



Advancing the Art of Technology Cost Estimating- a Collaboration between NASA and Boeing

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Boeing and NASA Have Successfully Applied P-BEAT

Application Category	P-BEAT Past Applications	P-BEAT Applications In Work
Technology Development Cost Estimating	<ul style="list-style-type: none"> • Boeing Air Traffic Management • NASA “N+3”Supersonic Aircraft Technology Study • NASA Advanced engine studies 	<ul style="list-style-type: none"> • Boeing technology planning • NASA technology cost studies
Design Trade Studies	<ul style="list-style-type: none"> • Boeing Unmanned Aircraft design • Boeing Directed Energy weapons • NASA Crew Exploratory Vehicle • Advanced Engine Cost-Performance Studies 	<p>Conceptual Aircraft Design Trade Studies</p> <p><i>(Perform rapid cost estimates from computer aided design models)</i></p>
Manufacturing Cost Reduction	<ul style="list-style-type: none"> • Boeing V-22 cost reduction • Commercial aircraft derivatives • F/A-18/ F-15, C-17 cost reduction 	<ul style="list-style-type: none"> • Cost reduction of production parts • Quicker cost estimates for engineers • Tool to control cost of production <p><i>(Manufacturing Make-buy decisions)</i></p>

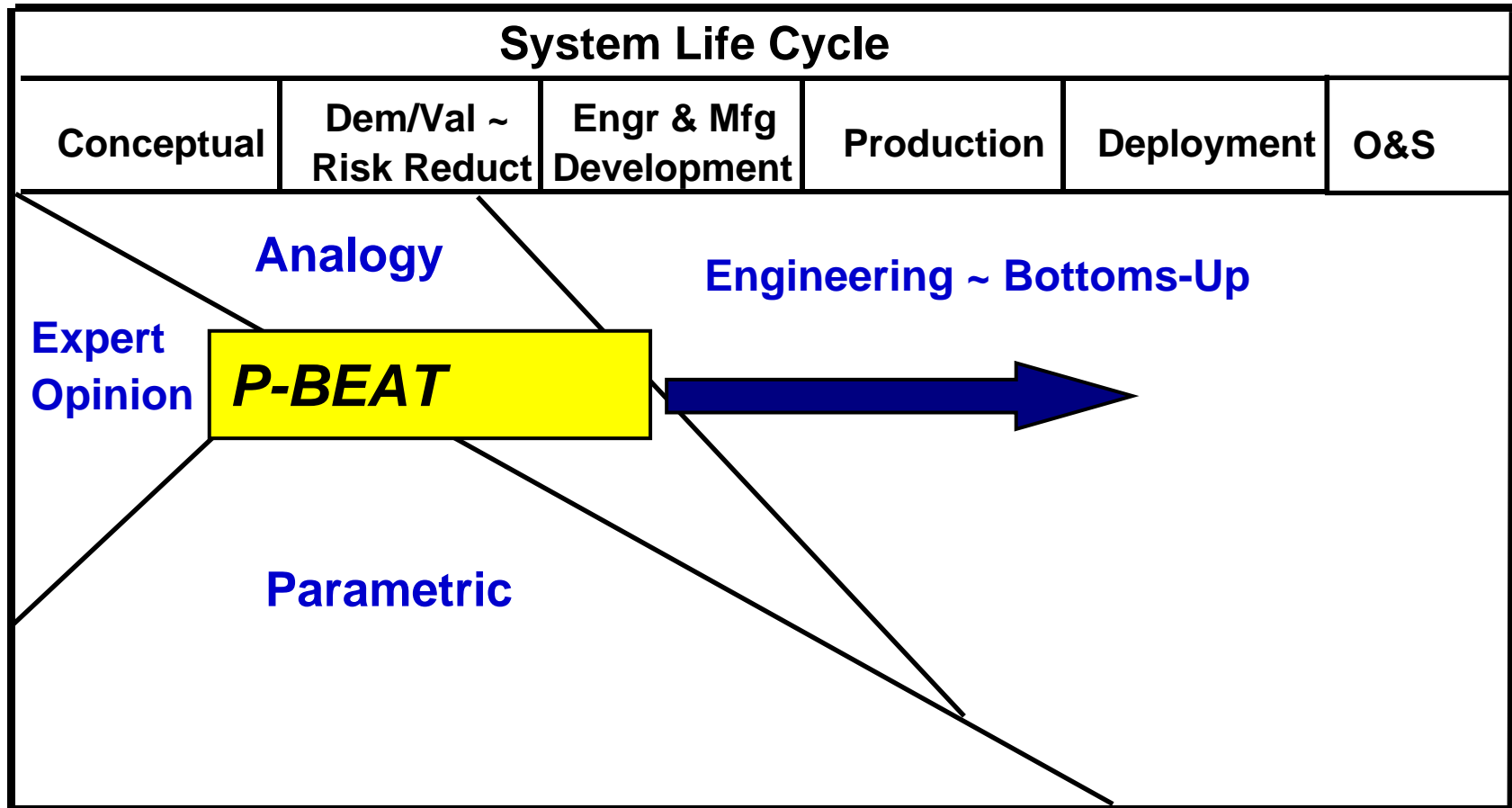
NASA & Boeing have Demonstrated P-BEAT Cost Estimating Capabilities Needed For All Life Cycle Phases

