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Customer Success Is Our Mission

Kinetic Energy Interceptor (KEI) Affordability Process

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Overview

- This presentation package is intended to serve as a guide for how the Affordability process will be deployed on the Kinetic Energy Interceptor (KEI) program during development
- The process leverages several affordability enablers:
  - Robust Design (Design For Six Sigma)
  - Producibility (Design For Manufacture and Assembly)
  - Cost As an Independent Variable (CAIV)
- Examples of these enablers are shown in the context of an architectural concept trade study on KEI
  - Midcourse trade study

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Background

- The Kinetic Energy Interceptor (KEI) program is part of the national Ballistic Missile Defense System (BMDS)
- The KEI program is pre-Systems Design Review (SDR)
  - Specifications and requirements are being developed and allocated
- The case study presented herein is an analysis of the KEI Midcourse trade study
  - Results are limited to the Interceptor
- The KEI Affordability process did not formally exist at the time of the trade study
  - Portions of the process were done retroactively
  - A training package for KEI personnel has been developed which includes materials contained in this presentation

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KEI Value to Ballistic Missile Defense System (BMDS)

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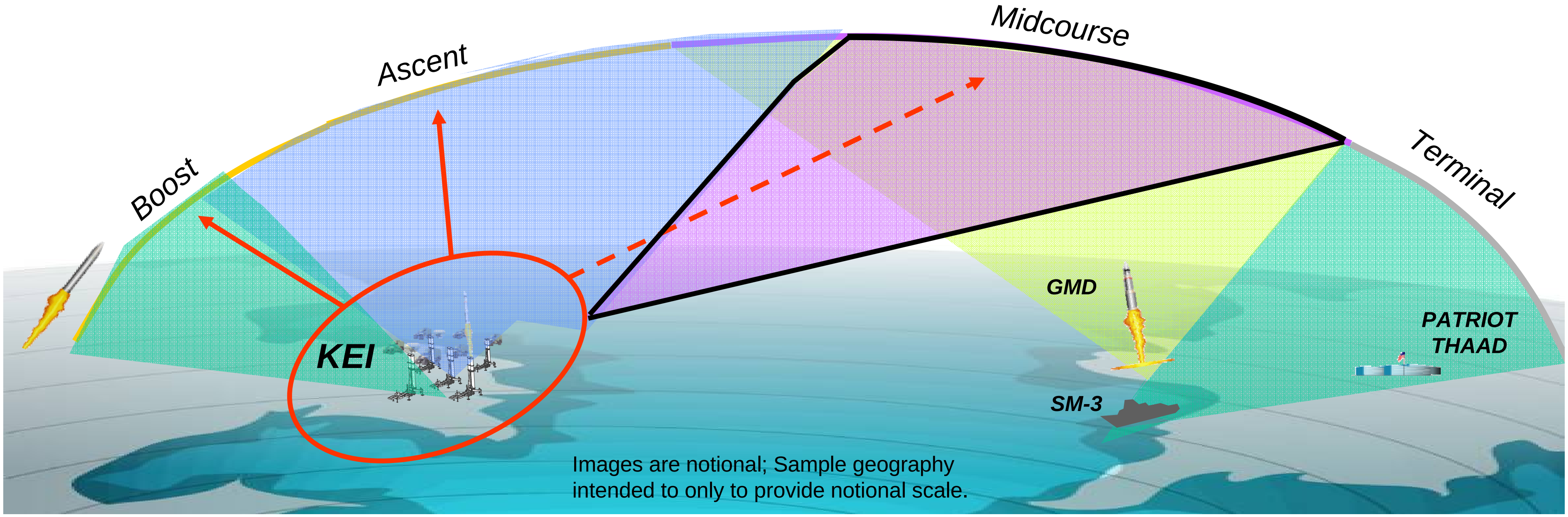
- KEI's original mission was to provide a mobile ground-based weapons system to counter threat ballistic missiles in the boost and ascent phases of flight
  - The Midcourse trade study was developed to evaluate the option of adding a midcourse capability to the KEI system



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KEI Components

KFC/C Component

- Track and prediction processing
- Engagement planning
- Tasking processing
- Human-in-Control insertion

Mobile Fire Control and Communication

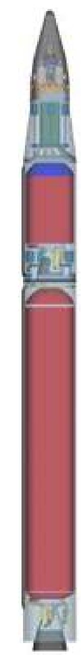
Launcher Component

- Each Launcher provides platform to store, transport, stabilize, erect, and launch the Interceptor

