Early Identification of Systems Engineering-Related Risks

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Summary

- Good evidence reduces risk
  - Risk Exposure = Prob (Loss) * Size (Loss)
  - Weak evidence increases uncertainty, Prob (Loss)
- Evidence-based reviews enable early risk resolution
  - They require more up-front systems engineering effort
  - They have a high ROI for high-risk projects
  - They synchronize and stabilize concurrent engineering
  - The evidence becomes a first-class deliverable
    - It requires planning and earned value management
- Need for in-process risk assessment
  - Evidence-based risk assessment tools recently developed
    - Systems Engineering Performance Risk Tool (SEPRT)
    - Systems Engineering Competency Risk Tool (SECRT)

Outline

- Evidence-based reviews and deliverables
- Evidence planning and preparation steps
- Evidence-based in-process risk assessment
- Evidence-based risk assessment tools

Types of Milestone Reviews

- Schedule-based reviews (contract-driven)
  - We'll hold the PDR on April 1 whether we have a design or not
  - High probability of proceeding into a Death March
- Event-based reviews (artifact-driven)
  - The design will be done by June 1, so we'll have the review then
  - Large "Death by PowerPoint and UML" event
    - Hard to avoid proceeding with many unresolved risks and interfaces
- Evidence-based commitment reviews (risk-driven)
  - Evidence provided in Feasibility Evidence Description (FED)
    - A first-class deliverable
  - Shortfalls in evidence are uncertainties and risks
  - Should be covered by risk mitigation plans
  - Stakeholders decide to commit based on risks of going forward

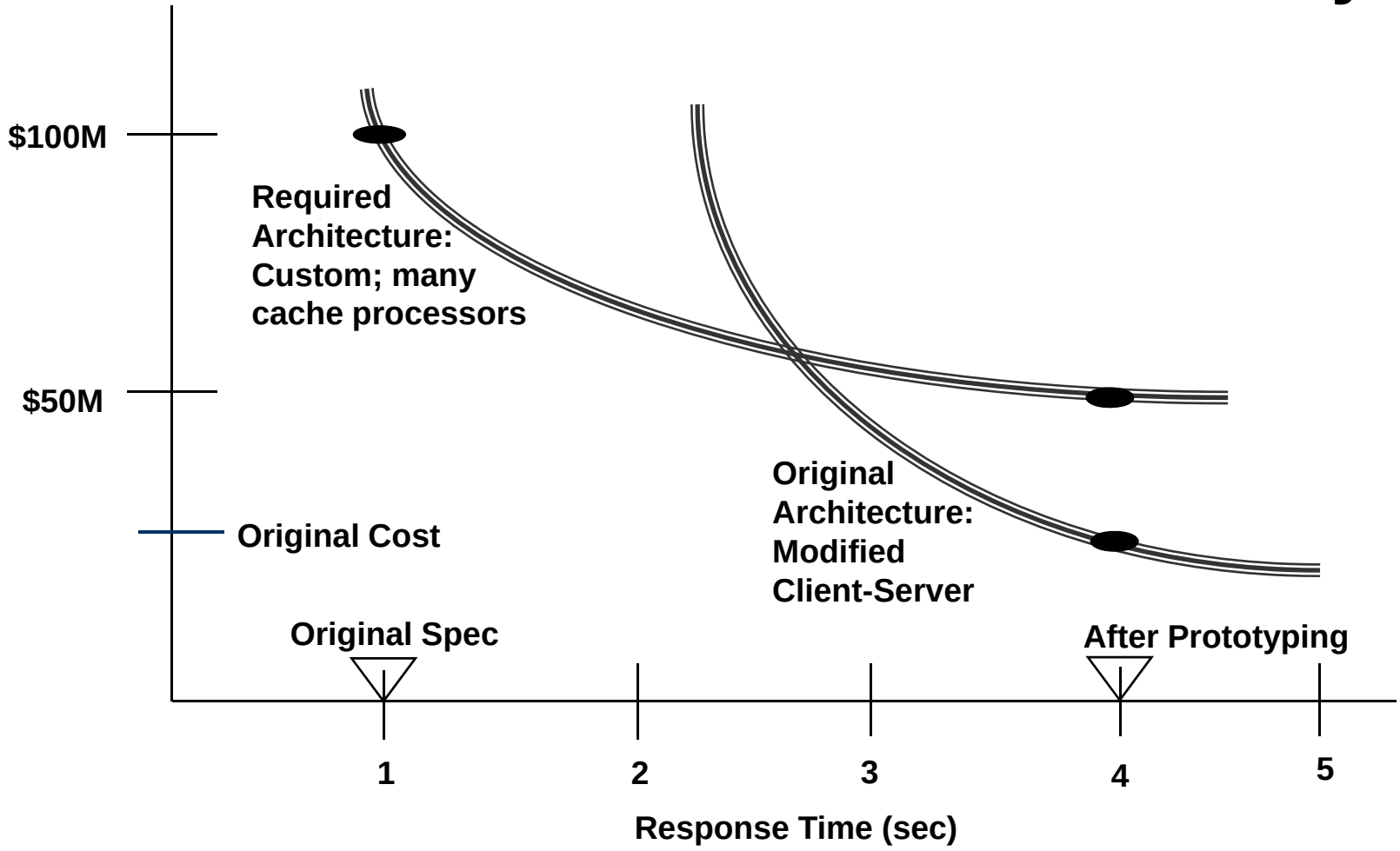
Nature of FEDs and Anchor Point Milestones

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

  If the system is built to the specified architecture, it will
  - **Satisfy the specified operational concept and requirements**
    - **Capability, interfaces, level of service, and evolution**
  - **Be buildable within the budgets and schedules in the plan**
  - **Generate a viable return on investment**
  - **Generate satisfactory outcomes for all of the success-critical stakeholders**
- **Shortfalls in evidence are uncertainties and risks**
  - **Should be resolved or covered by risk management plans**
- **Assessed in increasing detail at major anchor point milestones**
  - **Serves as basis for stakeholders' commitment to proceed**
  - **Serves to synchronize and stabilize concurrently engineered elements**