P-BEAT Cost Analysis has been successfully used on Boeing and NASA programs

D	E	F	G	H	I
Program Name: JIMO					
Show BOM	Save Trade	Save Baseline			
Show Chart	Get Trade	Get Baseline			
Trade Baseline					
Study Name: Thruster					
Description: Alternate - 2 SSME Hardware 13					
Year \$:	2001	2001			
Development Cost:	\$534,862,677	\$250,000,000			
Prototype First Unit Cost:	\$2,897,896	\$2,500,000			
Avg. Unit Prod. Cost:	\$2,530,591	\$2,183,118			
Programmatics					
Prod. Qty. Req'd:	3.0	3.0			
Least:	3	3			
Likely:	3	3			
Most:	3	3			
Prod. Lot Size:	3.0	3.0			
Platform:	Space	Space			
Rating:	Manned	Manned			
Mobility:	Mobile	Mobile			
Standards:	Military	Military			
Reusability:	Expendable	Expendable			
Platform Value:	2.267	2.267			
Acquisition Philosophy:	Ratio	Percent	Ratio	Percent	
Design & Build:	1	50%	1	100%	
Sub-contract:	1	50%		0%	
Build-to-print:		0%		0%	
Buy & Integrate:		0%		0%	
Supplier Furnished Equipment:		0%		0%	
Development Wrap Rate %:	123.0%		123.0%		
Production Wrap Rate %:	123.0%		123.0%		
Composite Labor Rate:	\$45.00		\$45.00		
Design Maturity: Design Characteristics					
Least:	Simple Modification	Simple Modification			
Likely:	New Design	Extensive Modification			
Most:	Advanced State of the Art	New Design			
Design Capability:		Extensive experience			

