

## **Principles of Enterprise Systems**

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### **Abstract:**

*The Massachusetts Institute of Technology (MIT) through its Lean Advancement Initiative (LAI) research team has been conducting research and facilitating enterprise-level transformations in large complex sociotechnical enterprises for over fifteen years. These enterprises have spanned a broad base of industries and governmental organizations including aerospace, automotive, electronics, health care, transportation, construction, defense acquisition and logistics, research labs and many others. What has emerged from both the action research in the field and its application in case studies in graduate courses is the concept of “overarching” enterprise principles and transformation methodologies that are independent of the industry or organization. A framework for transformation that consists of a set of interdependent methodologies, tools and enterprise principles that support holistic enterprise transformation is described and includes the following five elements: 1) Key Principles of Enterprise Thinking, 2) Enterprise Transformation Roadmap, 3) Lean Enterprise Self Assessment Tool (LESAT), 4) Enterprise Strategic Analysis for Transformation (ESAT) and 5) Enterprise Architecting Framework. The application of this framework to the enterprise systems analysis and design of various industry and governmental organizations is discussed.*

### **Key Words**

*engineering systems, enterprise systems, enterprise architecting, enterprise transformation*

## **1. Introduction**

Most organizations are compelled to continuously transform the way they perform in order to achieve their strategic business objectives. The Massachusetts Institute of Technology (MIT) through its Lean Advancement Initiative (LAI) research team has been conducting research in enterprise-level transformations in large complex sociotechnical enterprises since its inception in 1993. The focus of this research has been aimed at determining effective strategies for successful

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enterprise transformation. Additionally, enterprise transformation and architecting is being taught in two graduate level courses: “Integrating the Lean Enterprise” and “Enterprise Architecting”. In these courses, we leverage LAI research and deployment experiences to teach the concepts and the methodologies. Students carry out live enterprise case studies to apply the methodology, as well as demonstrate understanding. In total, over seventy different enterprises have been studied across a broad span of industries and governmental organizations including aerospace, automotive, electronics, health care, transportation, construction, defense acquisition and logistics, research labs and many others. What has emerged from both the transformation research and its application in practice in the field is a set of “overarching” enterprise principles that are implementable through non-domain specific transformation methodologies. A framework for transformation that consists of a set of interdependent methodologies, tools and enterprise principles that support holistic enterprise transformation is described in this paper.

Figure 1 depicts some of the key issues and questions in enterprise transformation along with the methodologies and tools that aid in conceptualizing and executing transformation in an integrated holistic fashion.

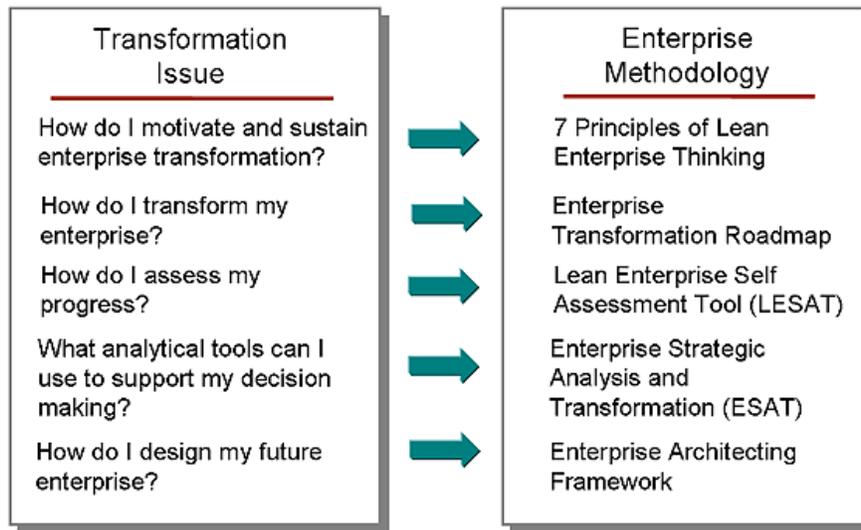


Figure 1. Framework for Enterprise Transformation

## 2. Key Elements of Enterprise Transformation Framework

Two elements in the transformation framework assist in how to think about the key elements that are critical for sustainable transformation: the seven enterprise principles and the enterprise architecting framework.

