



Everything You Always Wanted to Know about Affordability ...*

***but Were Afraid to Ask**

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Abstract

Everything you always wanted to know about Affordability ...

... but were afraid to ask

- The term “*Affordability*” means different things to different people, depending upon one’s employer, organization, function, background, etc. The term has morphed over the years - expanded or narrowed - based on one’s viewpoint. During ICEAA’s OEM-COG* discussions on Affordability, diverse opinions were revealed. We will present various interpretations & implementations of Affordability from multiple perspectives, provide historical background, and explore how the community can clarify, standardize, and promote the concept of Affordability.

* OEM-COG: Original Equipment Manufacturer’s Cooperative Opportunities Group

Outline

- What does Affordability mean to YOU?
- Definitions & Terminology
- Affordability Process from a Systems Engineering Perspective
- Affordability Analysis / Trade Studies
- Examples of Affordability on Programs
- How to Promote Affordability
- Wrap up



Let's learn about what Affordability really means!

Affordability Definitions across the Spectrum

- 1 – INCOSE
- 2 – NDIA
- 3 – MORS Aff WG
- 4 – DAU/DAG
- 5 – Cambridge dictionary

Industry – Professional Societies

- **Affordability** is the balance of system performance, cost and schedule constraints over the system life while satisfying mission needs ... ¹
- **Affordability** is the practice of ensuring program success through the balancing of system performance (KPP*s), Total Ownership cost, and schedule constraints while satisfying mission needs in concert with long-range investment, and force structure plans of the DoD ²
- **Affordability** means being cost efficient in executing a program, from beginning to end ... getting the most bang for the buck (Little “a”) ³
- **Affordability** is the degree to which the capability benefits are worth the system’s total life-cycle cost and support DoD strategic goals ⁴

General - Dictionary Definition

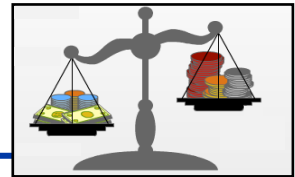
- The state of being cheap enough for people to be able to buy ⁴



*KPP = Key Performance Parameter

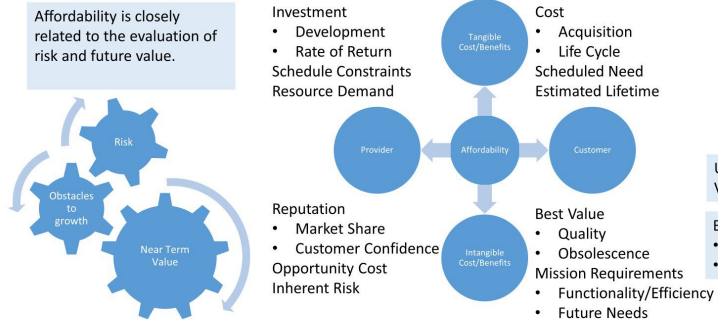
Balancing the cost and “other considerations”

Affordability Perspectives from OEMs



Affordability Perspective

Defining the nature of affordability is like grasping mist, it's relative meaning and importance are solely dependent on the context within which it is discussed.



A Perspective on Affordability

- In a perfect world, the PM's, SE's, Executive Approvers and Budgeteers, would ensure a Program is designed to minimize Lifecycle costs, achieving perfect affordability...however...this never happens

Affordability → Affordable: able to be Afforded → Afford: to manage to bear without serious detriment

~ Budget Constraint + Mission Needs

Expected Skills & Knowledge Base	LCC	Trade Studies	Cost Strategy	Price to Win (PTW)	DTC	BoE Support	EVM & Risk Analysis	Cost Reduction Initiatives
Systems Engineering	x	x		x	x	x	x	x
Software	x	x				x	x	
Production	x					x	x	x
Business Management			x		x	x	x	
Pricing & Estimating	x		x		x	x	x	
Strategy & BD	x	x	x	x	x	x	x	x

Affordability spans the entire life cycle and is an integrated responsibility across functions and teams

Purpose of Program Affordability

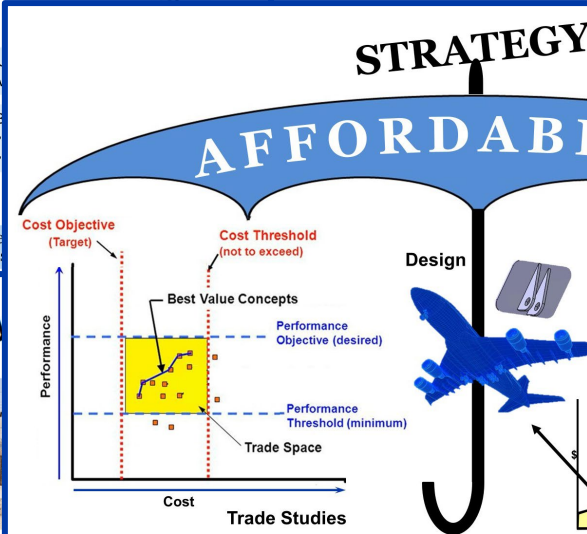


M1126 Stryker™ ICV

M1A2 SEP Abrams™ Tusk

- To Track Cost As a Technical Performance Measure (TPM) of the Deliverables
- Assist the Program in Achieving a Proper Balance Among Technical Performance, Affordability (Development, Production, Operating and Support), and Producibility.

Minimize Total Life Cycle Costs to the Customer, While Meeting all Requirements



Affordability Perspectives

Customer Perspective

Affordability = Value

- DEGREE benefits are worth the cost and support strategic goals
- CONDITIONS when costs are in consonance with requirements
- RESULTS from analysis of costs versus resources available

Contractor Perspective

Affordability = Value

- PROPOSAL PHASE objective is to offer customer value to secure contract award
- PROGRAM EXECUTION objective is to deliver customer value per contract commitment

Systems Engineer Perspective

Affordability = Value

Value Engineering = Affordability

Value Engineering Skills = Technical Skills x Cost Skills

Body of Knowledge

Competition Guidelines, Best Value Continuum, Value Adjusted Total Evaluated Price, GAO Best Practices, Reduction of Total Ownership Costs, Trade Space and Strict Dominance

Target Costing and Design to Cost, Cost as an Independent Variable, Quality Function Deployment, Design for Manufacturing, Activity Based Costing, Lean Initiatives and Cost Benefit Analyses

Supply Chain Affordability Perspective

Three Steps for Cutting Supplier Costs in Aerospace and Defense

MAY 15, 2017

By Robert Tevelson, Matt Aaronson, Philippe Plouvier, Thomas Peddicord, and Henry Caffrey

The aerospace and defense (A&D) industry faces much tougher market conditions today than it did a decade ago. Most governments are reducing their overall military spending and focusing their shrinking budgets on a smaller number of core programs and systems. Government and civilian customers are emphasizing affordability rather than sophisticated features.

(Although the Trump administration is calling for an increase in US defense spending, it will also likely push to keep prices down for individual platforms and systems.) In this environment, prime contractors and tier one integrators need to reduce costs in order to win contracts and preserve margins.

