Effect of Learning on Stakeholder Negotiation Outcomes: Modeling and Analysis of Game-Generated Data

by

Aleksandra Markina-Khusid

SB in Physics, Massachusetts Institute of Technology, 1999
SM in Electrical Engineering, Massachusetts Institute of Technology, 2001
PhD in Electrical Engineering, Massachusetts Institute of Technology, 2006

Submitted to the Faculty in partial fulfillment of the requirements for the degree of Master of Science in Engineering and Management at Massachusetts Institute of Technology January 2015

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Signature redacted

Aleksandra Markina-Khusid
System Design and Management Program

Certified by: .................................................................

Donna Rhodes
Thesis Supervisor
Principal Research Scientist, Engineering Systems Division

Accepted by: .................................................................

Patrick Hale
Chairman and Senior Lecturer, Engineering Systems Division
Director, System Design and Management Program
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Abstract

A design negotiation game based on a stakeholder salience framework was created by the APACE research team to explore negotiation dynamics between stakeholders with individual attributes and agendas. Experimental data was collected anonymously during games played by groups of human participants through a web interface. It was found that the negotiation process takes a non-zero number of iterations even under conditions that strongly favor agreement. A realistic scenario was created based on extensive interviews with the major stakeholders involved in a real negotiation of a plan for a new government information technology system. Solution space exploration of this scenario demonstrated that the experimentally obtained solutions lie far from the optimality frontier. Performance differed significantly in two groups of participants with dissimilar professional experience; games played by interns achieved higher scores than those played by senior staff.

An agent-based model was built to simulate multi-stage design negotiation. Utility functions of individual players were based on their private agendas. Players voted for a design according to the relative attractiveness of the design as established by the individual utility function. The negotiation process helps players discover other players’ agendas. It was hypothesized that knowledge of each other’s private objectives would enable groups of players to achieve design solutions that are closer to optimal. Effects of learning were introduced into the model by adding a fraction of the sum of all players’ utility function to each individual utility function. Simulated games with learning effects yielded solutions with higher total player scores than simulated games without learning did. Results of simulated games with a substantial level of learning effects were similar to average experimental results from groups of interns. Results of simulated games without learning were close to the average results of games played by senior staff.

Thesis Supervisor: Donna Rhodes
Title: Principal Research Scientist, Engineering Systems Division
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Acknowledgments

I would like to thank the MITRE Corporation for sponsoring my SDM studies. I am grateful to Marie Francesca and George Rebovich for introducing me to systems engineering practitioners and their work at MITRE. I thank Dr. Barbara Blaustein and David Allen for welcoming me to the systems engineering APACE research project, and Peter Leveille and Betsy Cole for its exciting progress and many thought-provoking discussions.

I am grateful to Dr. Donna Rhodes for guiding me in a new research field with humor and insight. I expect to come back to many of the topics she introduced me to in my future work.

I am thankful to Pat Hale and the entire SDM faculty and staff for making me feel a part of a family. I treasure connections with my fellow SDM students and their families. I appreciate the fellowship of MITRE SDMs: Steve Ajemian, James Barkley, Ioannis Kyratzoglou and Jeff Manning. I appreciate all the thoughts and advice Moise Solomon shared on connecting SDM lessons to our daily work.

I am grateful to my family and friends for their love and encouragement. I am especially indebted to my husband Michael and our children for their amused patience with my educational endeavors. It would not have been possible without your support.
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Chapter 1: Introduction

Background

This work is based on the MITRE Corporation Innovation Program Fiscal Year 2014 systems engineering research project APACE devoted to the study of stakeholder characterization and dynamics that manifest themselves in negotiations on large, complex projects. The project is directed by Principal Investigators Dr. Barbara Blaustein and Mr. David Allen. The APACE team formulated a research strategy, built a serious game platform and conducted a series of experiments with MITRE staff participants.

Research Approach

The APACE team based its research approach on a stakeholder salience framework described in Chapter 2. A serious game was designed to study negotiation dynamics between different types of stakeholders during a design negotiation. The stakeholders were characterized by different levels of each of the salience attributes and assigned individual agendas. Experimental data was gathered during games played by groups of anonymized human participants through a web interface. Two types of groups participated in the experiments: summer interns and senior staff. The data was gathered on the resulting designs, number of state design changes during negotiations, and negotiation tactics employed. Sensitivity of the empirical data to player agenda and attributes as well as to the professional experience of the game participants was explored.

Two game scenarios are described in this work. In a baseline Utopia scenario all players were assigned the same agenda. A realistic BigSystem scenario was crafted based on interviews with
the major stakeholders of a real negotiation of a plan for a new government information technology system. Solution space exploration of the BigSystem scenario was performed and experimentally obtained solutions were compared to those on the optimality frontier. An agent-based model was built to represent stakeholder negotiations in the multi-stage design of the BigSystem scenario. Utility functions of simulated players were based on their individual agendas. Players voted for or against a design according to the relative attractiveness of the design as established by their individual utility function.

It was hypothesized that the negotiation process helps players learn other players’ agendas. It was posited that knowledge of each other’s individual agendas enables groups to achieve solutions that are closer to optimal. Effects of learning were introduced into the model by modifying each individual utility function to include a fraction of the sum of all players’ utility function. Simulated games with learning effects produced solutions with higher total player scores than did simulated games without the learning effects. Results of simulated games with various level of learning effects were compared to the empirical data. A potential explanation was proposed for the discrepancy between the results obtained by groups of participants with different levels of professional experience.

Original Contributions

Original contributions of the author detailed in this thesis include the following:

1) A study of the solution space and examination of the locations that the experimental results occupy in that space for selected game scenarios.

2) Analysis of dynamic aspects of stakeholder negotiations as exhibited during the game.
3) An agent-based model that simulates effects of stakeholder learning of each other’s private objectives in the course of a negotiation.

A description of APACE project in Chapter 3 is followed by details of the analysis listed above.

Overview

Chapter 2 presents a literature survey on the topics of collaboration challenges, stakeholder theory with a special attention to a stakeholder salience framework, serious games and a brief discussion of agent-based modeling. Chapter 3 describes the APACE project’s stakeholder negotiation game, including scenario design, experiments and associated results, and the author’s exploration of the solution space. Chapter 4 presents a modeling approach developed to explore effects of player’s learning of each other’s agendas on the overall results of simulated games. Chapter 5 presents conclusions and suggestions for future research.
Chapter 2: Literature Survey

Collaboration Challenges

Complex projects require participation of multiple organizations that bring a variety of resources and agendas into the partnership (Crowder, Robinson, Hughes, & Sim, 2012) (Fitzgerald & Ross, 2013). Patterns and outcomes of collaborative behavior as well as typical challenges affecting group efforts are of interest to business, government and not-for-profit communities. Research literature on collaboration covers a wide range of inquiry directions and approaches. A few are described below.

Margerum highlights two phases of collaboration: consensus building and implementation (Margerum, 2008). He points out contextual and functional dimensions of collaborative arrangements and describes three types of collaboratives: action collaborative, organizational collaborative and policy collaborative. The types of collaboratives and their attributes are detailed in (Margerum, 2008). Margerum’s collaboration typology is derived from observations of public sector projects, making it particularly relevant to the study of consensus-building within a government program addressed in this thesis (Margerum, 2008).

<table>
<thead>
<tr>
<th>Table 1 Type of Collaboratives (Margerum, 2008)</th>
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<tbody>
<tr>
<td><strong>Typical stakeholders</strong></td>
</tr>
<tr>
<td>• Local stakeholders</td>
</tr>
<tr>
<td>• Community leaders</td>
</tr>
<tr>
<td>• Agency field staff</td>
</tr>
<tr>
<td><strong>Management arrangements</strong></td>
</tr>
<tr>
<td>• Arrangements for implementation similar to consensus building phase</td>
</tr>
<tr>
<td><strong>Implementation approach</strong></td>
</tr>
<tr>
<td>• Change through direct action</td>
</tr>
<tr>
<td><strong>Organizational collaboratives</strong></td>
</tr>
<tr>
<td>• Local/Regional stakeholders</td>
</tr>
<tr>
<td>• Interest group representatives</td>
</tr>
<tr>
<td>• Government entities</td>
</tr>
<tr>
<td><strong>Policy collaboratives</strong></td>
</tr>
<tr>
<td>• Regional/State Stakeholders</td>
</tr>
<tr>
<td>• Government entities</td>
</tr>
<tr>
<td>• Policy makers</td>
</tr>
<tr>
<td><strong>Management arrangements for implementation</strong></td>
</tr>
<tr>
<td>• New management arrangement for implementation</td>
</tr>
<tr>
<td><strong>Implementation approach</strong></td>
</tr>
<tr>
<td>• Change through organizations (programs, budgets, etc.)</td>
</tr>
<tr>
<td>• Change through policy (legislation, policies, etc.)</td>
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</tbody>
</table>
In an action collaboratives participants tend to represent themselves, management arrangements persist from consensus building to the implementation stage, and results are brought about by direct action. In a policy collaboratives actors tend to represent organizations, interest groups and the public (through participation of elected officials). New management arrangements are made for implementation phase, and desired changes are brought about through policies and legislations. Organizational collaboratives fall between the two ends of the spectrum (Margerum, 2008).

Lamb discusses factors contributing to performance of engineering teams. Members of teams are motivated by desire for achievement and conformance (Lamb, 2009). She notes that engineers’ pronounced orientation toward achievement motivation represents a challenge for a team’s ability to make progress when a threshold level of conformity is not attained (Lamb, 2009). A team can be high functioning and creative when the members possess “a sense of group efficacy (the belief that the team can perform well and that group members are more effective working together than apart)”. Group efficacy is enhanced though the team’s self-evaluation, either as a constant activity or a formal event (Druskat & Wolff, 2001).

