping to AP233 for legacy
  - Complexity measures like number of interfaces drive cost models
- Requirements Management
  - STEP AP233 for property-based requirements
- Systems Engineering
  - SysML mapping to AP233

Materials and BOM

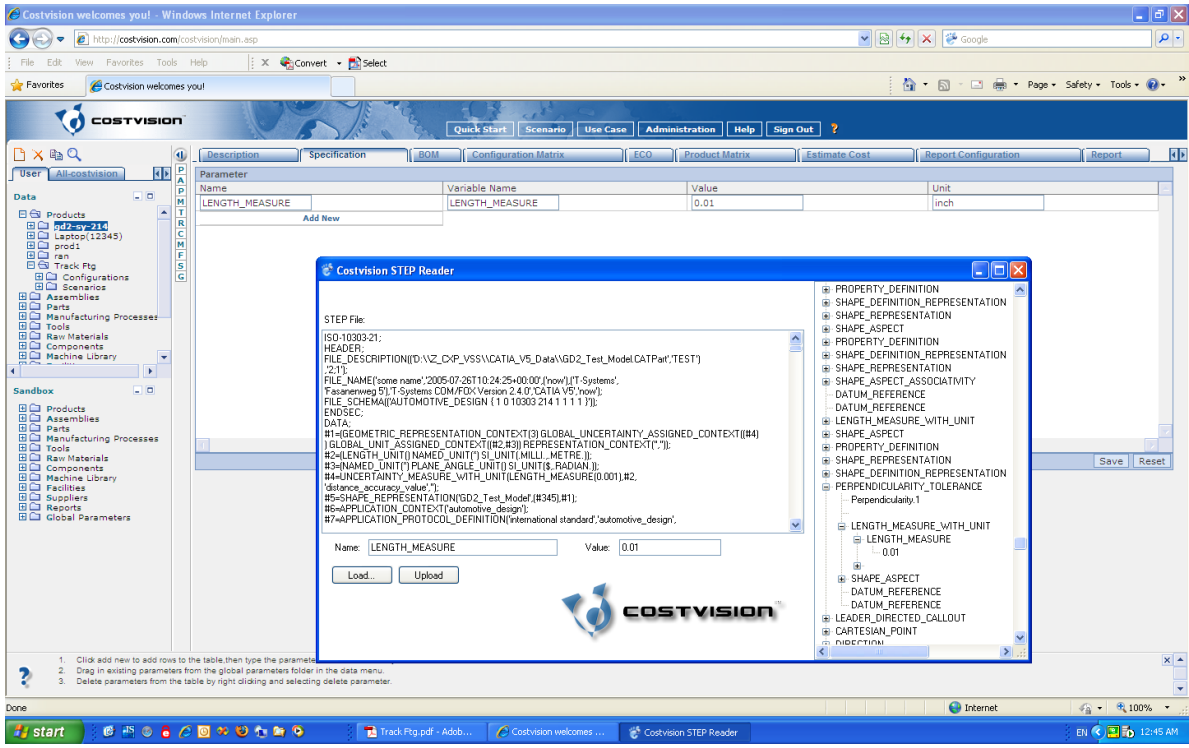
- BOM
  - Raw Materials
  - Components
  - Supplier Parts/Assemblies
  - Sub-assemblies
  - Multi-level
- Material Library
  - Suppliers
  - Volume pricing
  - Lead times
  - Price schedules
  - Landed costs





CAD Product Manufacturing Information (PMI)

