**Identifying Potential Open Source
Ecosystem Participants Based Upon
Organizational Motivation and Ability**

by

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A thesis submitted to the Faculty of Graduate Studies and Research in
partial fulfillment of the requirements for the degree of Master of Applied Science in
Technology Innovation Management

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May 2009

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Your file   Votre référence
ISBN: 978-0-494-52045-1
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ISBN: 978-0-494-52045-1

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ABSTRACT

This research shows that a rigorous articulation of organizational motivation and ability can help a manager or initiator of an open source (OS) ecosystem identify potential participants. It does so by analyzing the potential for OS ecosystem creation from a theoretical sample of 21 organizations in the distributed simulation industry. Organizational motivation and ability are rated for each organization, and used to produce a scatter plot of the industry context. Four categories of organizations are identified from the scatter plot, including the Hotbed category with the most promise for OS ecosystem participation. The research identifies: potential OS ecosystem participants; levers to increase organizational motivation and ability; barriers to OS ecosystem participation; and concludes that the distributed simulation industry context is favourable to an OS ecosystem. The research operationalizes Christensen's Motivation/Ability Framework, defines three tools for managers, and illustrates the transition from an attribute- to circumstance-based categorization of organizations.

ACKNOWLEDGEMENTS

I would first like to acknowledge the unwavering support of my husband and family throughout this research endeavour. Your constant encouragement and steadfast belief in my abilities helped to keep me moving forward, even in times of frustration or doubt.

A number of other important thank yous are also warranted:

To my thesis advisor, Dr Trevor Pearce, a heartfelt thanks for your constant guidance, encouragement, and patience. I have learned a great deal from you and hope to learn a great deal more. Also, thank you ever so much for your support in the final push to the finish (and my apologies for eating up a few of your weekends).

To Dr John Callahan, thank you for getting me on the right track with respect to the methodology sources at the outset of my research. Thank you also for your willingness to meet and discuss my data analysis approach and results. Your insight was most helpful and reassuring at a time when I was trying to make sense of what I had found.

To Professor Steven Muegge, thank you for your tremendous amount of support and insight as I tried to wade into my data analysis. Your willingness to meet with me and discuss potential approaches was extremely helpful.

To Mr Bob Elliott of the Canadian Forces Synthetic Environment Coordination Office, thank you for your encouragement and insight throughout my research and your support of my travels to meet with the interview respondents. All the best to you in your retirement.

To all of the interview respondents, thank you for your willingness to meet with me and for your valued input to my research. I look forward to working with you in future.

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1 INTRODUCTION

The overarching aim of this research was to develop theory related to the creation and evolution of open source (OS) ecosystems, with specific focus upon identifying potential ecosystem participants. The researcher analyzed the current organizational motivation, ability and constraint of a theoretical sample of 21 organizations in the distributed simulation industry. The resulting theory was developed by cycling through: data collection (interviews, supporting documents); data reduction (detailed case write-ups, tables, matrices); data display (scatter plots); validation; and drawing of conclusions.

The literature purports that future business battles will be waged between business ecosystems or ecosystem domains, and not between individual companies (Iansiti & Levien, 2004c). As a result, it is imperative that organizations acknowledge and understand the ecosystem approach to business (Bailetti, 2009; Moore, 2006). The business ecosystem literature predominantly provides strategies related to existing business ecosystems, and largely fails to address the notion of creating new ones.

The advent of OS ecosystems has not been effectively addressed by the existing literature related to business ecosystems, OS, and open innovation. It does not provide applicable strategies for their creation or offer an effective treatment of their unique aspects. This literature fails on several accounts since it predominantly: considers organizational sponsorship of pre-existing OS communities; ignores the possibility of a fully open platform; ignores the existence of a non-profit governance structure; and presumes that there is a requirement for levels of secrecy and a strong leader.

Within the specific industry context of distributed simulation, the circumstances appear ripe for a consideration of OS ecosystems. A number of distributed simulation

frameworks exist, and the High Level Architecture (HLA) (IEEE, 2000) is among these. As part of the HLA, specific software called the Runtime Infrastructure (RTI) is required to enable dispersed simulations to interact with one another. This software is generally commercial in nature, though several OS implementations do exist.

The distributed simulation literature highlights the fact that an OS RTI implementation is needed, and also that the lack of an OS RTI community needs to be addressed (Pokorny, 2006, 2007b; Stratton, Miller, & Parr, 2004). It has been suggested that the progress of the existing OS RTI initiatives has been hampered by their lack of a supporting business ecosystem (Pearce & Bailetti, 2007). A paper published after this research was undertaken, suggests that a potentially growing OS community exists to support an OS RTI (Noulard, Rousselot, & Siron, 2009).

1.1 Definition of Key Terms

Several definitions are central to this research. These were either drawn directly from the literature or developed by the researcher through reference to the literature.

A business ecosystem is an intentional community of economic actors (organizations and/or individuals) who use a platform to co-create and deliver value to customers, partners, themselves and their community (Bailetti, 2009; Moore, 2006).

An OS ecosystem differs somewhat from a business ecosystem. It includes both a business ecosystem that leverages a platform, and an OS community that directly works on creating and evolving that platform (Milinkovich, 2009).

The notion of resources is central to organizational motivation, ability and constraint. Resources are anything that is perceived as valuable by an organization; this may include capital, information, relationships, material, or access to markets (Tillquist,

King, & Woo, 2002). Organizational motivation involves an organization needing, wanting or lacking resources; it will endeavour to access, obtain, possess, generate, create and/or control resources. Organizational ability is defined as an organization's capability or freedom to access, obtain, possess, generate, create and/or control resources. Organizational constraint means that an organization is unable to, or prevented from, accessing, obtaining, possessing, generating, creating, and/or controlling resources.

1.2 Research Question

This thesis answers the following research question:

Can a rigorous articulation of organizational motivation and ability help a manager or initiator of an open source ecosystem identify potential participants?

1.3 Summary of Key Findings

With a specific focus upon potential OS ecosystem participants, this research found that organizational motivation and ability can provide valuable insight to OS ecosystem managers or initiators. It also enabled the researcher to do the following within the specific industry context of distributed simulation:

- Identify unique indicators of organizational motivation, ability and constraint
- Identify dimensions of organizational motivation, ability and constraint
- Move from an attribute-based categorization of organizations to a circumstance-based one
- Identify potential ecosystem participants who may be motivated and able
- Identify potential levers to increase organizational motivation and ability
- Identify potential barriers to organizational OS ecosystem participation
- Make conclusions about whether the context is favourable to an OS ecosystem

1.4 Contributions

This research makes four contributions. First, it contributes to the existing literature that addresses business ecosystems, OS ecosystems, and organizational participation in OS. It considers a context in which new OS ecosystems are created and evolved by organizations and individuals, instead of one involving organizational sponsorship of a pre-existing OS community. The research focuses upon identifying potential ecosystem participants by analyzing not just organizational motivation, but also organizational ability and constraint.

Second, this research makes a contribution by defining a process for researchers that operationalizes the Motivation/Ability Framework (Anthony, Roth, & Christensen, 2002; Christensen, Anthony, & Roth, 2004). This process can be used to analyze organizational motivation, ability and constraint in a specific industry context in order to determine whether or not it is favourable to an OS ecosystem.

The third contribution that this research makes is to identify tools for managers to assess if a particular industry context is favourable to an OS ecosystem. It identifies: key dimensions of organizational motivation, ability and constraint; levers to increase organizational motivation and ability; and barriers to OS ecosystem participation.

Lastly, this research facilitated industry connections between a major OS ecosystem and an existing OS RTI project. It remains to be seen if this will assist in propelling that particular OS RTI project forward.

1.5 Relevance

The contributions of this research may be of interest to at least three groups. First, top management teams may be able to use the contributions to assess the viability of an

OS ecosystem approach. In so doing, they may identify: potential participants; levers to increase their motivation and ability; and barriers to their participation.

The second group that may be interested in this research is that of researchers in the domain of business ecosystems. It may highlight the fact that there is a dearth of literature that addresses the creation of new ecosystems. It may also highlight the fact that further research is required to fully incorporate the concept of an OS ecosystem. Consideration of this emergent business form must evolve beyond simply a treatment of organizational sponsorship of pre-existing OS communities.

The third group that may be interested in this research is that of researchers in the domain of OS ecosystems. They may see value in using the operationalized Motivation/Ability Framework to analyze other industry contexts to determine whether or not they would support an OS ecosystem. The process outlined in this research may assist in identifying potential participants, levers to increase their motivation and ability, and also barriers that may restrict their participation in the ecosystem.

1.6 Organization

This thesis is organized into seven sections. This section provides an introduction to the research. Section two covers the relevant literature in the areas of: ecosystems; OS; the specific industry context; and the guiding methodology sources. Section three uses this literature to demonstrate that the research question has not been answered and is important to address. Section four explains the theory building through case study research method. Section five outlines the results, while section six provides a discussion of how the results may be generalized to other industries. Lastly, section seven covers the conclusions, limitations of the research, contributions, and areas for future research.

2 LITERATURE REVIEW

This literature review situates the research within the context of business ecosystems, OS ecosystems, open innovation and organizational participation in OS. It also describes the specific industry context that was the focus of this research. Lastly, it describes the methodology sources which guided the researcher.

2.1 Business Ecosystems

The existing literature strongly purports that a business ecosystem approach is essential in the current and future economic environments. Moore (2006) indicates that it is a key addition to modern business thinking. Competition among ecosystems is ultimately a fight over who will direct the future (Moore, 1993). Iansiti and Levien (2004c) also note that “battles in the future will be waged between ecosystems or between ecosystem domains” and not between individual companies. Gawer (2009) states that companies today cannot act in isolation; they must devise new strategies for competing within ecosystems. Bailetti (2009) provides a final note of caution: “ignore business ecosystems at your peril”.

The business ecosystem literature owes its origins in part to Moore’s stance that:

*“Innovative businesses can’t evolve in a vacuum. They must attract **resources** of all sorts, drawing in capital, partners, suppliers, and customers to create **cooperative networks**...[few theories existed to] help executives anticipate the managerial challenges of nurturing the **complex business communities** that bring innovations to market.” (Moore, 1993)*

Moore (2006) subsequently defines a business ecosystem as an intentional community of economic actors whose individual business activities largely share in the fate of the whole community. It is an explicit approach to organizational design and industry structure.

Bailetti (2009) goes further to define a business ecosystem as being comprised of both “companies and individuals that use a platform (assets, processes, norms) to co-create and deliver value to customers, partners, themselves and their overall community”.

These definitions highlight three key points about a business ecosystem. First, it is an intentionally created business community. Second, the members of this community may be organizations or individuals; and these members are motivated by their respective business models and objectives. Lastly, these members co-create and deliver value not only to customers, but also to themselves, their partners, and the entire community.

Several research streams address different aspects of business ecosystems. These include Moore’s work directly addressing business ecosystems (1993, 2006), the Platform Leadership work of Gawer and Cusumano (2002, 2008, 2009), and the Strategy as Ecology work of Iansiti and Levien (2004a, 2004b, 2004c, 2004d).

These streams address specific aspects of business ecosystems including: types of ecosystem participants; the importance of resources; the role of a platform; as well as participant roles and associated strategies. These aspects are discussed below, along with areas where the literature falls short of addressing how to create new ecosystems.

2.1.1 Participants

Business ecosystems are complex systems that involve a large number of interconnected and interdependent participants (Cusumano & Gawer, 2002; Iansiti & Levien, 2004c; Moore, 2006). These participants share a vision and a future (Cusumano & Gawer, 2002; Moore, 1993, 2006), and ultimately have a shared fate (Iansiti & Levien, 2004a, 2004c; Peltoniemi, 2006). The fact that the participants are continuously making decisions on their own behalf adds to the complexity of the system (Moore, 1993;

Peltoniemi, 2006). Participants in an ecosystem concurrently compete and cooperate (Cusumano & Gawer, 2002; Iansiti & Levien, 2004b), a practice that is referred to as co-evolution (Moore, 1993). Ultimately, the long-term success of the ecosystem depends upon the ability of its participants to continually innovate (Bailetti, 2008, 2009; Moore, 1993, 2006; Peltoniemi, 2006).

Several types of ecosystem participants have been suggested. Bailetti (2008) identifies six groups with which a company may interact in an ecosystem, and alludes to the fact that there may be additional groups. These groups and their distinct responsibilities are outlined in Table 1.

Table 1: Distinct Responsibilities of Business Ecosystem Participants

Leaders	• Sell key products and services that address a customer solution • Strong influence over: (i) foundation platform; (ii) network of producers and users; and (iii) customer solution
Complementors	Sell other products and services which increase the attractiveness of a company's offer
Competitors	Sell substitutes of a company's offer
Intermediaries	Integrators and distributors that must adopt a company's offer before it reaches customers
Customers	Pay for solutions and provide feedback on the value of solutions
Suppliers	Give, sell, or make available inputs to a company

Source: Bailetti (2008)

Iansiti and Levien (2004c) define a broader scope of ecosystem participants to include a loose network of: suppliers; distributors; outsourcing firms; complementors; technology providers; financial institutions; competitors; customers; regulatory agencies; and even media outlets. Of particular note, they suggest that it is impossible to draw precise boundaries around an ecosystem. Instead, they propose that a company should “systematically identify the organizations with which [its] future is most closely intertwined and determine the dependencies that are most critical to [its] business”.

2.1.2 Resources

The notion of resources may be considered central to a discussion of business ecosystems. Business ecosystems are distributed in nature, and as a result competition is less focused upon internal resources. Instead, the focus is upon the management and influence over assets that are external to an organization in terms of both ownership and control (Iansiti & Levien, 2004b, 2004d).

The success of a business ecosystem can be defined by the ability of its members to “produce outcomes and attract more resources with the ecosystem than without it” (Bailetti, 2009). In essence, an ecosystem has the potential to become greater than the sum of its parts (Cusumano & Gawer, 2002).

2.1.3 The Platform

The platform has a critical role in a business ecosystem. Gawer and Cusumano (2008) define an industry platform as “a foundation technology or service that is essential for a broader, interdependent ecosystem of businesses”. It attracts the investment and innovation of other firms in the form of complementary products/services (Gawer, 2009).

Iansiti and Levien (2004c) define a platform as an asset in the form of services, tools or technologies that offer solutions to other members of the ecosystem and enable them to enhance their own performance. The asset may be either physical (e.g. manufacturing capability) or intellectual (e.g. software platform).

Bailetti (2008) views an ecosystem foundation platform as the “combined base of technologies; architectures, designs and assets used to build market offers; components, products and services; contracts; and processes...[that] anchor [the] economic community”.

While Gawer (2009) purports that industry platforms are emerging or have emerged from existing ecosystems, others contend that a platform is fundamentally required in order for an ecosystem to exist. Milinkovich (2008a, 2008b) goes so far as to state that “without a platform, there can be no ecosystem”.

2.1.4 Participant Roles and Associated Strategies

Another way of looking at business ecosystems is to consider the roles that participants may play. The literature defines such roles and provides associated strategies. It presupposes that the business ecosystem already exists, and the strategies are tailored to its current and potential members. A review of this literature highlights that ecosystem creation requires a multi-faceted approach beyond simply a consideration of participants. It also identifies key constructs and concepts that are central to developing an understanding of business ecosystems.

Iansiti and Levien (2004a, 2004b, 2004c, 2004d) present the three key roles of keystone, niche player and dominator. These roles are not static. An organization contributes to the health and stability of its ecosystem by determining its role in the ecosystem and aligning its strategy accordingly.

Keystone organizations play a crucial role in business ecosystems and their removal could lead to the catastrophic collapse of the entire system (Iansiti & Levien, 2004c). They provide a stable and predictable set of common assets for other ecosystem members to leverage and build their own offerings upon (e.g. a platform). They also facilitate connections among ecosystem participants and encourage the creation of products complementary to the platform and existing offerings.

Niche players are organizations who become focused experts in a particular domain in order to differentiate themselves from other companies within the ecosystem. They “represent the bulk of the ecosystem and are responsible for most of the value creation and innovation” (Iansiti & Levien, 2004c).

Lastly, physical dominators aim to own and manage a large portion of the network. In so doing, they extract the maximum short term value from the portion of the system that they control. Once they have done so, an ecosystem strategy is no longer relevant (Iansiti & Levien, 2004c).

Iansiti and Levien offer strategies for keystones (Iansiti & Levien, 2004a, 2004b, 2004c) and niche players (Iansiti & Levien, 2004d). These are summarized in Table 2.

Table 2: Keystone and Niche Player Strategies

Two parts of a keystone strategy	Three drivers of a niche strategy
(1) Create value within the ecosystem. • Must do so effectively or fail to attract and retain members. • First requirement usually involves creating a platform. After doing so, the keystone generally leaves the majority of value creation to other ecosystem members. (2) Share value with other ecosystem participants. • Balance sharing with need to retain some of the value created. • Ensure the value of the platforms increase with the number of ecosystem members using them.	(1) Value creation: • Specialize in unique capabilities to defend against keystones or dominators trying to expand. • Leverage capabilities from keystones (tools, technologies, services, products). • Continually innovate. (2) Value sharing and risk management: • Tight coupling to a keystone can increase switching costs, vulnerability. • Loose coupling to several ecosystem members increases mobility, flexibility. (3) Innovation and niche evolution: • Create a novelty. • Seek out new terrain to remain distinct.

Source: Iansiti & Levien (2004a: 92-97, 2004b, 2004c, 2004d)

It is important to note that keystones generally create a platform in order to create value in an ecosystem; they then commonly leave the majority of value creation to the other members of the ecosystem. To create value, niche players specialize in unique

capabilities, leverage capabilities from the keystone, and continually innovate. By seeking out new terrain to remain distinct, a niche player may succeed in creating a new platform and become a keystone.

Cusumano and Gawer (2002) define the three key roles of platform leader, wannabe and complementor. Platform leaders are organizations that “drive industry wide innovation for an evolving system of separately developed pieces of technology”. Wannabes are striving to become platform leaders themselves. Lastly, complementors are organizations that produce “ancillary products that expand the platform’s market”.

The literature provides strategies for platform leaders (Cusumano & Gawer, 2002; Gawer & Cusumano, 2002), complementors (Cusumano & Gawer, 2002) and wannabes (Gawer & Cusumano, 2008). Table 3 provides a summary of these strategies.

Table 3: Platform Leader and Wannabe Strategies

Platform Leaders	Complementors	Wannabes
Four levers: (1) Scope: amount of internal vs. external innovation. (2) Product Technology: broader platform, product architecture, modularity, openness, interfaces, intellectual property (IP). (3) Relationships with external complementors: how collaborative or competitive? (4) Internal organization: internal structure, culture, processes, communication.	Complementors must: • Commit resources to innovations the platform leader likely won’t offer. • Track platform leader’s product plans for possible expansion into complementor domain. • React quickly to platform leader demands to avoid encouraging them to compete with complementor in future. • Create products that enhance, and evolve with, the platform leader’s core product.	Two key strategies: (1) Coring (how to create a new industry platform) • activities a company can use to identify or design an element (technology, product or service) to make it fundamental to a technological system and market. (2) Tipping (how to win platform battles) • activities companies can use to affect market dynamics and win a platform war.

Sources: Cusumano & Gawer (2002), Gawer & Cusumano (2002, 2008).

Platform leaders must consider issues related to the: scope of innovation they intend to perform; product technology; degree of collaboration and competition they wish to engage in; and required internal organization structure and processes. Complementors need to work closely with platform leaders and keep their business distinct. Wannabes can employ coring or tipping strategies to become platform leaders themselves.

Moore (1993) defines the roles within a business ecosystem less sharply. The roles of leaders, central ecological contributors, follower companies, supporters, members, producers and consumers are discussed and are not necessarily defined.

The role of the leader is valued by an ecosystem's members. Leadership enables ecosystem members to align their investments, find mutually supportive roles, and achieve a shared vision. Strong leaders may play the role of central ecological contributor, an organization that: the other members depend upon; maintains its status partly through follower investments; reinforces its role by making important innovative contributions to the ecosystem; and is valued by followers for its grip on customers.

Follower companies are those that enable a leader to provide a complete value package to customers. Leaders may compete with other ecosystems for the support of such follower companies and may seek to constrain followers from becoming leaders.

2.1.5 Building Business Ecosystems

Business ecosystems continue to be poorly understood (Iansiti & Levien, 2004c; Moore, 2006). Much of the literature focuses upon strategies for current and potential members of existing business ecosystems, and significantly less focus is placed upon strategies to create and evolve new ecosystems. This section highlights where the

literature falls short of addressing business ecosystem creation and identifies some of the possible insights that may be of value in this regard.

The existing business ecosystem literature does not directly address the challenge of building new ecosystems. Unfortunately, it only hints at what is required to do so. The previous sections suggest that the creation, and subsequent evolution, of a business ecosystem likely requires the consideration of many critical technical, organizational, and business issues. It highlights the fact that a multi-faceted approach is required.

Iansiti and Levien (2004c) indicate that a keystone's two-part strategy of value creation and sharing usually involves creating a platform to create value within the ecosystem. Their main focus is however, upon the health of existing ecosystems.

Moore's (1993, 2006) use of the term "intentional community" in his business ecosystem definition suggests that they are intentionally built and then evolve over time. Moore (2006) also presents the following key ideas related to building ecosystems:

- Managers establish business ecosystems to coordinate innovation
- Contributors must take the initiative and join together to create an ecosystem
- As an ecosystem forms, the combined base of technologies, designs, contracts, products and services become an infrastructure within which new contributors and customers can be added

Moore goes on to outline the four stages that every business ecosystem passes through: birth; expansion; leadership; and self-renewal. The actions of a company in the birth stage include: seeking to win by best defining and implementing the customer value proposition; and cooperating with follower companies to produce a complete value package for customers. A leader must emerge in the birth stage in order to guide the community in a process of rapid and ongoing innovation.

Unfortunately, Moore's work does not provide a focused strategy for potential initiators or managers of new business ecosystems. He provides only a general framework for describing a proposed ecosystem. To do so, managers must: identify the critical contributions (or niches) that are required to develop a business opportunity; make preliminary distinctions about modularization; and define the initial niche contributions and contributors that are required.

Gawer and Cusumano (2002, 2008) provide strategies related to ecosystem platform leadership. The four levers of platform leadership (recall Table 3) identify key issues that platform leaders must address (Cusumano & Gawer, 2002). These apply to participants in existing ecosystems; however, the levers could be taken into account in defining a plan to develop and evolve a new ecosystem.

In order to become a platform leader, a wannabe must address challenges that are both technological (i.e. architecture, interfaces, connectors, IP disclosure) and business-related (i.e. either make complements or encourage third parties to do so) (Gawer & Cusumano, 2008). These considerations may also inform creators of new ecosystems.

The coring strategy for wannabes provides several technology and business actions worthy of consideration by potential ecosystem initiators (see Table 4).

Table 4: Coring – Technology and Business Actions

Technology Actions	Business Actions
• Solve an essential ecosystem problem • Facilitate the provision of add-ons • Keep core technology IP closed • Maintain strong interdependencies between platform and complements	• Solve an essential business problem • Create incentives for complementors • Protect your main source of value • Maintain high switching costs to competing platforms

Source: Gawer and Cusumano (2008)

The Eclipse Foundation is a non-profit organization that provides an out-of-the-box framework for building the collaboration required to create an ecosystem (Milinkovich, 2008a). Its Executive Director indicates that four critical processes must be in place before creating an ecosystem, these are: a licensing framework; a governance process; a development process; and a project management process. These can be built from scratch in order to create a new self-governing consortium; however, initiators may lose momentum as they endeavour to coordinate the agendas of each potential participant.

2.2 Open Source

Open source (OS) has emerged as a development method for software (Open Source Initiative, 2007b; Pearce & Bailetti, 2007). The OS development approach encourages openness, transparency, meritocracy, and allows anyone to participate (Milinkovich, 2008b). Its licensing permits competing vendors to collaborate on the infrastructure technology without the requirement for royalties or a single point of control for IP (Milinkovich, 2008b). The OS business model also encourages the rapid adoption of technology because it is offered at no cost and is easy to access (Milinkovich, 2008b).

OS is not simply about providing access to source code. The OS definition maintained by the Open Source Initiative states that the distribution terms of the software must comply with certain criteria beyond simply the provision of source code (Open Source Initiative, 2007a). These criteria include: free redistribution; permission to allow modifications and derived works; protection of the author's source code; and no discrimination against persons, groups, or fields of endeavour. As well, the OS license must apply to all those to whom the program is distributed, and cannot be specific to a product or technology, or restrict other software.

2.3 Open Source Ecosystems

There has been little focused research upon OS ecosystems (Wynn, 2008). The business ecosystem, OS, open innovation, and OS ecosystem literature all fails in some way to fully address the concept, and unique aspects, of OS ecosystems.

This section first discusses the definitions of an OS community and an OS ecosystem that are provided in the literature. It then presents the contributions and shortcomings of the business ecosystem, open innovation, and OS ecosystem literature.

2.3.1 OS Community

In order to define an OS ecosystem, it is first important to discuss the definition of an OS community. An OS community is traditionally defined as “a group of developers and users who share a common interest in a project, and who regularly interact with one another to share knowledge, and collaborate in the solution of common problems” (Weiss & Moroiu, 2008: 48). This definition suggests the absence of organizational participation.

Wynn (2008) describes a typical OS project as one in which the developers are primarily volunteers and the software emerges from a loosely coordinated, unsupervised community of developers and other contributors who come together for reasons of: self-interest, profit motives, or protest against large closed-source software providers. There is typically no formal organization or corporate structure. This definition suggests a lack of organizational participation in addition to the absence of a strict governance structure.

An OS development community has also been defined in the literature as “a community composed of individuals who collaborate toward a common goal but do not share a common employer and are not generally governed by an employment hierarchy”

(West & O'Mahony, 2008). This definition does not necessarily suggest the absence of organizational involvement but it does allude to the lack of a strict governance structure.

2.3.2 OS Ecosystems

The limited OS ecosystem literature suggests that the types of participants and focus of an OS ecosystem differ from that of an OS community. An OS ecosystem includes both individuals and organizations, and generally encompasses a greater business focus than an OS community.

Wynn (2008: 242) describes an OS ecosystem as a complex web of vendors, supporting foundations, external service partners, integrators, distributors, consultants, third party entities, developers, and users. He defines an OS ecosystem as:

“an arrangement of individual and organizational units, involved in or affecting the circulation, transformation, and accumulation of capital (in various forms) in order to provide cooperative development, testing, marketing, distribution, implementation, and support of open source software”.

The various forms of capital are defined in Table 5. This research suggests that an OS ecosystem involves both organizations and individuals, as well as a clear business focus. It also suggests that an OS ecosystem is not purely driven by financial motives.

Table 5: Forms of Capital in OS Ecosystems

Form of Capital	Definition
1. Human	The skills, knowledge, and abilities of an individual that can be used to generate income or other useful outputs.
2. Social	Has three dimensions: structural, cognitive and relational.
3. Symbolic	The accumulation of goodwill and prestige within a social system would be a fitting example of symbolic capital.
4. Organizational	The accumulation of routines and processes by an organization/group.
5. Economic	The financial form of capital (\$\$\$\$).

Source: Wynn (2008: 244)

Pearce and Bailetti (2007) base their OS ecosystem discussion upon Moore's (1993) business ecosystem definition of “a community of organizations and individuals

that generate value to a set of customers”. This community is “often anchored around a central set of products...that are offered by lead producers and the open source projects on which they depend”. The lead producers provide the direction for product evolution and ecosystem leadership. The community is comprised of: lead producers; producers of complementary products; competitors; customers; and additional stakeholders as applicable. Again, this definition suggests that an OS ecosystem involves the participation of organizations and individuals, and implies a clear business focus.

The aforementioned research suggests that an OS initiative enters the realm of OS ecosystem when it evolves to include organizational participation and a clear business focus. It is possible to envision that an OS ecosystem could evolve from, include, or be led by an OS community. Alternatively, an OS ecosystem could be created solely by organizations out of commercial interest. The scope of OS ecosystem participants extends beyond that of an OS community of developers and users to include the complex interactions, interdependencies, and shared fate of organizations, groups, and individuals. It also includes a clear business focus and a formal governance structure.

