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

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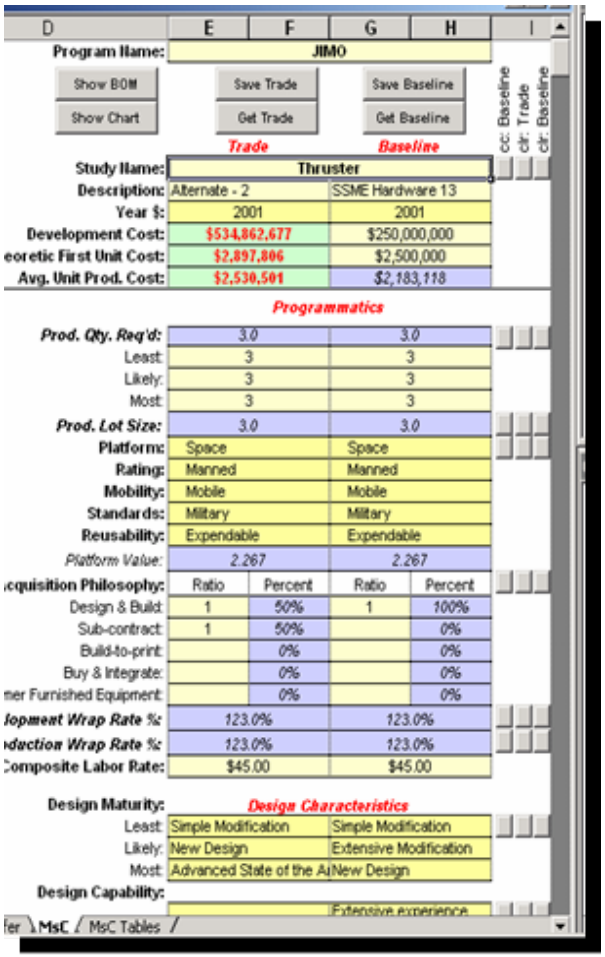
Boeing and NASA Have Successfully Applied P-BEAT

Application Category	P-BEAT Past Applications	P-BEAT Applications In Work
Technology Development Cost Estimating	• Boeing Air Traffic Management • NASA "N+3"Supersonic Aircraft Technology Study • NASA Advanced engine studies	• Boeing technology planning • NASA technology cost studies
Design Trade Studies	• Boeing Unmanned Aircraft design • Boeing Directed Energy weapons • NASA Crew Exploratory Vehicle • Advanced Engine Cost-Performance Studies	Conceptual Aircraft Design Trade Studies (Perform rapid cost estimates from computer aided design models)
Manufacturing Cost Reduction	• Boeing V-22 cost reduction • Commercial aircraft derivatives • F/A-18/ F-15, C-17 cost reduction	• Cost reduction of production parts • Quicker cost estimates for engineers • Tool to control cost of production (Manufacturing Make-buy decisions)

