

Architecting the Enterprise for Innovation: Transformation for Technology in Support of National Security

by

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Abstract

Technology is fundamental to national security. Therefore making wise and timely investments in the most relevant research and development questions to address real and pressing needs is critical.

This thesis is an investigation of the application of Enterprise Architecting frameworks and Systems Design methods to explore novel enterprise concepts, alternative enterprise architectures and relevant values to determine if they enhance and add measurable value to enterprise architecture of the early R&D collaboration, teaming, proposal refinement, selection and funding processes at MIT Lincoln Laboratory.

The overall aim is to answer the holistic question of can we create and identify emergent value by applying an enterprise framework to the challenge of enterprise transformation.

Particular emphasis is placed on examining the elements of culture as it relates to adopting new technology and processes to enable enterprise transformation.

Thesis Supervisor: Donna Rhodes

Title: Principal Research Scientist, Sociotechnical Systems Research Center

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Terminology and Acronyms

Activity - set of cohesive tasks of a process [1, p. 5]

System - A definition offered by Cameron, Crawley, and Selva (2016) is “a set of entities and their relationships, whose functionality is greater than the sum of individual entities.” [2, p. 9]

Systems Engineering – “Systems Engineering (SE) is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem: operations, cost and schedule, performance, training and support, test, manufacturing, and disposal. SE considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.” (INCOSE) [1, p. 6]

Process - set of interrelated or interacting activities which transforms inputs into outputs [1, p. 5]

MIT Lincoln Laboratory Related Terminology

FFRDC - Federally Funded Research and Development Center. A Federally funded R&D facility managed by a university or non-profit corporation with a mission area aligned with a government agency or department.

Line Funding or Line Program – Federally funded R&D projects in technology areas related to national security

Group – The primary organizational unit of Lincoln Laboratory R&D

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Chapter 1 Introduction

This chapter introduces the objective and motivation for this thesis, the research questions used for exploration of the topic along with the approach. Lastly, this chapter describes the structure and organization of the thesis.

1.1 Objective

This thesis explores the application of systems and enterprise architecting frameworks to find opportunities to enhance and add value to the management, processes, infrastructure and culture of innovation at MIT Lincoln Laboratory.

The objective of this thesis is to investigate how engineering and management practices, enterprise architecting frameworks, systems design techniques, and transformational leadership methods developed in academia and industry can be used to better manage innovation in support of national security.

1.2 Motivation

Future innovation is not a certainty. Regardless of past success, today's enterprises are under constant pressure to demonstrate new results and provide measurable future successes.

Anecdotes of past technological marvel and demonstrations of technical capabilities are often no longer deemed sufficient in an age of big data analytics. Value metrics are even harder to come by when the mission is not to make money as a return on investment but to support national security. The enterprise is challenged to find those metrics of value which enable improvements to the process of innovation itself.

The author is motivated to holistically consider the ways in which best practices drawn from industry and academia along with principles, methods and practices taught through MIT System Design and Management joint program in engineering and management can be

applied to envision a future enterprise architecture that enables even greater innovation at Lincoln Laboratory in support of national security.

1.3 Scope

The scope of this thesis includes a holistic view of MIT Lincoln Laboratory utilizing systems thinking and enterprise architecting frameworks with a focus on the innovation culture, innovation processes and IT systems which support innovation.

1.4 Research Questions

The thesis emerged from a project to transform the processes around internal early phase R&D proposal and selection. The “line” funding program is one of the main internal processes for selecting such early innovative proposals in technical areas aligned with national security needs.

Prior to the author’s participation a series of workshops were held to identify and allocate “pain points” in the existing line funding proposal and selection process. Analysis from these workshops resulted in an effort to examine in a “proof of concept” how an IT system could facilitate communications, capture and better organize more information during the proposal and selection process and in the future provide a more integrated “synoptic” or portfolio view of innovative ideas, concepts and proposals being put forward by researchers.

The experiences of the proof of concept team effort in which the author took part will provide the basis for many of the research observations of this thesis. In addition the author was motivated to look holistically at the process of innovation at Lincoln Laboratory to discover more generally applicable best practices and put forward additional questions for investigation.

Three questions are formulated as the research questions addressed, the first is about applying an enterprise architecting framework to the transformational efforts, the second is

about the choice of an architecture, and the last question is about the interplay of culture in the planning and implementation for enterprise change.

- Within the context of a research and development organization and focusing on innovation management, does applying an enterprise architecting framework and generating holistic alternative architectures add perceivable value?
- Does a focus on adopting new IT systems make definitive stakeholders within the organization more receptive to transformational enterprise change?
- What part does the culture of MIT Lincoln Laboratory play in planning and executing transformational change?

1.5 Research Approach

In approaching the work the author is drawing upon principles, practices and techniques of MIT's System Design and Management program. The SDM program is MIT's master's degree in engineering and management jointly offered by MIT's School of Engineering and MIT Sloan School of Management.

Centered around "systems thinking" the core program draws upon systems architecting, systems engineering and project management principles, values and practices while drawing together management and engineering curriculum from the two schools.

The research uses principles and techniques of systems architecture and the ARIES framework to apply systems architecting to the enterprise.

Research techniques include:

- Literature reviews
- Analysis of information and data provided by the enterprise
- Stakeholder interviews

- Stakeholder surveys and analysis

1.6 Thesis Structure

The second chapter describes the background of the enterprise, including history, culture, vision, strategy and strategic directions. It describes the motivation for the enterprise change, a problem statement for the enterprise change and summary

The third chapter is a review of literature relating to systems thinking, systems architecture, systems engineering and the ARIES enterprise architecting framework.

The fourth chapter describes the enterprise landscape, describes a stakeholder analysis methodology, identifies the stakeholders, maps stakeholder salience and relationships and provides a summary.

The fifth chapter describes the current or as-is enterprise architecture using an enterprise model, ARIES view elements, an X Matrix and summary.

The sixth chapter describes a holistic vision of the future with vignettes that align with stakeholder values along with a discussion of applicable metrics for measuring value and comparing future outcomes.

The seventh chapter focuses on enterprise culture as a key element for enabling and sustaining transformational change. It examines some main stream systems that incorporate elements of culture and cultural change.

The eighth chapter develops the enterprise architecture with enough detail to evaluate alternatives. Finally a high level implementation strategy is put forward.

Finally the ninth chapter offers conclusions and recommendations, addresses the research questions and suggests future work.

Chapter 2 Background

This Chapter discusses the origins, culture, and organization of the Enterprise and then discusses the motivations, strategy and scope of the current transformational efforts.

2.1 Description of Enterprise

MIT Lincoln Laboratory is a Federally Funded Research and Development Center (FFRDC) focused on technology in support of national security and is primarily located in Lexington and at Hanscom Air Force Base in Massachusetts.

2.1.1 Historical Background

Founded in 1951, Lincoln Laboratory evolved out of MIT's many contributions of new technologies to the American and allied war efforts of World War II. One of the most notable of these war efforts was through the MIT Radiation Laboratory which was tasked with developing radar systems. These systems gave the United States and allied forces effective and sometimes decisive advantages in capabilities over enemy forces. [3]

While the United States had projected power across the globe to win the war, the new threat of strategic bombers armed with nuclear weapons made the country potentially vulnerable to attack at home. MIT Lincoln Laboratory was established to counter this threat with a design and development of a new integrated air defense system.

From radar, communications, satellites, early computers, lasers, fiber optics, lidar systems, ballistic missile defense, large format CCD imaging, bio sensors and advanced computing the laboratory has been at the cutting edge of technologies.

MIT Lincoln Laboratory has been providing the United States with technology in support of national technology in response to current and future challenges. [4]

2.1.2 Culture of the Enterprise

The roots of MIT Lincoln Laboratory's culture go back to its founding as a part of MIT, but its own distinct cultural attributes have emerged.

Within the management sciences the culture of an organization is recognized as being an important enabler of the ability of a company to overcome challenges and find opportunities.

How to define the culture of an organization? The Merriam-Webster defines culture as it applies to an organization to mean "*the set of shared attitudes, values, goals, and practices that characterizes an institution or organization*" [5]

Sociologists go further to describe culture as "the values, beliefs, systems of language, communication, and practices that people share in common and that can be used to define them as a collective. Culture also includes the material objects that are common to that group or society." [6]

MIT itself has been an archetype of innovation for many decades and widely emulated. Likewise Lincoln Laboratory has been an archetype of innovation in support of national security since its founding.

The attributes of culture at MIT Lincoln Laboratory include the dedication to national security demonstrated by leadership and staff and reflected in writings, history and artifacts.

Mission is central to the organization and so is security. This dedication to national security is apparent to anyone allowed to enter the facilities.

The technical achievements and artifacts of the laboratory's work are plentiful and displayed prominently in the hallways and common spaces. From prototypes in glass cases, to interactive technical displays, the laboratory is proud of its achievements and technical

capabilities and strives to build upon past successes.

Technical excellence is also a key attribute of culture at the laboratory and more broadly at MIT in general. A belief that technological innovation can help address most any problem is as ingrained in the culture as any other belief system.

2.1.3 Organizational Context

Within the overall MIT organization the director of Lincoln Laboratory reports to the Vice President of Research and the Provost.

The Office of the Director is composed of 12 offices with different areas of responsibility.

OFFICE OF THE DIRECTOR		
Executive Officer and Chief of Staff	Chief Strategy Officer	Chief Technology Officer
Chief Technology Ventures Officer	Assistant to Director for Diversity and Inclusion	Capital Projects
Business Transformation Office	Safety and Mission Assurance Office	Flight Test Facility
Communications and Community Outreach	Program Management Office	MIT Counsel

Figure 1 Office of the Director [7]

Supporting the work of the technical divisions and the director’s office are 6 service departments which comprise contracting services department (CSD), Facility Services Department (FSD), Financial Services Department (FSD), Human Resources (HR), Information Services Department (ISD) and Security Services Department (SSD)

SERVICE DEPARTMENTS		
Contracting Services	Facility Services	Financial Services
Human Resources	Information Services	Security Services

Figure 2 Organization of Service Departments [7]

The organization is divided along eight broad technical R&D areas. Each of the technical divisions has between five and eight groups.

The technical groups are aligned with a research area, technology or capability at the laboratory. It is within these technical groups that the research and development work takes place.

TECHNICAL DIVISIONS			
Air, Missile, and Maritime Defense Technology	Homeland Protection and Air Traffic Control	Cyber Security and Information Sciences	Communication Systems
Engineering	Advanced Technology	Space Systems and Technology	ISR and Tactical Systems

Figure 3 Organization of Technical Divisions [7]

The technical divisions and groups are the basic organizational units of the R&D efforts of the laboratory. Some groups and divisions have an emphasis on mission area, some emphasize expertise in a technical area and others place more emphasis on systems, engineering and/or prototyping.

**MIT LINCOLN LABORATORY
ORGANIZATION OF TECHNICAL DIVISIONS**

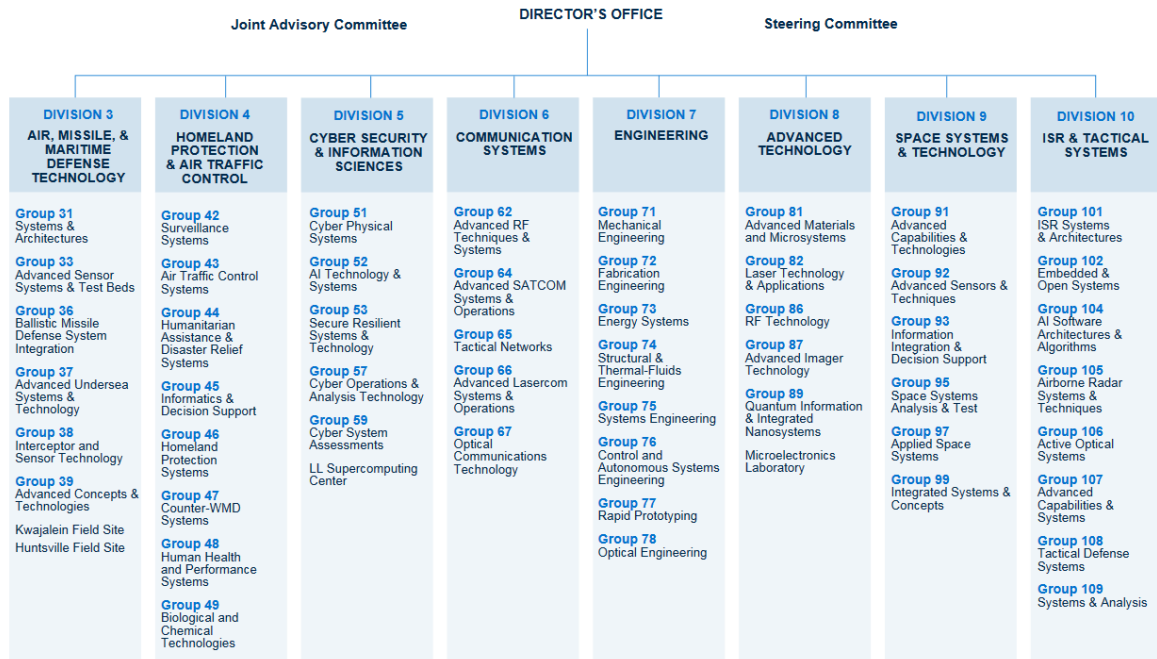


Figure 4 Organization of Divisions and Groups [7]

2.1.4 Federally Funded R&D

MIT Lincoln Laboratory is one of the United States' 42 Federally Funded Research Development Centers (FFRDCs). These FFRDCs and the 17 University Affiliated Research Centers (UARCs) hold special places in the ecosystem of United States Government funded R&D. Placed at the intersection of the research efforts of academic universities, non-profits, commercial industry and government sponsors, these centers engage in research in science and technology areas as directed by their sponsoring agencies. Research and development is aligned with the needs of their government sponsors in the fields of defense, energy, aviation, space, health and human services. [8]

Although government laboratories, these institutions are managed by Universities and non-profit corporations under government contract. Many of the researchers and staff at these

institutions are employees of the managing entity or of a separate non-profit corporation.

2.2 Enterprise Mission and Strategy

The mission of the laboratory is: *Technology in support of national security*

Key roles towards this mission are: systems architecture and systems engineering, technology development, and systems prototyping and demonstration. This section describes the enterprise vision, values and strategic directions.

2.2.1 Enterprise Vision

The MIT Lincoln Laboratory Annual Report puts forward the vision *To be the nation's premier laboratory that develops advanced technology and system prototypes for national security problems. To work in the most relevant and difficult technical areas And To strive for highly effective program execution in all phases* [9]

2.2.2 Enterprise Values

The enterprise values stated by MIT Lincoln Laboratory are:

The Laboratory is committed to technical excellence through the people it hires and through its system and technology development, prototyping, and transition.

The Laboratory strives to develop and present correct and complete technical results and recommendations, without real or perceived conflicts of interest.

The Laboratory bases career advancement on an individual's ability and achievements. A diverse and inclusive culture is critically important for a well-functioning meritocracy.

The Laboratory is committed to service to the nation, to the local community, and to its employees. [9]

2.2.3 Strategic Directions

Also, in the 2018 annual report the strategic directions of the laboratory are enumerated in figure 5. These strategic directions provide a comprehensive overview of the values and priorities of the laboratory. The strategic directions encompass bolstering the core strengths of the laboratory in mission and technology area; increasing collaboration with University researchers and technology transfer to industry; becoming more efficient in operations; becoming more diverse and inclusive; enhancing community outreach and education; and continuing to improve the laboratory's facilities.