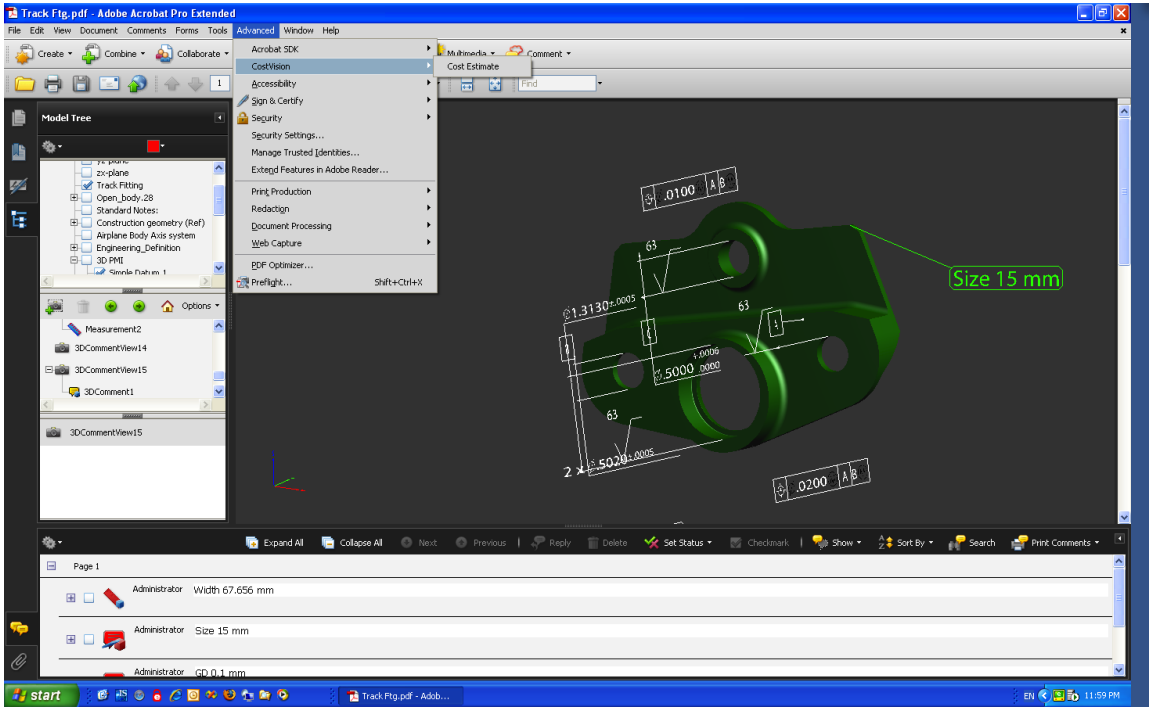
- Neutral STEP CAD format
- Cost Drivers
  - Geometric Dimensioning & Tolerancing (GD&T)
  - User defined attributes
  - Material name



STEP Part 21 File with GD&T extracted and web service sent to drive cost model

Lightweight CAD Viewer

- For non-CAD casual users
- View & Measure 3D Models
- Translates in all major CAD formats
- Cost Drivers
  - Material
  - Dimensions
  - Annotations



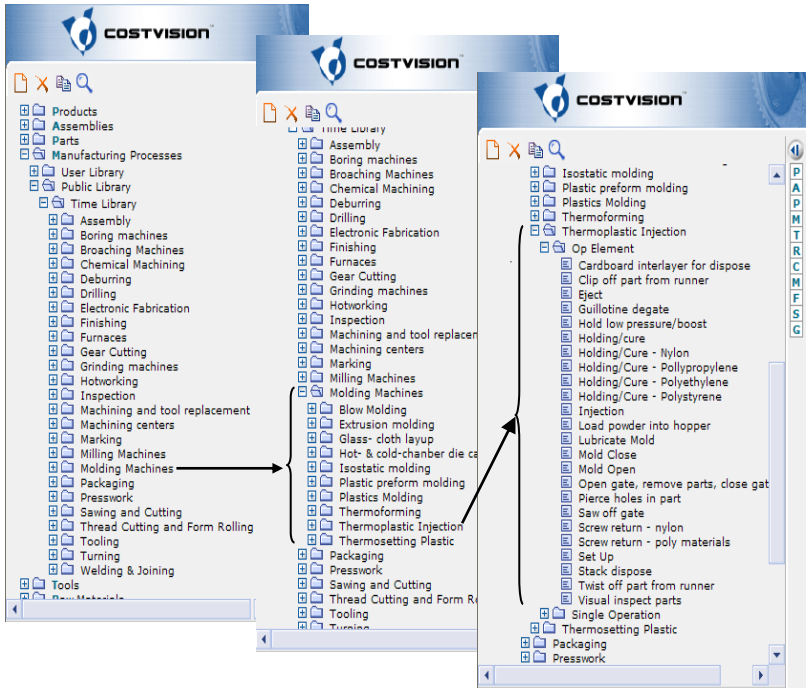
Lightweight viewer with annotations extracted and web service sent to CostVision

