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The Costs and Risks of Maturing Technologies, Traditionally vs. Evolutionary Approaches

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Knowledge and Skills for Enterprise Transformation.

The Costs and Risks of Maturing Technologies

Traditional vs. Evolutionary Approaches

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Introduction

- Traditional acquisition programs utilize promising but immature technology.
- The use of immature technology can add substantial risk to an acquisition program that tends to increase its cost and duration.
- Evolutionary approaches to acquisition emphasize the use of mature, proven technologies to shorten and reduce the cost of acquisition cycles.

Introduction

- Thus, evolutionary vs. traditional acquisition reduces to the question of how mature should a technology be when a commitment is made to incorporate it into a system design?
- Does an evolutionary technology policy increase the performance and reduce the cost of operating the defense acquisition system?
- To address these questions, a discrete event simulation was developed to model both a technology development process and the defense acquisition life-cycle.

Approach

- One can consider the output of an R&D process to be technology options.
  – Developed technologies provide the option to incorporate new capabilities into a system.
- Early commitment to a technology inherently limits future design options.
- Late exercise, on the other hand, maximizes flexibility, but also incurs costs to develop and maintain technology options.
- We could characterize traditional acquisition as the former and evolutionary acquisition as the latter.

Approach

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- Thus, the key issue is the level of maturity at which a technology is selected for use in acquisition program.
- To understand this issue it is necessary to model the linkage between technology development and the acquisition life cycle.
- A discrete event simulation was developed in Arena 10.0 that models both the flow of new technologies through a maturation process as well as the flow of acquisition programs through their life-cycles.

Approach

- The simulation of the acquisition system was deliberately scaled down and idealized.
- It is intended to model the “physics” of the defense acquisition system.
- This was both to improve tractability and allow for imperfections to be added selectively to isolate their effects.
- The model consists of three parts:
  - A staged model of technology development.
  - A model of the acquisition life-cycle.
  - A model of technical progress.

Technology Development Process

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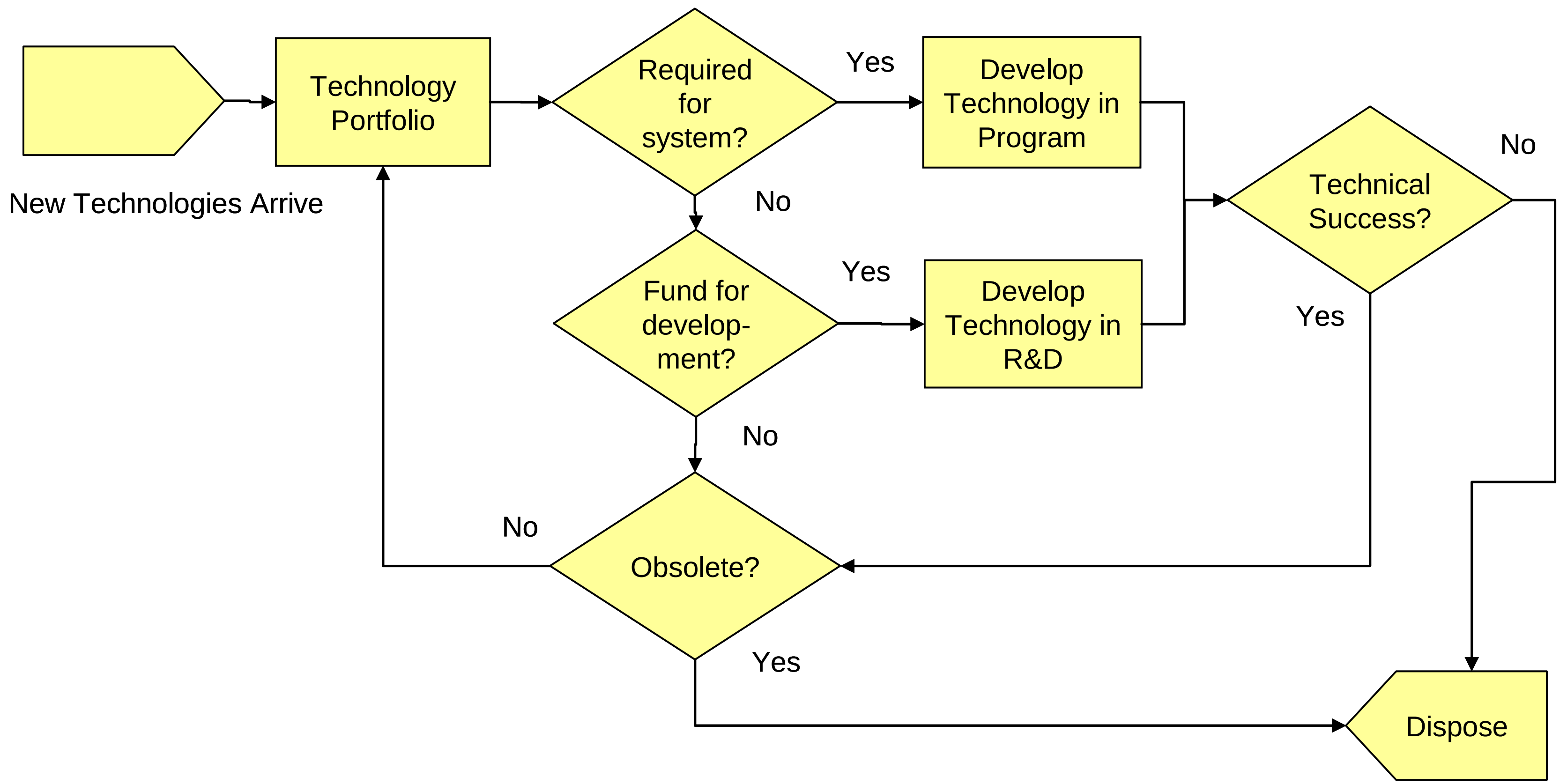
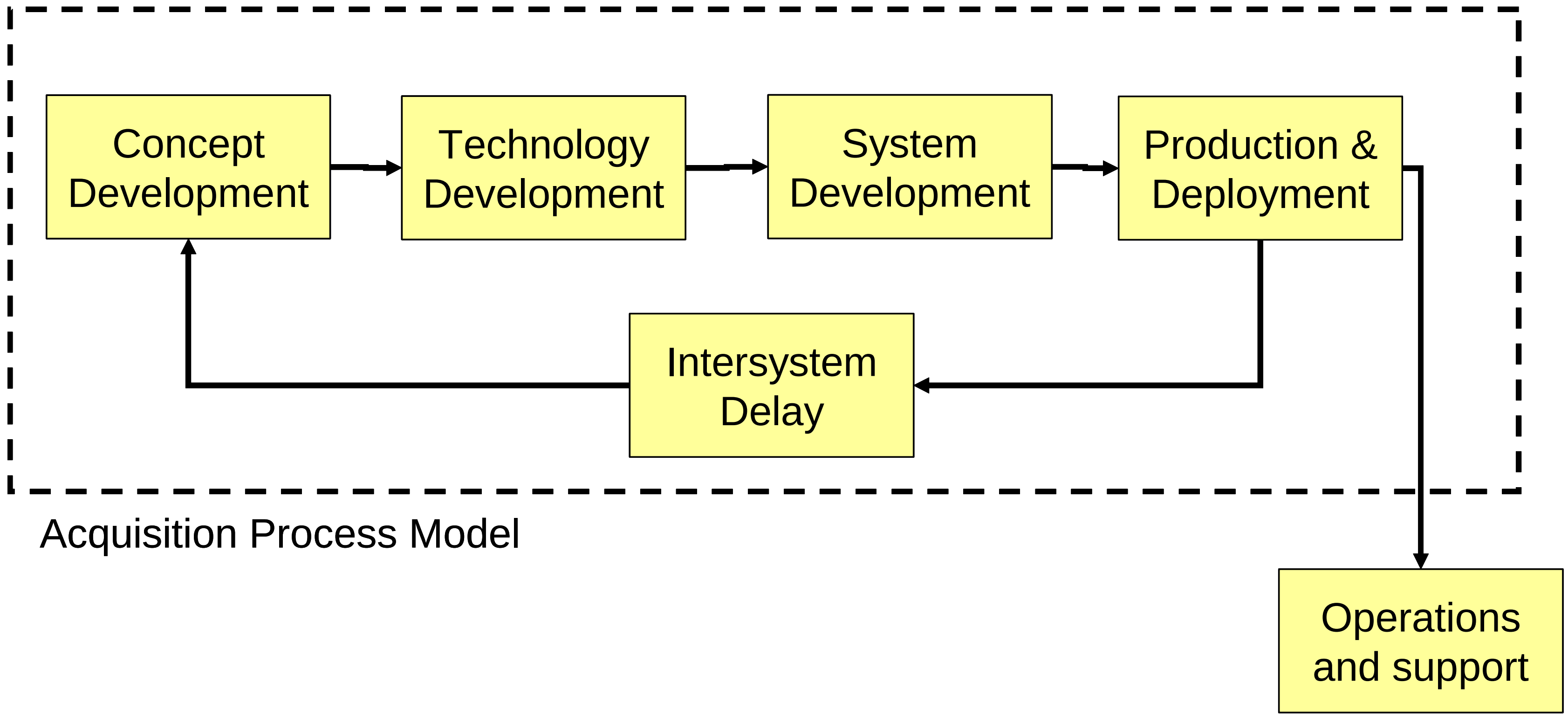


