Systems Engineering Principles Applied to Basic Research and Development

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The Whale Chart maps the Life Cycle to the Readiness Levels and R&D Stages

- A technology’s usefulness changes over time
  - Utility increases as a technology matures
  - Utility decreases as a technology becomes obsolete
## Knowledge Growth

<table>
<thead>
<tr>
<th>Key Question</th>
<th>Basic Research</th>
<th>Applied Research</th>
<th>Advanced Research</th>
<th>ATD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who is your customer?</td>
<td>Partial</td>
<td>Nearly Complete</td>
<td>Complete</td>
<td>Complete</td>
</tr>
<tr>
<td>What are customer's requirements?</td>
<td>Partial</td>
<td>Partial</td>
<td>Nearly Complete</td>
<td>Complete</td>
</tr>
<tr>
<td>How will you demonstrate you have met the requirements?</td>
<td>Partial</td>
<td>Partial</td>
<td>Nearly Complete</td>
<td>Complete</td>
</tr>
<tr>
<td>What are the technology options?</td>
<td>Extremely Limited</td>
<td>Nearly Complete</td>
<td>Complete</td>
<td>Complete</td>
</tr>
<tr>
<td>Which is the best approach?</td>
<td>Extremely Limited</td>
<td>Nearly Complete</td>
<td>Complete</td>
<td>Complete</td>
</tr>
<tr>
<td>What are the risks to developing the selected technology?</td>
<td>Partial</td>
<td>Partial</td>
<td>Nearly Complete</td>
<td>Complete</td>
</tr>
<tr>
<td>How will you structure your program to meet requirements and mitigate risk?</td>
<td>Partial</td>
<td>Nearly Complete</td>
<td>Complete</td>
<td>Complete</td>
</tr>
<tr>
<td>What is your business-based transition plan that meets customer approval?</td>
<td>Extremely Limited</td>
<td>Partial</td>
<td>Nearly Complete</td>
<td>Complete</td>
</tr>
</tbody>
</table>
Key Questions and Systems Engineering

Key questions provide the loops & Balance & Control mechanisms of the Systems Engineering process!

Requirements Analysis

Who is your customer? What are customer’s requirements?

How will you demonstrate you have met the requirements?

Functional Analysis / Allocation

What are the technology options?

Which is the best approach?

Balance & Control

How will you structure your program to meet requirements and manage risk?

What are the risks to developing the selected technology?

Solution Synthesis

What is your business-based transition plan that meets customer approval?

Gov’t Lead

Industry Lead

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Two of the Key Questions Focus on Risk in R&D:

• **What** are the risks to developing the selected technology?

• **How** will you structure your program to meet requirements and manage risk?
RM Tailored to R&D Goals

• Three Distinct Levels of Research and Development
  – Basic Research – develop a fundamental understanding of selected physical properties
  – Applied Research – investigate application of physical properties to selected technical needs
  – Advanced Technology Development – explore application of technology to assess military relevance
Philosophy of RM in Basic Research

What Are the Risks?

- Develop cost estimates for advancement of technology to useful level
- Identify development options and relative difficulty of options
- Maintain budget within pre-defined boundaries

How Will You Structure the Program?

- Establish knowledge incremental goals
- Estimate cost/time needed to achieve
- Determine risks associated with maintaining cost/schedule
- Track variances for periodic cost/schedule replan

Primary purpose of RM in Basic Research is to refine development roadmap
# Investment Roadmap for Modular Spacecraft Technologies

## Potential Applications
- **Tacsat - 3**
- **Tacsat - 4**

## Plug & Play
- **Electronics**
  - Basic Research
  - Advanced Research
  - Tech Development

## Modular Hardware
- Basic Research
- Advanced Research
- Tech Development

<table>
<thead>
<tr>
<th>FY05</th>
<th>FY06</th>
<th>FY07</th>
<th>FY08</th>
<th>FY09</th>
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<tr>
<td>Funds ($M)</td>
<td>2.3</td>
<td>3.8</td>
<td>3.1</td>
<td>1.9</td>
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</tbody>
</table>

- **CDR**
- **Brassboard**
- **Prototype**
- **Testing**

- **Future Tacsat prgms**
Philosophy of RM in Applied Research

What Are the Risks?

- Develop technology into a repeatable engineering capability
- Identify extent of applicability of technology to military needs
- Determine the cost/benefit parameters of this new capability

How Will You Structure the Program?

- Explore range of application of technology
- Refine development roadmap for specific applications
- Determine risks associated with achieving required performance at known cost/schedule
- Identify issues of repeatability and define mitigation approaches

Primary purpose of RM in Applied Research is to balance cost & performance
Philosophy of RM in Advanced Technology Development

**What Are the Risks?**

- Apply engineering capability to specific military need
- Identify issues causing uncertainty in application
- Refine cost/performance relationship.

**How Will You Structure the Program?**

- Manage to cost/schedule
- Provide mitigation options and go/nogo gates
- Determine risks early, maintain constant awareness
- Identify potential of cost/schedule failure early (precursors), manage proactively

Primary purpose of RM in ATD is to balance cost, performance, schedule
Summary

- Key Questions (What Are the Risks and How Will You Structure the Program?) provide the basis of the AFRL Risk Management process

- Questions apply to R&D programs at all stages of maturity

- Knowledge available to the program manager changes with program maturity

- Risk Management philosophy changes with program maturity
Conclusion

The AFRL Systems Engineering Initiative is a method of managing risk in Science and Technology

Risk Management is applicable early in the technology life cycle
Discussion / Questions