



Commercial Applications for Predictive Analytics: Requirements-Driven Forecasting

ICEAA 2018 Workshop

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PRICE Systems

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1. Introduction
2. Overview
3. Case Studies
 - a) Automotive
 - b) Jet Engine
 - c) Aircraft
 - d) Software
4. Lessons Learned

Commercial Applications of Predictive Analytics: Requirements-Driven Forecasting

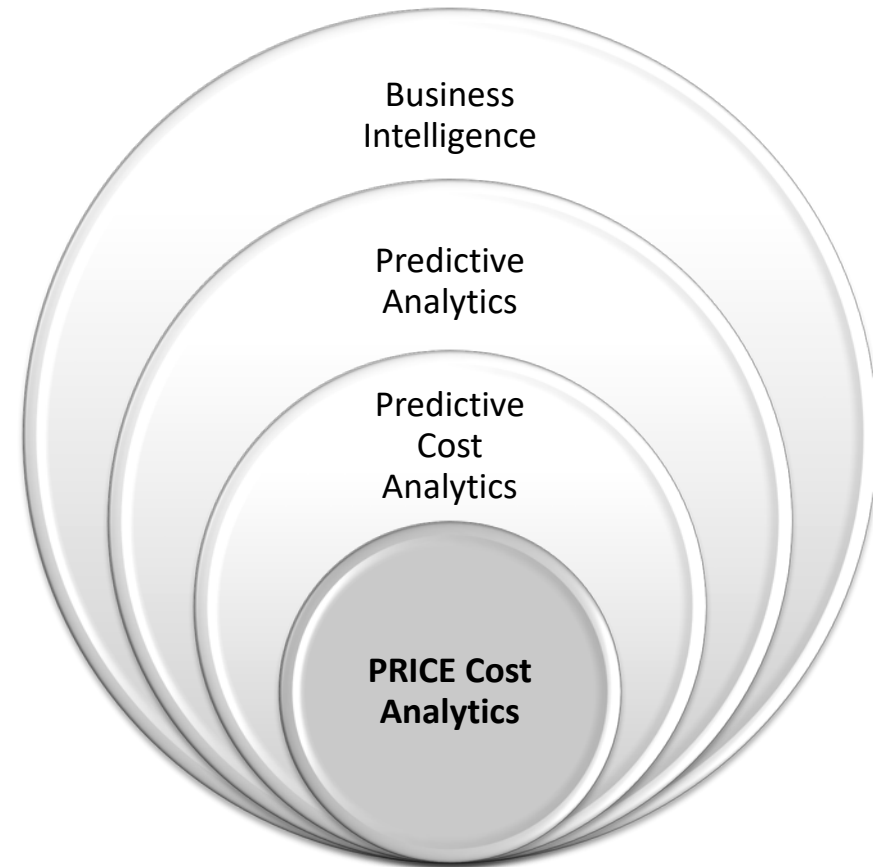
Our job is often to fine-tune a predictive capability, process or system by best applying knowledge to justify key drivers for forecasting.

Regardless of methodology, internally-developed or licensed, the common objective is creating valid/defensible estimates based on actual historical data as well as performance parameters.

This paper will examine four commercial case studies where unique Predictive Analytics methods were implemented to both leverage proprietary knowledgebases as well as reflect requirements metrics to create justifiable forecasts.

Cost Analytics Overview

- **Business intelligence (BI)** is the set of techniques and tools for the transformation of raw data into meaningful and useful information for business analysis purposes (Wikipedia 2015)
- **Predictive Analytics** encompasses a variety of statistical techniques from modeling, machine learning, and data mining that analyze current and historical facts to make predictions about future, or otherwise unknown, events (Wikipedia 2015)
- **Predictive Cost Analytics** a field of predictive analytics specifically targeting cost and schedule estimating for products, projects, on-going operations, other cost-incurring activities
- **PRICE Cost Analytics** a prescriptive, targeted implementation of predictive cost analytics encompassing a suite of proven processes, automation software, and predictive models

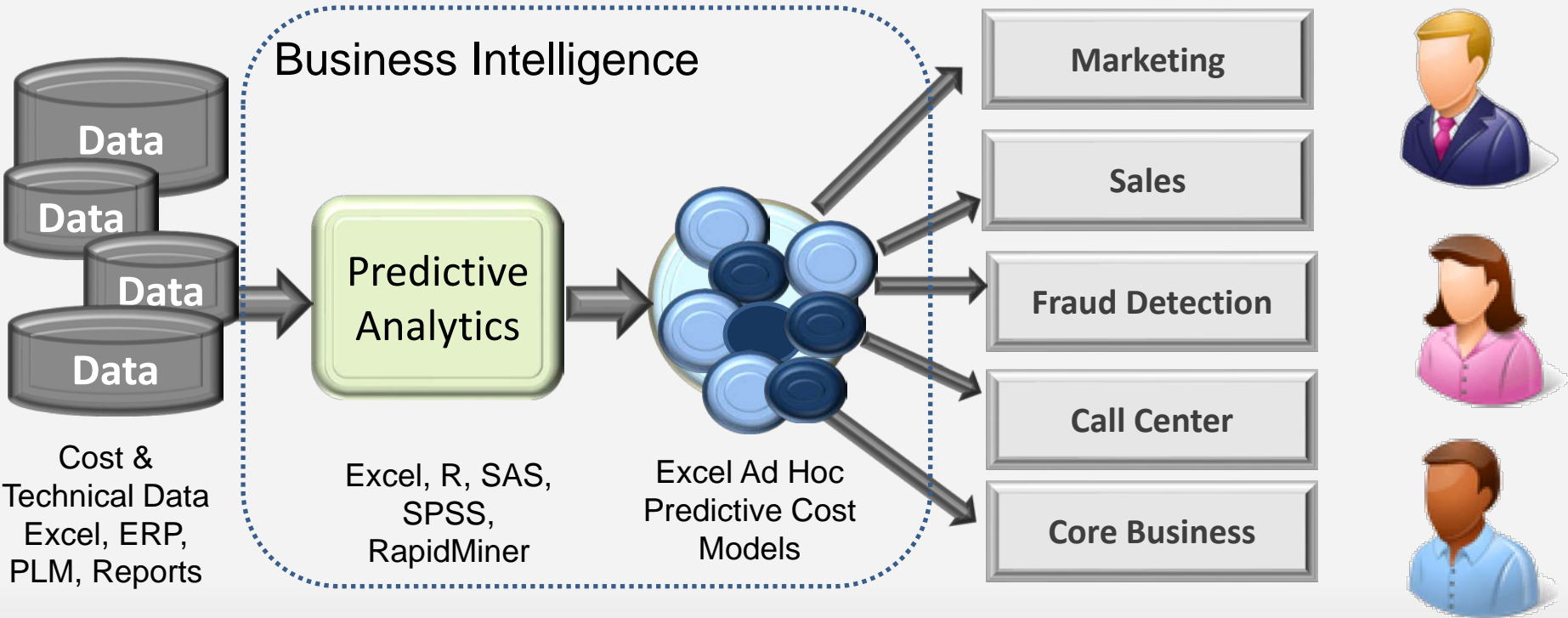


Predictive Cost Analytics

Enterprise

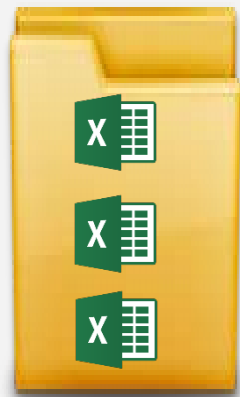
Customers

Business Units



Enterprise

Data



Cost & Technical Data
Excel

Business Intelligence

Predictive Analytics

TrueFindings



TruePlanning & the PRICE Models



Business Units

Business Development (Price-to-Win)

