Systems Engineering Advancement Research Initiative

RESEARCH OVERVIEW

Real Options in Enterprise Architecture

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Researcher's Background

Tsoline Mikaelian

- Education
  - Doctoral candidate in Aeronautics and Astronautics
  - S.M. Aerospace Engineering (MIT, 2005)
  - B.Sc. Space and Communication Sciences (York University, 2002)
- Research Interests
  - Decision-making under uncertainty in complex systems and enterprises
  - Flexibility as means to managing uncertainty
  - Automated diagnosis and planning for complex systems
- Professional Experience
  - MIT CSAIL
  - Toyota Technical Center

Motivation

Complex systems and enterprises are subject to uncertainties that may lead to suboptimal performance or failure if unmanaged.

Challenger and Columbia accidents:

→ Revealed flaws in the decision making processes at NASA

→ Highlighted need for organizational change

Failures may be rooted at the organizational level, not necessarily at the engineering design level

How to manage uncertainties facing complex enterprises?

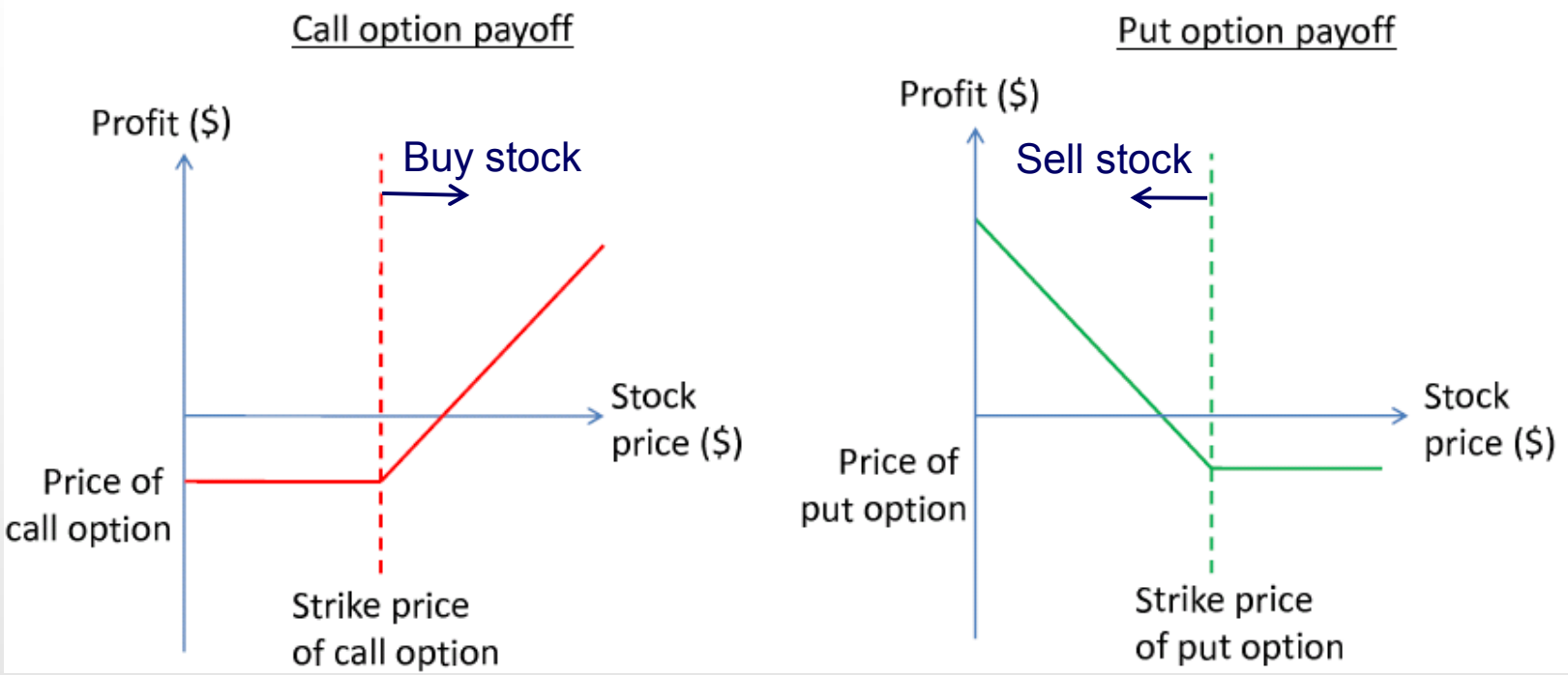
Research Questions

Problem:

How can real options be used for holistic decision making and architecting of socio-technical enterprises under uncertainty?

1. What type of flexibility, if any, is desirable for uncertainty management?
2. How to enable flexibility?
3. Where to enable flexibility in a socio-technical enterprise?
4. How to enable holistic thinking to systematically identify and evaluate all of the above?

