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The Lifecycle Integration Framework – Extending Affordability Simulation through Cost and Engineering Model Interoperability

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Zachary L. Jasnoff

PRICE Systems, L.L.C.
17000 Commerce Parkway – Suite A
Mt. Laurel, NJ 08054
Zachary.Jasnoff@PRICESystems.com

“Resource management issues continue to be the number one challenge to organizations that practice project management.”


A BENCHMARK OF
CURRENT BUSINESS PRACTICES
cbp
the center for business practices

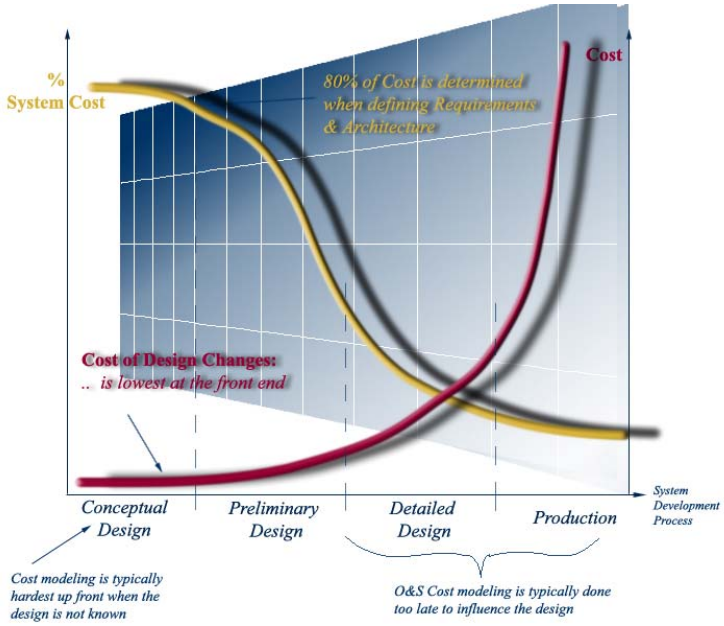
According a 2009 Study by the Center for Business Practices, the top resource challenges that threaten organizational effectiveness are:

1. Resource capacity planning is poor
2. Not enough appropriately skilled resources
3. Too many unplanned requests for resources
4. Resource use is not optimized
5. Effort estimation is inaccurate

Resource Management Challenges, A BENCHMARK OF CURRENT BUSINESS PRACTICES

Problems with Traditional Resource Estimating/Management

- Gap between designers and estimators
- Lack of visibility into Total Ownership Cost when early design decisions are made
- Amount of time it takes to get cost feedback
- Reluctance to change design late in the development cycle
- Inability to follow a repeatable process
- Lack of in-grained design trade-offs in the engineering process

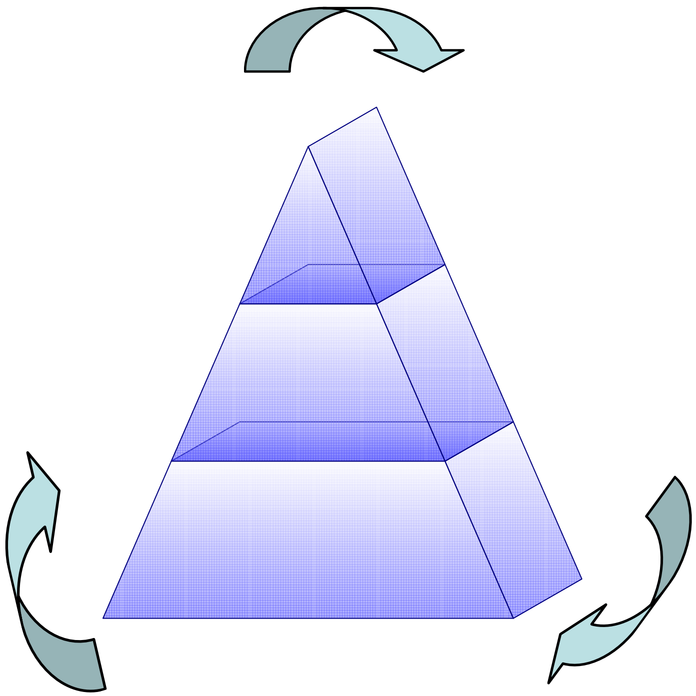


Today's Resource Estimating Landscape

- Integration of performance models is needed to rapidly assess the trade space treating costs as any other design variable.
- Need to estimate more complex "Systems of Systems" projects
- "Systems of Systems" modeling drives the need for integrated cost models. Without model integration, "Systems of Systems" modeling is difficult and time consuming
- Integrated cost models must tie all cost elements (Hardware and Software) across the lifecycle.
- Need ability to rapidly build new cost models for integration into a Systems of Systems framework.

Tying Cost to Performance
Cost as an Independent Variable

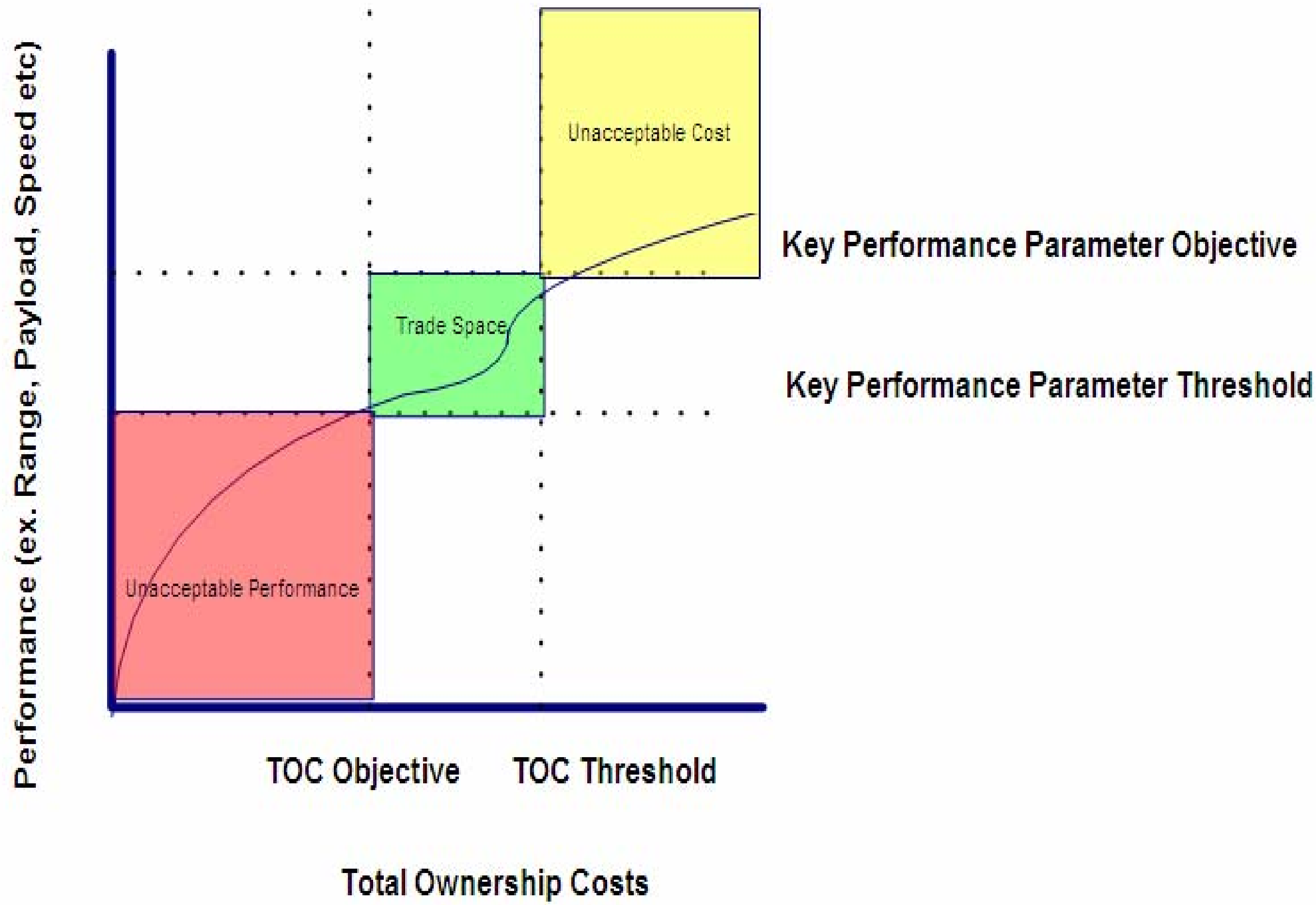
- **Cost as an Independent Variable (CAIV)**
  - CAIV means a traceable connection among requirements, cost estimate, and budget
  - CAIV means performing cost, schedule and performance trade-off analysis early and often .
  - Development of a robust trade space and analysis of alternatives
  - Focuses on life cycle costs



Example of cost/performance trade parameters

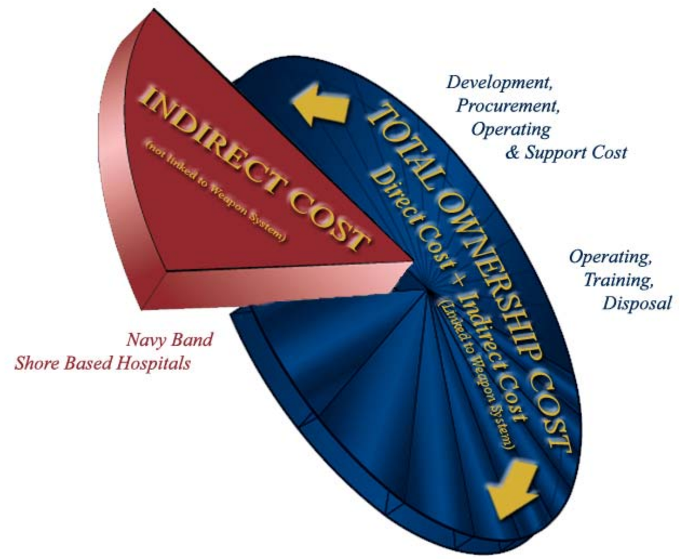
Tie Performance Models to Cost Models to Establish the Trade Space

Resource Optimization – Cost As An Independent Variable (CAIV)



Tying Performance to Lifecycle – *Total Ownership Costs*

- Defines the costs of a system on a lifecycle basis
- Cost is treated as a function of design and it is only through repeated design-cost estimate iterations that one can achieve a design that meets affordability goals.
- Cost/performance trade-offs can be slow, error-prone, un-repeatable and cumbersome This hinders them from becoming an in-grained part of the engineering process.