Traditionally, prime contractors and tier one integrators (we'll refer to as OEMs) have struggled to pass cost reductions to customers. (Procurement, February 2016.)

This publication discusses three tactical steps that both aerospace and defense OEMs can take to improve their overall supply-chain performance, meeting customer expectations for affordability while still generating attractive margins.

Government and civilian customers are emphasizing affordability rather than sophisticated features.



costs

performance

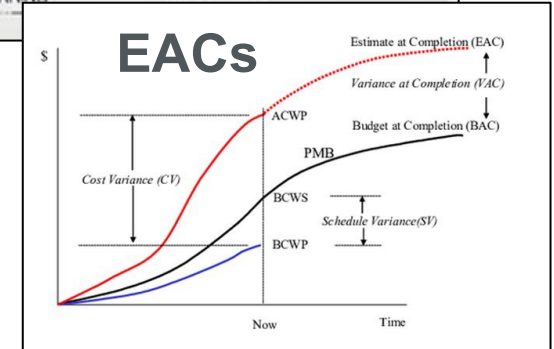
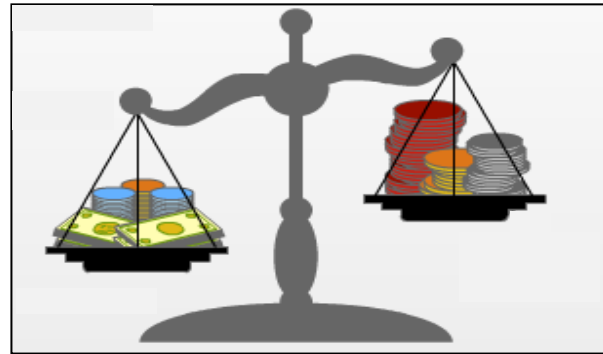
willing and able to pay
and profit

... steps ... OEMs can take to

- improve their overall supply-chain performance,
- meeting customer expectations for affordability
- while still generating attractive margins.

Does Cost Cutting = Affordability? ... If balanced with "other things"

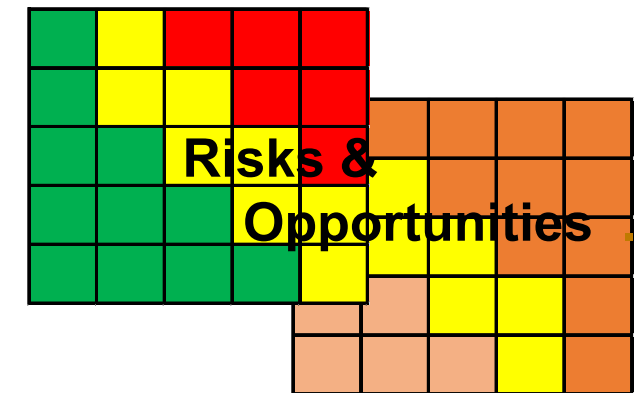
Business Operations Perspective



Investment	---	ROI
Source A	---	Source B
Make	---	Buy
Risks	---	Opportunities
Pay up front	---	Save Later
Estimates	---	Actuals



OR



ROI = Return on Investment
EAC = Estimate at Completion

Business Operations – Budgetary Planning – Program Management

Affordability Analytic & Management Approaches

Via Modeling & Analyses

- *Cost Modeling (Life Cycle)*
 - *Cost Driver Analysis*
 - *Cost Target Allocation*
 - *Cost Risk / Uncertainty Analyses*
- *Cost-Performance* Trade Studies***
- *Cost of / Value of Requirement(s)*
- *Multi-disciplinary Design, Analysis & Optimization*
- *Digitalization / Model-based Systems Engineering*
- *Value Analysis*
- *Reverse Engineering / Teardown*

EARLY in the life cycle

Via Management & Execution

- *Documentation*
 - *Internal processes / guidance*
 - *DOD Directives / Instruction / Handbooks*
- *Strategy*
- *Lean Principles*
- *Standardization*
- *Cost Visibility*
- *Cost / Risk Reduction Initiatives*
- *Managing/Executing to cost targets*
- *Collaboration / Cross-functional Teams*

During EXECUTION phase

* Performance ~ Utility ~ Value

** Cost As an Independent Variable (CAIV), Design to Cost (DTC)

“Affordability is not only an engineering problem; it is also a policy and management problem.”¹

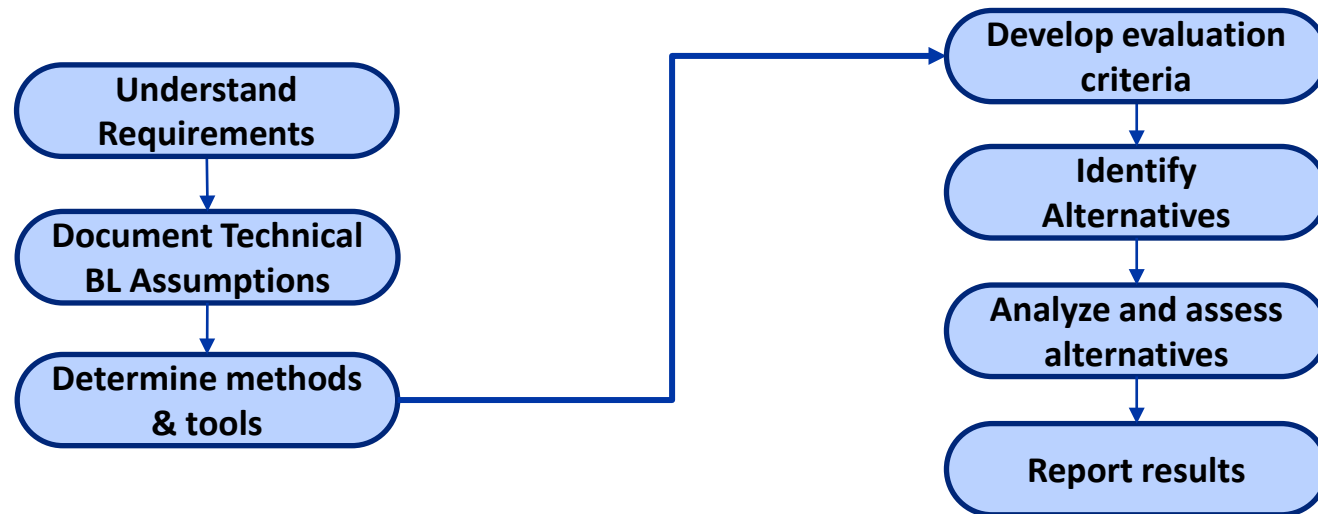
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Affordability from a Systems' Engineering Perspective

Affordability Process (from a Systems Engineering Perspective)