Can be used to strengthen current schedule- or event-based reviews

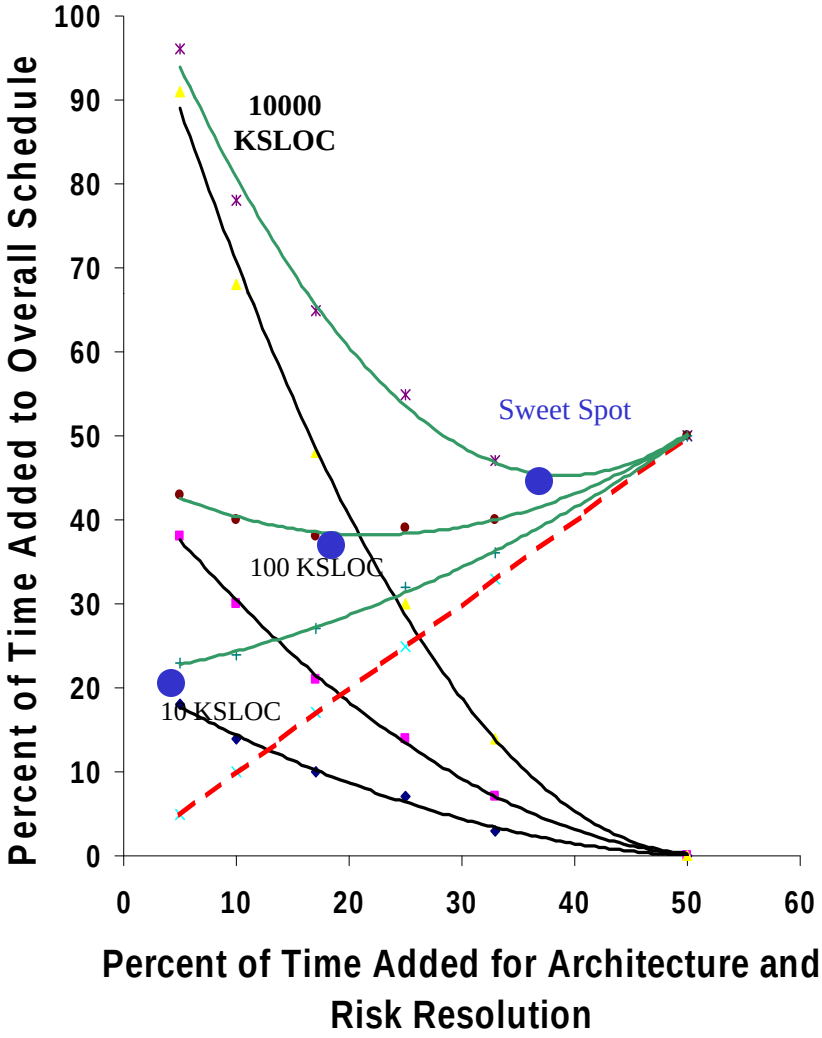
Problems Encountered without FED: 15-Month Architecture Rework Delay



Problems Avoidable with FED

- Attempt to validate 1-second response time
  - Commercial system benchmarking and architecture analysis: needs expensive custom solution
  - Prototype: 4-second response time OK 90% of the time
- Negotiate response time ranges
  - 2 seconds desirable
  - 4 seconds acceptable with some 2-second special cases
- Benchmark commercial system add-ons to validate their feasibility
- Present solution and feasibility evidence at anchor point milestone review
  - Result: Acceptable solution with minimal delay

