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Knowledge and Skills for Enterprise Transformation.

Development vs Deployment

How mature should a technology be before it is considered for inclusion in an acquisition program?

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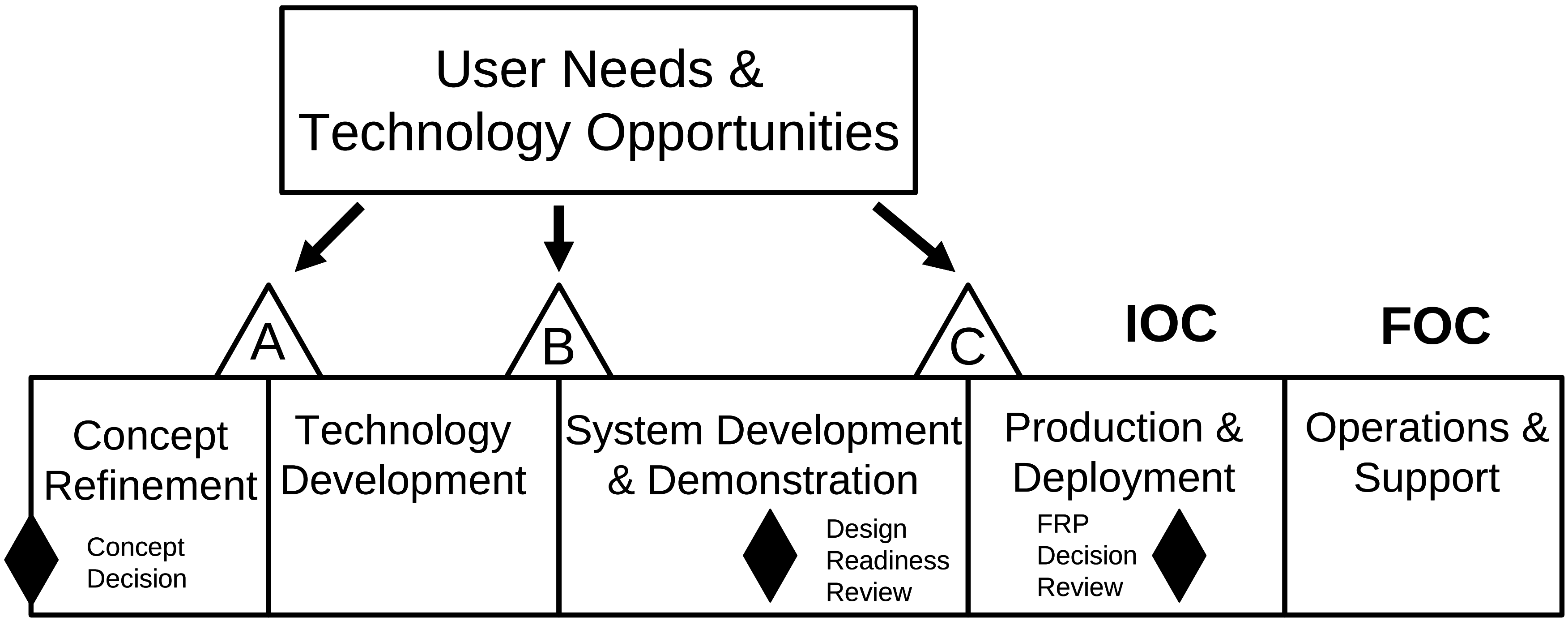
Background

- Over the past several years, the Department of Defense has attempted to reform its acquisition process by utilizing knowledge-based business practices and evolutionary acquisition.
- A knowledge-based acquisition process requires that the acquisition process be divided into phases where passage of a milestone is required to move from one phase to the next.
- To pass a milestone, program management must demonstrate that program components have reached a requisite level of maturity.

Defense Acquisition Management Framework



Revolutionary Acquisition

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- Traditional acquisition programs are often referred to as revolutionary because they attempt large leaps in capability beyond what is currently deployed.
- Achieving these large leaps in capability requires the use of promising but immature technology that tends to increase the cost and duration of an acquisition program.
- While these revolutionary leaps in capability are often achieved, it is only after substantial delays and cost overruns.
- As a consequence warfighters must make do with dated equipment for long periods.

Evolutionary Acquisition

- Evolutionary acquisition is an attempt to remedy the shortcomings of traditional, revolutionary acquisition.
- Under evolutionary acquisition, each acquisition cycle targets a modest increase in capability through the use of mature, demonstrated technology.
- Because the technology is more mature, acquisition cycle times are shorter, and as a result, systems and upgrades are fielded more quickly.
- Implementation of evolutionary acquisition requires a knowledge-based acquisition process to ensure that technology maturity requirements are met.

