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Addressing Risk in the Acquisition Lifecycle with Enterprise Simulation

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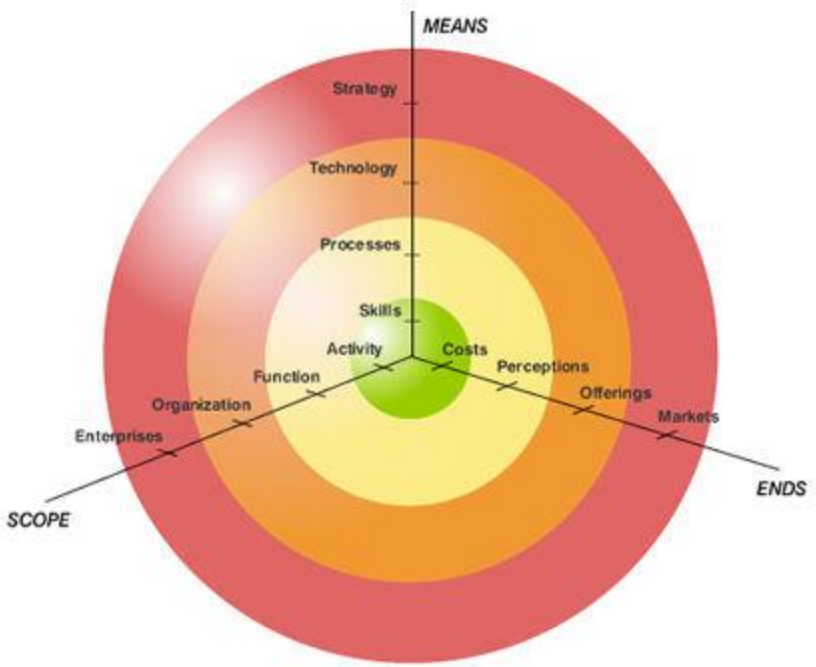
Outline

- Motivation
- Enterprise simulation
- Risk analysis
- F-35 case study
- Conclusions and future research

Motivation

- Many enterprises are in need of transformation due to challenges or opportunities
- Defense acquisition is one such enterprise
  - Fiscal challenges
  - Aging system portfolio
  - New system complexity
  - New and emerging threats
- Enterprise transformation entails risk
- Computational models such as simulation are one way to discover, understand and mitigate risk