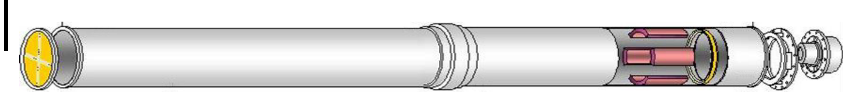
Mobile Launcher

Interceptor Component

- Two-Stage solid fuel booster
- Third Stage Rocket Motor (TSRM)
- Canister



Fast Action Interceptor



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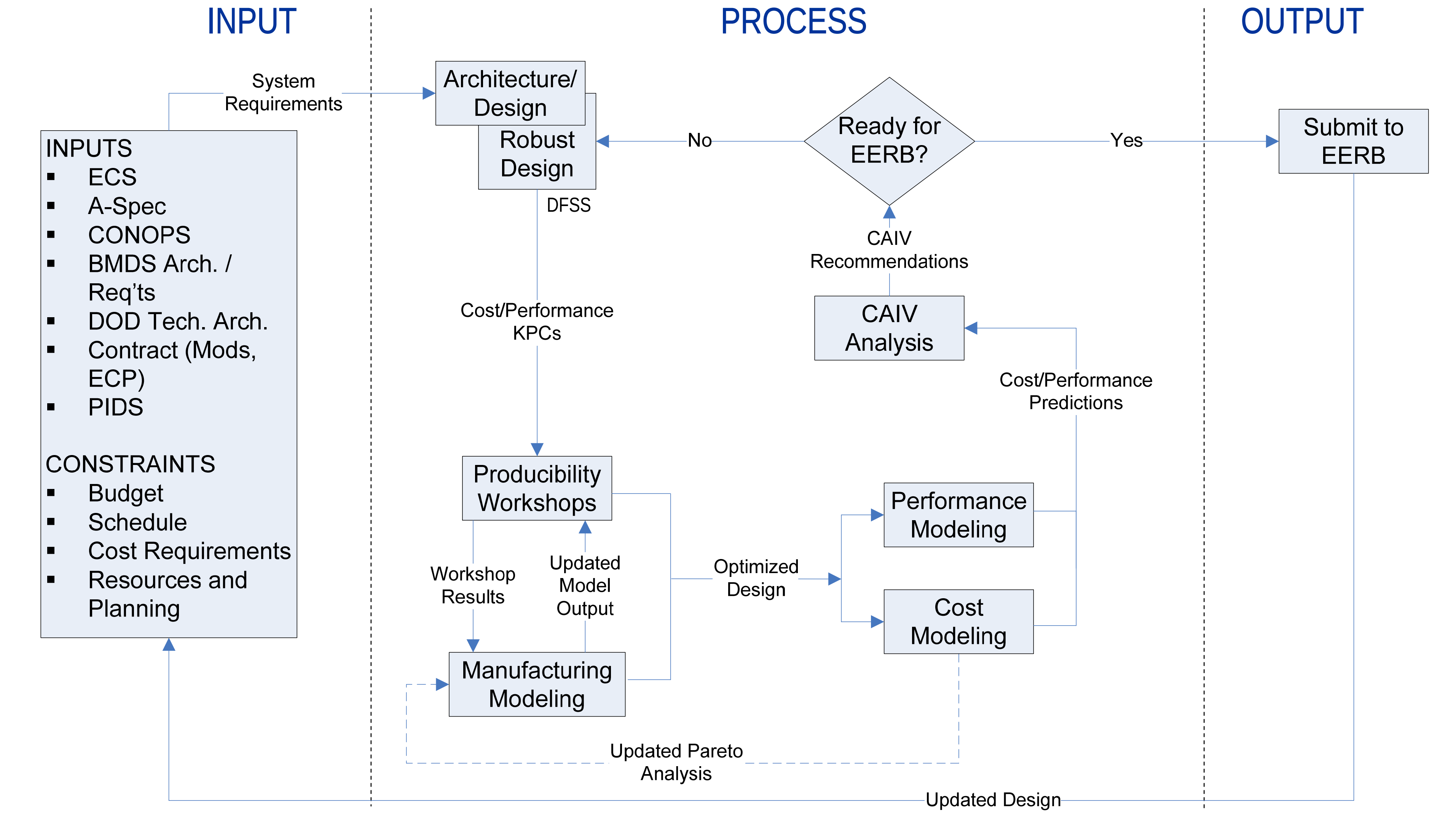
KEI Affordability Process



Note: Process did not exist at time of trade--portions were done retroactively

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Affordability Case Study – Midcourse Interceptor

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- Trade study of midcourse options
  - Add midcourse capability

Config	Seeker			Propulsion			Mod-2	LDACS Propellant
	Baseline	Mod-0	Mod-1	TSRM	L 3rd	S Kick + 20"		
C1	X			X				
C2		X		X				X
C3		X		X			X	X
C4		X			X			X
C5		X			X		X	X
C6		X				X		X
C7		X				X	X	X
C8			X	X			X	X
C9			X		X		X	X
C10			X			X	X	X

Evaluation Metrics	Weighting	
Mission Assurance	**0.30**	
Maturity		0.25
Producibility/Manufacturability		0.21
Environmental		0.16
Compatibility		0.16
Reliability		0.12
Testability		0.1
		Sum
Schedule	**0.25**	
Schedule to DR-1		0.5
DR-1 to end of last flight test		0.5
		Sum
Performance	**0.25**	
Boost Phase PES Performance		0.22
Boost Phase LAD Performance		0.22
Midcourse Phase PES Performance		0.18
Enhanced Environment Performance		0.12
Midcourse Phase DA Performance		0.08
Number of Countermeasure Classes		0.08
Deployability		0.05
Seeker data value to other BMDS assets		0.05
		Sum
Cost	**0.20**	
Cost to DR-0		0.35
Cost to DR-2		0.25
D&T Cost		0.15
Unit Production Cost		0.25

- Ten alternative configurations
  - Three seeker alternatives
  - Three propulsion alternatives
  - Two additional features
- Weighted trade study scorecard
  - Mission Assurance 30%
  - Schedule 25%
  - Performance 25%
  - Cost 20%

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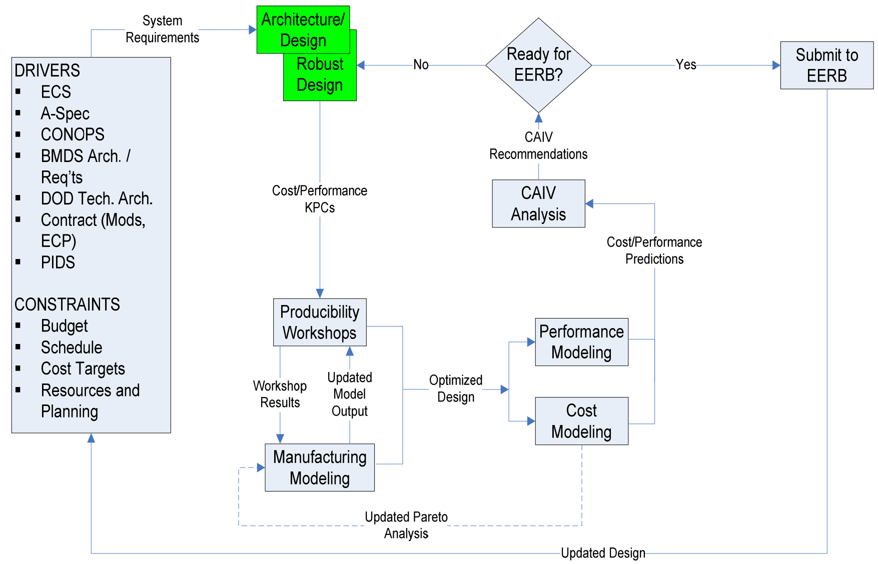
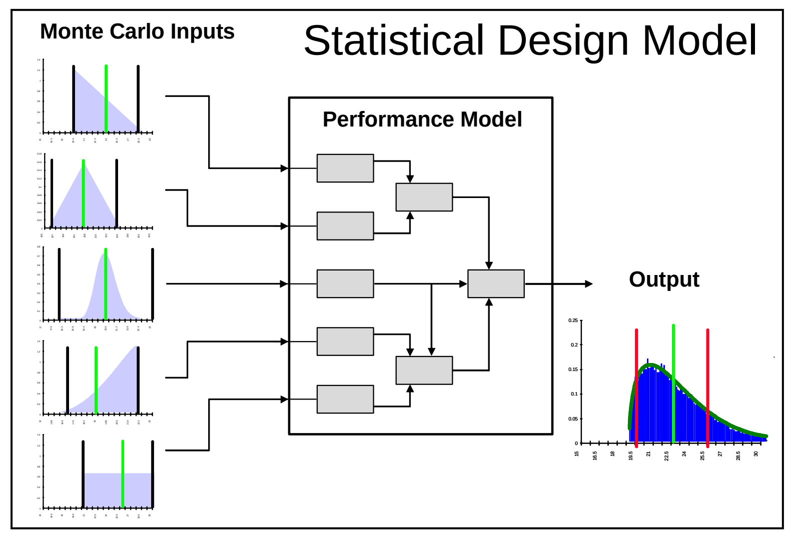
Architecture/Design and Robust Design

