Modeling Government ERP Acquisition Methods Using System Dynamics

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Submitted to the System Design and Management Program
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ABSTRACT

A large percentage of companies implementing ERP experience schedule and budget overruns. In the two Air Force ERP projects studied in this thesis, DoD has experienced a schedule slippage of 3-4 years and life-cycle cost estimates almost doubled in each of these projects. Given the scale and complexity of these projects, and the number of different stakeholders involved, evaluation of the delay by checking off the high-level critical success factors as per literature does no good.

Misaligned incentives between stakeholders especially sponsor organization and system integrator, failure to accommodate rework in the master project plan, choosing the right contract terms, lack of in-house technical expertise, control of sponsor over project execution were some of the aspects which emerged to be important during the case study analysis; and were re-validated using the system dynamics model. The impact of the different contract models on the Critical Success Factors, depending on the level of knowledge on legacy and the completeness of requirements, has also been examined.

A System Dynamics model is developed to help in evaluating Lead System Integrator v/s Project management in-house governance models. We consider factors such as the sponsor's ability to adjust the RICE component estimations and the credibility of the contractor-staff working on the project. This thesis sets an outline for importance of governance models and delving deeper onto the process of selecting a contractor and setting incentives which help align the goals of the contractor to those of the sponsor organization.

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Acronyms

AFOTEC	Air Force Operational and Test Evaluation Center
ATEC	Army Test and Evaluation Command
BPR	Business Process Re-engineering
COTS	Commercial off the shelf solution
CR	Change Requests
CSF	Critical Success Factors
DEAMS	Defense Enterprise Accounting and Management System
DoD	Department of Defense
EBS	Enterprise Business System
ECSS	Expeditionary Combat Support System
ERP	Enterprise Resource Planning
EVM	Earned Value Management
GAO	Government Accountability Office
LSI	Lead System Integrator
MDA	Milestone Decision Authority
PMO	Program Management Office
RFP	Request for Proposal
RICE	Reports, Interfaces, Conversions and Extensions
SEA	Systems Engineering Advisor
SI	System Integrator
SME	Subject Matter Experts
UI	User Interface
USAF	U.S. Air Force
USTRANSCOM	U.S. Transportation Command

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1. Introduction

1.1 What is ERP?

ERP stands for Enterprise Resource Planning. The definition of ERP is 'packaged business software system that enables a company to manage the efficient and effective use of resources by providing a total, integrated solution for the organization information-processing needs' (F. F.-H. Nah, Lau, & Kuang, 2001). Consider a supply chain system which tracks information from procurement and inventory to automatically raise purchase orders for approval; and is capable of generating multiple reports on a single click. ERP systems are capable of accessing data from all the modules and run it as an enterprise-wide system.

Most of the organizations these days have large complex operations for which manual tracking becomes extremely difficult. Some of these organizations are in a new phase of transforming the way they handle their operations, while some others already have legacy systems which intend to do the job. Legacy systems are the old systems which were built for the same functionality and are continued to be used primarily because the end users are used to it, and/or there are certain functionalities in the legacy which are not yet replicated in the new system. However, the common issue with legacy is that the different functional systems behave as independent silos and hence it becomes difficult to have these silos talk to each other and therefore data exchange or automating processes across silos becomes difficult. Yet another issue with the legacy system is its complexity and lack of documentation, therefore making it difficult to do effective error corrections.

Commercial Off-the-shelf (COTS) Packages are the ones which are available commercially for purchase and organizations adopt these packages for many benefits such as outsourced system maintenance, system improvements and error corrections (JS Consulting Group Inc., n.d.). There are many COTS ERP packages available in the market, such as Oracle, SAP, BAAN etc. ERP systems also help organizations in adopting industry standard solutions; and reviving their business practices. Organizations implementing ERP can have different goals: from replacing legacy systems to transforming their business operations. These different goals have different implications that must be considered.

1.2 Challenges Facing ERP Implementations

An organization implementing an ERP needs to have clear goals in mind. Is the goal to replace legacy systems, achieve significant capability over existing systems or change internal business processes as per industry standards, or all of the above? When the goal is merely to replace legacy systems in order to have the maintenance and support external to the organization, factors such as data conversions, redesigning the organizational processes based on available technology, also termed as Business Process Re-engineering (BPR) (Snabe, Rosenberg, & Møller, 2008) play a crucial role. When the goal is to achieve significant capability over the existing legacy, then the sponsor organization will have to develop metrics to evaluate the functional goals desired. If the COTS ERP package fails to deliver on the metrics identified by the sponsor, then the entire process of ERP implementation consuming time, resources and money would fall short on its expectations.

Different organizations have different ways to measure success. However, the common definition would be to meet the ERP implementation within schedule and budget. Figure 1 illustrates the definition of "Complete" in an ERP project implementation (Deloitte Consulting, 1998). The figure demonstrates that the notion of implementation work being complete when the system goes live is true for only 34% of the respondents. As many as 49% of the respondents feel that this process is never complete, and the transformation is an on-going activity. 3% of the respondents believe that completeness is achieved when the legacy is turned off.

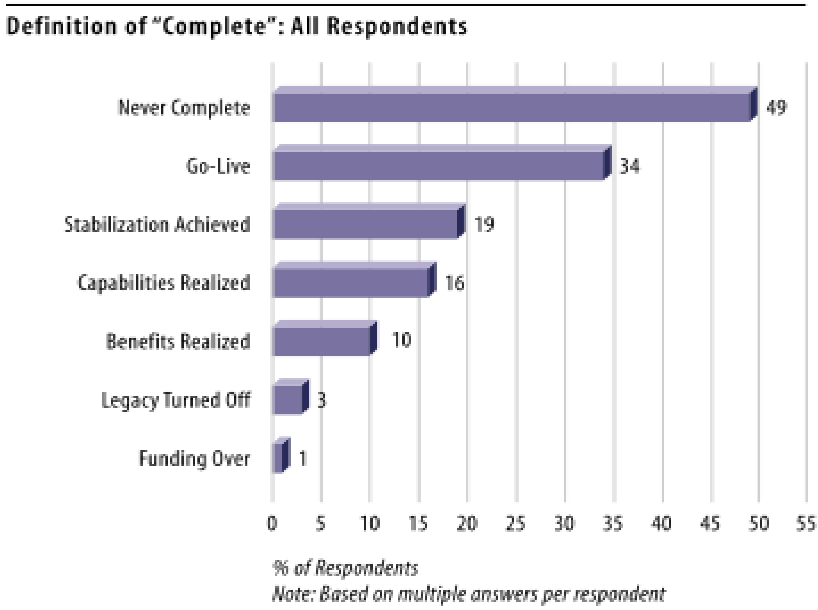

Figure 1: Definition of "Complete" by respondents who implemented ERP

As an example of problems faced by ERP implementations, Hershey, the chocolate company, started implementing ERP and selected the COTS packages - SAP along with Manugistics[1] and Siebel[2] (Perepu, Gupta, & (ICFAI Center for Management Research), 2008). Due to a delayed module implementation at Hershey's, the company suffered process inefficiencies and lost out on orders for Halloween and Christmas in the year 1999. Hershey had opted for all modules shifting to the new system at one instance, to accelerate the process of implementation; however not all of the modules could be thoroughly tested due to lack of time. Hershey suffered significant drop in revenues as they suffered problems related to order management.

1.3 Research Motivation

There are many reasons why an organization implements an ERP, some of which cited from literature (Ross, 1999) are: need for a common IT platform, process improvement, data visibility,

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[1] Manugistics is a software application company founded in 1969 as Scientific Time Sharing Corporation. The-name was changed to Manugistics in 1992. The company was a pioneer in supply chain software but its fortunes were adversely affected by cut-throat competition and the dotcom crash in March 2000. In 2006, it was sold to JDA Software. (Perepu et al., 2008)

[2] Siebel Systems Inc. was founded by Thomas Siebel in 1993, and was involved in designing, developing, and marketing of CRM applications. In September 2005, Oracle Corporation acquired Siebel for US$ 5.8 billion. (Perepu et al., 2008)

operating cost reductions, increased responsiveness to customers and improvements in strategic decision making. However, many ERP implementations experience over-runs in schedule and budget. As per the interviews conducted by Panorama Consulting Group in 2011, 74 percent of projects exceeded budget constraints and 61 percent of projects took longer than expected (Panorama Consulting Group, 2011).

The critical success factors (CSFs) required for an ERP implementation have been well documented in the literature. Top management support, project team competence, interdepartmental cooperation, clear goals and objectives, project management being the top five factors (Somers & Nelson, 2001). The conflicting interests of the different stakeholders and the information asymmetry have also been cited as additional factors for ERP implementation failure. Are these necessary at all stages of the project implementation life-cycle? Are there any missing CSFs which need deeper attention, especially in a Department of Defense (DoD) world, where primary research indicates that the in-house information technology (IT) expertise is minimal? It is crucial to un-wrap the black box perspective on the CSF's to understand the dynamics on the different stages of ERP implementation life-cycle.

The primary objective of this thesis was to approach this problem through a careful analysis of case studies from the DoD ERP implementations; and then compare the acquisition methods adopted by the management with literature. Then, a systems dynamics model is developed to capture the effects of loss of control over project execution with the adoption of different governance models, rework generation during the course of the project, and the significance of validating contractor-staff expertise with ERP implementations, during the bidding process of contractor selection.

1.4 Thesis Structure

Chapter 1 gives an introduction of ERP and why companies prefer to implement ERP, followed by some of the challenges in its implementations. Chapter 2 is the literature review of the common pitfalls in ERP implementations; and the critical success factors to be considered at each stage of the life cycle. This chapter also demonstrates the way a contractor can bring the moral hazard factor into the project; and the different governance models that the sponsor organization should consider while setting up contracts. Chapter 3 gives a detailed analysis of the two case studies conducted on ERP Implementation in the US Air Force; and the common issues that occurred causing a delay in schedule and budget overrun. Chapter 4 proposes a system dynamics model describing some of the key elements causing productivity changes, such as rework cycles and the impact of sponsor's control over project execution on the schedule. Chapter 5 lists some conclusions that can be derived from the case studies and the system dynamics modeling; and proposes future work in this direction.

2. Literature Review

2.1 Major Phases of ERP Life Cycle

The organization implementing the ERP is referred as the Sponsor Organization. Often due to lack of in-house expertise, a third party organization, referred as the Contractor, is hired for executing the entire process of COTS installation, implementation and meeting the sponsor's goals. Figure 2 represents the relationship between ERP Vendor, Implementation Contractor and Sponsor Organization. The contractor offers implementation services in exchange for contract price, after the selection of ERP package is done by the sponsor organization. In some situations, the vendor could also act as the contractor offering customization and implementation services.

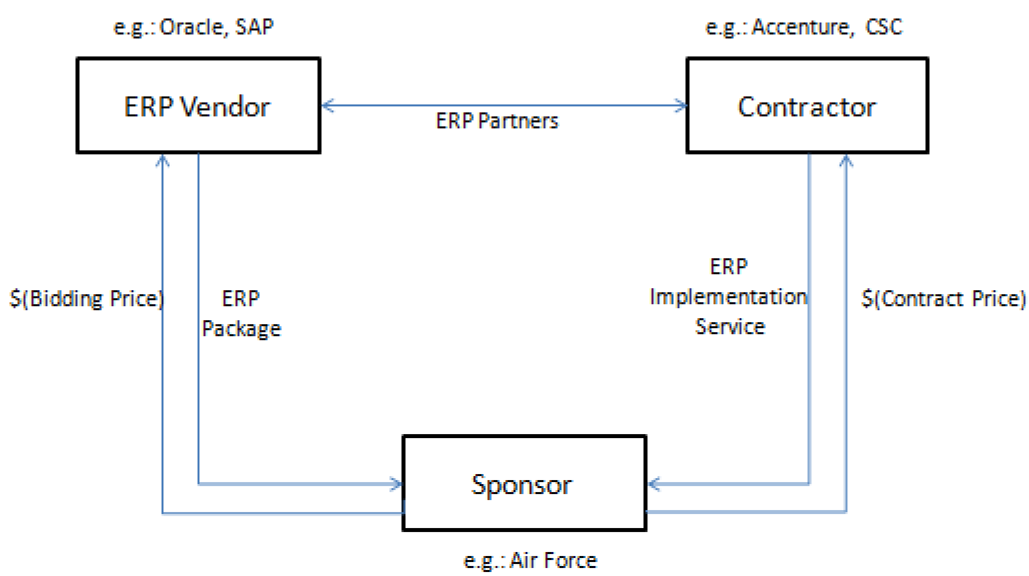

Figure 2: Vendor-Sponsor-Contractor Relationship

The major phases of ERP Life cycle are acquisition, implementation and maintenance. Acquisition refers to the phase of careful package selection and "presents the opportunity for both researchers and practitioners to examine all the dimensions and implications (benefits, risks, challenges, costs, etc) of buying and implementing ERP software, prior to the commitment of formidable amounts of money, time and resources" (Verville, Palanisamy, Bernadas, & Halingten, 2007). Verville et al have described the acquisition stage as a six stage process of planning, information search, pre-selection, evaluation, choice and negotiation. The planning process entails identifying the resources responsible for making the ERP purchase decision, defining requirements, establishing selection and evaluation criteria for COTS selection, marketplace analysis, choosing the acquisition strategy and anticipating acquisition related issues. All the activities help in identifying the organizational goals and choosing the right package after careful analysis of all available products in the market.

The implementation phase starts once the ERP source selection is complete. The process of identifying the mismatch between COTS product selected and the organizational goals, recruiting an implementation team in-house or selecting a contractor for the transition of legacy onto the new system fall under the implementation phase. Other activities included in this phase are: ERP set-ups, development effort for customizations required, data transfer from legacy to ERP, training of end-users and deployment.

Maintenance phase refers to addressing problems post deployment. Any updates in the ERP package or issues encountered by the end users are corrected with the help of implementation contractor or ERP vendor; based on the contract terms identified during the acquisition and implementation phases.

Although the conventional definition of acquisition phase ends at the selection of ERP package, the government DoD projects have a much broader definition of “ERP acquisition”. The process of identifying capabilities desired by the Air Force, integration activities between the implementation contractor and the functional experts in the DoD to refine the capabilities and identify the customizations desired, development and deployment onto test centers also fall under the Acquisition phase. A detailed description of each stage in the DoD ERP Acquisition is described under the Case Studies section.

2.2 What are RICE Components

In any ERP implementation, there are specific requirements that are required by the sponsor organization which might not be offered by the ERP package. Hence, depending on these business needs, the ERP package might require further customizations, referred as the RICE components – Reports, Interfaces, Conversions and Enhancements. The definitions are as follows ("What are RICE Components? | Oracle Apps.," n.d.):

- Reports refer to the custom reports required, that are not available as standard reports in the core ERP module.
- Interfaces refer to the interfacing with the external/legacy systems.
- Conversions refer to the programs required to transfer data from legacy to the ERP module.
- Enhancements refer to the additional functionality required by the existing system with no disturbance to the core functionality.

In the design stage of identifying gaps in the requirements document, the sponsor organization most of the times has no knowledge on the ERP software and the corresponding user interfaces (UIs). It is the responsibility of the contractor to brief the sponsors with the existing functionality in the ERP; and then take it further to map the requirements onto the ERP. At this stage, the gap between the needs and what ERP has to offer are compared, and the list of changes in terms of RICE components is identified.

In carrying out the above responsibilities, the contractor should not only have the technical knowledge in implementing the RICE components, but also have significant in depth understanding of the functionalities offered by the COTS software and the different UIs. A lack of this understanding could lead to discovery of additional work later on in the project therefore impacting the scope. A prior knowledge of the functionalities offered by ERP helps estimate the amount of effort required in meeting the sponsor's expectations by accounting for customizations required early on in the project. Thus, the risk of discovering tasks that were not anticipated during the requirements definition phase, also referred as the "unknown unknowns" reduces.

Among the RICE components, Table 1 summarizes the level and depth of knowledge required by the sponsor and the contractor in correctly estimating the effort during the solution design stage:

Table 1: Knowledge Required for Each RICE Component

Component	Knowledge Required
Reports	To be identified during the design stage, need significant knowledge of what COTS has to offer, and what the requirements are.
Interfaces	Need significant legacy knowledge, and what elements of legacy are to be retained.
Conversions	Need knowledge on both legacy and COTS, to correctly estimate the number of conversion programs and their effort estimates.
Extensions	Need information on what COTS has to offer and identify gaps with the capabilities.

Hence, for better estimations of the RICE components, the following information is required:

- Knowledge on ERP module
- Capabilities desired by the sponsor
- Legacy knowledge

2.3 Critical Success Factors (CSFs) for ERP Implementation

An ERP implementation demands a huge investment of time, money and organizational commitment. There are a number of reasons why an organization decides to invest in an ERP. The six primary reasons as stated by Ross (Ross, 1999) are: need for a common IT platform, process improvement, data visibility, operating cost reductions, increased responsiveness to customers and improvements in strategic decision making. The traditional legacy systems could have many independent silos to satisfy their respective functionality and might not be able to interact with each other. Due to these various disadvantages of traditional legacy systems, many organizations are implementing ERP systems.

There is a huge risk involved in this process. "If a wrong acquisition is made, it can adversely affect the organisation as a whole, in several different areas and on several different levels - even to the point of jeopardising its very existence" (Verville et al., 2007). A number of case studies clearly speak of the many organizations which failed drastically and underwent huge losses in the process.

In a large organization with hundreds of divisions and multi-site operations, it becomes really important to choose the right implementation strategy. The two most widely discussed implementation strategies are: Big Bang and Phased approach (Neal, 2010).

Big Bang: *Implementation happens in a single instance*. The entire processes are moved at once from the legacy to the new system. The implementation is quick and very risky. Proper planning has to be done prior to implementation, as the legacy system is shut down as soon as the new system starts to operate.

Phased: A phased implementation is done in phases, over a period of time. The phases are rolled out either on the basis of modules, business units or geography. This type of implementation works out when it is a large organization and the users can adapt themselves as they go along. The experience and learning from the initial phases could help in better planning of the later phases. However, this is a costly and lengthy approach compared to the Big Bang, as the legacy systems need to run in parallel until the transition is complete.

When integrating one module at a time, there comes a need to develop integration elements which can temporarily connect to the existing legacy system so that the business processes are consistent and running until the next phases of the remaining modules are implemented. This is important but ultimately results in an effort which eventually has to be trashed when the ERP implementation is complete. The system integrators or contractors play an important role here. The potentially conflicting relationship between project sponsors and contractors has been analyzed in detail by McKenna (Mckenna, 2005). The key motivation of contractors is to secure revenue, by minimizing the re-use of components and raising variation orders for these temporary integration elements. With unclear scope and lack of understanding of the requirements, the chances of variation orders being generated grows. This could lead to a number of after-effects directly impacting the schedule and budget of the project. McKenna has also emphasized its effect on the working relationship between the two parties leading to reduced communication in the integration activities; thereby contributing to the reinforcing loop of increased variation orders.

There are a number of papers which talk about the Critical Success Factors in the successful implementation of an ERP. The following section summarizes some of the important CSFs and their importance across the different stages of a project lifecycle.

Critical Success Factors in ERP Implementation

Rajagopal (Rajagopal, 2002) has modeled the ERP implementation process into six phases: (1) initiation (2) adoption (3) adaptation (4) acceptance (5) routinization and (6) infusion. Ross and Vitale (Ross & Vitale, 2000) have described the ERP process in a five stage journey – (1) design (2) implementation (3) stabilization (4) continuous improvement and (5) transformation.

There is extensive literature dedicated to the key CSFs required in the success of ERP implementation. However, not all of these CSF's might be necessary throughout the life-cycle of the project. In a study done by Somers and Nelson (Somers & Nelson, 2001), they propose a comprehensive list of 22 CSF's recommended by practitioners and academicians. Table 2 lists these CSFs by degree of importance.

Critical success factor	Mean	Std. Dev
1. Top management support	4.29	1.16
2. Project team competence	4.20	1.07
3. Interdepartmental cooperation	4.19	1.20
4. Clear goals and objectives	4.15	1.14
5. Project management	4.13	0.96
6. Interdepartmental communication	4.09	1.33
7. Management of expectations	4.06	1.37
8. Project champion	4.03	1.58
9. Vendor support	4.03	1.60
10. Careful package selection	3.89	1.06
11. Data analysis & conversion	3.83	1.27
12. Dedicated resources	3.81	1.25
13. Use of steering committee	3.79	1.95
14. User training on software	3.79	1.16
15. Education on new business processes	3.76	1.18
16. Business Process Reengineering	3.68	1.26
17. Minimal customization	3.68	1.45
18. Architecture choices	3.44	1.19
19. Change management	3.43	1.34
20. Partnership with vendor	3.39	1.21
21. Use of vendors' tools	3.15	1.57
22. Use of consultants	2.90	1.20

Table 2: Mean Rankings of CSFs by degree of importance in ERP Implementation (Scale=5) (Somers & Nelson, 2001, pp. 7)

When the implementation responsibility is completely outsourced, then the CSFs such as "Project Team Competence", "Dedicated Resources" should comply with respect to the contractor team. This survey was addressed to the top management, who were believed to have the most knowledge on CSFs required (with more than 50% companies having either a CIO or Implementation Manager as their key respondent). It was surprising to see that "Use of consultants" did not emerge as one of the top CSFs. The internal IT expertise of these companies can be presumed to be significantly knowledgeable about ERP, as most of the respondents were IS department heads. Was this the reason why the "use of consultants" did not emerge important as they already had an internal expertise?

In other research studies done by Willcocks and Syke, it was stated that "In practice, the need to identify and build key in-house IT capabilities before entering into ERP projects emerges as one of the critical—and neglected—success factors" (Willcocks & Sykes, 2000).

Later in 2004, Somers and Nelson (Somers & Nelson, 2004) segregated the 22 CSFs into "players" and "activities" and ranked their importance across the different stages of the ERP lifecycle based on their research through data collection from Fortune 500 firms and random sample of 200 organizations using ERP systems. Table 3 lists the expected importance of the players and activities across the six stages of the implementation stages:

Expected importance of players and activities across implementation stages[a]

Players and activities		ERP implementation stages					
		Initiation	Adoption	Adaptation	Acceptance	Routinization	Infusion
P	Top management	H	H	H	H	H	H
P	The project champion	H	H	H	H	M	M
P	The steering committee	H	H	H	H	L	L
P	Implementation consultants	H	H	H	M	L	L
P	The project team	H	H	H	H	L	L
P	Vendor–customer partnership	H	H	H	H	M	L
P	Vendors' customization tools	L	H	H	L	L	L
P	Vendor support	L	L	L	M	H	H
A	User training and education	H	H	H	H	M	L
A	Management of expectations	H	H	H	H	M	L
A	Careful package selection	H	H	L	L	L	L
A	Project management	H	H	H	H	M	L
A	Customization	H	H	H	L	L	L
A	Data analysis and conversion	H	H	H	M	L	L
A	Business process reengineering	H	H	H	M	L	L
A	Architecture choices	H	H	M	L	L	L
A	Dedicating resources	H	H	H	H	M	L
A	Change management	L	H	H	H	M	L
A	Clear goals and objectives	H	H	H	H	H	H
A	Education on new business processes	L	H	H	H	M	L
A	Interdepartmental communication	H	H	H	H	M	L
A	Interdepartmental cooperation	H	H	H	H	M	L

[a] Assessment of expected importance based on literature review: high (H) 0.60; medium (M) 0.30; low (L) 0.10.