- Start with a Generic Trade Study Process

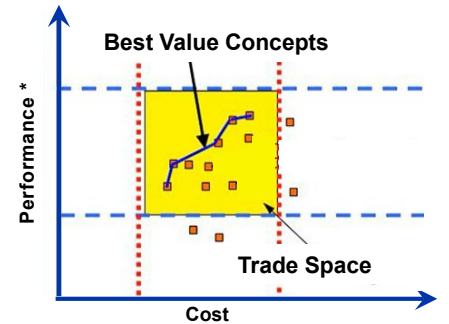


BL = Baseline

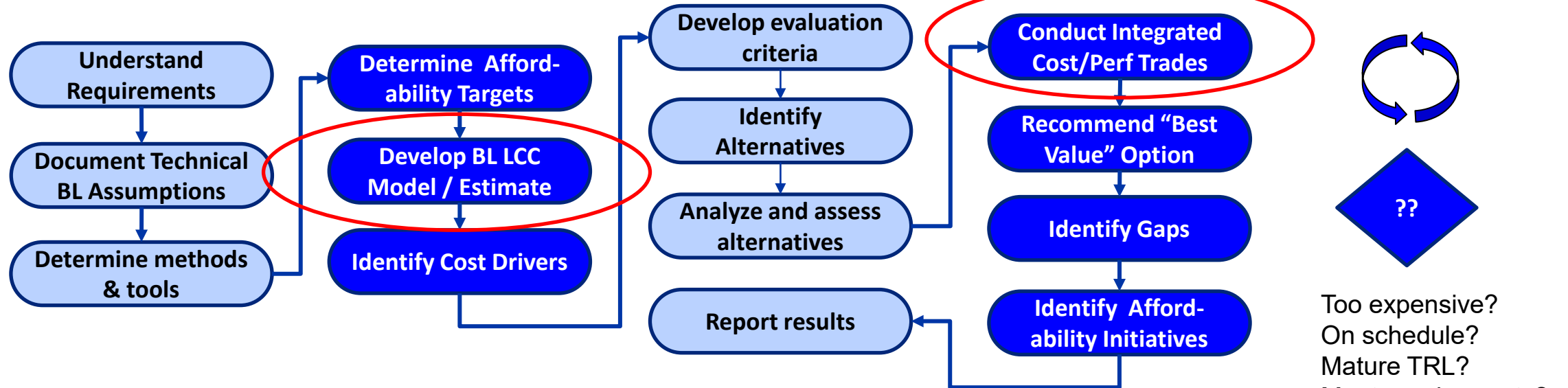
Affordability Analysis is part of Systems Engineering Trade Studies

Affordability Process (from a Systems Engineering Perspective)

- Start with a Generic Trade Study Process
- Add in the Affordability Analysis steps



Generic *Affordability* Trade Study Process



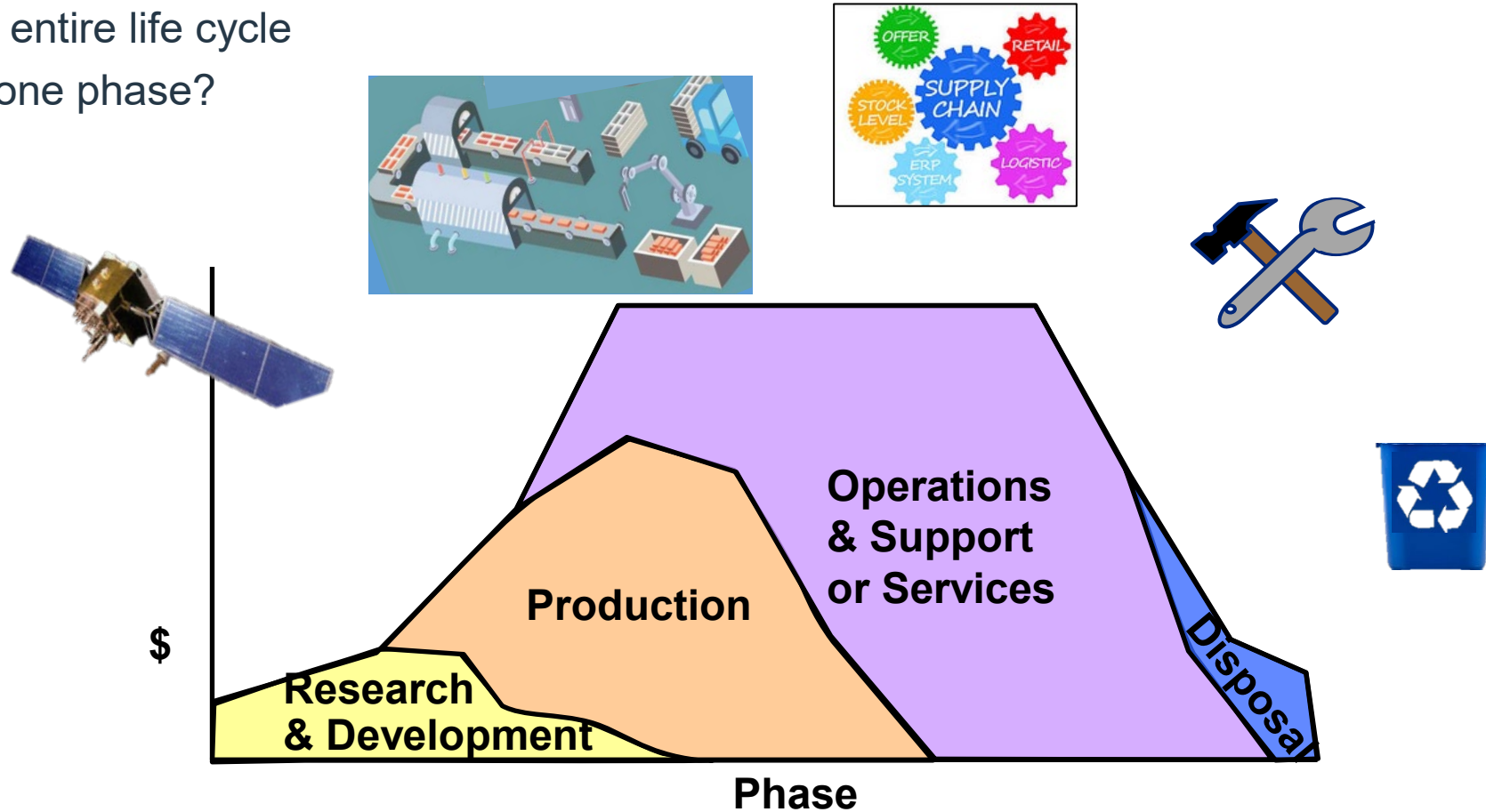
BL = Baseline
LCC = Life Cycle Costs
TRL = Technology Readiness Level

Too expensive?
On schedule?
Mature TRL?
Meet requirements?
Qualified Suppliers?
...