Motivation

- Despite the fact that the DoD acknowledges knowledge-based acquisition and evolutionary acquisition as best practices and has committed them to policy, most major acquisition programs still experience major cost overruns and schedule delays!
- The GAO reports that most DoD acquisition programs bypass milestone requirements and are revolutionary not evolutionary [GAO 2006].
- OSD admits that it is common practice to allow programs to bypass milestone requirements. It seems that every program is an exception.
- Why does this happen, and is it reasonable?

Motivation

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- There are two likely possibilities:
  - One, evolutionary acquisition is not effective. Consequently, when program managers are given flexibility, they will not employ it.
  - Two, despite the fact that evolutionary acquisition is superior, the nature of the acquisition system works against its implementation.
- To address this issue, we must consider the impact of a program's technology strategy on the level of capability actually deployed in the field.

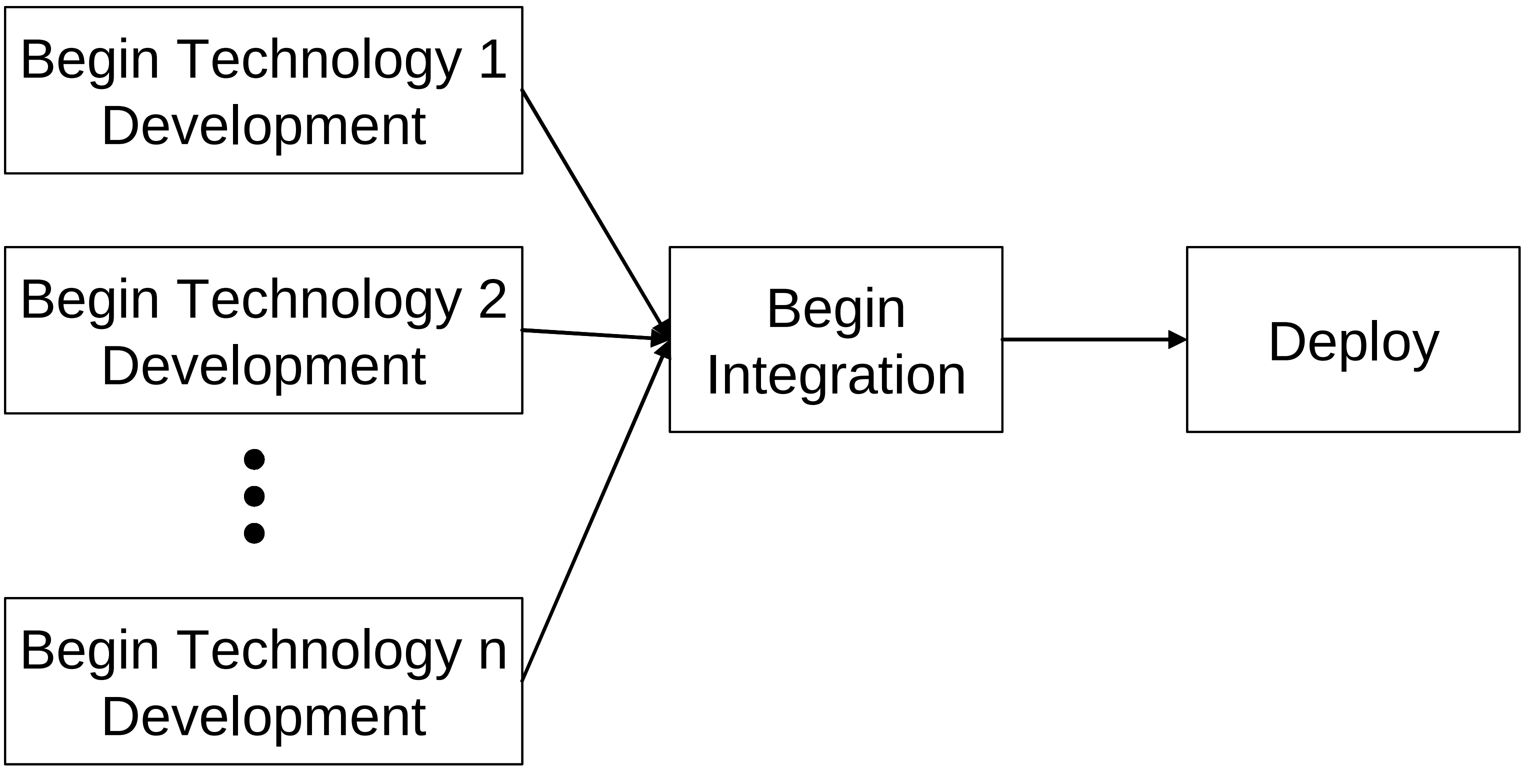
Hypothesis

- Our hypothesis is that as more advanced and hence, likely immature, technology is employed in defense acquisition programs, the length of acquisition program increases and deployment is delayed.
- Since stakeholders see increasing deployment delays, they know that they will have to make do with each deployed system for longer. Thus, they push for the most advanced technology they can get into each new system.
- This behavior exacerbates the problem and leads to even longer acquisition programs and deployment delays.