Budgeting

Design Affordability Tradeoffs

Strategic Sourcing

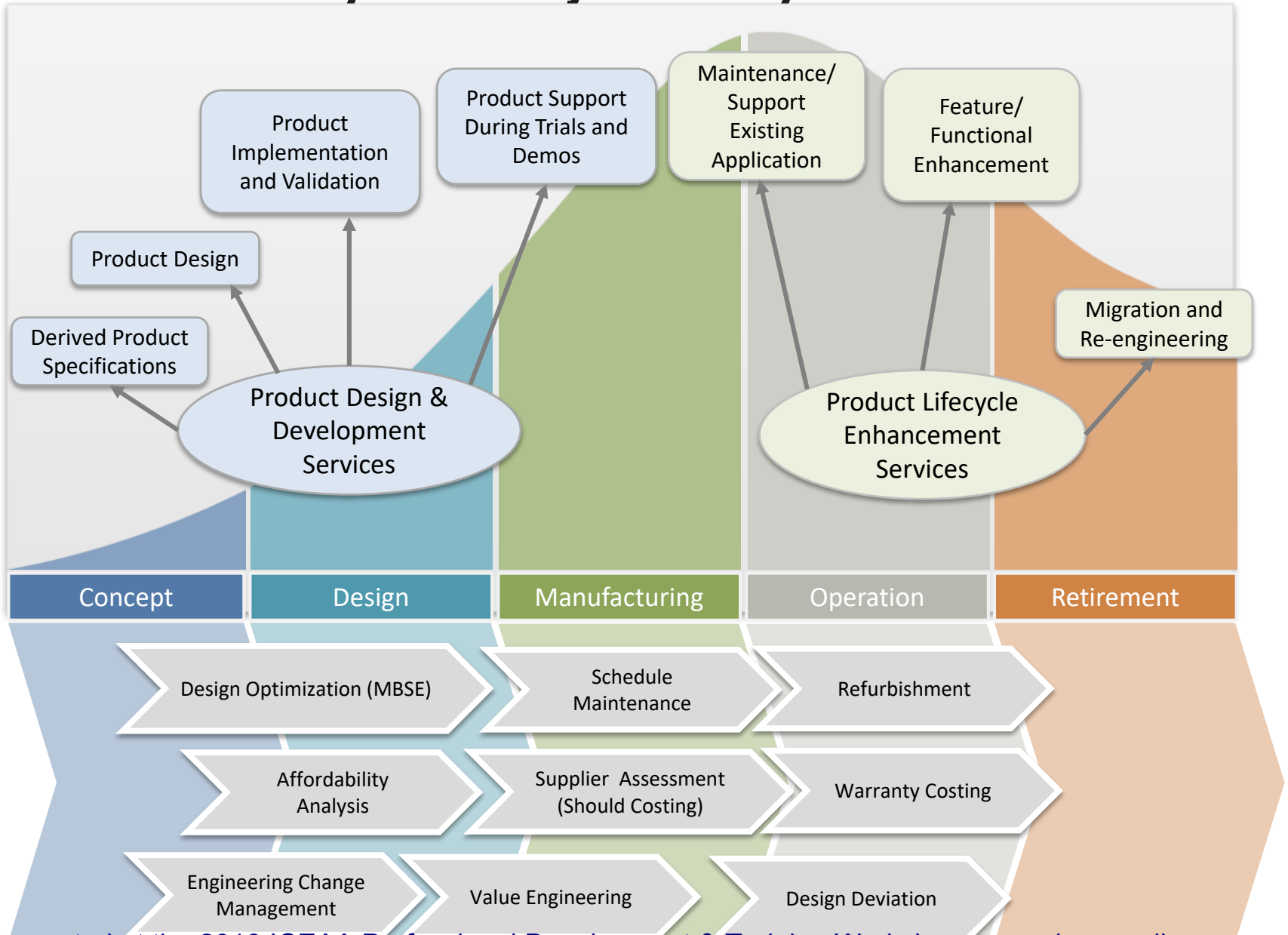
Bid & Proposal

TrueMapper

Customers

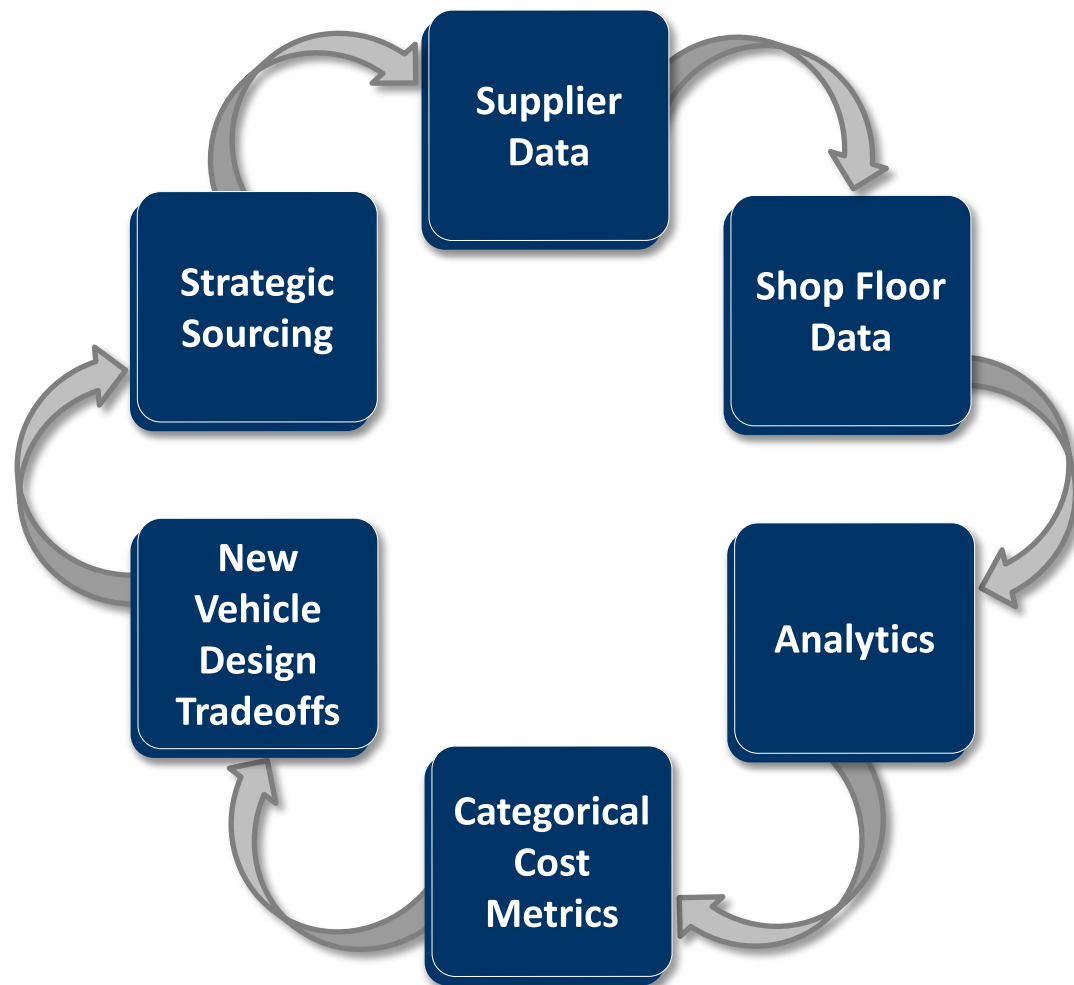


PRICE® Cost Analytics - Project Lifecycle View



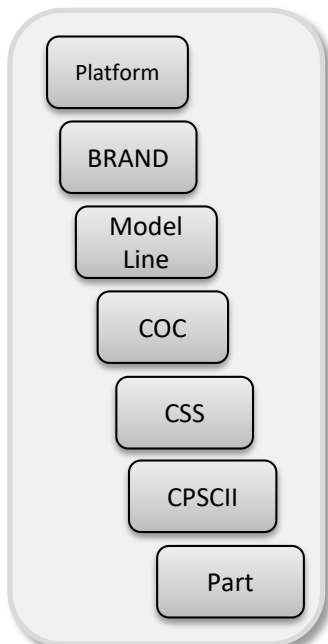