Enterprise Transformation Framework



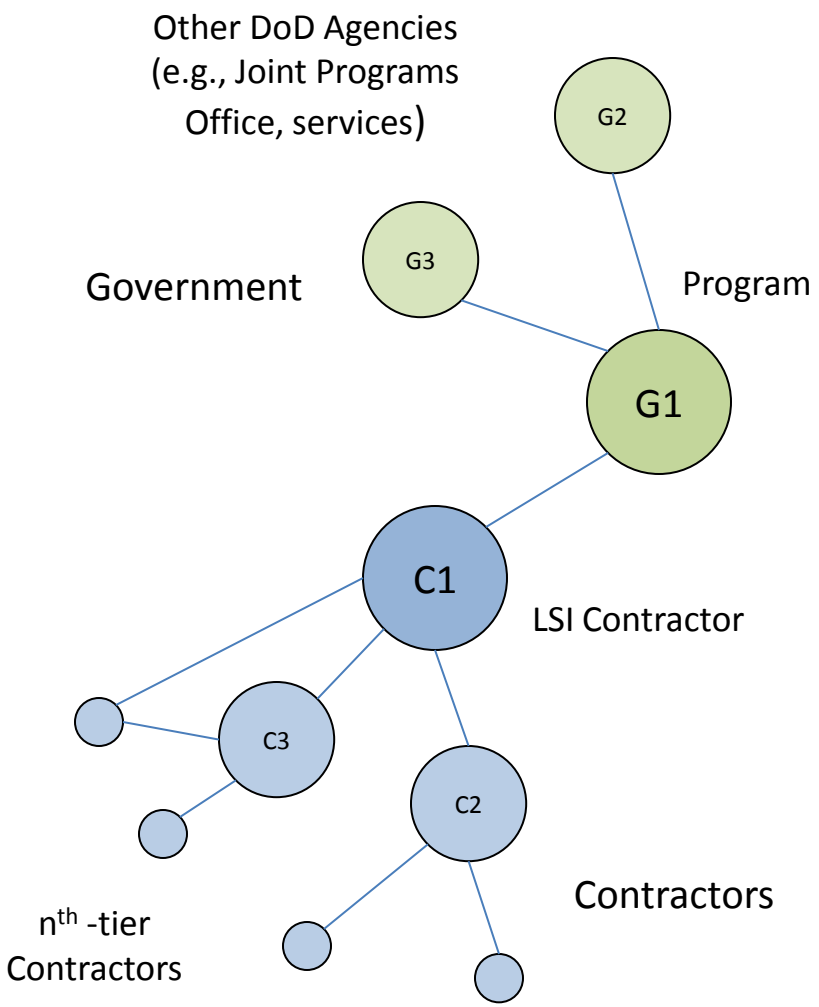
Rouse, Enterprise Transformation, 2006

- Transformation efforts in the green and yellow circles are less risky, but only have limited pay-offs
- Efforts in the orange and red circles are enormously risky, but can change the whole market
- Successful transformations in the orange and red circles typically require competitors to respond at least with efforts in the green and yellow circles

Enterprise Simulation

- Traditional simulation
  - Analysis of behavior and performance over time under different scenarios
  - Uncertainty incorporated
  - Primary emphasis on processes
- Enterprise simulation
  - Socio-technical phenomena modeled
  - Co-emphasis on firm or individual behavior via agent-based simulation
  - Representations of organizational behavior
  - Risk drivers modeled

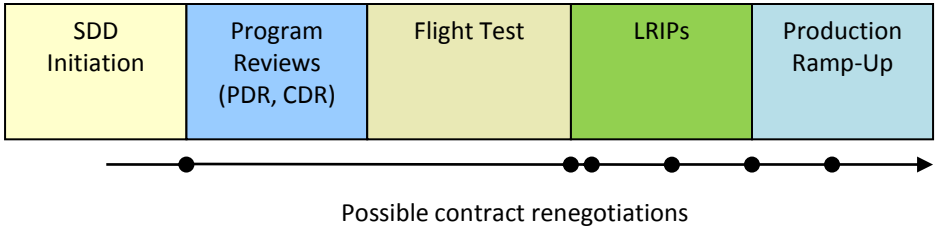
Agent-Based Organizations

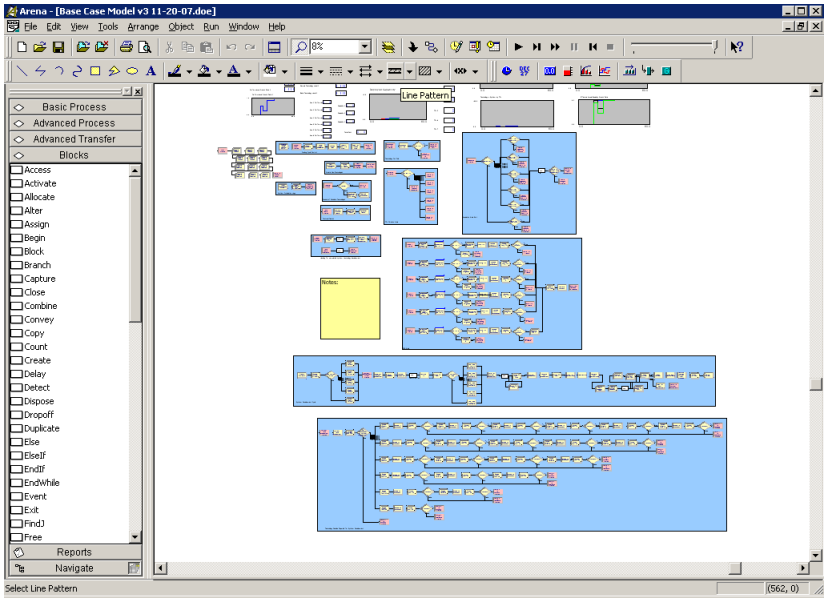


- Communicate with other agent organizations
- Accrue costs
- Dispense funds
- Progress through processes or tasks
- Restructure a program
- Terminate a program

