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The Effect of Processes and Incentives on Acquisition Cost Growth

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Knowledge and Skills for Enterprise Transformation.

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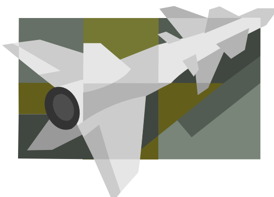
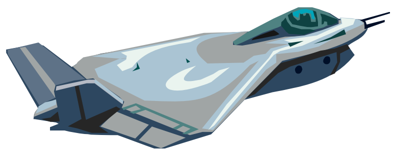
Doug Bodner, I-Hsiang Lee and Bill Rouse

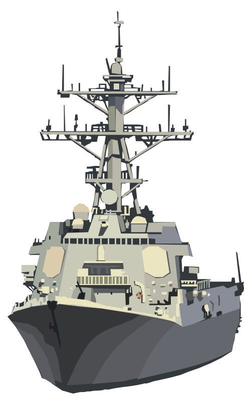
Agenda

- Motivation
- Cost growth
- Model
- Simulation implementation
- Simulation results
- Current work

Motivation







- Cost growth evident in weapons programs
  - $296 billion in 2008 portfolio
  - $135 billion since 2008
  - $70 billion unexplained by quantity changes
- Pressure to rein in costs due to fiscal and political environment
- Decision-making regarding processes and incentives

Process Drivers

- Evolutionary acquisition
  - Each development cycle occurs at lower cost
  - Increased number of development cycles contributes to potentially higher cost
- Phase concurrency
  - Concurrency might be used to regain schedule (e.g., between development and production)
  - Concurrency introduces risk of rework and wasted production
- Uncertainty
  - Technology immaturity poses cost growth risk
  - Requirements volatility poses cost growth risk

Incentive Drivers

- Cost-plus contracts
  - Cost growth tends to be enabled
- Competition vs. non-competition
  - Competition should incentivize cost performance
  - Low bids are potentially incentivized by competition
- Incentives
  - Evidence shows award/incentive fees ineffective
  - Recommendations for using fees include
    - Set base fee and tie overall fee to outcomes, not time
    - Using rollovers judiciously

Organizational Simulation

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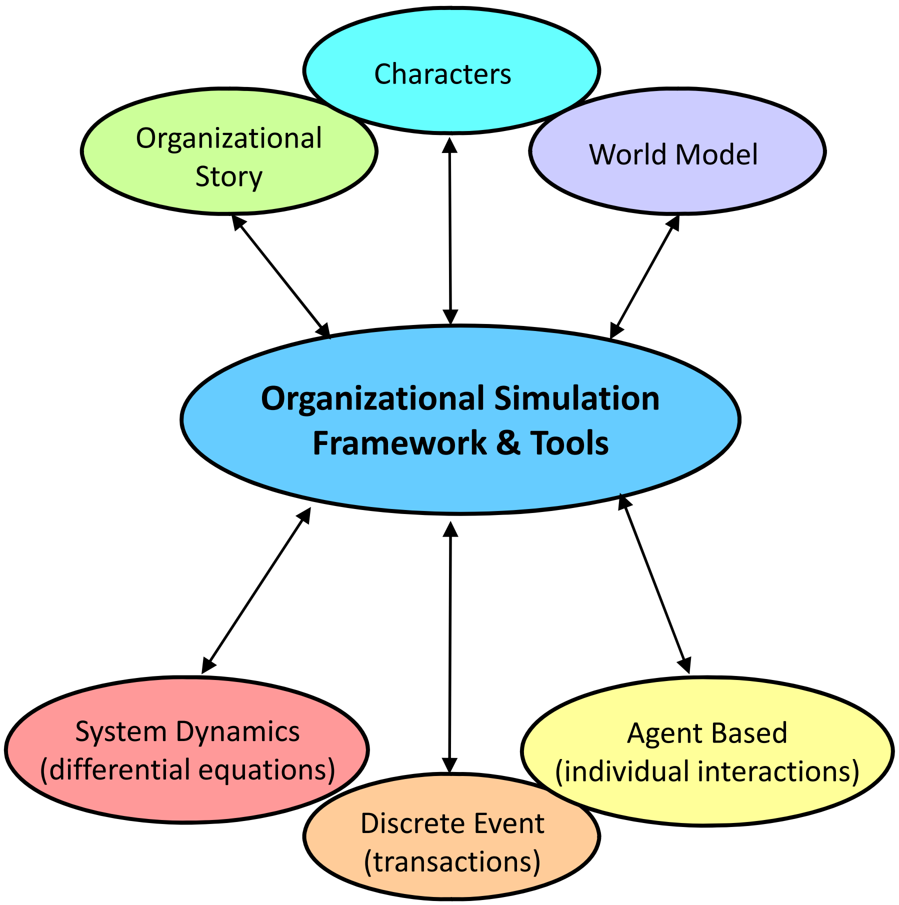