Generic Affordability Trade Study Process

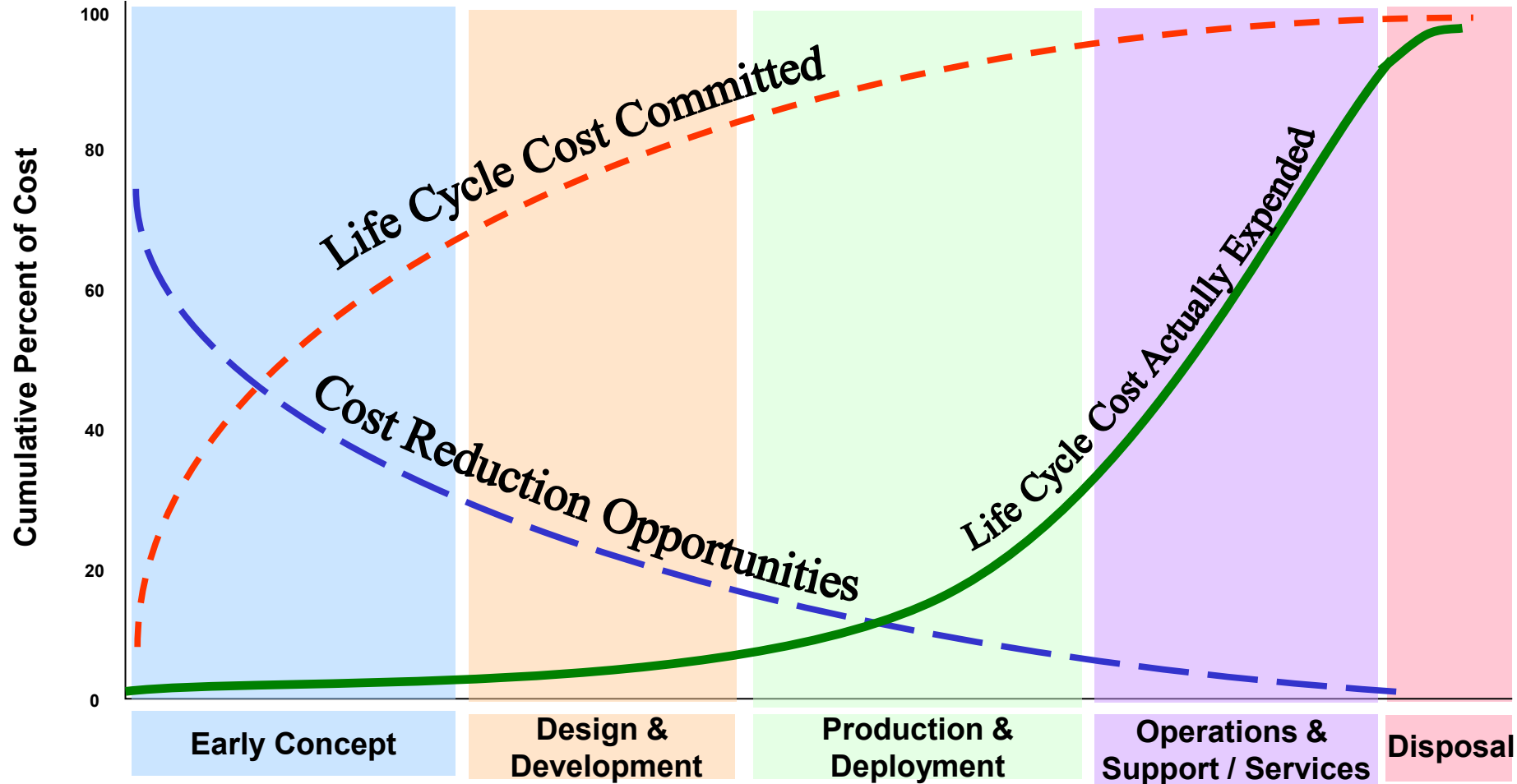
Typical Cost Per Life Cycle Phase

- Life Cycle Cost Modeling
 - Analyzing impacts of decisions on cost
 - Across the entire life cycle
 - Limited to one phase?



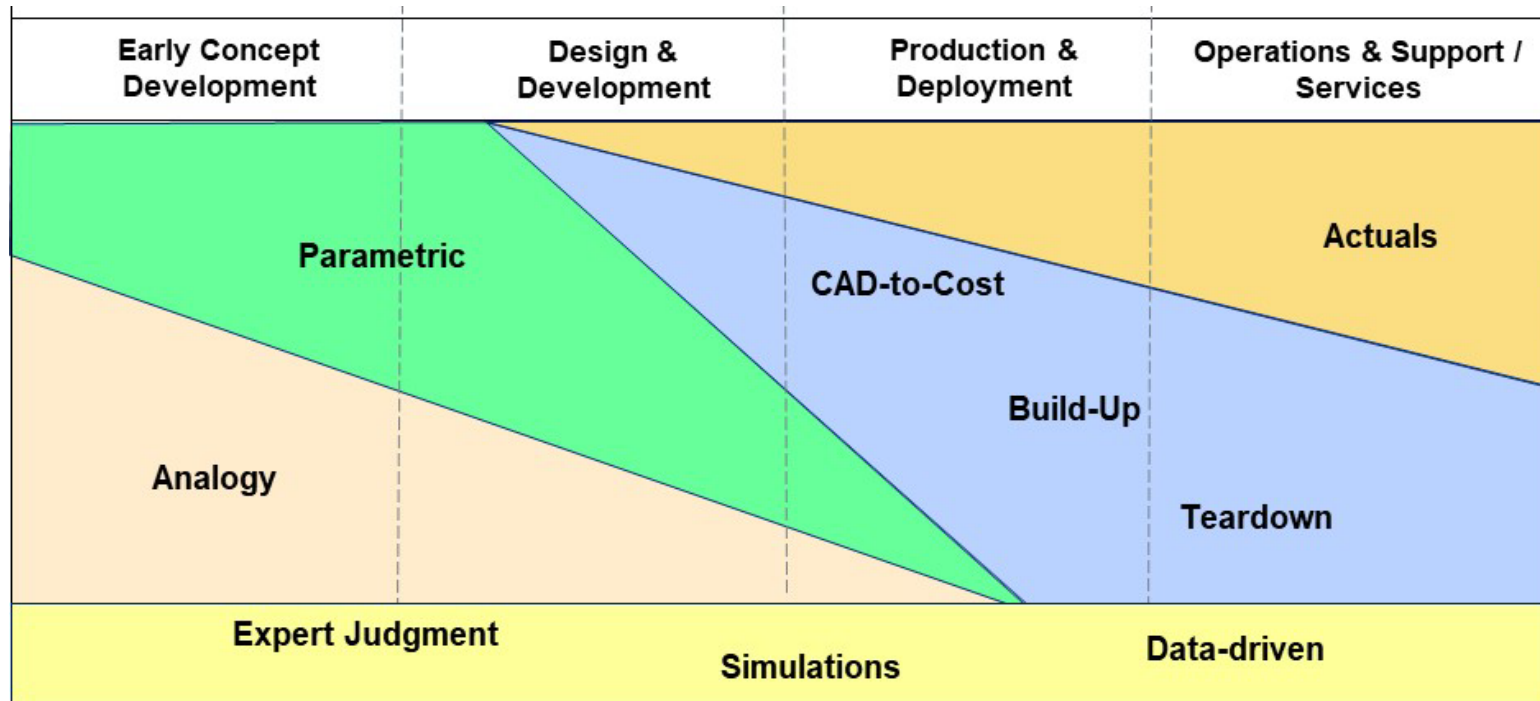
Consider Design Impacts on the Entire Life Cycle