- Technical trade space factors
  - Seeker boundaries
    - Baseline two-color 12 lbs
    - Mod-0 three-color 19 lbs
    - Mod-1 four-color 39 lbs
  - Third Stage boundaries
    - SM-3 TSRM (Baseline)
    - Liquid Third Stage
    - Solid Kick Motor With 20” Length To Stage 2
- Statistical design model developed to evaluate Mod-1 seeker design robustness
  - Utilized Raytheon Analysis of Variability Engine (RAVE) tool





Robust Design Example – Mod-1 Seeker

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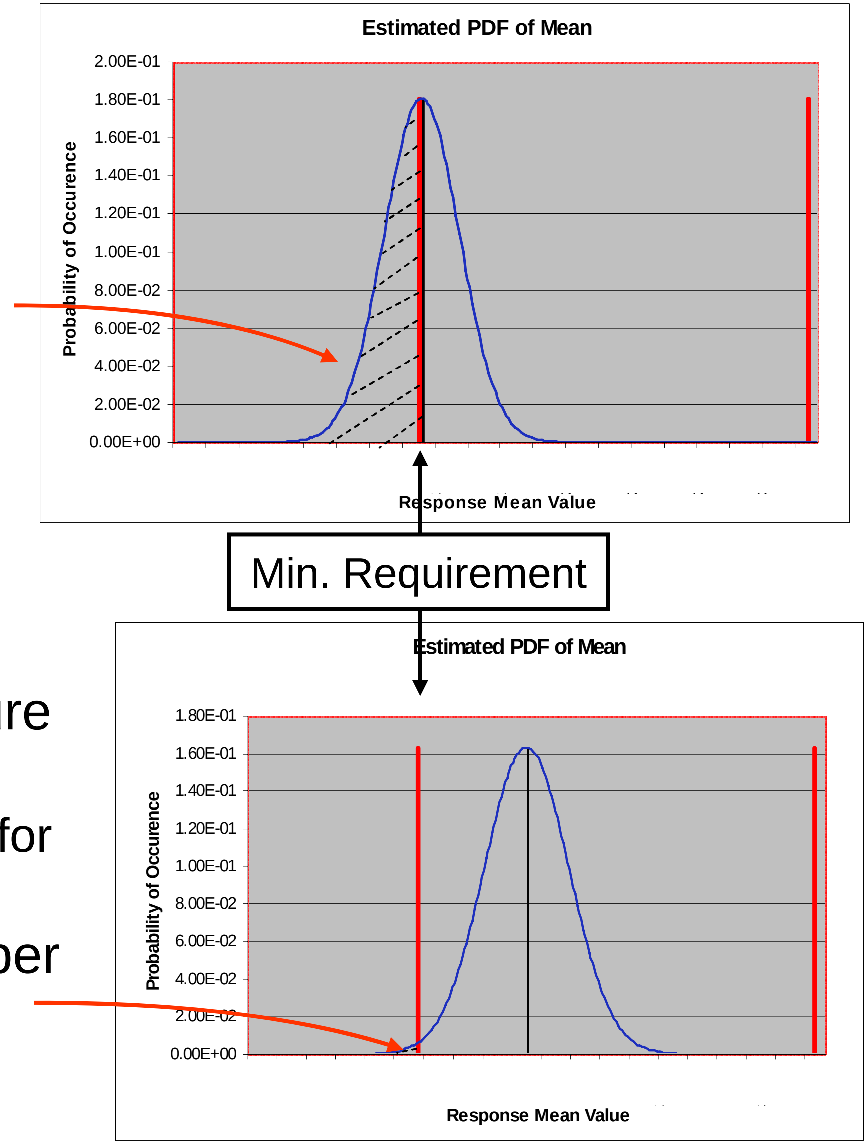
- Seeker model estimates the number of photons received to acquire target at specified range
  - Initially assessed a 50/50 probability of target acquisition
    - Design sigma = 0.7
- Major changes to baseline model:
  - Range variable had excessive margin, was driving failure rate
    - Reduced margin on range distance
  - Target acquisition is sensitive to aperture diameter
    - Reduced the variance on this parameter for diamond-turned machined process
  - Probability of not getting required number of photons at specified range now less than 0.5%
    - Design sigma of 2.8