Modeling Approach

- Each acquisition program will be modeled as a PERT chart and consist of two phases, a technology development phase followed by an integration phase.
- The technology development phase matures critical technologies requisite for program success.
- The time required to develop each technology is beta distributed – a standard assumption for PERT.
- Development of multiple technologies occurs in parallel.
- All critical technologies must be fully developed before the integration phase can proceed. Thus, the time required for the technology development phase is the maximum of all realized development times.

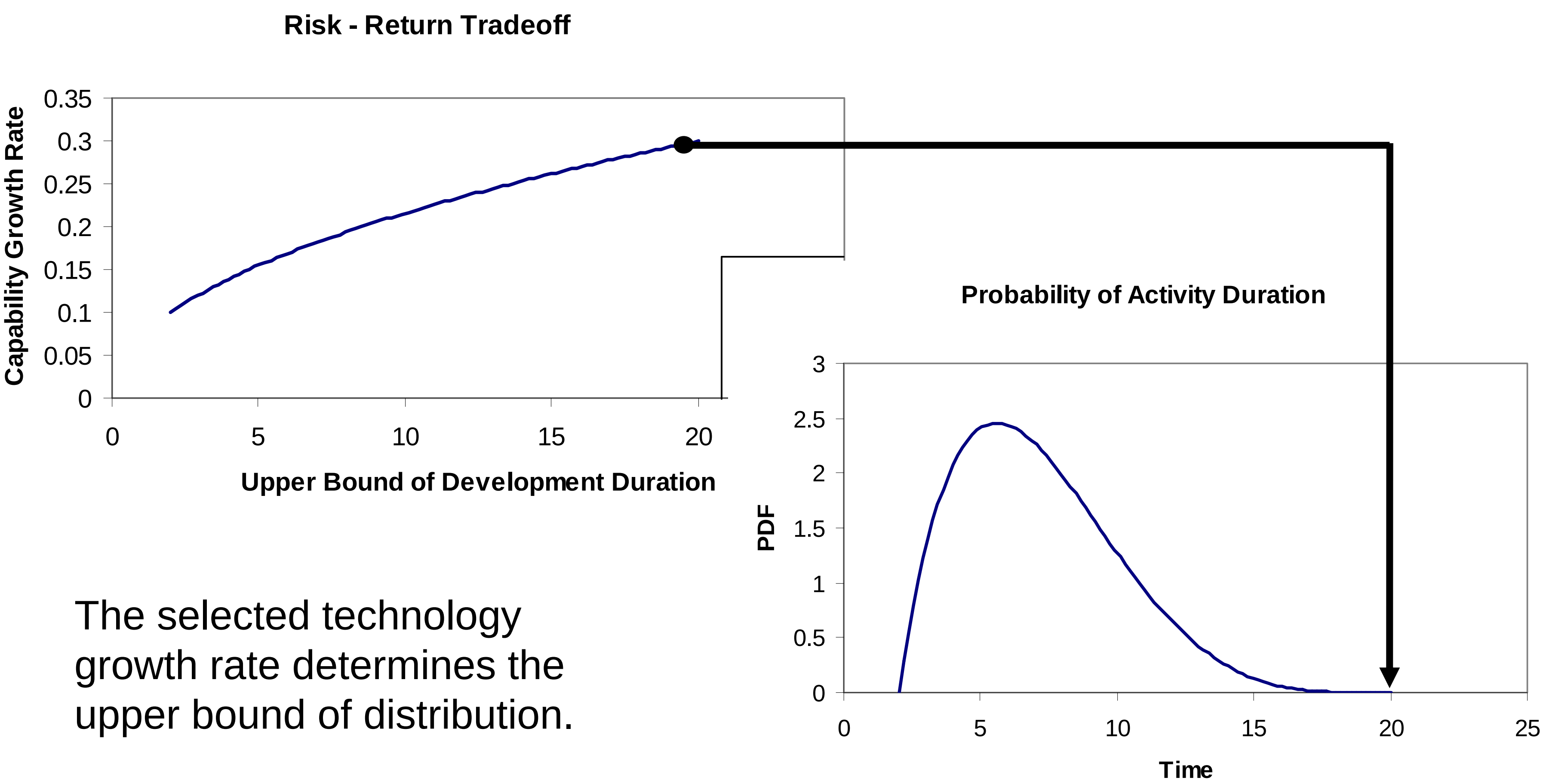
Program Structure



Modeling Approach

- A technology policy is the set of technologies selected for each acquisition program.
- Generally speaking, these technologies are selected to achieve targeted increases in capability beyond the currently deployed system.
- More aggressive capability targets require more immature technologies and, consequently, more risk.
- We can characterize a technology policy as a percent increase in capability beyond the currently deployed system.
- As we accept additional schedule risk, we receive a diminishing return in capability.
- This behavior is modeled by increasing the upper bound of the distribution for technology development.