Simple Financial Options

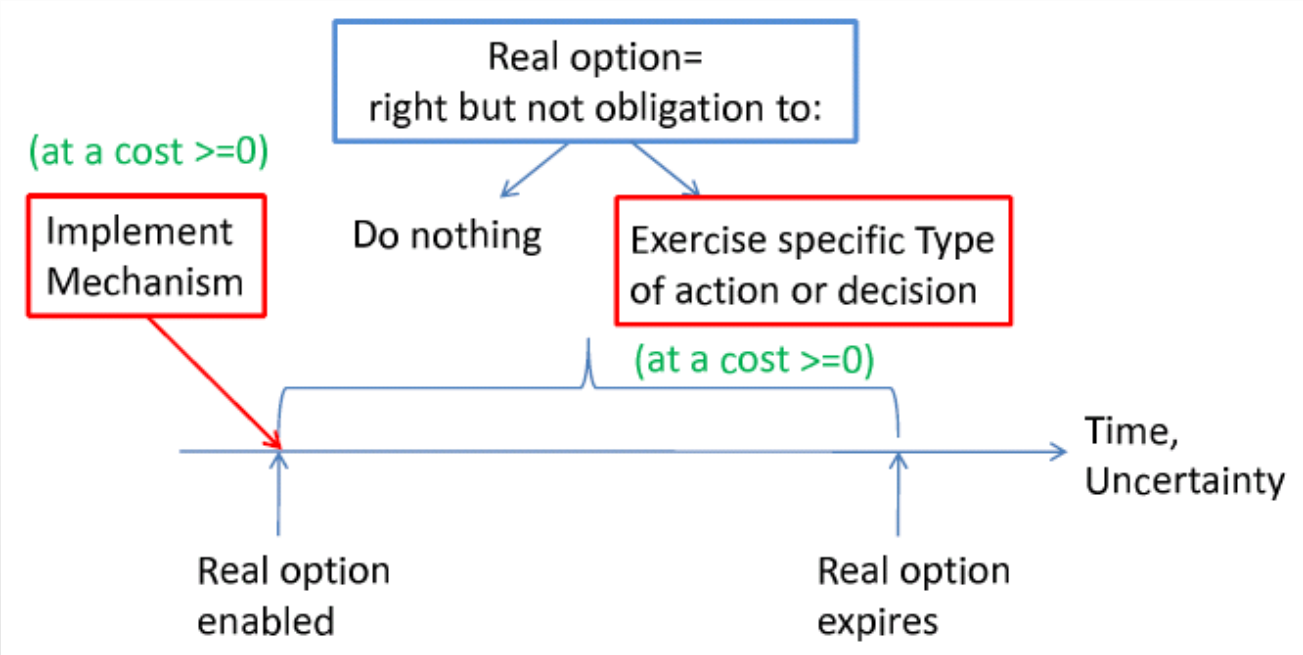


Financial option: right, but not the obligation,
to buy or sell an underlying security at a specified price, on or before expiration date of the option

Real option: right, but not the obligation,
to take an action at a later time

Methods for valuation of financial options:
Black-Scholes, binomial pricing, Monte Carlo

Real Option Characterization

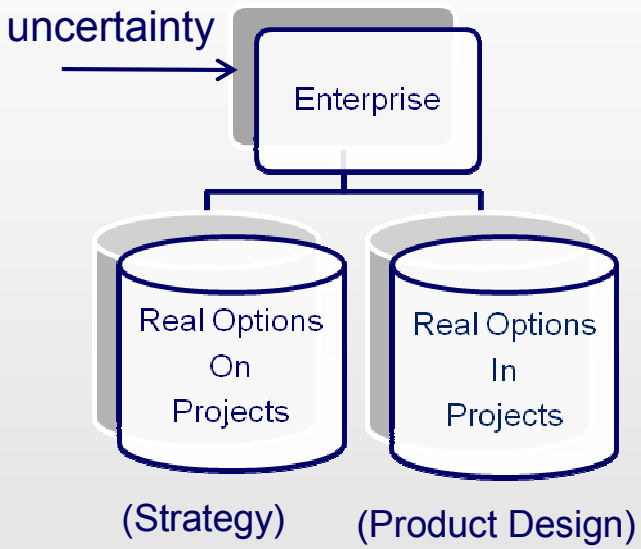


1. Real Option Mechanism:
   actions/decisions that enable a real option

2. Real Option Type:
   actions/decisions that may be exercised by the owner of the real option

Integrating the Real Options Silos

Traditional View



Holistic View

Real Option Mechanism	Real Option Type: In Design	Real Option Type: In Strategy
In Design	MAV design enables a reuse option in future design	MAV design enables future market expansion
In Strategy	MAV development partnership enables option to use new type of technology in design	Investment in MAV project enables option to expand development to swarm in future

MAV = Mini Air Vehicle

→Explore interactions between "real option silos"

May "classify" the location of both the mechanism and type of real option

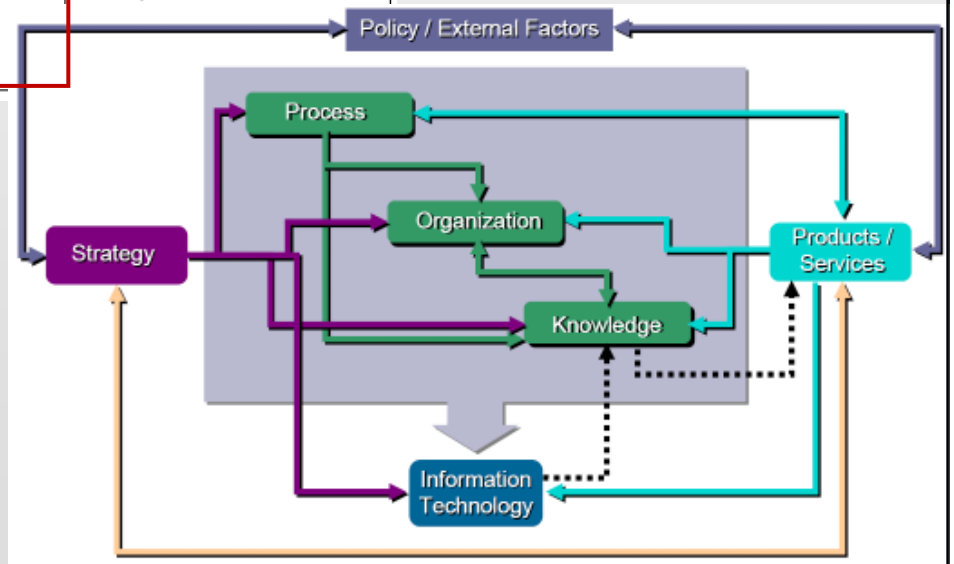
Eight Views of a Socio-Technical Enterprise