Optimization routines are needed to fully explore the cost/performance trade space

Optimizing Resource Estimating/Management

- **Bridging the gap between designers and estimators**
- **Providing visibility into Total Ownership Cost**
- **Speeding up traditional design-to-cost**
- **Providing the ability to make feasible design decisions**
- **Creating the opportunity for a repeatable process**
- **Enabling integrated design-to-cost to become an in-grained part of the engineering process**

But…..How Does This Hold Up in Practice?

Resource Challenges in the DoD Environment

According to the US GAO - While the Department of Defense's (DoD) acquisition process has produced the best military systems in the world, it is also prone to yielding some consistently undesirable consequences in these programs – cost increases, late deliveries to the war fighter, and performance shortfalls

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Navy cancels third LCS amid cost overruns

By Christopher P. Cavas - Staff writer
Posted : Friday Apr 13, 2007 17:09:43 EDT

The Navy on Thursday canceled one of two new Littoral Combat Ships being built by Lockheed Martin.

Calling Lockheed's best offer "unaffordable," Rear Adm. Chuck Goddard, the Navy's program executive officer for ships, said the service initiated a "termination of convenience," on LCS 3, the second of two LCS ships that were to have been built by Lockheed.

The Navy was seeking to renegotiate the construction contract for the ship, awarded in June 2006, from a cost-plus agreement to a fixed-price incentive deal. Navy Secretary Donald Winter, following revelations that Lockheed's first LCS was $130 million to $155 million over its planned $220 million budget, issued a stop-work order on the LCS 3 in January ...d it in March pending a renegotiated contract meant to hold down ...st increases.

U.S. NAVY

The Navy has issued a stop-work order on the LCS 3 after talks with its builder, Lockheed Martin, stalled. Here, the first Littoral Combat Ship, Freedom (LCS 1) makes a spectacular side launch during her christening at the Marinette Marine shipyard in Marinette, Wis., in September.

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DoD Blasts Lockheed Missile Program

Associated Press | June 07, 2007

WASHINGTON - The U.S. Defense Department on Wednesday said a $5.8 billion Lockheed Martin Corp. cruise-missile program faces termination if its performance does not improve soon.

The Joint Air-to-Surface Standoff Missile, or JASSM, drew criticism during a major review triggered by cost overruns. Recent test failures led the Pentagon to seek further review, rather than immediate restructuring, chief Air Force weapons buyer Sue Payton said.

Over the next 30 days, the U.S. Air Force and the Pentagon will decide whether to keep the program, or cancel it and seek other options. For now, the Air Force believes the program is still probably the best way to go, Payton said. But Bethesda, Maryland-based Lockheed Martin must convince the government it has a way to fix navigation glitches and improve reliability.

U.S. Navy, General Dynamics continue contract talks

Tue Oct 2, 2007 12:44am BST

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By Andrea Shalal-Esa

WASHINGTON, Oct 1 (Reuters) - General Dynamics Corp (GD.N: Quote, Profile, Research) and the U.S. Navy met on Monday to discuss switching to a fixed-price contract for the company's shore-hugging Littoral Combat Ships (LCS) after the program was between 50 percent and 75 percent over budget.

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Some History…..1996 – DoD CAIV Flagship Programs

PROGRAM	PROGRAM DESCRIPTION	PROGRAM STATUS
EELV	A more cost-effective space launch vehicle for medium and heavy lift requirements	Pre-EMD start Dec. 1996
AIM-9X	Next generation Sidewinder air-to-air missile	EMD start Jan. 1997
TACMS-BAT P3I	Upgrade of tactical ground-to-ground missile - new seeker	Currently in PDRR EMD start in 1998
MIDS	Third generation secure, jam-resistant, communications system for NATO family	EMD contract awarded in Mar 1994 Restructured Jun. 1994 CDR in-process
JASSM	Long-range air-to-surface standoff missile	Entered 2-year competitive PDRR
CRUSADER	155MM self-propelled Howitzer and armored resupply vehicle	Completion of PDRR in FY 2000 Single contractor team
JSF	Advanced Strike Fighter Aircraft	Pre-PDRR
SBIRS	Space-based infrared surveillance system for missile defense	Entered EMD for GEO in FY 1996 PDRR for LEO with MS II in FY 1999

Selected 1996 DoD CAIV Flagship Programs – Where are They Now?

EELV (2007)

Program Cost +79%
Unit Cost +135%
Nunn McCurdy Breach

Source: 2001 Raytheon Company.

AIM-9X (2002)

Unit Cost -2.5%,
mature technology

Source: JASSM Program Office.

JASSM (2002)

Program Cost +93%
Unit Cost +7.2%
Nunn McCurdy Breach

SBIRS High (2007)

Program Cost +250%
Unit Cost +315%
Nunn McCurdy Breach

Selected 1996 CAIV Flagship Programs – Where are They Now?

Crusader → Terminated, technology now part of FCS

JSF → Program Cost +14%
Unit Cost +32%

- Almost all of the original 1996 CAIV Flagship programs have experienced unacceptable cost growth including Nunn-McCurdy breaches.
- What about more recent programs?

CAIV in Today's Environment (2008) – Littoral Combat Ship Example

Lockheed Martin LCS 1 → Program Cost + ~ 70 - 90%

Lockheed Martin LCS 3 → Terminated 2007

General Dynamics LCS 2 → Program Cost + ~ 70- 90%

General Dynamics LCS 4 → Terminated 2007

Case In Point: Littoral Combat Ship

- **LCS was a CAIV Program starting the Pre-Concept Phase**
- **Strict Key Performance Parameters**
  - Range
  - Payload
  - Speed
- **Strict Cost Parameter**
  - Capped at $220M per ship
- **Awarded May, 2004**
- **Lockheed Martin First ship delivered September 2006**
- **General Dynamics First Ship under construction**
- **In 2007, the Navy cancelled LCS ships 3 through 6**
  - $130-$150 over $220 per ship budget
  - CAIV target exceeded

Lockheed Martin LCS

General Dynamics LCS

Why is CAIV Failing as a Resource Management Tool?

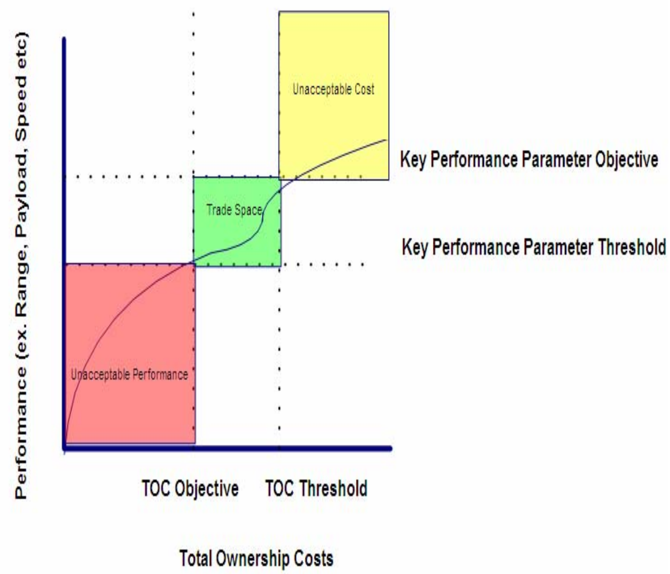
- CAIV is often not extended over the program lifecycle
  - CAIV proves most used during concept and preliminary design phase for:
    - Sizing of the initial design
    - Linkage of performance parameters to cost.
    - Optimizing design for Key Performance Parameters in relation to cost.
- CAIV seen as discriminator for proposal win, but does not extend into detail design and manufacturing
- No consistent framework exists to link engineering tools to cost tools over the program lifecycle
- Cost impact of engineering and programmatic changes not fully evaluated within engineering tools.

Fixing CAIV – Linkages between tools needed!

- Once programs enter final design, automated linkages between CAD systems and parametric cost models are needed to give engineers early and continuing feedback on CAIV target objectives.
- Linkages should continue over the entire lifecycle.
- Without these linkages, it is difficult for engineers to understand the cost impacts associated with detail design thus CAIV targets are easily exceeded.
- At the program level, automated linkages would give Business Managers a complete view of the program.

Extending CAIV Effectiveness

- For CAIV to remain effective across all program phases, it must be integrated with engineering tools
- Avoid "disconnect" between final design and CAIV targets.
- Need to integrate the need for engineers and cost estimators to jointly understand the impact of design on cost in real time – and quickly evaluate alternatives.
- CAIV is extended through cost interoperability – tying cost models directly with engineering design tools.



