The Incremental Commitment Model (ICM), with Ground Systems Applications

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Outline

• **Challenges for developing next-generation ground systems**
• Overview of ICM
  – How ICM implements the new DoDI 5000.02
• Risk-based balance of agility and assurance
• ICM process decision table
• Ground system example for using the ICM
• Conclusions
Future Ground Systems Challenges-I

• Multi-owner, multi-mission systems of systems
  – Ground system must simultaneously interoperate with a wide variety of independently evolving Service, joint, interagency, and commercial systems of systems
  – Need to satisfice among multiple stakeholders
  – No one-size-fits-all solutions or processes

• Emergence and human-intensiveness
  – Requirements not pre-specifiable
  – Budgets and schedules not pre-specifiable
  – Need for evolutionary growth
  – Need to manage uncertainty and risk
Example: SoSE Synchronization Points

SoS-Level

Exploration Valuation Architecting Develop Operation

Source Selection

Candidate Supplier/Strategic Partner n

Candidate Supplier/Strategic Partner 1

System x

Develop Operation Operation Operation Operation

OCR_x1 OCR_x2 OCR_x3 OCR_x4 OCR_x5

System C

Exploration Valuation Architecting Develop Operation

FCR_C DCR_C OCR_C1 OCR_C2 OCR_C3

System B

Exploration Valuation Architecting Develop Operation

FCR_B DCR_B OCR_B1 OCR_B2

System A

Exploration Valuation Architecting Develop Operation

FCR_A DCR_A OCR_A1

Example: SoSE Synchronization Points

LCO-type Proposal & Feasibility Info

Rebaseline/Adjustment FCR_1

OCR_1 OCR_2

FCR_B DCR_B OCR_B1 OCR_B2

FCR_A DCR_A OCR_A1

OCR_x1 OCR_x2 OCR_x3 OCR_x4 OCR_x5

System C

System B

System A
The Broadening Early Cone of Uncertainty (CU)

- Need greater investments in narrowing CU
  - Mission, investment, legacy analysis
  - Competitive prototyping
  - Concurrent engineering
  - Associated estimation methods and management metrics

- Larger systems will often have subsystems with narrower CU’s
Current System Acquisition Methods
Easy to misinterpret as one-size-fits-all

- **V-Model**¹
  
  - Concept of Operations
  - Requirements and Architecture
  - Detailed Design
  - System Verification and Validation
  - Integration, Test, and Verification
  - Operations and Maintenance

- **Spiral Model**²

  1. Determine objectives
  2. Identify and resolve risks
  3. Development and Test
  4. Plan the next iteration

High level guidance assumes that acquirers have extensive acquisition experience...
Without experience, too easy to misinterpret and auger in with disastrous results...

Typical Acquisition Process

• Military pilot coming off a fighter plane is assigned to manage the acquisition of a new satellite ground system
  – Excellent understanding of aircraft operator needs
  – No experience with ground system/software development
  – Conditioned to plan the flight and fly the plan
  – Will interpret V-model diagram sequentially
  – Will interpret spiral diagram as one-size-fits-all
Future Ground System Challenges-II

• Rapid pace of change
  – In competition, mission priorities, technology, Commercial Off-the-Shelf (COTS), environment
  – Need incremental development to avoid obsolescence
  – Need concurrent vs. sequential processes
  – Need both prescience and rapid adaptability
    • Software important; humans more important

• Brownfield vs. Greenfield development
  – Need to provide legacy continuity of service
  – Need to accommodate legacy, OTS constraints

• Always-on, never-fail systems
  – Need well-controlled, high-assurance processes
  – Need to synchronize and stabilize concurrency
  – Need to balance assurance and agility
Rapid Change Creates a Late Cone of Uncertainty – Need incremental vs. one-shot development

Uncertainties in competition, technology, organizations, mission priorities

Relative Cost Range

Feasibility
Concept of Operation
Plans and Rqts.
Rqts. Spec.
Product Design
Product Design Spec.
Detail Design Spec.
Detail Design
Devel. and Test
Accepted Software

Phases and Milestones

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Outline

• Challenges for developing next-generation ground systems
• **Overview of ICM**
  – *How ICM implements the new DoDI 5000.02*
• Risk-based balance of agility and assurance
• ICM process decision table
• Ground system example for using the ICM
• Conclusions
What is the ICM?

