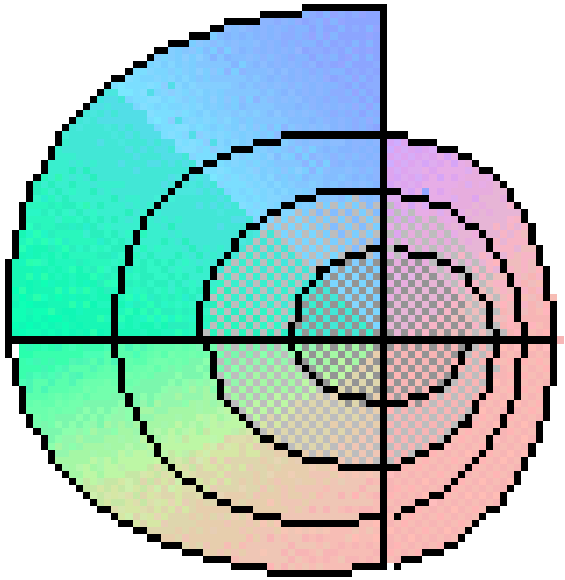
Evolutionary Acquisition and Cost Estimation



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Session Topics

- Definitions and Background
- Spiral Development of Systems
- Cost Estimation Approaches
- Estimating Under Uncertainty
- Technology Cycles and Life Cycle Planning
- User Issues

Evolutionary Acquisition

Evolutionary acquisition is DoD's preferred strategy for rapid acquisition of mature technology for the user. An evolutionary approach delivers capability in increments, recognizing, up front, the need for future capability improvements. The success of the strategy depends on the consistent and continuous definition of requirements and the maturation of technologies that lead to disciplined development and production of systems that provide increasing capability towards a materiel concept.

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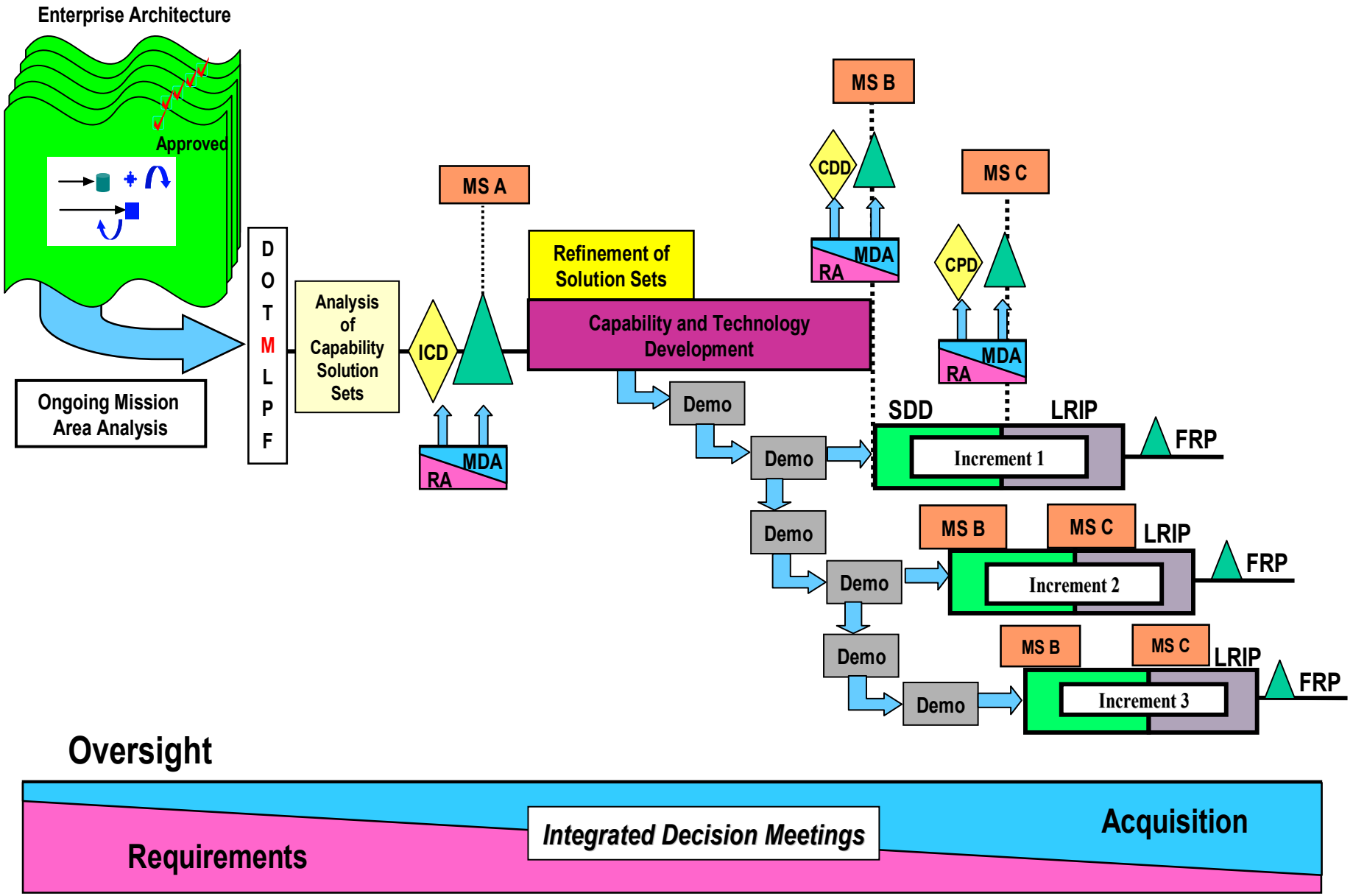
Requirements/Acquisition Process



Evolutionary Acquisition Characteristics

- General description of desired full system functional capability
- Concise statement of full system operational concepts
- Flexible overall architecture allowing incremental design
  - Use of Open Systems Architecture is one method
- Plan to incrementally achieve desired total capability
- Early definition, funding, development, testing, supporting and operational evaluation of initial increment of operational capability
- Continual dialogue and feedback among users, developers, supporters and testers

Relationship of EA to SD and ID

- Evolutionary Acquisition is an *acquisition strategy*
- Spiral Development and Incremental Development are *development processes* or *methodologies* in which a product is developed and acquired in increments vice the complete system.
  - Which process is used depends on whether the requirements are known up front.

Incremental Development

- Incremental Development (ID) definition
  - In this process, a desired capability is identified, **an end-state requirement is known**, and that requirement is met over time by development of several increments, each dependent on available mature technology.

[Emphasis added]

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Incremental Development Example

- F/A-18 E/F Super Hornet
  - Low Risk Approach
    - Immature technologies deferred to later increments
  - Allowed earlier delivery of initial system
  - P3I Improvements
    - Advanced Tactical FLIR
    - Active Electronically Scanned Radar
    - Helmet Mounted Cueing System
    - Engines Upgrade
    - Integrated Defense Electronic Countermeasures

Spiral Development

- Spiral Development (SD) definition
  - In this process, a desired capability is identified, but **the end-state requirements are not known at program initiation**. Those requirements are refined through demonstration and risk management; there is continuous user feedback; and each increment provides the user the best possible capability. The requirements for future increments depend on feedback from users and technology maturation.

[Emphasis added]

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Spiral Development Example

- Predator UAV
  - Developed by CIA
  - Initial requirement for unmanned aircraft to provide real-time reconnaissance
  - As a result of operational use, new requirement to strike time critical targets
    - Armed with Hellfire missile
    - Can carry laser designator
  - Further improvements in work as the result of operational feedback are improved engines, sensors and increased payload
  - Lessons learned from Iraqi Freedom?

Major difference is that requirements for upgrades were generated by feedback from operational use

Advantages of Spiral Development

- Spiral development is designed to be more responsive to user needs
  - Shorten turn around time for emergent user needs
  - Focus on the most critical user needs at the current time
  - Avoid developing things the user may have thought they needed, but later discovered were not that critical.