Life Cycle Cost Impact



Early phases provide largest opportunities to reduce Life Cycle Costs

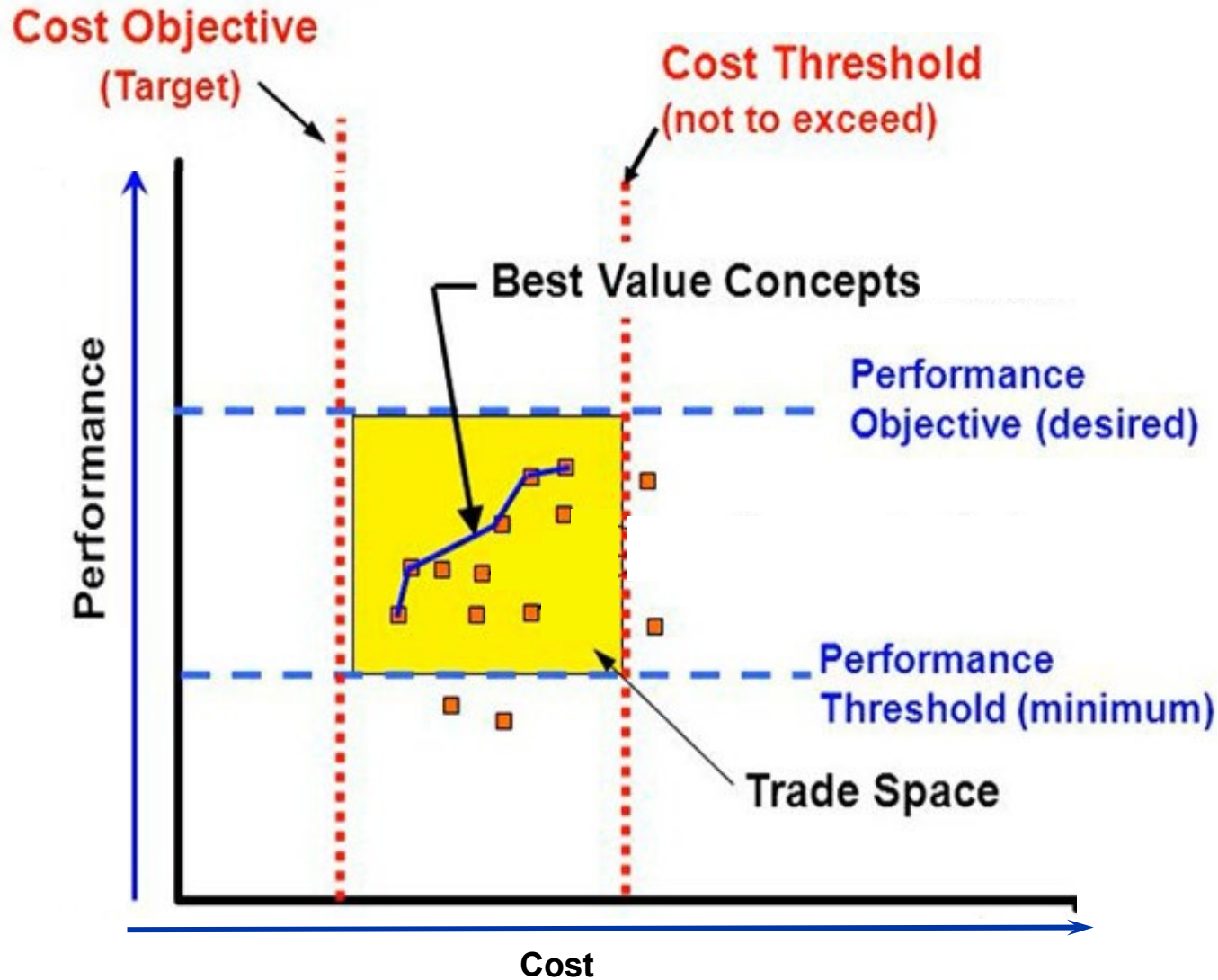
Life Cycle Cost Estimating Methods



Scope range from Entire Platform to Detailed Components

Recommended LCC Modeling Methods depend upon the life cycle phase and scope

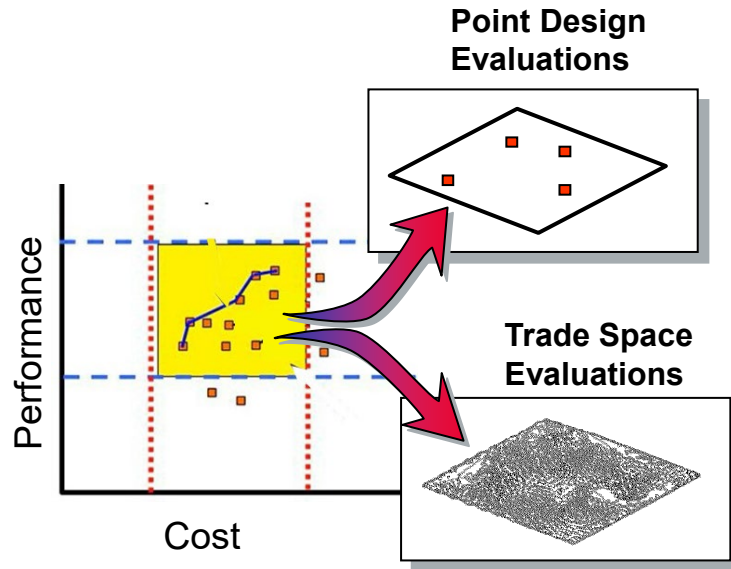
Affordability Trade Space



- Performance can be “defined” in many ways
 - Physical Attributes
 - weight, volume, material, ...
 - Functional Capabilities
 - Platform range, speed, ...
 - Payload sensor resolution, # passengers, ...
 - Producibility Measures
 - Manufacturing rate, utilization, safety, ...
 - Operational Factors
 - Reliability, repair-ability, maintainability, ...
 - Support or Services
 - Availability, spares, ...
 - Plus more