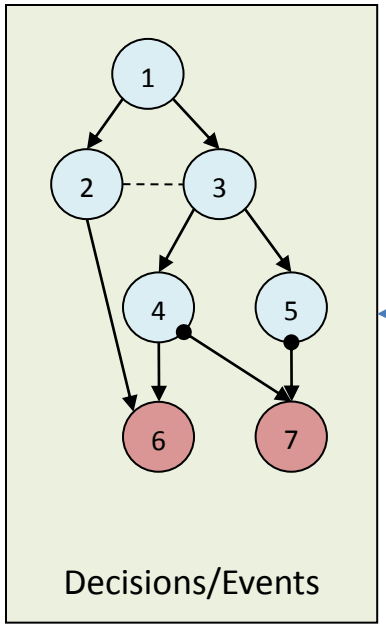
Acquisition Processes

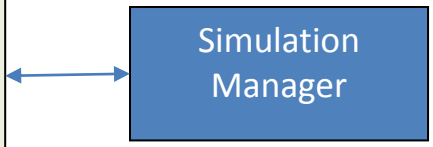
- Decision points
- Cost accruals by agent organizations
- Progress through acquisition milestones
  - Program design
  - Program reviews
  - Development/test
  - LRIPs
- Concurrency and uncertainty
- Contract renegotiations





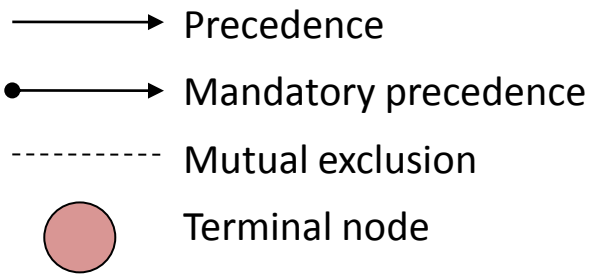
Decision/Event Network



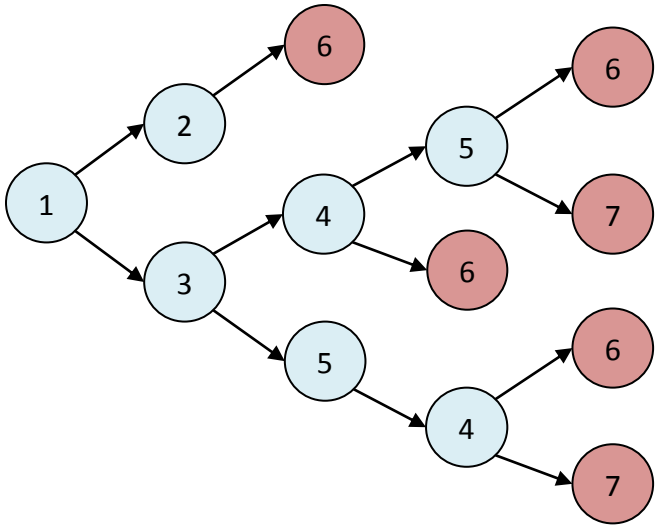


Actions
- Enable/disable node
- Make node more/less likely

- Directed acyclic graph of precedence relationships between important nodes
  - Decisions by agents
  - Events in simulation
- Important events abstracted from simulation model
- Concept of simulation manager borrowed from interactive drama
- Simulation manager seeks to guide the simulation through a "path" of decision/event nodes
  - Receive state information from simulation
  - Takes actions to influence determination of next node in decision/event network
  - Actions based on evaluation function of future paths from candidate next nodes
  - Evaluation function based on a certain goal for the outcome



Partial Game Tree



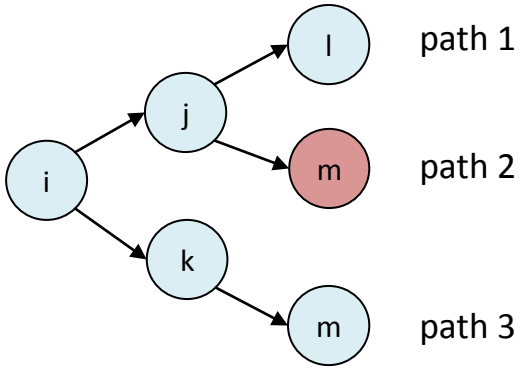
Potential Outcomes

- 1 → 2 → 6
- 1 → 3 → 4 → 5 → 6
- 1 → 3 → 4 → 5 → 7
- 1 → 3 → 4 → 6
- 1 → 3 → 5 → 4 → 6
- 1 → 3 → 5 → 4 → 7

