



PRICE[®]

Just-In-Time Cost Estimate in a Multidisciplinary Design Environment

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2018 PROFESSIONAL DEVELOPMENT & TRAINING WORKSHOP



Presented at the 2018 ICEAA Professional Development & Training Workshop - www.iceaaonline.com

The Problems

“IDA effort examined the front end of the processes that result in initiation of major acquisition programs and noted the lack of rigorous evaluations of need, technical feasibility, affordability, and risk.”

<https://www.ida.org/en/SAC/ExploreSACResearch/2/EvaluatingSystems.aspx>

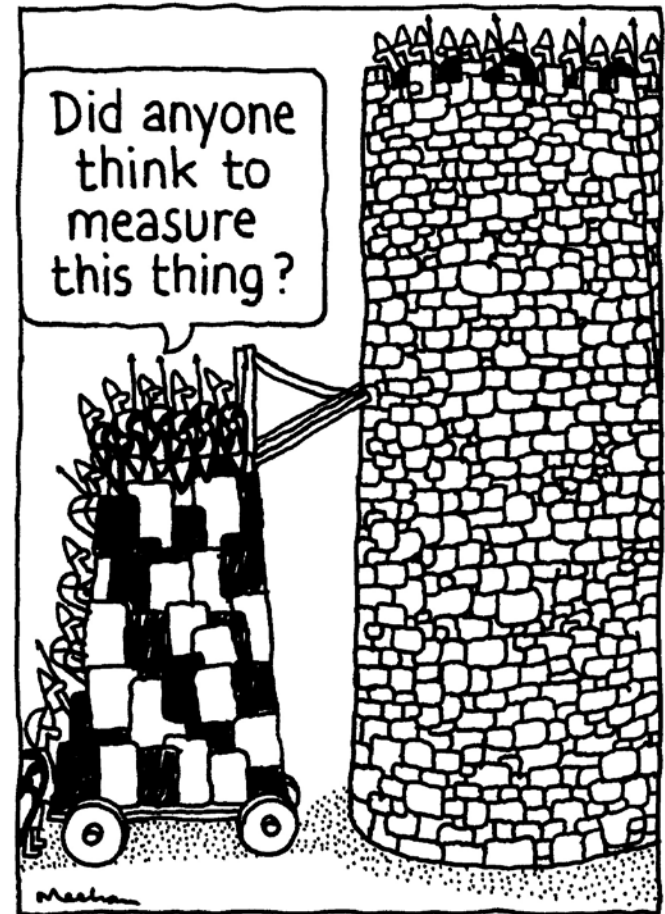
■ Engineering teams have to cope with many unknowns associated with

– High-performance expectations

- *Performance gaps*
- *Integration challenges*
- *ilities factors*
- *Requirements creep*

– Low cost constraints

- *Highly capable system – high complexity*
- *Complex operating environment*
- *Having long operational life*
- *Unpredictable production volume*



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Opportunities

- **Advanced engineering design methods and principals**
 - Heuristic process supported by stochastic analytic
 - Optimize system as a whole
 - Proven design framework
 - *Concurrent Engineering: Integrated Product and Process Development*
 - *Taguchi Methods: Robust Design Simulation*
 - *Value Engineering: max[Function/Cost]*
- **Efficient use of new technology**
 - Balance performance, cost, schedule, and risk
- **Adapt to changes**
 - Modeling and Simulation
 - *What-if analysis, assumption testing, probabilistic analysis*
- **Cost management**
 - Scalable, traceable, adaptable, and consistent

Better Buying Power 4.0



Best Practices: Strengthen DoD's buying power, improve industry productivity, provide affordable, value-added capability to the Warfighter

1. **Achieve Affordable Programs**
 - Constrained by the maximum resources allocated for a capability
 - No longer performance at any cost
 - Nor merely eliminating capability to achieve cost reduction
2. **Control Costs Throughout the Product Lifecycle**
 - Ability to understand and control future costs from a program's inception
3. **Incentivize Productivity and Innovation in Industry and Government**
 - Reward efficiency
4. **Eliminate Unproductive Processes and Bureaucracy**
5. **Promote Effective Competition**
 - Standardized Value Function
6. **Improve Tradecraft in Acquisition of Services**
7. **Improve the Professionalism of the Total Acquisition Workforce**

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Key Take-Away

Performance-
Based Acquisition

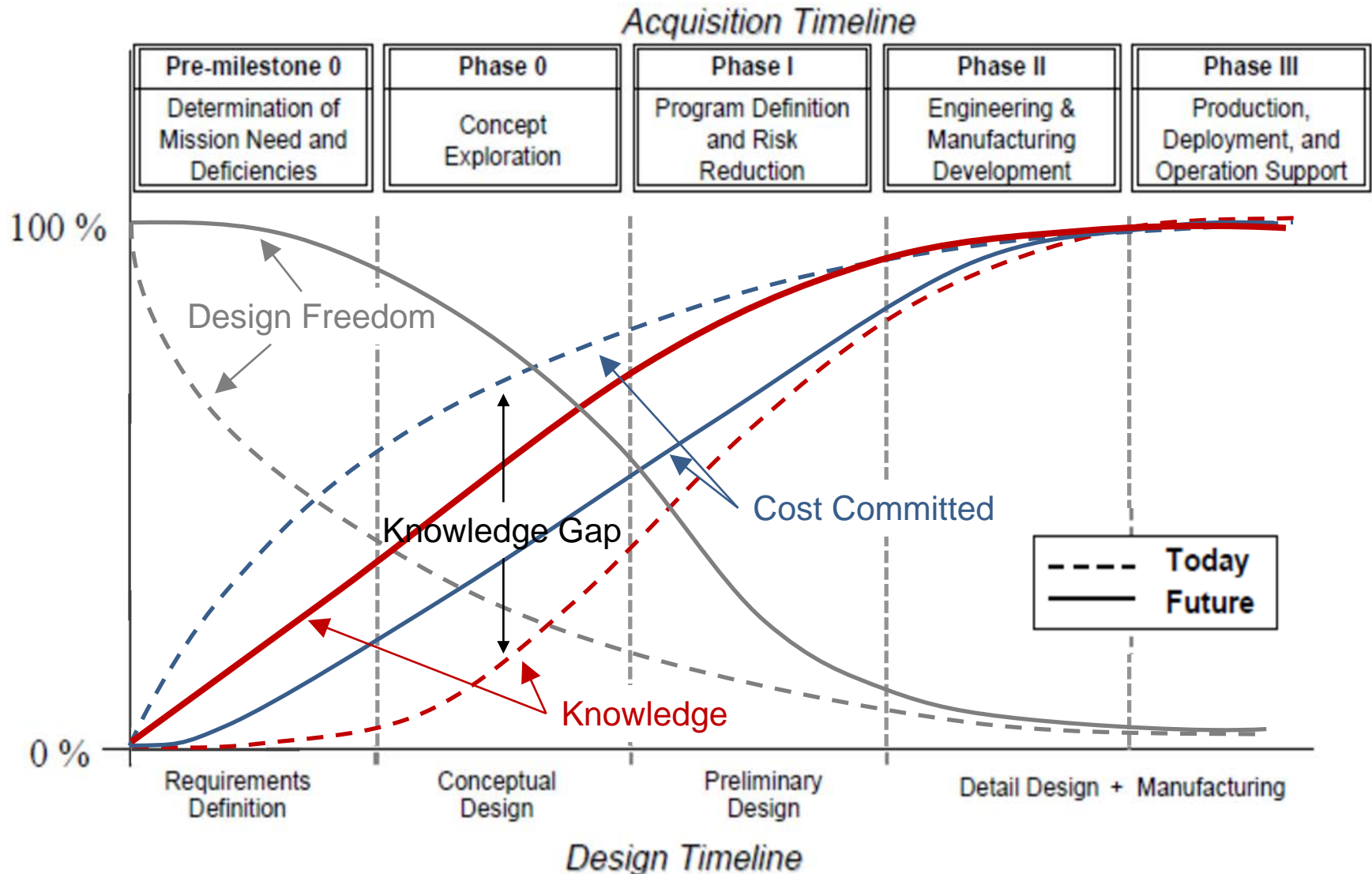


Affordability-
Based Acquisition

- Performance at any cost
 - Independent product and process development
 - Focus on upfront costs
- Best value -- balance all aspect of performance, cost, risk, schedule
 - Integrated product and process development
 - Focus on total ownership cost

Integrate Downstream Knowledge

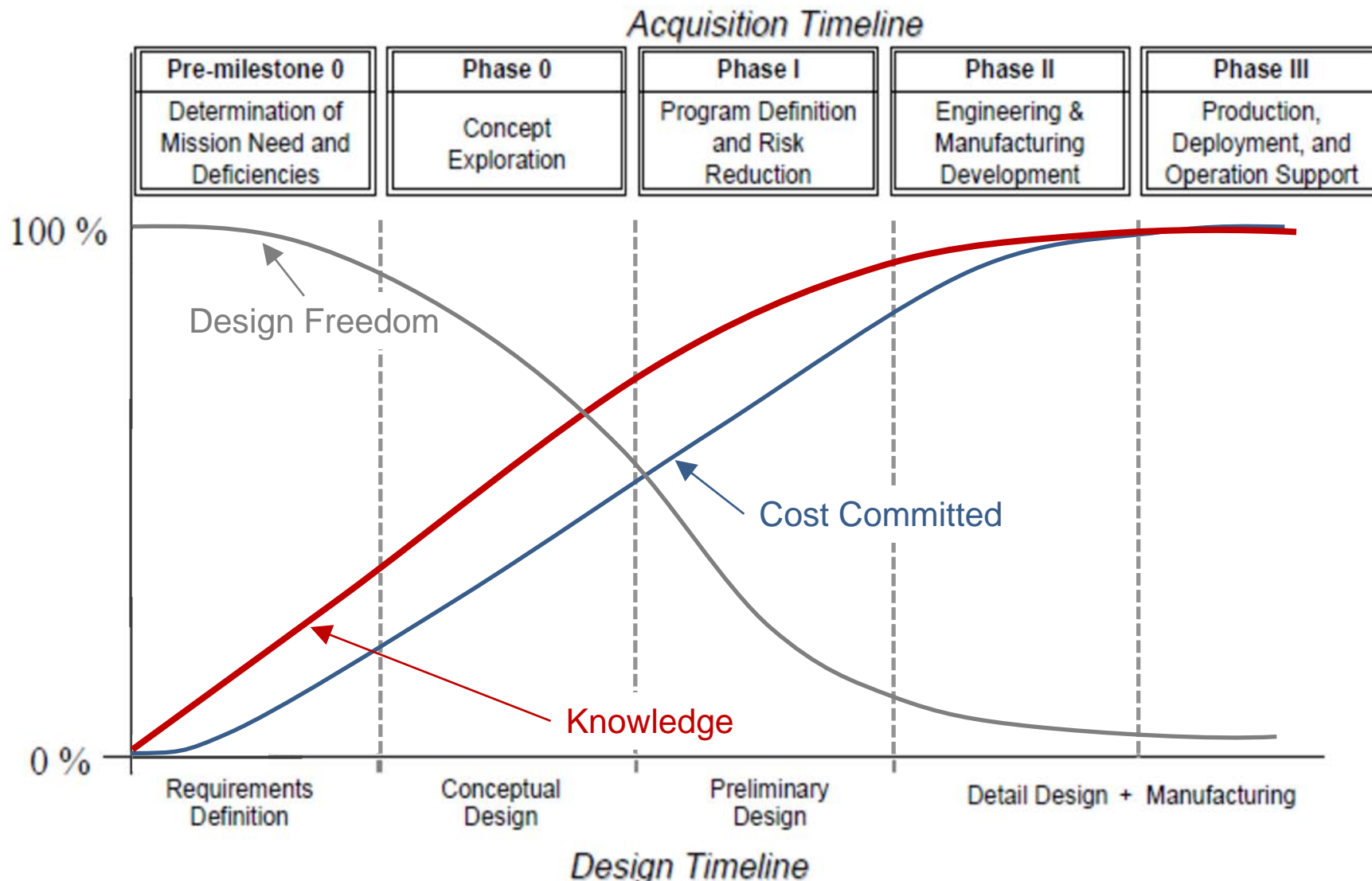
Accelerate the s-curve



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Integrate Downstream Knowledge