### 2.A Seven Principles of Enterprise Thinking

The seven principles of lean enterprise thinking provide the guiding philosophy for achieving sustainable enterprise transformation. These principles have been distilled from extant academic research and from field experiences in enterprise transformation. The focus of this section is on the seven principles, as shown in Figure 2.



Figure 2. Seven Principles of Enterprise Thinking

### **Principle 1: Adopt a Holistic Approach to Enterprise Transformation**

Organizations undergoing transformation often struggle to find the balance between demonstrating short term success and achieving long term enterprise level benefits. Research documented in *Lean Enterprise Value* (Murman et al, 2002) describes how taking a reductionist approach to transformation results in “islands of success”. Improvement in enterprise silos without consideration of the “enterprise system” may result in short term improvement but often is not sustainable and may actually sub-optimize the enterprise as a whole. It has further been determined that a holistic approach to consideration and integration of lifecycle processes (e.g., design, development, manufacturing), enabling processes (e.g., finance, Information Technology, and HR) as well as key leadership processes (e.g., strategy, planning, resources). The need for a holistic approach is further highlighted through the multiple instances wherein organizations attempting to replicate the Toyota Production System (TPS) have only found only limited success, as they replicated the practices, but not the context within which the practices became successful. A classic example is the use of Kaizen/ Rapid Improvement events within transformation efforts (Manos, 2007). Transformation has to operate at two levels: the strategic level, where improvement events are coordinated to achieve enterprise level benefits, and the tactical level, in which localized improvements are demonstrated (Kosandal and Ferris, 2004). Gathering the benefits at the tactical level is often referred to as ‘harvesting low-hanging fruit’, and has diminishing returns when not coordinated at a strategic level.

### **Principle 2: Identify Relevant Stakeholders and Determine their Value Propositions**

LAI defines a Lean Enterprise as *An integrated entity that efficiently and effectively creates value for its multiple stakeholders by employing lean principles and practices* (Nightingale, 2009 [8]). This definition is unique in that it articulates the fact that enterprises have multiple stakeholders, who each find particular worth, utility, benefit or reward for their contributions to the enterprise. Transformation requires that the enterprise identify what each of the stakeholders value, specify the value that is currently being delivered both to the enterprise by its stakeholders and by the enterprise to the respective stakeholders, and determine the effectiveness of the enterprise in delivering value (Murman et al, 2002). This is not to say that all stakeholders are created equal (Philips, Freeman and Wicks, 2003), and that the enterprise has to uniformly distribute value to all of them (Gibson, 2000). Stakeholders may include customers, suppliers, partners, employees,

stockholders, and the community in which the enterprise operates. The principle requires that the enterprise account for more than just the customer (as is the case in traditional lean theory) or the dominant stakeholder (as is the case in publicly traded firms, where the dominant stakeholder is the shareholder).

### **Principle 3: Focus on Enterprise Effectiveness before Efficiency**

Efficiency is the easiest aspect to monitor, improve, and control (Katz and Kahn, 1978); however, it is only one part of the overall ability of the enterprise to effectively deliver value to its stakeholders. Transformation efforts targeted at gaining efficiencies have to necessarily be scoped at the process level, and often neglect to determine whether the process itself delivers the requisite value. Georgopoulos and Tannenbaum (1957) define organizational effectiveness as *the extent to which an organization as a social system, given certain resources and means, fulfills its objectives without incapacitating its means and resources and without placing undue strain upon its members*. From an enterprise perspective, this requires an understanding of the enterprise strategic objectives, the resources available to deliver the enterprise value proposition and the enterprise value delivery mechanisms. In effect, the transformation effort has to focus on ‘doing the right thing’ before ‘doing it right’.

### **Principle 4: Address Internal and External Enterprise Interdependencies**

The enterprise transformation effort has to be understood through the three lenses of what is controllable by the enterprise, what the enterprise influences, and what the constraints are on the enterprise. The enterprise boundary that is specified to scope the transformation effort determines which segments of the enterprise value stream fall within the controls, influences, and constraints lenses. For example, an enterprise transformation effort that is focused on improving time to market for new product introduction has to account for the internal interdependencies between the design, manufacturing, and marketing value streams, the external interdependencies between the supply network, the enterprise under transformation, and the distribution network value streams; and the constraints imposed by the changing customer preferences on the enterprise. LAI’s enterprise transformation research has shown that often the greatest opportunities for improvement lie at the boundaries of the enterprise.