The issues of knowledge sharing are central to the discussions of collaboration dynamics. Hansen et al. highlights three phases of knowledge sharing: the decision to seek knowledge, seeking of knowledge and knowledge transfer (Hansen, Mors, & Lovas, 2005). Conventional wisdom has it that established inter-organizational relationships facilitate knowledge sharing, but the reality appears more nuanced; weak ties between teams appear to encourage seeking of knowledge, but impede knowledge transfer. A strong network of relationships inside a team makes the team less likely to seek outside knowledge, while a relatively larger number of ties to
other teams make it more likely (Hansen, Mors, & Lovas, 2005). Virtual teams are more
dynamic and flexible than traditional collocated teams (Townsend, Demarie, & Hendrickson,
2004). Although flexible team membership facilitates knowledge transfer between teams
(Lamb, 2009), the local knowledge base may be eroded when team members leave.
Knowledge sharing often takes place through exchange of artifacts such as documents, with
related artifacts forming a network of concepts (Godart, 2000). Cooperation relies on the
willingness of participants to share intermediate results. Shared knowledge artifacts undergo an
iterative revision process in which later versions progress toward agreement as the group’s
feedback is incorporated into the documents. Godard notes that agreement is often forced by
deadlines rather than gradual convergence of the view (Godart, 2000).
Self-silencing - withholding of information or opinions that disagree with the current direction
of the group’s thinking - is prominent due to the reputational risk of non-conformity. Incentives
structured to reward correct group decision help individuals identify with group success and
ensure the sharing of information critical to group performance. Anonymous voting also
insulates actors from reputational pressures (Sunstein & Hastie, 2014). Access to a variety of
information technologies enhances team performance by facilitating solution space exploration
(Lamb, 2009). In knowledge management, avenues for sharing information need to be
complemented by arenas for collaborative thinking (McDermott, 2004). Shah notes that
cooperation between competing actors is fragile and highly context-dependent (Shah, 2013).
Kumar and van Dissel rely on concepts from organizational theory to explore conflict and
cooperation in interorganizational systems (Kumar & van Dissel, 1996). Interdependence
between members of an alliance largely determines the dynamics between the participants. Of
special interest is the authors’ discussion of the so-called networked interorganizational systems characterized by reciprocal interdependence between participating organizations. Such systems often are created in order to enable joint projects – ventures of finite duration with a specific goal of a product or a service development. Allen also noted that the degree of coordination required from team constituents depends on the level of interdependence of their tasks (Allen, 2001). Kumar and van Dissel examine risks of conflict of economic, technical and socio-political nature. They argue that a large variety of reciprocal relationships within an interorganizational system introduces structural uncertainty and risk of miscommunications stemming from cultural mismatches. The authors also discuss three sources of transaction risk: asset-specificity risk, information asymmetries and loss of resource control. Asset-specificity risk is present when certain investments by one of the participants are of low value to other participants outside of a narrow use. Information asymmetries make it challenging for group participants to appraise each other’s performance, increasing a risk that some of the parties may shirk their responsibilities. Loss of resource control refers to situations where resources committed to a joint venture cannot be returned to the original owner when the relationship ends, even though these resources could potentially be put to other uses by the original owner (Kumar & van Dissel, 1996).

Drury et al. conducted empirical studies of collaboration challenges in crisis management (Drury, et al., 2010). The majority of the challenges identified in the study are related to knowledge management. Among the knowledge-sharing challenges Drury et al. describe is the difficulty of bringing a partner’s attention to relevant information for a variety of reasons including the sensitivity or constantly changing nature of the information. Absence of
established protocols for information sharing, shortage of trust in the information itself as well as in the knowledge sharing tools and lack of mechanism for fusing all significant current information results in “limited joint situational awareness” (Drury, et al., 2010). Similar findings were reported by Utter in her investigation of challenges in collaborative, distributed systems engineering (Utter, 2007).

Stakeholder Theory

The traditional view of the corporation centers on the firm’s fiduciary responsibilities to its shareholders’ investment (Friedman & Miles, 2006). In 1984 Freeman pointed out in his book Strategic Management: A Stakeholder Approach that shareholders are not the only parties whose interest a company has to take into account – he introduced the so called "principle of who or what really counts" (Freeman, 1984). The goal of the stakeholder concept is to extend the scope of management’s concern beyond maximization of profit and toward inclusion of interests of non-owners such as employees, customers, vendors, regulators and financiers (Kochan & Rubinstein, 2000) (Mitchell, Agle, & Wood, 1997). The concept of stakeholders became widely accepted in strategic management and enjoyed further theoretical development and wider range of application. A stakeholder approach has been employed for examination of relationships between government and non-governmental organizations in international development (Smillie, Helmich, & Randel, 1999), for garnering local participation in development projects (Zimmermann & Maennling, 2007), for evaluating value creation in a bureaucratic program enterprise (Matty, 2011), for analysis of China’s energy conservation program (Fu, Feng, Li, Crawley, & Ni, 2011), for evaluation of space exploration sustainability
and for space systems architecting (Aliakbargolkar, 2012).

Donaldson and Preston designate three aspects of stakeholder theory: descriptive/empirical, instrumental and normative (Donaldson & Preston, 1995). Descriptive/empirical stakeholder theory aims to describe the relationships of an organization with groups and individuals to whose claims the organization affords consideration. Instrumental theory is employed when researchers attempt to measure how adherence to stakeholder principles affects an organization’s performance. Normative stakeholder theory concerns itself with guidelines for an organization’s operations (Donaldson & Preston, 1995).
The early definition of stakeholders is “any group or individual who can affect or is affected by the achievement of the organization’s objectives” (Freeman, 1984). Miles recently surveyed and discussed a number of competing stakeholder definitions (Miles, 2012). She concluded that the stakeholder concept is essentially contested rather than underdeveloped, ambiguous or merely confused. An essentially contested concept is characterized by wide acceptance accompanied by persistent disagreement about its instantiation and application. The disagreement about an essentially contested concept is not expected to be resolved as it is
based on philosophical or political disagreements of its users, where each side of the argument insists on its definition while acknowledging that it is contested by the other sides (Collier, Hidalgo, & Maciuceanu, 2006). The concept of stakeholders meets the major criteria of essentially contested concepts (Miles, 2012).

There is a tension between researchers who prefer a broad definition of a stakeholder and those who desire to craft a narrower definition (Mitchell, Agle, & Wood, 1997). Mitchell et al. noted that proponents of the narrow definition of stakeholders tend to rely on the notion of legitimate stakeholders – those whose claims deserve attention based on legal or moral rights. A broad view on stakeholders acknowledges the reality where a wide variety of actors can be significantly affected or affect an organization. The latter view is centered on stakeholders’ power to influence a corporation’s behavior. Mitchel et al. attempted to reconcile the two divergent views by incorporating notions of stakeholder power and legitimacy into a framework of stakeholder salience (Mitchell, Agle, & Wood, 1997).

Stakeholder Salience

In 1997 Mitchell et al. proposed a stakeholder salience framework and a corresponding set of stakeholder types in order to help identify stakeholders and determine their relative importance to an organization. The stakeholder salience concept relies on three stakeholder attributes: power to influence the corporation, legitimacy of the stakeholder’s connection with the corporation and urgency of stakeholder’s claim on the corporation (Mitchell, Agle, & Wood, 1997). In this framework stakeholders with a greater number of salience attributes are considered to have a higher level of salience.
Power

Power is defined as an ability of a group to produce desired outcomes by imposing its will on others (Mitchell, Agle, & Wood, 1997). Another, equivalent definition of power is an ability of actor A to compel actor B to take actions that B would not have taken otherwise (Agle, Mitchell, & Sonnenfeld, 1999). Dahl notes that power may have to be defined operationally rather than conceptually (Dahl, 1957).

Frooman discusses the means stakeholders have at their disposal to achieve desired outcomes. These means are also referred to as influence strategies. Frooman contends that direct and indirect strategies stakeholders use with respect to resource allocation and usage are determined by stakeholder’s power relationship with the company and the level of interdependence between the stakeholder and the firm (Frooman, 1999). Project managers are reminded that the conflicting nature of stakeholder demands more often than not makes it impossible to please all of them. Instead of trying to maximize every stakeholder’s satisfaction, the managers are advised to maintain satisfactory relationships that allow them to pursue project goals (Pinto & Kharbanda, 2004).

Some scholars distinguish between three types of power: coercive, utilitarian and normative (Etzioni, 1978). Coercive power involves threats of adverse consequences by means of violence, enforcement, courts or legislation (Parent & Deephouse, 2007). The use of coercive power is most effective and appropriate when the target actor is already alienated, and it is likely to deepen the alienation. Utilitarian power is based on incentives and self-interest of the target actors. Utilitarian power is the most effective for achieving economic goals. It is unlikely to produce alienation, but it is equally unlikely to increase commitment of other players to the
cause. Normative power relies on “shared symbols, a common ideology, and commitment to existing norms” (Etzioni, 1978). The media is often used to exercise normative power (Parent & Deephouse, 2007). The concept of normative power may be related to the concept of moral legitimacy described below.

Although power is usually represented in symbolic ways, it typically has a basis in unequal access to scarce resources (Zimmermann & Maennling, 2007). Zimmermann and Maennling provide a list of seven key types of authority:

- Setting objectives, norms and quality control
- Allocation of or denying resources
- Defining roles, tasks and responsibilities
- Structuring the participation in decision-making process
- Controlling access to information and knowledge
- Allocating rewards, recognition and sanctions
- Channeling messages to superiors and external bodies (Zimmermann & Maennling, 2007)

Empirical studies have shown that power is the most influential stakeholder characteristic in driving managers’ perceptions of stakeholder salience (Parent & Deephouse, 2007). Additionally, stakeholders possessing several types of power appear to have higher overall salience.

Legitimacy

Mitchell’s stakeholder salience framework (Mitchell, Agle, & Wood, 1997) relies on Suchman’s definition of legitimacy as “a generalized perception or assumption that the actions of an entity
are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions” (Suchman, 1995). Suchman proposes that there are three types of legitimacy: pragmatic, moral and cognitive.

Pragmatic legitimacy can also be viewed as exchange legitimacy or influence legitimacy. Each of these terms aims to describe a situation where a stakeholder merits attention of an organization’s management because the stakeholder’s support is important to the organization. It is in a firm’s self-interest to afford attention to a stakeholder with pragmatic legitimacy (Suchman, 1995). Recent work by Neville et al. argues that pragmatic legitimacy is equivalent to some forms of power and should not be accounted for independently in stakeholder salience, as it is already captured in the power attribute (Neville, Bell, & Whitwell, 2011).