Accelerate the s-curve



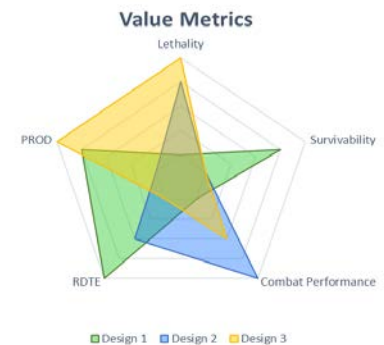
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Case Study: Notional Aircraft Derivative

The Need

Customer-Driven Value Metrics

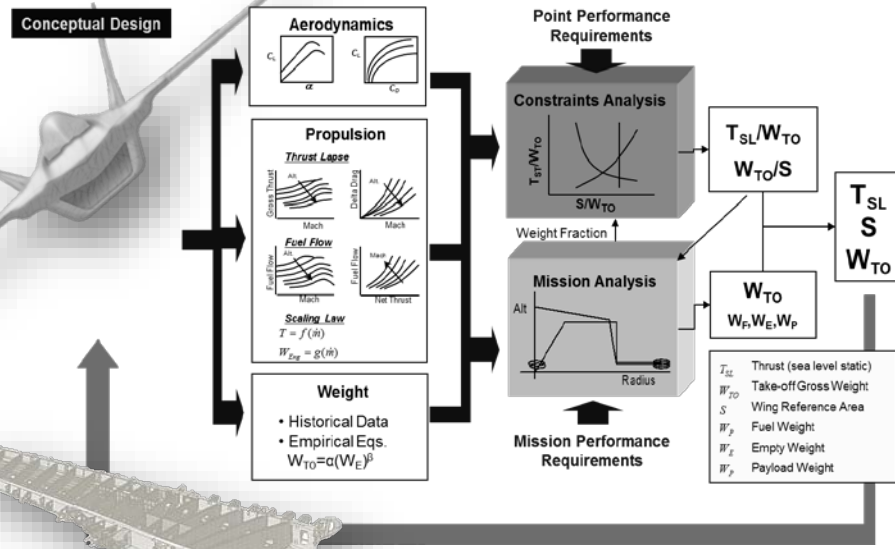
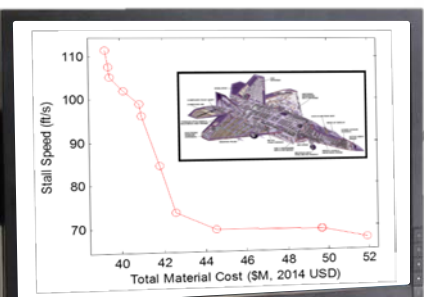
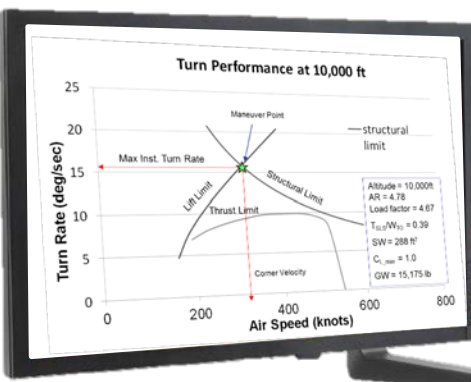
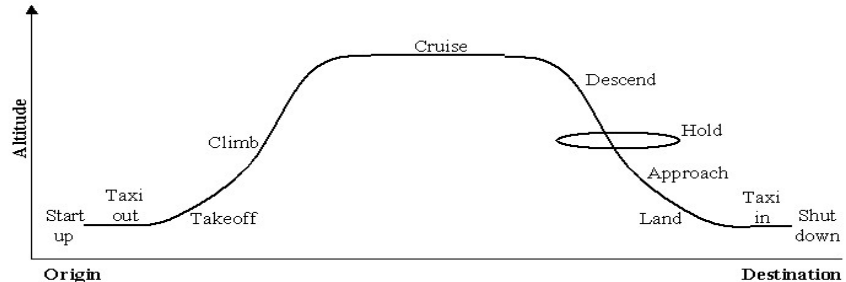
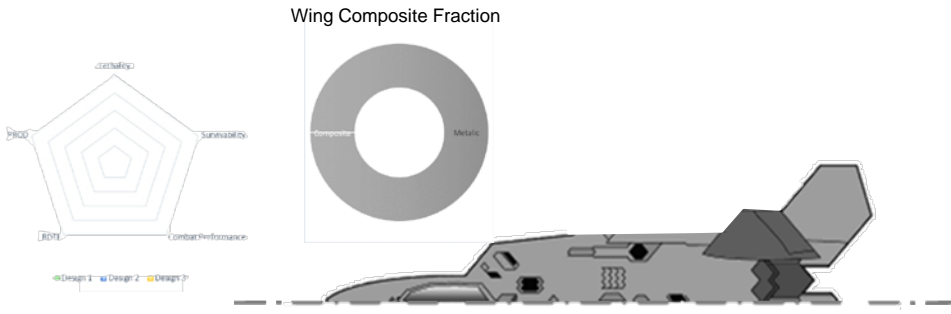
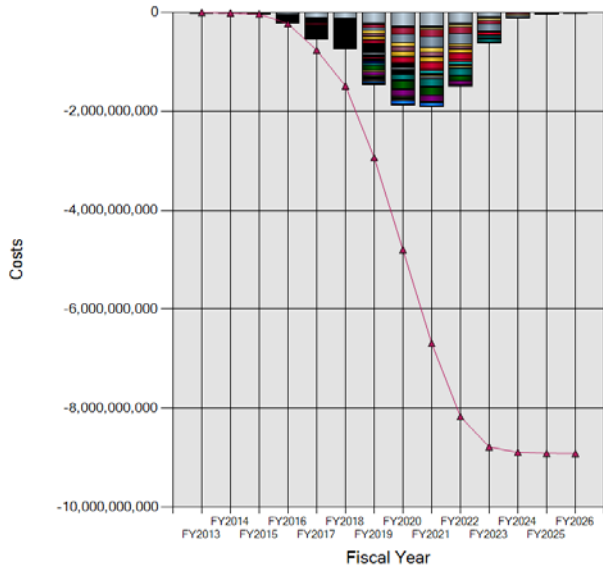
- **Lethality**
 - Extra Payload Capacity
 - *Excess Fuel*
- **Combat Performance**
 - High Speed Maneuver
 - *Sustained Turn Rate*
- **Survivability**
 - Climb Out Performance
 - *Power-to-weight*
 - *Stall speed*
- **Cost**
 - R&D
 - Production
 - O&S