- *Continue evolving mission areas and programs*
- *Strengthen core technology programs*
- *Increase MIT campus/Lincoln Laboratory collaboration*
- *Strengthen technology transfer to acquisition, user, and commercial communities*
- *Find greater efficiencies and reduce overhead process*
- *Improve leverage through external relationships*
- *Improve Laboratory diversity and inclusion*
- *Enhance Laboratory facilities*
- *Enhance Laboratory community outreach and education*

Figure 5 Lincoln Laboratory Strategic Directions [9]

2.3 Enterprise Transformation

Central to transformational efforts is the Business Transformation Office (BTO) within the Director's Office. The mission of the BTO is to *Enable state-of-the-art technology research by optimizing enterprise operational processes, modernizing business systems, and improving staff capabilities.*

The overall vision of the BTO efforts is “*within the next five years establish efficient, accurate, and integrated business processes and a culture of ownership and continuous improvement to manage operational risk and enable world-class research.*”

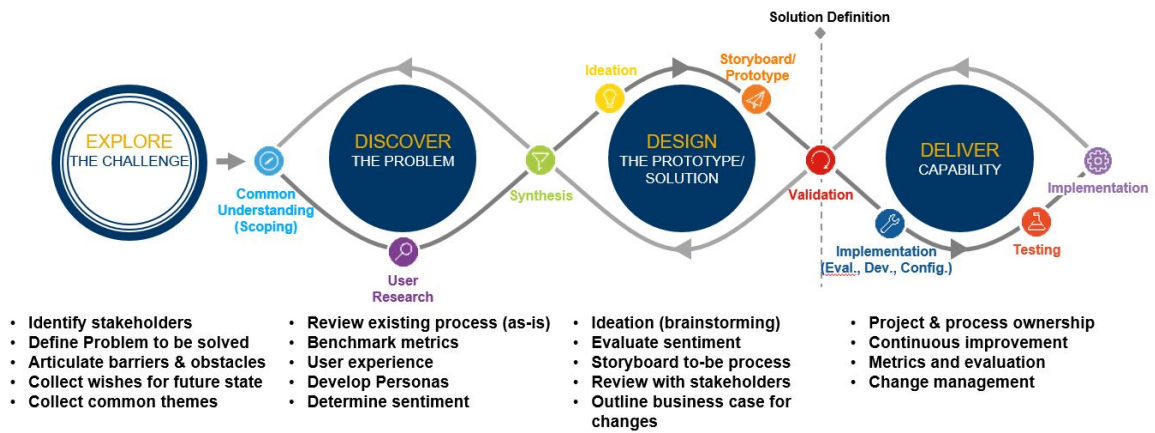


Figure 6 Lincoln Laboratory Business Transformation Office Approach

2.3.1 Motivations for Transformation

Like many organizations the enterprise wishes to streamline operations for maximum efficiency and to address identifiable issues with existing processes. Unlike many organizations return on investment cannot be truly measured in dollars, but rather in value provided to national security.

For future scientists and engineers to be given the freedom, opportunity and resources to continue to innovate, the research and development enterprise must find ways to utilize the best methods and technology to create, measure and communicate value.

2.4 Transformation Project for Innovation Management

The thesis research has taken place within and alongside one specific collaborative project between the Technology Office, the Business Transformation Office, the Information Services Department and stakeholders in the Technical R&D divisions and groups, which has set up a proof of concept system in order to consider how that IT system, or one like it, might enable transformation of innovation work at Lincoln Laboratory.

The potential for information technology to enable transformational change is an important view element within the context of the enterprise that this thesis studies.

2.4.1 System Problem Statement for Innovation Management

Key to systems architecture or systems engineering is the systems problem statement. The following problem statement was taken from the PowerPoint presentation prepared by the BTO for the Innovation Management Proof of Concept project:

Develop an efficient process to select the most innovative and technically challenging proposals for the Laboratory's Line portfolio by implementing a user friendly Portfolio Management Tool

Here we have many of the essential elements of the thesis, including the interplay of process, innovation, and information technology. Other elements can be inferred and will be expanded upon as the thesis looks back holistically at the enterprise.

2.5 Summary

MIT Lincoln Laboratory is one of the United States' premier Federally Funded Research and Development Centers with its focus on technology in support of national security.

The laboratory is motivated to maintain its leading edge capabilities, its culture of innovation and find the most efficient use of resources in its internal processes.

The leadership of the laboratory has well-defined strategic objectives, an enterprise vision and aligned strategic directions. Transformational efforts are ongoing in multiple areas of the enterprise and the laboratory.

This thesis investigates the research questions presented to the transformational efforts relating to innovation management that the laboratory has already begun, and looks forward to how a holistic and systems approach to enterprise architecting might be utilized to gain even greater insights moving forward.

Chapter 3 Systems Thinking, Systems Architecture and Architecting the Enterprise

This chapter is largely a review of literature related to systems thinking, systems architecture, systems engineering and Architecting Innovative Enterprise Strategy (ARIES). These provide the systems approach and methods to investigate the research questions of this thesis, as applied to innovation at MIT Lincoln Laboratory.

3.1 Systems Thinking, Theory and Architecture

System thinking is, quite simply, thinking about a question, circumstance, or problem explicitly as a system—a set of interrelated entities.

– Crawley et al. [2, p. 8]

Systems thinking should be considered for its utility compared to and along with other forms of reason including creative thinking, critical reasoning or even the scientific method itself. These are all methods of human reason which may be employed in different circumstances to derive some greater value or utility from a set of known facts, observations and context.

A system is a set of entities and their relationships, whose functionality is greater than the sum of the individual entities. – Crawley et al. [2, p. 9]

In the book *Systems Architecture: Strategy and Product Development for Complex Systems* (2016) the authors describe four tasks that aid with systems thinking:

- 1. Identify the system, its form, and its function*
- 2. Identify the entities of the system, their form and function, and the system boundary and context*
- 3. Identify the relationships among the entities in the system and at the boundary, as well as their form and function*
- 4. Identify the emergent properties of the system based on the function of the*

entities, and their functional interactions [2, p. 8]

The authors describe the basic building block of a system as being an entity. The entity has both form and function. For the most part form is the physical form of an entity and the function is what effect that entity has on some input or on other entities. While the entities of the system are the building blocks, the relationship between entities is where architects can have the most influence.

According to Eberhardt Rechtin, in *Systems Architecting of Organizations* (2000): “*The greatest leverage, risk, dangers, and opportunities in a complex enterprise are in the interfaces and the interrelationships*” [10] It is the entities placed in relationship with one another that are what create emergent form and function. In other words the whole is greater than the sum of the parts. The emergent systems behavior is often where value is realized and where the value of architecture comes into play.

Crawley et al. describe systems architecture as “*an abstract description of the entities of a system and the relation-ships between those entities.*” [2, p. 9] The representation of the architecture can take many forms, but often systems can be represented through a series of diagrams that relate and describe form, function and relationships between entities.

The idea of a “system-of-systems” may be defined as a system with “components that are themselves significantly complex, enough so that they may be regarded as systems and that are assembled into a larger system.” [11]

3.2 Systems Engineering

The field of Systems Engineering is an approach to designing, building and managing complex systems over their life cycle. The “Vee” model represents the planning and architecting activities of the systems engineer. Where the required architecture and decomposition of the system should align with the plan for the integration, verification and validation.

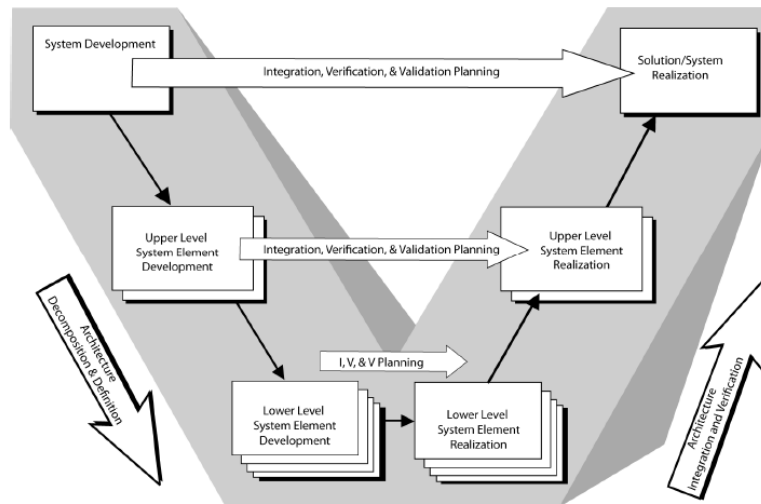


Figure 7 Systems Engineering Vee Model [1, p. 27]

The “saw tooth” model represents an incremental and iterative approach that more closely resembles agile methodologies today. Later in the writing, there is further analysis of agile, lean six sigma and how they relate to culture and cultural change.

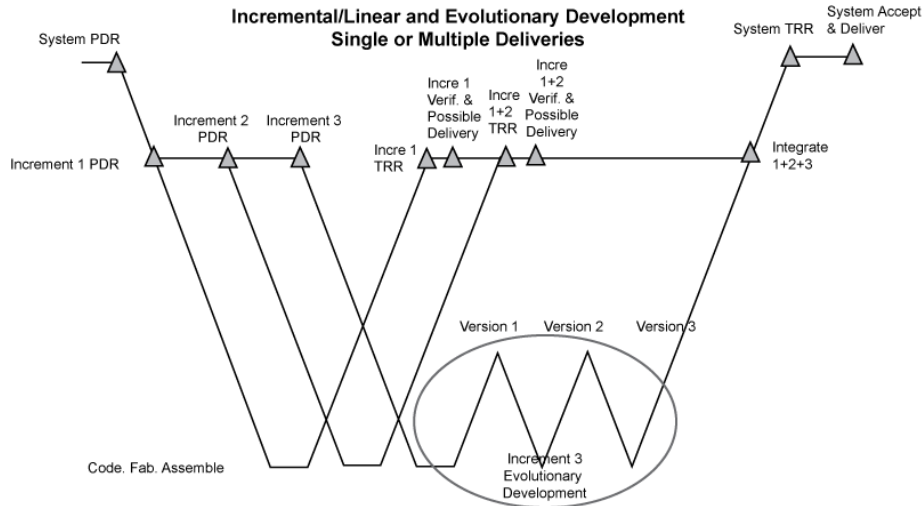


Figure 8 Incremental and Iterative (and Evolutionary) Development [1, p. 34]

3.3 Architecting Innovative Enterprise Strategy (ARIES)

In Western astrology, Aries is the first sign of the astrological zodiac. A part of an ancient system where the movements of the celestial bodies of the night sky influenced the lives of the people on the earth below.

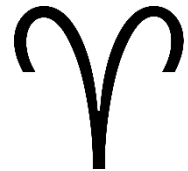


Figure 9 Aries Symbol

While the framework shares its name from this ancient system, Architecting Innovative Enterprise Strategy (ARIES) is a “holistic approach to creating a blueprint for future enterprise transformation” [12]

Unlike our ancient understanding of the Universe, this approach is a flexible framework for enterprise architecting built on an evolving synthesis of the latest engineering and management science approaches and techniques.

3.3.1 Elements

The four elements of the ancient world were considered fire, earth, air and water. The ARIES framework views the enterprise through ten elements. Ecosystem and stakeholders are the first elements and come together with the view elements of strategy, information, infrastructure, products, services, process, knowledge and organization.

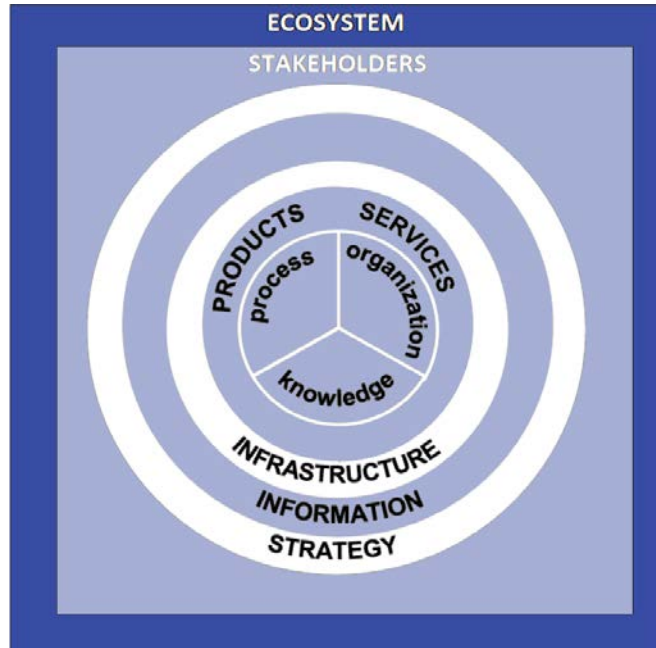


Figure 10 ARIES Enterprise Element Model [12, p. 16]

Table 2 describes the ten elements of the ARIES element model which are used to give a holistic view of the enterprise.

Table 1 ARIES Enterprise View Elements [12, p. 19]

Element	Description
Ecosystem	The external regulatory, political, economic, market, and societal environment in which the enterprise operates and competes/cooperates.
Stakeholder	Individuals and groups who contribute to, benefit from, and/or are affected by enterprise.
Strategy	The vision, strategic goals, business model, and enterprise-level metrics.
Information	The information the enterprise requires to perform its mission and operate effectively.
Process	Core, leadership, lifecycle, and enabling processes by which enterprise creates value for its stakeholders.
Organization	The culture, organizational structure, and underlying social network of the enterprise.

Knowledge	The competencies, explicit and tacit knowledge, and intellectual property resident in enterprise.
Infrastructure	Enterprise systems and information technology, communications technology, and physical facilities that enable enterprise performance.
Products	The products that the enterprise acquires, markets, develops, manufactures, and/or distributes to stakeholders.
Services	Offerings derived from enterprise knowledge, skills, and competences that deliver value to stakeholders, including support of products.

3.3.2 Process

The ARIES process can be described as a cycle of enterprise strategy and architecting. The process starts with understanding the enterprise landscape focusing as appropriate on areas related to the given enterprise strategy. The stakeholder analysis comes next and will inform later steps in the process and also help inform additional requirements gathering. The next step is to understand and describe the existing enterprise architecture at a high level according to the enterprise elements.

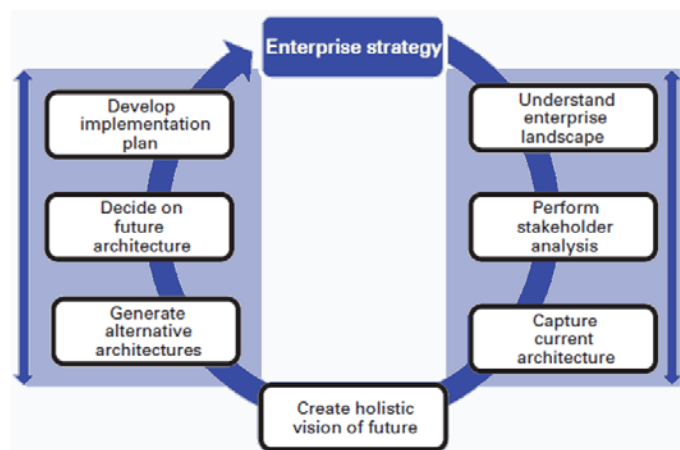


Figure 11 ARIES Process [12, p. 23]

From a base of understanding about the existing enterprise the next step is to create a holistic vision of the future which will give the enterprise architecting something to work towards. Generating alternative architectures, selecting the future architecture and developing a high level implementation plan are the last three steps of the ARIES process.

3.3.3 Techniques

The ARIES framework contemplates use of a variety of techniques during the architecting process. Techniques used in this thesis are SWOT analysis, ideation, x-matrix, modeling, and future proofing.

