The Conversation
SE Tailored to Science and Technology

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RXBT Planning Offsite
18 November 2010
Applying Systems Engineering to the Science and Technology Phase of Acquisition

• A recent emphasis within the DOD is to apply the essential elements of systems engineering earlier in the acquisition cycle to include even the early aspects of science and technology.

• The objective of S&T is to deliver the right high impact technology to the AF and our Systems Engineering approach helps assure we understand what prospective warfighters/end users want and need. It helps us identify the obstacles to implementing that technology as well.
The DOD Acquisition Cycle (Simplified)

- User Needs
- Technology Opportunities & Resources

- Materiel Solution Analysis
  - Materiel Development Decision
- Technology Development
  - (Program Initiation)
- Engineering and Manufacturing Development
  - Post-PDR
  - Post-CDR
- Production & Deployment
  - LRIP/IOT&E
  - ERP Decision Review

Science and Technology Life Cycle

- Decision
- Milestone Review
- Decision Point if PDR is not conducted before Milestone B

DODI 5000.2, pg 12.
5-Step Streamlined Planning

1. Form Team
2. Determine Requirements
3. Generate Alternatives
4. Evaluate Alternatives
5. Deliver S&T Plan

8-Key Question Assessment

1. Customer
2. Requirements
3. Demonstration
4. Tech Options
5. Best Approach
6. Risks
7. Program Structure
8. Transition Plan

S&T to External Customers

S&T to Internal Lab Customers

Simplified S&T Life Cycle

“Plan the Program Right”

“Consistent SE Assessment ...6.1, 6.2, 6.3, ATD”

Iterative
AFRL’s S&T SE Process: Consistent With DAG SE Processes

**What We Do**

- Requirement Development
- Establish S&T Criteria
- Design Solution
- Perform Value Analysis
- Develop Technology Alternatives
- Develop and Demonstrate Technology
- Implementation
- Integration
- Verification
- Validation
- Analyze and Deliver Project Results

**How We Do It**

- Decomposition & Design
- S&T Systems Engineering
- Design Engineering

**DAG Technical Mgmt Processes**

- Decision Analysis
- Tech Planning
- Tech Assessment
- Requirements Mgmt
- Risk Mgmt
- Configuration Mgmt
- Data mgmt
- Interface Mgmt
The Fundamental Benefit Applies to the Science and Technology Phase

Cumulative LCC

- Percent of Baseline LCC Incurred
- Percent of Baseline LCC Committed

Adapted from Boeing study on ICBM Life Cycle Cost, 1973
Systems Engineering and Its Place in S&T

...technique of using knowledge from various branches of engineering and science to introduce technological innovations into the planning and development stages of a system.

...more of a planning and design function.

Probably the most important aspect of systems engineering is its application to the development of new technological possibilities.

...it may be seen as the midwife of technological development.

Encyclopedia Britannica Online, “Systems Engineering”

Laboratory hook?
Focus on the Planning Stage. Proper use of the SE principles early can improve the transition of new technologies and thus result in improved systems solutions.

Look at all alternatives rather than pre-selected solutions
Interrogate advanced technologies (Low TRL; High Payoff)
Seek to get the appropriate REQUIREMENTS linked up with the lab folks.

Look at all alternatives rather than pre-selected solutions — Interrogate advanced technologies (Low TRL; High Payoff)
The S&T Response

How do we most effectively deploy Systems Engineering in Early S&T?

Some without tools
Some without tools or tools tailored to need

% SE Rigor

6.1 6.2 6.3

Case-by-Case

“The Conversation”

• Quantitative SE With MS&A
• Quantitative SE Trade Analysis
• More Rigorous Qualitative SE
• Streamlined Qualitative SE
• Training/References on LiveLink
• 8 SE Questions & AFRLI 61-104
What is “The Conversation”?

• The right people organized to address a “technical” problem using some form of structured approach.

• In the earliest instantiations of S&T, the conversation could be simply between a project leader and an appropriate decision maker.

• As the maturity of the problem space increases, the conversation needs to be more structured:
  • A multidisciplinary team approach is key
    • All necessary expertise represented in the team
    • Team members committed to team roles
    • A team charter or “contract” defined, including the “process”
    • Each step in the process must be documented

• In any event, the team and process must be consistent in pursuit of the best possible solution (“best value”?) to achieve the best result.

• The heart of such an approach is captured in a concept involving:
  • A structured process to guide the conversation
    - We use a streamlined 5 Step process
  • A technique to get from requirements to best approach
    - We prefer a creative technique based on the concept of “desirements”
Desirements
Desirements

• There are numerous ways to apply technical criteria to customer requirements and engage a team of subject matter experts to arrive at the “best” course of action

• Desirements are very well suited to S&T project planning
Why Desirements

Customer Requirements are usually at a high level

Measure of merit that characterizes the range between what the customer wants and needs.