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AUTOMOTIVE CASE STUDY



Feature
Attribute

Feature	609
Attribute	16
Platform	5
Brand	3
Model Line	10
COC	5
CSS	32
CPSCII	340
Part	



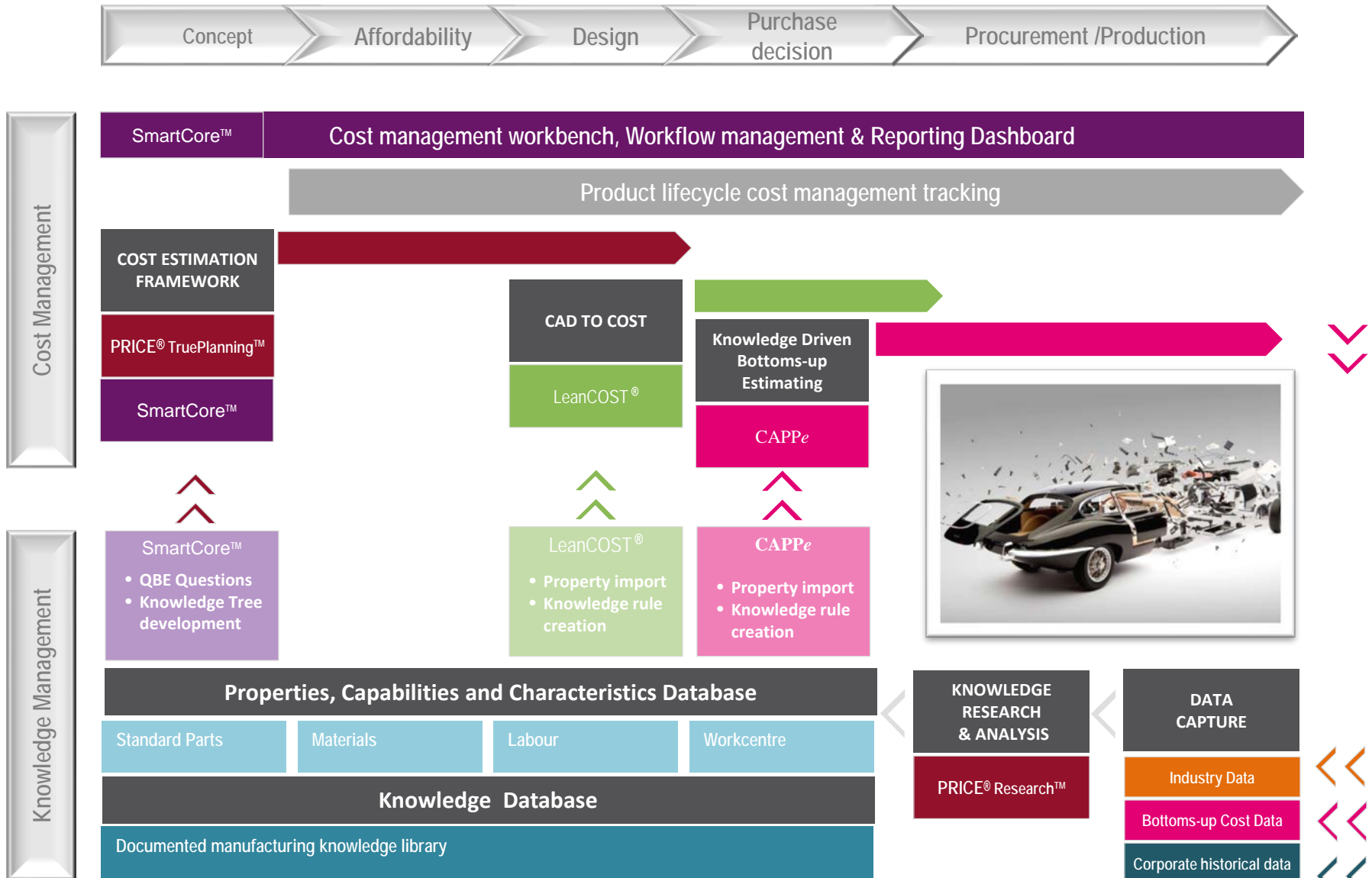
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Cost Management Platform – Current State