Process Models for MRLs

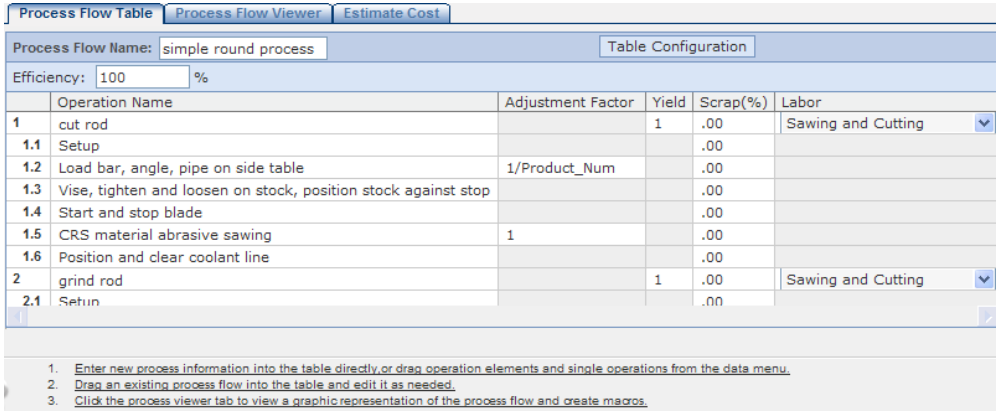
MRL Process Model	3 Process Chart	4 Process Details	5 Value Stream Map	6 Manufacturing Simulation
Information Contents	Tooling Equipment Labor Materials Times (set-up, cycle)	Parts list Equipment types Skills Facility Rates & Yield	Rework Scrap WIP Capacity Learning curve	Requirements/specs Tolerances Master schedule Facility plans Training resources
Standards Needs	Graphical symbols Neutral format	Process capability Product-Process integration	Process capability requirements & constraints Capacity constraints	Simulation Trade-studies
Purpose	Scale-up issue analysis Cost driver analysis Fund initiatives to avoid costs	Producibility assessment Design concept selection Component selection	Make vs buy Quality strategy Design validation	Value stream analysis Supply chain plan Technology insertion plan

Manufacturing Process Plans

- Standard Operation Library
  - IE time standards
  - MIL-STD +-5% accuracy
  - Mech., Elec., Assembly