The Executive Director of the Eclipse Foundation has a much different view of OS communities and OS ecosystems that is based upon the Foundation’s practical experience as the non-profit keystone of a well-established OS ecosystem (Milinkovich, 2009). In the broadest sense of its definition, an OS ecosystem is said to include “everyone who has ever downloaded a copy of Eclipse, anybody that has ever used Eclipse in any of its forms” (Milinkovich, 2009).

The Eclipse Foundation aptly thinks of an OS community as a smaller subset of the broader ecosystem. It is the “group of people and companies [that] are actually actively

engaged with other people and self-identify as [being] involved in [the OS ecosystem]” (Milinkovich, 2009). The Foundation considers the definition of an OS community made up of “a group of developers and users” (Weiss & Moroiu, 2008: 48) to be a classic, and potentially limiting, view of OS. From an Eclipse perspective, it is more appropriate to use the following definitions (Milinkovich, 2009):

- The business ecosystem is the business network that lives on top of the platform.
- The OS community is a form of collective that is usually working on creating and evolving the platform.

Essentially, the traditional discussions “are really talking about the group of people that are building the platform that is enabling the ecosystem” (Milinkovich, 2009).

2.3.3 Business Ecosystem Literature and Open Source Ecosystems

The business ecosystem literature largely fails to contemplate and adequately address the concept of an OS ecosystem. It does so by: generally not considering a completely open platform; generally assuming for-profit leaders; implying the need for varying degrees of secrecy; and assuming that a strong central player is required to control a platform and guide the ecosystem (Milinkovich, 2008b).

OS is only briefly considered in a business ecosystem context by Moore (2006). Unfortunately, he focuses solely upon organizational involvement in pre-existing OS ‘volunteer developer communities’. Companies subsidize these for two reasons: to lower the costs of their goods; and to commoditize or destabilize commercial rivals. They “selectively enhance a pre-existing, volunteer-centered peer-production community and fuse its capabilities into their own...more commercial business ecosystems”. This treatment of OS is similar to that of Milinkovich (2009), where an OS community is said

to be a subset of a larger ecosystem; however, it does not consider that organizations and individuals could create a new OS ecosystem and associated OS community.

2.3.4 Open Innovation Literature and Open Source Ecosystems

Open innovation is similar to the concepts of business and OS ecosystems. It involves a firm realigning its innovation strategy to extend beyond a firm's boundaries (West & Gallagher, 2006) in order to harness collective creativity (Chesbrough & Appleyard, 2007). This requires new strategies because the focus is shifting from ownership to openness (Chesbrough & Appleyard, 2007); where openness is defined as "the pooling of knowledge for innovative purposes where the contributors have access to the inputs of others and cannot exert exclusive rights over the resultant innovation".

The open innovation literature uses OS development as an example of open innovation, however, it largely: focuses upon OS communities of individual developers; can be openly critical of commercial involvement in OS; and complicates the understanding of the differences between OS communities and ecosystems. It does, however, provide some insights that may be extended to OS ecosystems.

Chesbrough and Appleyard (2007) indicate that the key strategic challenge of open innovation is to determine how to capture and sustain the created value without alienating the individuals, communities, or ecosystem members that are responsible for the continued innovation. Despite its reference to ecosystems, their work focuses upon OS communities of individual developers. Commercial involvement in OS is harshly criticized as: skewing the governance of OS projects; diminishing the role of the individual; as well as co-opting or hijacking the agendas of OS communities.

West and Gallagher (2006) define three open innovation challenges: finding ways to exploit internal innovation; incorporating external innovation into internal development; and motivating external innovations. They also provide four OS strategies:

- **Pooled R&D/Product Development** – firms donate IP to an OS project and exploit the contributions of others to sell related products (e.g. Linux).
- **Spinouts** –firms transform internal development projects to externally visible OS projects (e.g. Eclipse).
- **Selling complements** – firms leverage OS software to sell complementary products and services (e.g. Apache).
- **Donated complements** – firms make money off of the core innovation, but also seek donated labour for valuable complements (e.g. Half-life).

Without expressly saying so, the researchers are addressing firm involvement in OS ecosystems and OS communities. Unfortunately, they do not address the possibility of firms building and leading their own OS ecosystems and associated OS communities.

West and O'Mahony (2008) come the closest to considering an OS ecosystem; however, their use of the following terminology presents some potential confusion:

- **Autonomous OS community**: one that is presently independent of any one firm and is community managed.
- **Sponsored OS community**: one where one (or more) corporate entities control the community's short and long-term activities.

The definition of an autonomous OS community resembles the traditional definition of OS community provided by Weiss and Moroiu (2008: 48) (recall Section 2.3.1). The sponsored OS community definition more closely resembles that of an OS ecosystem.

The authors examine how a sponsor designs and builds an OS community as compared to the autonomous approach (West & O'Mahony, 2008). The concept of a

participation architecture is used as the basis of comparison. The architecture's design affects the level of participation in the community, so a sponsor must address issues of: organization of production; governance; and intellectual property (IP). Organization of production covers: live code access; openness of the commit process; and support for subproject creation. Governance involves issues of membership and fees, release authority, and whether to take a non-profit foundation approach. Issues related to IP include licensing, content and subproject ownership.

The authors make a key point about OS licensing: it may be reciprocal, permissive, or have elements of both (West & O'Mahony, 2008). A reciprocal license imposes obligations on the recipient, for example they must return modifications or changes. A permissive license allows recipients to use the code largely without restriction, for example it would impart favourable redistribution rights and allow derivative works.

2.3.5 Levels of Governance

Several approaches to OS ecosystem governance are discussed in the literature, these include: a management team; a non-profit foundation; or corporate sponsorship.

Pearce and Bailetti (2007) suggest that the governance structure of an OS ecosystem often mirrors the three tiers of roles commonly found in OS projects:

- **Management team (top tier):** most influential tier; team provides project direction, makes high-level design decisions, maintains the project roadmap.
- **Maintainers (middle):** individuals with trusted status within the project; manage and participate in code base development; allocate development tasks to lowest tier; often the only developers permitted to upload files to the current code base.
- **Supporting developers:** individuals who provide bug fixes and code enhancements to the maintainers; provide the bulk of the code-level contributions.

The management tier provides the ecosystem leadership and controls the product direction; the middle tier controls the source code details; and the lowest tier provides the work force to drive the project forward.

The management tier of an OS ecosystem “often has a consortium of stakeholders who participate” in this tier and who may incur costs in the form of membership fees and a commitment to support the project (Pearce & Bailetti, 2007). Similar to West and Gallagher’s (2006) notion of membership and membership fees, “a common model for participation [in the management tier] includes a process whereby participants can purchase a seat [in this tier and]...provide contributors and developers in support of particular aspects of the project” (Pearce & Bailetti, 2007).

West and O’Mahony (2008) compared autonomously- and sponsor-created OS communities. They found that all five of the individually founded, and only two of the twelve sponsor-founded, communities “created a formal, legal, non-profit foundation to help manage community governance and assets”. Non-profit foundations “provide institutional permanence independent of any one individual, as well as legal status to negotiate with external entities (largely for the provision of resources)”.

Non-profit and for-profit ecosystem leaders play very different roles within their respective ecosystems. This was articulated by Milinkovich (2009):

“When the ecosystem keystone is a not-for-profit entity as opposed to a for profit entity, [it is] a trusted agent in the behaviour of the ecosystem as opposed to a potential competitor...In the commercial context, the keystone is creating the ecosystem for their own commercial gain. It is pretty obvious that if there is any niche that gets too big or if there is a business opportunity, they will feel free to enter into that niche and take out the incumbents. Because as the platform vendor they will have an incredible opportunity and they will always win those competitions.”

2.4 Organizational Participation in Open Source

The majority of the literature related to participation in OS focuses upon the motivations of the individual developer. Very little literature addresses organizational participation in OS, and even less addresses such participation in OS ecosystems. This literature is largely not applicable to the consideration of participation in OS ecosystems.

Wichmann (2002) indicates that company motivations to participate in OS are not as well understood as those of individual developers. Some firms contribute to OS projects as part of a deliberate strategy to finance the development of OS software, while others make previously proprietary software available as OS. As well, companies may proactively release their code as OS in order to boost the profits of a complementary segment. Table 6 outlines the four major firm motivations.

Table 6: Four Major Motivations of Firm Participation in Open Source Activities

1. Standardization
• Avoid multiple variants of software   • Reduce the number of combinations of hardware and software
2. OS software as low cost component
• OS is lower cost   • Bundle OS with other software and hardware to lower the cost to the customer.
3. Strategic considerations (contributing to OS projects or releasing proprietary code as OS)
• To steal market share from competitors or weaken a competitor   • To prop up the competitors of their rivals
4. Enabling compatibility
• Make their own software or hardware compatible with OS software

Source: Wichmann (2002)

Bonaccorsi and Rossi (2006) empirically analyze the motivations of firms in comparison to those of individual programmers. They found significant differences in motivations: "Firms emphasize economic and technological reasons for entering and contributing to open source and do not subscribe to many of the social motivations that

are typical of individual programmers” (Bonaccorsi & Rossi, 2006). Table 7 outlines the taxonomy of firm motivations developed by the authors.

Table 7: Taxonomy of Firm Motivations to Carry Out Open Source Activities

Area	Specific Motivations
Economic	• Independence from price and license policies of large software firms • Make money on complementary services or by selling related products • Afford innovation by exploiting the R&D activity of an OS community • Source of good IT specialists
Technological	• Exploit developer contributions to cut costs, improve the software • Exploit user community contributions to test/improve the software • Cut hardware costs • Promote standardization • Address security issues
Social	• Conform to the values of the OS community • Share code/knowledge with the community • Believe software should not be a proprietary good

Source: Bonaccorsi & Rossi (2006)

The Eclipse Foundation’s Executive Director applied a five-stage maturity model for firm participation in OS to a consideration of participation in OS ecosystems (Bailetti, 2006; Carbone, 2006, 2007; Milinkovich, 2008b). Figure 1 depicts the model.

Figure 1: The Open Source Ecosystem Engagement Model

Source: Carbone (2007)

“The way we look at a company’s ability [to participate in the Eclipse ecosystem] almost intersects with the maturity model. If [a company] is not at least a level or two up the maturity curve, there is not a lot of point in talking to them at all” (Milinkovich, 2009). Milinkovich (2008b) also describes the business reasons associated with engaging in an OS project at each stage in the maturity model (see Table 8).

Table 8: Business Reasons for Companies to Engage in OS Projects

Stage	Business reasons relevant at this stage
1. Use	• Explore • Reduce build costs • Decrease time to market
2. Contribute	• Fill gaps in feature set of a company’s product • Improve software quality
3. Champion	• Lead, represent, and support an OS project • Steer new functionality and its evolution
4. Collaborate	• Gain positional advantage for a company’s product in a market segment
5. Redefine	• Change the value proposition of the customer offer

Source: Milinkovich (2008b)

2.5 Specific Industry Context

In order to conduct this research, the researcher chose to analyze the specific industry context of distributed simulation. This section provides the background required to understand this industry context by explaining the broader modeling and simulation (M&S) context, and then addressing the specific distributed simulation context. There are several frameworks for distributed simulation, and this research focused upon one of these: the High Level Architecture (HLA).

2.5.1 Modeling and Simulation

Modeling and simulation (M&S) has a wide range of uses within industry, government, research and academia. While the technical literature contains various

definitions of model and simulation (Coolahan, 2005), the following define what is meant by M&S in this research:

- **Model:** a physical, mathematical, or otherwise logical representation of a part of the real world in which only those properties believed to be relevant to the problem being examined are represented explicitly.
(Applied Mathematics and Operational Research Group, Cranfield University.
As quoted in (DND SECO, 2007))
- **Simulation:** a method for implementing a model over time.
(Department of Defense, 1995)

M&S plays a key role within defence activities worldwide. The business implications of involvement with defence M&S cannot be ignored. The United States' Department of Defense (US DoD) alone spends billions of dollars annually on its M&S-related activities (US DoD M&S Steering Committee, 2007).

M&S has a presence within defence communities around the world. The US DoD's M&S Coordination Office (M&S CO) has defined six major defence communities that are highly enabled by M&S, these are: acquisition; analysis; planning; testing; training; and experimentation (US DoD M&S Coordination Office, 2008).

The Canadian Department of National Defence (DND) defined a role for M&S in the modernization of the Canadian Forces (CF) in its Strategy 2020 (Department of National Defence, 2008). The DND Synthetic Environment Coordination Office (DND SECO) was also created to "provide a full time focal point for information, coordination and support concerning DND/CF modeling and simulation activities" (DND SECO, 2007). DND SECO has promulgated two CF administrative orders which outline both DND M&S policy and management (DND, 2006a, 2006b).

On an even broader scale, the North Atlantic Treaty Organization's (NATO) Research and Technology Organization (RTO) contains the NATO Modeling and Simulation Group (NMSG). The NMSG mission is to "promote cooperation among Alliance bodies, NATO Member Nations and [Partnership for Peace] Nations to maximize the effective utilization of M&S" (NATO RTO, 2009).

2.5.2 Distributed Simulation and the High Level Architecture

Within the broad M&S domain, this research focuses upon the distributed simulation industry. Distributed simulation is primarily used to create a unified simulation model by composing two or more individual simulation models that are located on networked systems (Law, 2007). These systems may be co-located or geographically dispersed.

Distributed simulation may incorporate any combination of the three basic types of simulation: live, virtual and constructive. These are defined as (DND SECO, 2007):

- **Live:** involve real people, real equipment and simulated effects
- **Virtual:** involve real people, simulated equipment, and simulated effects
- **Constructive:** involve simulated people, simulated equipment and simulated effects.

Interest in distributed simulation is said to have originated from a defence interest in creating real-time, human-in-the-loop simulations for training military personnel (Hollenbach & Alexander, 1997; Law, 2007). Initially a set of protocols for interconnecting simulations, called the Distributed Interactive Simulation (DIS) (IEEE, 1993), was created; DIS was then followed by the High Level Architecture (HLA).

The HLA was developed by a US DoD-led consortium that consisted of major simulation programs and representatives from government, academia and industry

(Hollenbach & Alexander, 1997). This approach was meant to: enable broad community participation in the development process; foster ownership of the HLA; and expand the technical experience base (Hollenbach & Alexander, 1997).

The US DoD initially maintained the HLA specifications. In 2000, it was formally approved by the Institute of Electrical and Electronics Engineers (IEEE) as the 1516 series of HLA specifications. Despite evolving into an IEEE standard, the HLA is still predominantly used within a defence context. Several small forays have been made into domains such as health and transportation, but not to the same extent as in defence.

The HLA is an architecture that was designed to promote simulation reuse and interoperability (Coolahan, 2003; Law, 2007). Coolahan (2003) described that “the need for the HLA was based on the premise that no single simulation system could satisfy the needs of all users, and thus an architecture was required for composing unified simulation environments from multiple, interacting simulation systems”. Hollenbach and Alexander (1997) provide a fitting summary of the HLA:

“The HLA is not software but a set of rules and specifications that prescribe how simulations, live systems (e.g. command and control systems), and supporting utilities such as data collectors and wide-area viewers will work together...The HLA separates the representations, provided by simulations or live systems, from the general interconnection services, provided by a Runtime Infrastructure (RTI).”

There are two key constructs which are central to an understanding of the HLA, these are federates and federations. A federation is defined as “a set of software applications interacting together...to form a unified simulation environment” (Coolahan, 2003). Each member of a federation is called a federate. A federate is a “software

application [that] can represent a simulation, a runtime tool, or an interface application to a live participant in the federation” (Coolahan, 2003).

The HLA is made up of three key components: rules; an interface specification; and an object model template. Their roles are as follows (Hollenbach & Alexander, 1997):

- **HLA Rules:** establish the requirements for federates and the federation.
- **HLA Interface Specification:** describes the ways simulations interact with the supporting RTI software during a federation operation.
- **HLA Object Model Template:** specifies a standard form in which to describe federates and federations.

2.5.3 The Runtime Infrastructure

The RTI is a “distributed operating system with services that support and control the exchange of information among federates during execution” (Coolahan, 2003). In simpler terms, it is the operating system of a distributed simulation (Pokorny, 2008). It is important to note that the HLA does not specify a particular software implementation of the RTI, it simply states that there must be an RTI (Hollenbach & Alexander, 1997).

Initially, the US DoD freely and openly distributed an RTI. This RTI is no longer freely available or easily accessible. With the HLA’s evolution to an IEEE standard, the development, maintenance, and provision of RTIs shifted to a commercial model. M&S companies now develop and sell RTIs and complementary tools.

Despite strong commercial involvement in the HLA, defence still has a pervasive role. The US DoD funds the certification of commercial RTI compliance to the HLA standard (Coolahan, 2008; Saunders, 2008). The certification process involves rigorous testing and verifies RTI compliance to the HLA Interface Specification. A small number of commercially- and consortium-developed RTIs have obtained such certification.

The weight associated with compliance to the HLA standard is significant. NATO recognizes the HLA as its preferred simulation interoperability standard. It also states in its Standardization Agreement (STANAG) 4603 that “when procuring or developing applicable new modeling and simulation systems, they will, based on their national requirements, ensure that the systems are compliant with the IEEE 1516 series of standards” (Tolk, Turnitsa, Ohlund, & Sursal, 2006).

2.6 Open Source and the High Level Architecture

This section addresses both the presence and lack of OS within the distributed simulation HLA industry. The literature suggests that this industry lacks a cohesive OS community. It also suggests that both the industry and the HLA standard would benefit from an OS RTI implementation. Some literature even purports that the industry would benefit from an OS ecosystem that leverages an OS RTI and complementary products. This section also discusses the state of existing non-commercial RTIs.

2.6.1 Lack of an Open Source HLA Community

The noticeable absence of an OS community surrounding the HLA and distributed simulation has been noted by Pokorny (Pokorny, 2006). Despite the existence of the following characteristics in common with mainstream software development industries, the distributed simulation domain still lacks a thriving OS community:

- Strong technological focus
- Large emphasis on standards
- Involvement of enterprise software vendors and global corporations
- Software development focus
- Strong need for tool support

Stratton et al (2004) stress the need for an OS RTI community. They suggest that the development of such a community would address the risks to the HLA standard of: ceasing to evolve; remaining viable; and preventing its being bypassed by a newer and more relevant simulation standard. They identify the following three key motivations for developing an OS RTI community:

- Develop a reference RTI for research and development (R&D) purposes
- Increase responsiveness to user needs
- Reduce the cost of entry

After studying three existing non-commercial RTIs that were available as either open source or source-available, they suggest that each would make “a strong starting point for developing an open source RTI community”.

2.6.2 Open Source Needs of the HLA Community

The OS needs of the HLA distributed simulation community are not solely focused upon an OS RTI. As stated by Pokorny (2006), “while essential to the development of any HLA-based distributed simulation, there are numerous needs beyond the provision of a freely available RTI”. The literature suggests that the following are also required: OS federates and federations, freely accessible educational resources (Pearce & Bailetti, 2007); and OS tools which support development (Pokorny, 2006). Stratton et al (2004) suggest that an OS RTI could provide commercial opportunities to fill the aforementioned needs in the areas of: training; consulting; development of complementary products; publications; and distribution.

The importance of an OS RTI to the research community is also stressed. The literature suggests that an active R&D community is necessary for maintaining the

evolution and currency of a standard (Stratton et al., 2004). It also suggests that such a community requires access to a reference implementation of that standard in order to prototype, validate, and propose changes (Stratton et al., 2004). Without a freely available and open source implementation of the RTI in the research domain, considerable effort is expended in creating the baseline environment in which to conduct research; this reduces the time available to address the focus of the research and may lead to the 'reinvention of the wheel' (Pokorny, 2006).

2.6.3 Non-Commercial Runtime Infrastructures

Within the distributed simulation community there is an awareness of the existence of many non-commercial HLA RTIs. A search of the Internet will also yield reference to several (Google, 2009a, 2009b; Wikipedia, 2009). A listing of these is provided in Appendix 1.

Many of these non-commercial RTIs are immature implementations, likely dormant, and implementations of the early US DoD standard (Canazzi, 1999, 2000; Kapolka, 2003; Mendez, 2007; Newcomb, 2007). One appears to only be available in Chinese (Beihang University, 2009), another requires reworking to update components that are no longer supported (Van Ham & Pearce, 2006), and yet others control or restrict access in some way (Calvin, Chiang, McGarry, Rak, Hook, & Salisbury, 1997; Ceranowicz & Torpey, 2005; Georgia Tech, 2003a, 2003b; Huiskamp, 2008; Jansen, Huiskamp, Brasse, & Boomgaardt, 2004; McLean & Fujimoto, 2001).

There are, however, several mature implementations for which documentation and source code is readily available and accessible online (CERTI; Noulard et al., 2009;

ONERA; P&P Software, 2007, 2009; Pokorny, 2009b; Pullen, Laviano, & Moreau, 1997; Pullen & Moreau, 1997a, 1997b; the poRTico project, 2008b).

The non-commercial RTIs listed in Appendix 1 have been created either as personal initiatives, or in response to the needs and interests of academic institutions, research institutions, or government agencies. None of these RTIs was initially created with an OS ecosystem in mind. It has been suggested that the progress of some of these has been “hampered by [their] lack of a supporting ecosystem motivated by business models” (Pearce & Bailetti, 2007).

Of the RTI initiatives listed in Appendix 1, only two have publicly articulated their desire to increase adoption and take action to grow their respective communities beyond their initial target audience. These are CERTI and the Portico Project.

CERTI is an OS RTI project that was developed at ONERA, the French Aerospace Lab (ONERA). It was open sourced in 2002, after which time it saw varying degrees of activity driven by the needs and funding of its research projects (Noulard et al., 2009). From 2006 onward, it has experienced a surge in development activity as a result of interest from the OS user community (Noulard et al., 2009). It is now described as an OS project that is structured around a user community. CERTI’s OS community has been instrumental in contributing complimentary software components to the project. The goals of the CERTI project are now to increase the adoption and awareness of the HLA, as well as to develop an international OS community around distributed simulation. Noulard et al go so far as to preliminarily conclude that “there is a potentially growing open source community for [an] Open Source RTI”.

The precursor to the Portico Project, jaRTI, was initially developed to meet the core development team's need for a freely available RTI (the poRTIco project, 2008a). The Portico Project superseded jaRTI in order to achieve broader acceptance, present a more professional image, and garner funding to sustain the project's development and long-term growth (Pokorny, 2007a; the poRTIco project, 2008a). While a major goal was to "provide a free RTI", the project was also "motivated by a desire to connect a community" (Pokorny, 2007b). The re-branding of jaRTI was meant to help "expand the user base of the project and continue to grow the community" (Pokorny, 2007a).

Stratton et al (2004) suggest that in order to build the requisite momentum behind an OS RTI, that the following elements are necessary:

- A strong inner circle of developers (e.g. from existing simulation research centres, academic institutions, and government funded groups)
- Processes for maintaining and distributing the RTI
- A stable 1.0 version to facilitate R&D and prototyping activities
- An awareness campaign

These elements are similar in nature to the requirements necessary for initiating an OS ecosystem noted by Milinkovich (2008a), including: a licensing framework; governance, development and project management processes; and a platform.

Stratton et al (2004) further suggest that given the size of the HLA community, a possible approach to rapidly developing the necessary support network could involve the participation of a number of educational institutions that are willing to form the initial core group.

2.7 Methodology Sources

Three key methodology sources guided this research: a categorization framework; a theory; and a process. The most important of these was the Motivation/Ability Framework. It provided the necessary elements to analyze the specific industry context, identify potential OS ecosystem participants, and draw conclusions about whether the context was favourable to creating an OS RTI ecosystem. Resource Dependence Theory was key to defining motivation, ability and constraint in terms of the resources an organization considers valuable. The Cycles of Theory Building provided guidance to develop circumstance-based theory rather than attribute-based theory and defined a process of theory building. The following sections discuss these sources.

2.7.1 The Motivation/Ability Framework

The Motivation/Ability Framework provides an approach to analyze the current state of an industry and identify the action required to ensure that innovation thrives within that industry (Anthony et al., 2002; Christensen et al., 2004). It is specifically geared towards non-market actors (e.g. governments, regulators) who assess and take action to stimulate a market. According to the framework, two factors are present in markets where innovation flourishes, these are (Christensen et al., 2004: 21, 74):

- **Motivation:** pot of gold or market incentives to entice companies to innovate.
- **Ability:** the capability to obtain resources, craft them into a business model, and offer products and services to customers.

There are many non-market factors that affect the motivation and ability of would-be innovators within a market. These factors can include industry standards, cultural norms, the state of technological development, and government regulation, to name a few.

The framework revolves around a 2x2 matrix (see Figure 2). Each quadrant within the matrix defines a distinct industry situation. Essentially, the framework suggests that innovation will flourish when companies have the requisite motivation and ability.

Figure 2: The Motivation/Ability Framework

Generally determined by: - Market size/growth - Competitive dynamics, industry standards - Economics of opportunity, business model attractiveness - Competitive forces Government levers: - Tax treatment (credit, subsidies, etc) - Antitrust policy - Competitive policy - Rate regulation - Regulatory asymmetry - Network element pricing	Motivation	High	Looking for a Target Firms constrained in accessing resources or reaching potential customers	The Hotbed Teeming with innovation		
		Low	The Dilemma No readily available avenues to create profitable businesses	Looking for the Money Firms struggle to find ways to monetize an opportunity		
		Low			High	
		Ability				
			Generally determined by: - Resource availability - Standards - Market access - Industry development	Government levers: - Resource-related regulation - Unbundling - Standards		

Source: Christensen et al. (2004: 75)

The framework assists in defining separate levers to increase motivation and ability, and can also be used to assist in identifying barriers that impede the progress of innovation. It is important to note that (Christensen et al., 2004):

- Given enough motivation, organizations can overcome constraints on their ability
- Ability is often less powerful than motivation
- The best approach to resolving a dilemma is to address one or two of the primary barriers first; and it is best to address motivation before ability.

Several key points associated with the distinct industry situations are worthy of note, these include (Christensen et al., 2004):

- **The Hotbed:** this is where innovation flourishes, and is generally where technology-related industries reside.
- **Looking for a Target:** firms can see the incentives but they are constrained in their ability to reach them. Given enough motivation, innovators can overcome constraints on their ability.
- **Looking for the Money:** this is where firms have the ability to create and offer products and services to customers, but they have no motivation to do so. Without incentives to innovate, innovation is unlikely to occur.
- **The Dilemma:** firms neither have the motivation nor ability to innovate. Firms will be unable to create and exploit innovations in this situation.

The application of the Motivation/Ability Frameworks involves the three steps shown in Table 9. The first step requires an analysis of the motivation and ability of current and potential market players. The participants are then plotted on the motivation/ability matrix according to their motivation and ability. This facilitates classifying the participants, identifying primary barriers to innovation, and drawing conclusions about whether the context is favourable to innovation. The second step involves assessing if there are any actions currently being taken by other non-market players. As well, other possible actions may be considered that may address the barriers that exist. The final step involves determining if the chosen actions address the primary barriers to innovation. The evidence of this would be that industry players have moved towards the Hotbed situation.

Table 9: Steps to Applying the Motivation/Ability Framework

Step	Key Points
1. Analysis and Mapping	• Identify the target market or technology • Analyze current and potential players • Classify the participants by plotting them on the Motivation/Ability matrix • Identify the primary barriers to innovation
2. Assessment of Actions	• Identify non-market players currently taking action to effect motivation and ability • Identify potential actions that will address the primary barriers
3. Act Against Primary Barriers	• Take action, assess actions currently being taken • Determine if actions address the primary barriers (will successfully promote innovation)

Source: Anthony et al. (2002), Christensen et al. (2004: 21, 91)

Several important implications of using the framework are identified by Anthony et al (2002). These are as follows:

- **Motivation's double-edged sword.** Increasing motivation for one class of industry participant may lead to a decrease in motivation for another.
- **Motivation is often more powerful than ability.** Giving ability may appear to be an easy solution; however, without motivation, doing so can be ineffective. Ability is often less powerful than motivation.
- **Avoid the do-everything approach.** In a dilemma, avoid the desire to attempt to resolve everything at once. It is best to address one or two of the primary barriers, and also to address motivation before ability.

The framework also has one key shortcoming in that it is not effectively operationalized for use by practitioners. There is no comprehensive process to follow in order to analyze the current and potential market players and plot them on the motivation/ability matrix. The application of the framework currently involves more of a conceptual thought process.