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



- **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:**

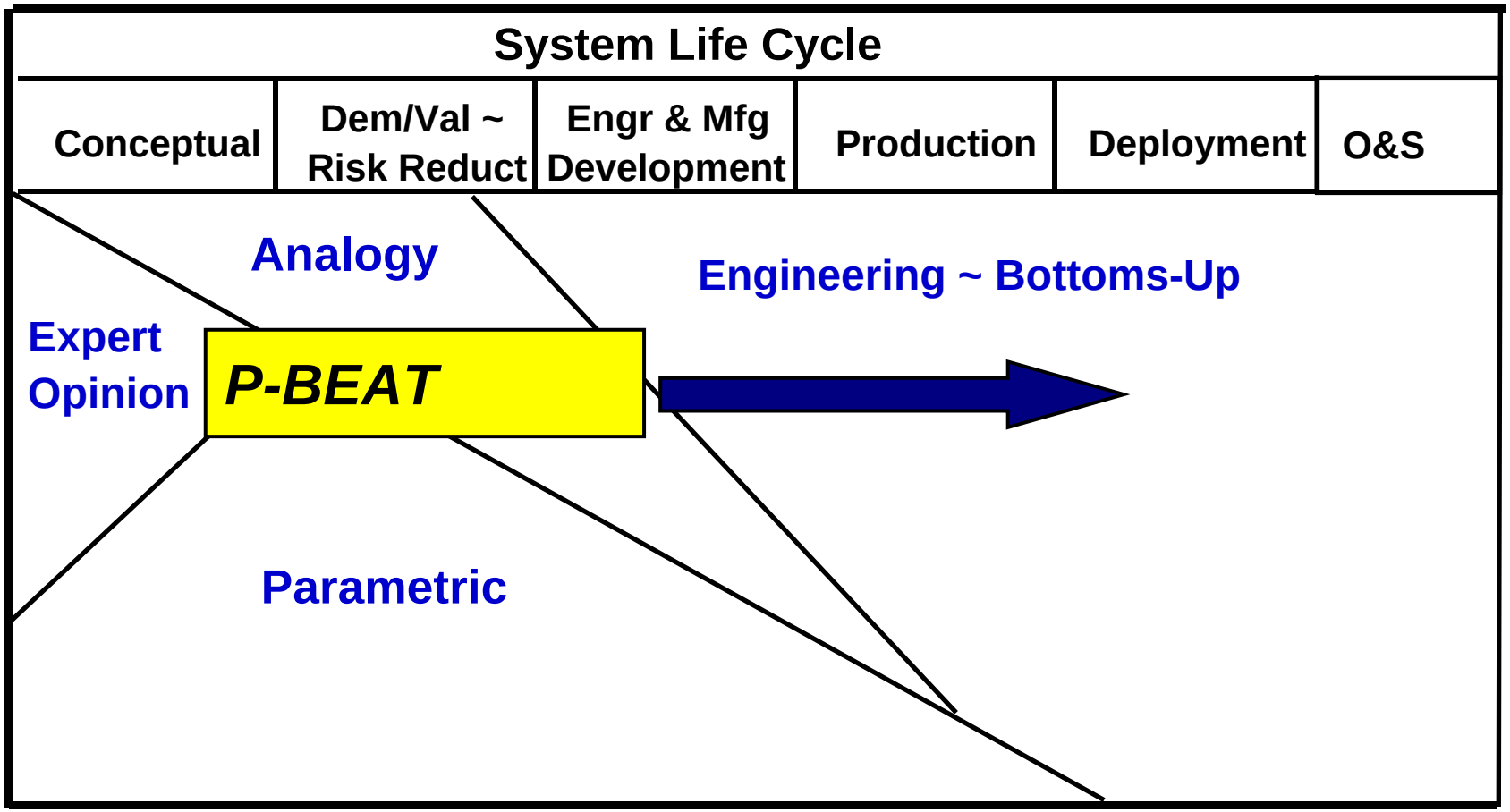
Customer contracts (CRAD):

- **N+3 Supersonic aircraft design (NASA-Langley)**
- **VAATE Affordable engine design trade study**
- **UAV sub-system technology study (NASIC)**

Boeing programs:

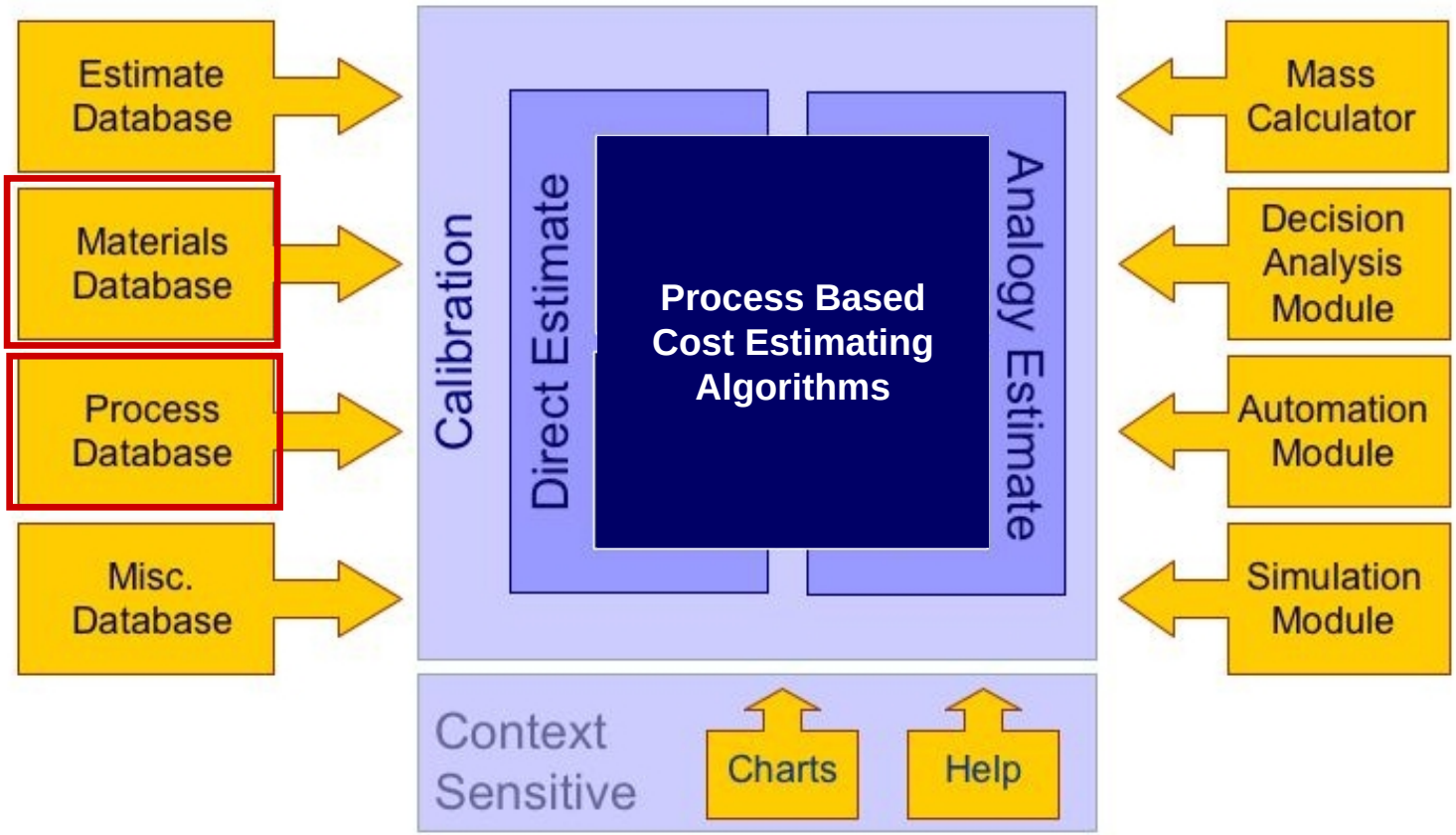
- **Supplier part "should cost"(F/A-18, F-15, C-17)**
- **Air Traffic Management technology study**