- Simulation methodology focused on the organizational experience
  - People
  - Social behavior
  - Rules and processes
  - Artifacts
  - Architecture
- Tools for designing, testing, prototyping and experimenting with organizational systems
- AnyLogic implementation with Java class library for organizational modeling

Process Model

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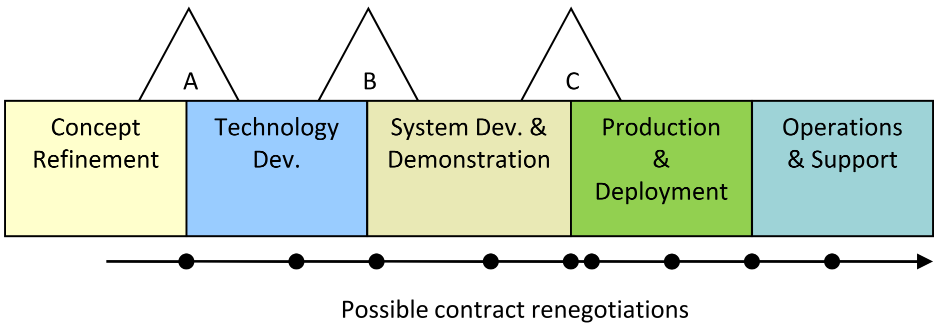
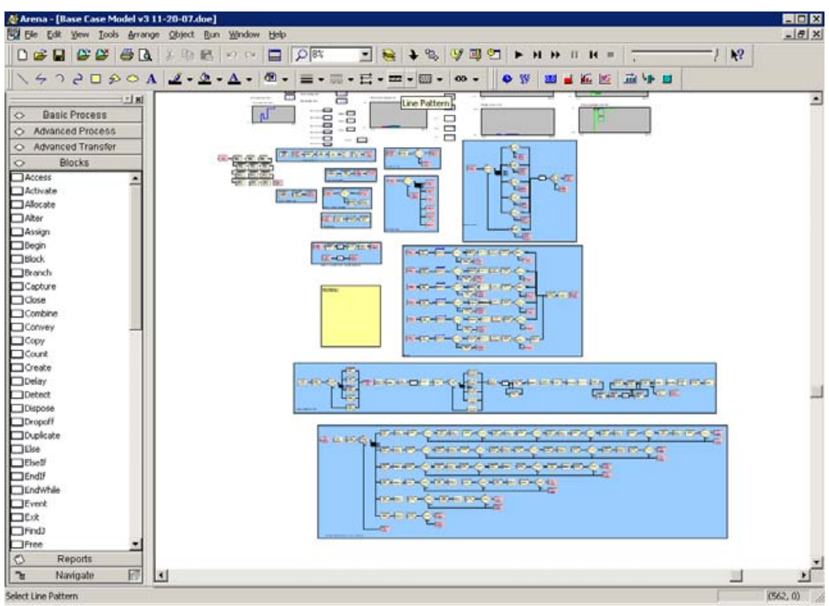
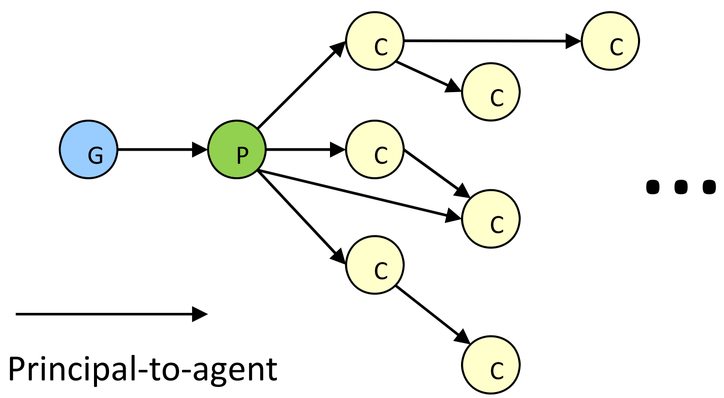