Moral legitimacy reflects whether taking into account the interests of a certain group is “the right thing to do” and “effectively promotes social welfare” (Suchman, 1995). Moral legitimacy in turn takes several forms, including consequential legitimacy, procedural legitimacy, structural legitimacy and personal legitimacy. Consequential legitimacy is based on social desirability of outcomes of stakeholder’s operations. Procedural legitimacy is afforded to organizations that embrace socially accepted methodologies. Procedures become especially important in activities where metrics related to outcomes are difficult to define and where it is accepted that outcomes have a significant random component. An organization is judged to be structurally legitimate when it displays socially accepted structural traits. Structural legitimacy often accompanies and is complemented by procedural legitimacy. Personal legitimacy relies on the charisma of the organization’s leader and it not easily institutionalized. (Suchman, 1995)
Cognitive legitimacy is a relatively controversial concept. Suchman explains that cognitive legitimacy is ascribed to a stakeholder when the stakeholder’s claim is easily understood, recognized without questioning, or taken for granted (Suchman, 1995). Grossi uses a detailed multi-dimensional definition of stakeholder legitimacy in his empirical study of value creation in lean enterprises (Grossi, 2003).

As it is defined, cognitive legitimacy is difficult to recognize as an attribute of the stakeholder. Neville et al. point out that the vague and multifaceted nature of the legitimacy attribute in Mitchell’s salience framework is a weakness of the theory and strongly argue for excluding pragmatic legitimacy and cognitive legitimacy from stakeholder identification analysis (Neville, Bell, & Whitwell, 2011). Neville et al. further contend that the legitimacy attribute should apply to the stakeholder’s claim rather than to the stakeholder, and take into account “considerations of the net benefits, right or justice... implicit within the claim” (Neville, Bell, & Whitwell, 2011).

Urgency

According to Mitchell, introduction of urgency as a stakeholder attribute establishes a dynamic dimension to the stakeholder salience theory (Mitchell, Agle, & Wood, 1997). Urgency is comprised of two aspects: time sensitivity and criticality. Time sensitivity refers to the degree to which a delay in action is unacceptable to the stakeholder, while criticality refers to the importance of the action to the stakeholder. Overall, urgency is defined as the extent to which “stakeholder claims call for immediate attention” (Mitchell, Agle, & Wood, 1997). Additionally, higher urgency may be ascribed to a stakeholder’s claim when the claim is perceived to have a high probability of occurring (Driscoll & Starik, 2004).
Neville et al. argue that urgency is not relevant to the process of stakeholder identification (Neville, Bell, & Whitwell, 2011). They believe that groups that possess urgency, but lack power and legitimacy are not recognized by organization as stakeholders, as shown by others in empirical studies (Parent & Deephouse, 2007). They contend that stakeholder identification and stakeholder prioritization are distinct processes, and, while the urgency attribute is not relevant to the former, it is significant to the latter. That is, Neville et al. argue that urgency is important in determining relative importance of stakeholders who possess power and legitimacy (Neville, Bell, & Whitwell, 2011).

**Extension and Application of Stakeholder Salience Theory**

![Stakeholder Typology](attachment:Figure_2_Stakeholder_Typology.png)

*Figure 2 Stakeholder Typology (Mitchell, Agle, & Wood, 1997)*

Mitchell proposed classification of stakeholders based on the attributes of power, urgency and legitimacy (see Figure 2). The classes are based on the number of salience attributes a
stakeholder possesses. The low salience stakeholders have only one of the attributes and are also termed “latent” stakeholders. Stakeholders with any two attributes are considered moderately salient. They are also referred to as “expectant” stakeholders. The highly salient stakeholders are those with all three attributes; they are also labeled “definitive” stakeholders (Mitchell, Agle, & Wood, 1997). Table 2 lists stakeholder classes according to Mitchell in order of increasing salience.

<table>
<thead>
<tr>
<th>Salience Level</th>
<th>Stakeholder Class</th>
<th>Power</th>
<th>Legitimacy</th>
<th>Urgency</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Non-Stakeholder</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Low</td>
<td>Latent</td>
<td>Dormant</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Discretionary</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Demanding</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Moderate</td>
<td>Expectant</td>
<td>Dominant</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dependent</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dangerous</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>High</td>
<td>Definitive</td>
<td>Definitive</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

A number of empirical studies were conducted based on the stakeholder salience framework (Agle, Mitchell, & Sonnenfeld, 1999) (Easley & Lenox, 2006) (Parent & Deephouse, 2007). Neville et al. propose to consider groups designated as demanding stakeholders in Mitchell’s typology as non-stakeholders, based on these scholars’ belief that urgency is not relevant to stakeholder identification, as described above (Neville, Bell, & Whitwell, 2011).

Some researchers make a distinction between the attributes of the claim and characteristics of the stakeholder (Easley & Lenox, 2006). Neville et al. argue that only legitimacy of the claim is relevant to the normative, or prescriptive, view of stakeholder salience (Neville, Bell, &
Whitwell, 2011). That is, managerial action should be driven only by the legitimacy of the claim, not the stakeholder presenting the claim. The same group of scholars also contends that salience attributes should not be represented as dichotomous – either present or absent – but on a continuum. They point out that a stakeholder with a high level of only two salience attributes may take precedence over a stakeholder with modest levels of power, legitimacy and urgency, even though the latter would be considered the most salient, definitive stakeholder in the original formulation of the stakeholder salience framework (Neville, Bell, & Whitwell, 2011) (Mitchell, Agle, & Wood, 1997). Neville et al. point out that evaluating salience attributes on a continuum allows for dynamic development of a claim’s salience over time. To reconcile the continuous and dichotomous approaches to salience attributes Neville et al. propose to consider threshold levels of attributes. A claim that fails to achieve threshold level of salience would be declined (Neville, Bell, & Whitwell, 2011). Based on their corrections and refinements to the original framework, Neville et al. propose the following definition of stakeholder salience:

“Stakeholder salience is the prioritization of stakeholder claims by managers based on their perception of the degree of power of the stakeholder and the degree of moral legitimacy and urgency of the claim.” (Neville, Bell, & Whitwell, 2011)
Serious Games

Most common definitions of a game agree that a game is a structured, rule-based, goal-directed competitive activity, with competition against oneself, other players or a computer (Wouters, van der Spek, & van Oostendorp, 2009). Salen and Zimmerman state in their book *Rules of Play: Game Design Fundamentals* that game fundamentals involve "understanding design, systems, and interactivity, as well as player choice, action, and outcome. They include a study of rule-making and rule-breaking, complexity and emergence, game experience, game representation, and social game interaction" (Salen & Zimmerman, 2004). Michael and Chen borrow six characteristics of play from Johan Huizinga’s 1950 book *Homo Ludens* to describe games (Michael & Chen, 2006):

1. Voluntary participation.
2. Separation from real life.

3. Immersive nature of activity (high demand on the player’s attention).

4. Limitation of activity to prescribed time and place.

5. Reliance on rules.

6. Creation of a social group out of players.

In addition, games typically enable players to monitor their progress towards their objectives through continuous feedback (Wouters, van der Spek, & van Oostendorp, 2009). Serious games are further refined as games that have a primary purpose other than entertainment (Michael & Chen, 2006).

Serious games have been deployed in a number of contexts, covering a range of disciplines from education and training to simulation and modeling. A large body of literature is dedicated to educational and training games (Ulicsak & Wright, 2010). Crawford notes that “games are the original educational technology, the natural one, having received the seal of approval of natural selection” (Crawford, 2011). Minović et al. review published research related to game-based education and suggest that a unified framework is needed to guide methods, techniques and tools in the field of educational game development (Minović, Miloš, & Starcevic, 2013).

The parallels between serious games and complex systems are observed by Mayer and Bekebrede (2006). Elements characterizing complex systems include a large number of elements and variables connected through nonlinear relationships, hidden and distributed information, and uncertainty about the state of elements, variables and relationships. The characteristics of complex systems are intrinsic to most games, allowing researchers to observe emergent behavior in serious games (Mayer & Bekebrede, 2006).
Faithful mapping of real world systems and scenarios into the virtual world of a game presents a number of challenges. Stone urges game designers to pay attention to interaction fidelity and context fidelity in game design (Stone, 2008). Game researchers are also keenly interested in participant characteristics that are most likely to be related to performance in a game. Literature indicates that participant motivation, team cohesion, team organization and team goal setting are among such characteristics (Faria, 2001).

Van Bilsen et al. argue that simulation games can be instrumental in dealing with complexity of large-scale socio-technical systems because games allow players to gain experience with and insight into the workings of such systems (van Bilsen, Bekebrede, & Mayer, 2010).

Choosing a serious games approach to the study of stakeholder negotiation dynamics is supported by recent literature. Mayer states “the methodology of gaming was seen as the most appropriate candidate for designing computer-mediated interaction among policy stakeholders. Gaming could provide insights into how to arrange an experimental context with players, roles, rules, and a scenario.” (Mayer, 2009) Simulation games appear uniquely suited for the study of human behavior in negotiations within complex systems because simulation games can provide a framework that includes human players and their “social interactions, social and physical rules... as well as individual and collective goals “ (van Bilsen, Bekebrede, & Mayer, 2010).

As human players interact with each other while playing a serious game, patterns of social behaviors can be discerned from the data on the in-game performance. Ruskov and Ruskov describe a dialogue-based negotiation game intended to train players in the use of optimal strategies (Ruskov & Ruskov, 2006). Vavier details the development and use of a resource-management board game. The goal of the game is to provide negotiation training and stimulate
positive perception change in order to improve stakeholder cooperation in a challenging water resource management scenario (Vavier, 2014).

Radner gives an extensive set of examples of using a game theoretic approach in the study of organizations (Radner, 1991). Mathematical game theory can be viewed as a bridge between empirical games and agent-based simulation models discussed in the next section.