Cost Estimating Approaches vs. Program Phases



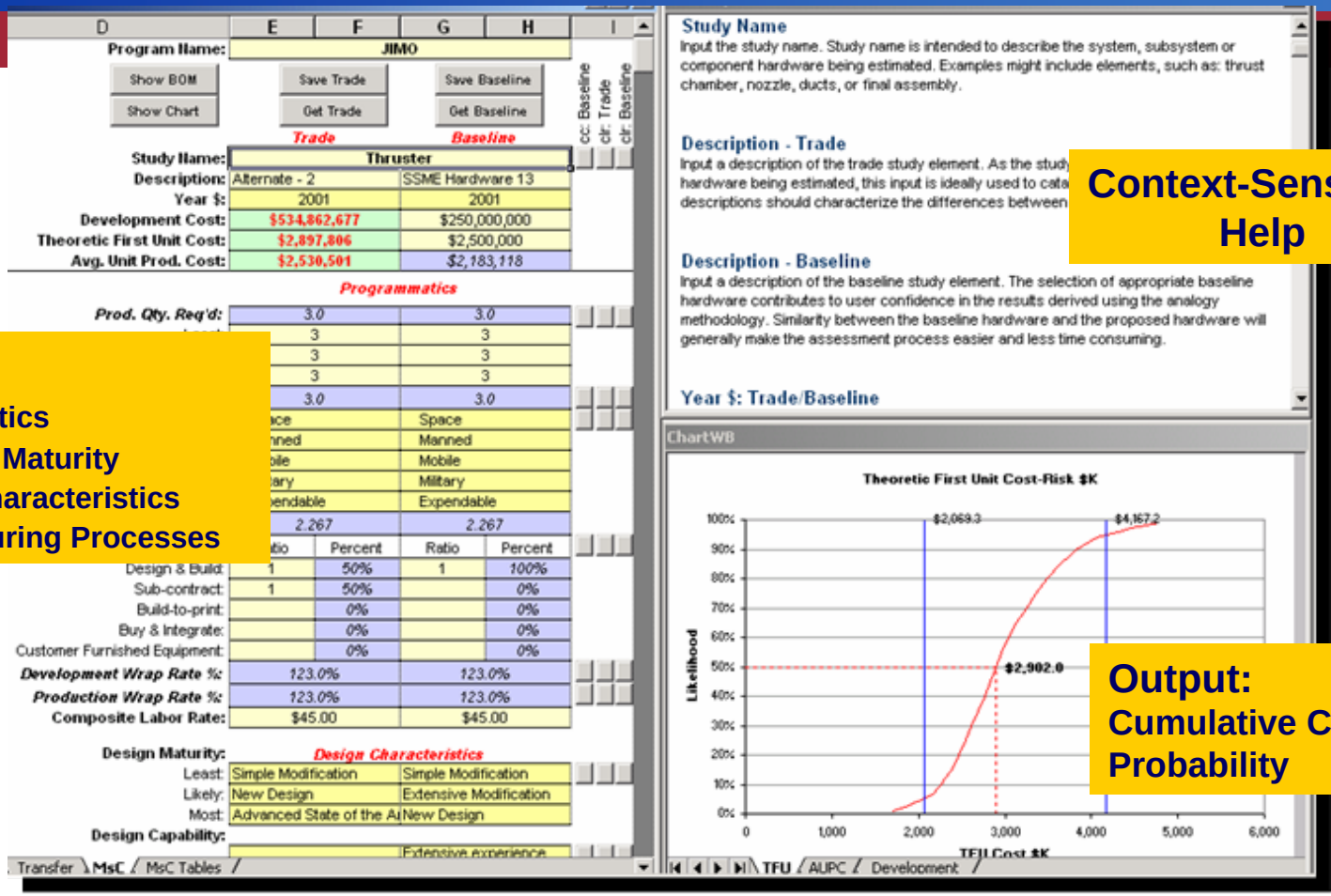
P-BEAT Provides Analogy Cost Estimating Approach Needed During Early Life Cycle Phases