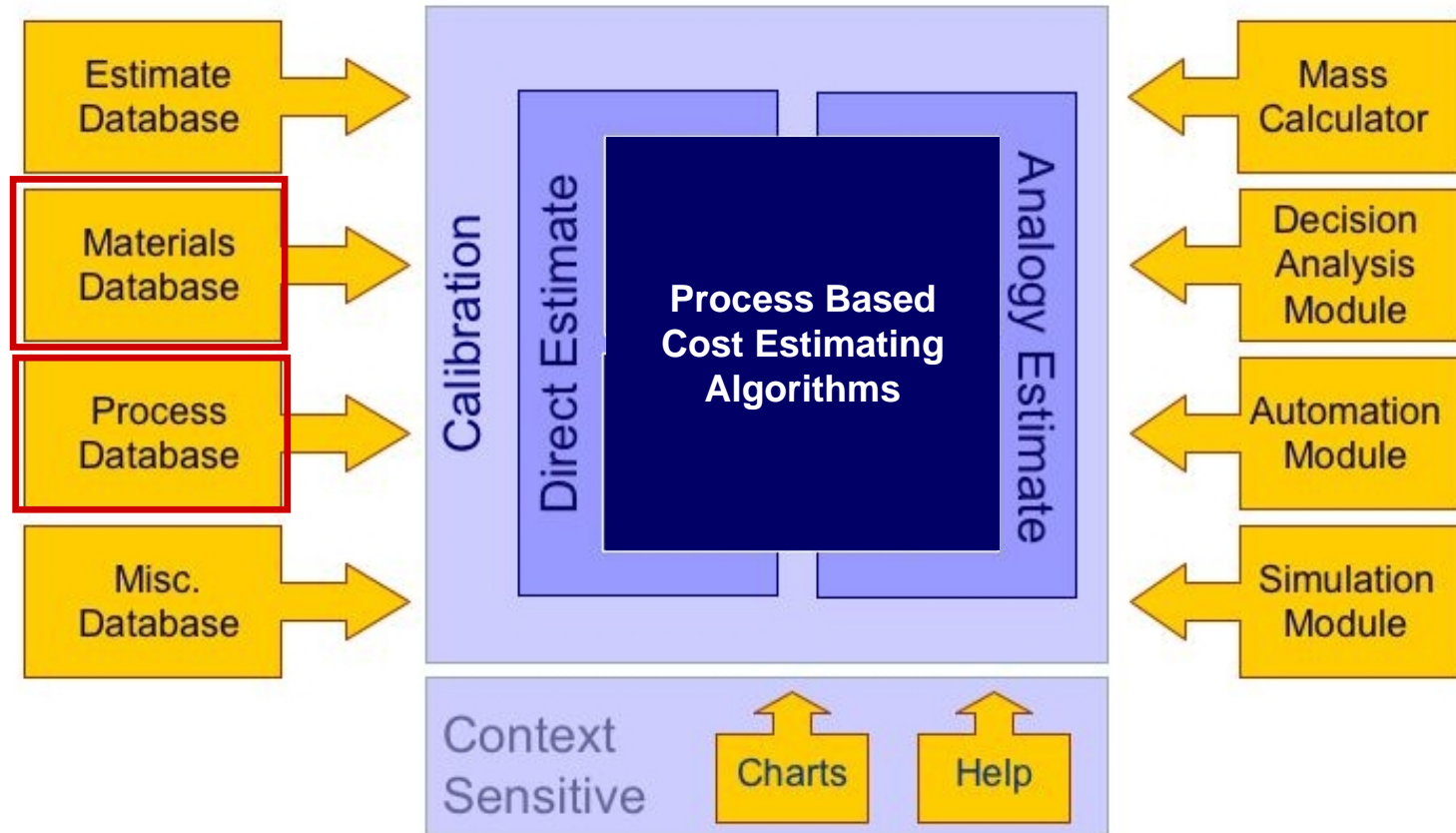
- Supports Conceptual Design Trade Studies
- Estimates cost to Develop Technologies
- Used by NASA Centers (Glenn, Marshal, Johnson)
 - NASA Crew Exploratory Vehicle Design
 - NASA Aries Design
- Boeing Applications:
 - Customer contracts (CRAD):**
 - N+3 Supersonic aircraft design (NASA-Langley)
 - VAATE Affordable engine design trade study
 - UAV sub-system technology study (NASIC)
 - Boeing programs:**
 - Supplier part “should cost”(F/A-18, F-15, C-17)
 - Air Traffic Management technology study

Cost Estimating Approaches vs. Program Phases



P-BEAT Provides Analogy Cost Estimating Approach Needed During Early Life Cycle Phases

P-BEAT is Built on a Set of Tools & Databases



P-BEAT relies on a Benchmark database of known design characteristics and costs. Database is built with each cost estimate.

P-BEAT Screen Layout is Designed for Usability

The screenshot displays the P-BEAT software interface. On the left, there are input fields for Program Name (JIMO), Study Name (Thruster), Description (Alternate - 2, SSME Hardware 13), Year (2001), Development Cost (\$534,862,677), Theoretic First Unit Cost (\$2,897,806), and Avg. Unit Prod. Cost (\$2,530,501). Below these are Programmatic requirements and Design Maturity/Design Capability sections. On the right, there are help screens for 'Study Name', 'Description - Trade', and 'Description - Baseline'. At the bottom right, a 'ChartWB' displays a cumulative cost probability curve for 'Theoretic First Unit Cost-Risk \$K'. The chart shows a likelihood of 50% at a cost of \$2,902.0K, with other points at \$2,069.3K and \$4,167.2K.