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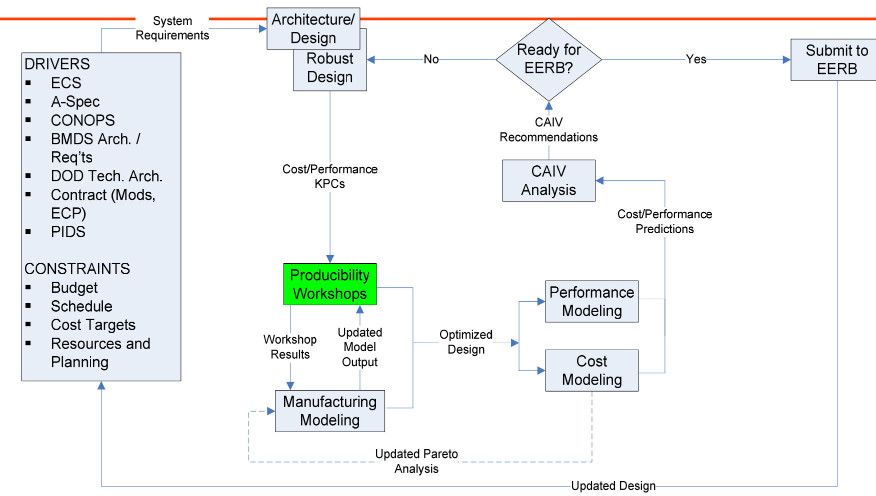
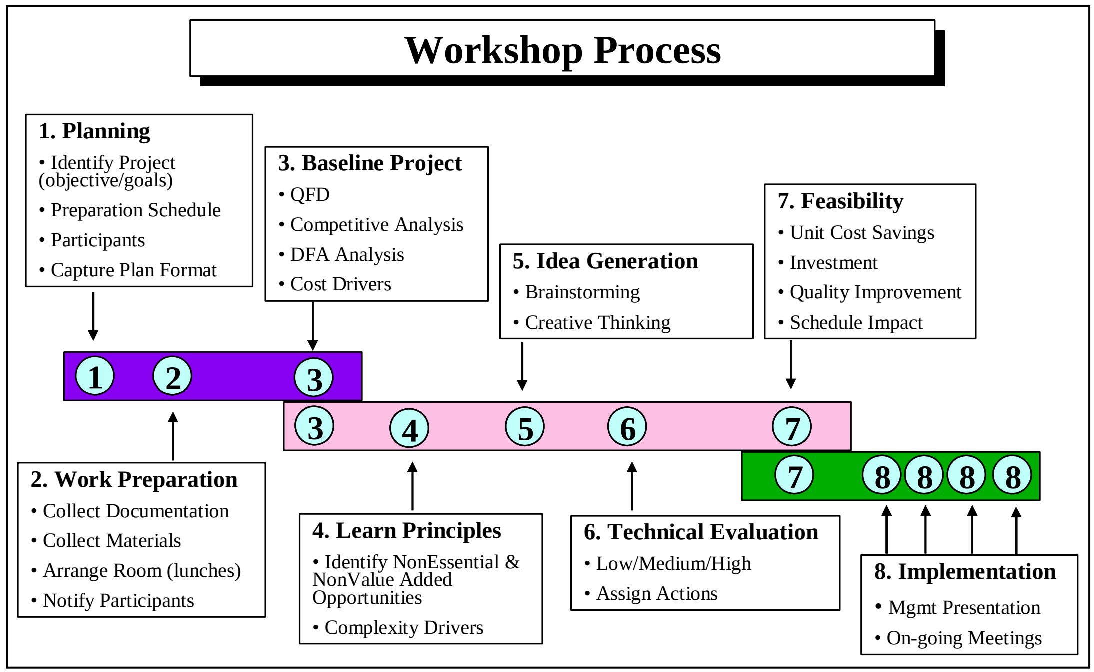
Producibility Workshop

- Assess manufacturability for cost, yield, and/or cycle time
  – Two-color IR detector wafer yields are low
  – Unit costs are high
  – Lead times are long
- Design For Manufacture and Assembly (DFMA) Workshop conducted on two-color IR wafer yield
  – Subject Matter Experts (SMEs) participated in one-day workshop
    - Manufacturing Engr
    - Design Engr
    - Key Supplier





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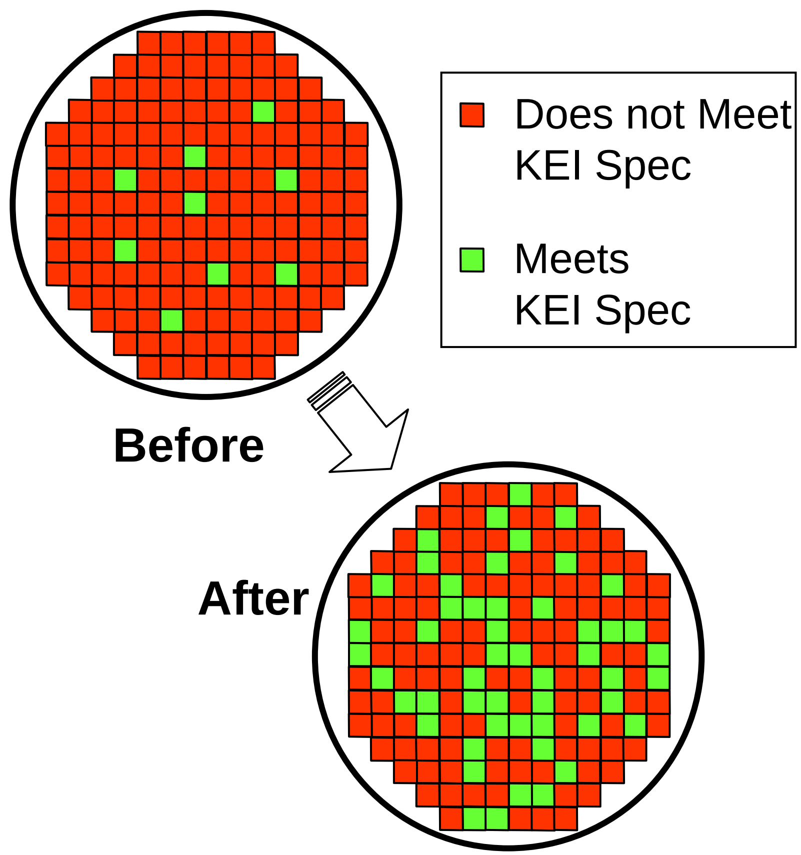
Producibility Workshop Example – Two Color Wafer

- Proposed design and/or manufacturing solutions
  - Based on DFMA workshop, the recommendation was to:
    - Modify specification to match current process capabilities of the wafer fabrication line to increase yields six-fold
  - Additional brainstorming idea:
    - Employ a system software solution enabled by faster processing times to help with discrimination algorithms
- Impact of component design on system design and production
  - Modification of the specification improves yields, reduces product cost, and lead time
  - System software alternative improves system performance
    - Probability Of Engagement Success