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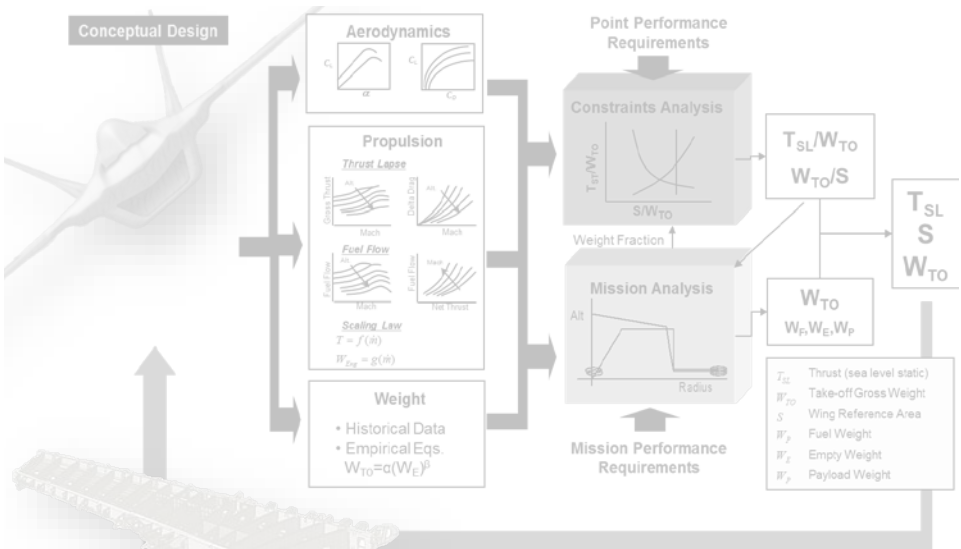
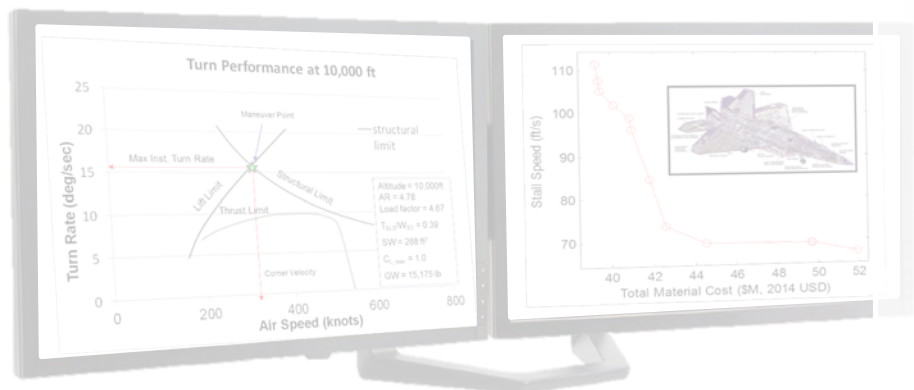
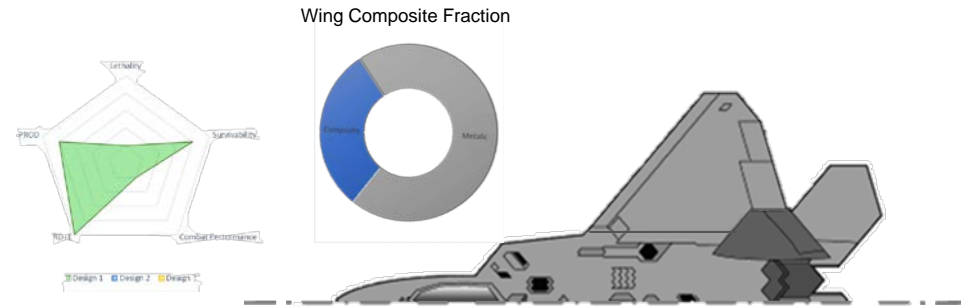
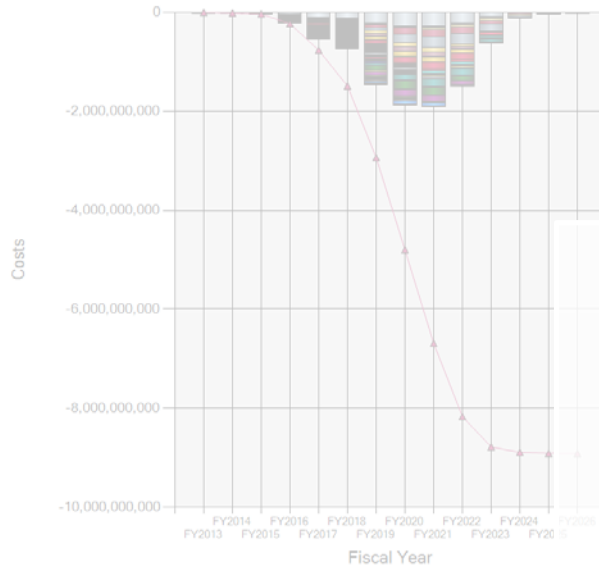
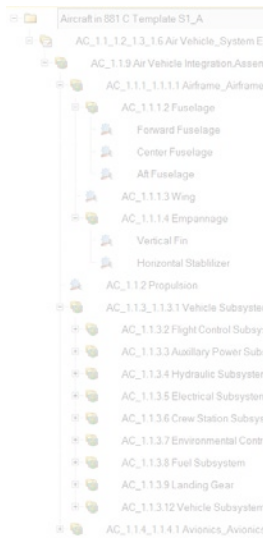
Notional Aircraft Derivative Design Process

- Aircraft in 881 C Template S1_A
 - AC_1.1.2_13_16 Air Vehicle_System E
 - AC_1.1.9 Air Vehicle Integration_Assen
 - AC_1.1.1_13.1.1 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_13.1.1 Vehicle Subsystem
 - AC_1.1.3.2 Flight Control Subsy
 - 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_1.1.4_13.1.2 Vehicle Subsystem
 - AC_1.1.4.1 Avionics_Avionics



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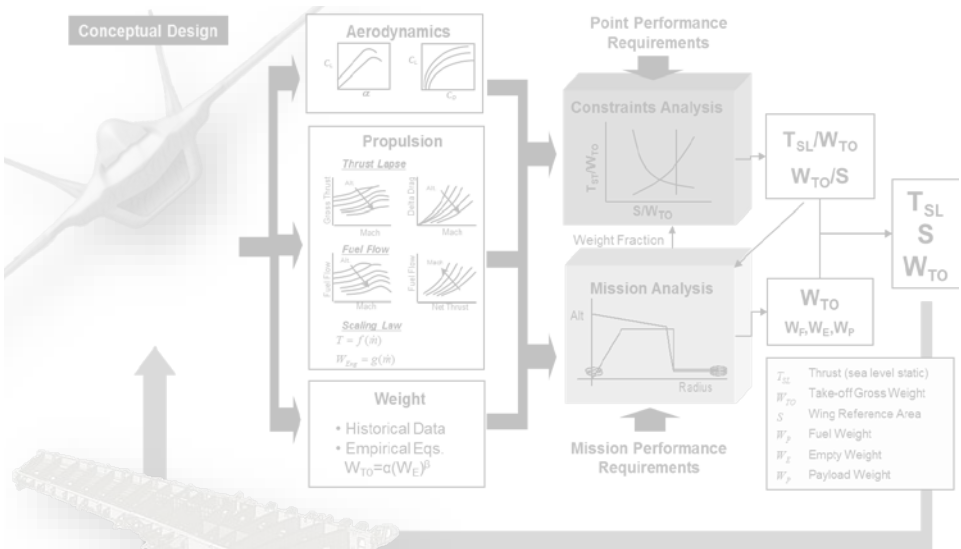
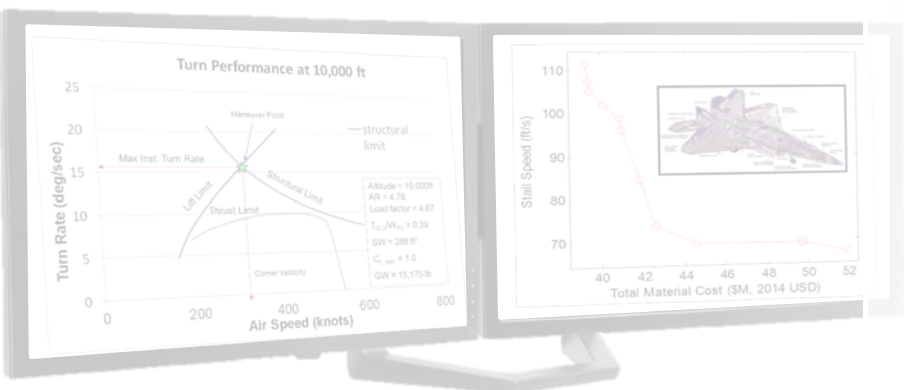
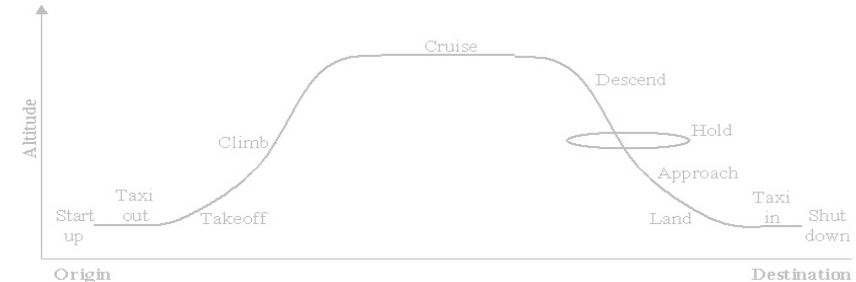
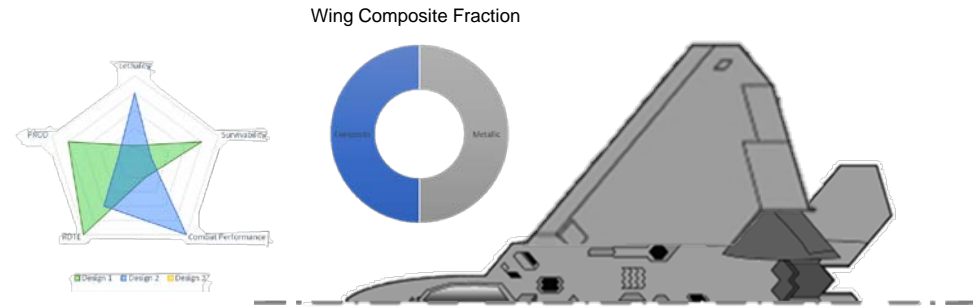
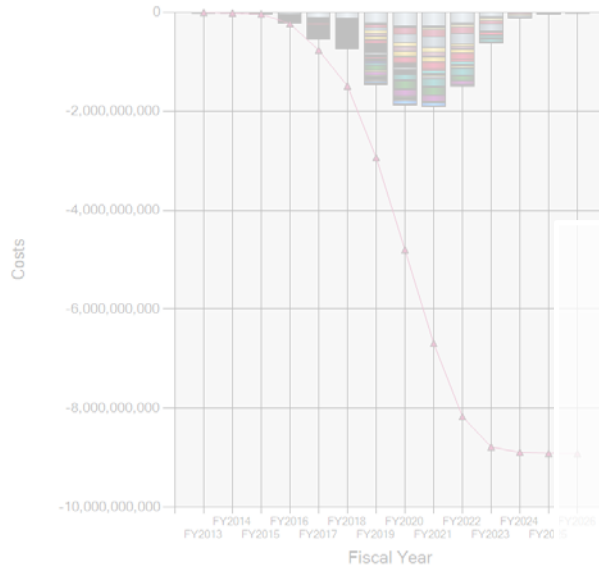
Notional Aircraft Derivative Design Process