Table 3: Expected importance of players and activities across implementation stages (Somers & Nelson, 2004, pp. 262)

As the motivation of this thesis is to look at the implementation problems in a phased ERP approach, it would be reasonable to look at the CSFs which have the highest impact in the initiation, adoption and adaptation stages. From Table 3, the players that seem to play a key role in these stages are: top management, project champion, steering committee, implementation consultants, the project team and vendor-customer partnership. The activities that are crucial are:

careful package selection, management of expectations, project management, customization, data analysis and conversion, business process reengineering, architecture choices, dedicating resources, clear goals and objectives, interdepartmental communication and interdepartmental cooperation.

Careful Package Selection

There are many ERP packages in the market, and they differ from each other in one way or another. Some ERP packages might suit large organizations while some other may be more appropriate for small organizations. Similarly, the compatibility of a package to an industry might differ. "Choosing the right ERP packaged software that best matches the organizational information needs and processes is critical to ensure minimal modification and successful implementation and use. Selecting the wrong software may mean a commitment to architecture and applications that do not fit the organization's strategic goal or business processes" (Somers & Nelson, 2001).

When choosing the right package, a careful analysis and comparison of the ERP application with the organization's business process will help in estimating the extent of customization required. Choosing a wrong package would either mean extensive customizations or changing the business processes in the organization to match up to the ERP functional capabilities. The decision between customizations and BPR is an organizational wide decision involving multiple stakeholders, and has to be evaluated based on its impact on organizational competencies, end users and budget available for customizations.

Some of the questions that arise from the implementation perspective are: Is it possible to identify all the customizations required in the 'Initiation' phase of the project? Were they included in the goals and objectives? How to tackle new customization requests after the 'Initiation' phase?

Top Management Commitment

"Implementing an ERP system is not a matter of changing software systems, rather it is a matter of repositioning the company and transforming the business practices" (Bingi, Sharma, & Godla, 1999). Any organization has its own competitive advantage in the market through its business processes. Implementing an ERP could change their positioning; and hence, an ERP implementation has to be treated as a strategic choice rather than a mere IT implementation. Top management must be involved throughout the project implementation in managing this change and resolving any conflicts. Re-emphasis from the top management on the motivations and reasons for this transformation will keep the employees informed and contributing; rather than opposing the change. As per the survey done by Fiona et al (F. F.-hoon Nah, Zuckweiler, & Lau, 2003) on the Chief Information Officers' Perceptions of Critical Success Factors, top management support was cited as "the only way to get started" and to get "compliance and commitment from divisions". Involvement of top management helps improve inter-departmental cooperation and allocating the necessary and dedicated resources of the organization.

2.4 Agency Theory – Relevance to the Relationship between Contractor and Sponsor

When an organization plans to implement an ERP, it might not have the necessary in-house IT expertise to successfully replace the legacy system. The external contractors are hired by an organization after a careful selection of the ERP package has been done. Although the ideal expectation of the organization is to have the contractors do the best job in the shortest amount of time, with the least resources, and within budget; it would be impractical to ignore their self interests. When hiring external contractors, the factors that need to be considered from a project management perspective increase.

In 2003, Haines and Goodhue (Haines & Goodhue, 2003) used the Agency Theory (Eisenhardt, 1989) to establish how contractor involvement and their motivations affect the outcome and direction of any ERP implementation. The following is the summary of their research; following which an attempt to model these findings using system dynamics has been made.

The two key issues that are significantly important with respect to implementation contractors are: "the extent of the involvement that contractors have and second, the level of knowledge held by the organization implementing the ERP system (the sponsor) as well as the transfer of knowledge between the vendor, contractor, and the sponsor."

The contractors generally offer the following services: configuring the new ERP to fit the organization; transferring the legacy data and processes onto the new ERP; customizing the ERP package to fit to the business needs of the organization; and directing the organization to adapt to the new business processes as offered by the ERP.

Application of Agency Theory in the Context of the Sponsor Organization and the External Contractors

Agency theory talks about the structure of relationship between two parties, principal and agent, who are engaged in a common goal; but have different incentive structures and attitudes towards risk. In the context of the current problem at hand, the principal is the sponsor organization and the agent is the external contractor.

The three characteristics of this relationship are: goal differences, risk tolerance differences, and information asymmetry (Eisenhardt, 1989). The primary goal of an external contractor is to earn revenues and profits.

Some contractors work hard to create relationships with their clients and maintain/build reputation; however this is likely to be true for larger companies like Oracle, SAP and BAAN who have already established their credentials and might not want to risk their reputation; although SAP suffered bad press from the Hershey case. Smaller players who are primarily interested in earning profits might seek such opportunities at the expense of the sponsor organization.

Information Asymmetry: The information that each party has may or may not be transparent in the relationship. Especially in terms of a fixed price contract, the sponsor might hold back some information like business processes of the organization or subtle business requirements which might eventually demand more work from the contractor's side. Similarly, the contractor might portray a different picture about their expertise and the internal workforce; and "ways in which they can cut corners in carrying out the project" and increase the contract duration beyond schedule to earn more revenues. After the contact has been signed, some of this information might surface which could eventually have negative impact on the working relationship.

*The two types of agent opportunistic behavior are: **adverse selection** and **moral hazard.***

Adverse Selection: "Misrepresentation of ability by the agent".

Moral Hazard: "Agent might not act as diligently as expected in carrying out the will of the principal."

Agency theory proposes two basic control strategies to monitor the agent's behavior and evaluate their performance - outcome-based and behavior-based. Outcome-based relies on evaluating the performance of the contractor based on the outcome of the project. This is a risky approach as these projects involve huge investments of time and money and lack of early evaluation could be destructive both for the relationship and the project. The behavior-based approach is much more practical in this situation. However, as Kirsch (1996) pointed out, the principal's ability to effectively evaluate the agent's behavior is severely limited by the principal's knowledge about the task.

Impact of the Sponsor's Knowledge

When the sponsor has sufficient knowledge of its legacy business processes and the technical knowledge on the integration elements and the customization efforts required, then it is easier for the sponsor to gauge the behavior of the contractor. For example, when a "Change Order" is raised by the contractor, sponsors are in a better position to judge whether it is valid or is it just another opportunistic behavior by the contractor.

Haines and Goodhue propose that when hiring a contractor, it is essential to define (a) the level of involvement and (b) the role the contractor assumes. The level of involvement is the number of contractor-staff working on the project and the depth of their responsibilities. The role of the contractor is whether they are assigned the responsibility of project management and strategic planning along with technical implementation.

The control of the sponsor over the project timelines and budget is severely affected when the contractor is responsible for the project management. That gives the contractor more opportunity to run the project as per its terms, incentives and risk assessments. When the sponsor has no technical knowledge and lacks experience dealing with IT implementations, then the contactor has all the opportunities to drive the budget as per its interests. Hence, there needs to be the right balance of power between sponsor and contractor for successful project implementation.

Knowledge Transfer from the Contractor to the Sponsor Organization

Adverse Selection: According to the interviews conducted by Haines and Goodhue, organizations were unsatisfied with the expertise of the contractors; and felt there was more on-the-job learning i.e. the project team did not have sufficient implementation knowledge and built upon their expertise while working on the project, therefore performing at a pace below expected and causing a delay in project completion.

Moral Hazard: With the differing goals and incentives of the contractor from the sponsor, contractors might want to perform work at a pace that is more in favor of their interests; or create additional work to generate additional revenue. Thus, it is important to understand how to monitor the progress of contractor's work and have the project management responsibilities assigned to people within the sponsor organization.

How can we solve the above two problems in the following two different situations?

(1) The sponsor organization has weak or no IT skills

(2) The sponsor organization has an IT department which has sufficient capability to develop ERP related skills and benefit from the contractor's knowledge transfer, thus being able to develop/maintain future phases of the implementation.

The above two questions are discussed in detail in the case study analysis.

2.5 Different Models of Governance for Large Projects

Figure 3 below demonstrates different ways of governing large system projects and the impact of each governance type on the external environment (Sapolsky, 2009).

	Arsenal	**Contract**	**Weapon System Manager**	**Outsourcing To Private Arsenal**	**Lead System Integrator**
Program Requirements	Government	Government	Government	Government	Industry
Technical Direction	Government	Government	Government	Industry	Industry
Program Management	Government	Government	Industry	Industry	Industry
Technical Execution	Government	Industry	Industry	Industry	Industry
External Environment	▪ Infrequent wars ▪ Little commercial application of military tech	▪ Some commercial application of military tech ▪ Private sector private sector pays better, can be more responsive	▪ Weapons become more complicated / complex ▪ Coordination of sub-systems becomes important ▪ Large companies can better leverage political support	▪ Government begins to lose in-house tech capabilities ▪ Outsourcing becomes increasingly acceptable	▪ Loss of in-house government tech capabilities leads to inability to define what's possible

Figure 3: Program Responsibility Format Types (Sapolsky, 2009, pp. 26)

In the Lead System Integrator (LSI) model, all the responsibilities are completely outsourced; which could result in a loss of in-house competence and loss of control on the project execution. The Arsenal model is at the other end where all responsibilities are fulfilled in-house. This would require the government to employ people with the relevant skill sets and keep them employed even when the implementation phase is completed. This could also be done by contracting these people from external service organizations for the duration of the project. The government DoD projects started with the LSI model, and are now moving towards Contract model; where the program requirements and program management are all in-house and an external systems engineering advisor, who is well experienced with ERP package, is hired for technical direction. The technical execution is the only role outsourced to the contractor in this model. The government is leveraging the experiences gained from Air Force ERP implementations and collaborating with the external advisor to develop a center of excellence in-house; which could help future program implementations adopt the Contract model of governance.

This chapter summarizes the critical success factors and the role of agency theory in defining contracts and maintaining control over project execution. The next chapter describes the interview process and the analysis of case studies conducted.

3. Industry Lessons on factors impacting ERP implementation

3.1 Interview Preparation

In understanding reasons behind a delayed project, an excellent approach is to think of "The Iron Triangle" of cost, scope and time (Chatfield & Johnson, 2007).The Iron Triangle in Figure 4 represents the tension between cost, scope and schedule. Having a control on all the three aspects of a given project is often an unrealistic aspiration. It is usually necessary to compromise on one of the three factors in order to optimize the other two.

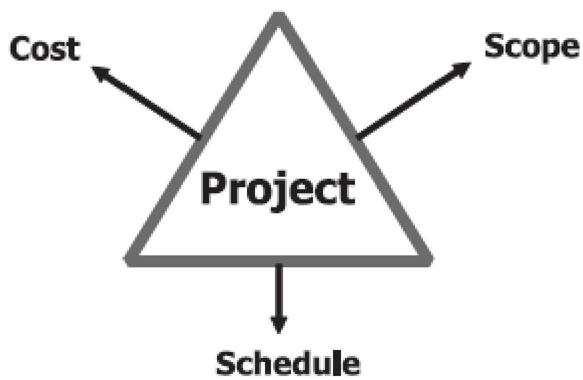

Figure 4: The Iron Triangle

DoD had hired an external advisor organization which can provide the technical support to monitor the progress of the project. The case studies were greatly informed by the interviews conducted with this advisor organization, hereafter also referred to as the "Systems Engineering Advisor" in the following text.

During the initial rounds of interviews, the approach was to understand the background of the ERP implementations within DoD. The initial understanding was that the size and the risks of the DoD ERP projects were significantly high, as the expectations were to replace around 80-200 legacy systems in each program implementation. As the DoD budgets are being shared between ERP and all its other functions, it is a challenge to secure revenue for increased scope of projects. Another concern was the maintenance cost of the legacy systems while the new system deployment is being delayed, thus causing further stretch on the DoD budgets.

The acquisition model adopted by DoD was "COTS based contractor driven acquisition". In this process, a COTS package is selected which matches closely with the high level capabilities identified; and a contractor is hired through a bidding process for the detailed level design, implementation, testing and system integration. There have been subsequent changes to this acquisition process which are discussed in detail under the case study analysis. During these initial rounds of interview with the Systems Engineering Advisor, one major concern raised was that the motivations of contractors were different from the sponsor organization, which could lead to moral hazard issues, for example, the contractor proposing significantly large interfaces involving more time and effort, thus earning them increased revenues. These insights helped to frame the questions for the detailed interview with the Systems Engineering Advisor teams involved with DEAMS and ECSS.

Given this initial understanding of the complexity of the system, governance with no in-house IT or ERP expertise and problems of moral hazards, a list of questions were identified which could capture the measures taken by the two DoD projects to overcome these risks. The complete list of questions are in Appendix A. The questions were classified into five main categories:

- **Objectives of ERP Implementation**: Whether the aim of the project was to replace the legacy systems, and/or achieve operational improvements? Were there any metrics to measure the organizational effectiveness?
- **Contractor Selection and contract agreements**: To determine the basis on which the system integrator was selected, and the responsibilities were assigned. It was important to know whether the project management responsibility was kept in-house, or outsourced to the contractor; as this could significantly affect the sponsor's control over the project.
- **Specifications:** This section dealt with the process of identifying system specifications. Was it a phased/big-bang/parallel adoption, and who were the technical and functional experts.
- **Change Orders and their frequency:** A major cause of a delayed project is the generation of unknown unknowns (as described in section 2.2). This section helped understand what kinds of reworks were generated, and what fraction of them could be attributed to the functional design. Other reasons for generation of rework could be the

in-efficiency of the project team, leading to technical errors. Was there efficient tracking of the kind of rework generated?

- **Project Management:** Another major factor in the delay of a project is the efficiency of project management. This section helped capture the responsibilities of the in-house PMO (Program Management Office) and their control on the project execution. Were there any milestones identified, and what was the procedure in identifying if the project was on track?

3.2 Stakeholder Analysis – Using Exchange Model of Stakeholder Interaction

Figure 5 below shows a model that represents the different stakeholders and their interactions in a DoD ERP implementation (Adapted from: Ed Crawley and Bruce Cameron (2011), Exchange Model of Stakeholder Interaction, ESD.34 System Architecture Slides, Massachusetts Institute of Technology).

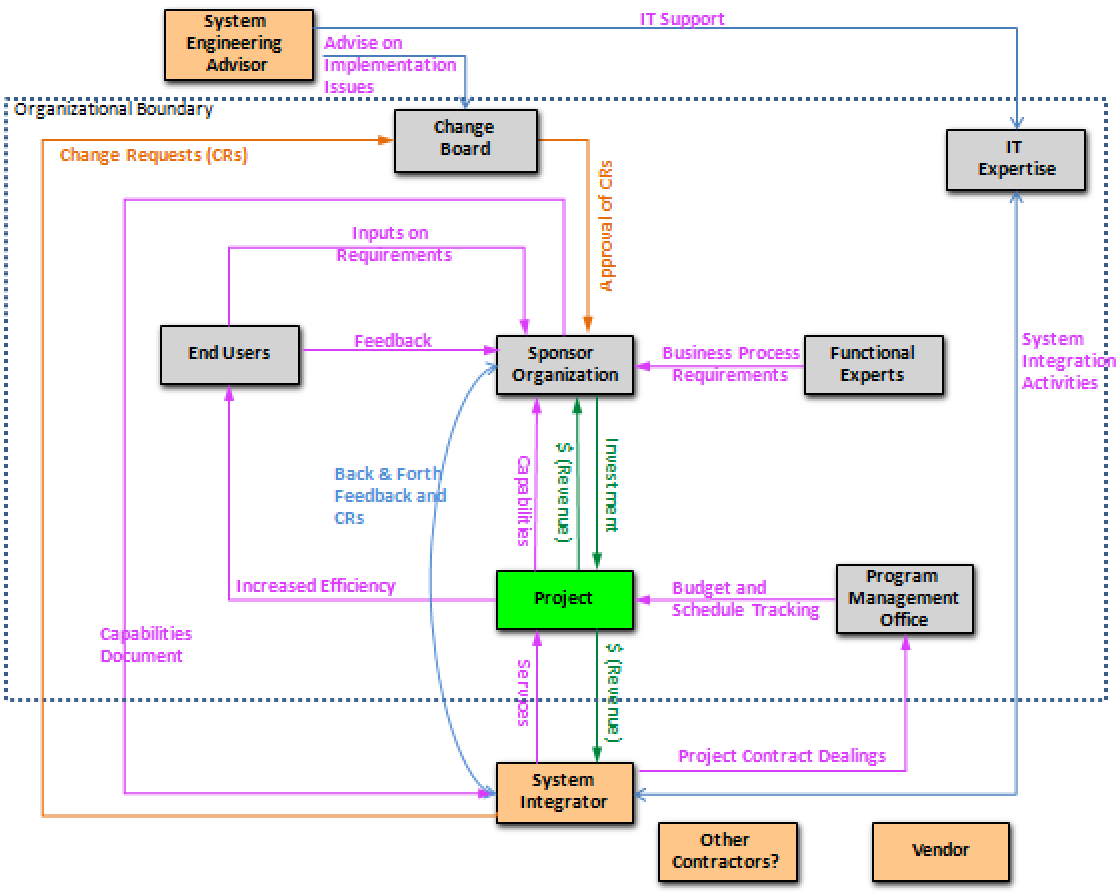

Figure 5: Stakeholder Analysis of ERP Implementation

Here is a short description of each of the stakeholders:

Project

The project has also been represented in the above diagram so as to show the contributions of the stakeholders to the project in return for benefits.

Program Management Office (PMO)

The program manager is responsible for budget and schedule monitoring of the project. The typical way to track and control the project is through Earned Value Management (EVM) which helps to verify the budgeted or planned schedule with the actual performance. The PMO is internal to the sponsor organization. DoD hired the Systems Engineering Advisor into the PMO office to be able to make better decisions on project execution.

Sponsor Organization

It refers to the organization adopting the ERP. However, in the DoD Air Force, every ERP being implemented has a program owner, an official from the top management of the department implementing the ERP, who represents the sponsor organization.

The initial set of capabilities generated by the sponsor should have a significant contribution from the various functional experts who know how Air Force works; existing end users and IT experts in order to ensure that organization's business processes are adhered to, as well as the concerns of the end users are addressed. The inputs from the IT experts, knowledgeable on the legacy silo systems and their stability, might generate some additional capabilities to be met. Any decision to incorporate changes to the organizational processes need to be taken only after analyzing its consequences and impact on the stakeholder's day-to-day operations.

Contractor/System Integrator

The contractor is the organization which has been hired by the sponsor to implement the ERP system. There could be multiple contractors hired by the sponsor. For example, separate contractors could be hired for design and development. Typically, the system integration responsibilities lie with the external contractor; who is also responsible for directly reporting to the PMO on cost and schedule.

The role of the system integrator could vary based on the contract terms. In a Lead System Integrator (LSI) model, the responsibilities range from requirements definition, project management, procurement of systems, development, testing, system integration, deployment and support. The DoD has reported oversight issues in implementing the LSI model, thus causing loss of control over the project (Grasso, 2010).

IT Expertise

During the process of ERP implementation, there is possibility of discovery of new work which has not been identified during the design phase. Any such work which is critical for the project, as agreed upon by the sponsor and contractor is raised as a "Change Request" (CR). The evaluation and approval of implementation related CRs requires an independent IT expertise to avoid any opportunistic behavior by the contractors. This IT related capability can either be in-house or outsourced to another contractor. In the implementation of these large systems, the government requires outside support to help manage until they can build enough in-house expertise within the DoD. As mentioned earlier, in the two projects that were studied, DoD has hired a Systems Engineering Advisor to provide them the technical support to oversee any implementation related decisions.

End Users

The end users refer to the individual users of the system and are internal to the sponsor organization. During the requirements phase, if the end users input are not considered, then there is a possibility that there would be significant change requests during the test-run of the system by the end users. The main concern of the end users is their reluctance to change. The challenge would be to get them involved by engaging them in this transformation process and communicating the management goals in a transparent fashion. In DoD ERP implementations, Change Management and Training Integrated Product Team (CMTIPT) is responsible for the successful change management and training in getting the end users comfortable with the new system (DEAMS Strategic Communications, n.d.).

Systems Engineering Advisor

Due to the lack of IT expertise within the DoD, it becomes critical to hire an external advisor organization which can provide the technical support to monitor the progress of the project and evaluate any change requests raised by the lead system integrator. Without a technical oversight in the past projects, the DoD felt a loss of control over the project execution with no valid justifications to the schedule and budget overruns.

Change Board

The change board is responsible for evaluating any change requests and measuring its impact on the schedule and budget. The change board in the two projects was internal to the sponsor organization evaluating the functional impact of any change request generated.

There could be possibilities of information asymmetry between the sponsor and the contractor. For example, a functional specification could mean two different things to the two parties. As the project progresses, any change in the scope or any new work identified by the contractor has to be approved by the sponsor organization.

Unless there is a clear understanding of the requirements identified during the design phase which reduces the information asymmetry between the sponsor and the contractor, there are chances of change requests being generated. Yet another reason for the generation of change requests could be the discovery of temporary interfaces during a phased implementation. It could be difficult to identify the points of integration with legacy for all the phases during the requirements definition stage. As and when the project proceeds, the requirements become more transparent and any additional work needs to be approved by the sponsor before proceeding.

To the sponsor organization, verifying and validating the change requests is critical, to prevent moral hazard by the contractor, effectively trace the project scope and reasons for delay in project schedule and also prioritize the importance of any change request functionality.

3.3 Interview Analysis

3.3.1 DoD Acquisition Process

The DoD Acquisition Process has been explained in detail in Figure 6 below. This information is gathered from the interviews, DoD Project Management Guide and the DoD GAO Report (Defense Acquisition University (DAU) & Project Management Institute (PMI), 2003; United States Government Accountability Office (GAO), 2010).