Need for FED in Large Systems of Systems



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

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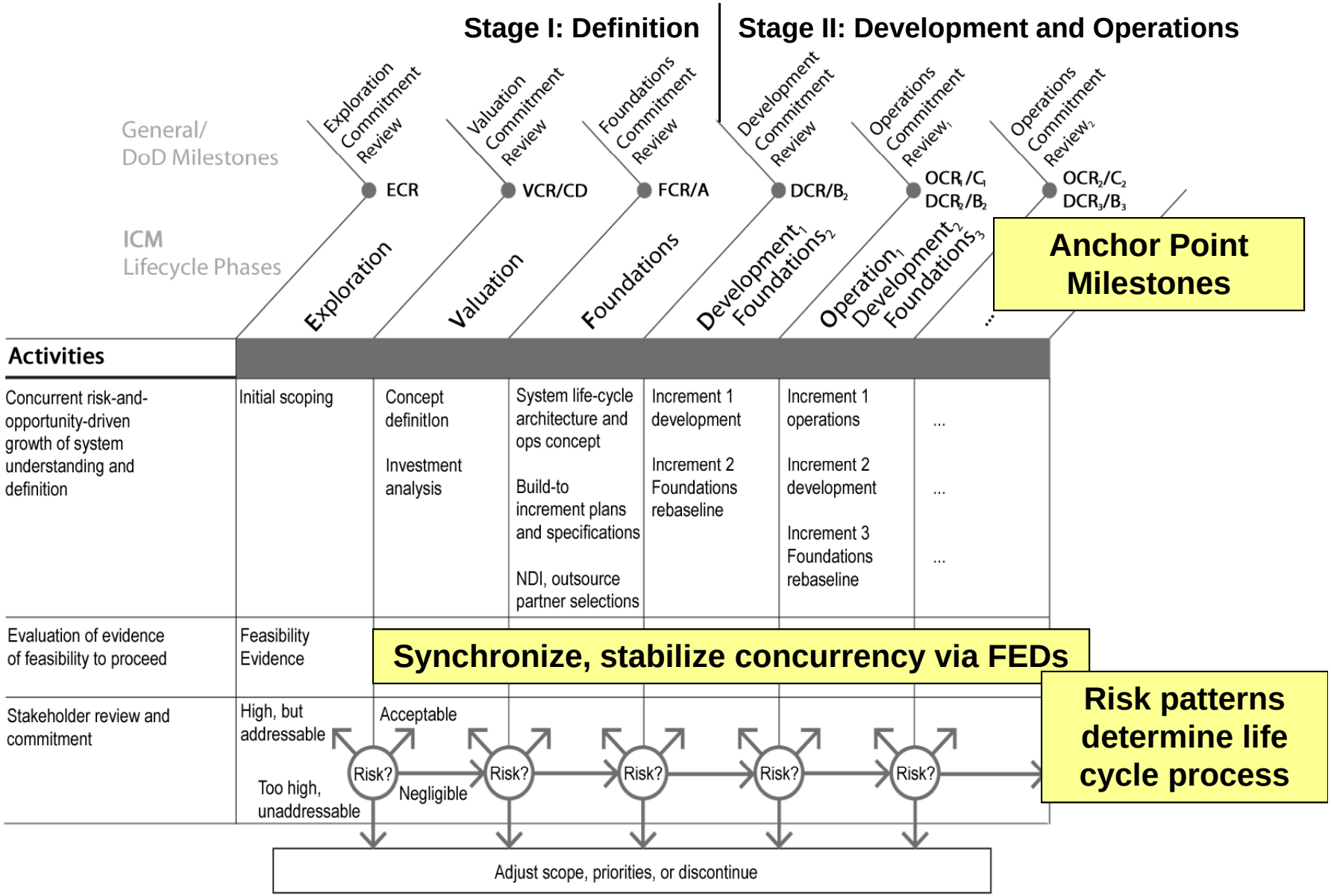
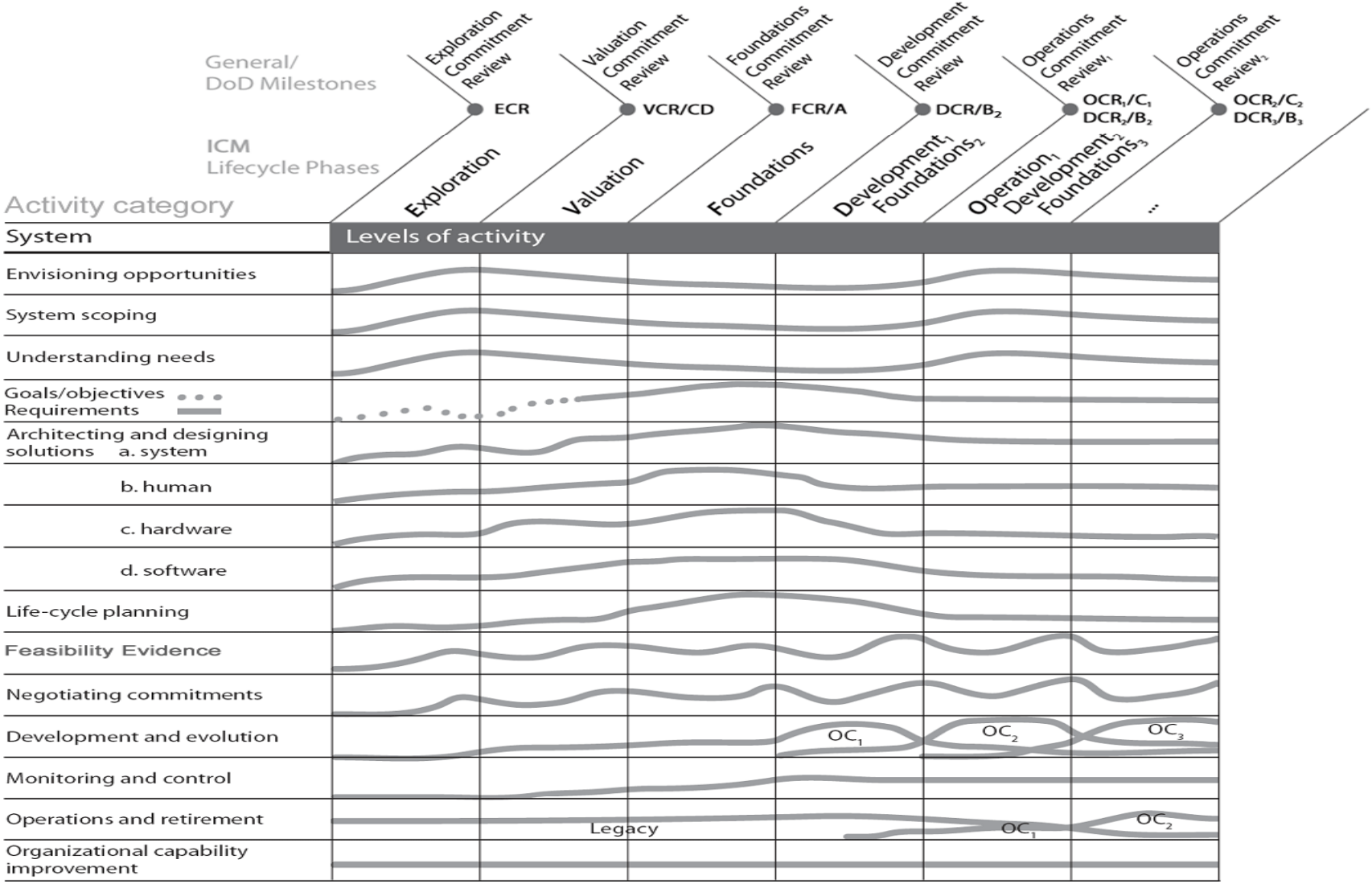
The Incremental Commitment Life Cycle Process: Overview