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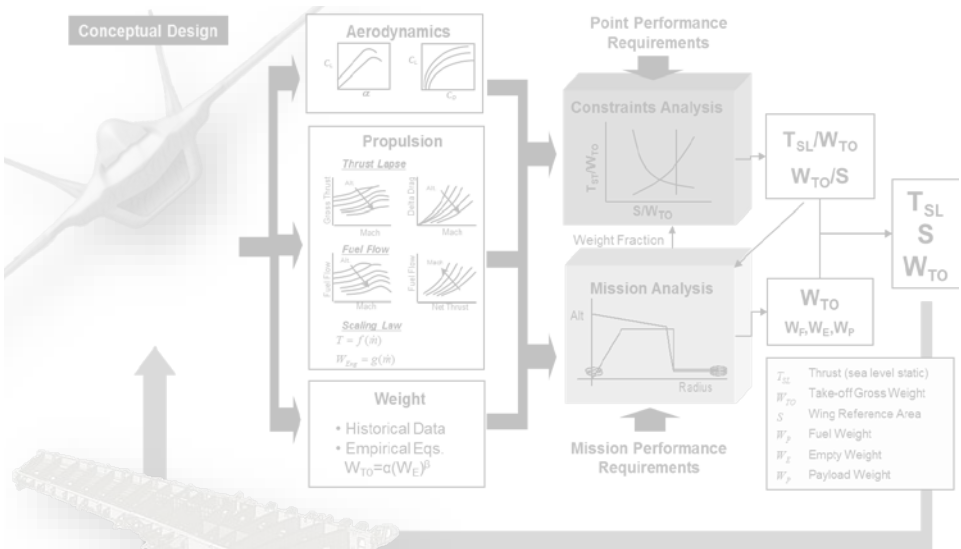
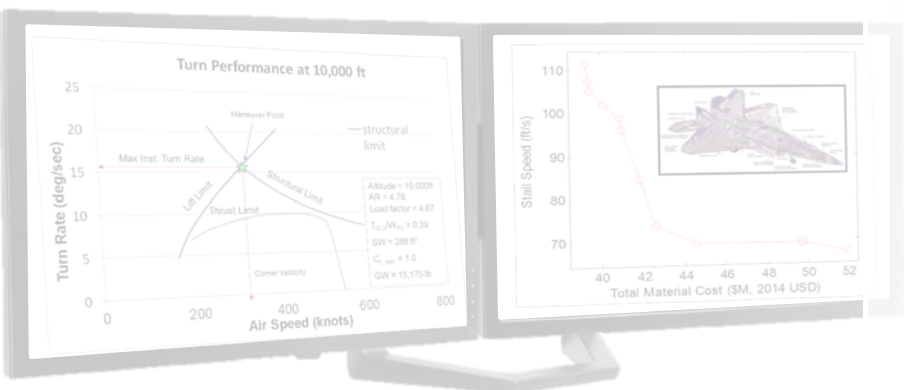
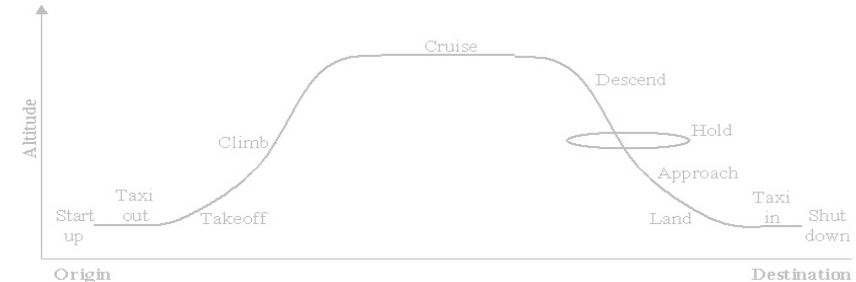
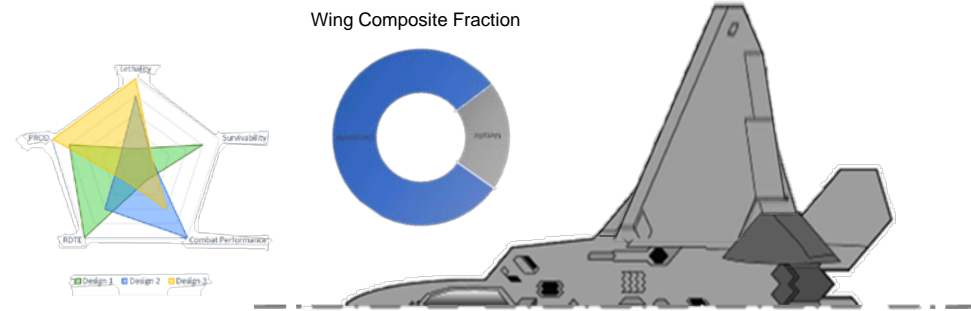
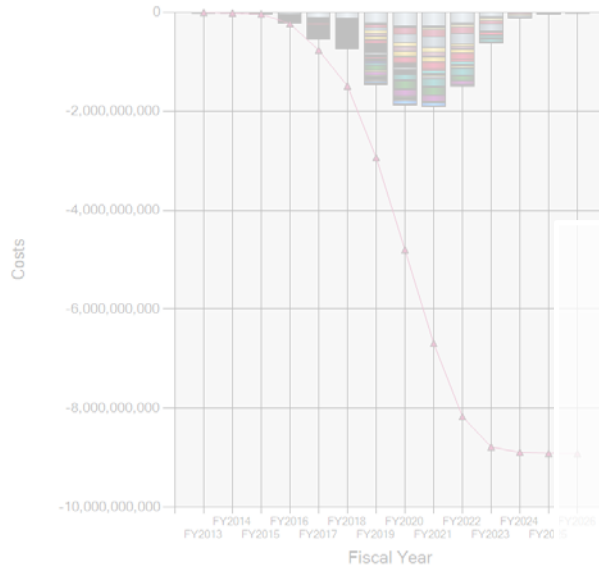
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 - AC_1.1.3.1.1.3.1 Vehicle Subsystem
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 - AC_1.1.3.9 Landing Gear
 - AC_1.1.3.12 Vehicle Subsystem
 - AC_1.1.4.1.1.4.1 Avionics_Avionics



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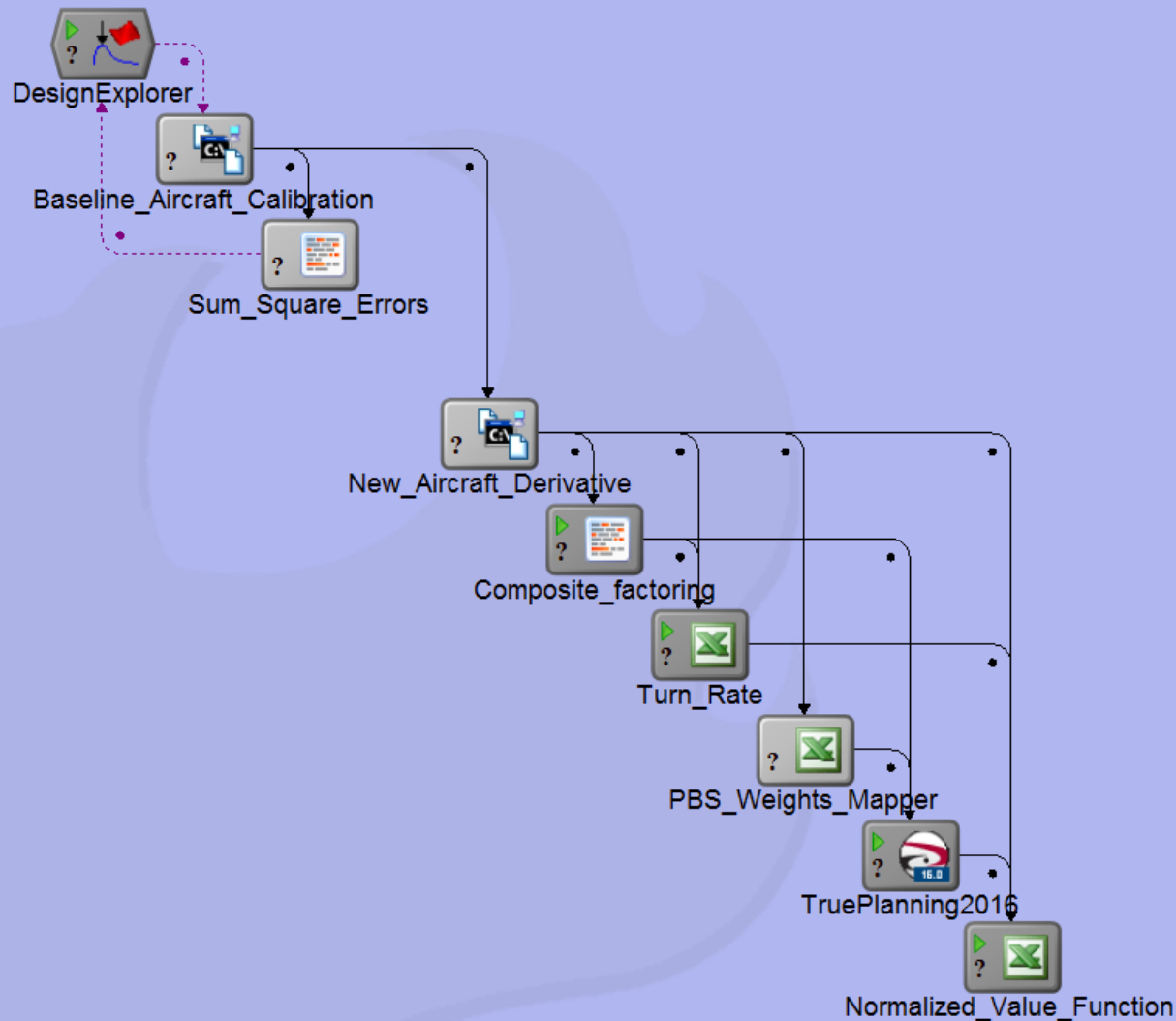
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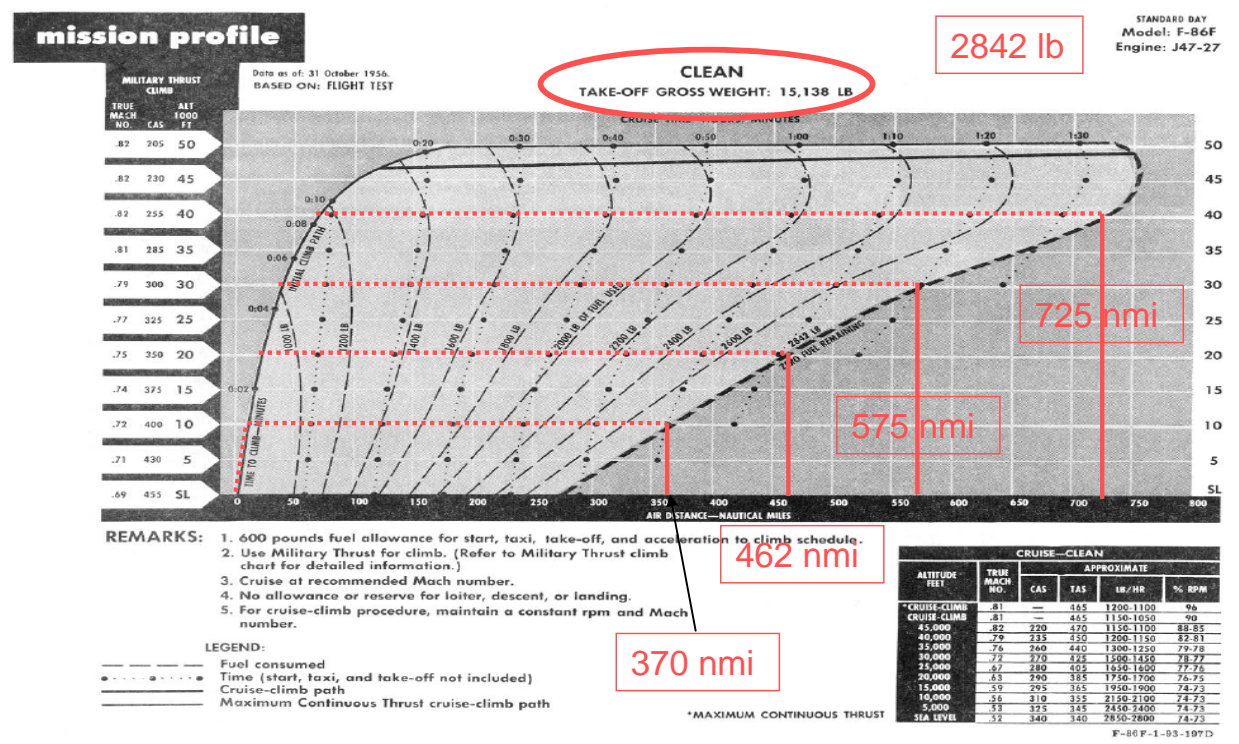
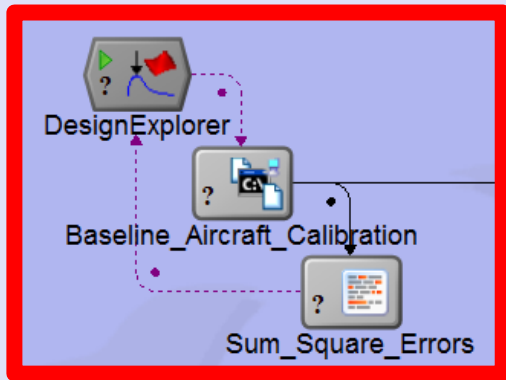