Agent-Based Modeling

Agent-based modeling (ABM) is an approach to simulation modeling that relies on emergence of a high-level system behavior from characteristics, actions and interaction of autonomous individual entities referred to as agents (Railsback & Grimm, 2011). The use of ABM is appropriate when the system under study includes active participants displaying individual behavior (Peter, 2010). The foundations of ABM lie in game theory and complexity science (Borshchev & Filippov, 2004). Agent-based modeling is applicable to the study of artificial intelligence, ecology, biology, and economics (Niazi & Hussain, 2011). ABM has also been used for education, training and social research (Li, Zeng, Wang, & Mao, 2008). Nature advocated the use of agent-based modelling techniques for modeling of complex economic phenomena in the 2009 editorial (A Model Approach, 2009). A comprehensive study of published research literature that employs agent-based modeling methods uncovered a strong presence of agent-based techniques in social sciences (Niazi & Hussain, 2011). ABM is particularly attractive to social scientists because social phenomena arise from the actions of multiple individuals (Li, Zeng, Wang, & Mao, 2008).
A model is based on a set of abstractions that map a real world situation onto a virtual world. A simulation model is dynamic as it is based on a set of rules that prescribe how the system of interest will change with time from its current state (Crowder, Robinson, Hughes, & Sim, 2012).

In agent-based modeling each individual or organization is represented as an “agent”. A theory is then developed for agent behavior (Railsback & Grimm, 2011). A typical ABM includes heterogeneous agents whose individual behavior is governed by simple rules (Peter, 2010). Decision-making of individual agents can be based on a rational judgment or an emotional state (Li, Zeng, Wang, & Mao, 2008). ABM agents may experience learning, adaptation, and reproduction (Niazi & Hussain, 2011). The agents can take part in direct or indirect interaction (Borshchev & Filippov, 2004).

Agent-based models represent a fitting metaphor for human behavior because they are characterized by lack of global control, decentralized data, agents who possess incomplete information about their environment and computation and decision-making is asynchronous (Crowder, Robinson, Hughes, & Sim, 2012). Among the challenges of ABM is finding the right level of model complexity (Railsback & Grimm, 2011) and the appropriate compromise between an accurate representation and a simplified generalization (Peter, 2010).

Li et al. suggest that ABM methods should be used to study conflict and cooperation, formation of trust and norms, and group decision-making (Li, Zeng, Wang, & Mao, 2008). Bas and van der Lei used ABM with elements of cooperative game theory to study behavior of agents in a competitive environment with an application to supply chain partnerships (Bas & van der Lei, 2014). Crowder et al. used ABM to develop a framework for modeling engineering team work. The authors explored ABM parameters such as shared mental models, communications, trust,
and learning time. Such a model is appropriate for study of impact of change in team composition or processes on performance (Crowder, Robinson, Hughes, & Sim, 2012). Peter further notes agent-based models lend themselves to parameter and sensitivity analyses of systems where extensive experimentation would be impractical (Peter, 2010).
Chapter 3: Stakeholder Negotiation Game

Motivation for APACE project

Many large, complex system engineering projects, including those in the public sector, have a number of stakeholders from organizations with dissimilar, sometimes contradictory agendas. Some have a stake in almost every decision while others care only about a few specific aspects of the design. Some stakeholders may have a strong preference for particular technology while others may be less interested in technical details, but have an overriding concern about the project staying on schedule and on budget. One of the goals of the APACE project is to create a platform for exploring negotiation dynamics between stakeholders with diverging agendas.

When stakeholder agendas significantly diverge, compromise inevitably becomes necessary. The particular shape of the compromise solution and the path for achieving it depends not only on the stakeholder agendas, but also on stakeholder characteristics. Certain stakeholders carry more weight in the decision-making process than others, with differences manifest along more than one dimension. It is desirable to develop a way to characterize and even gauge stakeholder “weight” in real-world negotiations. In this project the concept of three-dimensional stakeholder salience is used for stakeholder characterization (Mitchell, Agle, & Wood, 1997). The project attempts to determine if particular combinations of stakeholder saliences and agendas are unfavorable for reaching an efficient compromise solution. Such knowledge would be useful for alerting project managers of a heightened risk that the negotiation process will be stalled or derailed.

Another challenging aspect of stakeholder interactions during negotiations is lack of transparency into each other’s agendas. Observations show that an individual stakeholder’s
objectives are often not communicated fully and explicitly with the entire group. Sometimes the very success of the system being designed is not equally important for every stakeholder involved in the design process. One of the hypotheses of the project is that shared understanding of the group goals and individual goals would lead to a smoother, faster negotiation process and superior outcomes.

Processes that take place during negotiations between stakeholders with varying salience and agendas are currently not well understood. Yet it is the perceived fairness and efficiency of those processes, in addition to the quality of the solution itself, that determine willingness of individual stakeholders to participate in and support the project in its subsequent stages. The goal of the APACE project is to use stakeholder salience analysis and an awareness of individual stakeholder agendas to identify system engineering principles that contribute to efficient compromise at realistic levels of stakeholders’ satisfaction and to develop key metrics for measuring negotiation processes.

The project is aimed at addressing the following questions:

- Which combinations of stakeholder categories produce quicker/better consensus? What combinations represent a risk to the negotiation process?
- Does shared understanding of group and individual stakeholder agendas improve consensus?
- What tactics do stakeholders with certain attributes use to negotiate and otherwise influence the process?
- What factors determine the level of a stakeholder’s buy-in to the product?
APACE Project Research Approach

To represent different “weights” stakeholders bring into the negotiations, the APACE project builds on the stakeholder salience framework proposed by Mitchell et al (Mitchell, Agle, & Wood, 1997). This framework characterizes each stakeholder along dimensions of power, urgency and legitimacy. The APACE project extends the original framework beyond binary characterization along each salience dimension to a relative weighing of stakeholders along all three dimensions. Salience weights for a model representing a specific project are derived from interviews with the main stakeholders.

A serious game was built in order to observe stakeholder interactions in their progress towards a design solution. The game, described below, represents a platform for deploying a wide range of scenarios that can represent a variety of stakeholder salience and agenda combinations.

Some of these scenarios can be highly stylized to exemplify situations where compromise is particularly easy or extremely challenging, whereas a combination of stakeholder salience and agenda can be conducive or adverse to achievement of a quick agreement. Other scenarios can be built to represent, as closely as possible, situations observed on actual projects. Both approaches to scenario building were employed in the APACE project.

Experiment games are played by groups of four anonymous players, each logged onto the game web interface from a separate terminal. A number of variables are recorded, including in-game events, resulting design and scores of each player. In addition the players fill out a questionnaire reflecting their satisfaction with both the design and the negotiation process following every round. The data is then available for analysis along multiple dimensions.
While the game platform was developed in order to observe and analyze stakeholder behavior, the platform also has potential for engagement and training of stakeholders and facilitating discussions between them.

APACE into Space Game

The APACE project team designed and built a multi-player game web-based game platform referred to the APACE into Space game. Four anonymous players are given a task of designing a multi-stage spaceship. Each stage of the spaceship is negotiated in a distinct game round, with four design decisions to be made: material and color of the stage and two facilities. The players aim to fulfill common public goals and reconcile potentially conflicting individual agendas.

Player characteristics are based on the salience framework described above and need not to be balanced.

The APACE into Space game platform is a vehicle for testing stakeholder dynamics in scenarios of interest. The following subsections describe the game as it is experienced by a participant, provide a list of major types of data collected, and explain design options available to a scenario designer.

Game Participant’s Experience

Each player enters the game through the APACE game web site. The initial screen presents a description of the game. The player is then informed about the number of players and number of rounds in the current game and provided with a list of common (“public”) goals, including possible budget and time constraints. Each player is also given a personal agenda and an individual amount of influence and Player Powers. Information about personal agendas,
influence and powers is kept hidden from other players. The players are asked to work together on the spaceship design one round at a time.

Each round represents a design stage, with design parameters being two facilities, one color and one material. All design aspects are achieved by consensus of all players, as described below. Each player chooses a color, a material and two facilities. By default each choice is given one vote. A player with influence available can add votes to one or more of the choices. These additional votes cannot be revoked and decrease the player’s remaining available influence points. Up to date information on other players’ votes is visible to each player throughout the round. The resulting group design is determined by adding all of the player votes for each value in the design. In case of a tie for a certain design category the design appears incomplete with the respective field of the consensus panel blank. An incomplete design cannot be approved by the players.

The choice of color has no influence on the cost of the design. Facilities vary in cost, and so do materials. Aluminum is the cheapest, followed by steel and then titanium. The sturdiness of the design depends solely on the choice of materials. It is calculated by adding sturdiness of individual stages. Titanium adds the most to sturdiness and aluminum the least, with steel in between. Aluminum has sturdiness of 1 arbitrary unit per stage, steel has sturdiness of 5 and titanium 10 units per stage. Hence, for example, a 5 stage design with three aluminum stages, one steel stage and one titanium stage has total sturdiness of $3 \times (1) + 5 + 10 = 18$.

Budget is decremented with passage of game time and with allocation against elements of agreed-in design. Remaining budget, project cost, cumulative design sturdiness, remaining time for the current round and remaining time for the game are also continuously displayed. Rounds
do not end when the allotted time runs out. Likewise, the game continues even if the starting budget is exceeded. Some players may have agendas specifically incentivizing on-time and within-budget completion of the design.

Several types of interactions are available to all players. For instance, all players are allowed to make suggestions or alert each other to certain design needs. Some players are able to offer bargains or bribes or to make threats. The player who is offered a negotiation has a choice to accept or reject the offer. Choices based on an outcome of a negotiation can no longer be altered. Some players may have power to end a round or to force another player to make a specific choice with respect to one design attribute. The use of these special powers is limited by a pre-allocated “budget” of power points. The player can review a history of interactions he or she has been involved in during the current round.

A round concludes when every player approves the consensus design. If some, but not all players approve a design, and consensus design is subsequently altered by changes in votes or through power plays, all prior approvals are cleared.

Players are polled about their satisfaction with the quality of the design and quality of the process after each round. The game clock is paused while the players answer the questionnaire. The new round begins after every player completes the poll.

At the end of the game the player is informed whether common project goals have been accomplished. If group goals are met, all individual scores are displayed. Each score is based on the alignment of the achieved design with the respective player’s individual agenda.
Data Collected

A variety of data is recorded during a game experiment and is available for subsequent analysis. In addition to the relevant scenario data, information on process and outcomes is detailed.

**Outcome Data**

*Budget* – Starting resources and ending resource figures are recorded.

