

*Module J*

**Trade Study Process**

# Trade Study Objectives

- Support the decision needs of the system engineering process
- Evaluate alternatives (requirements, functions, configurations)
- Integrate and balance all considerations (cost, performance, producibility, testability, compatibility, supportability, etc)
- Develop and refine a system concept
- Determines if additional analysis, synthesis, or trade-off studies are required to make a selection

***Trade studies support selection of the best or most balanced solution***

# Purposes of Trade Study

- Trade studies - General
  - Identify and execute trade-offs among requirements, design, schedule, and cost
  - Support decision needs of system engineering process
  - Level of study commensurate with cost, schedule, performance, and risk impact
- Requirements analysis trade studies
  - Establish alternative performance and functional requirements
  - Resolve conflicts between requirements
- Functional analysis/allocation trade studies
  - Support functional analysis and allocation
  - Determine preferred set of requirements for function interface
  - Determine requirements for lower-level functions
  - Evaluate alternative architectures
- Synthesis trade studies
  - Establish system/CI configurations
  - Assist in selecting system concepts and design
  - Select HW/SW, make or buy, examined proposal changes, etc.
- System/cost effectiveness analysis
  - Develop MOEs hierarchy
  - Identify critical MOEs as TPMs

# Trade Study Guidelines

- Boeing Systems Engineering Manual
  - Disciplined process
  - Fair and consistent evaluations
  - All affected aspects of program participate
  - Trade study leader to help focus and coordinate
- DSMC Systems Engineering Fundamentals
  - Formal decision analysis method
  - Solve complex problems with more than one selection criterion
  - Provide documented decision rationale



**Best  
balanced  
solution**



**Integrate and  
balance all  
requirements**

# Value of Trade Study Process

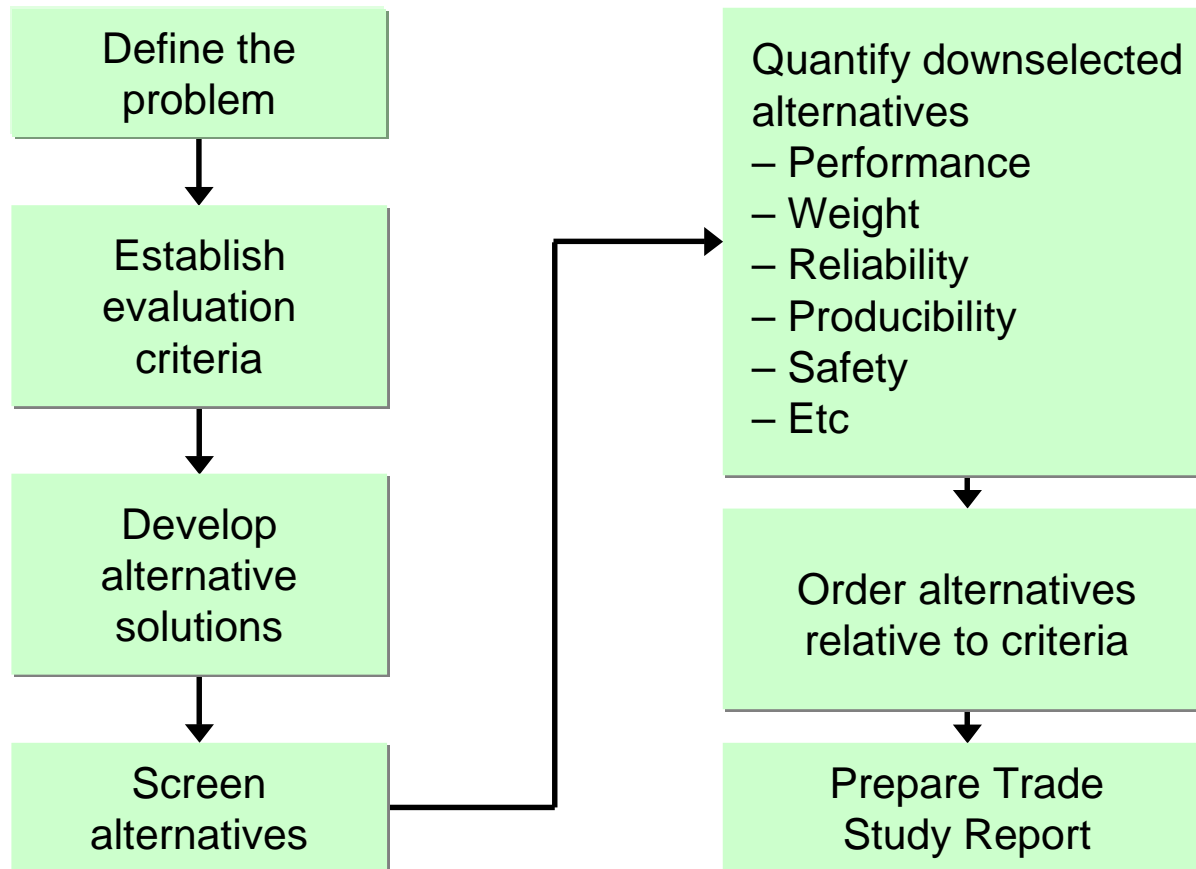
- Systemization of thought
- Clarification of options, problem structure, and available trade-offs
- Improved communication of ideas and professional judgement within the organization
- Improved communication of rationale for action to others outside the organization
- Confidence that all available information has been accounted for in a decision

