Early Warning Indicators in the Acquisition of Software-Intensive Systems

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Keynote Address

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Outline

- Trends in Defense Software-Intensive Systems
- Need for New Acquisition Approaches
- Trilateral SIS Working Group Effort to Develop SIS Acquisition Early Warning Indicators
- Current Goal/Critical Success Factor Framework
- Community Opportunity to Improve Framework

Trends in Defense Software-Intensive Systems

- Transformational, network-centric systems
  - These are fundamentally software-intensive
- Emphasis on joint, interoperable, capability-based systems
  - And increasingly, systems of systems
- Increasing requirements emergence, COTS-dependence, environmental change
- Traditional sequential acquisition practices increasingly inadequate
  - Fixed-requirements, -cost, -schedule contracting
  - Waterfall legacies: MIL-STD-1521B, parts of Software CMM

Waterfall Legacies: SW CMM v.1.1

- **Requirements Management, Ability 1:**

  "Analysis and allocation of the system requirements

  is not the responsibility of the software engineering group

  ***but is a prerequisite for their work*."**

Defense Management Evolving New Acquisition Approaches

- US: 5000.1 and 5000.2, CMMI, Acquisition CMM, evolutionary acquisition
- UK: DPA Stocktake Initiative
- Australia: Software Material Reform Program, Capability Systems Life Cycle

Trilateral Working Group Addressing Early Warning Indicators

- US, UK, and Australian participants
- Mix of traditional and emerging indicators
- Current version a work in progress; seeking community feedback
- Organized around program goals and critical success factors
- Focused on readiness for milestone decision reviews

Trilateral Working Group

- Matt Ashford, AUS MOD
- Shonnag Allison, UK DPA
- Barry Boehm, USC
- Julien Burridge, UK DPA
- Kathleen Dangle, Fraunhofer Center – Maryland
- Brian Gallagher, SEI
- Jim Linnehan, USA(ALT)
- Peter Nolte, OUSD(AT&L)/DS
- Don Reifer, USC
- Richard Turner, GWU

Current Goal/Critical Success Factor Framework

- Counterexamples of what happens if factors not addressed
- Examples of more detailed checklists from current working group material
- Examples of potential early warning indicator tracking system displays.

Software Acquisition Goals

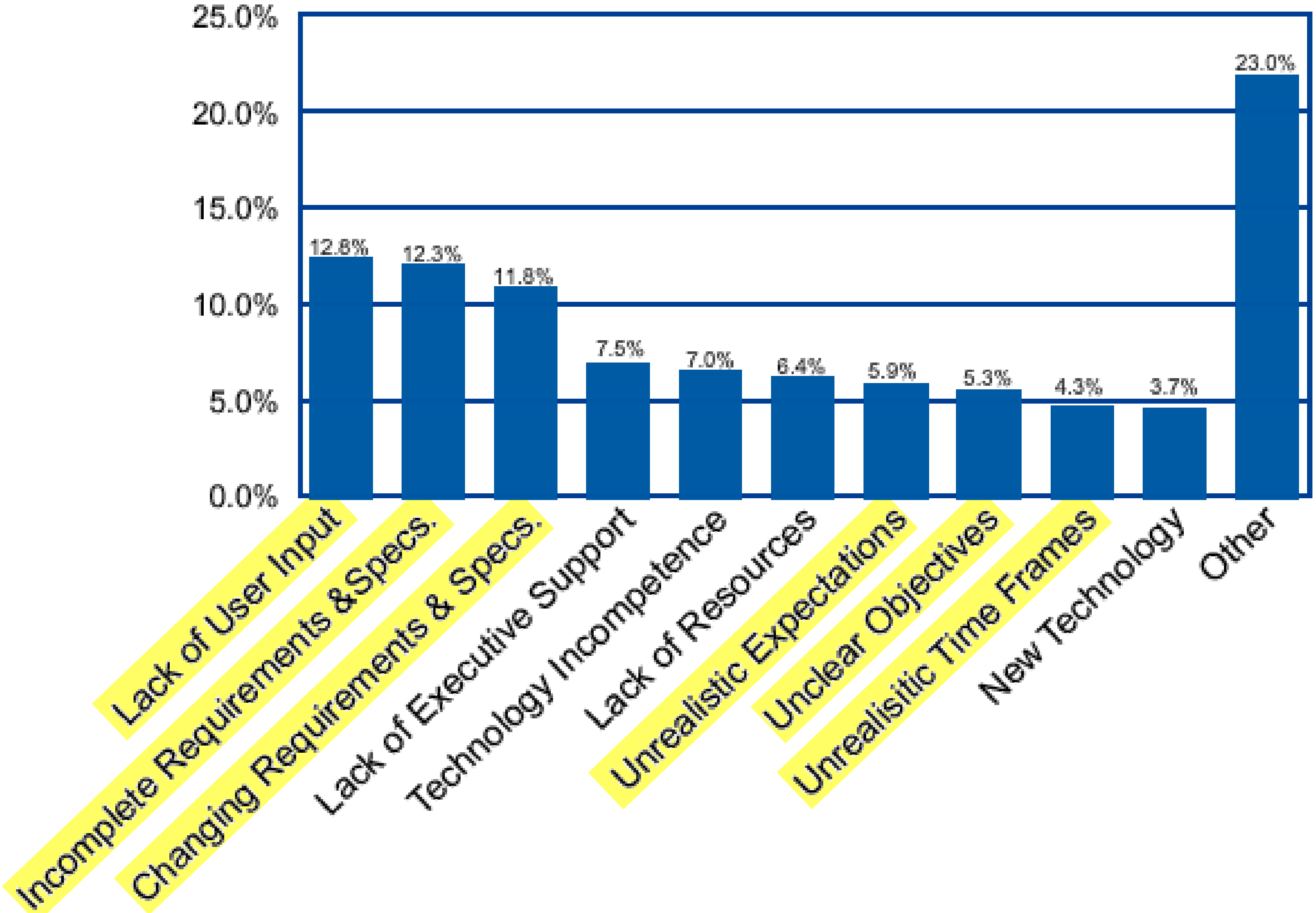
- Goal 1. System and software objectives and constraints have been adequately defined and validated.
- Goal 2. The system and software acquisition strategies are appropriate and compatible.
- Goal 3. The success-critical stakeholders have committed adequate software capability to perform their software-related tasks.
- Goal 4. The software product plans and process plans are feasible and compatible. A Feasibility Rationale provides convincing evidence that:
- Goal 5. Software progress with respect to plans is satisfactory.