Strategy View	Policy View	Process View	Organizational View
Business model, business strategies and internal/external strategic drivers; enterprise metrics and objectives	Policies that impact the enterprise as well as policies internal to the enterprise that affect performance	Key business processes, and activities that capture, manipulate, and manage the business information to support business operations.	The organizational structure of the enterprise, major operations performed by organizations, types of workers, work location, and distribution of organizations to locations

Knowledge View	Information Tech. View	Product View	Service View
All information and knowledge needed to perform the enterprise business operations and relationships among that information	Key IT infrastructure (both hardware and software) that supports the enterprise.	Product(s) developed by the enterprise; key platforms; modular vs integral architectures,	Services(s) delivered and or supplied by the enterprise.

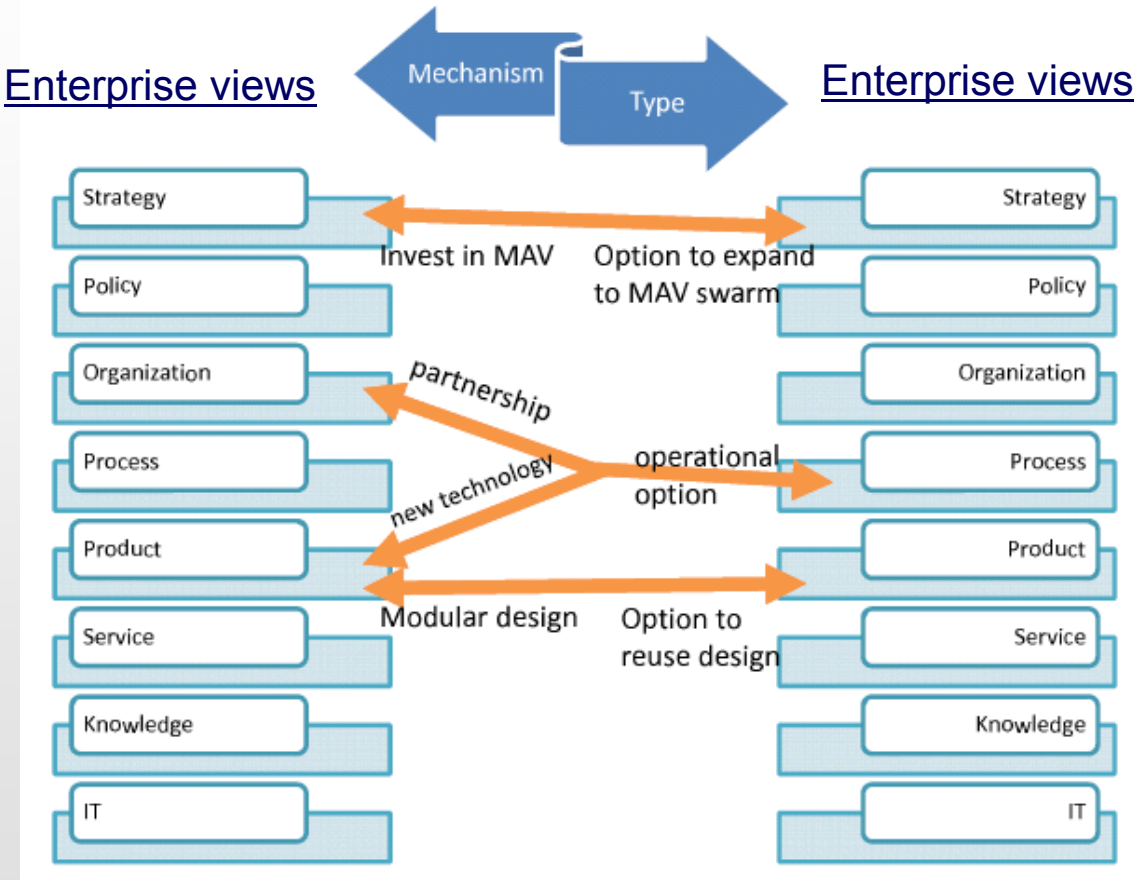
Traditional "enterprise architecture"

Traditional system architecture



(Nightingale and Rhodes, 2007)

