2007-05-01

Too Little Too Soon? Modeling the Risks of Spiral Development

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http://hdl.handle.net/10945/33250
Too Little Too Soon?
Modeling the Risks of Spiral Development

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Spiral Development, Real Options, and Other Development Methodologies

DATE: June 5, 2006
TIME: 8:30 a.m. - 12:15 p.m.
LOCATION: CSIS
B-1 Conference Center
1800 K Street, N.W.
Washington, D.C.
"Evolutionary Acquisition" Is a Promising Strategy, But Has Been Difficult to Implement

In 2003, the U.S. Department of Defense (DoD) specified evolutionary acquisition (EA) as the preferred approach to weapon system acquisition and spiral development as the preferred means of implementation. EA strategies aim to develop new capabilities in multiple increments, as opposed to the traditional strategy of developing a full capability in a single, lengthy step. EA strategies are meant to reduce the time it takes to field operationally useful equipment, control technical risk and cost growth, and make cost estimates more reliable for each stage of development, while allowing greater flexibility to evaluate and improve a program based on experience in the field. This greater flexibility arises in part from the fact that, with the spiral development approach, the end-state requirements are not known at program initiation, but rather emerge and evolve through an iterative process of phased development and...
“Evolutionary acquisition strategies shall be preferred approach to satisfying operational needs.”
DoDI 5000.2

Evolutionary Acquisition

Further defined:

- **Incremental Development**: A desired capability is identified; the end-state requirement is *known*; and that requirement is met over time by developing several increments, each dependent on available, mature technology.

- **Spiral Development**: A desired capability is identified, but the end-state requirements are *not known* at program initiation. Requirements are refined through demonstration and risk management; there is continuous user feedback; and each increment provides the user the best possible capability.
“Paradigms influence our study between revolutions” Kuhn
Barry Boehm’s Spiral Model of Software Development

PMI’s PMBOK:

“Progressive Elaboration”
Evolutionary Acquisition Issues

• Number of OSD-Level Reviews
  - Off-Core Activities
  - Significant Transaction Costs
• Unplanned work is inestimable.
• Fielding of obsolete technology -- if SDD isn’t short
• Continued conceptual and definitional ambiguity (RAND)
• 1\textsuperscript{st} increment: Militarily useful vs. all desired capabilities
• Organizational impacts of concurrent production and development of follow-on increments
• Maintaining of funding priority for follow-on increments
• GAO examples are mostly from cyclical commercial models, versus fleet ownership (i.e., United, UPS, Fedex)
• Variety brings benefits and costs
Everything Changes, But…

A one-size-fits-all development methodology may not be appropriate for all product commodities.
Product Attributes May Affect the Development Strategy

- Mutability
- Range of Requirement Attainment (Binary vs. Continuous)
- User Risk (Safety and Time Criticality)
  - Time-critical or enhanced survivability systems (NMD, ARCI)
  - Non-man-rated Systems (UAVs)
  - Man-rated Systems (munitions)
  - Production Quantity (not a factor)
- Logistical Support Planned During Service/Shelf Life
- Net Amount of Change - and the Lure of Modularity
  - Changes propagate with relative modular interdependency
Relative Concurrency of Increments

Development Increments Concurrent with Later Production

Development Increments Concurrent with Initial Production
A Tale of Two Missiles

Spiral and Incremental Development

ARMY TACMS
MISSILE DESIGNED FOR GROWTH WARHEADS

M74 Submunition

ALTERNATIVE BLOCK II WARHEADS CONTAIN “SMART” ANTI-ARMOR SUBMUNITIONS

BLOCK I - APAM

MISSILE DESIGN OPTIMIZED FOR BLOCK II PAYLOAD

BLOCK II - TYPE 1

BLOCK II - TYPE 2

Single Step to Full Capability
## A Tale of Two Missiles:  
Technology Maturity – A Key Difference

