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Teaching the Elephant to Dance:
Agility Meets Systems of Systems Engineering and Acquisition

Keynote, GSAW 2005
March 3, 2005

Outline

- Nature of systems of systems engineering and acquisition
  - Particularly, network-centric systems of systems (NCSOS)
  - Acquisition is more like doing C4ISR than buying fruitcake
- Agile methods and NCSOS: strengths and difficulties
  - Helpful, but not a silver bullet
- Integrating agile and plan-driven methods
  - Workshop results and integration framework
- Critical success factors
  - Evolutionary, risk-driven spiral framework and plan-driven builds
  - Compatible acquisition and contracting methods and skills
  - Knowing when not to system engineer
- Conclusions, references

The Need for NetCentric Systems of Systems (NCSOS)

- Lack of integration among stovepiped systems causes
  - Unacceptable delays in service
  - Uncoordinated and conflicting plans
  - Ineffective or dangerous decisions
- NCSOS can strongly boost performance of
  - National Defense
  - Supply Chain Management
  - National Air Traffic Control
  - Crisis Management

System Acquisition Trends

Traditional Acquisition

- Standalone systems
- Stable requirements
- Rqts. determine capabilities
- Control over evolution
- Enough time to keep stable
- Failures locally critical
- Reductionist systems
- Repeatability-oriented process, maturity models

Current/Future Trends

- Everything connected (maybe)
- Rapid requirements change
- COTS capabilities determine rqts.
- No control over COTS evolution
- Ever-decreasing cycle times
- Failures globally critical
- Complex, adaptive, emergent systems of systems
- Adaptive process models

NCSOS Acquisition is More Like Doing C4ISR – than buying fruitcake

- No detailed plan survives the first engagement
- Acquisition C4ISR via spiral OODA loops
  - Observe, Orient, Decide, Act
  - Vs. Requirements, Delay, Surprise
- Concurrent tasking, collaboration technology essential
  - Spanning deep chains of command
    - *Customer, LSI, IPT's (C4ISR), Decision Support, COP Refresh, Sensor Fusion, Sensors, Sensor components*
- Common strategy essential; microplanning risky
- Competition, technology, marketplace ISR essential
- Rapid adaptability essential

Acquisition C4ISR Via Spiral OODA Loops
– Example: ARPANet/Internet Spiral

Observe new/updated objectives, constraints, alternatives

- Usage monitoring
- Competition, technology, marketplace ISR

Orient with respect to stakeholders priorities, feasibility, risks

- Risk/Opportunity analysis
- Business case/mission analysis
- Prototypes, models, simulations

Operate as current system

Accept new system

Act on plans, specifications

- Keep development stabilized
- Change impact analysis, preparation for next cycle (mini-OODA loop)

Decide on next-cycle capabilities, architecture upgrades, plans

- Stable specifications, COTS upgrades
- Development, integration, V&V, risk management plans
- Feasibility rationale

Life Cycle Architecture Milestone for Cycle

NCSOS Acquisition Practice Implications

- **Need to stimulate agility during Observe, Orient, Decide sectors**
  - **With flexibility-oriented contract, award fee provisions**
- **Need to stimulate stability during Act sector**
  - **Current stability-oriented contract provisions a good match**
- **Risk-driven spiral process generator accommodates both**
- **Waterfall and V-models have their risk-driven place**
  - **Acquiring precedented systems in stable marketplace**
  - **Executing stable Act sector**

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The Agile Manifesto

We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:

- **Individuals and interactions** over processes and tools
- **Working software** over comprehensive documentation
- **Customer collaboration** over contract negotiation
- **Responding to change** over following a plan