Real options across enterprise views



→ Mechanisms, types may exist within any of the enterprise views

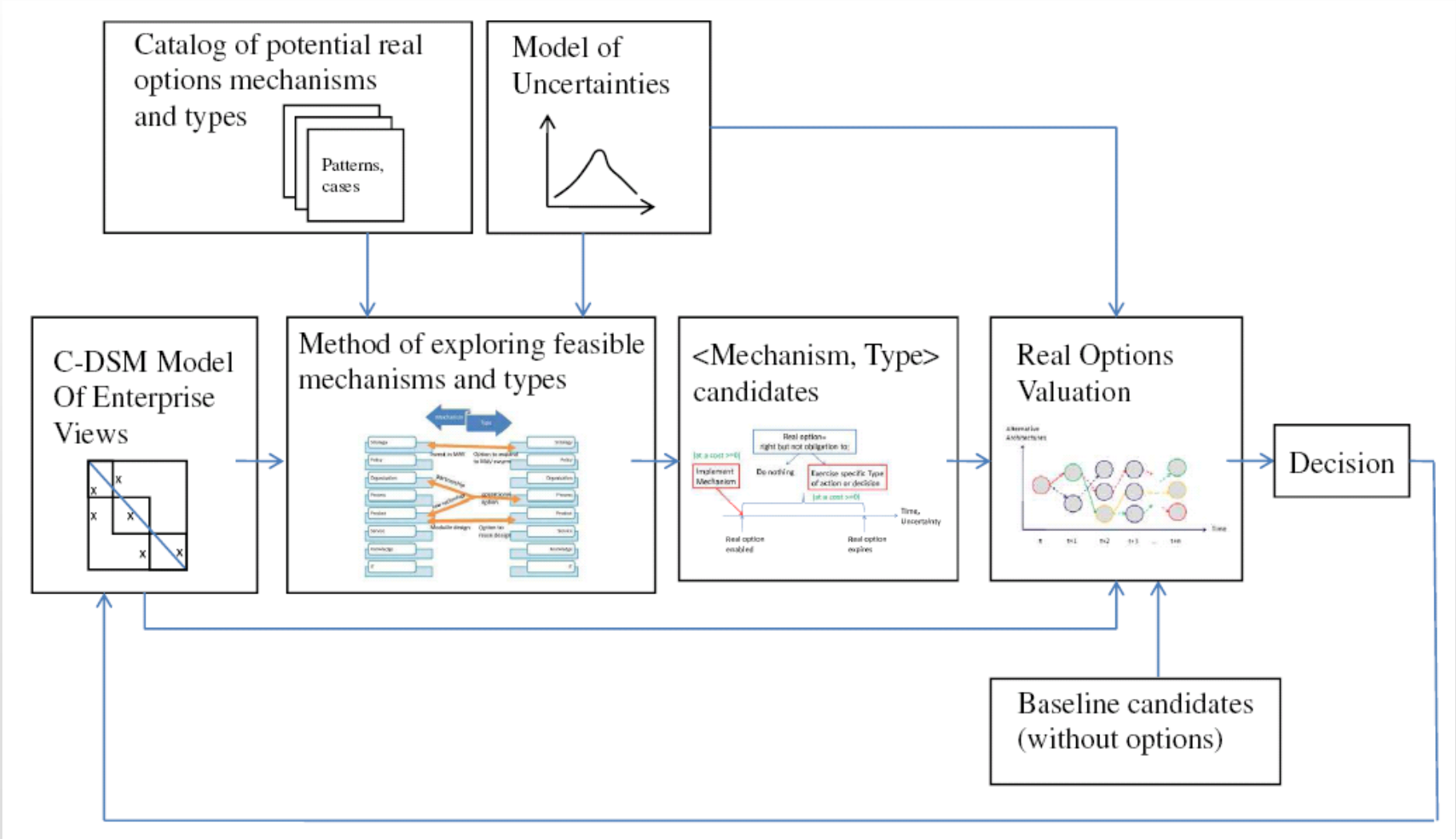
→Extend the real options approach to encompass all views of an enterprise or a socio-technical system

Examples of Mechanisms and Types of Real Options in Enterprise Views

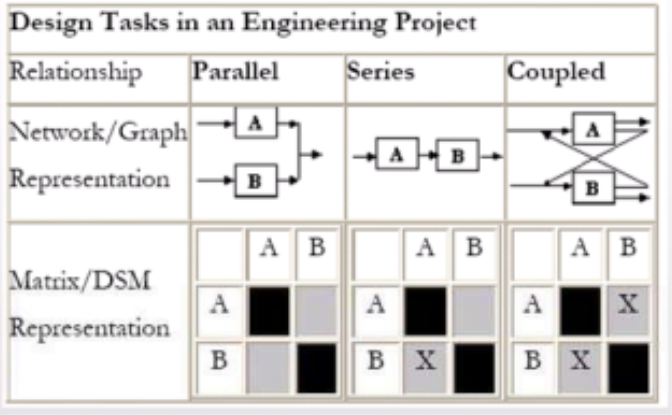
	Mechanism that enables real option	Type of real option
Strategy	Investments/staging/joint ventures/deal structuring, vesting schedule	expand/cancel projects, shift resources, delay decisions
Policy	Company policies, policy to hire interns, work hours	Policy changes
Organization	Partnerships, mergers/acquisitions	Shifting personnel, collaboration among projects/departments
Process	Milestones, pair programming, training, installing machine	Operational, development process options – switch production
Product	Design features, modularity, COTS availability/quality	Reuse, changeability in design
Service	On-orbit servicing system, web deployment of service, tracking mechanism	On-orbit servicing (#, types of satellites), online access to services
Knowledge	Patenting	Leveraging, licensing patent
IT/Resource	IT investments, database design, modularity	Adapt IT infrastructure, expand/abandon/defer investment