### **Principle 5: Ensure Stability and Flow within and across the Enterprise**

Ensuring Stability and Flow are foundational to any enterprise transformation effort. Stability of value delivery enables us to determine the current state of enterprise, and form a baseline for improvement. In other words, stability enables us to determine the watermark of enterprise performance. Flow of value within the enterprise allows us to determine the focal points for improving enterprise value delivery to its key stakeholders. Focusing on flow is critical to streamlining enterprise performance. At the enterprise level, information is often the most significant entity that is flowing, in contrast to material flow. Given that the enterprise boundary plays a significant role in determining the selection of transformation projects, we emphasize the need for seeing end-to-end value delivery both within and across the enterprise.

### **Principle 6: Cultivate Leadership to Support and Drive Enterprise Behaviors**

Leadership at all levels is critical to successful enterprise transformation (Zaccaro and Klimoski, 2001), Senior leadership buy-in and commitment ensures that the transformation efforts are strategically focused and resourced adequately both in terms of finances as well as in terms of

human resources (Conger and Konungo, 1988). Grass-roots level leadership is critical for transformation to become part of the organizational DNA. People within the enterprise have to be empowered to drive transformation within the strategic framework specified by senior leadership. Given that middle management acts as the translator between the senior leadership and the lower levels of the organization, their commitment is key to avoid the ‘flavor of the month’ syndrome (that results in enterprise inertia and significant resistance to enterprise improvement efforts). When all three layers of leadership are aligned, the enterprise speaks with a single transformation voice, and the transformation effort becomes self-sustaining.

**Principle 7: Emphasize Organizational Learning**

Transformation efforts must be both top down and bottom up (Johnson 1992). That is, the organization must be engaged and involved at all levels. The “learning organization” (Senge 2006) is continuously experimenting and gaining knowledge about its processes and the manner in which it creates value. This learning translates into deeper insights that motivate and support transformation execution. The improvement efforts carried out have to necessarily address the contextual challenges of the location at which they are being carried out. The principle focuses on enabling the enterprise to learn from each of the localized improvement efforts and to improve the effectiveness of the improvement efforts that are undertaken.

*2.B Enterprise Architecture Framework*

A second set of overarching concepts for thinking about enterprises relates to its architecture. Enterprises have long been studied by management, social and information scientists; however, this has largely been through taking one single view of the enterprise such as studying the organizational structure or the information technology architecture. The inadequacy of single or even pairwise analysis of enterprises is well documented (Drazin and Van de Ven, 1985): Our research on enterprise transformation and design has determined that *enterprise architecting* must take a systems perspective, viewing the entire enterprise as a holistic system that can be understood by examining the enterprise through multiple perspectives or views of an overall integrated framework. (Nightingale and Rhodes, 2004, Rhodes and Nightingale, 2009). These include the strategy view, policy/external environment view, organization view, process view, knowledge view, enabling information technology view, product view, service view and the interrelationships between these views. Table 1 provides descriptions of each of the 8 views:

Table 1: Enterprise Architecture View Descriptions

Strategy	Strategic goals, vision and direction of the enterprise including the business model; enterprise metrics and objectives
Policy/External Environment	The external regulatory, political and societal environments in which the enterprise operates
Process	Core leadership, lifecycle and enabling processes by which the enterprise creates value for its stakeholders
Organization	The organizational structure of the enterprise as well as relationships, culture, behaviors and boundaries between individuals, teams and organizations
Knowledge	The implicit and tacit knowledge, capabilities, and intellectual property resident in the enterprise

Information	Information needs of the enterprise, including flows of information as well as the systems and technologies needed to ensure information availability
Product	Product(s) developed by the enterprise; key platforms; modular vs. integral architectures, etc.
Services	Services(s) delivered and or supplied by the enterprise, including in support of products