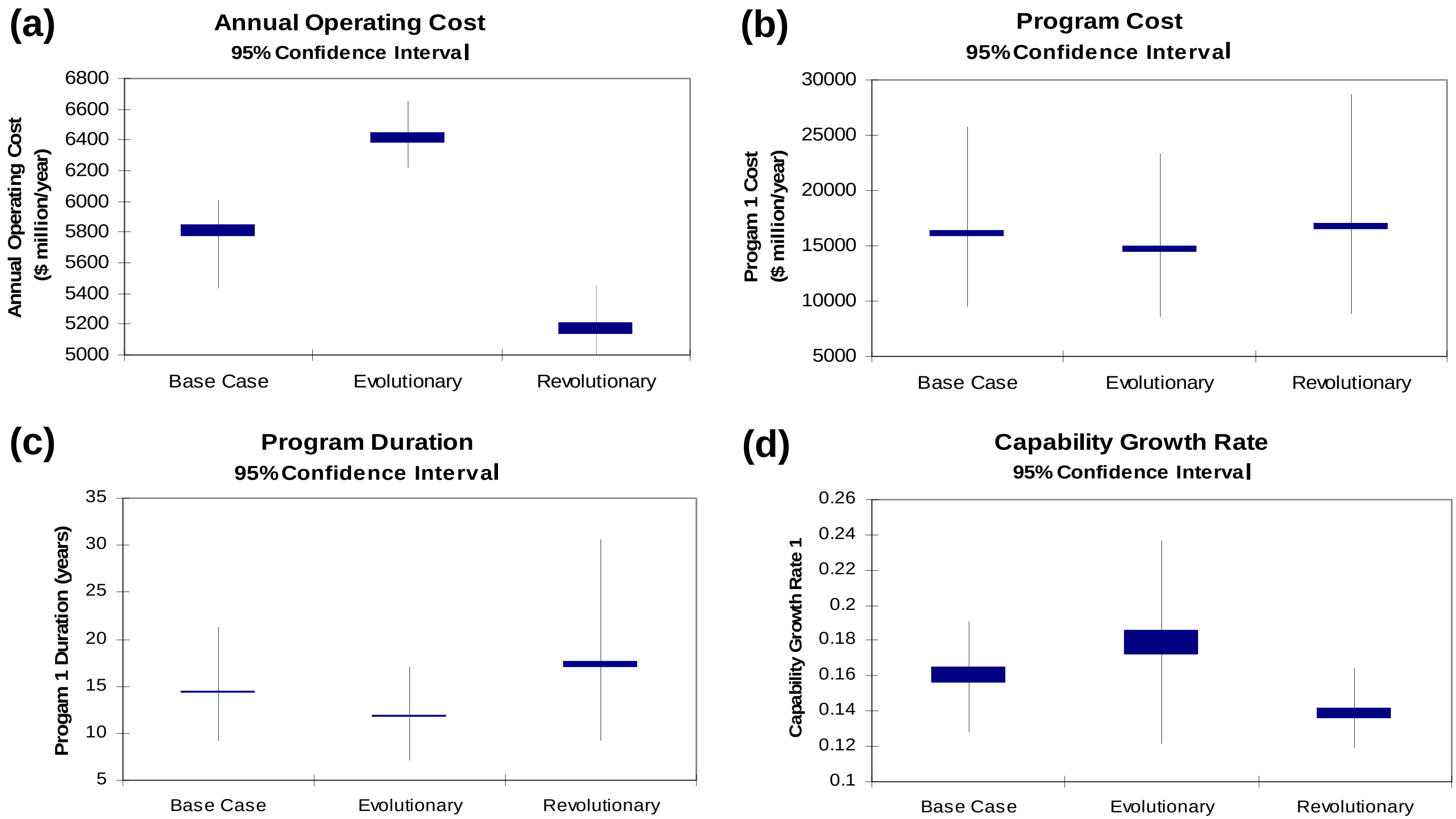
System Acquisition Process



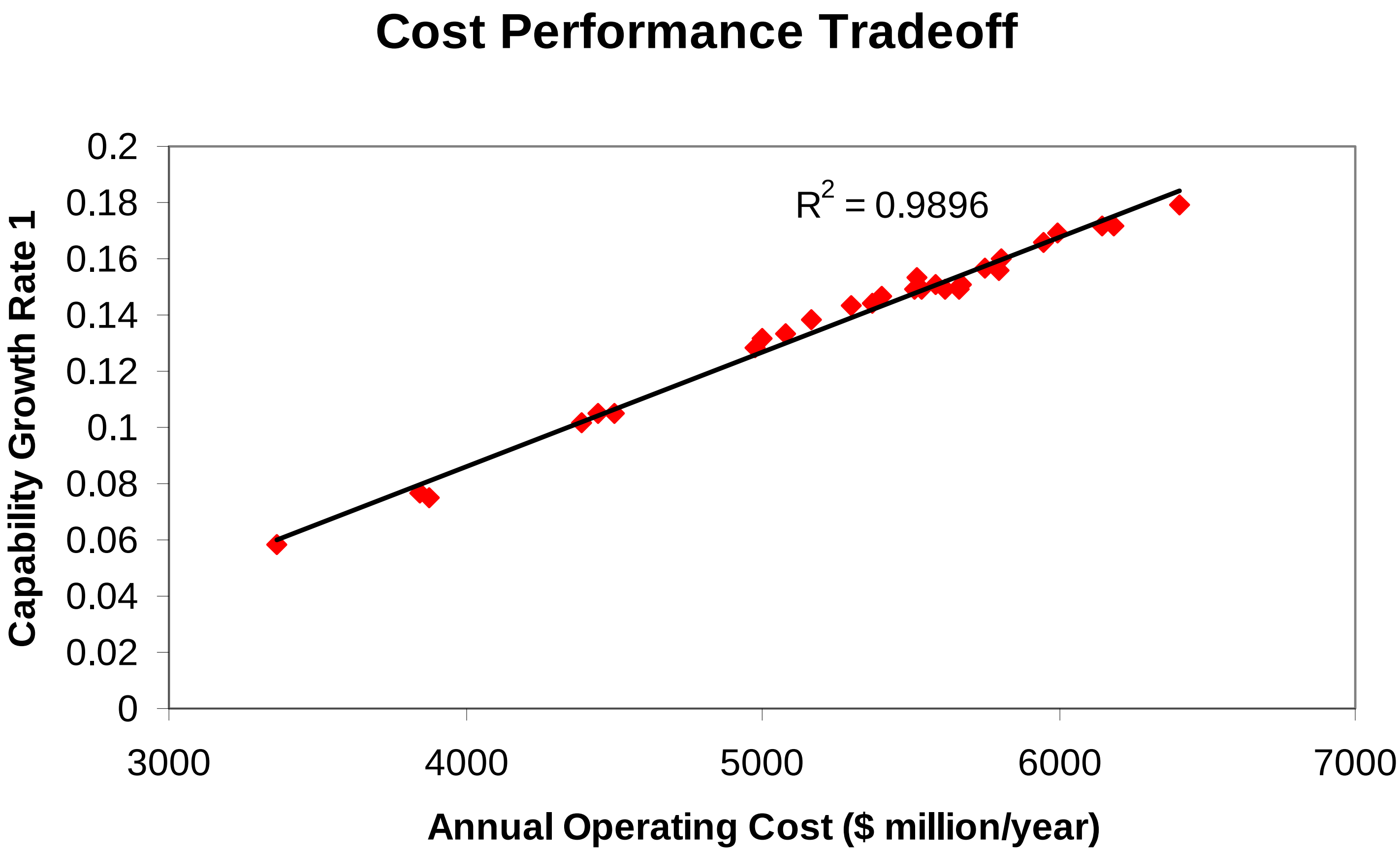
Experimental Design

- The key decision variable was the minimum level of maturity at which an acquisition program may utilize a particular technology.
- Three main cases were considered
  - Base Case: Min TRL = 4, Fallback TRL = 7
  - Evolutionary: Min TRL = 7
  - Revolutionary: Min TRL = 4, Fallback TRL = 4
- Additionally, extensive sensitivity analyses were performed on the model parameters.
- The warm-up period was 50 years, and statistics were collected over a 150 years.
- There were 40 replications for each experiment.