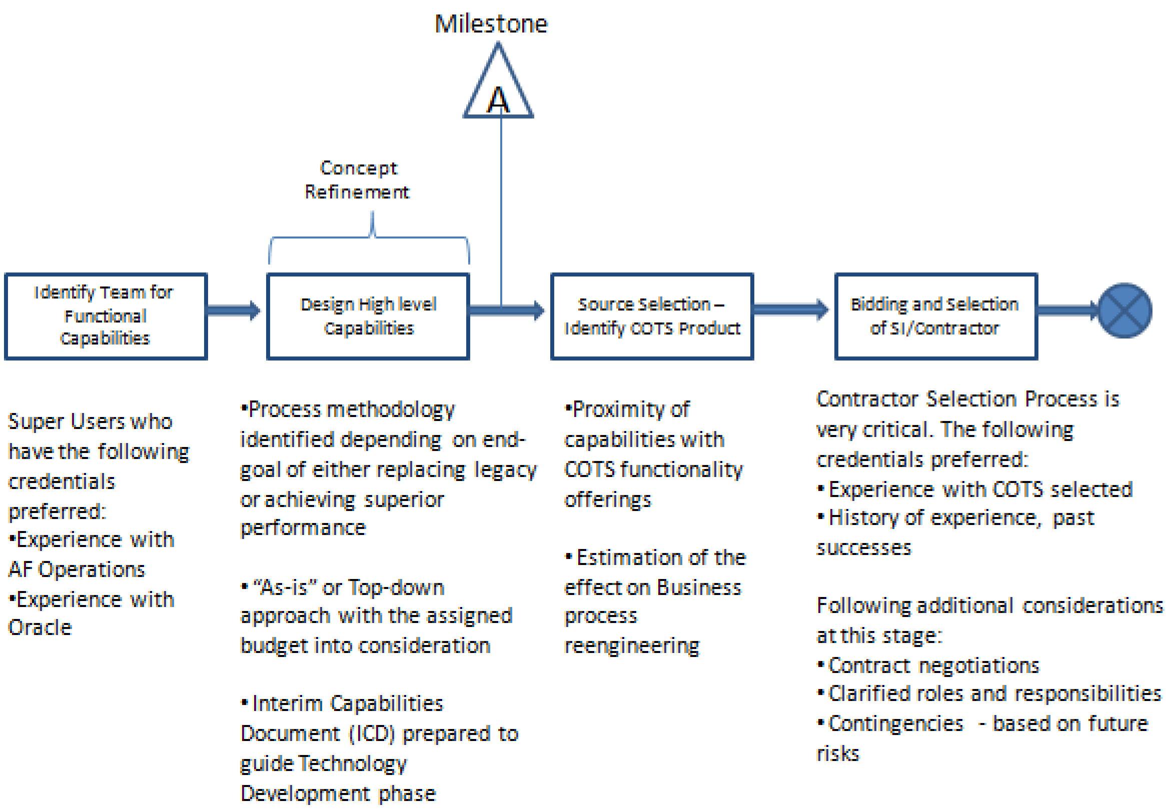

Figure 6: DoD Acquisition Life-cycle Process (A)

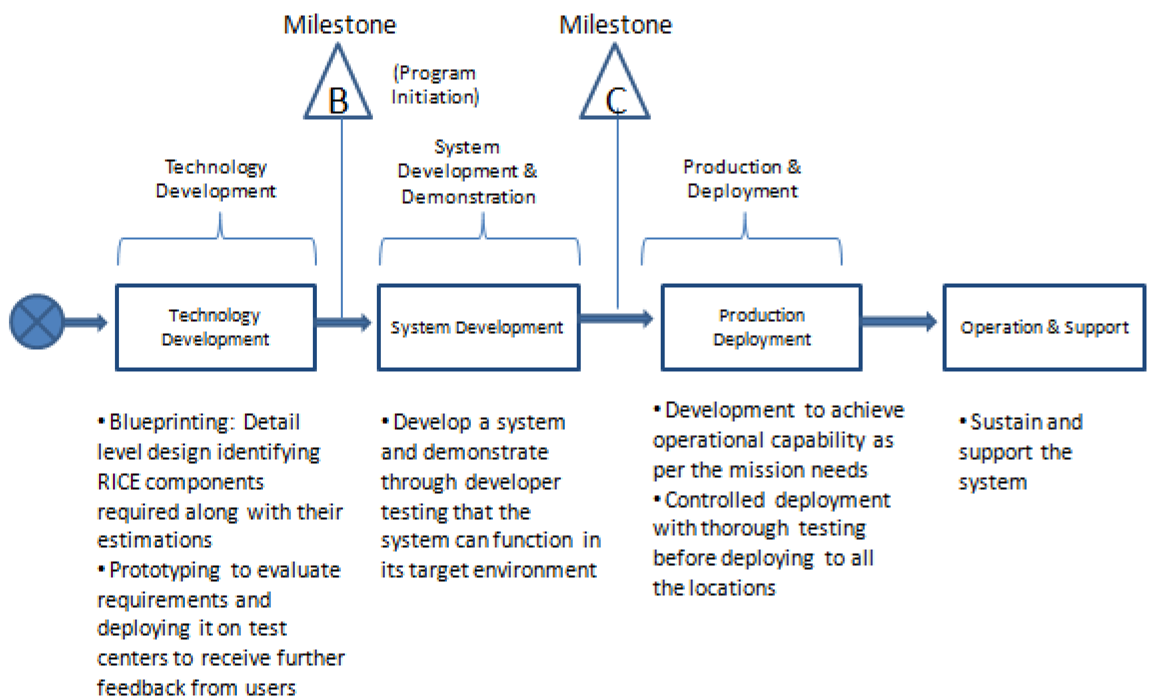

Figure 6: DoD Acquisition Life-Cycle Process (B)

Figure 6 above depicts the DoD Acquisition stages. As explained in the previous section, many different stakeholders are involved in the acquisition process. There are five life-cycle phases and three major milestones; each qualifying whether the project can be moved to the next phase based on certain criteria. Milestone A marks the completion of the capabilities identification. The purpose of Milestone B is to identify the technologies and refine the user requirements after a bidding process for source selection. Milestone C is achieved after the system development and an initial demonstration of the system and its ability to meet the target requirements at the desired environment. A description of each stage is as follows:

Identifying Team for Functional Capabilities

To be able to generate requirements which contribute to the required operational effectiveness, it is desirable to have experts who not only have the functional knowledge of how the Air Force operates, but also relevant COTS package experience. However, having an internal ERP expertise is difficult for DoD considering the difficulties in retaining the ERP talent as this requirement is only temporary and the support of these systems after deployment is also outsourced. The end users' inputs are also valuable as they have experienced the best and the worst of the legacy system and have clear expectations from the new system.

Designing High level Capabilities

In designing the high-level capabilities, the end goal has to be kept in mind. For instance, one of the reasons the two projects studied in this thesis were implemented by the Air Force was to improve the "asset visibility" i.e. provide detailed information on accountable items by integrating multiple logistics systems and finance processes (United States GAO, 2011). The definition of asset visibility is "the capability to provide timely, accurate information on the location, movement, status or condition, and identity of units, personnel equipment, and supplies DoD-wide and having the capability to act on that information" (United States Government Accountability Office (GAO), 2008). The approach in drafting requirements could either be "as-is" or "top-down". As-is refers to capturing how the legacy works and replicating the same functionality in the new system. Top-down refers to identifying what the broad operational requirements desired are, and then drilling down to the details of functionality.

In either of these approaches, the high level capabilities are documented by the DoD without any bias towards any ERP package. The end goal can be met if there are metrics to evaluate the improvements desired in the processes.

Source Selection – COTS Package

The DoD followed a two-step acquisition process: (1) COTS Package selection (2) Selection of contractor. The first step is the selection of COTS package after a list of desired capabilities is identified.

It would be optimal to select the COTS package which has the business functionalities in close proximity to what is desired, so that the customizations required would be minimal. Else, either the RICE components would have to be increased or business processes within the organization would have to be changed. As already mentioned in Section 2.1, Verville et al (Verville et al., 2007) have described the acquisition stage as a six stage process of planning, information search, pre-selection, evaluation, choice and negotiation. A thorough step-by-step procedure in adopting the practices proposed by the literature will help in making a calculative selection of the COTS package. DoD raised Requests for Proposal (RFPs) to the government accepted ERP vendors to demonstrate the way the package would be able to meet their capabilities.

Bidding and Selection of Contractor

The second step of the two-step acquisition process is the selection of contractor/LSI. The lead system integrator (LSI) is responsible for the entire implementation - detailed level requirements, code, test, deployment, maintenance and support. Hence, it becomes important for the contractor to not only have enough expertise in ERP implementations, but preferably on the COTS package selected. A past record of successful implementations would build credibility for the LSI and therefore the sponsor can be assured of quality work and minimal moral hazard problems.

DoD organized a bidding process where each of the contractors participating has to demonstrate the way they would address the set of capabilities with the selected COTS package as the implementation environment.

Contract Terms

Some of the common contracts terms used in the government DoD projects are: Firm Fixed Price, Time and Material and Cost-plus contracts (Defense Contract Management Agency, n.d.).

A **Firm Fixed Price (FFP) contract** is used when "a fair and reasonable price can be established at the outset"; meaning there is an initial fixed price negotiated between the sponsor and contractor for the estimated work. This contract type is generally preferred when the amount of work is expected to remain the same. Another motive in using this contract type is to control the costs incurred by the contractor.

A **Time and Material (T&M) contract** is used when it is not possible to correctly predict the amount of work required to be done. This contract type has no control over the expenses incurred by the contractor and a careful surveillance over the billing hours is required by the sponsor.

A **Cost-plus Award Fee Contract** is used to provide incentives to the contractor on the basis of the quality or adherence to the timeline. An initial fixed price is identified in the contract.

However, due to the uncertainties involved in contract performance, the incentive system can help align the contractor's interests with those of DoD. This is used to avoid moral hazard element and motivate the contractor to perform as per DoD's expectations.

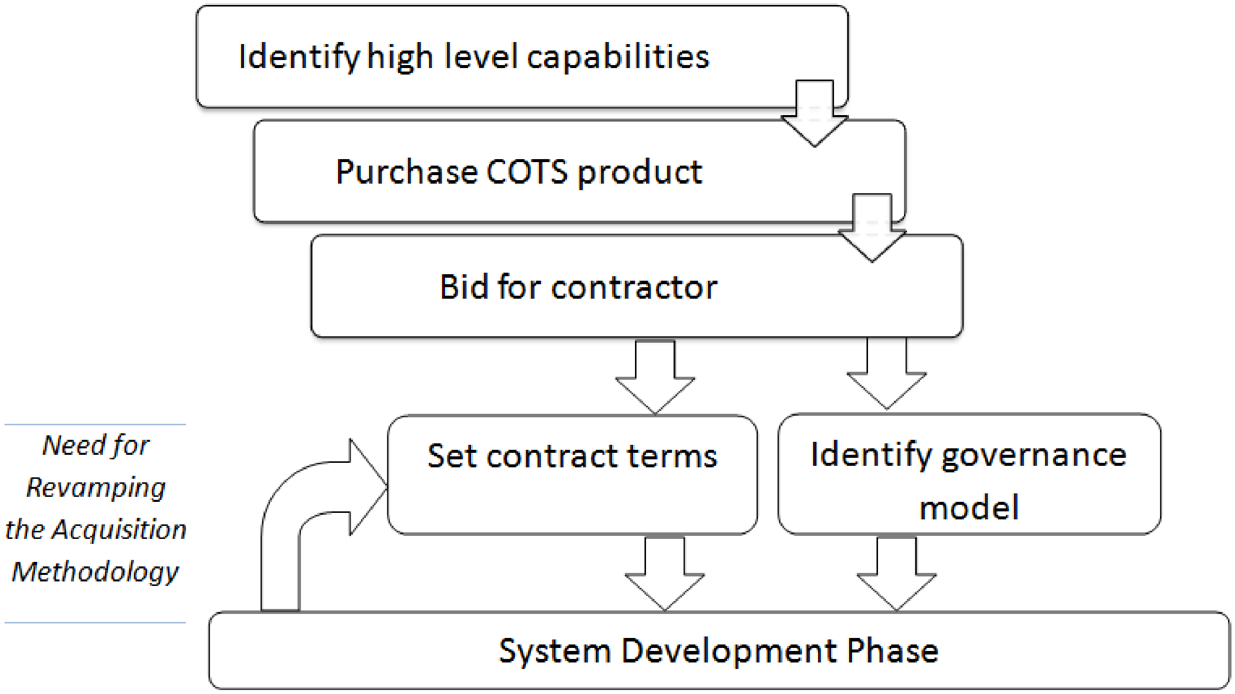

Figure 7: Representation of Revamping Process of Governance Model and Contract Terms

In both the DoD projects, the initial contract was a firm fixed price contract and the governance type selected was the LSI model. The capabilities identified in each of these projects were very high level, and having a fixed price contract on a design which was evolutionary; caused problems in scope management. The governance model caused significant problems to the sponsor in maintaining control over project execution and the ability to align the LSI's incentives with that of DoD. All these issues, along with changes in acquisition rules, led to revamping of the acquisition method for both the projects during the System Development phase, as depicted in Figure 7 above. Detailed analysis of the changes in governance can be found under the case studies.

Technology Development

Under the technology development phase, the DoD projects go through a detailed blue printing process and system prototyping and test deploying to verify the design; thus marking completion of Milestone B. The blue-printing process is described in detail in the following section:

Blue-printing Process

Figure 8 represents the evolution of high level capabilities into detail level requirements, along with the stakeholders involved in the process:

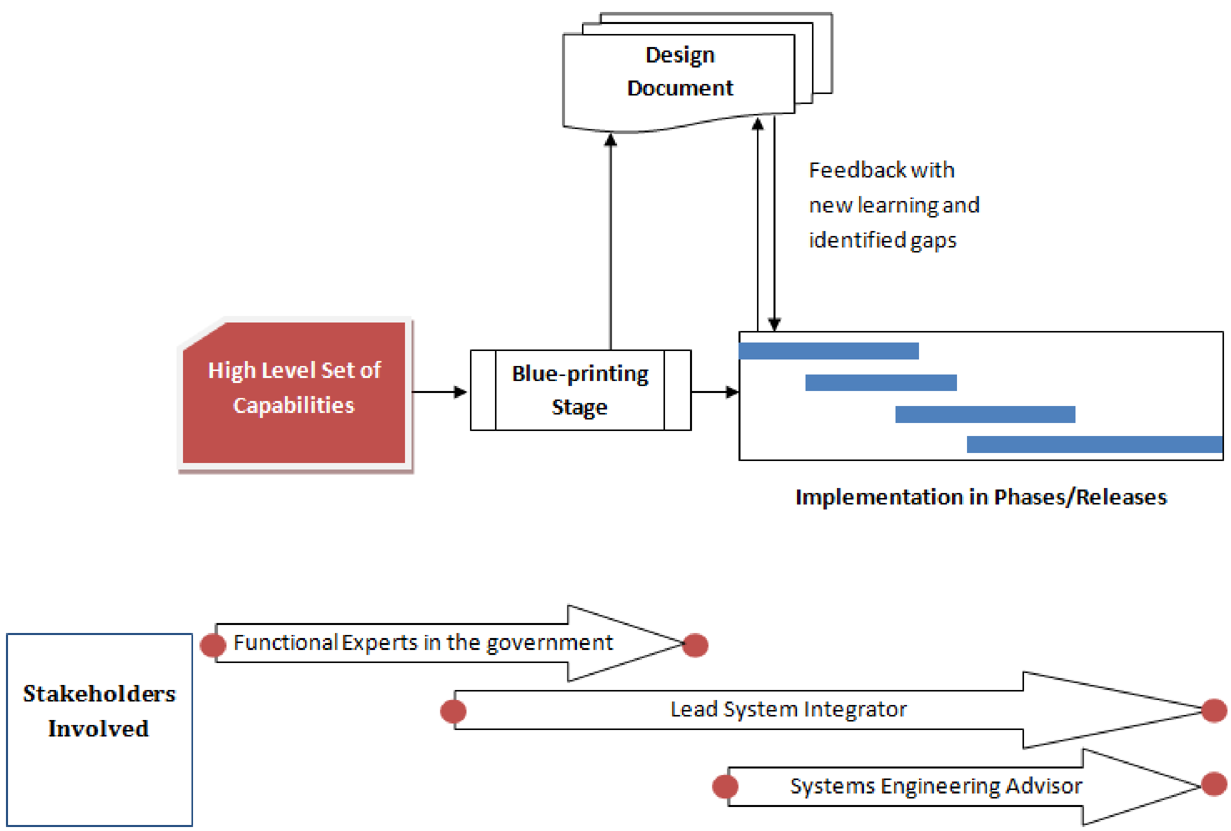

Figure 8: Evolution of high-level capabilities to detailed level specifications

As seen from Figure 8 above, the system requirements go through a number of stages. A set of high-level capabilities desired from the system are compiled by the functional expertise within DoD. These capabilities are non-biased towards the COTS package, and the two step acquisition process is conducted to identify the ERP package and the Contractor.

The contractor selection should not be done solely on the basis of the lowest bid price. Prior expertise of the contractor in implementing ERP preferably on the same COTS package helps in improved capability on part of the contractor in identifying the gaps in the capabilities document with respect to the business processes in the ERP COTS package. Also, any integration elements like the RICE components or temporary interfaces required during phased implementation will be known during the blue-printing stage, and therefore reduce the uncertainties in the estimated cost and schedule.

The blue-printing stage is primarily to develop a detail design level specifications from the capabilities document matching up against the business processes available in the COTS package. This can be best done with the functional expertise and the selected contractor working jointly in identifying the gaps between what is desired and what COTS has to offer. This quality of the blue-printing stage is mainly affected by two parameters:

1. Level of knowledge of the contractor in the COTS package
2. The level of clarity of the DoD on the functional requirements

Unless the contractor has sufficient technical knowledge and expertise on the COTS software, it would be difficult to predict the number of RICE components required and the effort for each. Similarly, if the contractor has no experience on the specific modules of the ERP that are required for this implementation, it would be unable to give an expert opinion during the blue-printing stage, and thus they could under-estimate the number of customizations or functional elements required as part of the implementation. With growing number of implementations, the contractor experiences a learning curve, and hiring the same contractor for the future program implementations would prove beneficial.

There has to be clarity on the functional capabilities desired from the system and the priorities between the different capabilities. In other words, to what extent would the sponsor organization be willing to pay for the customizations to meet a given business requirement, if it is not already met by the COTS package. Lack of this prioritization could lead to indecisiveness with respect to adopting the COTS business processes within the organization. The functional experts could also discover some features from the legacy during testing phase which they would want to retain in the new system. Thus, there is more scope of rework when there is no clear understanding of the desired requirements and the legacy knowledge.

A Capabilities Design Document (CDD) is required for the completion of Milestone B; which converts the Interim Capabilities identified during high-level capabilities definition into system specific requirements.

Program Initiation

The end of Milestone B normally triggers program initiation. This decision is made by a DoD Authority MDA (Milestone Decision Authority) and is dependent on the completion of three factors – approval of Capability Development Document, maturity of technology, and funding approval.

System Development

As the name suggests, the system development and demonstration phase entails developing the system and demonstrating its performance through developer testing. This phase marks the achievement of Milestone C. This phase seems to consume most of the time and effort, however, significant effort and top management approvals are required to receive the Milestone B approval which initiates the System Development phase. This phase however has lower involvement from the functional experts within DoD, and the responsibility lies primarily on the contractor in developing and demonstrating the system.

GCSS-AF Integration Framework

During system development, the contractor has to ensure that the system is compatible with the GCSS-AF Integration Framework, which is a Combat Support enterprise infrastructure providing enterprise services capabilities such as application hosting, security, presentation, data services as well as hosting environments for ERPs (U.S. Air Force, n.d.). The need for having one common platform across the different Air Force services to streamline, find and combine information, led to the development of the GSCC-AF integration framework with a standardized approach across the different programs. Both ECSS and DEAMS were integrated into this framework. This additional configuration had to be considered during project estimations.

Production Deployment

Once Milestone C is achieved, further development of the system is done to meet the operational capability desired by the mission. The deployment is initially done in selected locations to perform system testing and evaluation, after which full deployment is achieved.

Operations & Support

This phase related to the sustainment of the system over its life time, with the most cost-effective way to maintain the system.

Reported Full Deployment Schedule Slippage of ECSS and DEAMS as of December, 2009

The next two sections describe the two programs being implemented by DoD. The two programs ECSS and DEAMS have already experienced schedule and cost slippages. Table 4 below summarizes their statistics (United States Government Accountability Office (GAO), 2010):

Component/ System Name	Originally Scheduled fiscal year for full deployment	Actual or latest estimated fiscal year for full deployment	Schedule Slippage	Original life-cycle cost estimate (millions)	Current life-cycle cost estimate (millions)	Reported Cost Increase (millions)
DEAMS	2014	2017	3 years	$1100	$2048	$948
ECSS	2012	2016	4 years	$3000	$5200	$2200

Table 4: Schedule and Cost Slippage Statistics of DEAMS and ECSS

3.3.2 Case Study - DEAMS (Defense Enterprise Accounting and Management System)

Air Force had undertaken the DEAMS (Defense Enterprise Accounting and Management System) initiative to "perform the financial management functions for the Air Force's general funds". The motivation for DEAMS implementation is to provide a single integrated financial management system and will be shared by US Air Force and USTRANSCOM ("Defense Enterprise Accounting and Management System - FAQ Topic," n.d.).

3.3.2.1 DEAMS Statistics

As per the GAO Report on the Reported status of DoD's Enterprise planning systems dated March, 2012 (United States Government Accountability Office (GAO), 2012a), following are the statistics of DEAMS:

Program Timeline:	
• Initiation Date	August 2003
• Original Scheduled Date of full deployment	Fiscal Year 2014
• Current Scheduled Date of full deployment	Fourth quarter fiscal Year 2016
Program Costs	
• Original life-cycle cost estimate	$1.1 billion
• Current life-cycle cost estimate	$1.6 billion
• Amount expended	$334 million
Program Deployment Details	
• Current Number of system users	1053
• Expected Number of system users at full deployment	30,000
• Current number of locations using system	2
• Expected number of locations at full deployment	170
• Legacy systems to be replaced	8
• Annual cost of legacy systems	$56 million
• Number of System interfaces	84
Other Statistics from GAO Report dated October 2010 (United States Government Accountability Office (GAO), 2010)**:**	
Causes of slippage as per PMO	• Problems caused by software code defects, Integration test delays • Standardization of computer desktops across the Air Force caused schedule slippages • Change in implementation strategy from 2 to 3 phases
Program Owner:	Assistant Secretary of the Air Force for Financial Management and Comptroller

3.3.2.2 Interview Review

As part of the case study analysis, an interview was conducted with the Systems Engineering Advisor team who was involved with DEAMS. The following is a summary of the interview analysis:

Designing High-level Capabilities

The decision to acquire ERP was made by DEAMS, as the ERP has already proven to work with other users in the commercial world. The high level requirements or capabilities before source selection were generated by the financial management community based on new government accounting rules and these were significantly different from the way Air Force had been doing accounting. For example, the Lines of Accounting formats to be used by Defense Travel Administrators will undergo changes with the new accounting rules. (Defense Travel Management Office, 2011). With these changes, there was no complete design that was functional to demonstrate the requirements. The motivation was to resist desires to replicate legacy and leverage out of the box functionality to the extent possible. A series of analysis of alternatives was conducted to leverage COTS best processes leading to Process enabled process reengineering effort, i.e. leveraging out of the box functionalities offered by COTS and re-engineering the Air Force processes to the extent possible.

Source Selection Process

As part of the two-step acquisition process, Oracle was selected as the COTS product from DoD approved ERP vendors through a competitive selection process. The second step was the selection of a contractor. The contractor selected in DEAMS had significant experience with Oracle ERP.

Contract Terms

The contract agreement for DEAMS was a firm fixed price contract, with a cap on the number of RICE components. The governance type selected was the LSI model, with all the responsibilities of technical execution, technical direction and program management assigned to the contractor.

