



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

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

A BENCHMARK OF
CURRENT BUSINESS PRACTICES

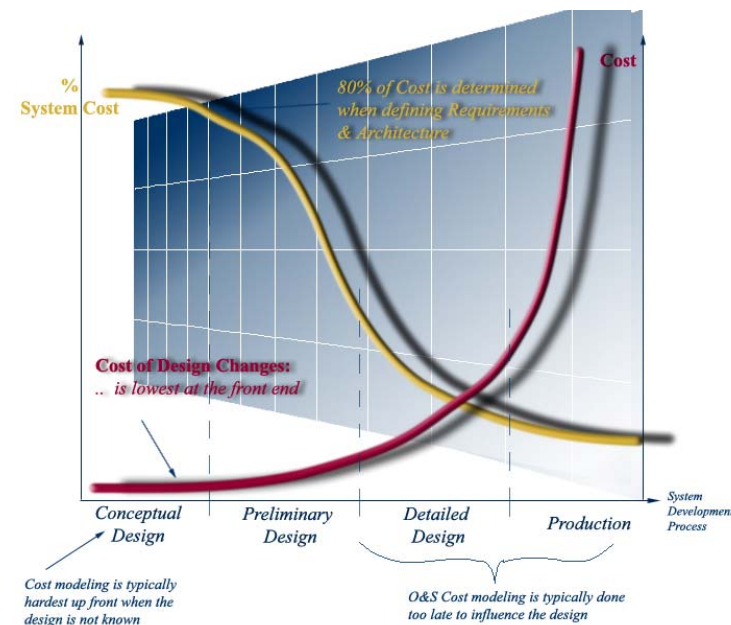


According a 2009 Study by the Center for Business Practices, the top resource challenges that threaten organizational effectiveness are:

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

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

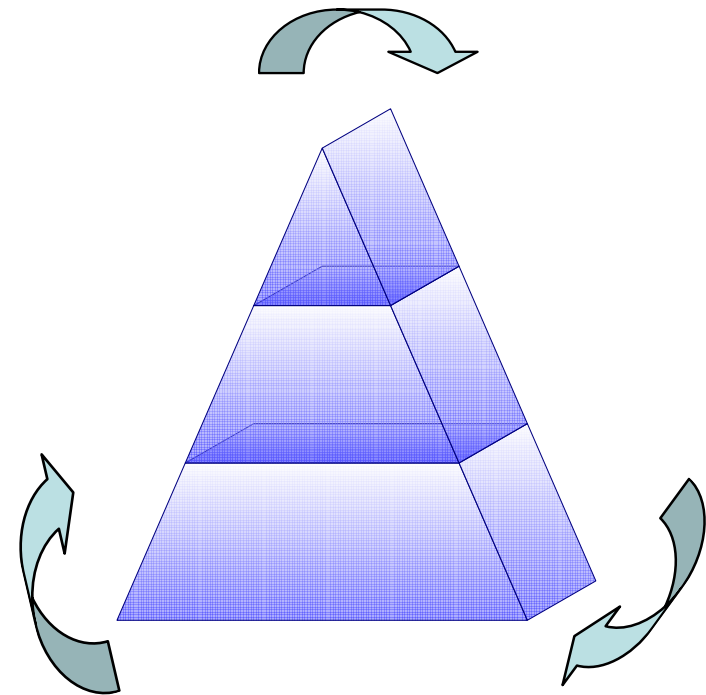


Today's Resource Estimating Landscape

- 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*

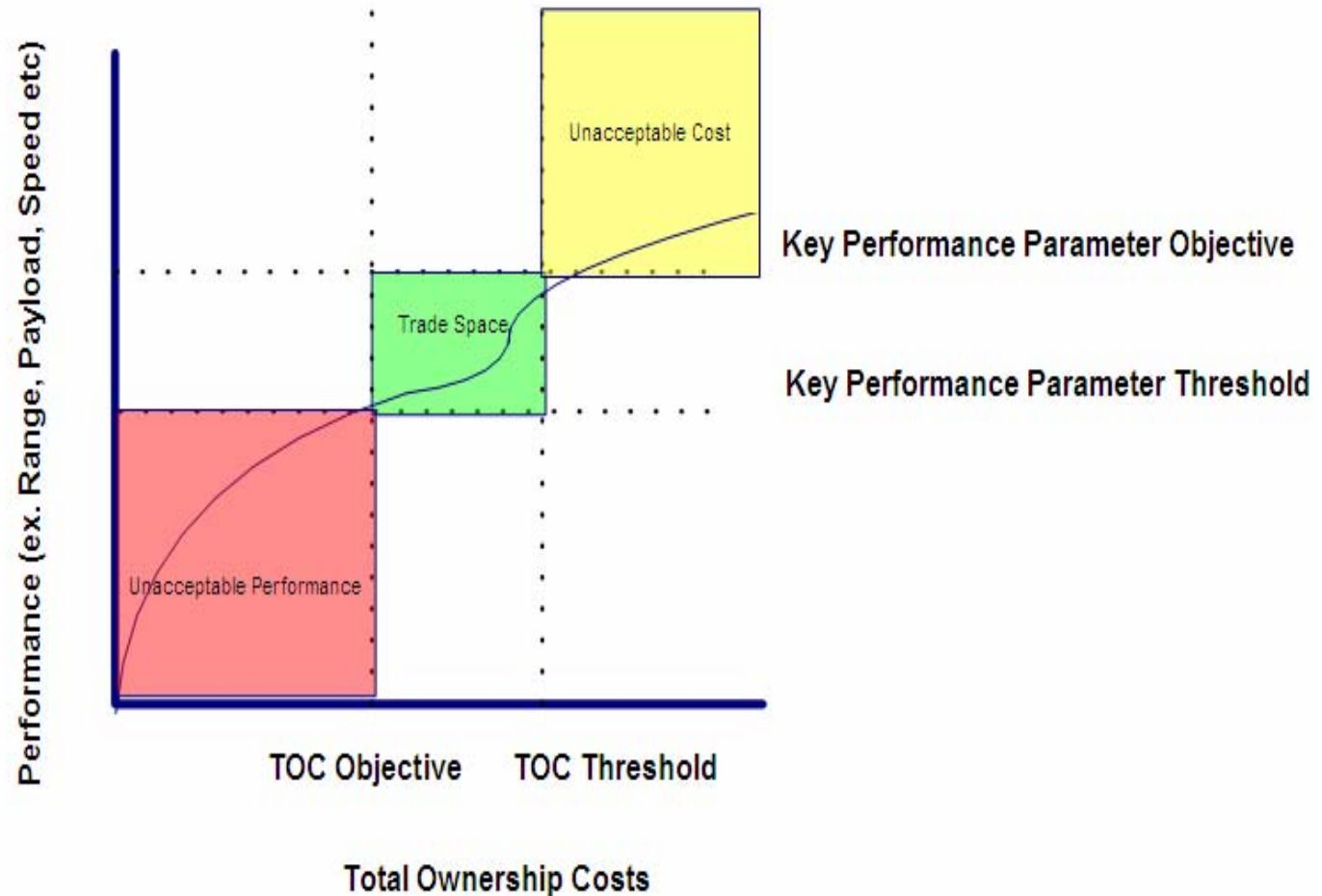
- **Cost as an Independent Variable (CAIV)**
 - CAIV means a traceable connection among requirements, cost estimate, and budget
 - CAIV means performing cost, schedule and performance trade-off analysis early and often .
 - Development of a robust trade space and analysis of alternatives
 - Focuses on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