ICM Levels of Activity for Complex Systems



Nature of Feasibility Evidence

- Not just traceability matrices and PowerPoint charts
- Evidence can include results of
  - Prototypes: of networks, robots, user interfaces, COTS interoperability
  - Benchmarks: for performance, scalability, accuracy
  - Exercises: for mission performance, interoperability, security
  - Models: for cost, schedule, performance, reliability; tradeoffs
  - Simulations: for mission scalability, performance, reliability
  - Early working versions: of infrastructure, data fusion, legacy compatibility
  - Previous experience
  - Combinations of the above
- Validated by independent experts
  - Realism of assumptions
  - Representativeness of scenarios
  - Thoroughness of analysis
  - Coverage of key off-nominal conditions

Common Examples of Inadequate Evidence

1. Our engineers are tremendously creative. They will find a solution for this.
2. We have three algorithms that met the KPPs on small-scale nominal cases. At least one will scale up and handle the off-nominal cases.
3. We'll build it and then tune it to satisfy the KPPs
4. The COTS vendor assures us that they will have a security-certified version by the time we need to deliver.
5. We have demonstrated solutions for each piece from our NASA, Navy, and Air Force programs. It's a simple matter of integration to put them together.

Examples of Making the Evidence Adequate

1. Have the creative engineers prototype and evaluate a solution on some key nominal and off-nominal scenarios.
2. Prototype and evaluate the three examples on some key nominal and off-nominal scenarios
3. Develop prototypes and/or simulations and exercise them to show that the architecture will not break while scaling up or handling off-nominal cases.
4. Conduct a scaled-down security evaluation of the current COTS product. Determine this and other vendors' track records for getting certified in the available time. Investigate alternative solutions.
5. Have a tiger team prototype and evaluate the results of the simple matter of integration.

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Steps for Developing Feasibility Evidence

A. Develop phase work-products/artifacts
   - For examples, see ICM Anchor Point Milestone Content charts

B. Determine most critical feasibility assurance issues
   - Issues for which lack of feasibility evidence is program-critical

C. Evaluate feasibility assessment options
   - Cost-effectiveness, risk reduction leverage/ROI, rework avoidance
   - Tool, data, scenario availability

D. Select options, develop feasibility assessment plans

E. Prepare FED assessment plans and earned value milestones
   - Try to relate earned value to risk-exposure avoided rather than budgeted cost

"Steps" denoted by letters rather than numbers to indicate that many are done concurrently

Steps for Developing Feasibility Evidence
(continued)

F. Begin monitoring progress with respect to plans
   - Also monitor project/technology/objectives changes and adapt plans

G. Prepare evidence-generation enablers
   - Assessment criteria
   - Parametric models, parameter values, bases of estimate
   - COTS assessment criteria and plans
   - Benchmarking candidates, test cases
   - Prototypes/simulations, evaluation plans, subjects, and scenarios
   - Instrumentation, data analysis capabilities

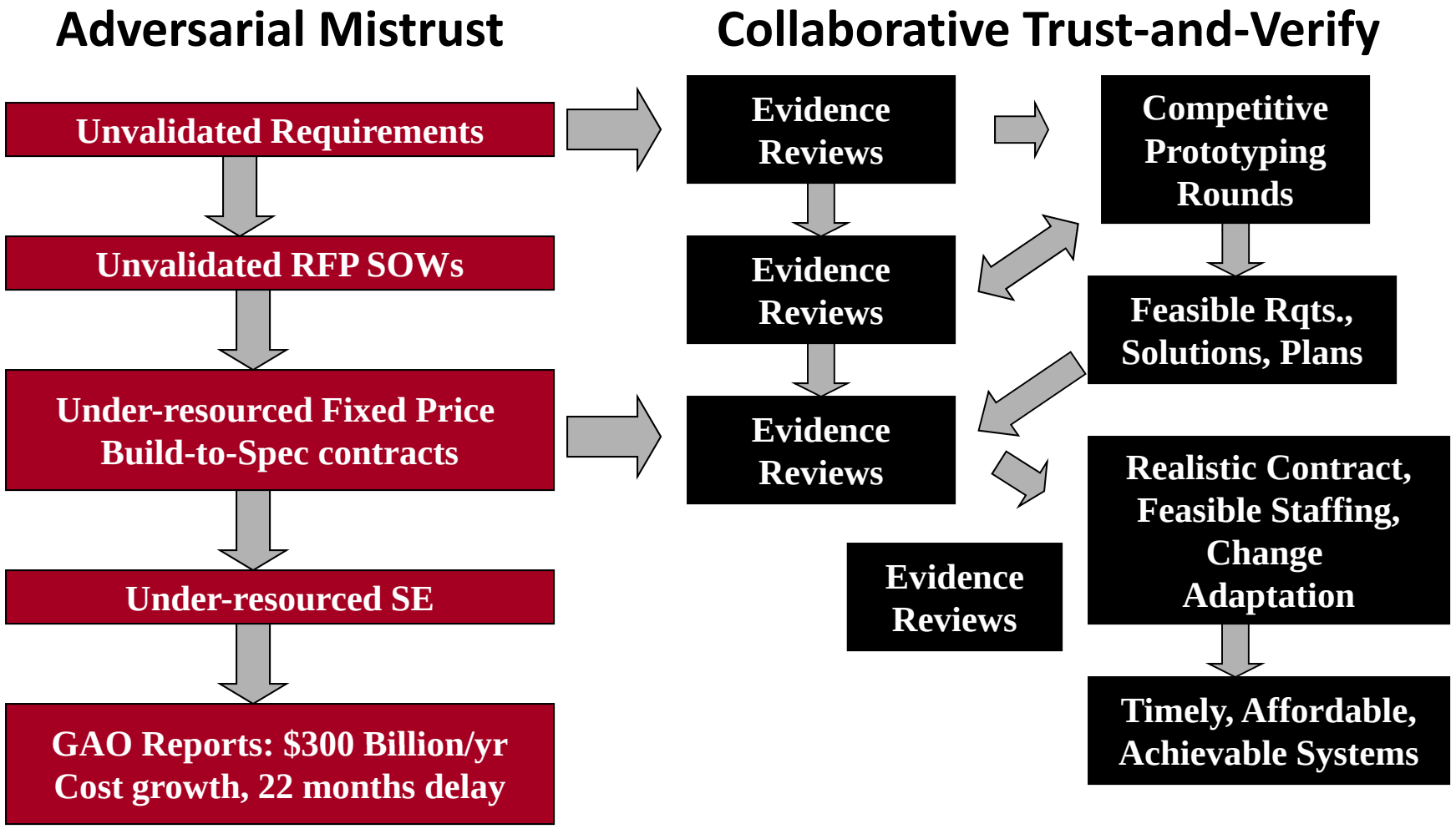
H. Perform pilot assessments; evaluate and iterate plans and enablers