Spiral Development Background

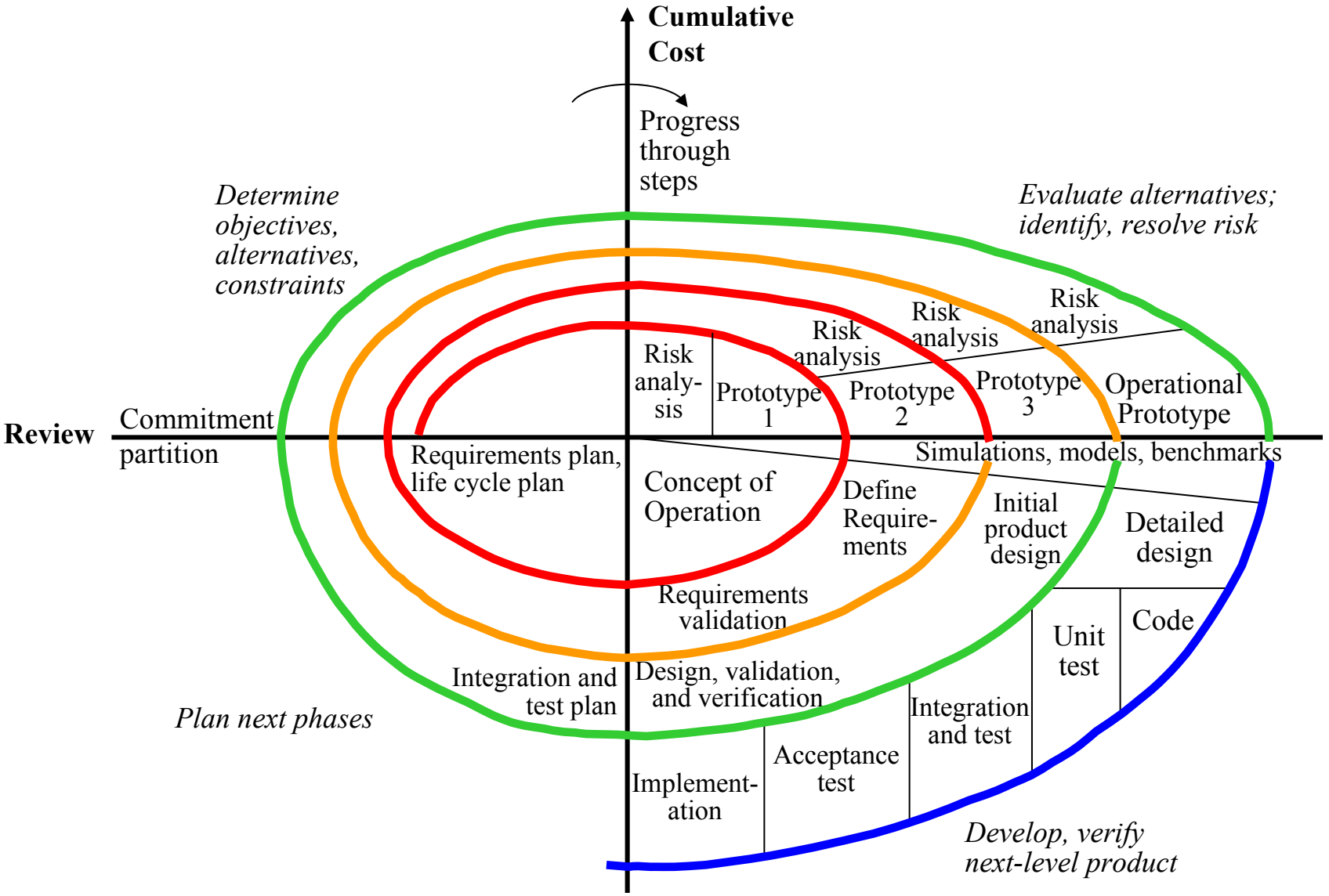
- First articulated by Barry Boehm in1988
  - Generally accepted, recently refined:

"The Spiral Development Model is a **risk-driven** process model generator for guiding **multi-stakeholder** concurrent engineering of software-intensive systems. Its distinguishing features include a **cyclic approach** for **incrementally** growing a system's degree of definition and implementation, and a set of **anchor point** milestones for ensuring feasibility of the incremental definitions and implementations"--Boehm, *"Spiral Development - Experience and Implementation Challenges",* CMU/SEI-2000-SR-006 February 9-11, 2000, Page 9.

[Emphasis added]

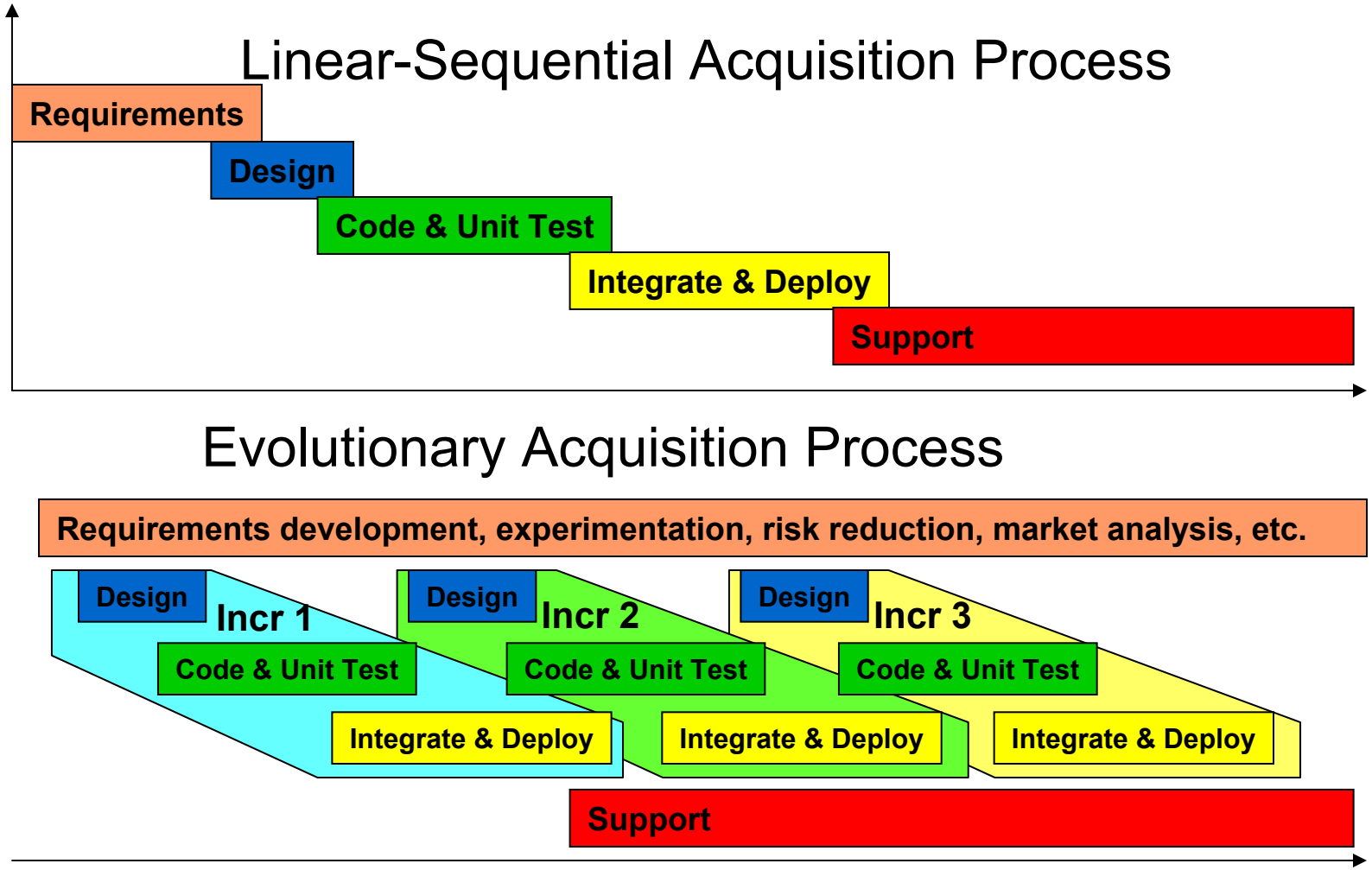
  - Spiral Development came out of the software community as a response to the high number of large software development failures