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



Context-Sensitive Help

Inputs:

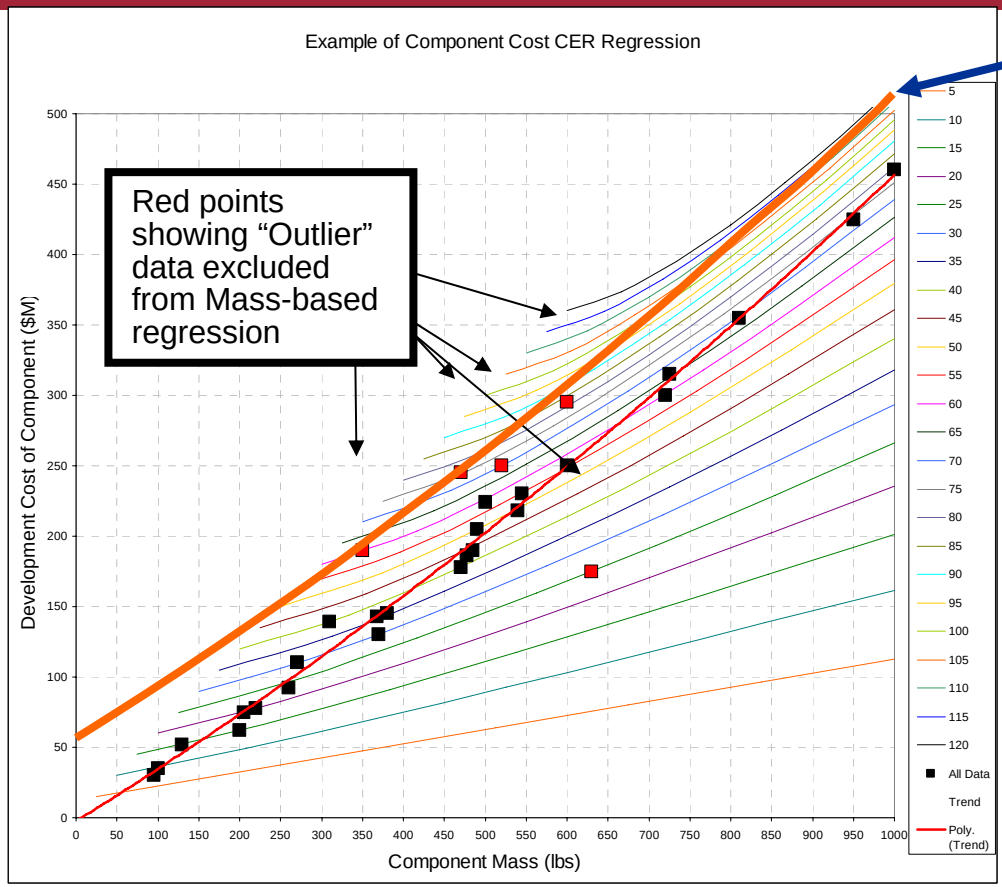
- **Programatics**
- **Technical Maturity**
- **Design Characteristics**
- **Manufacturing Processes**