TruePlanning Suite

- Meeting Resource Management Estimating Challenges Across The Lifecycle

Pre-concept	Concept	Development	Demonstration	Produce/Deploy	O&S	Disposal
Top-down	Top-down	Parametric	Parametric	Detailed	Detailed	Detailed

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Project Portfolio Management

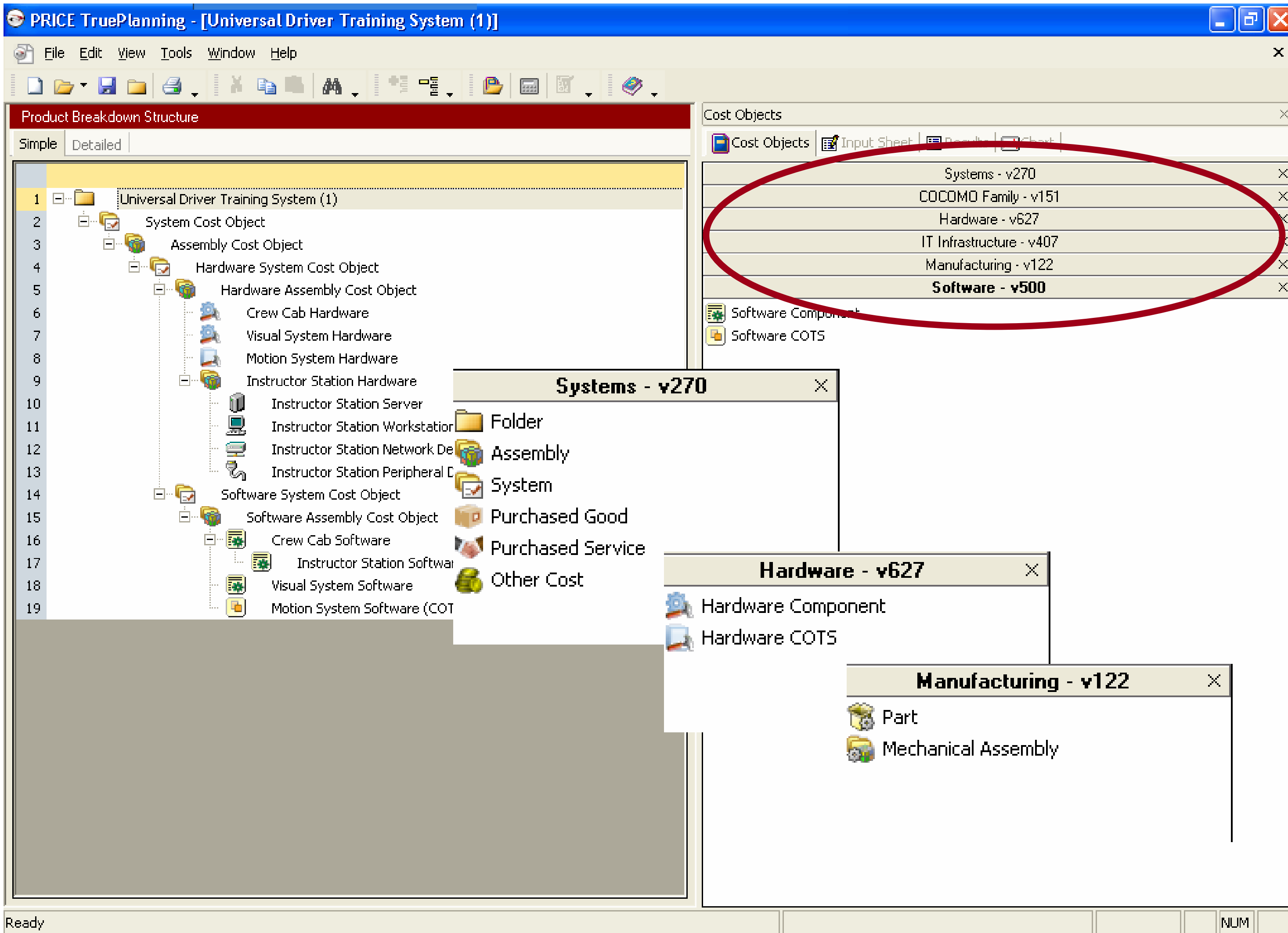
Application Lifecycle Management

Product Lifecycle Management

Enterprise Resource Management

TruePlanning Suite

A single framework to estimate and manage costs thru the lifecycle



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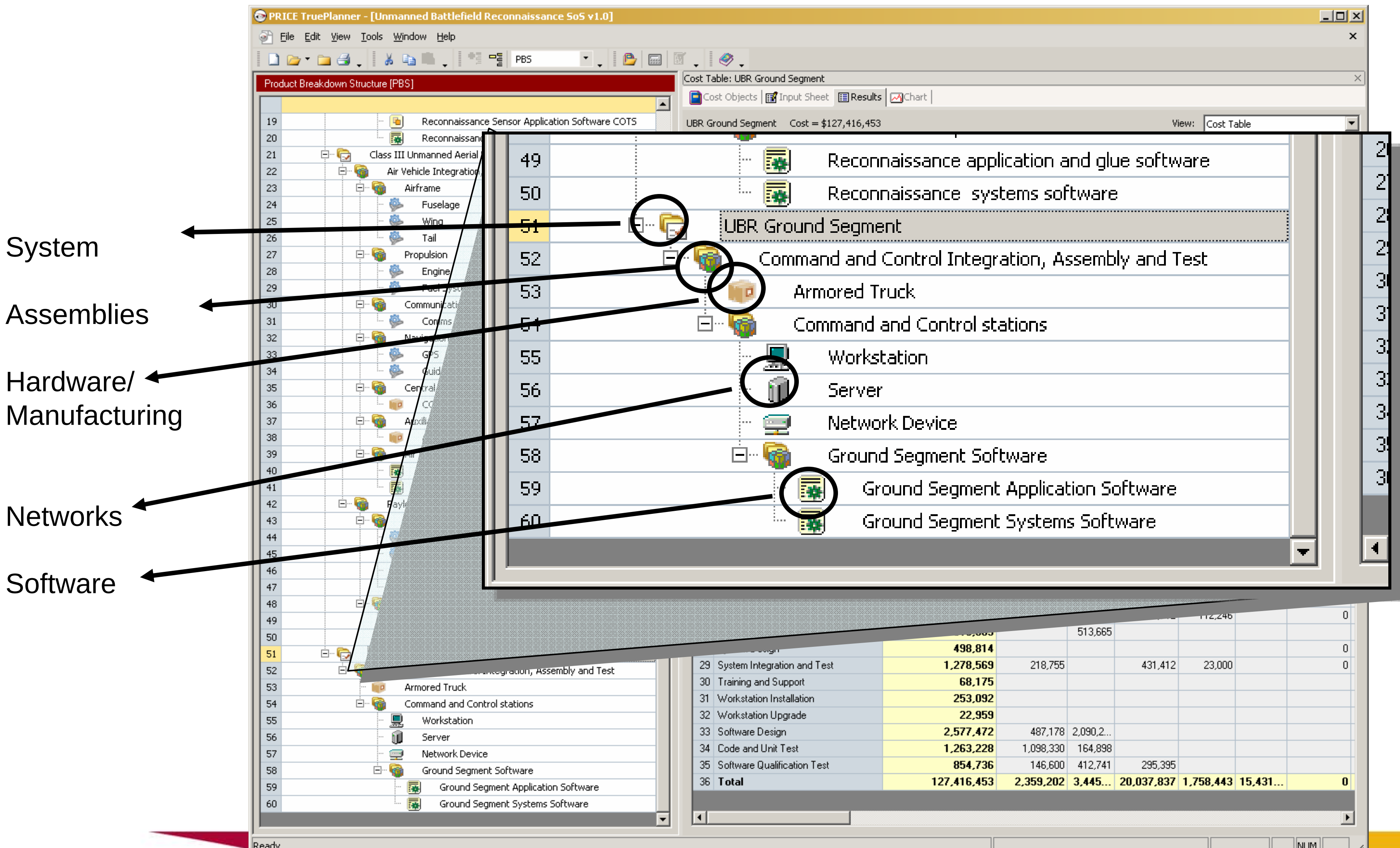
TruePlanning Suite



Cost Modeling Interoperability - Vision

ANALYTICS/DECISION MAKING

- Dashboard
- Knowledge Management
- Knowledge Bases
- Metrics
- Business Case Analysis

COST MODELING

- Manufacturing
- IT Infrastructure
- Software Engineering
- Operations & Support
- Systems Engineering
- Project/Program Management
- Hardware Development & Production

BENEFIT MODELING

- Increase Revenue
- Process Effectiveness
- Cost Avoidance
- Operational Efficiency
- Opportunity Creation

WEB SERVICES/API

Microsoft Office Project 2007 · Pro|ENGINEER Wildfire 4.0 · 3DS SIMULIA · PHOENIX INTEGRATION · Microsoft Office · ACEIT

- Project Portfolio Management
- Application Lifecycle Management
- Product Lifecycle Management
- Enterprise Resource Management