3.4 Common Risks and Pitfalls to Avoid

The overall risk of enterprise transformation is that the realized value at the end of the transformation simply does not offset the resources in time and money. Or worse, there is less value creation and/or higher costs after the transformation.

Nightingale and Rhodes' *Architecting the Future Enterprise* (2015) identifies 5 common architecting failures which can be avoided with attention to a holist approach to transformation.

Common Failures	Impacts to Enterprise
When in doubt, reorganize	Reorganizing can be disruptive when performed in isolation, with failure to achieve targeted outcomes.
Forgetting stakeholders	Inadequate stakeholder analysis can lead to decisions that are misaligned with what stakeholders need and expect from the enterprise.
It is all about technology	Expensive technology applications frequently address only a portion of the strategic issues and often fail in isolation.
Silo effects	Silo implementations almost always create fiefdoms and sub-optimize the enterprise by failing to consider other parts of the organization.
Information technology will fix everything	Focusing on IT without considering other elements frequently leads to expensive failures.

Table 2 common architecting failures [12, p. 3]

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Chapter 4 Enterprise Landscape and Stakeholder Analysis

This chapter follows the *Understanding the Enterprise Landscape* and *Performing Stakeholder Analysis* activities of the ARIES framework as applied to MIT Lincoln Laboratory and Innovation Management at the laboratory. The chapter also provides a description of the enterprise landscape and analysis of the stakeholders within the defined system boundary.

4.1 Internal Landscape and System Boundary

Before contemplating new enterprise architectures, the ARIES framework's first activity is a review and analysis of the enterprise landscape relating back to the enterprise transformation being contemplated. [12, p. 27]

While current focus of the Laboratory efforts are on the potential of an IT systems to enhance the efficiency of processes, the problem statement also envisions a holistic enterprise systems approach that will work well within the objectives and research questions of this thesis.

Moving the systems boundary to include only the IT system encompassing the data architecture, server architecture and process flow within the system is a perfectly valid approach. However, the author wanted to explore the question of whether a holistic approach to the enterprise architecture would add additional value to the enterprise.

Therefore areas that will be considered within the enterprise system boundary are:

- IT systems that support the line funding (and potentially other early R&D) processes.
- Activities and processes that support the line funding and other early R&D programs.
- The organizations that support the line funding including

- Director's Office (Technology Office, BTO)
- Information Services Department (Enterprise Applications, Enterprise Collaboration)
- Knowledge Services which is responsible for managing and maintaining information over time
- Line leads, who are each responsible for different technology areas
- Division and Groups who put forward proposals and manage execution.
- Culture of the enterprise as it relates to these changes and other transformation efforts
- The value of the R&D itself and how to recognize and measure that value or other strategic values in the work being done.

Outside the enterprise system boundary for the purposes of this thesis:

- Other sponsored research activities
- Other support services (Facilities, Finance)
- External stakeholder processes
- Indirectly related IT systems simply viewed as interfaces or utilities

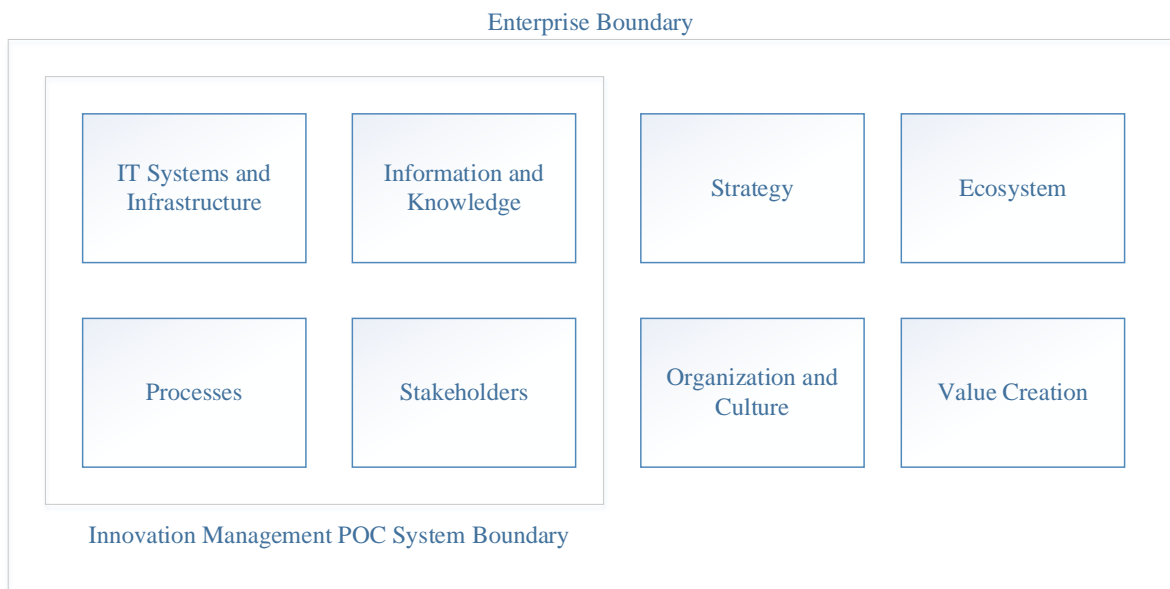


Figure 12 Enterprise and System Boundaries

4.2 External Landscape

A review of the external landscape is important for understanding potential stakeholders, regulatory compliance issues or constraints on the proposed transformation efforts.

In this enterprise context, one of the most important considerations of the external landscape is that the “Line” in Line Program is a reference to the line in the Federal budget that provides the funding for the research.

Along with this funding comes the compliance and reporting requirements of a Federal program.

The technology areas for which proposals may be submitted are determined in advance and therefore outside of the scope of any changes subsequently envisioned.

And it should be noted that potential opportunities to transform important laboratory processes for greater efficiencies and value creation must be carefully weighed against the risks of changing something that is fundamentally working.

4.3 Force Field Analysis

The underlying idea behind a force field analysis is that the current state is held in equilibrium by motivational forces driving change and forces resisting change. In any transformational effort there are going to be pros and cons, for and against, costs and benefits that stakeholders and decision makers will either directly weigh or be influenced by while approaching a transformational effort.

The origin of the force field analysis goes back to Kurt Lewin in the 1940s and was used in his work as a social psychologist. [13] And, this technique is a useful tool for enterprises in the ARIES framework [12, pp. 161-162].

A number of forces for and against change have been mapped out in table 3 from observations derived from a series of workshops held by the Business Transformation Office prior to the start of the author’s thesis research and also through stakeholder interviews observed or participated in by the author:

Table 3 Force Field Analysis for Lincoln Laboratory Innovation Management

Forces Driving Change	Forces Resisting Change
<ul style="list-style-type: none"> • More timely communication • More data on process itself • Potential for improving quality of collaboration • Recognizing value of collaboration across technology areas • Potential elimination of “pain points” 	<ul style="list-style-type: none"> • Cost of change • Ownership of change • Risk of negative net value • Resource conflicts over schedule • Lack of cultural willingness to change • Lack of willingness to adopt “off the shelf” IT solutions

From these observations we can see that stakeholders are going to value increases in collaboration, more transparency in the process, the potential ability to capture more value in the process itself while reducing the overhead so they can focus on value adding activities.

On the other side, stakeholders are reluctant to commit to any costly or time consuming changes that haven’t been validated first. The people who may benefit most from change are not necessarily the decision makers. And, there is a chicken and egg problem with enterprise IT solutions that could be expensive to implement in a customized way and stakeholders who are reluctant to make investments in IT before they can evaluate how the resulting systems would integrate with existing processes.

For any transformational change to move forward the forces driving change must be recognized and bolstered while the forces resisting change must be diminished, resolved or

overcome.

4.4 Stakeholder Analysis

A critical part of understanding an enterprise, a system, a problem or opportunity is understanding those individuals or groups of people who derive some value from, provide some value to or have some other interest in the system. The second activity of the ARIES framework is performing the stakeholder analysis. [12, p. 41]

4.4.1 Methodology

A stakeholder saliency model recognizes that there are different categories of stakeholders with their own values, requirements and considerations in the architecture of the enterprise as a system. Other approaches to defining stakeholders could include defining “primary” and “secondary” stakeholders or giving some score relating to their importance. Attributes of stakeholders can be assigned and categorized.

The approach and definitions employed here are derived from Mitchell et al.’s stakeholder saliency model shown below.



Figure 13 Stakeholder Saliency (Mitchell et al.) [14]

4.4.2 Power, Legitimacy and Urgency

The definition of power in the context of an enterprise stakeholder relates to the ability of a stakeholder to impose their will or decision over that of another stakeholder. [14, p. 869]

Power in this way can be considered synonymous with authority although this authority or power could be either formal or informal depending on the circumstances.

Legitimacy in the context of an enterprise stakeholder means that the interests of the stakeholder related to the enterprise are perceived as “desirable, proper or appropriate” [14, p. 869]. This may be more nuanced consideration such as expertise in the area of interest, or a stakeholder that represents a real perceivable need or interest in the system.

Urgency on the other hand is defined as “The degree to which stakeholder claims call for immediate action.” [14, p. 869] The sense of immediate need versus something that is less urgent can be derived from a stakeholders’ perspectives and evaluated according to the other stakeholder attributes. It is possible that a stakeholder has an urgent claim which is

not perceived as being legitimate, which would be considered as a “demanding stakeholder”. Otherwise, a high urgency stakeholder with legitimacy would be either be considered as a dependent or definitive stakeholder.

4.4.3 Saliency

Saliency reflects the notion of priority within this stakeholder identification methodology. Mitchel et al. define saliency as “The degree to which managers give priority to competing stakeholder claims.” [14, p. 869]

Use of the word saliency in place of other more sensitive terms like importance allows for stakeholder prioritization according to the enterprise change being contemplated rather than as a measure of power, authority or legitimacy and urgency which are considered separately.

This allows us to recognize the power of a stakeholder along with the important attributes of legitimacy and urgency within the problem space being addressed.

4.5 Stakeholder Descriptions

For the purpose of this thesis and the system boundary, internal stakeholders are described using both the department level and the smallest relevant organizational unit, while external stakeholders are defined more broadly to reflect that there is an external interest without being inside the enterprise system boundary.

The following stakeholders are then described along the lines of the model of stakeholder identification and saliency.

4.5.1 Lincoln Laboratory Director’s Office

The Director’s Office manages Lincoln Laboratory. Within the Director’s Office there are several additional offices to which the director has given authority. In relation to the programs within the scope of this analysis the Director’s Office has the final say in the portfolio of proposals which are accepted for funding under the line program. The

Director's Office therefore has both power and legitimacy and is a dominant stakeholder with high saliency

4.5.2 Technology Office

The technology office is the process owner for the line funding program and has power, legitimacy and urgency within the enterprise for innovation efforts with the laboratory. The TO is therefore a definitive stakeholder with high salience.

4.5.3 Business Transformation Office

The BTO has responsibility (and legitimacy) within the Director's Office to lead enterprise transformation efforts. There is also urgency to their transformation efforts. However, the TO and Director's Office would have say over how those transformation efforts are implemented. This would put the BTO in the dependent stakeholder category with high salience because it is responsible for guiding transformational efforts, but lower salience relative to the definitive stakeholders.

4.5.4 Information Services Department

Information Services Department (ISD) is responsible for a variety of IT systems, services and networks. The primary way in which the department interfaces with the enterprise as it relates to innovation management is through the Enterprise Applications Team. The characteristics of ISD make them a dependent stakeholder with lower salience.

4.5.5 Enterprise Applications Team

The Enterprise Applications Team is responsible for systems and enterprise data architecture. Primarily responsible for operations, development and business analysis for the laboratory's primary ERP system which is SAP and some non-SAP applications including Oracle database applications. EA Team is a dependent stakeholder.

4.5.6 Enterprise Collaboration and Web Services Team

This team is responsible for maintaining the entry form for the current line proposal submission process. The ECWS team is a dependent stakeholder with medium saliency.

4.5.7 Knowledge Services

Knowledge Services has a legitimate role in making sure that information artifacts are collected, organized and archived. However they often lack power over other organizations and processes to make it happen. Under the stakeholder model they are defined as either dependent or discretionary depending on the degree to which their requirements are seen to be urgent.

4.5.8 Line Leads

Line leads are essentially the ambassadors of the Technology Office for the purposes of the the line program. They are managers of technical groups within the laboratory that are given primary responsibility for the proposal process within their technology area of expertise. With Power, Legitimacy and Urgency the Line Leads are definitive stakeholders with a high saliency.

4.5.9 Research Proposers/Principal Investigators

The research proposals and PIs have a high degree of legitimacy and saliency. And their relationship to the innovation management enterprise is urgent. The proposals and therefore the proposers are at the heart of the process. However the power is somewhat indirect, but as a group they have power, so they will be categorized as definitive stakeholders with high saliency.

4.5.10 Research Staff

Research staff, other than the author of the proposal, are considered separately as stakeholders although they would be peers of the PIs. Most proposals will require some

sort of team of staff to participate at various levels. These stakeholders are important to the research efforts themselves and therefore have legitimacy, however their claims are somewhat less urgent. They should be either categorized as discretionary or dependent stakeholders.

4.5.11 Technical Groups and Divisions

The technical “group” is primary way researchers are organized within technical divisions. These are groups and divisions are aligned with technology areas or capabilities. They exist to work on either sponsored research or early stage R&D as determined through the Line Funding or other early phase R&D programs. They have legitimacy and urgency so they are dependent stakeholders with high saliency.

4.5.12 MIT (Campus)

MIT Lincoln Laboratory is the largest laboratory at MIT and has a completely separate research laboratory located miles away from Cambridge. In addition to the physical separation from the Cambridge “Campus” there is also a degree of separation due to the nature security constraints on the laboratory operations and research. Due to the organizational structure MIT has power, but would not use that power to intervene in the line funding process. Within the stakeholder methodology defined above MIT would be a dormant stakeholder.

4.5.13 United States and Congress

The “line” in line program refers to a line in the US Budget which designates funds for the program. Therefore as a stakeholder the needs of Congress have both power over all other stakeholders and legitimacy. In terms of enterprise architecting especially focused on internal enterprise systems it is difficult to imagine interfacing with Congress. However they or the representatives would be a dominant stakeholder.

4.5.14 Department of Defense (Executive Branch)

The DoD is a definitive stakeholder with power to set the terms of the relationship with the enterprise, urgency in that needs become urgent especially in times of war, and legitimacy in that the needs of the stakeholders the DoD represents have the ultimate legitimacy.

Yearly presentations of line funded research are a required part of the current management process. This interface with the DoD will be seen as a firm requirement for the system.

Other values can be represented through other stakeholders.

4.5.15 External Research Partners

External research partners are possible, but not required. These are most easily defined at discretionary stakeholders.

4.5.16 Defense Industry

The defense industry, in general, is also a discretionary stakeholder. Any technology that results from line funded R&D should by the nature of the laboratory make its way to industry for production.

4.6 Stakeholder Salience Map

Using the above stakeholder descriptions the identified stakeholders can be mapped on the Mitchell stakeholder salience model.