- Enumeration of possible event paths and outcomes
- Generated from decision/event network
- "Partial" game tree due to simulation manager actions not being represented
- Computational complexity is an issue for large simulations

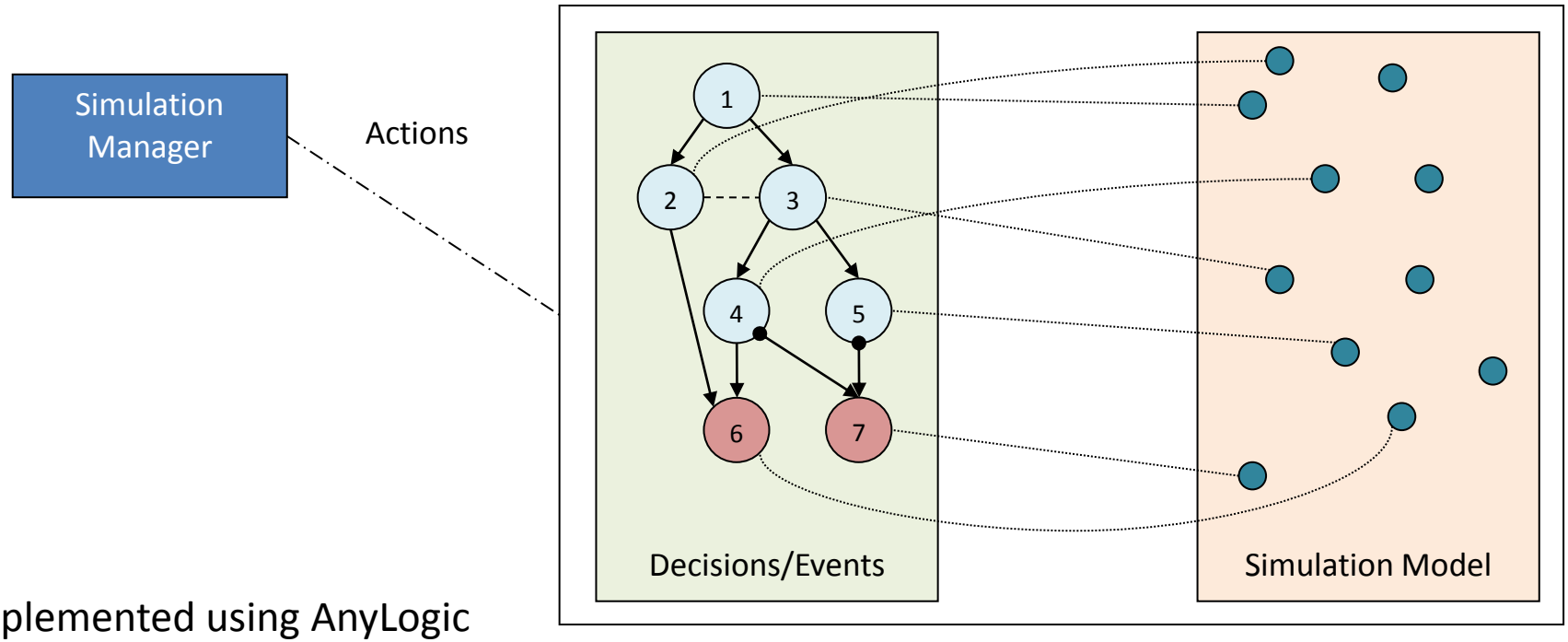
Evaluation Function for Risk

- Risk is one outcome type of interest
- Risk is the expected value of an undesired outcome
- Schedule and cost are two types of risk
- Schedule risk
  - Expected additional schedule growth S
- Cost risk
  - Expected additional cost growth C
- Evaluation uses
  - Estimates of S and C along each remaining path
  - Probabilistic weightings for each path
  - Initial estimates and weightings are used then are updated as simulation progresses