There is a relationship among the different views whereby some views drive or determine the architectures and the required attributes of other views as depicted in Figure 2. For example, the arrow connecting “process” and “organization” implies that the process architecture should drive or influence the organizational architecture. Additionally, the framework suggests that the “process”, “organization” and “knowledge” views should drive the information technology architecture. This is one of the key issues in contemporary enterprises; all too often the IT architectures are established without due consideration of these critical dimensions. Similarly, the “strategic” direction of the enterprise will determine the appropriate product architecture (e.g., modular vs integral) that best suits its needs. Conversely, the selected product architecture will be instrumental in driving the capabilities needed for growth or to achieve competitive advantage. The EA framework has been proven to be a useful structure in many different types of product and service enterprises for examining interrelationships and synergies across the views in both understanding the current state and in architecting potential future states.

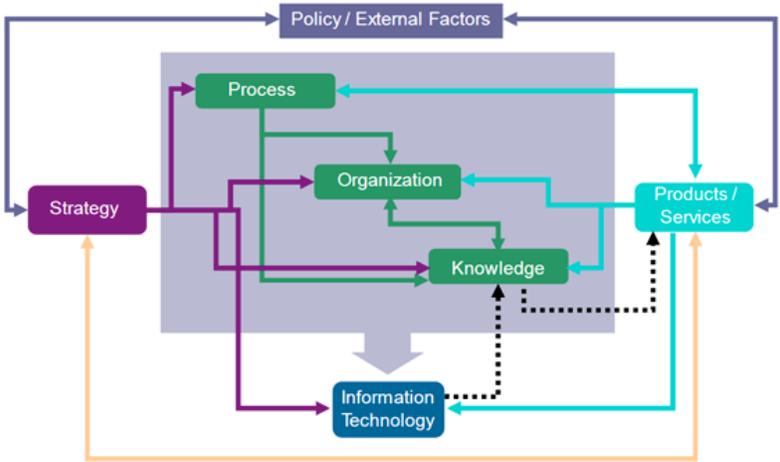


Figure 2. Enterprise Architecting Framework (Nightingale and Rhodes, 2008)

2.C Enterprise Transformation Roadmap

The Enterprise Transformation Roadmap was developed based on ten years of enterprise research to provide leadership with a decision aid for consideration of cultural, organizational and change management considerations in the strategic analysis and transformation of enterprises. This roadmap development was motivated by the fact that most transformation efforts fail in that they are often not sustainable or do not achieve the desired strategic objectives. The roadmap consists of three cycles: 1) a *strategic* cycle where the business case for transformation is made along with the engagement of leadership, 2) a *planning* cycle where both the current state and future state are analyzed and defined, along with a transformation plan to achieve the future vision, and 3) an *execution* cycle that puts the plan into practice. It has been

employed by enterprise leaders to enhance the quality of thinking on enterprise transformation issues and has provided guidance for increasing the value delivery for the maximum benefit of the entire enterprise.