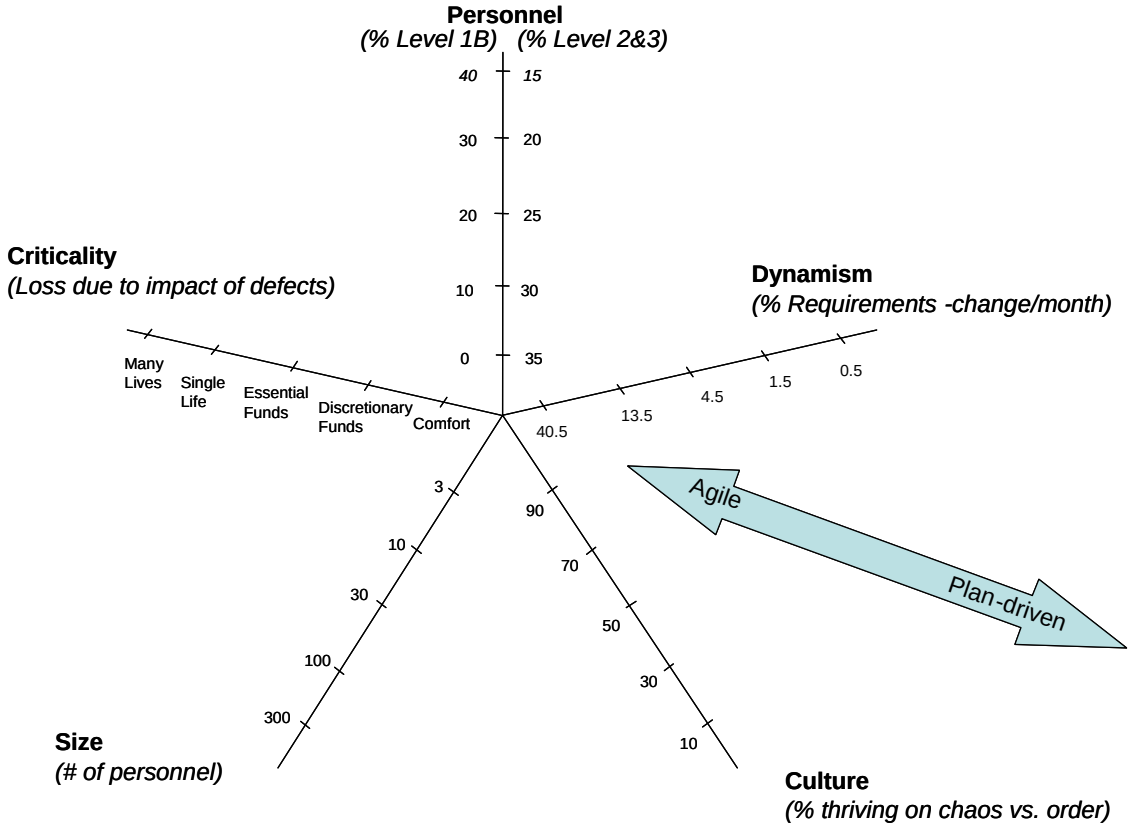
That is, while there is value in the items on the right, we value the items on the *left* more.

NCSOS-Relevant Agile Practices

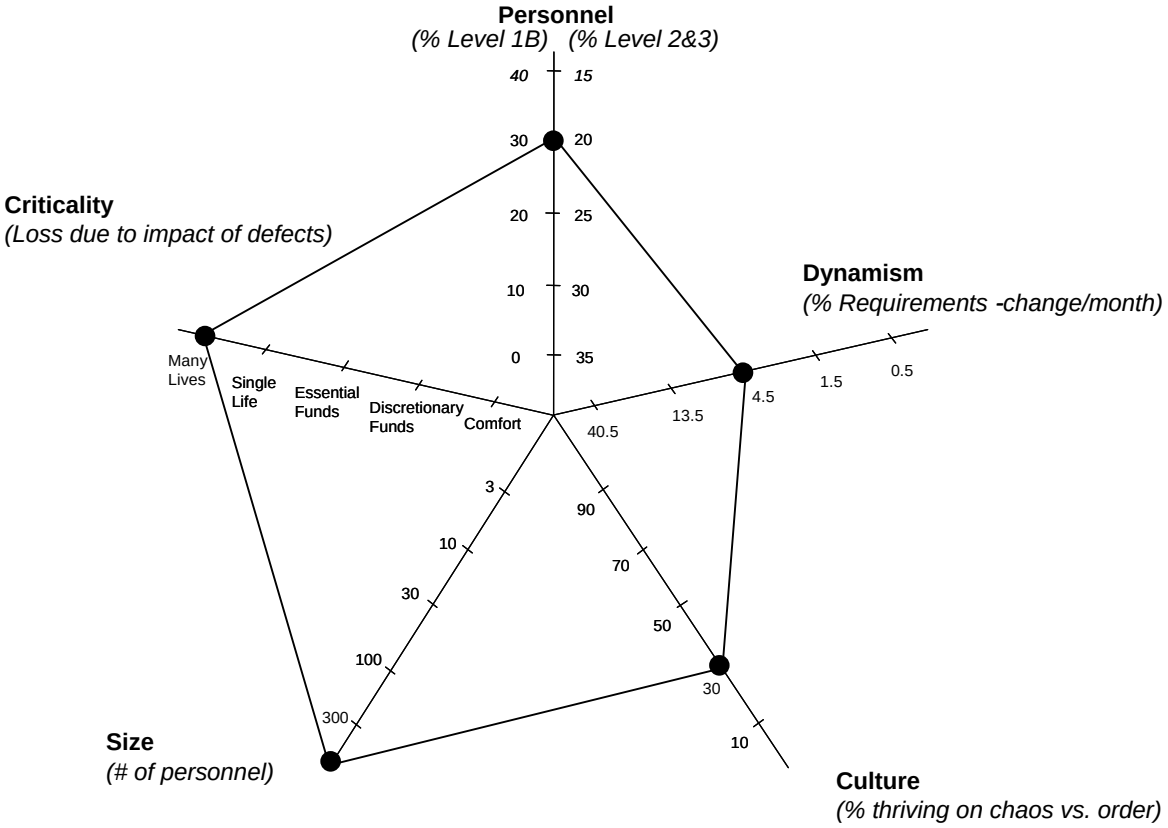
- Short stabilized increments (+)
  - Prioritized feature backlog
- Continuous customer-developer participation (+)
- Early test; continuous integration (+)
- Tacit interpersonal vs. explicit documented knowledge (±)
- Welcome changing requirements (±)
- Simple design (-)
  - Just for current increment
  - Refactor to accommodate later capabilities