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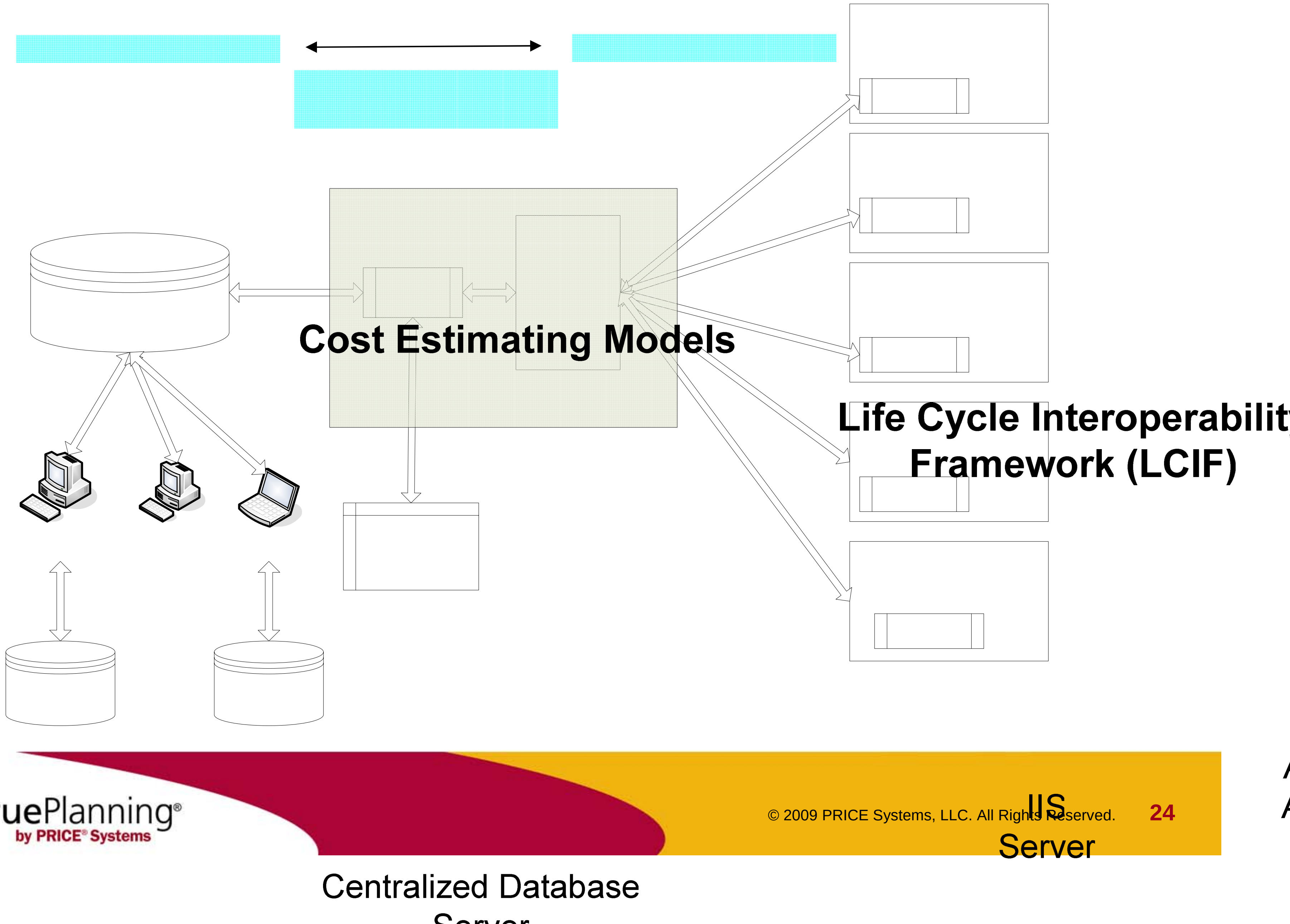
Life Cycle Integration Framework (LCIF) Concept

- Today, cost models tend to be stand alone and are used as an independent element of the program office or development contractor.
- Future cost modeling needs to be fully integrated and interoperable with the product life cycle tools used throughout DoD and its contractors.
- Technology has evolved to make this possible. Software languages have evolved to a standard interface language (XML) that allows communication between applications that once were standalone
- A Cost Model data exchange standard is needed

Life Cycle Interoperability Framework (LCIF)



LCIF Benefits

Surfacing cost/performance problems much earlier where solutions are less costly – helping to prevent future program failures due to unexpected cost growth.

Development of a Service Oriented Architecture (SOA) standardized language seamlessly facilitates the links between engineering models and cost models.

Integration of cost estimating models with engineering tools is needed so that CAIV management and reporting is enabled throughout the lifecycle of a program

LCIF Applications

Current Interoperability Applications

- **Optimization:** **Integration with ModelCenter 8.0 and Insight FD**
- **MCAD:** **Integration with Pro/Engineer 3.0 and 4.0**

Future Interoperability Applications

- **PLM:** **IBM Rational**
- **Logistics:** **TFD MAAP and EDCAS**
- **Customized:** **Applications for specific modeling from Armaments to Engines**

LCIF Specific Application – True Cost Engineer

True Manufacturing Cost Model

- New catalog, part of the TruePlanning framework,
- Driven with artifacts from an automated design/engineering tool
- New Cost estimating relationships facilitate process trade studies/material trade studies
- Can manually populate and run with inputs from MCAD design tools such as Pro/E. CATIA, Autodesk, etc.

The Affordability Companion

- Interacts with the design engineer to automatically and seamlessly capture and automatically pass essential design parameters to the True Manufacturing Cost model for affordability simulation.
- Results of the affordability simulation are returned directly to the engineer's workstation for further analysis such as trade studies.

LCIF Application - The Affordability Companion

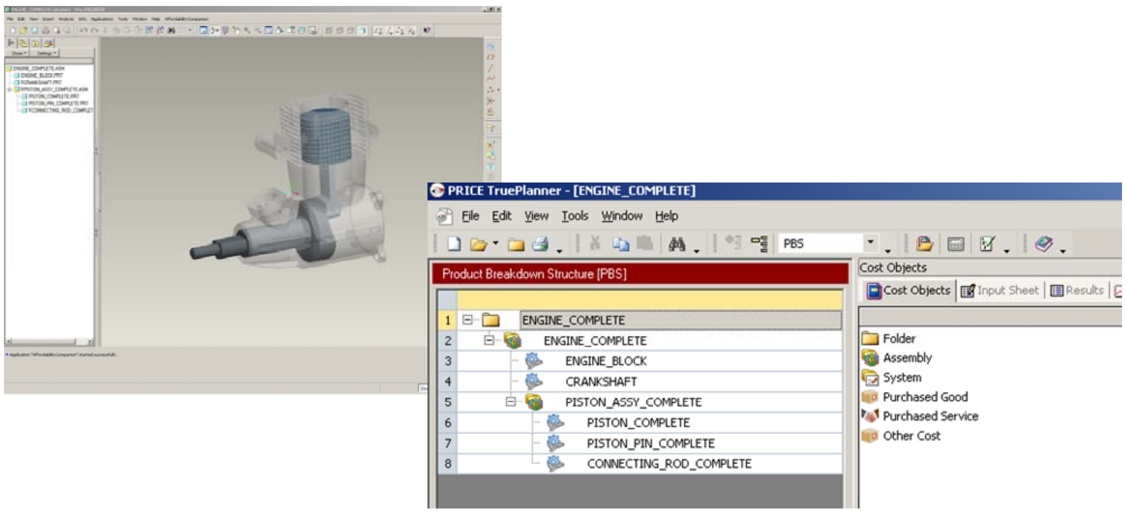
The Affordability Companion resides within the engineers' design tools, enabling engineers to treat cost as a design parameter

- Allows engineers the ability to trade off between performance and cost in real time before unaffordable designs are established
- Provides program managers a quantitative, repeatable methodology to understand cost tradeoffs, and ultimately produce better decisions, and save already limited funds. .

Recent Integration Success Story

True Engineer

Pro/E Affordability Companion



Elements of True Cost Engineer

- **True Manufacturing Cost Model**
  - new catalog, part of the TruePlanning framework,
  - driven with artifacts from an automated design/engineering tool
  - new Cost estimating relationships facilitate process trade studies/material trade studies
  - can manually populate and run with inputs from MCAD design tools such as Pro/E. CATIA, Autodesk, etc.
- **Pro/Engineer Affordability Companion**
  - Interacts with the design engineer to automatically and seamlessly capture and automatically pass essential design parameters to the True Manufacturing Cost model for affordability simulation.
  - results of the affordability simulation are returned directly to the engineer's workstation for further analysis such as trade studies.

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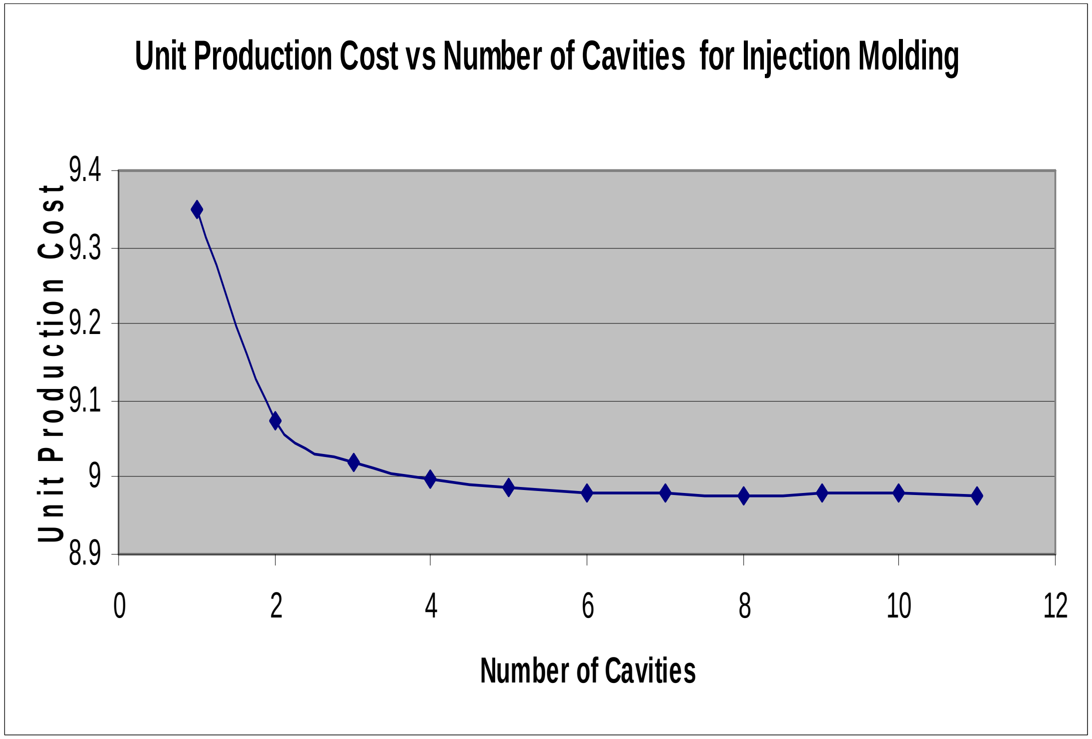
TruePlanning Manufacturing Cost Model

- Activity Based Statistical Model
- Cost estimating relationships facilitate process trade studies/material trade studies



