Spiral Acquisition of Defense and Space Systems of Systems

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Outline

- Trends in Defense and Space Systems of Systems
- Role of Spiral Development
  - Concurrent engineering of requirements and architecture; systems and software
  - Emphasis on risk management
- Example system-of-systems top-10 risk list
  - Representative risks and mitigations
- Conclusions

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:**

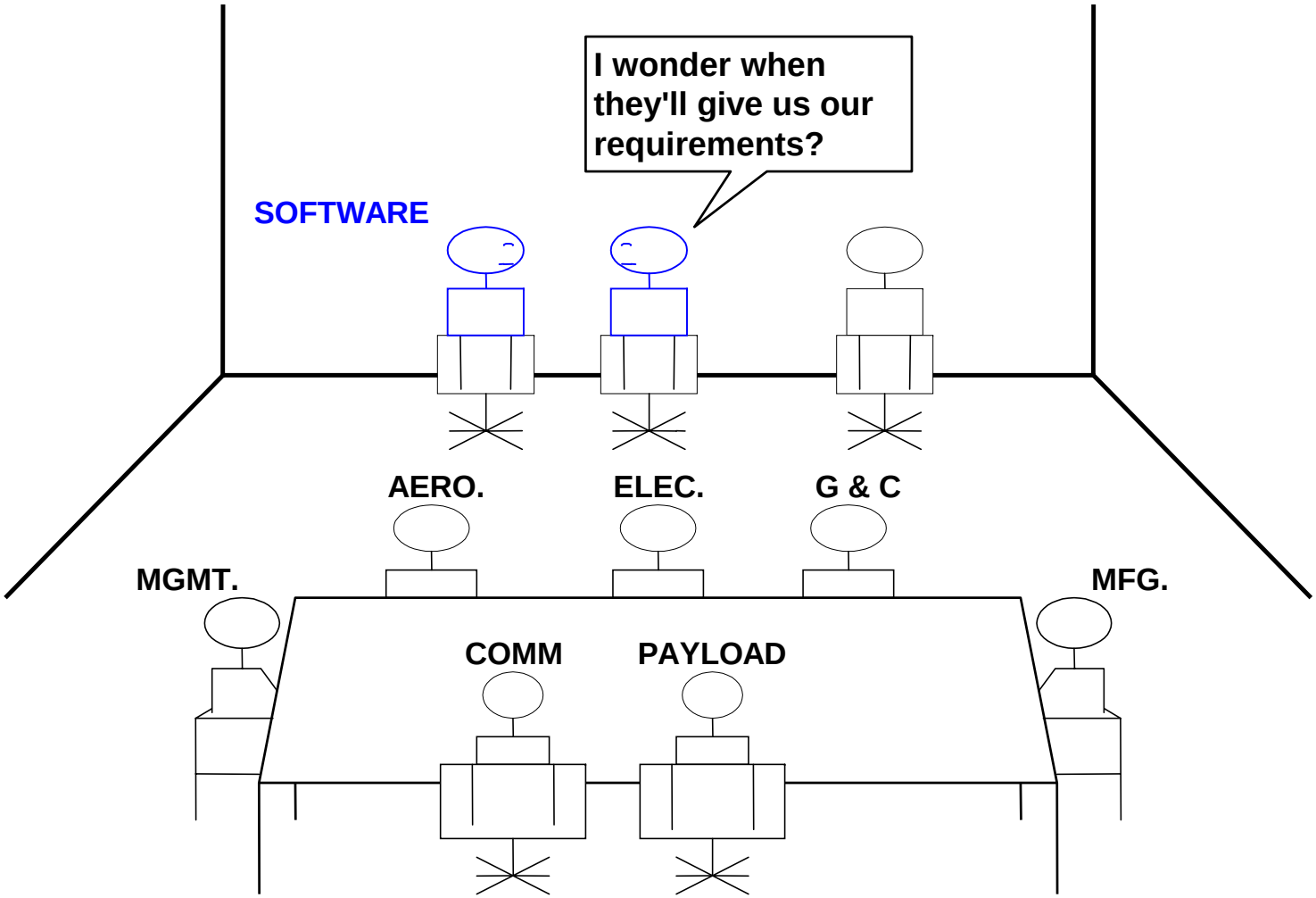
  "Analysis and allocation of the system requirements

  is not the responsibility of the software engineering group

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

- **Concurrent engineering emphasized in CMMI, DoDD 5000.1, DoDI 5000.2**

Resulting Project Social Structure



DoDI 5000.2 "Spiral Development"