- Assuming current node is i:
  - Compute $E_j(S)$ = $\sum_{r=1}^{2} p_1 \hat{S}_1 p_2 \hat{S}_2$
  - Compute $E_k(S)$ = $\hat{S}_3$
  - Execute simulation manager to prefer one (based on risk analysis preference)

Simulation Implementation



Implemented using AnyLogic

- Commercial simulation tool
- Supports multi-paradigm simulation
- Java-extensible

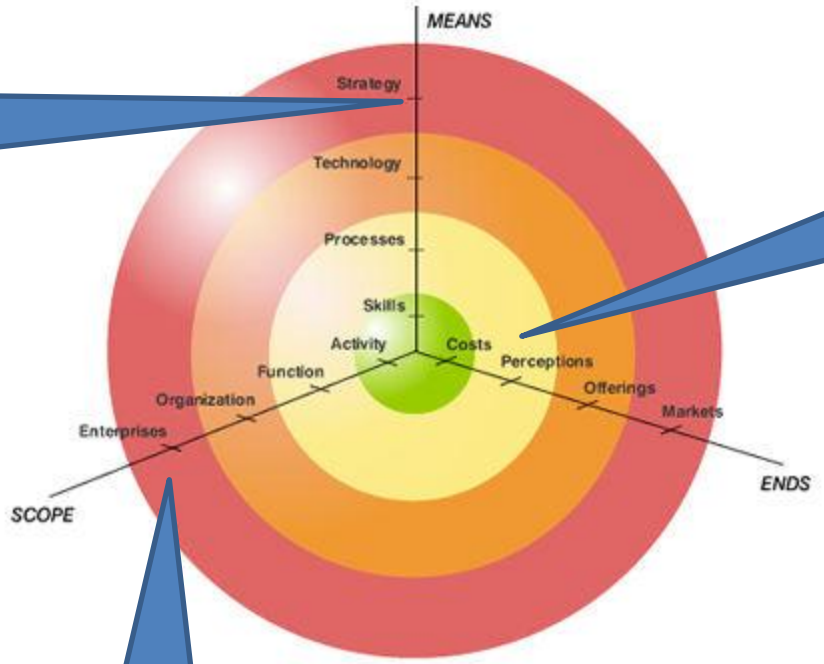
F-35 Program Background

- Next generation replacement for tactical fighter fleets (F-16, F-18)
- Concept aircraft competition between consortia led by Lockheed Martin Aeronautics and Boeing
- SDD contract awarded to LM Aeronautics consortium in 2001
- Three variants envisioned:
  - Conventional take-off and landing (CTOL) – Air Force
  - Carrier variant (CV) – Navy
  - Short take-off and vertical landing (STOVL) – Marines
- 2,852 total U.S. aircraft planned for procurement
- Schedule and cost issues

F-35 Transformative Risk Elements

Traditional Approach	F-35 Approach
Single lead firm with command-and-control business model	Collaborative partnership model among three lead firms (LM Aero, BAE, NG)
U.S.-based design, development and production with foreign sales as secondary consideration	Global design, development and production with foreign sales as major strategy
Most testing done with real articles; limited-to-medium concurrency	Substantial testing done with modeling & simulation; high concurrency
Two technically complex capabilities per aircraft at most • F-22 (stealth, supersonic) • F-14 (supersonic, carrier-capable)	Three variants on a common platform with four technically complex capabilities across the family • Stealth, supersonic, STOVL, carrier-capable
Separately managed production and sustainment networks	Combined production and sustainment networks