Inputs:

- Programatics
- Technical Maturity
- Design Characteristics
- Manufacturing Processes

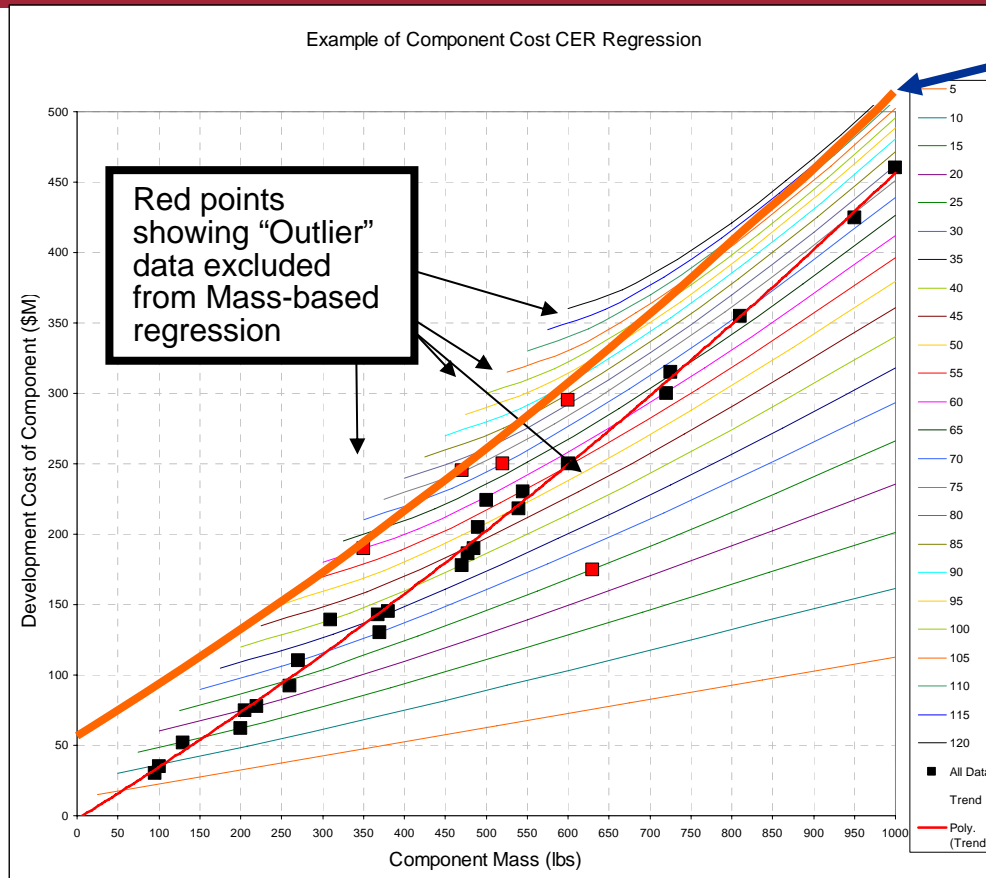
Context-Sensitive Help

Output: Cumulative Cost Probability

Tool Features

- Help screens readily available
- Data stored in MS Access files
- Use only inputs at indenture level required
- Extensive Benchmark Database
- Simulation Tool for cost-risk
- Sensitivity analysis module