Section 3.3.2.1

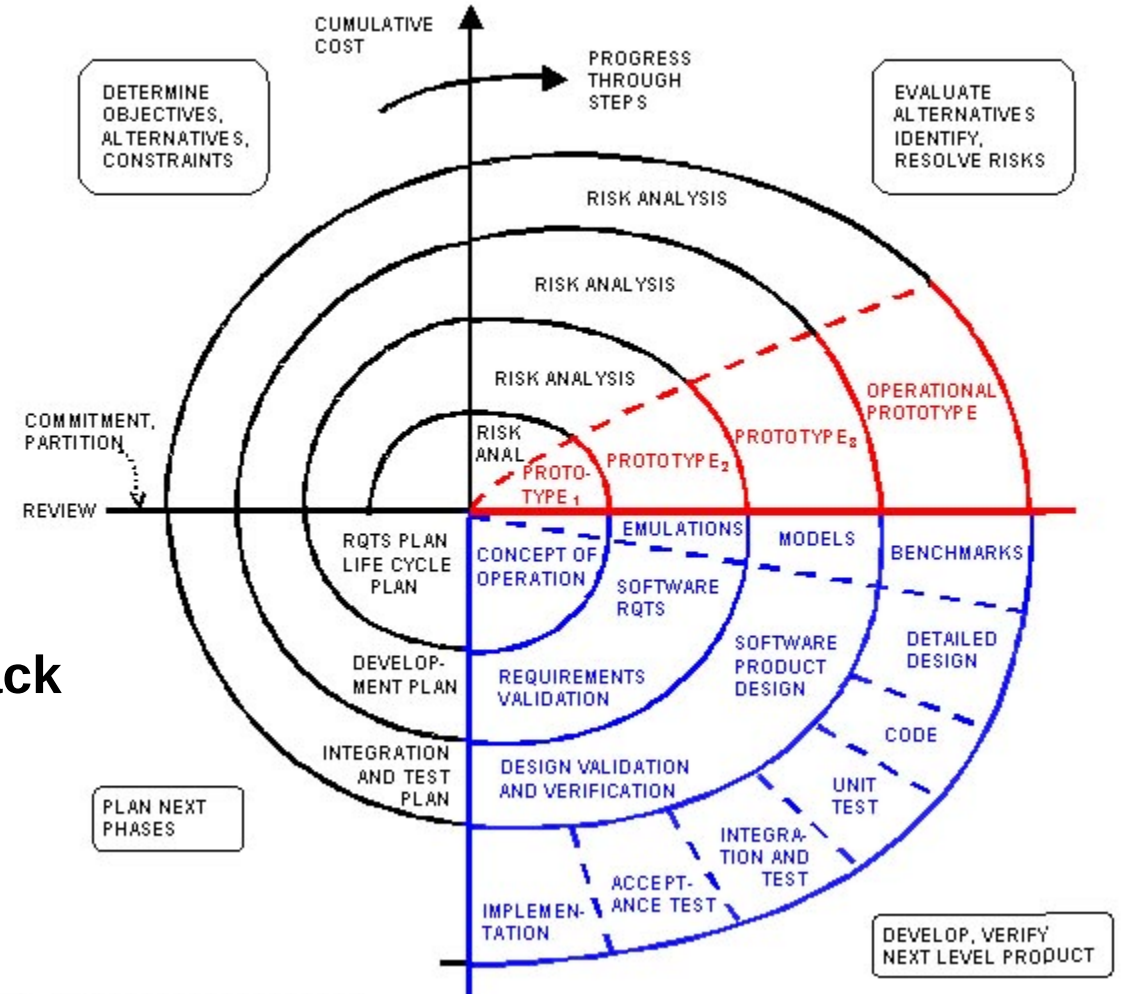
- Desired capability is identified
  - End-state requirements not initially known
- Requirements refined through demonstration and risk management
  - Continuous user feedback
  - Each increment provides user the best possible capability
- Requirements for future increments depend on feedback from users and technology maturation

What Is The Win Win Spiral Model?