2.7.2 Resource Dependence Theory

Resource Dependence Theory's (RDT) fundamental contribution to this research is the use of the concept of resources to think about organizational motivation, ability and constraint. RDT is also said to be applicable to an understanding of ecological theories of organizations (Tillquist et al., 2002). Two key definitions are important to RDT:

- **Resource:** anything that is perceived as valuable by an actor, such as information, material, capital or access to markets (Tillquist et al., 2002).
- **Dependency:** a state in which one actor relies on the actions of another to achieve particular outcomes (Tillquist et al., 2002).

RDT argues that all organizations need to engage in exchanges with their environment in order to obtain resources (Barringer & Harrison, 2000). Organizations enter into inter-organizational relationships either to exert power or control over other organizations that have scarce resources, or in order to fill a perceived resource need. RDT focuses on resources that must be obtained from external sources in order for an organization to be successful.

In RDT, dependencies between organizations are said to arise out of the need to acquire resources, since organizations that are lacking in essential resources will seek to establish relationships with other organizations that will meet their resource needs (Barringer & Harrison, 2000; Tillquist et al., 2002). In order to successfully manage these dependence relationships, organizations seek to: acquire control over resources that minimize their dependence on other organizations; and acquire control over resources that maximize the dependence of other organizations on themselves (Barringer & Harrison, 2000; Ulrich & Barney, 1984).

2.7.3 Cycles of Theory Building

The value of theory is said to be its predictive power (Carlile & Christensen, 2005).

A theory may be defined as a “statement predicting which actions will lead to what results and why” (Christensen & Raynor, 2003). Good theories help make predictions and interpret the present in order to better understand what is happening and why (Christensen & Raynor, 2003). In order to achieve the lofty goal of a ‘good theory’, it must be circumstance-based rather than attribute-based (Christensen & Raynor, 2003). Carlile and Christensen (2005) refer to circumstance-based theory as normative theory, and attribute-based theory is referred to as descriptive theory. It is normative theory that has the greater predictive power.

Christensen and Raynor (2003) define a process of theory building that includes three stages. These stages are depicted in the pyramid in Figure 3. The first stage for both descriptive and normative theory begins with observing, describing and measuring the phenomenon that is to be understood. The second stage involves the categorization: normative theory groups and sorts circumstances into categories and descriptive theory groups and sorts attributes. The last stage involves the forming of hypotheses. In normative theory, statements are made about what causes the phenomenon to happen and why. In descriptive theory, only statements of correlation are made. Researchers transition from descriptive to normative theory when they “move beyond statements of correlation to define what causes the outcome of interest” (Carlile & Christensen, 2005).

Theory is cumulatively built by cycling up the pyramid in an inductive process and down the pyramid in a deductive process. Researchers cycle up the pyramid to define their statements, and then cycle down in order to test them. Future researchers further

improve on the theory by exploring whether the same statements may be made in relation to a different set of data. In this context, a theory is defined as “a body of understanding that researchers build cumulatively as they work through each of the three steps in the descriptive and normative stages [of theory building]” (Carlile & Christensen, 2005).

Figure 3: Cycles of Theory Building

Source: Carlile and Christensen (2005)

In order to build useful theory it is important to get the circumstance-based categories right (Christensen & Raynor, 2003). In so doing, a better understanding of what causes an outcome can be achieved. If researchers simply categorize a phenomenon based upon attributes, the best they can achieve are statements of correlation. With circumstance-based categorization, researchers can work towards statements of causality.

Theories that are circumstance-based are more useful to managers than attribute-based ones because they can help: identify the circumstances they find themselves in; predict what will and will not lead to the desired outcome; and understand what it is about the present situation that enabled their strategies or tactics to succeed (Carlile & Christensen, 2005; Christensen & Raynor, 2003).

2.8 Lessons Learned

The following lessons learned were gleaned from the literature review:

Business Ecosystems

- The existing business ecosystem literature predominantly focuses upon strategies for organizations within pre-existing ecosystems; very little structured advice is provided for those who wish to create and evolve a new ecosystem.
- Creating and evolving a business ecosystem requires a multi-faceted approach. There are many issues to consider, including: identifying the participants; defining the participant roles; defining the initial niche contributions and contributors that are required; understanding the requirement for a platform; establishing the necessary processes (e.g. related to development, licensing, governance, project management); as well as addressing a myriad of other technical, organizational and business issues.

OS Ecosystems

- An OS community may be thought of as a subset of an OS ecosystem.
- The business ecosystem literature largely fails to contemplate the notion of an OS ecosystem by: only considering organizational sponsorship of pre-existing OS communities; not considering a completely open platform; assuming for-profit leaders; implying the requirement for varying degrees of secrecy; and assuming that a strong central player is necessary for platform control and ecosystem leadership.
- There is little focused research on OS ecosystems. The existing OS ecosystem literature purports to borrow from the business ecosystem literature; however, it largely fails to contemplate the possibility of an OS ecosystem that includes Moore's "intentional community of economic actors" who create and evolve a new OS

ecosystem. Instead, the focus is predominantly upon the commercial sponsorship of pre-existing OS communities.

- The open innovation literature has some similarities to business and OS ecosystem literature. In some cases it is critical of corporate involvement in OS communities. In other cases, it only considers corporate involvement in existing OS ecosystems or OS communities. Finally, in other cases it speaks of one or more corporate sponsors designing and building their own OS community; this resembles an OS ecosystem.
- Several OS ecosystem governance approaches exist: management team; non-profit foundation; corporate sponsorship.

Organizational Participation in OS

- There is a distinct lack of literature that looks at organizational participation in OS. What does exist is largely not applicable to a consideration of participation in OS ecosystems.

The HLA Distributed Simulation Domain

- An OS community is largely absent from the distributed simulation domain.
- There is a need for an OS RTI ecosystem. Reasons for this include that it would: contribute to the HLA standard's evolution and viability; prevent HLA from being bypassed by another simulation standard; provide a reference implementation to support R&D; increase responsiveness to user needs; and reduce the cost to entry.
- There are many existing non-commercial RTIs. Of these, only a small number are mature, readily available and accessible, and truly OS. It has been suggested that several of these would make a strong starting point for the development of an OS RTI

ecosystem. It has also been suggested that the progress of some of the OS RTI efforts has been hampered by their lack of a supporting business ecosystem.

- None of the existing non-commercial RTIs was created with an OS ecosystem in mind. Two of these have now clearly articulated their desire to increase HLA adoption and to grow their communities beyond their initial target audience.
- There is a potentially growing OS community for an OS RTI.

Methodology Sources

- Organizational motivation and ability can be used to analyze organizations within a specific industry to determine whether the context is favourable to innovation.
- The Motivation/Ability Framework can be used to analyze current and potential participants in a specific industry context. This framework may be considered as an output of stage two of the theory-building process; it is not a theory. As well, it has not been operationalized for use by interested researchers or managers; it is currently only a conceptual thought process.
- The concept of resources can be used to think about organizational motivation and ability. All organizations need to engage in exchanges with other organizations in their environment in order to obtain resources.
- Circumstance-based categorizations lead to theory that has greater predictive power than attribute-based categorizations. Circumstance-based theory is more useful to managers because it helps them to: identify the circumstances that they are in; predict what will and will not lead to the desired outcome; and understand the nature of their current situation that allowed their strategies or tactics to work.

3 RESEARCH QUESTION

The research question that this thesis endeavours to address is:

Can a rigorous articulation of organizational motivation and ability help a manager or initiator of an open source ecosystem identify potential participants?

This question is previously unanswered. The business ecosystem literature does not effectively address how to methodically create an ecosystem; its strategies are predominantly geared towards companies that are members of pre-existing business ecosystems (Cusumano & Gawer, 2002; Gawer & Cusumano, 2002, 2008; Iansiti & Levien, 2004a, 2004b, 2004c, 2004d). Its treatment of business ecosystems does, however, highlight the fact that building one would require a multi-faceted approach. The business ecosystem literature presents several aspects to consider when creating and evolving an OS ecosystem, including: the participants; the participant roles; the platform; the initial contributors and contributions that are required; and the necessary development, licensing, governance and project management processes.

In addition, the business ecosystem literature fails to effectively address the concept of an OS ecosystem. First, it does not contemplate the creation of an OS ecosystem that includes an intentional community of economic actions, as defined by Moore (2006). Second, it only considers organizational sponsorship of pre-existing OS communities. Lastly, it generally: does not consider a completely open platform; assumes a for-profit leader; implies the need for degrees of secrecy; and assumes that a strong central player must control the platform and lead the ecosystem (Milinkovich, 2008b).

There is also a distinct dearth of OS ecosystem literature to guide practitioners. This literature largely focuses upon the sponsorship of pre-existing OS communities of individual developers.

An understanding of OS ecosystems requires the consideration of the combination of OS community, business ecosystem, and the platform (Milinkovich, 2009). Each of these is an essential part of the whole: the business ecosystem is the business network that lives on top of the platform; and the OS community is a form of collective that works on creating and evolving the platform (Milinkovich, 2009). The platform is critical to an OS ecosystem as it creates value (Iansiti & Levien, 2004a, 2004c) and its absence may even preclude the very creation of the ecosystem (Milinkovich, 2008a, 2008b).

This research question is a worthwhile one to answer as it may have broader implications to the domains of both business and OS ecosystems. If future economic battles are going to be waged between business ecosystems as opposed to individual companies, research must begin to provide strategies for managers to address creating and evolving an ecosystem. As well, it must begin to address the unique aspects of OS ecosystems in order to provide strategy that is appropriately tailored to this domain.

The HLA distributed simulation domain is a ripe area in which to conduct research into OS ecosystems. Despite having many characteristics in common with mainstream software development industries, the distributed simulation domain still lacks a thriving OS community (Pokorny, 2006). It has been suggested that an OS community is very much required in this domain (Stratton et al., 2004). Not only is an OS RTI needed, but OS federates and federations, development tools, and freely accessible educational tools are also required (Pearce & Bailetti, 2007; Pokorny, 2006; Stratton et al., 2004). An OS

ecosystem approach would involve a broader scope than simply creating an OS community, and would be better equipped to meet this perceived need.

While many non-commercial RTI initiatives exist, none of these was created with an OS ecosystem in mind. As well, very few of these are mature and easily accessible online (see Appendix 1). Their progress has likely been hampered by their lack of supporting business ecosystems (Pearce & Bailetti, 2007). It is, however, believed that any one of the few mature non-commercial RTIs could create a strong foundation for the development of an OS RTI community (Stratton et al., 2004).

The time is right for the consideration of OS ecosystems within the HLA distributed simulation domain. Of note, two existing OS RTI initiatives have voiced their desire to increase HLA adoption and to grow their respective communities beyond their initial target audience. The CERTI team has indicated that it wishes to develop an international OS community around distributed simulation (Noulard et al., 2009). They also believe that there is a potentially growing OS community for an OS RTI. The Portico Project has recently promulgated its first version 1.0 release candidate, and its team continues to strive to grow their community and ensure the project's sustainability long-term (Pokorny, 2007a, 2009b; the poRTIco project, 2008a). These initiatives are perfectly poised to consider OS ecosystems and the benefits that this approach would provide to supporting their future progress, growth, sustainability and success. As a result, addressing the issue of potential participants would form a key part of the multi-faceted approach to creating their respective OS ecosystems.

4 RESEARCH METHOD

This research is exploratory in nature. It follows Eisenhardt's (1989) theory building approach, augmented with Yin's (2003) guidance for research design/method and Miles and Huberman's (1994) insights related to data analysis. An overview of the research process is given in Table 10. This process is highly iterative and should not be read as a strictly sequential set of steps.

Table 10: Theory Building Process

Step	Activities
1. Preliminary Work	• Defining the research question • Identification and definition of constructs • Development of data collection methods
2. Data Collection	• Selection of cases through theoretical sampling • Interviews coupled with data obtained through reports, papers, and organizational websites • Field notes were taken following each interview • Data collection and data analysis overlapped
3. Data Analysis	• Within-case analysis carried out by generating detailed write-ups for each case • Cross-case analysis and data reduction through iterative use of tables, matrices, and plots in order to shape hypotheses
4. Validation	• Comparison with limited existing literature • Validation through domain experts
5. Closure	• Selection of cases logically constrained by the time required to collect and analyze the data • Iteration between theory and data ended once the incremental improvement to the theory was found to be minimal

Source: based upon Eisenhardt (1989)

In this research, the aim was to build new theory related to OS ecosystems in part by applying to Motivation/Ability Framework to a distributed simulation industry context. The framework has not previously been operationalized for use by practitioners. This section describes the process by which the framework was operationalized and applied in this research. Section 5 presents the OS RTI ecosystem-specific results. Section 6 discusses how the process can be generalized for use by other practitioners.

4.1 Unit of Analysis, Study Period and Sample Selection

The unit of analysis was an organization that was currently engaged in the M&S domain (i.e. in 2008), and more specifically had experience and expertise with distributed simulation. Experience or expertise with HLA was not a prerequisite for selection.

A theoretical sampling approach was taken to specifically select useful cases that would replicate, contrast and extend the emergent theory (Eisenhardt, 1989; Eisenhardt & Graebner, 2007). This approach involves iteratively selecting cases based upon theory and not for predetermined statistical reasons (Eisenhardt, 1989). As a result, the cases were not selected randomly. Ultimately, 21 organizations were selected from five attribute-based categories: (i) defence organizations; (ii) M&S companies; (iii) academic institutions; (iv) research institutions; (v) OS RTI initiators.

4.2 Preliminary Work

The preliminary work involved defining the research question and key constructs, as well as developing the interview instrument. The research question was defined in order to focus the researcher's efforts. The key constructs of business ecosystem, OS ecosystem, OS community, resources, motivation, ability and constraint were defined using the extant literature to better inform the data collection and analysis stages of the research process. These definitions are contained in Table 11.

The interview instrument was developed by drawing upon literature regarding interview techniques (Foddy, 1993) and data collection preparation (Yin, 2003), as well as literature pertinent to the research question (recall Section 2). It contained: an introduction to the research; introductory questions related to the organization's background, and its experience and expertise with both OS and the HLA; and core

questions related to the organization's current resource needs, capabilities, and hurdles. Appendix 2 contains a sample of the instrument. It included open-ended questions to solicit descriptive responses and probing questions to establish details. The aim was to be flexible to take advantage of opportunities for unforeseen, yet relevant, lines of discussion. The instrument was trialed three times to improve its flow and content.

Table 11: Definitions of OS Ecosystem, Resources, Motivation, Ability, Constraint

Construct	Definition
Business Ecosystem	An intentional community of economic actors (organizations and/or individuals) who use a platform to co-create and deliver value to customers, partners, themselves, and their overall community.
OS Ecosystem	An OS ecosystem includes both a business ecosystem that leverages a platform (in the same manner as the previous definition), and an OS community that directly works on creating and evolving that platform.
OS Community	A form of collective that includes both individuals and organizations, which works directly on creating and evolving the OS ecosystem's platform.
Resources	Anything that is perceived as valuable by an organization (e.g. capital, information, relationships, material, or access to markets).
Motivation	An organization needs, wants or lacks resources. It strives to access, obtain, generate, create, and/or control them.
Ability	An organization has the capability or freedom to access, obtain, possess, generate, create, and/or control resources.
Constraint	An organization is unable to, or prevented from, accessing, obtaining, possessing, generating, creating, and/or controlling resources.

4.3 Data Collection

Theoretical sampling was used to select 21 cases from the following five attribute-based categories of organizations: (i) defence organizations – 6 cases; (ii) M&S companies – 5 cases; (iii) academic institutions – 4 cases; (iv) research institutions – 5 cases; (v) OS RTI initiator – 1 case.

Nine of the organizations were identified through their affiliation with the international Simulation Interoperability Standards Organization¹ (SISO, 2009). Another nine organizations were identified through the researcher's affiliation with the Canadian DND/CF. Of the remaining organizations, one was identified through a key published paper and the other through the researcher's affiliated university. The types of interview respondents from each attribute-based category are outlined in Table 12.

Table 12: Types of Interview Respondents

Attribute-based Category	Type of Respondents	Country of Origin
1. Defence organizations	- Organizational directors - Organizational M&S advisors - Key M&S scientists and engineers	All Canadian
2. M&S companies	- CEOs and co-founders - Directors of Product Development, Marketing, and Sales - Senior program/project engineers	USA Australia Sweden
3. Academic institutions	- M&S-related faculty members - M&S lab leaders and key personnel - M&S research associates	Canada USA Australia
4. Research institutions	- Chief scientists/leaders of M&S groups - Key M&S scientists and engineers	Canada USA Netherlands
5. OS RTI initiator	Lead developer	Australia

Data was collected through semi-structured interviews with individual respondents, coupled with secondary sources such as reports, papers, and organizational websites. The interviews were conducted in eight waves that were dictated both by the theoretical sampling approach and the availability of respondents. They were conducted over a period of five months from July to November 2008. A total of 37 people were interviewed, representing 21 organizations. Each interview lasted 60 to 90 minutes.

¹ SISO is an international organization that is "dedicated to facilitating simulation interoperability across a wide spectrum...SISO and its affiliates provide forums, educate the M&S community on implementation, and support standards development" they also host several annual M&S conferences (Simulation Interoperability Standards Organization, 2009).

Field notes were taken after each interview in order to capture specific insights and suggestions for further sources of information or respondents.

4.4 Data Analysis

The data analysis effort began in the latter stages of data collection. It was guided by concepts from Eisenhardt (1989), Yin (2003), as well as Miles and Huberman (1994).

Eisenhardt (1989) suggests within-case analysis to develop familiarity with the data and to begin early theory generation; and also suggests cross-case analysis using multiple methods to identify patterns and further improve the theory. Yin (2003) suggests developing case descriptions as one of three possible analytic strategies. Miles and Huberman (1994) indicate that qualitative data analysis consists of three concurrent activities: data reduction; data display; and conclusion drawing and verification. Figure 4 depicts the iterative data analysis process that was followed in this research.

Figure 4: Data Analysis Process

4.4.1 Detailed Organizational Write-Ups

The first step of the data analysis process involved generating detailed write-ups for each organization. These were created using the data from the interviews and supporting documents such as reports, papers and organizational websites. Each write-up was ten to fifteen pages, single-spaced, and had four sections: organizational information; and three sections of specific examples of motivation, ability, and constraint as drawn from the data. These write-ups were used to conduct within-case analysis and increased the researcher's familiarity with each organization. They contributed to the data reduction effort by focusing the researcher upon the key constructs of motivation, ability and constraint. These write-ups formed the basis for all subsequent cross-case data analysis.

4.4.2 Tabular Summary of Motivation, Ability and Constraint Indicators

Data reduction was first carried out by creating a tabular summary of the detailed organizational write-ups. Each of the text-based examples of motivation, ability and constraint from the write-ups was reduced to one or several indicators. No effort was made to sort like indicators; this was strictly an initial step to identify the readily apparent indicators for each organization. The table contained point form descriptions of each indicator and was organized as shown in Table 13.

Table 13: Sample Layout of Tabular Summary of Indicators

	Organization 1	Organization 2	Organization 3	...
Motivation	- want to make a profit - want to ensure their presence in the market - lack M&S personnel	- want to develop... - want to pursue... - want research funding	- want to gain... - want credibility... - need RTI source code	
Ability	- actively involved in.. - benefit from... - have existing...	- have expertise from... - actively involved in...	- have sufficient funding - contribute to...	
Constraint	- recruiting personnel is difficult - OS is a threat if it...	- funding is declining - organizationally constrained from...	- lack a visible champion for M&S - dependent upon...	

4.4.3 Data Reduction of Motivation, Ability and Constraint Indicators

Following the first pass at data reduction, a significant amount of time was then spent refining the table of indicators. In this stage, like motivation, ability and constraint indicators were sorted into mutually exclusive categories rather than by organization. Three separate tables were created to sort the motivation, ability and constraint indicators. The categories contained one or several unique indicators of motivation, ability or constraint. The organizations which demonstrated evidence of each indicator were listed below the indicator.

The ultimate goal of this stage was to capture the categories and unique indicators that emerged from the data. Eisenhardt (1989) suggests defining categories in order to look for similarities and differences among the cases. The researcher regularly referred back to the data in the detailed write-ups in order to confirm the accuracy of this sorting and to discover additional indicators. Table 14 provides a sample of this table's layout.

Table 14: Sample Layout of Refined Table of Indicators

MOTIVATION			
<i>(category)</i> 1. Want, need, or lack money	<i>(category)</i> 2. Want to establish or improve relationships	<i>(category)</i> 3. Want, need, or lack an OS RTI or an OS RTI ecosystem	...
<i>(indicator)</i> A. Want to make a profit. - organizations 1, 10, 19...	<i>(indicator)</i> A. Want to improve relationships with research institutions. - organizations 4, 12, 20...	<i>(indicator)</i> A. Specifically want to be involved in an OS RTI initiative, or an OS RTI ecosystem. - organization 3,8,11...	
<i>(indicator)</i> B. Want sources of funding other than from profit or research funding. - organizations...	<i>(indicator)</i> B. Want to improve relationships with academic institutions. - organizations...	<i>(indicator)</i> B. Need access to RTI source code (e.g. for greater control, flexibility...). - organizations...	

Two passes were made through this data reduction process of refining the indicator categories and unique indicators. Subsequently, a matrix was created in order to better capture the occurrence of these indicators by organization. This matrix was no longer in text form, but rather was used as a checklist to determine patterns across the 21 organizations and to better refine the categories and unique indicators. A sample layout of this matrix is shown in Table 15.

Table 15: Sample Layout of Organization-Ordered Matrix of Indicators

MOTIVATION	Organization			
	1	2	3	...
1. Want, need, or lack money				
A. Want to make a profit.	✓	-	-	
B. Want sources of funding other than from profit or research funding.	-	✓	✓	
2. Want to establish or improve relationships				
A. Want to improve relationships with research institutions.	✓	-	✓	
B. Want to improve relationships with academic institutions.	✓	-	✓	

Three more lengthy passes were made through both the refined table of indicators and the organization-ordered matrix to effectively capture the overarching categories and unique indicators of motivation, ability and constraint that emerged from the data. Regular reference was made to the detailed write-ups in order to confirm both the presence and accuracy of the indicators and also to identify additional indicators. With each pass through the data, the categories and unique indicators were better refined.

The final products of this stage of the data analysis process included: an organization-ordered matrix that summarized the unique motivation, ability and constraint indicators that emerged from the data for each organization; and a refined tabular summary of these unique indicators to provide textual amplification for the matrix. The final organization-ordered matrix is contained in Appendix 3.

4.4.4 Organizational Motivation and Ability Ratings

The final organization-ordered matrix was then used to generate an overall rating of motivation and ability for each organization. This was done so as to plot each organization on a matrix similar to that of the Motivation/Ability Framework.

First, a weight of 1 was assigned to each indicator. If an organization displayed strong evidence of an indicator, they received a 1 for that indicator. If they displayed possible evidence of an indicator they received only 0.5. If they displayed no evidence at all, they received a 0. The overall motivation rating was obtained by adding the totals from each indicator of motivation. The overall ability rating was obtained by subtracting the total constraint rating from the total ability rating. A depiction of the assigning of weights to each indicator is shown in Table 16.

Table 16: Sample Layout of the Weighted Organization-Ordered Matrix of Indicators

MOTIVATION	Org 1	Org 2	Org 3	..
1. Want, need, or lack money				
A. Want to make a profit.	0.5	0	0	
B. Want sources of funding other than from profit or research funding.	0	1	1	
2. Want to establish or improve relationships				
A. Want to improve relationships with research institutions.	1	0	0.5	
B. Want to improve relationships with academic institutions.	1	0	1	

4.4.5 Plotting on the Motivation/Ability Matrix

The organizational motivation and ability ratings obtained in the previous step were calculated as percentages and plotted on a matrix with ability along the x-axis and motivation along the y-axis. The motivation percentages were calculated by dividing an organization's motivation rating by the total possible weight of the indicators for motivation (i.e. 38). The same was done for ability, where the total possible weight was

47. Figure 5 is only a sample of such a plot. The actual plots that were generated are included, and discussed further, in Section 5.

Figure 5: Sample Plot of Organizations on the Motivation/Ability Matrix

This data display approach is similar to the scatter plots suggested by Miles and Huberman (1994) as a method for cross-case display. Scatter plots are “figures that display data from all cases on two or more dimensions of interest that you think are related to each other” (Miles & Huberman, 1994: 198). The researcher is warned not to settle on conclusions drawn from the display alone, and is advised to “clarify and confirm (or qualify) the conclusions through reference back to case reports” (Miles & Huberman, 1994: 200). As a result, the researcher analyzed the plot by making reference back to the detailed case write-ups.

4.4.6 Weighting of Three Key Indicators

The plot obtained from the previous step was not an entirely helpful data display. A thorough review of the indicators in the organization-ordered matrix resulted in one indicator from each of the tables for motivation, ability and constraint being assigned an additional weight of 10. The percentages were then calculated out of a total possible

weight of 48 for motivation and 57 for ability. The impact of this additional weighting and a comparison of the resulting scatter plots are discussed in Section 5.

4.5 Validation by Domain Experts

Eisenhardt (1989) indicates that “tying the emergent theory to existing literature enhances internal validity, generalizability, and theoretical level of theory building”. The literature review demonstrated that there was a distinct lack of literature with which to do so. As a result, the analysis of the results in relation to the literature was amplified by an additional validation step.

The additional validation involved interviewing two key individuals with specific areas of expertise related to the research. The first of these was the Executive Director of a non-profit keystone of an OS ecosystem, and the second was the lead developer of an OS RTI. The additional validation served several purposes, it: augmented the limited validation that could be carried out with the existing literature; validated the weighting of the key indicators; identified the potential usefulness of the results; and added depth to the literature review. This will be discussed further in Section 5.

4.6 Closure

Eisenhardt (1989) identifies two issues that have an impact upon reaching closure in theory-building research. First, the researcher should stop adding cases once theoretical saturation has been reached. Second, the cycling between theory and data should cease once there is only minimal incremental improvement to the theory.

In this research, the selection of cases was constrained by the time required to collect and analyze the data. Complete theoretical saturation may not have been reached; however, the researcher was satisfied with the samples taken from all of the categories

except OS RTI initiators. Further OS RTI initiator samples could have been taken; however, it must be recognized that there is a very limited pool of initiators from which to draw such samples. The process of cycling between theory and data was concluded following a consideration of the insights gleaned from the expert validation effort. At that point, final conclusions were drawn and the elements of the theory were solidified.

5 RESULTS

This section presents the research results. First, it presents the organizations in the theoretical sample. Second, it presents the categories of organizational motivation, ability and constraint indicators which emerged from the data. Third, it discusses the dimensions of organizational motivation, ability and constraint that were developed. Fourth, it discusses the process by which the Motivation/Ability Framework was operationalized. Next, it describes the development of a circumstance-based categorization of organizations. It then discusses the possible levers to increase organizational motivation and ability, as well as the possible barriers to OS ecosystem participation. Lastly, the validation of the results is discussed. A generalization of the results for application to other OS ecosystem contexts is discussed in Section 6.

5.1 Organizations in the Sample

Twenty-one organizations were included in the sample. This section provides a descriptive overview of each of these organizations. Appendix 3 contains a more in-depth synopsis of each organization based upon their motivation, ability and constraint.

The defence organizations in the sample have a variety of different M&S roles and responsibilities (see Table 17). All of these organizations are part of the Canadian defence community. One organization has a strictly advisory and coordination-type role. Three of the organizations are focused upon specific defence environments (e.g. Army, Navy, Air Force) and have roles related to experimentation, simulation, concept development, and the provision of policy and advice. One organization is a program directorate responsible for the management of several M&S-related capital projects. The final organization has a national defence experimentation role. It is also responsible for

capturing lessons learned from theatres of operation, the development of defence doctrine, and the provision of distributed simulation network support.

Table 17: Defence Organizations in the Sample

Organization	Description
Defence 1	Awareness, coordination, cooperation, support, and advisory role in relation to M&S activities within national defence community.
Defence 2, 3, 4	National defence environment-specific experimentation, simulation, concept development, policy and advisory roles.
Defence 5	National defence program directorate responsible for managing several M&S-related capital projects.
Defence 6	National defence experimentation role. Responsible also for lessons learned, doctrine and distributed simulation network support.

The M&S companies in the sample vary in size, business activities, and type of business model (see Table 18). The companies vary in size from 15 to 45,000 employees. Those with smaller numbers of employees are predominantly focused upon the provision of M&S solutions to various user communities. The larger companies have business areas which extend beyond the M&S domain. Each company has an international reach and customer base; the scope of which varies among them. Two of the smaller companies were recently acquired by large international companies.