Spiral Development Model*

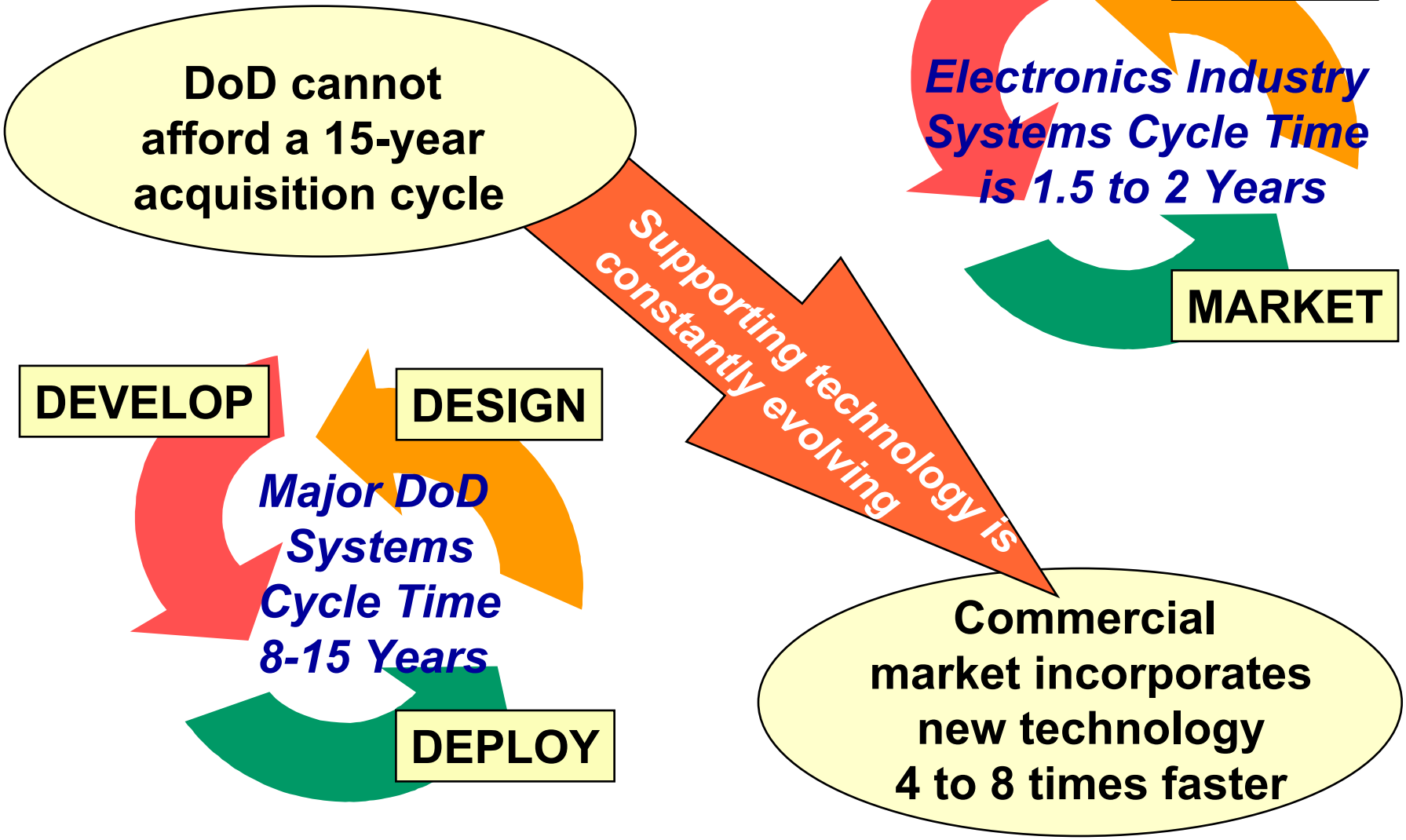


*Reference: "The Spiral Model as a Tool for Evolutionary Acquisition" Crosstalk -The Journal of Defense Software Engineering, May 2001; Dr. Barry Boehm

Evolutionary Acquisition versus Linear-Sequential Acquisition



Why Do We Need To Cut Cycle Time?



Evolutionary Cost Challenges

- Cost Estimation
  - Difficult to estimate the cost when requirements and technologies are evolving
  - How much will the full capability cost?
  - Color of money
    - Parts of the system may be in development, production, operations and support simultaneously
- Funding stability
  - Commitment to follow-on blocks
- Full funding policy

Fundamentals of EA/SD Cost Behavior

- EA & SD do not avoid the cost of requirements and technology change over the system development cycle
- EA & SD require a substantial investment in process management, with attendant overhead costs
- EA & SD program measures may depart significantly from traditional software measures
  - Productivity measures
  - Expenditure profiles (colors of money)

Cost Implications of Spiral Development

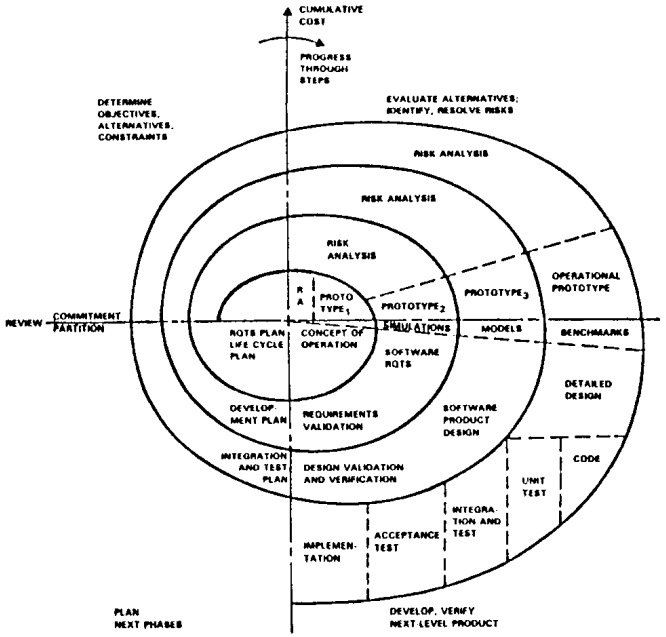
- First, understand the expected output
  - Full-up product, or define/refine requirements
  - For both instances, effort is expended and costs are incurred for non-deliverable interim products
- Second, understand the process
  - What resources are committed to each spiral?
  - What are the exit criteria for each spiral?
  - How many iterations are expected for a given set of functionality?
- Then, tailor the estimating methodology to the product and process
  - No school book solutions--Sorry.

Estimating SD: Possible Approaches

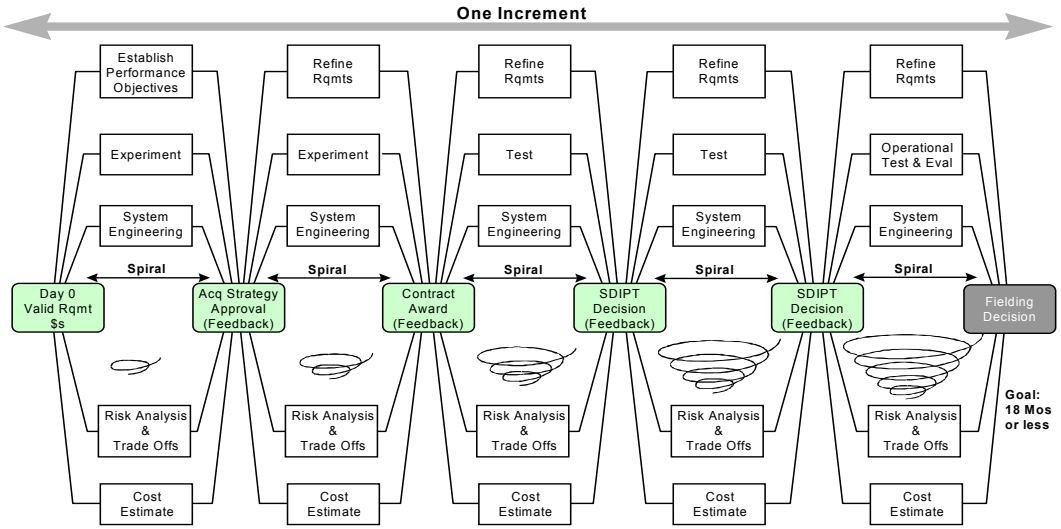
- Approach 1:
  - Start with size estimate of final delivered product; Crank in a scale factor for each spiral [e.g. Prototype LOC = DSI (0.3+0.6+0.9+1.0)],
  - Assume reuse ratios for each spiral.
- Approach 2:
  - "Unroll" the spiral (see diagram on chart 8), and estimate the effort/cost of each element and activity.
- Approach 3:
  - If SD is only used for risk reduction (no deliverable software)
  - Assume Level-of-effort (# staff months times development duration).
- Use these in combination to cross-check