Comparison of Process-based vs. Mass-based Cost Data Regression

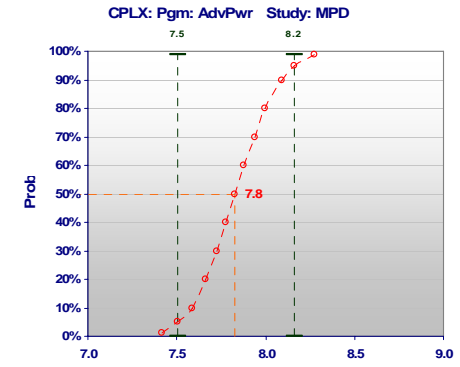
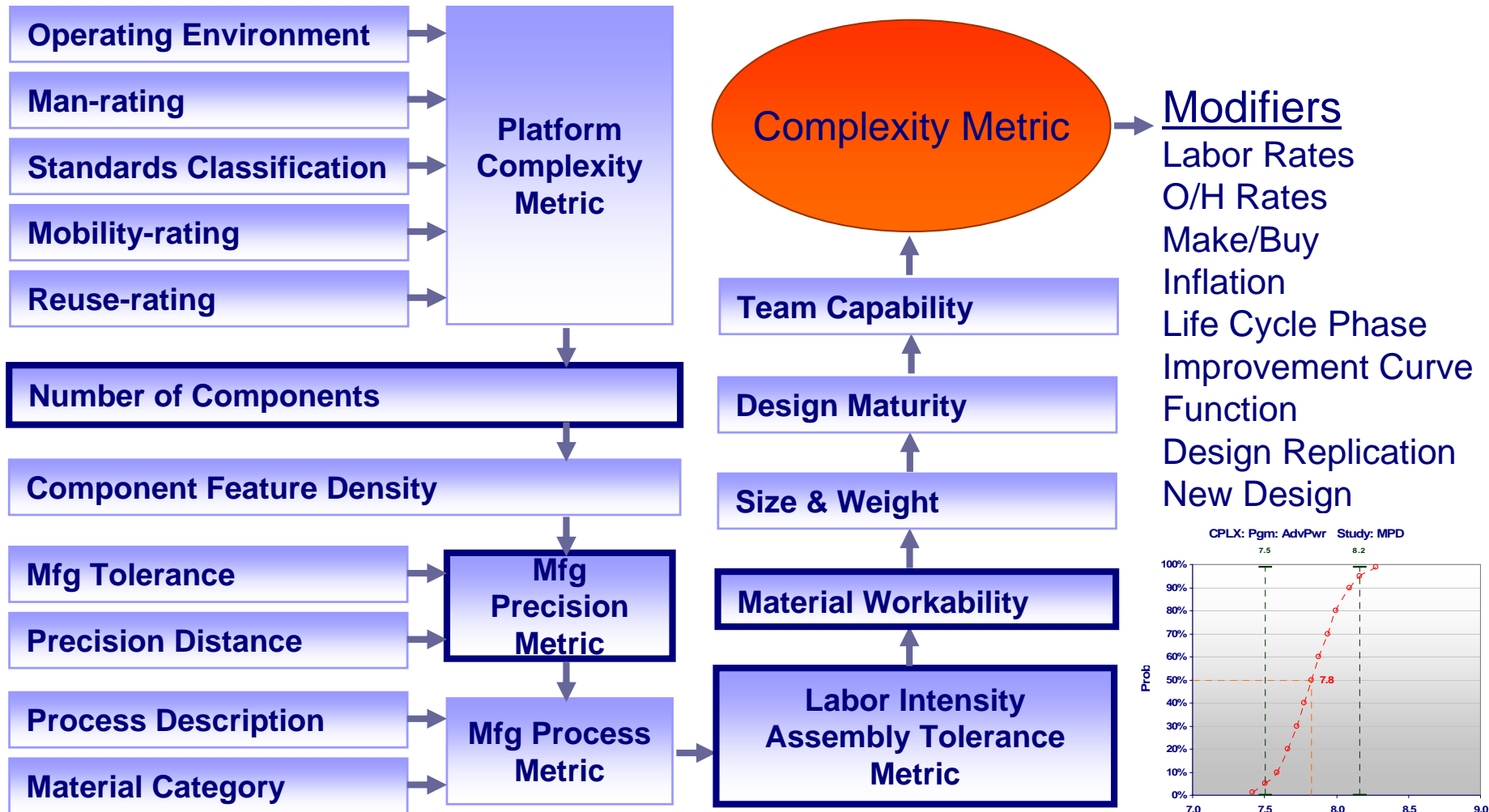


Orange line showing traditional **Mass-based CER.**

Multi-colored lines showing **Process-based CERs** of constant component feature count (5 to 120 as determined by the # of engineering drawings) as well as component mass.