Example of cost/performance trade parameters

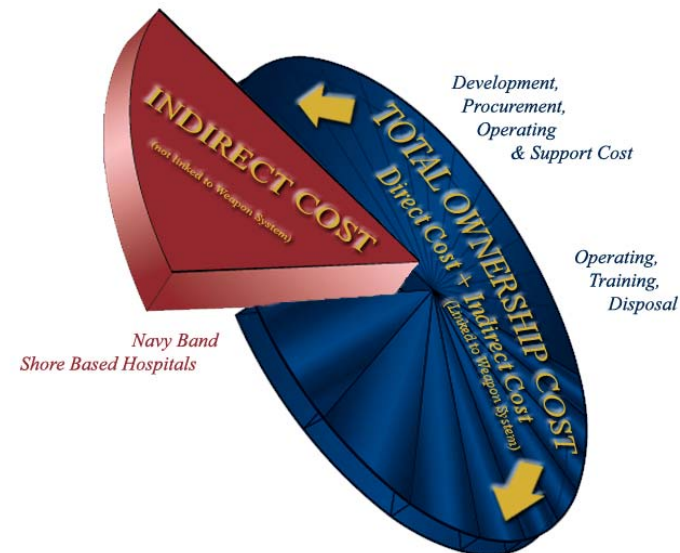
Tie Performance Models to Cost Models to Establish the Trade Space

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 ingrained 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 official 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. It in March pending a renegotiated contract meant to hold down cost 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.

« Previous 1 of 1 Next »

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DoD Blasts Lockheed Missile Program

Associated Press - June 27, 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-bugging Littoral Combat Ships (LCS) after the program was between 50 percent and 75 percent over budget.

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?

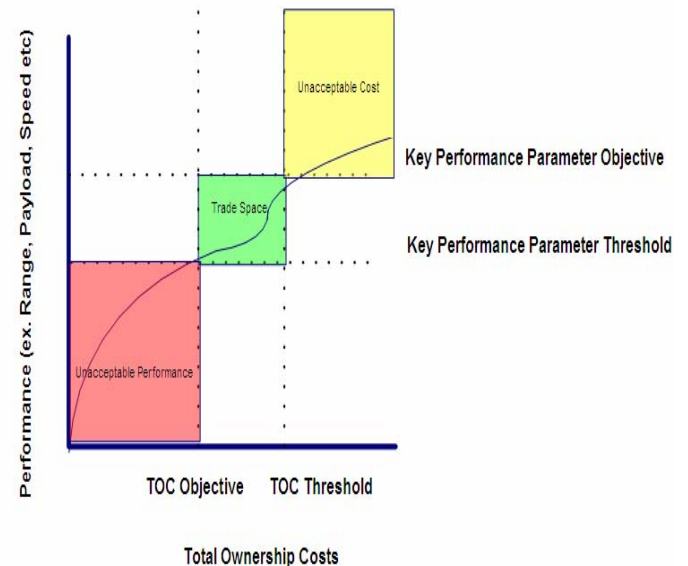
- CAIV is often not extended over the program lifecycle
 - CAIV proves most used during concept and preliminary design phase for:
 - Sizing of the initial design
 - Linkage of performance parameters to cost.
 - Optimizing design for Key Performance Parameters in relation to cost.
- CAIV seen as discriminator 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

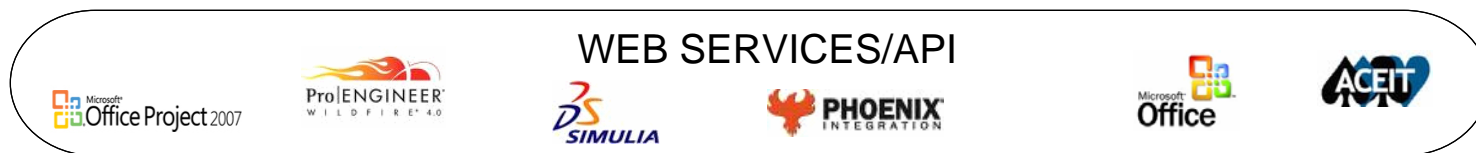
- For CAIV to remain effective across all program phases, it must be integrated with engineering tools
- Avoid “disconnect” between final design and CAIV targets.
- Need to integrate the need for engineers and cost estimators to jointly understand the impact of design on cost in real time – and quickly 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
 <h1>TruePlanning[®]</h1> <h2>by PRICE[®] Systems</h2>						
Top-down	Top-down	Parametric	Parametric	Detailed	Detailed	Detailed