Transformation Map – Partnership

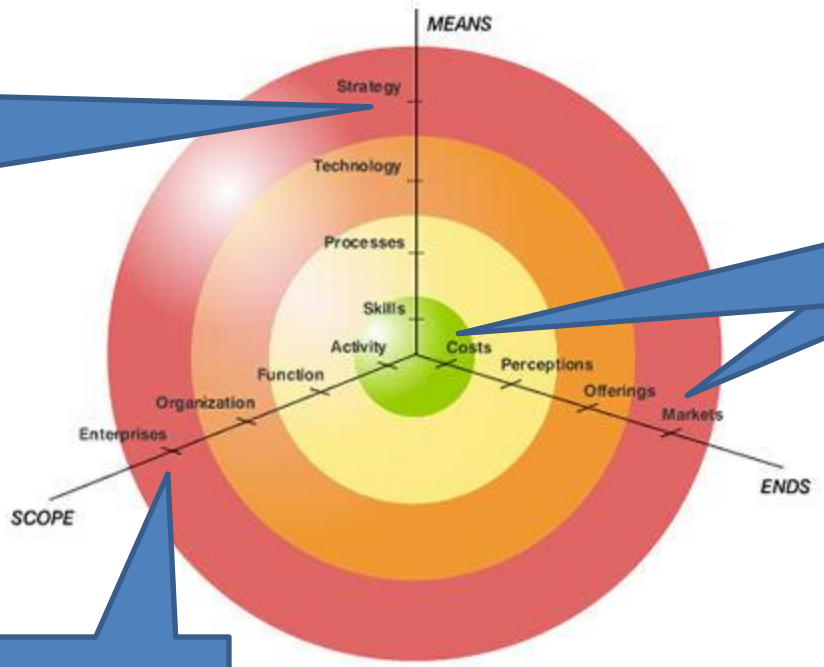


Collaborative partnership model

Collaborative partnership model

Collaborative partnership model

Transformation Map – Global Program

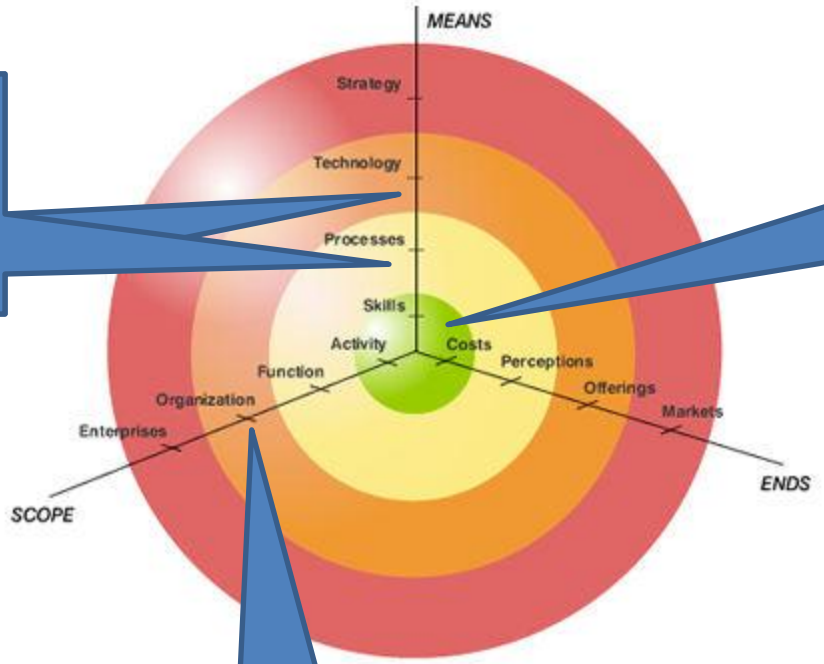


Global design, development, production & sales

Global design, development, production & sales