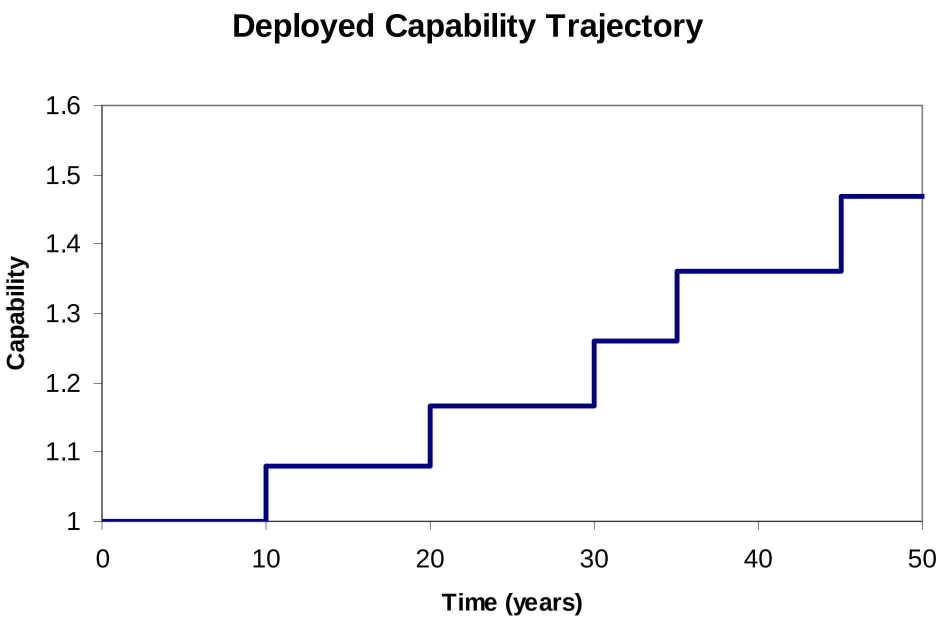
Modeling Approach



The selected technology growth rate determines the upper bound of distribution.

Modeling Approach

- For a selected technology policy, Monte Carlo simulation is used to determine the outcome of that policy over several acquisition cycles.
- The discrete nature of acquisition results in a stair step capability trajectory.
- The efficacy of a technology policy is measured via the average deployed capability.

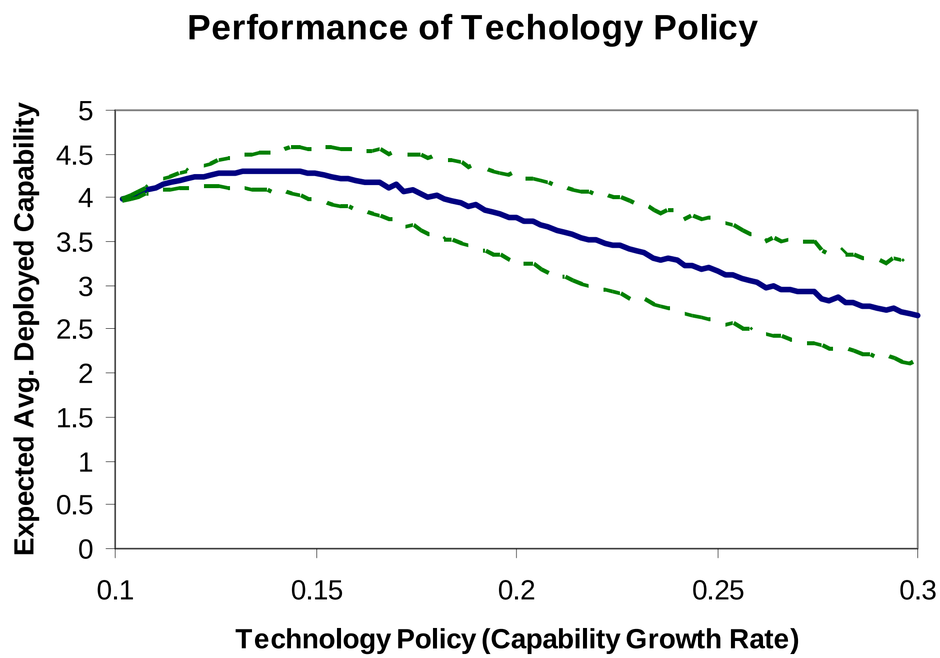


Modeling Approach

- Iterating over many sample paths provides the expected performance of the policy.
- The question then is what is the technology policy that maximizes the average deployed capability?
- First, we will consider the case where the acquisition program depends on only one critical technology.
- We allow the decision maker to choose a capability increase between 10% and 30%, and we evaluate deployed capability over a 50 year horizon. Initially, we will assume that the integration phase of the program is instantaneous, and the starting capability is normalized to one.