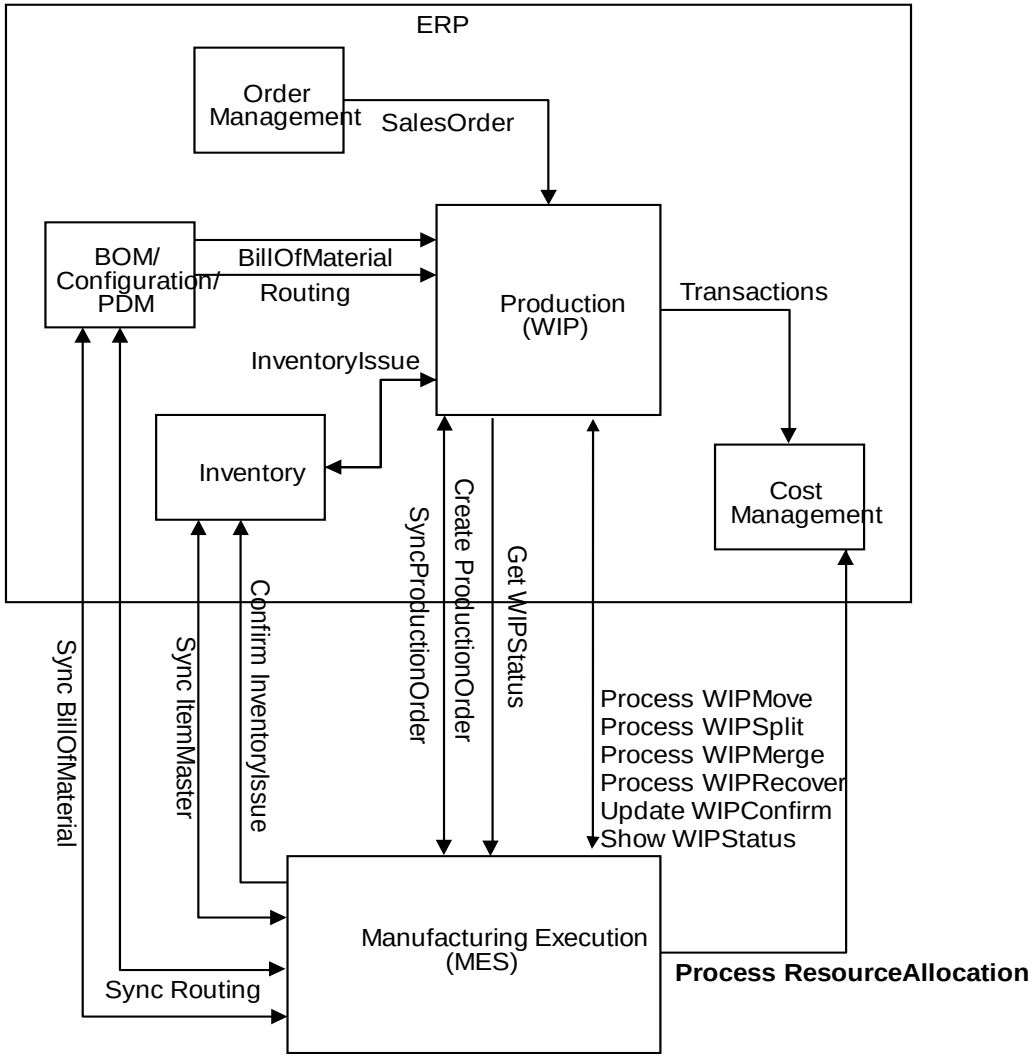


- Mfg Process Flow
  - Steps, yield, scrap
  - Labor, tools, equipment
  - Integrate to simulation
  - Store in library



OAGIS Shop-Floor Information

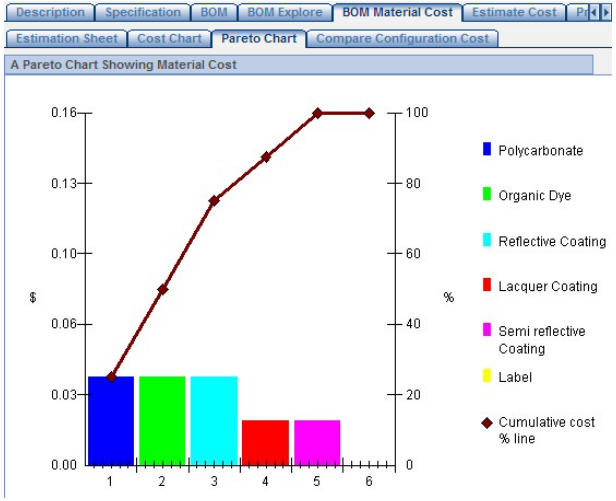
- COMET Program
  - SCRA, Boeing, CostVision
- Cost Driver Information in OAGIS
  - RFQ, BOM, Routing, WIP, Resource Allocation, InventoryIssue
- OAGIS to connect to ERP and MES transactional systems



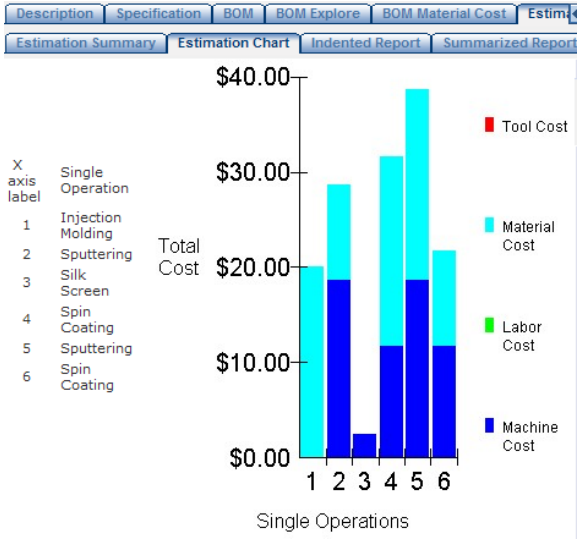
Should Cost Analysis

- Compare different manufacturing approaches
  - Volume
  - Cost
  - Lead-time
- Reports
  - Income statement
  - Material usage
  - …
  - Time-based