The Framework

Holistic identification of real options mechanisms and types that encompass all views of an enterprise

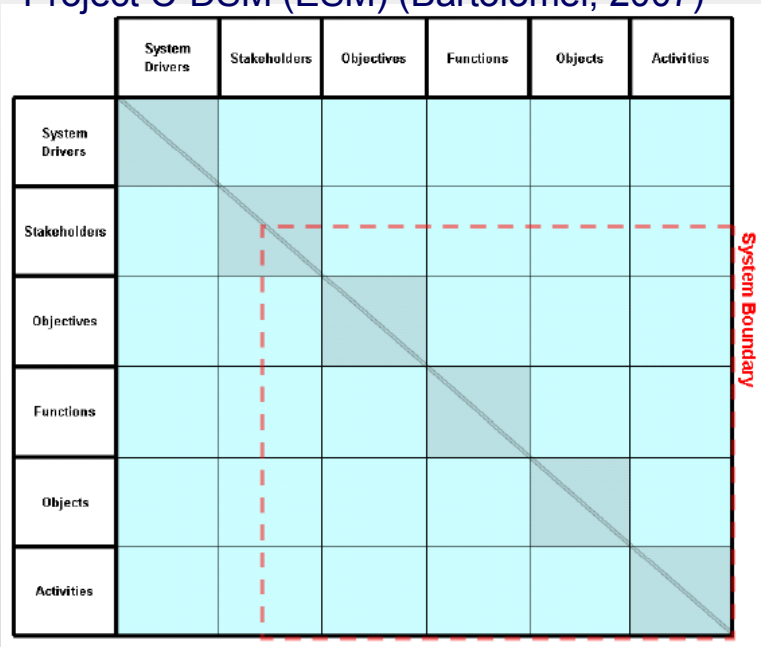


Enterprise C-DSM

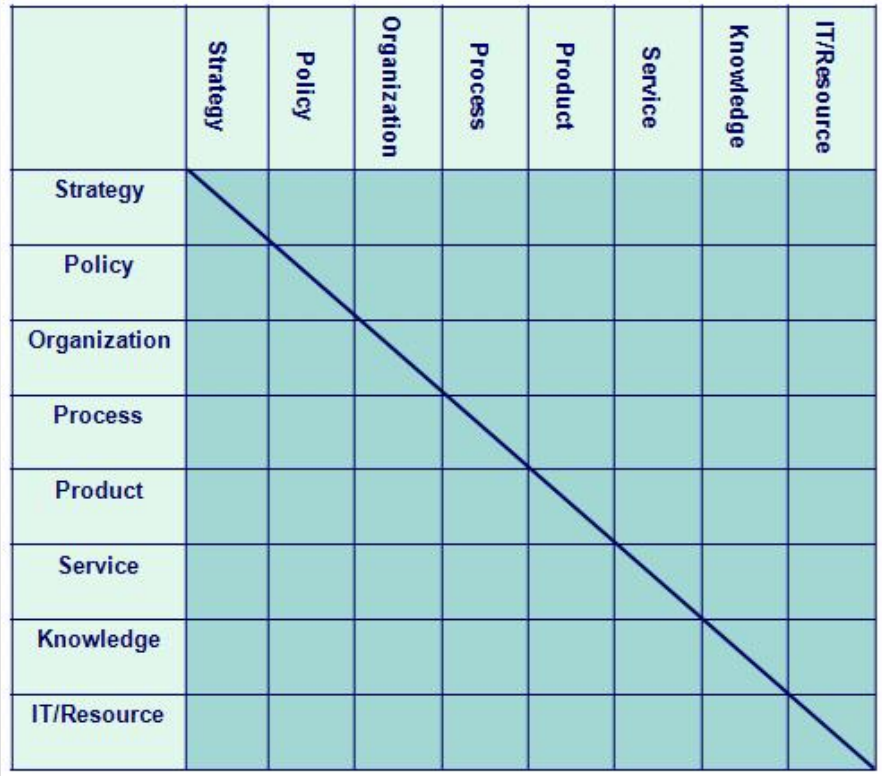


Source: dsmweb.org

Project C-DSM (ESM) (Bartolomei, 2007)



Enterprise C-DSM

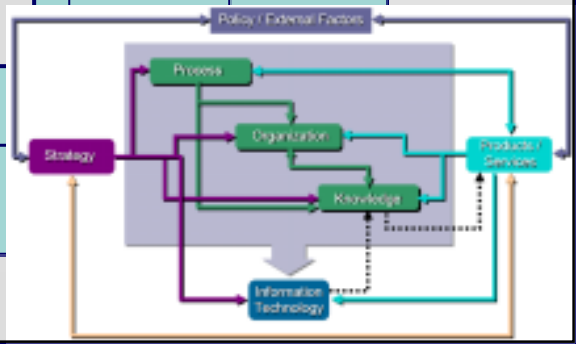


Enterprise C-DSM

	Strategy	Policy	Organization	Process	Product	Service	Knowledge	IT/Resource
Strategy								
Policy								
Organization (Structure)								
Process (Functional)								
Product (Functional + Structural)								
Service								
Knowledge (Data)								
IT/Resource								