# Trade Study Functions in Each Acquisition Phase

Acquisition phase	Trade study emphasis
Pre-Concept Exploration	<ul style="list-style-type: none"><li>• Compare alternative sets of requirements to see how they meet general customer needs</li></ul>
Concept Exploration and Definition	<ul style="list-style-type: none"><li>• Compare technologies and approaches</li><li>• Evaluate concepts for meeting mission needs</li><li>• Select alternate system configurations</li></ul>
Program Definition & Risk Reduction	<ul style="list-style-type: none"><li>• Select preferred technologies</li><li>• Reduce alternatives to a testable number</li></ul>
Engineering & Manufacturing Development	<ul style="list-style-type: none"><li>• Select component/part designs</li><li>• Select testing methods</li><li>• Select support processes</li></ul>
Production & Deployment	<ul style="list-style-type: none"><li>• Examine advantages of proposed design changes</li><li>• Evaluate new mission requirements</li><li>• Assess incorporation of new technologies</li></ul>

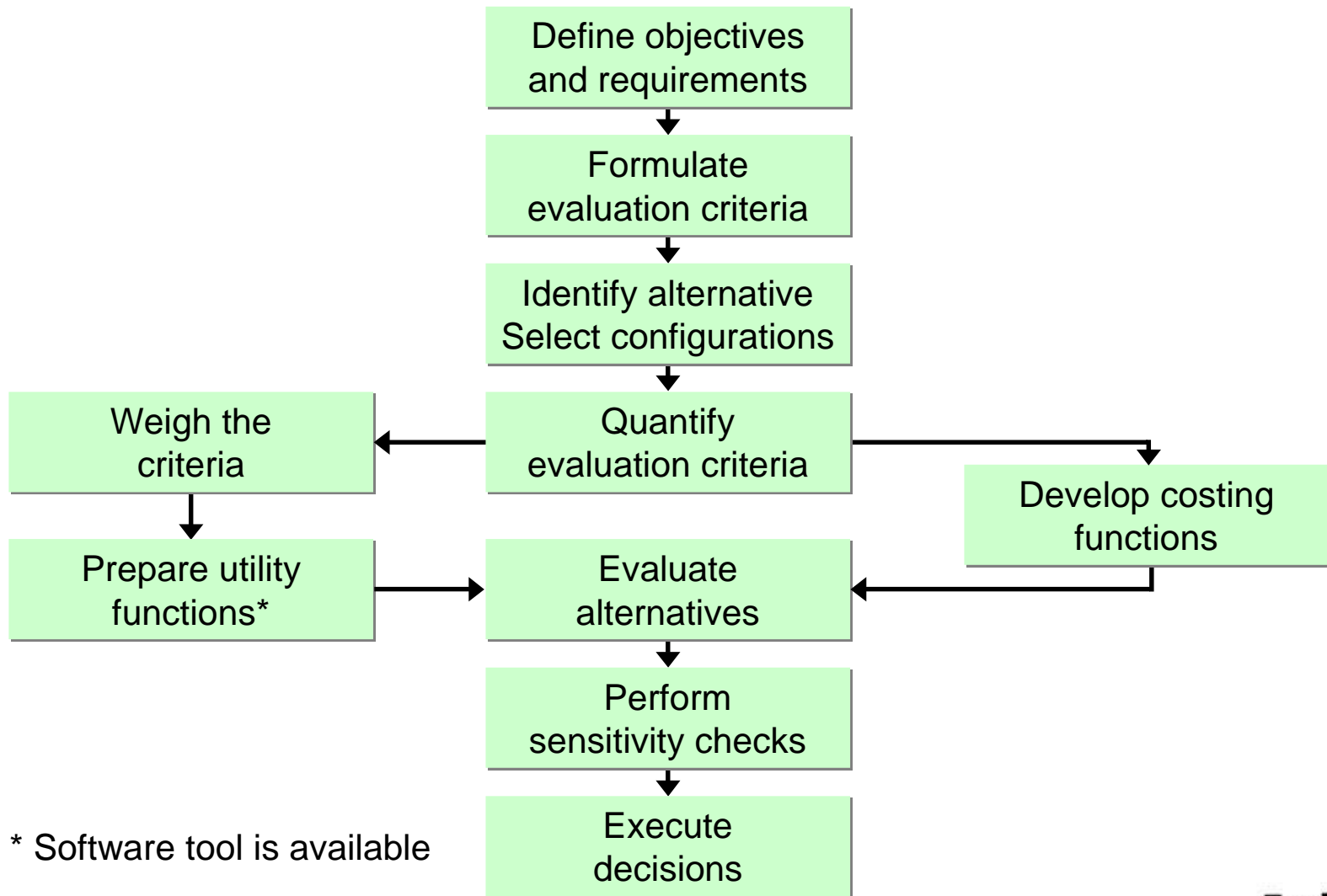
***Trade study emphasis areas change throughout the acquisition process***