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The Setup

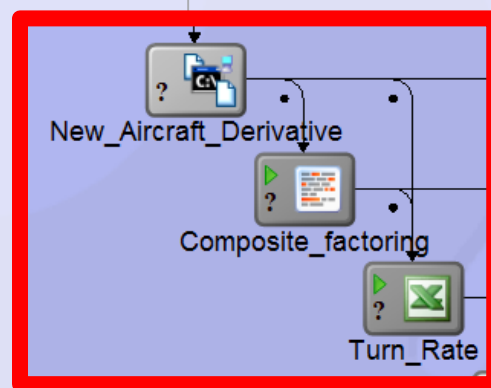
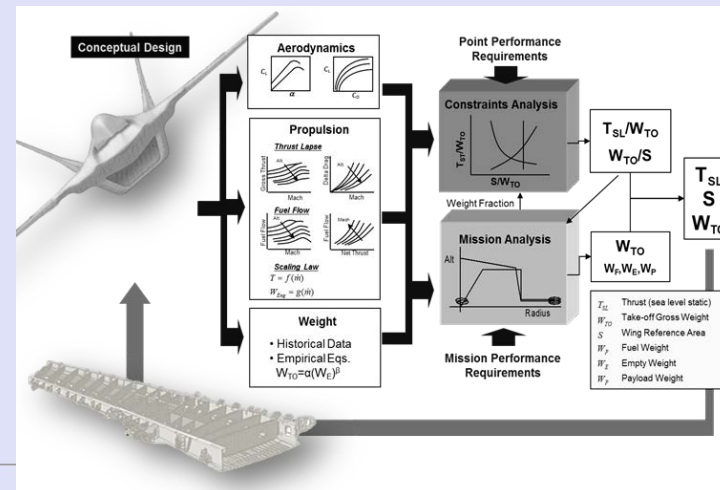
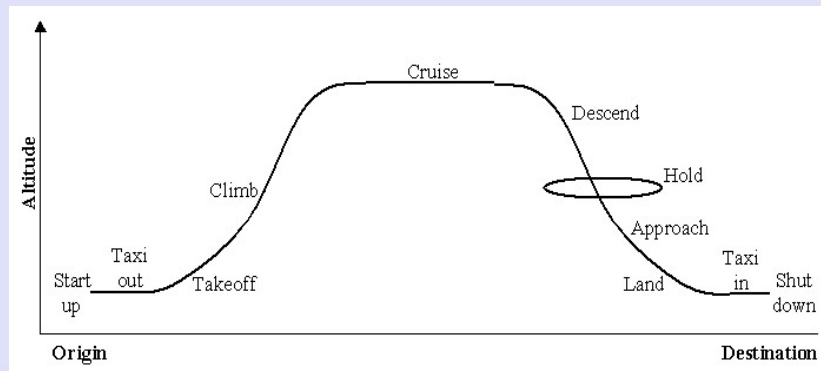


Baseline Calibration



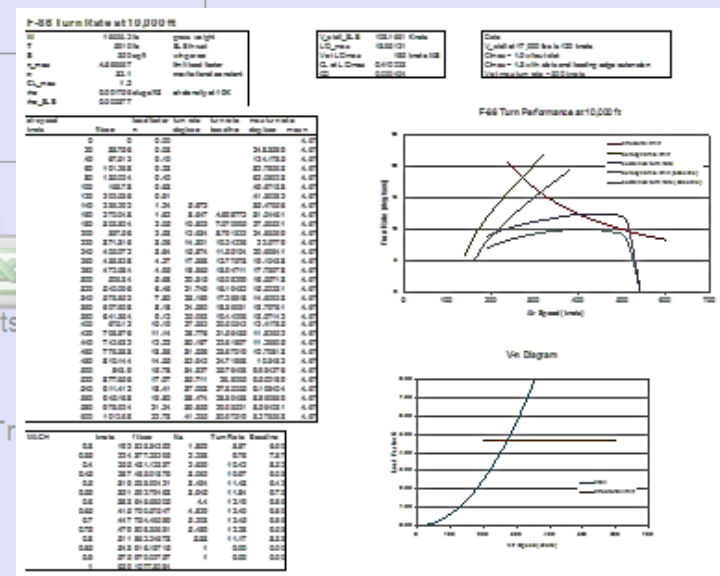
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Performance, Sizing and Synthesis



Design Outputs

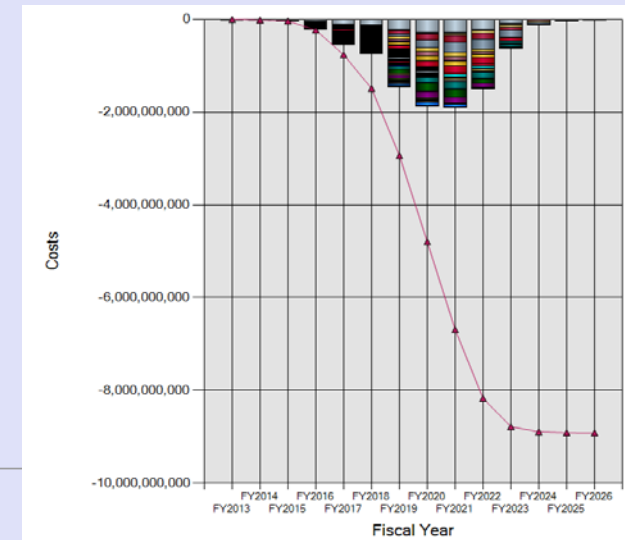
- Component weights
- Payload weights
- Turn rate
- Stall speed



Callout Boxes:

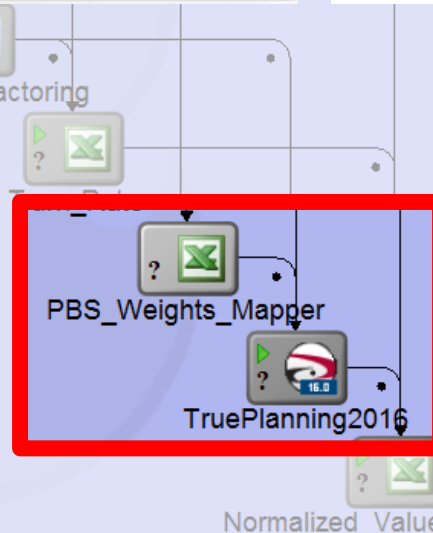
- PBS
- Sorting
- I/O Toggle
- Keyword search
- Select/Unselect All

IsSelected	PBS	Item Name	IOType	Value	Unit
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<input type="checkbox"/>		KFX-05 Aircraft R. Number of Produ...	Input	100.00	
<input type="checkbox"/>		KFX-05 Aircraft R. Number of Syste...	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	
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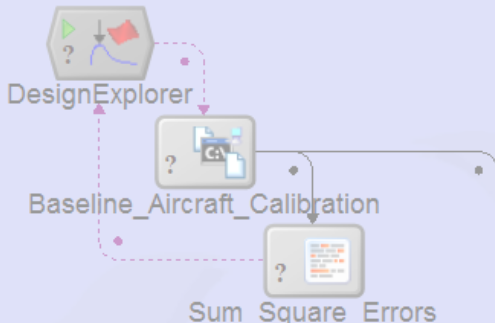


Aircraft in 881 C Template S1_A

- 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 Airframe_Airframe Integration, Assembly, Test, and Checkout
 - AC_1.1.1.2 Fuselage
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 - Horizontal Stabilizer
 - AC_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