Table 18: M&S Companies in the Sample

Organization	Description
Company 1	Develop M&S products/provide M&S services. Focus predominantly upon implementation/deployment/use/training services and less on commercial-off-the-shelf (COTS) software development and sales. About 200 personnel.
Company 2	Simulation and training domain focus. Conduct software development, R&D, and engineering. Develop and sell a COTS product line. About 40 personnel.
Company 3	Primary focus on M&S domain. Develop and sell a COTS product line. Provide R&D and consulting services, and support. About 60 personnel.
Company 4	Heavily involved in M&S, also has broader foci including national security, energy, environment, critical infrastructure, health. Primary customer is national government. Mainly sells the time of its employees as engineering services. About 45,000 employees.
Company 5	Provide products, services, solutions and training. Mainly focus upon interoperability for distributed simulation. About 15 personnel.

Each of the academic institutions in the sample also has an affiliated M&S research centre or institute (see Table 19). Three of these are sizeable interdisciplinary and cross-department research centres, while the fourth is strictly a departmental research centre. Some of these are well-established and internationally-renowned, while others are in the initial stages of growth or are quite small in size. The number of M&S faculty varies among the institutions. Two of the universities offer formal M&S graduate programs, while the remaining two strictly provide M&S course offerings.

Table 19: Academic Institutions in the Sample

Organization	Description
University 1	University with an M&S research center that is interdisciplinary and cross-domain/department. M&S course offerings. Two key M&S faculty members.
University 2	University with an M&S research center that is interdisciplinary and university-wide. Offers M&S graduate programs. 15 designated M&S faculty.
University 3	Government-funded postgraduate university with an M&S research institute. Offers M&S graduate programs. Solid core of M&S instructors/researchers.
University 4	University with a departmental M&S research centre. M&S course offerings. Two key M&S faculty members.

The research organizations in the sample were either not-for-profit or government research organizations (see Table 20). M&S is in use across each of these organizations. The two not-for-profit organizations have defined M&S groups with specific M&S-related roles and areas of expertise. Two of the government research organizations do not have a specific group that is responsible for M&S; instead, M&S use and expertise is spread throughout these organizations. The third government research organization is tailored quite differently from the other four research organizations. It does not conduct research in-house, but rather sponsors government, industry and academic research in order to address its goals. It is the only research organization in the sample that does not have a strong level of experience and expertise in distributed simulation and the HLA.

Table 20: Research Institutions in the Sample

Organization	Description
Research 1	Not-for-profit research organization (4000 personnel). Multiple contracts with the national government. Broad range of areas of expertise (e.g. space, missile defence, national security). M&S is in use across the organization. Contains an M&S group with an organization-wide M&S coordination role. It is also an unofficial organizational point of contact for M&S, and manages M&S-related programs. The group has strong expertise in HLA, and focuses on simulation software, assessment and M&S applications.
Research 2	Not-for-profit research organization (4500 personnel). Five core business areas: defence, security, safety; health; environment; science and industry; and information and communications technology. M&S is in use across the organization. Has an M&S group located within one of its business areas whose key customers are national defence and government departments. Its research focuses upon: environment modeling; interoperability and distributed simulation architectures (including HLA); modeling of human and sensor system behaviour; and simulation systems engineering.
Research 3	One of seven research centres of a national defence research agency. Research focuses upon combat, electro-optical systems, and command and control information systems. M&S is in use across the organization. No specific M&S group within the organization.
Research 4	One of seven research centres of a national defence research agency. Research focuses upon maritime-related domains. M&S is in use across the organization. Contains a group specifically formed to build expertise in distributed simulation, with a strong research focus on HLA. It conducts research, provides advice, and has developed M&S training.
Research 5	One of seven research centres of a national defence research agency. Focus is upon national safety and security. Works in partnership with 21 federal science-based and national security departments and agencies. Structured differently than other six research centres: small centre of about 50 people that releases calls for proposals to leverage the work of government, industry and academia on research initiatives. The organization is working towards developing its M&S capabilities and those of its partners. Its experience and expertise in HLA is limited.

The OS RTI initiator in the sample is an OS RTI project with a team of three developers. It was initially created to meet the needs of the developers, but has since grown to garner the attention of a defence organization sponsor. The lead developer of the project is employed by an M&S company. It is through this company that the defence organization sponsors the OS RTI project's development.

5.2 Indicators of Organizational Motivation, Ability and Constraint

The data analysis process served to identify the unique indicators of motivation, ability and constraint that emerged from the data. These were then grouped into overarching categories of one or several unique indicators. The number of categories defined within each construct was as follows: motivation – 12; ability – 15; and constraint – 14. The categories are listed in Appendix 4. The weighting of the indicators within each category, coupled with the analysis of which organizations displayed evidence of those indicators, enabled the researcher to obtain overall ratings of motivation and ability for each organization.

5.3 Dimensions of Organizational Motivation, Ability and Constraint

The overarching categories of indicators (see Appendix 4) were used to develop the dimensions of organizational motivation, ability and constraint. Like categories were further grouped together in order to define the nine dimensions of organizational motivation, seven dimensions of organizational ability, and eight dimensions of organizational constraint. In the case of motivation, categories one through four were combined to define the first dimension, while the remaining categories each represented a distinct dimension. In the case of ability the following reduction was carried out: categories one through five were combined to define the first dimension; categories six and seven became dimension two; categories 10 and 11 became dimension 3; categories 13 to 15 became dimension four; and the remainder of the categories represented distinct categories. In the case of constraint: categories one through five became dimension one; categories six through eight became dimension two; and the remainder represented

distinct categories. These dimensions simplify the conceptualization of organizational motivation, ability and constraint.

5.3.1 Dimensions of Organizational Motivation

The nine dimensions which define organizational motivation are outlined in Table 21 and are discussed in this section using specific examples.

The first dimension of organizational motivation relates to the desire or need to address a specific M&S or OS capability. This may involve addressing needs or requirements that are either external or internal to the organization. An organization may display evidence of motivation to address external needs or requirements because they want to provide a specific M&S or OS capability to their stakeholders (e.g. a testbed, a persistent distributed simulation network, distributed simulation connectivity, or an OS product). They may also want to develop and sell COTS products that will meet the needs of a large customer base, provide services in the form of training or simulation development, implementation and use. As well, organizations may want to provide an OS collaborative medium for education and research, or meet the needs of their external sponsoring organizations.

An organization may display evidence of motivation to address internal needs or requirements because they want to improve their own M&S capabilities (e.g. specific simulation environments, distributed simulation infrastructure/connectivity), create M&S education and research opportunities for students, or use M&S to enable other groups within their organization. With respect to an internal OS focus, organizations may display evidence of motivation because they want to: investigate OS for use in

simulation; manage and lead OS projects; use OS methods for teaching; improve OS simulation tools for their own use or to improve their internal capabilities.

Table 21: The Nine Dimensions of Organizational Motivation

1. Want or need to develop or address specific M&S or OS capabilities.			
External M&S focus	Internal M&S focus	External OS focus	Internal OS focus
2. Want or need to achieve a specific M&S outcome.			
Related to their M&S work or business.	Related to the science of M&S.	Related to M&S knowledge.	Related to the M&S industry.
3. Want to perform specific M&S roles or functions, or participate in specific M&S activities.			
Roles (research, education, training)		Activities (international M&S exercises)	
4. Want, need or lack an OS RTI.			
Specifically want to be involved in an OS RTI initiative or OS RTI ecosystem.	Want, need, lack RTI source code.		Want, need RTI that is cost-free and has a permissive license.
5. Want, need or lack OS software.			
Specifically want to participate in OS activities (aside from OS RTI).		Want, need, lack OS product source code.	Want, need OS products that are cost-free and have permissive licenses.
6. Want, need or lack money.			
Profit.	Research funding.	Other sources of funding.	Expand client base.
7. Want, need or lack personnel.			
In general.		With M&S expertise.	
8. Want to establish or improve inter- and intra-organizational relationships.			
With industry.	With academic institutions.	With research institutions.	With government or defence organizations.
Within their own organization, environment, or community.			
9. Want, need or lack certain intangibles.			
Recognition	Credibility	Presence or visibility.	Customer, client, or stakeholder satisfaction.

The second dimension addresses an organization's desire or need to achieve specific outcomes. These outcomes may be related directly to their M&S work or business, or may relate to the science of M&S, M&S knowledge, or the M&S industry. Organizations may exhibit motivation to achieve a specific M&S outcome related to their work or business through their desire to: make M&S relevant to their stakeholders; promote cooperation among partners and stakeholders to avoid duplication of effort; establish a good research trail of funded projects; create flexible and interoperable simulation components; or shape their organization to effectively meet their customers' needs.

Organizations may exhibit motivation to achieve a specific M&S outcome related to the science of M&S by specifically endeavouring to advance the state of the art. They may also want to create an M&S research stream, conduct interdisciplinary M&S, or conduct advanced research in emerging simulation areas. Motivation may be demonstrated in relation to M&S knowledge through an organization's desire to: increase the M&S body of knowledge; establish greater M&S awareness within their organization or among their partners/stakeholders; arm their students with M&S knowledge; or accumulate their own knowledge and expertise.

Specific outcomes that organizations may want to achieve that are related to the M&S industry may include: creating a larger pool of companies with expertise in M&S and distributed simulation from which to draw resources; shaping the industry to meet their business objectives; increasing HLA adoption; growing the HLA community beyond simply the defence domain; and encouraging a new set of HLA users.

The third dimension relates to an organization's desire to perform specific M&S roles or functions, or to participate in specific M&S activities. The types of roles or functions may be related to research, formal education, or training. The organizations predominantly articulated that they wanted to participate in specific M&S activities in the form of international M&S exercises.

The fourth dimension is a very important one, as it specifically addresses the organizational motivation to be involved in an OS RTI initiative or ecosystem. Organizations may demonstrate motivation to participate in an OS RTI initiative by clearly stating they want to do so. They may articulate a desire to spearhead an OS RTI initiative, contribute specific resources such as source code or complementary applications, or simply provide funding support to the initiative in order to benefit their organization. They may also indicate their desire to secure a seat on the management team in order to gain knowledge and build relationships.

The fourth dimension also addresses the need or desire for RTI source code and an RTI that is cost-free and has a permissive license. The need for RTI source code may stem from a desire to effectively conduct research. Organizations may require more than a commercial RTI can provide in order to delve deeper into advanced issues such as simulation interoperability, or may simply need greater control and flexibility that source code would provide. RTI source code may also be needed to support development work, enable users to diagnose and fix problems themselves, or to modify it to suit their needs. Organizations may also wish to have access to RTI source code in order to support standards development efforts or increase HLA adoption. An RTI that is cost-free and has a permissive license is desired by some because the commercial RTI license costs are

prohibitive to them. It is also needed by some organizations who wish to ensure that others can repeat their work without having to procure the appropriate license. Other organizations also wish to have more favourable redistribution rights. As well, it is desired by some who wish to avoid a cumbersome procurement process.

The fifth dimension of motivation relates to the need, desire or lack of OS software in general (not including the OS RTI). It includes the desire to participate in OS activities like international OS conferences, and organizational desires or needs for source code and cost-free/permissive license alternatives to commercial software.

The sixth dimension of motivation relates to an organization's need want or lack of money. Organizations may seek money in the form of profit, research funding, or other sources of funding such as contract work. They may also seek to increase their access to money by increasing their customer base. The seventh dimension of motivation relates to an organizations desire for, need or lack of personnel. This may involve meeting personnel needs in general, or hiring personnel with specific M&S expertise.

The eighth dimension of motivation relates to an organization's desire to establish or improve intra- and inter-organizational relationships. These relationships are valuable because they provide access to resources such as knowledge, expertise, lessons learned, funding, and personnel. They may be with industry, government/defence organizations, academic or research institutions, or within their own organization or community.

The last dimension of motivation relates to the desire or need to achieve certain intangibles. These may include an organization's desire or need to gain recognition, establish credibility, develop a presence, or achieve customer/client/stakeholder satisfaction.

5.3.2 Dimensions of Organizational Ability

The seven dimensions which define organizational ability are outlined in Table 22 and are discussed in this section using specific examples.

The first dimension of ability is demonstrated through an organization's existing relationships. These may be with industry, government/defence organizations, research or academic institutions. Also of import are their positive dependence relationships; that is, those relationships where other organizations depend upon them.

Table 22: The Seven Dimensions of Organizational Ability

1. Have existing inter-organizational relationships which are valuable and beneficial.			
With industry.	With academic institutions.	With research institutions.	With government or defence organizations.
Have positive dependence relationships (others depend upon them).			
2. Participate in, or contribute to, M&S activities.			
Participate in large-scale national or international M&S exercises or activities.		Contribute to the advancement of M&S activities or initiatives external to their organization (receive direct or indirect ROI).	
3. Have existing M&S capabilities.			
Existing technical capabilities.		Existing organizational capabilities or resources.	
4. Have existing involvement, knowledge, expertise or resources.			
Specific distributed simulation and HLA knowledge and expertise.	Specific OS RTI involvement, knowledge, expertise and/or resources to contribute to OS RTI initiative.		Specific OS involvement and expertise.
5. Involved in national or international organizations devoted to M&S, distributed simulation, HLA.			
6. Have beneficial organizational practices or roles.			
7. Actively and willingly share their knowledge.			

The second dimension of ability relates to an organization's existing capacity to participate in, or contribute to, M&S activities. By doing so, an organization receives a direct and/or an indirect return on their investment in the form of resources.

Organizations may demonstrate such ability by participating in: military distributed simulation exercises with their joint or coalition partners; large-scale national or international simulation activities aimed at creating new defence capabilities; or major programme experiments. They may also support their clients by building HLA federations and employing them for various purposes. In addition, they may lead international research experiments.

An organization may also demonstrate ability by contributing to the advancement of external M&S initiatives. They may do so by sponsoring and/or contributing resources other than funding to major exercises or activities, or organizations devoted to M&S (e.g. SISO, NMSG). They may contribute to the large-scale M&S procurements of partner organizations; fund the development of external simulation capabilities; or fund M&S-specific training for their stakeholders. As well, they may provide input to national M&S policy development processes; mentor other organizations that are looking to develop M&S research centers; or provide their work to the international community as OS.

The third dimension of ability relates to an organization's existing M&S capabilities. These may be in the form of technical capabilities such as M&S infrastructure and distributed simulation connectivity. They may also be in the form of organizational capabilities. Organizational capabilities may be demonstrated in at least six ways. First, an organization may have a beneficial structure (e.g. may be modeled after existing reputable simulation-focused organizations, or may have an affiliated M&S research centre). Second, they may conduct, facilitate or provide formal M&S education, formal or informal M&S-specific training, M&S research, or M&S advice and support. Third, they may have their own certified RTI, or may feel that their needs are met by a

commercial RTI. Fourth, they may employ key individuals within the M&S domain, may have sufficient personnel, or may have ways of accessing additional personnel. Fifth, they may have sufficient funding or additional sources of funding. Lastly, they may be an organization with a neutral stance within the M&S industry.

The fourth dimension of ability relates to an organization's existing involvement, knowledge, expertise and resources specifically in the areas of distributed simulation, HLA, OS RTIs, and OS. Organizations may possess specific distributed simulation and HLA knowledge and expertise. Of particular importance in the area of OS RTIs is the fact that organizations may have resources that they have specifically earmarked to contribute to an OS RTI initiative. They may also have experience with using OS RTIs, have expertise in developing one, see potential uses for one within their organization or client base, and would consider using one if they are not already doing so. In the area of OS, organizations may: have expertise from producing or consuming OS products; follow OS projects; see value in OS; use OS to benefit their organization or business; or have beneficial relationships with existing OS projects.

The fifth dimension of ability involves an organization's participation in national or international organizations that are devoted to M&S, distributed simulation, or the HLA. These may include: the Simulation Interoperability Standards Organization (SISO); the NATO Modeling and Simulation Group (NMSG)²; The Technical Cooperation Program (TTCP)³; professional organizations; and M&S industrial development groups.

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² The NMSG mission is to "promote cooperation among Alliance bodies, NATO Member Nations and [Partnership for Peace] Nations to maximize the effective utilization of M&S" (NATO RTO, 2009).

³ The TTCP is "an international organization that collaborates in defence scientific and technical information exchange; program harmonization and alignment; and shared research activities for five

The sixth dimension of ability relates to an organization's existing beneficial organizational practices or roles which provide them with resources. These may result from their acting as contractors on major programs, creating profitable products that solve key problems, gaining access to products for free through research sponsors, diversifying their government contracts, or diversifying into domains other than defence. It may also involve their building communities of practice, science clusters, and working groups. As well, it may involve having beneficial contracts or standing offers in place, or reciprocal arrangements with other organizations (e.g. joint marketing and sales). Lastly, it could involve producing their own IP or creating government-owned IP.

The last dimension of ability relates to how actively and willingly an organization shares its knowledge with others. Organizations may be fully willing to share their knowledge, or may refrain from sharing knowledge in specific areas.

5.3.3 Dimensions of Organizational Constraint

The eight dimensions which define organizational constraint are outlined in Table 23 and are discussed in this section using specific examples.

The first dimension of constraint relates to those constraints which an organization imposes upon itself. These may result from management practices, organizational structure, business model or role, or from negative dependence relationships. They may also relate specifically to OS or OS RTIs.

Of particular import within the first dimension are the constraints associated with OS RTIs. Most notable is the constraint which arises from an organization's stance that they have no need for an OS RTI (key constraint indicator). Organizations may also be

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nations (Australia, Canada, New Zealand, United Kingdom, United States)" (The Technical Cooperation Program, 2008).

unable or restricted from participating in or creating an OS RTI initiative or ecosystem.

They may also feel that there are technical issues associated with the use of an OS RTI.

Table 23: The Eight Dimensions of Organizational Constraint

Table 25: The Eight Dimensions of Organizational Constraint			
1. Organizational constraints			
Constrained by management practices.	Constrained by organizational structure, business model or role.	Organizationally constrained with respect to OS.	Organizationally constrained with respect to OS RTI.
Negative dependence relationships (dependent upon others).			
2. Externally imposed constraints			
Client, customer, stakeholder imposed constraints.		Government imposed constraints.	M&S industry imposed constraints.
3. Personnel constraints			
Challenge to find qualified personnel (M&S or otherwise).	Existing personnel are constrained in some way.	Organizationally constrained from creating new personnel capabilities, hiring new personnel.	
4. Financial constraints			
5. HLA-specific constraints			
6. Simulation infrastructure or connectivity constraints			
7. Security-related constraints			
8. Difficulty maintaining M&S awareness			

Constraints imposed by management practices may include lack of M&S direction, support or priority, lack of a strategic M&S champion, or restrictive M&S policies.

Constraints imposed by organizational structure may stem from a lack of M&S visibility within the organization, acquisition by an international company, or a lack of a central group responsible for M&S. An organization's business model or role may also impose constraints. Negative dependence upon other organizations may also impose constraints. In the area of OS, organizations may be constrained in their pursuit of OS. They may also have specific business reasons for disliking or lacking interest in OS.

The second dimension of constraint relates to those constraints which are externally imposed upon an organization. Clients, customers, or stakeholders may impose constraints by dictating practices, tools, or project direction. They may also impose technical or operational constraints due to their lack of awareness, or may make it difficult to address their needs due to their lack of coherence. Government may impose constraints in at least three ways by: creating government-owned products that compete directly with commercial vendor products; favouring larger contractors; or imposing cumbersome contracting processes. Lastly, constraints may be imposed by the M&S industry itself. This may be in the form of a lack of strong support for an OS RTI initiative. Organizations may also be constrained by the fact that M&S is not a recognized profession, the size of the market can only support so many RTI implementations, and the fact that the industry is very much vendor-driven.

The third dimension of constraint relates to personnel. Organizations may find it difficult to find qualified personnel. Their existing personnel may also be constrained because the organization is short staffed, or because they are tasked to perform functions that detract from their time to commit to M&S work. Organizations may also be constrained from hiring new personnel or creating new M&S groups.

The fourth dimension of constraint is financial in nature. Organizations may be constrained financially because they: must compete for limited sources of funding; have limited funding in general; or have no guaranteed funding from year to year.

The fifth dimension of constraint relates specifically to the HLA. Organizations may not be large HLA users or may be moving away from the HLA. They may also be

constrained by technical hurdles associated with the HLA. As well, while they may be using the HLA, they may be constrained from conducting HLA- focused research.

The sixth dimension of constraint relates to an organization's simulation infrastructure and distributed simulation connectivity. Organizations may have shortfalls in these areas that have yet to be addressed and that are hampering their efforts to conduct M&S-related work.

The seventh dimension of constraint involves those imposed upon an organization due to security reasons. Organizations may be prevented from implementing certain simulation infrastructure or connectivity due to security policies. They may also be prevented from taking on certain research work due to the security level of the sponsoring organization and the lack of commensurate security within their facilities.

The final dimension of constraint relates to the difficulty organizations face in maintaining M&S awareness. Failure to maintain appropriate awareness can lead to the duplication of effort, wasting of time and resources, and reinvention of the wheel. Organizations may experience such difficulty due to shortages in personnel, pace of work, or restrictive policies towards attendance at conferences/working groups.

5.4 Operationalizing the Motivation Ability Framework

This research followed a process which operationalized the Motivation/Ability Framework. It is highly iterative in nature (recall Figure 4) and can be used to analyze current and potential organizations in a target industry to determine if it would support an OS ecosystem. The process may be of more interest to researchers, and the conclusions that may be drawn from it may be of interest to researchers, ecosystem managers and initiators alike. Figure 6 depicts a simplification of this process without the iteration.

Figure 6: Process of Operationalizing the Motivation/Ability Framework

As outlined in Section 4, the process involved cycling through data collection and analysis to arrive at meaningful conclusions. Data was collected through interviews and other sources. It was reduced through the use of a series of tables and matrices to draw out all of the unique indicators of organizational motivation, ability and constraint. These were used to calculate overall ratings of motivation and ability for each organization and plot them on a scatter plot in order to visually depict the results.

The remainder of this section discusses the scatter plots and presents the insights they provided. Sections 5.5 to 5.7 present three more crucial results from the operationalization of the framework, these are: the circumstance-based categories of potential OS RTI ecosystem participants; possible levers to increase organizational motivation and ability in an OS RTI ecosystem context; and possible barriers to OS RTI ecosystem participation. Section 5.8 provides a validation of the overall results.

5.4.1 Initial Weighting, Ratings and Scatter Plot

The motivation, ability and constraint indicators were initially assigned weights of 0, 0.5 and 1 in order to calculate overall organizational ratings of motivation and ability.

Table 24 provides a rank-ordering of the organizations by ability and motivation.

Table 24: Initial Motivation and Ability Ratings

	Sorted by Ability		Sorted by Motivation	
	Organization	A (%)	Organization	M (%)
1	Research 4	64	University 1	67
2	University 2	62	University 2	58
3	Research 2	56	Research 4	55
4	University 3	55	Research 5	54
5	Company 2	55	Research 2	53
6	Defence 5	51	OS 1	53
7	University 1	50	University 3	51
8	Defence 3	49	University 4	49
9	Company 1	46	Research 3	43
10	Company 5	46	Defence 5	42
11	Research 5	44	Research 1	42
12	OS 1	44	Defence 2	42
13	Research 1	43	Company 1	39
14	Defence 6	41	Company 2	38
15	University 4	40	Defence 1	37
16	Company 4	37	Defence 3	32
17	Defence 1	36	Defence 6	32
18	Company 3	36	Defence 4	32
19	Defence 2	35	Company 5	32
20	Defence 4	28	Company 3	28
21	Research 3	27	Company 4	17

Note: A = Ability, M = Motivation

A review of Table 24 identifies the following key patterns within the theoretical sample. The notion of discussing the rank-ordering of the organizations based upon the top 10 (or 50%) is simply used to provide a basis for a discussion of the results.

- The top four organizations in terms of ability are two research and two academic institutions (Research 2, 4; University 2, 3).
- The top five organizations in terms of motivation are three research and two academic institutions (Research 2, 4, 5; University 1, 2).
- Six specific organizations are in the top 10 for both motivation and ability.
- Academic institutions and companies make up 60% of the top 10 for ability.

- Academic and research organizations make up 80% of the top 10 for motivation.
- Percentage of each type of organization in the top 10 for ability:
75% of the universities, 60% of the companies, 40% of the research institutions, and 33% of the defence organizations from the sample.
- Percentage of each type of organization in the top 10 of motivation:
100% of the universities, 100% of OS RTI (1 of 1), 80% of the research institutions, and 17% of the defence organizations from the sample.

From these observed patterns, the following statements may be made:

- The organizations with the highest ability and motivation ratings are academic and research institutions.
- A greater percentage of the academic institutions (75%) and companies (60%) have higher ability.
- A greater percentage of the research (60%) and defence (67%) organizations have lower ability.
- A greater percentage of the academic (100%) and research (80%) organizations have higher motivation.
- A greater percentage of the defence organizations (83%) and companies (100%) have lower motivation.
- The OS RTI initiator ranks higher in terms of motivation than it does for ability when ranked with the other organizations in the sample.

The motivation and ability ratings were then used to produce a scatter plot to graphically display the motivation and ability of the organizations. The goal was to determine if this would provide a useful depiction of the data. The initial scatter plot is depicted in Figure 7.

Figure 7: Initial Scatter Plot of Organizations in the Sample

Legend: Rsch = Research, Comp = Company, Univ = University, Def = Defence, OS = OS RTI

5.4.2 Subsequent Weighting, Ratings and Scatter Plot

The initial scatter plot of the organizations was not entirely useful because clear groupings of the organizations were not readily apparent. As a result, the researcher returned to the organization-ordered matrix of indicators to determine if certain key indicators might warrant being assigned additional weight. Three key indicators – one within each of motivation, ability and constraint – were assigned an additional weight of 10 to determine if this might provide a better visual display of the data. Organizations

that clearly articulated evidence of these indicators were assigned an additional value of 10 to their ratings. Organizations that appeared to demonstrate evidence of the indicators were awarded an additional value of 5. The three key indicators were:

- Motivation (7A): Specifically want to be involved in an OS RTI initiative or an OS RTI ecosystem
- Ability (15F): Have resources to contribute to an OS RTI initiative
- Constraint (11A): Have no perceived need for an OS RTI

The decision to add weight to particular indicators may be perceived to skew the data.

As a result, validation of the subsequent results is required. This will be discussed in this section and also further in Section 5.8.

The impact to the motivation and ability ratings caused by the additional weighting of the three key indicators is shown in Table 25. The table provides a rank-ordering of the organizations based upon ability and motivation after the additional weighting of the three key indicators was taken into account. The table identifies which organizations displayed evidence of the three key indicators as well as the additional value which was factored into the calculation of their overall rating of motivation and ability (columns +A, +C, +M). The overall rating for ability was calculated by adding the values of all ability indicators and subtracting the value of all of the constraint indicators. The overall rating for motivation was calculated by adding all of the values of the motivation indicators.

Table 25: New Motivation and Ability Ratings

Sorted by Ability							Sorted by Motivation					
	Organization	*	A (%)	+A	+C	+M	Organization	*	M (%)	+A	+C	+M
1	Research 4	=	70	10	-	10	University 1	=	74	10	-	10
2	University 2	=	68	10	-	5	Research 4	↑	65	10	-	10
3	Research 2	=	64	10	-	10	Research 5	↑	64	10	-	10
4	Company 2	↑	63	10	-	10	Research 2	↑	63	10	-	10
5	University 1	↑	59	10	-	10	OS 1	↑	63	10	-	10
6	Research 5	*	54	10	-	10	University 2	↓	56	10	-	5
7	OS 1	*	54	10	-	10	Company 2	*	51	10	-	10
8	Defence 6	*	52	10	-	10	University 4	=	49	5	-	5
9	Defence 1	*	47	10	-	5	Defence 6	*	46	10	-	10
10	University 3	↓	46	-	-	-	University 3	↓	41	-	-	-
11	Research 1	↑	44	5	-	-	Defence 1	↑	40	10	-	5
12	University 4	↑	42	5	-	5	Research 3	*	34	-	-	-
13	Defence 3	*	40	-	-	-	Research 1	↓	33	5	-	-
14	Company 5	*	29	5	10	-	Defence 5	*	33	-	10	-
15	Defence 5	*	25	-	10	-	Defence 2	↓	33	-	10	-
16	Defence 4	↑	23	10	10	-	Company 1	↓	31	-	10	-
17	Research 3	↑	22	-	-	-	Defence 3	↓	25	-	-	-
18	Company 1	*	20	-	10	-	Company 5	↑	25	5	10	-
19	Company 4	↓	13	-	10	-	Defence 4	↓	25	10	10	-
20	Company 3	↓	12	-	10	-	Company 3	=	22	-	10	-
21	Defence 2	↓	11	-	10	-	Company 4	=	14	-	10	-

Note: A = Ability; M = Motivation; +A, +C, +M denote the organizations which received the additional value of 5 or 10 for displaying evidence of the key indicators; = denotes no change from initial ranking in Table 24, ↑ and ↓ denote a change in ranking within the top 10 or bottom 11 organizations, and * denotes a major shift in ranking into or out of the top 10 organizations.