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

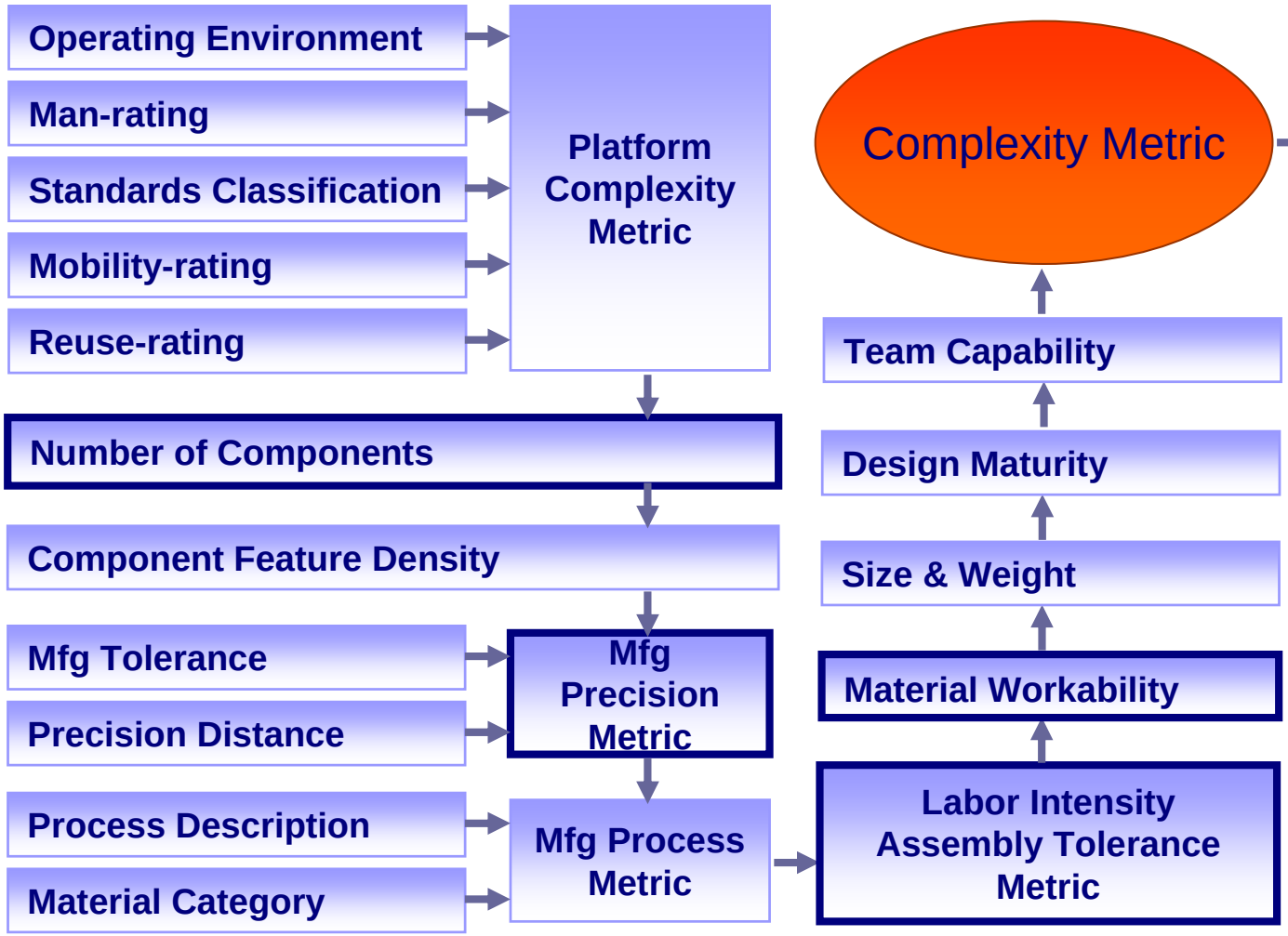


Orange line showing traditional **Mass-based** CER.

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.

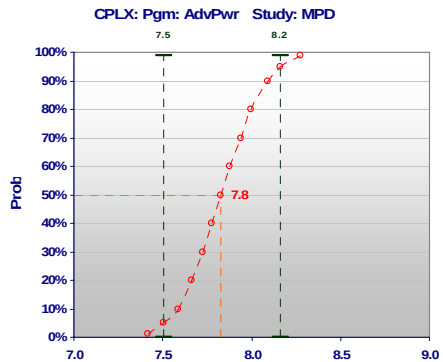
- **Mass-based CERs cannot account for full spread of cost data**
- **CERs with process-based parameters yield regression fits that use ALL the data**
- **Process-based CERS provide greater insight as to why the cost data varies**

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



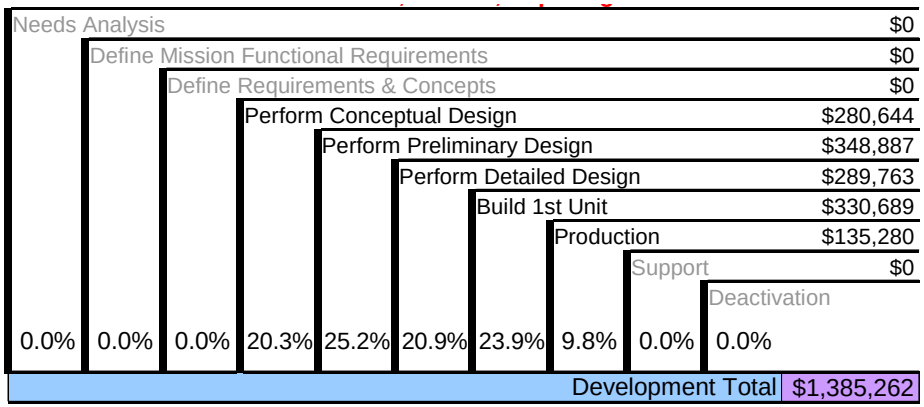
Modifiers

Labor Rates
O/H Rates
Make/Buy
Inflation
Life Cycle Phase
Improvement Curve
Function
Design Replication
New Design