Critical Success Factors: Goal 1

Goal 1. System and software objectives and constraints have been adequately defined and validated.

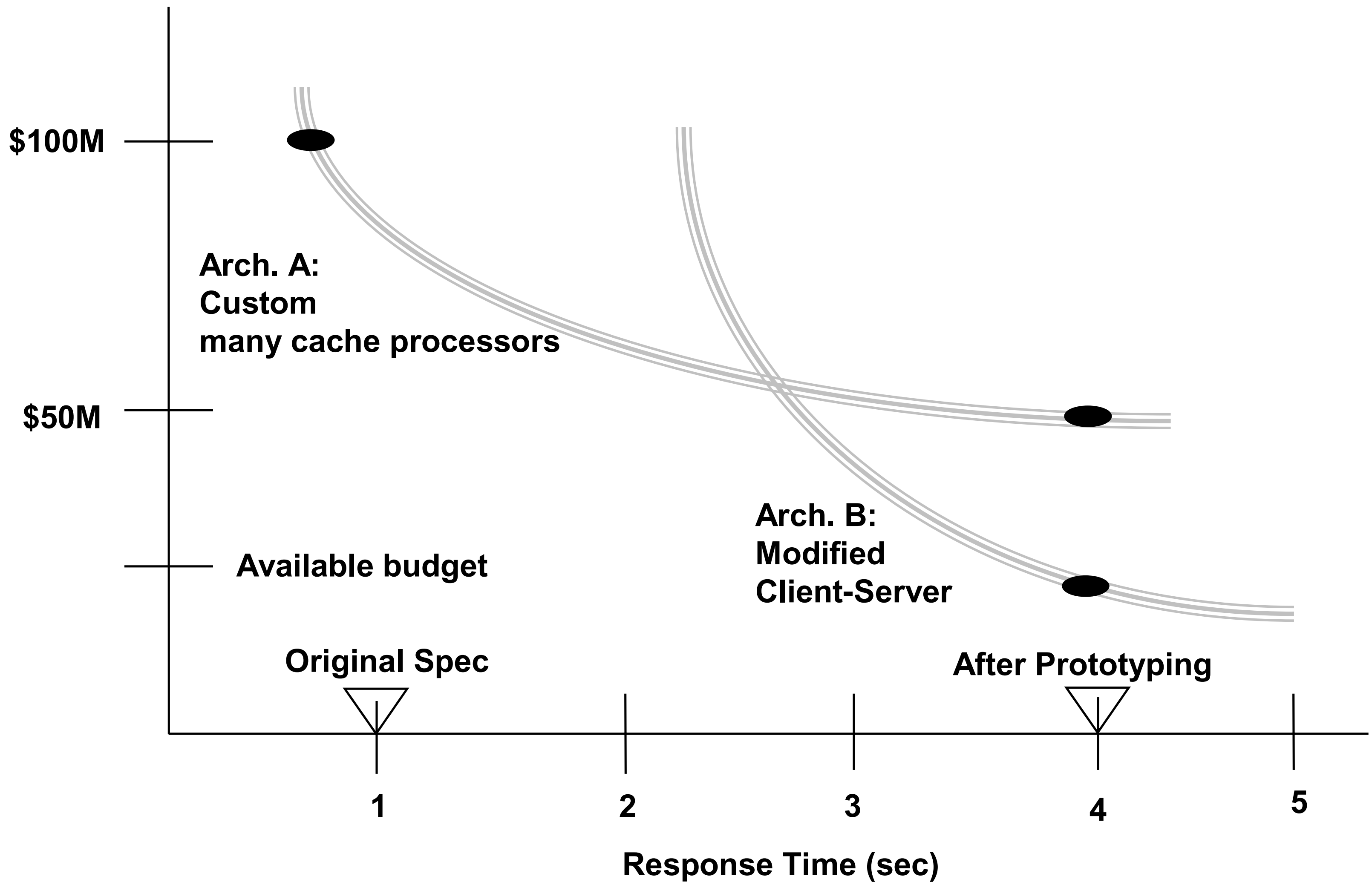
- **1.1 System and software functionality and performance objectives have been defined and prioritized.**
- **1.2 The system boundary, operational environment, and system and software interface objectives have been defined.**
- **1.3 System and software flexibility and evolvability objectives have been defined and prioritized.**
- **1.4 System and software environmental, resource, infrastructure, and policy constraints have been defined.**
- **1.5 System and software objectives have been validated for overall achievability within the system and software constraints.**

Why Software Projects Fail



352 companies - 8,000 software projects. Source: *The Standish Group, 1995*

Effect of Unvalidated Requirements



Effect of Unvalidated Software Schedules

- Original goal: 18,000 KSLOC in 7 years
  - Initial COCOMO II, SEER runs showed infeasibility
  - Estimated development schedule in months for closely coupled SW with size measured in equivalent KSLOC (thousands of source lines of code):

    Months =~ 5 * ^{3} KSLOC

- KSLOC	300	1000	3000	10,000
- Months	33	50	72	108

•Solution approach; descope features; architect for decoupled parallel development