Project Portfolio Management

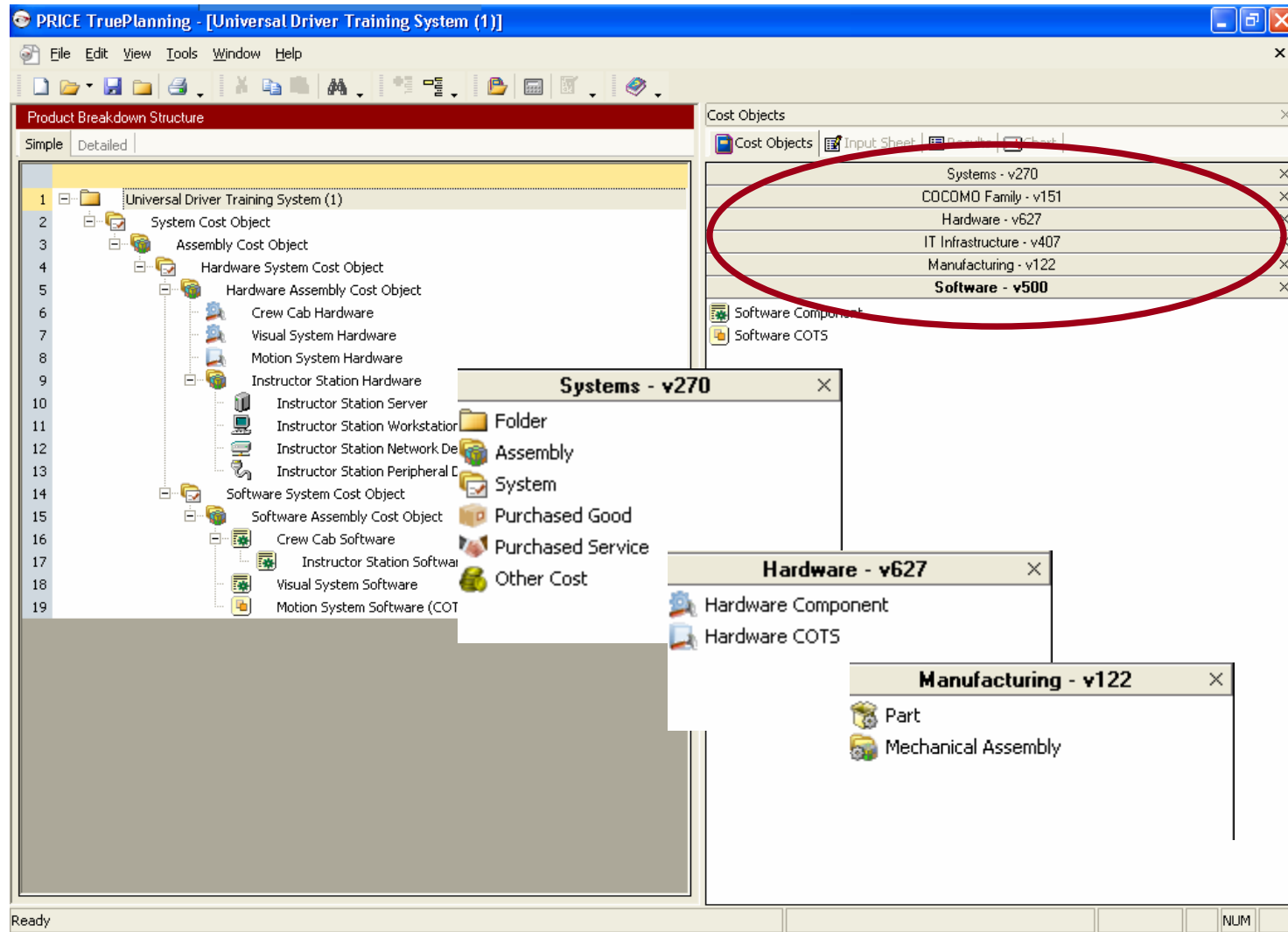
Application Lifecycle Management

Product Lifecycle Management

Enterprise Resource Management

TruePlanning Suite

A single framework to estimate and manage costs thru the lifecycle



TruePlanning Suite

Product Breakdown Structure [PBS]

- 19 Reconnaissance Sensor Application Software COTS
- 20 Reconnaissance
- 21 Class III Unmanned Aerial
- 22 Air Vehicle Integration
- 23 Airframe
- 24 Fuselage
- 25 Wing
- 26 Tail
- 27 Propulsion
- 28 Engine
- 29 System Integration, Assembly and Test
- 30 Armored Truck
- 31 Command and Control stations
- 32 Workstation
- 33 Server
- 34 Network Device
- 35 Ground Segment Software
- 36 Ground Segment Application Software
- 37 Ground Segment Systems Software
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Cost Table: UBR Ground Segment


Item	Cost
49 Reconnaissance application and glue software	
50 Reconnaissance systems software	
51 UBR Ground Segment	\$127,416,453
52 Command and Control Integration, Assembly and Test	
53 Armored Truck	
54 Command and Control stations	
55 Workstation	
56 Server	
57 Network Device	
58 Ground Segment Software	
59 Ground Segment Application Software	
60 Ground Segment Systems Software	