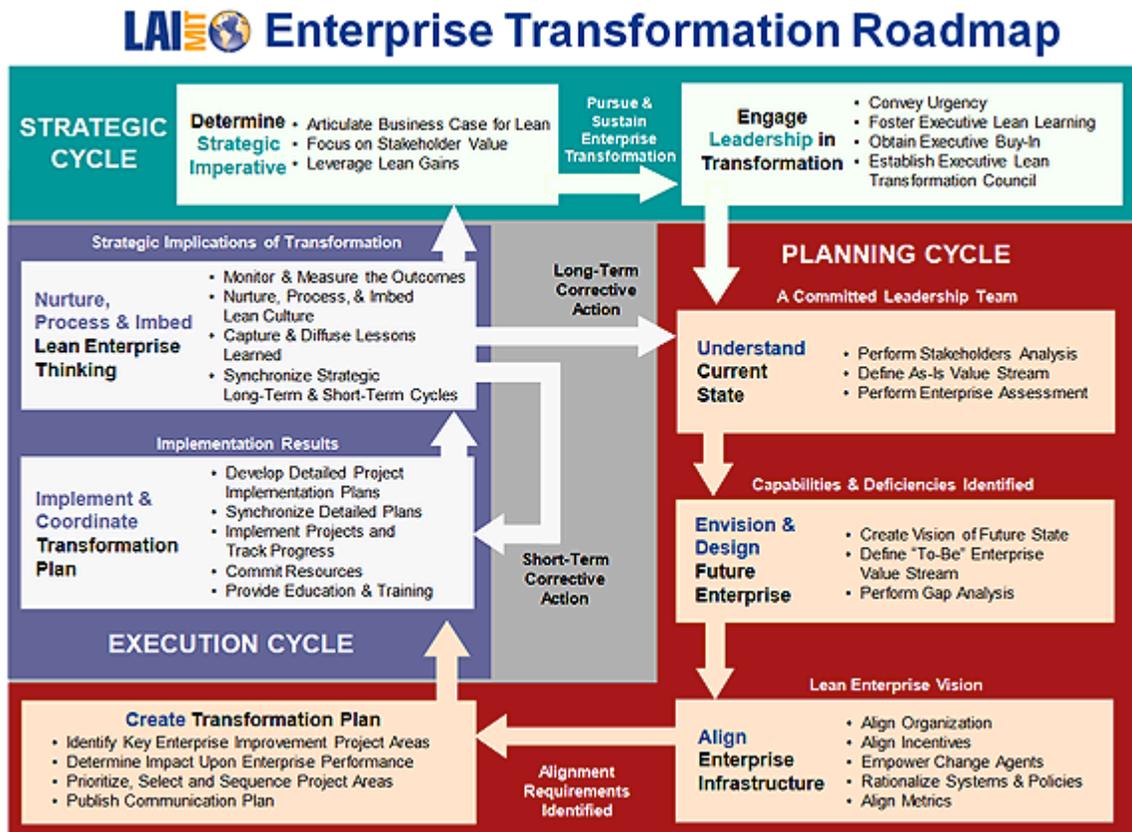


Figure 3. Enterprise Transformation Roadmap (Nightingale, Mize, Srinivasan, 2008)

### 2.D Enterprise Strategic Analysis for Transformation (ESAT)

ESAT (Nightingale, Stanke and Bryan, 2008) is a holistic analytical process for analyzing and improving overall enterprise performance (see Figure 4). It utilizes engineering system methodologies and decision support tools in support of the Planning cycle of the Enterprise Transformation Roadmap described in the previous section. ESAT focuses on enterprise-wide processes and considers the needs and values of all stakeholders. (Steps 1 and 2). In Steps 3. and 4., the current state is analyzed and identifies key process interfaces along with resulting disconnects and delay. It provides a cohesive method for diagnosing an enterprise to expose sources of waste and barriers to value delivery. Steps 5 and 6 establish an enterprise vision for the future and identifies improvement opportunities that will lead the enterprise to its future state. The integrated transformation plan is developed in Steps 7 and 8.