### Key Program Characteristics - First Increment of Capability

<table>
<thead>
<tr>
<th>Program Aspects</th>
<th>ATACMS</th>
<th>JAVELIN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DARPA Predecessor</strong></td>
<td>Assault Breaker 1977-82</td>
<td>Tank Breaker 1981-82</td>
</tr>
<tr>
<td><strong>Ultimate Capability</strong></td>
<td>“Deep Attack”</td>
<td>“Fire &amp; Forget”</td>
</tr>
<tr>
<td><strong>Critical Technologies &amp; Readiness Levels:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Munition</td>
<td>9 - Lance M74 Bomblet</td>
<td>5 - Tandem Shaped Charges</td>
</tr>
<tr>
<td>Propulsion</td>
<td>9 - Solid Rocket Motor</td>
<td>5 - Two-Stage Solid Rocket Motor</td>
</tr>
<tr>
<td>Flight Control</td>
<td>9 - Fin surfaces</td>
<td>6 - Fins + Thrust Vector Control Vanes</td>
</tr>
<tr>
<td>Guidance and Control</td>
<td>9 - Inertial</td>
<td>4 - Tracker Software Algorithm</td>
</tr>
<tr>
<td>Safe/Arm Fusing</td>
<td>7 - Mechanical</td>
<td>4 - Electronic</td>
</tr>
<tr>
<td><strong>Software Function (Target Acquisition, Fire Control, etc.)</strong></td>
<td>6 - Various</td>
<td>6 - Various</td>
</tr>
<tr>
<td>Sensor</td>
<td>N/A</td>
<td>5 – Focal Plane Array</td>
</tr>
</tbody>
</table>

| Capability Leap Area            | Range                           | Range, Lethality, Survivability   |
| Cost of development             | ~$700M                          | ~$700M                           |
| Contract Type                   | Fixed Price                     | Cost Reimbursable                 |

| Tech Development Phase          | 0 Months                        | 27 Months                        |
| Advanced Development Phase - Planned | 48 Months                      | 36 Months                        |
| Advanced Development Phase - Actual | 51 Months                      | 54 Months                        |

| Total Time in Development       | 51 Months                       | 81 Months                        |
| Advanced Development Phase Contract Cost Growth | 0%                              | >150%                            |
Modeling the Drivers and Impacts of Evolutionary Acquisition

- Need to validate the impacts of Evolutionary Acquisition suggested by the ATACMS and Javelin cases
- Need to identify other, less clearly visible, impacts of Evolutionary Acquisition
- Need to understand impacts using many strategies

Built computer simulation model of work and information in an Evolutionary Acquisition project
Information Flows in a Single-block Acquisition Project

Models inter-phase concurrence & information dependencies
Work Flows and Backlogs through a Development Phase

Coordination Rate

Known Rework Backlog

Rework Rate

Quality Assurance Backlog

Discover Needed Rework rate

Initial Completion Rate

Initial Completion Backlog

Work Approved

Approval Rate

Release Rate

Work Finished and Released

Return Rework Rate

Work flows are constrained by resources and availability of work
Information Flows in an Incremental Acquisition Project

- Contracting, etc. modeled with indirect work at start of each phase
- Reviews modeled with indirect work at end of each phase
Modeling Performance and Resources

- **Acquisition Project Performance**
  - *Schedule* – when how many requirements are satisfied
  - Total project *cost* (labor as proxy)
  - *Risk* of satisfying requirements by a deadline

- **Resources**
  - *Two workforces*: Development & Project Management
  - Resource progress rate = allocated workforce * productivity
  - Development allocated to reduce work backlogs
  - Project management allocated to coordinate development activities
Model Calibration and Testing

- **Model was calibrated to Javelin project**

![Graph showing active phases over time](image)

**Work packages being developed**
(also proxy for development effort)

- **Model structure and behavior is consistent with the Javelin project**
Impacts of Multiple Development Blocks

- Javelin project (single block)
- Base Case (single-block)
- Base Case (3 even blocks)

