An Approach to Examining Technical Alternatives

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The Bait

- Systems engineering provides a method for examining alternatives. Mr. King will discuss the application of technological forecasting, engineering, ship design, cost analysis, and operations research analysis to examine alternative approaches to solving naval problems. We will show examples of integrated analysis.
The Switch

• Systems engineering provides a method for examining alternatives. Mr. King will discuss the fundamentals of systems engineering and the implications for technology and application of technological forecasting, engineering, ship design, cost analysis, and operations research analysis to examine alternative approaches to solving naval problems. He will show an example of integrated analysis. He will present current challenges.
Outline

• The Principles of Systems Engineering
  – Implications for Technology
• The Dimensions of Technology Selection
  – Some Methods of Technology Selection
    • Cost-Benefit Analysis
• The Role of Probability
• Risk
• Current Challenges
PRINCIPLES OF SYSTEMS ENGINEERING

• THE FUNDAMENTAL PRINCIPLE OF SYSTEMS ENGINEERING
  Maximize the Expected Value

• THE PRINCIPLE OF EVENTS OF LOW PRIORITY
  The fundamental missions of the system should not be jeopardized, nor its fundamental objectives significantly compromised, in order to accommodate events of low probability.

Systems Engineering Handbook
Robert E. Machol
McGraw-Hill
Principles (Cont’d)

• THE PRINCIPLE OF CENTRALIZATION
  Centralization of authority and decision-making, that is, the centralization of information as distinguished from material.

• THE PRINCIPLE OF SUBOPTIMIZATION
  The optimization of each subsystem independently will not, in general, lead to a system optimum and, more strongly, improvement of a particular subsystem may actually worsen the overall system.
Some Methods of Technology Selection
Why is Technology A Concern

• Cannot afford everything
  – Not everything in basic research can be applied
  – Not everything can be implemented

• Choices

• A Systems Engineering problem
  – Cannot view each thing independently

So, how do we decide?
The Big Lie

If you say something often enough, and with enough enthusiasm, it becomes fact
New York Floor

In the New York state legislature, who gets the floor?
In the New York state legislator, who gets the floor?

The one who yells the loudest.
Friends in High Places
Variants

- Pareto Analysis
- Pain Analysis
- Pair wise Comparisons
- etc
Strengths

• Organized
• Transparent
• Repeatable
• Sensitivity Analysis

What Is the Key Weakness?
Another Approach: Cost-Benefit Analysis
Design, Cost, and Effectiveness Impacts of Surface Combatant Topside Signature Reduction in Littoral Environments

JAMES H. KING, Naval Architect
Head, Signature Control Technology Department
and
DANIEL J. PLATT, Naval Architect
Systems Assessment & Engineering Department

Naval Surface Warfare Center, Carderock Division
Purpose

• Traditionally, goals based on threat weapon performance

• Go beyond:
  – Impact of signature control on combat system
  – Impact of signature control measures on ship design
  – Cost drivers

• Evaluate signature control in littoral warfare
Process

- **Signature Control Methods**
- **Signature Performance Prediction**
- **Ship Variants**
- **Specific Ship Impacts**
- **Concept Development**
- **Cost Analysis**
- **Operational Effectiveness Analysis**
- **Cost-Effectiveness Analysis**
- **Goals**
- **R&D Needs**
- **Baseline Ship**
- **Scenarios**
- **Threats**

**FORMULATION**

**COMPUTATION**

**DETERMINATION**
## Ship Variants

### Signature Reduction Alternatives

<table>
<thead>
<tr>
<th></th>
<th>0 (Baseline)</th>
<th>1 (separate RCS / IR)</th>
<th>2 (limited integration)</th>
<th>3 (integrated RCS / IR)</th>
<th>4 (aggressive reduction)</th>
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<tbody>
<tr>
<td><strong>A</strong> (Baseline)</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td><strong>B</strong> (passive cueing)</td>
<td></td>
<td>✓</td>
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<tr>
<td><strong>C</strong> (no area AAW)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td><strong>D</strong> (autonomous ESSM)</td>
<td></td>
<td></td>
<td>✓</td>
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</tbody>
</table>

### Combat System Alternatives

- **A** (Baseline)
- **B** (passive cueing)
- **C** (no area AAW)
- **D** (autonomous ESSM)
Candidate Ships