Selected Results



Cost/Performance Trade



Cost/Performance Trade

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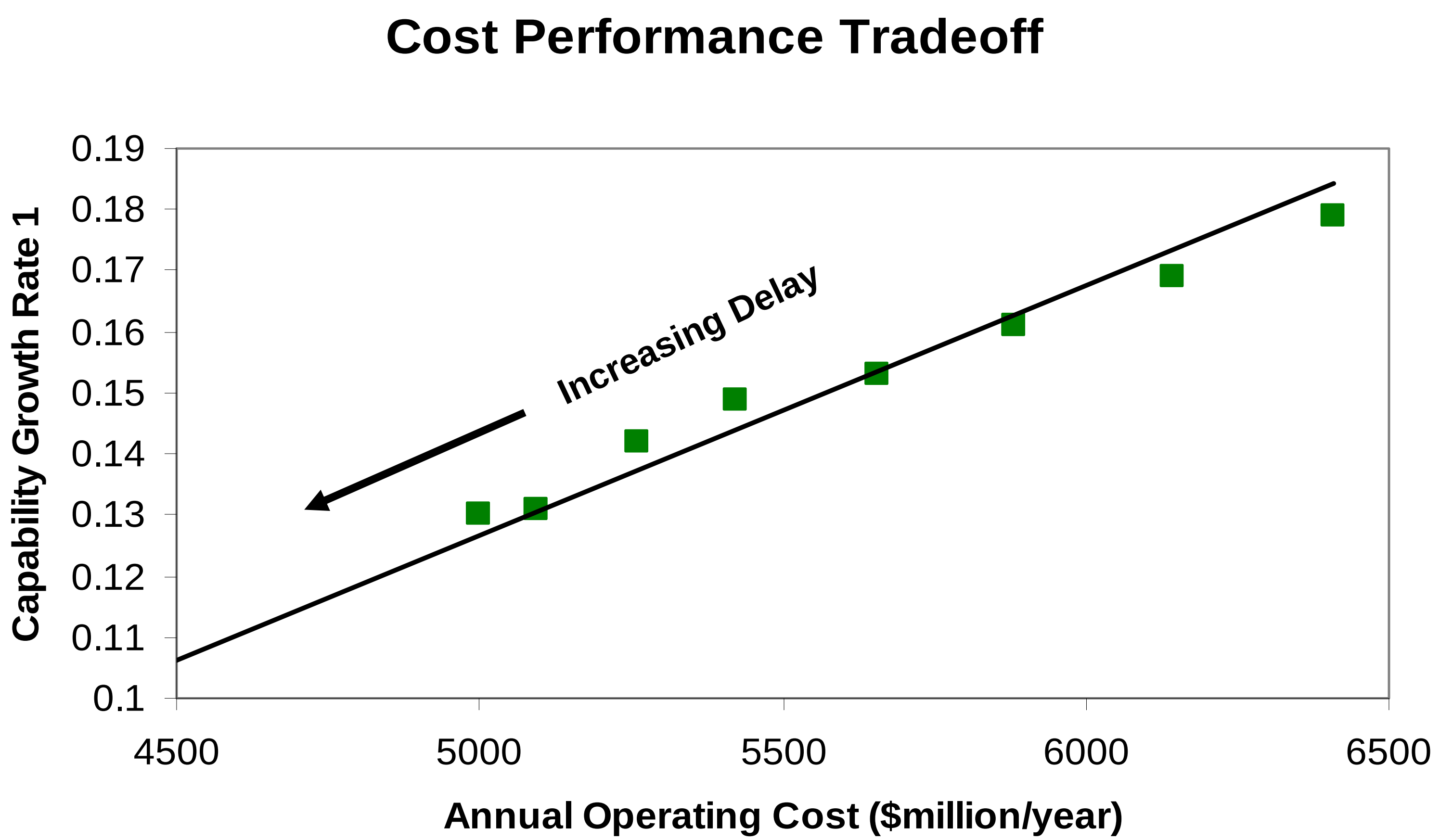


Discussion

- Why does this happen?
- Imagine you had one week cycles that cost $10 per cycle. If you were able to speed up the cycles to twice per week and cut costs to $8 per cycle, each individual cycle is cheaper, but the total cost would be $16 per week.
- The reason is that there is a certain amount of overhead in terms of design, production, and deployment. If this overhead is not reduced sufficiently, faster cycles simply increase costs.

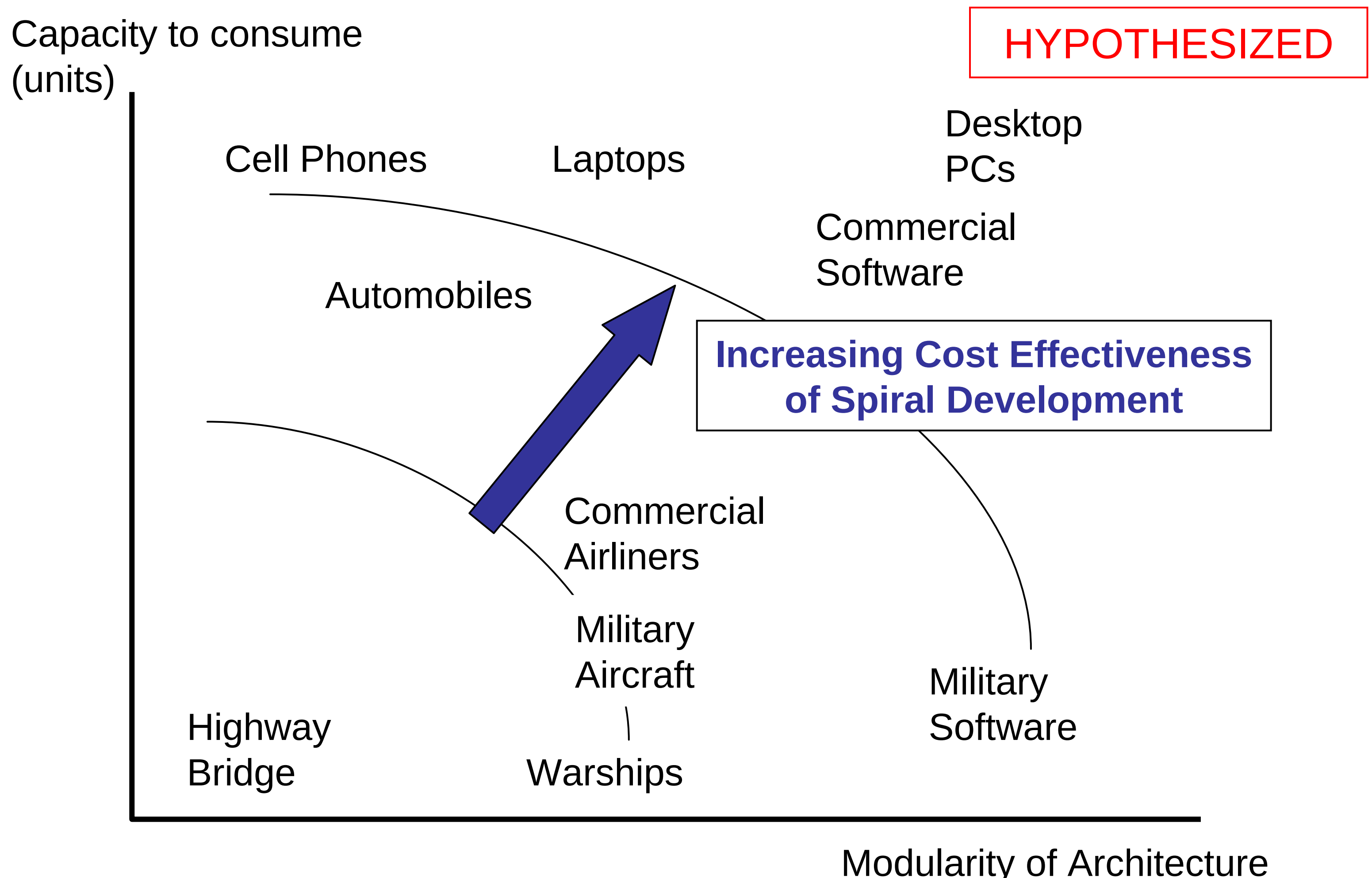
Discussion

- If evolutionary acquisition is more expensive, then how is it that commercial firms have employed evolutionary approaches so successfully?
- Commercial firms sell products in competitive markets. Rapid improvements to products often cost more than leaving products unchanged. However, moving superior products to market faster than competitors allows commercial firms to maintain or increase sales.
- The DoD does not sell national defense. Outcompeting an adversary does result in additional revenue to compensate for the additional cost.