The Cost-Performance Trade Space is multi-dimensional

Affordability Trade Studies and Analyses



Discrete Trade

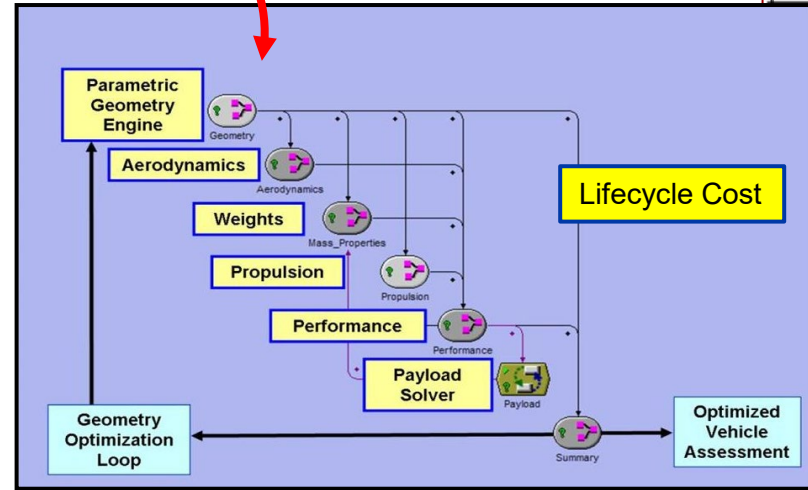
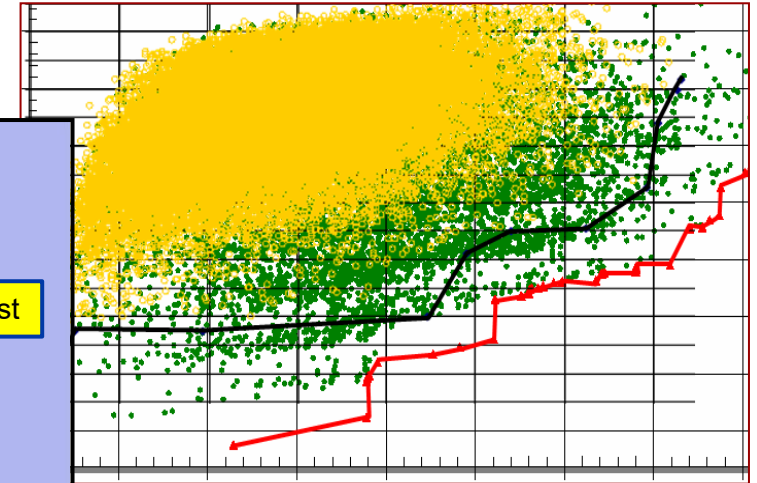
Optimization

Airplane Conceptual Design Trade Study

Baseline design : an "Aluminum Structure"
 Alternate design: a "50% Composite Structure"

- Weight reduced by ~20% (per 787 public data)

Wing	Case 1	Case 2
Complexity Inputs	Aluminum (100%)	Composites (50%)
Construction	Sheet Metal	Laminated Construction
Function	Significant Dynamic Forces	Structural frames
Weight (lbs)	45,000	36,000
Primary Material	Aluminum Alloys	Composite Laminate
Number of Parts	1000	1000
Machinability Index	120	18
Machin. Idx Material	Aluminum Alloys - 7075	Laminated Composites
Complexity factor	6.37	6.98
AUPC \$M	12	17



Modeling, Simulation, & Analysis enhances Affordability Trade Studies

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Affordability across the Life Cycle

Affordability Analysis Examples per Phase



T-7A



Airplane Development

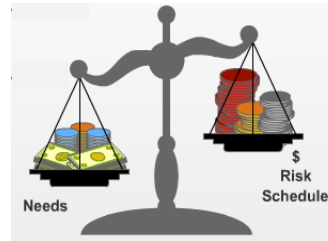
Early Concept

Design & Development

Production & Deployment

Operations & Support

GPS



Apache Attack Helicopter



My Affordability Experience

Boeing T-7A Advanced Pilot Training



Purpose Built – Aircraft

- Designed for AETC
- Advanced cockpit
- Stadium seating
- Fighter-like performance
- Safe, stable, fly-by-wire controls

AETC = Air Education & Training Command



Purpose Built – Ground Based Training

- Highly immersive training
- Offload skill development
- Complete advanced training solution
- Embedded training



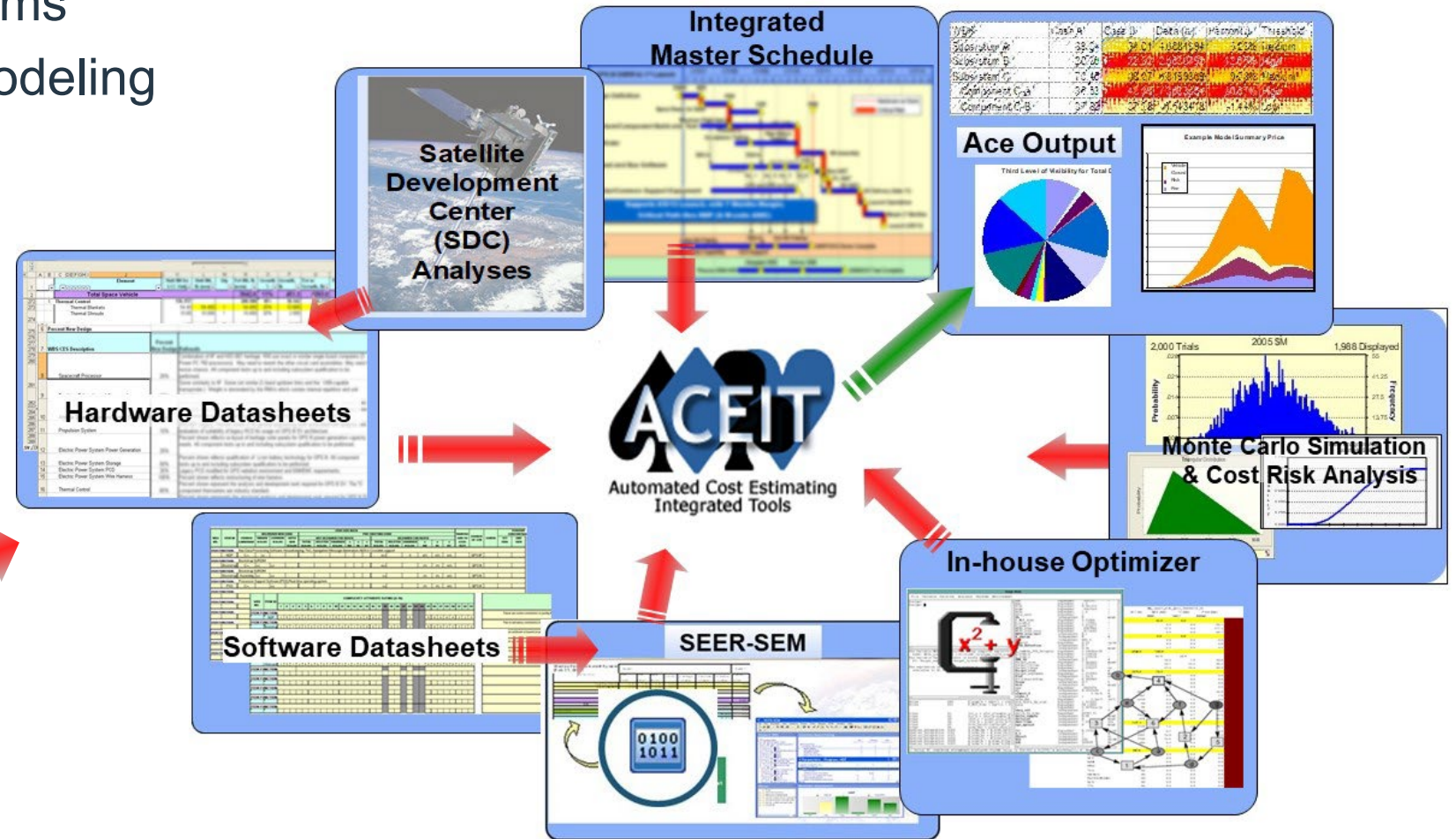
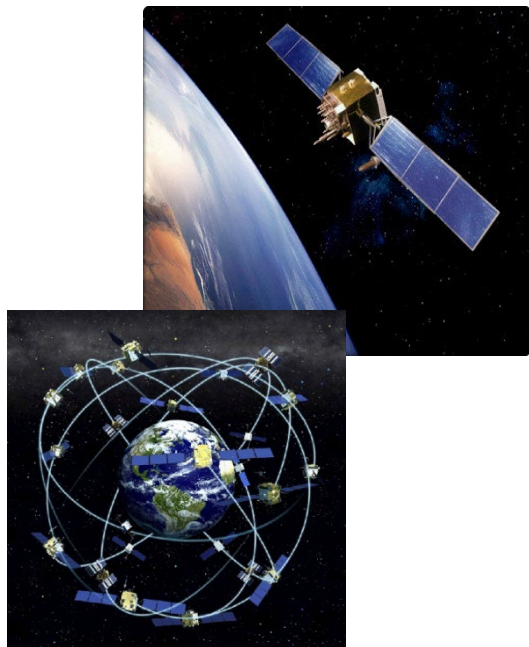
Purpose Built – Support