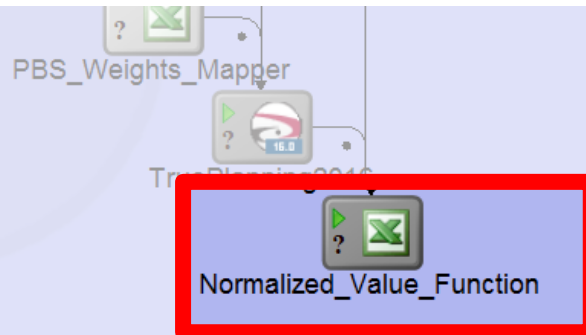


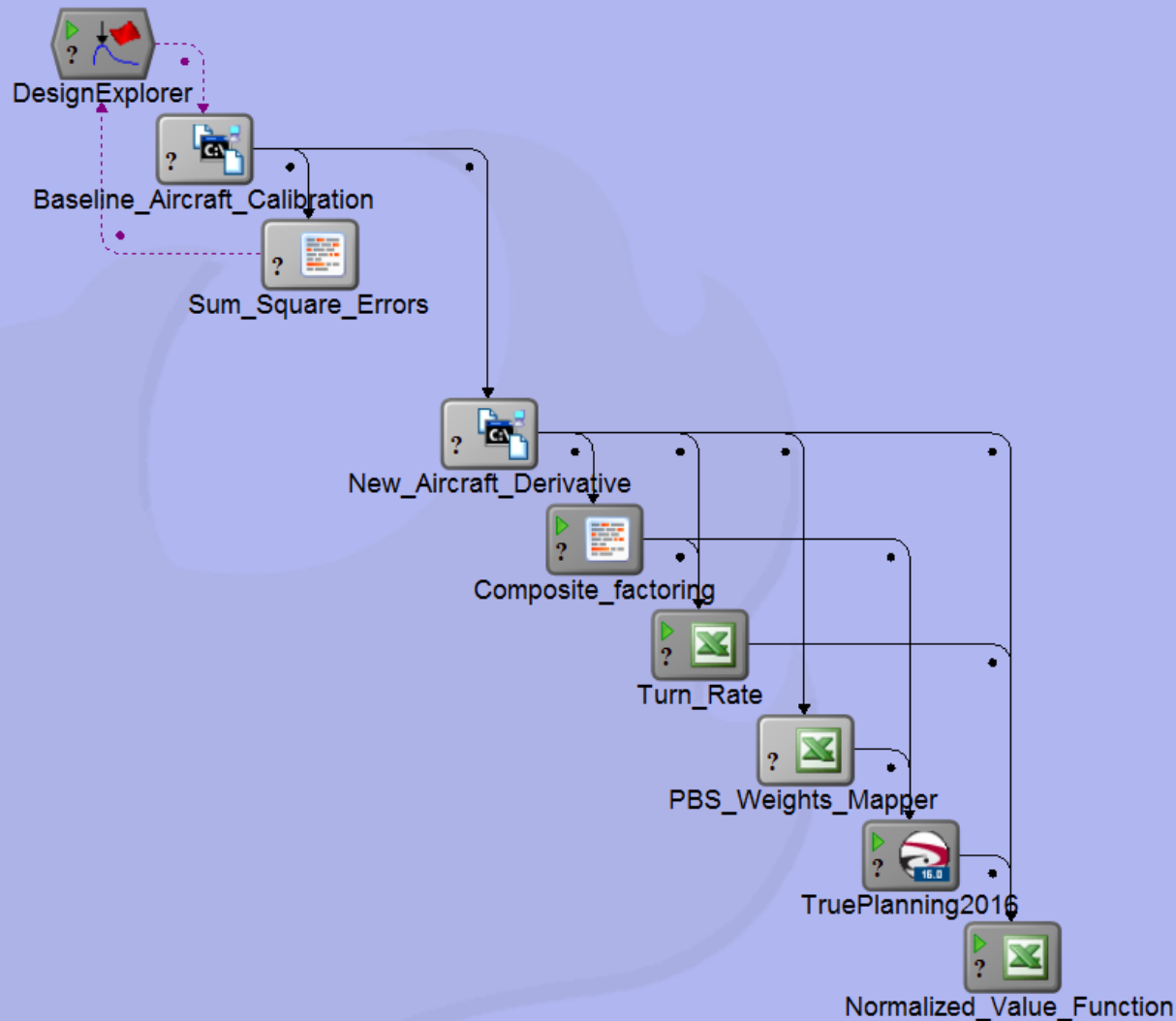
- ### Design-Driven Cost Factors
- Component Weights
 - Complexities
 - Component/product
 - Process
 - Integration
 - Technology Readiness Levels
 - Production Units
 - Learning Curves
 - Etc.



Cost - Capability Index

$$CCI = \frac{\alpha \cdot (\widehat{W}_{Payload}) + \beta \cdot (\widehat{V}_{Stall}) + \gamma \cdot (\widehat{\omega}_{Sust.Turn})}{\widehat{NPV}_{Unit.Amortized}}$$

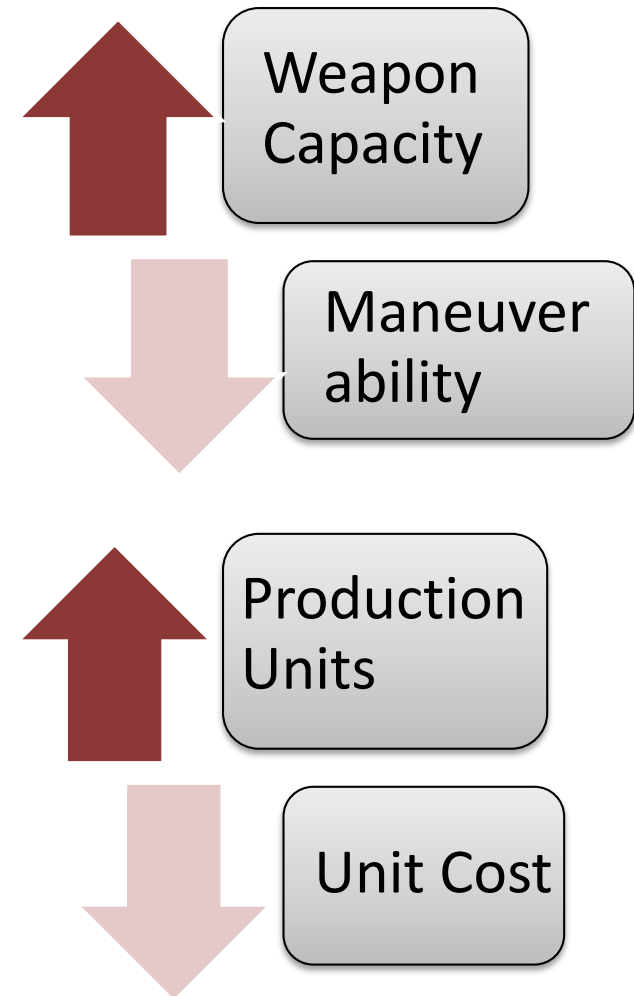




The Analysis

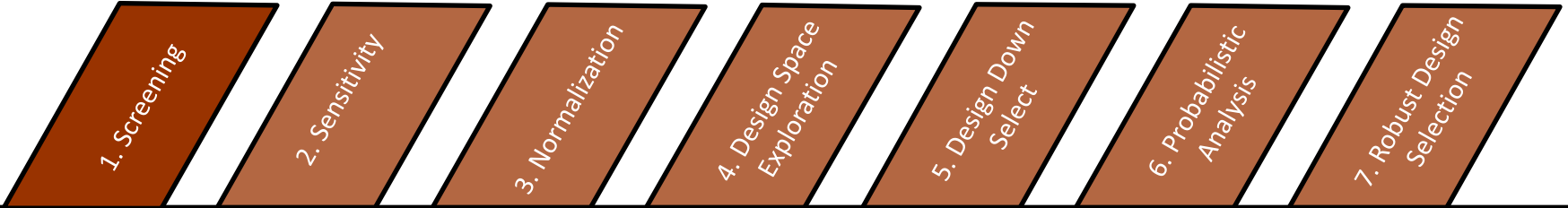
At First Glance

- **Independent variables**
 - SW/AR/SWEEP/Other aerodynamic properties
 - *Can verify with performance model*
- **Technology risks**
 - Use of composite
 - *Can verify with manufacturing expert. Feasible to do?*
- **External uncertainties**
 - Production unit?
 - *Require assumption to be made*
 - Requirements/Customer preference
 - *Need to find robust design options.*

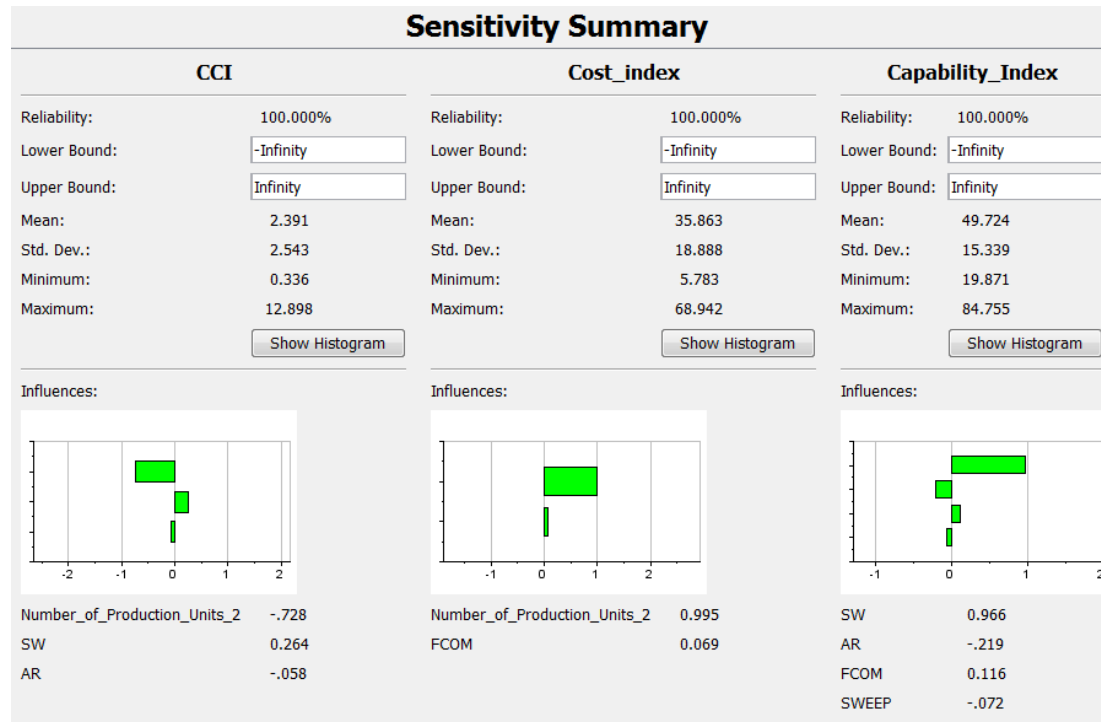


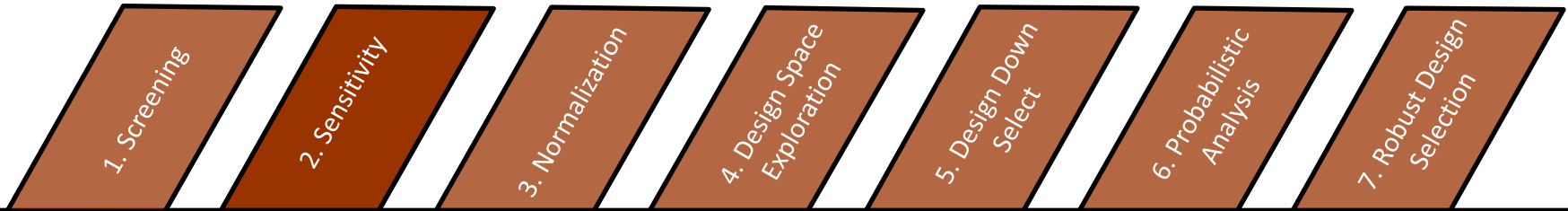
Design Alternatives

- | | |
|-----------------------------|------------|
| 1. Screening | 10M - 100K |
| 2. Sensitivity | 100K - 10K |
| 3. Normalization | |
| 4. Design Space Exploration | 10K - 1K |
| 5. Design Down Select | 20 - 10 |
| 6. Probabilistic Analysis | |
| 7. Robust Design Selection | 10 - 3 |