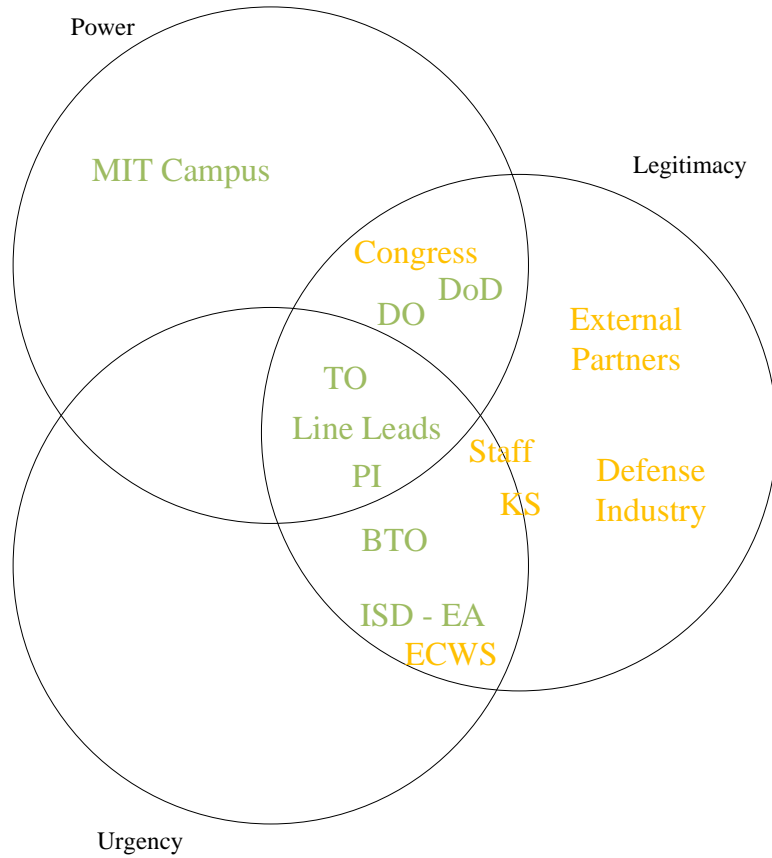


Figure 14 Stakeholder Saliency Mapped

4.7 Stakeholder Value Exchanges

In architecting the enterprise for innovation management, it is important to understand what relevant values are exchanged by the stakeholders. Understanding where important or necessary values are exchanged allows focus on important areas of value exchange or understanding the need to manage relationships between stakeholders. [12, p. 46]

Table 4 Stakeholder Value Exchanges

Value from Innovation Management	Stakeholder	Value contributed to Innovation Management
Overall view of the enterprise R&D interests and emerging capabilities	Director's Office (DO)	Overall portfolio management can override recommendations and rebalance the portfolio.

Value from Innovation Management	Stakeholder	Value contributed to Innovation Management
Overall view of the enterprise R&D interests and emerging capabilities. Metrics for process improvement	Technology Office (TO)	Overall portfolio management and can override recommendations to rebalance portfolio. Process owner.
Successfully improving innovation management means success for the BTO	Business Transformation Office (BTO)	Responsible for improving innovation management process.
Recognition of IT support mission fulfillment Enterprise success means better recognition of value provided and better relationships within the enterprise	Information Services Department (ISD)	Aligns with mission to support and enable R&D using IT
Enterprise success means better recognition of value provided and better relationships within the enterprise	Enterprise Applications Team (ISD – EA)	Provides enterprise business system solutions for enterprise needs.
Enterprise success means better recognition of value provided and better relationships within the enterprise.	Enterprise Collaboration and Web Services Team (ISD - ECWS)	Provides collaboration tools and web solutions for enterprise needs. Current provider and maintainer of web submission form for Line submission
Requires data for knowledge management. Enterprise success means better recognition of value provided.	Knowledge Services	Provides knowledge management services to ensure longer term usability of information.
Innovative proposals fuel the R&D enterprise	Line Leads	Line Leads provide the technical leadership. Mentor researchers on their proposals, encourage teaming and provide sound judgement.

Value from Innovation Management	Stakeholder	Value contributed to Innovation Management
Early funding for new research and technology development. Chance for greater recognition for contributions to R&D efforts.	Principal Investigators and Researchers	Researchers provide the innovative proposals that fuel the enterprise.
Staff (who are not the proposers) may get the chance to contribute to proposed research and gain valuable experience.	Research Staff	Provide valuable supporting contributions to the proposed R&D
Get additional work to supplement sponsored research	Technical Groups and Divisions	Provide staff and expertise to the proposed research activities.
Pipeline of early R&D proposals keep MIT working on cutting edge research and bolster capabilities	MIT (campus)	Provides the infrastructure environment and track record of success that enables continuity of mission.
Gets technology to bolster national security. Also, technology has the potential for creating economic benefits through value creation.	US Congress	Provides funding and oversight
Gets technology to bolster national security.	DoD	Provides funding and oversight
Gets funding for R&D	External Research Partners	Provides capabilities outside of the core enterprise
Gets technology transfer from R&D.	Defense Industry	Provides supporting technology for R&D. Provides outlet for further R&D through commercialization and supported deployment of technology

4.8 Stakeholder Relationships

Lower level process diagrams with swim lanes provide a formalized step-by-step look at how the stakeholders interact for the given business case. This can also be useful to map out the higher level relationships between stakeholders and consider the values that are exchanged.

These can be organizational relationships, some indications of formal role relationships within the scope of the enterprise system or indication of value exchanges that the architecture of the future system may need to consider.

4.9 Summary

Understanding stakeholder values is one of the key activities in architecting the future enterprise. Stakeholder relationships, values and saliency allow the architecting team to focus on the important attributes of the existing architecture and future system.

Strong relationships with important value exchanges can be bolstered. Weak relationships can be examined to find greater value. And, stakeholders that are rarely considered can be evaluated for what additional value they can provide the enterprise system.

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Chapter 5 Existing Enterprise Architecture

This chapter describes the as-is enterprise architecture of MIT Lincoln Laboratory with an emphasis on elements related to innovation. “Capturing the Current Architecture” is the third activity in the ARIES framework. [12, pp. 55-69]

The purpose of this activity is to come to a common understanding about the current state of the enterprise. This builds upon the background work to look at the enterprise strategy holistically and based upon a good understanding of stakeholders and their values.

The ARIES elements of ecosystem, stakeholder, strategy, information, infrastructure, products, services, process, organization, and knowledge are used for analysis and description of the enterprise.

5.1 Ecosystem

MIT Lincoln Laboratory is a Federally Funded Research and Development Center (FFRDC) with a particular focus on technology areas applied to national security: advanced technology, air traffic control, air missile and maritime defense technology, communication systems, cyber security and information systems, engineering, homeland protection, ISR systems and technology, space systems and technology and tactical systems.

The laboratory fills an important need for research and development between government and industry. The research performed and prototypes developed by the laboratory are intended to demonstrate, validate or evaluate technology for national security purposes. However the laboratory does not sell products and services back to government sponsors. Transitioning technology developed at the laboratory to industry is a goal of the laboratory.

5.2 Stakeholders

Director’s Office (DO), Technology Office (TO), Business Transformation Office (BTO), Information Services Department (ISD), Enterprise Applications Team (ISD – EA),

Enterprise Collaboration and Web Services Team (ISD - ECWS), Knowledge Services, Line Leads, Principal Investigators and Researchers, Research Staff, Technical Groups and Divisions, MIT (campus), US Congress, DoD, External Research Partners, Defense Industry

These stakeholders were analyzed in the previous chapter and are reiterated here because they should be considered in the context of the enterprise architecture.

Stakeholders themselves are an element of the enterprise architecture that can be effected through transformational change. Stakeholders can be added, removed from consideration or actions can be taken to change or add value to stakeholder relationships.

5.3 Strategy

MIT Lincoln Laboratory has clearly enumerated strategic directions. The strategic directions which most strongly relate to managing innovation are the directions related to evolving mission areas and programs and strengthening core technology programs.

Increasing MIT campus collaboration and strengthening technology transfers are also important to innovation processes at the laboratory. While finding greater efficiencies relates to system problem statement for the proof of concept study.

- *Continue evolving mission areas and programs*
- *Strengthen core technology programs*
- *Increase MIT campus/Lincoln Laboratory collaboration*
- *Strengthen technology transfer to acquisition, user, and commercial communities*
- *Find greater efficiencies and reduce overhead process*
- *Improve leverage through external relationships*
- *Improve Laboratory diversity and inclusion*
- *Enhance Laboratory facilities*
- *Enhance Laboratory community outreach and education*

Table 5 Lincoln Laboratory Strategic Directions [9]

5.4 Information

MIT Lincoln Laboratory generates and maintains large amounts of information about its R&D efforts and operations much of which is captured in various repositories and IT systems.

In R&D areas research proposals, findings, raw data, white papers, emails, CAD, prototypes, and historical archives are all information artifacts of the work performed.

In operations budget and finance, HR, program and project management and IT operations all generate information which are stored in SAP, Oracle database, Microsoft or other IT systems.

5.5 Process

Processes relating to innovation at the laboratory involve seed funding, a “New Technology Initiatives” or NTI, the Line Program, ACC, sponsored research, release review, technology licensing and transfer.

For the thesis research the focus is on the existing line funding process.

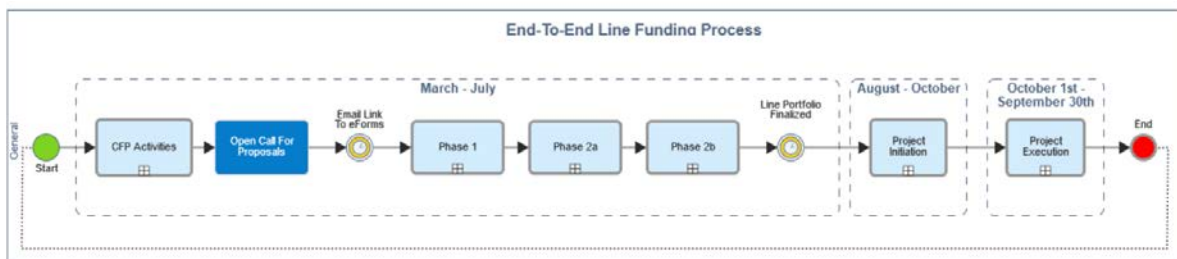


Figure 15 High Level View of Line Funding Selection Process (from BTO presentation slide)

Other processes are impacted by cross cutting concerns of the other elements, but the line funding process at a high level is a straightforward process. What is not reflected at the high level are all the various required communications and hand-offs during the process as well as the variations in processes at the division and group levels for ideation, team

formation and proposal preparation.

More generally laboratory processes often lack the associated time, cost and value metrics that could better enable prioritization of process improvements. Stakeholders are hesitant to change processes without knowing the costs and benefits of process change.

5.6 Organization and Culture

MIT Lincoln Laboratory has a culture that is similar but distinct from the greater MIT community it is a part of. Shared values with the institute as a whole include: integrity, meritocracy, commitment to diversity, creativity, collaboration, and educational opportunity.

With a culture of academic rigor and research, a belief in trying to develop solutions to the world's major challenges, diverse multi-disciplinary teams, with systems of governance that encourage input from all stakeholders. [15]

Lincoln Laboratory creates a distinct culture from MIT in that its focus on national security requires additional secrecy beyond merely the first to publish, first to patent or first to commercialize cultural attitudes of the academic community. This focus on security can lead to an enhanced silo effect that needs to be carefully balanced against the innovative mission of the laboratory.

5.7 Knowledge

The laboratory Knowledge base is in multiple technical areas, systems engineering, and operations.

Much of the knowledge lives in the expertise of the personnel and are transferred over time through experience, mentorship, training and direct knowledge of program work and applications.

5.8 Infrastructure

Robust computing resources, on site, remote and cloud data centers. Protected networks enable internal and external communications at varying degrees of security as required.

5.9 Products

Product outputs include works-like prototypes, technical papers and documentation and patents.

5.10 Services

The laboratory externally provides technology analysis to government sponsors and internally provided services enable research through IT enablement, facilities, contracting services and regulatory compliance.

5.11 Summary of Current Enterprise Architecture

The current enterprise elements have been reviewed individually, but here in table 6 are presented in summary form.

Table 6 Summary of Current Enterprise Architecture

Ecosystem	Exists at a nexus of institute research, government and national security needs	Innovation Nexus
Stakeholders	Connecting technical staff with technical leaders to create value for national security	Go-to provider of innovative technology
Strategy	Advanced technology and system prototypes for national security problems	Advanced technology and prototypes
Information	Multiple heterogeneous repositories of information.	Information Landscape
Process	Simple overall process, with multiple sub processes with manual steps and technical divisions and groups controlling their own sub processes.	Locally Efficient
Organization and Culture	Strong belief in collaboratively solving problems with technology	Innovation Culture
Knowledge	High levels of expertise in multiple areas.	Expert Silos

Infrastructure	Multiple enterprise IT systems facilitate the innovation processes.	Enterprise IT Silos
Products and Services	Works-like prototypes, technical papers and documentation and patents	Prototyping and Expertise

5.12 SWOT - Strengths, Weaknesses, Opportunities, Threats

A technique promoted within the ARIES framework is the strength, weaknesses, opportunities and threats analysis. SWOT analysis is a well-known business technique that can be applied to an evaluation of the enterprise architecture. A SWOT analysis involves identifying the internal strengths and weaknesses and external opportunities and threats that are favorable or unfavorable to achieving the objective. [12, p. 62].

The following sections analyze the elements of the enterprise as it relates to the laboratory's innovation mission.

5.12.1 Strengths

The current strengths of the laboratory have maintained a high reputation for innovation in areas of technology applied to national security. Even beyond the domain of national security many of the technologies developed at the laboratory have made their way into widespread use or have led to other major advances in technology. [16] [17]

The knowledge of advanced science, technology and engineering along with domain expertise in areas of technology related to the national security mission give the laboratory a great strength. As is the ability of the laboratory to gain hands-on knowledge by building and learning from advanced prototypes.

The organization is well aligned with key technology areas of interest to the national security community, yet has been flexible enough to change in response to both evolving and immediate needs.

5.12.2 Weaknesses

The Laboratory's mission is to develop the advanced technology prototypes and develop the skills, knowledge and expertise to advance the development of technology in key areas of national defense. However, the laboratory is not in the business of producing technology products for manufacturing beyond prototypes or for operational deployment.

Given this limitation on the mission of the laboratory, there is a need expressed by stakeholders to identify laboratory developed technology that may be suitable for further development and deployment by industry early in the R&D process so that technology transfers can be facilitated.

A weakness that is difficult to avoid due to national security considerations is the silo'd nature of the organization with respect to important areas of R&D. Another weakness created by security considerations is the difficulty in adopting new IT technology which must meet more stringent security requirements than might be necessary in other industry and commercial sectors. This can lead to delays in adopting commercial off the shelf products and longer lead times in procuring services from outside vendors.

5.12.3 Opportunities

Evolving national security needs from external stakeholders create opportunities in new technology areas. From an initial focus on radar and air defense, the laboratory has evolved its mission and technology areas over time to remain relevant to today's and future national security needs.

There are greater opportunities to work with the great resources that MIT as a whole can bring to bear on the technology being developed at the laboratory and vice versa. One recent example of campus collaboration is the Transiting Exoplanet Survey Satellite (TESS), which helped to bring Lincoln Laboratory technology to meet needs outside of national security, but of great interest to the broader society and scientific community. [18]

There are opportunities to work with industry in order facilitate the strategic goal of

technology transfer of needed technologies so they can be manufactured and supported by industry in support of the US government.

5.12.4 Threats

The term threat in the national security space is usually reserved for other foreign actors. Unlike an analysis focused on “market” threats. A threat analysis in the national security space should include consideration that competitor nations and organizations are constantly evolving their capabilities and intent so that national priorities in the US will need to shift in response.

Competition within the defense industry is also a consideration. Large defense contractors and other defense related laboratories may have some overlapping capabilities and their own strengths. Maintaining the laboratory’s unique strengths and capabilities while growing into new areas will be an ongoing challenge moving forward.

5.13 Business Transformation Workshop Findings

Through a series of workshops run by the Business Transformation Office participants developed a list of perceived weaknesses in the current process and were given a budget of “pain points” to assign.