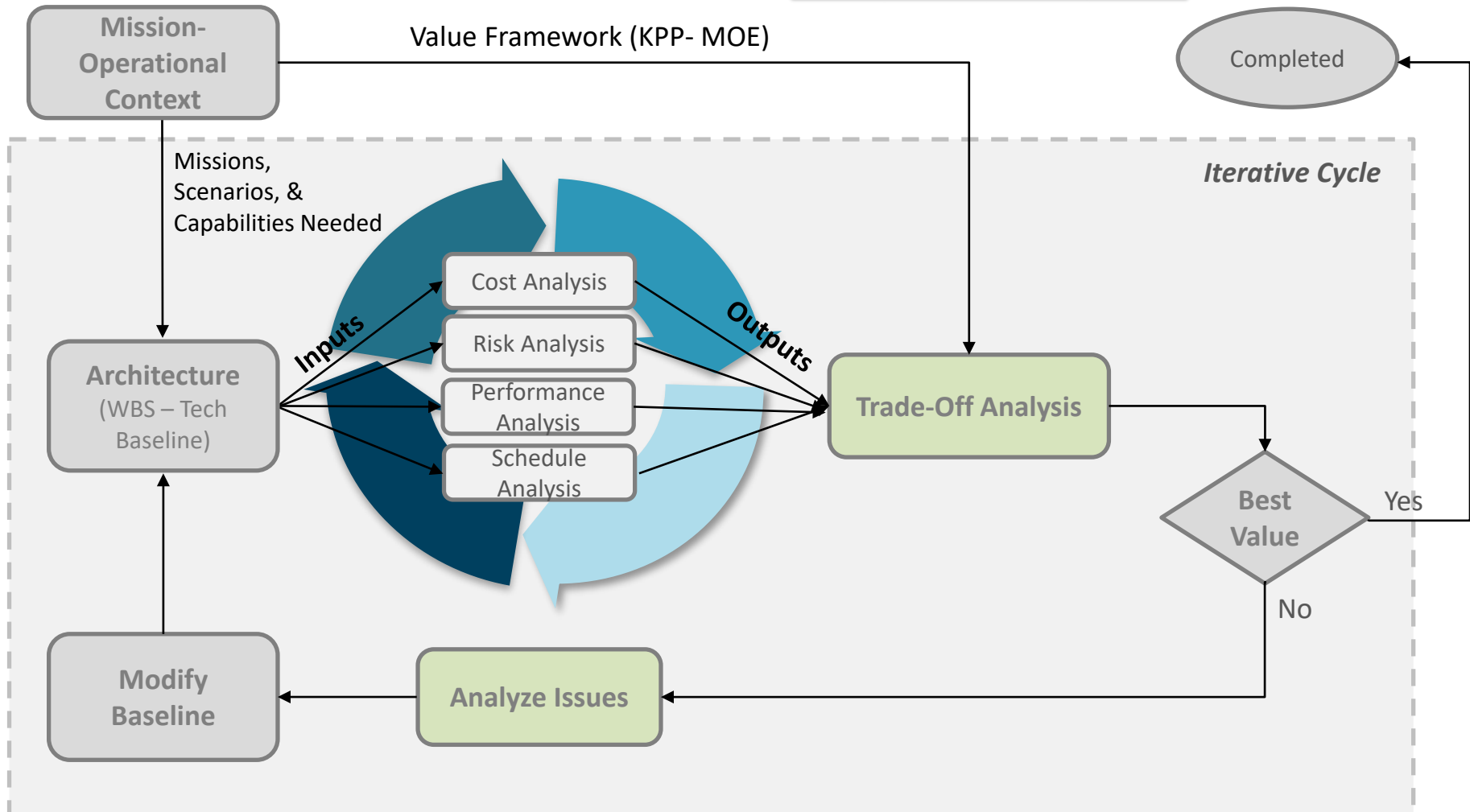
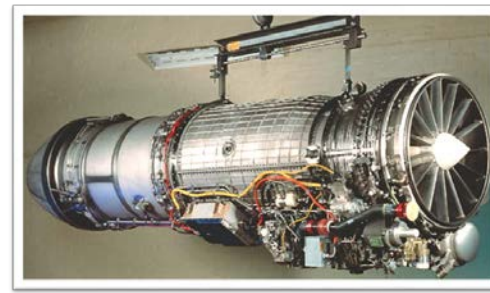
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Detailed Knowledge – Goal State



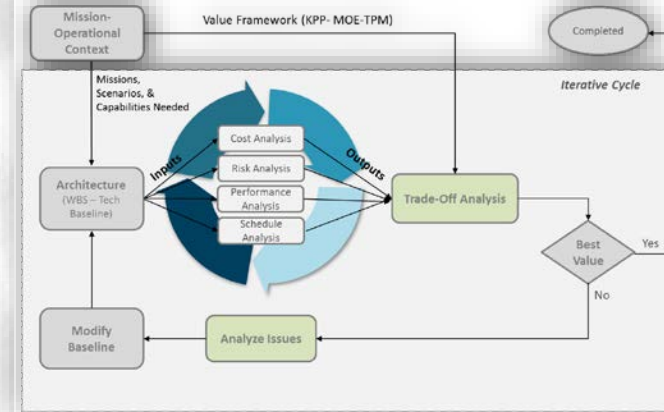
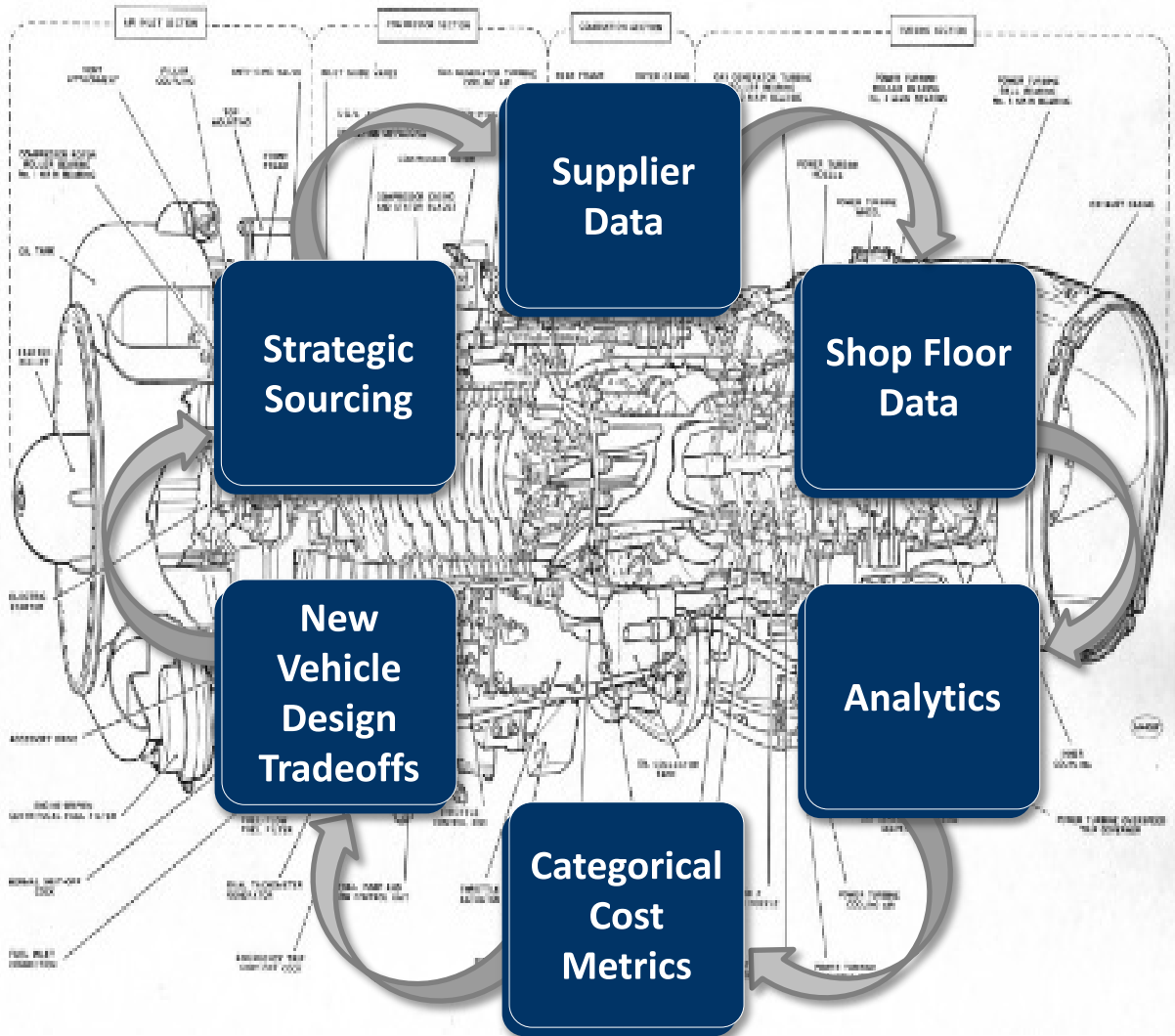
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JET ENGINE CASE STUDY