True Manufacturing Model Cost Model

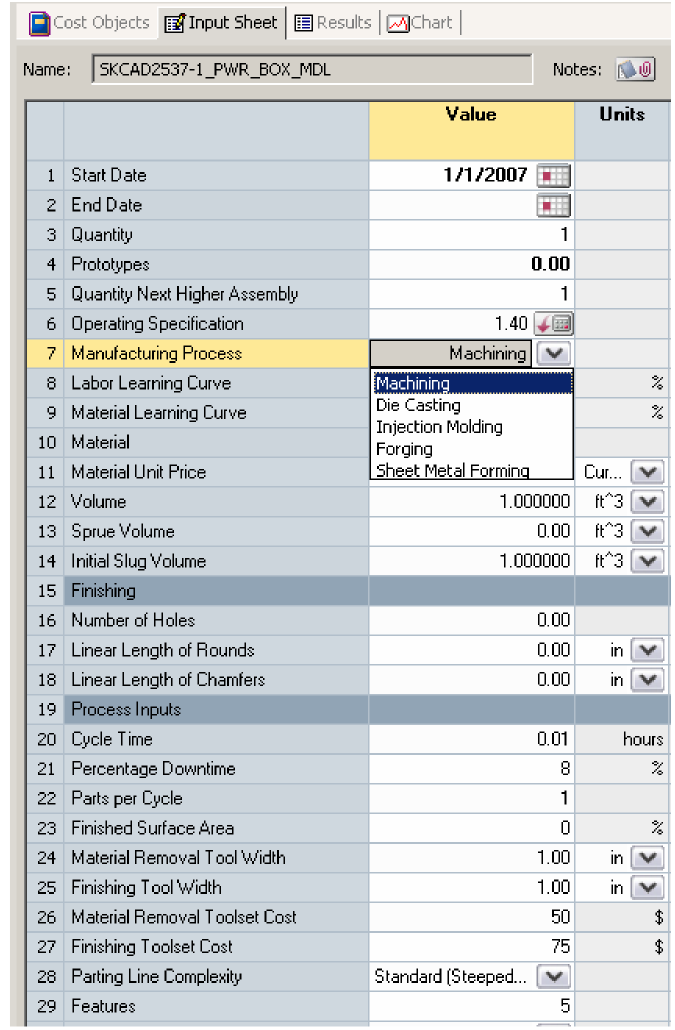
- Driven with artifacts from an automated design/engineering tool
  - Populate and run with inputs from MCAD design tools such as Pro/E, CATIA, Autodesk, etc.

Input Parameter	Machining	Die Casting	Injection Molding	Forging	Sheet Metal Forming
Initial Slug Volume	x				
Cycle Time		x	x	x	x
Parts per Cycle		x	x		x
Finished Surface Area	x				
Material Removal Tool Width	x				
Finishing Tool Width	x				
Material Removal Toolset Cost	x				
Finishing Toolset Cost	x				
Parting Line Complexity		x	x		
Features		x	x		
Number of Lifters		x	x		
Number of Piercing Stations					x
Number of Forming Stations					x
Number of Trimming Stations					x

TruePlanning Manufacturing Model

- Consists of two sub-models which account for Manufacturing and Tooling and Test activities across the Production and Development phases
  1. Mechanical Assembly
  2. Parts

- Ability to Model Manufacturing Processes, Assembly Processes, Tooling Time, Material Cost, Set Up Time



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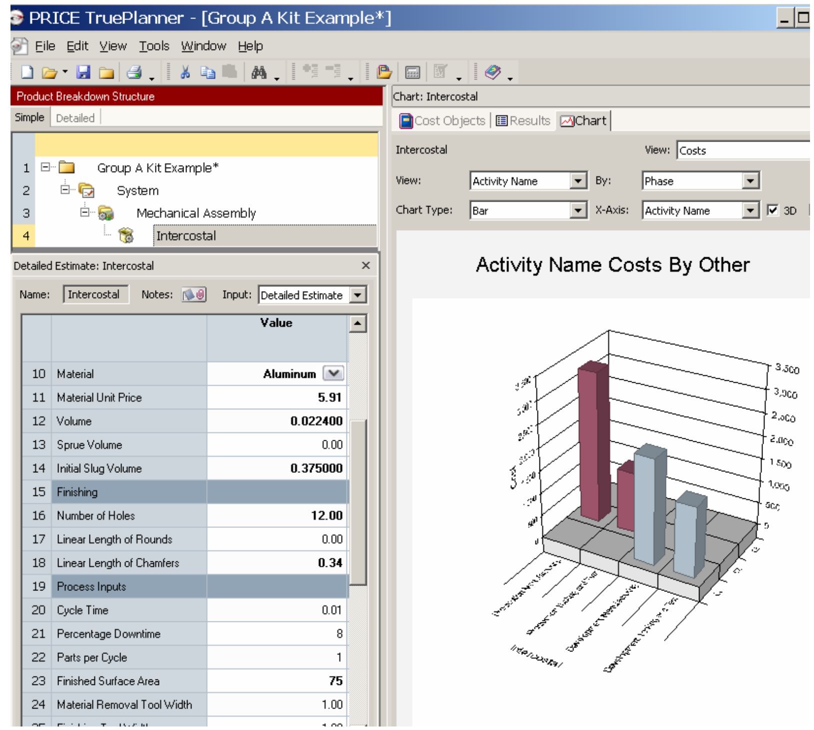
How does it work?

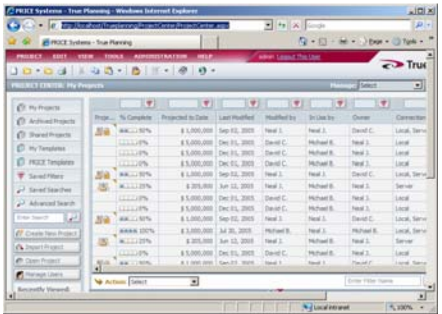
- **Cost Drivers for Production Manufacturing:**
  - Operator effort function of
    - Cycle Time, Size = Volume x Material Density, Quantity, Learning Curve, Downtime, Maturity/automation adjustment
  - Material Cost function of
    - Size, Material Unit Price, Learning Curve Effect, Waste Percent, Quantity
- **Cost Drivers for Tooling Costs:**
  - Volume and Sprue Volume, Parting Line Complexity, Features, Lifters, Parts Per Cycle (Number of cavities)

"Should Cost" for Manufacturing

Pro/E or CATIA Bill of Material and other model parameters (weight, volume, surface finish, material type, etc.)



Results (unit cost, total cost, etc.)