Summary Table:

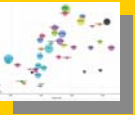
Item	Cost	Sub-item 1	Sub-item 2	Sub-item 3	Sub-item 4	Sub-item 5	Total
29 System Integration and Test	498,814						0
30 Training and Support	68,175						0
31 Workstation Installation	253,092						0
32 Workstation Upgrade	22,959						0
33 Software Design	2,577,472	487,178	2,090,2...				0
34 Code and Unit Test	1,263,228	1,098,330	164,898				0
35 Software Qualification Test	854,736	146,600	412,741	295,395			0
36 Total	127,416,453	2,359,202	3,445,...	20,037,837	1,758,443	15,431,...	0

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



Project Portfolio Management

Application Lifecycle Management

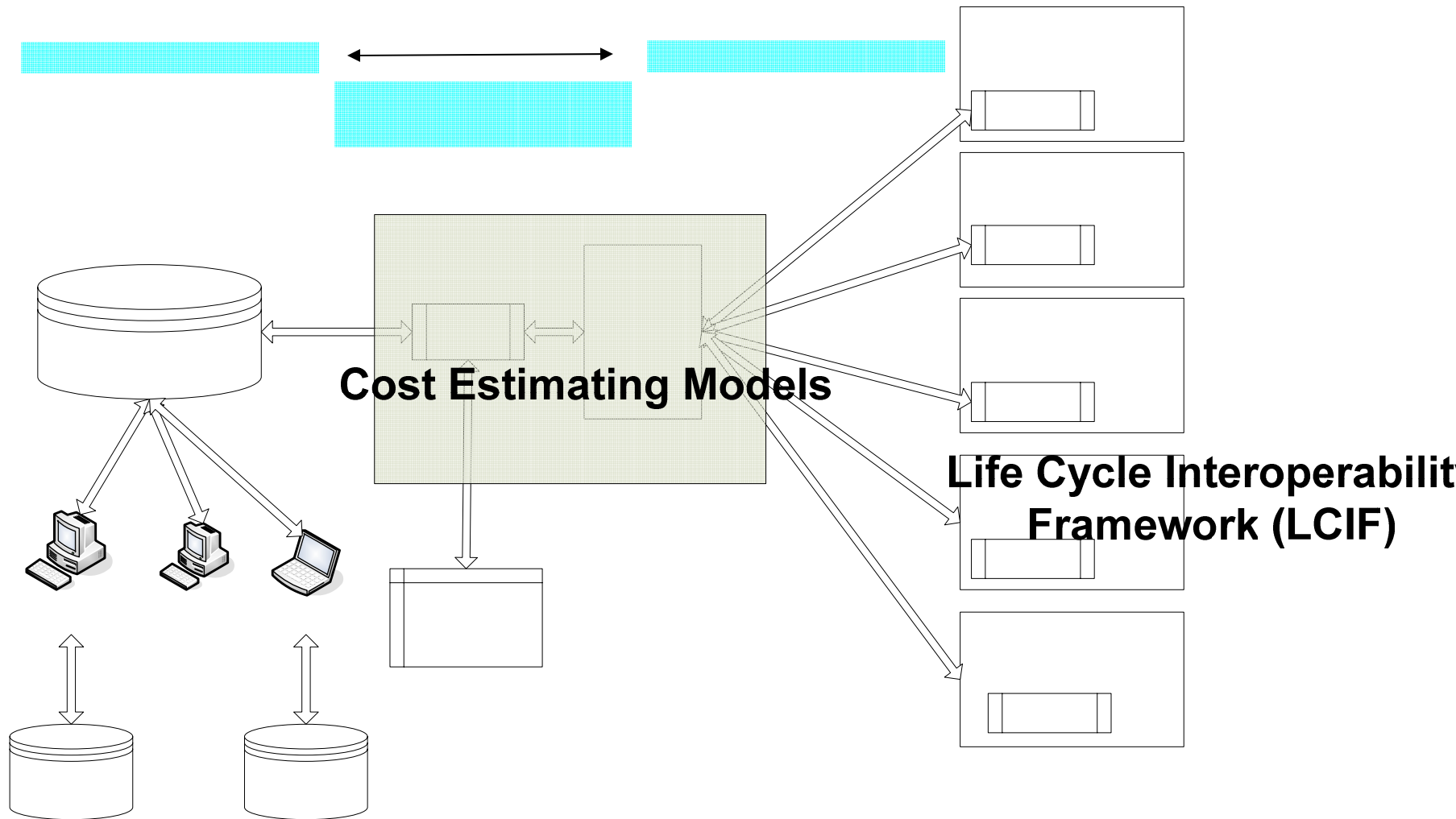
Product Lifecycle Management

Enterprise Resource Management

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

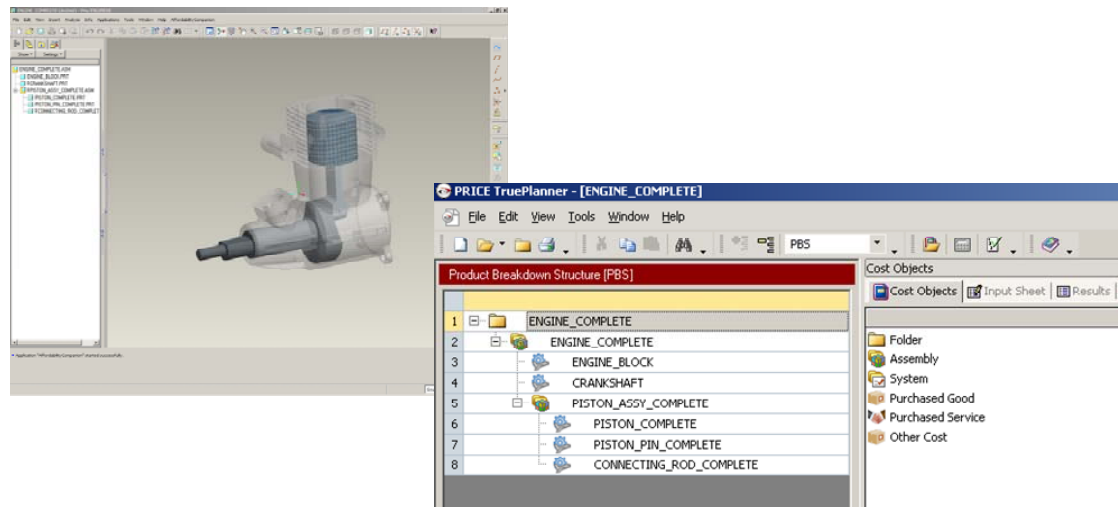
The Affordability Companion resides within the engineers' design tools, enabling engineers to treat cost as a design parameter