- Designed for the maintainer
- High wings
- Easy reach access panels
- Fewer / common fasteners
- Modular seat maintenance
- Easy seat changes
- Quick engine changes

Flexible for Future Growth

GPS – Global Positioning System

- Space and Ground Systems
- Detailed life cycle cost modeling
- Cost Risk Analyses
- Trade Studies

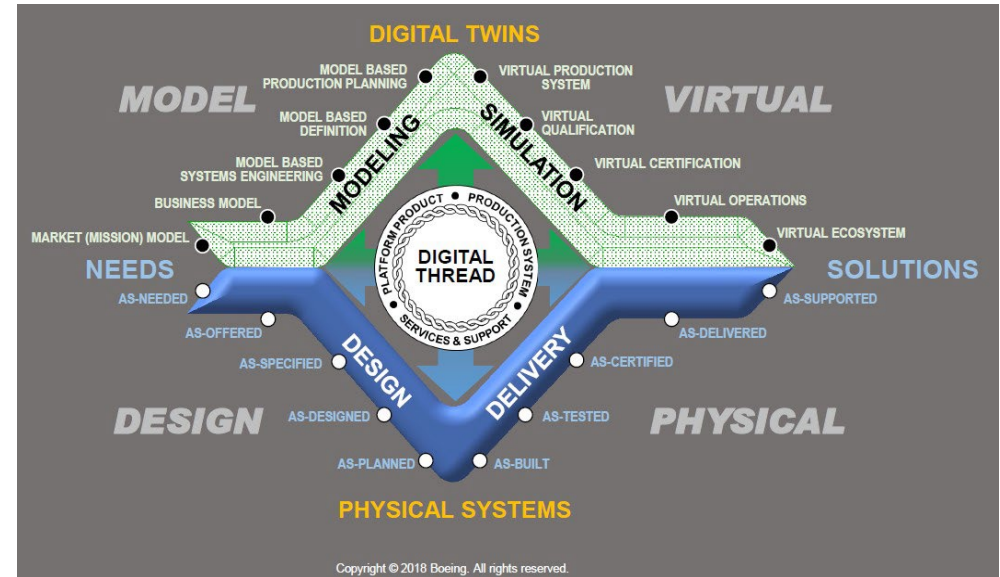
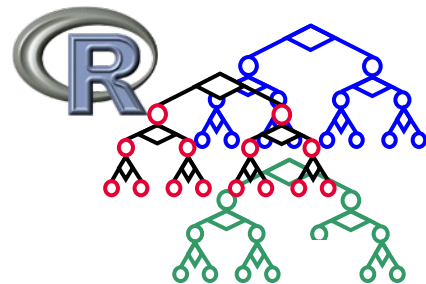


Baseline LCC Model imperative to conduct cost-performance trades

Airplane Development

- Affordability Analysis Integrated into the Model-based Engineering (MBE) Environment
 - To inform design decisions of affordability impacts
 - Early on and in a timely manner
 - And in a connected, integrated environment

- Machine Learning Methods for Logistics Analysis
 - Random Forest Prediction to predict freight costs
 - to determine best locations for manufacturing



Focusing on the Overall Best Value (and the Bigger Picture)

Apache Attack Helicopter – AH-64

- From the early 80s
 - AH-64A through the AH-64E v6
- More than 2000 produced
- Over 1200 in operation today
 - In ~15 countries
- Affordability Trades for Block Upgrades & Spares
 - Assembly / Part level
 - Manufacturing efficiencies
 - Reliability / Maintainability / Safety
 - Supplier Sourcing & Efficiencies
 - “Optimal” Cost Modeling & Analyses
 - Bottom-up & Top-down methods
 - Teardown analysis



AH-64 APACHE

The world's most advanced, proven attack helicopter for the U.S. Army and a growing number of international defense forces