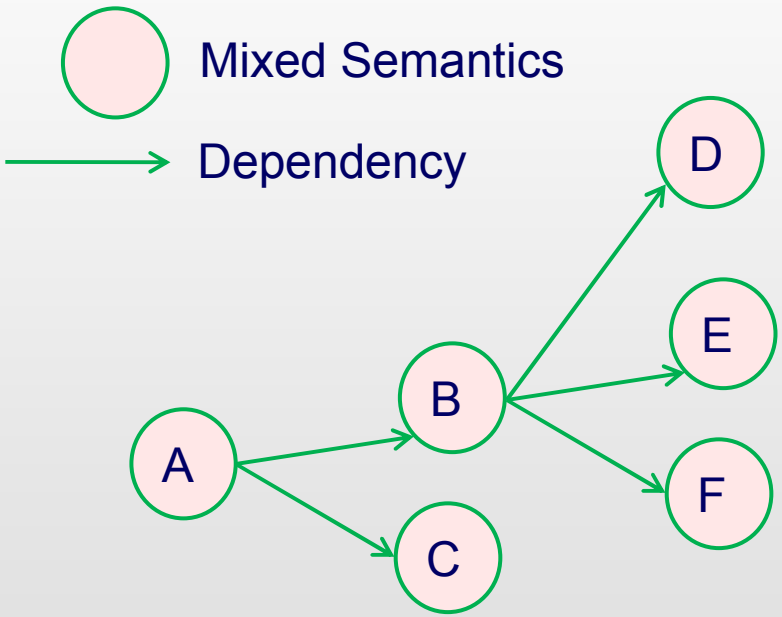
Process affected by Strategy:
- Time to market strategy affects development process

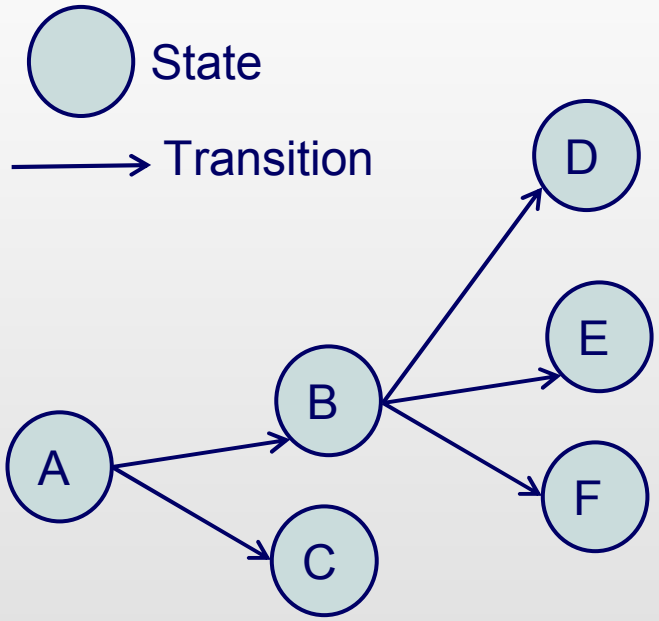
Strategy affected by Process:
- Mass production process leads to strategy of selecting a large target market to justify cost



Semantics of C-DSM

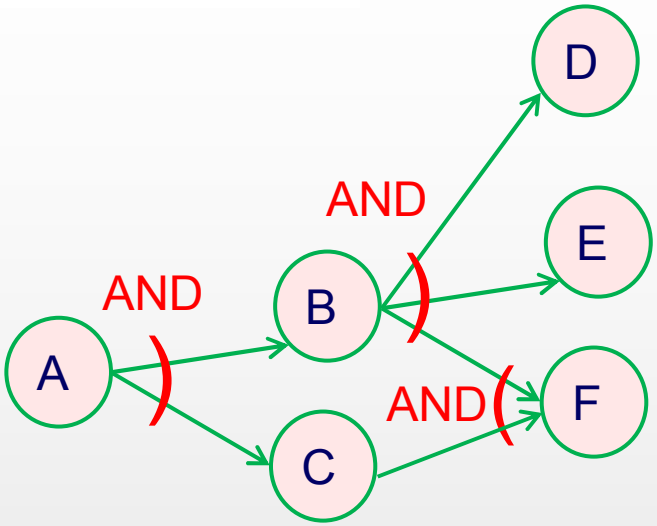
- Question: How can we devise a flexibility metric for C-DSM?

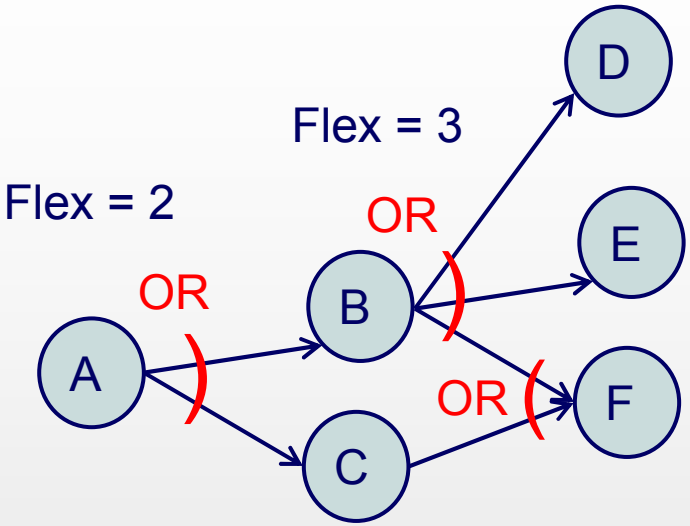




C-DSM = Dependency Network **versus** State Machine

Results





C-DSM = Dependency Network **<u>versus</u>** State Machine

- Default semantics of a dependency is AND
- C-DSM does not distinguish among AND's and OR's
- Flexibility metric evaluation based on OR's