Agile and Plan-Driven Home Grounds: Five Critical Decision Factors

- **Size, Criticality, Dynamism, Personnel, Culture**



NCSOS Agile/Plan-Driven Profile



Conclusions So Far

- Large global enterprises need NCSOS
- NCSOS acquisition is more like doing C4ISR
  - Acquisition C4ISR via spiral OODA loops
  - Need more adaptive vs. build-to-spec acquisition practices
- Key agile practices help, but scalability is difficult
- NCSOS acquisition needs to balance agility and discipline
  - Integrating agile and plan-driven methods

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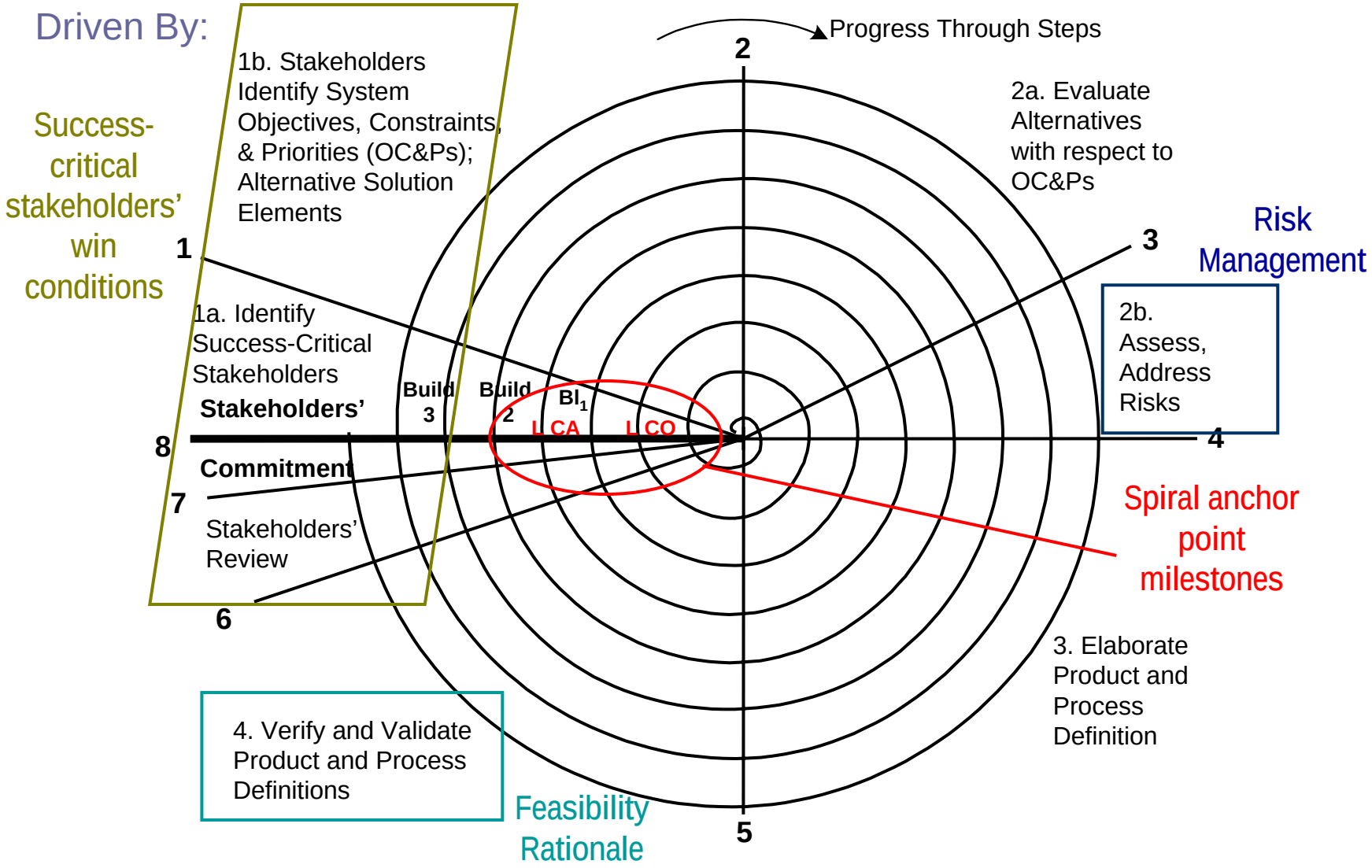
USC-CSE Agile/Plan-Driven Workshops, 2002-2005