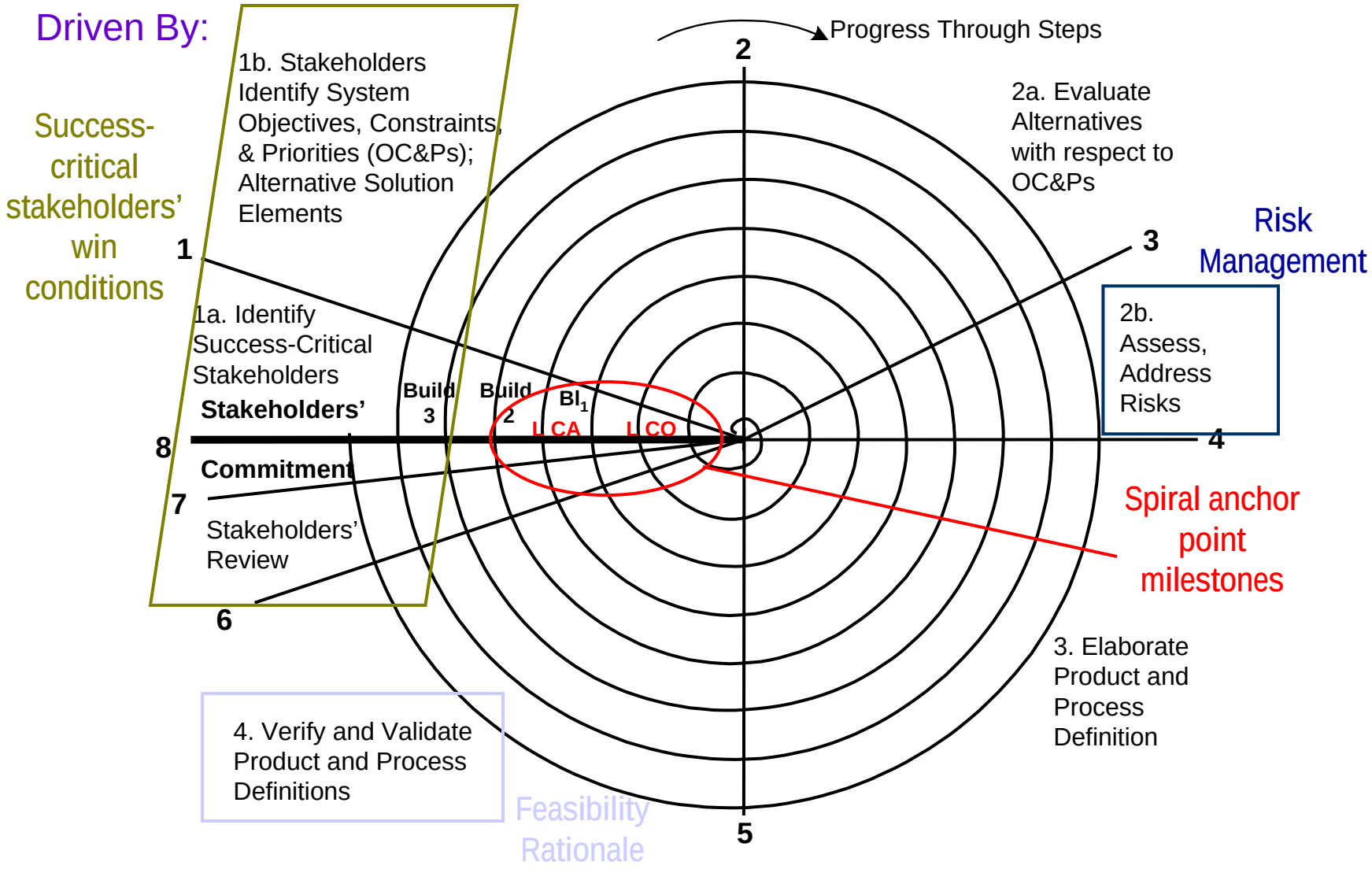
- A stakeholder-driven and risk-driven process model generator
  - There are no one-size-fits-all software process models
  - Different stakeholders and different risks generate different process models
- A way to perform controlled concurrent engineering
  - Of systems and software; of development and evolution; of product and process
  - Controlled by anchor point milestones and Feasibility Rationales
- An upward-compatible extension of the Rational Unified Process
  - Common risk and anchor-point orientation
  - With stakeholder and value-based extensions
  - Used successfully on a wide variety of applications
- A way to implement DoDD 5000.1 and DoDI 5000.2