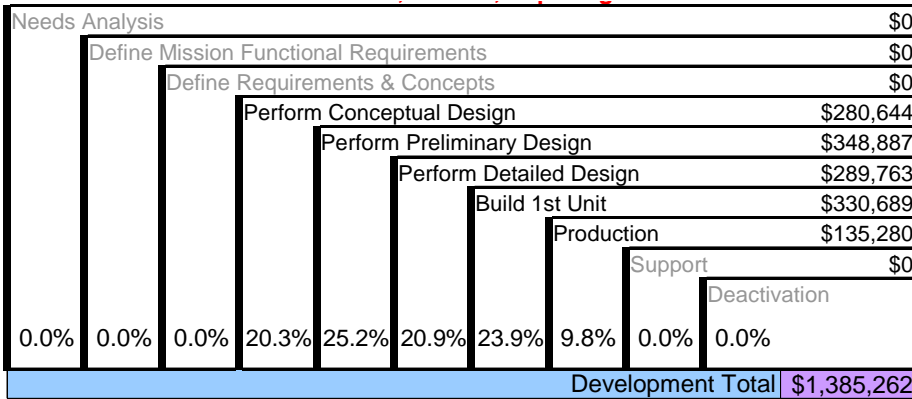
- **Mass-based CERs cannot account for full spread of cost data**
- **CERs with process-based parameters yield regression fits that use ALL the data**
- **Process-based CERS provide greater insight as to why the cost data varies**

Engineering Attribute Inputs Define P-BEAT Complexities that Determine Costs Relative to Baseline