- Acquisition phases
- Decision points
- Cost accruals
- Progress
  - Technology maturation
  - Design
  - Development
- Concurrency and uncertainty
- Contract renegotiations

Actor Model



G = Government
P = Prime contractor
C = Contractor

- Principal-agent model
  - Government as principal
  - Contractor as agent
- Are the interests of the agent aligned with those of the principal?
  - Contract structure
- Eventually extended to multi-tier principal-agent network
  - Complex
  - Non-transparent

Incentive Model

- Agent has a utility $U(w, a)$ from working for the principal
  - w = payment
  - a = effort
  - Reserve utility in case of no contract
- Payment each period
  - x_0^2 for low performance
  - x_1^2 for medium performance
  - x_2^2 for high performance
- Performance based on effort, incorporating uncertainty
  - $P(a_i) = P_j$ with probability p_j^i
  - Probabilities scaled so that lower efforts have higher probabilities of low performance and vice-versa

Optimization

- Principal's perspective
- Minimize expected payout
- Subject to
  - Agent's expected utility ≥ reservation utility
  - Agent's expected utility for high effort ≥ expected utility for low effort

Cost-Plus

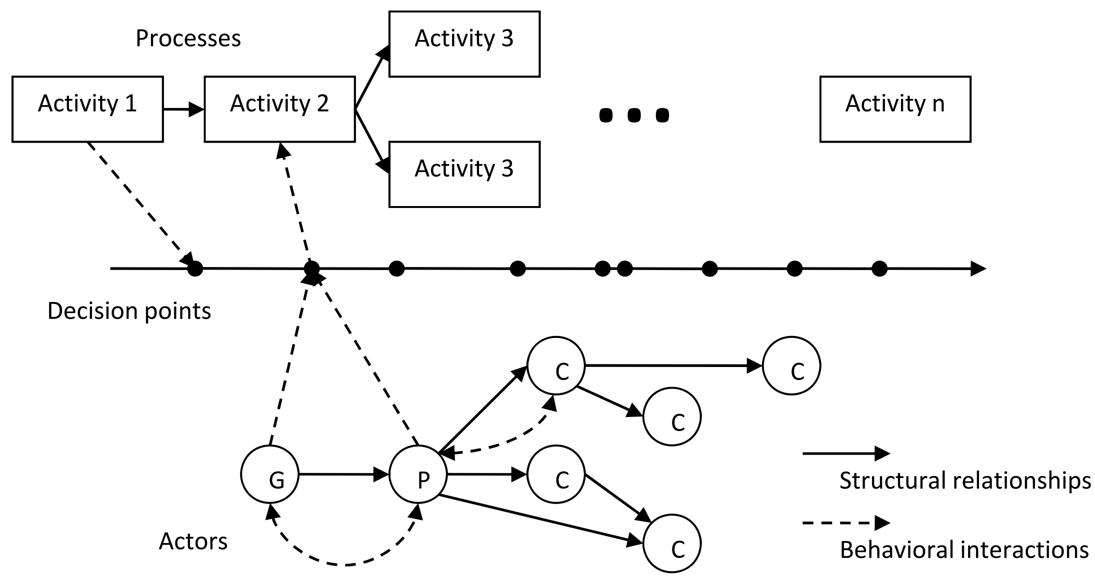
- Let T be total time for an acquisition phase, and let there be an estimate of time remaining at time t
- Agent's progress each period goes toward completion time, and estimate of time remaining is updated
- Principal pays x_i^2 per period depending on performance level
- An initial cost estimate is provided, and is updated with actual cost incurred plus an estimate for the remaining phase duration
- Cost growth and incremental cost growth can be measured by the difference of the actual and the estimate at time t