Spiral Model

A: Boehm's Spiral Model



B: The "Uncoiled" Spiral

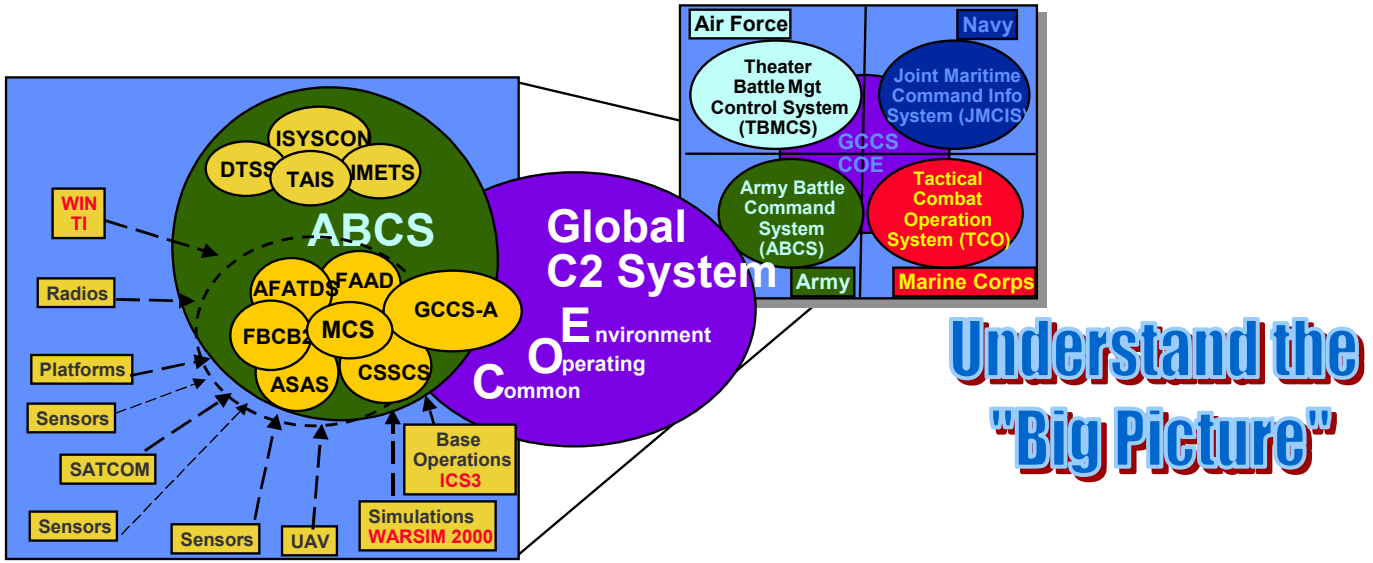


A: Boehm, B., "A Spiral Model of Software Development and Enhancement." *IEEE Computer* (May 1988): 61-72

B: McNutt, R., "Reducing Air Force Acquisition Response Times: Evolutionary Acquisition and Spiral Development U.S. Air Force Briefing, 13 Sept 2000

Estimating EA: Overall Considerations

- Look at overall requirements to scope program magnitude
  - ORD/CRD
  - Domain Engineering
  - System Architecture Analysis
  - Key interfaces
- Apply ROM "Rules of Thumb" for a sanity check



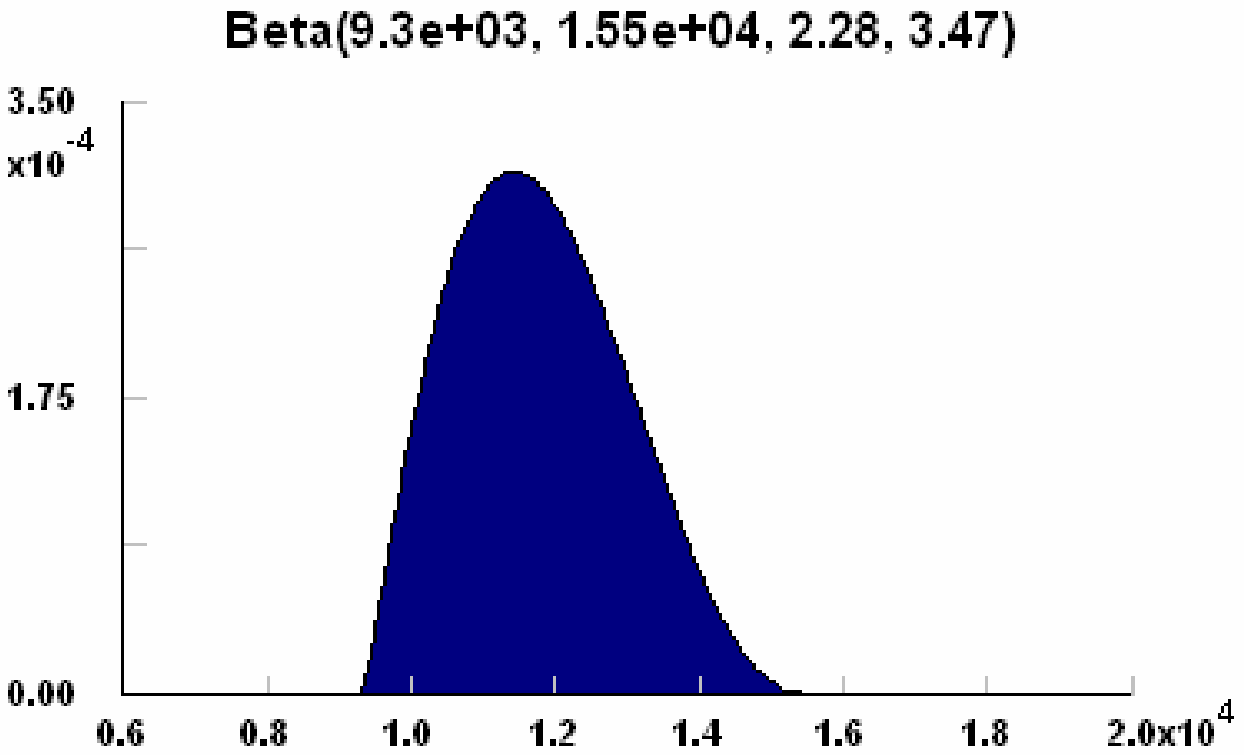
Cost Risk Assessment

- Fairly subtle errors in planning and management can have catastrophic results (from a cost standpoint)
  - Inadequate domain engineering
  - Failure to account for external dependencies
  - Poor requirements control
  - Over-optimistic expectations for functionality delivery
- Cost estimators must know a LOT about the process to make a reasonable judgment about risk
  - Compare the management approach to the best practices
  - Look for potential “gotchas”
- Distinguish between first, second, and third order effects
  - Don’t spend all your time in the weeds--you may get stomped by an elephant!

Estimating with High Uncertainty

- For areas were high uncertainty exists, estimating a probability distribution vice a single number or range of numbers may be more appropriate.
  - Point estimates provide no information on how much the estimate might vary
  - Ranges, gained from sensitivity analysis, provide a range of possible outcomes but no information on which answers are more or less likely within the range.

Probability Distributions

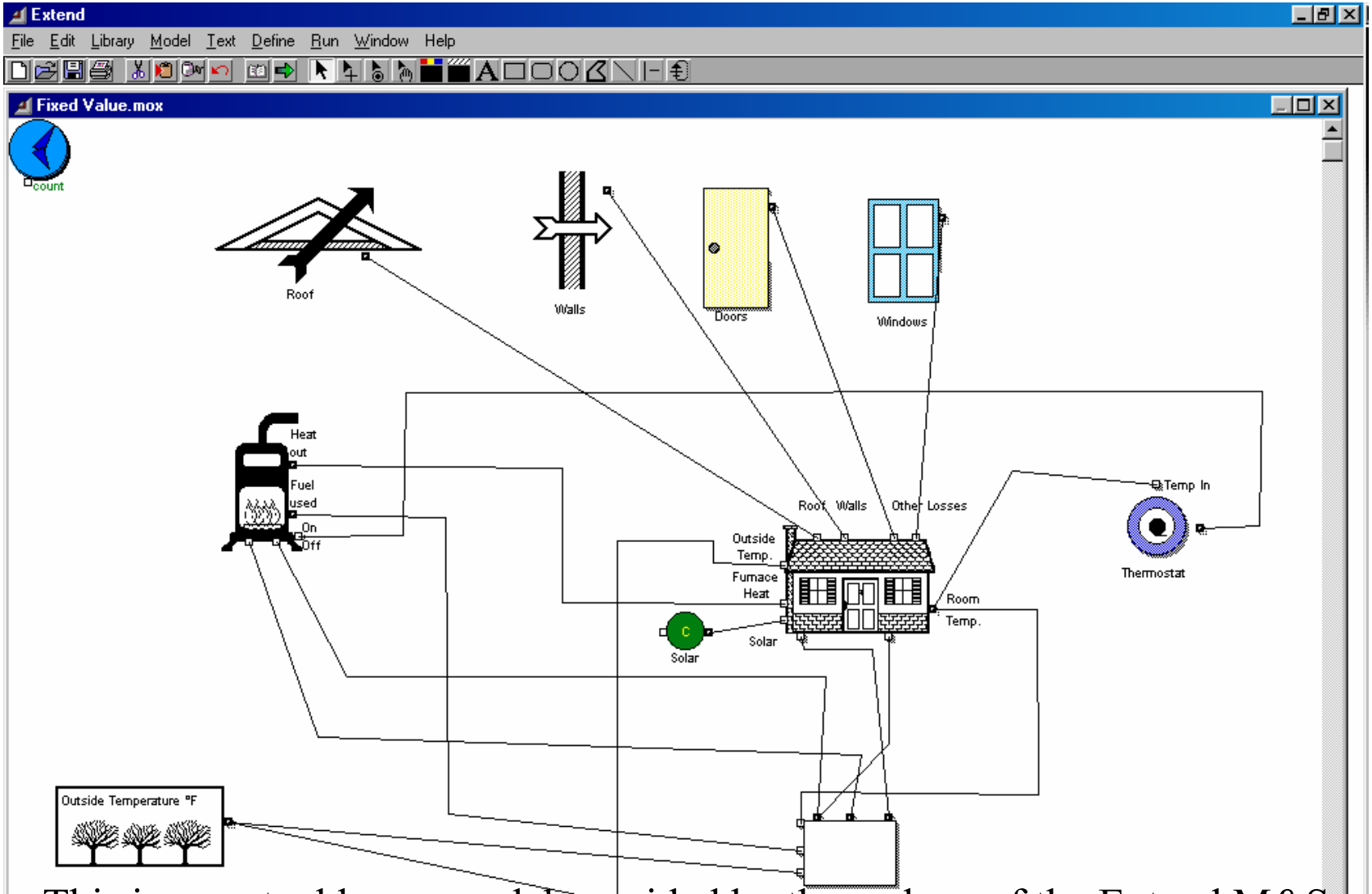


Provides not only the range of values, but how likely each of those values may occur.