*Design* – Selection of color, material and two facilities for every stage of the design are listed.

*Sturdiness* – Total sturdiness of the design depends on the choice of materials for each of the design stages. Sturdiness of individual levels is added to the total design sturdiness.

*Player Scores* – Final score of each player is calculated based on the player agenda and the final design created by the team.

*Goal Achievement* – Final design is assessed with respect to achievement of each of the public goals. The outcome of the game is considered a “WIN” if all public goals are achieved.

**Process Data**

*Stalled Time* – Since stalling the game is a negotiation tactic available to players with low power, time stalled could be useful for analysis of player dynamics.

*State Changes* – Every change in the proposed stage design is recorded. Design requires approval of each player every time any aspect of the design changes.

*Use of Influence* – Influence is used to add votes to specific aspects of record
**Negotiation Interactions** - Types of interactions used are documented along with, when applicable, whether a negotiation was accepted or rejected by the target user.

**Participant Feedback**

*Team Satisfaction* – Each participant gives a score on a scale from 1 to 5 to reflect individual satisfaction with team interaction after every round.

*Result Satisfaction* – Each participant gives a score on a scale from 1 to 5 to reflect individual satisfaction with the group’s stage design of every round.

*Comments* – Participant comments during the satisfaction survey at the end of each round are logged.

**Scenario Design**

A scenario designer has a number of degrees of freedom within the framework of the APACE into Space game platform. The following is a list of major decisions the scenario designer has available for representing content and context of a negotiation situation of interest.

*Budget* – Starting budget and the rate of budget reduction with time are to be specified.

*Time* – Time allocated to the task of deciding a stage design (a round) is stated, as well as the total time in the game.

*Rounds* – The number of rounds can be varied from scenario to scenario to study interaction between stakeholders with short-term and long-term goals, and tactics for achieving each type of goals by an individual player.

*Public Goals* – Public goals are presented to all players before the beginning of the design negotiations. Common goals may involve budget, time, overall sturdiness of the design and selected aspects of the design.
**Players** – The number of players, each player’s agenda, influence and powers have to be defined for a scenario. Influence is a number of additional votes available to the player throughout the game to put against the player’s selected design options.

**Player Agendas** – Each player is given a set of incentives – points to be gained if specific design features are achieved. Individual agendas can vary with respect to different aspects of the design. For instance, a player may be strongly incentivized toward particular choices of materials, but indifferent to color and facility types. Within each aspect of the design, a player may be encouraged to make the same choice (ex. red floors or aluminum) or aim toward variety. In addition, each goal can be formulated as proportional (points for each instance of design choice) or absolute (ex. at least three blue floors) with either a lump reward or a penalty in case the goal is not achieved.

There can be incentives where points are gained only after a threshold is reached, such as points for overall design sturdiness above a target level. The urgency characteristic of a player can be conveyed through careful crafting of the player’s agenda. For example, a player who receives the same number of points for every floor of a specified color experiences less urgency than a player who loses points if a minimum number of floors of a needed color is not achieved. The private agenda is hidden from other players. The range of scores for different players may vary considerably, reflecting dissimilar risk and benefit profiles present in real world situations.

**Player Powers** – While some of the in-game communications are unlimited and available to all players, additional interactions are specified through player powers. In addition to availability of particular actions, players are given individual power budgets.
For example, low-power players can stall the game for a pre-defined period of time, with the game clock running, or register their protest against the direction of the design. These actions do not require expenditure of power budget. High-power players have more forceful actions available to them, such as forcing another player to change the vote to the option preferred by the power player, or to end the round without approval of other players. The strong actions of high-power players require spending from the power budget. Thus the scenario designer can proactively decide on the balance between availability of dictatorial action from power players and additional votes available to legitimacy players.

Various elements of scenario design can interact to produce desired effects. For example, stalling the negotiation is more effective technique for a player with low power when game time is tied to the budget, and there are strong incentives for other players to keep on schedule and within the budget.

Experiments

The project team ran a series of play sessions with four MITRE staff as players. A typical session consisted of a tutorial and three or four games. A tutorial was a short three-round game designed to familiarize the players with the user interface and game play options. Every game played by the same group was based on a different five-round scenario. Except for the tutorial, the order in which scenarios were presented to each group of players was not preserved. A total of 41 games were played, 28 by summer interns and 13 by senior staff. Age and experience of players (intern or senior staff) was consistent throughout each group participating in a particular experiment session.
Two main scenarios were referred to as Utopia and BigSystem. Utopia was designed to provide a baseline for studying player behavior when each player has the same individual agenda. BigSystem aimed at modeling a stakeholder combination from a real project examined by the principal investigators. Design of the BigSystem scenario was based on extensive interviews with the major stakeholders of the project. The BigSystem scenario featured significant conflicts among various stakeholder agendas. In addition, the Attainable scenario was created to represent a situation where all stakeholders have distinct, but non-conflicting agendas. Finally, the Dystopia scenario was designed to represent a situation where conflict is inevitable because the stakeholders have opposing agendas on every aspect of the design.

Data from two of the scenarios, Utopia and BigSystem, are studied in this thesis. Ten Utopia games were played: 6 by groups of interns and 4 by senior staff. Fifteen BigSystem games were played: 10 by interns and 5 by senior staff.

Utopia scenario

The Utopia scenario was crafted to study player dynamics under conditions where agreement is easy because all players’ agendas are aligned. Player roles are Project Manager with significant power and moderate legitimacy, Funder with high power and low legitimacy, Vendor with low power and moderate legitimacy, and User with low power and high legitimacy. Since urgency is conveyed through player agendas, all players in this scenario have the same low-to-medium urgency. Public goals include staying within 10% of the budget, having at least one steel segment and at least two bunks. Individual agendas, identical for each of the players, support public goals. Each player receives 400 points for every steel segment, 200 points for every red segment, and 300 points for use of every different type of facility. Relatively low urgency is
achieved through the use of proportional individual goals supporting easy to achieve public 
goals.

Project Manager can reward another player with additional influence points. Project Manager 
also has the power to end a negotiation round without waiting for consensus. Project 
Manager’s power allows for a single action of acting a round or up to four reward actions. 
Funder has a power to reward another player with influence or punish another player by 
removing influence. Expenditure of power points is required for these actions, making 3-5 total 
power moves available to Funder player during the entire game. Vendor and User have no 
power budget, but can stall and protest the direction of design. 
The solution space is effectively one-dimensional since a given design gives every player the 
same score. The score can range from 300 to 4800 points, with a minimum score of 700 in a 
game with all public goals achieved. Data from ten Utopia games were analyzed, including six 
games played by interns and four games by senior staff. Only two games, one for each group, 
failed to achieve the maximum possible score. Even though the ideally aligned agendas were 
conducive to an easy agreement, design of each stage went through a number of iterations, 
referred to as state changes. Game scores, number of state changes and influence points used 
are shown in Table 3. The average number of state changes per round was around 6 for intern 
groups and 10 for senior staff groups. Both the average number of state changes and standard 
deviation in the state change number were significantly lower for both kinds of players when 
suboptimal games were removed from the sample. The results are shown in Table 4. That is, 
the games with design flaws were characterized by a larger number of state changes — longer, 
more difficult negotiation process.
Table 3 Games Based on Utopia Scenario

<table>
<thead>
<tr>
<th>Game ID</th>
<th>Player Group Type</th>
<th>Individual Player Score</th>
<th>Number of State Changes</th>
<th>Influence Points Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>I00102</td>
<td>Interns</td>
<td>4800</td>
<td>29</td>
<td>3</td>
</tr>
<tr>
<td>I00201</td>
<td>Interns</td>
<td>4400</td>
<td>53</td>
<td>24</td>
</tr>
<tr>
<td>I00302</td>
<td>Interns</td>
<td>4800</td>
<td>31</td>
<td>6</td>
</tr>
<tr>
<td>I00401</td>
<td>Interns</td>
<td>4800</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>I00503</td>
<td>Interns</td>
<td>4800</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>I10103</td>
<td>Interns</td>
<td>4800</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>P00102</td>
<td>Senior Staff</td>
<td>4800</td>
<td>44</td>
<td>10</td>
</tr>
<tr>
<td>P00301</td>
<td>Senior Staff</td>
<td>4800</td>
<td>47</td>
<td>9</td>
</tr>
<tr>
<td>P00402</td>
<td>Senior Staff</td>
<td>4600</td>
<td>70</td>
<td>44</td>
</tr>
<tr>
<td>P00501</td>
<td>Senior Staff</td>
<td>4800</td>
<td>37</td>
<td>12</td>
</tr>
</tbody>
</table>

The two sub-optimal games warrant a closer examination. In I00201 one of the stages used aluminum instead of steel, reducing player scores by 400. In P00402 the color purple was chosen for the last stage, reducing the score by 200. While the choice of aluminum could be motivated by cost considerations, the choice of color other than red appears irrational. In both cases influence was applied by one of the players to achieve a score-reducing decision.

Influence was also used by other players to oppose sub-optimal decisions. Use of influence by different players to drive opposing design choices resulted in an increased number of state changes. Figure 4 demonstrates strong linear dependence between the use of influence and the number of state changes.

Table 4 State Changes in Utopia Games

<table>
<thead>
<tr>
<th></th>
<th>Interns</th>
<th>Senior Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Number of</td>
<td>Mean Number of</td>
</tr>
<tr>
<td></td>
<td>State Changes</td>
<td>State Changes</td>
</tr>
<tr>
<td></td>
<td>Standard</td>
<td>Standard</td>
</tr>
<tr>
<td></td>
<td>Deviation</td>
<td>Deviation</td>
</tr>
<tr>
<td>All Utopia Games</td>
<td>49.5</td>
<td>32.3</td>
</tr>
<tr>
<td>Games with Maximum</td>
<td>42.7</td>
<td>28.2</td>
</tr>
<tr>
<td></td>
<td>5.1</td>
<td>4.6</td>
</tr>
</tbody>
</table>
Results of the games based on the Utopia scenario offer several insights. First, the negotiation process takes a non-zero amount of time and activity, manifest in multiple design state changes, even when there is a perfect alignment of individual agendas. This is likely the result of individual agendas being hidden from other players. It takes effort for the players to learn that the goals of others are in accord with their own. Since different groups of human players (in the case of APACE experiments, interns and senior staff) demonstrate different dynamics, Utopia games can provide information about baseline behavior. Second, a higher than average number of state changes, accompanied by active use of influence in the form of additional votes for specific design elements, can be indicative of a more difficult and less effective
negotiation process. Finally, Utopia games demonstrated that human players occasionally act against their best interest, perhaps due to misperception of their own goals or the group dynamics.