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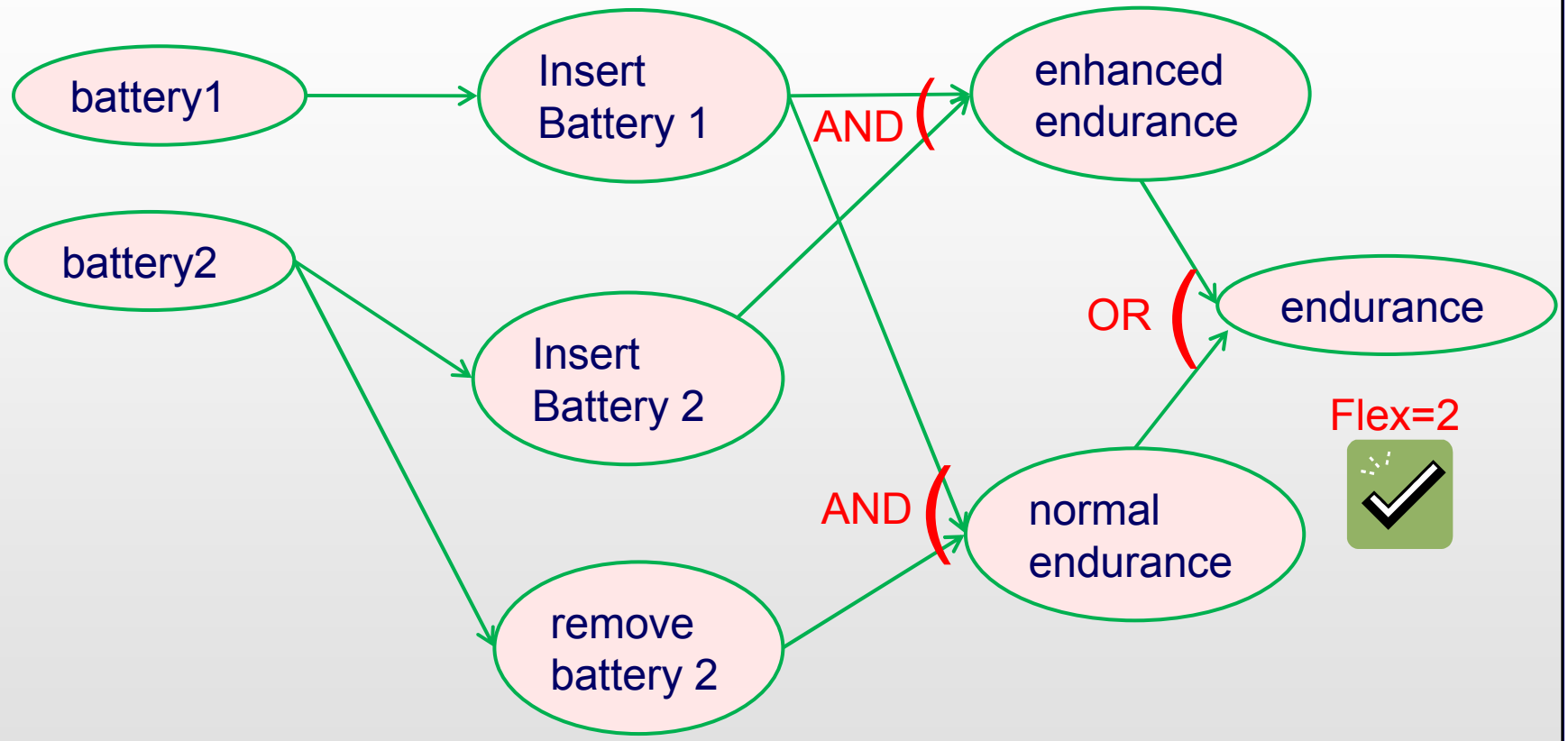
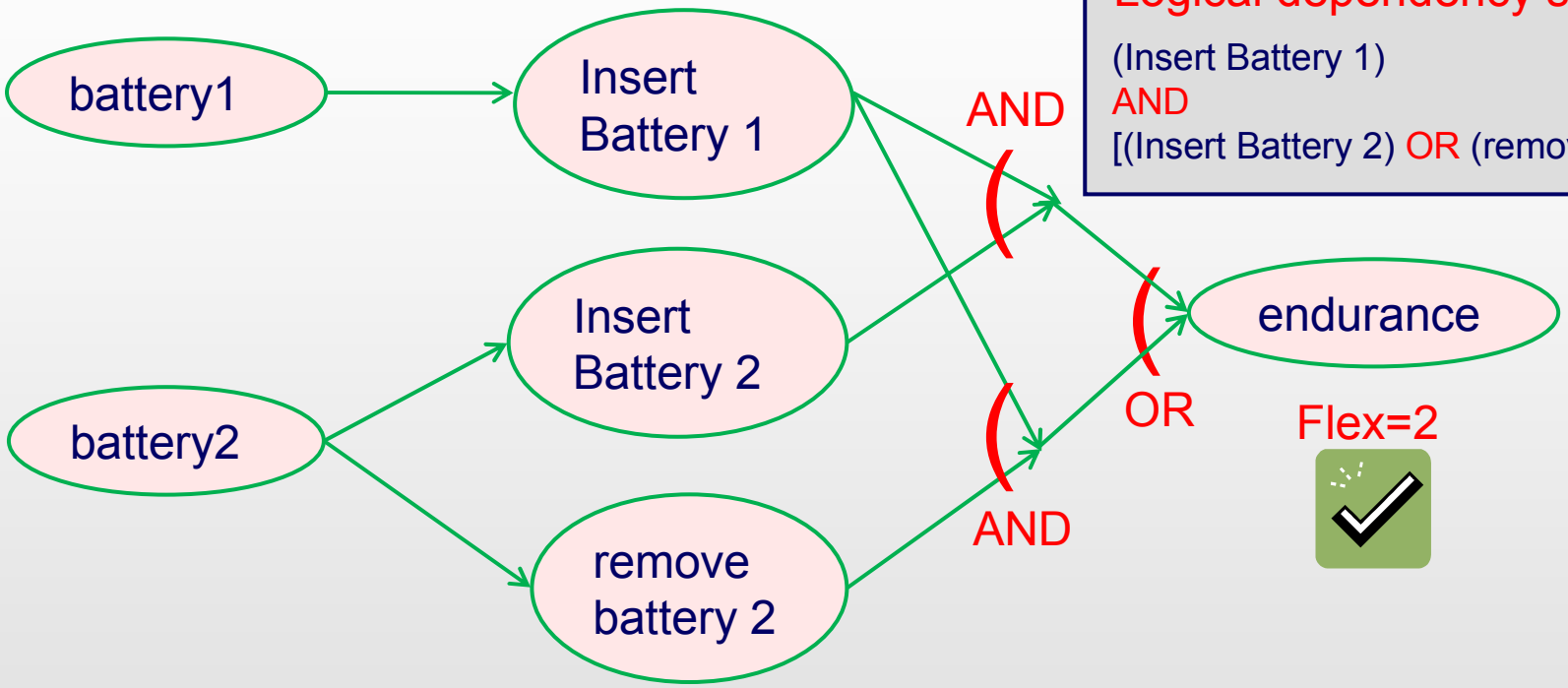
Need to Isolate AND's and OR's in dependency model!