Future Work

- The results presented are still dependent on some particular modeling assumptions.
- The simulation treated acquired systems generically.
- We hypothesize that the cost effectiveness of evolutionary acquisition will be heavily dependent upon the type of system being acquired.
  - E.g., aircraft, ships, software systems, electronic systems, etc.
- More specifically, systems that are either more modular in design or are acquired in large numbers will be more amenable to evolutionary acquisition than systems that are tightly integrated and acquired in small numbers.

Cost Effectiveness of Spiral Development



Additional Issues

- Comparative performance
- Requirements evolution
- Rework propagation
- Concurrency
- R&D portfolio management
- Architectural modularity

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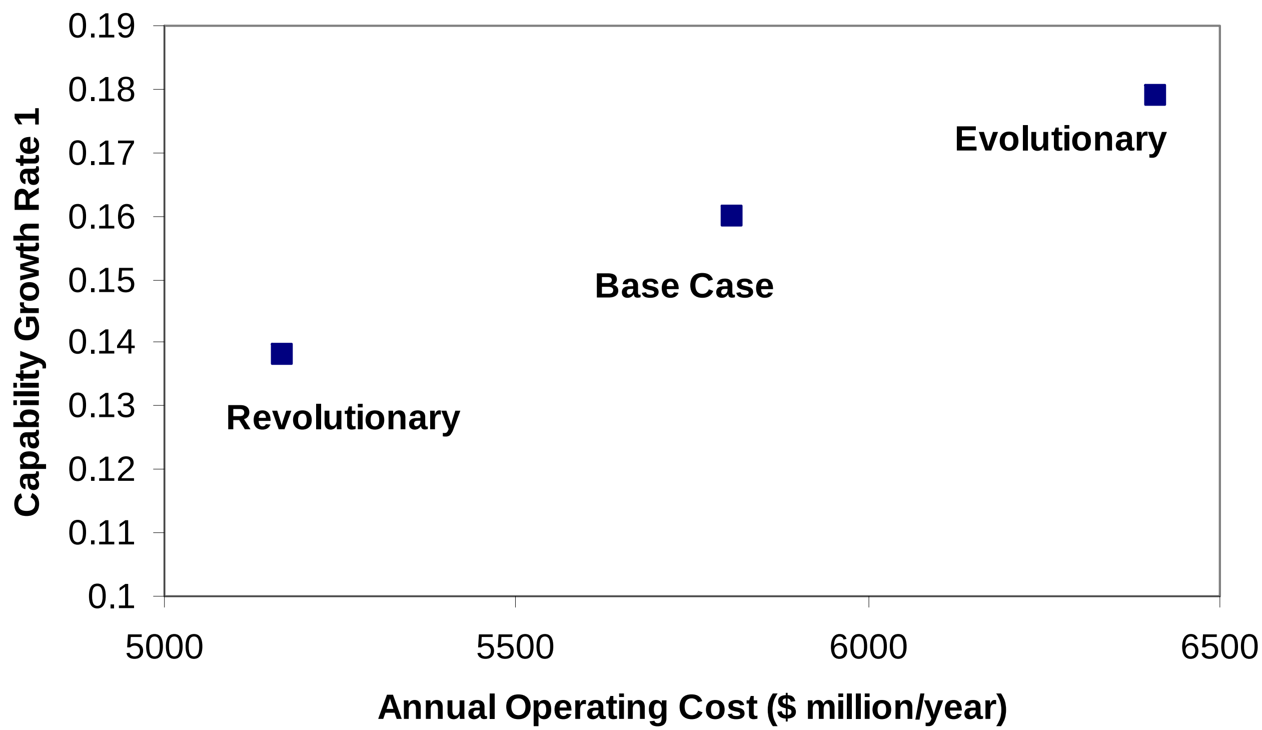
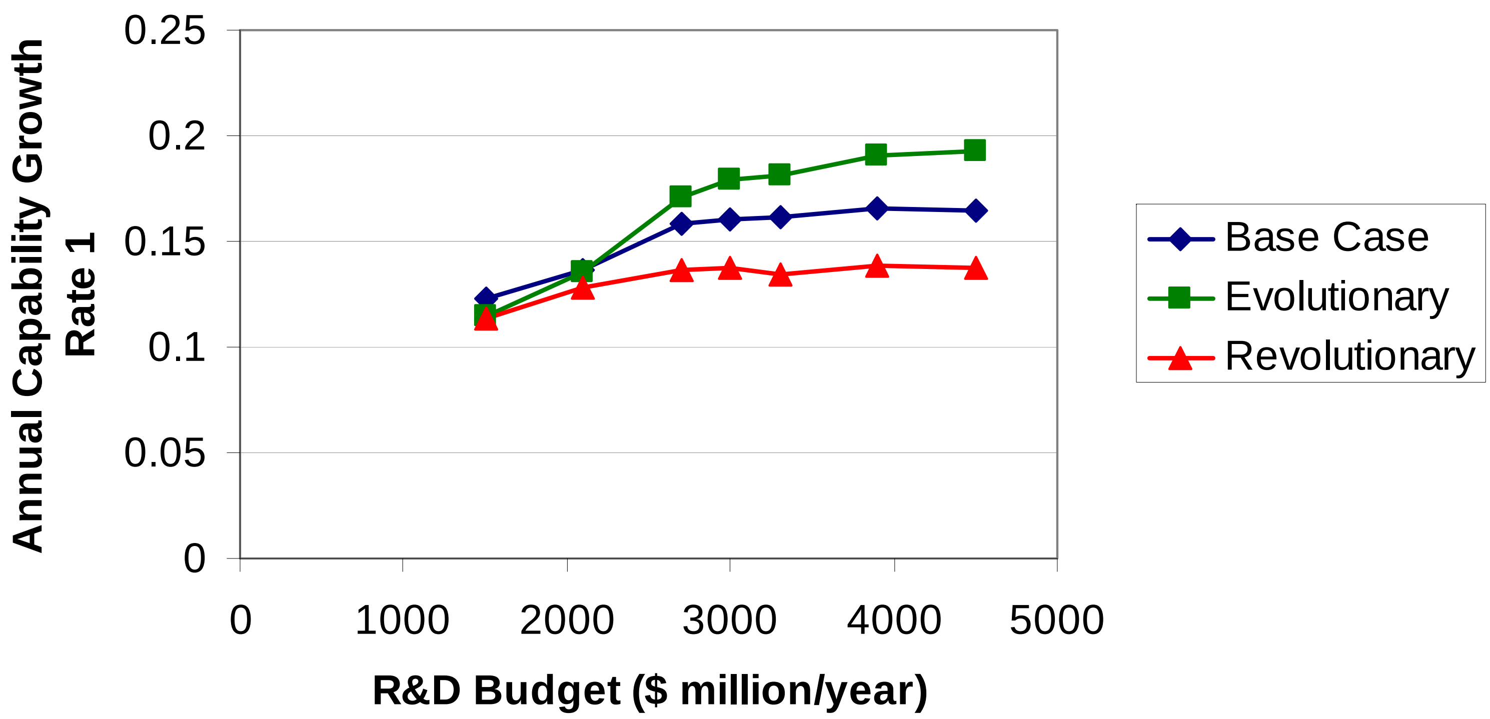
Backup

Output	Base Case	Evolutionary	Revolutionary
Total Acquisition System Operating Cost ($ million, annualized)	5807	6410	5169
Capability Growth Rate (System 1)	0.16	0.179	0.138
Program Duration (System 1, years)	14.3	11.8	17.2
Program Cost (System 1, $ million)	16091	14668	16736