Monte Carlo Simulation

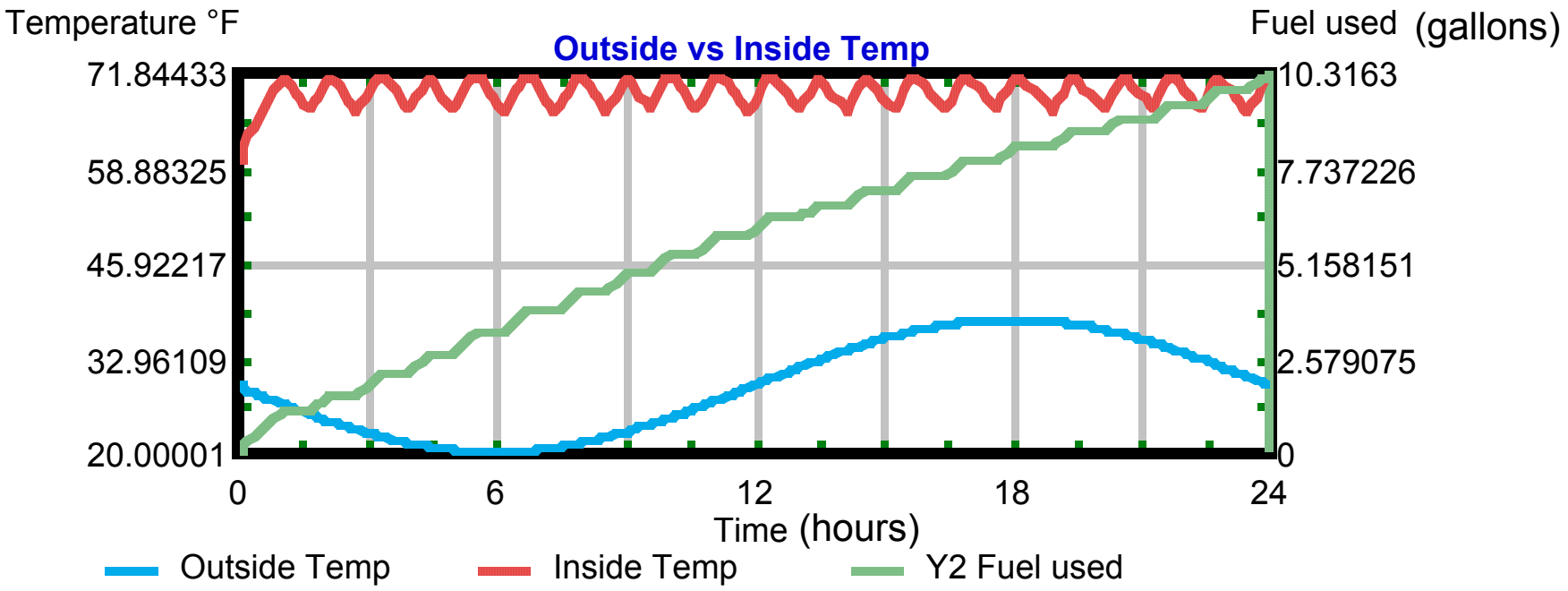
- Model all elements of the problem as probability distributions
  - Easier to estimate the distribution of smaller elements than complex systems
- When combined as a system, effects of correlation between variables is captured
- Example problem
  - Given a house in the Washington DC area, how much will it cost to heat per day in the month of January?

Home Heating System Model



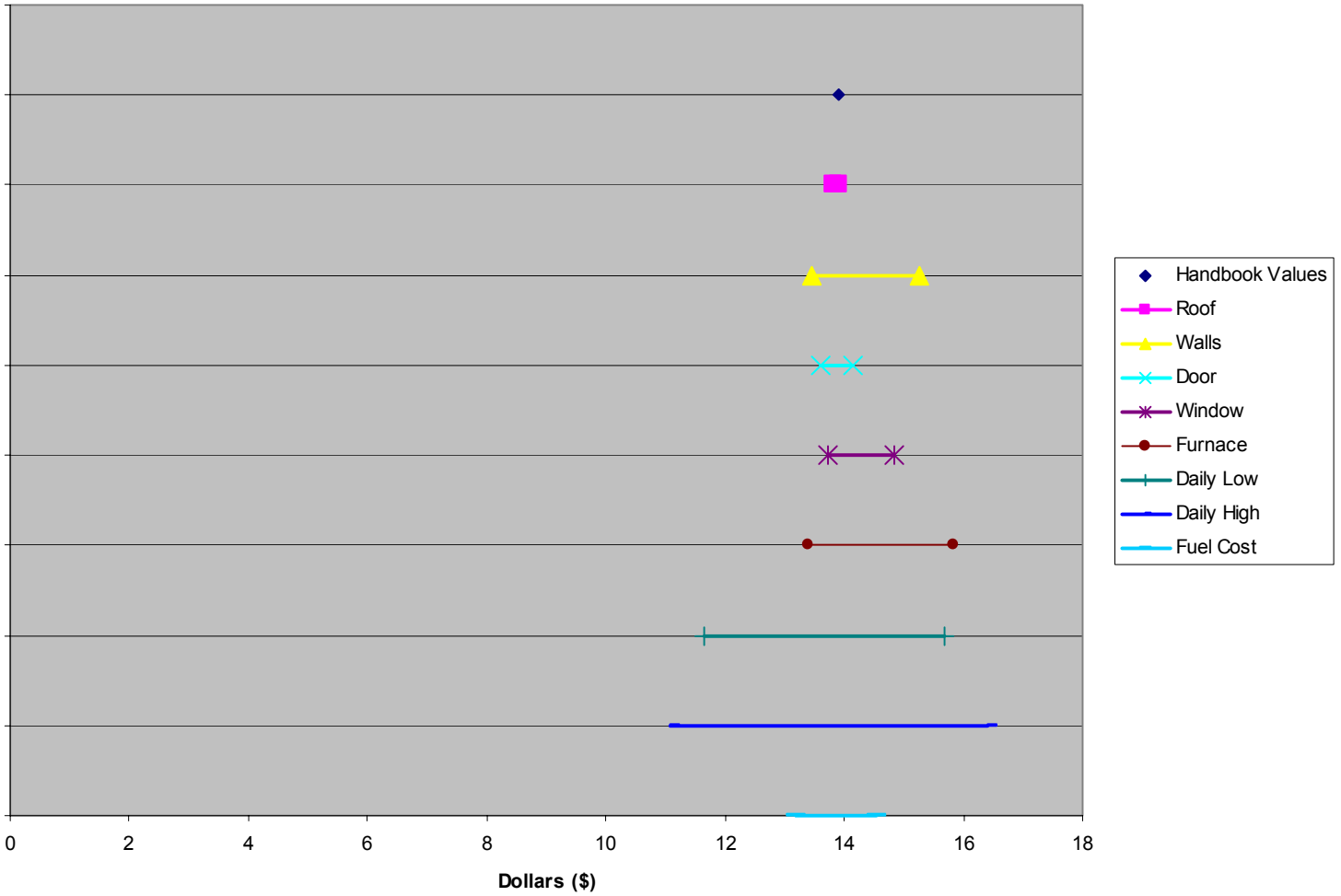
This is an actual home model provided by the makers of the Extend M&S software packages modified for discrete operation by Dave Brown

Model Output Example



Based on average day and night time temperatures and handbook values of building materials, this home uses about 10.3 gals/day of fuel oil for heating. Based on an average price of $1.44/gal, estimated cost is $13.73 per day