# Trade Study Process Key Elements



***Scope of application of any one step will vary depending on a program's current acquisition phase***

# Trade Study Process Flow







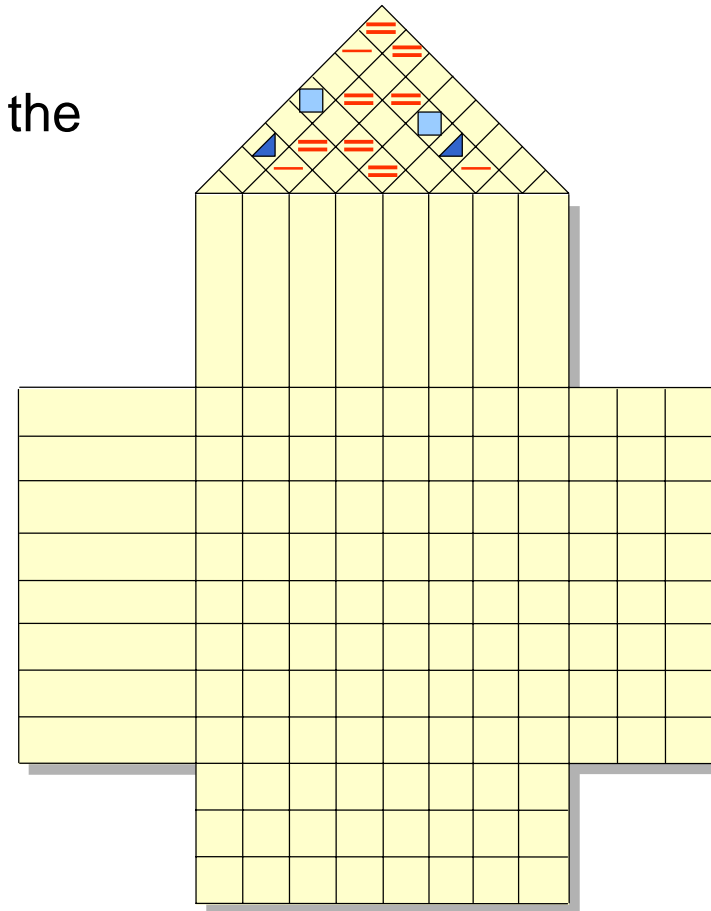
\* Software tool is available



# QFD Identifies and Supports Trade Studies

- The correlation matrix identifies the relationship between the HOWs

Correlation Matrix HOW vs HOW	
	Strong positive
	Positive
	No relation
	Negative
	Strong negative



***IPTs identify the conflicts or synergies between each of the HOWs in the roof of the house of quality***

# Establishment of Effective Evaluation Criteria

- Must reflect all technical requirements
- Must reflect business objectives
- Must be closely linked to TPMs
- Effective screening/evaluation criteria must:
  - Differentiate meaningfully between alternatives without bias
  - Relate directly to the purpose of the trade study, i.e., they are requirements based
  - Be broadly based to ensure coverage of all decision factors
  - Be independent of each other to the greatest degree possible
  - Be universally understood by all trade study participants

# Example of Evaluation Criteria

- Life Cycle Cost
- Supportability
- Performance

## Formulate

- Weight
- Power
- Accuracy
- Size
- Cost
- Schedule
- Risk
- Testability
- Supportability
- Complexity
- Reliability
- Maintainability
- Safety

## Quantify

- Weight = 565 lb
- Power = 32 kW
- Accuracy = 2 m
- Size = 2 ft<sup>3</sup>
- Cost = \$1.2M
- Schedule = 3.5 yr
- Risk = Medium
- Testability = 99% FD/FI
- Supportability = 3 tools
- Complexity = Medium
- Reliability = 500 hr MTBF
- Maintainability = 0.5 MMH/FH
- Safety = 99.999%