Detailed Software Cost and Schedule Checklist

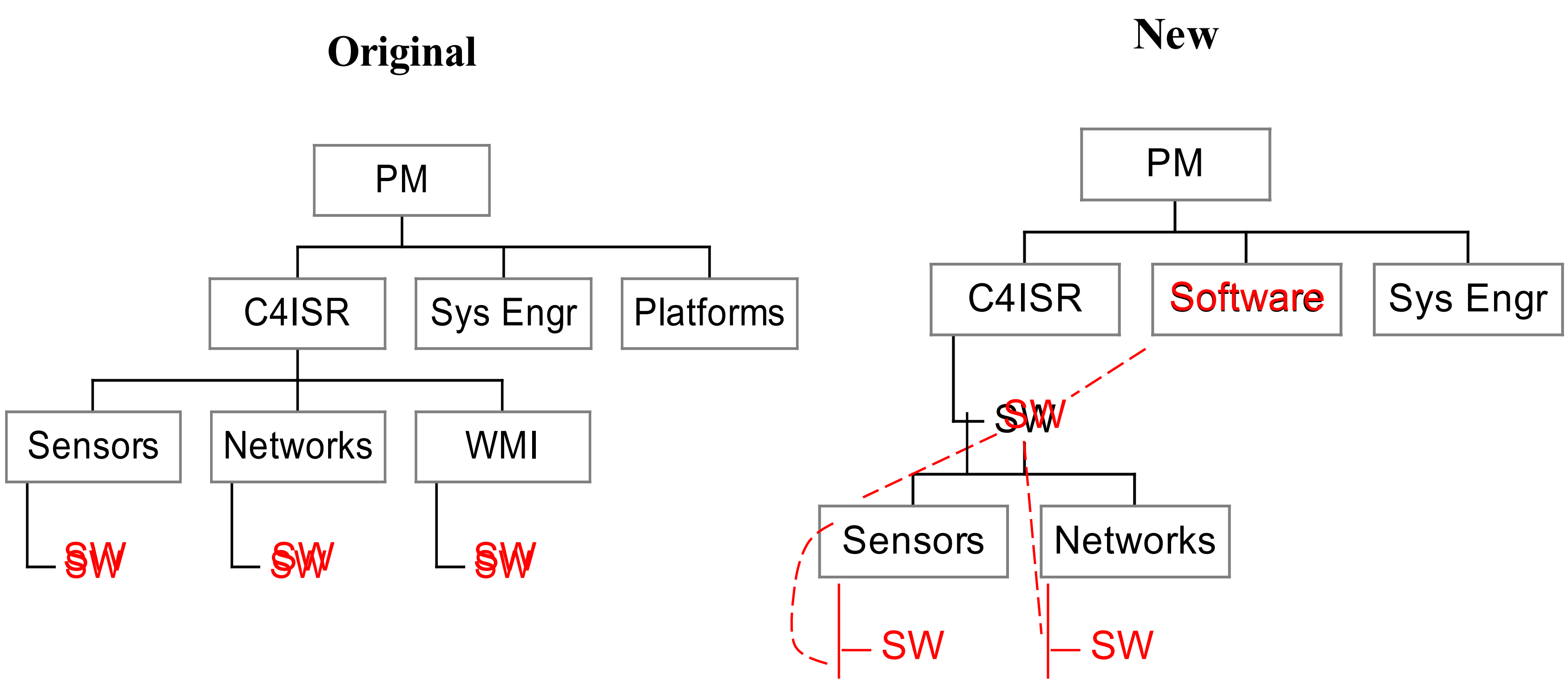
- Were multiple independent estimation methods used?
  - i. Individual expert judgment
  - ii. Group consensus (Delphi, group meeting, etc.)
  - iii. Analogy to previous experience
  - iv. Single parametric model
- v. Multiple parametric models
- Were the methods relevant to the project?
- For each method, were the inputs sufficient?
- For each input, is there a credible basis of estimate?
- Are the resulting estimates realistic?
- Were the inputs and estimates reviewed by experts?
- Are the estimates and the reviews current?
- Are there mechanisms to monitor and adjust assumptions and estimates?

Critical Success Factors: Goal 2

- Goal 2. The system and software acquisition strategies are appropriate and compatible.
- 2.1 They define the acquisition life cycle, success-critical stakeholder roles and responsibilities, contracting mechanisms, and progress milestones and success criteria.
- 2.2 They assign adequate levels of authority and responsibility for software integration and change management across the program elements, supplier chains, and external interfaces.
- 2.3 They identify the most critical system and software risks and an effective risk management process.
- 2.4 They are compliant with legal, policy, regulatory, standards, and security requirements.
- 2.5 They are compatible with each other and facilitate system and software engineering concurrency, synchronization, flexibility, and stability.

Effect of Software Underrepresentation

- Software risks discovered too late
- Slow, buggy change management
- Recent large project reorganization



Effect of Waterfall SEMP and Spiral SDP

- Delays in starting critical software infrastructure
  - OS, networking, DBMS, transaction processing, …
- Infeasible infrastructure
  - Premature performance requirements (e.g., 1 second)
- Premature hardware selection overconstrains software
  - Can also induce premature COTS commitments
- Waterfall-based progress payments undermine-spiral tasks
  - Develop prototypes or get paid for specifications

Early Risk Resolution Quotes

"In architecting a new software program, all the serious mistakes are made on the first day."