Requirements Tested and Approved by Users (% of all project requirements)
# Impacts of Multiple Development Blocks

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Units of Measure</th>
<th>Javelin (single block)</th>
<th>Base Case (single block)</th>
<th>Base Case (3 blocks)</th>
<th>Best Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration to first requirement satisfied</td>
<td>weeks</td>
<td>471</td>
<td>470</td>
<td>397</td>
<td>Base Case (3 blocks)</td>
</tr>
<tr>
<td>Duration to max. requirements satisfied</td>
<td>weeks</td>
<td>520</td>
<td>518</td>
<td>762</td>
<td>Base Case (single block)</td>
</tr>
<tr>
<td>Total development cost</td>
<td>$1,000,000</td>
<td>722</td>
<td>719</td>
<td>1,555</td>
<td>Base Case (single block)</td>
</tr>
<tr>
<td>Requirements satisfied by deadline</td>
<td>% of requirements developed</td>
<td>100</td>
<td>91</td>
<td>18</td>
<td>Javelin (single block)</td>
</tr>
<tr>
<td>Final requirements satisfied</td>
<td>% of requirements developed</td>
<td>100</td>
<td>91</td>
<td>91</td>
<td>Javelin (single block)</td>
</tr>
</tbody>
</table>

The (dis)advantages of Evolutionary Acquisition depend on what performance measures are most important.
Managing Iterative Development

Base Case (single block)

Work being Developed

Base Case (3 blocks)
Managing Iterative Development

![Graph showing the number of active phase interfaces over time for Base Case (3 blocks) and Base Case (single block).](image)

**Number of Active Phase Interfaces**

- Base Case (3 blocks)
- Base Case (single block)

Active phase and block interfaces:
- BaseCase-SingleBlock: dimensionless
- BaseCase-Spiral: dimensionless
Managing Iterative Development

Base Case with more developers and more project management – $1,753m!!

Base Case (3 blocks) - $939m

Base Case with more developers - $1,761m

Requirements Tested and Approved by Users

Average Percent of Requirement Provided: JavelinCalibration
Average Percent of Requirement Provided: Javelin3EvenBlocks
Average Percent of Requirement Provided: Javelin3EvenBlocksMoreDev
Average Percent of Requirement Provided: Javelin3EvenBlocksMoreDevPM
Conclusions – Evolutionary vs. Single Block Development Approaches…

• First Unit Equipped with some (but not all) requirements satisfied faster
• Satisfies requirements in multiple steps
• Requires more time to satisfy all requirements
• Costs more than single-block development for same requirements
• High risk of not satisfying all requirements by the time single-block development can satisfy all requirements
Implications for Evolutionary Acquisition
Project Managers

• More development phases and activities to manage and coordinate: larger and different PM needs

• More concurrence and resulting complexity: bottlenecks change and move…are more difficult to identify and manage ← focus more on this

• Creates counterintuitive behavior (e.g. reductions in project cost by adding resources) – opportunities to improve performance…IF you develop a deep understanding of the drivers and constraints of Evolutionary Acquisition progress.

Need more investigation of more EA projects.
Our Bottom Line on Risks

• DoD uniquely outsources development for internal use
  - owns the product over its life cycle
• There are inherent potential risks with incremental development
  - inefficiencies from re-work (duplication)
  - risk of project error (from discontinuous membership)
  - organizational impacts (queuing theory)
  - relative concurrency drives risk
  - variety in the fleet (support, failure cause, training, etc.)
• Don’t defer what you can do now
• Defer what you cannot do now – tech readiness
• Product attributes may affect development strategy
Our Top Line on Control

- Rigorous Preliminary Effort on Architecture
- Meticulous Configuration Management
- Individual Accountability
- Other control measures to balance risks
  - T&E, Interface Control, Peer Review
  - GPR, MOSA & OA Incentives, etc.

“Intelligent design is way faster than evolution.”
Robert N. Metcalfe
Questions?