Single Technology

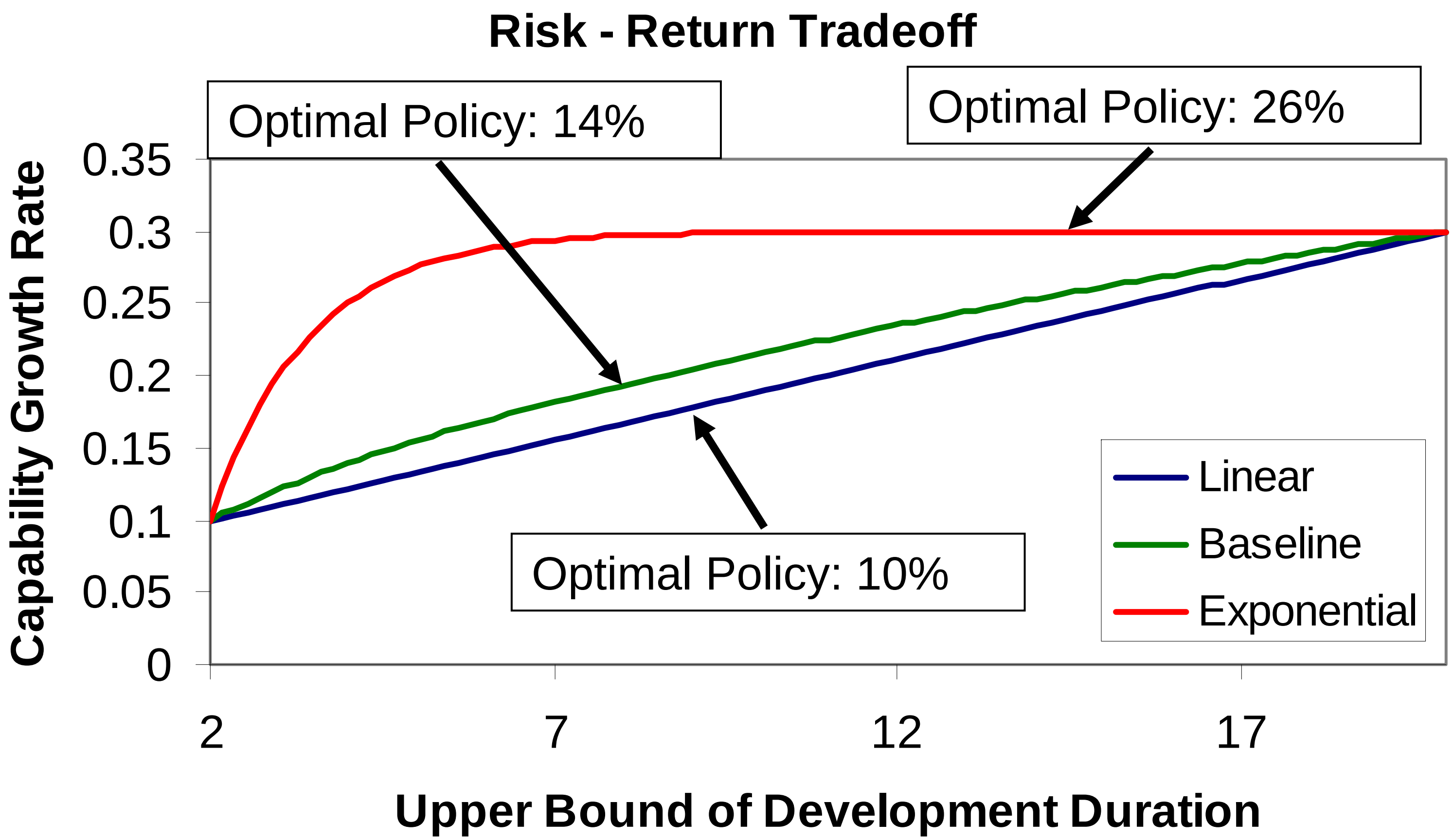
- We see that the maximum average deployed capability is achieved with a relatively modest policy of 14% which results in an average deployed capability of 4.31.



Single Technology

- This example suggests that an aggressive technology policy just increases the cycle time and actually reduces average deployed capability.
- Is the result robust?
- If we increase integration time to 2 years, the optimal policy increases to 20%. Thus, the addition of overhead increases the optimal capability increment.
- What about the risk-return tradeoff?