- 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

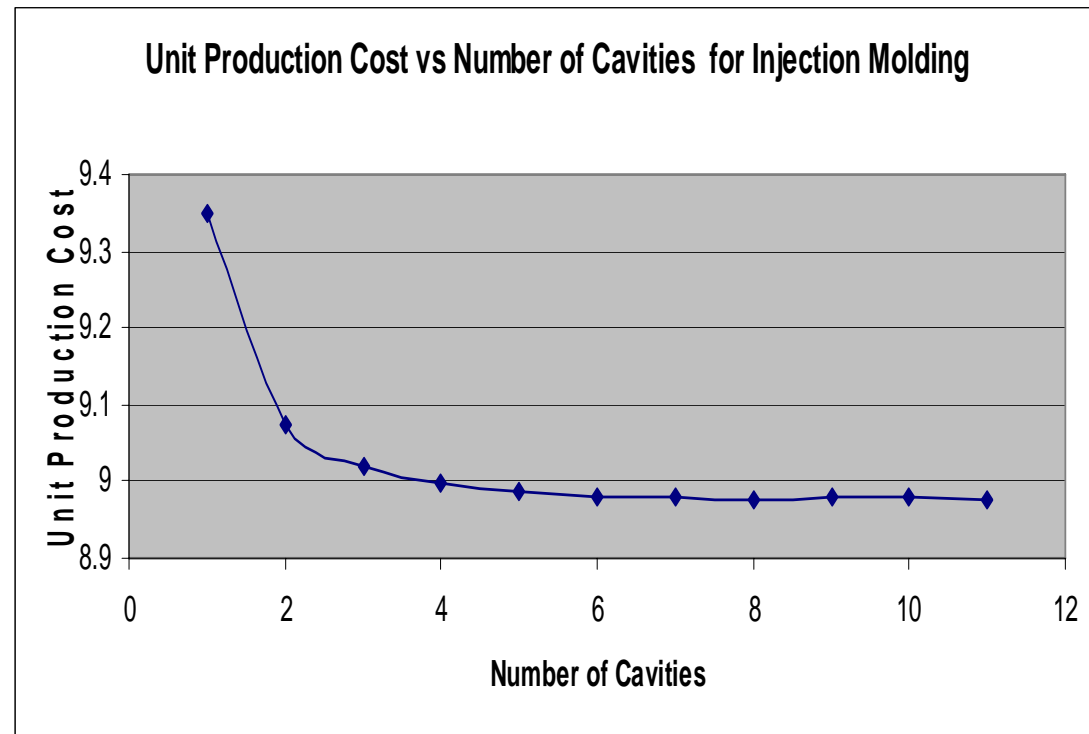
- new catalog, part of the TruePlanning framework,
- driven with artifacts from an automated design/engineering tool
- new Cost estimating relationships facilitate process trade studies/material trade studies
- can manually populate and run with inputs from MCAD design tools such as Pro/E, CATIA, Autodesk,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

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

	Value	Units
1 Start Date	1/1/2007	
2 End Date		
3 Quantity	1	
4 Prototypes	0.00	
5 Quantity Next Higher Assembly	1	
6 Operating Specification	1.40	
7 Manufacturing Process	Machining	
8 Labor Learning Curve	Machining	%
9 Material Learning Curve	Die Casting	%
10 Material	Injection Molding	
11 Material Unit Price	Forging	Cur...
12 Volume	1.000000	ft^3
13 Sprue Volume	0.00	ft^3
14 Initial Slug Volume	1.000000	ft^3
15 Finishing	Sheet Metal Forming	
16 Number of Holes	0.00	
17 Linear Length of Rounds	0.00	in
18 Linear Length of Chamfers	0.00	in
19 Process Inputs		
20 Cycle Time	0.01	hours
21 Percentage Downtime	8	%
22 Parts per Cycle	1	
23 Finished Surface Area	0	%
24 Material Removal Tool Width	1.00	in
25 Finishing Tool Width	1.00	in
26 Material Removal Toolset Cost	50	\$
27 Finishing Toolset Cost	75	\$
28 Parting Line Complexity	Standard (Steeped...	
29 Features	5	

How does it work?