I. Assess readiness for Commitment Review
   - Shortfalls identified as risks and covered by risk mitigation plans
   - Proceed to Commitment Review if ready

J. Hold Commitment Review when ready; adjust plans based on review outcomes

EM Processes and Tools Help Enable MDAP Transformation

Implements spirit of July 2009 Augustine BENS Report



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SE Effectiveness Measurement Methods Used

- NRC Pre-Milestone A & Early-Phase SysE top-20 checklist
- Services Probability of Program Success (PoPS) Frameworks
- INCOSE/LMCO/MIT Leading Indicators
- Stevens Leading Indicators (new; using SADB root causes)
- USC Anchor Point Feasibility Evidence progress
- UAH teaming theories
- NDIA/SEI capability/challenge criteria
- SISAIG Early Warning Indicators/ USC Macro Risk Tool

Additional Personnel Competency Sources

ASN (RD&A), Guidebook for the Acquisition of Naval Software-Intensive Systems, Version 1.0, September 2008

L. Bass et al., *Models for Evaluating and Improving Architecture Competence*, CMU/SEI-2008-TR-006, April 2008

INCOSE Systems Engineering Handbook, INCOSE-TP-2003-002-03.1, August 2007

ODNI, Subdirectory Data Collection Tool: Systems Engineering, 2008.

R. Pew and A. Mavor, *Human-System Integration in the System Development Process: A New Look*, National Academies Press, 2007.

C. Williams and M. Derro, *NASA Systems Engineering Behavior Study,* NASA Office of the Chief Engineer October 2008.

First-Order EM Evaluation Process

- Examine revised list of candidate EMs
  - Use NRC early SE checklist as concise starting point
  - Identify similar key elements of other EMs
  - 45x8 cross product of EMs and characteristics
- Evaluate EMs against identified criteria
  - Preliminary "quick-look" evaluation by USC
  - Evaluation by originators, where possible
  - Follow-up with independent evaluation by team
- Review coverage/commonality of elements
  - Incorporate suggested additions (now 51 items)

Initial EM Coverage Matrix

SERC EM Task Coverage Matrix V1.0

	NRC	Probability of Success	SE Leading Indicators	LIPSF (Stevens)	Anchoring SW Process (USC)	PSSES (U. of Alabama)	SSEE (CMU/SEI)	Macro Risk Model/Tool
Concept Dev								
Atleast 2 alternatives have been evaluated	X			x	x	x (w.r.t NPR)	(x)	
Can an initial capability be achieved within the time that the key program leaders are expected to remain engaged in their current jobs (normally less than 5 years or so after Milestone B)? If this is not possible for a complex major development program, can critical subsystems, or at least a key subset of them, be demonstrated within that time frame?	X		(x)	x	x (5 years is not explicitly stated)		(x) (seems to be inferrable from the conclusions)	(x) (implies this)
Will risky new technology mature before B? Is there a risk mitigation plan?	x	x	x		(x)		x	x
Have external interface complexities been identified and minimized? Is there a plan to mitigate their risks?	x		x		x	x	x	x
KPP and CONOPS								
At Milestone A, have the KPPs been identified in clear, comprehensive, concise terms that are understandable to the users of the system?	x	(x)	x	(x)	x (strongly implied)	(x) (implied)	x	x
At Milestone B, are the major system-level requirements (including all KPPs) defined sufficiently to provide a stable basis for the development through IOC?	x	x	(x)	x	x	(x)	(x) (There is no direct reference to this but is inferrable)	x
Has a CONOPS been developed showing that the system can be operated to handle the expected throughput and meet response time requirements?	x	x	(x)	(x)	x	(x) (there is a mention of a physical solution. That's the closest in this regard)	x	x

Legend:
x = covered by EM
(x) = partially covered (unless stated otherwise)

Structuring the 51 EM Elements

Systems Engineering Effectiveness Measurement Proposed New Framework	SEPP-Guide-Based Eval. Framework	SISAIG/ Macro Risk Framework	Coverage Matrix Items
1. Concurrent Definition of System Requirements & Solutions			
1.1 Understanding of stakeholder needs: Capabilities, Operational Concept, Key Performance Parameters, Enterprise fit (legacy)	1.1, 1.4, 3.1	1.1, 1.4	5, 7, 22, 36, 37
1.2 Concurrent exploration of solution opportunities; AoA's for cost-effectiveness & risk (Measures of Effectiveness)	4.1, 4.2	1.2	1, 14, 26, 27, 28
1.3 System scoping & requirements definition (External interfaces; Memoranda of Agreement)	1.2, 1.4	3.2	4, 6, 13, 50
1.4 Prioritization of requirements & allocation to increments	1.3	1.5	2, 11, 31