**BigSystem Scenario**

The BigSystem scenario was constructed to simulate a real government negotiation on planning a new information technology (IT) system. Player roles are Oversight with high power and low legitimacy, Umbrella with medium-high power and medium-low legitimacy, MainUser with low power and high legitimacy, and OtherUser with low power and medium legitimacy. Oversight and Umbrella players have identical agendas that include a very high-stakes all-or-nothing goal, conveying a high level of urgency. MainUser has some absolute goals in the agenda. A failure to achieve these goals leads to a modest negative impact on the score, representing medium level of urgency. All of OtherUser’s goals are proportionate, conveying low urgency.

The only public goal of the scenario is to stay within $100K of the budget, with an initial budget of 200K and reduction of $20 per second of game time. Legitimacy, power budgets, and available actions are listed in Table 5, and individual agendas are detailed in Table 6. Similar to the Utopia game, forceful actions are available to players with high power, while the only recourse of players who lack power is to stall or protest the direction of the design. The BigSystem scenario exemplified the tension between power and legitimacy players.
Table 5 Player Characteristics in BigSystem Scenario

<table>
<thead>
<tr>
<th>Influence Points</th>
<th>Power Points</th>
<th>Available Power Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Action</td>
</tr>
<tr>
<td>Oversight Player</td>
<td>0</td>
<td>Force a player to change their vote to anything you want</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>Add 10 influence points to any player</td>
</tr>
<tr>
<td></td>
<td></td>
<td>End the round without requiring player approval</td>
</tr>
<tr>
<td>Umbrella Player</td>
<td>10</td>
<td>Force a player to change their vote to anything you want</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>Add 10 influence points to any player</td>
</tr>
<tr>
<td></td>
<td></td>
<td>End the round without requiring player approval</td>
</tr>
<tr>
<td>MainUser Player</td>
<td>50</td>
<td>Stall for 30 seconds</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Protest the direction of the design</td>
</tr>
<tr>
<td>OtherUser Player</td>
<td>30</td>
<td>Stall for 30 seconds</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Protest the direction of the design</td>
</tr>
</tbody>
</table>

Table 6 Player Agendas in BigSystem Scenario

<table>
<thead>
<tr>
<th>Individual Agenda</th>
<th>Score Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oversight Player</td>
<td>400 points for every bunk (facility)</td>
</tr>
<tr>
<td></td>
<td>400 points for every aluminum section (material)</td>
</tr>
<tr>
<td></td>
<td>7000 points if all sections are blue (color)</td>
</tr>
<tr>
<td>Umbrella Player</td>
<td>400 points for every bunk (facility)</td>
</tr>
<tr>
<td></td>
<td>400 points for every aluminum section (material)</td>
</tr>
<tr>
<td></td>
<td>7000 points if all sections are blue (color)</td>
</tr>
<tr>
<td>MainUser Player</td>
<td>600 points for sturdiness over 20</td>
</tr>
<tr>
<td></td>
<td>-1000 if there are less than 3 different facilities</td>
</tr>
<tr>
<td></td>
<td>-1000 if there are less than 3 different colors</td>
</tr>
<tr>
<td>OtherUser Player</td>
<td>500 for every different facility</td>
</tr>
<tr>
<td></td>
<td>500 for every different color</td>
</tr>
</tbody>
</table>

Solution Space: Pareto Frontier and Experimental Results

It is useful to examine a scenario’s solution space in order to understand what compromises are available to the players and what portions of the solution space indicate success or failure of particular individual agendas. Even with a relatively simple scenario the design space can be very combinatorially large, precluding full enumeration. In solution space exploration there is a
place for both the sampling of the design space and reasoning about player agendas and the
tradeoffs they require. In this section the solution space for the BigSystem scenario is surveyed
using several complementary techniques.

The design space for a five round game with a choice of one color out of four, one material out
of three and two independently selected facilities out of six available types has \((4 \times 3 \times 6 \times 6)^5\) or
over \(1.5 \times 10^{13}\). Due to the fact that player agendas are relatively simple and involve only a few
aspects of the design according to straightforward rules, a large number of designs produce the
same score for a given player.

Even though there are four players in the BigSystem scenario, the solution space their scores
produce is effectively three-dimensional because Umbrella player’s agenda is identical to that
of Oversight player. In order to outline the shape of the solution space 25 million random
solutions were evaluated first. By observing the results of the initial computation and by
examining the agenda of Oversight player, the solution space has two disjoint regions
determined by whether Oversight player is able to achieve the goal of all blue floors. The region
of “all-blue” solutions is significant in the solution space, but has a much lower probability
weight than the region representing otherwise-colored solutions. Only \((1/4)^5\) or under 0.1% of
the entire design space belongs to the “all-blue” region favorable to Oversight player. To fill out
the “all-blue” region with more lower probability solutions an additional 25 million random
designs with an “all-blue” constraint were added. A few solutions were added manually,
including those on the optimality frontier. Some of the optimal solutions were found by
maximizing one of the player’s scores by satisfying all aspect of the chosen player’s agenda,
then maximizing another player’s score within the remaining design options, and finally
repeating the process for the third player. The process was repeated for all ordering of the players. Additional optimal solutions were found by gradually stepping back from the optimal design for one of the players and examining what gains then become available to the remaining players. Tradeoffs between two players were made while keeping the third player’s score constant.

Figure 5 shows BigSystem’s three dimensional solution space with a variety of possible solutions represented by blue dots and Pareto optimal solutions marked with black stars.

Results of experimental games played by groups of interns are shown as green circles and those played by groups of senior staff by red circles. Figure 6, Figure 7 and Figure 8 display the scores for two players at a time. Some of the optimal designs may not appear optimal in two dimensions, as the score of one player appears constant while the other player’s score varies due to trade-offs with the third player not visible in a given two-dimensional representation. To complicate interpretation of the two-dimensional figures further, optimal and sub-optimal designs can share values of two of the variables in the three-dimensional solution space and thus be represented by the same point in two dimensions. For clarity the scores of all players for the solutions on the optimality frontier are also presented in Table 7.

Figure 6 shows the trade-off between Oversight player’s and MainUser player’s goals. It can be seen that maximizing one of these player’s scores requires large sacrifices from the other, although several designs are fairly advantageous to both. Small concessions by Oversight player near the maximum can produce large gains for MainUser player. The same is true with respect to OtherUser player, whose score is at a minimum when Oversight player’s score is maximized. Oversight player’s score is severely limited for designs maximizing OtherUser player’s score, as
shown in Figure 7. Agendas of MainUser and OtherUser players do not oppose as both can achieve maximum scores simultaneously, as can be seen in Figure 8. At the same time, these two agendas are not entirely aligned, and there is a large selection of designs advantageous for one of these two users but not the other. Figure 9 summarizes and graphically represents a family of optimal solutions to BigSystem scenario.
Figure 6 Solution Space: Scores of Oversight Player and MainUser Player

Figure 7 Solution Space: Scores of Oversight Player and OtherUser Player
Figure 8 Solution Space: Scores of MainUser Player and OtherUser Player

Figure 9 Optimal solutions in BigSystem scenario
As seen in Figure 5 though Figure 8, most of the designs obtained in experiments with human participants of BigSystem scenario games fall far short of the optimality frontier. Individual player scores, number of state changes and influence points used are listed in Table 8. Intern groups did notably better in a number of games than senior staff groups. Most notably, intern groups had 8 out of 10 solutions fall in the “all-blue” region of the solution space, indicating significant success of Oversight and Umbrella players. Only 1 out of 5 solutions by senior staff groups fell into the same region. Additional research will be required to explain this discrepancy.

<table>
<thead>
<tr>
<th>Design</th>
<th>Oversight Player</th>
<th>MainUser Player</th>
<th>OtherUser Player</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13000</td>
<td>-2000</td>
<td>1000</td>
</tr>
<tr>
<td>2</td>
<td>12600</td>
<td>-2000</td>
<td>1500</td>
</tr>
<tr>
<td>3</td>
<td>12200</td>
<td>-1000</td>
<td>2000</td>
</tr>
<tr>
<td>4</td>
<td>11800</td>
<td>5200</td>
<td>1000</td>
</tr>
<tr>
<td>5</td>
<td>11800</td>
<td>-1000</td>
<td>2500</td>
</tr>
<tr>
<td>6</td>
<td>11400</td>
<td>10600</td>
<td>1000</td>
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<tr>
<td>7</td>
<td>11400</td>
<td>800</td>
<td>2000</td>
</tr>
<tr>
<td>8</td>
<td>11400</td>
<td>-1000</td>
<td>3000</td>
</tr>
<tr>
<td>9</td>
<td>11000</td>
<td>16000</td>
<td>1000</td>
</tr>
<tr>
<td>10</td>
<td>11000</td>
<td>3200</td>
<td>2000</td>
</tr>
<tr>
<td>11</td>
<td>11000</td>
<td>-1000</td>
<td>3500</td>
</tr>
<tr>
<td>12</td>
<td>10600</td>
<td>11600</td>
<td>2000</td>
</tr>
<tr>
<td>13</td>
<td>10200</td>
<td>17000</td>
<td>2000</td>
</tr>
<tr>
<td>14</td>
<td>10200</td>
<td>11600</td>
<td>2500</td>
</tr>
<tr>
<td>15</td>
<td>9000</td>
<td>17000</td>
<td>3500</td>
</tr>
<tr>
<td>16</td>
<td>4800</td>
<td>0</td>
<td>4000</td>
</tr>
<tr>
<td>17</td>
<td>4400</td>
<td>0</td>
<td>4500</td>
</tr>
<tr>
<td>18</td>
<td>4000</td>
<td>0</td>
<td>5000</td>
</tr>
<tr>
<td>19</td>
<td>3600</td>
<td>12600</td>
<td>3500</td>
</tr>
<tr>
<td>20</td>
<td>3200</td>
<td>18000</td>
<td>3500</td>
</tr>
<tr>
<td>21</td>
<td>2800</td>
<td>18000</td>
<td>4000</td>
</tr>
<tr>
<td>22</td>
<td>2400</td>
<td>18000</td>
<td>4500</td>
</tr>
<tr>
<td>23</td>
<td>2000</td>
<td>18000</td>
<td>5000</td>
</tr>
</tbody>
</table>
Similarly to the Utopia scenario experiments, there appears to be a strong linear relationship between the number of state changes and the number of influence points used within a given BigSystem game, as seen in Figure 10. Unlike in the Utopia experiments where interns tended to use influence far less than senior staff, in the BigSystem experiments interns consistently used more influence, triggering significantly higher number of state changes than senior staff did. The reversal of the negotiation trends between interns and senior staff is worth exploring further in future studies, especially considering superior outcomes in the BigSystem scenario achieved by the intern groups. It is possible that interns are simply more skilled in online game play, but it is also conceivable that they employ more efficient, perhaps less rigid negotiation tactics. Overall it appeared that interns were capable of obtaining faster agreement in easier situations and more effective solutions under somewhat challenging circumstances.