• Risk-driven framework for determining and evolving best-fit system life-cycle process
• Integrates the strengths of phased and risk-driven spiral process models
• Synthesizes together principles critical to successful system development
  – Commitment and accountability of system sponsors
  – Success-critical stakeholder satisficing
  – Incremental growth of system definition and stakeholder commitment
  – Concurrent engineering
  – Iterative development cycles
  – Risk-based activity levels and anchor point milestones

Principles used by 60-80% of CrossTalk Top-5 projects, 2002-2005
ICM Nature and Origins

• Integrates hardware, software, and human factors elements of systems engineering
  – Concurrent exploration of needs and opportunities
  – Concurrent engineering of hardware, software, human aspects
  – Concurrency stabilized via anchor point milestones

• Developed in response to DoD-related issues
  – Clarify “spiral development” usage in DoD Instruction 5000.2
    • Initial phased version (2005)
  – Explain Future Combat System of systems spiral usage to GAO
    • Underlying process principles (2006)
  – Provide framework for human-systems integration
    • National Research Council report (2007)

• Integrates strengths of current process models
  – But not their weaknesses
Incremental Commitment in Gambling

• **Total Commitment: Roulette**
  – Put your chips on a number
    • E.g., a value of a key performance parameter
  – Wait and see if you win or lose

• **Incremental Commitment: Poker, Blackjack**
  – Put some chips in
  – See your cards, some of others’ cards
  – Decide whether, how much to commit to proceed
Scalable Remotely Controlled Operations
Total vs. Incremental Commitment – 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

**Incremental Commitment [with a 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 FCR [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
## The Incremental Commitment Life Cycle Process: Overview

### Stage I: Incremental Definition
- **Activities**
  - Concurrent risk-and-opportunity-driven growth of system understanding and definition
  - Initial scoping
  - Concept definition
  - Investment analysis
  - System life-cycle architecture and ops concept
  - Build to increment plans and specifications
  - NDI, outsource partner selections

### Stage II: Incremental Development and Operations
- **Anchor Point Milestones**
  - DCR
  - Development
  - Operations

### Risk patterns
determine life cycle process

### Synchronize, stabilize concurrency via FEDs

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**ICM Anchor Points / DoD Milestones**
- ECR/MDP
- VCR/MDD
- FCR/A
- DCR
- Operations

**ICM Lifecycle Phases / DoD Phases**
- Exploration / Needs and Opportunities
- Valuation / Market Solution Analysis & AoA
- Foundations / Technology Development (TD) & CDD
- Development
- Manufacturing
- Engineering

**Activities**
- Feasibility Evidence
- High, but addressable
- Acceptable
- Too high, unaddressable

**Adjust scope, priorities, or discontinue**
ICM Activity Levels for Complex Systems
Anchor Point Feasibility Evidence Descriptions

- **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
  - Generate a viable return on investment
  - Generate satisfactory outcomes for all of the success-critical stakeholders

- All major risks resolved or covered by risk management plans

- Serves as basis for stakeholders’ commitment to proceed

*Can be used to strengthen current schedule- or event-based reviews*
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  - ICM Anchor Points
  - DoD Milestones
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  - Initial scoping
  - Concept definition
  - Investment
  - System life-cycle architecture and ops concept
- **Anchor Point Milestones**
  - ECR/MDP
  - VCR/MDD
  - FCR/A
  - DCR/B