A0, A1, A2, B2

B3

C0, C1, C2

C3, D3

C4, D4
Mission Analysis

Forward Presence

HVU Protection

TBMD

NSFS

AAW Picket

NEO

Spec Ops
## Mission Effectiveness

### Signature Reduction Variants

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<tr>
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<th>0</th>
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**Combat System Variants**

- **A**: FP, HVU, TBMD, NSFS
- **B**: FP, HVU, TBMD, NSFS
- **C**: FP, HVU, TBMD, NSFS
- **D**: FP, HVU, TBMD, NSFS

**Legend**

- FP = Forward Presence
- HVU = High-Value Unit Protection
- TBMD = Theater Ballistic Missile Defense
- NSFS = Naval Surface Fire Support
- AAW = Anti-Air Picket
- NEO = Noncombatant Evacuation Operations
- SPEC = Special Operations
- =Good
- =Fair
- =Poor

**Notes**

- FP = Forward Presence
- HVU = High-Value Unit Protection
- TBMD = Theater Ballistic Missile Defense
- NSFS = Naval Surface Fire Support
- AAW = Anti-Air Picket
- NEO = Noncombatant Evacuation Operations
- SPEC = Special Operations
Cost

Average DDG51 FLTIIA Cost

TY96SM

Variant

A0 A1 A2 B2 B3 C0 C1 C2 C3 C4 D3 D4

ESCALATION BUDGET
ORDNANCE
OTHER COST
HULL,MECH,ELECT
ELECTRONICS
CHANGE ORDERS
BASIC ADDERS
BASIC CONST/CONV
PLAN COSTS
Cost-Effectiveness

Cost-Effectiveness Score vs. SCN Cost (TY96$M)
Conclusions

• Study conclusions
  – The combination of signature control and appropriate combat systems yields cost-effective ship options
  – Increased cost of signature control is easily outweighed by decreased combat system cost
  – For some missions, signature control is vital to success
  – Future focus will be on the technologies appropriate to signature level 3

• Process conclusions
  – Small team, focused on limited missions and scenarios
  – Effective model for future studies
What are the Weaknesses of This Approach?
An Idea: A Hybrid Approach

Goal

Objectives

Sub-Objectives

Diagram:

- SCN COST (TY96$M)
- EFFECTIVENESS 'SCORE'

Graph with points labeled A0, A1, A2, B1, B2, B3, C0, C1, C2, C3, C4, D3, D4.
Hybrid Approach

• Use AHP, or a similar approach, to identify and weigh objectives
• Use rigorous cost-benefit analysis to evaluate alternative technology systems for achieving the objectives.
• Evaluate the alternative systems using AHP
• Guide investment decisions.
What is the Fundamental Principle of Systems Engineering?
What is the Fundamental Principle of Systems Engineering?

Maximize the Expected Value

What is Implied?
The Role of Probability

• Remember, Maximize the Expected Value
  – Performance
  – Cost
  – Weight
  – Risk
  – Etc

• Expected value implies probabilistic assessment.

• Results are rarely expressed this way
The Two Sides to Risk
### Risk

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<th>Risk Management Assessment</th>
<th>Event Probability</th>
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The Risk of Action
Risk

• But what about The Risk of Inaction?
  – Adversary development
  – Program delay
  – Increased cost
  – Technology abandonment
  – Etc.

This should be considered!
Technology Risk vs Potential

Size of Circle Indicates Technology Readiness Level

Which would you choose?
The Challenge
Current Challenges

• What is desired?

  – A fact-based technology evaluation system
    • Recognize uncertainty
    • Identify uncertainty
  – Balance risk of action and risk of inaction
  – Effective and efficient cost analysis
    • Suited to the immaturity and uncertainty of technology
Current Challenges

• Technology Solutions
  – Systems-based
    • Alternate technical system approaches
    • Use mixes of technologies that makes sense
  – Maximize expected value
  – Catch the revolutionary technology

• Institutionalize systems engineering approach to technology selection
Identify Functional Needs

Fact-Based Analysis

Technology Cloud

Cost
Performance
Risk

Maximized Expected Value

Probabilistic

Maximized Expected Value
Discussion

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