Business Manager

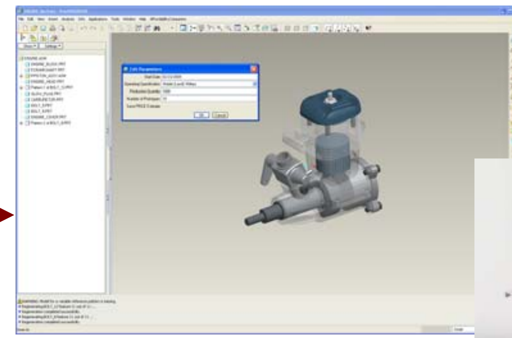
Lists/Reviews Projects

Analyzes Projects

Project Results

True Manufacturing

Pro/E Affordability Companion



Engineer

Trade Studies

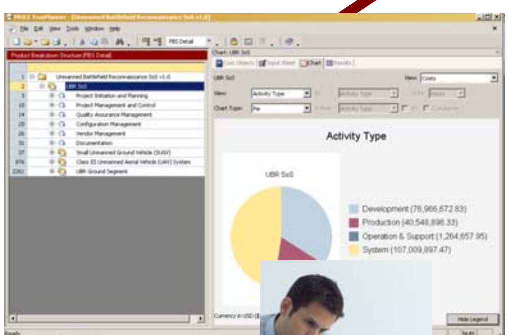
Generate PBS

Additional Inputs

Transfer Data

Create TP Project File

Return RoM Estimate



Cost Estimator

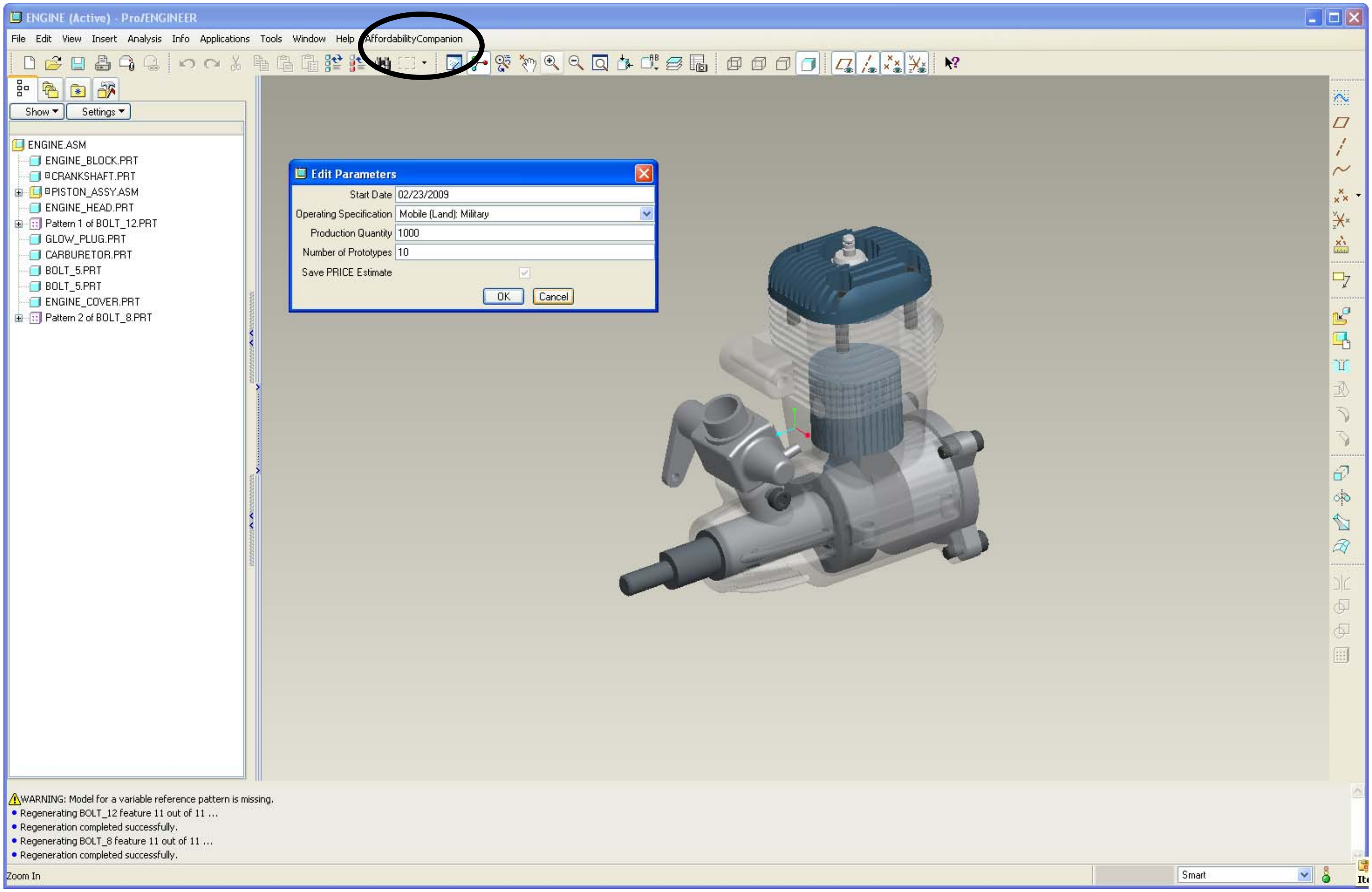
Conducts detailed estimate

Adds detailed information

Affordability Companion

- Interacts with the design engineer to automatically capture and pass essential design parameters for affordability simulation
- Results are returned to the engineer's workstation for further analysis such as trade studies
- Resides within the engineers' design tools
- Allows engineers the ability to trade off between performance and cost in real time before unaffordable designs are established
- Provides program managers a quantitative, repeatable methodology to understand cost tradeoffs, and ultimately produce better decisions, and save already limited funds

Pro/E Engineer & Affordability Companion



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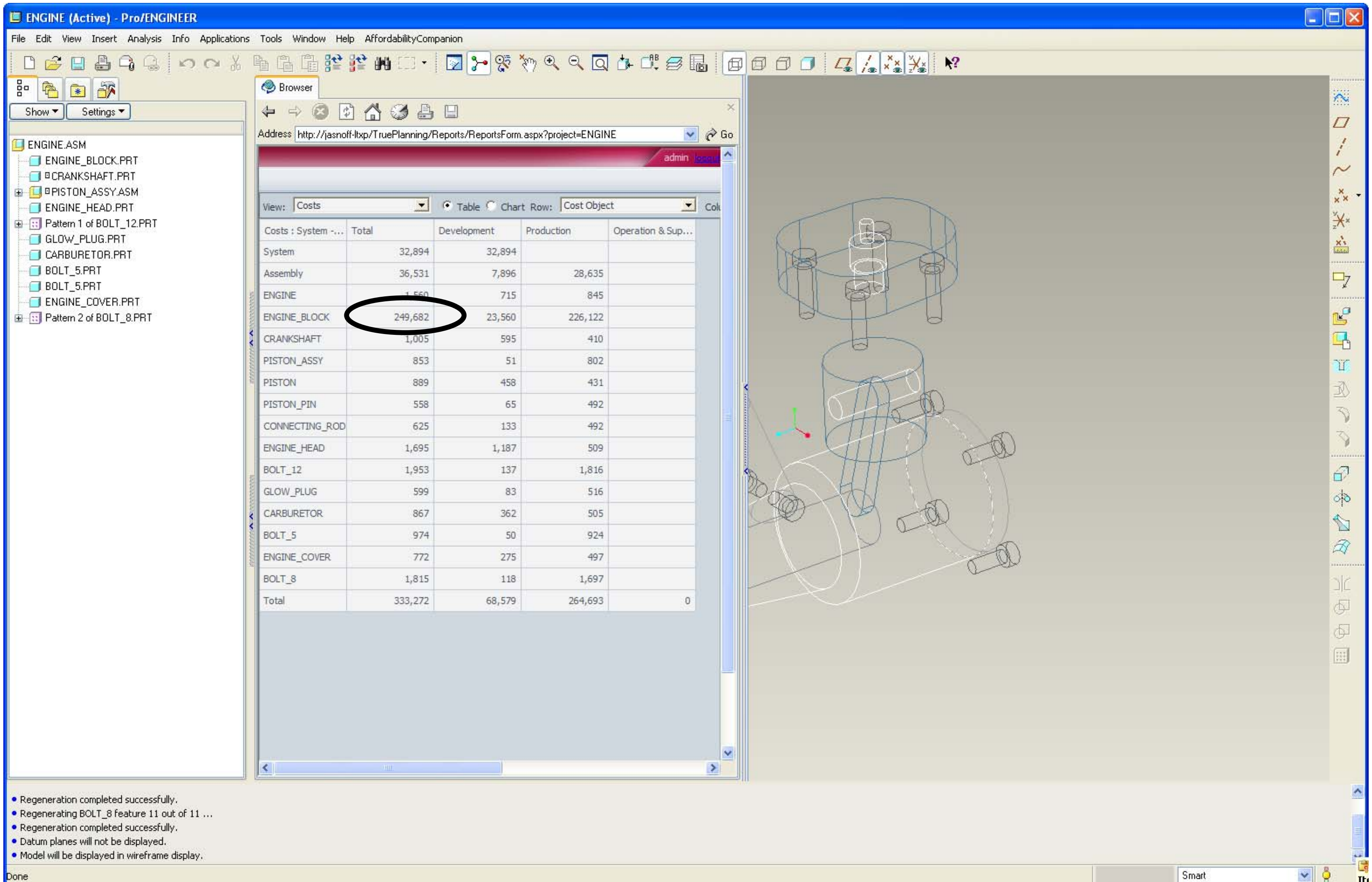
Baseline: Pro/E Engineer Workstation with Cost Estimating Results – Steel Engine Block/Forging Cost Driver



Costs : System -...	Total	Development	Production	Operation & Sup...
System	32,894	32,894		
Assembly	36,531	7,896	28,635	
ENGINE	1,560	715	845	
ENGINE_BLOCK	249,682	23,560	226,122	
CRANKSHAFT	1,005	595	410	
PISTON_ASSY	853	51	802	
PISTON	889	458	431	
PISTON_PIN	558	65	492	
CONNECTING_ROD	625	133	492	
ENGINE_HEAD	1,695	1,187	509	
BOLT_12	1,953	137	1,816	
GLOW_PLUG	599	83	516	
CARBURETOR	867	362	505	
BOLT_5	974	50	924	
ENGINE_COVER	772	275	497	
BOLT_8	1,815	118	1,697	
Total	333,272	68,579	264,693	0

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Baseline: TruePlanning Workstation with Cost Estimating Results

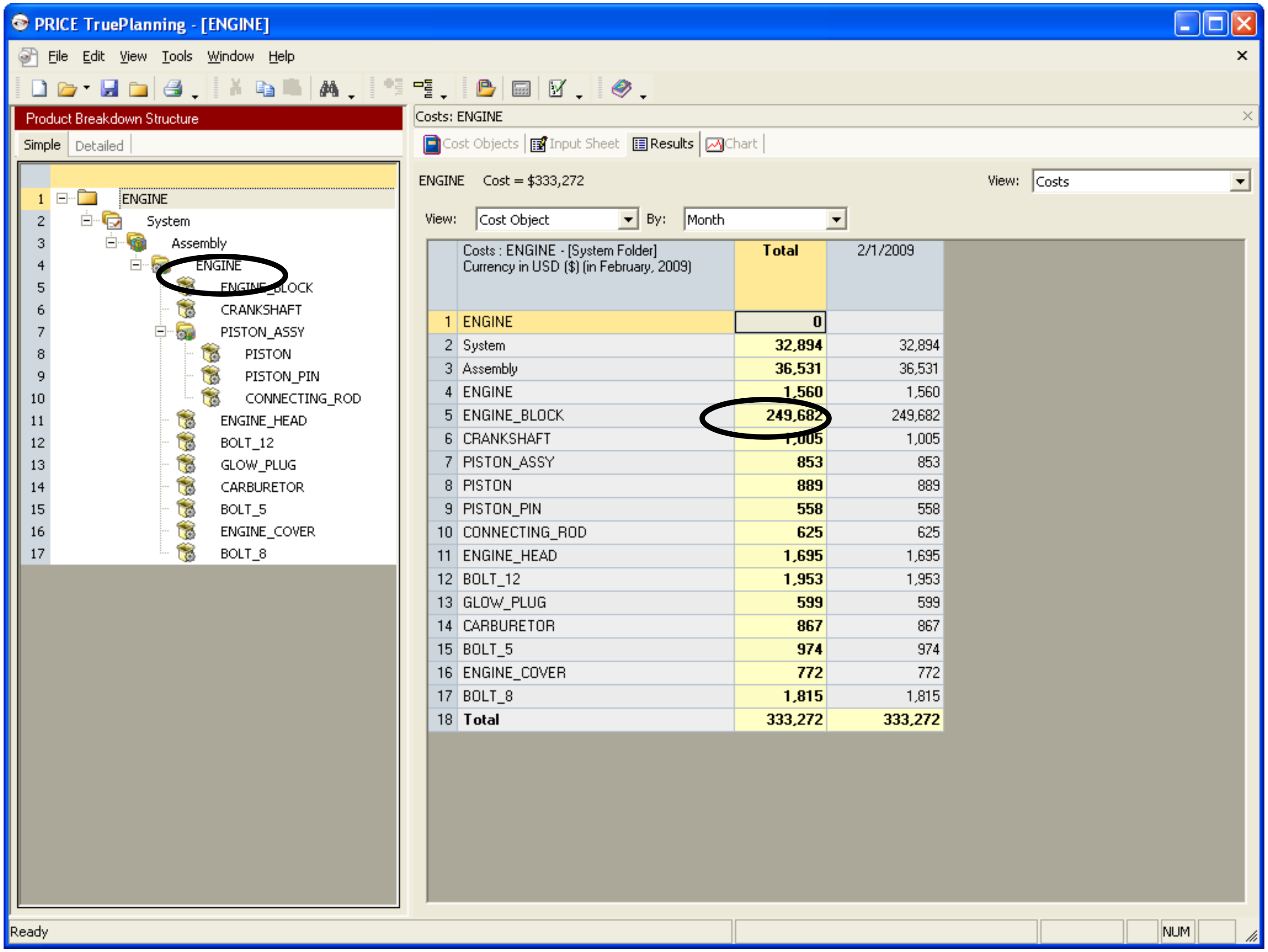
Cost Driver:

Engine Block

AUC = $30K

DTC Target = $11K

Cost Driver = Engine Block!