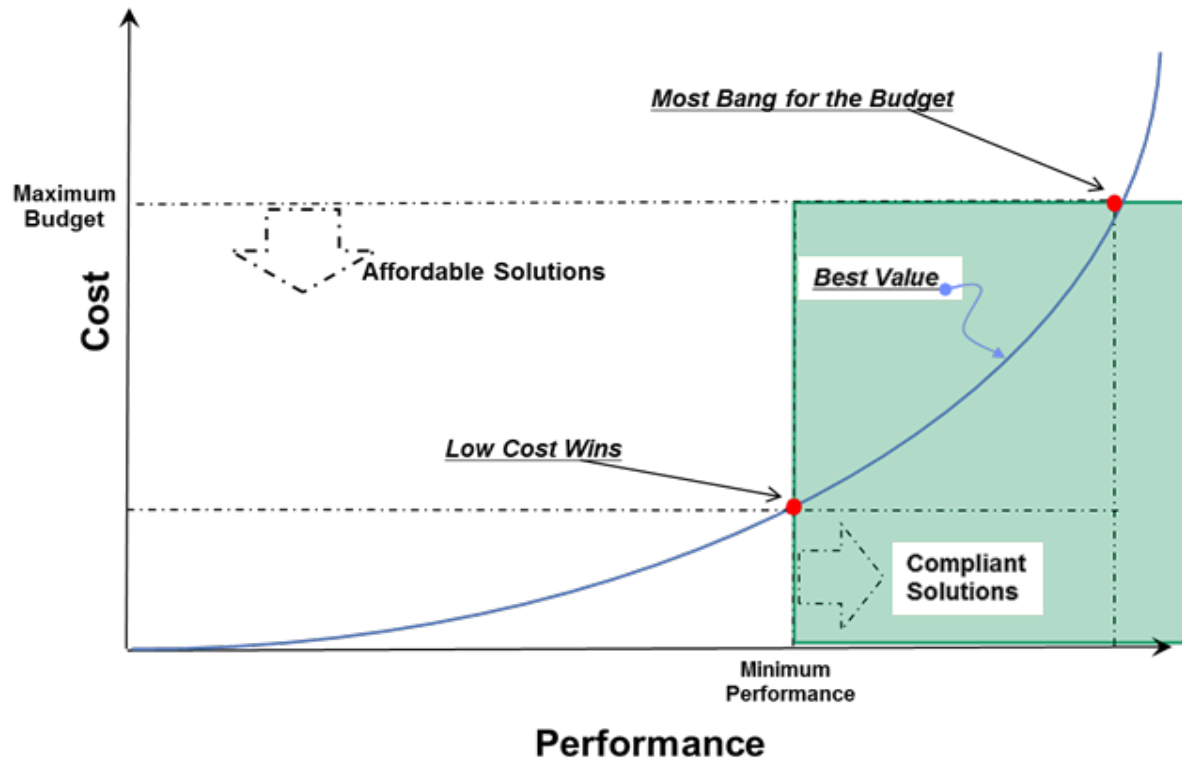
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PRICE Cost Analytics on Engine Parts & Assemblies



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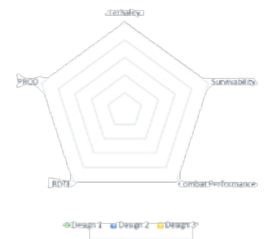
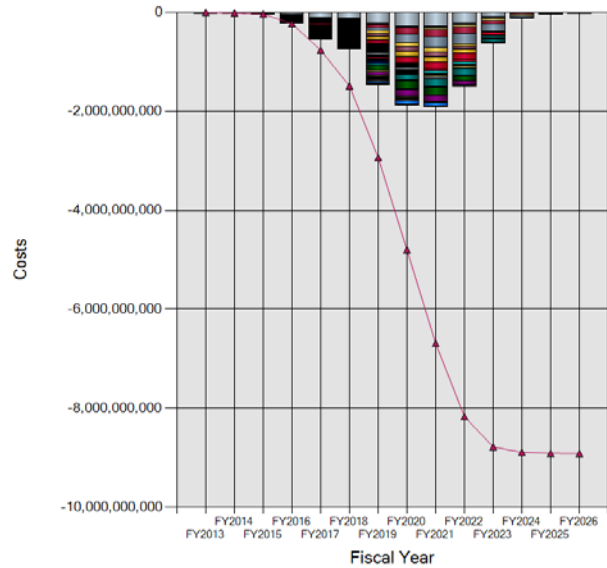
Cost versus Performance



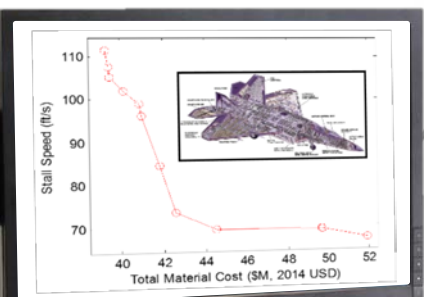
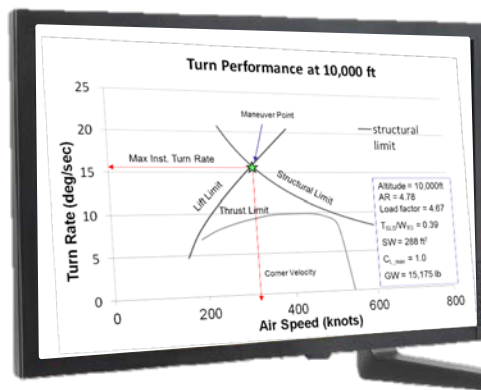
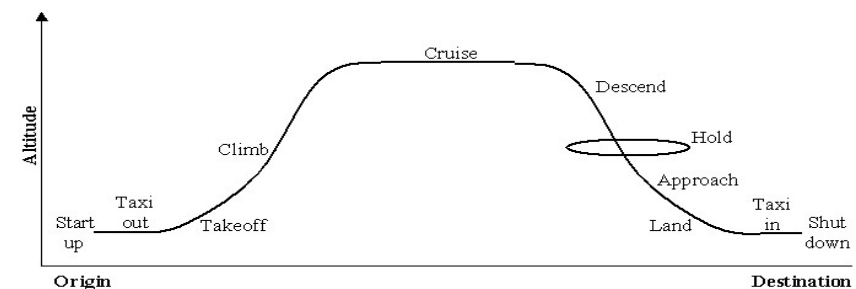
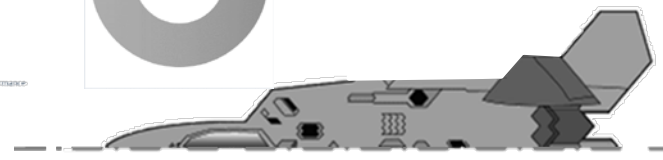
Tuttle & Bobinis (2013)
"Specifying Affordability"