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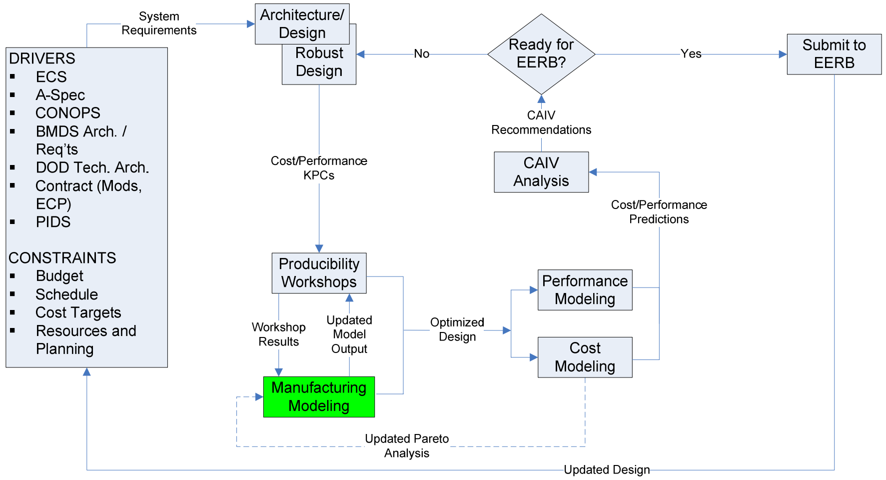
Manufacturing Modeling

- Assess manufacturing cost
  - – Outcomes from robust design and producibility workshops are assessed for their impact to manufacturing cost
    - Factory realizations are evaluated due to fewer failures by developing a more robust design
    - Impact from producibility workshop assessed for supplier costs for the wafer
- Update manufacturing model
  - – Reflect updated manufacturing flow
    - Hours per unit
    - Supplier costs
    - Others
  - – Statistical process control deployed on key control characteristics
    - Seeker aperture diameter



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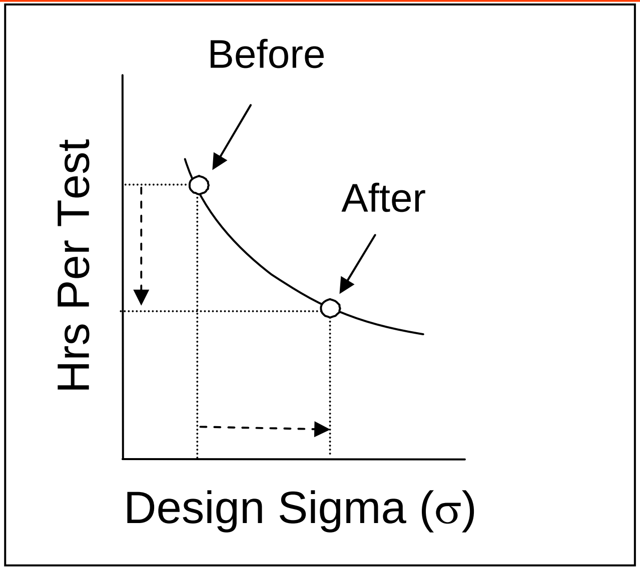
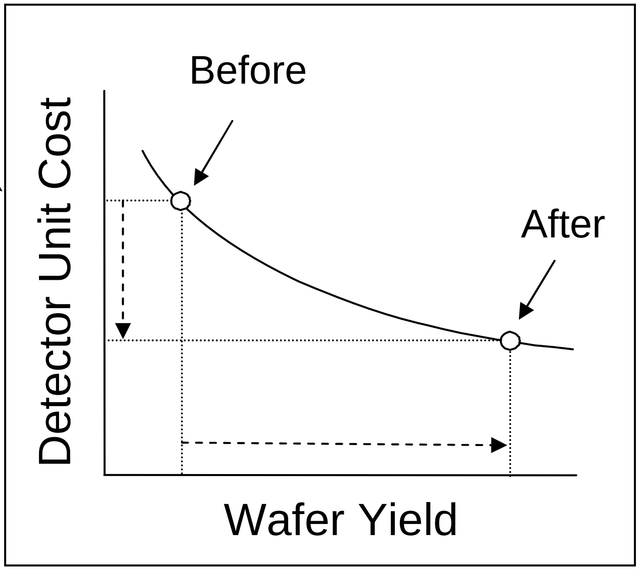
Mfg Model Example – Robust Seeker and Wafer Yields

- Mod-1 seeker design sigma was increased from ~1σ to ~3σ
  - Test failures for the acquisition test parameter are expected to decrease dramatically
  - The hours per test for this parameter should decrease as a result of fewer failures
    - Less rework and retest
- Two-color IR wafer yield was increased 6x
  - Cost per detector decreases due to amortizing wafer cost over greater number of acceptable detectors
  - One-sixth number of wafers now required to meet detector demand
- Both improvements apply to all seeker configurations
  - Two-color detector common to all alternatives
  - Robust design improvements common as well





Notional Data

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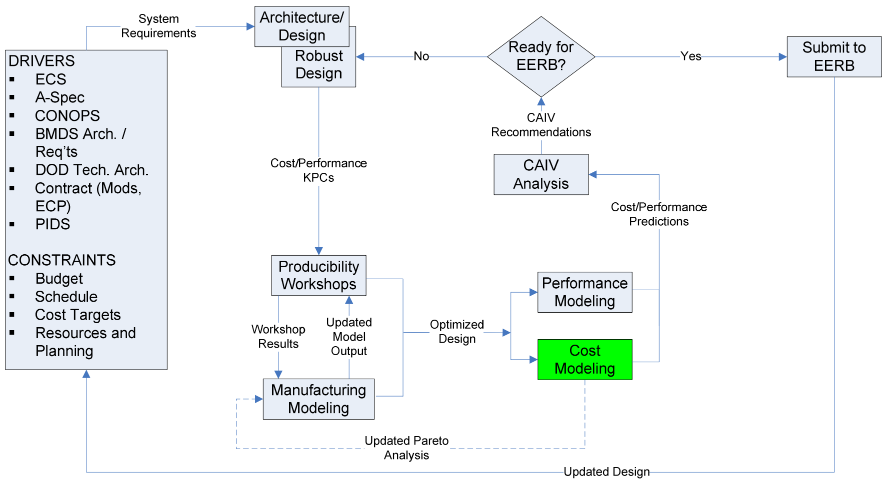
Cost Modeling

- Run cost model
  - Price the manufacturing estimates and determine impact to all phases of Life Cycle Cost
    - Development and Test (D&T)
    - Production
    - Operations and Support (O&S)
- Determine cost drivers
  - Pareto analysis identifies high cost items, points to design attributes and/or requirements that drive cost