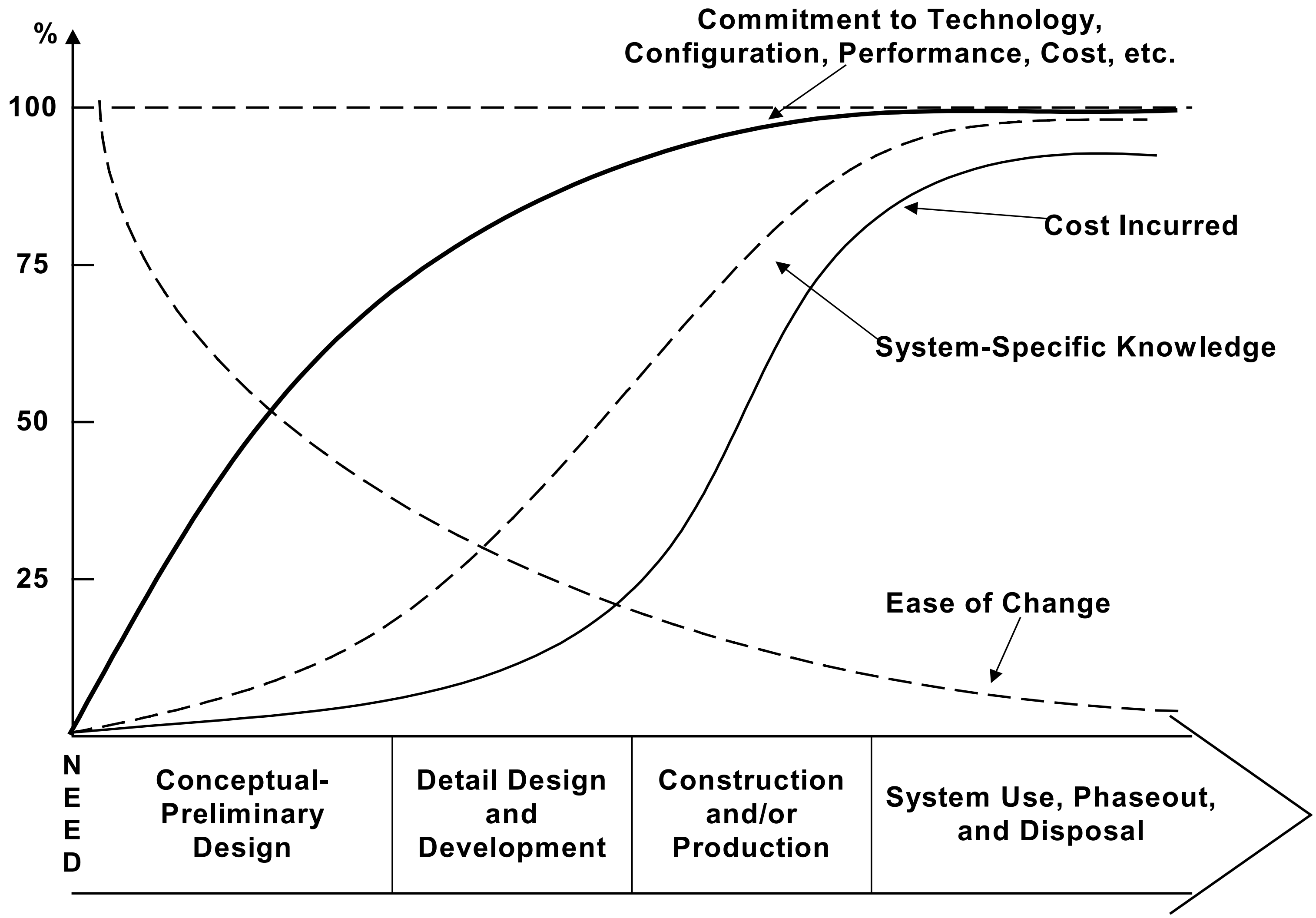
Robert Spinrad, VP-Xerox, 1988

"If you don't actively attack the risks, the risks will actively attack you."