AIRCRAFT CASE STUDY: Notional Derivative Design Process

- Aircraft in 881 C Template S1_A
 - AC_1_1_12_13_16 Air Vehicle_System E
 - AC_1.1.9 Air Vehicle Integration Assen
 - AC_1.1.1.1.1.1 Airframe_Airframe
 - AC_1.1.1.2 Fuselage
 - Forward Fuselage
 - Center Fuselage
 - Aft Fuselage
 - AC_1.1.1.3 Wing
 - AC_1.1.1.4 Empennage
 - Vertical Fin
 - Horizontal Stabilizer
 - AC_1.1.2 Propulsion
 - AC_1.1.3.1.1.1 Vehicle Subsystem
 - AC_1.1.3.2 Flight Control Subsys
 - AC_1.1.3.3 Auxiliary Power Sub
 - AC_1.1.3.4 Hydraulic Subsystem
 - AC_1.1.3.5 Electrical Subsystem
 - AC_1.1.3.6 Crew Station Subsys
 - AC_1.1.3.7 Environmental Contr
 - AC_1.1.3.8 Fuel Subsystem
 - AC_1.1.3.9 Landing Gear
 - AC_1.1.3.12 Vehicle Subsystem
 - AC_1.1.4.1.1.1 Avionics_Avionics



Wing Composite Fraction



Conceptual Design

Aerodynamics

Propulsion

Thrust Lines

Scaling Law

$$T = f(M)$$

$$W_{Eng} = g(W)$$

Weight

- Historical Data
- Empirical Eqs.
$$W_{TO} = a(W_E)^b$$

Point Performance Requirements

Constraints Analysis

Mission Analysis

Mission Performance Requirements

Weight Fraction

T_{SL}/W_{TO}

W_{TO}/S

T_{SL}

W_{TO}

W_F, W_E, W_P

T_{SL}

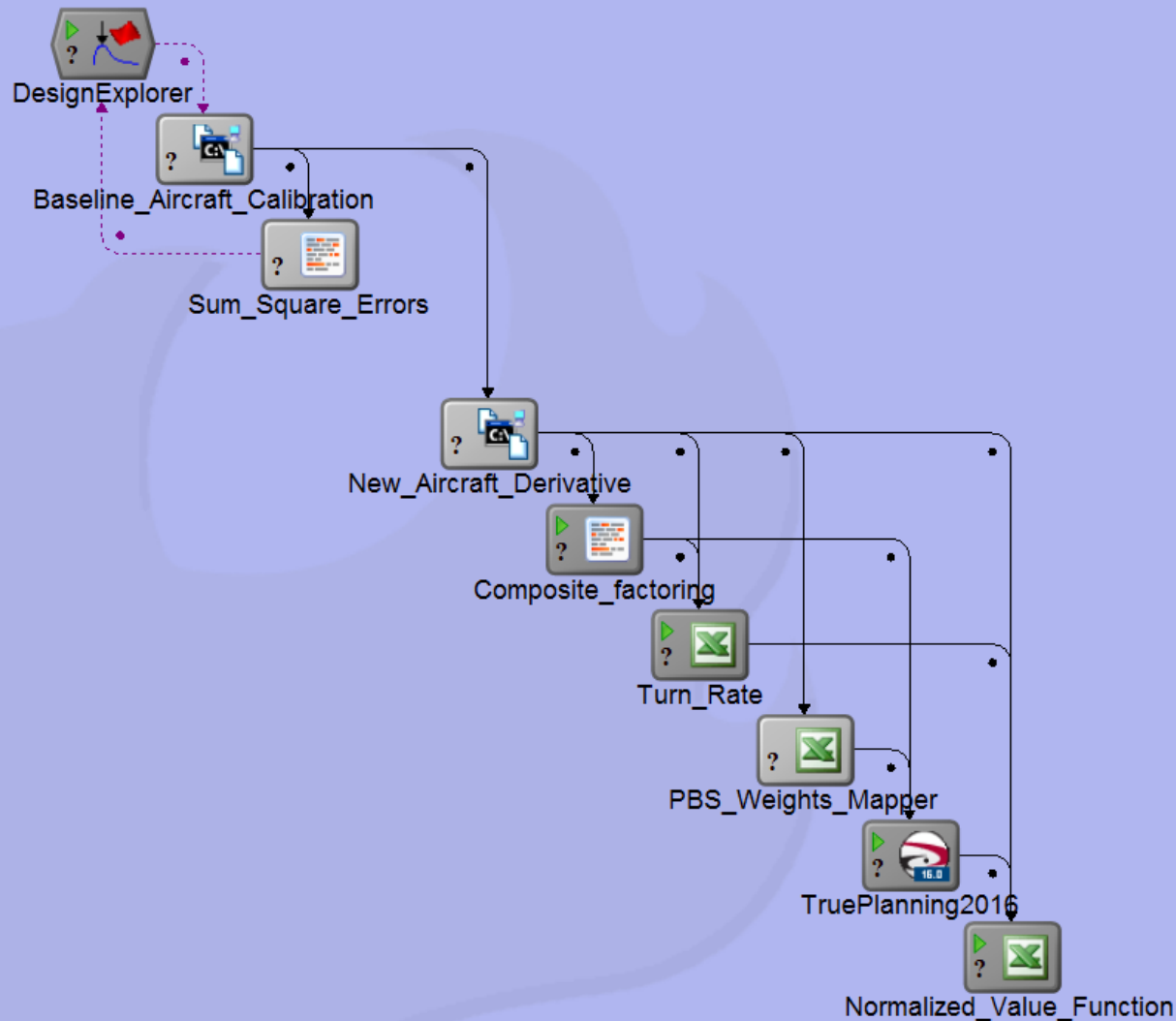
W_{TO}

Legend:

- T_{SL} : Thrust (sea level static)
- W_{TO} : Take-off Gross Weight
- S : Wing Reference Area
- W_F : Fuel Weight
- W_E : Empty Weight
- W_P : Payload Weight

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Simulation and Modeling Environment

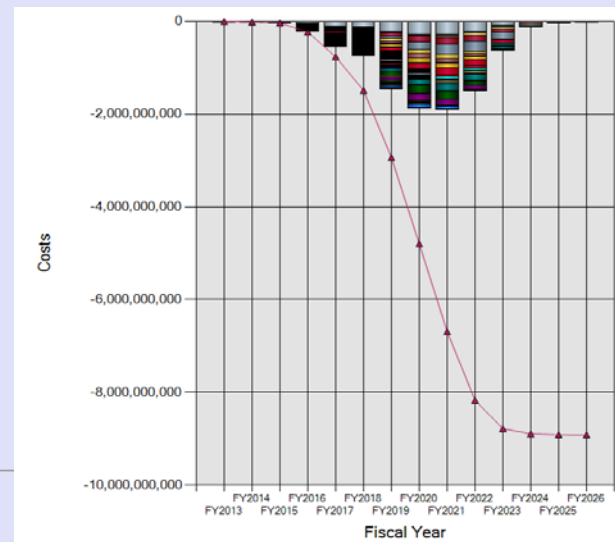


Cost Analysis

Callout Boxes:

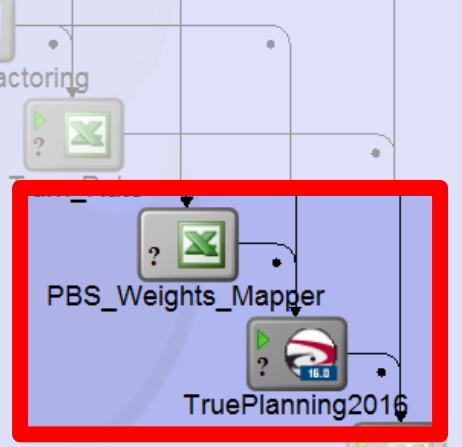
- PBS
- Sorting
- I/O Toggle
- Keyword search
- Select/Unselect All

IsSelected	PBS	Item Name	IOType	Value	Unit
<input checked="" type="checkbox"/>		KFX-05 Aircraft R. Estimated Cost	Output		
<input type="checkbox"/>		KFX-05 Aircraft R. Number of Protot...	Input	10.00	
<input type="checkbox"/>		KFX-05 Aircraft R. Number of Produ...	Input	100.00	
<input type="checkbox"/>		KFX-05 Aircraft R. Number of Syst...	Input	0	
<input type="checkbox"/>		KFX-05 Aircraft R. Prototype Suppor...	Input	1.00	
<input type="checkbox"/>		KFX-05 Aircraft R. Number of Facilit...	Input	1	
<input type="checkbox"/>		KFX-05 Aircraft R. Number of Shifts	Input	1	
<input type="checkbox"/>		KFX-05 Aircraft R. Production Gap L...	Input	1.00	
<input type="checkbox"/>		KFX-05 Aircraft R. Cost of Mth Unit...	Input	100	
<input type="checkbox"/>		KFX-05 Aircraft R. LRU Safety Stock...	Input	1.65	
<input type="checkbox"/>		KFX-05 Aircraft R. LRU Safety Stock...	Input	0.00	
<input type="checkbox"/>		KFX-05 Aircraft R. LRU Safety Stock...	Input	0.00	
<input type="checkbox"/>		KFX-05 Aircraft R. LRU Stock Round...	Input	0.999990	
<input type="checkbox"/>		KFX-05 Aircraft R. LRU Stock Round...	Input	0.999990	
<input type="checkbox"/>		KFX-05 Aircraft R. LRU Stock Round...	Input	0.999990	
<input type="checkbox"/>		KFX-05 Aircraft R. LRU Stock Round...	Input	0.200000	
<input type="checkbox"/>		KFX-05 Aircraft R. LRU Stock Round...	Input	1.65	
<input type="checkbox"/>		KFX-05 Aircraft R. Module Safety St...	Input	0.00	
<input type="checkbox"/>		KFX-05 Aircraft R. Module Safety St...	Input	0.00	
<input type="checkbox"/>		KFX-05 Aircraft R. Module Safety St...	Input	3.00	
<input type="checkbox"/>		KFX-05 Aircraft R. Module Stock Ro...	Input	0.999990	
<input type="checkbox"/>		KFX-05 Aircraft R. Module Stock Ro...	Input	0.999990	
<input type="checkbox"/>		KFX-05 Aircraft R. Module Stock Ro...	Input	0.999990	
<input type="checkbox"/>		KFX-05 Aircraft R. Module Stock Ro...	Input	0.50	
<input type="checkbox"/>		KFX-05 Aircraft R. Part Safety Stock...	Input	1.65	
<input type="checkbox"/>		KFX-05 Aircraft R. Part Safety Stock...	Input	0.00	
<input type="checkbox"/>		KFX-05 Aircraft R. Part Safety Stock...	Input	0.00	
<input type="checkbox"/>		KFX-05 Aircraft R. Part Safety Stock...	Input	3.00	
<input type="checkbox"/>		KFX-05 Aircraft R. Part Safety Stock...	Input	0.999990	



Aircraft in 881 C Template S1_A

- AC_1.1.1.2.1.3.1.6 Air Vehicle_System Engineering_Program Management_Data
 - AC_1.1.9 Air Vehicle Integration_Assembly, Test and Checkout
 - AC_1.1.1.1.1.1.1 Airframe_Airframe Integration, Assembly, Test, and Checkout
 - AC_1.1.1.1.2 Fuselage
 - Forward Fuselage
 - Center Fuselage
 - Aft Fuselage
 - AC_1.1.1.1.3 Wing
 - AC_1.1.1.1.4 Empennage
 - Vertical Fin
 - Horizontal Stabilizer
 - AC_1.1.1.2 Propulsion
 - AC_1.1.3.1.1.3.1 Vehicle Subsystems_Vehicle Subsystem Integration, Assembly, Test, and Checkout
 - AC_1.1.3.2 Flight Control Subsystem
 - AC_1.1.3.3 Auxiliary Power Subsystem
 - AC_1.1.3.4 Hydraulic Subsystem
 - AC_1.1.3.5 Electrical Subsystem
 - AC_1.1.3.6 Crew Station Subsystem_1
 - AC_1.1.3.7 Environmental Control Subsystem
 - AC_1.1.3.8 Fuel Subsystem
 - AC_1.1.3.9 Landing Gear
 - AC_1.1.3.12 Vehicle Subsystem Software
 - AC_1.1.4.1.1.4.1 Avionics_Avionics Integration, Assembly, Test, and Checkout



- ### Design-Driven Cost Factors
- Component Weights
 - Complexities
 - Component/product
 - Process
 - Integration
 - Technology Readiness Levels
 - Production Units
 - Learning Curves
 - Etc.

Normalized_Value_Function

- **Sensor-Software Development data in Excel**
 - Calibrated Complexity and Productivity Drivers

	A	B	E	F	G	H	I	J	K	L	M
	Name	Space Sensor/Detector Software Component (Text)	New Code Size - SLOC (Number)	Language (Text)	Normalized Dev. Time - Hours (Number)	Normalized Dev. Cost - 2013 \$USD (Number)	KPP#1 Operational Effectiveness (Number)	KPP#2 Differentiation Effectiveness (Number)	KPP#3 Operational Availability (Number)	KPP#4 Spectral Resolution (Number)	KPP#5 Electromagnetic Intensity (Number)
1											
2	Payload 1	Spectrometer SW	4,459	JavaScript	1,681	\$ 77,871	95	96	97	95	94
3	Payload 1	Electro-Static Analyzer SW	9,875	C++	8,172	\$ 254,287	95	96	95	94	95
4	Payload 1	Gamma Sensor SW	14,129	Java	12,048	\$ 357,427	96	97	96	95	96
5	Payload 1	Neutron Sensor SW	14,750	Java	12,257	\$ 367,696	97	97	98	98	99
6	Payload 1	Radiometer SW	153,824	Ada95	22,642	\$ 746,347	98	98	99	99	99
7	Payload 2	Spectrometer SW	6,237	JavaScript	3,252	\$ 133,449	95	96	95	94	95
8	Payload 2	Electro-Static Analyzer SW	8,032	C++	4,139	\$ 185,747	95	95	96	96	97
9	Payload 2	Gamma Sensor SW	12,056	Java	10,214	\$ 320,078	96	96	95	94	95
29	Payload 7	Gamma Sensor SW	7,495	JavaScript	3,967	\$ 145,581	95	96	97	97	96
30	Payload 7	Neutron Sensor SW	12,050	C++	9,413	\$ 306,413	95	96	97	95	94
31	Payload 8	Radiometer SW	6,132	Python	3,071	\$ 121,318	95	95	94	93	94
32	Payload 8	Spectrometer SW	9,860	C#	7,679	\$ 254,287	95	96	95	98	93
33	Payload 9	Electro-Static Analyzer SW	8,176	JavaScript	4,327	\$ 185,747	95	96	97	97	97
34	Payload 9	Gamma Sensor SW	13,146	C++	11,943	\$ 353,178	95	96	95	98	96
35	Payload 10	Neutron Sensor SW	5,451	Python	2,437	\$ 104,469	95	95	94	97	93
36	Payload 10	Radiometer SW	8,764	C#	4,668	\$ 189,816	95	96	97	95	95