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Cost Modeling Example – Interceptor Costs

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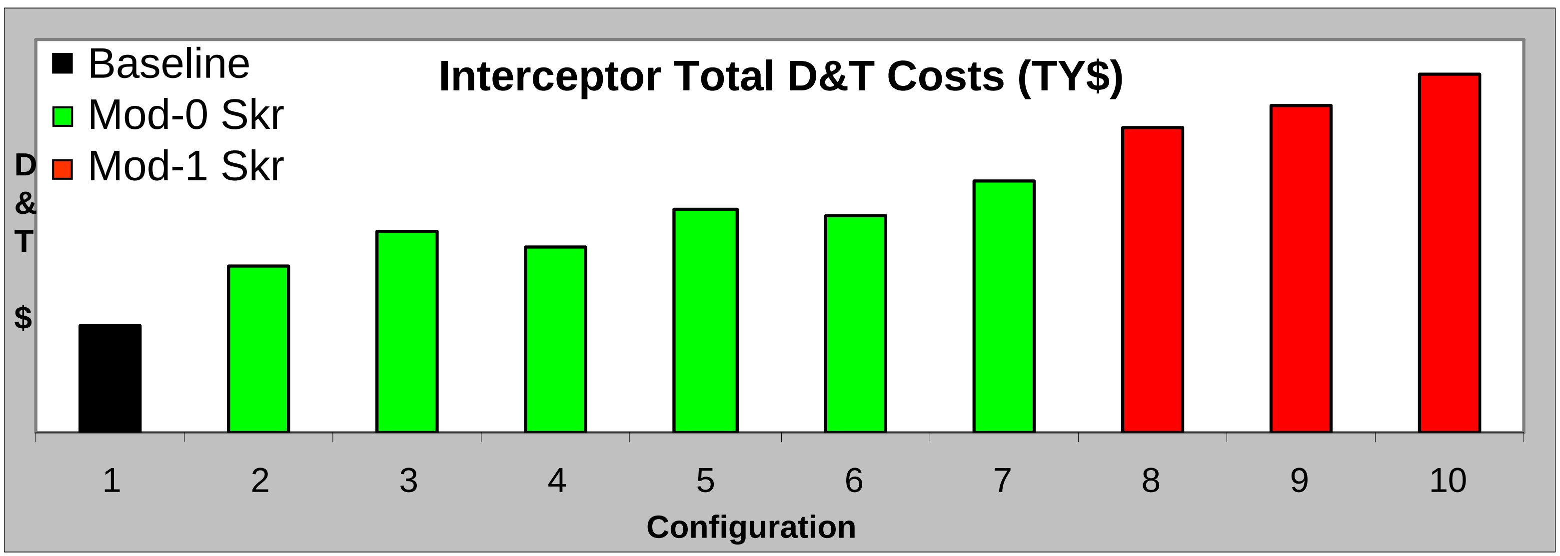
- D&T cost impacts estimated for non-recurring tasks
  - Used rationale from analogous KEI estimates scaled for complexity
- Cost impacts to production estimated using parametric models
  - Unit cost impact estimated to be similar for all alternates
    - Robust design and producibility workshop results apply equally
- O&S cost impact estimated to be negligible



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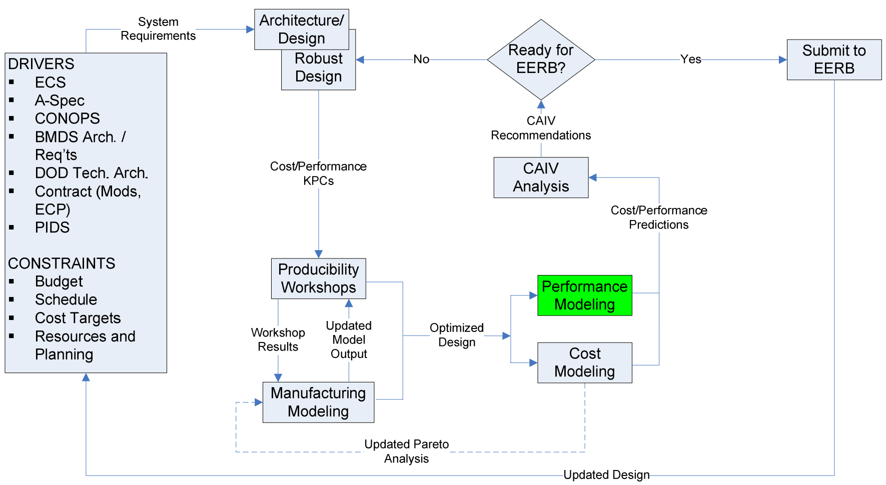
Performance Modeling

- Performance simulation
  - KEISim assesses impact to key Measures of Performance (MOP)
    - Launch Area Denied (LAD)
    - Defended Area (DA)
    - Probability Of Engagement Success (PES)
  - Determine performance drivers
    - Conduct sensitivity analyses