The * column provides an indication of the resulting impact of the key indicators.

Again, the notion of discussing the rank-ordering of the organizations based upon the top 10 (or 50%) is simply used to provide a basis for a discussion of the results. The key patterns that emerge from the theoretical sample are as follows:

- The top three organizations in terms of ability are two research and one academic institution (Research 2, 4; University 2). These three organizations were also ranked in the top three, and in the same order, in the initial ranking.
- The top four organizations in terms of motivation are three research and one academic institution (Research 2, 4, 5; University 1). These four organizations

were ranked in the top five in the initial ranking. University 1 was ranked in the same position (i.e. first) in both rankings.

- The top 50% for both motivation and ability contains the same nine specific organizations (an increase of three from the initial ranking). Five of these organizations were the same as those in the initial ranking.
- The bottom 50% for both motivation and ability contains the same ten specific organizations (an increase of three from the initial ranking). Five of these organizations were the same as in the initial ranking.
- Academic and research institutions make up 60% of the top 10 for ability and 70% of the top 10 for motivation.
- Three organizations displayed no evidence of any of the three key indicators. University 3 had high enough motivation and ability to be ranked in the top 50% for both despite this fact. Research 3 and Defence 3 were both in the bottom 50% for both motivation and ability as a result of this fact.
- All of the organizations with the constraint key indicator are ranked in the bottom 50% for both motivation and ability (4 companies, 3 defence organizations). This is because they generally did not display evidence of the motivation or ability key indicators. Two organizations (Company 5 and Defence 4) displayed evidence of both the ability and constraint key indicator, which simply resulted in their cancelling each other out (i.e. $10-10=0$) or reducing the impact of the ability key indicator (i.e. $5-10=-5$).
- Those organizations which displayed strong evidence of the key ability indicator (i.e. a value of 10) and no evidence of the constraint key indicator are all ranked within the top 50% for ability. The exception is University 3, which had no evidence of either indicator. Its ability rating was high enough to keep it within the top 50% of organizations.
- Those organizations which displayed evidence of the motivation key indicator are predominantly found within the top 50% for motivation. The exception was: Defence 1 which rose from a ranking of 15th to a ranking of 11th. University 3 did

not display evidence of the key motivation indicator; however, its motivation rating was high enough to keep it within the top 50%.

- The majority of the organizations that displayed no evidence of the key motivation indicator are in the bottom 50% for motivation. The exceptions are: University 3, whose motivation is high enough to project it into the top 50%; and Defence 1 which displayed possible evidence of the key motivation (i.e. value of 5 was awarded) but is still in the bottom 50% for motivation.
- Four organizations were elevated to the top 50% for ability as a result of displaying evidence of the key ability indicator (denoted in Table 25 by a *). Three organizations were relegated to the bottom 50% as a result of displaying evidence of the key constraint indicator. One organization was relegated to the bottom 50% as a result of being bypassed by other organizations; it displayed no evidence of the key constraint indicator.
- Two organizations were elevated to the top 50% for motivation as a result of displaying evidence of the key motivation indicator. Two organizations were relegated to the bottom 50% as a result of their lack of evidence of the key motivation indicator.
- Percentage of each type of organization in the top 10 for ability:
100% of OS RTI (1 of 1), 75% of the universities, 60% of the research institutions, 33% of the defence organizations, 20% of the companies from the sample. Compared to the initial ratings: the OS RTI is a new addition; the percentage of defence organizations remained the same (but the organizations were different from those in the initial ranking); the percentage of universities remained the same (as did the organizations); the research organizations increased by one; and the number of companies dropped from 3 to 1.
- Percentage of each type of organization in the top 10 for motivation:
100% of the universities (remained the same), 100% of OS RTI (remained the same), 60% of the research organizations (decreased by 1 organization), 20% of the companies (increased by 1 organization) and 17% of the defence organizations (remained the same) from the sample.

From these observed patterns, the following statements may be made:

- The organizations with the highest ability and motivation continued to be academic and research institutions. This would suggest that the additional weighting of the key indicators did not skew their overall placement in terms of ability and motivation.
- The OS RTI initiator is now among the top organizations for both motivation and ability. This seems intuitively logical considering: it is an OS initiative; it is endeavouring to expand its user base; and it has a version 1.0 release candidate.
- The constraint indicator only affected defence organizations and companies. This seems plausible considering the fact that the needs of several of the defence organizations are met by commercial RTIs. As well, one of these organizations is not a strong HLA user. It is also plausible in the case of the M&S companies. Several of these produce COTS RTIs and complementary products and see OS RTIs as direct competition. Others use commercial RTIs to satisfy the demands or risk aversion of their clients, and are not likely to use OS RTIs in their work.
- The organizations which displayed evidence of the ability and motivation indicators predominantly rose in the overall rankings for ability and motivation. There were two exceptions: one organization displayed evidence of the constraint indicator (Company 5 in ability ranking); and one was bypassed by those with higher scores (University 2 in motivation ranking).
- Five specific organizations were in the top 10 for both motivation and ability before and after the addition of the key indicators. These were: University 1, 2, 3 and Research 2, 4. Five specific organizations were in the bottom 11 for both motivation and ability before and after the addition of the key indicators. These were: Research 1, Defence 2, 4, and Company 3, 4. Therefore, the additional weighting of the key indicators did not alter the general placement of these 10 organizations. It had a more noticeable effect on the placement of the remaining 11 organizations, drawing them out into clearer groupings (see Figure 8).

- The ability and constraint indicators: did not affect the percentage of defence and academic organizations in the top 50% for ability; elevated the OS RTI; increased the research organizations by one; and decreased the companies by two.
- The motivation indicator: did not affect the percentage of OS RTI, defence and academic organizations in the top 50% for motivation; increased the companies by one; and decreased the research organizations by one.

The addition of the three key indicators with greater weights served to identify those organizations which: specifically wanted to contribute to, or participate in, an OS RTI initiative or ecosystem; had resources which they wanted to contribute to an OS RTI initiative; and had no perceived need for an OS RTI. The result of assigning additional weight to these indicators is depicted in the new scatter plot of the organizations in Figure 8. This new plot appears to provide a more useful depiction of the organizational ratings for motivation and ability, since clearer groupings of organizations can be identified. This may provide an indication of potential ecosystem participants and provide insight as to whether or not the context is favourable to an OS ecosystem.

The emergence of groups of potential participants will be discussed in the next section. Possible levers to increase their motivation and ability are discussed in Section 5.6, and barriers to OS RTI ecosystem participation are discussed in Section 5.7. Further validation of this new scatter plot result and the industry's likelihood of being able to support an OS RTI ecosystem are discussed in Section 5.8.

Figure 8: Inclusion of Key Indicators – Scatter Plot of Organizations in the Sample

Legend: Rsch = Research, Comp = Company, Univ = University, Def = Defence, OS = OS RTI

5.5 Moving from an Attribute-based to a Circumstance-based Categorization of Organizations

At the outset of this research, the theoretical sample was selected based upon the five attribute-based categories of: (i) defence organizations; (ii) M&S companies; (iii) academic institutions; (iv) research institutions; (v) OS RTI initiators. As discussed in Section 2.7.3, theory based upon circumstance-based categories is of greater value to practitioners. An important result of this research is that the scatter plot with the weighted key indicators (recall Figure 8) enabled the researcher to identify circumstance-

based categories of the organizations in the sample. These organizations represent a subset of the distributed simulation industry members.

This section discusses each of the circumstance-based categories that were identified within an OS RTI ecosystem context. These can provide insight to those who wish to create and evolve an OS RTI ecosystem because they identify a pool of potentially motivated and able participants. As well, organizations with circumstances that limit their participation are identified. These may warrant consideration in conjunction with the levers to increase motivation and ability that are discussed in Section 5.6 and the barriers to OS RTI ecosystem participation discussed in Section 5.7.

5.5.1 Circumstance-based Categorization

The circumstance-based categorization of the organizations in the theoretical sample was defined by making reference back to the data in the organization-ordered matrix (see Appendix 3). This was carried out to ensure that the categorization was based upon the common circumstances shared among the organizations within each category. The circumstance-based categorization is depicted in Figure 9.

The Motivation/Ability matrix (recall Figure 2) employs like-sized quadrants to define the four distinct industry situations of: the hotbed; looking for a target; looking for the money; and the dilemma. In this research, however, the 50% midpoints on the scatter plot were not found to be useful delimiters of the circumstance-based categories. Instead, the categories were defined using both the close groupings of the organizations in the scatter plot and a rigorous consideration of their common circumstances. This enabled the researcher to define the four unique categories depicted in Figure 9. Each of these is described below using the dimensions of organizational motivation, ability and

constraint from Section 5.3 to highlight their common circumstances. The one outlying organization is also discussed.

Figure 9: Final Circumstance-based Categorization

Legend: Rsch = Research, Comp = Company, Univ = University, Def = Defence, OS = OS RTI

It is important to note that motivation and ability appear to be strongly correlated.

The organizations lie along a diagonal that ranges from the Dilemma quadrant to the Hotbed, with very few organizations in the Looking for the Money or Looking for the Target quadrants. This would suggest that the strength of an organization's motivation mirrors that of its ability, and vice versa.

It should be noted that the theoretical sample represents only a subset of the distributed simulation industry. A focused search for cases in the near-empty quadrants must be conducted to either validate this motivation-ability correlation (i.e. if none are found) or to highlight a pattern different from this research. This is left for future research. As well, this scatter plot provides a snapshot of the current organizational motivation, ability and constraint at the time of the interviews. The ratings may have since changed and there may now be organizations that fall within each of the quadrants.

5.5.2 Category 1 – The Hotbed Organizations

The organizations in Category 1 represent those with the highest motivation and ability to participate in an OS RTI ecosystem. These are organizations that a manager or initiator of an OS RTI ecosystem should initially target as potential participants when creating or evolving their ecosystem. This category is made up of seven organizations: University 1 and 2; Research 2, 4 and 5; Company 2; and the OS RTI initiator.

The organizations in Category 1 are mostly research and academic institutions. There is a distinct lack of companies; the only company is the one currently sponsoring the development of an OS RTI. This category contains no defence organizations.

The circumstances common to all or most of the organizations in this category are outlined in Table 26. The key indicators are noted in the table in bold red. Of particular importance is the fact that all of the organizations specifically want to be involved in an OS RTI initiative or ecosystem and have resources that they are able to contribute; that is they all displayed evidence of the key motivation and ability indicators. None of the organizations articulated that they had no need for an OS RTI; that is, none displayed evidence of the key constraint indicator.

Table 26: Circumstances Common to Category 1 Organizations

Number	Motivation	Ability	Constraint
All	- want to specifically be involved in an OS RTI initiative or ecosystem - external M&S focus - want to achieve an outcome related to their work or business - want to achieve an outcome related to the M&S industry - want to conduct or facilitate research	- have resources to contribute to an OS RTI initiative - see potential uses for an OS RTI and would consider using one. - have relationships with industry, national and international research institutions, national academic institutions, national government or defence organizations - have positive dependence relationships - contribute to the advancement of external M&S initiatives (gain ROI) - consume OS products, follow OS, and use OS to benefit their work or business - have beneficial practices or roles	- this category shares few constraints in common - no organizations had the constraint indicator, meaning none articulated that they had no perceived need for an OS RTI - all organization had FEW or NO constraints that were: organizationally- or externally imposed; HLA-specific; or related to simulation infrastructure/connectivity, security, or M&S awareness.
6 of 7 (86%)	- internal M&S focus - external OS focus - want to achieve an outcome related to the science of M&S - want to achieve an outcome related to M&S knowledge - want/need RTI source code - want/need OS product source code - want to establish or improve relationships - want sources of funding other than from profit or research funding	- have knowledge of existing OS RTIs - have existing distributed simulation and HLA knowledge and expertise - have relationships with international academic institutions - produce OS products - participate in SISO and professional organizations devoted to M&S, distributed simulation, or HLA.	
5 of 7 (71%)	- internal OS focus - participate in international M&S exercises - want/need OS products that are cost-free and have permissive licenses - want sources of research funding	- already using an OS RTI or have experience using one - have relationships with international government or defence organizations - have beneficial organizational practices specific to intellectual property (IP)	- negative dependence relationships upon other organizations for funding - challenge to find qualified personnel - financial constraints (limited funding in general, compete for limited sources of funding, or funding is not guaranteed year to year)

In terms of motivation, six out of seven of the organizations in this category expressed a desire or need to have RTI source code, and also to have access to the source code for other OS products. Five out of seven of the organizations want or need OS products that are cost-free and have permissive licenses.

In terms of ability, all of the organizations in this category see potential uses for an OS RTI within their organization or for their clients/stakeholders, and would consider using one if they are not already doing so. They also all consume OS products, follow OS trends and advances, and use OS to benefit their business or work. As well, all of the organizations displayed evidence of strong inter-organizational relationships.

Six out of seven organizations in this category have: knowledge of existing OS RTIs; existing distributed simulation and HLA knowledge and expertise; and produce OS products. The same number of organizations also demonstrated strong participation in SISO and professional organizations that are devoted to M&S. Five out of seven of the organizations are already using an OS RTI or have experience using one. Of particular note, four of the seven organizations have developed an OS RTI.

The organizations in this category share few constraints in common. They either have no or very few constraints that would detract from their ability. The constraints that they do share are predominantly related to funding and personnel.

5.5.3 Category 2 – Second Wave Organizations

The organizations in Category 2 represent those with sufficient motivation and ability to be considered after the initial target organizations or as an additional pool of potential participants to complement those from Category 1. An OS RTI manager or initiator could either consider: approaching these organizations in a second wave of

recruitment to augment the number of participants; or could use them as an additional pool of participants to further complement existing or potential ecosystem participants. Since this category includes defence organizations and the first category does not, this category could be used as a source of potential defence participants. This category is made up of five organizations: University 3 and 4; Research 1; and Defence 1 and 6.

The organizations in Category 2 are a mix of defence, academic and research organizations. There are no companies in this category. The only OS RTI initiator in the theoretical sample is found in Category 1, not Category 2.

The circumstances common to all or most of the organizations in this category are outlined in Table 27. The key indicators are noted in the table in bold red. It is important to note that four of the five organizations have resources that they are able to contribute to an OS RTI initiative, and three of the organizations specifically want to be involved in an OS RTI initiative or ecosystem; that is to say that these organizations displayed evidence of the key motivation and ability indicators. As in Category 1, none of the organizations stated that they had no need for an OS RTI (i.e. none displayed evidence of the key constraint indicator). This is an important distinction between Category 2 and 3; it is part of the reason why Category 2 organizations are worth considering as a second wave of potential participants or as an additional pool of participants.

In terms of motivation, four of the five organizations want or need to meet an external OS need or requirement. Three of the five organizations want or need an RTI that is cost-free and has a permissive license.

In terms of ability, all of the organizations have strong inter-organizational relationships. Four of the five organizations have knowledge of existing OS RTIs and

see potential uses for one within their organization or for their clients/stakeholders. As well, four of five: have existing distributed simulation and HLA knowledge and expertise; participate in large-scale national or international M&S exercises; and

Table 27: Circumstances Common to Category 2 Organizations

Number	Motivation	Ability	Constraint
All	- external M&S focus - want to achieve an outcome related to M&S knowledge - want to conduct or facilitate M&S research	- have relationships with national research institutions, and national government or defence organizations - contribute to the advancement of external M&S initiatives (gain ROI) - have existing organizational capabilities	- NO constraints that are: related to OS RTIs; imposed by government or the M&S industry; or related to simulation infrastructure or connectivity. - mostly no HLA-specific constraints (only one organization indicated it was not a large HLA user) - no organizations had the constraint indicator, meaning none articulated that they had no perceived need for an OS RTI
4 of 5 (80%)	- internal M&S focus - external OS focus - want to achieve an outcome related to their work or business - want sources of funding other than from profit or research funding - want to establish or improve relationships	- have resources to contribute to an OS RTI initiative or plan to pursue one - have knowledge of existing OS RTIs, and see potential uses for one - have existing distributed simulation and HLA knowledge and expertise - have relationships with industry, international research institutions, and international government or defence organizations - participate in large-scale national or international M&S exercises or activities - have existing technical capabilities - have beneficial organizational practices or roles - participate in SISO and professional organizations devoted to M&S, distributed simulation, or HLA.	

3 of 5 (60%)	- want to specifically be involved in an OS RTI initiative or ecosystem - want/need an RTI that is cost-free and has a permissive license - want to achieve an outcome related to the science of M&S - want to achieve an outcome related to the M&S industry - want to conduct or facilitate formal or informal M&S training - want to participate in international M&S exercises - want research funding - want, need or lack personnel with M&S expertise	- would consider using an OS RTI. - have relationships with national and international academic institutions - have positive dependence relationships - produce OS products, consume OS products, follow OS, and use OS to benefit their work or business - participate in M&S industrial development groups.	- constrained by their organizational structure, business model or role - existing personnel are constrained in some way - have difficulty maintaining an awareness of M&S activities internal and external to their organization.

participate in SISO and professional organizations devoted to M&S. Three of the five organizations would consider using an OS RTI, and have strong OS experience from producing their own OS products, consuming OS, following OS projects, and using it to benefit their business or work. Only one organization in this category has developed an OS RTI, and this was carried out as part of a student's Master's thesis.

As in Category 1, the organizations in Category 2 share few constraints in common. They are not organizationally constrained from the pursuit or use of OS RTIs, and they did not identify government- or M&S industry-imposed constraints. Only some of the organizations are affected by constraints that are: organizationally-imposed; client or stakeholder- imposed; personnel or financially related; HLA-specific; or related to simulation infrastructure/connectivity, security, or maintaining M&S awareness.

5.5.4 Category 3 – The Dilemma Organizations

The organizations in this category represent those who have low motivation and ability compared to Categories 1 and 2 for a variety of reasons. They are organizations that would present a manager or initiator of an OS RTI ecosystem with some form of dilemma when trying to solicit their participation in the ecosystem. This category is made up of six organizations: Research 3; Defence 2, 4 and 5; and Companies 1 and 5.

The organizations in Category 3 are predominantly defence organizations and companies; there is also one research organization. This category does not include any academic institutions or the OS RTI initiator.

The circumstances common to all or most of the organizations in this category are outlined in Table 28. The key indicators are noted in the table in bold red. It is important to note that these organizations share much in common in terms of their ability; however they have much less in common in terms of their motivation and constraint. Five of the six organizations articulated that they have no perceived need for an OS RTI; that is they displayed evidence of the key constraint indicator. All of the organizations in this category displayed no evidence of motivation towards an OS RTI. Only two organizations indicated that they had resources that they could contribute to an OS RTI initiative; that is they displayed evidence of the key ability indicator. Overall, these organizations would present a manager or initiator of an OS RTI ecosystem with significant challenges in garnering their interest and securing their participation in the ecosystem.

Table 28: Circumstances Common to Category 3 Organizations

Number	Motivation	Ability	Constraint
All	- external M&S focus - want to achieve an outcome related to their work or business - want to conduct or facilitate M&S research	- have relationships with industry, national academic institutions, national and international government and defence organizations - contribute to the advancement of external M&S initiatives (gain ROI) - consumer of OS, follow OS and see value in it, use OS to benefit their organization or business	Indicators of constraint are common to smaller groups of organizations.
5 of 6 (83%)	- want to achieve an outcome related to M&S knowledge	- have knowledge of existing OS RTIs - have existing distributed simulation and HLA knowledge and expertise - participate in large-scale national or international M&S exercises or activities - have relationships with national research institutions - participate in NMSG and professional organizations devoted to M&S, distributed simulation, or HLA - have beneficial organizational practices or roles	- have no perceived need for an OS RTI
4 of 6 (67%)	- want to achieve an outcome related to the science of M&S - want to provide or facilitate formal/informal M&S training - want, need or lack M&S personnel - want to establish or improve relationships - want to establish a presence in their community/market	- have relationships with international academic institutions - have positive dependence relationships - have existing technical capabilities - have beneficial organizational practices specific to intellectual property (IP)	- lack direction or support from their higher headquarters to pursue M&S - lack a strategic M&S champion - have negative dependence relationships upon other organizations for reasons other than funding - Client, customer or stakeholders lack M&S knowledge and awareness; or the ability to properly articulate their needs. This can impose technical or operating constraints. - face challenges in finding qualified personnel
None	None of the organizations:	None of the organizations:	

	specifically want to be involved in an OS RTI initiative; want or need RTI source code; want or need an RTI that is cost free and has a permissive license; or want to leverage an OS RTI for business opportunities.	have developed an OS RTI; have beneficial or valuable relationships with OS projects; or participate in existing M&S consortia.	

When looking at their motivation, the organizations share a common lack of desire to become involved in an OS RTI initiative. No organization expressed a desire or need for OS RTI source code or interest in leveraging an OS RTI to pursue business opportunities. Only one organization was interested in acquiring access to RTI source code. Half of the organizations expressed a desire or need for OS product source code, and only two expressed a need for OS products that are cost-free and have permissive licences. The two companies in this category did, however, express an interest in leveraging OS to benefit their business.

An analysis of the ability of the organizations reveals that most, if not all: have strong inter-organizational relationships; participate in large-scale national or international M&S activities; contribute to the advancement of M&S initiatives external to their organization; have existing distributed simulation and HLA knowledge and expertise; and are aware of existing OS RTIs. These organizations are mostly not producers of OS; however, they all consume OS, follow OS projects, see value in OS, and use it to benefit their organization or business. The majority of the organizations participate in the NMSG and also in professional organizations which are devoted to M&S, distributed simulation and HLA. They also largely have beneficial organizational practices or roles which provide them with resources. Two organizations in this category indicated that they have resources to contribute to OS RTI initiative or interest in

participating in one, but these same organizations also expressed that they have no perceived need for an OS RTI. None of the organizations have developed their own OS RTI, and none have existing beneficial or valuable relationships with OS projects.

One key area where the organizations in this category differ from the first two categories is in the area of constraint. While these organizations exhibit many of the indicators of ability, their organizational ability ratings are decreased significantly by the evidence of organizational constraint that they display. The fact that five of the six organizations in this category clearly expressed that they have no perceived need for an OS RTI had a detrimental effect upon their overall ability ratings. The sixth organization simply has low ability due to its many other constraints. Four of the six organizations: lack direction, support or priority M&S from their higher headquarters; have negative dependencies upon other organizations related to issues other than funding; have clients or stakeholders who lack M&S knowledge or awareness; and also expressed difficulty in finding qualified personnel. Beyond these constraint indicators, the organizations in this category largely did not share common indicators of constraint. Generally, only one to three organizations displayed evidence of each indicator (not the same one to three in each case).

5.5.5 Category 4 – Disinterested Companies

Category 4 is composed strictly of two companies: Companies 3 and 4. These organizations do not fit neatly into Category 3 and were therefore assigned their own category. Further investigation of these organizations would be required to determine if they warrant consideration by an OS RTI ecosystem initiator. The data suggests that they

are neither motivated nor able to participate based upon the definitions of motivation and ability in this research.

The low motivation of these organizations may be attributed to the fact that they displayed no evidence of indicators related to the OS RTI. That is, they expressed no desire to: be specifically involved in an OS RTI initiative (the key motivation indicator); have access to RTI source code; have an RTI that is cost-free and has a permissive license; or leverage an OS RTI for business opportunities. While they both expressed interest in facilitating or conducting research, they displayed no evidence of a desire or need to provide formal education, formal or informal training, or participate in international exercises. They also expressed little interest or need related to OS software. The predominant focus of these organizations appears to be serving the needs of their customers, making a profit, and expanding their customer base.

The organizations displayed strong evidence of many ability indicators. One notable exception was in relation to an OS RTI. While these organizations were involved in the early development of the HLA, they displayed no evidence of: current OS RTI use; whether they see potential uses for an OS RTI or would consider using one; or whether they had resources that they would contribute to an OS RTI initiative (the key ability indicator). Both organizations are consumers of OS, follow OS projects, and use OS to benefit their business. Both are also involved in SISO and professional organizations devoted to M&S, and displayed evidence of strong inter-organizational relationships. Despite the lack of evidence related to OS RTIs, the organizations had ability comparable to those organizations on the lower end of Categories 1 through 3. Unfortunately, their overall ability rating was negatively affected by their clear articulation that they have no

perceived need for an OS RTI (key constraint indicator). The organizations shared few constraints beyond this critical one.

5.5.6 Outlying Organization

Defence 3 is considered to be an outlying organization which does not fit neatly into any category. Its motivation is deemed to be too low for inclusion in Category 2 and its ability is too high for inclusion in Category 3. This organization might warrant consideration with the Category 2 organizations if the manager or initiator of an OS RTI ecosystem could successfully increase its motivation.

The organization's low motivation may be attributed to the fact that it expressed no evidence of indicators related to the OS RTI, money and personnel dimensions of motivation. There was also little evidence of indicators related to the OS dimension, though Category 2 organizations weren't strong in this regard either. The organization has less in common with Category 2 and 3 organizations in the area of motivation, as shown in the scatter plot in Figure 9.

An analysis of ability reveals that this organization has strong ability. It sees potential uses for an OS RTI and would consider using one, and is aware of existing OS RTIs. The organization also consumes OS, follows OS, sees value in OS, and uses it to benefit its organization. As a result, it may very well be that this organization has higher motivation than was expressed to the researcher. Therefore, this organization may warrant consideration with category 2 organizations. Further investigation of the organization's motivation would be required.

The organization faces several constraints which have reduced its overall ability rating. These include the organizational constraints related to a lack of direction, support

and priority for M&S, a lack of a strategic champion, and a lack of awareness among higher headquarters. It shares these in common with the two defence organizations in Category 2. These are all conditions which are in the midst of improving, which may serve to increase the organization's overall ability rating. The organization is also currently dealing with challenges in establishing its simulation infrastructure and connectivity, some of which are related to security policies and others are related to lack of support. Again, these conditions are in the midst of improving, so this may result in an increase to the organization's overall ability rating as well.

Of particular note in the area of constraint is the fact that the organization displayed no critical constraints related to an OS RTI. The organization did not indicate that it had no need for an OS RTI. Respondents from the organization did note that use of an OS RTI with existing simulation applications would require some reprogramming in order to ensure interoperability, but that this was not a monumental hurdle to its use. As a result, the organization may be open to efforts to increase its motivation and ability.

5.6 Possible Levers to Increase Organizational Motivation and Ability

An analysis of the indicators of motivation and ability reveals that a select group of these could potentially be influenced by an OS ecosystem manager or initiator in order to increase an organization's overall motivation and ability. There are other areas of motivation and ability which cannot be influenced. These should not be considered barriers per se, but rather are fundamental aspects of an organization that are likely not open to influence. These fundamental aspects would include: the areas upon which they focus their work or business orientation (i.e. internal or external); their desire to achieve specific outcomes (i.e. related to the science of M&S, M&S knowledge, or the M&S

industry); their M&S roles (i.e. research, formal education, training); their involvement in certain international organizations devoted to M&S (e.g. where membership is restricted); as well as their technical (i.e. infrastructure and connectivity) and organizational capabilities. The constraint indicators that cannot be influenced are considered to be barriers. These will be discussed in the Section 5.7.

5.6.1 Possible Organizational Motivation Levers

Five potential levers to increase motivation were identified in this research (see Table 29). The first three levers could be considered fundamental OS ecosystem building blocks. The first of these should be employed at the outset of the ecosystem's creation. The second and third should be early objectives of the ecosystem managers or initiators. The final two levers can be applied as the ecosystem grows in size and capability.