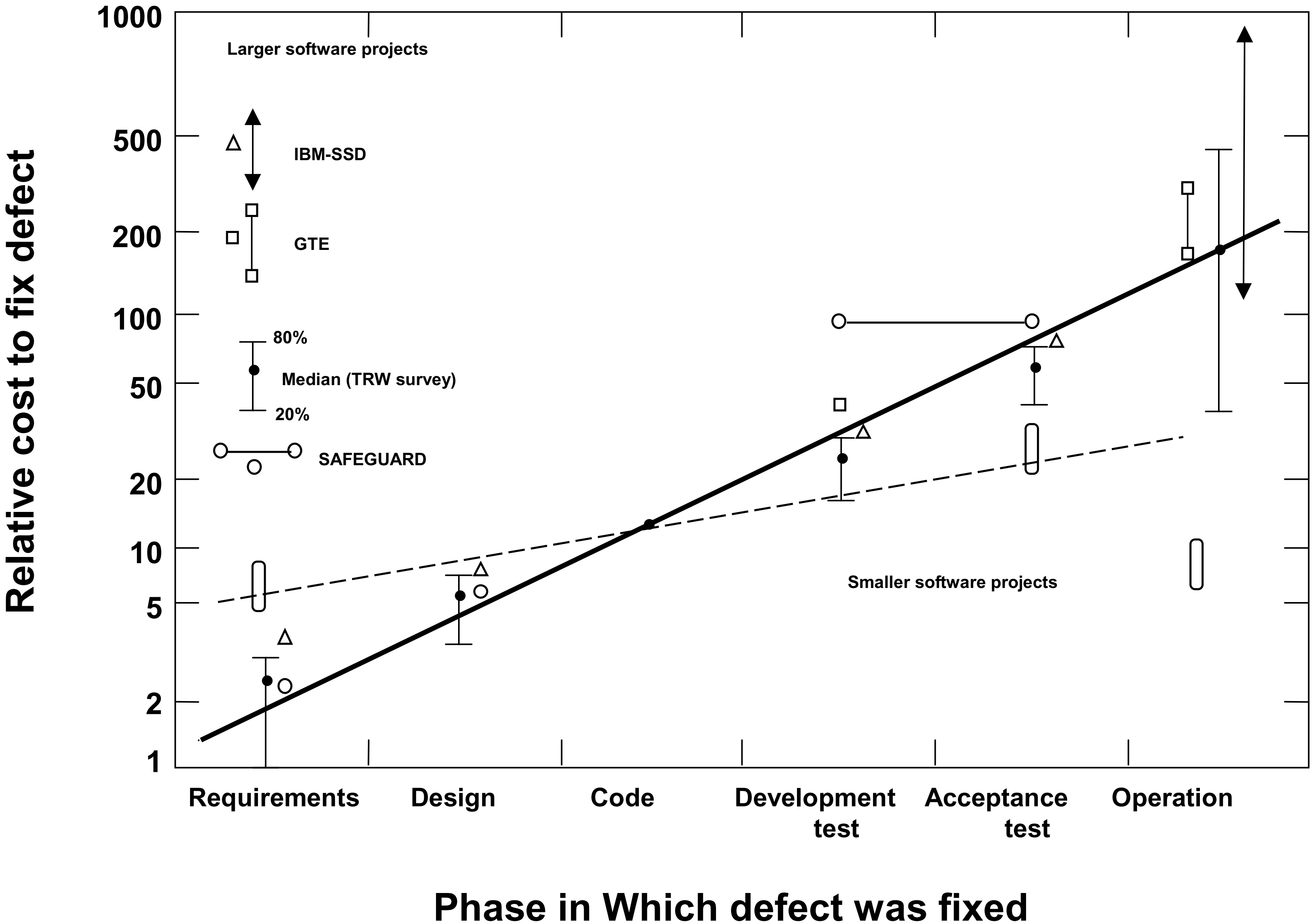
Tom Gilb, 1988

Risk of Delaying Risk Management: Systems

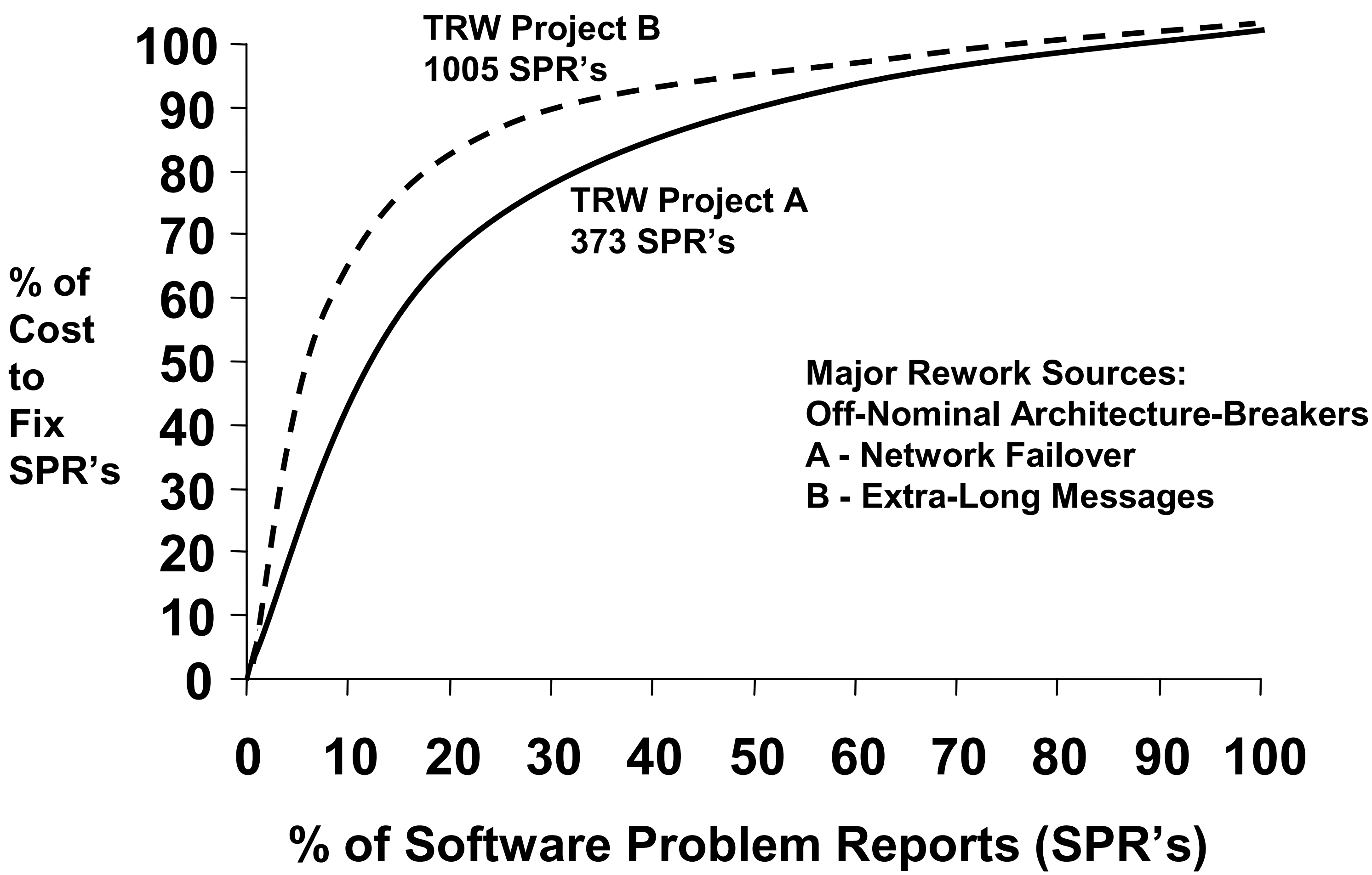
—Blanchard- Fabrycky, 1998



Risk of Delaying Risk Management: Software



Steeper Cost-to-fix for High-Risk Elements



Acquisition Strategy Checklist

- Is the acquisition strategy consistent with the level of software risk on the program?
  i. List of software risks (how many, how identified, what are they, breadth and depth, criticality, risk exposure)
  ii. List of mitigation strategies that address software risks (number of risks addressed by strategy, available resources to perform mitigation)
  iii. Map of software risks and mitigation strategies to reveal coverage
  iv. Milestone decision criteria that address software risks
  v. Activities performed to assure acquisition strategy is appropriate
  vi. Positions of software experts within the acquisition program's organizational structure or hierarchy
  vii. System engineering trade off analyses to be performed and assessment of their impact on software; software trade off analyses and when they will be performed
- Are qualified stakeholders involved in the preparation and execution of the acquisition strategy?
- Do the acquisition strategy and pre-award processes (solicitation) address software-related qualifications in selecting contractor(s)?
- Do the post-award processes (contract monitoring) facilitate the acquisition strategy that addresses software issues?

Critical Success Factors: Goal 3

Goal 3. The success-critical stakeholders have committed adequate software capability to perform their software-related tasks.