BOM



Process



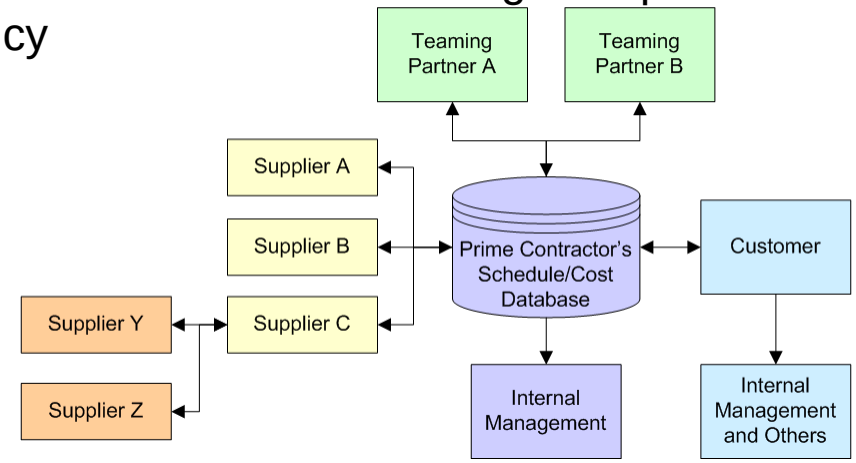
Operations and Support (O&S)

- Cost drivers from AP239 PLCS and OASIS DEX's
  - LOGSA (MTBF, MTTR)
  - Task_set (maintenance plans, resources, costs)

- DoD O&S Work Breakdown Structure (WBS)
  - Standardizing along with Mil-HBK-881a systems WBS
  - Other standard WBS in development like software, embedded software, facilities, etc.

Earned Value Management (EVM)

- US Government contract
  - Cost & schedule baseline & performance reporting
  - Program/project management
- Standards for EVM Systems
  - ANSI/EIA-748-A EVMS Guidelines
  - XML Schema based on ANSI X.12 806 & 839
    - NDIA Program Management Systems Committee XML Working Group
    - Defense Contract Management Agency
- EVM Central Repository
  - Required for major programs
  - Used for analysis
  - PM software vendors support
- Mapping EVM into 233
  - OWL Reference Data
  - Integrated Cost, Schedule, Engineering Models
- Need to map EVM Schema and 233-based Schema
  - Maintains upward compatibility and provides future extensions



Total Cost of Ownership

- Operations Model
- Reliability Availability & Maintainability
- Combine with R&D and Manufacturing cost models
- Enables cross-lifecycle cost trades
  - Should we increase material quality and price that increases development and manufacturing cost but will reduce operations and support costs?

Defense Manufacturing Networks: IT Constraints

- Each company has different software applications for a given function
  - Need data format & interface (API) standards
- Small companies with primitive IT
  - Need common tools like internet browser, Excel, Adobe Acrobat
- Defense agency and prime desktops and firewalls are locked down
  - Can only install plug-ins and use HTTP
- ITAR and Export Controls
  - Defense article design & mfg info cannot leave US or be accessed by non-US resident
- Proprietary Information
  - Some design, mfg., cost, capability, capacity info needs owner-defined access control

Cost Data Governance

- Traditional CRUD
  - Create, Read, Update, Delete
- Other operations
  - Where-Used, Publish-Subscribe, Execute
- Control by
  - Effectivity, Person, Organization, Context, Security Classification,
  - Access Frequency & Total # Accesses
- At each cost object, relation and attribute (classes and instances)

Supplier Working Relationship Index (SWRI)

- Cost Variables in the SWRI
  - Help company gives to supplier to reduce costs
  - Supplier given flexibility to meet cost/price targets
  - Company shares savings with suppliers' cost reduction proposals
  - Company covers sunk costs on canceled or delayed programs
  - Company concern for supplier profit margin when asking for cost reductions
  - Suppliers' opportunity to make acceptable return over long term
- SWRI accounts for 66% of automotive OEM profitability

*Prof. John Henke, Oakland University

Conclusions

- Cost models need to interoperate with models from other engineering domains
- Standard data models and interfaces increase accuracy, lower costs, increase flexibility
- Existing standards have much of the capability needed, and can be extended to fill gaps (e.g. adding cost drivers and data)
- Cost process and data governance best practices enhance collaboration and profitability