Figure 16 is a summary of those findings from an innovation management POC briefing slide.

Lack of Collaboration and Idea Sharing	<ul style="list-style-type: none"> - Foster collaboration through early visibility of ideas - Collect & consolidate stakeholder comments/voting - Increase technical feedback & communication
Need for Automation and Tools	<ul style="list-style-type: none"> - Clear, streamlined submission process -modern Ux - Tool with integrated workflow/ track status changes - Easy way to move proposals to different Tech Area
Need to Clarify and Streamline the Process	<ul style="list-style-type: none"> - Simplify quad chart submission process - Common tools, selection criteria, vocabulary - Make technical area of submission absolutely clear
Lack of Knowledge Management and Reporting	<ul style="list-style-type: none"> - Track idea from internal to external funding (track \$\$) - Ability to easily search historic submission info - Enhance reporting & track funding amount changes
Strategic Direction and Process Change	<ul style="list-style-type: none"> - Reduce time spent on entire process - Reduce requirements for continuing efforts - Include DO/TO strategic vision early in process

Figure 16 Line POC Project Summary of Workshop Findings

A key discovery from this approach was that there was a need for greater collaboration and idea sharing early in the process. There was a perceived opportunity for an IT system to facilitate asynchronous communications so that ideas could be posted and followed up on by others later on with easier accountability and visibility in the process.

Another area of opportunity for an IT system was to facilitate automation of workflow and communications during the review and approval process. This was largely a time saving and efficiency consideration; however it was also seen as important that timely communication would help decision makers give more robust feedback to unsuccessful proposals in a way to help avoid discouraging otherwise good proposals that could be refined and considered again for future work.

The need to clarify and streamline the process was considered important because different technology areas used similar, but somewhat different criteria to evaluate and rank proposals. Having a simple inline process with standard evaluation criteria was seen as helping making the process more transparent and uniform across the laboratory.

Another big area of difficulty was the ability to track ideas from conception to funding to contributing to additional R&D programs to eventually to some technology transfer.

The final area of finding was alignment with strategic priorities in that the process itself could be streamlined to achieve the efficiency goal and new R&D proposals themselves could be explicitly aligned with strategic objectives earlier in the process.

5.14 As-Is X Matrix

The X-matrix technique is used to look for areas of strong and weak (or absence of) alignment between the enterprise strategic objectives, performance measures, stakeholder values, and enterprise processes. [12, p. 66]

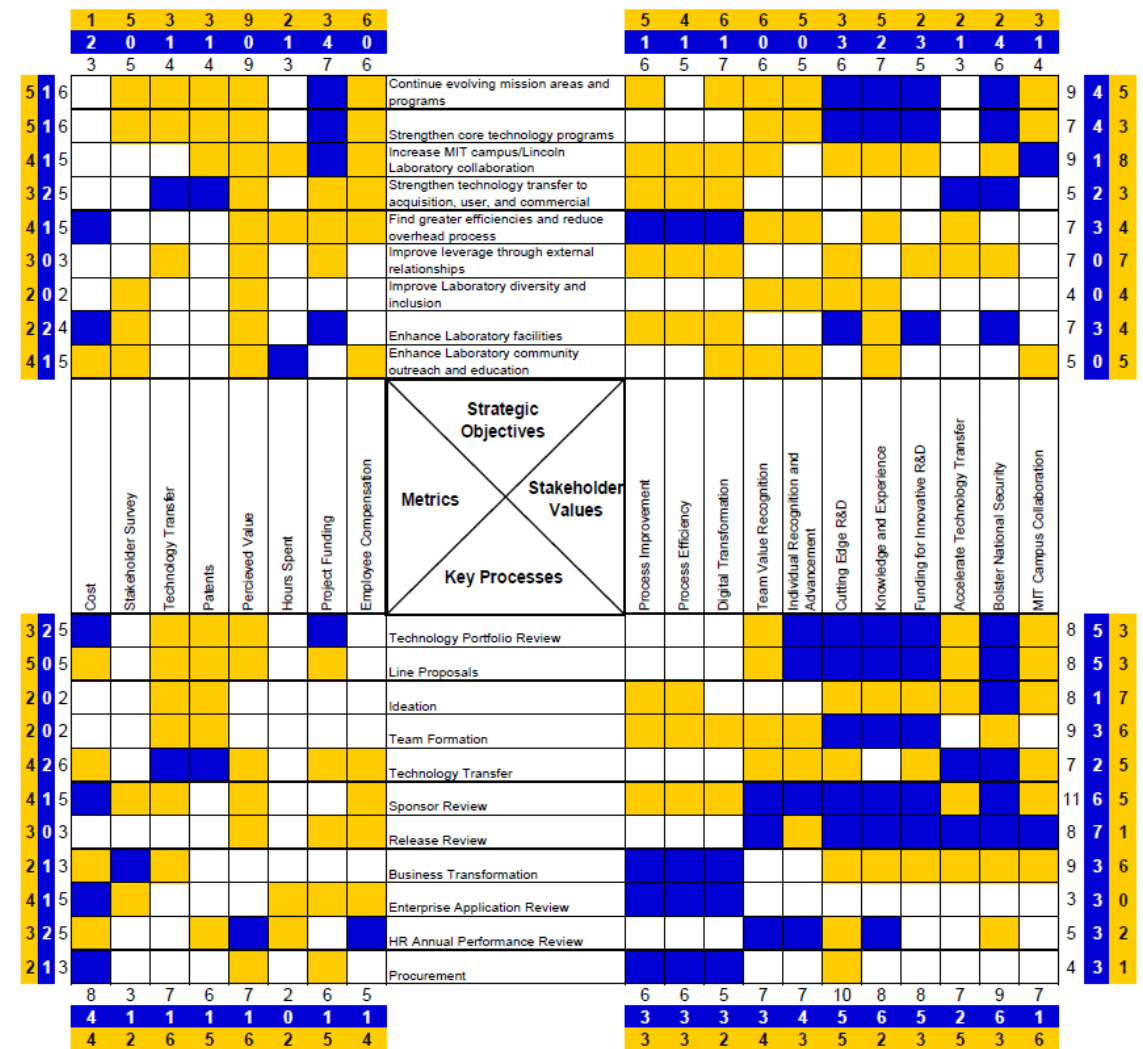


Figure 17 As-is X-Matrix

Strong relationships are shown in a dark shaded box, weak relationships are shown in a

light shaded box and areas missing any relationship are left blank.

The alignment of strategies, processes and metrics relating to innovation are of particular interest to the thesis research. Weak metrics on perceived value creation, value realization and weakly correlated metrics on patent creation are seen as opportunities for a future enterprise architecture to strengthen.

Notable as being absent are metrics on hours spent in multiple process areas. Time spent on processes are an important baseline for realizing process improvement and efficiency gains. Also, understanding time spent is important to relate to metrics of value so time spent on innovation and creating value can be maximized and time spent on tasks that do not add value can be minimized.

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Chapter 6 Holistic Vision of the Future

Previous chapters have discussed the background, history and current state of the enterprise. This chapter looks forward and envisions possible future states and scenarios following the “Creating a Holistic Vision of the Future” activity of the ARIES framework. The first section establishes the time horizon for the vision of the future. The next section describes vignettes that represent the future state of the enterprise from the perspective of key stakeholders. Section 6.3 describes the values pursued and exchanged by stakeholders as metrics for measuring future value and the success of transformational changes. The chapter concludes with a summary vision of the enterprise in a future state.

6.1 Time Horizon

Choosing a time horizon for a transformational change is an important step which will impact what visions of the future are possible and the likelihood for greater uncertainty. Sometimes the architecting team is given a timeframe for change.

In the case of Lincoln Laboratory the director’s office and the business transformation office have stated a 5 year transformation cycle. A 1 to 2 years of that time frame has elapsed; therefore a 2 to 3 year time horizon is reasonably chosen to be the target.

An argument against a shorter time horizon would be that the laboratory would simply not be able to execute a change on that time scale. Within a three year horizon the laboratory can plan for iterative changes to the chosen enterprise elements which can be described in both the future architecture and the implementation.

6.2 Vignettes

Stakeholder vignettes are a useful tool for envisioning the future enterprise. Software development methodologies employ user stories to help begin the process of encapsulating requirements. In a similar way ARIES employs stakeholder vignettes to describe how

stakeholders would see the future enterprise within the defined time horizon.

According to Nightingale and Rhodes, the time horizon, enterprise culture, ecosystem factors and enterprise capabilities should be considered in a way that is consistent with the enterprise mission and purpose. [12, p. 73]

This technique can give us a richer vision of the future beyond just the distillation of system level needs and wants in the requirements gathering process and may allow for more flexibility in the enterprise architecture.

The stakeholder analysis identified three definitive stakeholders in the technology office, the line lead/group leaders and the researcher with a proposal.

Vignette from the Chief Technology Officer perspective in 2023:

New and innovative proposals have been groomed with the help and advice of the line leads and other technical staff. The Technology Office has visibility into the process like we didn't have 3 years ago and we have extra confidence that proposals with good potential are getting the attention, support and encouragement they deserve. I trust the line leads and stakeholders to express sound judgement and record their reasoning with enough detail that most questions I have already have an answer and I can find those answers easily. I have good visibility into the efforts of the groups and the line leads to generate and solicit innovative proposals and when something appears to be working to increase the quality of proposals we have the ability to share those best practices across the laboratory.

Figure 18 CTO Vignette

Vignette from the Line Lead/Group Leaders perspective in 2023:

Our group has just about completed a major project and we have staff supporting two other laboratory projects. There are about twenty different lessons learned that have been discussed by researchers, some of the questions that arose from the research seem like they would be good candidates for additional opportunities. We have had a series of ideation sessions throughout the year both as part of our ongoing research projects and all of it was entered into the system, when doing so we found that others in the lab were already working on some of the ideas. Two staff members are now actively contributing to those other proposal. It seems like chaos, but at any point I can go onto our system and see what people are interested in and

Figure 19 Line Lead/Group Leader Vignette

Vignette of Technical Staff and Principal Investigators perspective in 2023:

I have been at the Laboratory for 3 years and had amazing opportunities to work on some cutting edge research and technology. At every turn I am supported by an amazing team of people that are really committed to the mission of the laboratory. The diverse backgrounds of my colleagues in different technology areas and depths of experiences make for an environment that challenges me like when I was in school, or later as a post-doc, but is really grounded in the kind of culture of real world problem solving. The last year I have been contributing ideas and early feedback to other researchers' proposals which has gained me recognition for my contributions and even some part on a couple different projects. Now that I am familiar with the laboratory culture and processes I am confident to take some of the lessons learned from the projects I have worked on and my technical background to make my own proposals for the next round of early R&D funding and my group leadership has encouraged me to submit a proposal.

Figure 20 Technical Staff Vignette

6.3 Evaluating the Future Enterprise

The for-profit enterprise measures value in monetary terms like revenue, profits, margins, or return on investments. Measuring net value creation in the not-for profit enterprise focused on national security creates additional layers of complexity.

Table 7 provides a list of potential metrics for measuring value creation in the future enterprise. These metrics were derived from stakeholder interviews, documentation analysis and team discussions.

Table 7 The Metrics of Innovation

Future Metric	Description
Patents	<ul style="list-style-type: none"> • Patent applications resulting from selected proposals could be directly linked to the originating proposals. • The potential for patents could be identified early in the proposal process so that it becomes a deliverable.
Publications	<ul style="list-style-type: none"> • Publications in the form of white papers, journal articles, or presentations disseminate knowledge gained from proposed R&D. • Measured by data capture through the release review process • Potential to start internally rating the perceived value of external publications. • Publications can affect external reputation which can be measured through surveys or measuring the number of external references back to the work.
Delivered Capabilities	<ul style="list-style-type: none"> • Capability delivered to government stakeholders. • Hard to measure value unless immediately applicable in

	<p>the short term.</p> <ul style="list-style-type: none"> • Metrics derived from questionnaires to stakeholders (Subjective and difficult to compare).
Other IP	<ul style="list-style-type: none"> • Internal data and analysis that proves useful for subsequent proposals or sponsored research. • Knowledge generated, captured and then transferred to government or industry in the form of documentation, specifications, schematics, software code or direct knowledge transfer.
Gained Expertise	<ul style="list-style-type: none"> • Researchers and staff gain valuable experience that can be measured through annual performance reviews, resume updates with related experience and are traceable to potential future R&D

6.4 Summary Vision

During stakeholder interviews it has been observed that forward and backward traceability of value creation from idea to technology transfer is a recurring theme.

Process overhead of innovation management is minimized so that the stakeholders can focused on greater value creation in their respective roles.

In the vision of the future enterprise IT systems will facilitate better communications, facilitate the organization of key artifacts of the innovation process into structured data that will allow leadership to learn through data analysis how to improve the innovation processes over time.

Finally, the vision is that the value of innovative research and development can be measured and evaluated throughout the innovation lifecycle.

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Chapter 7 Enterprise Culture

“The existence of the best ruler is barely known to the people.”
From the Dao De Jing, by Lao Zi [19, p. 28]

Previous chapters have touched on and highlighted the importance of enterprise culture for architecting the future enterprise.

James Hackett wrote in his book *The Culture Cycle* that an effective enterprise culture can account for 20-30 percent better performance compared to enterprises with mediocre cultures. [20]

In consideration of this potential for value (or risk) to the enterprise, this chapter reviews literature on enterprise culture, reviews some popular systems that have emerged over the past few decades. Special focus is on systems that have elements of cultural values. This chapter concludes with a review of literature related to innovation and managing creativity and fostering and sustaining a culture of innovation and leading transformational change.

7.1 Enterprise Culture

The Merriam Webster dictionary defines the word “culture” to mean: *“the set of shared attitudes, values, goals, and practices that characterizes an institution or organization”* or *“the integrated pattern of human knowledge, belief, and behavior that depends upon the capacity for learning and transmitting knowledge to succeeding generations”*

One part of the definition sets about a set of observable characteristics and behaviors of the people in an organization. The other part of the definition implies an implicit or explicit ability to pass down those characteristics or behaviors from one generation to the next.

Edgar Schein wrote in his book *Organizational Culture and Leadership* that *“The only thing of real importance that leaders do is to create and manage culture. If you do not manage culture, it manages you, and you may not even be aware of the extent to which this is*

happening." [21]

The culture of an organization emerges over time regardless of intent, but it can be cultivated and influenced deliberately. Some organizations ignore culture at their peril while others foster a positive culture by promulgating shared values and rewarding virtuous behaviors as a means of enabling value creation.

7.2 Elements of Culture

The elements of culture can be defined in different ways. Some definitions focus more formally on the higher level attributes of culture to ensure coverage of the elements, while others are more practical and immediately focus in on which attributes or elements of culture reflect best practices or are common among successful company cultures.

Paul Spiegelman lists the elements of a great company culture as core values, camaraderie, celebrations, community, communication and caring. [22]

In his 2013 Harvard Business Review article, John Coleman lists six elements of enterprise culture: vision, values, practices, people, narrative and place. [23]

In her 2015 article, Mandi Walls, listed: open communication, incentive and responsibility alignment, respect and trust as the characteristics of culture in an organization that successfully adopts DevOps.

A thorough review of literature on cultural change invariably leads back to the insights of Margaret Mead who wrote about the change of culture in disparate societies and that *“Cultural evolution depends, ultimately, on small crucial innovations that occur at points of divergence in history. Although each attained grade of development contains within it the possibility of a series of further grades, the potential advances toward the next grade actually are taken by groups of particular individuals... are at some point set in motion by the innovation or borrowing of some particular group.”* [24, pp. 32-33]

7.3 Lean Six Sigma

There are many books and articles that chronical the rise and evolution of Lean, Six Sigma philosophy, techniques and methodologies. The first book to popularize the idea of Lean manufacturing was *The Machine that Changed the World* by Womack, Jones and Woos. This book described the results of a study of how Toyota rose to become one of the largest and most successful car manufacturers in the world. [25]

While Lean and Six Sigma found their beginnings in manufacturing, there are lessons that can and have been applied to other types of organizations and to their culture.