Table 8 Games Based on BigSystem Scenario

<table>
<thead>
<tr>
<th></th>
<th>Oversight Player Score</th>
<th>Umbrella Player Score</th>
<th>MainUser Player Score</th>
<th>OtherUser Player Score</th>
<th>Number of State Changes</th>
<th>Influence Points Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>100101</td>
<td>Interns</td>
<td>9400</td>
<td>9400</td>
<td>8600</td>
<td>3500</td>
<td>117</td>
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<td>100202</td>
<td>Interns</td>
<td>2800</td>
<td>2800</td>
<td>800</td>
<td>4000</td>
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<tr>
<td>100204</td>
<td>Interns</td>
<td>9000</td>
<td>9000</td>
<td>11600</td>
<td>3500</td>
<td>176</td>
</tr>
<tr>
<td>100301</td>
<td>Interns</td>
<td>9000</td>
<td>9000</td>
<td>11000</td>
<td>3500</td>
<td>108</td>
</tr>
<tr>
<td>100304</td>
<td>Interns</td>
<td>9400</td>
<td>9400</td>
<td>14000</td>
<td>3000</td>
<td>89</td>
</tr>
<tr>
<td>100402</td>
<td>Interns</td>
<td>1600</td>
<td>1600</td>
<td>-1000</td>
<td>3000</td>
<td>66</td>
</tr>
<tr>
<td>100502</td>
<td>Interns</td>
<td>10600</td>
<td>10600</td>
<td>-1000</td>
<td>3500</td>
<td>86</td>
</tr>
<tr>
<td>110101</td>
<td>Interns</td>
<td>9400</td>
<td>9400</td>
<td>8600</td>
<td>3500</td>
<td>108</td>
</tr>
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<td>110105</td>
<td>Interns</td>
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<td>9400</td>
<td>11600</td>
<td>3500</td>
<td>92</td>
</tr>
<tr>
<td>110302</td>
<td>Interns</td>
<td>9000</td>
<td>9000</td>
<td>17000</td>
<td>3500</td>
<td>103</td>
</tr>
<tr>
<td>P00101</td>
<td>Senior Staff</td>
<td>1600</td>
<td>1600</td>
<td>7200</td>
<td>4500</td>
<td>88</td>
</tr>
<tr>
<td>P00302</td>
<td>Senior Staff</td>
<td>2400</td>
<td>2400</td>
<td>1800</td>
<td>5000</td>
<td>93</td>
</tr>
<tr>
<td>P00401</td>
<td>Senior Staff</td>
<td>9400</td>
<td>9400</td>
<td>2600</td>
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<td>89</td>
</tr>
<tr>
<td>P00502</td>
<td>Senior Staff</td>
<td>4400</td>
<td>4400</td>
<td>0</td>
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<td>57</td>
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<tr>
<td>P00505</td>
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<td>2000</td>
<td>2000</td>
<td>7200</td>
<td>5000</td>
<td>76</td>
</tr>
</tbody>
</table>
Number of State Changes and Individual Player Scores

Higher than average number of state changes during a game indicates greater player activity, including use of influence, negotiations and power plays. To determine if a high number of state changes appears more favorable to some player types than the others, player scores in BigSystem games were displayed as a function of number of state changes within the respective game. The results are shown in Figure 11, Figure 12 and Figure 13.

Oversight and Umbrella players whose agendas are identical do not appear to benefit from protracted negotiations. This observation holds true for both the games played by interns and those played by senior staff. MainUser player appears to benefit the most from higher number
of state changes, followed by OtherUser. These two players have the most influence. Repeated use of influence – addition of votes to desired aspects of the design – may explain how MainUser and OtherUser players achieve somewhat higher scores in games with larger number of state changes. Even for the latter two player types R$^2$ is low, indicating that the scores are not well explained by linear regression with respect to the state change number. In any case, the number of data points is hardly sufficient for making a solid conclusion. However, the observations presented in this section should encourage a closer examination of whether success of low-power, high-legitimacy players tends to depend on protracted negotiations.

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**Figure 11 Score of Oversight Player versus the number of state changes**
**Score of MainUser Player vs. Number of State Changes**

![Graph showing the relationship between MainUser Player score and number of state changes. The graph includes two linear regression lines for interns and senior staff, with corresponding equations and R² values.]

Figure 12 Score of MainUser Player versus the number of state changes

**Score of OtherUser Player vs. Number of State Changes**

![Graph showing the relationship between OtherUser Player score and number of state changes. The graph includes two linear regression lines for interns and senior staff, with corresponding equations and R² values.]

Figure 13 Score of OtherUser Player versus the number of state changes
Chapter 4: Modeling Effects of Learning

Game model

While the design space of the entire five stage spacecraft is very large, as discussed above, the number of possibilities for a single stage design is far more computationally manageable. The design space for a single round with a choice of one color out of four, one material out of three and two independently selected facilities out of six available types has $4 \times 3 \times 6 \times 6 = 432$ possibilities. Some of these are equivalent to each other because agendas do not distinguish between alternative placements of the same two facilities within the same stage. In addition, due to the relative simplicity of player agendas several stage designs typically result in the same score for an individual player.

A basic agent-based model was constructed to represent player interactions in BigSystem scenario games. For the first round the contribution of each of the 432 possible stage designs to every player’s score was calculated. Although the calculation was based on each player’s agenda, some of the formulas from the agenda had to be modified for this calculation. For example, Oversight and Umbrella players receive 7000 points if every stage is blue. In order to convey these players’ preference for blue color during the first round 1400 points were awarded to blue designs. Proportional goals were treated as they are in the agenda, for example, with granting a design with aluminum an additional 400 points for Oversight and Umbrella player’s scoring. In effect, all goals were treated as proportional, indicating the direction of the design preferable to each player. The raw scores for each possible stage design were converted to rankings of designs from the point of view of each player. Once the rankings were available, any of a number of voting schemes could be employed with varied weighing of
player’s votes. For example, Borda count voting was attempted (Saari, 2000). If Borda count scheme resulted in several top stage designs, one of these was chosen at random. For the second round each possible stage design variant was evaluated with the knowledge of the first round design. For example, if the earlier design stage choice made one of the absolute individual goals unachievable, the goal was subsequently disregarded (ex. color would no longer matter to a player with “all-blue” preference once one of the other colors was used anywhere in the earlier stages of the design). Otherwise the process for evaluating and ranking the 432 stage designs and using a consistent voting scheme to choose the winner for the current round was used.

It was discovered that the largely deterministic model described above leads to a small number of optimal solutions, depending on the voting scheme employed and the weighing of the player’s votes. Due to its extreme simplicity the deterministic model failed to represent negotiation dynamics and the highly suboptimal solutions observed in experiments.

Probabilistic Model

A simple probabilistic model was built to represent the basic interactions between individual stakeholders with different agendas within the BigSystem scenario. As with the equilibrium model, all possible solutions for a single round are scored and then ranked, with ties, according to the number of points they bring for each of the players. The negotiations round starts with a randomly selected player posing one of his highest-scoring designs to other players. Every other player has a certain probability to accept the proposed design. This probability depends on the rank proposed stage design is assigned by the individual player. For simplicity, probability of acceptance in the model depends linearly on the solution’s rank. Any of the top-ranked
solutions will have a 100% chance of acceptance by the player, while the lowest-ranking solutions have 5% chance of acceptance. If all four players accept the solution, the round is completed. If one or more of the players reject the proposed stage design, the process repeats with a new stage design posed for consideration. In its current form the model does not realistically represent the negotiation process as it assumes that at least one of the players achieves one of his top-ranked stage designs. In real games the players may all accept a stage design that requires a compromise from each of the players.

Incorporating learning into the model

One of the hypotheses of the APACE project is that knowledge of each other’s hidden agendas can improve the outcome of the negotiation. Although experiments with partially or fully transparent individual agendas are yet to be conducted, learning of each other’s agendas is also relevant to the experiments already carried out. In games where there is no explicit way to share individual goals, private agendas are partially revealed to other players through negotiations. The model described above assumes that each player’s preferences follow the utility of a given stage design for the respective player’s score. As mentioned above, under the BigSystem scenario each player’s agenda results in multiple-way ties in stage design rankings. Since player agendas in the BigSystem scenario give different weight to various aspects of the design, many individual player’s ties are easily broken by injecting the knowledge of other players’ preferences. Here it is assumed that the effects of the other players’ agendas on the preferences of a given player are significantly smaller than the impact of the player’s own agenda.
Learning is introduced into the model by “contaminating” each player’s utility function with the sum of all player’s utilities. Learning factor $f$ is introduced in order to parameterize the size of the effect. Learning of each other’s goals is assumed to start immediately at the beginning of the game and thus is applicable even to the first round, as player interactions during negotiations and design iterations take place in the initial round of the design. Learning is assumed to increase linearly with every round, reaching the maximum level in the final, fifth round of a game based on the BigSystem scenario.