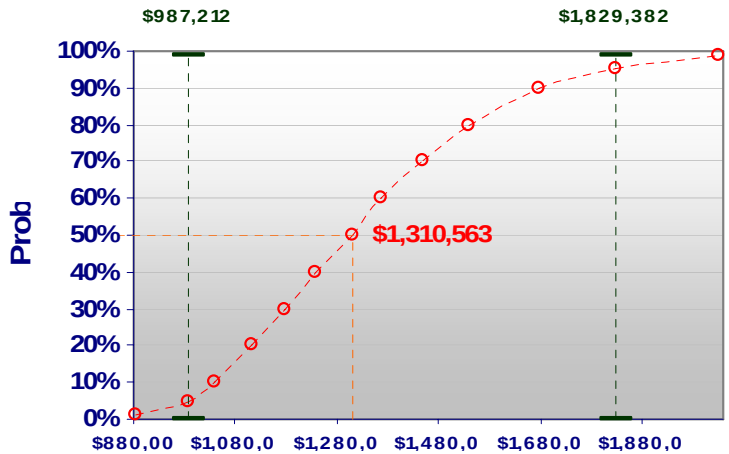


Example P-BEAT Chart/Table Outputs

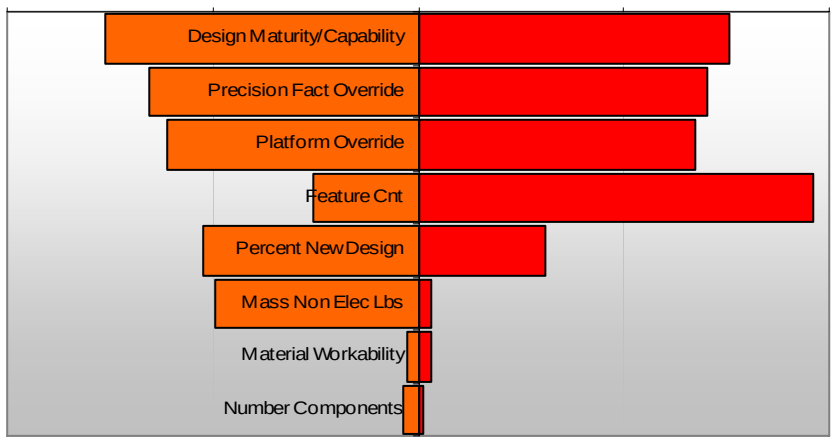
Cost Distribution by Phase



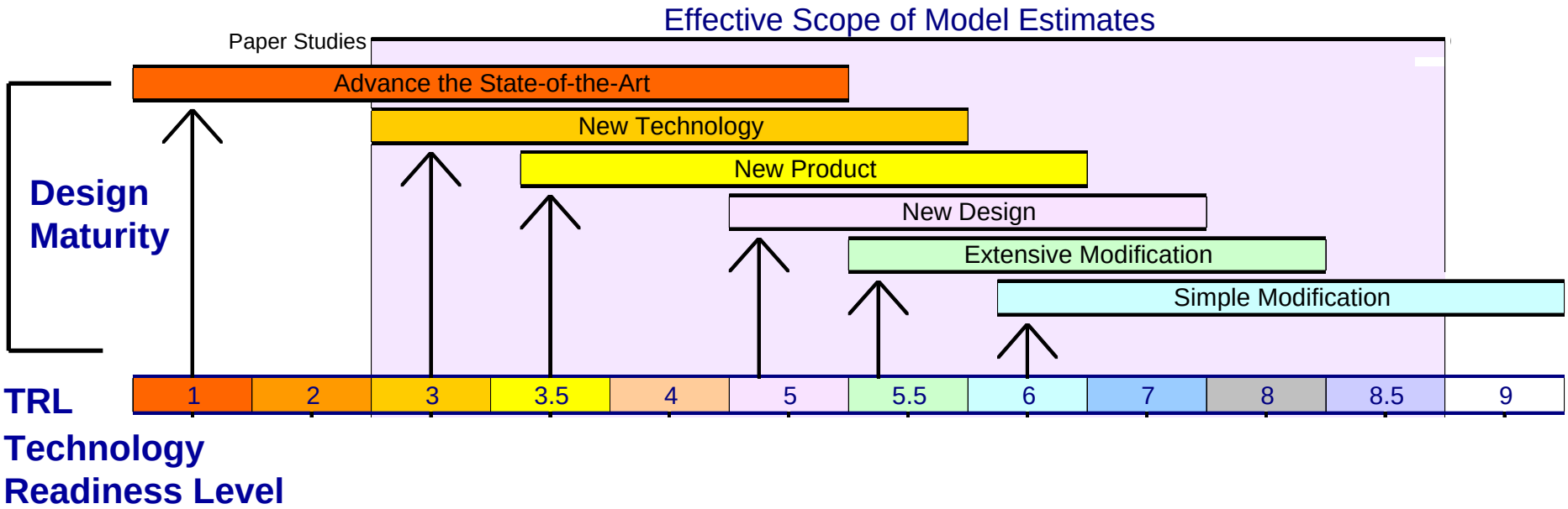
Cost Uncertainty



Cost Sensitivities