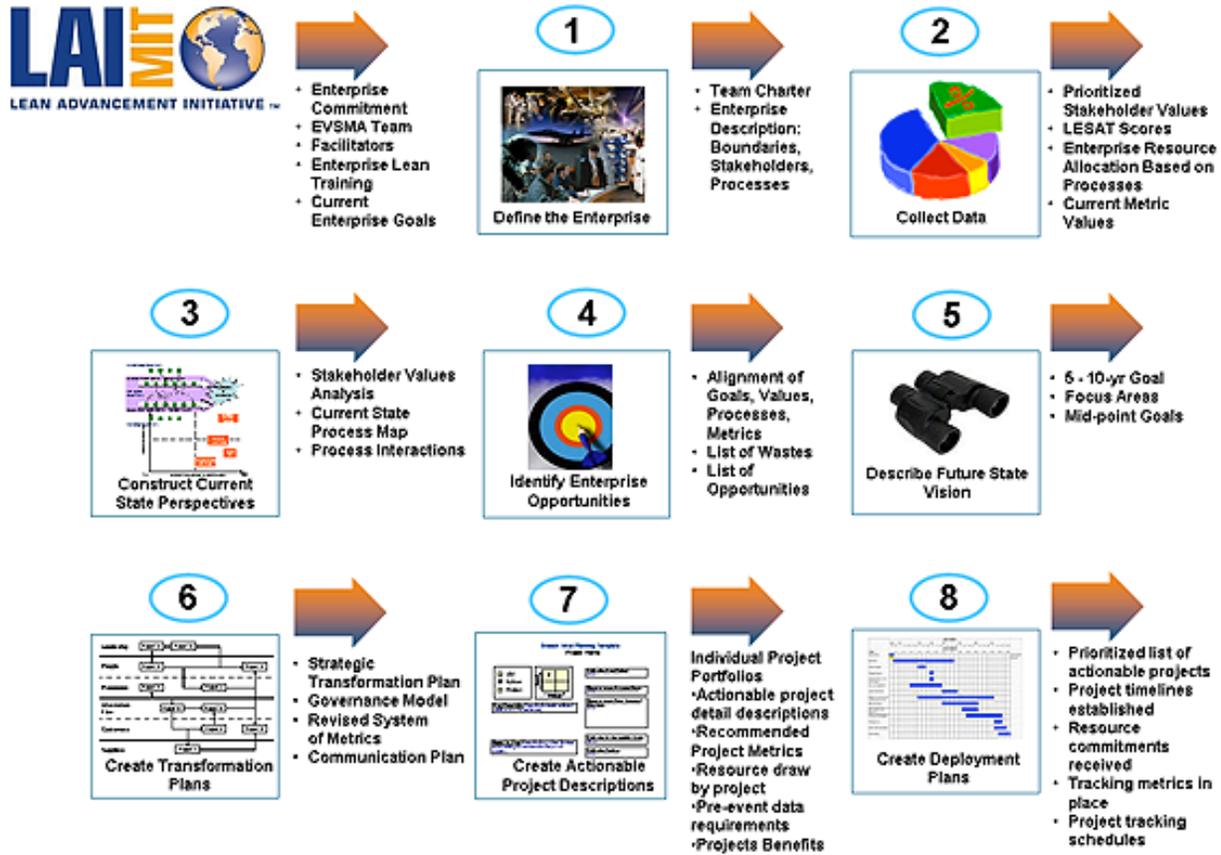


Figure 4. Enterprise Strategic Analysis for Transformation

### 2.E Lean Enterprise Self Assessment Tool (LESAT)

LESAT is a tool for assessing the maturity of an organization and its readiness to change (Nightingale and Mize, 2002). It includes a capability maturity model that addresses key integrative and strategic issues in life cycle, leadership and enabling processes. The 54 practices are employed to determine both the current state as well as desired future state of the enterprise. LESAT is linked to the Enterprise Transformation Roadmap and is based on the Seven Enterprise Principles. It has been downloaded from the LAI website nearly 3500 times on a global basis. When used in conjunction with ESAT it is a powerful tool for assessing gaps in enterprise performance.

## 3. Integrated Enterprise Transformation Framework

The above described enterprise transformation principles, methodologies and tools when used together comprise an integrated framework for enterprise transformation. The Seven Principles and the EA views provide a holistic way of thinking about and analyzing enterprises. The Enterprise Transformation Roadmap provides a framework for effective and efficient transformation strategy, planning and execution. The Enterprise Strategic Analysis for Transformation through its eight steps creates an environment for understanding the current state, creating a future state vision and developing an action plan for prioritized transformation.

LESAT and the EA views are used in concert with ESAT to analyze and assess both the current and future states. The interrelationship of these five enterprise methodologies is depicted in Figure 5.