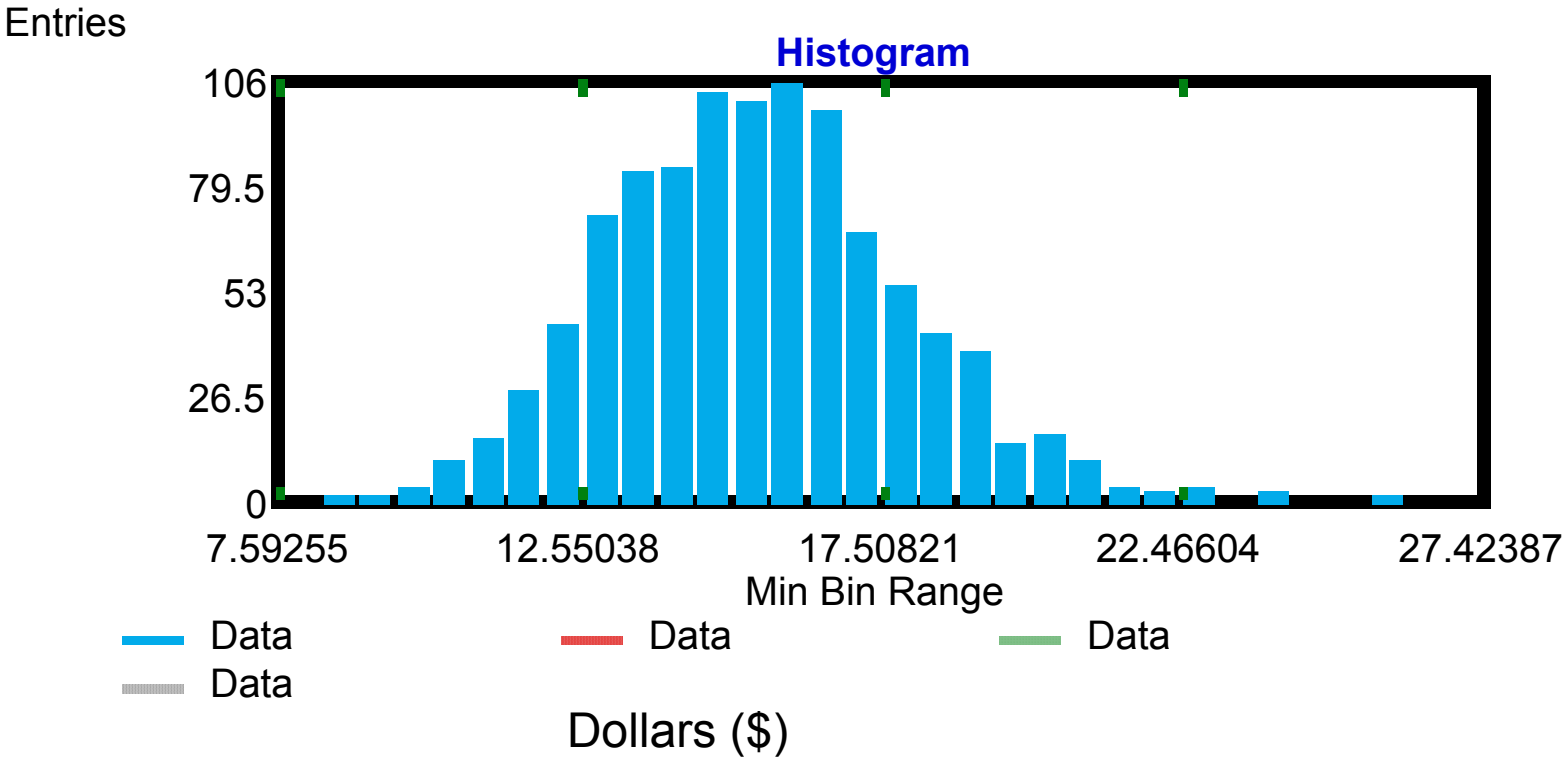
Sensitivity Analysis



A sensitivity analysis provides a range over which the answer may lie, but no information on where it is more or less likely to be.