Original Spiral and Misinterpretations

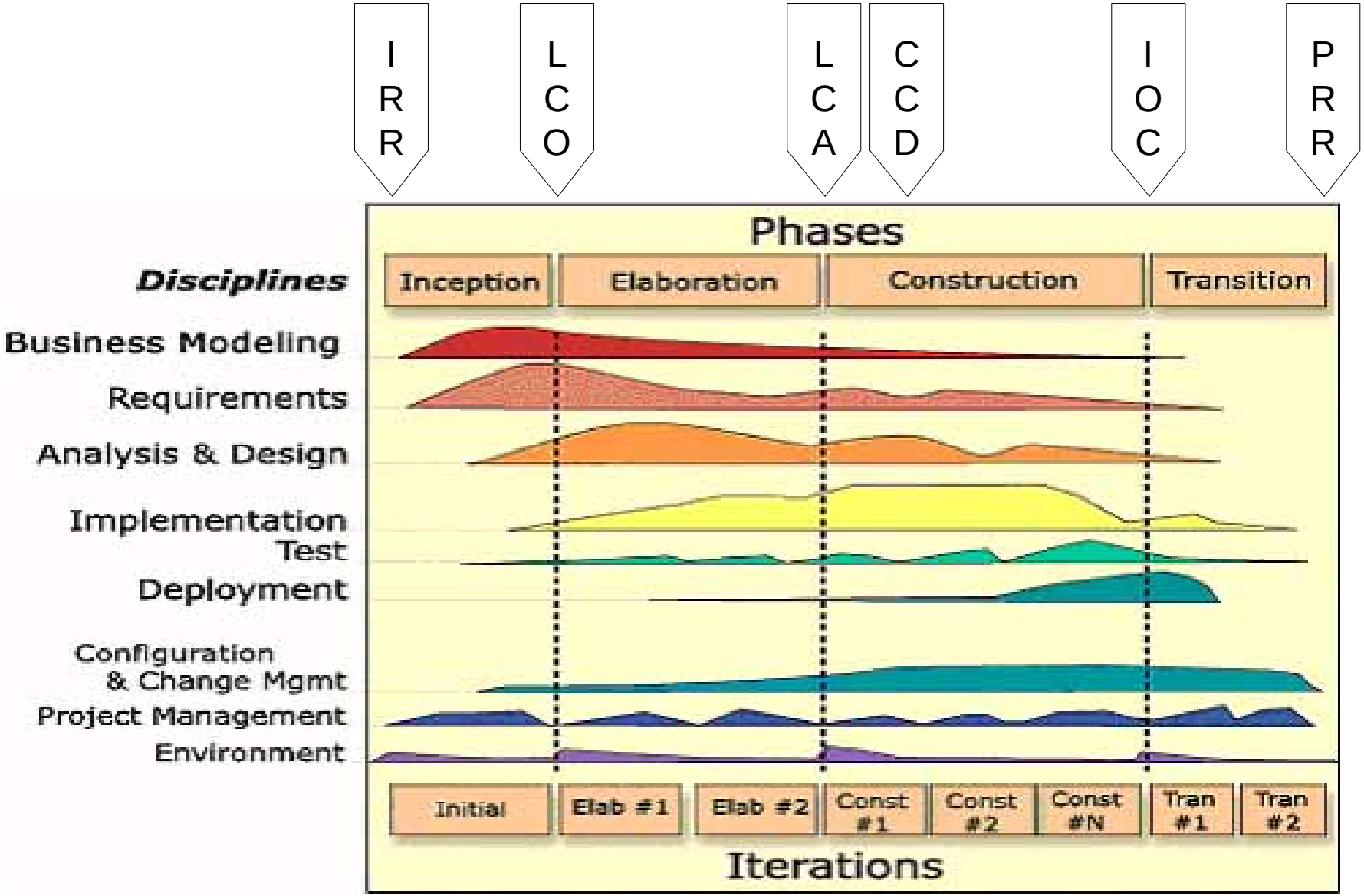
- **Common Misinterpretations**
  - **Hack some prototypes**
  - **Fit spiral into waterfall**
  - **Incremental waterfalls**
  - **Suppress risk analysis**
  - **No concurrency, feedback**
  - **One-size-fits-all model**