**Stage II: Incremental Development and Operations**
- **ICM Lifecycle Phases / DoD Phases**
  - ICM Lifecycle Phases
  - DoD Phases
- **Activities**
  - Development of follow-on operations
  - Development of follow-on development
  - Development of follow-on engineering
  - Evaluation of evidence of feasibility to proceed
  - Feasibility Evidence
- **Anchor Point Milestones**
  - OCR/O&G
  - DCR/O&G
  - OCR/Operations & Production
  - DCR/Operations & Production
- **Concurrently engr. OpCon, rqts, arch, plans, prototypes**

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**Concurrently engr.**
- Incr.N (ops), N+1 (devel), N+2 (arch)

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**Adjust scope, priorities, or discontinue**

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**MDP = Materiel Decision Preparation**

**MDD = Materiel Development Decision**

**AoA = Analysis of Alternatives**

**CED = Capability Development Document**

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Risk-Driven Scalable Spiral Model: Increment View

Rapid Change

Foreseeable Change (Plan)

Short Development Increments

Increment N Baseline

High Assurance

Stable Development Increments

Short, Stabilized Development Of Increment N

Increment N Transition/O&M
Risk-Driven Scalable Spiral Model: Increment View

- **Unforeseeable Change (Adapt)**
  - Rapid Change
  - Agile Rebaselining for Future Increments
  - Deferrals
  - Short, Stabilized Development of Increment N
    - Artifacts
    - Concerns
    - Increment N Transition/Operations and Maintenance
    - Future Increment Baselines
  - High Assurance
  - Continuous V&V
    - Current V&V Resources
    - Future V&V Resources
  - Foreseeable Change (Plan)
    - Short Development Increments
    - Stable Development Increments
  - Stable Development Increments
  - Continuous V&V
  - Current V&V Resources
ICM Compatibility with New DoDI 5000.02

- Both begin with Needs and Opportunities
- Both emphasize need for Preliminary Design Review before commitment to development
- Both emphasize evolutionary development
The DoDI 5000.02 Acquisition Life Cycle

- The Material Development Decision proceeds entry into any phase of the acquisition management system
- Entrance criteria met before entering phase
- Evolutionary Acquisition or Single Step to Full Capability

= Decision Point  △ = Milestone Review  ◊ = Decision Point if PDR is not conducted before Milestone B
Evolutionary Acquisition per New DoDI 5000.02
Overlapped Evolutionary
ICM Addresses Both Acquisition and Operations
And concurrent development and next-increment rebaselining

MDD/ECR  MDQ/VCR  A/FGR  B/V/DFR  C/R/PCR

User Needs & Technology Opportunities; ICD & FED
Material Solution Analysis; AoA, TDS, & FEDs
Technology Development; CDD, LCSP, PDR, & FEDs
Engineering & Manufacturing Development; PDR1, CDR1, & FEDs
Production & Deployment
Operations & Support

Risk?
Risk?
Risk?
Risk?
Risk?

A/PGR1  B/V/DFR1  C/R/PCR1

High, but addressable
Negligible
Too high; unaddressable

MDP: Material Decision Preparation
ECR: Exploration Commitment Review
ICD: Initial Capabilities Document
FED: Feasibility Evidence Description
MDD: Material Development Decision
VCR: Valuation Commitment Review
AoA: Analysis of Alternatives
TDS: Technology Development Strategy
FCR: Foundations Commitment Review
CDD: Capability Development Document
LCSP: Life Cycle Support Plan
PDR: Preliminary Design Review
CDR: Critical Design Review
CPD: Capability Production Document
PCR: Production Commitment Review
OCR: Operations Commitment Review

Continuous Technology Development and Maturation

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Incremental Commitment Model
Electronic Process Guidelines

Role: Operational Concept Engineer

Relationships

Operational Concept Engineer performs

Operational Concept Description (OCD)

Operational Concept Engineer is responsible for

Operational Concept Description (OCD)

Additionally Performs
- Analyze the Proposed System
- Client Interaction Report
- Initial Prototype Report
- Operational Concept Description (OCD)
- Prototype
- Supporting Information Document (SID)

Modifies
- Operational Concept Description (OCD)
Instructional ICM-Sw List > Operational Concept Development Practice > Tasks > Analyze Current System

**Task: Analyze Current System**

- Contains the guide to analyzing the current system

**Purpose**

To observe the current work process and analyze the current system being used at the organization.