From the moral hazard perspective, with a firm fixed price contract, the profit-maximizing incentives of the contractor would either be to exceed the cap limit on the RICE components, or reduce the effort to a significant level retaining the fixed price.

Blue-printing Process

The functional expertise on the DEAMS project comprised of senior functional leaders, 3 and 4 star generals who scrutinized and validated all the functional goals.

The requirements of an Air Force accounting system could have been fairly similar to the commercial US accounting system. Also DEAMS had a significant advantage with the choice of LSI selection, as they were well versed with Oracle ERP. Hence, although the LSI did not have knowledge on the Air Force processes, they were able to comprehend the accounting rules and the capabilities desired. When the LSI came on board, they could roughly estimate the impact of replacing each legacy on the number of RICE components in the blue printing stage.

The LSI discovered that the functionality proposed in the Billing part of the system was too complex and might result in a large number of temporary interfaces that might not fall within the DEAMS budget. The original count of 850 RICE components was scoped down to 350 by convincing DoD to postpone the replacement of the Billing legacy system to the next phase. The contract price was not re-negotiated with this reduction in scope. In total there were 85 data exchange interfaces with 12-15 core legacy financial systems.

Change in Governance Model

The DoD felt a loss of control over the project execution with the LSI model of governance. Also, DEAMS felt that it lacked the in-house technical expertise to evaluate the changes happening in the scope of the project. The LSI was successful in scoping down the project retaining the initial agreement of the contract price. A Systems Engineering Advisor (SEA) was hired by DEAMS for technical direction and to gain better oversight over the project.

The program management group along with the Systems Engineering Advisor was responsible for the technical and engineering review.

DEAMS Implementation Process

DEAMS was planned to be implemented in three increments and five spirals. The following spirals in Increment 1 have already been achieved.

Increment 1, Spiral 1 – Achieved a small capability set by replacing ABSS (Automated Business Services System) at USTRANSCOM.

Increment 1, Spiral 2 – The general accounting capability was achieved across all USTRANSCOM and all affected US air force base operations.

The Increment 2 consisting of Spirals 3 and 4 and Increment 3 consisting of Spiral 5 are yet to be accomplished.

Change Board

Any design change was approved by the PMO and the engineering community. After the hiring of the Systems Engineering Advisor, DEAMS had a very strong review board and the chances of moral hazard were substantially reduced.

Future Steps for DEAMS

With the improved oversight and better evaluation of change requests, the main issue concerning DEAMS was that the peer review committee lacked understanding on detailed design level requirements. From Figure 8, "Evolution of high-level capabilities to detailed level specifications", it is evident that the Systems Engineering Advisor was appointed only after the blue printing process. The committee involved during the blue printing was no longer accountable for the end result. The process of knowledge transfer from the functional committee to the peer review committee was not efficient, and therefore the latter lacked the knowledge on the evolution of the system requirements. DEAMS faced a number of issues on the first deployment location at the Scott Air force base.

A new regulation regarding the acquisition process, along with the above problems, triggered a major change to the way the future spirals of DEAMS will be conducted. According to this new regulation, delivery had to be done in 12-24 month increments.

The future releases 3,4,5,6 will have separate RFPs for design and development as shown in Figure 9 below. With this competitive selection, the risk factor reduces having additional hand off between different organizations from design to development. This could also help detect early design errors with an additional contractor perspective. With the earlier approach of LSI, there could have been a possibility of design errors extending into development as there is no intermediate validation between the two phases.

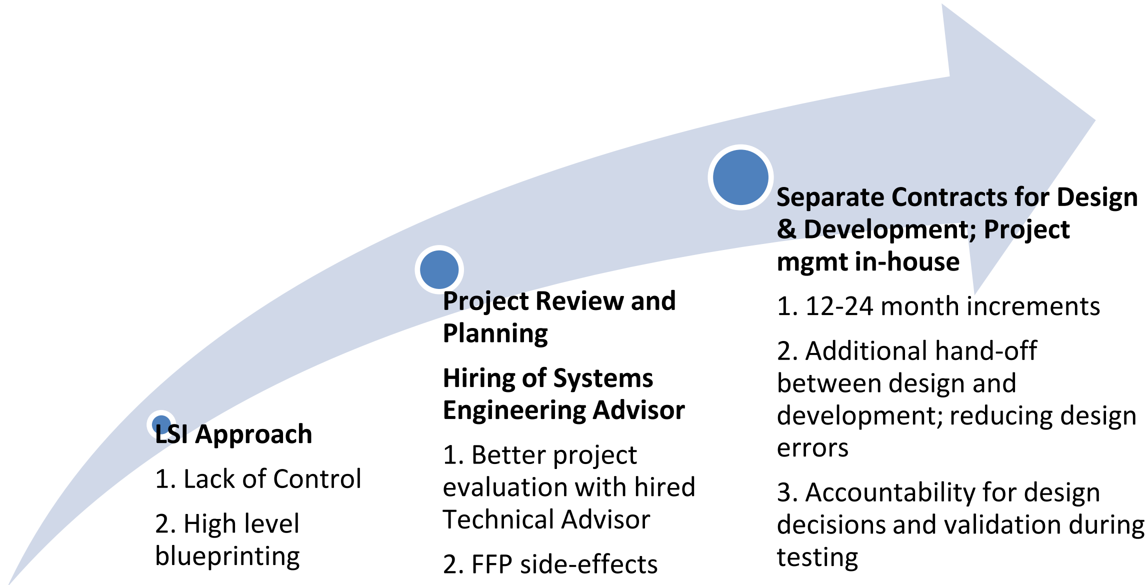

Figure 9: Changes in Acquisition Strategy for DEAMS

The DoD is in the process of hiring Oracle experts, who along with the Systems Engineering Advisor would be responsible for the joint system integration testing, training and deployment. The project management responsibility would also be brought in-house, with support from Systems Engineering Advisor organization.

3.3.3 Case Study - ECSS (Expeditionary Combat Support System)

ECSS along with DEAMS had been identified by Air Force as the key technology enablers to transform its logistics and financial management operations and achieve total asset visibility (United States Government Accountability Office (GAO), 2008).

As per the GAO report dated August 2008 (United States Government Accountability Office (GAO), 2008), ECSS is expected to provide a "single, integrated logistics system, including transportation, supply, maintenance and repair, and other key business functions directly related to logistics such as engineering and acquisition." Having accurate information of the above parameters will save inventory costs, improve the visibility of units; automate the order processing, inter-organization transfers, procurement requests etc.. Whereas, if the system does not work as desired, it could really affect the day-to-day operations and DoD could incur operational problems. If there are problems in information accuracy, there could be over-stock problems or shortage of units; the customer orders could be received believing to have the necessary inventory thus leading to failure in meeting deadlines and in the long-run affect the relationships with the suppliers and customers.

As per the April 2007 report by GAO on the Defense Inventory (United States GAO, 2007), it was reported that more than half of the Air Force's spare parts inventory worth an average of $31.4 billion was not needed. Additional consequences, as per the GAO report, were: In January 2007, Air Force had lost control and accountability over 5800 assets, valued at approximately $108 million due to lack of capability of the logistics systems to effectively manage, track and monitor deployed assets. To access and ascertain the benefits of the new system in business transformations and asset visibility, it is important to have performance metrics that can measure these improvements.

For a total asset visibility, integration between business systems, including logistics and financial management is required. The GAO report states that a lack of integration between business systems has adversely affected the ability of DoD and Air Force to ensure physical and financial accountability.

3.3.3.1 ECSS Statistics

As per the GAO Report on the Reported status of DoD's Enterprise planning systems dated March, 2012 (United States Government Accountability Office (GAO), 2012a), following are the statistics of ECSS:

Program Timeline: • Initiation Date • Original Scheduled Date of full deployment • Current Scheduled Date of full deployment	January 2004 Fiscal Year 2012 September 2017
Program Costs • Original life-cycle cost estimate • Current life-cycle cost estimate • Amount expended	$3 billion $5.2 billion $899 million
Program Deployment Details • Current Number of system users • Expected Number of system users at full deployment	225 250,000
• Current number of locations using system • Expected number of locations at full deployment • Legacy systems to be replaced • Annual cost of legacy systems • Number of System interfaces	6 186 240 $325 million 564
Other Statistics from GAO Report dated October 2010 (United States Government Accountability Office (GAO), 2010)**:**	
Few causes of slippage as per PMO	• Two contract award protests, causing stop-work actions • Change in implementation strategy (from 3 to 4 phases)
Program Owner:	Deputy Chief of Staff for Logistics, Installations, and Mission Support, Headquarters, U.S. Air Force

3.3.3.2 Interview Review

The interview with the Systems Engineering Advisor Team for ECSS provided clarifications on some of the processes followed by DoD in the ERP acquisition.

Source Selection Process

The ECSS project was started around 2004 timeframe. The COTS package was selected based on the capabilities identified in the Capabilities Definition Document. There were contract award protests which led to stop work actions, therefore ceasing any activities on the project, causing 6-8 months delay in total. The second step in the acquisition process was the selection of a contractor for technical execution through a bidding process.

During the bidding process, each contractor would specify how it would achieve the capabilities in a cost-effective manner. The source selection for LSI for ECSS was around the 2004-05' timeframe.

Contract Terms

The contract with the LSI was a firm fixed price contract. From the interviews conducted, it was learnt that there was a cap on the number of RICE components that would be implemented on the fixed price contract. Any additional components discovered during project execution would have to be raised as change requests.

In ECSS, during blueprinting, the number of RICE components identified was 1525 (out of which 735 were interfaces). However, during project implementation, the RICE components doubled to almost 3000 and these additional 1500 had to be raised as Change Orders.

The firm-fixed price contract is mainly driven and monitored by the sponsor organization by evaluating the Earned Value Management (EVM) metrics in addressing the list of functionalities specified in the design document. Thus, the main motivation of the contractor is to complete the tasks on time.

However, this could result in the system integrator trying every possible way to achieve the tasks completion on time and as per EVM schedule, even if that means having to do work around or deliver low-quality service. Unless there are strict peer reviews done by technical experts outside the contractor organization, this could eventually lead to poor quality and less robust system. The details on the errors reported by the users are listed in Section 3.3.4.

Change Board

The ECSS project has a tight governance mechanism. The Program Management Office (PMO) constituted of support contractors like Air Force "Blue-Suiters" (technical officers whose operational experience gives them a stamp of authenticity among industry, academia, and other government agencies (Beason, 2000)) , Engineering Contractors, a Systems Engineering Advisor and Logistics Transformation Office (LTO). Any change orders thus are thoroughly scrutinized by the Change Board and the governance was taken care of up to the lowest level of technical detail.

Peer Review Process

As mentioned earlier, a firm fixed price contract could drive the contractor to meet their schedules as per EVM at the cost of quality. An effective peer review process in place could balance these negatives. During ECSS, the Systems Engineering Advisor realized that the peer review committee from the sponsor organization did not necessarily have the same people who were involved in designing the functional requirements from the blue printing stage, as they moved on to new projects and new assignments. Thus, there was a lack of accountability and the peer review committee did not fully understand the requirements that were intended. The high level blue printing design also contributed to this gap. An effective transfer of knowledge is very important when a transformation in responsibilities is being done. Improving the accountability by assigning the peer review committee roles right in the beginning phases of the project, and involving some of the staff from the peer review committee in the blue printing stage will help set a background on the goals behind the ERP implementation, and help to understand any undocumented metrics to be kept in mind when conducting peer reviews. This could also save the time and effort of the Air Force Blue Suiters and the LTO officials in conducting knowledge transfer sessions.

Temporary Throw-away Interfaces

Most of the DoD projects follow phased implementation. In a phased implementation, if the roll-out is on different business units which do not interact with each other, then the effort is not majorly affected. However, if there are some legacy elements that are bound to be replaced in the next phase, then there needs to be temporary interface of the newly installed module so that the current legacy system is up and running and does not have to stop until the installation of the next phase. This results in additional effort in terms of temporary interfaces with legacy elements that would be thrown away once all the phases are implemented.

In identifying the number of temporary interfaces required and their efforts, a deeper understanding of the legacy system is required. Thus, a complete analysis of the temporary interfaces would be difficult during the blue printing stage, with the contractor having no expertise of the sponsor's legacy system. Thus in ECSS, the learning on legacy developed only during the project implementation.

Efficiency of Blue Printing stage

The ECSS team wanted to adopt the process-enabled process-reengineering approach in considering the best practices in the Oracle COTS package and working upwards to align it to the DoD business practices. In order to meet this requirement, they needed contractors who not only had an in depth knowledge of how Air Force process works but also expertise on Oracle Logistics system. In ECSS, the contractor hired as the LSI had prior ERP experience with SAP but was new to Oracle ERP package; the sponsor assumed that the contractor would be able to quickly adapt to Oracle with no major effort. On the other hand, DEAMS was particular on prior experience of the contractor on Oracle package. Thus, during the blue printing stage in ECSS, it was significantly difficult to arrive at the optimal requirements without delving deeper and having hands on experience with Oracle. A detailed blue printing was completed only in the 2007-08 timeframe.

An ideal blue printing document is one which would have a demonstration of the existing features and UIs already available in the ERP package; also displaying the changes that would be required if any changes/extensions were expected to be done. This gives the end-user of the sponsor organization a look and feel of the product thereby helping them visualize better. In hindsight, ECSS lacked this detailed demonstration and the blue printing was very high level, thus providing contractors an opportunity for moral hazard, by allowing flexibility to design in ways cost-effective to them. As mentioned earlier, the peer review committee was not involved in the blueprinting stage and therefore lacked in-depth understanding of the system requirements. Thus a very high-level design and the peer review committee's lack of understanding of the detailed design affected the requirements testability, therefore influencing the quality assurance reviews.

ECSS being an Air Force logistics system could have had requirements which are specific to the Air Force due to the complexity and difference in operations compared to a commercial logistics system. It would be fair to consider that ECSS blue printing was much more difficult than that of DEAMS, considering the commonality of the respective modules with the commercial sector.
This clearly gives us the contrast between the two cases – the ability of the two system integrators in correctly predicting the estimates and driving the DoD's expectations; one scoping down to fit the timelines and schedule; and the other expanding to meet the interface needs with the project progress resulting in cost and schedule overrun. Figure 10 below demonstrates the reduction in the number of interfaces during the blue-printing stage in the DEAMS case; as the contractor could convince DoD that the Billing system could raise large interfaces affecting the scope of the project. In ECSS, the number of interfaces almost doubled from 1500 to 3000, exceeding the cap of the RICE components as per the contract terms.

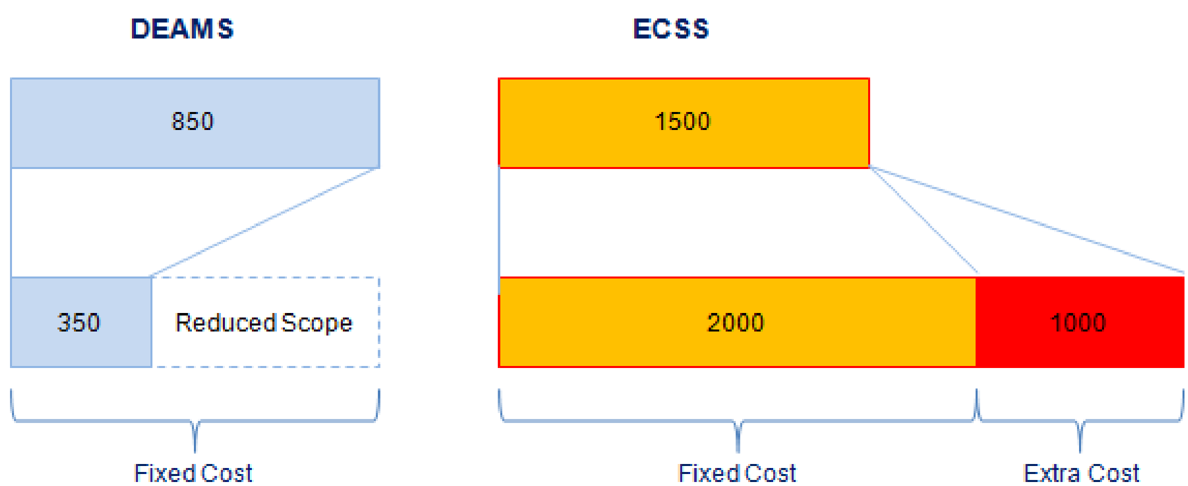

Figure 10: Contrast in Fixed Price Contract outcomes in DEAMS and ECSS

ECSS had significant problems in discovering interfaces with legacy during the blue printing stage. With the progress in development, there were new additions to the set of requirements;

thus generating moving targets. This turned into an evolutionary approach to system development. ECSS then adopted to do conference room pilots to discover the target configuration.

Change in Acquisition Strategy

ECSS had adopted the LSI governance model (Refer Section 2.5) in the beginning of the ECSS project in 2006. However, with the LSI approach, the DoD found itself unable to effectively track and monitor the progress of the project. The blue printing phase was completed around the 2008 timeline. DoD soon realized that FFP contract terms was driving wrong behavior on the LSI side, becoming more schedule driven even if it meant to have workarounds, thus compromising on quality. DoD came to a realization that the blue printing was not done to the level of detail required, and the process became more of an evolutionary approach to system requirements, thus discovering new requirements during the development stage.

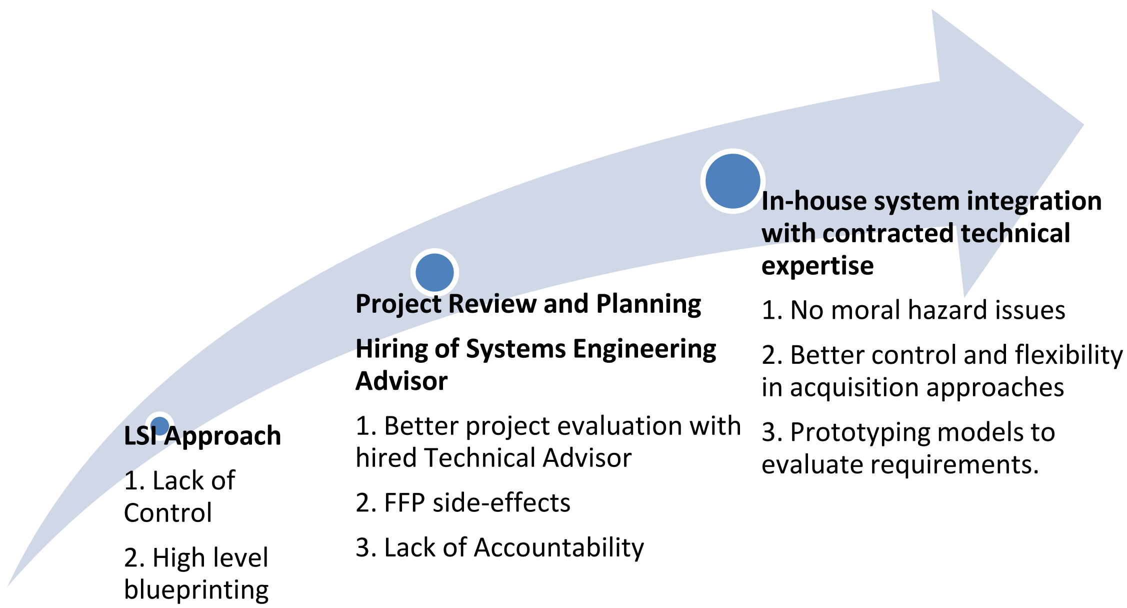

Figure 11: Changes in ECSS Acquisition Strategy

With the DoD ECSS team gaining more experience with Oracle, in 2008, Air Force hired more Oracle ERP experts to have technical oversight. The initial schedule had not accounted for rework, and the peer review quality on the work accomplished by LSI was not effective. The lack of clarity on the requirements due to high-level blue printing has led to ECSS revising its acquisition methodology.

Future Steps: ECSS now wants to move from LSI to having system integration in house with contracted technical expertise as depicted in Figure 11 above. Air Force will lead the system integration and the technical direction will be provided by the Air Force. Air Force is drafting a Critical Change Report (Conation & Morin, 2012) for the major restructuring as ECSS is now adopting to do conference room pilots to discover the target configuration.

Evaluating the RICE components

As per some of the interviews done, evaluating the effort required for each of the RICE components was the most difficult and uncertain part of the schedule and cost estimation. For DoD, lack of in-house Oracle expertise, led them to having absolutely no validation control over the estimations on the RICE components. For example, it was unclear whether a UI having a master-detail form format should be treated as a single or two RICE components. Such information asymmetries could lead to differences in initial estimations of RICE components from the sponsor v/s the contractor perspective. An initial understanding of the different types of components and rating them as per the complexity level will help in reducing this information asymmetry. For example, less than 10 parameters in the report could be treated as a low complexity report.

3.3.4 Reported Issues on DEAMS and ECSS

Independent assessments done by Army Test and Evaluation Command (ATEC) and Air Force Operational and Test Evaluation Center (AFOTEC) on the ERP systems have shown that there were significant inefficiencies and data inaccuracies which need to be sorted out. The following is the summary of the problems reported (United States Government Accountability Office (GAO), 2012b) :

DEAMS

- DoD Oversight authority has limited deployment of DEAMS as there were errors and missing functionalities that needed corrections.
- The monthly accounts receivable aging report, initially identified as per capability document, cannot be generated.
- The Defense Finance and Accounting Service (DFAS) personnel felt that the training received on DEAMS was insufficient and did not train them on the skills required to run day-to-day operations.
- Assessments conducted by ATEC and AFOTEC reported problems on data quality, data conversions and system interfaces.
- As per the AFOTEC, in January 2011, substantial manual intervention had to be done to enter data. Inoperable interfaces, and required reports were not available or had errors.
- As of May 2011, 245 problems were still to be addressed.
- Interface problems with 'Standard Procurement System' compelled them to turn off the interface due to data inconsistency.
- The ad-hoc query reports which were available in the legacy were not provided in the new system.

The issues reported for DEAMS raises questions about the importance of data conversions and the testing performed in verifying the data quality and consistency. There were certain reports from legacy that were also expected to be available in the new system. However, the capabilities identified failed to address these concerns of the end users.

ECSS

The following review corresponds to Release 1 Pilot A. With the limited scope of Pilot A, AFOTEC did not have sufficient data to validate all the requirements and access the performance of the system. Out of the 120 one-way interfaces to be developed for ECSS in Release 1, Pilot A had only two. Thus, with limited scope of completed deployment, the reviews on ECSS were substantially less than that of DEAMS.

- As per the AFOTEC review, many of the system requirements were written at a very high level and did not address the specific functional capabilities desired by ECSS.
- Interviews with SMEs identified concerns in "data quality, conversions, interoperability, usability, information assurance, and requirements testability".

Specific timelines were not yet identified for resolving the above issues neither for ECSS nor DEAMS.

The critical success factors and their importance have already been described in the literature review section. From the limited amount of exposure and restricted interview time, it was difficult to capture the significance of each of those factors and their impact in the government projects. However, with the available knowledge, a comparison of these projects and the extent to which the CSFs were adhered are discussed in the later part of this section. In trying to understand the main issues that were reported in the GAO report, here is an analysis of few of the critical success factors and the reasons why DoD experienced schedule and cost overruns.