The FCS Win-Win Spiral Model



The WWSM Enables Concurrent Engineering



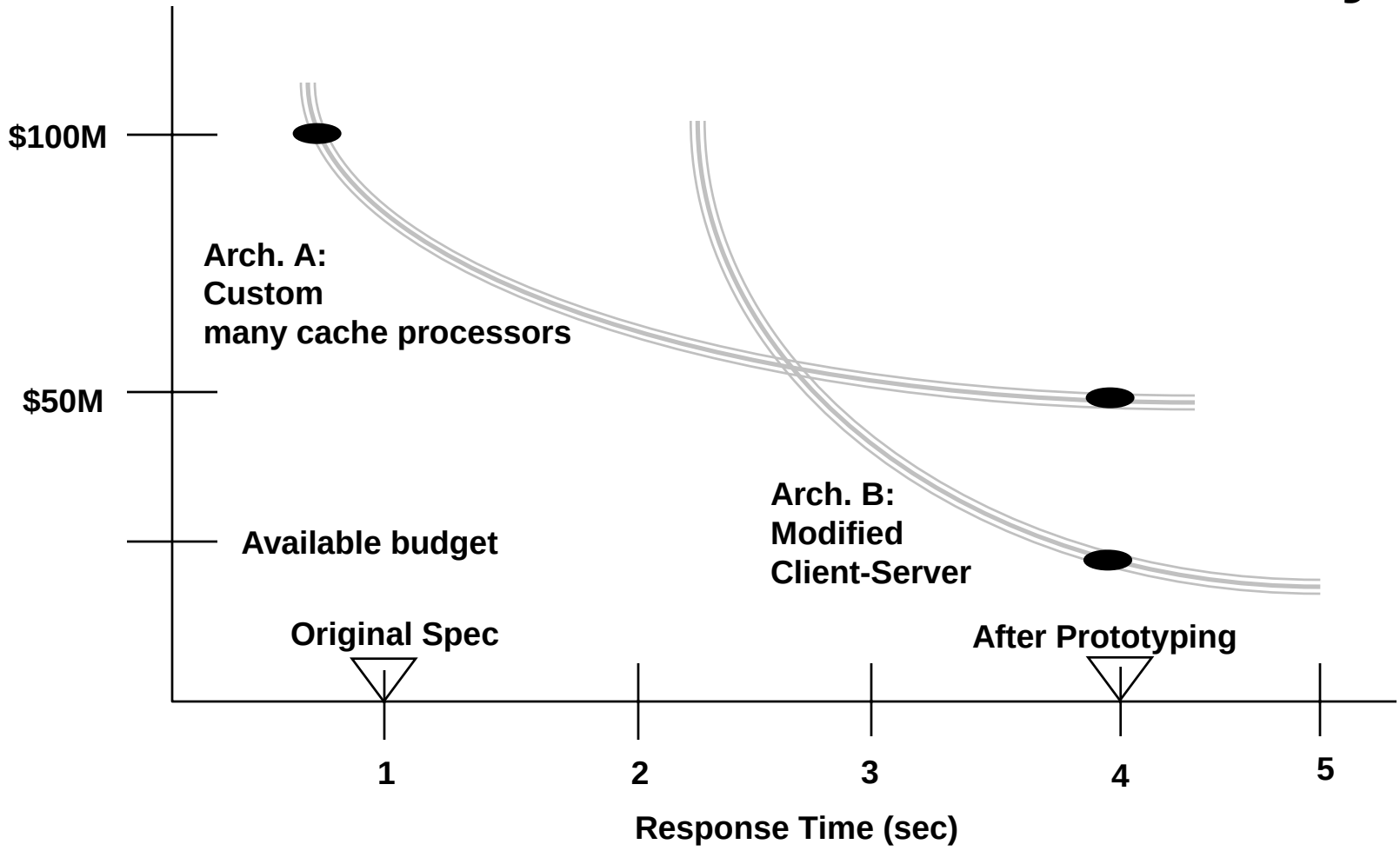
Pass/Fail Feasibility Rationales

- **Evidence provided by developer and validated by independent experts that:**

  If the system is built to the specified architecture, it will

  - **Satisfy the requirements: capability, interfaces, level of service, AND evolution**
  - **Support the operational concept**
  - **Be buildable within the budgets and schedules in the plan**
- **All major risks resolved or covered by risk management plans**
- **Serves as basis for stakeholders' commitment to proceed**