Fixed Price

- Assume Cobb-Douglas production function with increasing returns to scale
- Production efficiency is a function of effort, incorporating uncertainty
  - $\alpha(a_i) = \alpha_j$ with probability p_j^i
- Agent selects level of effort to maximize expected gain
  - Price per unit multiplied by number of units less expected cost to agent based on production function
- Discussion
  - Production efficiency of concern primarily to agent
  - Principal concerned with schedule
  - Discounted cash flows and penalties

Simulation Implementation

- Agent determines effort
- Performance level computed
- Cost incurred updated
- Estimated time to completion updated
- Estimated cost updated
- Cost growth estimated
- New probabilities generated



Probabilities

- Probabilities change at each period
- Random assignment
  - Each probability is assigned a new value from the Uniform (0, 1) distribution, subject to the earlier constraints
- Random addition
  - Each probability is assigned a new value by adding a random amount to the previous value
  - The new value is the probability multiplied by (1+rUnif(-1,1)), where $r = 0.1$
  - This simulates a random walk process
  - The same constraints are observed, as well as the constraint that probabilities are non-negative

Experimental Example

Probability of performance

Low Effort			High Effort		
Low	Medium	High	Low	Medium	High
0.6	0.3	0.1	0.1	0.3	0.6

Principal's cost based on performance

Low	Median	High
100	200	400

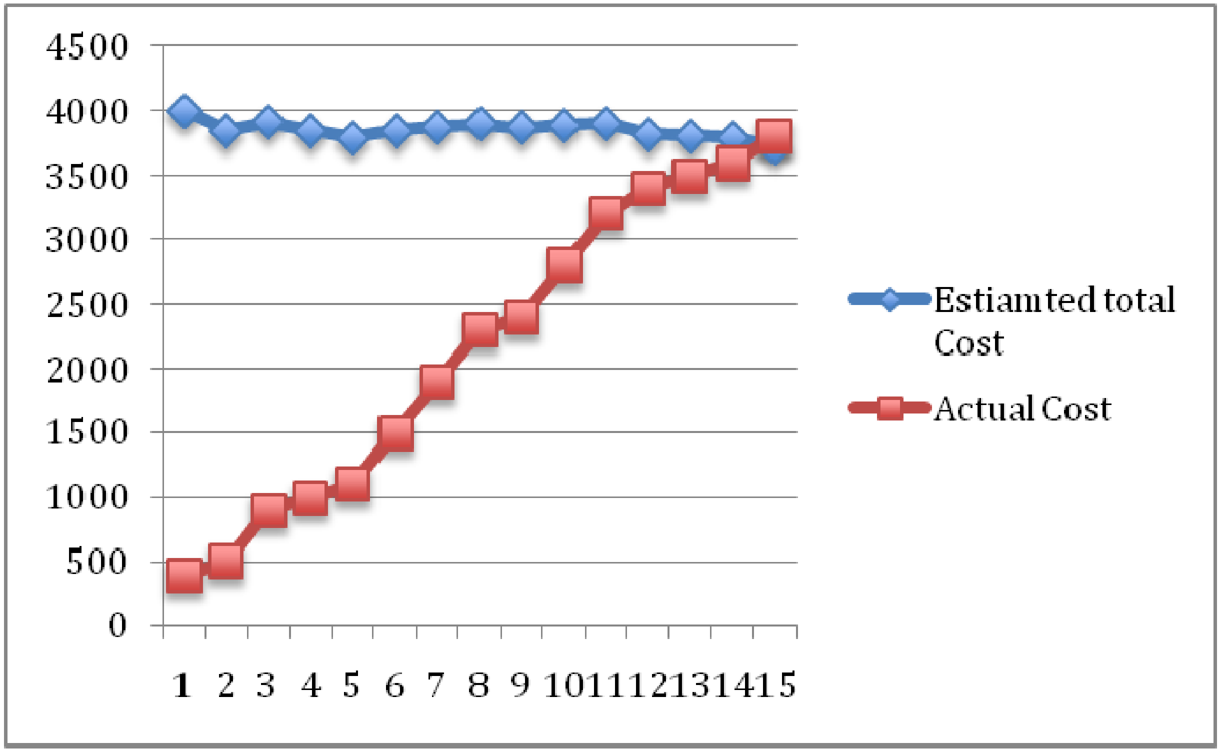
Agent's cost

Low effort	High Effort
50	150

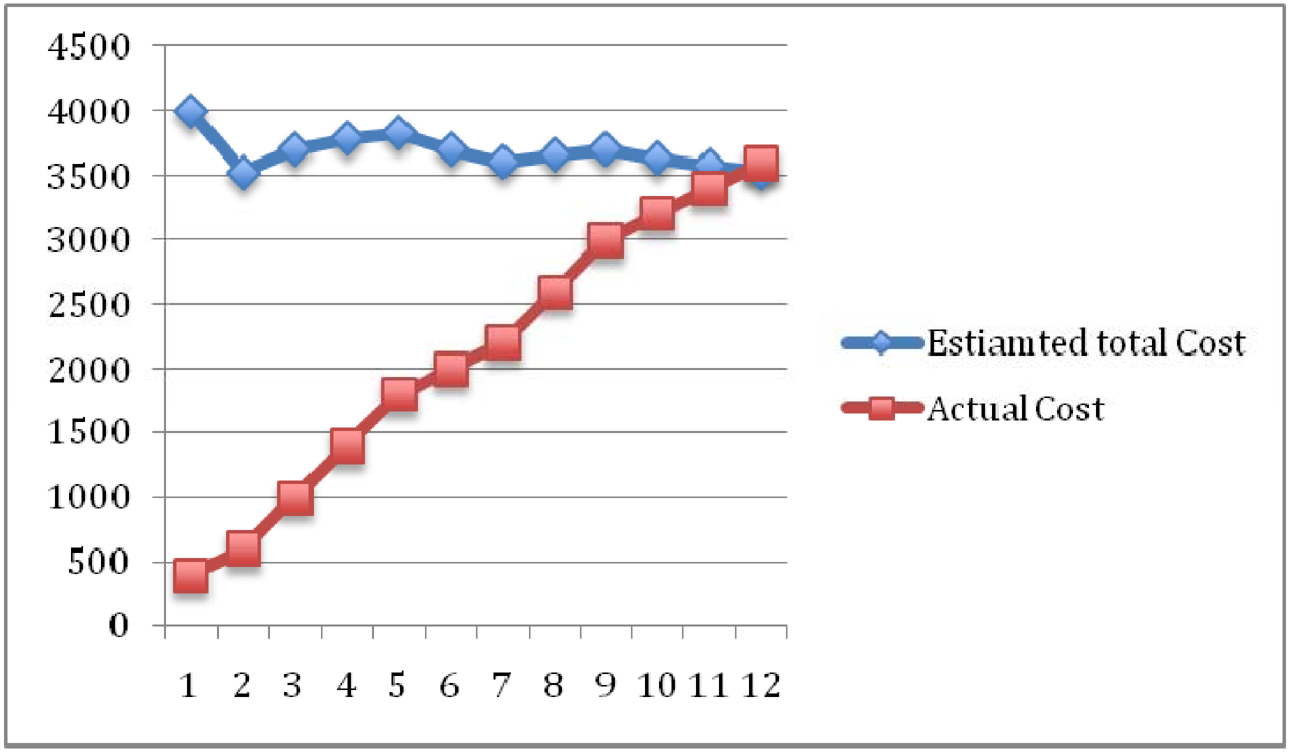
Other parameters

Est. Phase Duration (Yrs.)	Interaction Frequency	Reserve Utility
10	Annually	100

Random Assignment



Random Addition



Equal Probabilities

	Random Assignment		Random Addition	
	Original	Equal Prob	Original	Equal Prob
Mean	177.3	185.3	169.5	175.9
Std. Dev.	61.2	60.7	76.0	47.2

- Random addition has a lower variance than random assignment due to the generally smaller changes in probabilities between periods
- This difference is smaller under the equal initial probabilities since there is less switching between effort levels

Discussion

- Combined process and incentive modeling
- Micro-economic and technical behavior models
- Contract structure
- Simulation needed due to complexity

Current Research

- Scale up work with F-35 data and multi-tier principal-agent network
- Enhance fixed cost model
- Experimentation with incentive structures, transfer points and process concurrency

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Questions

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