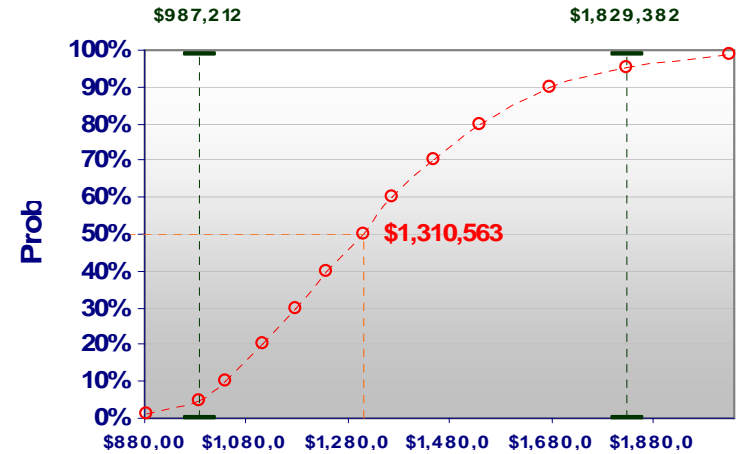


Example P-BEAT Chart/Table Outputs

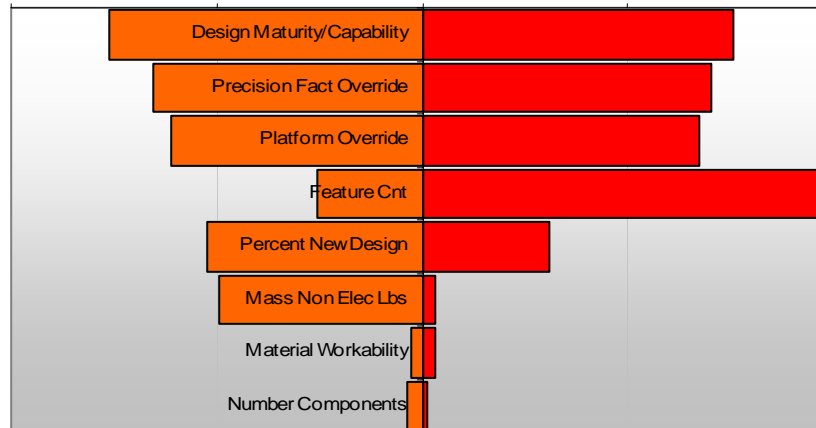
Cost Distribution by Phase



Cost Uncertainty

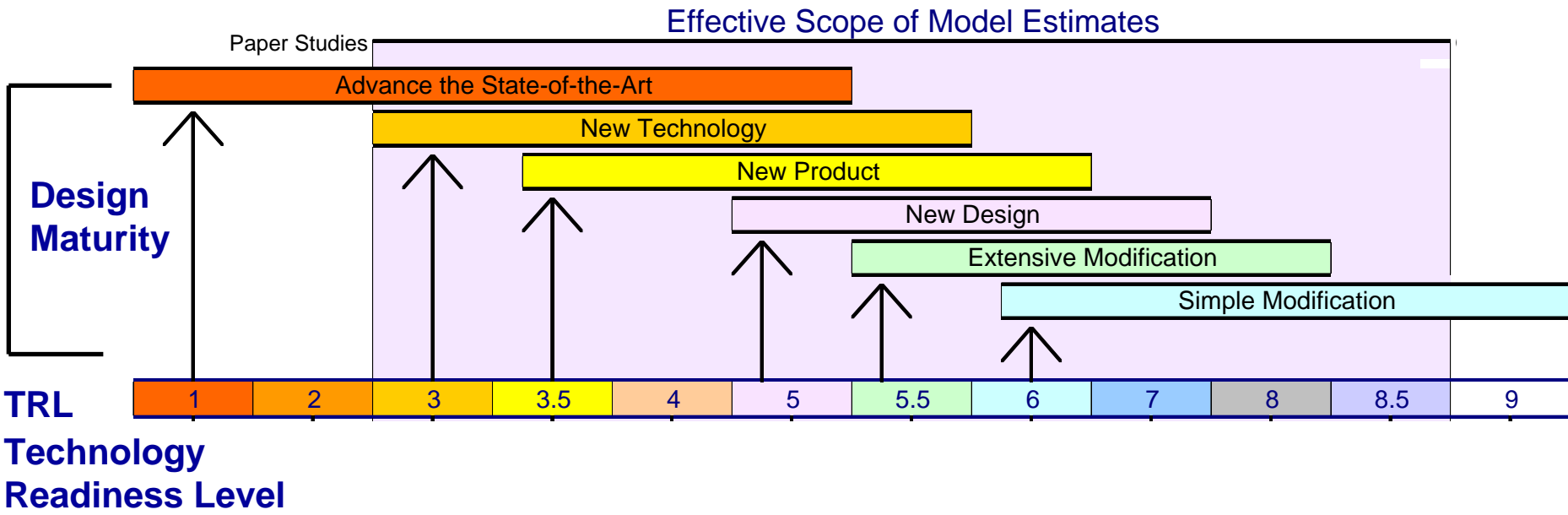


Cost Sensitivities



Technology Readiness Level and Design Maturity

Drive Technology Development Cost in P-BEAT

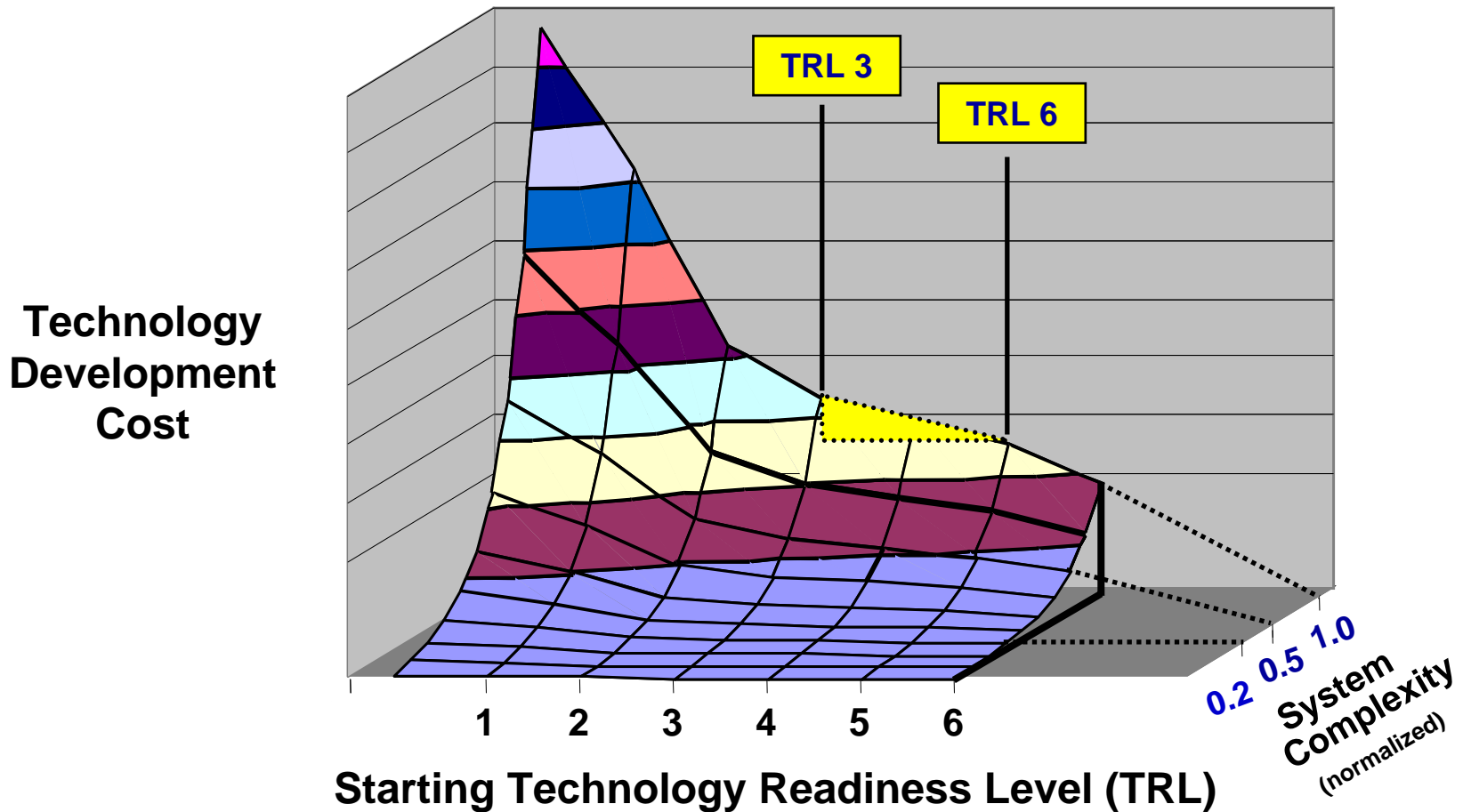


Technology Maturity and Readiness Levels are Cost Driver Inputs in P-BEAT Cost Methodology

Example P-BEAT Input Categories

1. **Engineering and Development Labor Rates**
Direct rate and wrap rate
2. **Production Life Cycle Phases**
Define Requirements
Conceptual Design
Preliminary Design
Build 1st Unit
3. **Mass Properties:**
Weight (lbs)
Materials (choose from database of 14,000 materials)
4. **Design Team Capability (Low, Normal, High)**
5. **Technical Readiness Level (Start and End)**
6. **Software Characteristics**
Language (choose from database of 100 languages)
Source Lines of Code
% Reuse
Maturity (choose from list)
Team Capability (choose from list)
7. **Manufacturing Process Description (choose from list of 800 processes)**

Cost Impact of Technology Maturity Is Modeled with P-BEAT Methodology



P-BEAT Can be Connected to CADD model data

Name	Value
Model	
Catia	
Sheet_Metal_Part_...	
Absolute_Axis...	
Sheet_Metal_...	