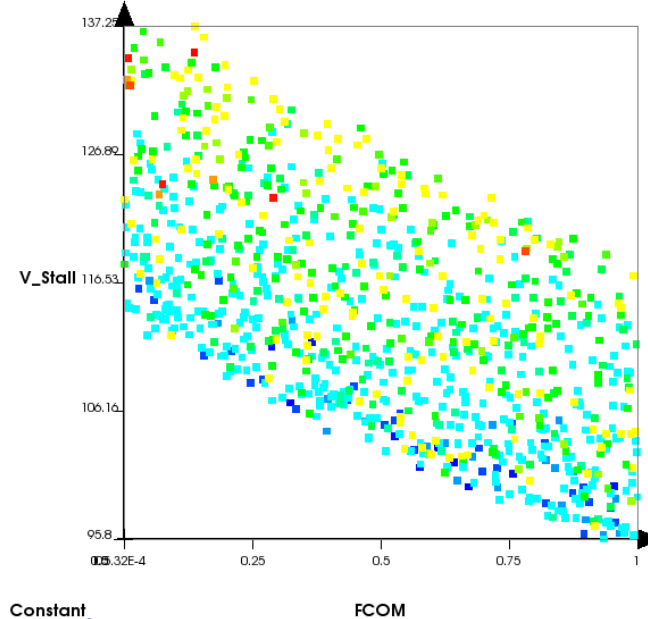
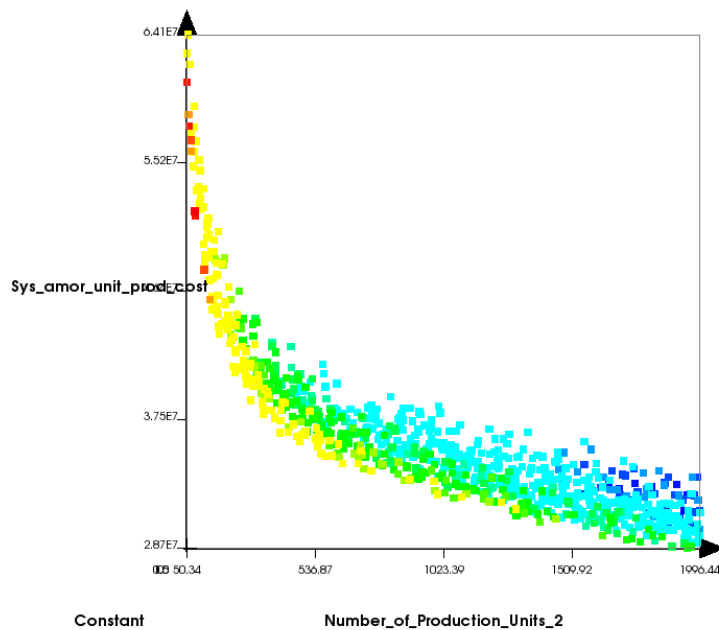


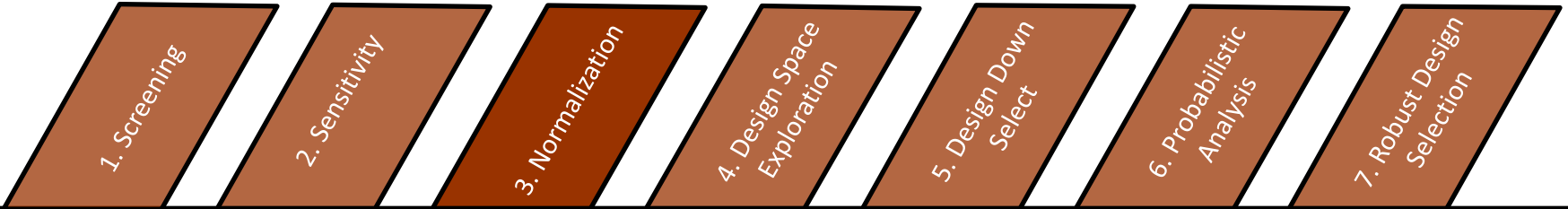
- Applying Pareto Principal to reduce number of input variables





- Verify the model
- Further Eliminate insensitive parameters
- Determine the appropriate ranges of Input/output values





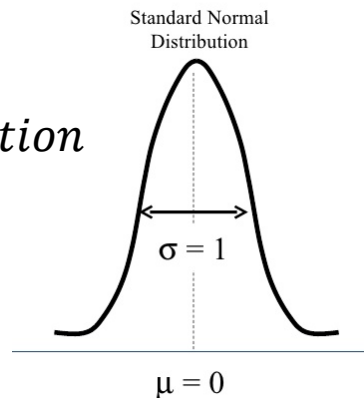
- Ensure equal contribution from each output metric

Cost - Capability Index

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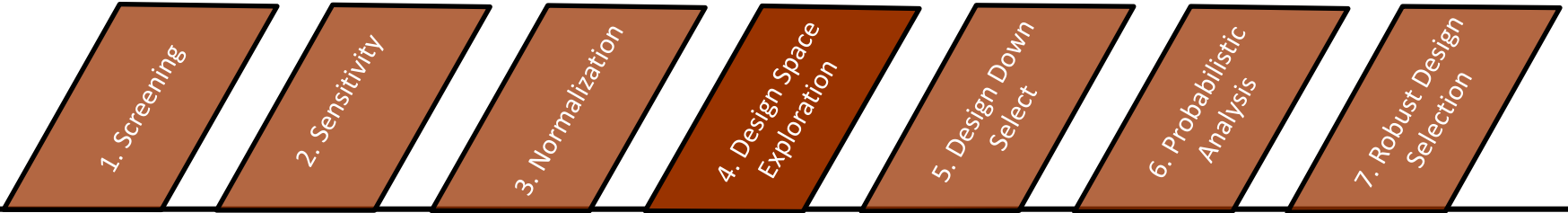
Z - transformation

$$Z = \frac{X - \mu}{\sigma}$$

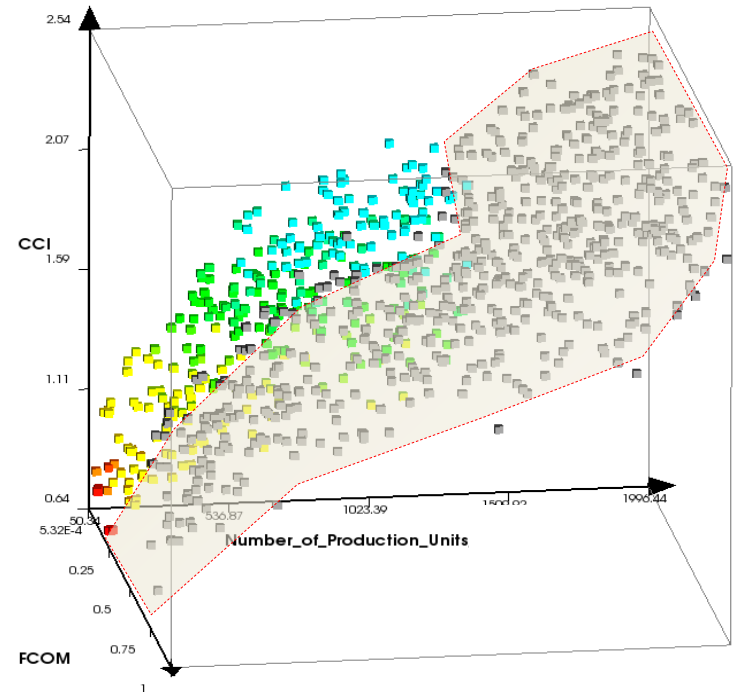
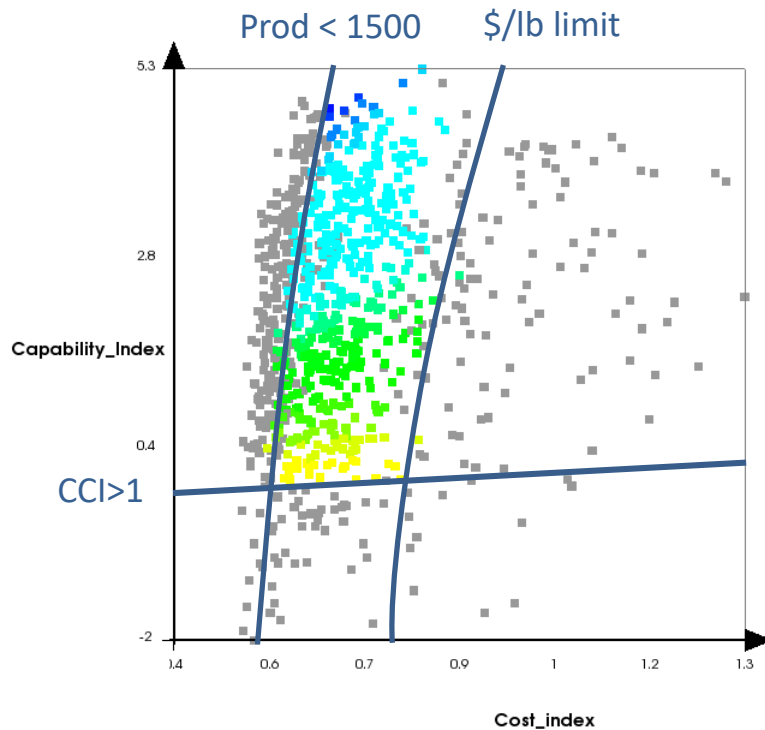