Table 29: Possible Motivation Levers

1. Create a credible OS RTI ecosystem infrastructure to attract potential participants. It should include: • An OS RTI with documentation   • A licensing framework as well as processes that address governance, development, and project management   • Defined membership levels and OS RTI ecosystem roles for participants (e.g. as developers, or providers of training, support or consulting)   • Support, training or consulting services
2. Build a strong offering of resources and opportunities (e.g. business, training). This should include: • Complementary applications (e.g. development tools)   • Sample federates and federations   • Freely accessible educational and training resources   • Distributed activities or exercises
3. Establish and grow a network of inter-organizational relationships.
4. Establish a reliable source of skilled M&S personnel and expertise.
5. Establish a source of funding for distributed simulation and HLA research, development, experimentation or other such initiatives.

The first, and most fundamental of the levers, would address many aspects of organizational motivation, build credibility and attract potential participants. It would

involve purposefully creating a credible infrastructure, as Moore (2006) describes, “of technologies, designs and contracts, and products and services...within which new contributors and customers can be added”.

This infrastructure should include a well-architected OS RTI with documentation for both users and developers. Second, it should include a licensing framework and processes for governance, development and project management to ensure the effective administration and operation of activities within the ecosystem. Third, there should be clearly defined ecosystem membership levels as well as ecosystem roles for participants (e.g. as providers of services or as developers of complementary tools). This will enable organizations or individuals to effectively position themselves within the ecosystem in accordance with their needs, goals, capabilities and existing resources. Lastly, the ecosystem should include services such as support, training or consulting.

A second motivation lever would involve building a strong offering of resources and opportunities that would meet the needs and requirements of potential participants. It would involve building a wealth of available OS resources that would be attractive and useful to current and potential participants, including: tools complementary to the OS RTI (e.g. for development); sample federates and federations; and freely available educational and training resources. It would also include the coordination or facilitation of distributed activities or exercises in which participants could gain experience and expertise, or training opportunities in which to do the same.

A third motivation lever would involve building a network of inter-organizational connections among distributed simulation industry players, partners, customers, stakeholders and so on. This would lend credibility to the ecosystem and would enable it

to potentially draw in participants that are looking to form relationships with organizations in the network. It would also facilitate the creation of new relationships.

A fourth motivation lever would involve developing the ecosystem such that it becomes a reliable source of skilled personnel and expertise. This is similar to Bonaccorsi and Rossi's (2006) assertion that organizations are motivated to participate in OS projects because they see them as a potential source of skilled IT specialists. This source of personnel could be in the form of independent consultants, support services provided by an organization, or any other possible business model.

A final motivation lever would involve the ecosystem establishing sources of funding to support distributed simulation research, development, or even experimentation. This funding could be provided by key organizational participants that are interested in fostering and sponsoring this type of work. The existence of such sources of funding could also serve to attract potential participants to the ecosystem.

5.6.2 Possible Organizational Ability Levers

Eight levers were identified that would contribute to increasing organizational ability (see Table 30). The first three levers are directly related to the OS RTI. The fourth involves facilitating new inter-organizational relationships. The fifth and sixth involve providing organizations with opportunities for training and business. The seventh lever involves increasing an organization's capabilities through the provision of skilled personnel and funding from the OS ecosystem. The final lever involves providing mechanisms to increase M&S awareness of ecosystem participants.

The first ability lever involves increasing organizational awareness of the ecosystem's OS RTI, complementary tools, and other offerings in comparison to other

OS RTIs in existence. This will provide organizations with an awareness of the existing offerings and how robust or mature they may be in relation to the ecosystem's offering.

The second lever involves enabling more organizations to use an OS RTI. An OS RTI already lowers an organization's barriers to entry; however, it must also be easy to use and come with compatible tools, sample federates and federations, training and support to improve a user's skills.

Table 30: Possible Ability Levers

1.	Increase organizational awareness of the ecosystems offerings in comparison to existing OS RTIs and complementary tools (e.g. their capabilities, characteristics, maturity and level of robustness).
2.	Enable organizations to easily use the ecosystem's OS RTI. It must come with user and developer documentation, and also have complementary tools, sample federates and federations, training and support in order to improve a user's skills.
3.	Raise awareness of potential uses for an OS RTI (e.g. research, experimentation, leverage for a business opportunity)
4.	Facilitate the creation of new inter-organizational relationships.
5.	Provide opportunities for organizations to develop their distributed simulation experience and expertise (e.g. exercises, activities, training, support).
6.	Identify opportunities for organizations to gain a return on their investment (e.g. access to additional resources, creation of business opportunities).
7.	Increase organizational capabilities by providing access to skilled personnel and sources of funding.
8.	Increase the M&S awareness of ecosystem participants through the use of online collaborative environments and tools.

The third ability lever involves raising awareness of the potential uses of an OS RTI, including applications to domains such as research, experimentation, or in order to spearhead business opportunities. This will serve to fuel the creativity of potential ecosystem participants.

The final four levers for ability also share aspects in common with the levers for motivation. As a result, the use or application of several motivation levers may also contribute to increasing organizational ability. The fourth ability lever would involve facilitating the creation of new inter-organizational relationships that would be valuable

and beneficial to ecosystem participants. The presence of an existing network of connections would serve to increase an organization's motivation to participate in the ecosystem, while the creation of actual relationships would increase their ability.

The fifth lever would involve providing organizations with opportunities to develop their experience and expertise in distributed simulation through the conduct, hosting, coordination or facilitation of exercises or activities, and the provision of online training and support. These activities also form part of the strong offering of resources that will assist in attracting potential participants into the ecosystem (motivation lever 2).

The sixth lever would involve the identification of clear opportunities for organizations to gain a return on their investment in the ecosystem. This could be in the form of access to additional resources from the ecosystem or from its participants in the form of tools, expertise, knowledge, lessons learned, or additional business opportunities. Similar to the fifth ability lever, these opportunities form part of the strong offering of opportunities that will assist in attracting potential participants into the ecosystem (motivation lever 2).

The seventh ability lever would involve providing the organizations with a means to increase their organizational capabilities by drawing personnel or funding from the ecosystem. Establishing such sources of expertise and funding will also serve to increase the motivation of potential ecosystem participants to join.

Lastly, a consideration of organizational constraint serves to identify a final ability lever related to organizational awareness of M&S, distributed simulation and HLA activities. Many organizations in the theoretical sample indicated that they had difficulty in maintaining awareness of M&S activities both internal and external to their

organization. Therefore, the ecosystem must become a vital source of knowledge, expertise and lessons learned for ecosystem participants. It must become a critical mechanism for maintaining organizational M&S and distributed simulation awareness. It can do so through the use of online collaborative environments and tools such as wikis, bulletin boards, mailing lists, or calendars of events.

5.7 Possible Barriers to Open Source Ecosystem Participation

This research identified several barriers that were not likely within the purview of OS RTI ecosystem managers or initiators to influence. These barriers may be grouped into three categories: organizationally-imposed; client, customer or stakeholder-imposed; and government-imposed. It is important for OS RTI ecosystem managers and initiators to be aware of the existence of such barriers when approaching potential participants.

The following are the organizationally-imposed barriers that will not likely respond to external influence: lack of organizational support, direction or priority for M&S; lack of a strategic champion for M&S; lack of M&S awareness at a higher headquarters; restrictive organizational policies or management; restrictive organizational structure, business models, or roles; and constraints imposed upon existing personnel. For instance, policies or management may prevent an organization from further developing its M&S infrastructure, collaborative relationships, or M&S expertise. As well, policies or management may prevent organizations from participating in forums that are not peer-reviewed. Organizational structure may impose barriers in several ways: it may be that an organization lacks a centralized entity with overarching responsibility for M&S coordination and activities, or it may have such an entity but it lacks visibility within the organization; or the organization may now be part of a much larger international

organization that imposes barriers. Existing personnel may be faced with barriers because they are assigned additional tasks that detract from their M&S work, or they may be affected by staff shortages that result in it taking longer to achieve their objectives.

The client, customer or stakeholder-imposed barriers include: the use of M&S practices and tools being dictated by the requirements, policies or degree of risk aversion of the client, customer or stakeholder; M&S work being dictated by the needs or requirements of the client, customer or stakeholder; the client, customer or stakeholder community lacks coherence, or is poorly defined or fragmented. For instance, organizations may be directed to use specific practices (e.g. DIS instead of HLA) or tools (e.g. a particular commercial RTI) to ensure compatibility with what their clients, customers, or stakeholders are already using or to satisfy perceived needs for reliability and commercial support. In several instances, an organization's work is dictated by its research or programme sponsors. Organizations may also find it difficult to meet the needs of their client, customer or stakeholder community if this community cannot articulate its specific simulation requirements or is fragmented with respect to its overall objectives or approach to simulation (e.g. community members may each be set upon using different approaches to distributed simulation such as DIS, HLA, or other newly emerging approaches).

Three forms of government imposed barriers were identified by the organizations in the sample. The first barrier involved the creation of government-owned products that compete directly with commercial offerings and were generally freely offered to government contractors or end users (i.e. Government-Off-The-Shelf products (GOTS)). The second barrier involved the government practice of solely relying upon large M&S

companies when contracting in support of major government programmes. The third barrier involved contracting processes put in place by the government that imposed undue restrictions upon organizations or were cumbersome to navigate through.

5.8 Validation of Results

In order to validate the results, the researcher applied a two-step approach. The first step involved analyzing the results in relation to existing literature. A second step was required due to the distinct lack of relevant literature; it involved interviewing key individuals with specific areas of expertise related to the research. This additional step served several purposes. First, it augmented the limited validation that could be carried out with the existing literature. Second, it validated the weighting of the key indicators. Lastly, it identified the potential usefulness of the results; and added to the depth of the literature review.

5.8.1 Comparison of Dimensions to Extant Literature

The organizational motivation, ability and constraint dimensions which emerged from the data are much broader than those found in the extant literature on participation in OS initiatives. As well, this research considered a broad scope of participants that included not only companies, but also research and academic institutions, defence organizations, and an OS RTI initiator. Lastly, it also focused upon an OS ecosystem context as opposed to simply an OS community or OS project context.

Wichmann (2002) and Bonaccorsi and Rossi (2006) looked only at the participation of firms in OS projects, and not ecosystems. As well, they only addressed the issue of organizational motivation and did not consider ability or constraint. Milinkovich (2008b) only considered companies engaging in OS ecosystems or projects with his OS

Ecosystem Engagement Model (recall Figure 1). His table of business reasons to participate in OS projects (recall Table 8) only considers organizational motivation.

Bonaccorsi and Rossi (2006) identify economic, technological and social motivation areas related to organizational motivation to carry out OS activities. Each of these motivation areas had several specific examples of motivations (recall Table 7). This research did not find evidence of the technological or social motivation areas. Some aspects of the economic motivation area did emerge, these included: the desire or need for freedom from commercial software costs and licensing; and the desire to leverage OS products or projects in order to pursue new business opportunities.

Wichmann (2002) identifies four major motivations for firms to participate in OS activities (recall Table 6). These include: for standardization purposes; to lower costs; for strategic reasons; and to enable compatibility. It is important to note that his work focused upon issues related to the proliferation OS operating systems and their compatibility with hardware. These were not issues raised within the OS RTI domain. This research did not find evidence of Wichmann's (2002) motivations related to standardization and enabling compatibility. It did, however, find evidence of motivation to use OS either to lower costs or as part of a business strategy.

The maturity model used by Milinkovich (2008b) to depict the evolution of a company's engagement in OS ecosystems and the business reasons associated with a company's participation in OS projects address issues of motivation. Elements of each of these are represented in the motivation indicators that emerged from this research. The following concepts all appear within this research's motivation indicators: using OS to explore, lower costs and decrease development time; contributing to OS; championing an

OS project or steering its evolution; collaborating to gain positional advantage; and redefining the value proposition of a customer offer.

This research expands upon the existing literature in several ways. First, it addresses the broader scope of an OS ecosystem driven by business considerations. Second, it considers the participation of non-profit and government organizations in addition to companies. Lastly, it considers organizational motivation and also takes into account the impact that organizational ability and constraint will have upon participation.

5.8.2 Expert Validation of Results

In order to augment the limited validation that could be conducted with the existing literature, the researcher interviewed two key individuals with expertise related to the research. The first was the Executive Director of the non-profit keystone of an existing OS ecosystem, and the second was the lead developer of an existing OS RTI initiative. These individuals were presented with the organization-ordered matrix and before-and-after scatter plots in order to initiate discussion and gain specific insight from them.

The Executive Director of the Eclipse Foundation, the non-profit keystone of a well-established OS ecosystem, provided his insight based upon experience with OS ecosystem creation and evolution (Milinkovich, 2009). He suggests that the plot of organizations on the motivation/ability matrix can assist an OS RTI ecosystem manager or initiator in devising an ecosystem implementation strategy:

“The thing that immediately struck me was...look in the top right quadrant and you’ve got a nice mix of entities in there. This is really what we look for if we want to start a new initiative in a new area...[you don’t want the potential candidate organizations to be too slanted] in one direction or another.

What I would do is talk to the OS person, the defence [organization] and maybe one or two of the universities and/or research organizations. If you can get a major company and a major chunk of code to agree to step one, then everybody else is actually gravy...because then you have a corporate backer that is going to put some resources into it and you've got some code to get started. The other people are there to basically act as validation and to help you get some momentum."(Milinkovich, 2009)

When starting a new initiative at Eclipse, they do not endeavour to elicit the participation of everyone in a particular industry before going ahead; instead, they aim to find one or two organizations from each niche in order to proceed. As a result, the scatter plot of Figure 9 can assist a manager or initiator with the task of identifying who these initial participants might be. The scatter plot suggests that there is a sufficiently varied pool of potential ecosystem participants from which to draw, that is if one takes Categories 1 and 2 into account.

In earlier discussions with the Eclipse Foundation Executive Director, he expressed interest in investigating the porting of an OS RTI initiative to Eclipse and requested an introduction to the lead developer of the Portico Project (Milinkovich, 2008a). At that time, he indicated that the industry context was likely ripe for the consideration of an OS ecosystem. Preliminary discussions between the two individuals took place; however, the lead developer is keen to produce a complete version 1 implementation before proceeding further (Pokorny, 2009a). The Executive Director of Eclipse suggests that the potential for creating an OS RTI ecosystem is very real:

"I already have a pretty clear idea of how an Open RTI could work. The challenge that you have got...the good news is that you are close to having a chunk of OS code that you need to kick start the platform...because without code there is no conversation and if there is no conversation there is no community. [The Portico Project] is getting something to work....that is the first step. But the second step then is going to be to figure out a way to

get that code into some kind of organization which is perceived as a vendor-neutral player that everybody is going to get comfortable participating in...My prediction is either Open RTI is going to end up at Eclipse or Apache or you'll try to set up something your own...a completely new organization, and the completely new organization is the much riskier way to do it." (Milinkovich, 2009)

The lead developer of an existing OS RTI initiative, the Portico Project, provided insight based upon his involvement in the distributed simulation domain, knowledge of its players, and expertise in creating an OS RTI project (Pokorny, 2009a). This individual is employed within an M&S company. The company is sponsored by a defence organization to further the development of the OS RTI project in order to meet their specific needs. This key expert provided five critical insights which served to validate different aspects of the results than the previous individual.

First, he indicated that the scatter plot of Figure 9 provides a realistic and valid representation of the industry based upon his expertise. He was not surprised to see that the research and academic organizations had higher motivation and ability, while the M&S companies and defence organizations generally had lower motivation and ability. His OS RTI project was initially geared toward research and academic pursuits, and was not meant to compete with commercial RTI offerings. It has since garnered defence sponsorship and most recently been set as the RTI that must be used on an international simulation contract.

Second, he agreed that the weighting of the three key indicators was a valid approach to have taken and that these were the most critical indicators to weight. He indicated that he did not identify, within the organization-ordered matrix, any other indicators that would warrant being assigned such significant weight. Other indicators

could have been awarded partial weights; however, this would have been overkill and would not likely have provided any additional insight.

Third, he indicated that the indicators of motivation, ability and constraint would provide a manager or initiator of an OS RTI ecosystem with a great deal of insight into the specific industry context. The organization-ordered matrix of indicators highlighted for him questions that he would not have immediately thought to ask of potential ecosystem participants.

Fourth, this expert highlighted an important and unique aspect of the specific industry context of distributed simulation, in that it is predominantly defence-focused. This could have a detrimental effect upon the launch and long-term success of an OS RTI ecosystem since they are the prime customers and users, and they are generally risk averse and slow to change.

Lastly, the lead developer of the OS RTI initiative indicated that the current economic climate may cause the motivation and ability of organizations to increase. This could certainly be of benefit to a potential OS RTI initiative. The increase to motivation and ability may come as a result of further budgetary constraints being placed upon organizations in light of the current economic crisis. It may also be one of the by-products of emerging government policies that are now dictating a renewed consideration of OS options.

5.8.3 Recent Work

In a paper published after this research was undertaken, the initiators of another existing OS RTI also provided key insights. The CERTI OS RTI was initially developed by ONERA, the French Aerospace Research Lab, in order to learn about HLA and its

inner workings, and also to have control over the source code for application in research projects (Noulard et al., 2009). In this recent work, members of the CERTI OS RTI team stated the following:

“As a preliminary conclusion, we can say that there is a potentially growing open source community for [an] Open Source RTI.”(Noulard et al., 2009)

The aforementioned statement was made in response to the surge in development of complementary contributions to the OS RTI that came from outside the users group within ONERA within the last two years. These contributions included multiple patches for fixing bugs in the OS RTI or complementary components, an HLA tutorial application, a partial implementation of an HLA Test Suite, and various bindings for compatibility with MATLAB, Fortran, and Python (Noulard et al., 2009).

5.8.4 Favourable Industry Context

The expert validation of the results, and recent work suggest that the context is favourable to support an OS RTI ecosystem. Milinkovich (2009) indicates that there is a good mix of organizations with which to launch the initiative. To get started, one or several corporate backers would be required in addition to the source code. Other potential participants exist to lend credibility to the initiative and to provide the momentum necessary to move forward. It is not necessary for all organizations within the industry to support the initiative; however, it is recommended that there be representation from each key niche.

Pokorny (2009a) indicates that the plot of organizations is valid and identifies a realistic pool of potential participants from which to draw. The organization-ordered matrix also provides key insights to consider when approaching organizations to join the

OS ecosystem. He cautions that the defence-focused domain may pose challenges; although, this may be offset by renewed government interest in OS in light of the current economic climate.

The existence of a possible OS RTI community coupled with the likely pool of potential OS RTI ecosystem participants identified in this research would suggest that there may be a critical mass with which to launch an OS RTI ecosystem initiative. It also suggests that the context is favourable to support an OS RTI ecosystem.

This research proved that a rigorous articulation of organizational motivation and ability can in fact help an OS ecosystem manager or initiator identify potential ecosystem participants. It identified a process by which to capture and analyze organizational motivation, ability and constraint in order to identify potential ecosystem participants, extract levers to increase organizational motivation and ability, identify barriers to OS ecosystem participation, and draw conclusions about whether an industry context is favourable to an OS ecosystem. It also defined dimensions of organizational motivation, ability and constraint that can simplify the analysis of a specific industry context.

6 DISCUSSION OF RESULTS

This section presents a generalization of the results for application to other OS ecosystem contexts. A manager or initiator of an OS ecosystem in another domain could analyze a specific industry context and begin to formulate a strategy for creating and evolving an OS ecosystem if they were armed with: the dimensions of organizational motivation, ability, and constraint; the possible levers to increase motivation and ability; and likely barriers to ecosystem participation. Researchers may also see value in the process set out in this research for operationalizing the Motivation/Ability Framework. They may seek to apply the process to an actual case of OS RTI creation, or may prefer to tailor it to a completely different case of OS ecosystem creation in a new domain.

6.1 Tools for Managers

In order to apply the results of this research to other industry contexts, some tailoring to the particular domain would be required. It is unlikely that managers in other domains would follow this research process. They may, however, benefit from considering the generalized dimensions, circumstance-based categories, levers and barriers in relation to their specific domain of interest.

6.1.1 Dimensions of Organizational Motivation, Ability and Constraint

The dimensions of organizational motivation, ability and constraint may translate into other contexts with little alteration. These may identify areas for ecosystem managers or initiators to focus upon when assessing potential participants. Table 31 provides a summary of the generalized dimensions that may be applied to domains other than distributed simulation.

Table 31: Generalized Dimensions of Organizational Motivation, Ability and Constraint

MOTIVATION
1. Want or need to develop or address specific [domain] physical capabilities.
2. Want or need to achieve a specific [domain] outcome (non-physical capability).
3. Want to perform specific [domain] roles or functions, or participate in specific [domain] activities.
4. Want, need or lack a [domain] OS platform.
5. Want, need or lack OS software.
6. Want, need or lack money.
7. Want, need or lack personnel.
8. Want to establish or improve inter- and intra-organizational relationships.
9. Want, need or lack certain intangibles.
ABILITY
1. Have existing inter-organizational relationships which are valuable and beneficial.
2. Participate in, or contribute to, [domain] activities or initiatives. Receive direct or indirect ROI.
3. Have existing capabilities (e.g. technical, organizational).
4. Have existing knowledge, involvement, expertise or resources related to the [domain], [domain]-related OS platform, or OS.
5. Involved in national or international organizations which are devoted to the [domain].
6. Have beneficial organizational practices or roles.
7. Actively and willingly share their knowledge.
CONSTRAINT
1. Organizational constraints.
2. Externally imposed constraints.
3. Personnel constraints.
4. Financial constraints.
5. [Domain]-specific constraints.
6. [Domain]-related technical constraints (e.g. infrastructure, connectivity).
7. Security-related constraints.
8. Difficulty maintaining [domain] awareness.

Motivation is influenced by wants, needs or deficits that may be categorized into nine dimensions. These dimensions highlight the importance of: both physical and non-physical capabilities; organizational roles, functions and activities specific to a domain; inter- and intra-organizational relationships; money and personnel; a domain-specific OS platform; OS software in general; and intangibles such as recognition, credibility, presence and customer satisfaction.

Ability is influenced by existing capabilities and resources, and it may be categorized into seven dimensions. These dimensions highlight the importance of existing: inter-organizational relationships; involvement in activities or initiatives which provide organizations with a return on their investment; capabilities (i.e. technical, organizational, or other); knowledge or expertise related to the domain, its OS platform, or OS software in general; involvement in organizations devoted to the domain; as well as beneficial organizational practices or roles.

Constraint is influenced by factors which lead to an inability to access resources or prevent an organization from accessing resources. It may be categorized into eight dimensions. These dimensions highlight the impact of: internal and external constraints; financial and personnel constraints; domain-related constraints (e.g. specific to the domain, technical issues, security); the difficulty in maintaining domain awareness.

6.1.2 Circumstance-based Categories of Organizations

The circumstance-based categories associated with a specific domain would likely depend upon the unique circumstances that are present within that specific industry. As a result, the categories which emerged from this research are less able to be directly translated into applications in other domains.

A manager intent on creating or evolving an OS ecosystem in a particular domain should analyze this specific domain by using the dimensions of organizational motivation, ability and constraint. This will enable them to develop an understanding of their particular industry context. Doing so may reveal circumstances similar to this research where: motivation and ability appear to be strongly correlated; and organizations fell predominantly in either the Hotbed or the Dilemma situations. Alternatively, it may

identify circumstance-based categories that fall within more than two of the four industry situations with less of a correlation between motivation and ability.

6.1.3 Organizational Motivation and Ability Levers

The levers to increase organizational motivation and ability can be applied to other domains with little alteration. Managers should be aware that motivation is often more powerful than ability. Therefore, it is recommended that motivation levers be applied before those for ability. The levers are listed in Table 32 in order of priority in which they should be considered.

Table 32: Levers to Increase Organizational Motivation and Ability

Motivation Levers	
1.	Create a credible infrastructure to attract potential participants. Should include: - Technologies, designs, products and services - Licensing framework as well as processes that address governance, development, and project management processes - Defined membership levels, business opportunities, and participant roles
2.	Build a strong offering of resources and opportunities. - Resources may include complementary applications and tools, freely accessible educational and training resources, or activities for ecosystem participants - Opportunities may be related to training or business, or other areas as desired
3.	Establish and grow a network of inter-organizational relationships.
4.	Establish a reliable source of skilled [domain] personnel and expertise.
5.	Establish a source of funding for [domain]-related research, development, experimentation or other such initiatives.
Ability Levers	
1.	Increase organizational awareness of the ecosystem's offerings in comparison to existing [domain]-specific OS platforms and complementary tools (e.g. their capabilities, characteristics, maturity and level of robustness).
2.	Enable organizations to easily use the ecosystem's OS platform. It must come with user and developer documentation, and also have complementary tools, training and support.
3.	Raise awareness of potential uses for the OS platform.
4.	Facilitate the creation of new inter-organizational relationships.
5.	Provide opportunities for organizations to develop their [domain]-specific experience and expertise (e.g. through activities, training, support).
6.	Identify opportunities for organizations to gain a return on their investment (e.g. access to additional resources, creation of business opportunities).
7.	Increase organizational capabilities by providing access to skilled personnel and sources of funding.
8.	Increase the [domain] awareness of ecosystem participants through the use of online collaborative environments and tools.

In order to attract and motivate participants, OS ecosystem managers must design an appropriate ecosystem infrastructure that is complemented by a strong offering of resources and opportunities for current and potential participants. They must also work to grow their network of inter-organizational connections, establish a pool of skilled personnel or support resources, and create funding opportunities for participant organizations. By doing so, they will enable the ecosystem to both retain current participants and attract new ones.

In order to increase the ability of organizations to participate in the OS ecosystem, managers should consider several levers. The first three of these relate directly to the creation of an OS platform. This platform should be easy to use and supported by complementary tools, training and support. The OS ecosystem should clearly identify and advertise the benefits and potential uses of this platform.

OS ecosystem managers should also consider several other levers. The first of these involves facilitating or coordinating the creation of new inter-organizational relationships for ecosystem participants. Another two levers involve creating opportunities for participant organizations to gain experience and expertise, and also a return on their investment in the ecosystem. Ecosystem managers should also endeavour to provide sources of personnel or support as well as sources of funding to ecosystem participants in order to enable them to further develop their capabilities. Finally, ecosystem managers should create online collaborative environments with which to raise the domain awareness of the OS ecosystem's participants.

6.1.4 Barriers to Ecosystem Participation

When analyzing their specific domain, OS ecosystem managers should look for evidence of internal and external barriers that will affect an organization's participation in the OS ecosystem.

Internal barriers are those which an organization imposes upon itself. These may include: lack of strategic support, direction, or awareness in relation to the specific domain; restrictive policies or management; restrictive organizational structure, business model or roles; or constraints upon existing personnel.

External barriers may be imposed by clients, customers or stakeholders, by government, by the particular industry, or by the domain-specific technology. Clients, customers or stakeholders may impose the use of certain practices or tools, or may direct work based upon their requirements, policies or degree of risk aversion. They may also lack domain awareness which will impose technical or operating constraints and make it difficult to effectively meet their needs. The client, customer or stakeholder community may also be fragmented or lack coherence which will make it difficult to address and meet its needs. The government may impose additional barriers by creating competing products that are provided at no cost to contractors or government users, by favouring large contractors, or by implementing and enforcing restrictive policies or procedures. OS ecosystem managers must also understand the domain-specific barriers imposed by the industry itself and by the technology. These will most likely be unique to a specific domain and not necessarily similar to those of this research effort.

6.2 Process for Researchers

This research defined a process for operationalizing the Motivation/Ability Framework. Future researchers may wish to follow, amend, or tailor this process for application to domains other than distributed simulation to determine the feasibility of creating an OS ecosystem. By analyzing organizational motivation, ability and constraint in a specific industry context, they can identify if it is favourable to the creation and evolution of an OS ecosystem, potential participants, levers to increase motivation and ability, and systemic barriers to OS ecosystem participation. Applying the process will also serve to identify unique indicators and dimensions of organizational motivation, ability and constraint for the specific industry context. These will assist with better conceptualizing the current industry circumstances.

Researchers must first identify their unit of analysis and develop an interview instrument that is tailored to their industry context. The key construct definitions (recall Table 11) coupled with the organization-ordered matrix (see Appendix 3) should be used as a guide to generate questions that will draw out examples of current organizational motivation, ability and constraint.

