RESEARCH OVERVIEW

Real Options in Enterprise Architecture

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Committee: D. Hastings (Chair), D. Nightingale, and D. Rhodes
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

Call option payoff

**Buy stock**

- **Profit ($)**
- **Price of call option**
- **Strike price of call option**
- **Stock price ($)**

Put option payoff

**Sell stock**

- **Profit ($)**
- **Price of put option**
- **Strike price of put option**
- **Stock price ($)**

**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.
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

- Explore interactions between “real option silos”

Holistic View

<table>
<thead>
<tr>
<th>Real Option Type</th>
<th>In Design</th>
<th>In Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAV design enables</td>
<td>MAV design enables future market expansion</td>
<td></td>
</tr>
<tr>
<td>a reuse option in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>future design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAV development</td>
<td>Investment in MAV project enables</td>
<td></td>
</tr>
<tr>
<td>partnership enables</td>
<td>option to expand development to swarm</td>
<td></td>
</tr>
<tr>
<td>an option to use new</td>
<td>in future</td>
<td></td>
</tr>
<tr>
<td>type of technology in</td>
<td></td>
<td></td>
</tr>
<tr>
<td>design</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

May “classify” the location of both the mechanism and type of real option

MAV = Mini Air Vehicle
Eight Views of a Socio-Technical Enterprise

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

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

Traditional "enterprise architecture"
Traditional system architecture

(Nightingale and Rhodes, 2007)
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
<table>
<thead>
<tr>
<th>Mechanism that enables real option</th>
<th>Type of real option</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strategy</strong></td>
<td>expand/cancel projects, shift resources, delay decisions</td>
</tr>
<tr>
<td>Investments/staging/joint ventures/deal structuring, vesting schedule</td>
<td></td>
</tr>
<tr>
<td><strong>Policy</strong></td>
<td>Policy changes</td>
</tr>
<tr>
<td>Company policies, policy to hire interns, work hours</td>
<td></td>
</tr>
<tr>
<td><strong>Organization</strong></td>
<td>Shifting personnel, collaboration among projects/departments</td>
</tr>
<tr>
<td>Partnerships, mergers/acquisitions</td>
<td></td>
</tr>
<tr>
<td><strong>Process</strong></td>
<td>Operational, development process options – switch production</td>
</tr>
<tr>
<td>Milestones, pair programming, training, installing machine</td>
<td></td>
</tr>
<tr>
<td><strong>Product</strong></td>
<td>Reuse, changeability in design</td>
</tr>
<tr>
<td>Design features, modularity, COTS availability/quality</td>
<td></td>
</tr>
<tr>
<td><strong>Service</strong></td>
<td>On-orbit servicing (#, types of satellites), online access to services</td>
</tr>
<tr>
<td>On-orbit servicing system, web deployment of service, tracking mechanism</td>
<td></td>
</tr>
<tr>
<td><strong>Knowledge</strong></td>
<td>Leveraging, licensing patent</td>
</tr>
<tr>
<td>Patenting</td>
<td></td>
</tr>
<tr>
<td><strong>IT/Resource</strong></td>
<td>Adapt IT infrastructure, expand/abandon/defer investment</td>
</tr>
<tr>
<td>IT investments, database design, modularity</td>
<td></td>
</tr>
</tbody>
</table>
Holistic identification of real options mechanisms and types that encompass all views of an enterprise
Enterprise C-DSM

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

Mixed Semantics

A → B
B → C
C → D
D → E
E → F

versus

State Transition

A → B
B → C
C → D
D → E
E → F

C-DSM = Dependency Network

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Results

C-DSM = Dependency Network  

- 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

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: estimate based on OR relationship
Flexibility Metric for a Dependency Model

Logical dependency structure
((Insert Battery 1) AND [(Insert Battery 2) OR (remove Battery 2)])

Formula $F$ is in DNF iff

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

Flex metric = number of terms in disjunctive normal form

- $\text{Flex} = 2$
- Logical dependency structure

- Battery 1
- Battery 2
- Insert Battery 1
- Insert Battery 2
- Remove Battery 2
- Endurance
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.
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