Effect of Unvalidated Requirements -15 Month Architecture Rework Delay



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

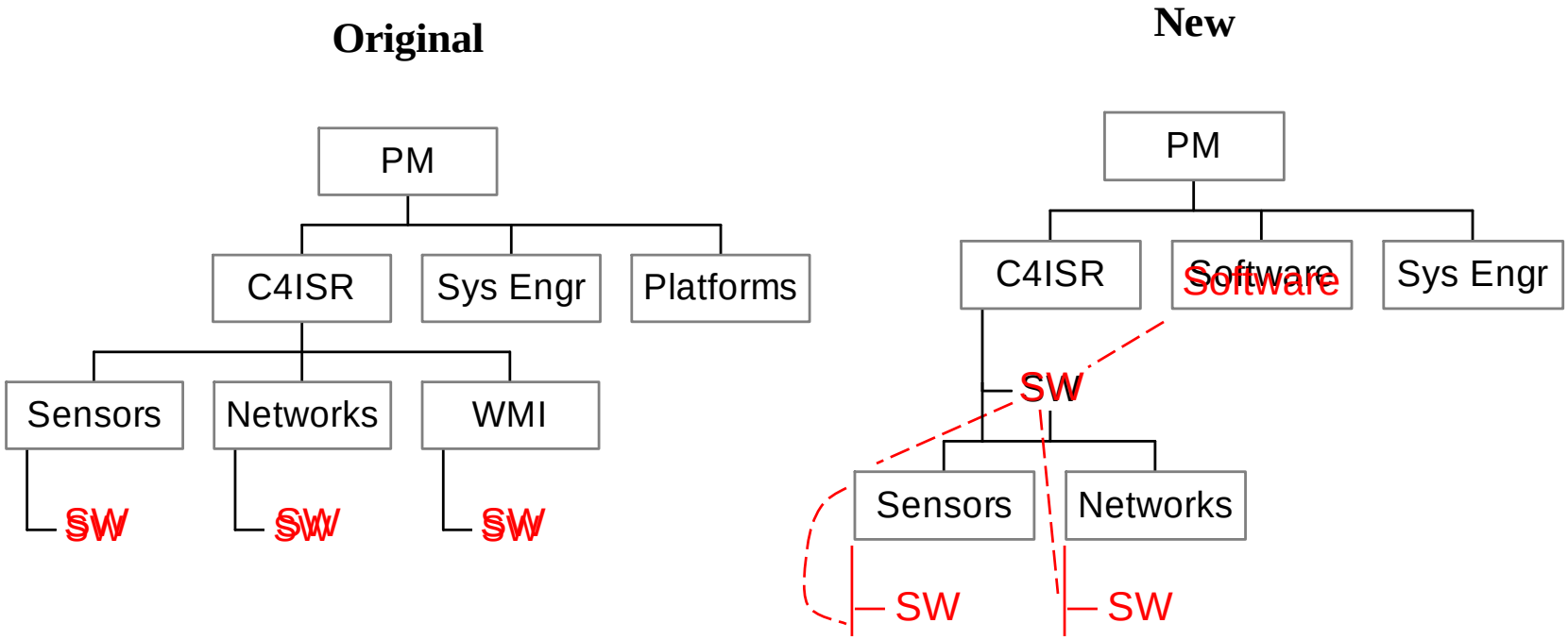
Top-10 Risks: Software-Intensive Systems of Systems

- CrossTalk, May 2004

1. Acquisition management and staffing
2. Requirements/architecture feasibility
3. Achievable software schedules
4. Supplier integration
5. Adaptation to rapid change
6. Quality factor achievability and tradeoffs
7. Product integration and electronic upgrade
8. Software COTS and reuse feasibility
9. External interoperability
10. Technology readiness