As outlined in Sections 4 and 5, the process was highly iterative in nature. Researchers will iterate between data collection and data analysis. The process begins with data collection from the theoretical sample. This may be carried out through the use of single respondent interviews and supporting sources of information such as reports, papers and organizational websites. Care should be taken to overlap the data collection and data analysis efforts in order to: identify further organizations to add depth to the

theoretical sample; refine the interview instrument; and begin the process of identifying patterns in the data.

The data analysis steps involve iteratively reducing, refining and displaying the data using several methods. First, detailed write-ups should be generated for each organization in the sample in order to capture all of the examples of organizational motivation, ability and constraint that emerge from the data. This will familiarize the researcher with each organization and will also form the basis for all subsequent cross-case analysis. Second, each of these examples should be further reduced to one or many indicators of motivation, ability and constraint and these should be arranged in tabular format by organization (recall Table 13). No effort should yet be made to sort like indicators across organizations; this is strictly an initial step to identify the readily apparent indicators for each organization. Third, the indicators should then be reduced by sorting like motivation, ability and constraint indicators into mutually exclusive categories instead of by organization (recall Table 14). These first three steps of data analysis will all be in text format. The fourth step involves creating a checklist-type matrix to effectively identify the indicators that are displayed by each organization (recall Table 15). The table from step three and matrix from step four should then be iteratively refined by making frequent reference back to the detailed organizational write-ups.

Once the researcher is satisfied of two key things, they may proceed to assigning weights to each of the indicators. First, they must be satisfied that the theoretical sample is acceptable. Second, they must be satisfied that the organization-ordered matrix of indicators is complete. Equal weights may initially be assigned to each indicator in the organization-ordered matrix in order to calculate overall ratings of motivation and ability

for each organization. The overall motivation rating is calculated from the total of the motivation indicators displayed for each organization. The overall ability rating is calculated by subtracting the total constraint rating from the total ability rating. Each organization should then be plotted on a scatter plot with ability along the x-axis and motivation along the y-axis. This plot may produce a useful result, or the researcher may find that further analysis of the indicators may be required to determine if key indicators warrant additional weighting. Subsequent plots may provide a more useful representation of the industry context and may even highlight the fact that the context is not favourable to an OS ecosystem.

Preliminary conclusions may be captured throughout the data analysis process. The ultimate conclusions will be drawn from the final scatter plot with support from the data table and matrix, as well as possible insight from the preliminary conclusions. This overall process will enable the researcher to identify the following within their specific industry context: unique indicators and dimensions of organizational motivation, ability, and constraint; a circumstance-based categorization of the potential participants; levers to increase motivation and ability; and barriers to ecosystem participation.

In the specific research context of distributed simulation, the theoretical sample of organizations was found to include a group of organizations with what may be interpreted to be high motivation and ability. Evidence was found of both the motivation to participate in the OS ecosystem and the ability to do so. In other industry contexts, the sample of organizations may not exhibit any evidence of high motivation and ability. In order to properly calibrate the process to account for such a situation, future researchers must take care to pre-define indicators of motivation and ability that would identify a

desire to participate in the OS ecosystem and the ability to do so. The organizations in the sample may not exhibit these indicators, and the absence of such evidence will serve to calibrate the process and enable the researcher to better interpret their data.

6.3 Towards Theory-Building

This research fulfills only part of the process of theory building in relation to OS ecosystems. According to the Carlile and Christensen's Cycles of Theory Building, a circumstance-based categorization is considered to be the product of the second stage in the inductive part of the normative theory-building process. In addition, theory is developed by the cumulative work of many researchers working through the three steps of theory building from both an inductive and deductive perspective. As a result, this research does not attain the lofty goal of theory, yet addresses part of the inductive theory building process and provides a stepping stone with which to carry on future research.

The circumstance-based categorization of this research can be used to move towards theory. In order to do so, effort must first be put towards hypothesizing with causality in mind and then testing these hypotheses (i.e. carry out the deductive portion of the theory-building process). Future researchers can define hypotheses such as:

- Research and academic organizations gain ability first and then develop motivation.
- Defence organizations and M&S companies develop motivation first and then develop or buy ability (i.e. through contracting external organizations (*defence*) or through the acquisition of other specialized companies (*M&S companies*)).
- OS RTI initiators are first motivated and then develop ability.
- Use of the levers will serve to increase motivation and ability over time.

7 CONCLUSIONS

This research analyzed the current motivation, ability and constraint of a theoretical sample of organizations. Previous research only addressed: strategies associated with existing business ecosystems; organizational sponsorship of pre-existing OS communities; and strictly organizational motivation to participate in OS communities or ecosystems. This is the first work to consider both strategies for creating and evolving new OS ecosystems, and organizational participation in OS ecosystems within the broader scope of organizational motivation, ability and constraint.

7.1 Key Findings

This research found that organizational motivation, ability and constraint can be used to better inform managers or initiators of an OS ecosystem. In the specific context of distributed simulation, the researcher was able to do the following:

- Identify unique indicators of organizational motivation, ability and constraint
- Identify dimensions of organizational motivation, ability and constraint
- Identify four circumstance-based categories of organizations
- Identify potential OS ecosystem participants who may be motivated and able
- Identify potential levers to increase organizational motivation and ability
- Identify potential barriers to ecosystem participation
- Make conclusions about whether the context is favourable to an ecosystem

The dimensions, levers, and barriers may be of value to managers of ecosystems in domains other than distributed simulation who plan to create and evolve an OS ecosystem. Researchers may be interested in the process of operationalizing the Motivation/Ability Framework for application to other OS ecosystem contexts.

7.2 Research Conclusions

This research led to the following seven conclusions:

1. The definition of an OS ecosystem encompasses the roles of a business ecosystem, an OS community and a platform.
2. Organizational motivation, ability and constraint can be used to help an OS ecosystem manager or initiator identify potential participants. By analyzing these constructs through a thorough application of the Motivation/Ability Framework, they may also identify: levers to increase organizational motivation and ability; barriers to OS ecosystem participation; and whether an industry context would support an OS ecosystem. In the specific industry context of distributed simulation, this research suggests that the context is favourable to an OS ecosystem.
3. An analysis of organizational motivation, ability and constraint provides greater insight into participation in an OS ecosystem than a consideration of just organizational motivation. It leads to the definition of key dimensions of organizational motivation, ability and constraint that can be used to better conceptualize these constructs within a specific industry context. As detailed in Section 5.3, this research defines nine dimensions of motivation, seven dimensions of ability, and eight dimensions of constraint within the distributed simulation industry context.
4. The dimensions of organizational motivation, ability and constraint from this research are broader and more applicable to a consideration of OS ecosystem participation than the limited dimensions of motivation provided in the literature

on organizational participation in OS projects. The dimensions defined in this research simplify the conceptualization of organization motivation, ability and constraint. They also help to identify areas for OS ecosystem managers or initiators to focus upon when assessing potential ecosystem participants.

5. Identifying OS ecosystem participants is only one element of a multi-faceted approach to OS ecosystem creation and evolution. It must be considered in conjunction with: defining the participant roles; addressing the need for a platform; defining initial niche contributions and contributors; and establishing processes for development, licensing, governance, and project management.
6. There are certain organizational circumstances which ecosystem managers or initiators may influence in order to increase organizational motivation and ability. Several levers exist that may be used to influence these circumstances. As detailed in Section 5.6, this research defines five levers for motivation and eight for ability in the specific industry context of distributed simulation.
7. Some organizational circumstances may not be within the purview of an OS ecosystem manager or initiator to influence. These are barriers to OS ecosystem participation that must be identified and taken into consideration when approaching potential ecosystem participants in a particular industry context. As detailed in Section 5.7, this research defines three groups of barriers in the specific industry context of distributed simulation: seven organization-imposed; three client, customer or stakeholder-imposed; and three government imposed (recall Section 5.7).

7.3 Limitations

There are two key limitations to this research. The first is that the results obtained for the specific industry context still need to be validated through application to an actual case. Future research must seek to determine – through an actual case of OS RTI ecosystem creation – if the application of organizational motivation and ability can truly provide a reliable identification of potential participants and a valid conclusion that the context is favourable to support an OS ecosystem.

The second limitation of this research relates to the fact that organizational participation is only one part of a multi-faceted approach to OS ecosystem creation. The results of this research form but one part of an overarching strategy for ecosystem creation and evolution and cannot be considered in isolation.

7.4 Contributions

This research makes four contributions, these are as follows:

1. It operationalizes the Motivation/Ability Framework. The process it defines is used to examine organizational motivation, ability and constraint in a specific industry context. These constructs are used to analyze current and potential industry participants to determine whether they are motivated and able to support an OS ecosystem. Through a process of data collection, reduction, and display, a researcher can draw conclusions about potential OS ecosystem participants and the feasibility of supporting an OS ecosystem within the industry.
2. It identifies three tools to assist managers in examining the feasibility of creating an OS ecosystem in a particular industry context. First, the dimensions of organizational motivation, ability and constraint can be used to assess and better

understand their industry. Second, the levers to increase organization motivation and ability can be used to improve the level of support for an OS ecosystem.

Third, systemic barriers to organizational participation in an OS ecosystem can be identified. These are not within their purview to influence and may pose significant challenges to the creation of an OS ecosystem.

3. It facilitated the introduction of the Eclipse Foundation, the non-profit keystone of a well-established OS ecosystem, to the Portico Project, an existing OS RTI project. In so doing, it created industry connections that did not previously exist and it generated greater awareness of the potential to create an OS RTI ecosystem.
4. It contributes to the existing literature for business ecosystem, OS ecosystem, and organizational participation in OS in two distinct ways. First, it goes beyond simply a consideration of organizational sponsorship of pre-existing OS communities. The focus is instead placed upon a context where organizations create and evolve an OS ecosystem. Second, it uses the broader scope of organizational motivation, ability and constraint to gain a greater understanding of participation in OS ecosystems.

7.5 Opportunities for Future Research

Participation in OS ecosystems is worthy of further consideration and treatment.

This work highlights the following opportunities for future research:

- Validate the process set out in this research by applying it to an actual case of OS RTI ecosystem creation.
- Validate the process set out in this research by investigating whether or not it can be extended to application in domains other than distributed simulation.

- Investigate other aspects of OS ecosystem creation that might combine with this research to generate overarching strategies for managers or initiators of new OS ecosystems. Rather than considering contexts where organizations sponsor pre-existing OS communities, investigate contexts where organizations create and evolve an OS ecosystem and associated OS community.
- As discussed in Section 6.3, use this research as a stepping stone to develop theory related to OS ecosystems. Do so by moving from the circumstance-based categorization stage of theory-building defined in this research, to the development and testing of statements of causality.
- As discussed in Section 5.5.1, conduct a focused search for cases in the near-empty quadrants of the Motivation/Ability Framework in order to either validate the motivation-ability correlation found in this research or to define a different pattern.

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APPENDICES

Appendix 1: Non-Commercial RTIs

Individual Initiatives	
1. Portico	• Core team of three developers, of which one is lead developer • http://www.porticoproject.org/index.php?title=Main_Page • Documentation and source code available online • Initially developed to meet the needs of the individual developers, has since broadened focus to meet the needs of two key Australian Defence Force clients • Development currently sponsored by the Australian Defence Simulation Office through a commercial company, Calytrix. • US DoD DMSO HLA 1.3 implementation (Pokorny, 2006, 2007a, 2007b, 2009b; the poRTIco project, 2008b)
2. Open HLA	• One developer, personal initiative • http://sourceforge.net/projects/ohla/ • Created in 2005, last activity in 2007 • Version 0.4.0 available for download online • Partial implementation of US DoD DMSO HLA 1.3 implementation and IEEE 1516 (Newcomb, 2007)
3. SXTA	• One developer, personal initiative • http://sourceforge.net/projects/sxta/ • Created in 2003, last activity in 2007 • Development status: Pre-Alpha • IEEE 1516 implementation • Appears to be inactive (Mendez, 2007)
4. yaRTI	• One developer, personal initiative • http://pagesperso-orange.fr/dominique.canazzi/dominique.htm • Designed for research and concept evaluation • Version 0.80 available for download online, last activity in 2000 • Appears to be inactive • US DoD DMSO HLA 1.1 implementation • Implemented in Ada (Canazzi, 1999, 2000)
Academic Institutions	
5. SIP-RTI	• Carleton University, Master's student initiative • Partial IEEE 1516 implementation • Still available upon request • Based on a SIP implementation that is no longer supported, so work would be required to fix/update the SIP component (Pearce, 2008; Van Ham & Pearce, 2006)
6. FDK	• Georgia Institute of Technology, Parallel and Distributed Simulation Research Group • FDK stands for Federated Simulations Development Kit

	- Designed as a research vehicle for exploring high-performance distributed simulation - Contains independent modules for building RTIs - Described as “source available”. FDK distributions are US export controlled, potential users must agree to the FDK Usage Agreement (©1997-2003) in order to be granted access - Partial US DoD DMSO HLA 1.3 implementation (Georgia Tech, 2003a, 2003b; McLean & Fujimoto, 2001)
7. XRTI	- Naval Postgraduate School, Master’s student initiative http://sourceforge.net/projects/npsnetv - Last updated in 2003 - Appears to be inactive (Kapolka, 2003)
8. GMU	- George Mason University http://netlab.gmu.edu/rti/ - Documentation and source code available online - Described as a light-weight RTI meant for distributed virtual simulation - RTI is a research prototype only and can only handle a small number of federates - US DoD DMSO HLA 1.1 implementation (Pullen et al., 1997; Pullen & Moreau, 1997a, 1997b)
9. BH-RTI	- Beihang University Virtual Reality Lab (Beijing, China) http://www.hlarti.com/ - Website in Chinese (Beihang University, 2009)
Research Institutions	
TNO-RTI	- TNO, non-profit research organization (Netherlands) - Developed own RTI in-house to meet research needs - Made available only to clients - Partial implementation of US DoD DMSO HLA 1.3 and IEEE 1516 (Huiskamp, 2008; Jansen et al., 2004)
CERTI	- Developed by ONERA, the French Aerospace Lab (France) http://savannah.nongnu.org/projects/certi/ - Documentation and source code available online - US DoD DMSO HLA 1.3 implementation - Latest release 3.3.1 in September, 2008 - Developed in 1996 initially to support research initiatives, open sourced in 2002 - Described as an OS project managed by a government research entity **Includes complementary software components beyond simply the RTI **Current goals to increase HLA adoption and grow an international OS community around distributed simulation (CERTI; Noulard et al., 2009; ONERA)
GERTICO	Developed by the Fraunhofer Institute for Information and Data

	Processing (Germany) • http://genesis.iitb.fhg.de/servlet/is/12436/ • US DoD DMSO HLA 1.3 implementation • **Certified as HLA-compliant by the former US DoD Defense Modeling and Simulation Office • Free access is provided following a user registration process. Unclear if source code and documentation are provided. • Registration form indicates that user's would use GERTICO "exclusively for the limited purposes of cooperation with the German Armed Forces Technical Centre for Information Technology and Electronics WTD 81, Greding". (Fraunhofer Institute for Information and Data Processing, 2008; SimInfra, 2007, 2009; WTD 81)
Government Agencies	
EODiSP	• Developed by P&P Software (Zurich, Switzerland) and the Swiss Federal Institute of Technology Zurich for the European Space Agency • http://www.pnp-software.com/eodisp/home.html • Specifically aimed at supporting the development of end-to-end simulators for earth-observation satellite missions • Can also support any HLA-based simulation • Partial IEEE 1516 implementation • Described as "free and open software", documentation and source code accessible via the website (P&P Software, 2007, 2009)
RTI-S	• Initially developed as an RTI prototype by MIT Lincoln Laboratory to support DARPA's Synthetic Theatre of War (STOW) program • Development effort officially ended in 1998 • Supported the evolution of the HLA specification and was incorporated into US DoD DMSO HLA RTI 1.3 • Roughly based on pre-draft of HLA specification version 1.0 • Only a partial RTI implementation • Appears to be government controlled now (US Joint Forces Command J9) (Calvin et al., 1997; Ceranowicz & Torpey, 2005; Dahmann & Morse, 1998; MIT Lincoln Laboratory, 2006; Torpey, Wilbert, Helfinstine, & Civinskas, 2001)

Appendix 2: Interview Instrument Sample

INTERVIEW INSTRUMENT

- The interview will be structured into 3 parts: (i) context, (ii) organization/OS/HLA, (iii) core questions.

PART 1 - CONTEXT

- For my thesis I am exploring the concept of an OS HLA RTI.
 - The hypothesis that I am going in with is that for this initiative to be sustainable it has to be supported by an ecosystem. I will explain...
 - First, I should stress that I am focused on the ecosystem concept and not the intricacies of creating the OS RTI. The OS RTI is but one example of an initiative around which an ecosystem can be formed.

- **Ecosystem**. The idea is that this ecosystem is an intentional community of economic actors who are coming together to leverage the OS-RTI.

- They are co-evolving, co-developing, co-innovating the RTI and also complementary products and services. So you could think of support and training, or tools as complementary services.
- These contributors join the ecosystem because they see a clear **business, knowledge, or learning opportunity** in doing so, not because of any altruistic drive.
- There would be a defined roadmap with clear milestones and also a defined end goal.
- There would be a core (or a strategic) group of members who would bring to the table money, knowledge and people with critical skill sets in order to populate the ecosystem.
- **Membership in the core** comes with a cost and provides the ability to have an impact on defining the roadmap and endgame.

- **Roadmap** would address things like what functionality would be present at each milestone, and at what time key contributors should be present.

- **End goal** would be for the ecosystem to include:

- A professional grade OS RTI (functionality comparable to proprietary versions)
- Source code with good documentation
- Testing harness: version control, bug fixes, nightly builds, keep development in accordance with the roadmap
- Support and training providers that would provide these services for a cost
- Sample federates and federation(s) and exercises in which to participate

- My goal is to take a cross-section of organizations in the M&S industry and **analyze** them based on their **current** motivations, abilities and constraints.
- To do this, I will be conducting interviews with key organizations in this industry including M&S companies, academic and research institutions, the Canadian military, and OS RTI initiators.
- The aim is that mapping the current state of the industry will:
  - Identify if a critical mass exists to support such an initiative.
  - Identify potential participants and their circumstances.
  - Provide insight into what the roadmap might look like.
  - Shed light on how to go about methodically building the ecosystem.
- **So why do this??** Business ecosystems and OS are emerging as viable approaches to doing business.
  - Ecosystems involve co-innovation, and are far removed from stove-pipe approaches to doing business.
  - OS is proving to be a viable development approach. Promises to deliver products of higher quality, reliability, flexibility and at a lower cost.
- While my focus is on ecosystems, it is worth mentioning that the existing literature purports an OS RTI may:
  - Assist in advancing and improving the HLA standard (avoid stagnancy, remain viable)
  - Make HLA available to a wider audience and therefore contribute to its sustainability/longevity
  - Improve interoperability and consistency in simulation
  - Allow for easier customization
  - Enable researchers to avoid having to build their own RTI from the ground up
  - Allow researchers to see inside the black box and conduct research, make advances.

PART 2 – INTRODUCTORY QUESTIONS

1. **(Org)** Briefly describe your organization and its structure.
2. **(Org)** To whom does your organization report?
3. **(Org)** Describe your role within the organization?
4. **(Org)** Describe your organization's area(s) of expertise?
5. **(OSS)** What is your organization's **knowledge** of OSS? Use the following scale.

<u>LOW</u> - Know very little about it. - Not interested.	<u>LOW TO MEDIUM</u> <i>Heard about it in passing.</i>	<u>MEDIUM</u> Aware of the concepts, some advantages and disadv.	<u>MEDIUM TO HIGH</u> - Read a great deal about it. - Do not work with OSS on a regular basis.	<u>HIGH</u> Actively use OSS on a daily basis (working knowledge)	<u>NONE</u> Not heard or read anything about OSS.

6. **(OSS – Ability/Constraint)** Describe your organization's **interest** in, and attitudes towards OSS?
7. **(OSS – Ability/Constraint)** What is your organization's **experience** with OSS?
8. **(OSS-Ability/Constraint)** What are your organization's **policies** towards OSS?
9. **(HLA)** Describe your organization's **involvement with, or use of HLA**, if any?
10. **(HLA)** Do you use a proprietary or an OS RTI? Why? Benefits to your organization?
11. **(HLA)** Did you **create your own** RTI? Why? Nature of its use? Needs met? Needs not met?
12. **(HLA)** Needs met by **proprietary** RTI? Needs not met? Hurdles involved with use of a proprietary RTI?
13. **(HLA)** Is your organization aware of any **existing OS RTIs**?
14. **(HLA)** Has it ever contemplated **using** them? Ever **tested** them? What were the OS RTI's **shortcomings**?

PART 3 – CORE QUESTIONS

The aim is to identify the current motivations, abilities and constraints of your organization.

The initial questions will deal with the notion of resources that your organization has, lacks, or desires.

****RESOURCES**

Think of your organization's mission, goals, assigned tasks and responsibilities. You may have different terms to describe these in your organization. Let's refer to these collectively as your organization's objectives. In this context then,

15. **(Resources)** In order to accomplish your organization's objectives, what resources do you consider critical to be critical?
 - *Don't be constrained by whether or not you already possess these resources or have access to them.*
 - *Examples, should they require any to start the discussion...*

Money/funding	Knowledge	Skill sets
Sufficient staff and expertise	Developers, designers	Tools
Processes	Training	Education
Support (consultants, contractors)	IT infrastructure	Standing offers (ie.contractors, tools, software)
Facilities	A visible champion	Support of the Chain of command, Management, Administration

16. **(Ability)** What critical resources does your organization **already have** access to/possess/control?
17. **(Motivation)** What critical resources does your organization **want/lack/need**? Is it actively working on filling a need right now? Are any of these open source?

18. **(Motivation)** Are there critical resources that your organization is working to **control/protect/prevent** other organizations from accessing? If yes, which ones and why?
19. **(Ability)** Is your organization **committing resources** (people, money...) to initiatives that are outside the organization, for the express purpose of gaining something in return, whether it is knowledge, a product, a tool?
20. **(Ability)** What kinds of **resource sharing arrangements (collaboration)** does your organization currently participate in? Describe.
21. **(Motivation)** Is your organization working to establish **resource sharing arrangements** or collaborative relationships with other organizations?
22. **(Constraint)** What is **preventing** your organization from accessing some of the resources that you want/need/lack? (*eg. too much in its infancy, too costly, not yet technically feasible...*)

Remembering that the term 'objectives' was used to collectively refer to your org's mission, goals, etc

23. **(Motivation)** If your organization achieves its objectives, what is the expected result? What drives your organization to achieve its objectives?
I am looking for you to define and explain your organization's motivation here...

This next series of questions deals with resource exchanges.

**DEPENDENCE RELATIONSHIPS (can constrain or enhance an organization's ability and motivation)

24. **(Ability)** Who is dependent upon your organization for resources? Are any open source?
25. **(Motivation or Constraint?)** Who is your organization dependent upon for resources? Are any open source?

This next series of questions deals with the subject of ecosystems. Think of this in the context that I previously described. An intentional community of economic actors who are coming together because they see a clear business, or learning or knowledge opportunity. Involvement is not based on altruism.

**ECOSYSTEMS

26. **(Ability)** Is your organization **already a member** of an ecosystem? If yes, which one, who are the **members**, what does your organization **gain** from this ecosystem membership?
27. **(Motivation)** Is there an OSS ecosystem or business ecosystem that your organization needs/wants to become a part of? If yes, what does your organization expect to gain from this membership? What does it expect to contribute?
28. **(Constraint)** Is there anything preventing your organization from becoming a member of that ecosystem?

This series of questions deals with knowledge sharing arrangements.

**KNOWLEDGE SHARING/LEARNING

29. **(Ability)** Does your organization currently participate in **knowledge sharing arrangements** with other organizations? If yes, what organizations and why?

OSS or business ecosystem	Universities or Research institutions	NATO, TTCP type alliances
Companies	Government organizations	Militaries

30. **(Motivation)** Is there a **knowledge sharing arrangement** that your organization wants/needs to be part of? If yes, what organizations and why?

OSS or business ecosystem	Universities or Research institutions	NATO, TTCP type alliances
Companies	Government organizations	Militaries

31. **(Constraint)** Is there anything **preventing** your organization from entering into this knowledge sharing arrangement?

32. Talk about the **coordination of M&S within your organization**, relationships...are they well established, not well established, where are you lacking? **Is M&S being advanced within your organization** from your perspective?

This last question deals with any remaining barriers that you feel your organization is faced with.

**ASIDE FROM THE BARRIERS ALREADY DISCUSSED...

33. **(Constraint)** Any other barriers that your org is confronted with in trying to accomplish its objs?