- Large companies having success with small agile pilot projects
  - ABB, Daimler Chrysler, IBM, LMCO, Motorola, Northrop Grumman, Raytheon, SAIC
  - Generally higher productivity, customer satisfaction, morale
- Some perceived agile problems were non-issues
  - Agile is monolithic, disorganized
  - No framework for quantitative management, quality assurance
- Some perceived agile problems were real issues

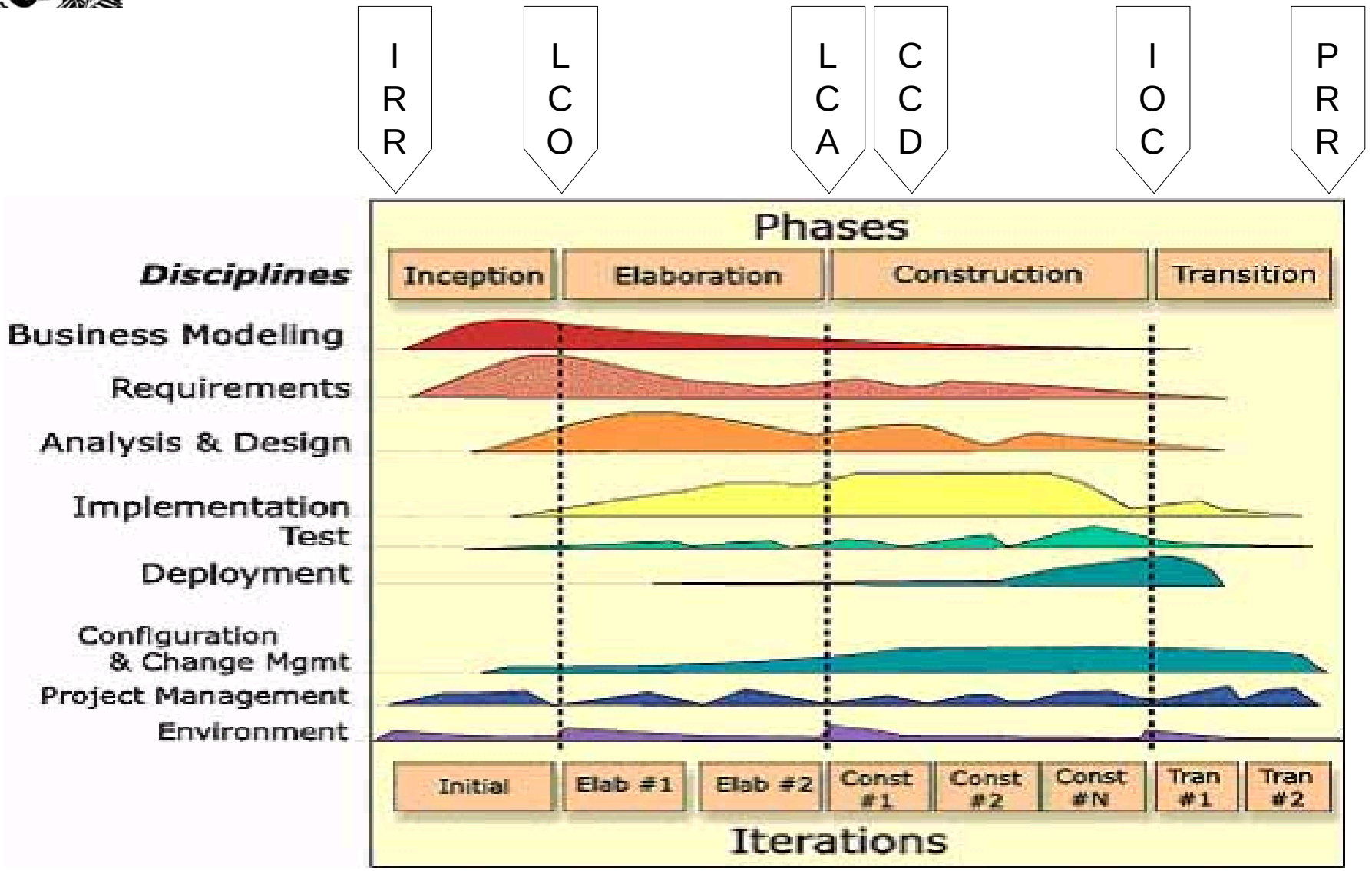
Large-Company Agile Assimilation Issues

- Scalability of agile methods
  - Tacit knowledge (propagation; personnel turnover; 5,000 requirements)
  - Multi-team coordination
- Avoiding agile stovepipes
  - Limitations on freedom of choice
    - *COTS, interfaces, GUIs, legacy systems*
- Traditional business practices
  - Contracting; earned value systems; timekeeping; waterfall/V-model standard, HR practices
- Inflexible maturity model interpretations
- Customer collocation, access
- Architecture suboptimization on early increments
  - Example: key performance parameters
- Predictable vs. unpredictable change