Affordability Trades and Methods depend upon the objective

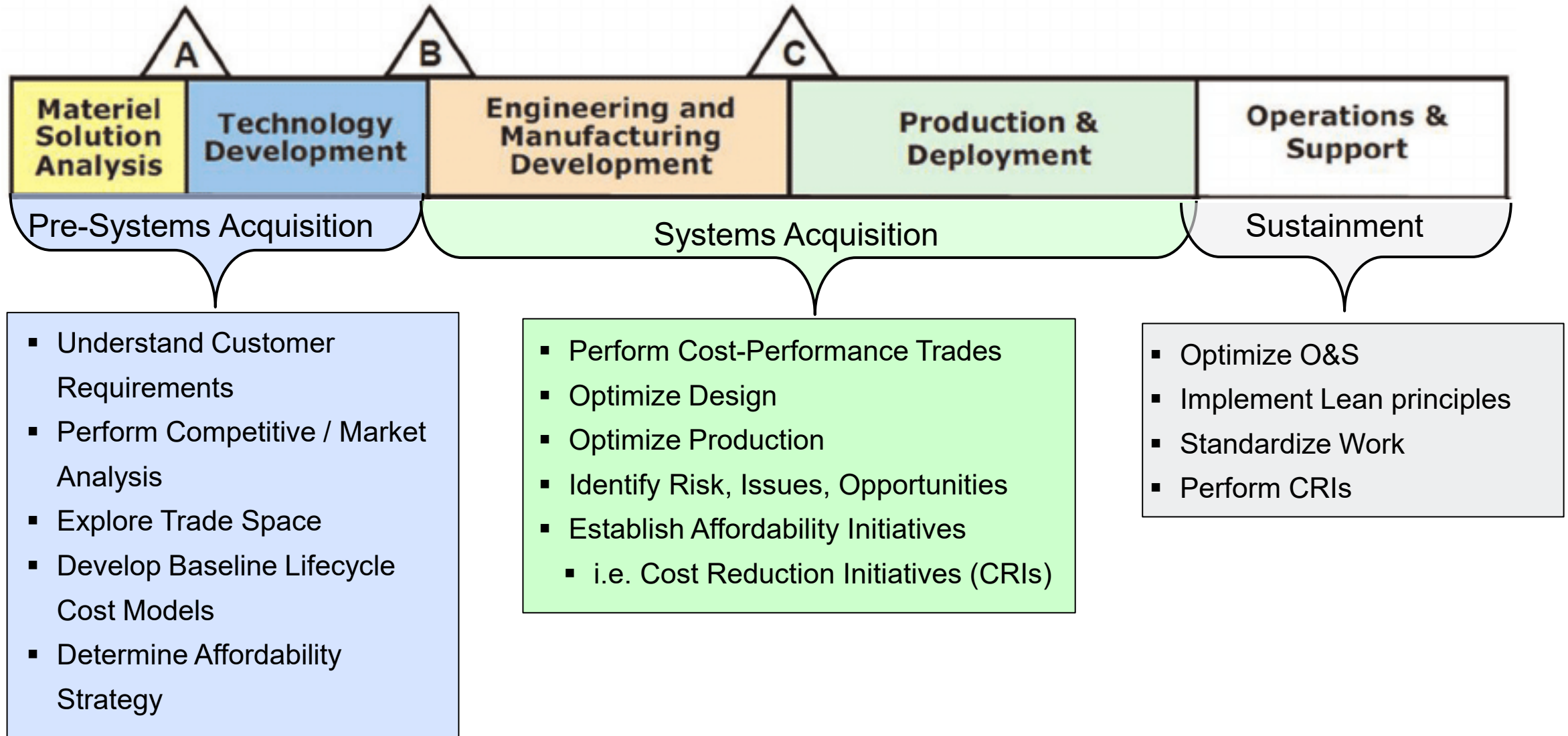
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What DOES Affordability mean?

How to Promote the Concept of Affordability

(Example)

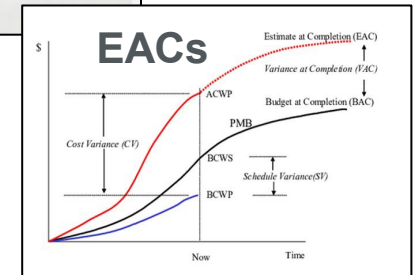
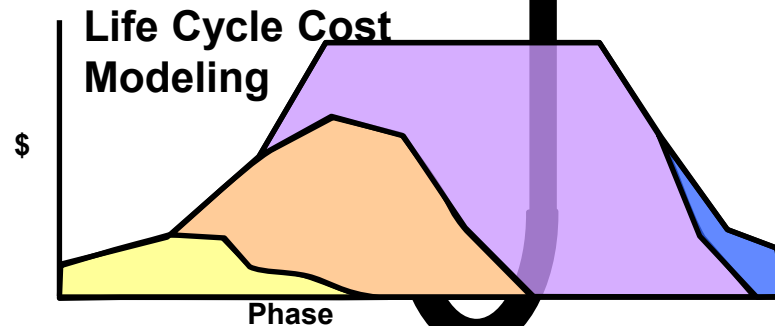
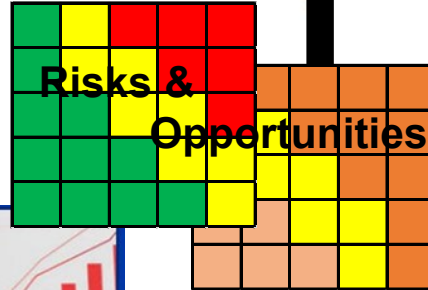
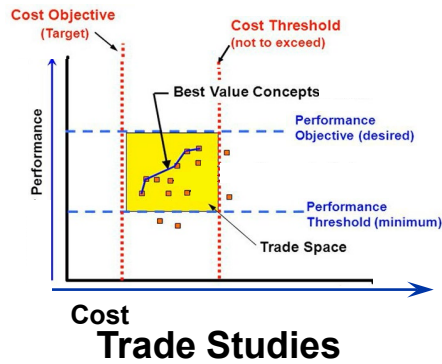


Describe Affordability Efforts Across the Life Cycle

Affordability Umbrella

(Example)

AFFORDABILITY



Describe Affordability as an Umbrella of activities – all of which contribute to Affordable Products

Wrap up

- **Affordability** means different things to different people
 - depending upon their employer, organization, function, background, ...
- Affordability Analysis can vary
 - depending upon phase of life cycle, methods, and objective

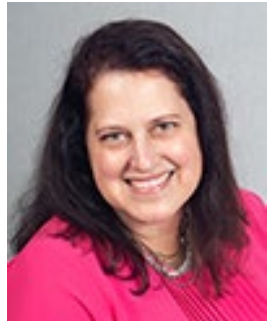
- Challenge for the Affordability Community
 - We all use the same terms but don't necessarily mean the same things
 - There are many nuances as evidenced by the plethora of definitions
 - If we can't decide on common definition
 - Make sure others understand what YOU mean by Affordability
 - And how it fits in with a broader perspective

Define what YOU mean by the term "Affordability"

Authors



Karen Mourikas is a Technical Fellow at the Boeing Company in Systems/Operations Analysis. Her current work focuses on integrating Affordability Analysis into Multi-disciplinary Design, Analysis, and Optimization (MDAO) and Model-based Engineering (MBE) environments, enabling integrated cost-performance trade studies early in a product's life cycle. Previous work includes Machine Learning for Cost Analyses, Product Teardown, and Operator-in-the-loop (OITL) Experimentation. Karen has MS degrees from USC in Applied Math and in Operations Research Engineering, and was the recipient of ICEAA's 2018 Technical Achievement of the Year award.



Denise Nelson currently leads the Boeing Defense Systems (BDS) Software Estimating processes and supporting tool set, which includes defining and collecting standard software metrics across BDS programs. Prior to her current position, Denise was a Systems Engineer specializing in Affordability trades, lifecycle cost estimates and parametric modeling, supporting various government and space customers. Ms. Nelson graduated from California Polytechnic University Pomona with a BS in Statistics and a MS in Pure Mathematics and was the recipient of ICEAA's 2021 Educator of the Year award.



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