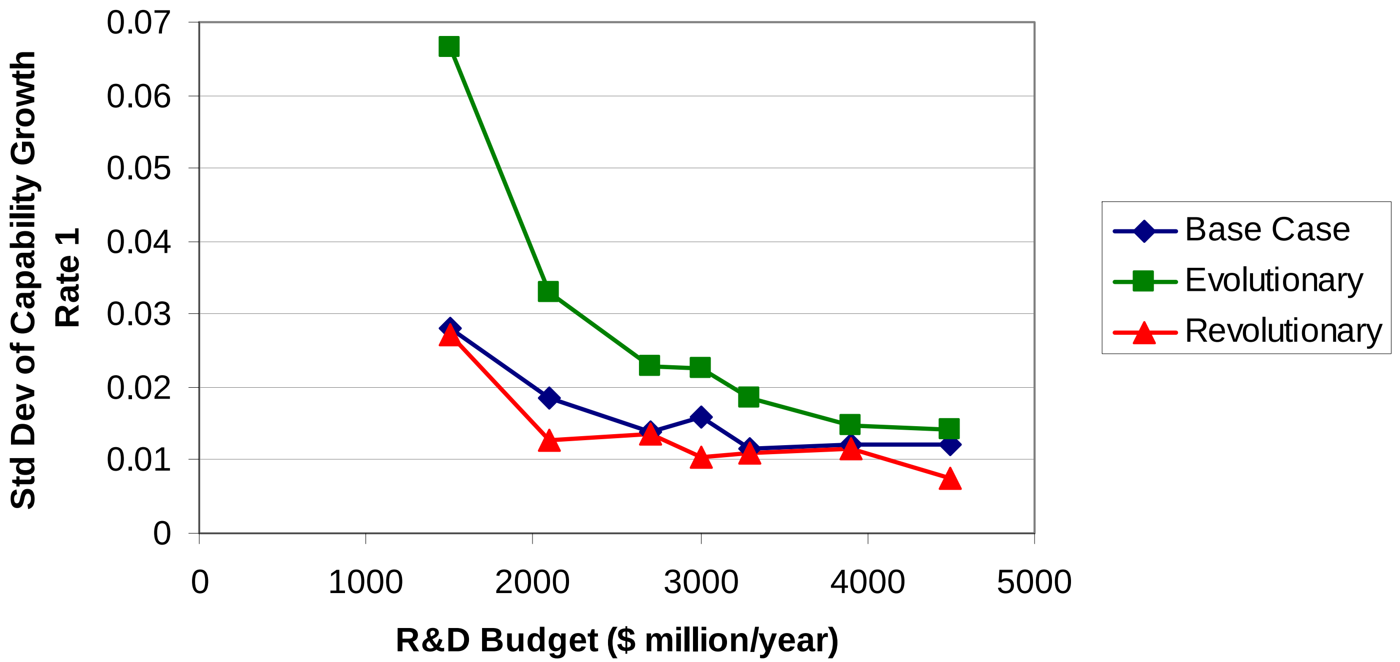
Cost/Performance Tradeoff

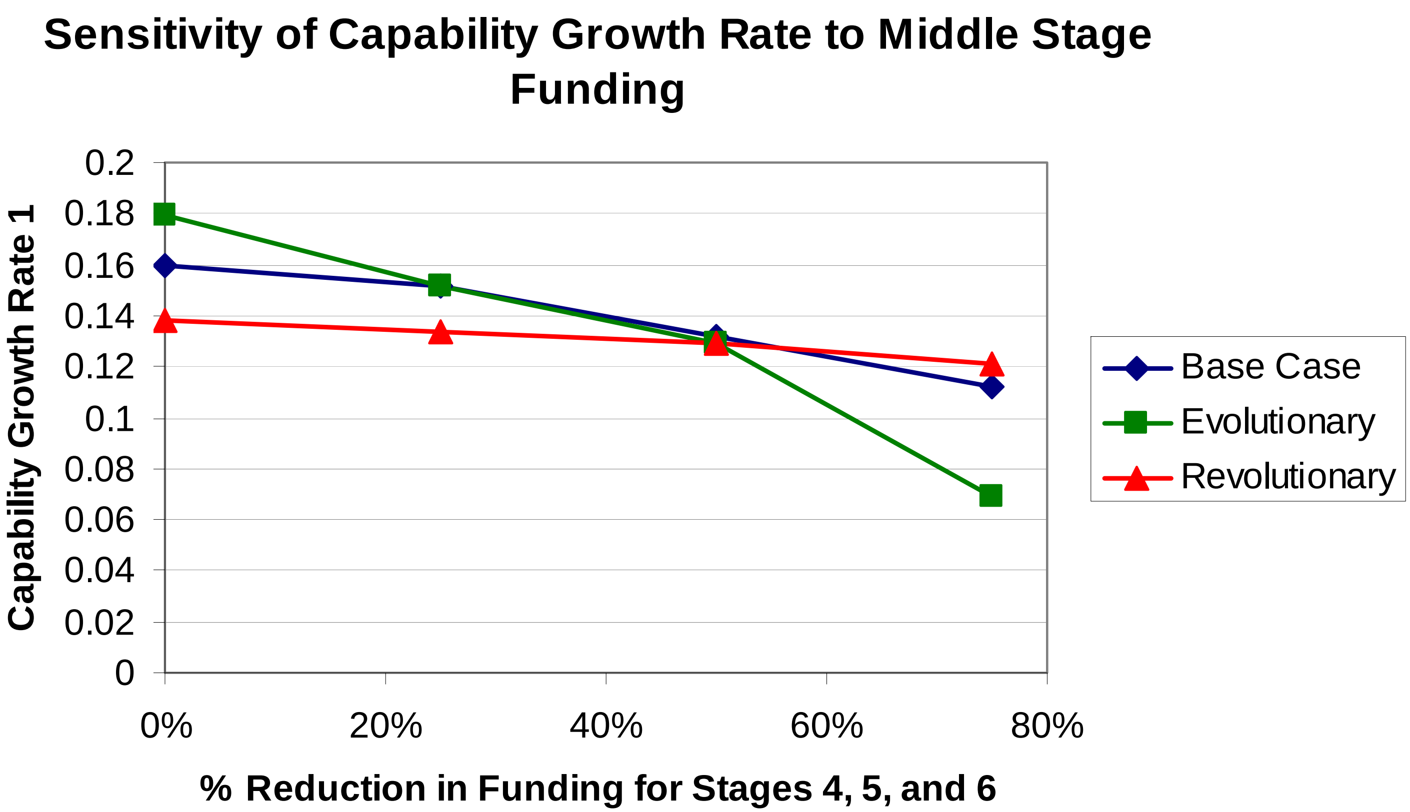


Capability Growth Rate vs R&D budget



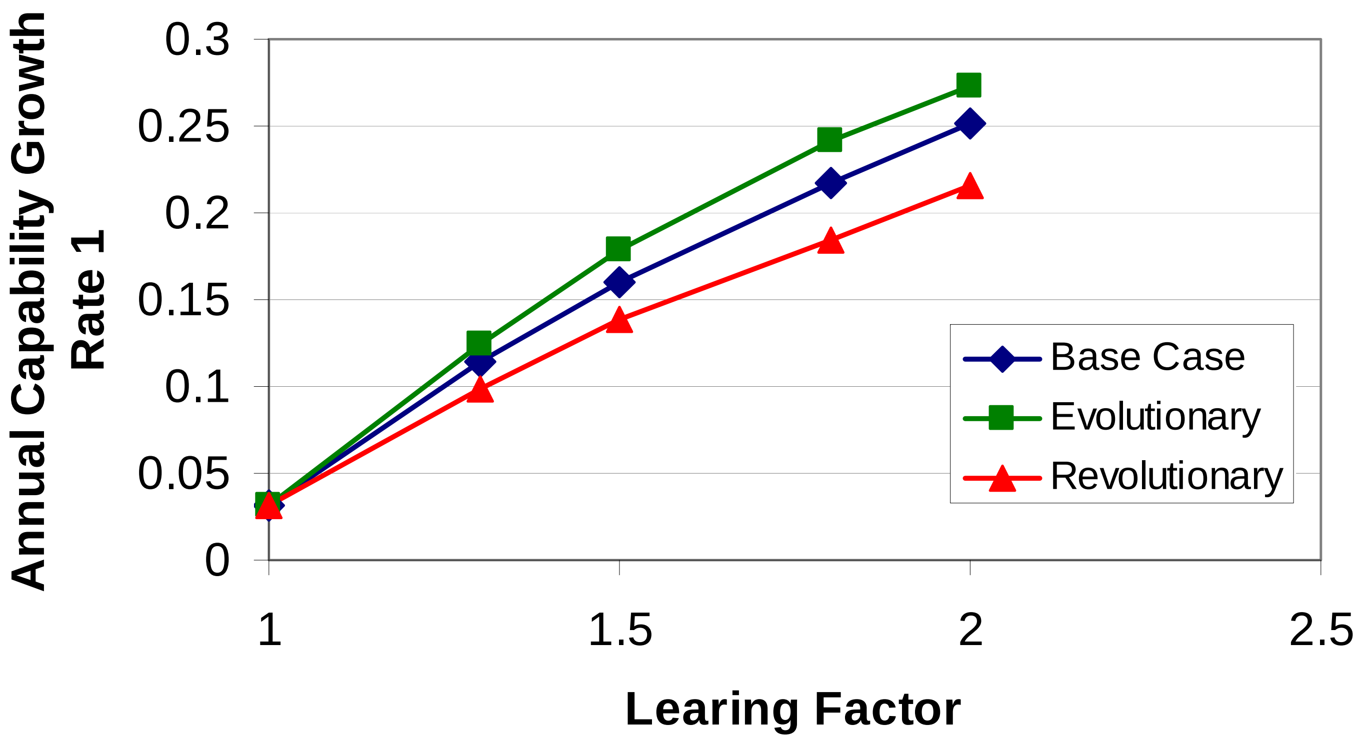
Std Dev of Capability Growth Rate vs R&D budget