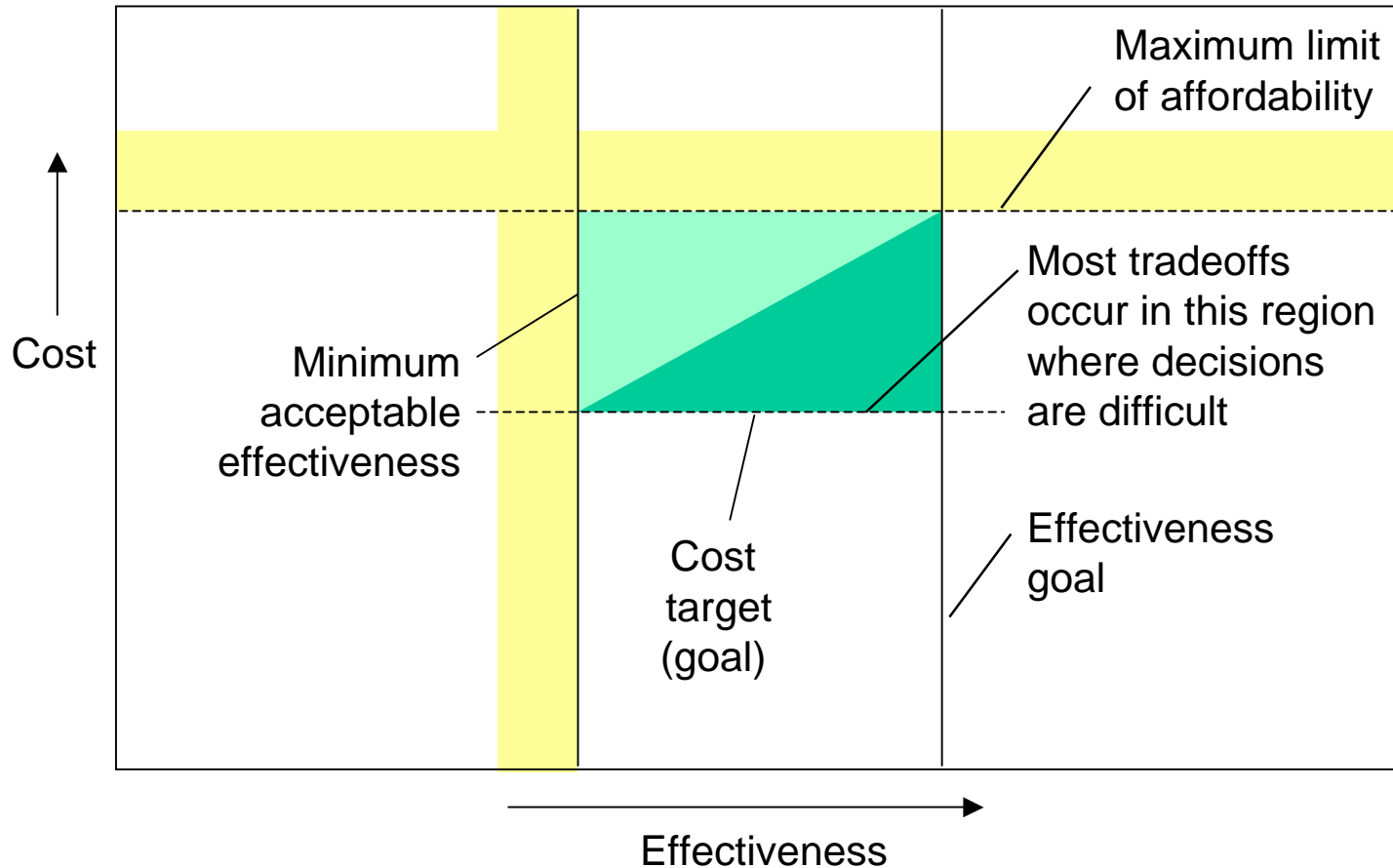
# Sources of Design Trade Study Decision Criteria

Business Objectives	<ul style="list-style-type: none"> <li>• Program management business plan</li> </ul>
Mission Area Analysis	<ul style="list-style-type: none"> <li>• Service mission roles</li> <li>• Mission area plans (MAPS)</li> <li>• Voice of the customer</li> </ul>
Concept Exploration	<ul style="list-style-type: none"> <li>• Justification for major system new start -Mission Need Statement (MNS)</li> <li>• System performance requirements</li> <li>• Acquisition decision memorandum</li> </ul>
Program Definition & Risk Reduction	<ul style="list-style-type: none"> <li>• Operational requirements Document (ORD)</li> <li>• System specification</li> <li>• Test and evaluation master plan</li> <li>• Technical Performance Measurements (TPMs)</li> <li>• Planning, programming, and budgeting system documentation</li> </ul>
Engineering & Manufacturing Development	<ul style="list-style-type: none"> <li>• Configuration Item Specifications (CIS)</li> <li>• Requirements Allocation Document (RADs)</li> <li>• TPMs</li> <li>• Integrated program Summary</li> <li>• Planning, programming, and budgeting system documentation</li> </ul>
Production & Deployment	<ul style="list-style-type: none"> <li>• Existing technical manuals</li> <li>• Logistics plan</li> <li>• Production plan</li> <li>• Fielding plan</li> </ul>

# Identification of Alternatives

- Reflect widest range of different solutions
- Sources include:
  - Predetermined, competitive bids
  - Developed
    - Customer
    - Synthesis
    - Brainstorming, all disciplines
    - QFD
    - Experience
    - Suppliers

# Identification of Alternatives



# Screen Alternatives

- Eliminate alternatives which do not appear to meet requirements (go/no-go tests or killer trades)
- Eliminate alternatives with low probability of successful implementation
- Eliminate alternatives which are expected to exceed cost and schedule constraints

# Example of Uncoupling and Killer Trades

- SOW Task:**
- Evaluate and select propulsion subsystem for long range conventional cruise missile
- System Req'ts:**
- Range 2,000 NM
  - Launcher-ship VLS, be compatible and maintain commonality
  - All other requirements held constant (e.g. lethality)

	Propulsion subsystem									
Type	Turbojet		Turbofan		Propfan		Rocket	Ramjet	Rocket	Scramjet
Speed	Subsonic						Supersonic		Hypersonic...	
Altitude	Low	High	Low	High	Low	High	High	High	High	High
Range, NM	1,200	1,600	1,600	2,000	2,100	2,600	500	800	200	300
Meets reqt	No	No	No	Yes	Yes	Yes	No	No	No	No