Table 9 below demonstrates how player utilities with respect to a few selected designs are modified by introducing the sum of all players’ goals with a small learning factor. Learning factor of 0.01, as shown here, means that 99% of an individual player’s utility for a given design is due to the individual agenda and 1% is due to the sum of all players’ agendas. (For ease of computation the player’s own score is not excluded from the sum, causing the overall effect of “contamination” to be smaller.) By varying the learning factor in the models, the amplitude of the learning effect can be calibrated against the actual results. Introduction of low levels of other players’ agenda influence on each individual utility breaks ties in the scores and corresponding rankings of the designs. As a result, among designs that would be equivalent according to the player’s own agenda, the player is now more likely to vote for the design favorable for others.
Table 9 Effects of Learning on Individual Player’s Utilities and Design Rankings

<table>
<thead>
<tr>
<th>Stage Design</th>
<th>Utilities Without Learning</th>
<th>Ranks Without Learning</th>
<th>Utilities With Learning</th>
<th>Ranks With Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oversight</td>
<td>Umbrella</td>
<td>MainUser</td>
<td>OtherUser</td>
</tr>
<tr>
<td>Stage Design 1</td>
<td>1800</td>
<td>1800</td>
<td>1600</td>
<td>1500</td>
</tr>
<tr>
<td>Stage Design 2</td>
<td>1400</td>
<td>1400</td>
<td>4000</td>
<td>1500</td>
</tr>
<tr>
<td>Stage Design 3</td>
<td>1400</td>
<td>1400</td>
<td>7000</td>
<td>1500</td>
</tr>
<tr>
<td>Stage Design 4</td>
<td>400</td>
<td>400</td>
<td>1600</td>
<td>1500</td>
</tr>
</tbody>
</table>

Effects of Learning in the Model

To examine the effects of learning on the solutions found by probabilistic agent-based model described above, a series of simulations was performed. Figure 14 shows solutions found by a model with zero learning (blue points) and solutions obtained from a model with a 0.5% learning per round (magenta points). These results were produced by 5000 runs of each version of the models. Figure 15 presents a histogram of total scores (sum of four individual player scores) for the resulting games. It can be seen from the histogram that the total scores improve significantly even with the low levels of learning.

In the current model learning appears so effective even at extremely low levels because of the unrealistic assumption that each player obtains information about other players’ preferences with regard to all possible stage designs at once. A more realistic model of learning would provide a player with incomplete information about other players’ preferences, with gradual increase in the number of stage designs for which such information is available.

Simulated games were repeated for learning factor ranging from 0 to 3% in increments of 0.5%, with 500 solutions obtained for each level of learning. Average total score per game as a
function of learning factor is shown in Figure 16. Average total scores of the two types of experimental groups, interns and senior staff, are also noted. Results of games by senior staff are consistent with a model without learning, while results of intern groups correspond to substantial levels of learning.

Figure 14 Solutions produced by the model with and without learning
Figure 15 Total scores for solutions produced by the model with and without learning

Figure 16 Average total scores from simulated solutions with varying learning factor and from experimental games
Discussion

A significant discrepancy in results between two types of participants was observed in games based on the same scenario. Results obtained from agent-based modeling with and without learning suggest that the discrepancy might be explained by differences in how efficiently each type of participants infers each other’s preferences. Learning efficiency is likely to be related to the negotiation approaches game participants take. For example, it was found that interns bargain a lot more often than senior staff do, while senior staff attempt to use bribes more than do the interns. It is possible that bargaining allows players to learn more about each other’s preferences than bribing does.

Effect of knowledge of each other’s private agendas on the effectiveness and efficiency of negotiation is a promising direction for further research on the APACE project. Perhaps the APACE into Space game also has potential to be used diagnostically in order to gauge a team’s capability for and tendency toward learning and taking into account each other’s objectives.
Chapter 5: Summary and Future Research Directions

Summary

A stakeholder salience framework was used by the APACE team as a basis for creation of a serious game aimed at studying negotiation dynamics between different types of stakeholders. The empirical data revealed that negotiation dynamics are sensitive to individual stakeholder agendas defined within a game scenario as well as to the characteristics of human participants in experimental games. The games based on the Utopia scenario where all players have an identical agenda were baseline studies. It was shown that the few suboptimal solutions were associated with a large number of state changes and use of influence as one of the players pursued a less than ideal design choice while others took actions to oppose it.

In this thesis a solution space exploration of BigSystem, a more complex scenario, was conducted. It was shown that design solutions obtained in the course of experiments with human participants fall far short of the optimality frontier. The experimental games played by interns produced significantly better results than those played by senior staff. Negotiation tactics favored by the two types of participants also differed, with interns using relatively more bargaining moves and senior staff engaging in bribing at higher rates.

An agent based model was built to represent stakeholder negotiations of a spacecraft design in the BigSystem scenario. Utility functions of individual players were based on their private agendas. Utilities were calculated for each possible stage design. All stage designs were then ranked from most favored to least favored by each player. Spacecraft design was negotiated one stage at a time with individual players voting for or against a proposed stage design.
according to the rank the present stage design. A stage design was accepted when all players voted affirmatively.

Effects of players’ learning of each other’s agendas were introduced into the model by adding a fraction of the sum of all players’ utility function to each individual utility function. This approach broke ties between previously equally ranked stage designs for individual players. The design solutions produced by simulated games with learning effects had higher total player scores than simulated games without learning. Experimental results from senior staff participants resembled simulated results without learning, while results of games played by interns were similar to simulated results with considerable levels of learning.

Future Research Directions

Model

Several improvements can be made to the agent based model of the stakeholder design negotiation. In the current model when a stage design fails to gain acceptance of all four players a new design is chosen among top ranking options of a randomly selected player. A more sophisticated handling of the negotiation process would allow for changes in design one variable at a time, in the direction that would make the design more favorable to one of the players who rejected the earlier version of the stage design.

The existing implementation of the learning effects injects information about all of other players’ preferences into the utility function of an individual player. Higher levels of learning are represented by a higher weight of other players’ agendas in the individual player’s utility function. A more complete and realistic model of learning would make incomplete information about other players’ preferences available to the individual player. For example, partial learning
may include information on how other players rank some, but not all of the possible stage designs. Greater levels of learning would involve revealing more information over time.

The simulation studies conducted to date demonstrated that learning improves the total score in the BigSystem scenario. The BigSystem scenario imposes moderate levels of tradeoffs between the interests of some of the players. It would be worthwhile to examine how the effects of learning interact with the degree of misalignment of the individual player agendas within a scenario. Learning of other players’ agendas would not have any effect on simulation results for the Utopia scenario: since all player agendas are identical, individual utility functions and rankings would be unaffected by the introduction of other players’ preference information.

Effects of learning would likely be the most beneficial in scenarios with somewhat divergent, but not completely conflicting individual player agendas.

Experiments

The effects of shared knowledge of individual preferences play an important role in the dynamics of negotiation. Games could be conducted specifically for the purpose of examining impact of the shared individual agenda information on the outcomes of the game. Several implementations of learning are possible. Scenarios can be designed where the human players are informed of some of the details of each other’s agenda, with varying amount of agenda information remaining private. Alternatively, the players may be given an option to reveal parts of their agenda to each other proactively. In real world negotiations the parties typically are unwilling to reveal the entirety of their private agendas to each other. However, keeping the entire agenda private is often also beyond a participant’s control. A rich variety of interactions around revelation of private agendas to others merits a detailed investigation.
The analysis of experimental results shows a correspondence between increased use of certain negotiation techniques such as bargaining and bribing and overall success of the game result. The simulated results indicate that learning of each other’s private agendas increases the total score. It is possible to hypothesize that some negotiation techniques are more conducive to player’s learning of each other’s agendas than the others. This hypothesis can be tested by limiting choices of available actions in a negotiation.

A larger question, perhaps beyond the scope of serious games research, is whether it is beneficial for negotiation participants to learn about the extent of the discord in their private agendas in cases where the misalignment of agendas is particularly significant. A revelation of a significant conflict between private agendas of two key stakeholders may bring about a swift and fruitless end to a project. It is not immediately clear if such a resolution is unwelcome or desirable. On the one hand, there could be hope that participants may reach a satisfactory compromise if the negotiations persisted. On the other hand, in the presence of strong discordant private agendas there is a risk that a compromise is in fact impossible, and the negotiation is destined to fail at a later stage after a considerable investment of time and effort by all involved parties.

In this thesis it was assumed that an individual player helps others to pursue their agendas as long as this course of action does not compromise the player’s own goals. This assumption is only sound if players view the game as a fundamentally cooperative one as opposed to a competitive one. It would be interesting to examine what factors persuade participants to view a negotiation situation as cooperative rather than competitive. One of the influences on the player perception may lie in the extent and importance of group goals. Scenarios may be
crafted to study the effects of common goals on players’ willingness to collaborate in a
negotiation environment.

The design of the APACE game can also provide a vehicle for the study of leadership styles and
their effectiveness in a negotiation. Crowder et al. (2012) propose a distinction between
transactional and transformational leadership. They explain that transactional leadership is
conveyed through rewards and punishments while transformational leadership is based on the
leader’s ability to motivate and inspire team members (Crowder, Robinson, Hughes, & Sim,
2012). The ability of certain players to reward and punish other game participants is already
available in the APACE game. Currently such transactional capabilities are given to some players
as a reflection of their power attribute. It would be possible to extend the set of available
negotiation moves to include actions that attempt to motivate and inspire. The game scenario
design process lends itself well to experimentation with a leadership role within the negotiation
game. The transactional and transformational forms of leadership could be concentrated in a
single role or assigned to different players. One or both leadership styles can be present in a
given scenario. Studies of interaction of leadership use with divergence of personal agendas
may provide valuable insight into beneficial and harmful patterns of negotiation dynamics.

Broader Perspective

Structured methods should be developed for translating information on stakeholder salience
attributes of real world actors into the player characteristics within a game. In more general
terms, platforms for seamless conversion of the empirical knowledge of a specific negotiation
environment and their corresponding stakeholder agendas and characteristics into serious
game scenarios would be valuable for research and business applications.
Significant differences in results from different types of participants playing games based on the same scenario suggest a promise of diagnostic use of serious games on groups struggling with negotiation challenges. Serious games might be useful for revealing weaknesses in negotiation tactics of certain groups and offer valuable tools for training, reflection and improvement.
References