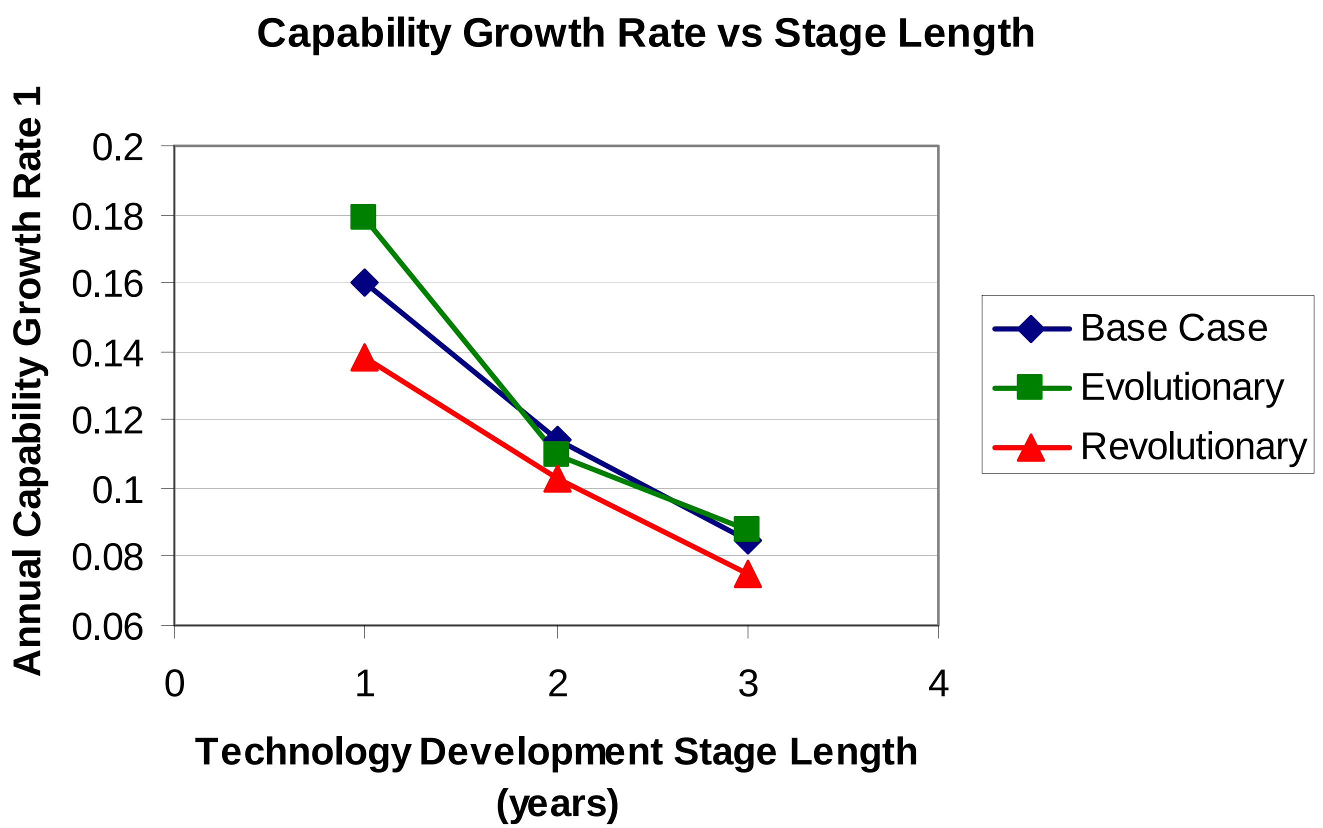




Sensitivity of Capability Growth Rate to Middle Stage Funding
Capability Growth Rate 1
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0%
20%
40%
60%
80%
% Reduction in Funding for Stages 4, 5, and 6
Base Case
Evolutionary
Revolutionary

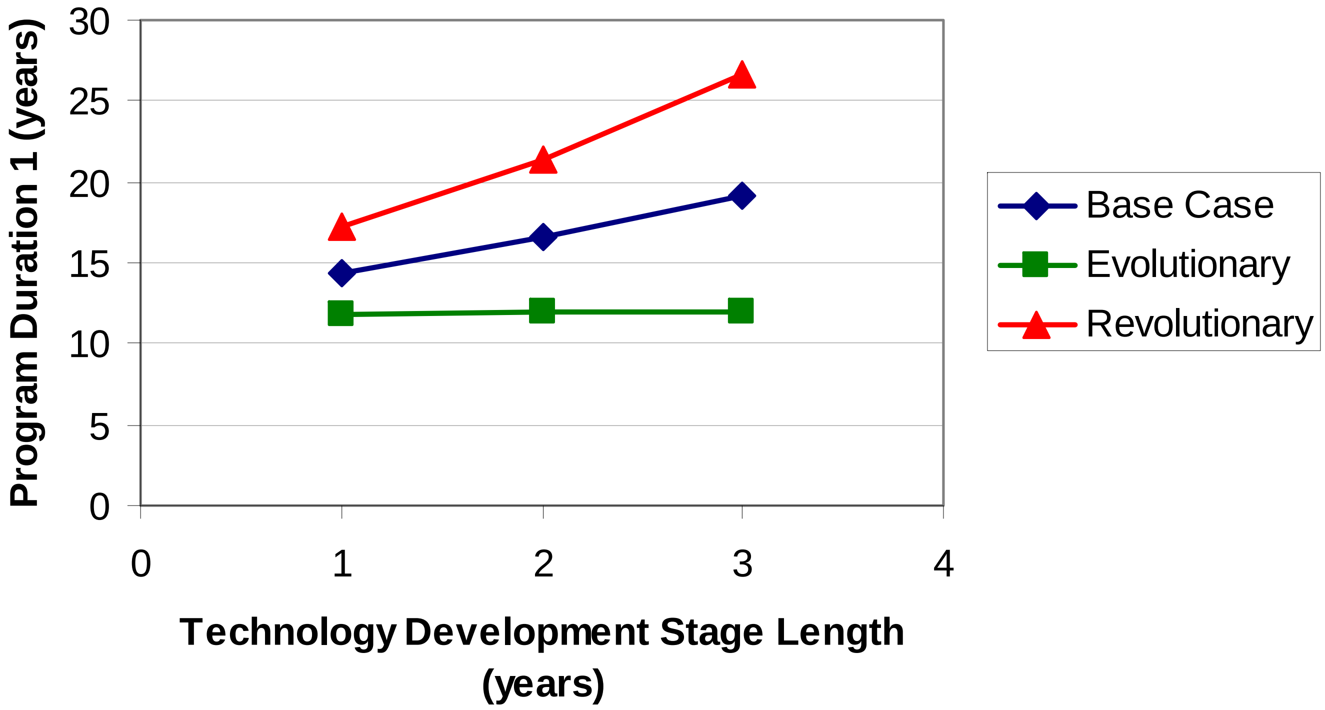
Capability Growth Rate vs Learning Factor