Single Technology



Two Technologies

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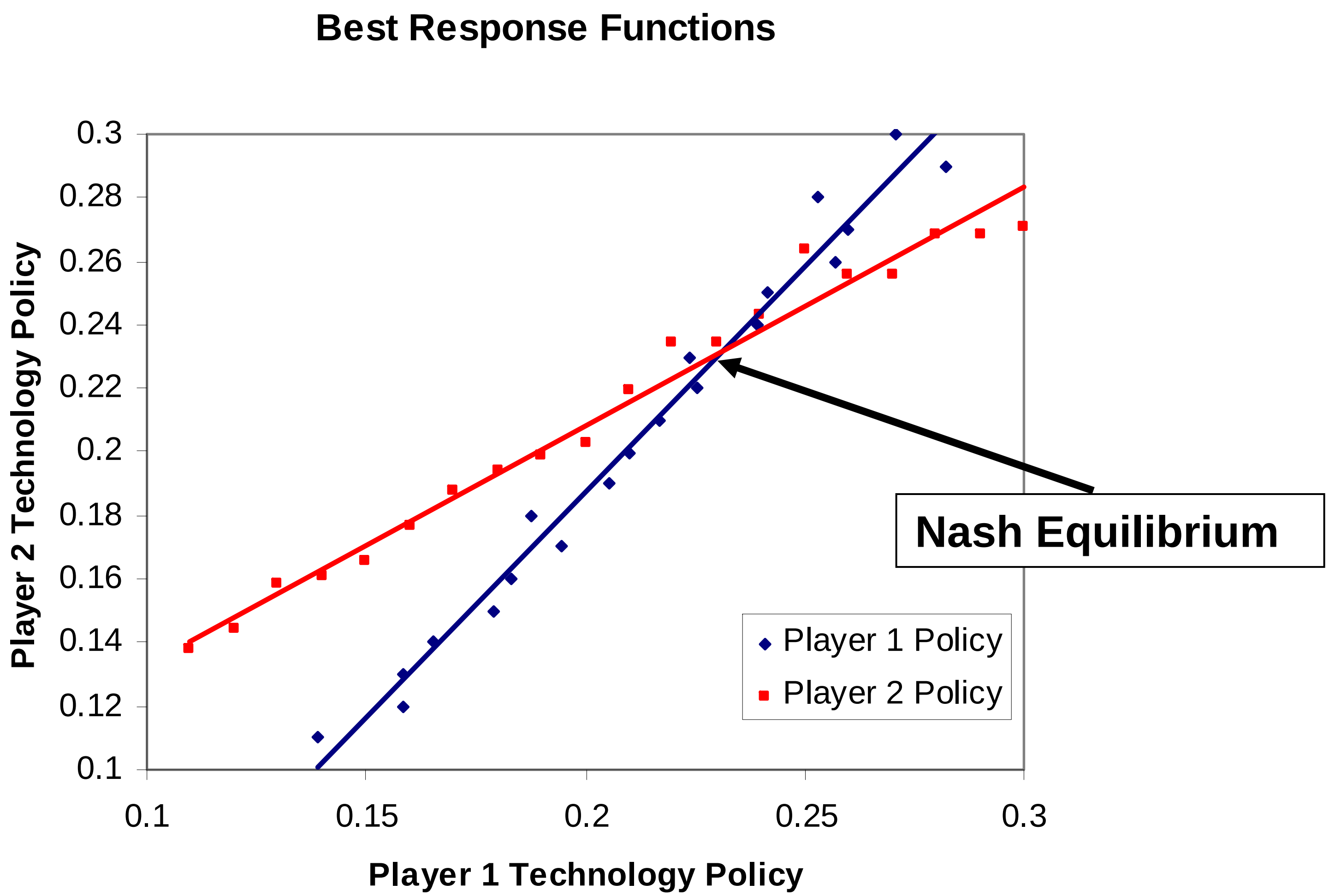
- Now we will assume that the system being acquired provides more than one capability. (e.g., a multi-mission surface combatant).
- Initially, we will assume that the system provides two capabilities each derived from a different critical technology.
- We assume that the stakeholders for each mission want to maximize the capability that will be available to their mission in the future.
  - Subsurface warfare wants the best anti-sub technology
  - Air warfare wants the best anti-aircraft technology.
- We will use game theory to analyze their behavior.

Best Response



Two Technologies

- We find that the two stakeholders exhibit reciprocating competition. That means that as each stakeholder raises his capability target, the best response of the other stakeholder is to raise his capability target as well.
- The result is that the Nash equilibrium is for both stakeholders to target a 23% increase in capability for each acquisition cycle and expect an average deployed capability of 2.7 for both.
- This is a significant decline from the optimal single stakeholder policy that resulted in an average deployed capability of 4.31.