Effect of Software Underrepresentation

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



Need for CRACK 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

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):**

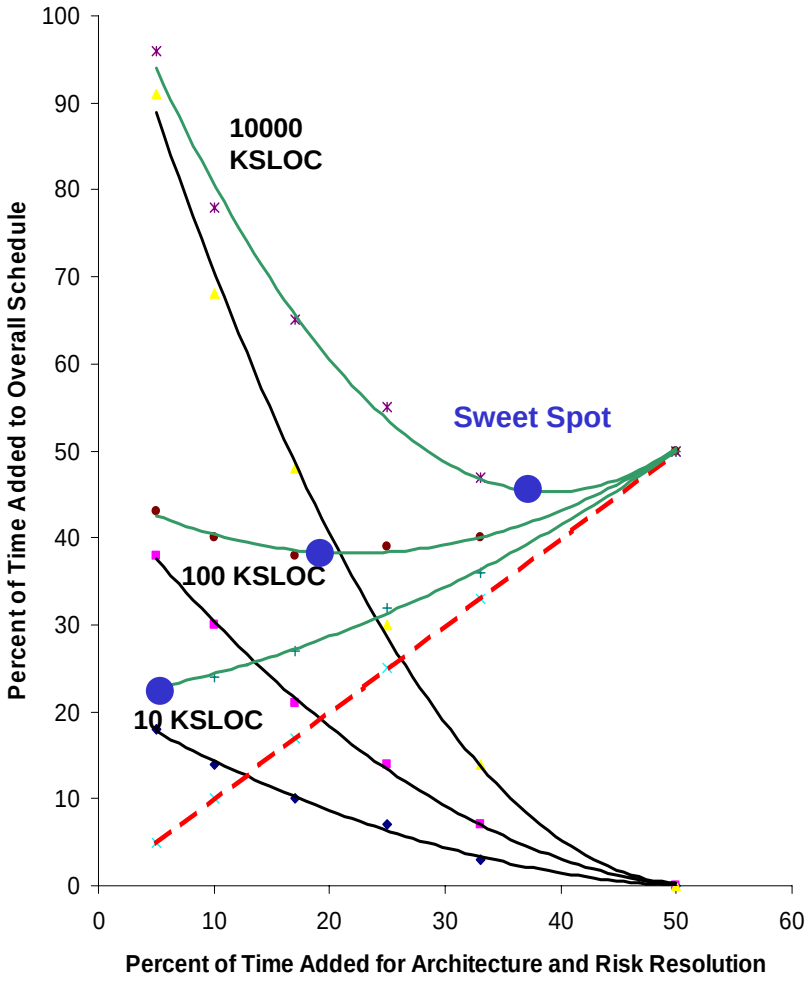
    Months =~ 5 * $\sqrt[3]{\text{KSLOC}}$

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

•Solution approach: architect for decoupled parallel development; Schedule As Independent Variable (SAIV) process

How Much Architecting Is Enough?

-A COCOMO II Analysis



Percent of Project Schedule Devoted to Initial Architecture and Risk Resolution

Added Schedule Devoted to Rework (COCOMO II RESL factor)

Total % Added Schedule

Sweet Spot Drivers:

Rapid Change: leftward

High Assurance: rightward

The SAIV* Process Model

– Cross Talk, January 2002 (http://www.stsc.hill.af.mil/crosstalk)

1. Shared vision and expectations management
2. Feature prioritization
3. Schedule range estimation and core-capability determination
   - Top-priority features achievable within fixed schedule with 90% confidence
4. Architecting for ease of adding or dropping borderline-priority features
   - And for accommodating past-IOC directions of growth
5. Incremental development
   - Core capability as increment 1
6. Change and progress monitoring and control
   - Add or drop borderline-priority features to meet schedule

*Schedule As Independent Variable; Feature set as dependent variable
– Also works for cost, schedule/cost/quality as independent variable

Supplier Integration: Rapid Adaptability to Change

- **Risk #4/5. Inflexible subcontracting will be a major source of delays and shortfalls.**
- **Strategy #4/5. Develop subcontract provisions enabling flexibility in evolving deliverables. Develop an award fee structure based on objective criteria for:**
  - **Schedule Preservation**
  - **Cost Containment**
  - **Technical Performance**
  - **Architecture and COTS Compatibility**
  - **Continuous Integration Support**
  - **Program Management**
  - **Risk Management**