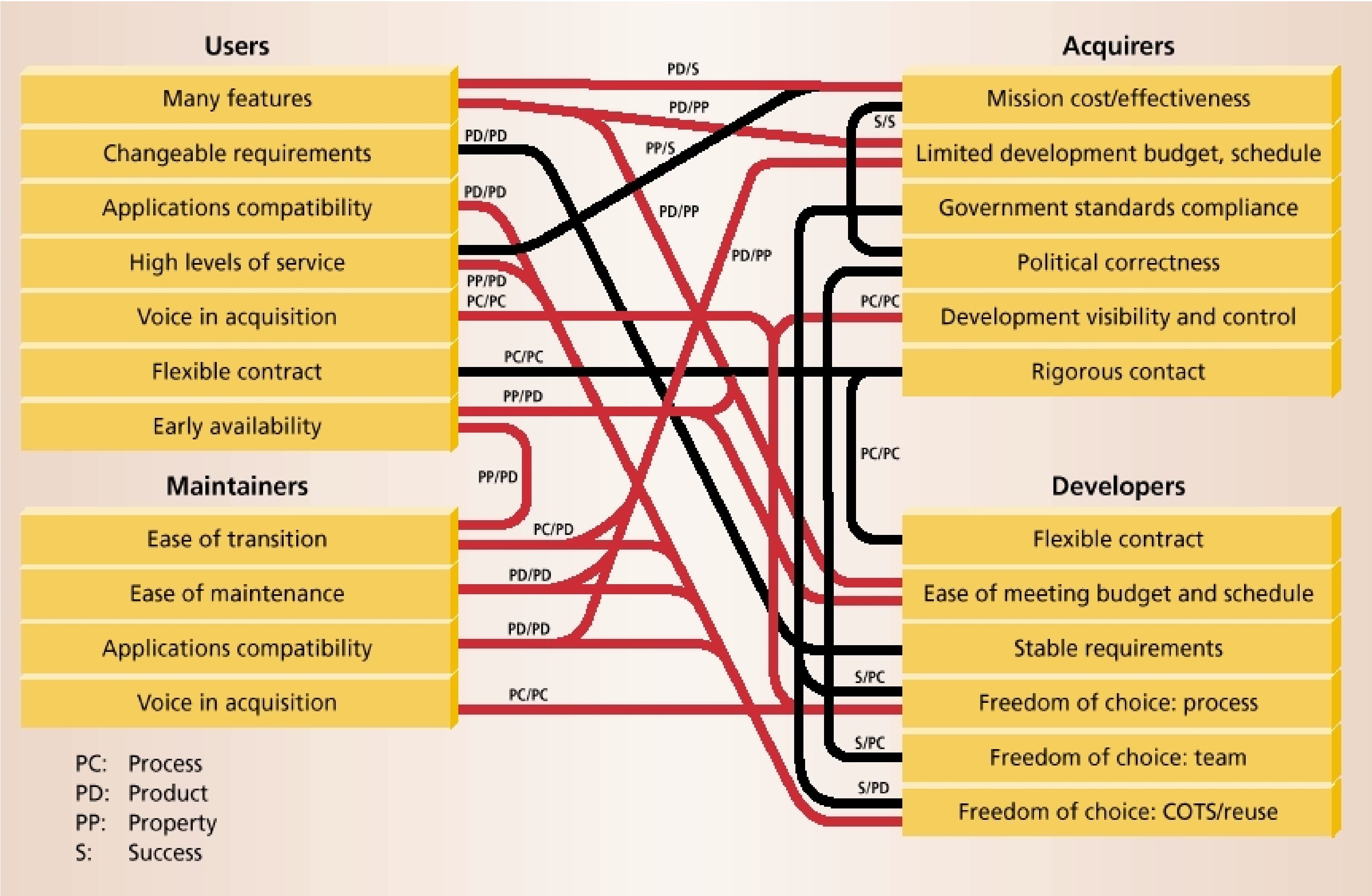
- 3.1 The success-critical stakeholders have been identified and their roles and responsibilities negotiated.
- 3.2 The stakeholders involved in software-related negotiations are represented by collaborative, representative, authorized, committed, and knowledgeable personnel.
- 3.3 Acquisition executives and contracting personnel have adequate software acquisition experience or training.
- 3.4 Suppliers, integrators, and acquirers have adequate software skills and process maturity for their software- related tasks.
- 3.5 Software staffing estimates have been validated for feasibility and achievability.

Effect of Missing Operational Stakeholders

- Interoperators: Problems detected during critical missions
- Maintainers: Slow, expensive response to change
- Users: Information overload, wrong mission decisions
- Administrators: Workflow slowdowns, unused flexibility

The Model-Clash Spider Web: Master Net

- Stakeholder value propositions (win conditions)



Critical Success Factors for Integrated Team Members

- CrossTalk, December 2003

- Not collaborative: Discord, frustration, loss of morale
- Not representative: Delivery of unacceptable systems, late rework
- Not authorized: Authorization delays, unsupported systems
- Not committed: Missing homework, discontinuities, delays
- Not knowledgeable: Unacceptable systems, delays, late rework

Critical Success Factors: Goal 4

Goal 4. The software product plans and process plans are feasible and compatible. A Feasibility Rationale provides convincing evidence that:

- 4.1 The lifecycle benefits determined by the system and software requirements are worth the lifecycle investments determined by the system and software architecture and choice of components.
- 4.2 A system built to the system and software architecture will support the operational concept, satisfy the requirements and success-critical stakeholders, and be buildable within the budgets and schedules in the process plans.
- 4.3 All major software risks have been either resolved or covered by risk management plans.
- 4.4 Plans for evolutionary/incremental software development and integration are validated for achievability and kept stable during each increment.

4.5 Software technologies, COTS, and NDI components have been validated for maturity and compatibility.

Life Cycle Anchor Points

- Common System/Software stakeholder commitment points
  - Defined in concert with 30 Government, industry organizations
  - Coordinated with Rational's Unified Software Development Process
- Life Cycle Objectives (LCO; DoD Milestone A)
  - Stakeholders' commitment to support system architecting
  - Like getting engaged
- Life Cycle Architecture (LCA; DoD Milestone B)
  - Stakeholders' commitment to support full life cycle
  - Like getting married
- Initial Operational Capability (IOC)
  - Stakeholders' commitment to support operations
  - Like having your first child