● **Cost Drivers for Production Manufacturing:**

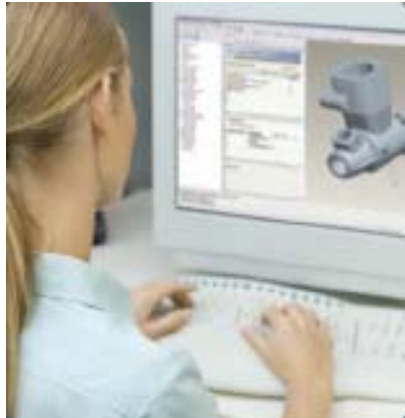
- Operator effort function of
 - Cycle Time, Size = Volume x Material Density, Quantity, Learning Curve, Downtime, Maturity/automation adjustment

- Material Cost function of
 - Size, Material Unit Price, Learning Curve Effect, Waste Percent, Quantity

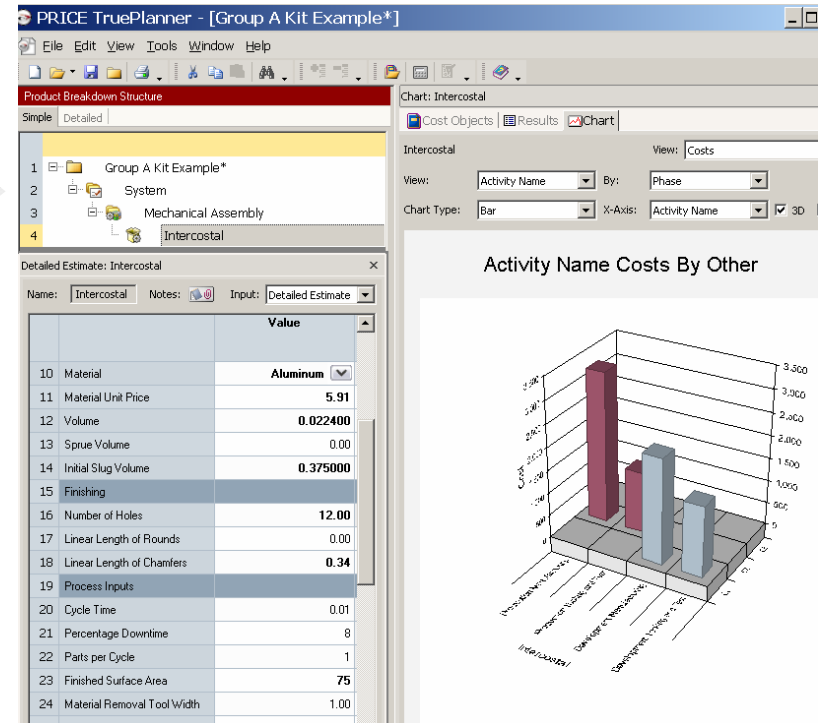
● **Cost Drivers for Tooling Costs:**

- Volume and Sprue Volume, Parting Line Complexity, Features, Lifters, Parts Per Cycle (Number of cavities)

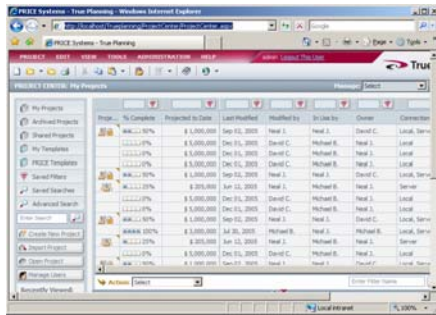
“Should Cost” for Manufacturing



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



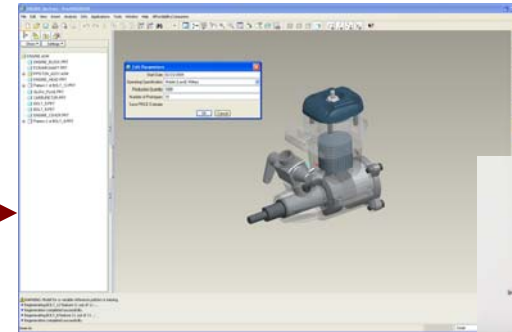
Results (unit cost, total cost, etc.)



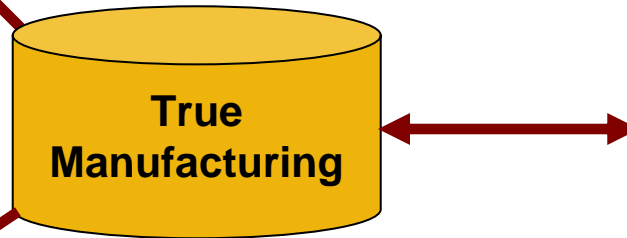
Lists/Reviews Projects
Analyzes Projects
Project Results

Business Manager

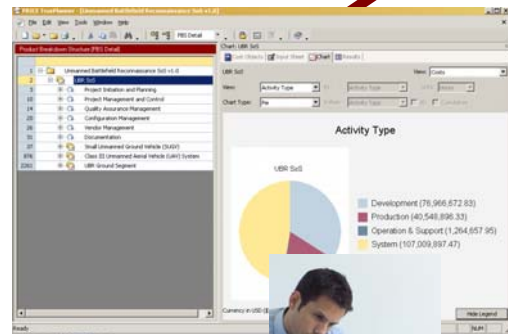
Pro/E Affordability Companion



Engineer



Trade Studies
Generate PBS
Additional Inputs
Transfer Data
Create TP Project File
Return RoM Estimate