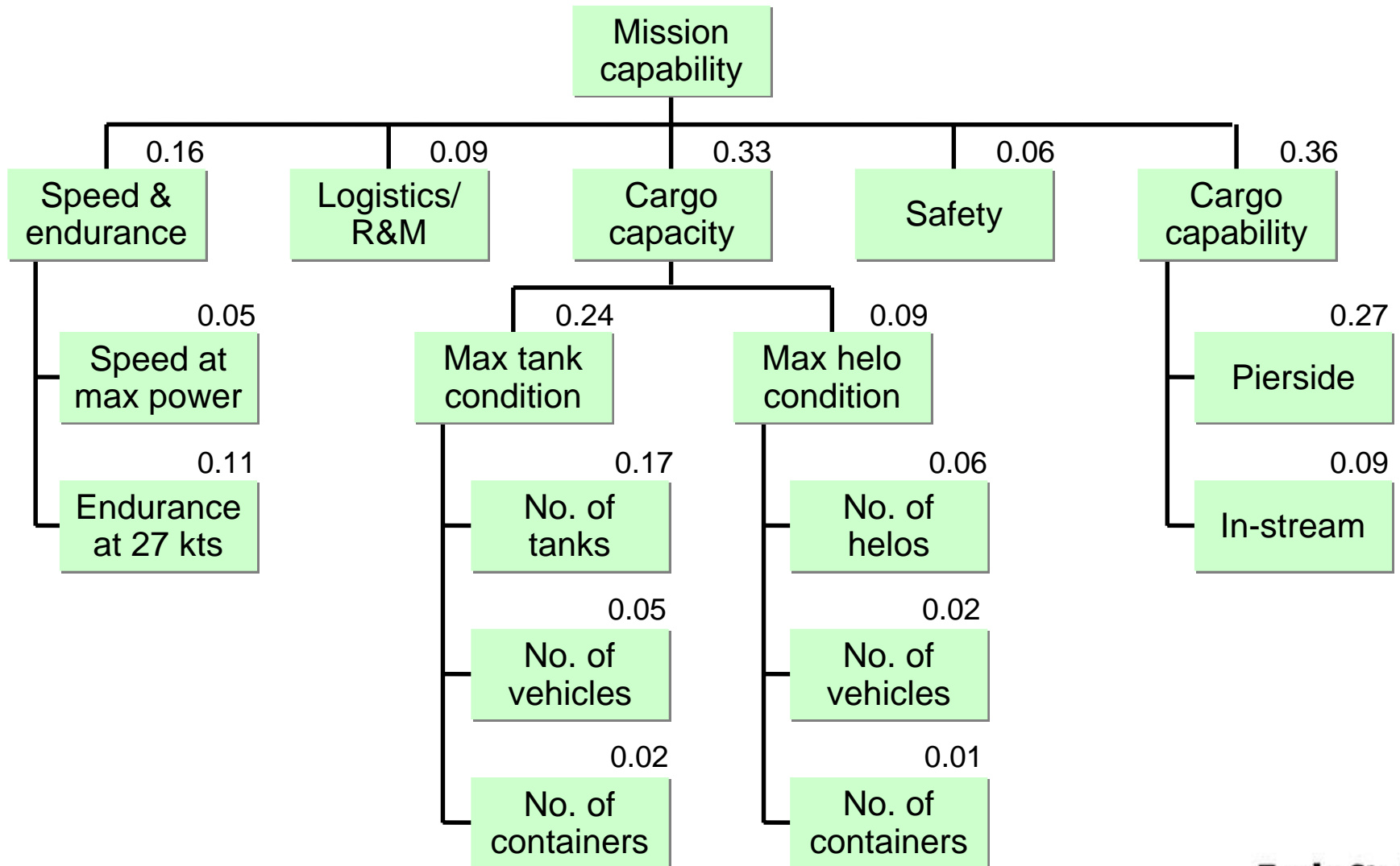
- Uncoupling allowed looking at propulsion subsystem only
- Killer trade reduced concepts from 10 down to 3 for more detailed analysis



# Quantify Downselected Alternatives

- Performance
- Weight
- Reliability
- Producibility
- Safety
- Affordability
- Schedule
- Risk
- Etc

# Sample Criteria Weighting



# Sample Prioritization Input Sheet

SL-7 CLASS CONVERSION TRADE-OFF STUDIES  
PRIORITIZATION SURVEY

WHAT IS YOUR OPINION AS TO WHICH MISSION  
CAPABILITY ATTRIBUTE IS MORE IMPORTANT  
TO MISSION SUCCESS?