Personnel Competency: Commonality of Goal Frameworks

SERC EM Framework	NDIA Personnel Competency FW	SEI Architect Competency FW
Concurrent Definition of System Requirements & Solutions	Systems Thinking	Stakeholder Interaction
System Life Cycle Organization, Planning, Staffing	Life Cycle View	Other phases
Technology Maturing and Architecting	SE Technical	Architecting
Evidence-Based Progress Monitoring & Commitment Reviews	SE Technical Management	Management
Professional/ Interpersonal (added)	Professional/ Interpersonal	Leadership, Communication, Interpersonal

Competency Assessment Purposes and Models

- **Personnel Certification Models**
  - **Assess degree of mastery of core SE knowledge, skills, abilities (KSAs)**
  - **Assessment via examination, resume, artifacts produced**
- **Enterprise KSA Inventory, Career Progression Models**
  - **Record degree of mastery of core and business-domain SE KSAs**
  - **Assessment via educational and project experience records**
- **Project SE Staffing Capability Models**
  - **Assess commitment to provide project-critical skills**
    - **Tailorable subset of core SE skills**
    - **Extendable for project-specific skills**
  - **Assessment via educational and project experience records, interviews**

Example Personnel Competency Questions

1. Concurrent Definition of System Requirements & Solutions

1.1 Understanding of stakeholder needs: Capabilities, Operational Concept, Key Performance Parameters, Enterprise fit (legacy). Evidence of ability to analyze strengths and shortfalls in current-system operations via:

a. **Participatory workshops, surveys, focus groups?**
b. **Operations research techniques: operations data collection and analysis, modeling?**
c. **Prototypes, scenarios, stories, personas?**
d. **Ethnographic techniques: Interviews, sampled observations, cognitive task analysis?**

1.2 Concurrent exploration of solution opportunities; Analysis of Alternatives for cost-effectiveness & risk (Measures of Effectiveness). Evidence of ability to identify and assess alternative solution opportunities via experimentation and analysis of:

a. **Alternative work procedures, non-materiel solutions?**
b. **Purchased or furnished products and services?**
c. **Emerging technology?**
d. **Competitive prototyping?**

SEPAT Seeks Performance Evidence

Exposure	Question #	Impact: Critical / 40-100%	Impact: Significant / 20-40%	Impact: Moderate / 2-20%	Impact: Little-No impact / 0-2%	Evidence/Risk: Little-None / p(0.4-1.0)	Evidence/Risk: Weak / p(0.2-0.4)	Evidence/Risk: Partial / p(0.02-0.2)	Evidence/Risk: Strong / p(0.0-0.02)	NOTE: Impact and evidence/risk ratings should be done independently. The impact rating should estimate the effect a failure to address the specified item might have on the program. The evidence rating should specify the qualtity of evidence that has been provided, which demonstrates that the specified risk item has been satisfactorily addressed.	Reset / Risk Exposure	
	Goal 1:									**Concurrent definition of system requirements and solutions**		
	Critical Success Factor 1.1									**Understanding of stakeholder needs: capabilities, operational concept, key performance parameters, enterprise fit (legacy)**	4	
1	1.1(a)	○	○	○	◉	◉	○	○	○	At Milestone A, have the KPPs been identified in clear, comprehensive, concise terms that are understandable to all stakeholders?		No forma
3	1.1(b)	○	○	◉	○	○	◉	○	○	Has a CONOPS been developed showing that the system can be operated to handle both nominal and off-nominal workloads, to meet response time requirements, and generally to meet the defined KPPs?		IT system
3	1.1(c)	○	○	◉	○	○	◉	○	○	Has the ability of the system to meet mission effectiveness goals been verified through the use of modeling and simulation?		IT system effectiven
4	1.1(d)	◉	○	○	○	○	○	◉	○	Have the success-critical stakeholders been identified, their roles and responsibilities negotiated, and their needs clearly represented by the KPPs and CONOPS?		Developm Stakehold
4	1.1(e)	◉	○	○	○	○	○	◉	○	Have issues about the fit of the system into the stakeholders' context -- acquirers, end users, administrators, interoperators, maintainers, etc. -- been adequately explored?		Explored after syst related to different

SECAT Seeks Competency Evidence

Exposure	Question #	Impact: Critical / 40-100%	Impact: Significant / 20-40%	Impact: Moderate / 2-20%	Impact: Little-No impact / 0-2%	Competency/Risk: Little-None / p(0.4-1.0)	Competency/Risk: Weak / p(0.2-0.4)	Competency/Risk: Partial / p(0.02-0.2)	Competency/Risk: Strong / p(0.0-0.02)	NOTE: Impact and evidence/risk ratings should be done independently. The impact rating should estimate the effect a failure to competently address the specified item might have on the program. The competency rating should specify the observed, historical experience and competency of the systems engineering staff on past programs with respect to the specified risk item.	Reset / Risk Exposure
	Goal 1:									**Concurrent definition of system requirements and solutions**	
	Critical Success Factor 1.1									Understanding of stakeholder needs: capabilities, operational concept, key performance parameters, enterprise fit (legacy). Evidence of ability to analyze strengths and shortfalls in current-system operations via:	4
4	1.1(a)	◉	○	○	○	○	○	◉	○	Participatory workshops, surveys, focus groups?	
4	1.1(b)	○	◉	○	○	○	◉	○	○	Operations research techniques: operations data collection and analysis?	
3	1.1(c)	○	○	◉	○	○	◉	○	○	Mission effectiveness modeling and simulation?	
3	1.1(d)	○	◉	○	○	○	○	◉	○	Prototypes, scenarios, stories, personas?	
4	1.1(e)	○	◉	○	○	○	◉	○	○	Ethnographic techniques: Interviews, sampled observations, cognitive task analysis?	