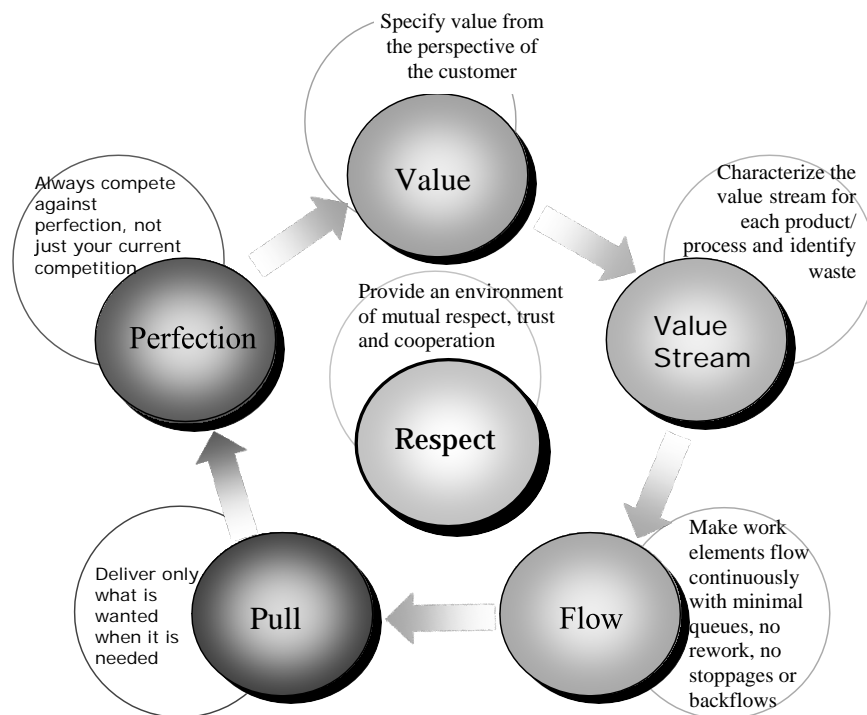


Figure 21 Lean Development Principles [1, p. 38]

The above figure represents the pillars of the Lean development principles. While some of those, like value stream, flow and pull, allude very much to the manufacturing line organizational efficiency perspective. Other pillars such as perfection and value are linked with quality yet have elements that are cultural because they involve shared values that

individuals should pursue across the organization. At the center of lean are clear cultural values of mutual respect, trusts and cooperation.

7.4 Agile

Agile reflects a similar duality of purpose as a system for operating software development teams and a system of cultural values.

The elements of culture highlighted within the Agile Manifesto highlight the importance of focusing on customers, teams, person to person interactions. Agile practices value maintaining a work tempo and pace that is sustainable via interactions based on mutual respect

12 Principles behind the Agile Manifesto

- *Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.*
- *Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.*
- *Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.*
- *Business people and developers must work together daily throughout the project.*
- *Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.*
- *The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.*
- *Working software is the primary measure of progress.*
- *Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.*
- *Continuous attention to technical excellence and good design enhances agility.*
- *Simplicity--the art of maximizing the amount of work not done--is essential.*
- *The best architectures, requirements, and designs emerge from self-organizing*

teams.

- At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.

Figure 22 Principles behind the Agile Manifesto [19]

The cultural theme of mutual respect, trust and cooperation and collaboration are common elements of Lean and Agile.

The principles of lean and agile have been refined and expanded over time. In 2011 “Scaled Agile” emerged as a framework for adopting agile and lean methods, techniques and culture in the enterprise.

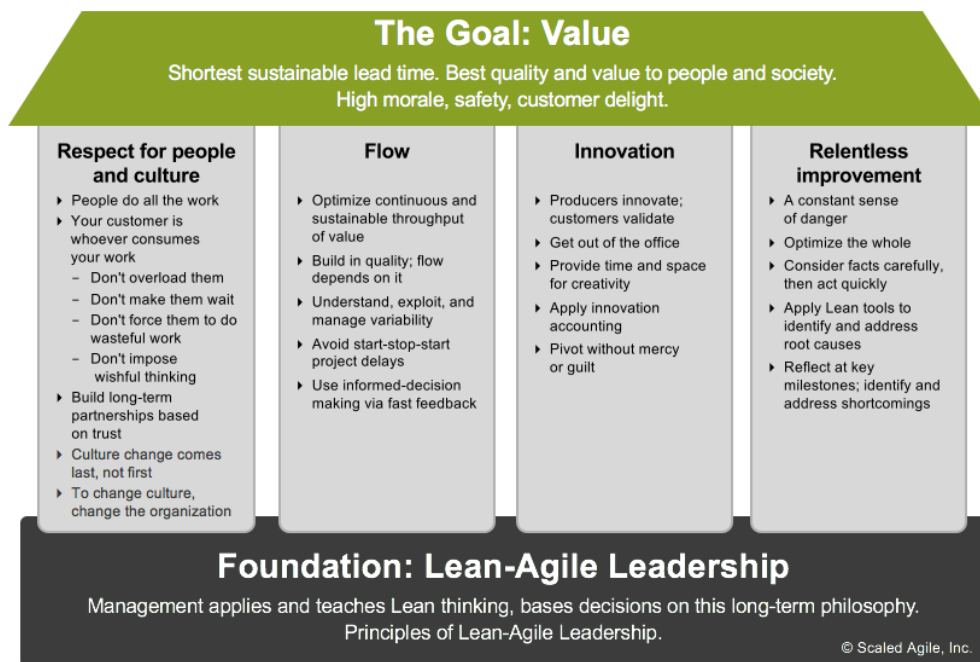


Figure 23 The SAFe House of Lean from Scaled Agile [26]

7.5 DevOps

DevOps is assembly of a number of best practices into an evolving framework that mostly applies to iterative software development in relation to IT operations. The focus is on

breaking down traditional barriers between dev and ops, so that what might have been more formalized processes can be replaced with better responsibility alignment and a more respectful and trusting culture working more quickly towards common goals. [27]

For instance, in a DevOps environment software developers would be expected to be available to troubleshoot operational issues where in a different environment operations may have been solely responsible for workarounds and development would have been engaged only with bug reports or formal change requests.

DevOps could be seen as an extension of an Agile like approach from software development to operations and quality assurance.

7.6 Protecting Innovation and Creativity

Ed Catmull, founder of Pixar and pioneering innovator in the field of computer animation and 3d rendering wrote in his book *Creativity Inc.* that his thesis was “there are many blocks to creativity, but there are active steps we can take to protect the creative process” [28, p. 4]

“Don’t confuse the process with the goal. Working on our processes to make them better easier and more efficient is an indispensable activity and is something we should continuously work on – but it is not the goal.” [28, p. 358]

While computer animation is largely outside the realm of national security, the insights relating to innovation and creativity gained from a perspective of a founder of a technically innovative and successfully disruptive enterprise are relevant.

Another insight that Ed Catmull provides is to “*protect the future not the past*”. [28]

7.7 Cultural and Transformational Change

Culture has characteristics that imply both fragility and durability. Culture can be influenced to a large degree by individual acts and examples of behavior. However, Baumeister, Bratslavsky, Finkenauer and Vohs (2001) show that there is strong evidence in the psychology literature that negative acts are far more memorable and longer lasting than positive ones. [29]

Given that many of the perceived elements of culture are based on the way people view and relate to one another. Whetten and Cameron (2011) argue that “*Managers must consciously choose to pay attention to the positive, uplifting, and flourishing side*” and that “*otherwise negative tendencies overwhelm the positive*”.

The author has experienced in a young organization a culture of common purpose, mutual respect and understanding rapidly take shape over a period of months only to have layoffs born of fiscal necessity completely undermine the those common values in a matter of days.

Changing a culture intentionally and deliberately to positively focus on longer term mission is hard and requires reinforcement, vigilance and awareness of how negative events can shape enterprise culture.

“Leading change and managing stability, establishing vision and accomplishing objectives, breaking the rules and monitoring conformance, although paradoxical, all are required to be successful.” [30, p. 538] -Whetton and Cameron (2011)

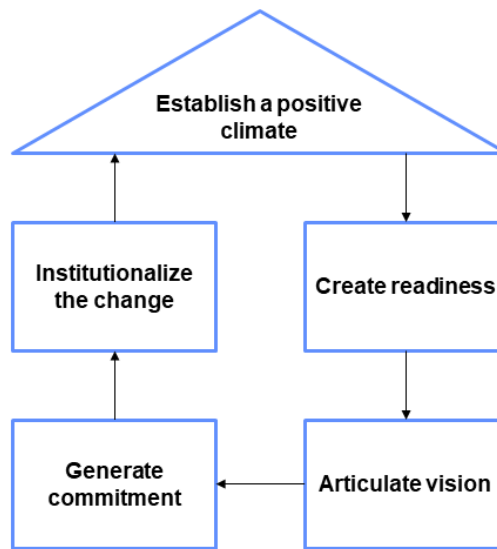


Figure 24 Cameron and Ulrich 5 steps for leading positive change [30, p. 544]

Ulrich and Cameron (1986) describe 5 steps necessary for leading positive change. The first and most crucial step being to establish a climate of positivity. Otherwise, the negative events will outweigh the positive and distract from the change.

Whetton and Cameron (2011) go further and describe establishing a culture of compassion, forgiveness and gratitude within the organization. [30, p. 545]

Kotter (2007) describes 8 stage process necessary for successfully creating major change in an organization. And that making leadership aware of this process and these steps can increase the likelihood of success. Otherwise major transformations have a high risk of failure. [31]

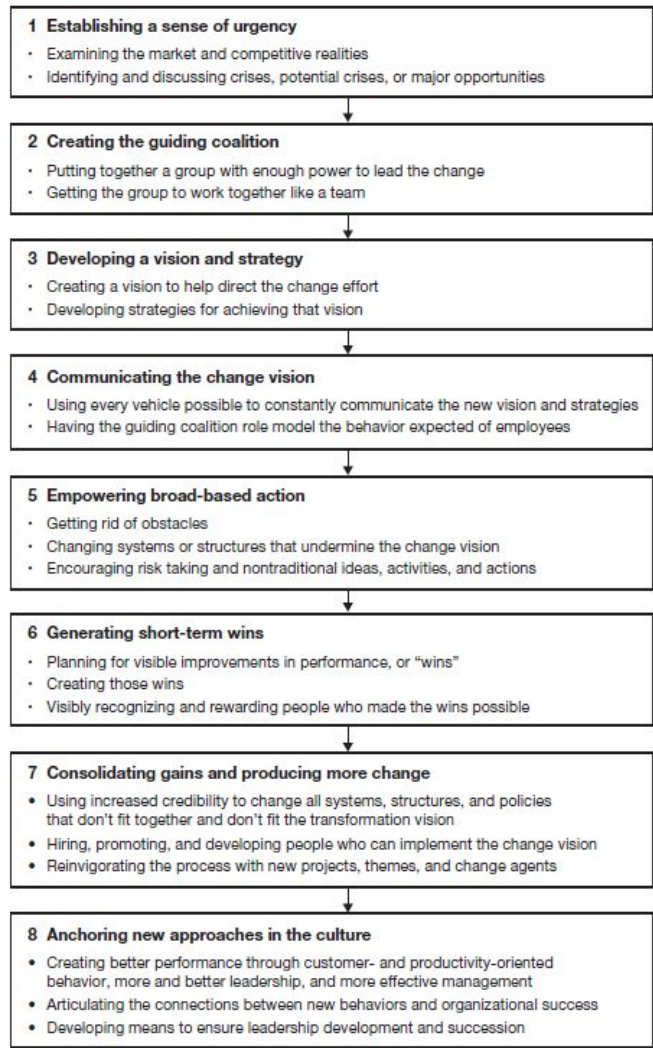


Figure 25 Kotter's eight stage process of creating major change [32]

Kotter also identifies common pitfalls of transformational efforts. These factors include complacency, failure to build a coalition of support, failing to communicate a vision, not overcoming obstacles and both failing to celebrate short term wins and declaring overall victory too soon. The final failure is a failure to cement the change in the culture of the organization.

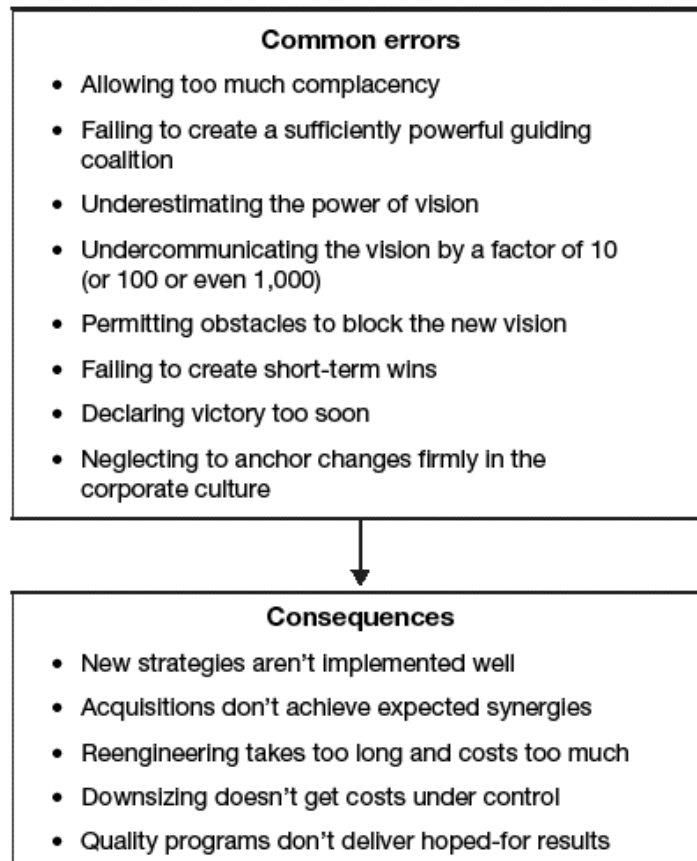


Figure 26 Kotter's Eight errors common to organizational transformation efforts [32]

7.8 Summary

Implementation of a transformational change to the enterprise architecture is as much art as it is science. Even more so when the enterprise value we are trying to manage, grow and foster is innovation itself.

The simplest change in a complex organization can be daunting and the pitfalls are many. Fortunately there are models and patterns of change that can help frame the opportunity and inform the execution of a plan for transformation.

As these views of culture are explored it is important to consider how the change may affect the enterprise culture and how the resulting cultural attributes may influence an innovation culture.

Given that negative events are more memorable than positive ones, a positive enterprise culture is often the most delicate to instill and requires leaders to reinforce over time.

Without continuous reinforcement an enterprise culture can succumb to negative influences. With reinforcement an enterprise culture may allow an innovation culture to endure beyond the founders, beyond the current generation of leaders and managers and be the foundation of future value creation at the enterprise.

It is the power of enterprise culture to build an enterprise which has the traits necessary to endure and to continue to create value moving forward.

When architecting a future enterprise for Lincoln Laboratory explicitly changing the culture or protecting the innovation culture when making other changes to the elements of the enterprise must be key considerations.