**Relationships**

- **Roles**
  - Primary Performer:
    - Client
    - Development Team
    - Operational Concept Engineer
  - Additional Performers:
    - Client Interaction Report
    - Operational Concept Description (OCD)

- **Outputs**
  - Client Interaction Report
  - Operational Concept Description (OCD)

**Main Description**

Knowing how the current business works and ways that the current system is being used is critical in understanding the needs for the new system to be developed. Improvements that can be made to the current system may become obvious, thus, allowing the developers to better understand clients and the projects.
Operational Concept Development Practice

The development of the operational concept is to capture the visions shared among all the success-critical stakeholders for the project being undertaken.

- Work Products
  - Client Interaction Report
  - Operational Concept Description (OCD)
  - Prototype
  - Initial Prototype Report
  - Supporting Information Document (SID)

- Tasks
  - Analyze Current System
  - Identify Shared Vision
  - Establish New Operational Concept
  - Identify System Transformation
  - Identify Organizational and Operational Transformation
  - Prototyping
  - Assess Operational Concept

- Guidance
  - Operational Concept Description Example
  - Operational Concept Description Template
  - Operational Concept Description Completion Criteria
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The Incremental Commitment Life Cycle Process: Overview

Stage I: Incremental Definition
- ECR/MDP: Exploration Needs and Opportunities
- VCR/MDD: Valuation/Material Solution Analysis & AoA
- FCR/A: Foundations/Technology Development (TD) & CDD

Stage II: Incremental Development and Operations
- DCR/BD: Development, Engineering and Manufacturing Development (EMD), TD & CDD
- OCR/OPS: Operations & Production, O&P

Activities
- Concurrent risk-and-opportunity-driven growth of system understanding and definition
  - Initial scoping
  - Concept definition
  - Investment analysis
  - System life-cycle architecture and ops concept
  - Build to increment plans and specifications
  - NDI, outsource partner selection
- Evaluation of evidence of feasibility to proceed
  - Feasibility Evidence
- Stakeholder review and commitment
  - High, but addressable
  - Acceptable
  - Too high, unaddressable

Risk patterns determine life cycle process
- Risk?
- Risk?
- Risk?
- Risk?
- Risk?

Synchronize, stabilize concurrency via FEDs
- Adjust scope, priorities, or discontinue

ICM Anchor Points / DoD Milestones
- ECR/MDP
- VCR/MDD
- FCR/A

ICM Lifecycle Phases / DoD Phases
- Exploration Needs and Opportunities
- Valuation/Material Solution Analysis & AoA
- Foundations/Technology Development (TD) & CDD
- Development, Engineering and Manufacturing Development (EMD), TD & CDD
- Operations & Production, O&P

Anchor Point Milestones
- MDP = Material Decision Preparation
- MDD = Material Development: Decision
- AoA = Analysis of Alternatives
- ECR = Exploration Commitment Review
- VCR = Valuation Commitment Review
- FCR = Foundations Commitment Review
- DCRn = Development Commitment Reviewn
- OCRn = Operations Commitment Reviewn

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The ICM as Risk-Driven Process Generator

- Stage I of the ICM has 3 decision nodes with 4 options/node
  - Culminating with incremental development in Stage II
  - Some options involve go-backs
  - Results in many possible process paths

- Can use ICM risk patterns to generate frequently-used processes
  - With confidence that they fit the situation

- Can generally determine this in the Exploration phase
  - Develop as proposed plan with risk-based evidence at VCR milestone
  - Adjustable in later phases
Different Risk Patterns Yield Different Processes

General/DoD Milestones
- Exploration Commitment Review (ECR)
- Valuation Commitment Review (VCR/CD)
- Foundations Commitment Review (FCR/A)
- Development Commitment Review (DCR/B₁)
- Operations Commitment Review (OCR/C₁, DCR/B₂)
- Operations Commitment Review (OCR/C₂, DCR/B₃)

Activities

Example A
Simple Enterprise Resource Planning (ERP) based application
- High, but addressable
- Acceptable
- Risk? Too high, unaddressable
- Risk?