Operational concepts for EM tool usage

- EM tools used to reach sponsor-performer consensus on way forward
  - Via EM-based risk assessments
- Three scenarios
  - Milestone A: Milestone Decision Authority (MDA) and Acquirer
    - MDAP and non-MDAP cases
  - Contract Negotiation: MDAP Acquirer and Developer
  - Project Execution: MDAP Developer Manager and Performers

Scenario 1. MDA and Acquirer at Milestone A

- Acquirer submits proposed acquisition plan to MDA with SEPAT, SECAT ratings and risk mitigation approaches
- MDA has independent experts review SEPAT, SECAT ratings
  - Major finding: Analysis of Alternatives rated No Impact, No risk
  - MDA asks Acquirer for AoA impact rationale
- Acquirer response: Case 1
  - Capability is needed quickly for limited but critical use
  - Evidence is available that Alternative A solution is sufficient
  - MDA response: Rationale is sufficient. OK to proceed
- Acquirer response: Case 2
  - DARPA demo has shown proof of principle. All that is needed is to implement it for the general case
  - MDA response: No evidence of scalability, ability to handle off-nominal scenarios. Resubmit using Competitive Prototyping

Competitive Prototyping Benefits Example – 4:1 RPV

- **Total Commitment**
  - **Agent technology demo and PR: Can do 4:1 for $1B**
  - **Winning bidder: $800M; PDR in 120 days; 4:1 capability in 40 months**
  - **PDR: many outstanding risks, undefined interfaces**
  - **$800M, 40 months: "halfway" through integration and test**
  - **1:1 IOC after $3B, 80 months**

- **CP-based Incremental Commitment [number of competing teams]**
  - **$25M, 6 mo. to VCR [4]: may beat 1:2 with agent technology, but not 4:1**
  - **$75M, 8 mo. to ACR [3]: agent technology may do 1:1; some risks**
  - **$225M, 10 mo. to DCR [2]: validated architecture, high-risk elements**
  - **$675M, 18 mo. to IOC [1]: viable 1:1 capability**
  - **1:1 IOC after $1B, 42 months**

Scenario 2. Acquirer-Developer

- Acquirer tailors SEPAT, SECAT to project specifics
  - Domain and project extensions
  - Question impact/priority ratings
- Acquirer coordinates SEPAT, SECAT usage with developer
  - As mutual instruments for monitoring SE effectiveness
  - At major milestones and project reviews
  - Portion of award fee based on review of evidence
- Developer analyzes implications for project SE effort
  - Options on evidence production, associated costs
- Developer, Acquirer converge on options
  - And adjustments to questions, impact ratings, SE budgets, milestone content, contract provisions

Scenario 2 Example

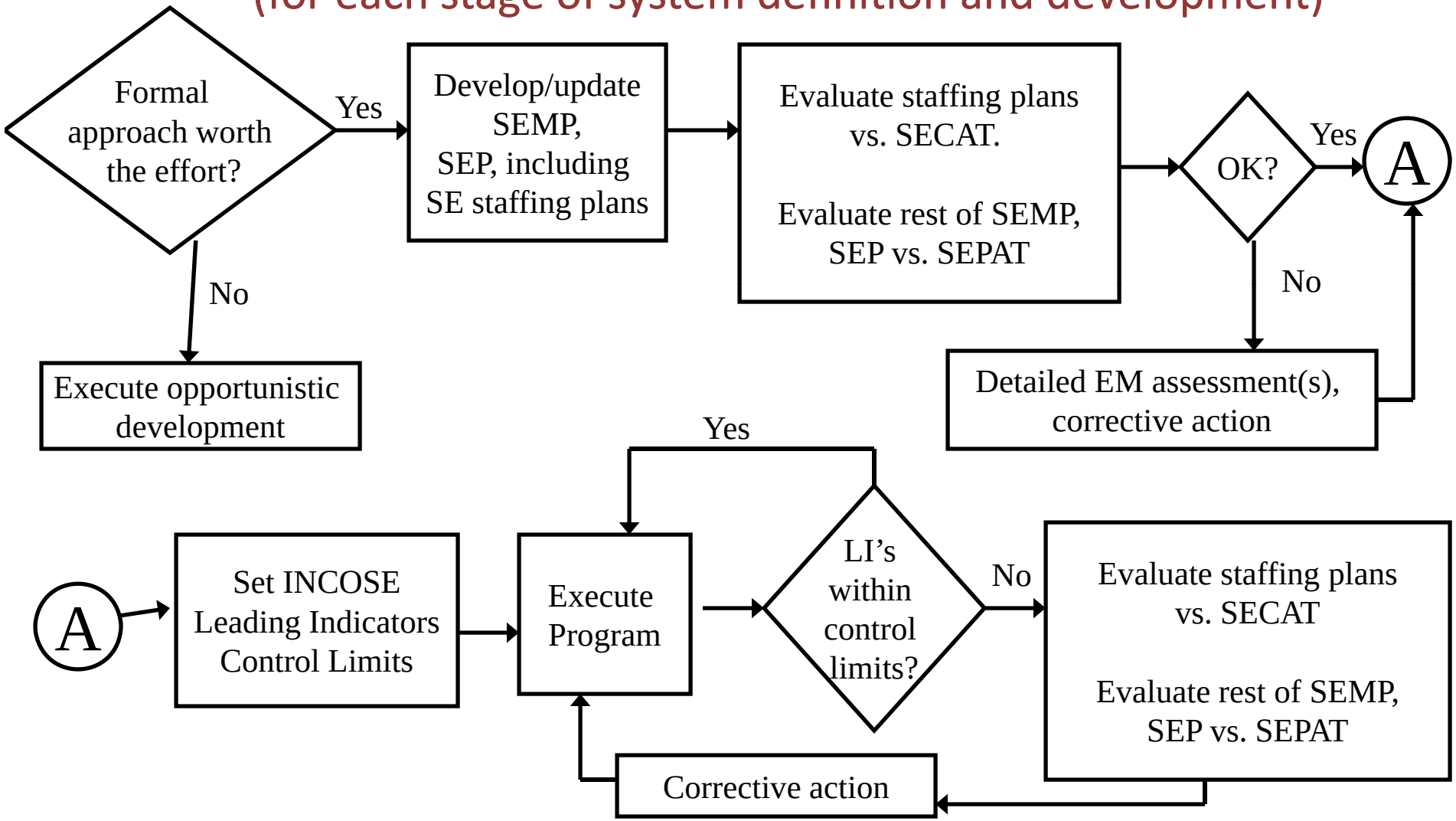
- **Acquirer specifies CSF 1.2(d) to have Critical impact:**
  - **Have the claimed quality of service guarantees been validated?**
- **Winning competitive prototyping developer responds:**
  - **This would be incompatible with your proposed contract, which ties our System Functional Requirements Review milestone progress payments and award fees to specifying functionality. Our proposed SE plans and budgets don't cover doing QoS guarantees by then.**
- **Acquirer responds:**
  - **Thanks. The contract clearly undercuts our intent to do evidence-based concurrent engineering, and sets us up for late overruns. We'll redo it and your SE plans and budgets. Next time, we'll address contracting compatibility earlier.**