Causes of Inaccurate Estimations

Although there could be many reasons for inaccurate estimations during the blue-printing stage, leading to schedule and budget slippage, Table 5 below represents the key issues that surfaced during the interview process:

Inaccurate Estimations		
Integration Issues	**BPR Issues**	**External Issues**
• Inexperienced Contractors - learning on the job, error-prone blue-printing. • Phased Implementation - Temporary throw-away interfaces • Lack of legacy knowledge - to determine the complexity in integration • Data conversion issues	• Lack of functional experts – incomplete/inaccurate list of requirements during blue-printing stage • Lack of legacy knowledge – if desirable to retain some best practices	• Policy changes in acquisition procedure • Issues outside the boundary of project execution: - Contract award protests (as in ECSS) - Need to adopt COTS to AF user interface desktops (as in DEAMS)

Table 5: Generic Causes of Inaccurate Estimations in DoD Projects

Integration Issues

If the contractor employed for system integration has no experience working on the COTS package selected by the sponsor organization, then it might be unaware on the level of complexity for a given interface and this might result in incorrect estimate of the work. For example, the contractor might have prior experience with SAP and not Oracle.

The estimates for the set ups during installation are also highly dependent on the level of expertise of the sponsor organization on the package and the module being implemented. To avoid this variation on the basis of the LSI experience level, firm fixed price contract is an appropriate way to charge the customers. The entire project works as per the initial estimates and the contractor performance is measured by their adherence to the EVM.

The loopholes of firm fixed price contract is that the contractors are motivated to adhere to the EVM, and this might result in them opting for work-around when there are schedule and time constraints.

BPR Issues

During the blue-printing stage, if the functional experts in the sponsor organization are not well versed with the way the organization works, there is no clarity on the functional requirements, which would further delay the decisions between retaining legacy and adopting the business processes to a later stage. As in DEAMS, some of the legacy reports which were very useful to the end users were missing in the new system. Was the blue-printing committee unaware of this requirement and its priority? If the legacy had sufficient useful reports, the decision of retaining that module could have been taken early on in the project. The functional knowledge will also help in identifying the priorities between the business requirements and make trade-off decisions in case of budget constraints.

A clear understanding of the functional specifications along with what legacy elements are to be retained will bring clarity in estimating the efforts.

External Issues

An update on the internet explorer 7 created compatibility issues with the GCSS-AF Integration framework (as discussed in Section 3.3.1) therefore causing a delay at the Scott Air Force base location, the first deployment location of DEAMS. ECSS faced stop work actions due to contract award protests at the time of source selection. These are external issues, which not only cause delay in schedule; but might require additional work. For instance, additional installers would have been required for DEAMS to be compatible with the new desktop configurations. For ECSS, the work on refining capabilities would have been in progress when the stop work actions happened. This ceased all the project work and would have caused degradation in the learning curves of the staff. Thus, any learning would have to start from phase 0, after the project resumes.

PMO (Program Management Office)

The initial phases of both the projects started with the LSI model; with the system integrator responsible for all the activities including project management. However, the DoD felt a loss of control over the project and is now moving towards the "Contract" (Refer section 2.4) governance model with only the technical execution outsourced to a contractor. DEAMS will have the requirements management and project management in house with the support of the Systems Engineering Advisor. The advisor's support will help not only in making better choices on the technology architecture and design, but also improves the review process after each phase. DEAMS suffered significant delay in integration testing and missed many of the requirements that were expected during the blue printing stage. The future spirals of DEAMS will have separate RFPs for design and development. With the additional hand-off between the design and development contractors, any design level errors can be detected early on. The completeness of the blue printing stage will also improve as the total ownership factor is brought in. There could be issues of information asymmetry between the two contractors in the understanding of the requirements; and any missing functionality would result in blame game between the two contractors. It is therefore important to identify the right contract terms, and identify contingencies and conflict resolution plans early on in the project.

In evaluating the methodology of hiring multiple contractors, Table 6 below lists the advantages and disadvantages of having a sole contractor v/s having multiple contractors (Thong, Yap, & Raman, 1994):

Multiple Contractors	Single Contractor
(+) Impartial assessment of the sponsor's requirements leading to better solution design, unlike the LSI model which incentivizes the contractor to jack up the estimations (+) Formalized approach to IS implementation, lengthy evaluation process (-) In an unsuccessful implementation, chances of parties blaming each other, difficulty for sponsor organization to track the causes	(+) Savings in cost with only one party being hired (+) Improved communication and coordination with sponsor organization (+) Less chance of blame game and easier conflict resolution (-) Contractors could use the information asymmetry to their advantage and drive the project scope to their advantage

Table 6: Pros and Cons of single v/s Multiple Contractors

3.3.5 Comparison of DEAMS and ECSS with CSFs from Literature

Table 7 below summarizes the processes followed in ECSS and DEAMS with a comparison of what literature suggests:

Critical Success Factor	**ECSS**	**DEAMS**	**Comparison with Literature**
Source Selection Process	Capabilities were identified followed by the selection of ERP package. ECSS faced contract award protests during the COTS selection; leading to a delay of 6-8 months.	DEAMS aimed to meet the new Air Force accounting rules; had its high level capabilities identified. An RFP was sent out to the ERP vendors to identify which COTS product was more appropriate.	Literature talks about ERP package selection based on the capabilities desired. Few of the ERPs processes could match closely with the desired goals, therefore reducing the number of customizations. However, it was unclear from the two cases; if a detailed level comparison was made, as the capabilities were also very high level.
Contractor Selection	LSI hired, although had SAP experience, did not have prior experience with Oracle	LSI hired, had prior experience working with Oracle, the COTS package selected	Literature speaks of having a contractor who has had experience working on the ERP and RICE implementations. Also since the contractor is also involved in the blue-printing stage in evaluating the number of RICE components and their timelines, it is crucial to have a party who is experienced. Lack of internal ERP expertise also puts the government in a risky situation.
Blue Printing Process	The blue-printing for ECSS was very high level as the LSI hired had no prior Oracle experience. Also, the ECSS being a logistics system would have differed from the commercial logistics system.	The blue-printing for DEAMS was more effective than ECSS as the LSI had prior Oracle experience. DEAMS was an accounting system which can be presumed to not differ much from the commercial accounting.	When the contractor is not well versed with the ERP package, it becomes difficult to arrive at the technical specifications. In such scenario, having a third party help with the design and scheduling would reduce the risks of inappropriate estimations and timelines.

Contract Agreement	Firm fixed price contract in the initial phases. Currently undergoing changes to identify the appropriate terms.	Firm fixed price contract in the initial phases. Might undergo changes in the contract terms as DEAMS will have separate RFPs for design and development.	Cost plus contracts are at the mercy of the contractor's productivity. A firm fixed price contract ensures that the contractor strictly adheres to the EVM. An effective peer review will help control the quality of work delivered by the contractor in their motivations to get work done quickly.
Change Board	PMO constituted of support contractors like Air Force Blue Suiters, Engineering Contractors, a Systems Engineering Advisor and Logistics Transformation Office.	The PMO in DEAMS also constituted the functional experts as well as technical expertise, and was efficient to identify and validate any change requests generated.	DEAMS and ECSS hired a Systems Engineering Advisor to have better oversight over the technical execution and solution design.

Table 7: Comparison of DEAMS and ECSS with CSFs from Literature

Comparison of Different Contract Models

DEAMS and ECSS are undergoing a change in the acquisition strategy. Previously, DEAMS and ECSS had hired a LSI and Systems Engineering Advisor, with the LSI responsible for the entire execution of the project. DoD experienced loss of control and therefore was unable to take corrective actions on schedule and budget slippages.

Both DEAMS and ECSS are revising their acquisition strategy. DEAMS will now opt for separate RFPs for Design and Development. ECSS on the other hand plans to have the project management in-house with contracted technical expertise. Table 8 below is a rough analysis of the pros and cons of the different model types.

Model	Advantages	Disadvantages
LSI	• Bidding procedure to be done only for single contractor • No sponsor responsibilities on project management, tracking etc • Entire responsibility of project completion on the LSI	As per the Defense Acquisition Document (Grasso, 2010), following are the loopholes in LSI model: • No transparency on project costs, oversight issues • Self certification issues – no external certification • Conflict of Interests - Design of requirements - Sub- contractor selection criteria • Any design errors are carried forward into development
Separate contracts for Design and Development; System Integration in-house	• DoD has the flexibility to frame the contract terms • Additional hand-off re-validates the design efficiency • Less chances of moral hazard with re-validation from the other contractor.	• Any rework or change requests would need multi-party approval process • Possibility of misinterpretation of requirements by the development contractor • Might be difficult to track causes in the event of failure • Cost of hiring two contractors • Possibility of conflicts, as undiscovered design elements might exist due to temporary interfaces – development contractor would be in a better position to design the interfaces as their experience and knowledge on legacy would have grown until then.
All in-house	• Possibility to assign the best people for the project • No issues of moral hazard. • A more transparent way to execute the project • Team's interests aligned with the success of the project	• Hiring the ERP talent and retaining is a challenge • Coping up with the technology trends and keeping the employees abreast is crucial to build their expertise • Difficult to lay off permanent employees

Table 8: Comparison of Different Contract Models

Each of the contract models has its own advantages and disadvantages. The sponsor organization will need to make a decision based on the clarity of goals, technology life-cycle and in-house expertise. Special attention is needed on the contract terms while dealing with contractors. Risk elements need to be identified during the design phase, and contracts should include decision processes for any such contingencies, to avoid unnecessary conflicts in the future.

Impact of the Different Contract Models on the Critical Success Factors

Table 9 below is an analysis of the impact of the different contract models on the critical success factors discussed in section 2.2. Attempts have been made to address these impacts in terms of the incentives of each of the stakeholders and how a different type of contract could align the motivations of a contractor with the sponsor's motivations.

Critical Success Factor	**LSI Model**	**Design & Development Contracts**	**In house**
Top Management Support	The ERP implementation is a strategic choice. In the LSI model, the involvement of top management in the decision making of the strategic choices is very limited. There has to be integration activities between the sponsor and LSI to ensure that the sponsor organization's goals are met.	The top management support in this model is extremely crucial, as there could be potential conflicts with multiple contractors involved. Also, the entire execution of this model requires close monitoring by the top management, as the multi-party communication requires their support for emphasizing the size and impact of the project	With the entire implementation handled internally, the goals are definitely much more transparent to the end users. However, the top management has to ensure that the project is taken seriously and organizational changes are conducted in a smooth fashion.

Project Team Competence	The sole responsibility is with the LSI. Difficult to predict their competence during the bidding stage. The credibility and reputation of the contractor can be one way to analyze their competence. However, within the LSI team, the good resources could also be in demand for other projects. One common approach to attract the best resources is to specify the skill sets and years of experience of the staff in the contract.	There are three teams to be evaluated – In-house system integration, Design contractor and development contractor teams. The development effort can be evaluated using peer review process.	The in-house model is quite straight-forward. The sponsor organization can assign the best people on the job. However, significant effort and expenses are required to retain and grow competent talent. The demand of good talent in other projects could be one hindrance to this model.
Interdepartmental Cooperation	The LSI is responsible for all the stages in the project life-cycle. The LSI will have to get the sponsor organization involved in the discussions with other departments for any collaborative effort, especially when the budget allotments for these departments are different, and the incentives for collaboration are low.	The design contractor would have to get the sponsor organization involved while designing the solution architecture to know the integration elements with other department design teams. There could be possibilities of conflict across the development teams if the integration elements are not well documented during the solution architecture stage.	As the entire team is in-house, it becomes much easier to negotiate with the other teams on the integration elements.

Clear goals and objectives	Although the capabilities required are communicated by the sponsor organization to the LSI, the clarity of goals is largely dependent on the LSI's prior experience with ERP and the functionality domain. Lack of experience has to be compensated in other ways – example, agile approach to development where the solution is developed in increments and validated with the end user at regular intervals	During the design phase, many of the goals might not be transparent. Hence, having the complete master plan during the design phase is improbable. Some of the elements of doubt that arise during the design phase have to be well documented, so that the development contractor does not oversee these risk elements and gets clarity as the project progresses.	An in-house team having experience with Air force processes as well as the ERP selected for implementation; ideally can generate clear goals and objectives. IT expertise in-house will also be knowledgeable on the legacy systems and know the integration difficulties and risks during design phase.
Project Management	In an LSI model, the sponsor organization has no control over project execution. Thus, it becomes difficult to track the progress and might result in schedule overrun if the incentive structure is not set appropriately.	With the project management in-house, the execution can very well be controlled in this model. However, the contract agreements are to be selected carefully on the basis of clarity of goals, technology life-cycle and economic conditions. Contingencies need to be identified in the contract to avoid compensating for outlier or risky situations in the future.	A project champion and a PMO office have to be identified to track and monitor the progress. Sponsor organizations often fall into the trap of taking things for granted when the project execution committee is internal.

Project Champion	With the LSI model, it becomes difficult if the project champion is internal, as there is no control of the sponsor organization on the project execution. The LSI would have its own plan of execution and therefore a project champion would have to coordinate with the LSI to successfully perform the transformation and conduct training sessions to the users. Training sessions should be included as part of the contract.	As the project management is internal to the sponsor organization, the project champion can therefore control the organizational change and conduct collaborative sessions with the design contractor, development contractor and the end users. The contract however, has to be carefully drafted to ensure that time is allotted for such sessions.	An in-house model can easily accommodate a project champion for coordinating the transformational leadership.
Minimal Customization v/s BPR	In the LSI model, although the initial capabilities are provided by the sponsor organization, the lack of in-house expertise would hinder in evaluating what extent of customization is appropriate. However, with the functional expertise in-house, the sponsor can request the impact of avoiding customization on the business process re-engineering. This helps them to evaluate the organizational changes and impact on the business.	With the design contractor having no incentives to jack up the RICE components, the expectation of this model is that the decision between customization and BPR will be taken after thorough analysis of impact on organizational changes. This however would demand extra effort from the design contractor. Thus, this motivation could be severely hit if the contract terms, for example, is a fixed price contract; as they would tend to wrap up the work with least effort.	With the in-house model, the motivations of the team are aligned with the organization's motivations; and thus can expect that any decisions between customization and BPR are taken only after analyzing the impacts on organizational processes; and whether the customizations are worth the effort and money. There has to be an active collaboration between the IT and functional experts to be able to conduct this analysis.

Table 9: Impact of Different Contract Models on Critical Success Factors

Each of the three models has its pros and cons. However, one crucial element common to any contracting is the way the incentives are aligned; and the contract terms set in the initiation stage of the project. This is highly dependent on the level of clarity in the requirements, the extent of oversight control that the sponsor has, and the risks identified during the blue printing stage.

4. System Dynamics Modeling

4.1 Introduction to System Dynamics

The concept of "Holistic" system design states that a system's functionality as a whole is greater than the sum of its parts. This gives us a background on why systems are not static and the changes in one sub-system can cause changes in the functionality of the other sub-systems and the system as a whole.

The study of "System Dynamics" was created by Professor Jay W. Forrester during the mid-1950s at the Massachusetts Institute of Technology (System Dynamics Society, n.d.). System Dynamics adopts the theory of non-linear dynamics and feedback control developed in mathematics, physics and engineering (Sterman, 2000).

Much of the non-linearities in System Dynamics modeling are represented using stock and flow diagrams and time delays. Any dynamics representing causation between variables generate feedback loops, which could either be positive (reinforcing) or negative (balancing). Stocks are accumulations, and have memory. Observation of a stock at any given point in time gives its value. The flow is the rate at which stocks accumulate. To identify a rate or flow, one has to measure it over a period of time, as they have no memory.

Consider a simple example of a system dynamics model represented in Figure 12 below.

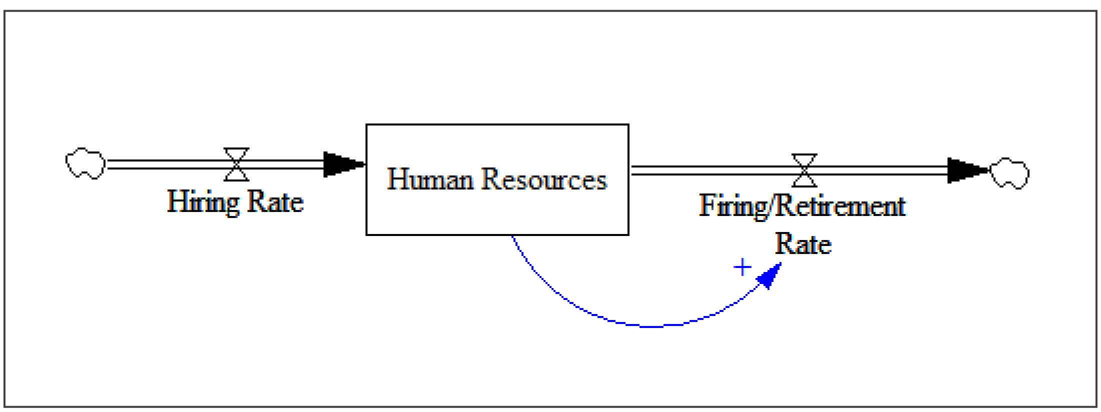

Figure 12: A simple demonstration of stock and flows

The stock in the Figure 12 above is "Human Resources". It has an accumulated value, and at any point in time in a given year, one can find out the number of people working in an organization by checking the Human Resource number. The flows are "Hiring Rate" and "Firing/Retirement Rate". The number of people being hired cannot be known at a single point in time, and has to be observed over the duration of a month or a year. This was a simple example to explain the stocks and flows which are central to System Dynamics.

Reinforcing and Balancing Feedback Loops

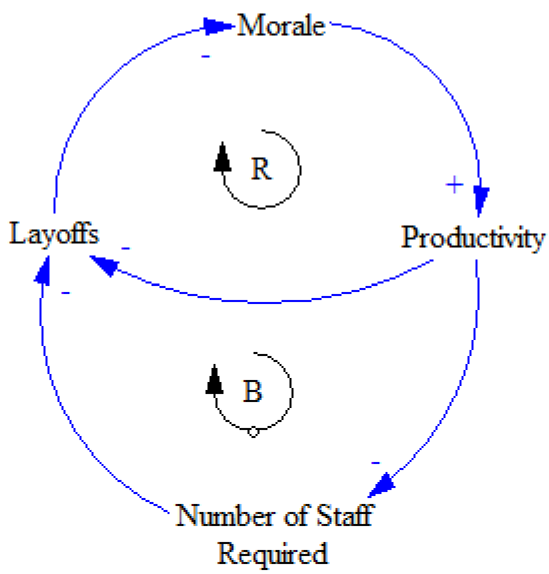

Figure 13: Simple Example of Reinforcing and Balancing Loops

Figure 13 is a simple example demonstrating the reinforcing and balancing loops. If layoffs increase, the morale of the employees reduces and hence productivity reduces causing further layoffs. This represents the upper half of the loop represented as "R" for reinforcing effect.

From the lower half of the figure, if the productivity increases, the number of staff required to do the job reduces, thus increasing layoffs, which negatively affects morale, thus decreasing productivity. This loop starts with an increase in productivity and ends with a decrease. Thus, this reflects a balancing loop. This introduction of the stocks and flows and positive and negative loops will help in understanding the actual model described in the following section.

4.2 Contractor Governance

As discussed in the literature review section on the Agency Theory, the following causal loop diagram demonstrates the way the contractor adopts for opportunistic behavior. If the Sponsor organization has no internal IT competence to evaluate the technical developments in the project, the gap in implementation knowledge increases resulting in lesser transparency of the contractor's technical competence and achievements within the project. This gives the contractor an opportunity for moral hazard thereby creating further information asymmetry between the contractor and the sponsor, reinforcing the knowledge gap, as depicted in Figure 14 below.

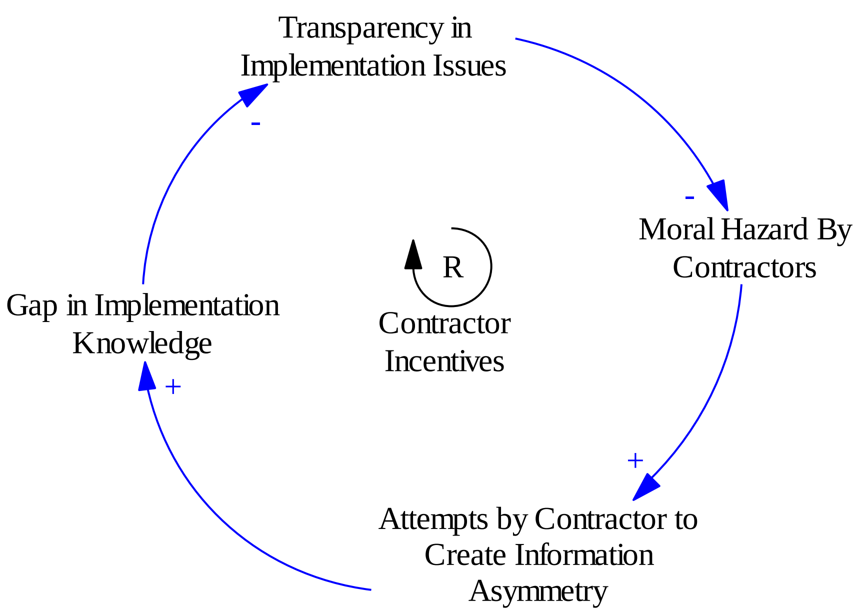

Figure 14: Contractor Incentives

McKenna (McKenna, 2005), in his paper "Projects with Contractors", has explained the Variation Order – communication loop. The following causal loop diagram in Figure 15 illustrates the same. With more contract variation orders raised by the contractor, the budget is bound to get affected thereby reducing the sponsor satisfaction with the contractor's performance. This could affect their working relationship and might curb down on the integration activities. Thus, the gaps between what capabilities are desired and what solution is being offered grows, leading to further generation of variation orders. Figure 15 below demonstrates the causal effects of variation order- communication loop (McKenna, 2005).