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Chapter 8 Future Enterprise Architecture

Chapter 6 discussed the holistic vision of the future. In this chapter that vision is related to elements of the enterprise, which will need to change in order to enable that vision and realize stakeholder values. Ideas generated by stakeholders and concepts generated from stakeholder interviews is described. Changes are described in terms of their view elements. Due to the nature of the scope of this thesis study a future architecture will not be chosen without the further engagement of stakeholders, but a process that could be undertaken to evaluate and choose a future architecture is described. Also, a way for evaluating alternatives is described. And finally, a high level implementation strategy is put forward which could be applicable to some of the changes described.

8.1 Developing the Architecture

Once you understand the enterprise as it is today, understand the stakeholders and landscape, then you can begin the process of creating alternative enterprise architectures. This starts with ideation.

There are many techniques for ideation that range from extremely chaotic and ad-hoc to the more structured. Each variation of technique has its pluses and minuses. And finding those truly transformational ideas is not a certainty regardless of the techniques employed.

Step 1	Generate ideas
Step 2	Learn from experience
Step 3	Ask for suggestions
Step 4	Think of extreme enterprises

Table 8 A four-step approach for ideation [12, p. 84]

8.1.1 Ideation and Concepts

The ideation for concept architectures has taken place in a combination of conversations that took place with stakeholder interviews, primarily the line leads and POC project team and the author.

The following table describes ideas derived from stakeholders and through team meetings categorized by the enterprise element that is affected.

Table 9 Ideas and Concepts

Idea or Concept	View Element(s)
Proposers of new research need more visibility into current and past proposals across technology areas and outside their groups.	Process, Infrastructure
Provide a common IT platform to facilitate team formation for new proposed research projects.	Infrastructure, Process, Organization and Culture
Increase sharing of best innovation practices across groups.	Organization and Culture, Process, Infrastructure
Use off the shelf commercially available software to enable existing innovation processes	Infrastructure, Process, Organization and Culture
Move to a more responsive DevOps model for enterprise software development	Infrastructure, Process, Organization and Culture, Knowledge
Create a more uniform process for line proposals, new technology initiatives and seed funding to enable greater process efficiencies	Infrastructure, Process, Organization and Culture, Stakeholders
Change enterprise culture as it relates to enterprise IT to minimize adoption of expensive and harder to maintain custom solutions	Organization and Culture, Process, Stakeholders
Provide more opportunities for ideation for new technical proposals	Organization and Culture, Process, Stakeholders
Provide tools for better tracking ideas and proposals to downstream value creation	Infrastructure, Process
Measure transformational efforts against strategic value creation more than cost and efficiency savings	Strategy, Information, Infrastructure,

Idea or Concept	View Element(s)
	Process,
Utilize software products as-is and use process change and manual workarounds to fill in the gaps.	Process, Organization
Use enterprise portfolio management and budgeting tools for holistic view innovation management	Process, Infrastructure, Information
Enhance an Innovation Management software system to provide additional needed portfolio functionality inline	Infrastructure
Experiment with changes in different technology areas	Process, Infrastructure, Organization, Information

8.1.2 Architecting at the Extremes

The process of describing extreme alternatives, especially ones that can be related to examples of other organizations, may put into perspective the different values affected by changes to the enterprise elements. [12, p. 86]

This section puts forward several extreme examples of future enterprise architectures to highlight how changes to IT infrastructure, processes and culture may be already be reflected in other organizations. These descriptions of alternatives are not meant to be taken as recommendations. Rather these alternatives take a plausible scenario to a somewhat logical extreme and suggest some real world examples to learn from.

Face to Face Collaboration

In this description of an extreme enterprise all value is placed on human to human interaction to the extreme exclusion of other forms of communication. Most forms of electronic communication during ideation, team formation and proposal preparation are excluded.

While being extreme, promoting face to face interactions has benefits over other forms of

communications and is highlighted in methodologies like Agile or Scrum which has been adopted to some degree or another by a wide variety of companies. [33]

Whetton and Cameron write: *“The problems with electronic communication are that (1) people are bombarded with an overabundance of information, often poorly presented, so they are less willing to consume all the messages aimed at them; (2) no one puts all these rapid-fire messages in context, so much of the information lacks significance or meaning; (3) effective interpretation and use of the information still depends on the relationship the recipient has with the sender.*

People can convey more meaning with face to face communications, conflicts can be resolved more quickly, ideas can be shared more efficiently between two individuals and teams can be formed when people can be brought together in the same physical location to communicate.

While face to face interactions are of benefit to team formation and execution, it is less clear what affect this would have on the quality of ideation.

Without the ability to formulate and share ideas in written form and communicate ideas more broadly through electronic asynchronous communication there appears to be a higher degree of likelihood that early compromises during the team formation process may “water down” innovation and without a broader dissemination of ideas enabled by asynchronous electronic communications experts from a variety of disciplines across the enterprise are less likely to be engaged.

All Data All the Time

Another extreme architecture for the enterprise would be to discourage, via reliance and dependence on technology, any offline face to face communication. Every communication, collaboration, interaction would be mediated and recorded by some electronic format and related to innovation products in some structured data.

Emails, chat messages, video interactions, document preparation would all be recorded. Participants would have their contributions recorded so there would be no question of the value of their contribution as managers could review the record at any point in the future.

This could be regarded as the Uber “god view” model of doing business. [34] A highly centralized and detailed digital view that enables a large diverse and loosely affiliated work force to provide services while a centralized IT infrastructure maintains tight control over key aspects of the organization.

However, the free flow of communication would be severely muted in such a scenario. A review of business and academic literature doesn’t suggest this would be a successful model for an innovation enterprise that broadly engages its employee resources in this way.

Grass Roots Innovation

This would be an extreme alternative architecture with bottom up democratic approach to innovation which would add much more community input to the existing processes. Something resembling Google’s 20% time for researchers to determine how they spend on average of one day a week working on some innovative R&D. [35]

Compared to the current proposal and ideation processes this architecture would require the addition of many more opportunities for facilitated ideation and team formation either in online form or through structured town meeting style workshops to put some structure around the otherwise independent research activities.

A series of formalized meetings would require more lead time than the current time-line and greater emphasis on process and communications to make sure that meetings had agendas, moderators or facilitators to conduct the workshops and were well promoted internally to get buy-in and participation.

This type of approach has some potential for recognizing that early ideation and early research adds value to the pre-funding stage of the process.

Directed Innovation

In this extreme version of an enterprise architecture, teams are carefully selected by management and assigned compelling problems of national security that are identified by senior leadership in-line with strategic directions.

This corresponds to a top down directed approach that keeps the focus on strategic objectives. An industry analog or example might be Apple Inc. with its focus on key technology areas and key projects. [35]

In this example, innovation is not only limited to the defined problem space by technology area, but to particular issues of current national security interest. This would largely follow the model of sponsored R&D programs, except with the requirements being defined internally by technical leaders.

While ideation would be an important early step performed by the teams to come up with the concepts this limited approach with chosen teams would allow a more directed approach towards innovation.

Additional organization and IT would be needed for management to review personnel and model team dynamics for the team selection process putting a greater emphasis on human resource management.

Self-organizing, except inside the selected teams, would be discouraged by management to focus teams on the problem space rather than team dynamics. Innovation leaders would be chosen more directly based on previously demonstrated or perceived skills and expertise rather than emerge through the quality of their innovative proposals.

While this would be a change to the culture of innovation which surrounds the laboratory's early phase R&D programs, arguably there would still be room for innovation within a tighter definition of the problem space. However there would be the potential to miss out on some of the more creative R&D approaches that have the potential to be of even greater value that can arise through welcoming a broader array of proposals.

Although this concept goes against the grain of seeking innovative proposals for R&D from as broad a community as possible there are strengths in this approach which should be considered.

Taking the Enterprise view it could be said that MIT Lincoln Laboratory already works in this way, with the majority of R&D funding coming from sponsored research with more defined problem spaces. Modeling other innovative early phase R&D programs at the laboratory on this successful model of earlier requirements definition could have value.

8.1.3 Selecting Concepts

A round of selection can be done via a scoring process or simpler process of elimination. At this point it is also possible to take some key attributes from eliminated concept architectures and recombine them into merged concept architectures.

8.1.4 Creating Alternative Architectures

This section takes the ideas gathered from stakeholder and team meetings and shows how a change to an element of enterprise architecture relates back to the as-is view of that element.

	As-is	To-be
Strategy	Find greater efficiencies and reduce overhead process	Find greater efficiencies to increase value and reduce overhead.

The purpose of this conceptual change of emphasis in the strategy to increasing productivity rather than simply reducing overhead is to recognize that value creation is important and to avoid falling into the trap of chasing efficiency gains without consideration of process improvement.

	As-is	To-be
Strategy	Find greater efficiencies and reduce overhead process	Find greater efficiencies to meet or exceed industry best practices.

The purpose of this change of emphasis in the strategy to meeting or exceeding the efficiency of industry best practices rather than simply reducing overhead or increasing efficiency is to focus on overall efficiency and use best practices as a guide for when the enterprise has reached its efficiency goals. This change recognizes that efficiency gains are not always going to be possible in every process and false efficiency gains can also be a pitfall.

	As-is	To-be
Infrastructure	Multiple heterogeneous repositories of information relating to innovation	One innovation management system to track ideas, proposals, authorship, evaluations with portfolio management and forward and backward traceability to ERP systems.

This innovation management system is the change contemplated by the Innovation Management Proof of Concept project. The costs and benefits of this approach are discussed in the conclusions and recommendations chapter.

	As-is	To-be
Infrastructure	Multiple heterogeneous repositories of information	System of Systems approach with focus on integration between best

	relating to innovation	available enterprise software systems
--	------------------------	---------------------------------------

In this flexible enterprise architecture software is chosen based on strength of alignment to requirements rather than for complete coverage of requirements. This could lead to systems with overlapping functionality. And this will require more integration between systems. Procurements processes and acquisition cycles may also need to be changed to reflect the need to acquire and integrate multiple systems at same time rather than stand-alone.

In the context of innovation management this might mean a system that meets key requirements of the innovation management process, while other systems such as portfolio and resource management are integrated.

	As-is	To-be
Infrastructure	Multiple heterogeneous repositories of information relating to innovation	System of Systems approach with focus on integration between best available enterprise software systems and a DevOps approach to fill key requirements not met by off the shelf software.

This envisioned change to the infrastructure is to take a DevOps approach for systems that support key innovation processes. This approach offers the flexibility of future options for process change, information collection and data analytics that haven't been envisioned. However, the platforms, teams and processes that can facilitate this iterative model of development must be put into place at an acceptable cost.

	As-is	To-be
Process	Simple overall process, with multiple sub processes with manual steps and technical	Same overall process. Manual sub-processes that don't add value facilitated by an IT system. Learning

	divisions and groups controlling their own sub processes.	processes to share best practices among divisions and groups.
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The overall innovation processes are working, however sub processes may be inefficient with too much manual overhead and could be facilitated with IT depending on whether the cost to benefit ratio is favorable. There are opportunities to share best practices and lessons learned between divisions, groups and technology areas.

	As-is	To-be
Information	Multiple heterogeneous repositories of information.	More information is captured during the processes in relational databases to allow for greater reporting and data analysis.

More information about the processes themselves will create the potential for iterative process improvements. Growing a database of ideas and relationships along with evaluations will give the potential to generate greater value in the future.

8.2 Process for Evaluating and Selecting Alternative Architectures

Given the constraints of operating in a real world enterprise which isn't synchronous with a thesis deadline this section describes a process for evaluating the alternative architectures without coming to a final recommended architecture which would require additional engagement with stakeholders and laboratory leaders.

8.3 Implementation

no plan survives contact with the enemy

– *Helmuth von Moltke the Elder* (english translation) [36, p. 45]

Understanding the need for flexibility in strategy doesn't alleviate the need for a strategic plan for how to implement the vision. To take the further advice of Moltke "Strategy is a system of expedients" [36, p. 47]

According to Nightingale and Rhodes, the high level implementation plan should therefore "specify the necessary and sufficient detail for moving forward to the implementation phase". [12, p. 111]

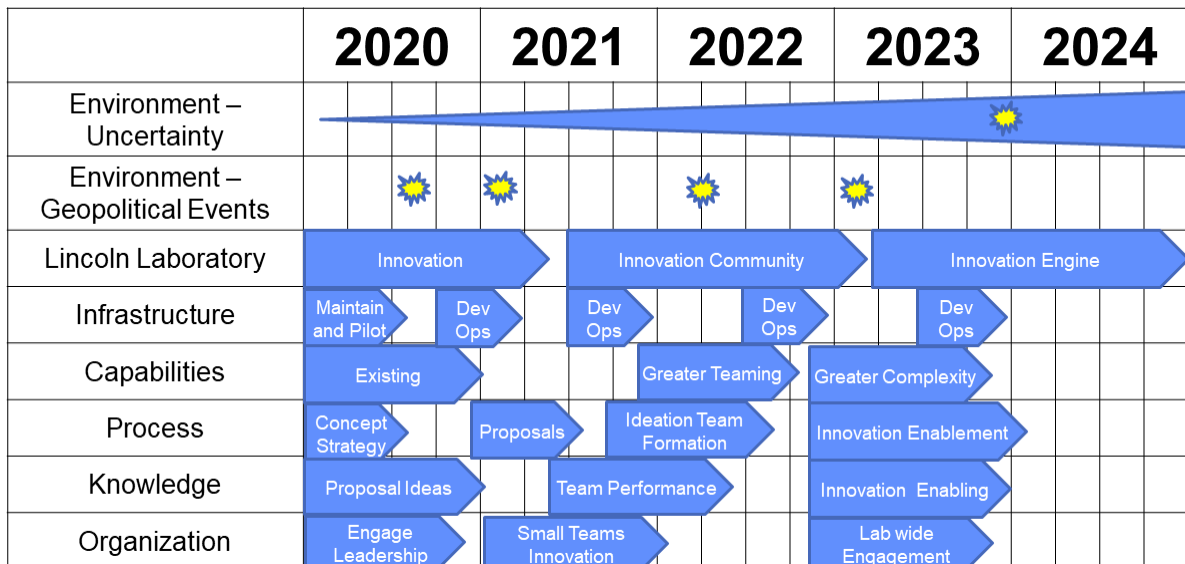


Figure 27 Implementation

The high level implementation strategy or road map in the above figure begins to convey the implementation strategy. A few things that should stand out are the desirability of an iterative approach to any enterprise IT changes using more of a DevOps model. This serves two purposes, one it makes up for some ambiguity in the specification of how the system should work and the other is that it will allow for greater experimentation to find out what functional IT and process changes are most effective at supporting the innovation processes.

8.4 Success Indicators

Changed elements of the enterprise should be aligned with key success indicators or metrics. Ideally these metrics can be quantifiable or easily measured. Less ideally these can at least be measured through stakeholder feedback or surveys in a qualitative yet comparable way. Therefore metrics should be aligned with the increased value stakeholders are seeking, enterprise strategy and values. These success indicators may also be used as evaluation criteria for evaluating of alternative architectures.

Table 10 Success metrics for the new architecture

Element	Goal	Metrics
IT Infrastructure	Increased visibility of colleagues proposals in system leads to higher quality of proposals	<ul style="list-style-type: none"> Higher quality as measured by survey of stakeholders at the portfolio level (ie TO and DO)
	Increased visibility of other proposals in system leads to greater collaboration	<ul style="list-style-type: none"> Greater collaboration as measured by number of co-authors Greater collaboration as measured by system of systems approach to problems – analysis of proposals
	Ease of inline communication documented within system	<ul style="list-style-type: none"> Survey of Line Leads and Proposers Interactions recorded in database
Process	Portfolio view is easier to prepare	<ul style="list-style-type: none"> Survey of time spent by staff preparing portfolio view.
	Portfolio is easier to manipulate	<ul style="list-style-type: none"> Survey of administrative staff familiar with change
	Decisions are persisted with data	<ul style="list-style-type: none"> Spot checks of data to see that process change is resulting in more data capture
Knowledge	Archive of past years proposals increases report-ability	<ul style="list-style-type: none"> Year over year reporting enabled without manual collection of data from multiple sources R&D trends emerge and become part of periodic review process.
Product and Services	Increasing relevance of early phase R&D to sponsored research	<ul style="list-style-type: none"> Traceability of sponsored research to early phase R&D
	Increasing traceability of early phase R&D to transition to industry	<ul style="list-style-type: none"> Traceability to and from patents Traceability to and from technology transfers

8.5 Summary

This chapter walked through the process of creating a strategy for developing a future enterprise architecture.