Example B
Complex, but feasible product development
- Acceptable
- Risk?

Example C
Stakeholders agree that more convergence of objectives is necessary
- Acceptable
- Risk? High, but addressable

Example D
A superior product enters the market
- Acceptable
- Risk? Too high, unaddressable
- Discontinue
The ICM Process Decision Table:
Key Decision Inputs

- Product and project size and complexity
- Requirements volatility
- Mission criticality
- Nature of Non-Developmental Item (NDI)* support
  - Commercial, open-source, reused components
- Organizational and Personnel Capability

* NDI Definition [DFARS]: a) any product that is available in the commercial marketplace; b) any previously developed product in use by a U.S. agency (federal, state, or local) or a foreign government that has a mutual defense agreement with the U.S.; c) any product described in the first two points above that requires only modifications to meet requirements; d) any product that is being produced, but not yet in the commercial marketplace, that satisfies the above criteria.
The ICM Process Decision Table: Key Decision Outputs

- Key Stage I activities: incremental definition
- Key Stage II activities: incremental development and operations
- Suggested calendar time per build, per deliverable increment
# Common Risk-Driven Special Cases of the ICM (Cases 1-4)

## Case 1: Use NDI
- **Example:** Small accounting system
- **Size, Complexity:** Size variable, complexity low
- **Typical Change Rate/Month:** Negligible
- **Criticality:** n/a
- **NDI Support:** Complete
- **Organizational Personnel Capability:** NDI-experienced (medium)
- **Key Stage I Activities (Incremental Definition):** Acquire NDI
- **Key Stage II Activities (Incremental Development/Operations):** Use NDI
- **Time/Build:** n/a
- **Time/Increment:** Vendor-driven

## Case 2: Agile
- **Example:** E-services
- **Size, Complexity:** Low
- **Typical Change Rate/Month:** 1-30%
- **Criticality:** Low to medium
- **NDI Support:** Good, in place
- **Organizational Personnel Capability:** Agile-ready, medium-high experience
- **Key Stage I Activities (Incremental Definition):** Skip Valuation and Architecting phases
- **Key Stage II Activities (Incremental Development/Operations):** Scrum plus agile methods of choice
- **Time/Build:** <= 1 day
- **Time/Increment:** 2-6 weeks

## Case 3: Architected Agile
- **Example:** Business data processing
- **Size, Complexity:** Medium
- **Typical Change Rate/Month:** 1-10 %
- **Criticality:** Medium to high
- **NDI Support:** Good, most in place
- **Organizational Personnel Capability:** Agile-ready, medium to high experience
- **Key Stage I Activities (Incremental Definition):** Combine Valuation, Architecting phases. Complete NDI preparation.
- **Key Stage II Activities (Incremental Development/Operations):** Architecture-based Scrum of Scrums
- **Time/Build:** 2-4 weeks
- **Time/Increment:** 2-6 months

## Case 4: Formal Methods
- **Example:** Security kernel; Safety-critical LSI chip
- **Size, Complexity:** Low
- **Typical Change Rate/Month:** 0.3%
- **Criticality:** Extra high
- **NDI Support:** None
- **Organizational Personnel Capability:** Strong formal methods experience
- **Key Stage I Activities (Incremental Definition):** Precise formal specification
- **Key Stage II Activities (Incremental Development/Operations):** Formally-based programming language; formal verification
- **Time/Build:** 1-5 days
- **Time/Increment:** 1-4 weeks
### Case 5: Hardware with Embedded Software Component