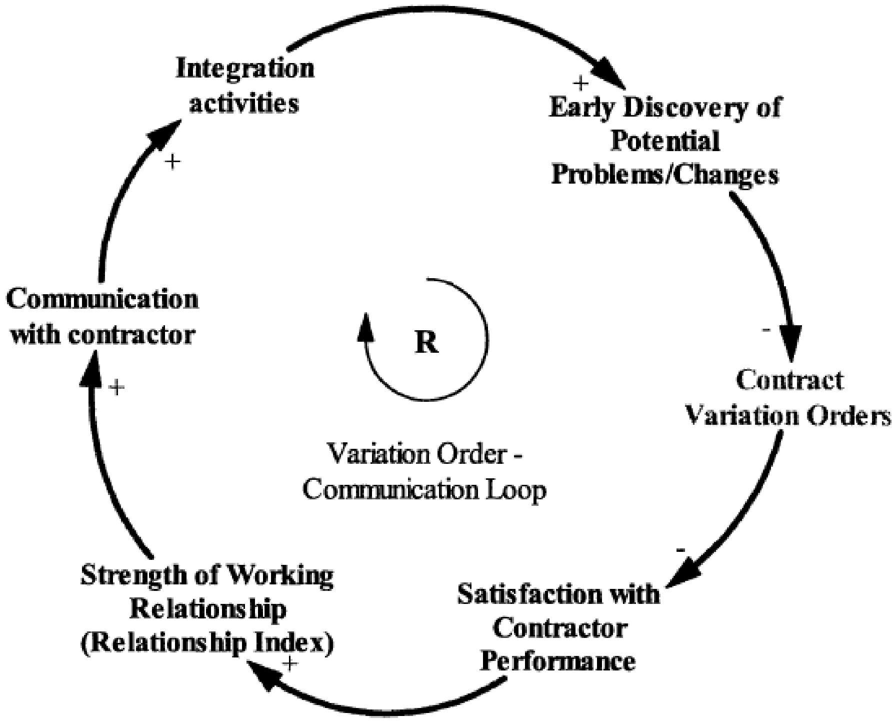

Figure 15: Variation Order - Communication Loop

Both DEAMS and ECSS projects had systems engineering advisor hired for the technical oversight. If the sponsor organization has no internal expertise to evaluate the progress and quality of the project, it becomes extremely difficult to have control on the contractor's behavior. Having an advisor would help in reducing the implementation knowledge gap and thus the sponsor would be able to better comprehend the contractor's activities. This in a way also keeps a check on the contractor in not opting for moral hazard, as their activities are more transparent and the risks of losing reputation increases. In the following causal loop, the balancing loop 'Control over Contractor Behavior' explains the above phenomenon.

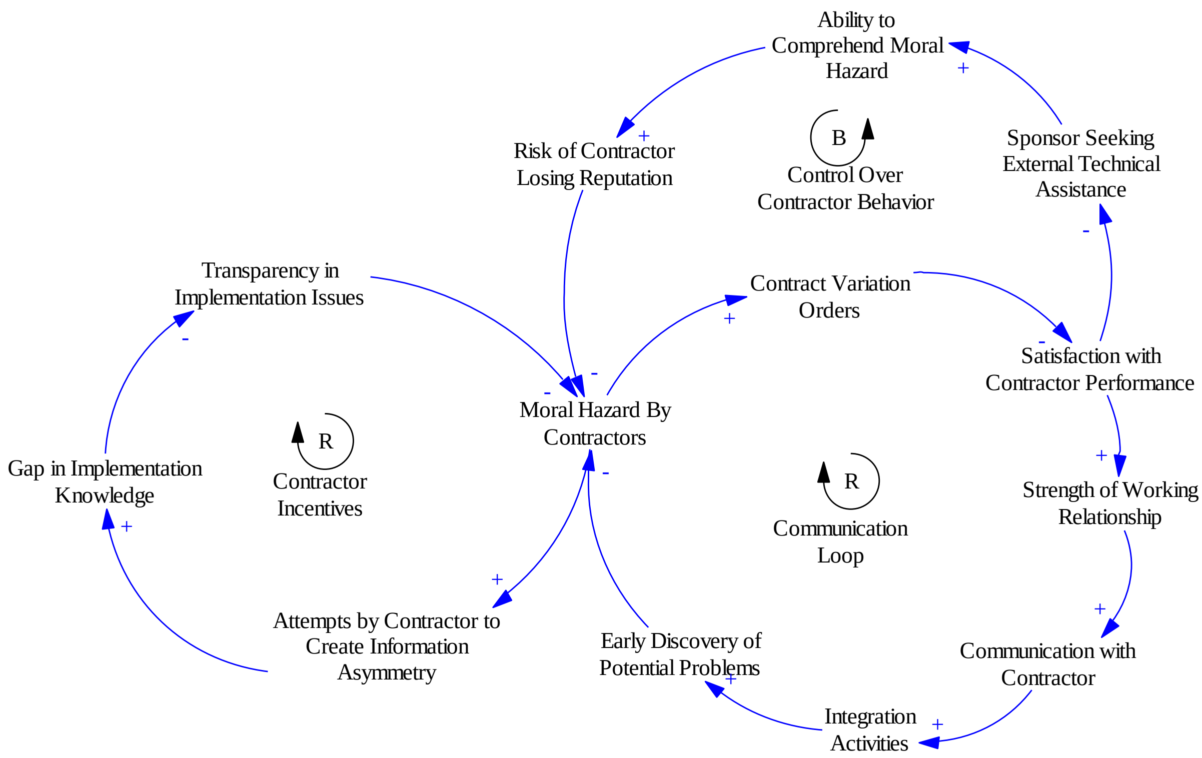

Figure 16: Incentives to Hire Technical Advisor

The above causal loop shown in Figure 16 supports the idea of having technical oversight on the contractor to avoid information asymmetry and moral hazard issues. This causal loop diagram illustrates the ability of the sponsor organization in being able to better predict the estimations of the RICE components in the project management in-house scenario in the system dynamics model.

4.3 Description of the Model

The system dynamics model attempts to address the impact of a few project management levers on the overall project schedule. The elements below are discussed in the following sections:

1. Classic Rework Model
2. Contractor's Comprehension on Requirements
3. Addition of New Work
4. Adverse Selection by Contractor
5. Staffing
6. Effect of Experience on Productivity

4.3.1 Classic Rework Model

The classic rework model (Abdel-Hamid & Madnick, 1991) is shown below in Figure 17. In conventional project planning, the master schedule constitutes all the tasks required to accomplish, with timelines against each of them. However, when the project is initiated, there could be uncertainties either in terms of technical understanding or functional requirements. Also, the initial requirements identified could have defects and the sponsor's perceptions could evolve over time. Under all these circumstances, there is a parallel generation of rework along with the work correctly done. The factor Fraction Correct and Complete (FCC) represents the extent to which the work being accomplished is correctly done. Thus, FCC represents the percentage of Work Being Accomplished moving into the stock of "Work Done". The remainder of the Work Being Accomplished i.e. *(1-FCC)*Work Being Accomplished* flows into the stock of "Undiscovered Rework". The discovery of this rework takes place after the project has been demonstrated to the end user, during unit testing or as the development team gains further experience with project implementation. This discovered rework gets added onto the stock of "Work To Do".

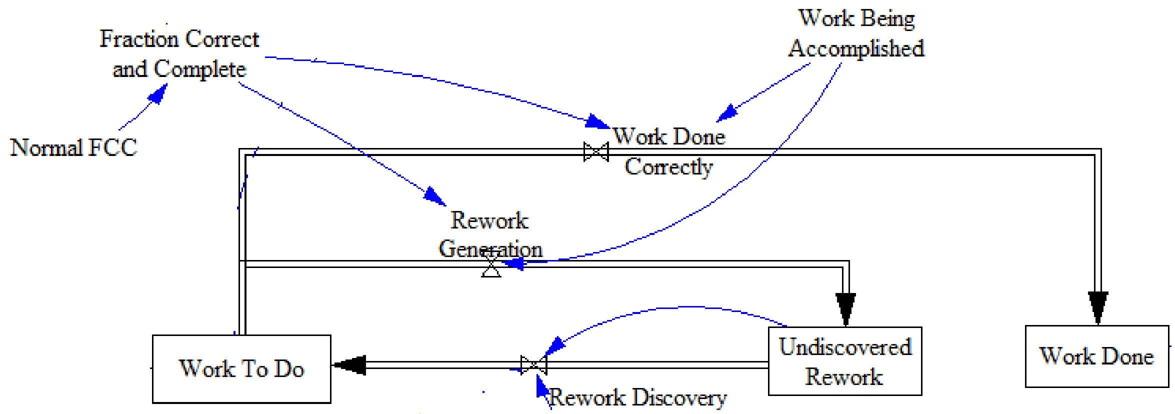

Figure 17: Classic Rework Model

Work Done Correctly = Work Being Accomplished*Fraction Correct and Complete

Rework Generation = Project Finished*Undiscovered Rework/Time to Discover Rework

The undiscovered rework can be of two types:

1. Undiscovered technical errors
2. Undiscovered functional change requests

LSI Model Behavior

In an LSI model, with the firm fixed price contract, the contractor is being paid the same amount of money irrespective of the technical rework generated. (The functional change requests might need re-negotiating the value of the contract depending on the impact). Thus, the incentives to stick to schedule are high in a firm fixed price contract and might drive the contractor in recruiting an experienced team, if the incentives for low peer review errors are set.

However, if the contract terms are on time and material labor hours, the lack of control of the sponsor in monitoring the errors generated due to technical incompetence, might drive the contractor in fixing the technical errors on paid hours. Thus, there is no incentive for the contractor to hire the best people on the job, as the rework is also raised as change requests and the labor is paid for all the extra hours.

Yet another behavior could be that the initial estimates provided by the contractor are on the basis of the level of experience in the team. Thus, the productivity of the team could be low, but could avoid creating technical rework as the staff has time to learn and implement.

Contract with Project Management In-house

In a contract where the project management is in-house, the discovery of rework can be closely monitored, and any technical errors can be excluded from the billing hours of the contractor. However, the effects on schedule due to these technical errors cannot be avoided if the contract is time and materials; and has no incentives to adhere to the schedule.

In an FFP, the contractor has to successfully accomplish a given number of RICE components within schedule. This ensures that the obvious technical gaps can be taken care of, within the fixed price budget. However, the not-so-obvious technical errors which determine the actual quality of the development effort would be compromised if sufficient time and effort is not dedicated to peer review process in the master schedule.

4.3.2 Contactor's Comprehension on Requirements

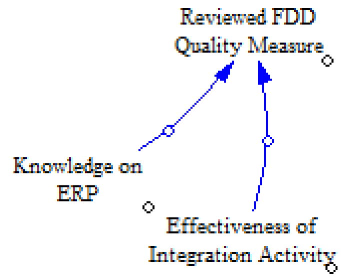

Figure 18: FDD Quality Measure

During the blue-printing stage, the contractor and the sponsor organization collaboratively work to address the gaps in the capabilities document, and refine the capabilities to generate system specifications. A prior knowledge of ERP will help in designing the requirements and demonstrating how the specifications can be met using the features in ERP. The functional design document (FDD) is generated, which has requirements to the lowest level of detail, and the design of any reports or user interfaces desired. There could be information asymmetry between what the sponsor desires and what the contractor has understood. If the functional design document can demonstrate in terms of prototyping or design look and feel, it could reduce this information asymmetry and the sponsor would be able to clarify the requirements during the design phase. Hence, the FDD quality measure depends on the following parameters, as shown in Figure 18.

1. Contractor's knowledge on ERP
2. Effectiveness of Integration activity

The law of garbage in garbage out says that if the requirements are not well understood, then the development will have to go through rework cycles. It could happen that the contractor misunderstands the requirements if it has no functional domain knowledge on the system being implemented. For example, it would be difficult for a contractor who has no Oracle manufacturing experience to be able to understand Oracle Costing methods.

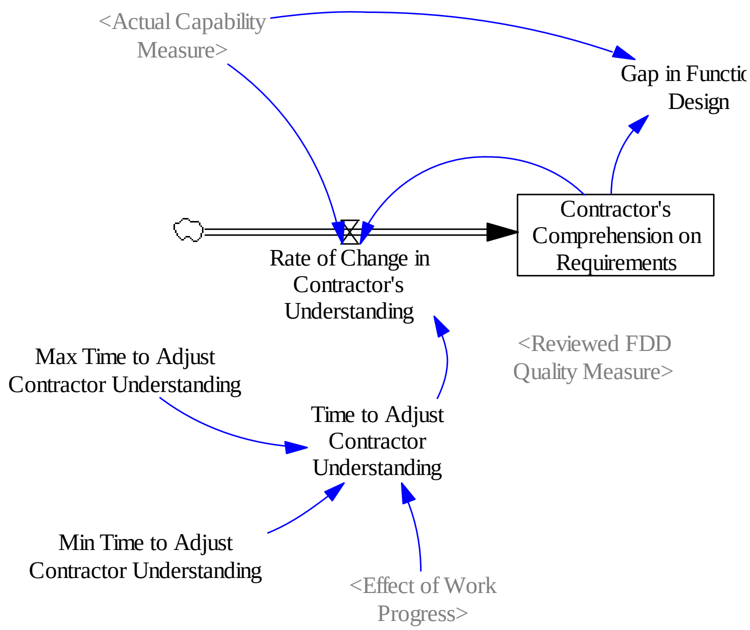

Figure 19: Information delay in Changing Contractor's Comprehension on Requirements

Figure 19 above demonstrates the phenomenon of change in contractor's comprehension of requirements. The stock "Contractor's Comprehension on Requirements" has an initial value of "Reviewed FDD Quality Measure". If the integration activity during blue printing was efficient and the functional design document was well understood and approved by the sponsor organization, then the value of "Reviewed FDD Quality Measure" is 1 and there is no gap in the understanding of the functional design.

If the value of "Reviewed FDD Quality Measure" is less than 1, then the Contractor's comprehension of the requirements gradually adjusts to 1 at the "Rate of Change in Contractor's Understanding". The time taken to adjust contractor's understanding is dependent on the work progress. Based on the work progress the time factor reduces from the maximum to the minimum.

Time to Adjust Contractor Understanding = Max Time to Adjust Contractor Understanding*Effect of Work Progress + (1-Effect of Work Progress)*Min Time to Adjust Contractor Understanding

Here, the maximum time to adjust contractor understanding can be treated as the time taken to receive feedback from the end user. Minimum time to adjust contractor understanding would be significantly less, say the time taken to complete two RICE components i.e. around 4 months. We do not have exact measure of what is the least amount of time taken; so we can assume it to be equal to two RICE components because once the next task in the critical path is completed, we get sufficient knowledge of what could be the issues with the previously completed task. As time progresses and as the contractor has achieved significant work progress, the time to adjust contractor's understanding of the requirements reduces drifting from the maximum time to minimum time.

The following is the graph of "Contractor's Comprehension on Requirements" with the following values for the contributing variables:

Minimum Time to Adjust Contractor Understanding = 0.25 years

Maximum Time to Adjust Contractor Understanding = 2 years

There are two simulations marked below with varying values of Reviewed FDD Quality Measure.

For (1): Reviewed FDD Quality Measure = 1

For (2): Reviewed FDD Quality Measure = 0.8

As shown in Figure 20, with Reviewed FDD Quality Measure = 1, the graph stays at 1. But with Reviewed FDD Quality Measure initially equal to 0.8, the graph for "Contractor's Comprehension on Understanding" follows a first order information delay.

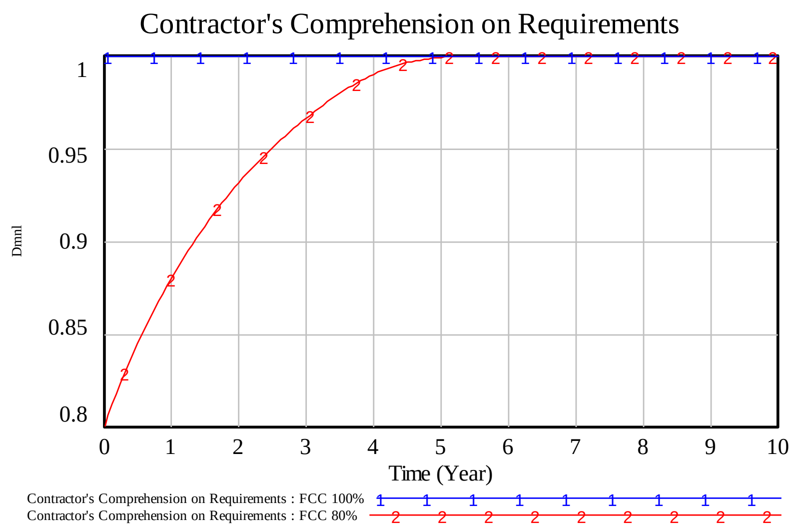

Figure 20: Simulations of Contractor's Comprehension on Requirements

Thus, if the initial blue printing is not efficient, the contractor's comprehension on requirements only improves as they gain experience with the accomplishment of work.

4.3.3 Addition of New Work

The ERP COTS package has frequent new patch releases to either resolve existing issues, or release new features. These packages could affect the database tables, look and feel of the UIs and also include additional functionality. However, the application of these patches requires additional work by the contractor, not only in the system upgrade but also additional activities such as re-validating whether the RICE components implemented works as expected after the patch application.

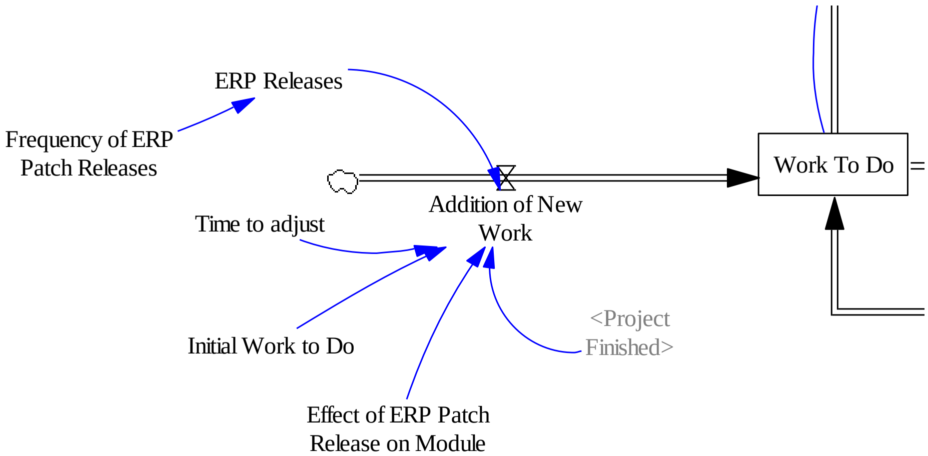

Figure 21: Addition of New Work Due to Patch Updates

Figure 21 above represents the process of new work addition with the release of new patches. The "Frequency of ERP Patch Releases" initially been set to 2 years, meaning new patches get released every 2 years; which adds significant work to the stock "Work To Do".

The variable "ERP Releases" has been set as a pulse input which gets triggered based on the Frequency of ERP patch releases.

Figure 22 represents the release of an ERP patch as an impulse , thus, from the figure, it can be interpreted that new patches are released at years 2, 4, 6, 8, 10 etc.

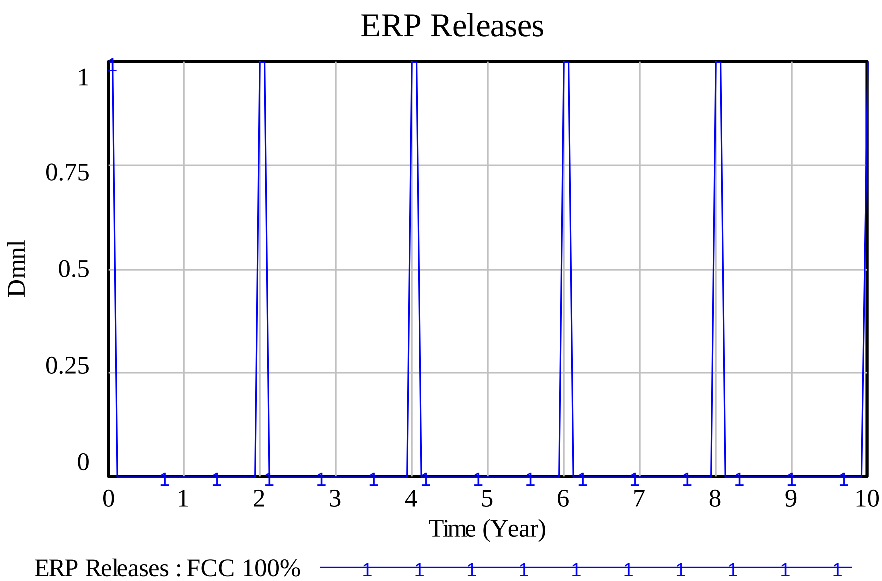

Figure 22: Graph of ERP Releases

The variable "Effect of ERP Patch Release on Module" represents how much of the work gets affected, which needs re-testing, and what percentage of the actual work is the effort required for the re-application of RICE components. Depending on the severity of the patch release effect on functionality, the DoD might even have to undergo a re-blueprinting process; where the entire design is re-validated and adjusted as per the new changes. In a long term project, this factor has a significant impact on the design. The variable "Effect of ERP Patch Release on Module" is treated as constant for the sake of simplicity, with a value of 2.5% or 0.025 times the initial work. Thus, this adds an additional work of 25 tasks every 2 years.

4.3.4 Adverse Selection by Contractor

As discussed in section 2.4 on Agency Theory, describing the differing motivations of contractor v/s sponsor, here are some of the possible ways in which a contractor would leverage the lack of in-house knowledge in the sponsor organization:

1. Jacked up RICE components to increase revenues
2. Technical errors occurred during the project testing raised as variation orders
3. Adverse Selection, leading to jacked up estimations on tasks

If the incentive of the contractor, based on contract terms, is to increase the length of the project or to increase the work so as to gain more revenues, then the options mentioned above are commonly used for moral hazard. Even in a firm fixed price contract, it is usual to over emphasize the amount of work that would be required as part of RICE implementations, to get a better first deal on the fixed price.

The adverse selection has been incorporated in the system dynamics model. Figure 23 below is the associated causal loop from the model:

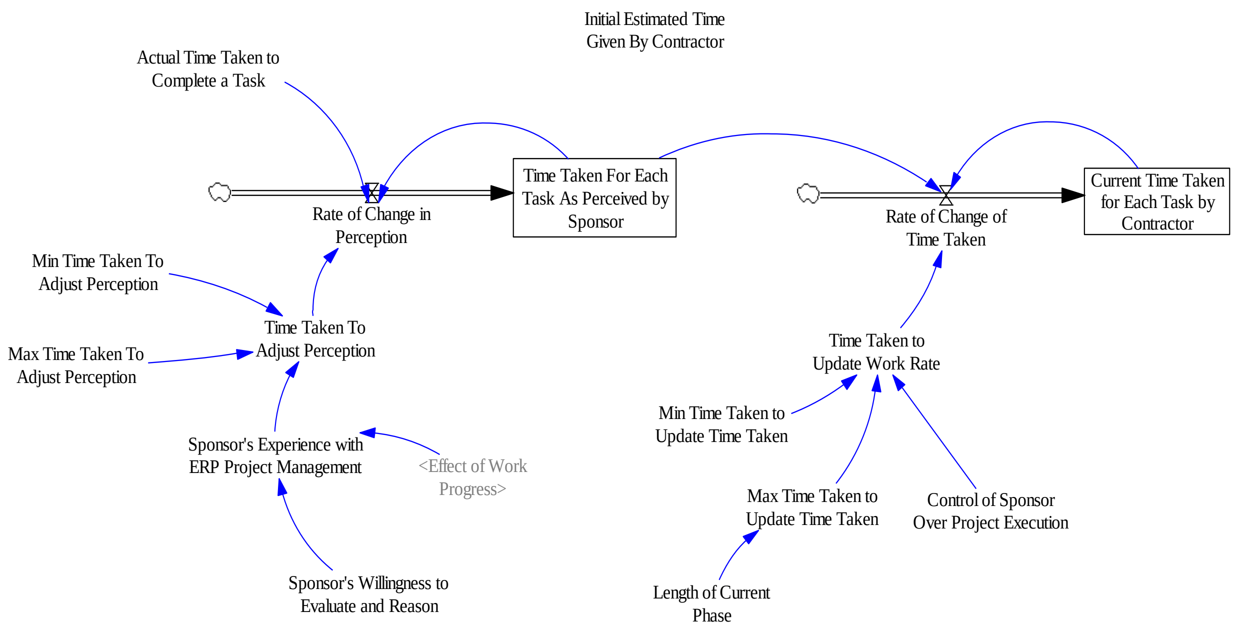

Figure 23: Representation to Adjust Adverse Selection by Contractor

The contractor might give a false impression on the expertise or the ability of people allotted for the project. There could be a significant number of new hires who have had very minimal experience working on ERP projects; and the contractor allots them to this project to learn on the job. To compensate for the time taken to get these new hires on the learning curve, the initial estimates of the project as proposed by the contractor could be overly pessimistic, meaning: a buffer is added to every task in the design document while giving estimations. This costs the sponsor organization not only additional time, but also additional costs, if the contract terms are cost-plus.