	Costs : ENGINE - [System Folder] Currency in USD ($) (in February, 2009)	Total	2/1/2009
1	ENGINE	0	
2	System	32,894	32,894
3	Assembly	36,531	36,531
4	ENGINE	1,560	1,560
5	ENGINE_BLOCK	249,682	249,682
6	CRANKSHAFT	1,005	1,005
7	PISTON_ASSY	853	853
8	PISTON	889	889
9	PISTON_PIN	558	558
10	CONNECTING_ROD	625	625
11	ENGINE_HEAD	1,695	1,695
12	BOLT_12	1,953	1,953
13	GLOW_PLUG	599	599
14	CARBURETOR	867	867
15	BOLT_5	974	974
16	ENGINE_COVER	772	772
17	BOLT_8	1,815	1,815
18	Total	333,272	333,272

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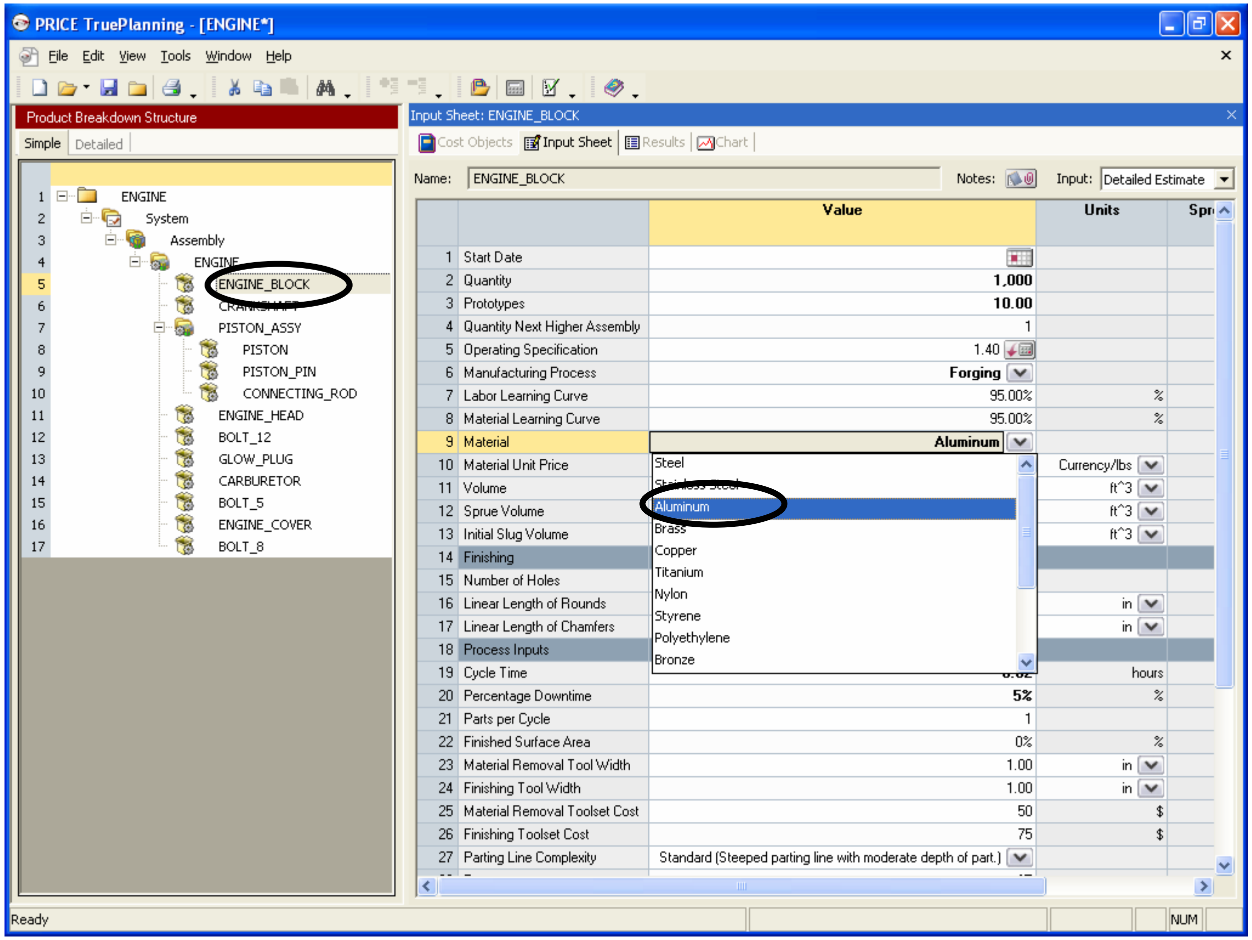
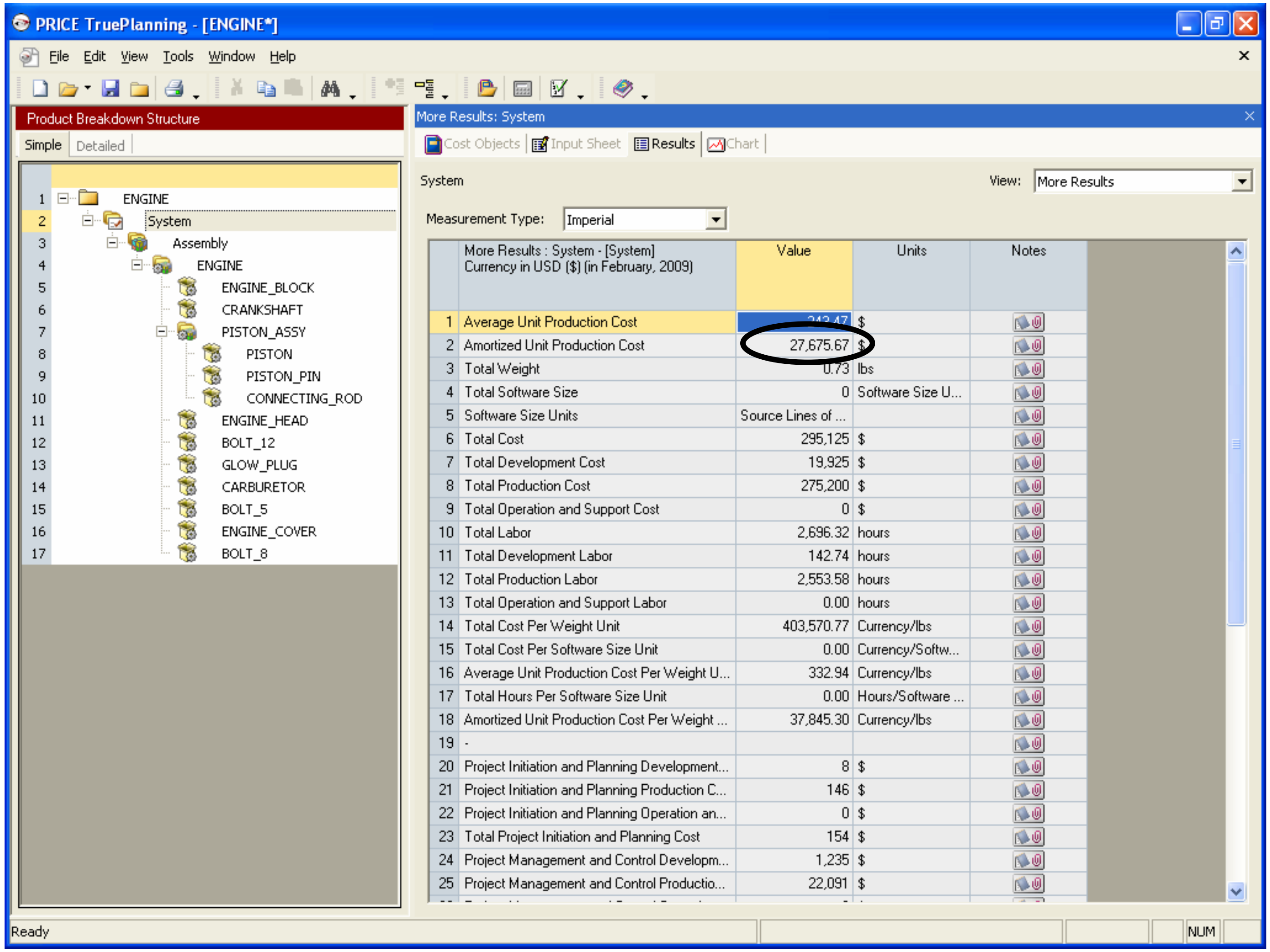
Trade #1: Material Trade – Change from Steel to Aluminum for Engine Block /Semi Automated Process