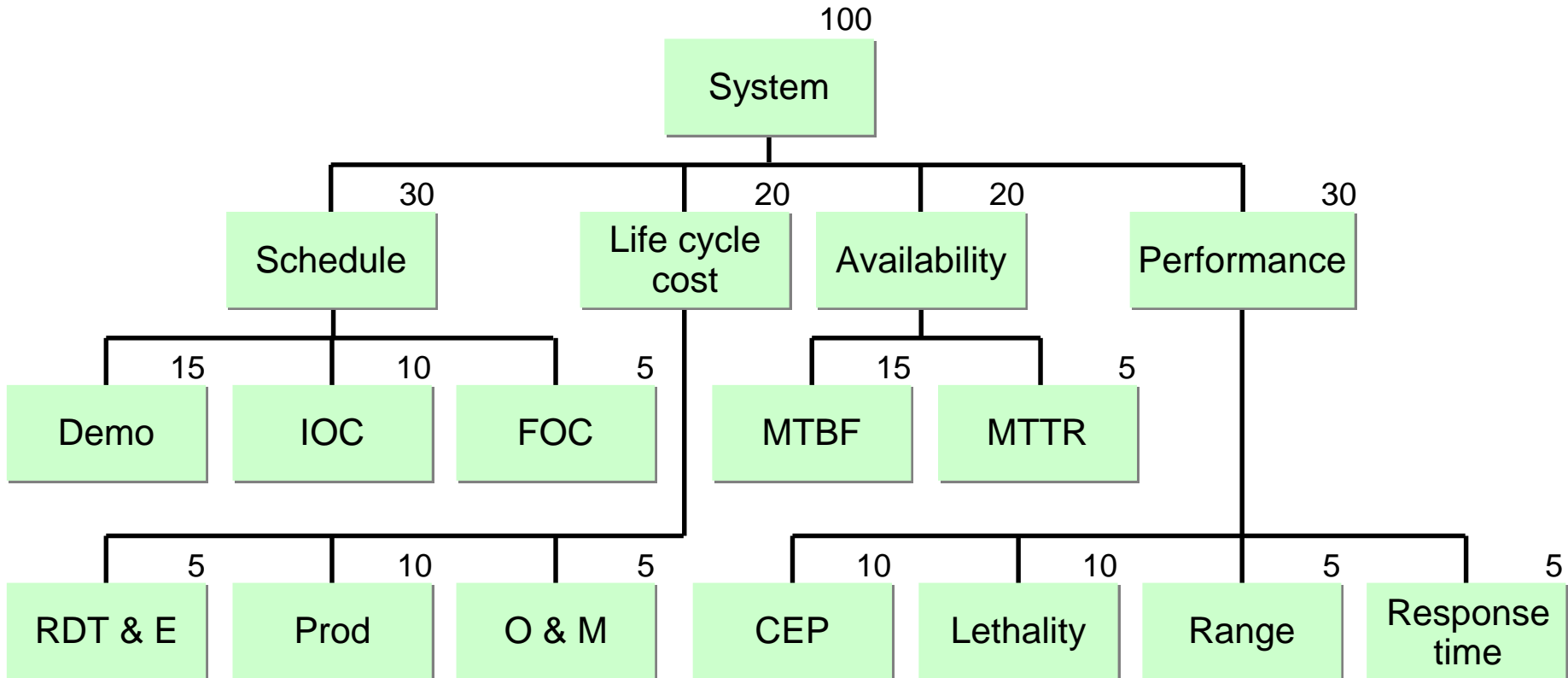
MISSION ATTRIBUTE

CARGO CAPACITY	9-8-7-6-5-4-3-2-1-2-3-4- <b>5</b> -6-7-8-9
CARGO CAPACITY	9-8-7-6- <b>5</b> -4-3-2-1-2-3-4-5-6-7-8-9
CARGO CAPACITY	9-8-7-6-5- <b>4</b> -3-2-1-2-3-4-5-6-7-8-9
CARGO CAPACITY	9-8-7-6-5- <b>4</b> -3-2-1-2-3-4-5-6-7-8-9
CARGO CAPABILITY	9-8-7- <b>6</b> -5-4-3-2-1-2-3-4-5-6-7-8-9
CARGO CAPABILITY	9-8-7- <b>6</b> -5-4-3-2-1-2-3-4-5-6-7-8-9
CARGO CAPABILITY	9- <b>8</b> -7-6-5-4-3-2-1-2-3-4-5-6-7-8-9
SPEED & ENDURANCE	9-8- <b>7</b> -6-5-4-3-2-1-2-3-4-5-6-7-8-9
SPEED & ENDURANCE	9- <b>8</b> -7-6-5-4-3-2-1-2-3-4-5-6-7-8-9
LOGISTICS/R&M	9-8-7-6-5-4-3-2- <b>1</b> -2-3-4-5-6-7-8-9