Technology Readiness Level and Design Maturity Drive Technology Development Cost in P-BEAT

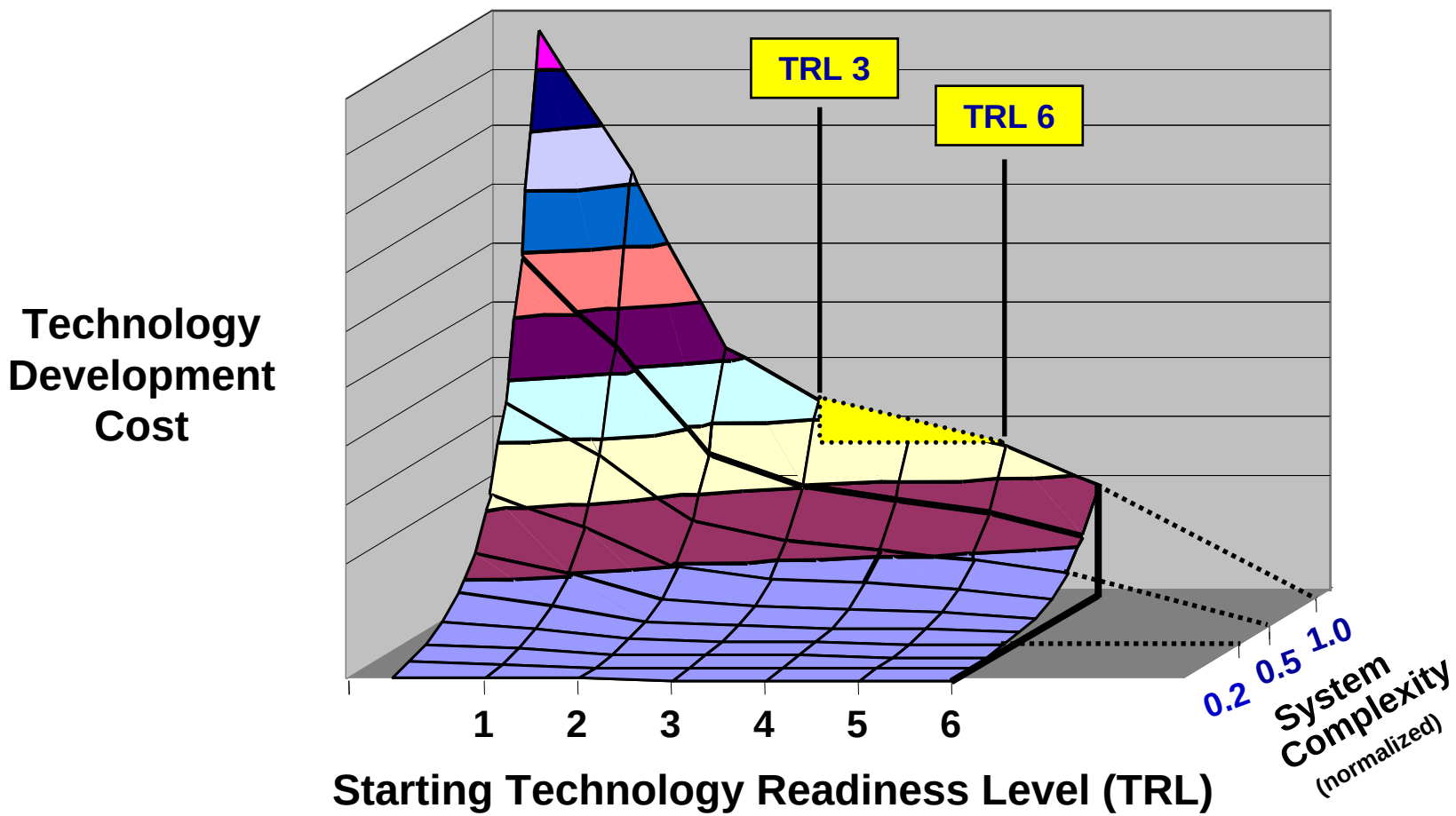


Technology Maturity and Readiness Levels are Cost Driver Inputs in P-BEAT Cost Methodology