**Example:** Multi-sensor control device  
**Size, Complexity:** Low  
**Typical Change Rate/Month:** 0.3 - 1 %  
**Criticality:** Medium to very high  
**NDI Support:** Good, in place  
**Organizational Personnel Capability:** Experienced, medium-high  
**Key Stage I Activities (Incremental Definition):** Concurrent hardware/software engineering. CDR-level ICM DCR  
**Key Stage II Activities (Incremental Development/Operations):** IOC development, LRIP, FRP. Concurrent version N+1 engineering  
**Time/Build:** Software 1-5 days  
**Time/Increment:** Market-driven

### Case 6: Indivisible IOC

**Example:** Complete vehicle platform  
**Size, Complexity:** Medium to high  
**Typical Change Rate/Month:** 0.3 – 1%  
**Criticality:** High to very high  
**NDI Support:** Some in place  
**Organizational Personnel Capability:** Experienced, medium to high  
**Key Stage I Activities (Incremental Definition):** Determine minimum-IOC likely, conservative cost. Add deferrable software features as risk reserve  
**Key Stage II Activities (Incremental Development/Operations):** Drop deferrable features to meet conservative cost. Strong award free for features not dropped.  
**Time/Build:** Software: 2-6 weeks  
**Time/Increment:** Platform: 6-18 months

### Case 7: NDI-Intensive

**Example:** Supply chain management  
**Size, Complexity:** Medium to high  
**Typical Change Rate/Month:** 0.3 – 3%  
**Criticality:** Medium to very high  
**NDI Support:** NDI-driven architecture  
**Organizational Personnel Capability:** NDI-experienced, medium to high  
**Key Stage I Activities (Incremental Definition):** Thorough NDI-suite life cycle cost-benefit analysis, selection, concurrent requirements/architecture definition  
**Key Stage II Activities (Incremental Development/Operations):** Pro-active NDI evolution influencing, NDI upgrade synchronization  
**Time/Build:** Software: 1-4 weeks  
**Time/Increment:** Systems: 6-18 months

### Case 8: Hybrid Agile/Plan-Driven System

**Example:** C4ISR system  
**Size, Complexity:** Medium to very high  
**Typical Change Rate/Month:** Mixed parts; 1-10%  
**Criticality:** Mixed parts; Medium to very high  
**NDI Support:** Mixed parts  
**Organizational Personnel Capability:** Mixed parts  
**Key Stage I Activities (Incremental Definition):** Full ICM, encapsulated agile in high change, low-medium criticality parts (Often HMI, external interfaces)  
**Key Stage II Activities (Incremental Development/Operations):** Full ICM, three-team incremental development, concurrent V&V, next-increment rebaselining  
**Time/Build:** 1-2 months  
**Time/Increment:** 9-18 months
### Case 9: Multi-Owner Directed System of Systems

**Example:** Net-centric military operations  
**Size, Complexity:** Very high  
**Typical Change Rate/Month:** Mixed parts; 1-10%  
**Criticality:** Very high  
**NDI Support:** Many NDIs, some in place  
**Organizational Personnel Capability:** Related experience, medium to high  
**Key Stage I Activities (Incremental Definition):** Full ICM; extensive multi-owner team building, negotiation  
**Key Stage II Activities (Incremental Development/Operations):** Full ICM; large ongoing system/software engineering effort  
**Time/Build:** 2-4 months  
**Time/Increment:** 18-24 months

### Case 10: Family of Systems

**Example:** Medical device product line  
**Size, Complexity:** Medium to very high  
**Typical Change Rate/Month:** 1-3%  
**Criticality:** Medium to very high  
**NDI Support:** Some in place  
**Organizational Personnel Capability:** Related experience, medium to high  
**Key Stage I Activities (Incremental Definition):** Skip Valuation and Architecting phases  
**Key Stage II Activities (Incremental Development/Operations):** Scrum plus agile methods of choice  
**Time/Build:** 1-2 months  
**Time/Increment:** 9-18 months