What do I want?
What am I willing to pay for?
What do I need?

A Laboratory, by mission, should explore what might be possible

Requirements / Desirements must be iterated with the Customer
A Structured Process
• Laboratory scientists and engineers are wary of systems engineering in S&T, claiming their creativity will be stifled.

• We emphasize Lab-Friendly processes that are flexible, quick, and efficient.
  – Two such processes we use are:
    • Streamlined Systems Engineering Process
    • SynGenics Corp SETFST Decision Support Process

• For today, we are suggesting a variation of the RX Streamlined Process
Streamlined Systems Engineering Process

Step 1: Form Team
- Define Problem
- Identify all stakeholders
- Establish Team

Do:
- Define requirements
- Define tech challenges
- Define S&T Exit Criteria (KPP sets)
- Validate with customer

Step 2: Determine Requirements
- Understand applicable state-of-the-art & near term technologies
- Brainstorm different solution approaches

Do:
- Prioritized Requirement Set
  - Performance Set
  - Affordability
  - Producibility
  - Reliability
  - Supportability
- S&T Exit Criteria

Step 3: Generate Alternatives
- Compare alternatives across Req’ts / S&T Exit Criteria
- Solicit Customer approval for proposed solution

Do:
- Alternative Definitions

Step 4: Evaluate Alternatives
- Finalize AF Problem / Goal / Solution Objectives
- Prepare for intended action course

Do:
- Tech Readiness Assessment (TRA)
- Manufacturing Readiness Assessment (MRA)
- Risk Analysis
- Value Analysis
- Cost Estimate
- Schedule / Key Milestones

Step 5: Deliver S&T Plan
- AF Problem / Goal / Solution Objectives statement
- Program Roadmap
- Action Plan

Document:
- Problem Definition
- Team Directory (includes roles & responsibilities)
- Team Charter (Optional)

Based on S&T IPPD Process (Version 3 – 2002)
From Requirements to Preferred Alternatives
Requirements to Preferred Alternatives

FLOW

A. **ESTABLISH DESIREMENTS**

B. **DEFINE BENEFITS / ATTRIBUTES OF DESIREMENTS**

C. **ESTABLISH ALTERNATIVES**

D. **DEFINE ALTERNATIVES**

E. **CONDUCT VALUE ANALYSIS of ALTERNATIVES**

F. **DETERMINE THE PREFERRED ALTERNATIVE(S)**
A. Establish Desirements

- Requirements come from the Customer
- Desirements are negotiated by the team
- Iterative Process

PROBLEM SPACE
Engage the Team, Consider the Problem from the Customer and Technologist Views
**Table A1 Desirements**

**TEAM** negotiates a list of Desirements (Not specific to any alternative)

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Desirements evolve in this process and are grouped into Categories

• Typical Categories of Desirements:
  – **Performance** (e.g. resolution, power, weight, footprint),
  – **Cost** (e.g. acquisition costs, deployment costs, and development costs)
  – **Schedule** (e.g. initial operating capability and technical feasibility demonstration)
  – **Human Factors** (e.g. skill level required for use, manpower to operate),
  – **Logistics / supportability**
  – **Operational Environment** (e.g. emissions, compatibility with infrastructure)
  – **System Reliability**
  – **System Producibility**

This may be a good time to focus, combine or reduce the number of Desirements
• Typical Categories of Desirements:
  – **Performance** (e.g. resolution, power, weight, footprint),
  – **Cost** (e.g. acquisition costs, deployment costs, and development costs)
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TEAM agrees on grouping of Desirements

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Table A2  Desirements in Categories

**TEAM** agrees on grouping of Desirements

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B. Define Benefits / Attributes of Desirements

- Team defines the Desirements by adding quantitative measures

PROBLEM SPACE
Engage the Team, Consider the Problem from the Customer and Technologist Views
**Table B. Benefits / Attributes of Desirements**

**TEAM** defines the Desirements by adding Quantitative Attributes

This is another opportunity to focus or combine Desirements

<table>
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<tr>
<th>ID</th>
<th>Name</th>
<th>Units</th>
<th>Preferred Objective</th>
<th>Acceptable Threshold</th>
<th>Unacceptable Limit (Low / High)</th>
<th>Rationale behind the values</th>
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### C. Establish Alternatives

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<th>Step 4</th>
<th>Step 5</th>
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<tr>
<td>Form Team</td>
<td>Determine Requirements</td>
<td>Generate Alternatives</td>
<td>Evaluate Alternatives</td>
<td>Deliver S&amp;T Plan</td>
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</table>

- Team collaborates on candidate solutions that **might** satisfy the desiresments

**SOLUTION SPACE**

- Engage the Team;
- Creatively explore;
- Expand the solution space;
- Low TRL to High TRL
**Table C. Alternatives**

TEAM negotiates a list of Alternatives

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<th>Alternative</th>
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</table>
D. Define Alternatives

- Team defines key attributes of each alternative, aligning with the attributes of the Desirements.