The ability of the sponsor organization to validate the initial estimates provided by the contractor largely depends on its experience with ERP project management and in-house technical expertise. In the two case studies, it was evident that DoD had minimal or no in-house technical expertise. However, DoD had eventually hired a Systems Engineering Advisor to have technical oversight on the contractor.

In an LSI contract model (as discussed in section 2.5 and 3.3.5), the entire responsibility of requirements definition, design, development, testing, deployment, support is with the LSI, and the sponsor has no control on the project execution. This gives the contractor an ability to propose initial estimates of work way above the actual work rate.

Even in other contract models with project management in-house, the lack of in-house expertise paralyzes the sponsor from validating the complexity of the RICE components and their estimates. With growing experience in project management of ERP implementations and willingness to evaluate with other DoD program managers; the sponsor's perception of work rate gets adjusted to the actual work rate over time.

Although the sponsor's perception on the time required to complete a task has been updated to actual, the problem lies in re-negotiating the estimates with the contractor. The "Control of Sponsor over Project Execution" determines whether the estimates could be re-negotiated or will have to be changed only after the current phase. The power of the sponsor organization depends a great deal on the type of contract negotiated with the contractor, and the extent to which the sponsor is locked-in with the current contractor. The sponsor has the pressure of lock-in effects if the contract is substantially long and the sponsor is already half way into the project.

Thus, from the causal loop diagram in Figure 23, the initial value of "Time Taken for Each Task as Perceived by Sponsor" is the "Initial Estimated Time Given by Contractor". The flow "Rate of Change of Perception" is dependent on the "Sponsor's Experience with Project Management", which in turn is dependent on Work Progress.
The "Current Time Taken for Each Task by Contractor" represents the actual time being taken by the staff in performing a task. It's initial value is again the initial estimates proposed by the contractor. This value however gets influenced by the "Control of Sponsor over Project Execution".

The more control of sponsor over project execution, the sooner the "Current Time Taken for Each Task by Contractor" is updated to "Actual Time Taken to Complete a Task". Hence, the Productivity Desired by Sponsor which is initially influenced by the initial estimates given by contractor is updated more quickly to the efficient productivity levels.

In the Lead System Integrator (LSI) model, with a lack of control of sponsor, the "Current Time Taken for Each Task by Contractor" does not get updated quickly and hence, the Productivity Desired By Sponsor remains to be the same as the initial estimates proposed by Contractor.

In the Project Management In-house (PMI) model, with more control over project execution i.e. value of "Control of Sponsor Over Project Execution" equal to 1, the "Current Time Taken for Each Task by Contractor" soon gets updated to the "Actual Time Taken to Complete a Task", and hence "Productivity Desired By Sponsor" gets updated to the actual efficient productivity level.

4.3.5 Staffing

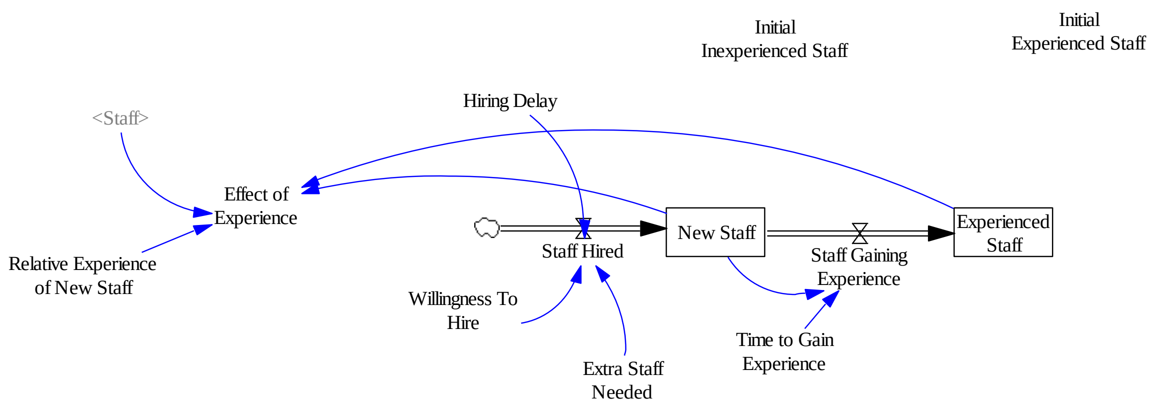

Figure 24: Representation of New and Experienced Staffing

The staffing model is represented in Figure 24 above. The segregation of new and experienced staff is to represent the adverse selection effect by the contractor. As mentioned in the previous section, the initial estimates of any task proposed by the contractor might have a buffer factor to it, in order to accommodate the learning curve of their newly hired staff.
There are two stocks "New Staff" and "Experienced Staff". The relative experience of new staff could vary from 0 to any value less than 1, with 1 representing the base for the experienced staff. As the project progresses, the new staff gains experience and moves into the stock of "Experienced Staff". For the sake of simplicity, we have assumed that the Willingness to Hire is 0, meaning no new staff is hired during the course of the project.

4.3.6 Effect of Experience on Productivity

From sections 4.3.4 and 4.3.5, there are two productivity levels discussed.

Section 4.3.4 discusses the desired productivity as perceived by the sponsor organization, "Productivity Desired by Sponsor", which also represents the rate at which the staff is currently working. Section 4.3.5 describes the productivity based on the experience of the ERP staff in the contractor organization "Productivity as per Experience". There are two situations which could arise:

1. Productivity Desired by Sponsor > Productivity as per Experience
2. Productivity Desired by Sponsor < Productivity as per Experience

LSI Model Behavior

In an LSI model, the contractor has all the power with the sponsor organization having no major control on the project execution. In such a scenario, the time taken to complete a task as perceived by sponsor organization is driven majorly on what LSI proposes.

Thus, the contractor can suggest durations which have enough buffer time for the new hires to learn on the job.

Thus, the probability of the 1st situation of Productivity Desired by Sponsor being greater than Productivity as per experience is not really possible in the case of LSI model.

Contract with Project Management In-house

In a contract with project management in-house, the initial time taken for each task as perceived by the sponsor are the estimates proposed by the contractor. However, with close monitoring, and with the help of the Systems Engineering Advisor, the gap between perceived and actual time taken reduces, and the sponsor's ability to estimate RICE components improves.

In a situation where the sponsor has the actual time taken to complete a task, but the contractor does not have all the experienced people – the new hires are unable to adhere to the allotted time and hence, there are workarounds and the quality of the task performed is negatively affected. This corresponds to the 1st situation where *Productivity Desired by Sponsor > Productivity as per Experience*. In other words, the staff is working at a faster pace than their capability. The impact on the quality of work is not seen directly; however, the undiscovered rework increases with a dilution in fraction correct and complete.

In the 2nd situation where Productivity Desired by Sponsor < Productivity as per Experience, the staff works at a pace lower than their capability therefore causing no rework.

4.4 Analysis and Results

4.4.1 Ideal Scenario

The ideal scenario would be:

1. Reviewed FDD Quality Measure is 1
2. Effect of Experience on FCC = 0
3. "Initial Estimated Time Given by Contractor" is same as the "Actual Time Taken to Complete a Task" = 0.25 years
4. Initial Experienced Staff = 50; Initial Inexperienced Staff = 0

Figure 25 represents Work Done in the ideal scenario, with project finishing in 5.6 years.

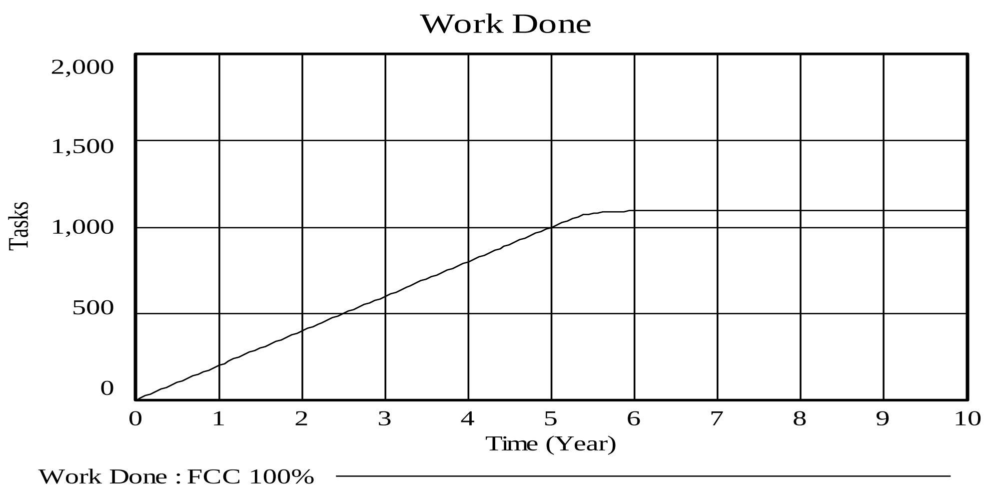

Figure 25: Ideal Scenario - Graph of Work Done

4.4.2 Experiments

Assumptions

The assumptions of the model are:

1. When the productivity is as per the initial estimated time proposed by contractor, then the technical expertise work as per their pace and experience, and no technical rework is generated.
2. When the productivity desired by sponsor exceeds the productivity as per experience, then there is schedule pressure and there are technical errors made during the implementation, therefore requiring rework.
3. The experiments below have been represented as either LSI model or Project Management In-house models (PMI) primarily on the basis of the value of variable "Control of Sponsor over Project Execution"; with a value of 0 and 1 for LSI and PMI models respectively.
4. There might be other factors differentiating the LSI from PMI models, which have not been covered in these experiments.

LSI Model

With the LSI model, the contractor would be better off adding buffer time to the tasks. Hence, we could assume that the Initial Estimated Time Given by Contractor is much more than the Actual Time Taken to Complete a Task.

The following parameters are set for the LSI model:

1. Actual Time Taken to Complete a Task = 0.25 years
2. Initial Estimated Time Given By Contractor = 0.4 years
3. Initial Experienced Staff = 10
4. Initial Inexperienced Staff = 40
5. Knowledge on ERP = 0.9
6. Effectiveness of Integration Activity = 0.8
7. Maximum time to Adjust Contractor Understanding = 5 years
8. Control of Sponsor over Project Execution = 0

Project Management in-house (PMI) Model

The following parameters are set for the model:

1. Actual Time Taken to Complete a Task = 0.25 years
2. Initial Estimated Time Given By Contractor = 0.4 years
3. Initial Experienced Staff = 10
4. Relative Experience of New Staff = 0.2
5. Initial Inexperienced Staff = 40
6. Knowledge on ERP = 0.9
7. Effectiveness of Integration Activity = 0.8
8. Maximum time to Adjust Contractor Understanding = 5 years
9. Control of Sponsor over Project Execution = 1
10. Max Time to Adjust Perception = 1 year

Following is the comparison of the two simulations:

With the above two simulations, we could expect that the fraction correct and complete for the LSI model would be better than the PMI model because; in the LSI model, the sponsor has no control over the project execution and the LSI has the leisure to perform the activities at their initial pace and as per our assumption, this produces quality work. Thus, the technical rework in LSI is 0. Figure 26 below demonstrates the difference in FCC between the two models:

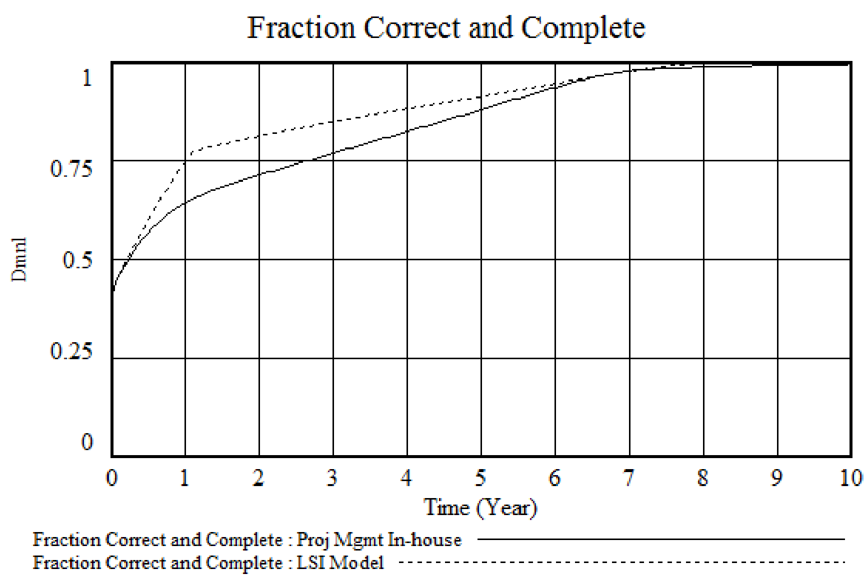

Figure 26: Comparison of Fraction Correct and Complete for LSI and PMI Models

Figures 27 and 28 present the comparison of Productivity as per Experience and Productivity desired by Sponsor for both the cases LSI and PMI models. In the PMI model, the Productivity desired by Sponsor is more than the Productivity as per experience (as shown in Figure 27), and hence the technical staff is working under pressure and thus, rework is bound to get generated.

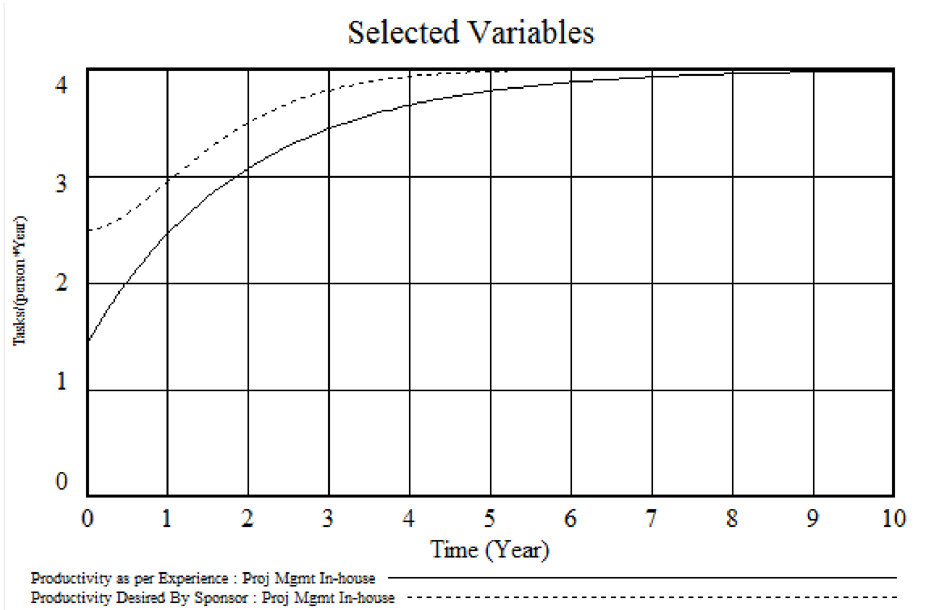

Figure 27: Comparison of Productivity as per experience and as desired by sponsor for PMI model

In the LSI model, the Productivity as per Experience outgrows the Productivity desired by Sponsor (as shown in Figure 28); and so the technical staff has the liberty to work at a slower pace than their capability. Thus, although technical rework is minimal in this case, there is a factor of "work expands to the time you have".

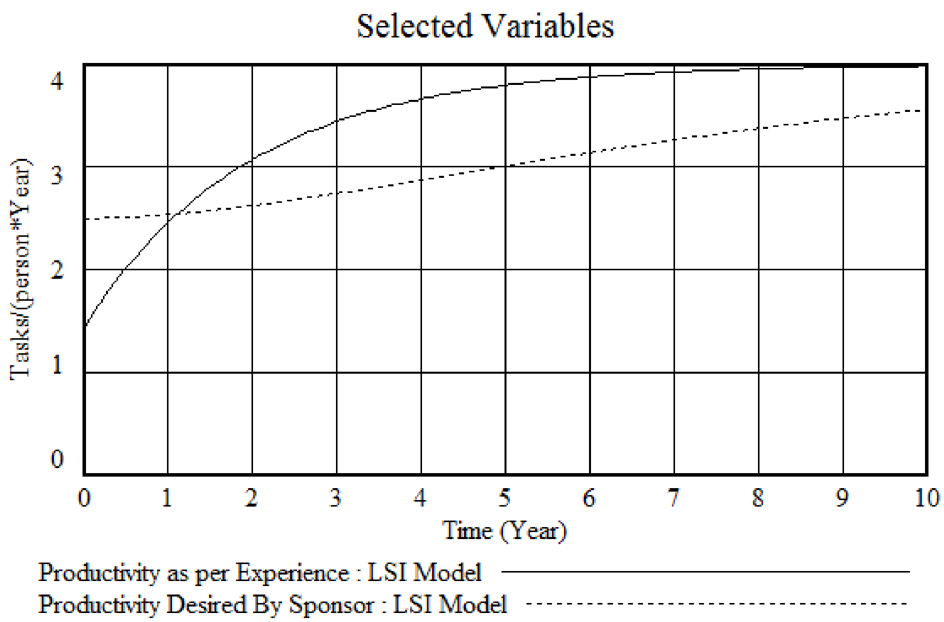

Figure 28: Comparison of Productivity as per experience and as desired by sponsor for LSI Model

Figures 29 and 30 represent the rework generation and work done correctly for the two cases:

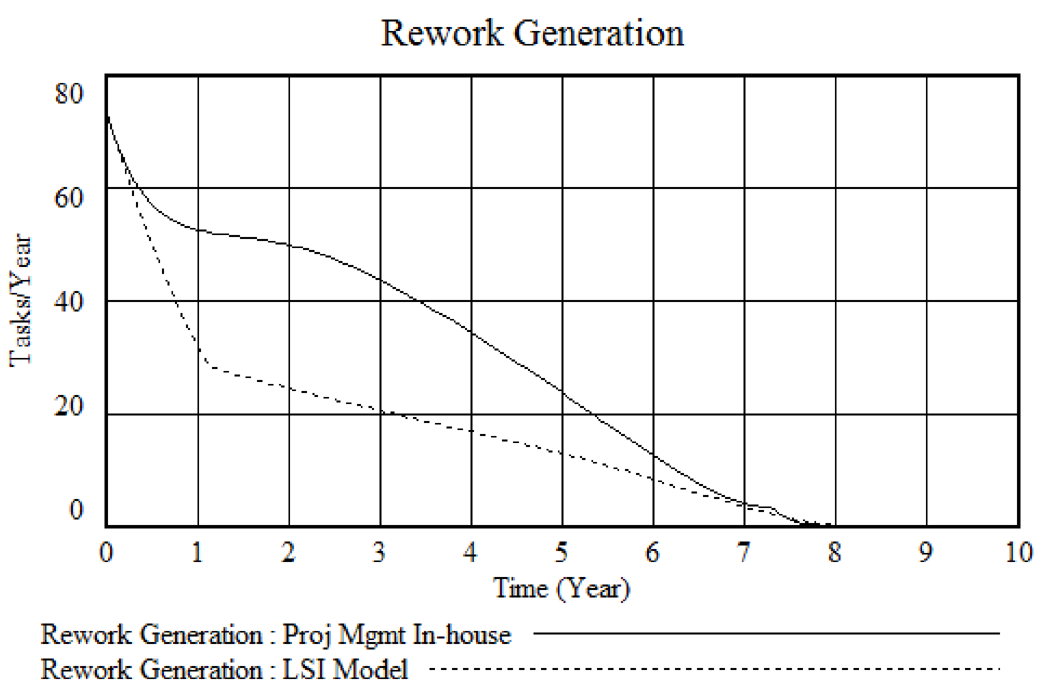

Figure 29: Comparison of Rework Generation for LSI and PMI Models

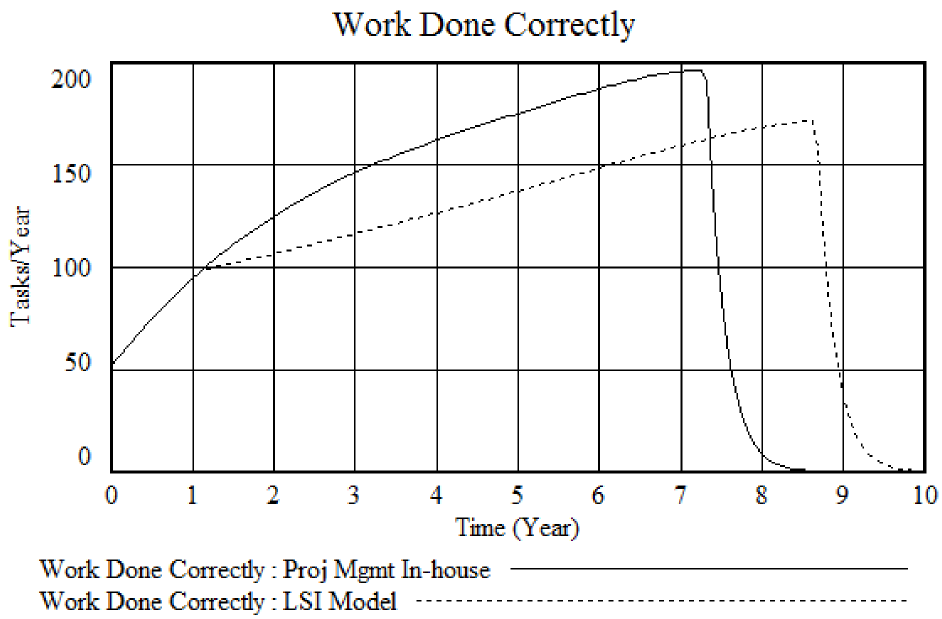

Figure 30: Comparison of Work Done Correctly for LSI and PMI Models

Although the rework generation in the LSI model is lesser than the PMI model (Figure 29), the work done correctly is significantly higher in the PMI case than in LSI (Figure 30). Hence, although there is some rework being generated, but due to the faster pace of work in PMI model, the technical contractors have a faster learning curve, thus the Effect of Work Progress is better off in the PMI model, as demonstrated in Figure 31 below. Also, the undiscovered rework in the LSI model will be discovered much later in the process due to the slower rate of improvement in "Effect of Work Progress" in the LSI model compared to PMI.