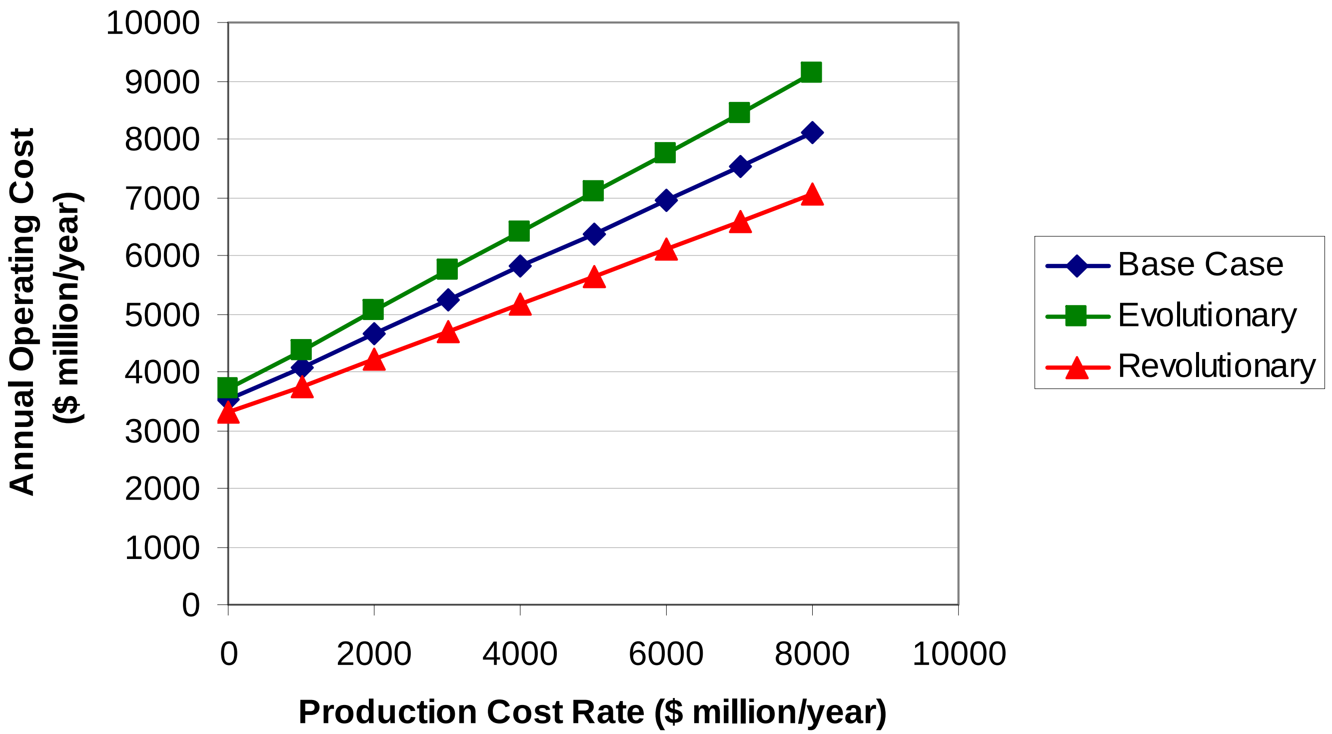


Capability Growth Rate vs Stage Length
Annual Capability Growth Rate 1
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0
1
2
3
4
Technology Development Stage Length (years)
Base Case
Evolutionary
Revolutionary

Program Duration vs Stage Length



Operating Cost vs Production Cost Rate



System Types	3
Application Area Types	6
R&D Budget ($ million per year)	3000
Intersystem Delay (years)	0
Exogenous Technology Growth Rate	0.01
Internal Learning Factor	1.5

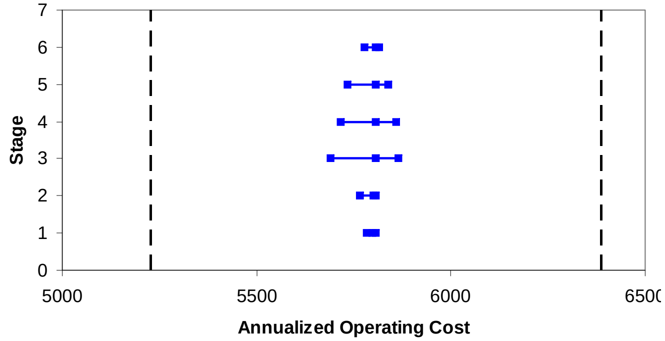
Stage	Stage Costs ($ million/year)	Stage Budgets ($ million/year)	Success Probabilities (%)	Stage Length (years)
1	1	100	50	1
2	2	100	50	1
3	10	200	50	1
4	20	200	60	1
5	200	1000	70	1
6	400	1400	80	1

	Application Areas					
Systems	**1**	**2**	**3**	**4**	**5**	**6**
1	**X**	**X**	**X**			
2				**X**	**X**	**X**
3		**X**	**X**		**X**	

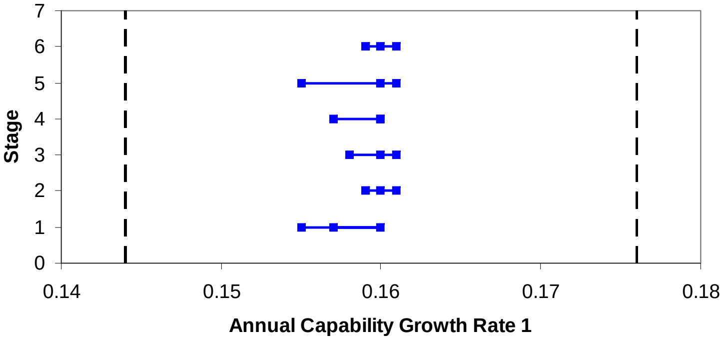
Phase Costs ($ million/year)	Phase		
System	Concept Development	System Development	Production
1	20	1000	4000
2	20	1000	4000
3	20	1000	4000

	Min	Mode	Max
Base Cost Multiplier	0.5	1	2
Performance Gain Multiplier	0.8	1	1.2
Concept Development Duration (years)	2	4.9	7.5
System Development Duration (years)	1.5	2.125	8
Production Duration (years)	1.5	2	4.7

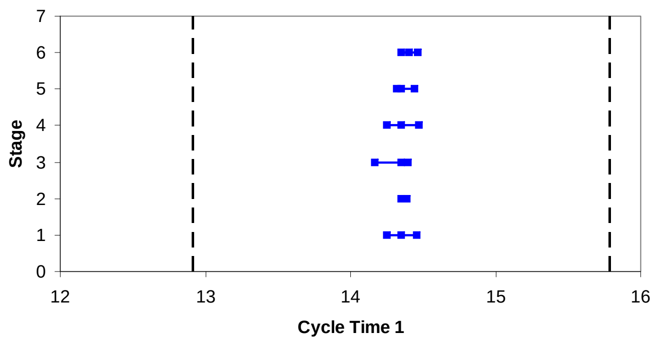
Sensitivity of Annual Cost to Staging Probabilities



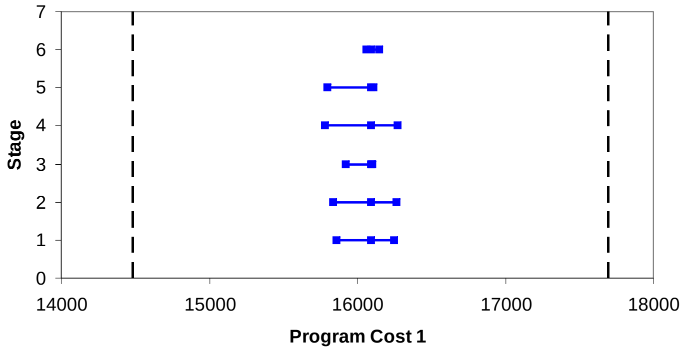
Sensitivity of Capability Growth Rate to Staging Probabilities



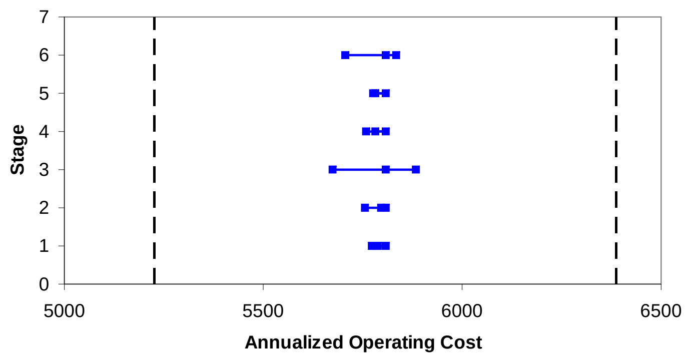
Sensitivity of Cycle Time to Staging Probabilities



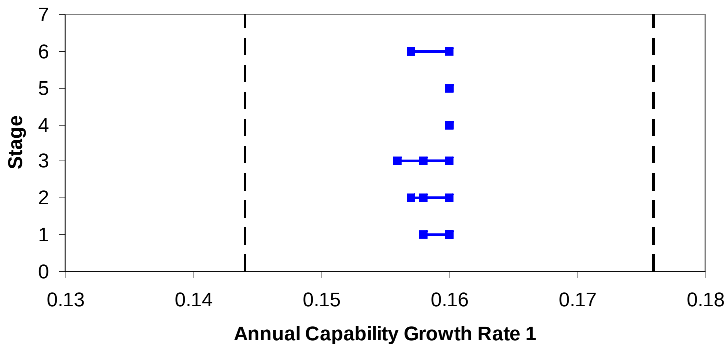
Sensitivity of Program Cost to Staging Probabilities