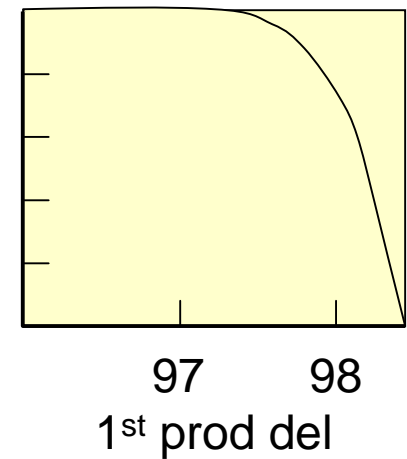
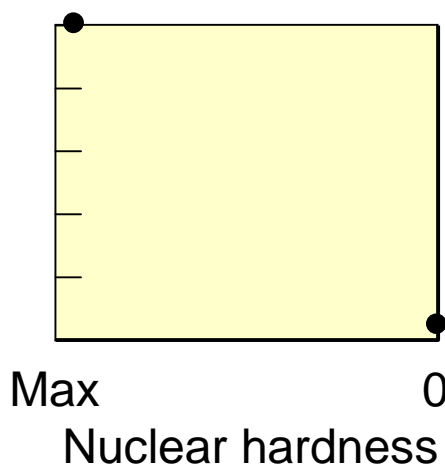
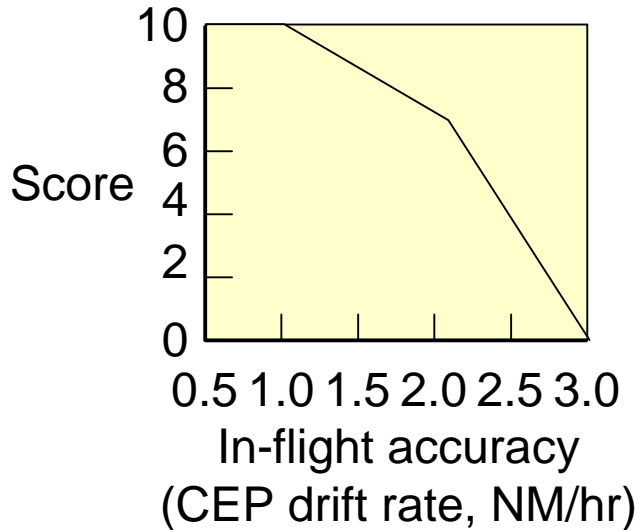
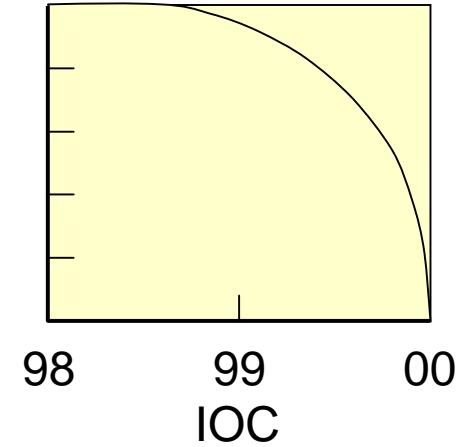
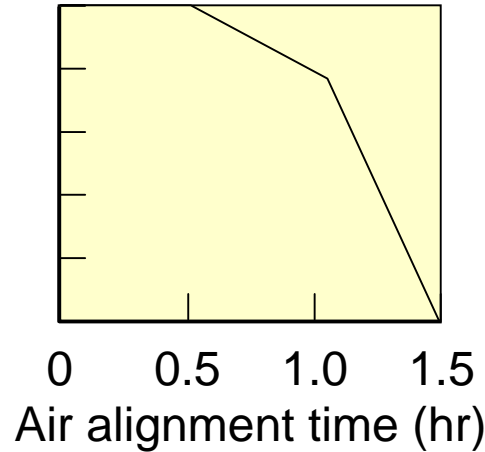
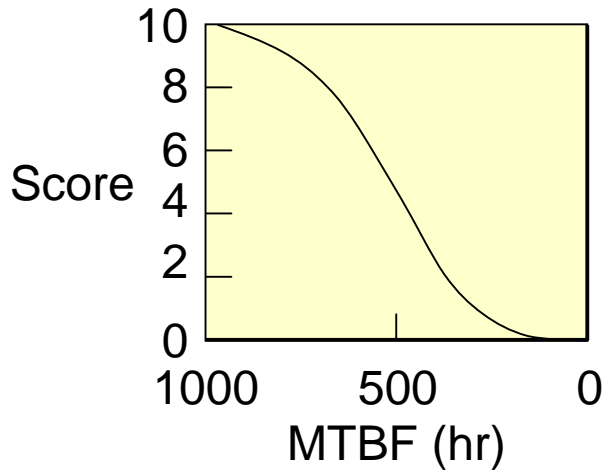
MISSION ATTRIBUTE

CARGO CAPACITY
SPEED & ENDURANCE
LOGISTICS/R&M
SAFETY
SPEED & ENDURANCE
LOGISTICS/R&M
SAFETY
SPEED & ENDURANCE
SAFETY
SAFETY

# Sample Multi-Attribute System Effectiveness Model



# Sample Utility Curves



# Sample Weighted Summary Table

Criteria [weight]	Alternatives									
	Alternative 1		Alternative 2		Alternative 3		Alternative 4		Alternative 5	
	Score	Weighted score	Score	Weighted score	Score	Weighted score	Score	Weighted score	Score	Weighted score
A [15]	3.1-3.5	46.5-52.5	4.2-5.9	63.0-88.5	6.0-6.5	90.0-97.5	3.5-5.2	52.5-78.0	4.5-5.0	60.0-82.5
B [20]	3.9-4.6	78.0-92.0	7.8-8.2	156.0-164.0	8.9-9.2	178.0-184.0	6.4-6.9	128.0-138.0	7.6-8.1	152.0-162.0
C [10]	5.2-6.0	52.0-60.0	4.3-6.0	43.0-60.0	7.0-8.2	70.0-82.0	7.3-8.5	73.0-85.0	9.2-9.5	92.0-95.0
D [35]	9.0-9.5	315.0-332.5	7.0-7.3	245.0-255.5	8.5-9.0	297.5-315.0	9.7-9.9	339.5-346.5	6.7-7.2	234.5-252.0
E [20]	5.0-6.7	100.0-134.0	3.5-4.5	70.0-90.0	5.0-6.0	100.0-120.0	6.9-7.2	138.0-144.0	7.8-8.2	156.0-164.0
Total		591.5-671.0		577.0-658.0		735.5-798.5		731.0-791.5		694.5-755.5