LCO (MS A) and LCA (MS B) Pass/Fail Criteria

– Cross Talk, December 2001

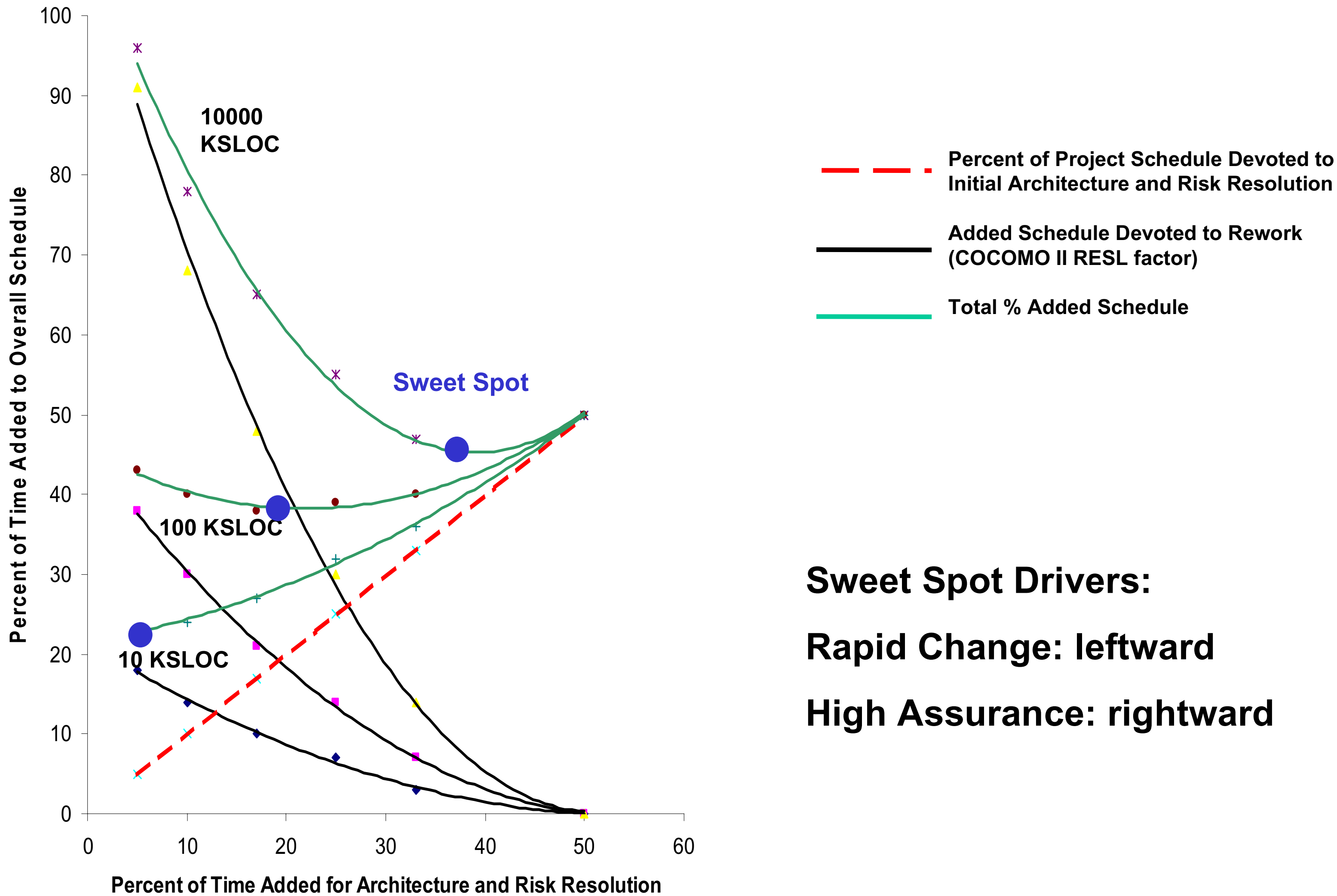
A system built to the given architecture will

- Support the operational concept
- Satisfy the requirements
- Be faithful to the prototype(s)
- Be buildable within the budgets and schedules in the plan
- Show a viable business case
- Establish key stakeholders' commitment to proceed

LCO: True for at least one architecture
LCA: True for the specific life cycle architecture;
All major risks resolved or covered by a risk management plan

How Much Architecting Is Enough?

-A COCOMO II Analysis



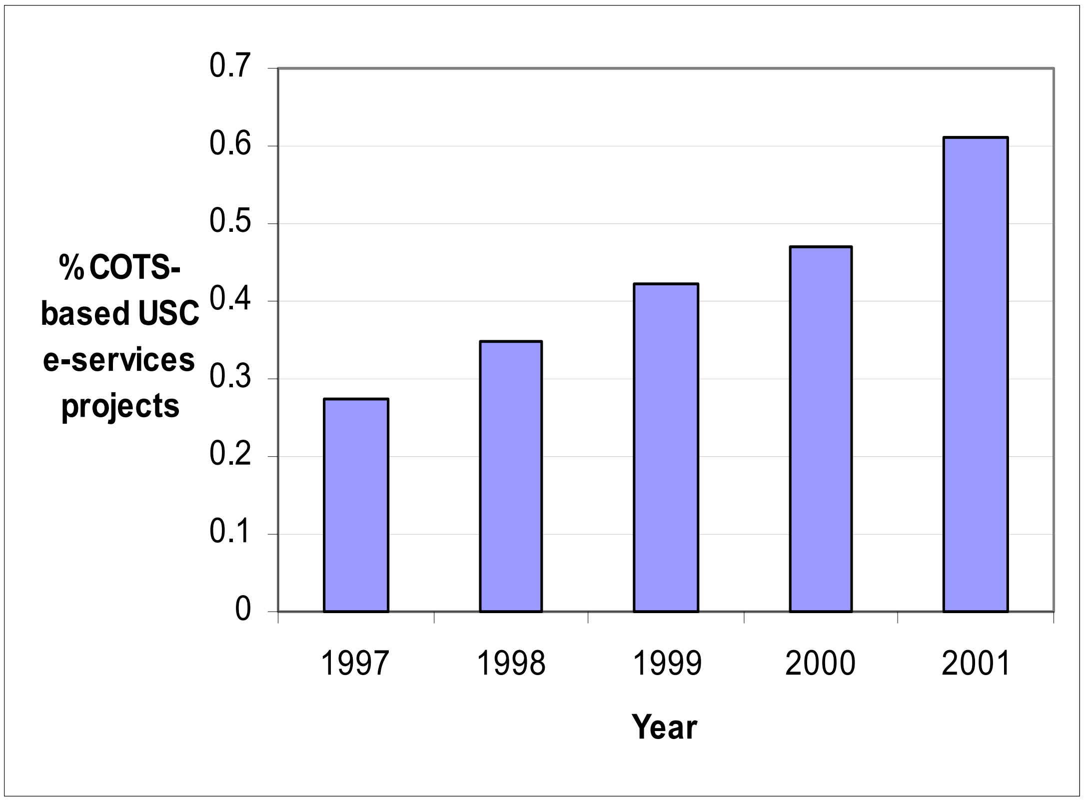
Sweet Spot Drivers:

Rapid Change: leftward

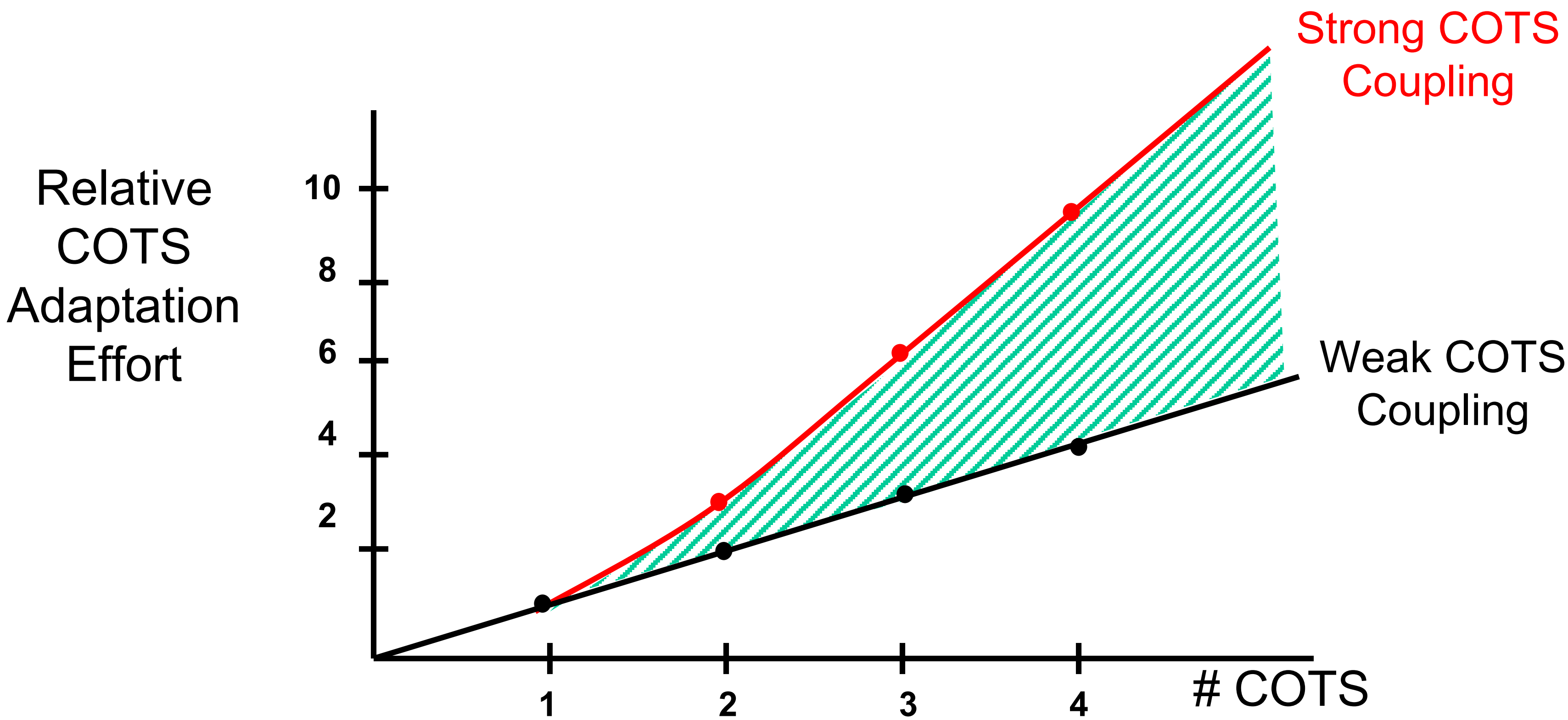
High Assurance: rightward

COTS: The Future is Here

- **Escalate COTS priorities for research, staffing, education**
  - **It's not "all about programming" anymore**



COTS-Based System Effort Scaling



- **Reduce # COTS or Weaken COTS coupling**
  - **COTS choices, wrappers, domain architectures, open standards, COTS refresh synchronization**

COTS Upgrade Synchronization and Obsolescence

- **Risk #1: Many subcontractors means a proliferation of evolving COTS interfaces**
- **Risk #2: Aggressively-bid subcontracts can lead to delivery of obsolete COTS**
  - **New COTS released every 8-9 months (GSAW)**
  - **COTS unsupported after 3 releases (GSAW)**
  - **An actual delivery: 120 COTS; 46% unsupported**
- **Strategy #1: Emphasize COTS interoperability in source selection process**
- **Strategy #2: Contract provisions ensuring delivery of refreshed COTS products.**

Critical Success Factors: Goal 5

- Goal 5. Software progress with respect to plans is satisfactory.
- 5.1 Software cost, schedule, and progress metrics are defined and monitored, and are acceptably consistent with plans.
- 5.2 Software development, integration, verification and validation, and risk management milestones are being successfully met.
- 5.3 Progress toward satisfying the software Feasibility Rationale is monitored, and shortfalls are identified as risks to be managed.
- 5.4 Likely changes in software-related policy, technology, requirements, COTS/NDI components, and interfaces are monitored and analyzed for impact, and are pro-actively being addressed.
- 5.5 Independent assessments of software aspects are performed periodically.

Project Top 10 Risk Item List: Satellite Experiment Software

Risk Item	Mo. Ranking This	Mo. Ranking Last	Mo. Ranking #Mo.	Risk Resolution Progress
Replacing Sensor-Control Software Developer	1	4	2	Top Replacement Candidate Unavailable
Target Hardware Delivery Delays	2	5	2	Procurement Procedural Delays
Sensor Data Formats Undefined	3	3	3	Action Items to Software, Sensor Teams; Due Next Month
Staffing of Design V&V Team	4	2	3	Key Reviewers Committed; Need Fault-Tolerance Reviewer
Software Fault-Tolerance May Compromise Performance	5	1	3	Fault Tolerance Prototype Successful
Accommodate Changes in Data Bus Design	6	-	1	Meeting Scheduled With Data Bus Designers
Testbed Interface Definitions	7	8	3	Some Delays in Action Items; Review Meeting Scheduled
User Interface Uncertainties	8	6	3	User Interface Prototype Successful
TBDs In Experiment Operational Concept	-	7	3	TBDs Resolved
Uncertainties In Reusable Monitoring Software	-	9	3	Required Design Changes Small, Successfully Made

Independent Assessments

- Help programs and broaden understanding
  - Fight PM tunnel vision
  - Identify issues across programs
  - Capture lessons learned
- Example: Tri-Service Assessment Initiative
  - Over 50 assessments
  - Direct impact on programs (e.g. FCS, Comanche)
  - Systemic findings from macro-analysis
    - Common causes of problems
    - Chains of events that may signify risks
    - Unintended consequences from policies
  - A major input to this Goal/CSF framework

Example Assessment Summary

	Previous actual	**Current projected**	**Current actual**	Next projected	Comments
1. System and software objectives and constraints	Y	G	Y	G	New interoperability O&Cs
1.1 Functionality and performance objectives	G	G	G	G	
1.2 System boundary, environment, interfaces	Y	G	Y	G	Interoperability more complex
1.3 Flexibility and evolvability objectives	Y	G	G	G	
1.4 Environment, resource, policy constraints	G	G	Y	G	Interoperability more complex
1.5 Objectives validated with respect to constraints	Y	G	Y	G	New objectives to validate

Challenge to Community

- Goal/CSF Framework improvement suggestions
- Techniques for avoiding problem situations
- Experimental application and feedback