Global design, development, production & sales

Transformation Map – Testing



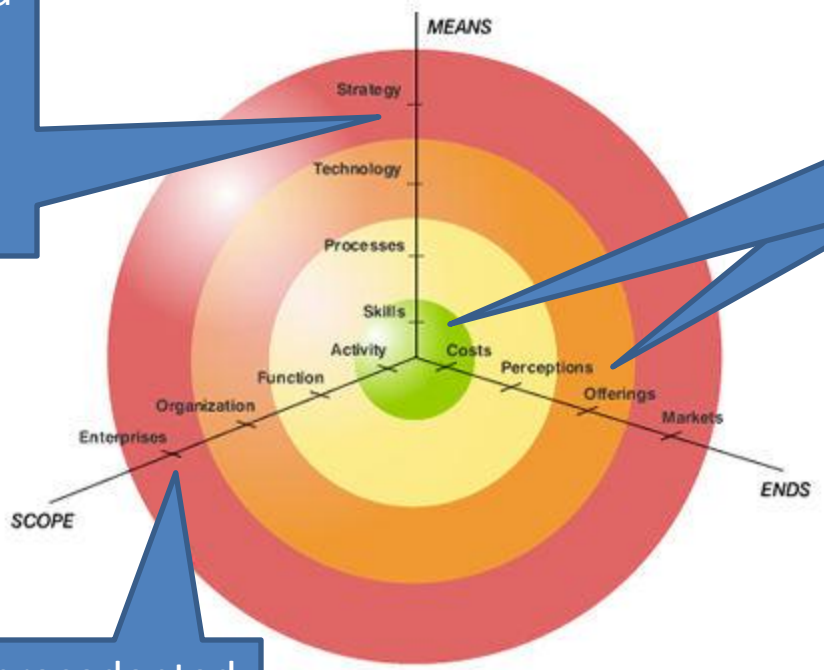
Model-based testing and concurrency

Model-based testing and concurrency

Model-based testing and concurrency

Transformation Map – Capabilities

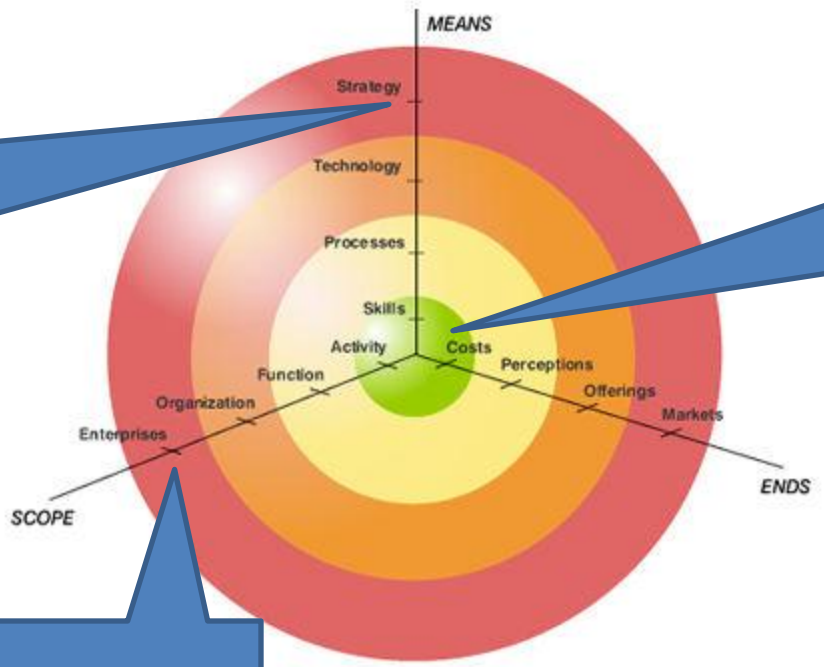
Unprecedented number of technically challenging capabilities