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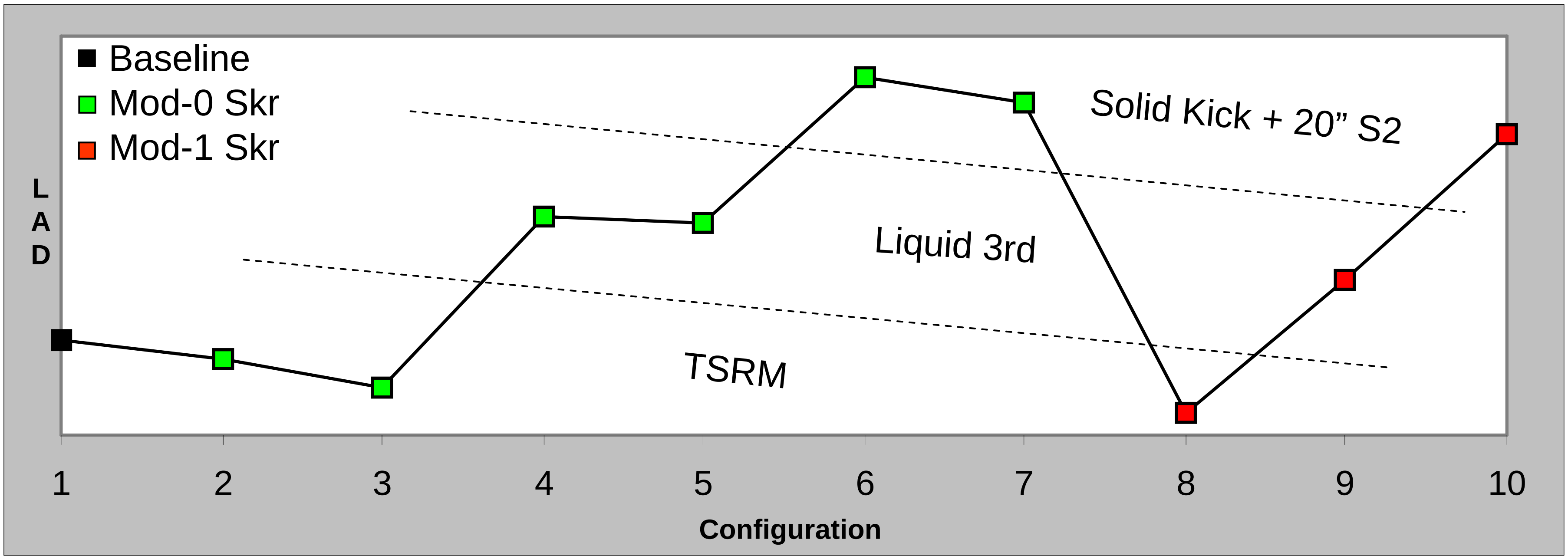
Performance Modeling Example – Launch Area Denied

- For midcourse, the Launch Area Denied (LAD) was assessed for the composite performance of two launcher locations for each configuration
  - Configurations 6, 7 and 10 had the highest LAD
  - Configurations 2, 3, and 8 were lower than Baseline



  - LAD appears to be fairly sensitive to third stage propulsion alternatives

Note: Weight increases from left to right

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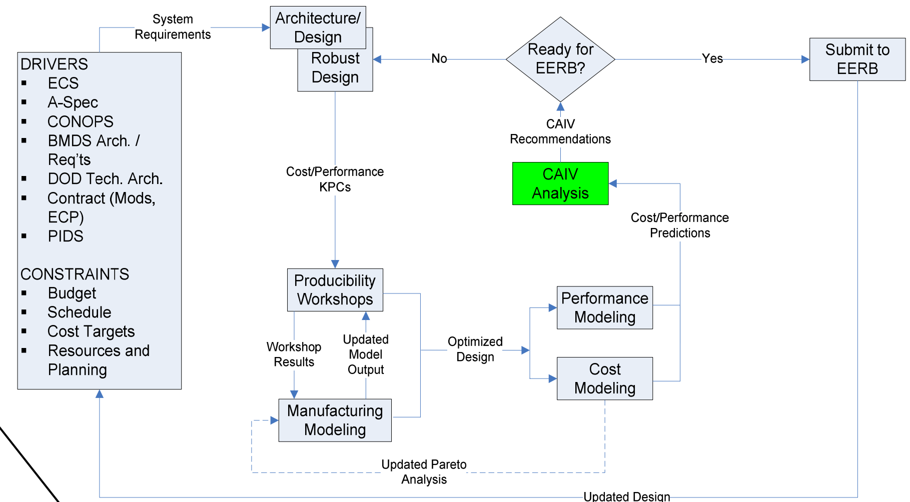
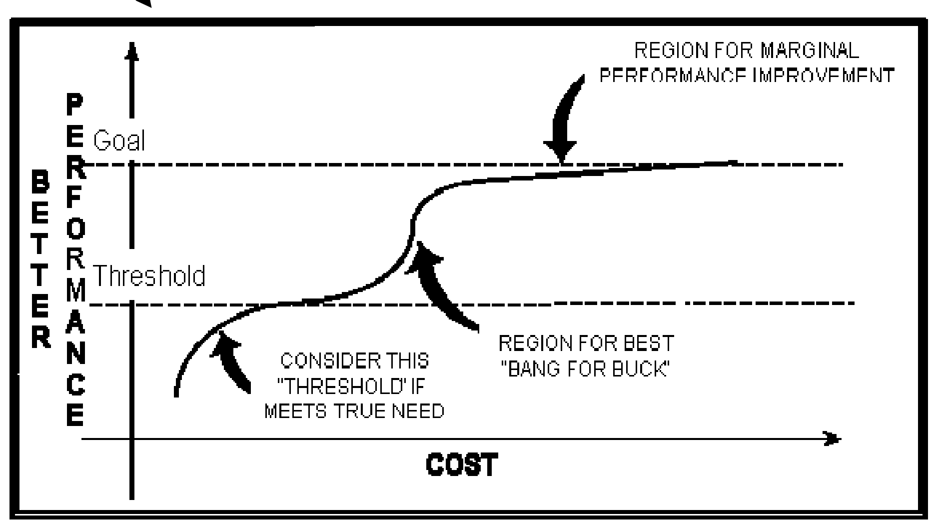
Cost As An Independent Variable (CAIV)

- Evaluate performance as a function of cost
  - Graph the measure of performance on the Y-axis and the cost on the X-axis (scatter diagram)
    - Identify the Knee In The Curve
- Develop Affordability metric
  - Determine the cost per unit of performance by dividing cost by the measure of performance
    - Dollars per LAD (in this example)
    - Lowest cost per unit of performance is the most efficient solution





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CAIV Example – Cost Performance Analysis