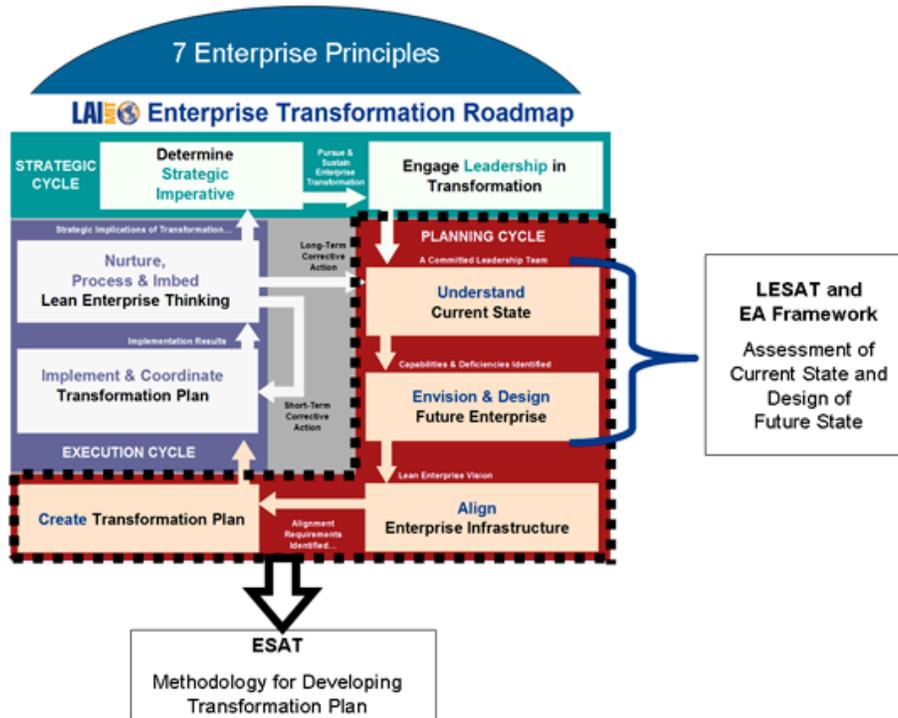


Figure 5. Enterprise Transformation Framework

#### 4. Enterprise Transformation Cases

Numerous enterprises have utilized these enterprise systems frameworks and methodologies in analyzing, designing and transforming their enterprises. Table 3 reflects some representative case studies where the framework has been applied in various domains including aerospace, healthcare, defense acquisition, and service sector. In each case significant insights were gleaned from taking an enterprise perspective.

Table 3. Transformation Case Studies

Industry	Organization	Reason to Transform	Insights from Enterprise Analysis
Aerospace	Air Cargo Carrier Program	Reduce costs and cycle times	Multiple stakeholder (industry, government regulatory) essential for enterprise success
	Space Center	Long development /procurement times at high cost	Criticality of including extended enterprise, including key suppliers and requirements generators
Healthcare	Mental Health Hospital	Breaking cultural norms to drive needed change, improve service and reduce costs	While experts in patient care, enterprise analysis uncovered traditional behaviors were inadequate for enterprise optimization and operation across boundaries.
	Hospital	Emergency Dept. overcrowding	Traditional lean approaches prone to sub-optimization. Enterprise thinking unveiled strong interdependencies with other hospital units

			(inpatient, operating rooms, etc) and external entities (insurance companies, primary care, etc). Ensuing transformation efforts adopted holistic principles.
	Medical Device Manufacturer	High growth rate; improve quality and profitability	Requires governance structure to oversee enterprise transformation; critical to span cross-organizational boundaries
Services	Commodity Provider	Misalignment of customer service with development and delivery platform	Leveraged front end enterprise interface while supplying holistic stakeholder value propositions; adopted both effectiveness as well as efficiency measures
Automotive	Auto Manufacturer	Reduced time-to-market in global product development	Required more than just traditional R&D – streamlined cross functional information exchange across organizational boundaries key to transformation
Government	Air Logistics Center	Increase aircraft availability, Commercial competition for logistics support	Shared enterprise strategic vision provided focus for prioritizing projects to achieve increased mission effectiveness
	Acquisition, Technology and Materiel Support	Higher levels of support to the field at reduced costs and cycle time; organizational integration	Integrated enterprise model requires extensive involvement of leadership, inclusion of supply base and integration of processes with IT systems

## 5. Conclusion and Future Research

Principles were drawn from lean principles and practices and scaled to drive enterprise level transformation, not just local suboptimal change. The Enterprise Transformation Framework provides an integrated set of methodologies that make these key enterprise principles actionable. Elements of this framework have been successfully utilized by a large cross section of industries in their enterprise transformations and research has shown them to be both domain independent and scalable.

Additional research in performing longitudinal studies of organizations engaged in enterprise transformation will yield additional insights into both the mechanisms of transformation as well as principles of leadership and change management. It is anticipated that enhancements to the framework will emerge in terms of modifications to its specific content as well as determining additional systems engineering tools and methods applicable at the enterprise level. These methods could include real options (Mikaelian et al, 2009), simulation models (Glazner, 2009) and social network theory.

## Acknowledgement

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