Two Technologies

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- Why does this happen?
- Basically, if one stakeholder increases his targeted capability, the expectation of the other stakeholder is that the cycle time will increase, and he will have to wait longer for his relatively modest increase in capability.
- Since the stakeholder is going to have to wait, he might as well increase his target capability to compensate for the increased waiting time.
- This, of course, increases the cycle time and creates a feedback effect.

Two Technologies

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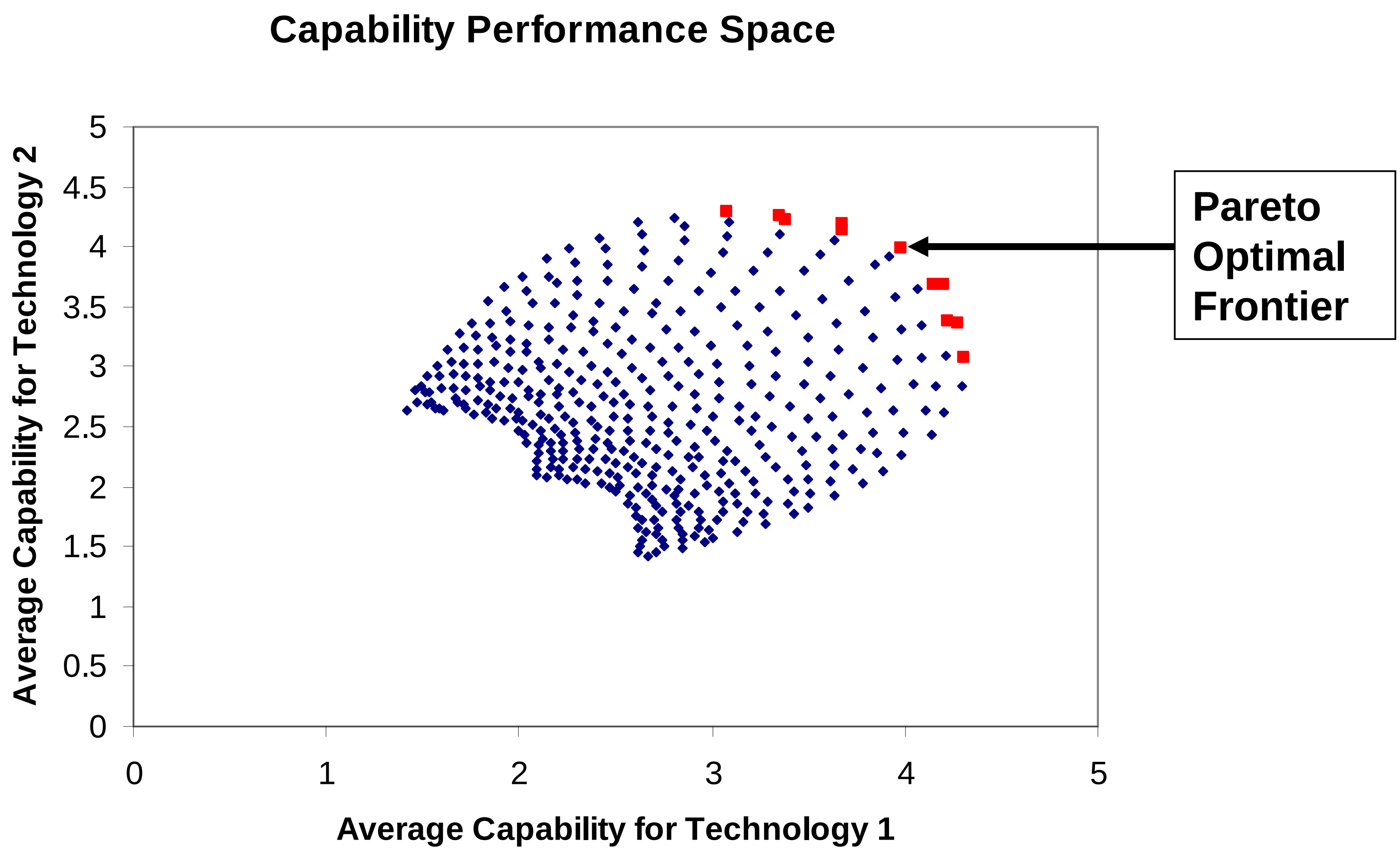
- This result seems to conform with the behavior we see in defense acquisition where programs are burdened with multiple, immature technologies.
- But what would happen if there was better coordination and consideration of overall program risk?
- We would need to look for the Pareto optimal frontier of technology policies.

Two Technology Performance Space



Two Technologies

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- On the Pareto optimal frontier, the capability goals are much more moderate, and one capability can be traded to improve another.
- For comparison purposes, the Pareto optimal symmetric solution is to target a 12% increase in capability for both areas and achieve an average deployed capability of 3.99 for each.
- This not quite as good as for the single technology case, but it is much better than the competitive case.
- This reveals that there is a price to be paid for packaging multiple capabilities into a single system.