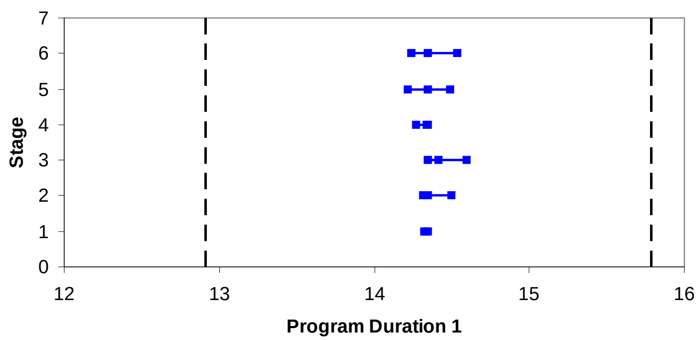
Sensitivity of Annual Cost to Stage Costs



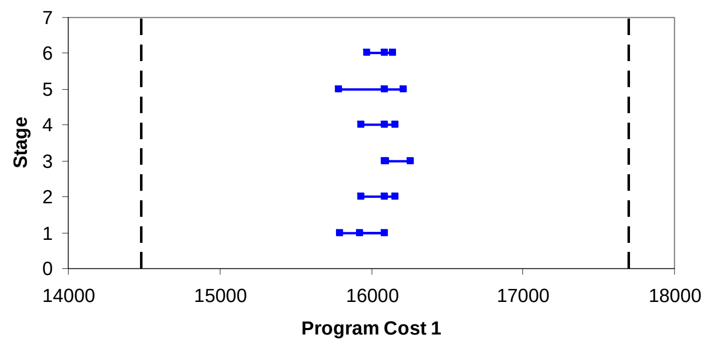
Sensitivity of Capability Growth Rate to Stage Costs



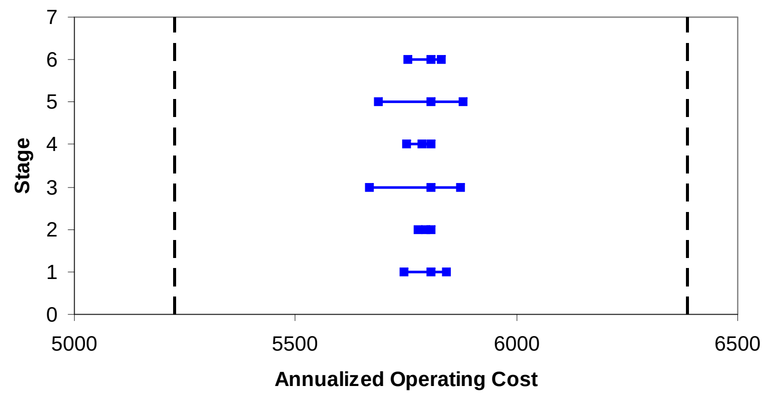
Sensitivity of Program Duration to Stage Costs



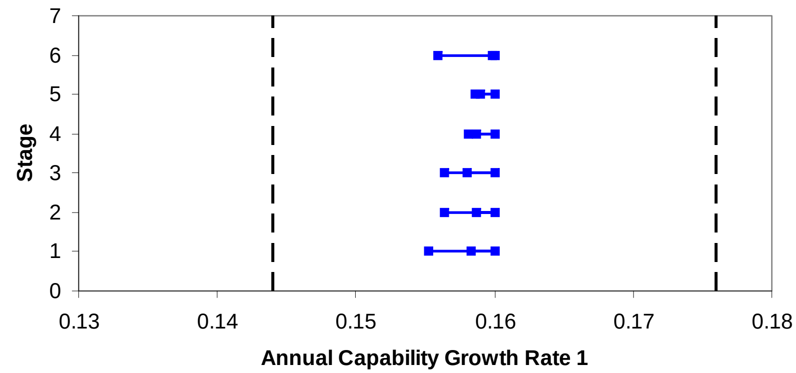
Sensitivity of Program Cost to Stage Costs



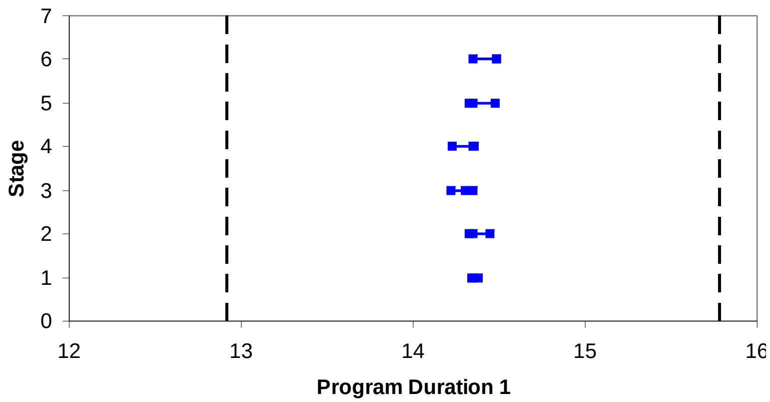
Sensitivity of Annual Cost to Stage Budgets



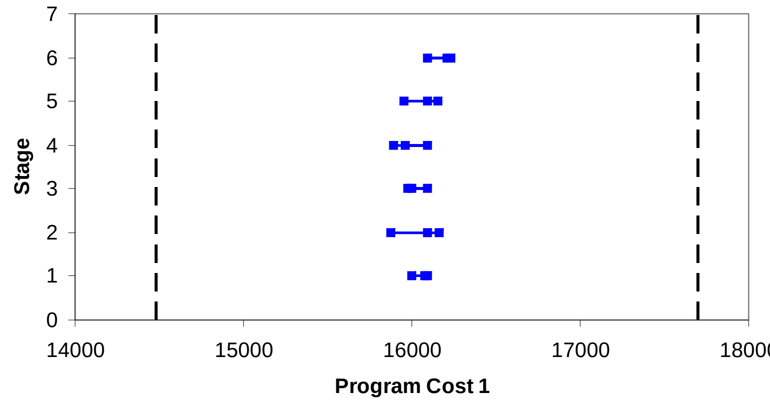
Sensitivity of Capability Growth Rate to Stage Budgets

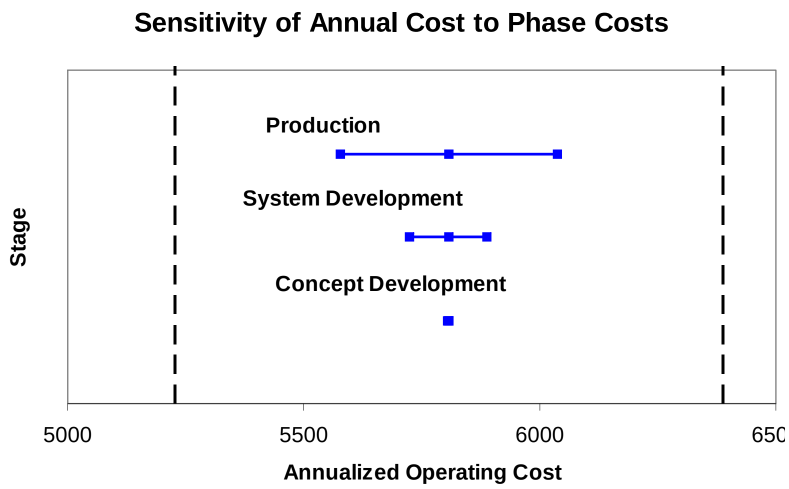


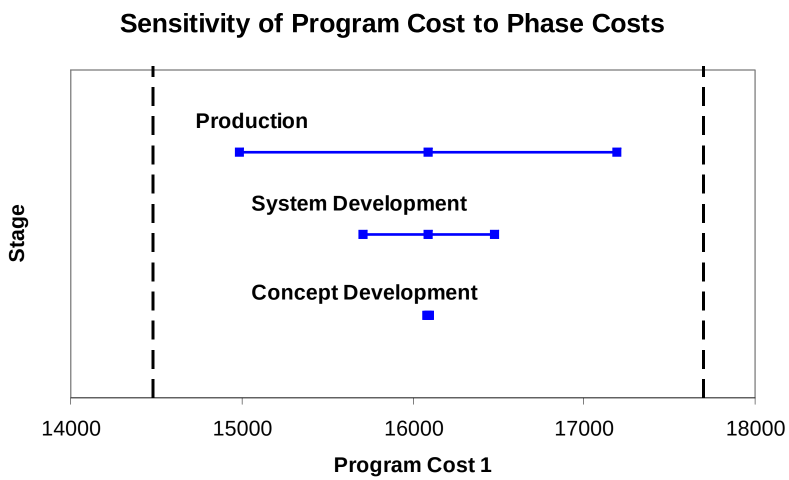
Sensitivity of Program Duration to Stage Budgets



Sensitivity of Program Cost to Stage Budgets




Sensitivity of Annual Cost to Phase Costs
Production
System Development
Concept Development
Stage
5000
5500
6000
650
Annualized Operating Cost


Sensitivity of Program Cost to Phase Costs
Production
System Development
Concept Development
Stage
14000
15000
16000
17000
18000
Program Cost 1