Unprecedented number of technically challenging capabilities

Unprecedented number of technically challenging capabilities

Transformation Map – Supply Network

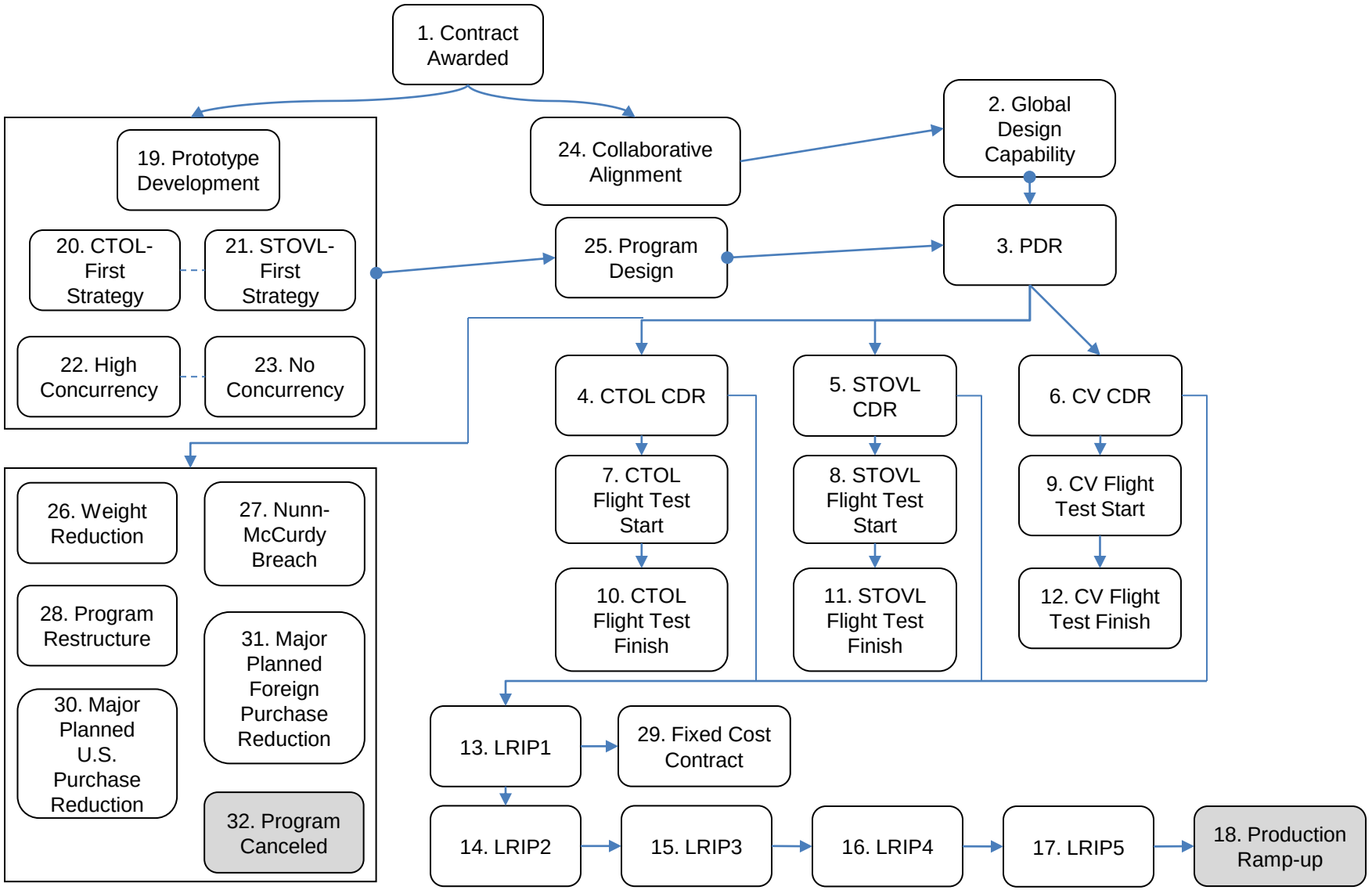


Combined production & sustainment networks

Combined production & sustainment networks

Combined production & sustainment networks

F-35 Decision/Event Network



Simulation Model

- Government and lead contractor modeled as agents
- SDD and LRIP phases of acquisition processes
- Simulation variables track:
  - Cost targets
  - Schedule targets
  - Progress on milestones
  - Status of weight TPM

Analysis

- Simulation has been run for a subset of the decision/event network
  - Collaborative alignment
  - Program design – concurrency and prototype
  - Technical aspects – design capability, reviews, test
  - LRIPs
- Cost risk and schedule risk have been assessed
- Since many probability parameters are unknown, sensitivity analysis is being conducted to determine sensitivity over ranges

Results to Date

- Achieving collaborative alignment by leadership is critical to risk reduction
- High concurrency has a higher schedule and cost risk than no concurrency
  - Without concurrency, schedule and cost targets cannot be met
  - With concurrency, risk of not meeting schedule and incurring additional costs
- Prototype reduces schedule and cost risk

Conclusions

- Enterprise transformation analysis suggests that the F-35 program was enormously risky
- Enterprise simulation is used as a way to understand risks by modeling risk drivers
- Results to date indicate
  - Alignment is critical reduce risk associated with collaboration
  - Concurrency leads to increased risk (sensitivity analysis needed to improve characterization)
  - A prototype of a complex system can lead to reduced risk (sensitivity analysis needed to improve characterization)

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Questions?