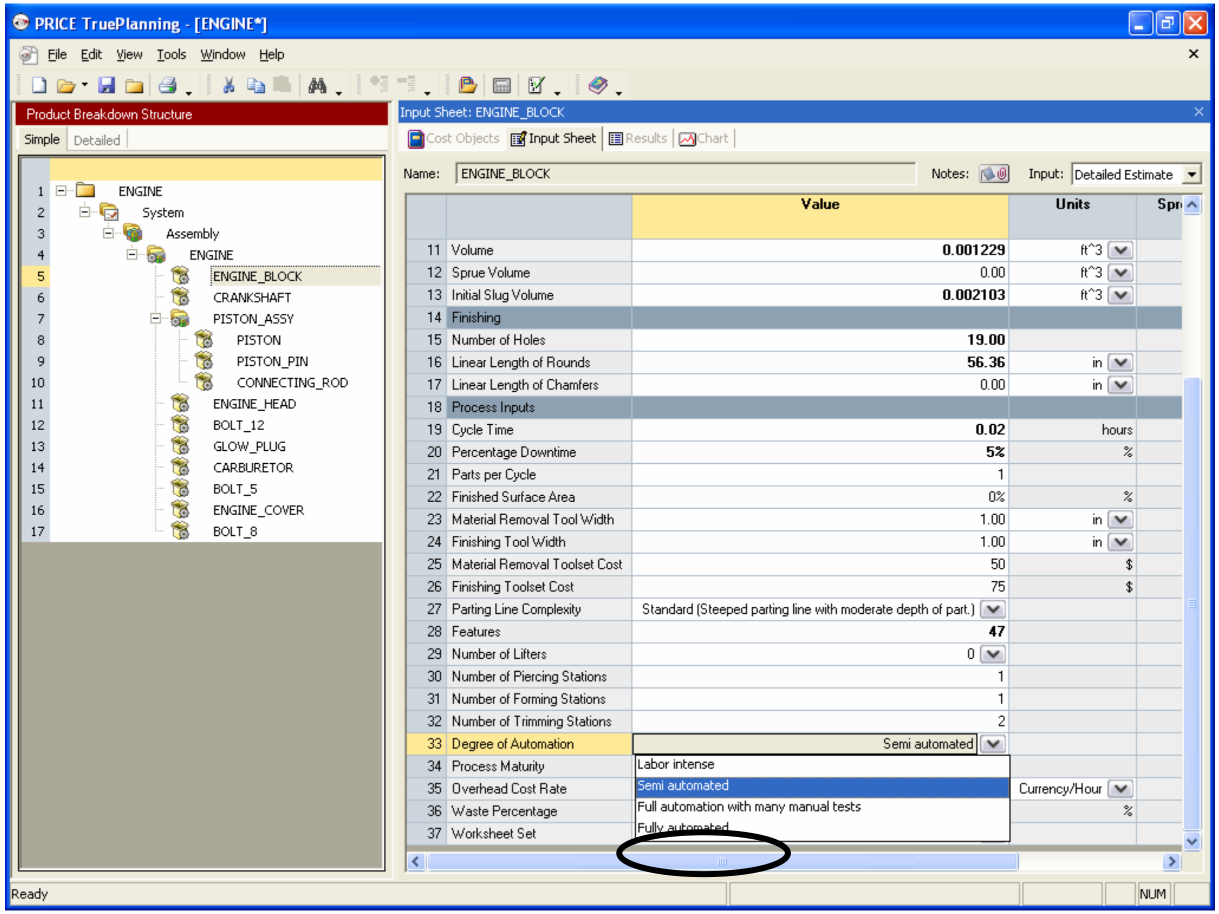
Trade #1: Material Trade Result – Change from Steel to Aluminum for Engine Block

AUC $ 27.6K (Semi-Automated)



	More Results : System - [System] Currency in USD ($) (in February, 2009)	Value	Units	Notes
1	Average Unit Production Cost	243.47	$	
2	Amortized Unit Production Cost	27,675.67	$	
3	Total Weight	0.73	lbs	
4	Total Software Size	0	Software Size U...	
5	Software Size Units	Source Lines of ...		
6	Total Cost	295,125	$	
7	Total Development Cost	19,925	$	
8	Total Production Cost	275,200	$	
9	Total Operation and Support Cost	0	$	
10	Total Labor	2,696.32	hours	
11	Total Development Labor	142.74	hours	
12	Total Production Labor	2,553.58	hours	
13	Total Operation and Support Labor	0.00	hours	
14	Total Cost Per Weight Unit	403,570.77	Currency/lbs	
15	Total Cost Per Software Size Unit	0.00	Currency/Softw...	
16	Average Unit Production Cost Per Weight U...	332.94	Currency/lbs	
17	Total Hours Per Software Size Unit	0.00	Hours/Software ...	
18	Amortized Unit Production Cost Per Weight ...	37,845.30	Currency/lbs	
19	-			
20	Project Initiation and Planning Development...	8	$	
21	Project Initiation and Planning Production C...	146	$	
22	Project Initiation and Planning Operation an...	0	$	
23	Total Project Initiation and Planning Cost	154	$	
24	Project Management and Control Developm...	1,235	$	
25	Project Management and Control Productio...	22,091	$	

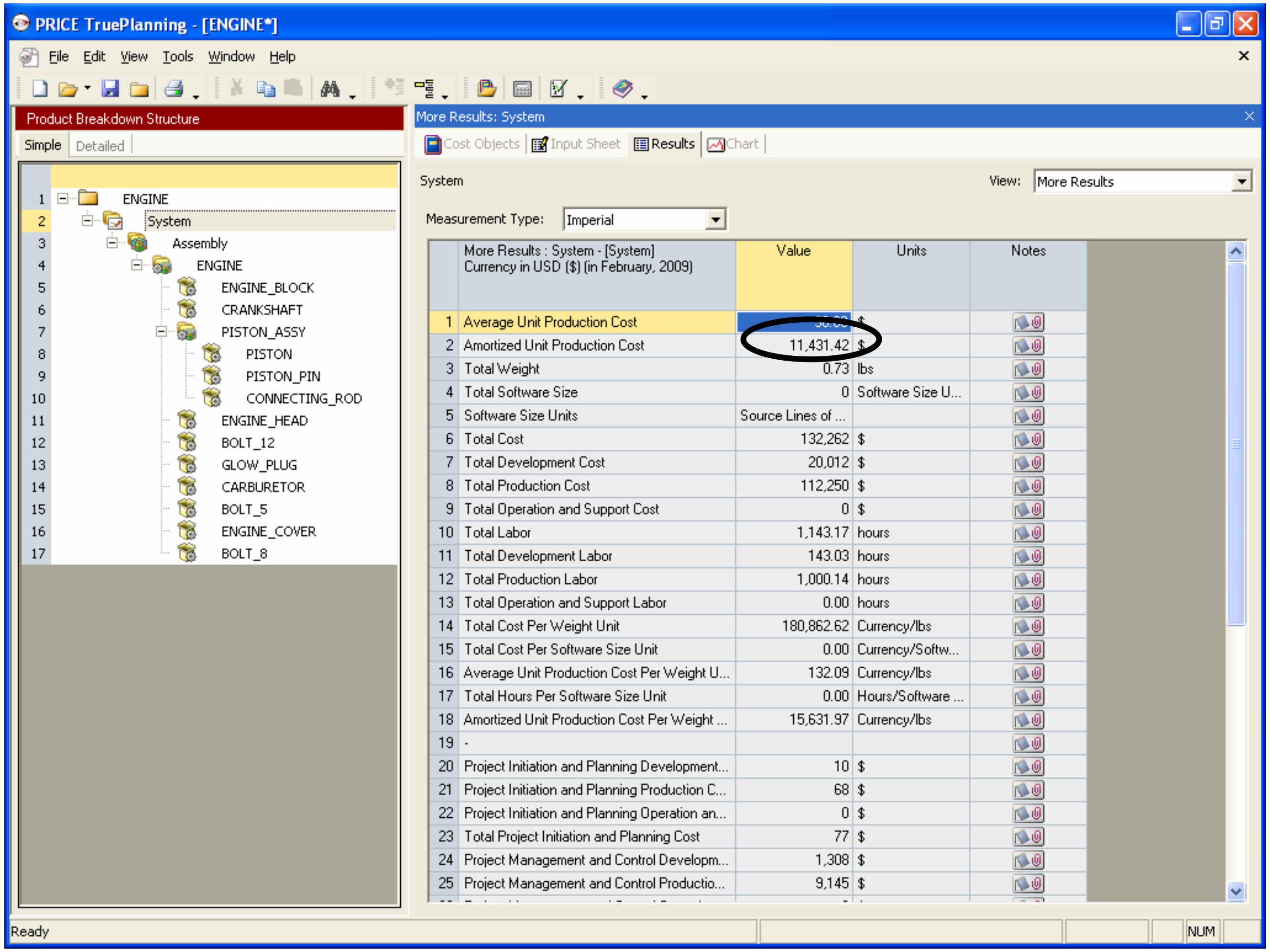
Trade #2: Automation Trade: Change from Semi to Fully Automated for Engine Block



Trade #2: Degree of Automation Trade Result: Change from Semi-Automated to Fully Automated for Engine Block

AUC $ 11.4K
Fully Automated

DTC Target = $11K



Summary

- When engineering and cost estimating tools are not integrated, a “reactive” stovepipe approaches to CAIV often occurs leading to cost growth.
- The need for an integrated, standardized framework (LCIF) and common cost language (XML) is essential for providing the greatest degree of interoperability between engineering and cost models.
- PRICE Systems recent development of True Cost Engineer highlights a recent success in the cost interoperability arena and demonstrates the need to rapidly extend cost interoperability to many more engineering tools.

What's Next?

- **Continued R&D in Cost Interoperability across the lifecycle**
- **Additional cost research to expand the True Manufacturing Catalog**
  - expand the models depth and breadth to work with additional MCAD parameters,
  - commodity pricing interface
  - Ability to estimate Operations and Support Cost.
- **Customization of the PRICE Systems cost estimating framework (TrueManufacturing) for specific advanced weapons systems.**
- **Build new Affordability Companions to work with additional engineering design tools**
  - such as CATIA, UGS and Autodesk.
  - integration of True Cost Engineer within the Windchill environment.