### Case 11: Brownfield

**Example:** Incremental legacy phaseout  
**Size, Complexity:** High to very high  
**Typical Change Rate/Month:** 0.3-3%  
**Criticality:** Medium-high  
**NDI Support:** NDI as legacy replacement  
**Organizational Personnel Capability:** Legacy re-engineering  
**Key Stage I Activities (Incremental Definition):** Re-engineer/refactor legacy into services  
**Key Stage II Activities (Incremental Development/Operations):** Incremental legacy phaseout  
**Time/Build:** 2-6 weeks/refactor  
**Time/Increment:** 2-6 months
Common Risk-Driven Special Cases of the ICM (Cases 12a/b)

<table>
<thead>
<tr>
<th>Case 12a: Net-Centric Services – Community Support</th>
<th>Case 12b: Net-Centric Services – Quick Response Decision Support</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Example:</strong> Community services or special interest group</td>
<td><strong>Example:</strong> Response to competitor initiative</td>
</tr>
<tr>
<td><strong>Size, Complexity:</strong> Low to medium</td>
<td><strong>Size, Complexity:</strong> Medium to high</td>
</tr>
<tr>
<td><strong>Typical Change Rate/Month:</strong> 0.3-3%</td>
<td><strong>Typical Change Rate/Month:</strong> 3-30%</td>
</tr>
<tr>
<td><strong>Criticality:</strong> Low to medium</td>
<td><strong>Criticality:</strong> Medium to high</td>
</tr>
<tr>
<td><strong>NDI Support:</strong> Tailorable service elements</td>
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<tr>
<td><strong>Organizational Personnel Capability:</strong> NDI-experienced</td>
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</tr>
<tr>
<td><strong>Key Stage I Activities (Incremental Definition):</strong> Filter, select, compose, tailor NDI</td>
<td><strong>Key Stage I Activities (Incremental Definition):</strong> Filter, select, compose, tailor NDI</td>
</tr>
<tr>
<td><strong>Key Stage II Activities (Incremental Development/Operations):</strong> Evolve tailoring to meet community needs</td>
<td><strong>Key Stage II Activities (Incremental Development/Operations):</strong> Satisfy quick response; evolve or phase out</td>
</tr>
<tr>
<td><strong>Time/Build:</strong> &lt;= 1 day</td>
<td><strong>Time/Build:</strong> &lt;= 1 day</td>
</tr>
<tr>
<td><strong>Time/Increment:</strong> 2-12 months</td>
<td><strong>Time/Increment:</strong> Quick response-driven</td>
</tr>
</tbody>
</table>

**LEGEND**
- C4ISR: Command, Control, Computing, Communications, Intelligence, Surveillance, Reconnaissance.
- CDR: Critical Design Review.
- DCR: Development Commitment Review.
- FRP: Full-Rate Production.
- HMI: Human-Machine Interface.
- HW: Hardware.
- IOC: Initial Operational Capability.
- LSI: Large Scale Integration.
- LRIP: Low-Rate Initial Production.
- NDI: Non-Development Item.
- SW: Software.
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Ground System COTS: Is This A Risk?

- We just started integrating the software
  - and we found out that COTS* products A and B just can’t talk to each other
- We’ve got too much tied into A and B to change
- Our best solution is to build wrappers around A and B to get them to talk via CORBA**
- This will take 3 months and $300K
- It will also delay integration and delivery by at least 3 months

*COTS: Commercial off-the-shelf
**CORBA: Common Object Request Broker Architecture
Ground System COTS: Is This A Risk?