Spiral Integration of Agile and Plan-Driven Processes



Spiral Anchor Points Enable Concurrent Engineering



Need Concurrently Engineered Milestone Reviews

Life Cycle Objectives (LCO); Life Cycle Architecture Package (LCA)

Operational Concept	• Elaboration of system objectives and scope by increment • Elaboration of operational concept by increment
System Prototype(s)	• Exercise range of usage scenarios • Resolve major outstanding risks
System Requirements	• Elaboration of functions, interfaces, quality attributes, and prototypes by increment - Identification of TBD's (to be determined items) • Stakeholders' concurrence on their priority concerns
System and Software Architecture	• Choice of architecture and elaboration by increment - Physical and logical components, connectors, configurations, constraints - COTS, reuse choices - Domain architecture and architectural style choices • Architecture evolution parameters

Need Concurrently Engineered Milestone Reviews

Life Cycle Objectives (LCO); Life Cycle Architecture Package $(LCA)_2$

Life-Cycle Plan	• Elaboration of WWWWWHH* for Initial Operational Capability (IOC) • Partial elaboration, identification of key TBD's for later increments
Feasibility Rationale	• Assurance of consistency among elements above • All major risks resolved or covered by risk management plan.

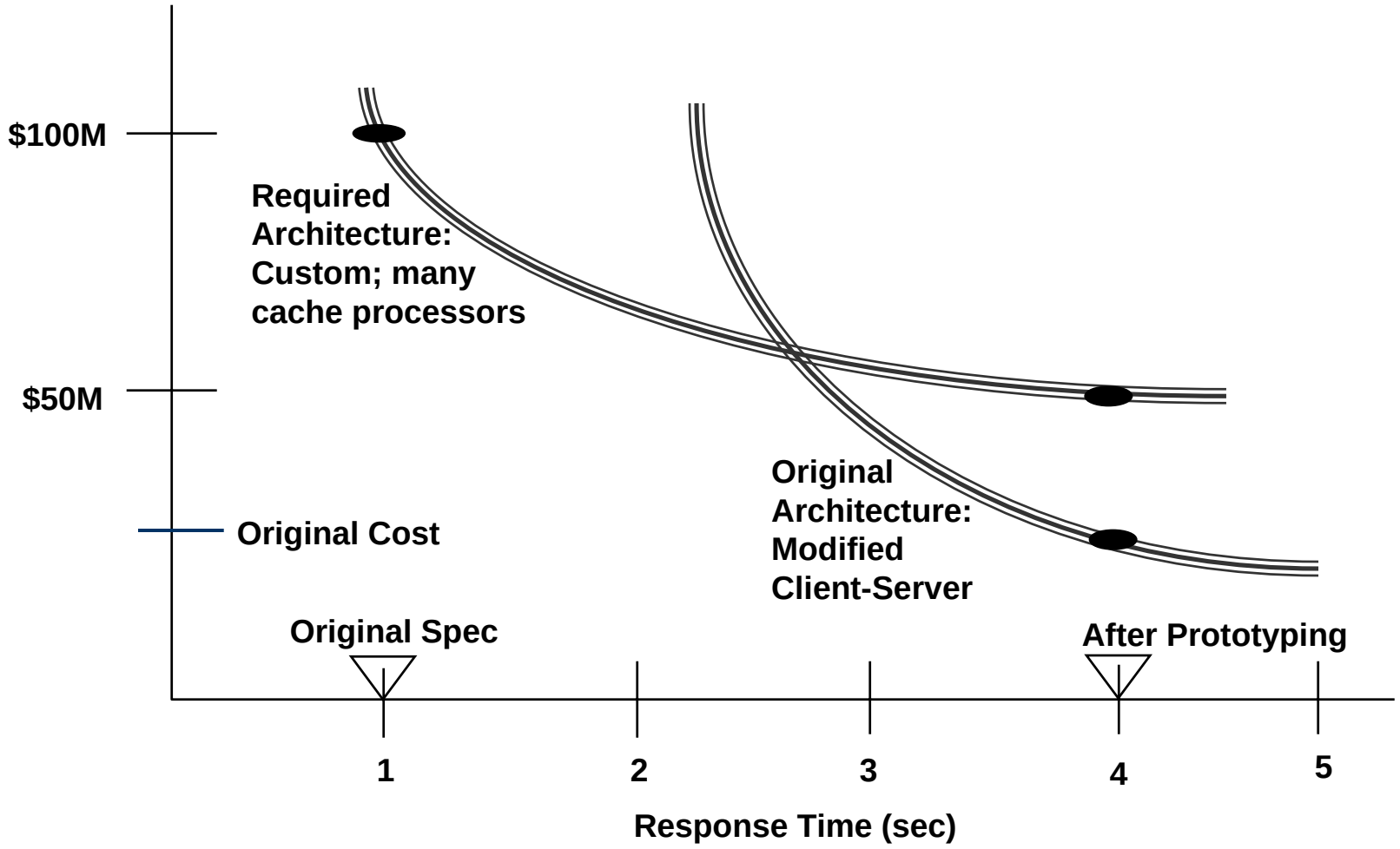
***WWWWWHH: Why, What, When, Who, Where, How, How Much**