Example P-BEAT Input Categories

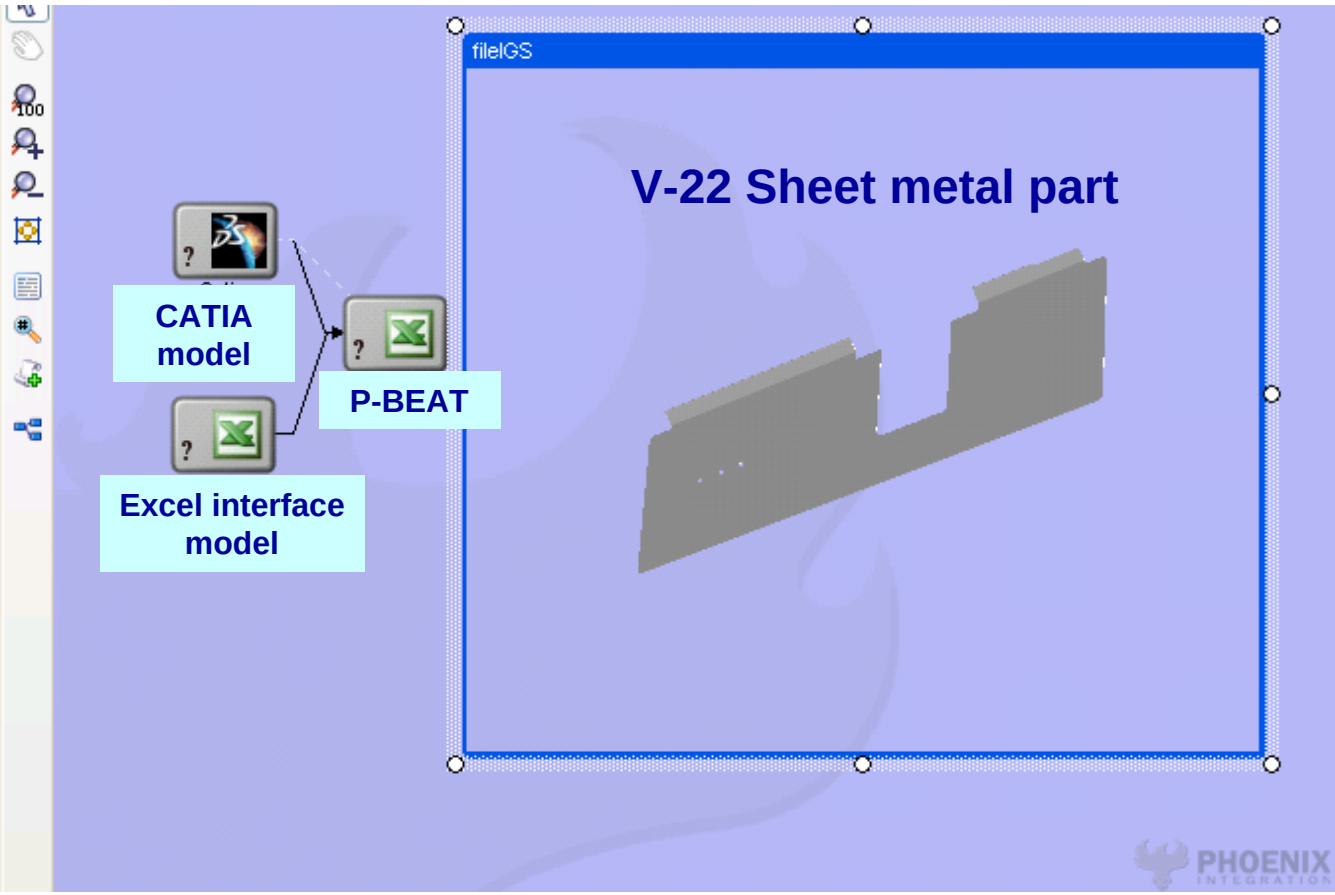
1. ***Engineering and Development Labor Rates***
   - ***Direct rate and wrap rate***
2. ***Production Life Cycle Phases***
   - ***Define Requirements***
   - ***Conceptual Design***
   - ***Preliminary Design***
   - ***Build 1st Unit***
3. ***Mass Properties:***
   - ***Weight (lbs)***
   - ***Materials (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	| 7075-0 - 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	



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