# Trade Study Report

## Ref Boeing Systems Engineering Process Manual

1. Introduction
  - Problem description
  - Ground rules/assumptions
  - Constraints
2. Concepts
  - Range of options
  - Procedure used
  - Drawings/data sheets
3. Downselected alternatives
  - Screening/downselection process
  - Evaluation criteria
  - Weighting factors
  - Results of screening
4. Quantified technical impact
  - Detailed studies
  - Additional assumptions
  - Additional analysis
5. Conclusions and recommendations
  - Reasoning
  - Additional recommendations

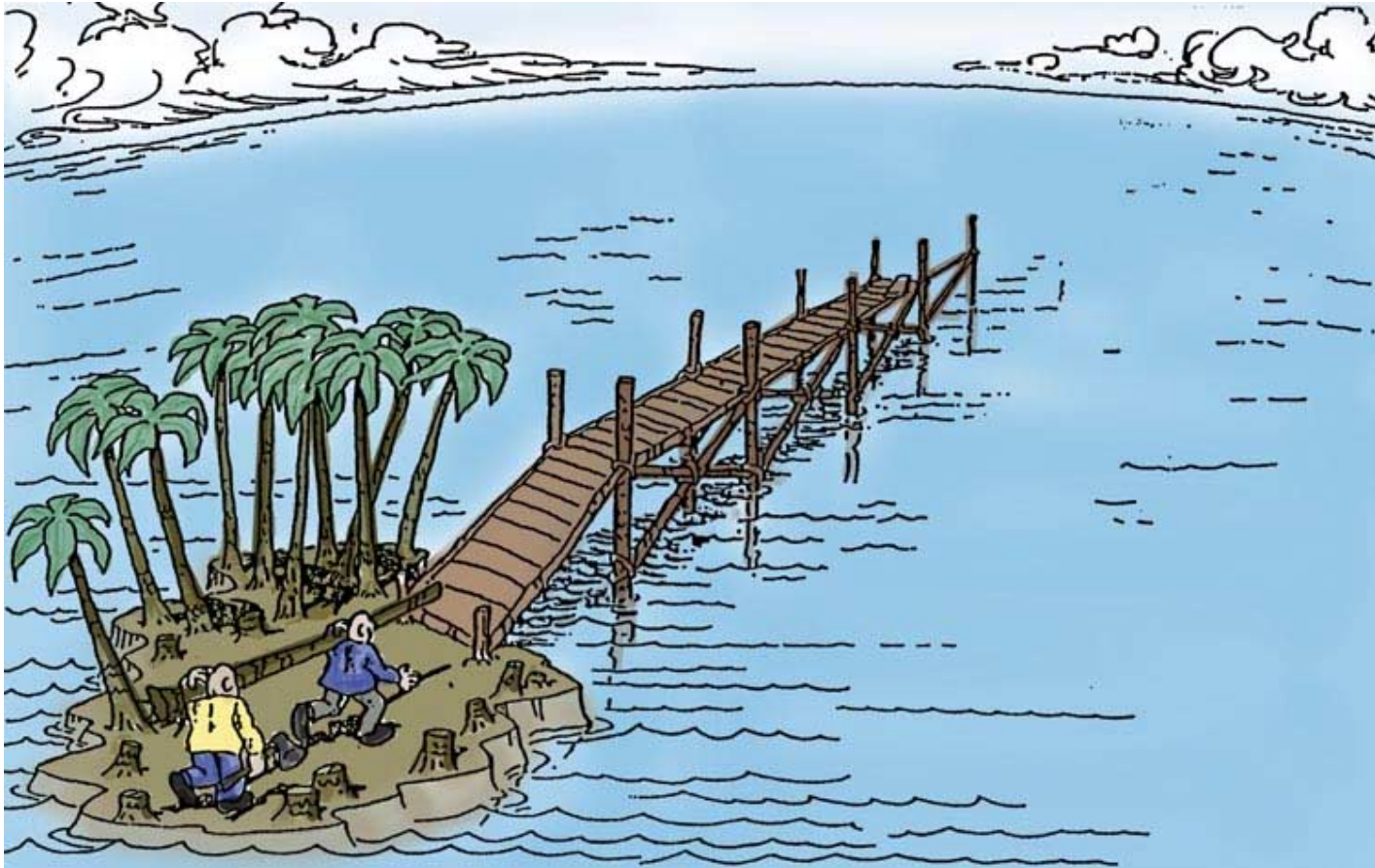
# Trade Study Product Characteristics

*In order to meet customer quality requirements, each Trade Study conducted within Product Definition is expected to be characterized by a consistent set of elements which include . . .*

- Clear problem statement
- Identification of requirements that must be achieved
- Ground rules and assumptions
- Decision criteria
- Resource requirements statement (source/man hrs reqd)
- Schedule to accomplish (proposed and actual)
- Potential solutions and screening matrix
- Comprehensive array of feasible alternatives
- Comparisons of alternatives using decision criteria
- Technical recommendation of trade study leader
- Documentation of decisions leading to recommendation



# Why Do Trade Studies?



*Have all the alternatives been considered?*

**Trade Study  
Process**

# The Name of the Game - Trade-Offs