Need to Isolate OR's



- No flexibility in achieving enhanced endurance
- No flexibility in achieving normal endurance
- Flexibility of achieving the endurance objective: <u>estimate based on OR relationship</u>

Flexibility Metric for a Dependency Model



Logical dependency structure

(Insert Battery 1)
AND
[(Insert Battery 2) OR (remove Battery 2)]

[(Insert Battery 1) AND (Insert Battery 2)]

OR

[(Insert Battery 1) AND (remove Battery 2)]

Formula F is in DNF iff

$$F = \left(\bigvee_{i=1}^{n} \underbrace{\left(\bigwedge_{j=1}^{m_i} L_{i,j}\right)}_{\text{term}}\right)$$

Flex metric = number of terms in disjunctive normal form

Conclusion

- C-DSM model is being extended in the following ways
  - First, it is being adapted to modeling at the more holistic enterprise level
  - Second, it is being augmented by logical dependency models to support integration with real options analysis, by enabling the representation and estimation of flexibility and other relevant metrics.
  - Flexibility metrics used as heuristic to identify both existing and potential types of options (flexibilities) based on C-DSM model
- New method of identifying real options opportunities
  - First, the new approach distinguishes between types of flexibility and mechanisms that enable flexibility. This has led to the identification of some new “ilities” such as optionability and realizability and development of metrics that are relevant to addressing the options identification problem.
  - Second, the new approach may identify mechanisms and types of options spanning any of the enterprise views, rather than solely focusing on product level options.

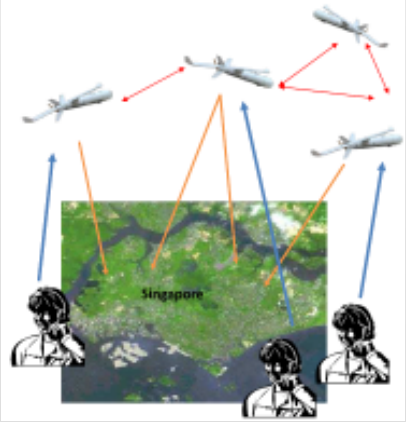
Implications

Applications:

- Case study of Singapore DSO Labs UAV swarm project
- Venture capital strategies

Broader Impact:

- Holistic framework for recommending options investments to manage uncertainty in an enterprise
  - Develop holistic dependency model of enterprise/system
  - Identify uncertainties facing enterprise
  - Identify existing flexibilities in enterprise
  - Identify new mechanisms and types of options
  - Recommend options through valuation



Further Information

Mikaelian, T., Rhodes, D.H., Nightingale, D.J. and Hastings, D.E., “Managing Uncertainty in Socio-Technical Enterprises using a Real Options Framework”, *Conference on Systems Engineering Research*, Los Angeles, CA, April 2008

Mikaelian, T., Bartolomei, J., and Hastings, D., “Managing Operational Uncertainties using Real Options”, *Conference on Systems Engineering Research*, Hoboken, NJ, March 2007

Bartolomei, J., “Qualitative Knowledge Construction for Engineering Systems: Extending Design Structure Matrix Methodology in Scope and Procedure”, MIT doctoral dissertation, June 2007