• We just started integrating the software
  – and we found out that COTS* products A and B just can’t talk to each other
• We’ve got too much tied into A and B to change

• No, it is a problem
  – Being dealt with reactively
• Risks involve uncertainties
  – And can be dealt with pro-actively
  – Earlier, this problem was a risk
ICM FCR Milestone: Expert Evidence Review

- The Java telemetry COTS package A and the dotNet Health Monitoring COTS package B perform best
  - But it is likely that they will have interoperability problems
  - Probability of loss $P(L)$
- If we commit to using A and B
  - And we find out in integration that they can’t talk to each other
  - We’ll add more cost and delay delivery by at least 3 months
  - Size of loss $S(L)$
- We have a risk exposure of
  \[ RE = P(L) \times S(L) \]
Options for Responding to Risk Finding

• Buying information
• Risk avoidance
• Risk transfer
• Risk reduction
• Risk acceptance
Developer Risk Management Plan: Begin by Buying Information

• We’ll spend $30K and 2 weeks prototyping the integration of A and B
• This will buy information on the magnitude of $P(L)$ and $S(L)$
• If $RE = P(L) \times S(L)$ is small, we’ll accept and monitor the risk
• If $RE$ is large, we’ll use the information to choose the best of the other strategies
Other Risk Management Strategies

• Risk Avoidance
  – The Java-based Health Monitoring COTS product C performs 80% as well as B, and it can interoperate with A
  – Delivering on time may be worth more to the customer than the small performance loss

• Risk Transfer
  – If the customer values the extra performance obtained by using A and B, have them establish a risk reserve.
  – To be used to the extent that A and B can’t talk to each other

• Risk Reduction
  – If we build the wrappers and the CORBA connections right now, we add cost but minimize the schedule delay

• Risk Acceptance
  – If we can solve the A and B interoperability problem, we’ll have a big competitive edge on the future procurements
  – Let’s do this on our own money, and patent the solution

• Customer agrees to enter Foundations phase based on plan
Outline

• Challenges for developing next-generation ground systems
• Overview of ICM
  - How ICM implements the new DoDI 5000.02
• Risk-based balance of agility and assurance
• ICM process decision table
• Ground system example for using the ICM
• Conclusions
ICM Summary

• Current processes not well matched to future challenges
  – Emergent, rapidly changing requirements
  – High assurance of scalable performance and qualities

• Incremental Commitment Model addresses challenges
  – Assurance via evidence-based milestone commitment reviews, stabilized incremental builds with concurrent V&V
    • Evidence shortfalls treated as risks
  – Adaptability via concurrent agile team handling change traffic and providing evidence-based rebaselining of next-increment specifications and plans
  – Use of critical success factor principles: stakeholder satisficing, incremental growth, concurrent engineering, iterative development, risk-based activities and milestones
  – Can be adopted incrementally

• Major implications for funding, contracting, career paths
Implications for funding, contracting, career paths

- **Incremental vs. total funding**
  - Often with evidence-based competitive downselect

- **No one-size-fits all contracting**
  - Separate instruments for build-to-spec, agile rebaselining, V&V teams
    - With funding and award fees for collaboration, risk management
    - Compatible regulations, specifications, and standards
    - Compatible acquisition corps education and training
  - Generally, schedule/cost/quality as independent variable
    - Prioritized feature set as dependent variable

- **Multiple career paths**
  - For people good at build-to-spec, agile rebaselining, V&V
  - For people good at all three
    - Future program managers and chief engineers
ICM Transition Paths

• Existing programs may benefit from some ICM principles and practices, but not others
• Problem programs may find some ICM practices helpful in recovering viability
• Primary opportunities for incremental adoption of ICM principles and practices
  – Supplementing traditional requirements and design reviews with development and review of feasibility evidence
  – Stabilized incremental development and concurrent architecture rebaselining
  – Using schedule as independent variable and prioritizing features to be delivered
  – Continuous verification and validation
  – Using the process decision table
• See http://csse.usc.edu (tech report 2009-500)
References - I

- Electronic Industries Alliance (1999); EIA Standard 632: Processes for Engineering a System
References -II

- Krygiel, A., Behind the Wizard’s Curtain; CCRP Publication Series, July, 1999, p. 33