Scenario 3. Project EM

- **Primary responsibilities, authority, accountability (RAA)**
  - **Primary assessment consumers: Persons with management responsibility for program results**
    - **Contractor PM, DoD acquirer PM/PEO, oversight personnel**
  - **Primary assessment conveners, monitors: Chief Engineers, Chief Systems Engineers**
  - **Primary assessors: Independent experts**

Project SysE EM Operational Concept

(for each stage of system definition and development)



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- Evidence-based reviews and deliverables
- Evidence planning and preparation steps
- Evidence-based in-process risk assessment
- Evidence-based risk assessment tools

Backup Charts

Pilot Feedback Highlights

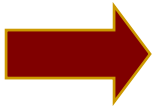
- Primarily useful during early stages
  - SEPAT: Tech Development, 60%; System Development, 100%
  - SECAT: Tech Development, 50%; System Development, 75%
  - Between “Very Effective” and “Somewhat Effective”
- Too many Red and Yellow risks
  - Rating scales reworked
- Overly DoD-specific (NASA responder)
- Need versions for different domains, project types
  - Quick-response/agile; legacy-driven; KPP-driven; sea; space; …
- Make question format uniform across SEPAT and SECAT

Project and Tool Status and Plans

- We have two tools for evaluating systems engineering (SE) effectiveness in the definition and development stages of Major Defense Acquisition Programs
  - SE Performance Assessment Tool (SEPAT)
  - SE Capability Assessment Tool (SECAT)
  - Based on analysis and synthesis of major sources of DoD SE EMs
  - Including concepts of operation for project usage, sponsor-developer coordination, SE EM knowledge base development
- We have piloted the tools on 7 projects
  - And evaluated them with respect to the ODDR&E-SSE Systemic Analysis Database (SADB)
  - Feedback mostly positive; some good improvement suggestions
- We are incorporating some suggestions and have drafted plans for followon improvement efforts

Bottom Line Message

- SE shortfalls are a major source of DoD system acquisition problems
  - Systemic Analysis Database analysis results
- SE EM shortfalls are a major source of SE effectiveness problems
  - You can't control what you can't measure
- The SECAT and SEPAT tools enable a measurement-driven SE process
  - Via negotiated MDA-acquirer-developer EM-based approach
- EM-driven SE improvement has high ROI for MDAPs
  - ROI varies with system size, criticality, volatility
- The SERC SE EM tools are approaching general-use maturity
  - Core tools are in the TRL 5-6 (alpha-beta test) range
  - Domain/life cycle extensions, risk summaries, mitigation guidance TBD
- Draft plan to mature, extend, transition technology in work



Looking for collaborators, early adopters interested in reducing their overrun and delivery shortfall rates

References

ASN (RD&A), Guidebook for the Acquisition of Naval Software-Intensive Systems, Version 1.0, September 2008.

N. Augustine et al., *Getting to Best: Reforming the Defense Acquisition Enterprise*, Business Executives for National Security Report, July 2009, http://www.bens.org/mis_support/Reforming the Defense.pdf

L. Bass et al., *Models for Evaluating and Improving Architecture Competence*, CMU/SEI-2008-TR-006, April 2008.

B. Boehm, D. Ingold, K. Dangle, R. Turner, P. Componation et al., "Early Identification of SE-Relared Program Risks," UC-CSSE-TR-2009-518, http://csse.usc.edu/csse/TECHRPTS/

B. Boehm and J. Lane, "Guide for Using the Incremental Commitment Model (ICM) for Systems Engineering of DoD Projects, v.0.5," USC-CSSE-TR-2009-500, http://csse.usc.edu/csse/TECHRPTS/

INCOSE Systems Engineering Handbook, INCOSE-TP-2003-002-03.1, August 2007.

P. Kaminski et al., *Pre-Milestone A and Early-Phase Systems Engineering*, National Academies Press, 2008.

ODNI, Subdirectory Data Collection Tool: Systems Engineering, 2008.

R. Pew and A. Mavor, *Human-System Integration in the System Development Process: A New Look*, National Academies Press, 2007.

C. Williams and M. Derro, *NASA Systems Engineering Behavior Study,* NASA Office of the Chief Engineer, October 2008.

List of Acronyms

CD	Concept Development
CP	Competitive Prototyping
DCR	Development Commitment Review
DoD	Department of Defense
ECR	Exploration Commitment Review
EV	Expected Value
FCR	Foundations Commitment Review
FED	Feasibility Evidence Description
GAO	Government Accounting Office
ICM	Incremental Commitment Model
KPP	Key Performance Parameter
MBASE	Model-Based Architecting and Software Engineering
OCR	Operations Commitment Review
RE	Risk Exposure
RUP	Rational Unified Process
V&V	Verification and Validation
VB	Value of Bold approach
VCR	Valuation Commitment Review