**SOLUTION SPACE**

Engage the Team; Establish Attributes needed for comparing with each Desirement
**TEAM** defines the Attributes of potential solutions

<table>
<thead>
<tr>
<th>Final List of Desirements</th>
<th>For Each Alternative</th>
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<td>S2. Name</td>
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</table>

Team Develops Alternative definition with sufficient depth to judge the Alternative against Every Desirement
<table>
<thead>
<tr>
<th>Quad Chart</th>
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<tr>
<td><strong>Technology Description</strong></td>
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<td>Graphic and/or description to quickly convey the nature of the technology, the current state.</td>
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<td><strong>Cost of current technology</strong></td>
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| **Proposed Technical Approach** | **Cost and Schedule** |
| How will the problem be approached. | **Timeline** |
| High level task description. | **Milestones (including TRL levels)** |
| Describe the key technical challenges, assumptions, limitations. | Rough budget (5 zeros) |
| Dependent technologies, e.g. displays need input | |
| Ancillary benefits or related programs this technology could benefit | |
| Who are the technology leaders? Agencies or vendors | |
E. Conduct Value Analysis of Alternatives

- Team scores each alternative against every desirement, and agrees to a Desirability and Risk Score

**SOLUTION SPACE**

Team compares Alternatives against every Desirement, including assessment of Desirability and Risk

- **Form Team**
- **Determine Requirements**
- **Generate Alternatives**
- **Evaluate Alternatives**
- **Deliver S&T Plan**
Desirability

• Measure of goodness/customer satisfaction.
  – Degree of achievement vs the Desirements
    • For our streamlined process, we are using the “Expert Opinion” method to judge desirability.
    • The team constitutes the RX SME capability for this activity
• Desirability represents the Team’s assessment of how well the Alternative performs against the Desirement, on a Score of 1 (Low) to 10 (High)
  – For Example, the Performance Objective of a Desirement is a Recycle time of 2 hours. The Team agrees the best an Alternative can be expected to produce is 5 hours. The Customer requirement says the Unacceptable limit is 7 hours. Based on this the team scores the desirability as a 4.
  – If the Expected Value were to be 7 hours or greater, the Alternative would fail against this Desirement and be scored a Zero.
Include risk management in program and technical planning.
Continuously implement risk management process during program execution.
Table E. Conduct Value Analysis of Alternatives

Complete this table for each alternative against each desirement.

<table>
<thead>
<tr>
<th>Alternative Name:</th>
<th>Desirement</th>
<th>Expected Value</th>
<th>Desirability (D) (1 -10)</th>
<th>Risk (R) 1,5,10</th>
<th>SCORE (D x R)</th>
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For a problem of 5 Desirements and 5 Alternatives, there will be 25 score sheets.
F. Determine Preferred Alternative(s)

- Team reviews Alternative Rankings and Scores
  - Verify reasons for all Zero scores
  - Verify sense of correctness for relative ranking

SOLUTION SPACE
Team compares Alternatives against every Desirement, including assessment of Desirability and Risk
F. **Determine** Preferred Alternative(s)

- n - Desirements
- k - Alternatives

- Total number of “Individual Scores” (s) = n x k

- Aggregate Score of Alternative = sum of individual scores except where an alternative fails to pass the unacceptable limit.

- Rank Order Alternatives 1-> k

- Should lead to a Team “Conversation”
  - Are the Results consistent / satisfactory to the team?
  - If not, repeat the process; checking all assumptions
Summary

• Systems engineering is a powerful tool at every level of the acquisition process

• Early application of the SE principles is where the highest potential benefit accrues

• We are moving SE into the culture of our laboratories and tailoring…

• Early planning is the key to best program solutions, even in early S&T

• The “Conversation” is our shorthand for applying technical expertise and creativity to push the boundaries of research at all levels

• We have seen numerous cases where even a high performance laboratory team discovers new insights and directions when they apply the SE discipline.

• There is great benefit to be derived from taking the time to look at technical, and even non-technical, options in a disciplined manner
• Some Other Considerations
Some Caveats
May help focus your thinking

• The RX SE process is designed for a problem in search of a solution (in this case, we are focused on early SE - program planning).
• If we have solutions in search of a problem, there is an additional step which would be titled something like “Develop a technology based relationship with a prospective end user/customer,” or “Develop an end user’s vision.”
• If needed, the S&T team can create at least a reasonable “straw man” set of desirements/requirements and proceed with the process.

• We need the customer focus to get started on requirements/desirements…at the point of any significant investment, there needs to be a “business” or “investment” case built. The “Streamlined SE Process” is the best and most flexible approach.