Perform Predictive Analytics to determine method for fine-tuning software cost drivers as a function of KPPs

File Home View Help

Functional

Copy Import Create

Paste Export

Clipboard Import/Export Finding

Search TrueFindings Database

Your Search

- Space Sensor/Detector Software Component
- Electro-Static Analyzer SW

KeyWord Characteristics

- Language
- Performance
- Functional Complexity (7)
- Organizational Productivity (7)
- New Code Size - SLOC (7)
- Normalized Dev. Time - Hours (7)
- Normalized Dev. Cost - 2013 \$USD (7)
- KPP#1
- Operational Effectiveness (7)
- KPP#2
- Differentiation Effectiveness (7)
- KPP#3
- Operational Availability (7)
- KPP#4
- Spectral Resolution (7)
- KPP#5
- Electromagnetic Intensity (7)

	Name	Space Sensor/Detector Software Component	Functional Complexity	Organizational Productivity	New Code Size - SLOC	Language	Normalized Dev. Time - ...	Normalized Dev. Cost - 2013 \$USD	KPP#1 Operational Effectiveness	KPP#2 Differentiation Effectiveness	KPP#3 Operational Availability	KPP#4 Spectral Resolution	KPP#5 Electromag netic...
1	Payload 1	Electro-Static Analyzer SW	6.13	1.08	9875	C++	8172	254287	95	96	95	94	95
2	Payload 2	Electro-Static Analyzer SW	5.82	1.19	8032	C++	4139	185746.62	95	95	96	96	97
3	Payload 3	Electro-Static Analyzer SW	5.76	1.26	12845	Python	11235.4	337054.3	95	95	96	93	94
4	Payload 4	Electro-Static Analyzer SW	4.99	1.26	7846	JavaScript	4139	167768	95	95	96	97	93
5	Payload 5	Electro-Static Analyzer SW	7.18	0.99	11358	C#	9192	277811.94	96	97	96	99	97
6	Payload 6	Electro-Static Analyzer SW	6.19	1.05	10955	C++	8851	277000.5	95	96	95	94	94

Distribution Finder Dependency Finder Curve Finder MultiCurve Finder Findings

Dependent Variables

Dependent Vari... Functional

Functional Complexity Distribution

Statistics

Chart Type: Box Plot Observations: 7

Statistics	Data	LogNormal	Normal	Triangular
Min	4.990			
Max	7.180			
25%	5.790			
75%	6.185			
Mean	6.036	6.041	6.036	6.117
Median	6.130	6.005	6.036	6.132
Mode	4.990	5.934	6.036	6.180
Standard Deviati...	0.656	0.660	0.656	0.447
Coefficient of Va...	0.109	0.109	0.109	0.073

Settings

Whiskers Percentiles: 15/85th Percentile Remove Outliers

■ Example Software Development data: Distribution Finder

– Spreadsheet rows become knowledgebase fields for search/filtering

– 1st tab-function shows descriptive statistics for all or (above) selected data

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File Home View Help

Functional Copy Import Create Paste Export

Selected Column Clipbo... Import/E... Finding

Search TrueFindings Database Data (35 rows)

	Name	Space Sensor/Det...	Functional Complexity	Organization al...	New Code Size - SLOC	Language	Normalized Dev. Time - ...	Normalized Dev. Cost - 2013 \$USD	KPP#1 Operational Effectiveness	KPP#2 Differentiation...	KPP#3 Operational Availability	KPP#4 Spectral Resolution	KPP#5 Electromagn etc...
1	Payload 1	Spectromet...	5.94	1.1	4459	JavaScript	1681	77871	95	96	97	95	94
2	Payload 1	Electro-Sta...	6.13	1.08	9875	C++	8172	254287	95	96	95	94	95
3	Payload 1	Gamma Se...	7.34	0.99	14129	Java	12048	357426.9	96	97	96	95	96
4	Payload 1	Neutron Se...	7.54	0.94	14750	Java	12256.8	367696.079...	97	97	98	98	99

Keyword Characteristics: Space Sensor/Detector, Software Component, Language, Performance: Functional Complexity (35), Organizational Productivity (35), New Code Size - SLOC (35), Normalized Dev. Time - Hours (35), Normalized Dev. Cost - 2013 \$USD (35), KPP#1, Operational Effectiveness (35), KPP#2, Differentiation Effectiveness (35), KPP#3, Operational Availability (35), KPP#4, Spectral Resolution (35), KPP#5, Electromagnetic Intensity (35)

Distribution Finder Dependency Finder Curve Finder **MultiCurve Finder** Findings

Regression MultiCurve Equation

Dependent Variable: Functional

Selected Independent Variables: KPP#1, Operational Effectiveness, KPP#2, Differentiation Effectiveness, KPP#3, Operational Availability, KPP#4, Spectral Resolution, KPP#5, Electromagnetic Intensity, New Code Size - SLOC, Normalized Dev. Cost - 2013 \$USD, Normalized Dev. Time - Hours, Organizational Productivity

Linear Model: $FunctionalComplexity = 0.449 * [KPP\#1OperationalEffectiveness] + 0.468 * [KPP\#2Differentialiation]$

Dependent Variable: FunctionalComplexity

Independent Variables: KPP#1OperationalEf..., KPP#2Differentialiatio...

Statistics

Regression Table

Statistics	Value
Multiple R	0.972
R Square	0.945
Adjusted R Square	0.942
Standard Error	0.220
Observations	35.000

Anova Table

Source	Sum of Sq...	Degrees o...	Mean Squ...	P-Value	F-Statistic
Regression	26.913	2	13.457	6.291E-021	276.886
Error	1.555	32	0.049		
Total	28.468	34	0.837		

Coefficients Table

Name	Coeffici...	Std. Error	t Test	P-Value	Upper C...	Lower C...
KPP#1O...	0.449	0.053	8.522	9.740E-...	0.556	0.342
KPP#2D...	0.468	0.074	6.321	4.300E-...	0.619	0.317
Intercept	-81.391	4.321	-18.838	6.999E-...	-72.591	-90.192

■ Example Software Development data: Multicurve Finder

- 4th tab-function shows multiple (two or more predictors) regression and tables
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Typically, predictive analytics requires painstaking processes for normalizing data and creating “one-off”, multivariate models to predict outcomes. Tailoring generic predictive analytics tools to estimate costs and schedules is complicated and time consuming. It is faster and easier to “calibrate” existing, proven models that are tested and supported by experts...

PRICE Cost Analytics

- Specifically designed to predict costs and schedules
- Integrated tools combine to speed the process and lower the cost to predict costs and schedules
- Proven, reusable cost models that capture the common cost drivers of like-items to be estimated
- PRICE subject matter experts know the process, and are available to help you along the way