Top-10 Risks: Software-Intensive Systems of Systems

- CrossTalk, May 2004

1. Acquisition management and staffing
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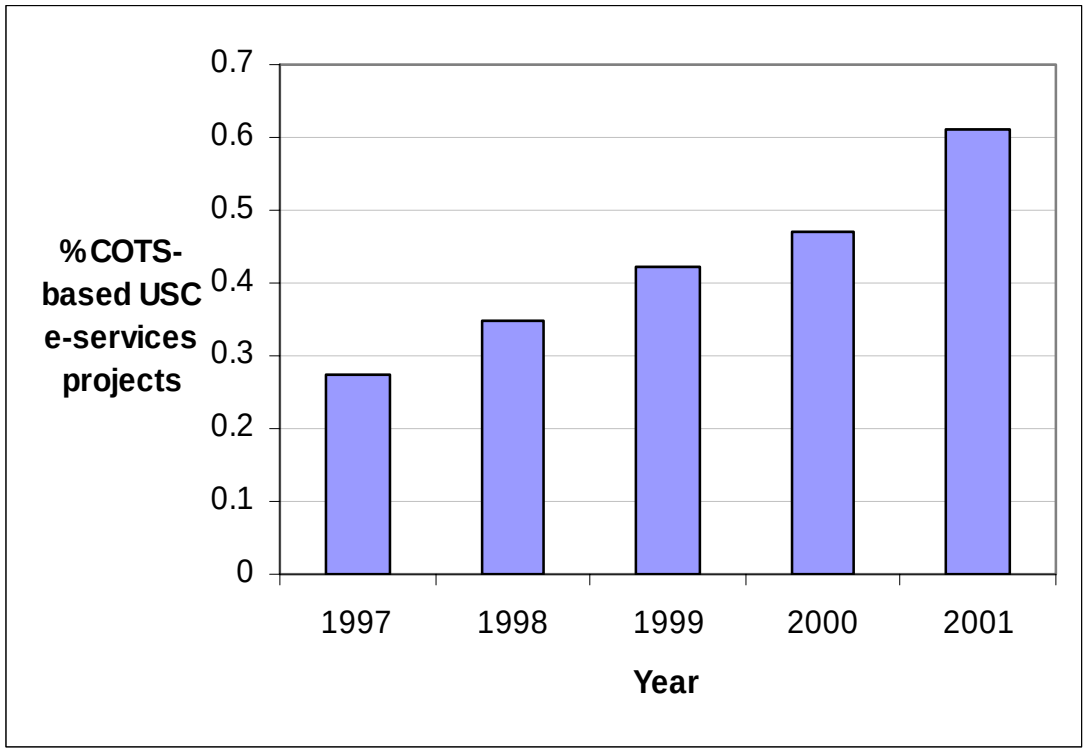
Rapid, Synchronous Software Upgrades

- Risk #7. Out-of-synchronization software upgrades will be a major source of operational losses
  - Software crashes, communication node outages, out-of-synch data, mistaken decisions
  - Extremely difficult to synchronize multi-version, distributed, mobile-platform software upgrades
  - Especially if continuous-operation upgrades needed
- Strategy #7a. Architect software to accommodate continuous-operation, synchronous upgrades
  - E.g., parallel operation of old and new releases while validating synchronous upgrade
- Strategy #7b. Develop operational procedures for synchronous upgrades in software support plans
- Strategy #7c. Validate synchronous upgrade achievement in operational test & evaluation

COTS: The Future is Here

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



COTS Upgrade Synchronization and Obsolescence

- Risk #8a: Many subcontractors means a proliferation of evolving COTS interfaces
- Risk #8b: 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 #8a: Emphasize COTS interoperability in source selection process
- Strategy #8b: Contract provisions ensuring delivery of refreshed COTS products.

Conclusions

- Defense and space systems undergoing transformation
- Need emphasis on spiral systems engineering
- Need to integrate systems and software engineering
- Spiral approach enables concurrent engineering
  - And emphasis on risk management
- New systems of systems risks emerging
  - And new mitigation approaches

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CrossTalk articles: www.stsc.hill.af.mil/crosstalk