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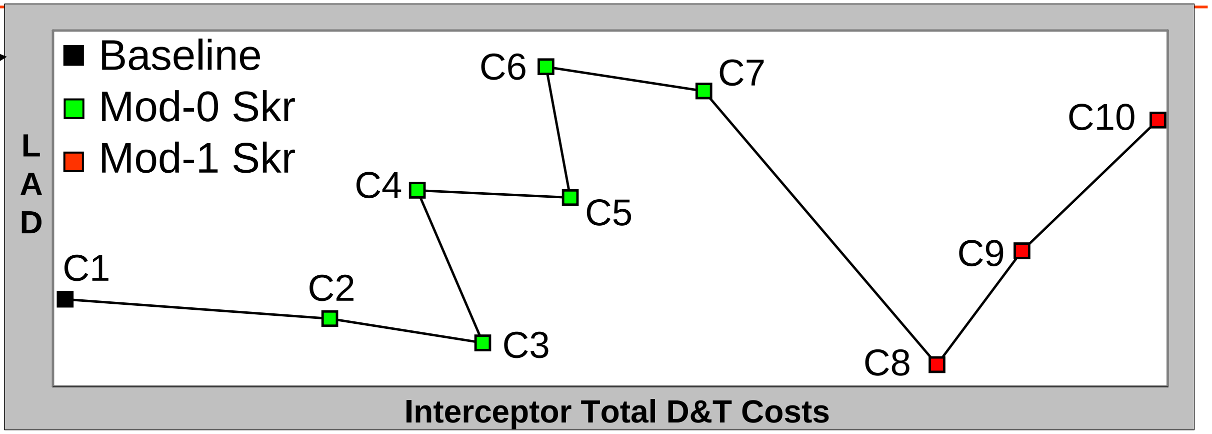
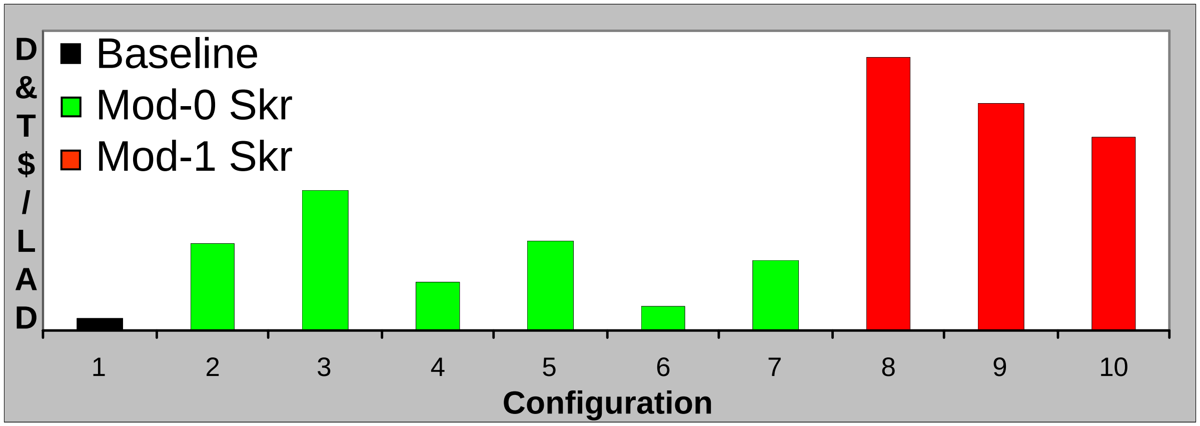
- Cost-performance analyses measures LAD as a function of cost
  - Treats Cost As An Independent Variable (CAIV)
  - Knee in the Curve occurs with Configuration 6 (C6)
- Affordability metric shows how many $ for each percent of LAD
  - Baseline is lowest
  - C6 is comparable cost efficiency to Baseline



Configuration 6 Provides "Best Value"
- Highest bang per buck
- Low cost per LAD percent



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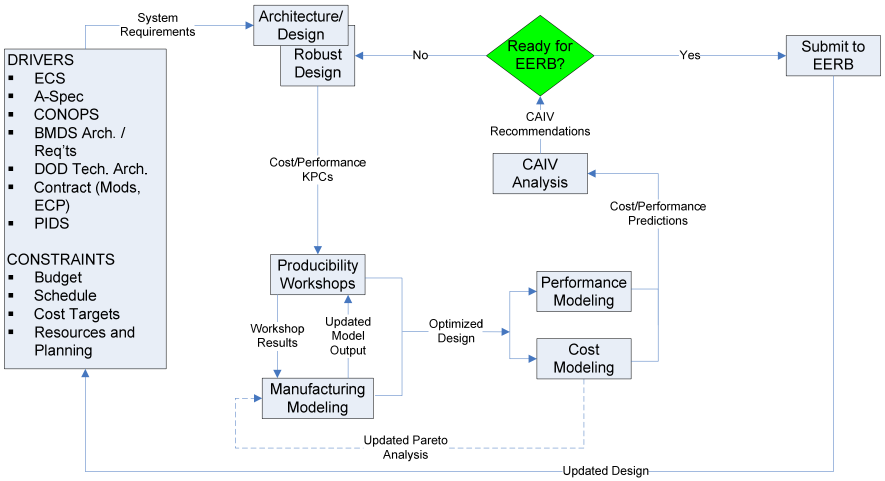
Element Engineering Review Board

- Both the technical analyses and the cost-performance analyses are reviewed with appropriate management teams for approval to take to Element Engineering Review Board (EERB)
- EERB can recommend further analysis, terminate the effort, or take the decision to Element Change Control Board (ECCB)



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EERB Example – Midcourse Interceptor

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- Prior to EERB, the liquid 3rd stage alternatives were withdrawn
  - Hypergolics made them unsuitable for sea-based applications

Config	Seeker			Propulsion			Mod-2	LDACS Propellant
	Baseline	Mod-0	Mod-1	TSRM	L 3rd	S Kick + 20"		
C1	X			X				
C2		X		X				X
C3		X		X			X	X
~~C4~~		~~X~~			~~X~~			~~X~~
~~C5~~		~~X~~			~~X~~		~~X~~	~~X~~
~~C6~~		~~X~~				~~X~~		~~X~~
~~C7~~		~~X~~				~~X~~	~~X~~	~~X~~
C8			X	X			X	X
~~C9~~			~~X~~		~~X~~		~~X~~	~~X~~
~~C10~~			~~X~~			~~X~~	~~X~~	~~X~~

- Due to the sensitivity of LAD to the propulsion alternatives, a follow-on trade study (Common Booster) was developed to evaluate several alternative third stages
  - Decisions regarding configurations 6, 7, and 10 were deferred
- Customer selected Mod-0 seeker without change to the baseline propulsion stack (Configuration 3)
  - Stage 3 propulsion decision is subject to a follow-up Common Booster trade study

Summary

- Cost performance analysis (CAIV) aids the decision-making process
  - The Customer expects us to consider Affordability in our trade studies
- Systems engineers influence cost through specifications, requirements, and margin
  - Specifications that don't match manufacturing capabilities can create low yields and high cost
  - Allocating excessive margin can also create low yields and costly solutions
- Value is ultimately determined by the Customer
  - Need to include them in the decision making process