Org policies, culture, attitudes	Lack of power	Industry standards
Techn hurdles, state of techn dev, not yet technically feasible	Dependence relationships (ie. dependent on others)	RCTI – must spend % of \$ in Canada
Budgetary constraints	IP issues	Govt regulation

Appendix 3: Organization-Ordered Matrix of Indicators

	1	2	3	4	5	6	7	8	9	10	11
	Def 1	Def 2	Def 3	Def 4	Def 5	Def 6	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5
A – Want or need to meet an external M&S capability need or requirement.	1	1	1	1	1	1	1	1	1	1	1
B – Want or need to create a new M&S organization (brand new organization).	0	0	0	0	0	0	1	0	0	0	0
A – Want or need to meet an internal M&S capability need or requirement.	0	1	1	1	0	1	0	0	0	0	0
B – Want or need to create new M&S group, section, branch within their organization.	1	0	0	0	0	1	0	0	0	0	0
C – Want/need/lack a procurement system that is responsive to their needs/requirements.	1	1	1	1	0	1	0	0	0	0	0
A – Want or need to meet an external OS capability need or requirement.	1	0	0	0	0	0	0	1	0	0	0
A – Want or need to meet an internal OS capability need or requirement.	0	1	0	1	0	0	0	0	0	0	0
A – Outcome related to their M&S work/business.	1	1	1	1	1	0	1	1	1	0	1
B – Outcome related to the science of M&S.	0	1	1	1	1	0	0	0	0	1	0
C – Outcome related to M&S knowledge (and awareness).	1	1	1	1	1	1	1	0	0	0	0
D – Outcome related to the M&S industry (e.g. lower the barrier to entry).	0	0	0	0	1	0	1	1	1	0	1
A – Want to conduct or facilitate M&S research.	1	1	1	1	1	1	1	1	1	1	0.5
B – Want to provide formal M&S education (university, college, academic institution).	0	0	0	0	0	0	0	0	0	0	0
C – Want to provide or facilitate formal/informal M&S training (e.g. contractor provided, company provided, in-house, online...).	1	0	0	1	1	0	1	0	0	0	1

	1	2	3	4	5	6	7	8	9	10	11
	Def 1	Def 2	Def 3	Def 4	Def 5	Def 6	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5
D – Want to participate in international M&S exercises.	0.5	1	1	0	1	1	0	0.5	0	0	0
A – Specifically want to be involved in an OS RTI initiative, or an OS RTI ecosystem.	0.5	0	0	0	0	1	0	1	0	0	0
B – Want/need access to RTI source code (for reasons of greater control, access, flexibility, interest, ability to troubleshoot, optimization).	0	0	0	0	0	0	0	0	0	0	0
C – Want/need RTI that is cost-free and has a permissive license.	1	0	0	0	0	0	0	0	0	0	0
D – Want to pursue new business opportunities by leveraging an OS RTI.	0	0	0	0	0	0	0	1	0	0	0
A – Want to participate in international OS activities (aside from OS RTI).	0	0	0	0	0	0	0	0	0	0	0
B – Want/need OS product source code (for reasons of control, flexibility, time savings customization).	0	1	1	1	0	0	0	0	0	0	0
C – Want/need OS software that is cost-free and has a permissive license.	0	0	0	0	1	0	0	0	0	0	0
D – Want to pursue new business opportunities by leveraging OS in general.	0	0	0	0	0	0	1	0	1	0	1
A – Want to make a profit.	0	0	0	0	0	0	1	1	1	1	1
B – Want or need other sources of funding (other than from profit or from research funding, e.g. contract work, development work, sponsored work, sponsors, investment capital).	0	0	0	0	1	1	1	1	0.5	0.5	0.5
C – Want research funding.	0	0	0	0	0	0	0	0	0	0	0
D – Want to expand their customer or client base.	0	0	0	0	0	0	1	1	1	1	1
A – Want, need, or lack personnel in general.	0	1	0	0	0	0	1	0	1	0	1
B – Want, need, or lack personnel with M&S expertise.	1	1	0	1	1	1	1	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11
	Def 1	Def 2	Def 3	Def 4	Def 5	Def 6	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5
A – Want to establish or improve relationships within their own organization, environment, or community.	1	1	1	0	0	0	0	0	0	0	0
B – Want to establish or improve relationships with research organizations.	0	0	0	1	1	0	0	0	0	0	0
C – Want to establish or improve relationships with academic organizations.	0	0	0	0	1	0	0	0	0	0	0
D – Want to establish or improve relationships with industry (i.e. companies).	0	0	0	0	0	1	0	0	0	0	0
E – Want to establish or improve relationships with government/defence organizations.	1	1	1	0	1	0	0	1	0	0	0
A – Recognition (**for what they do).	0	0	0	0	0	0	1	1	0	0	1
B – Credibility.	0	0	0	0	1	0	0	0	0	1	1
C – Presence, visible (**awareness that they exist, visibility).	1	1	1	0	1	0	1	1	1	0	1
D – Customer satisfaction.	0	1	0	0	0	1	0	1	1	0	0

	1	2	3	4	5	6	7	8	9	10	11
	Def 1	Def 2	Def 3	Def 4	Def 5	Def 6	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5
A – Relationships with international government/defence organizations.	1	1	1	1	1	1	1	1	1	0.5	1
B – Relationships with national government/defence organizations.	1	1	1	1	1	1	1	1	1	1	1
A – Relationships with international universities.	0.5	0	0	0	0.5	0	0.5	0	1	0	1
B – Relationships with national universities.	1	1	1	1	1	0	1	1	1	1	0.5
A – Relationships with international research organizations.	1	0	1	0	0.5	1	0	1	0.5	0.5	1
B – Relationships with national research organizations.	1	1	1	0	1	1	1	1	1	0.5	0.5
A – Industry organization to industry organization relationships (i.e. company to company).	0	0	0	0	0	0	1	1	1	0.5	1
B – Academic organization to industry organization relationships.	0	0	0	0	0	0	0	0	0	0	0
C – Research organization to industry organization relationships.	0	0	0	0	0	0	0	0	0	0	0
D – Government/defence organization to industry organization relationships.	1	1	1	1	1	0	0	0	0	0	0
E – OS to industry organization relationships.	0	0	0	0	0	0	0	0	0	0	0
A – Have positive dependence relationships.	0	0	0	0	1	1	1	1	1	1	0.5
A – Participate in large-scale national or international M&S activities from which they can draw resources, or in which they can share resources.	0.5	1	1	1	1	1	1	0	0	1	0

	1	2	3	4	5	6	7	8	9	10	11
	Def 1	Def 2	Def 3	Def 4	Def 5	Def 6	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5
A – Contribute to the advancement of M&S capabilities external to their organization (provides them with ROI).	1	1	1	1	1	1	1	1	1	1	1
B – [Member, stakeholder, contributor] to M&S-related consortia, ecosystems, groups (provides them with ROI).	0	0	1	0	0	0	0	0	0	0	0
A – Actively and willingly share their knowledge.	1	1	1	1	1	1	1	1	1	0.5	1
A – Involved in international Standards Org (SISO).	1	0	0	0	0	0	1	1	1	1	1
B – Involved in international Defence M&S Group (NMSG).	1	0	1	1	0.5	1	1	0	0	0	1
C – Involved in TTCP.	1	0	0	0	1	1	0	0	0	0	0
D – Involved in professional M&S organizations (e.g. I/ITSEC, SCS).	1	1	1	1	0.5	0.5	1	1	0.5	1	1
E – Involved in M&S industrial development groups.	0.5	0	0	0	0.5	0	1	0.5	0	0	1
A – Have existing M&S and/or distributed simulation infrastructure.	0	1	1	1	1	1	0	0	0	0.5	0
B – Have existing distributed simulation connectivity.	0	1	1	1	1	1	0	0	0	0.5	0
A – Organizational structure is of benefit in some way.	0	1	1	0	0	0	0	0	1	0	0
B – Conduct or facilitate M&S research.	1	1	1	1	1	1	1	1	1	1	0.5
C – Provide formal M&S education (university, college, academic institution).	0	0	0	0	0	0	0	0	0	0	0
D – Provide or facilitate formal/informal M&S training.	1	0	0	1	1	1	1	0	0.5	0	1
E – Provide M&S advice or support.	1	1	1	1	1	1	1	0	1	0.5	1
F – Have their own certified RTI.	0	0	0	0	0	0	0	0	1	0	1

	1	2	3	4	5	6	7	8	9	10	11
	Def 1	Def 2	Def 3	Def 4	Def 5	Def 6	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5
G – Needs are met/can be met by commercial RTI.	0	1	1	1	1	0.5	1	0	0	1	0
H – Have specific key M&S, distributed simulation or HLA personnel.	0	0	1	1	1	0	1	1	0	1	0
I – Have sufficient personnel or access to additional personnel.	0	0	1	1	1	0	0	0	0	0	0
J – Sufficient or adequate funding.	1	1	1	0	1	1	0	0	0	0	0
K – Access to external or additional funding.	1	0	1	0	0	1	0	1	1	0	0
L – Neutral organization, impartial, non-competitive role.	1	1	0.5	0.5	0.5	0.5	0	0	0	0	0
A – Have organizational practices, roles, which provide their organization with resources.	1	1	1	1	1	1	1	1	1	1	1
B – Create/control proprietary information, products, etc.	0	1	0	0	0	0	1	1	1	1	1
A – Federation creation or support expertise.	0.5	0.5	0.5	0.5	1	1	1	0.5	0.5	1	1
B – Have, or are developing, distributed simulation expertise.	0.5	1	1	1	1	1	1	1	1	1	1
C – Extensive or deep HLA expertise.	0.5	1	1	0	1	1	1	1	1	1	1
A – Knowledge/awareness of OS RTIs (e.g. investigated and/or tested one or several).	1	1	1	0	1	0	1	1	1	0	1
B – Already using an OS RTI. Have experience with using an OS RTI.	0	0	0	0	0	0	0	1	0	0	0
C – Developed an OS RTI.	0	0	0	0	0	0	0	1	0	1	0
D – See potential uses for OS RTI (in their organization or for a client of theirs).	1	0	1	1	0	1	0	1	0	0	0
E – Would consider using an OS RTI.	0	0	1	1	0	1	0	1	0	0	0
F – Have resources to contribute to an OS RTI initiative.	1	0	0	1	0	1	0	1	0	0	0.5

	1	2	3	4	5	6	7	8	9	10	11
	Def 1	Def 2	Def 3	Def 4	Def 5	Def 6	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5
A – Have produced their own OS.	0	1	0	1	0	0	0	1	0	0.5	1
B – Consumer of OS (M&S and otherwise).	0	1	1	1	1	1	0.5	1	1	0.5	1
C – Follow OS software. See value in OS.	1	1	1	1	1	0	1	1	1	0.5	1
D – Use OS to benefit their business or organization.	0	1	1	1	1	1	0.5	1	1	0.5	1
E – Have valuable and beneficial relationships with OS projects, ecosystems, organizations.	0	0	1	0	0	0	0	1	0	0.5	0

	1	2	3	4	5	6	7	8	9	10	11
	Def 1	Def 2	Def 3	Def 4	Def 5	Def 6	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5
A. Lack direction or support from higher organization to pursue M&S activities, initiatives, or approaches.	1	1	1	1	1	1	0	0	0	0	0
B. Lack a strategic M&S champion.	1	1	1	1	1	1	0	0	0	0	0
C. Faced with lack of awareness of the benefits of M&S in higher organization.	1	1	1	1	0	1	0	0	0	0	0
D. Organizational policies/management constrain M&S (constraints within own organization).	1	0	0	0	0	0	0	0	0	0	0
A. Organizational structure imposes constraints.	1	0	0	1	0	0	0	0	1	0	1
B. Organizational business model imposes constraints.	0	0	0	0	0	0	0	1	0	0	0
C. Organizational role imposes constraints.	1	0	0	0	0	0	0	0	0	0	0
A. Challenging to find qualified personnel.	0	1	0	1	1	1	0	1	1	1	1
B. Existing personnel are constrained in some way.	1	0	0	1	0	1	0	0	0	0	0
C. Organizationally constrained in their ability to create an M&S personnel capability (group, section, etc) or from hiring additional personnel.	1	0	0	0	0	1	0	0	0	0	0
A. M&S practices, tools used are dictated by their [client, customer, or stakeholder] requirements, policies, or degree of risk aversion.	0	0	0	0	0	0	0	0	0	1	0
B. M&S work is dictated by the needs/requirements of [client, customer, stakeholder].	0	0	0	0	0	0	0	0	0	0	0
C. [Client, customer, or stakeholder] lack knowledge and awareness of M&S. Lack ability to properly articulate their needs. Lack HLA expertise. Impose technical or operating constraints as a result.	0	1	1	1	0	1	1	0	0	0	0
D. [Client, customer, or stakeholder] community lacks coherence, poorly defined, fragmented with respect to M&S.	0	0	0	0	0	0	1	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11
	Def 1	Def 2	Def 3	Def 4	Def 5	Def 6	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5
A. Constraints imposed by government contract award or internal product development practices.	0	0	0	0	0	0	1	0	1	0	1
A. Constraints imposed by lack of distributed simulation infrastructure or connectivity.	0	1	1	1	0	0	0	0	0	0	0
A. Constraints imposed by security-related restrictions.	0	1	1	0	0	0	0	0	0	0	0
A. Difficult to maintain awareness of M&S activities within and outside their organization.	1	0	1	0	1	0	0	0	0	0	0
A. Mixed support for OS RTI within the M&S industry.	0	0	0	0	0	0	0	1	0	0	0
B. Constraints imposed by nature of M&S industry, market.	0	0	0	0	0	0	1	0	1	0	0
A. Pursuit of OS is constrained in some way.	0	0	0	0	0	0	0	0	0	1	0
B. Business reasons for dislike or lack of interest in OS (competition, OS-averse clients).	0	0	0	0	0	0	0	0	1	1	0
A. Have no perceived need for an OS RTI.	0	1	0	1	1	0	1	0	1	1	1
B. Constrained from participating in an OS RTI ecosystem.	0	0	0	1	0	0	0	0	1	0	0
C. Constrained from developing an OS RTI ecosystem.	0	0	0	0	0	0	0	1	0	0	0
D. Perceived technical constraints related to using OS RTI.	0	0	1	0	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11
	Def 1	Def 2	Def 3	Def 4	Def 5	Def 6	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5
A. Not historically large HLA users.	0	0	0	1	0	0	0	0	0	0	0
B. Moving away from HLA.	0	0	0	1	0	0	0	0	0	0	0
C. Constraints imposed by Federation Object Model.	0	1	1	1	0	0	0	0	0	0	0
D. Constrained in their ability to conduct research into infrastructure/middleware of HLA.	0	0	0	0	0	0	0	0	0	0	0
A. Must compete for limited sources of funding. Limited funding in general. No guaranteed funding from year to year.	0	0	0	0	0	0	0	0	0	0	0
A. Dependencies upon other organizations other than funding.	0	1	1	1	1	1	0	0	1	0	1
B. Funding dependencies upon other organizations.	0	0	0	0	0	0	0	0	0	0	0

	12	13	14	15	16	17	18	19	20	21
	Univ 1	Univ 2	Univ 3	Univ 4	Rsch 1	Rsch 2	Rsch 3	Rsch 4	Rsch 5	OS 1
A – Want or need to meet an external M&S capability need or requirement.	1	1	1	1	1	1	1	1	1	1
B – Want or need to create a new M&S organization (brand new organization).	0	0	0	0	0	0	0	0	0	0
A – Want or need to meet an internal M&S capability need or requirement.	1	1	1	1	1	1	1	1	1	1
B – Want or need to create new M&S group, section, branch within their organization.	0	0	0	0	0	0	0	0	0	0
C – Want/need/lack a procurement system that is responsive to their needs/requirements.	0	0	0	0	0	0	0	0	1	0
A – Want or need to meet an external OS capability need or requirement.	1	1	1	1	1	1	0	0	1	1
A – Want or need to meet an internal OS capability need or requirement.	1	0	1	1	0	1	0	1	1	1
A – Outcome related to their M&S work/business.	1	1	1	1	1	1	1	1	1	1
B – Outcome related to the science of M&S.	1	1	1	1	1	1	1	1	1	1
C – Outcome related to M&S knowledge (and awareness).	1	1	1	1	1	1	1	1	1	1
D – Outcome related to the M&S industry (e.g. lower the barrier to entry).	1	1	1	1	1	1	0	1	1	1
A – Want to conduct or facilitate M&S research.	1	1	1	1	1	1	1	1	1	1
B – Want to provide formal M&S education (university, college, academic institution).	1	1	1	1	0	0	0	0	0	0
C – Want to provide or facilitate formal/informal M&S training (e.g. contractor provided, company provided, in-house, online...).	1	1	1	0	1	0	0	1	0	0

	12	13	14	15	16	17	18	19	20	21
	Univ 1	Univ 2	Univ 3	Univ 4	Rsch 1	Rsch 2	Rsch 3	Rsch 4	Rsch 5	OS 1
D – Want to participate in international M&S exercises.	0	0.5	0.5	0	0	1	0.5	1	0.5	0
A – Specifically want to be involved in an OS RTI initiative, or an OS RTI ecosystem.	1	0.5	0	0.5	0	1	0	1	1	1
B – Want/need access to RTI source code (for reasons of greater control, access, flexibility, interest, ability to troubleshoot, optimization).	1	1	1	1	0	1	0	1	1	1
C – Want/need RTI that is cost-free and has a permissive license.	0	0	1	1	0	1	1	0	1	1
D – Want to pursue new business opportunities by leveraging an OS RTI.	1	0	0	0	0	1	0	0	0	1
A – Want to participate in international OS activities (aside from OS RTI).	0	0	1	0	0	0	1	0	0	1
B – Want/need OS product source code (for reasons of control, flexibility, time savings, customization).	1	1	1	1	0	1	1	1	1	1
C – Want/need OS software that is cost-free and has a permissive license.	0	1	1	1	0	1	1	1	1	1
D – Want to pursue new business opportunities by leveraging OS in general.	0	0	0	0	0	0	0	0	0	0
A – Want to make a profit.	0	0	0	0	0	0	0	0	0	0
B – Want or need other sources of funding (other than from profit or from research funding, e.g. contract work, development work, sponsored work, sponsors, investment capital).	1	1	1	1	1	1	0	1	0	1
C – Want research funding.	1	1	1	1	1	1	1	1	1	0
D – Want to expand their customer or client base.	0	1	0	0	0	1	0	0	0	1
A – Want, need, or lack personnel in general.	1	0	0	1	0	0	0	0	1	1
B – Want, need, or lack personnel with M&S expertise.	0	1	0	1	0	0	0	1	0	0

	12	13	14	15	16	17	18	19	20	21
	Univ 1	Univ 2	Univ 3	Univ 4	Rsch 1	Rsch 2	Rsch 3	Rsch 4	Rsch 5	OS 1
A – Want to establish or improve relationships within their own organization, environment, or community.	1	0	0	0	1	0	0	1	0	0
B – Want to establish or improve relationships with research organizations.	0.5	0	0	0	0	0	1	1	0	0
C – Want to establish or improve relationships with academic organizations.	1	1	0	0	0	0	0	1	1	0
D – Want to establish or improve relationships with industry (i.e. companies).	1	0	1	0	0	1	1	1	1	0
E – Want to establish or improve relationships with government/defence organizations.	1	0	0	0	0	0	1	0	1	0
A – Recognition (**for what they do).	1	1	0	0	1	0	1	0	0	0
B – Credibility.	1	1	0	0	1	0	1	0	0	0
C – Presence, visible (**awareness that they exist, visibility).	1	1	0	0	1	0	0	0	0	1
D – Customer satisfaction.	0	0	0	0	1	0	0	0	0	0

	12	13	14	15	16	17	18	19	20	21
	Univ 1	Univ 2	Univ 3	Univ 4	Rsch 1	Rsch 2	Rsch 3	Rsch 4	Rsch 5	OS 1
A – Relationships with international government/defence organizations.	0	1	1	0	1	1	1	1	1	0
B – Relationships with national government/defence organizations.	1	1	1	1	1	1	1	1	1	1
A – Relationships with international universities.	0.5	1	0.5	0	0.5	0.5	0.5	0.5	1	0.5
B – Relationships with national universities.	0.5	1	0.5	0	1	1	1	1	1	1
A – Relationships with international research organizations.	0.5	1	0.5	0	0.5	1	0.5	1	1	1
B – Relationships with national research organizations.	0.5	1	0.5	1	1	0.5	1	1	1	1
A – Industry organization to industry organization relationships (i.e. company to company).	0	0	0	0	0	0	0	0	0	0
B – Academic organization to industry organization relationships.	1	1	1	1	0	0	0	0	0	0
C – Research organization to industry organization relationships.	0	0	0	0	1	1	1	1	1	0
D – Government/defence organization to industry organization relationships.	0	0	0	0	0	0	0	0	0	0
E – OS to industry organization relationships.	0	0	0	0	0	0	0	0	0	1
A – Have positive dependence relationships.	0.5	1	1	0	1	1	1	1	1	1
A – Participate in large-scale national or international M&S activities from which they can draw resources, or in which they can share resources.	0	0.5	0.5	0	1	1	0.5	1	0.5	0

	12	13	14	15	16	17	18	19	20	21
	Univ 1	Univ 2	Univ 3	Univ 4	Rsch 1	Rsch 2	Rsch 3	Rsch 4	Rsch 5	OS 1
A – Contribute to the advancement of M&S capabilities external to their organization (provides them with ROI).	1	1	1	1	1	1	1	1	1	1
B – [Member, stakeholder, contributor] to M&S-related consortia, ecosystems, groups (provides them with ROI).	0	0	0	0	1	0	0	1	0	0
A – Actively and willingly share their knowledge.	1	1	1	1	1	1	1	1	1	1
A – Involved in international Standards Org (SISO).	1	1	1	0.5	1	1	0	1	0	1
B – Involved in international Defence M&S Group (NMSG).	0	1	0	0	0	1	1	1	1	0
C – Involved in TTCP.	0	0	0	0	0	0	1	1	0	0
D – Involved in professional M&S organizations (e.g. I/ITSEC, SCS).	0.5	1	0.5	0	1	0.5	0	0.5	0	1
E – Involved in M&S industrial development groups.	0	0	0.5	1	0	0	0	0	0.5	1
A – Have existing M&S and/or distributed simulation infrastructure.	1	1	0.5	0.5	0.5	0.5	0.5	1	0	0
B – Have existing distributed simulation connectivity.	0.5	1	0.5	0.5	0.5	0.5	0.5	1	0	0
A – Organizational structure is of benefit in some way.	1	1	1	1	0	0	0	0	0	0
B – Conduct or facilitate M&S research.	1	1	1	1	1	1	1	1	1	0
C – Provide formal M&S education (university, college, academic institution).	1	1	1	1	0	0	0	0	0	0
D – Provide or facilitate formal/informal M&S training.	0	1	1	0	1	0	0	1	0	0
E – Provide M&S advice or support.	1	1	0.5	1	1	1	1	1	1	0
F – Have their own certified RTI.	0	0	0	0	0	0	0	0	0	0

	12	13	14	15	16	17	18	19	20	21
	Univ 1	Univ 2	Univ 3	Univ 4	Rsch 1	Rsch 2	Rsch 3	Rsch 4	Rsch 5	OS 1
G – Needs are met/can be met by commercial RTI.	1	1	0	0	0	0	1	0	0	0
H – Have specific key M&S, distributed simulation or HLA personnel.	1	1	1	1	1	0	0	1	1	1
I – Have sufficient personnel or access to additional personnel.	0	1	1	0	0.5	0	0	0	1	0
J – Sufficient or adequate funding.	0	0	0	0	0	0	0	0	0.5	0
K – Access to external or additional funding.	1	1	0	0	1	0	0	1	0.5	1
L – Neutral organization, impartial, non-competitive role.	0.5	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	1
A – Have organizational practices, roles, which provide their organization with resources.	1	1	1	0	1	1	0	1	1	1
B – Create/control proprietary information, products, etc.	0	0.5	0	0	1	0.5	0.5	1	0.5	0
A – Federation creation or support expertise.	1	1	0	1	1	1	1	1	0	0.5
B – Have, or are developing, distributed simulation expertise.	1	1	1	1	1	1	1	1	0	1
C – Extensive or deep HLA expertise.	1	1	0	1	1	1	1	1	0	1
A – Knowledge/awareness of OS RTIs (e.g. investigated and/or tested one or several).	1	1	1	1	1	1	1	1	0	1
B – Already using an OS RTI. Have experience with using an OS RTI.	1	0	0	1	0	1	1	1	0	1
C – Developed an OS RTI.	1	0	0.5	0	0	1	0	0	0	1
D – See potential uses for OS RTI (in their organization or for a client of theirs).	1	1	1	1	0	1	1	1	1	1
E – Would consider using an OS RTI.	1	1	1	1	0	1	1	1	1	1
F – Have resources to contribute to an OS RTI initiative.	1	1	0	0.5	0.5	1	0	1	1	1

	12	13	14	15	16	17	18	19	20	21
	Univ 1	Univ 2	Univ 3	Univ 4	Rsch 1	Rsch 2	Rsch 3	Rsch 4	Rsch 5	OS 1
A – Have produced their own OS.	1	1	1	0.5	1	1	0	0.5	0	1
B – Consumer of OS (M&S and otherwise).	1	1	1	1	0	1	1	1	1	1
C – Follow OS software. See value in OS.	1	1	1	1	0	1	1	1	1	1
D – Use OS to benefit their business or organization.	1	1	1	1	0	1	1	1	1	1
E – Have valuable and beneficial relationships with OS projects, ecosystems, organizations.	1	0	1	1	0	0	0	0.5	0	1

	12	13	14	15	16	17	18	19	20	21
	Univ 1	Univ 2	Univ 3	Univ 4	Rsch 1	Rsch 2	Rsch 3	Rsch 4	Rsch 5	OS 1
A. Lack direction or support from higher organization to pursue M&S activities, initiatives, or approaches.	0	0	0	0	0	0	1	0	0	0
B. Lack a strategic M&S champion.	0	0	0	0	0	0	1	1	0	0
C. Faced with lack of awareness of the benefits of M&S in higher organization.	0	0	0	0	0	0	0	0	0	0
D. Organizational policies/management constrain M&S (constraints within own organization).	1	0.5	0	1	0	0	1	0	0	0
A. Organizational structure imposes constraints.	0	0	0	0	0	0	1	0	0	0
B. Organizational business model imposes constraints.	1	0	0	0	1	0	0	0	0	1
C. Organizational role imposes constraints.	1	0	0	1	1	0	1	0	0	0
A. Challenging to find qualified personnel.	1	1	0	1	0	0	0	1	0	1
B. Existing personnel are constrained in some way.	0	0	0	1	0	1	1	0	0	1
C. Organizationally constrained in their ability to create an M&S personnel capability (group, section, etc) or from hiring additional personnel.	0	0	0	0	0	0	0	0	0	0
A. M&S practices, tools used are dictated by their [client, customer, or stakeholder] requirements, policies, or degree of risk aversion.	0	1	0	0	1	1	1	0	0	0
B. M&S work is dictated by the needs/requirements of [client, customer, stakeholder].	0	1	0	0	1	0	1	0	0	0
C. [Client, customer, or stakeholder] lack knowledge and awareness of M&S. Lack ability to properly articulate their needs. Lack HLA expertise. Impose technical or operating constraints as a result.	0	0	0	0	0	0	1	0	1	0
D. [Client, customer, or stakeholder] community lacks coherence, poorly defined, fragmented with respect to M&S.	0	0	0	0	0	0	0	0	0	1

	12	13	14	15	16	17	18	19	20	21
	Univ 1	Univ 2	Univ 3	Univ 4	Rsch 1	Rsch 2	Rsch 3	Rsch 4	Rsch 5	OS 1
A. Constraints imposed by government contract award or internal product development practices.	0	0	0	0	0	0	0	1	0	0
A. Constraints imposed by lack of distributed simulation infrastructure or connectivity.	0	0	0	0	0	0	0	0	1	0
A. Constraints imposed by security-related restrictions.	0	1	1	0	0	0	0	0	1	0
A. Difficult to maintain awareness of M&S activities within and outside their organization.	0	0	0	1	1	0	1	1	0	0
A. Mixed support for OS RTI within the M&S industry.	0	1	0	0	0	0	0	0	0	1
B. Constraints imposed by nature of M&S industry, market.	0	0	0	0	0	0	1	1	0	1
A. Pursuit of OS is constrained in some way.	0	1	0	0	0	0	0	0	0	0
B. Business reasons for dislike or lack of interest in OS (competition, OS-averse clients).	0	0	0	0	1	0	0	0	0	0
A. Have no perceived need for an OS RTI.	0	0	0	0	0	0	0	0	0	0
B. Constrained from participating in an OS RTI ecosystem.	0	0	0	0	0	0	1	0	0	0
C. Constrained from developing an OS RTI ecosystem.	1	0	0	0	0	0	0	0	0	1
D. Perceived technical constraints related to using OS RTI.	0	0	0	0	0	0	0	0	0	0

	12	13	14	15	16	17	18	19	20	21
	Univ 1	Univ 2	Univ 3	Univ 4	Rsch 1	Rsch 2	Rsch 3	Rsch 4	Rsch 5	OS 1
A. Not historically large HLA users.	0	0	1	0	0	0	0	0	1	0
B. Moving away from HLA.	1	0	0	0	0	0	0	0	0	0
C. Constraints imposed by Federation Object Model.	0	0	0	0	0	0	0	0	0	0
D. Constrained in their ability to conduct research into infrastructure/middleware of HLA.	0.5	1	0	0	0	0	1	0	0	0
A. Must compete for limited sources of funding. Limited funding in general. No guaranteed funding from year to year.	1	0	0	1	1	1	1	0.5	0.5	0.5
A. Dependencies upon other organizations other than funding.	0	0	0	0	0	0	0	0	0	0
B. Funding dependencies upon other organizations.	1	1	1	0	1	1	0	1	0	1

Appendix 4: Organizational Motivation, Ability, Constraint Categories

Categories which Describe Motivation
1. Want or need to meet an external capability need or requirement specific to M&S.   2. Want or need to meet an internal capability need or requirement specific to M&S.   3. Want or need to meet an external capability need or requirement specific to OS.   4. Want or need to meet an internal capability need or requirement specific to OS.   5. Want or need to achieve a specific M&S outcome; establish a specific M&S ability.   6. Want to perform certain M&S roles or functions, participate in specific M&S activities.   7. Want, need or lack an OS RTI or an OS RTI ecosystem.   8. Want, need or lack OS software.   9. Want, need or lack money.   10. Want, need or lack personnel.   11. Want to establish or improve inter-organizational relationships.   12. Want, need or lack certain intangibles (e.g. recognition, credibility).
Categories which Describe Ability
1. Have valuable and beneficial relationships with government/defence organizations.   2. Have valuable and beneficial relationships with academic institutions.   3. Have valuable and beneficial relationships with research institutions.   4. Have valuable and beneficial relationships with industry.   5. Have positive dependence inter-organizational relationships (others depend on them).   6. Able to participate in large-scale national or international M&S activities.   7. Able to contribute to M&S initiatives external to their organization (provide direct or indirect return on investment (ROI)).   8. Actively, willingly share their knowledge.   9. Involvement in national or international organizations devoted to M&S, distributed simulation, HLA.   10. Have existing technical capabilities.   11. Have existing organizational capabilities, resources.   12. Have beneficial organizational practices.   13. Have existing organizational M&S knowledge, expertise.   14. Have specific OS RTI knowledge or expertise, or have specific interest.   15. Have specific involvement with OS (produce, consume, interest in, benefit from).
Categories which Describe Constraint
1. Constrained by lack of organizational support or priority for M&S.   2. Constrained by organizational structure.   3. Organizationally constrained with respect to OS.   4. Organizationally constrained with respect to OS RTI.   5. Have negative dependence relationships (they depend on others).   6. Client, customer, stakeholder imposed constraints.   7. Government imposed constraints.   8. Constraints imposed by the M&S industry.   9. Personnel constraints.   10. Financial constraints.   11. Simulation infrastructure and connectivity constraints   12. Security related constraints.   13. Difficulty in maintaining M&S awareness.   14. HLA-specific constraints.