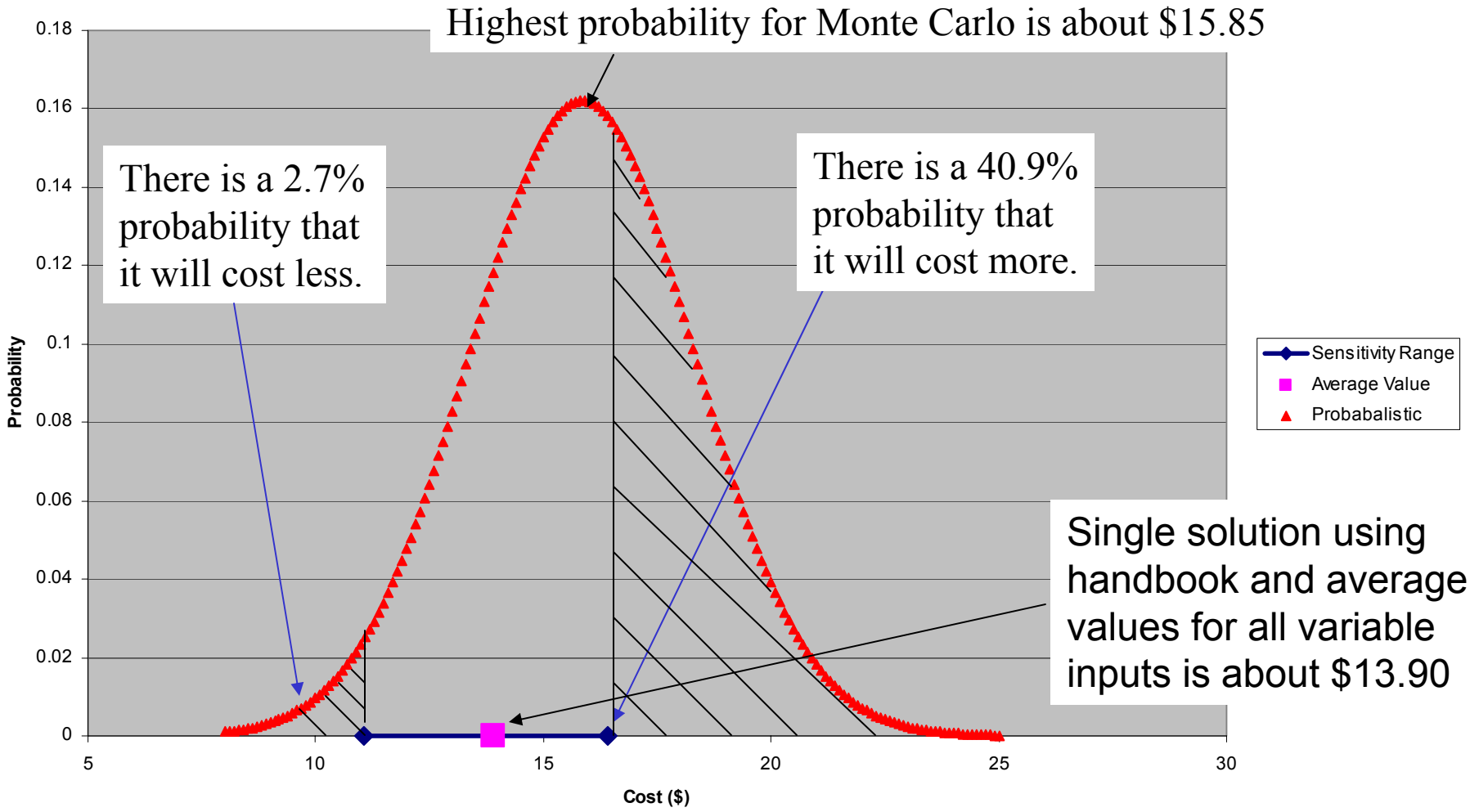
Probabilistic Solution

Home Heating Problem



1000 simulation runs

Solution Comparison

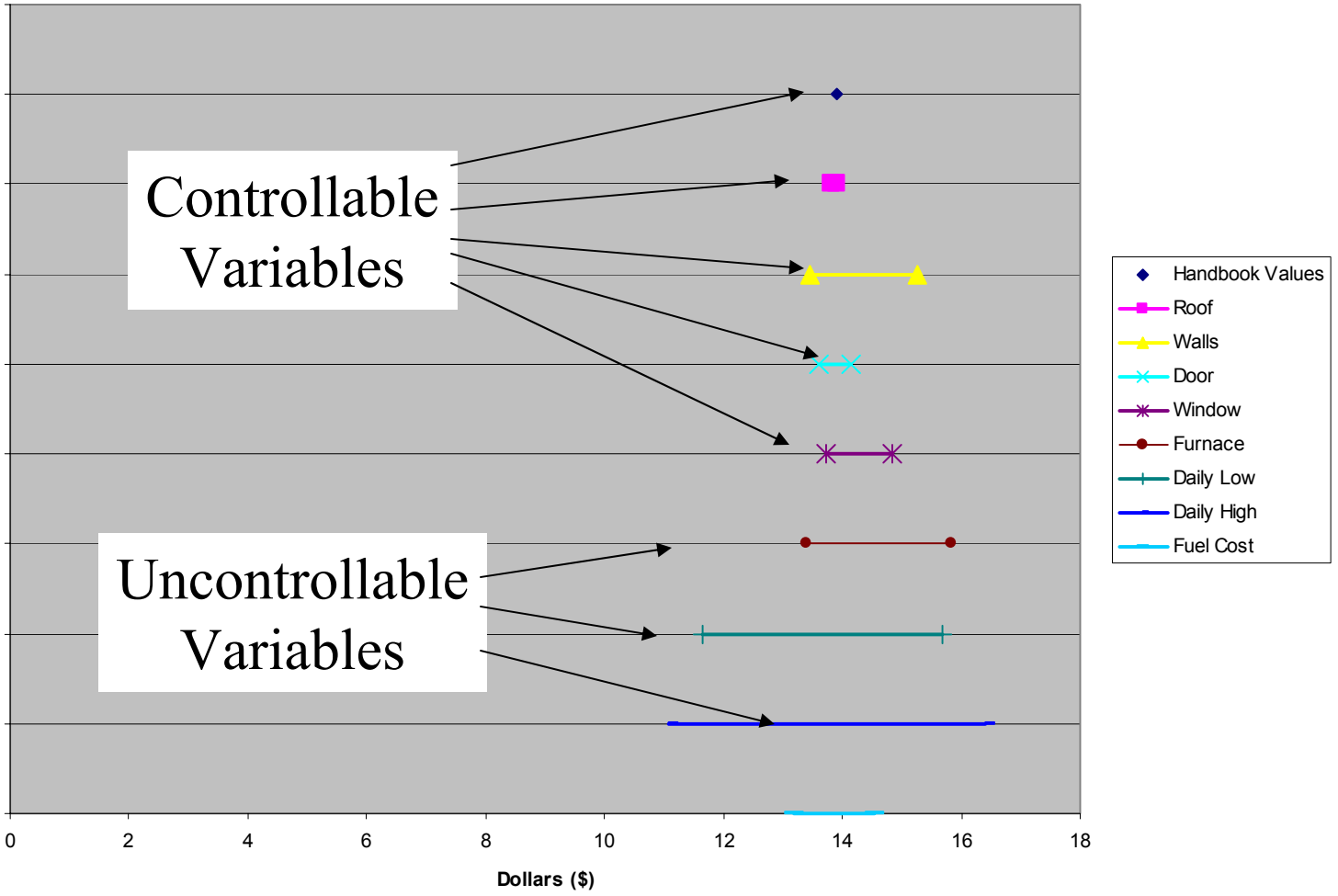


The shape or type of distributions will change the outputs

Bounding the Problem

- The result is a large distribution of possible outcomes.
  - One can tighten the bounds on the problem by eliminating some of the variability
  - Sensitivity analysis shows which variables have the greatest influence
  - Reduce the spread of the cost estimate by focusing on reducing variability of controllable variables

Reducing Variability



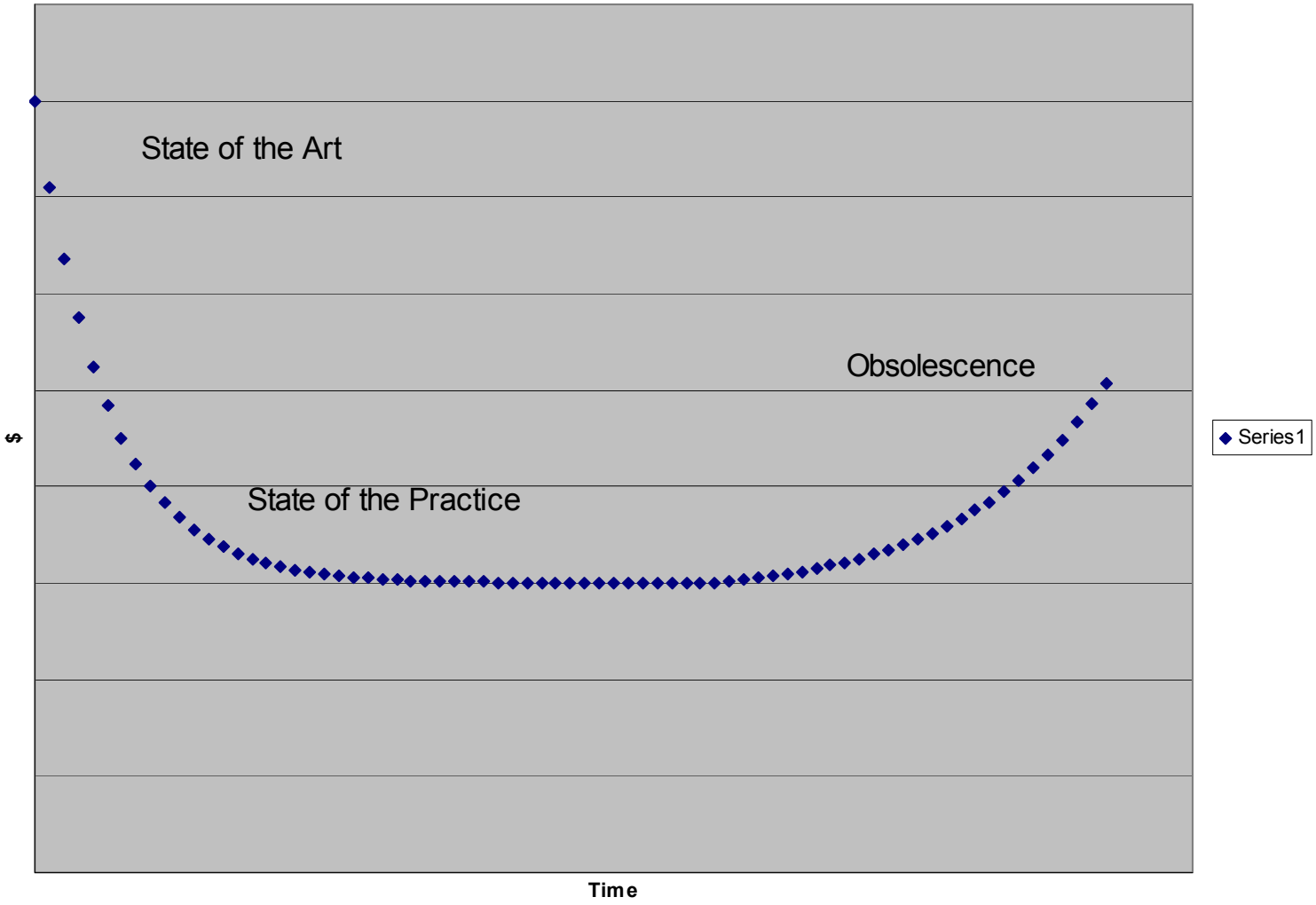
Application to Spiral Development

- Should be possible to apply similar methodology to estimating spiral development efforts.
  - Estimate system elements or individual spirals as probability distributions
  - Use Monte Carlo simulation to combine elements or spirals into a system or total program development distribution
  - Conduct sensitivity analysis to identify cost drivers
  - If possible, tighten the variability of high sensitivity inputs to refine the system probability distribution

Planning Technology Refreshment

- How and when do I plan technology refreshment?
  - Minimize LCC
  - Avoid obsolescence
  - Avoid diminishing support manufacturing sources