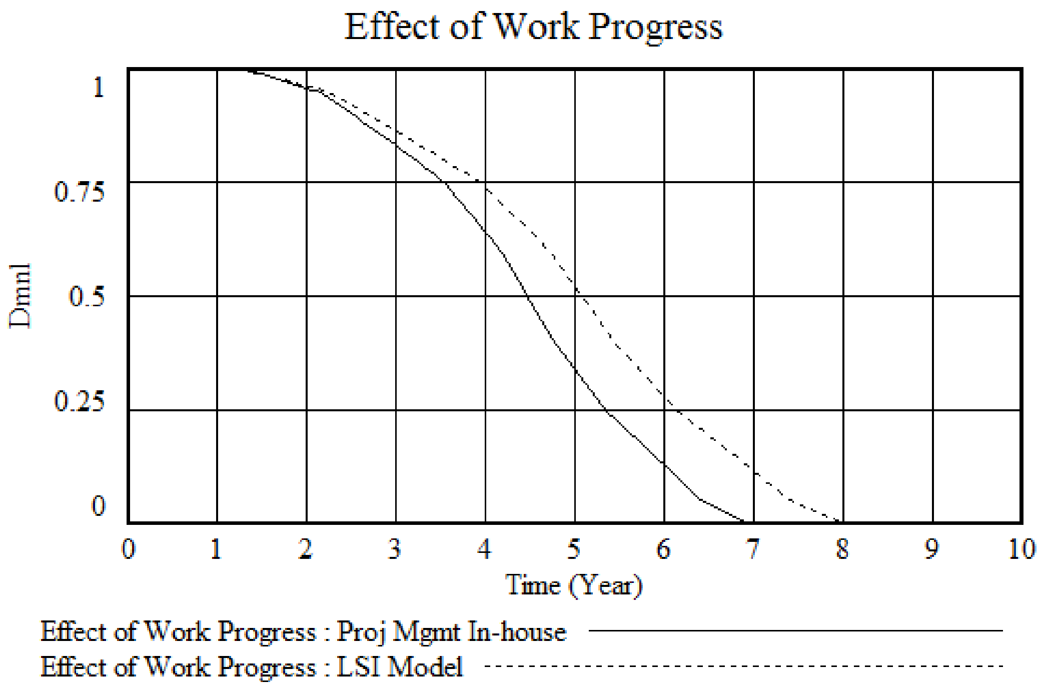

Figure 31: Comparison of Effect of Work Progress for LSI and PMI Models

Hence, the time to adjust contractor understanding reduces at a faster pace with the PMI model; with an accelerated improvement in the FCC over the LSI model.

Overall, Figure 32 demonstrates the comparison of the time taken to complete the project in the two cases, with PMI model being better off than the LSI model.

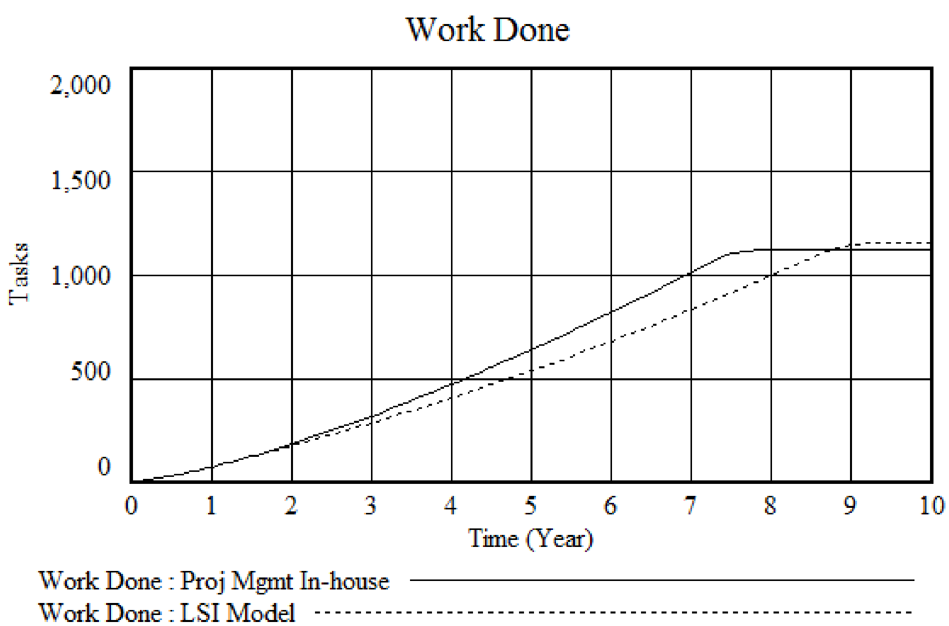

Figure 32: Comparison of Work Done for LSI and PMI Models

Figure 33 compares the undiscovered rework in the two models:

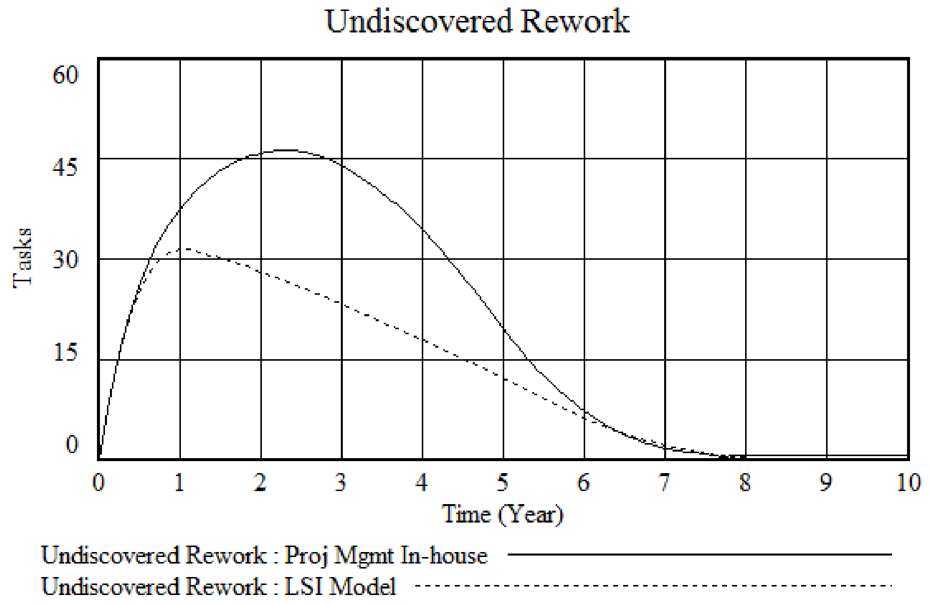

Figure 33: Comparison of Undiscovered Rework for LSI and PMI Models

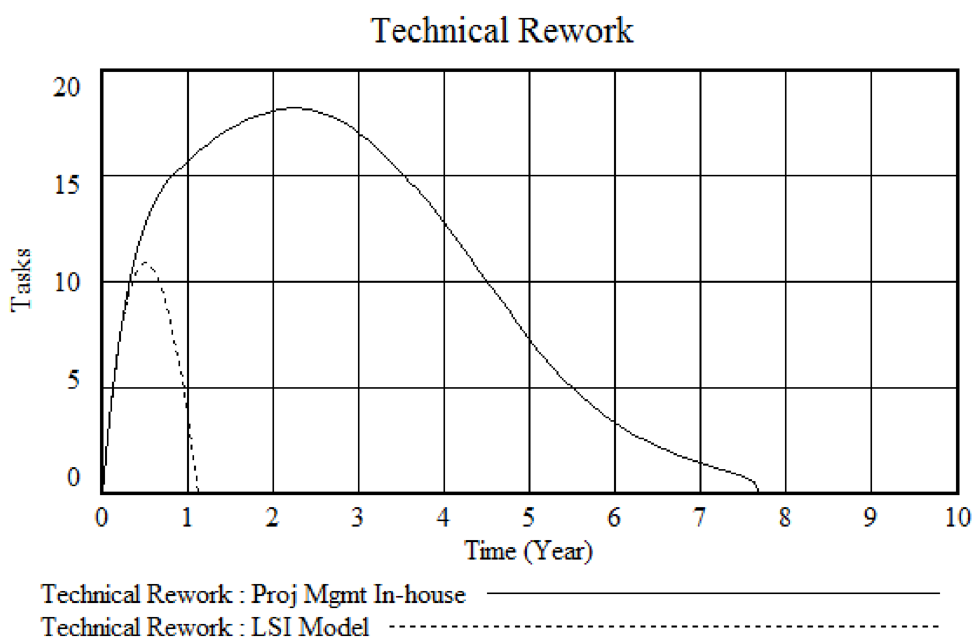

Figure 34: Comparison of Technical Rework for LSI and PMI Models

The undiscovered rework in the LSI model is significantly less than in the Project management in-house model. This is because the technical staff has the leisure to perform their tasks at their pace and as per our assumptions, staff working at their own pace produce no technical rework. Figure 34 demonstrates that the technical rework in the Project management in-house model could be high due to schedule pressure exerted over the staff in adhering to the schedule. Even though the rework is significantly higher in the project management in-house case, the project is better off than the LSI model (when the experience level of contractors is the same in both the models).

So, when is the Lead System Integrator Model better? And to what extent should the moral hazard be ignored?

Sensitivity Analysis

Variable	**LSI Model**	**Project Mgmt In-house**	**LSI Model Case-2**	**Project Mgmt In-house Case-2**	**LSI Model Case-3**	**Project Mgmt In-house Case-3**
Initial Experienced Staff	40	40	25	25	40	40
Initial Inexperienced Staff	10	10	25	25	10	10
Initial Estimated Time Given by Contractor	0.4 years	0.4 years	0.3 years	0.3 years	0.3 years	0.3 years
Control of Sponsor Over Project Execution	0	1	0	1	0	1

Table 10: Sensitivity Analysis

With the scenarios mentioned in the Table 10 above, Figure 35 represents the graph of work done comparison between the LSI Model Case 2, LSI Model and Project Management In-house scenarios.

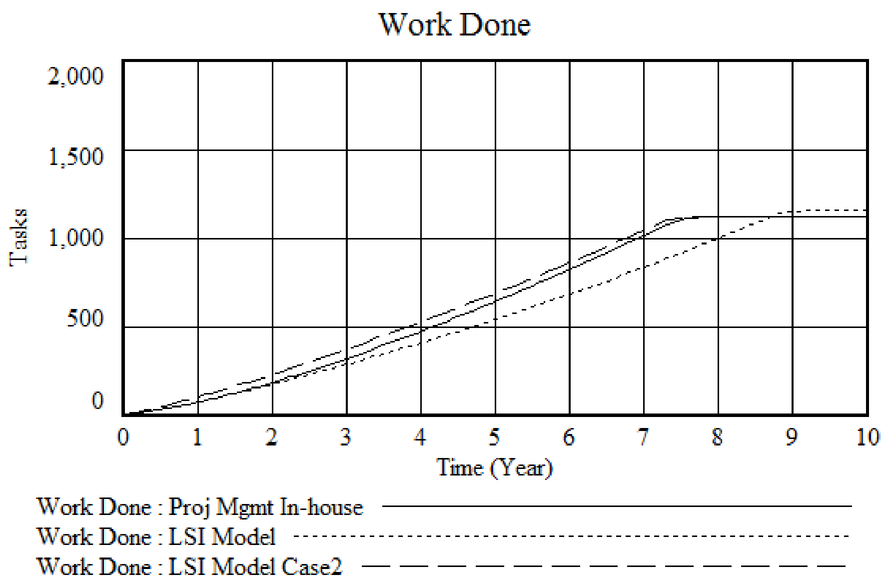

Figure 35: Work Done for LSI Model Case-2

In the LSI Model Case 2, although the Control of sponsor over project execution is 0, the project finishes before the other two scenarios. The factors contributing for this difference is that the initial estimated time given by contractor is 0.3, lesser than the other two scenarios; and the level of experience is significantly higher than the other two scenarios. In the Project Management In-house scenario, the sponsor would have control over the project execution, the productivity desired would be more than the current productivity as per experience and there would be cycles of rework as the staff is still newly hired, and cannot perform at the desired rate. Hence, between the two scenarios LSI Model Case 2 and Project Management In-house, the former is more efficient.

Figure 36 below is a simulation for case -2 on LSI and Project Management In-house. With the reduced value of “Initial Estimates given by Contractor”, the difference in time taken to complete the project is very minimal. However, one key difference between the costs in the two models would be that the technical rework could be deducted from the billing hours of the contractor in the Project Management In-house model; as the sponsor has the transparency of the rework contributed by experience levels.

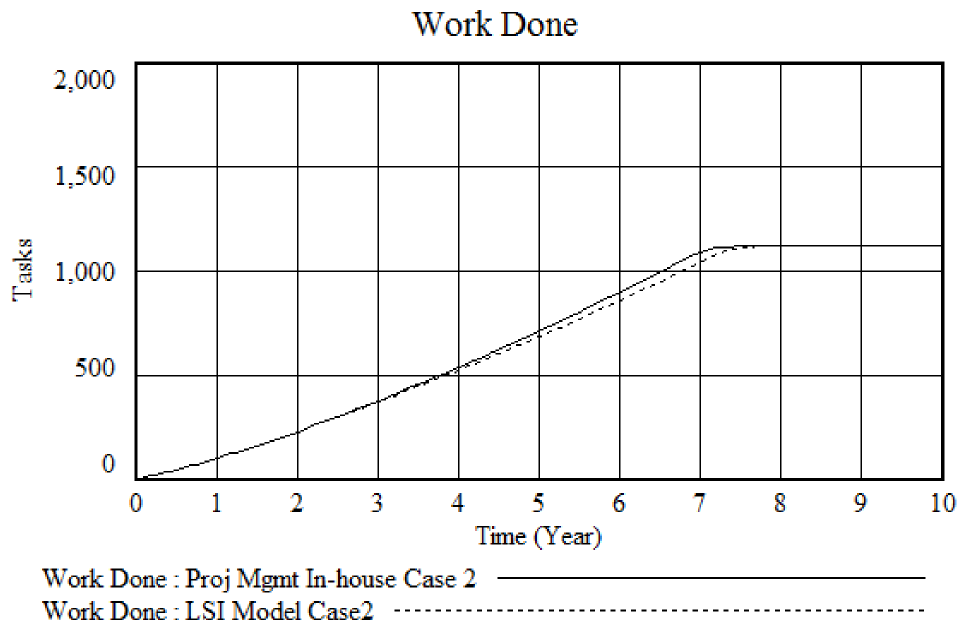

Figure 36: Comparison of Work Done for LSI Case-2 and PMI Case-2

Case-3 simulations for LSI and PMI models give similar results (see Figure 37):

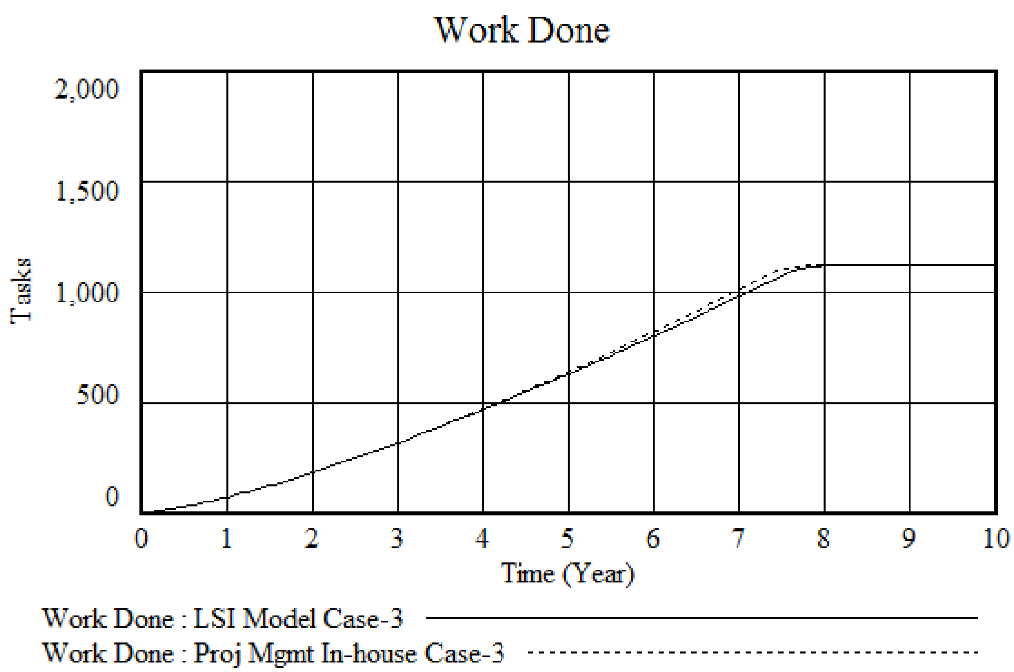

Figure 37: Comparison of Work Done for LSI Case-3 and PMI Case-3

Thus, the Initial Estimated Time Given by Contractor plays a crucial role. If the initial estimates are close to the actual, then there is no major difference between the LSI and Project Management In-house with all other parameters being the same; and with constraints in the model. However, with the Initial Estimates far from reality, it is better to have rework in the model, rather than striving for perfection at every task using the LSI model.

Conclusions

If the initial estimates projected by contractor are unrealistic, then Project Management In-house will help adjust the productivity based on reality even if that incurs rework cycles.
It becomes more desirable to exert schedule pressure on the contractor and after the rework is accounted, the project is still better off than the LSI model.

However, if there is a comparison between an LSI Model with initial estimates closer to reality and better experienced contractors v/s Project Management In-house Model with initial estimates buffered and inexperienced contractors: the LSI model would be better off even if there is a small factor of moral hazard associated to it; as the moral hazard impact is much lesser than the rework impact from the PMI model with inexperienced contractors.

Thus, when evaluating bids, basing decision on the lowest bid is not the best option, a detailed comparison of the estimates for RICE components, an approximate idea of the ERP experience level of the contractor employees, and credibility of the contractor could be some of the other factors crucial for consideration.

5. Discussion and Future Work

The work covered in this thesis has been primarily in evaluating the reasons for delay and cost overrun in ERP acquisitions, using the two cases studied as motivating examples. The system dynamics modeling of LSI versus Project Management in-house in this report has focused on two factors:

(a) Sponsor's control over Project Execution

(b) Impact of experience level of the contractor-staff

However, there could be additional factors that differentiate the two models – for example, impact of the integration activity between project sponsor and contractor, the length of the phases of implementation, frequency of product demonstration and end user feedback, availability of resources etc.

The other levers which could impact the control of sponsor over the project are the way the terms are set - firm fixed price, cost-plus, or time and materials; and the impact of each of these on the contractor's incentives. The contract should also identify contingencies depending on the risks or uncertainties identified during the blue-printing stage.

The government should leverage the experiences gained from Air Force ERP implementations and develop a center of excellence in-house; who would be responsible for any future program implementations. The Systems Engineering Advisor has had the experience of supporting the Air Force with both the projects and their technical learning will help the government in refining their future implementations.

All the arguments made and the levers discussed in the model have been considered for a waterfall approach of system development. With the ECSS adopting the evolutionary approach to requirements identification using conference room pilots, the contract terms will have to consider the contingencies and risks involved in this process.

The government ERP implementation is significantly different from the commercial world; with external impacts such as changes in acquisition rules influencing the process of contractor selection and the length of increments in a project phase. When designing the contract terms, this thesis can help identify the impact of the different contract models on the Critical Success Factors. Additional considerations include the correctness of requirements during blueprinting stage and the level of knowledge of the legacy systems depicting the probability of future discovery of work. Thus, this thesis sets a background to the government's ERP acquisition methodology. Future work could involve evaluating and refining the critical success factors for a DoD world.

Appendix A – Interview Questions

The interview was conducted primarily with the Systems Engineering Advisor teams involved in the two case studies, as well as other people in their organization who have had experiences implementing ERP systems in both commercial and government worlds.

The Questionnaire is as follows:

The following questions require only **unclassified, non-sensitive** information, which can be easily shared. We are primarily looking for information that can help us gauge the effect of a factor on project performance.

Objectives and Requirements:

1. What was the primary objective of the sponsor organization in adopting an ERP implementation? Lower cost or improved capability?
2. How can you rate the internal expertise of the sponsor organization?
   (a) Is there any IT related training in-house?
   (b) Significant capability to trace and evaluate each change order

Contractor Selection, its capabilities and agreements:

1. How was the external contractor selected? Reputation for previous implementations, research on similar industry clients, price bidding?
2. What were the contract agreements with the external contractor?
3. Was there more than one external contractor? If yes, what were the responsibilities?
4. Which roles were assigned to the external contractor?
   (a) Technical implementation only
   (b) Technical implementation and Project management
5. Does the sponsor thinks that there was a difference in the ability/skill set/expertise of the contractors as projected and as performed?

Specifications:

1. Was there a master plan? Who was responsible for creating it? Can you elaborate on the milestones of the project?

2. What was the procedure for writing requirements? Who were the stakeholders involved?
3. Were the business users actively involved during the requirements development phase? Or were there any objections at a later stage, leading to change requests?
4. Was the implementation done in a phased/module-by-module approach?
5. Who had the responsibility to make the choice between retaining legacy business processes and customizing ERP to fit to the business needs or changing the organizational processes?
6. Any business process decision must be an organizational initiative; not just an IT initiative to reduce customizations. How was a business process decision taken? Which parties were involved – consultant, internal departments, higher management?
7. Could the specifications have been better written? In what way?

Change Orders and their frequency:

1. How was the frequency of the generation of change orders?
   (a) Were there change orders initiated as soon as the contractor got on-board? What was the frequency over the project/module implementation life-cycle?
   (b) Can you segregate the change orders? % of CO's which are related to Customizations, implementation issues, others?
2. How were the change orders accepted? How does the process work?
3. There are four types of Undiscovered work:
   - Undiscovered work that wasn't in the specifications – errors in framing specifications
   - Undiscovered mismatch between specifications and what business needs
   - Work generated as the legacy system evolves. (this could also fall under undiscovered rework)
   - Throwaway interfaces

   Are there any further types of undiscovered work? Evidence or impressions and how these play a role in the different phases of life cycle. For example, how are the approvals handled for each of these types and when does the contractor take up these jobs?
4. What were the contractor agreements and how have they changed over time? Was there more than 1 contractor in the life-cycle of the project? How did the agreements change and the process of knowledge transfer?

Project Management:

1. What was the procedure for tracing if the project was on track (as waiting until a milestone deadline has reached might be too late to take any corrective measure)?
2. Can you share the initial estimates of the work and costs; and how did it change throughout the project life-cycle?
3. Can we look at the lifecycle of the design documents? Were there substantial revisions to the requirements? What were the major documents and their approvals?

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