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

- **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

The Cost of Hasty Fixed Requirements: 15-Month Architecture Rework Delay

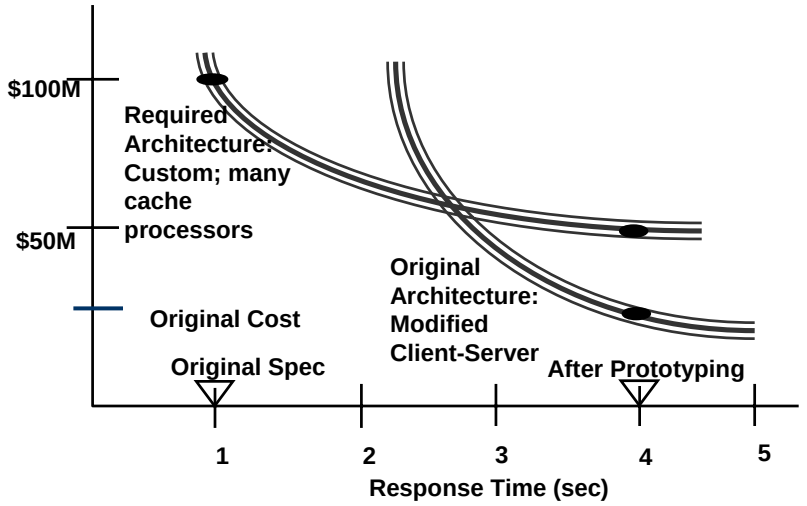


KPP Validation with Spiral Model

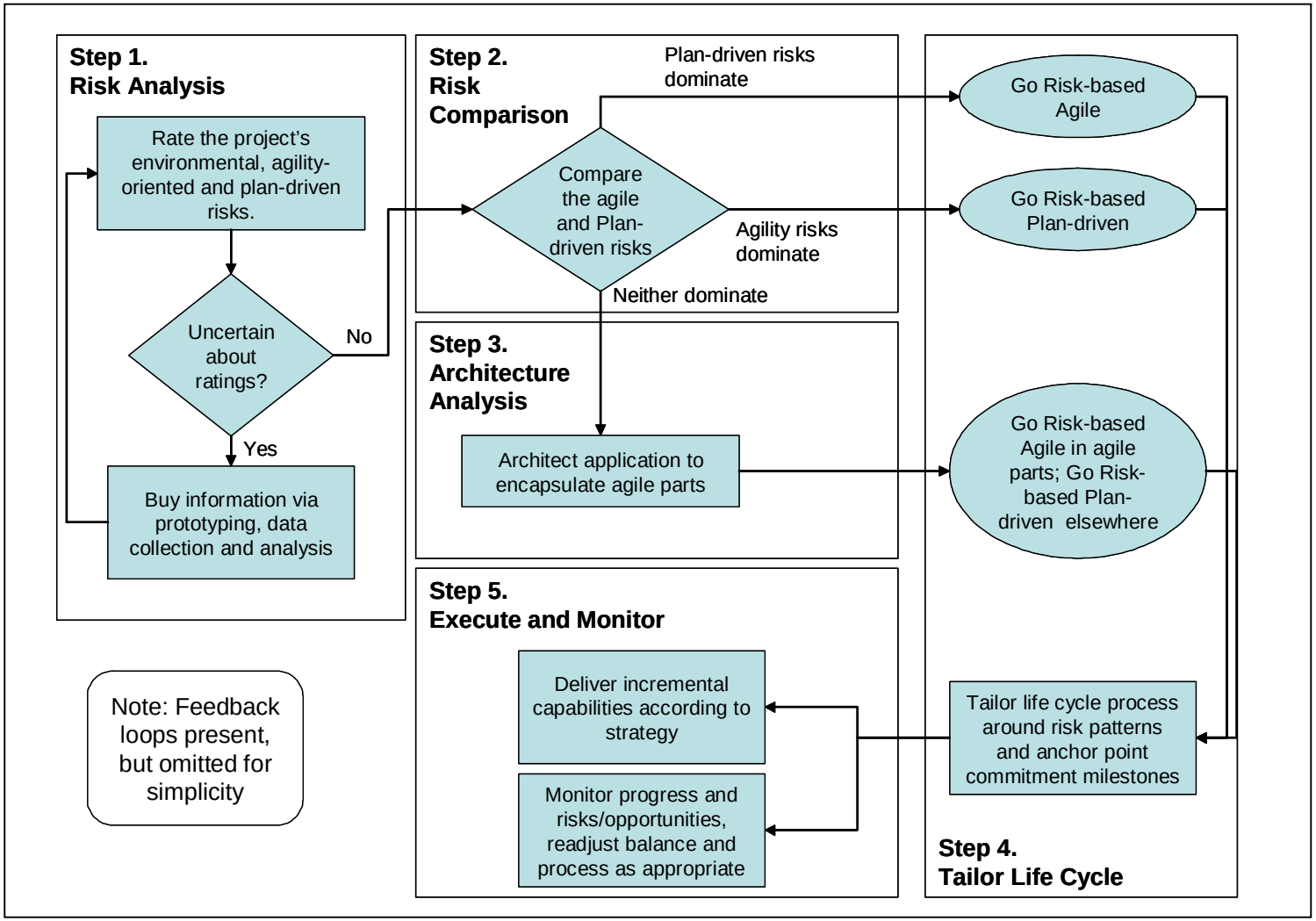
- Attempt to validate 1-second KPP
  - Architecture analysis: needs expensive custom solution
  - Prototype: 4-seconds OK 90% of the time
- Negotiate KPP ranges
  - 2 seconds desirable
  - 4 seconds acceptable with some 2-second special cases
- Benchmark client-server to validate feasibility
- Present solution and feasibility rationale at anchor point milestone review
  - Result: Acceptable solution with minimal delay