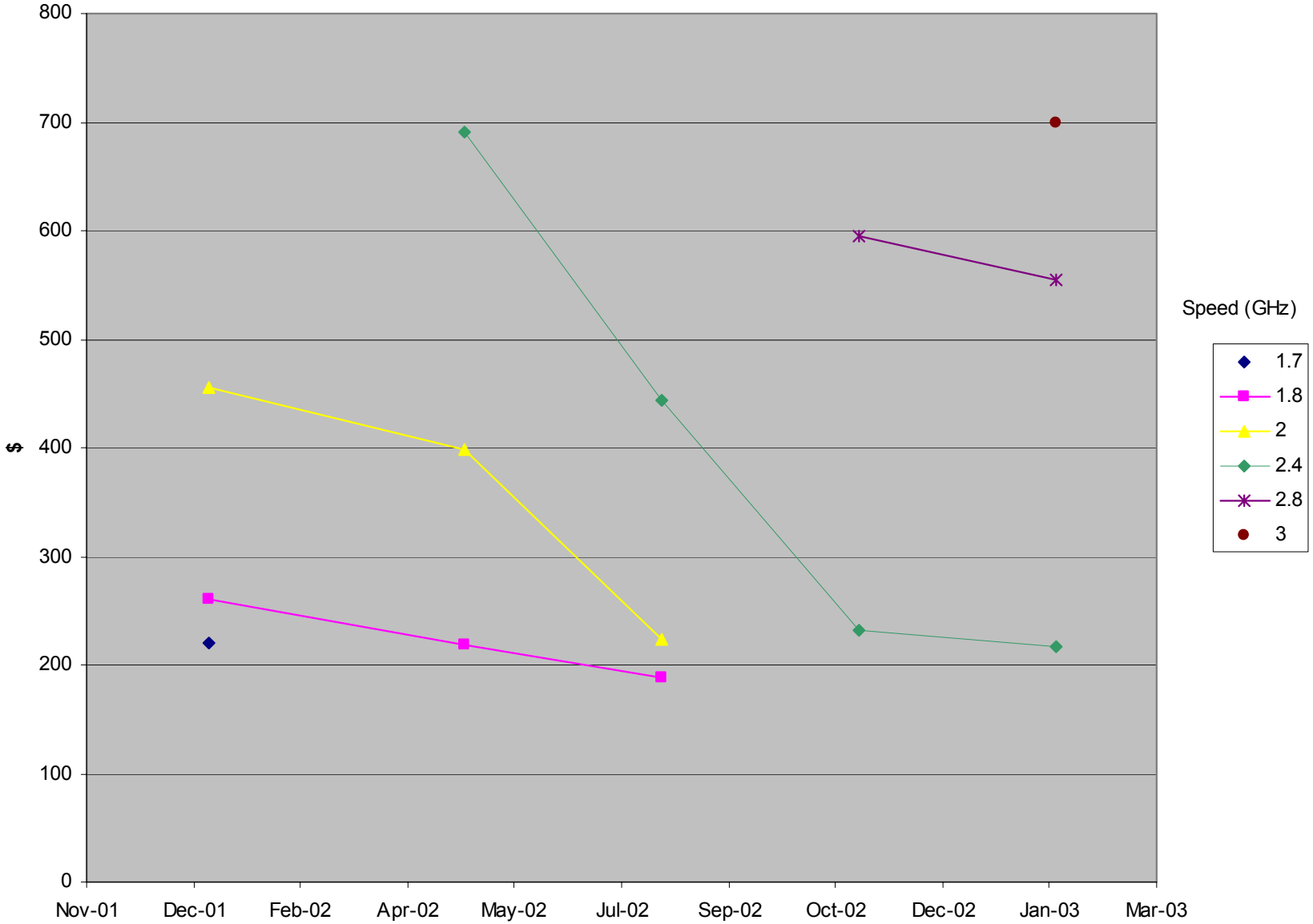
Technology Cycle



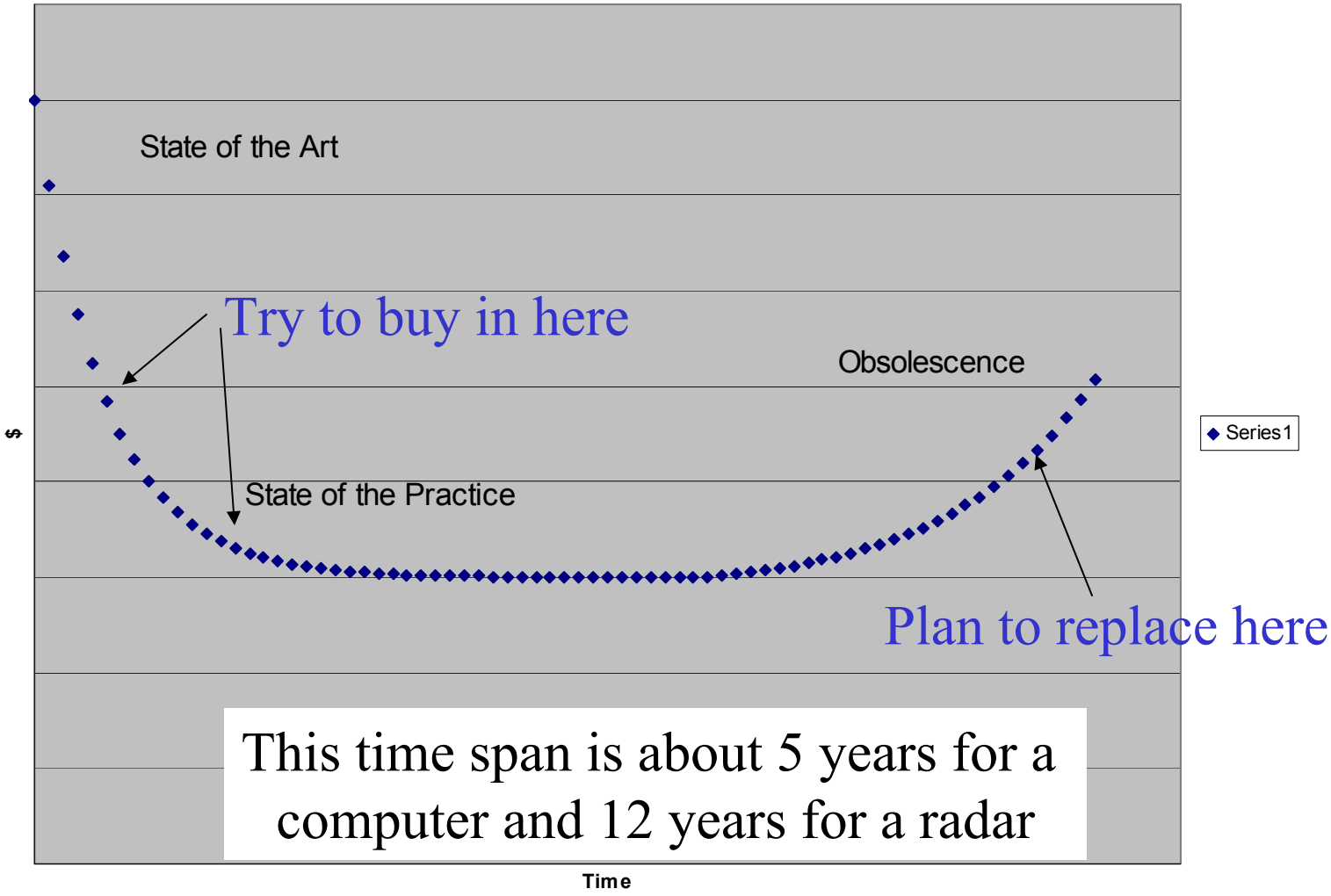
Technology Cycle

- State of the Art
  - New, cutting edge technology
  - Best Available
  - Few manufacturers in the market
  - Production processes still being worked
  - Scarcity of supply
  - High Cost
- State of the Practice
  - Mature technology
  - Multiple manufacturers
  - Production learned out
  - Lean manufacturing implemented
  - Plentiful Supply
  - Low Cost
- Obsolescence
  - Old technology
  - Major manufacturers leave the market
  - Niche suppliers move in
  - Manufacturing in small batches
  - Quantities more difficult to find with time
  - Higher costs

CPU Prices


800
700
600
500
400
300
200
100
0
$
Nov-01
Dec-01
Feb-02
Apr-02
May-02
Jul-02
Sep-02
Oct-02
Dec-02
Jan-03
Mar-03
Speed (GHz)
1.7
1.8
2
2.4
2.8
3

Technology Refreshment



EA User Issues

- Acquisition Community must prove they can deliver under this new process
  - Must deliver what is agreed to when it is agreed to
- In the past, people and resources fall dramatically when a system meets IOC
  - Under an evolutionary approach, up to 40% of the capability may still be in some stage of development
  - Follow-on blocks must receive the same priority and commitment as the first

Cuts in VA-class R&D pay for multiyear EOQs

YOUNG CITES PROGRESS IN BLOCK BUY TALKS, BUT DIFFERENCES REMAIN

Date: March 31, 2003

With less money for R&D, the spiral development of the Virginia-class program's technology would not progress as quickly, he said. Asked if the Navy would bring the R&D numbers back up, Mullen said it would evaluate the impact on the program, concurrent with a Navy-wide R&D assessment that is intended to make sure that the dollars are going to the right places.

“When you remove resources, you're going to slow down the advancement or the insertion, in this case, of the technology that you planned,” Mullen said. “[In] this budget, as in all budgets, there are very difficult tradeoffs that needed to be made.

Evolutionary Acquisition Summary

- Delivers initial capability to the user in a shorter time period
- Improves technology available to the user in the final product
- Reduces the risk of embarking on an unexecutable development plan
  - Allows earlier cancellation if problems arise
- But, is not cheaper to develop
  - Savings are in cost avoidance from bad requirements and rework
- And, will take longer to reach the final capability
- Cost estimating is more difficult due to requirements uncertainty.
  - Bottoms up approach using probability distributions and sensitivity analysis may provide one approach.