Material	17075-0 - ALUMI...
volume	33274.9
mass	0.09304
wetArea	164450
CGx	5070.9
CGy	-304.214
CGz	2615.66
fileSTP	<view...>
fileIGS	<view...>
GeomInfo	
CalculatedCatiaData	
PBEAT	
Envelope	
FeatureCount	20
PartCount	1
Mass	0.09
Material	WROUGHT ALU...
cost	\$1,716,919
GeomInfo	

V-22 Sheet metal part

CATIA model

P-BEAT

Excel interface model

PHOENIX INTEGRATION

CATIA model

Cost driver data: mass, no. parts, feature count, size, materials, tolerances, manufacturing process

Summary and Conclusions

- **R&D investment decisions require a cost tool to estimate relative technology development costs of candidate projects.**
- **P-BEAT is designed to be sensitive to technology and design cost drivers.**
- **Mass-based only cost estimating relationships do not account for full spread of cost data. Complexity cost drivers must be included.**
- **P-BEAT combines Analogy with Parametric cost estimating methods to obtain greater accuracy and cost estimate confidence. These methods are well suited to estimate relative technology project costs.**
- **P-BEAT can be integrated to geometry based design tools for rapid cost estimates needed in design trade studies.**

Boeing and NASA-Glenn are Applying Technology Cost Analysis Techniques and Tools to Improve Technology Investment Decisions