Conducts detailed estimate
Adds detailed information

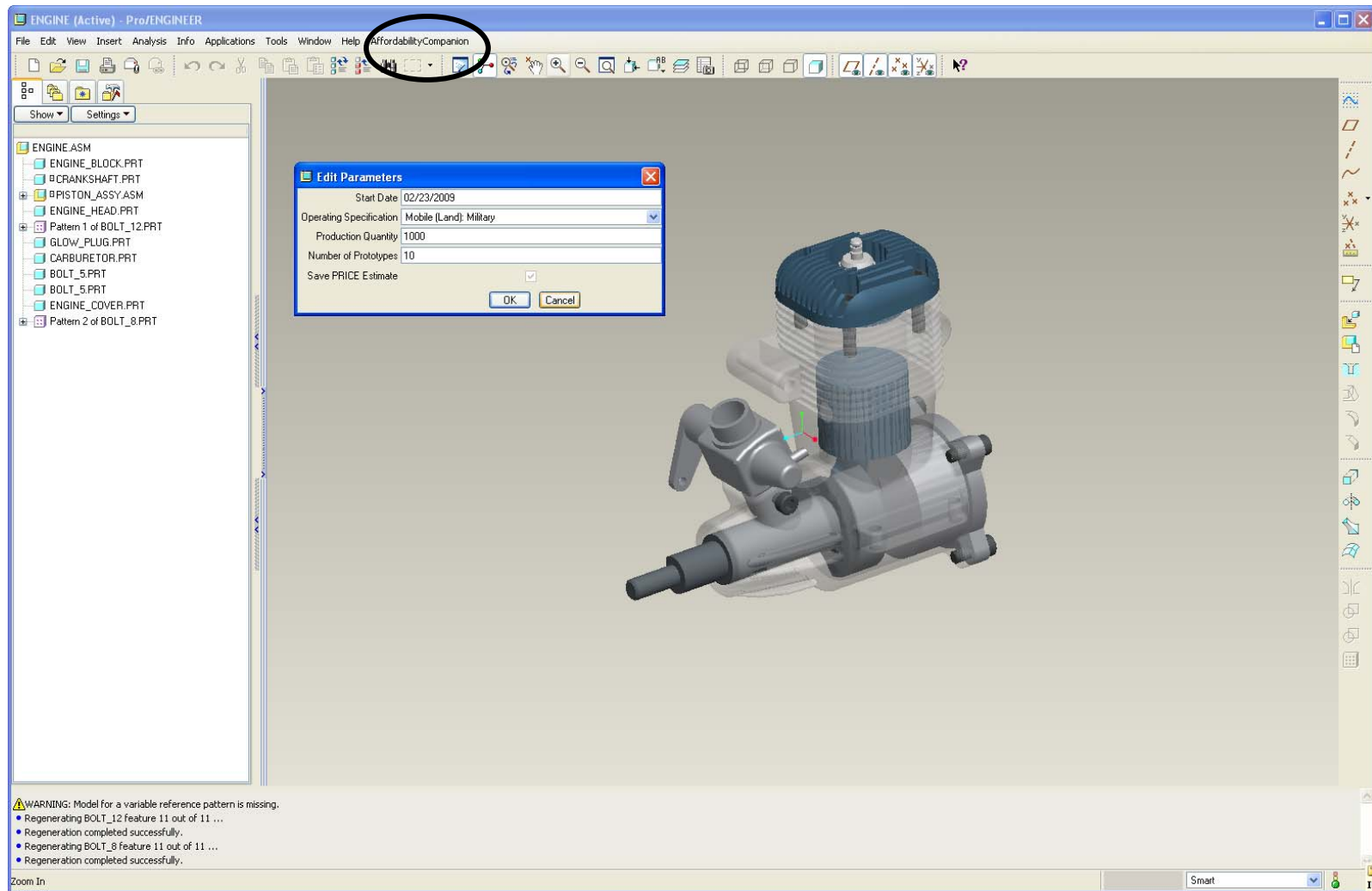


Cost Estimator

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



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

The screenshot displays the Pro/ENGINEER software interface with a cost estimating report open. The report table is as follows:

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

The 'ENGINE_BLOCK' row is circled in red. The 3D model on the right shows a wireframe of an engine block with various components like the crankshaft, pistons, and connecting rods.

At the bottom of the window, a status bar shows the following messages:

- Regeneration completed successfully.
- Regenerating BOLT_8 Feature 11 out of 11 ...
- Regeneration completed successfully.
- Datum planes will not be displayed.
- Model will be displayed in wireframe display.

Baseline: TruePlanning Workstation with Cost Estimating Results

Cost Driver:

Engine Block

AUC = \$30K

DTC Target = \$11K

Cost Driver =
Engine Block!

The screenshot displays the PRICE TruePlanning software interface. On the left, the 'Product Breakdown Structure' shows a hierarchy starting with 'ENGINE', which is circled in red. Below it are sub-components like 'ENGINE_BLOCK', 'CRANKSHAFT', 'PISTON_ASSY', etc. On the right, the 'Costs: ENGINE' window shows a table of costs. The table has columns for 'Cost Object', 'Total', and '2/1/2009'. The 'ENGINE' row is highlighted in yellow, and its 'Total' value of 0 is circled in red. The 'ENGINE_BLOCK' row is also highlighted in yellow, and its 'Total' value of 249,682 is circled in red. The 'Total' row at the bottom shows a total cost of 333,272.

Cost Object	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

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

The screenshot displays the PRICE TruePlanning software interface. On the left, the 'Product Breakdown Structure' tree shows the 'ENGINE_BLOCK' component highlighted. The main window, 'Input Sheet: ENGINE_BLOCK', shows a list of parameters for the 'ENGINE_BLOCK' component. The 'Material' parameter (row 9) is currently set to 'Aluminum', which is circled in blue. A dropdown menu is open, showing a list of materials including 'Steel', 'Aluminum', 'Brass', 'Copper', 'Titanium', 'Nylon', 'Styrene', and 'Polyethylene'. The 'Aluminum' option is selected and circled in blue. Other parameters include 'Quantity' (1,000), 'Prototypes' (10.00), 'Operating Specification' (1.40), 'Manufacturing Process' (Forging), and 'Material Learning Curve' (95.00%).