Policy Comparison

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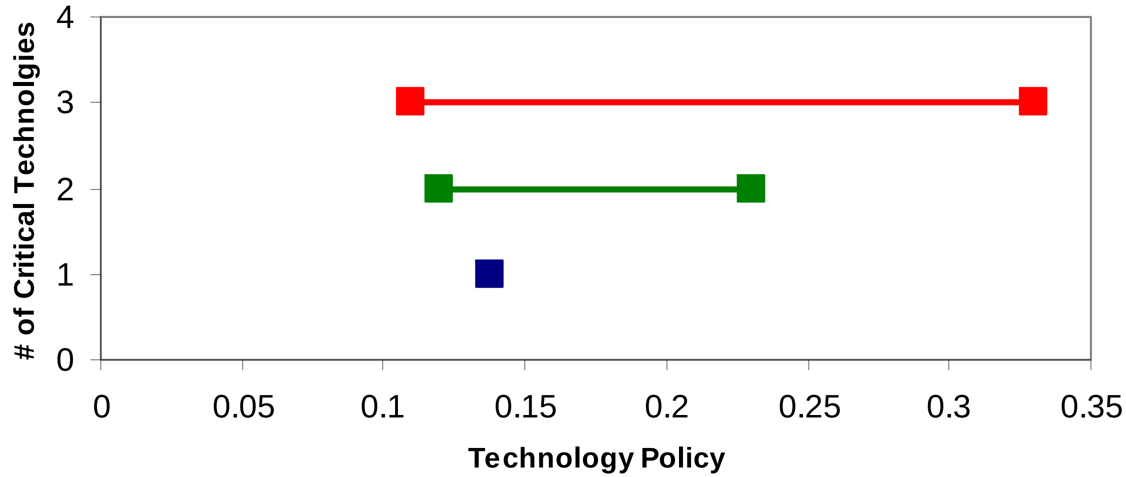
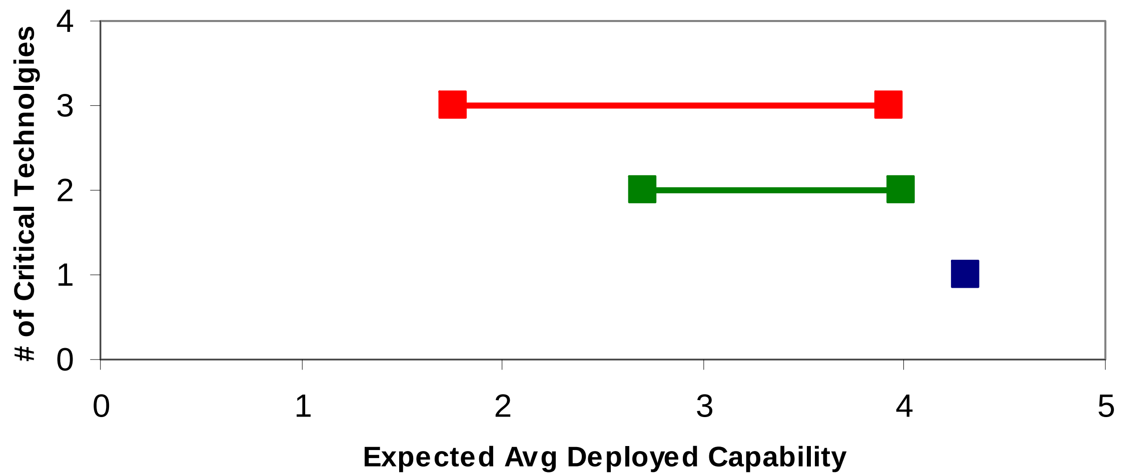
Coordinated



Competitive

Competitive



Coordinated

Sensitivity

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For two critical technologies:

Excursion	Policy	Performance
2 year integration – Competitive	29%	1.78
2 year integration – Cooperative	18%	2.05
Exponential – Competitive	27%	11.7
Exponential – Cooperative	24%	12.74

Conclusions

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- Evolutionary acquisition is likely superior to revolutionary acquisition from a performance standpoint.
  – The optimal magnitude of an evolutionary step depends upon the both the acquisition system and system being acquired.
- The increased emphasis on multi-mission platforms creates a tension between competing missions and capabilities as some capability must be sacrificed relative to a specialized system.
- Consequently, evolutionary acquisition results in an unstable technology policy that incentivizes stakeholders to deviate from that policy.
- DoD cannot expect voluntary compliance!

References

GAO (2006b), *Defense Acquisitions: Major Weapon Systems Continue to Experience Cost and Schedule Problems under DOD's Revised Policy*, GAO-06-368, Washington, D.C., April 13, 2006.