Key Points

- **It's not a requirement if you can't afford it**
  - **Or fit it into your schedule**
- **Spiral approach avoids late rework**
- **Beware of sub-optimization on small-scale early iterations**

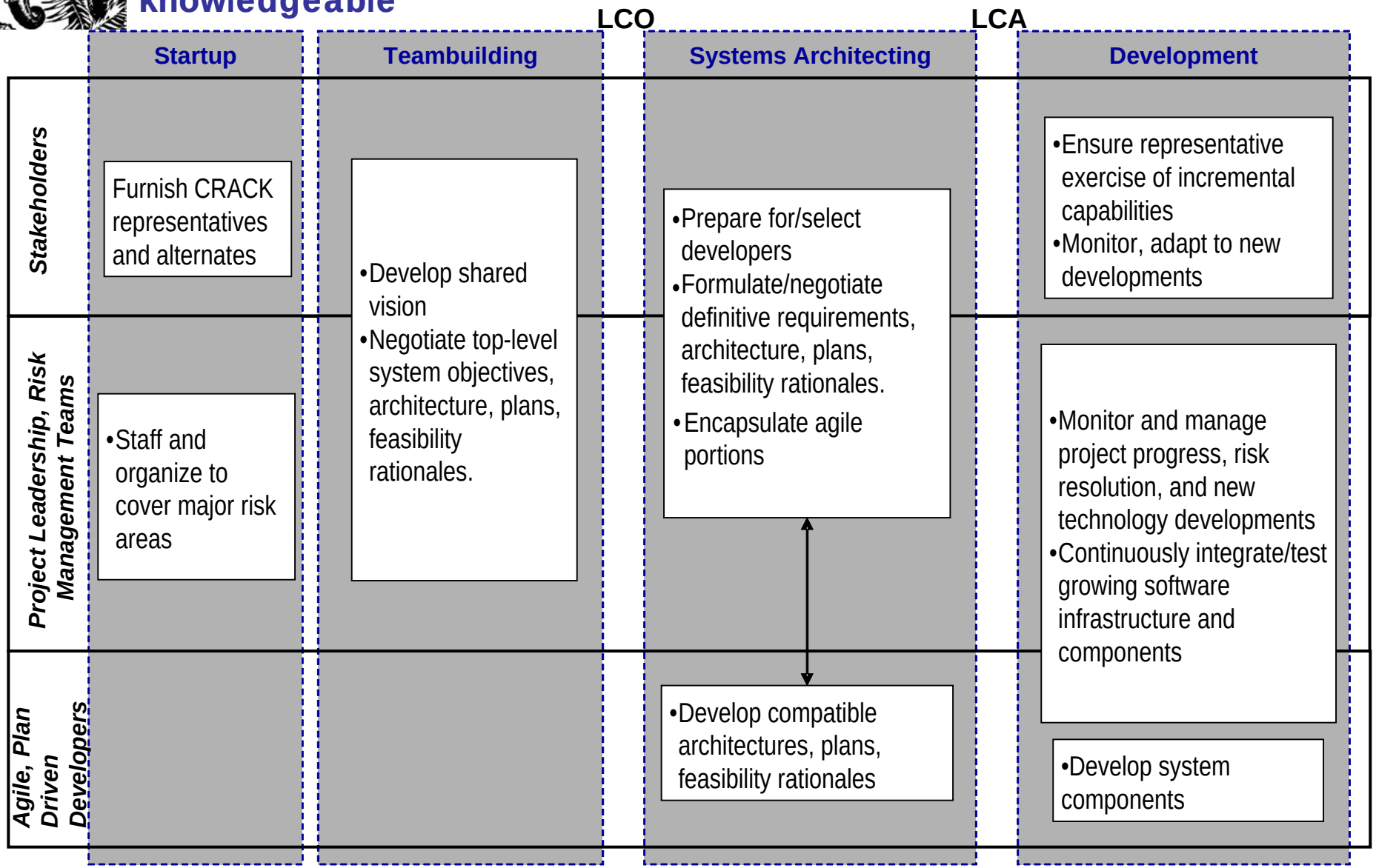


Using Risk to Balance Discipline and Agility - Overview



NCSOS Agile/Plan-Driven Strategy

– CRACK: collaborative, representative, authorized, committed, knowledgeable



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NCSOS Acquisition: Critical Success Factors

- Risk-driven spiral processes and organizations
  - Project manager's risk/opportunity team
- Stabilized evolutionary builds
  - Concurrent plan-driven construction, agile rebaselining
  - Anchor point milestones and Feasibility Rationales
- Rethinking supplier management
  - Teambuilding and plans/architecture participation
  - Balanced agile/plan-driven contracts, award fees
- Knowing when not to system engineer

Agile Rebaselining Mini OODA Loop

- **Many sources of next-build volatility**
  - **Supplier chain slippages, changes in current build**
  - **External interface volatility**
    - ***COTS; interoperating systems***
  - **New threats, technology, policies**
  - **Organizational, top-management volatility**
- **Next build needs to hit the ground running**
- **Requires critical-mass budget, talent, tools for**
  - **Change impact analysis (observe, orient)**
  - **Solution rebaselining (decide, act)**
    - ***Renegotiating future builds' content, associated plans and resources***
    - ***Integrated COTS refresh preparation***

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**

NB: This section of 5000 is under revision and all reference to spiral may be removed

Knowing When Not to System Engineer – A multi-platform NCSOS example

- Customer system-engineers an optimized product line architecture for platform functions