	Value	Units	Spn
1 Start Date			
2 Quantity	1,000		
3 Prototypes	10.00		
4 Quantity Next Higher Assembly	1		
5 Operating Specification	1.40		
6 Manufacturing Process	Forging		
7 Labor Learning Curve	95.00%	%	
8 Material Learning Curve	95.00%	%	
9 Material	Aluminum		
10 Material Unit Price	Steel	Currency/lbs	
11 Volume	Steel	ft^3	
12 Sprue Volume	Aluminum	ft^3	
13 Initial Slug Volume	Brass	ft^3	
14 Finishing	Copper		
15 Number of Holes	Titanium		
16 Linear Length of Rounds	Nylon	in	
17 Linear Length of Chamfers	Styrene	in	
18 Process Inputs	Polyethylene		
19 Cycle Time	Bronze	hours	
20 Percentage Downtime		5%	
21 Parts per Cycle		1	
22 Finished Surface Area		0%	
23 Material Removal Tool Width		1.00 in	
24 Finishing Tool Width		1.00 in	
25 Material Removal Toolset Cost		50 \$	
26 Finishing Toolset Cost		75 \$	
27 Parting Line Complexity	Standard (Steeped parting line with moderate depth of part.)		

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

**AUC \$ 27.6K
(Semi-Automated)**

The screenshot displays the PRICE TruePlanning interface. On the left, the 'Product Breakdown Structure' shows a hierarchy for 'ENGINE' (System) including components like ENGINE_BLOCK, CRANKSHAFT, PISTON_ASSY, PISTON, PISTON_PIN, CONNECTING_ROD, ENGINE_HEAD, BOLT_12, GLOW_PLUG, CARBURETOR, BOLT_5, ENGINE_COVER, and BOLT_8. On the right, the 'More Results: System' window shows a table of metrics. The 'Amortized Unit Production Cost' is circled in red, indicating a value of 27,675.67 \$.

	Value	Units	Notes
1 Average Unit Production Cost	27,675.67	\$	
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

The screenshot displays the PRICE TruePlanning software interface. On the left, the 'Product Breakdown Structure' shows a tree view of components under 'ENGINE', with 'ENGINE_BLOCK' selected. On the right, the 'Input Sheet: ENGINE_BLOCK' is shown, containing a table of parameters and their values. A dropdown menu for 'Degree of Automation' is open, showing options: 'Labor intense', 'Semi automated', 'Full automation with many manual tests', and 'Fully automated'. The 'Fully automated' option is highlighted, and a red circle is drawn around it.

Name	Value	Units	Spr
11 Volume	0.001229	ft^3	
12 Sprue Volume	0.00	ft^3	
13 Initial Slug Volume	0.002103	ft^3	
14 Finishing			
15 Number of Holes	19.00		
16 Linear Length of Rounds	56.36	in	
17 Linear Length of Chamfers	0.00	in	
18 Process Inputs			
19 Cycle Time	0.02	hours	
20 Percentage Downtime	5%	%	
21 Parts per Cycle	1		
22 Finished Surface Area	0%	%	
23 Material Removal Tool Width	1.00	in	
24 Finishing Tool Width	1.00	in	
25 Material Removal Toolset Cost	50	\$	
26 Finishing Toolset Cost	75	\$	
27 Parting Line Complexity	Standard (Stepped parting line with moderate depth of part.)		
28 Features	47		
29 Number of Lifters	0		
30 Number of Piercing Stations	1		
31 Number of Forming Stations	1		
32 Number of Trimming Stations	2		
33 Degree of Automation	Semi automated		
34 Process Maturity	Labor intense		
35 Overhead Cost Rate	Semi automated	Currency/Hour	
36 Waste Percentage	Full automation with many manual tests	%	
37 Worksheet Set	Fully automated		

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

The screenshot displays the PRICE TruePlanning interface for an engine system. On the left, the 'Product Breakdown Structure' shows a hierarchy starting with 'ENGINE' (1), followed by 'System' (2), 'Assembly' (3), and 'ENGINE' (4). Under 'ENGINE' (4), components include 'ENGINE_BLOCK' (5), 'CRANKSHAFT' (6), 'PISTON_ASSY' (7), 'PISTON' (8), 'PISTON_PIN' (9), 'CONNECTING_ROD' (10), 'ENGINE_HEAD' (11), 'BOLT_12' (12), 'GLOW_PLUG' (13), 'CARBURETOR' (14), 'BOLT_5' (15), 'ENGINE_COVER' (16), and 'BOLT_8' (17).

On the right, the 'More Results: System' window shows a table of cost metrics. The 'Value' column for 'Average Unit Production Cost' (row 1) is highlighted with a red circle and contains the value 11,431.42. The 'Units' column for this row is empty. The 'Notes' column contains icons for each row.

	Value	Units	Notes
1 Average Unit Production Cost	11,431.42		
2 Amortized Unit Production Cost			
3 Total Weight	0.73	lbs	
4 Total Software Size	0	Software Size U...	
5 Software Size Units	Source Lines of ...		
6 Total Cost	132,262	\$	
7 Total Development Cost	20,012	\$	
8 Total Production Cost	112,250	\$	
9 Total Operation and Support Cost	0	\$	
10 Total Labor	1,143.17	hours	
11 Total Development Labor	143.03	hours	
12 Total Production Labor	1,000.14	hours	
13 Total Operation and Support Labor	0.00	hours	
14 Total Cost Per Weight Unit	180,862.62	Currency/lbs	
15 Total Cost Per Software Size Unit	0.00	Currency/Softw...	
16 Average Unit Production Cost Per Weight U...	132.09	Currency/lbs	
17 Total Hours Per Software Size Unit	0.00	Hours/Software ...	
18 Amortized Unit Production Cost Per Weight ...	15,631.97	Currency/lbs	
19 -			
20 Project Initiation and Planning Development...	10	\$	
21 Project Initiation and Planning Production C...	68	\$	
22 Project Initiation and Planning Operation an...	0	\$	
23 Total Project Initiation and Planning Cost	77	\$	
24 Project Management and Control Developm...	1,308	\$	
25 Project Management and Control Productio...	9,145	\$	

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.