Ideas generated by stakeholders and concepts generated from stakeholder interviews were put into idea form. Extreme enterprise architectures were envisioned and related to real world enterprises for comparison. Enterprise changes were described in terms of their view elements. Due to the nature of the scope of this thesis study a future architecture was chosen without the further engagement of stakeholders. Finally, a high level strategy described a timeline for implementing changes.

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Chapter 9 Conclusion and Recommendations

This chapter explains the conclusions and recommendations of this thesis. It explains how the research questions have been addressed within the limitations of the research. Direct findings are discussed along with recommendations for the enterprise, recommendations more broadly applicable and future research that might be of broader interest and utility.

9.1 Research Questions Addressed

In addressing the questions put forward in this thesis the author took part in a proof of concept effort to put in place an innovation management enterprise IT system. The observations of this effort provide the basis for the following conclusions. The first question of the thesis was:

Within the context of a research and development organization and focusing on innovation management, does applying an enterprise architecting framework and generating holistic alternative architectures add perceivable value?

The holistic approach to enterprise architecting added value to the transformational effort focused on innovation management in three definite ways.

The first is in potential cost avoidance. Requirements gathered and generated by the Innovation Management project resulted in the identification of the potential need for a portfolio view of innovation proposals. This could have resulted in an investment in customized software that would meet the needs of stakeholders of the process at the focus of the project.

Looking across silos and back up towards strategic alignment with the enterprise architecture at least two other potential alternatives were generated that could be a better holistic solution for more stakeholders

The second way value was added was by identifying the need for a holistic approach for evaluating value creation across the enterprise. By looking back towards strategic values of the laboratory the team was able to create a simple scoring matrix that could be used to predict and evaluate value creation against those strategic values rather than merely in dollar terms.

Does a focus on adopting new IT systems make definitive stakeholders within the organization more receptive to transformational enterprise change?

The author observed during stakeholder meetings that the potential for an IT system to improve process efficiency created an opportunity and framework for discussion of the related processes. Stakeholders could envision real value in utilizing enterprise IT solutions to make the innovation management processes simpler and to gather more data that could be of value moving forward.

However, the potential costs of custom IT solutions and unknown risks of time and resources associated with developing new software based on limited specifications became an impediment to further concept development.

A review of the literature and observations of the current efforts supports the conclusion that a holistic enterprise architecting approach has a greater potential to realize gains in value creation and efficiency than an enterprise IT infrastructure solution alone.

What part does the culture of MIT Lincoln Laboratory play in planning and executing change?

The mission and culture of MIT Lincoln Laboratory is focused on technology in support of national security. The engineers' focus makes a technology solution to enterprise change both an appealing lure and potential pitfall.

More than just facilitating or inhibiting change, culture itself has great potential to create

value in the laboratory. Maintaining cultural values that work and reducing negative influences that might occur over time are key elements of creating and maintaining the ability of the laboratory to continue to create value for national security.

There are already many strengths to the innovation culture of the laboratory as demonstrated by a history of timely technical innovation in support of national security. A shared mission, a fundamentally common belief in the ability of people to solve problems with new technology, a commitment to technical excellence in recruiting, training and retaining the most talented research staff should be protected in any transformational change.

9.2 Limitations

Time limitations and resource conflicts limited the scope of the thesis research. Perhaps most importantly schedules of some of the definitive and dependent stakeholders made it difficult to iterate through potential areas of further research and study.

Lack of access to additional cost and accounting data prevented more detailed differential analysis from a managerial accounting perspective. Limited sharing of cost and resource information did lead to key insights, so it is possible that greater access to that data could have led to additional findings.

Overall, there were limitations natural to the approach taken. Gathering information and observations aimed at a holistic understanding of the enterprise primarily through the means of an IT and process design proof of concept project for an Innovation Management system means a necessarily skewed perspective.

However, given that this active project coincided with the author's research timeline the benefits of actively participating in a project team, with time and resources and with management support for the additional thesis research far outweighed a blank slate independent approach.

9.3 Findings and Recommendations

The findings and recommendations will to varying degrees address the metrics of cost, time, and with an emphasis on value creation

These 3 metrics themselves are a finding in the way that they are different than the for-profit enterprise and require more focus on metrics of value creation. Unlike for-profit enterprises, which can combine and transform time and value creation more readily into a cost versus revenue or a profit metric, Lincoln Laboratory's mission and strategic objectives require value creation to be more directly related to mission and strategic objectives rather than distilled down to monetary value or return on investment.

The author observed that the process of distillation of value creation to dollar value is a destructive rather than illuminating process.

For technology in support of national security if something takes more time then the stakes are higher than the for-profit enterprise where "time is money". Time saved in the national security space means technical advantage over existing and potential adversaries. In a world where the United States relies on technical superiority for strategic advantage, using R&D time and money wisely are of critical importance.

While the author asserts that non-monetary metrics are of special emphasis in the not-for-profit national security enterprise, it should be reflected that today's more successful for-profit high-tech enterprises also appear to place more emphasis on the value of mission and strategic objectives over nearer term financial costs and gains.

9.3.1 Alignment with an Enterprise Architecting Approach Provides Value to the Transformational Efforts.

Despite the fact that this thesis research was conducted alongside just one part of a larger effort to transform the Line Funding process, looking holistically at the enterprise and undertaking a process of enterprise architecting in conjunction with the project provided both immediate insights applicable to the project and created the potential for longer term value.

In the requirements gathering and prioritization process itself it is potentially a cost savings insight that a systems of systems approach which looks 2 up and 1 down can facilitate a realignment of key requirements with different sub systems.

Maintaining alignment with the enterprise view elements creates a greater potential for future value and cost savings.

In particular, the focused view of the requirements for one IT system in the enterprise application landscape creates a myopic view that can lead to missed opportunities for utilizing systems that are common to multiple areas of the enterprise.

In the case of innovation management a focus on requirements generation for one system to address a specific need could have resulted in an increased expenditure for custom development which may be unnecessary.

9.3.2 Transparency and Traceability

Observed during the Innovation Management proof of concept project, and in the author's previous experience, the silo is a recurring pattern at the laboratory. The specialized needs of stakeholders in a silo approach dominate the requirements. Localized requirements lead to localized maximums or localized minimums in the trade space.

Generating alternative systems architectures at the enterprise level with more flexibility to change enterprise elements such as cross organizational processes have the potential to realize cost savings, greater efficiencies and more potential to generate value.

In this case the potential to shift a subset of requirements from one project and into another already ongoing project could result in a cost avoidance that might otherwise be incurred with a costly software development effort of a specialized solution.

9.3.3 Managerial Accounting

Much of this thesis has been discovering that monetary metrics cannot be used reliably as a measure of enterprise value in the national security enterprise. However money and time are finite resources and must be managed appropriately to maximize efficiency. Efficient utilization of resources is a strategic value of the organization. Rightly so in that time and money spent in one area cannot be spent in another area.

Decision making stakeholders have an interest in getting better early cost estimates which can help make enterprise architecting decisions. These high level or even rough cost estimates are needed early in the architecting process in such a way that the architecting team or other decision makers can make high level cost avoidance decisions early.

However, just avoiding a large expenditure without a holistic view of the costs and value benefits of alternative solutions is itself can be a pitfall if seemingly costly alternatives are rejected early in favor of alternatives that might have even higher long term costs.

9.3.4 Maximizing Value Creation

Value creation is at the heart of innovation. When the primary motivation is not creating future revenue then it is hard to measure return on investment. Therefore it becomes even harder to answer the question: Is it worth it?

During a meeting to determine evaluation criteria for Innovation Management POC, the team set up proposal evaluations with metrics derived from the line leads evaluation process. These evaluation metrics were one of the things that got the most positive feedback during the two POC demos.

Metric	Score
Benefit to Mission Area	8
Alignment to LL Mission	3
Relevance to Sponsor	5

Figure 28 Screenshot from IM POC System for Benefit to Mission Area Metrics

Applied more broadly, metrics which are related back to laboratory values and mission could be used to quickly evaluate and score proposals and then afterwards to evaluate results to see if the potential value was realized.

Scoring is often qualitative and judgements will vary across the portfolio, so to have some consistency there would have to be averaging of multiple evaluations along with traceability back to the individual scores for accountability.

Technical Merit	Technical Merit	8	
			<input type="text" value="Comment"/>
Originality	Originality	0 <input type="range" value="4.5"/> 5	5
			<input type="text" value="Comment"/>
Soundness	Soundness	0 <input type="range" value="2.5"/> 5	3
			<input type="text" value="Comment"/>
Expected Cost/Effort Rating Rate the expected overall cost on a scale from 1-5 (1 low, 3 medium, 5 high)		1 <input type="range" value="2.5"/> 5	3
			<input type="text" value="Comment"/>
Expected Benefits Rate the expected overall benefit on a scale of 1-5 (1 Low, 3 Medium, 5 High)		1 <input type="range" value="4.5"/> 5	5
			<input type="text" value="Comment"/>

Figure 29 Screenshot from IM POC system for Technical Merit and Value Metrics

Along with consistency in the criteria, some training and documentation on how evaluators should approach the scoring is a necessary part of rolling out a system of metrics.

Ultimately to provide value to stakeholders, the use of value metrics must be subject to a variance analysis to compare predicted value with realized value. This will enable decision makers to recognize individual efforts which are providing the most value and to help better identify potential patterns of value creation.

The author believes a scoring rubric, something like the one which was refined during the

Innovation Management Proof of Concept project, which requires an evaluation of alignment with strategic values, could be of great value in prioritizing projects and resources.

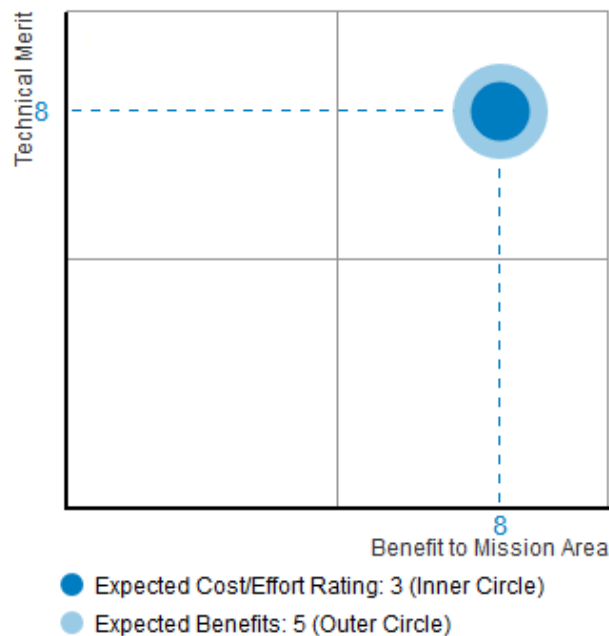


Figure 30 cost/benefit/value bubble chart

Over three POC demonstrations the general feedback to this approach was that this proposal evaluation capability was perceived as having the potential to provide a simple and consistent evaluation framework that could be applied across technology areas providing more comparable detail than existing evaluation rankings without getting into too much specificity that might not be applicable across different technology areas.

9.3.5 Tuning the Innovation Engine

A cross-cutting finding of this research is that the laboratory benefits from ongoing and holistic introspection of all aspects of innovation across the laboratory. With a more holistic system of value metrics in place for measuring value creation aligned with strategic objectives the laboratory could study itself systematically in order to continue to add depth to a broad awareness of the strengths and potential areas of improvement.

Rather than just focusing on process efficiency in time and dollar terms the laboratory can

use additional metrics of value creation to continue to experiment with different methods and adopt practices from across industry and academia.

9.4 Future Work

This section describes future work that could be of value to the enterprise or be of potential broad interest to academia and industry.

9.4.1 Measuring Readiness for Digital Change

One observation that could use further study is that there was a certain amount of change fatigue or skepticism expressed by some stakeholders. Understanding and measuring the readiness for enterprise change, not just IT change, should be an early priority for change proponents.

Other stakeholders expressed a readiness for changing enterprise IT because they could see the potential value being of benefit to their interests. Skepticism can be overcome by demonstrating value to a sufficient number of stakeholders. Alternatively, if the cost of some aspect of the change is not going to be overcome by the potential value then change proponents must adapt.

Methods of measuring stakeholder's readiness for change and testing change strategies based on level of readiness could be an area of future research.

9.4.2 Future Innovation Experiments and MIT Campus

Collaboration

Ideation, team formation, project management and project execution provide much opportunity for further study. In collaboration with MIT campus (which aligns with a strategic direction of the laboratory) there is a great opportunity for MIT to study itself from the management sciences, engineering management and engineering leadership perspectives.

9.4.3 Strategic Value as Currency

Prioritization of resources in the for-profit enterprise is relatively well understood. Leaders and managers can employ the tools of managerial accounting to look at cost, price, demand, and margin. In this way capital investment can be measured for their return on investment in dollars.

However, with a mission focused on technology for national security as a non-profit enterprise value cannot be measured just in dollars.

An area of future research of interest to the author would be to design a future enterprise architecture with an incentive system based on both top down prioritization of strategic direction, managerial discretion and peer to peer judgement of individual stakeholders and contributors.

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Appendix A: COUHES Exemption

Subject: Exempt Evaluation: Determination: E-1783, O'Reilly

Date: Tuesday, November 19, 2019 at 5:51PM

From: COUHES_CONNECT@MIT.EDU

To: Patrick O'Reilly, Donna H Rhodes

The proposed research activities outlined in Exempt ID: E-1783: Architecting the Enterprise for Innovation Management **have been determined to be exempt.**

No further actions in COUHES Connect are required.

As the Principal Investigator or Faculty Sponsor, you must adhere to the policies within the [Investigator Responsibilities for Exempt Research](#) and ensure that all members of the research team comply with these policies.

Your study may proceed as long as all research procedures correspond with responses within the Exempt Evaluation. If the scope or procedures of the research undergo significant alterations, you must submit a new Exempt Evaluation.

Any deviation or violation of the Investigator Responsibilities for Exempt Research or alterations from the study as described in the Exempt Evaluation must be reported to the COUHES office for further review.

E-1783, Architecting the Enterprise for Innovation Management.

Principal Investigator: O'Reilly, Patrick S.

Faculty Sponsor: Rhodes, Donna H

Start Date: NOV-25-2019

End Date: JAN-17-2020

Determination(s): Exempt

Exempt Category 3 - Benign Behavioral Intervention

Research involving benign behavioral interventions where the study activities are limited to adults only and disclosure of the subjects' responses outside the research could not reasonably place the subjects at risk for criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation. Research does not involve deception or participants prospectively agree to the deception. 45 CFR 46.104(d)(3)

Exempt Category 2 - Educational Testing, Surveys, Interviews or Observation

Research involving surveys, interviews, educational tests or observation of public behavior with adults or children and disclosure of the subjects' responses outside the research could not reasonably place the subjects at risk for criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation. Research activities with children must be limited to educational tests or observation of public behavior and cannot include direct intervention by the investigator. 45 CFR 46.104(d)(2)

If you have questions, please contact COUHES directly:

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