  - Estimates cost savings from reuse
- Customer solicits best-of-breed platform suppliers
  - Contracts with most cost-effective bidders
- Customer discovers that supplier bids are based on product line – incompatible components
  - Too expensive to refit to product line architecture
- Better to risk-manage degree of product line achievability
  - Involve potential suppliers in product line option exploration

Conclusions

- Large global enterprises need NCSOS
- NCSOS acquisition is more like doing C4ISR
- Critical success factors include
  - Risk-driven spiral processes and organizations
  - Concurrent plan-driven builds, agile rebaselining
    - *And associated budgets, talent, tools*
  - Rethinking supplier management
    - *Balanced agile/plan-driven contracts, award fees*
    - *Teambuilding and plans/architecture participation*
    - *Knowing when not to system engineer*

References

B. Boehm, R. Turner, Balancing Agility and Discipline, Addison Wesley, 2004.

B. Boehm, W. Hansen, "The Spiral Model as a Tool for Evolutionary Acquisition," Cross Talk, May 2001.

B. Boehm, D. Port, "Balancing Discipline and Flexibility with the Spiral Model and MBASE," CrossTalk, December 2001, pp. 23-28.

B. Boehm, D. Port, L. Huang, and W. Brown, "Using the Spiral Model and MBASE to Generate New Acquisition Process Models: SAIV/ CAIV, and SCQAIV," CrossTalk, January 2002, pp. 20-25.

D. Reifer and B. Boehm, "A Model Contract/Subcontract Award Fee Plan for Large, Change-Intensive Software Acquisitions," USC-CSE Technical Report, April 2003.

B. Boehm, A.W. Brown, V. Basili, and R. Turner, "Spiral Acquisition of Software-Intensive Systems of Systems," Cross Talk, May 2004, pp. 4-9.

MBASE web site : sunset.usc.edu/research/MBASE

Agile workshops web site : www.cse.usc.edu/events/2004/arr

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