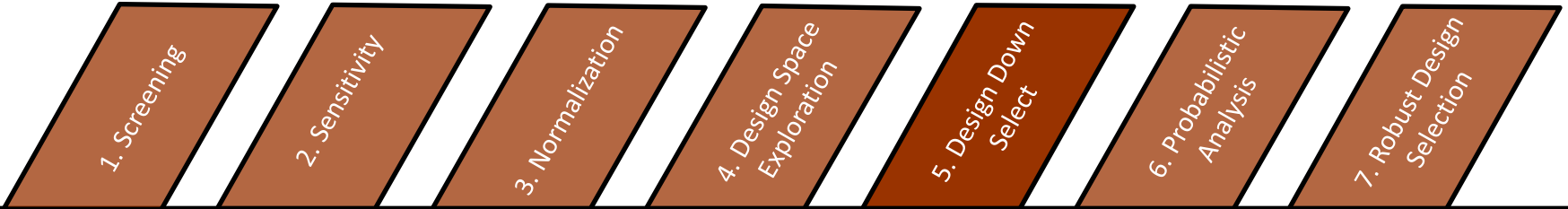
Range transformation

$$x' := (x - x_{\min}) / (x_{\max} - x_{\min})$$

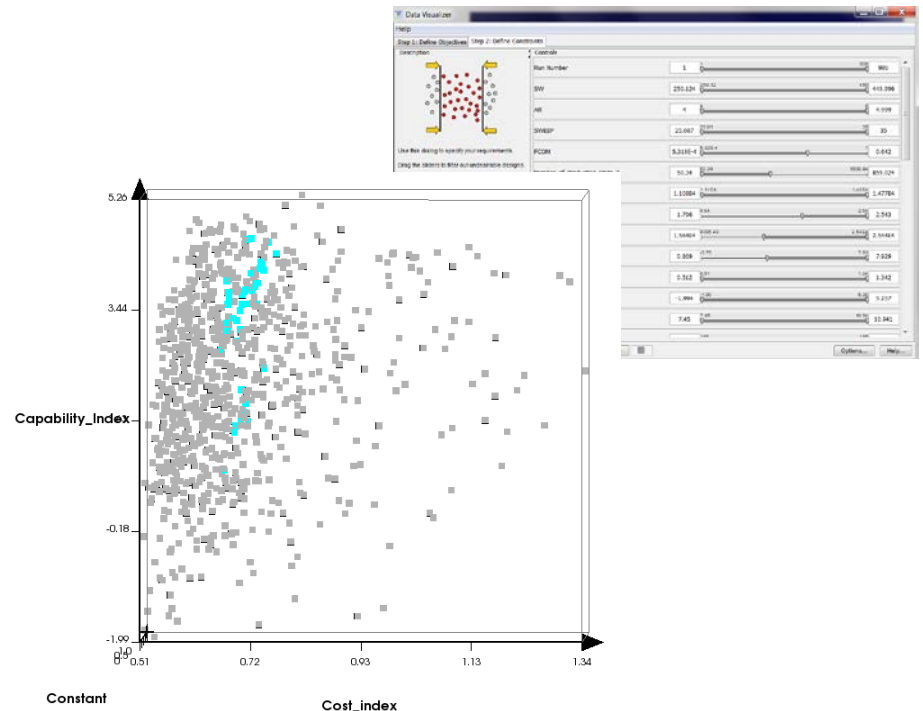
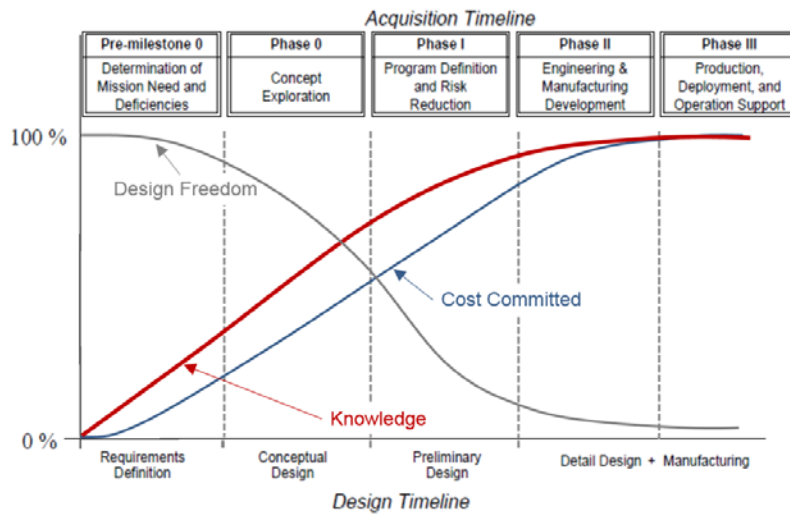


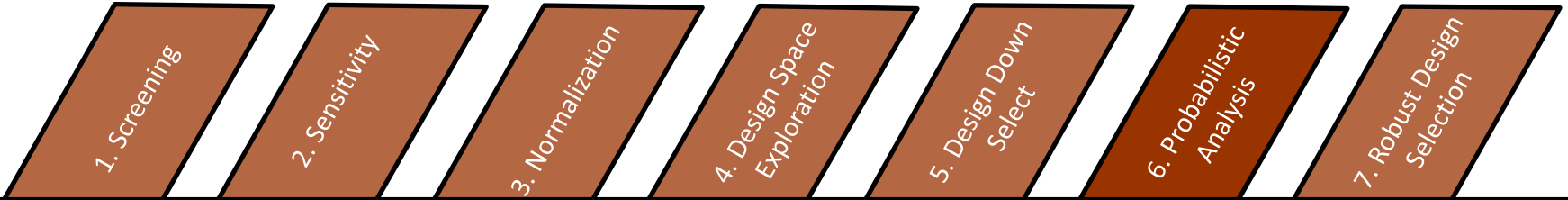
- Develop better understanding of the problem and its cause-effect
- Explore limitations



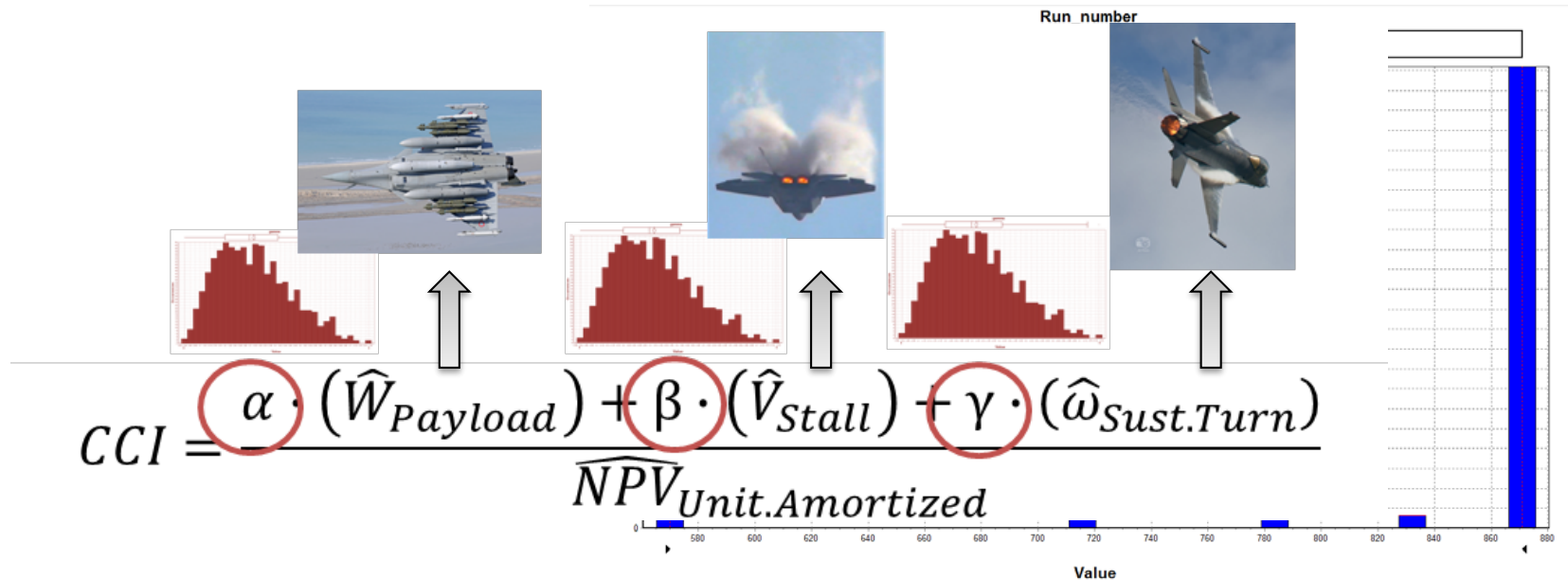


- Incorporate downstream knowledge
 - Impose limitations – product, process, technology, budget, schedule, etc.
 - Limit exposure to risky designs





- Quantifying uncertainties in the requirements
- Robust designs are the ones with better survival rates



Design Process

1. Screening

2. Sensitivity

3. Normalization

4. Design Space Exploration

5. Design Down Select

6. Probabilistic Analysis

7. Robust Design Selection

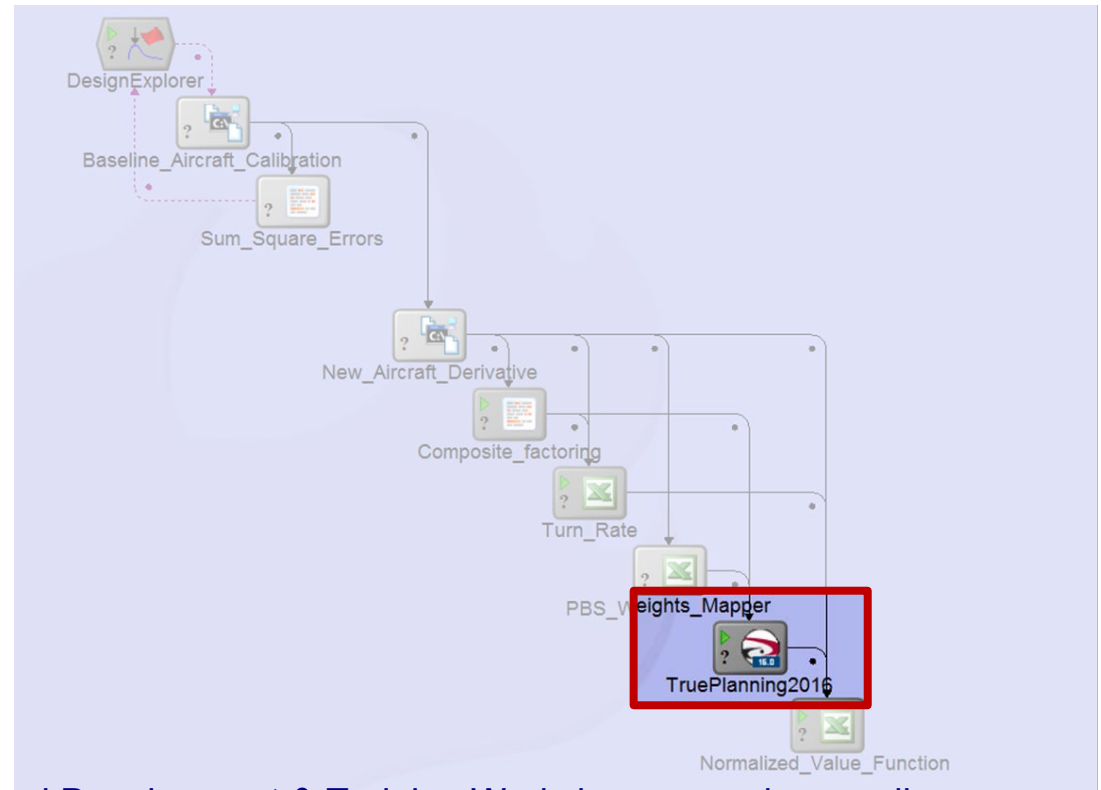


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Summary

Design Affordability Summary

- Systems-of-Systems Capability
- Assembly & Integration
- Varying producibility parameters
- Varying material parameters
- Vary subcontractor rate decks
- Vary escalation assumptions



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- Accelerate the knowledge S-curve
 - Take full advantage of downstream expertise and enterprise knowledge in early cost estimate
 - Incorporate risk and uncertainty quantification
- Fidelity of cost estimate can increase overtime
- Leverage enterprise knowledge
- Support integration with Systems Engineering process, Earned Value Management and other affordability frameworks

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