**KNOWLEDGE TRANSFORMATION
IN THE UNITED STATES AIR FORCE CIVIL ENGINEER
CAREER FIELD: A SYSTEM DYNAMICS APPROACH**

THESIS

Gregory Ward, First Lieutenant, USAF

AFIT/GEM/ENV/10-M13

**DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY**

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GEM/ENV/10-M13

KNOWLEDGE TRANSFORMATION IN THE UNITED STATES AIR FORCE CIVIL ENGINEER CAREER FIELD: A SYSTEM DYNAMICS APPROACH

THESIS

Presented to the Faculty

Department of Systems and Engineering Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Engineering Management

Gregory Ward, BS

First Lieutenant, USAF

March 2010

AFIT/GEM/ENV/10-M13

KNOWLEDGE TRANSFORMATION IN THE UNITED STATES AIR FORCE CIVIL ENGINEER CAREER FIELD: A SYSTEM DYNAMICS APPROACH

Gregory Ward, BS
First Lieutenant, USAF

Approved:

//SIGNED//	19 Feb 2010
Michael L. Shelley, PhD (Chairman)	Date
//SIGNED//	19 Feb 2010
Daniel T. Holt, Lt Col, USAF (Member)	Date
//SIGNED//	19 Feb 2010
William A. Sitzabee, Lt Col, USAF (Member)	Date

AFIT/GEM/ENV/10-M13

Abstract

Recent operations in Iraq and Afghanistan have brought the level of expeditionary contractors to historically unprecedented levels, altering the work composition for military engineers. The alteration has shifted emphasis from technical knowledge areas toward managerial knowledge associated with supervising the increased number of contractors. This research utilizes System Dynamics modeling to analyze this shift in the United States Air Force Civil Engineer officer career field and resulting transformative effect on career field knowledge levels, both technical and managerial. The model is then tested with multiple external policy adjustments in the areas of career field structure, training, and operating policy.

Results indicate the shift from technical to managerial knowledge not only diminishes technical knowledge, but also hinders managerial knowledge which requires a strong technical foundation; this creates an overall degradation of both knowledge areas. Therefore, the external policies implemented focused on limiting technical knowledge loss. The recommended policy included a combination of additional technical training and bifurcation of entry-level officers to focus on core technical knowledge, simultaneously providing the foundation for successful managerial knowledge levels.

Acknowledgments

This research would not have been possible without the support of many people. I wish to express gratitude to my research advisor, Dr. Michael Shelley who was abundantly helpful and offered invaluable assistance, support and guidance. Special gratitude is also due to the committee members, Lt Col Daniel Holt and Lt Col William Sitzabee, without whose knowledge and assistance this study would not have been successful. Additionally I would like to thank Lt Col Christopher West who, although he had to depart before the research's completion, offered valuable support and insight in the early stages of development.

Finally, I would like to thank my family, friends, and colleagues who supported me throughout the research process. Special thanks is also especially due to my loving wife for all the encouragement and support she's given to me over the past 18 months. Without her I would simply be lost.

Gregory Ward

Table of Contents

Page

List of Figures

Page

Page

List of Tables

KNOWLEDGE TRANSFORMATION IN THE UNITED STATES AIR FORCE CIVIL ENGINEER CAREER FIELD: A SYSTEM DYNAMICS APPROACH

I. Introduction

The United States Military, eighteen years into military operations in the Middle East, is facing intense challenges in conducting 21st Century Irregular Warfare which calls for not only a swift, precise conflict against a measured, indistinct enemy, but a strong civil support role to rebuild nations (AFDD 3-2, 2007). A significant portion of this civil support role falls under the responsibility of Civil Engineers, who must balance this mission with traditional wartime engineering mission requirements (Brown, 2008). To fulfill these missions, the military has dramatically increased utilization of contractors in the expeditionary environment; now at historically unprecedented levels (Congressional Budget Office, 2008).

Specifically, the United States Air Force Civil Engineer career field, the focus of this research, has been called upon to fill regular Air Force rotations and additional deployments for sister services who are unable to meet current requirements (Eulberg, 2009). With these requirements showing little sign of decline in the foreseeable future (Eulberg, 2009) and operational tempos approaching unsustainable levels (AFPC, 2009), many have begun to ask what adverse impacts will result. Studies have researched the impact of a high operational tempo on areas such as health and morale (e.g. Rona, Fear, Hull, Greenberg, Earnshaw, Hotopf, & Wessely, 2007) and turnover and retention (e.g. Huffman, Adler, Dolan, & Castro, 2005); however, there is a gap in research exploring operational tempo's correlation to transformation of organizational knowledge base.

Research Purpose

Due to the scale of the current conflicts in Iraq and Afghanistan, expeditionary contractors are being utilized at unprecedented levels (Government Accountability Office, 2008). This large number of contractors requires extensive oversight in the areas of contract management, quality control and inspection, and auditing; activities which correlate to an Engineering Manager occupation (O*NET, 2010). Previously military engineers balanced both the technically-oriented Civil Engineer role and the managerially-oriented Engineering Manager role. However, as the demand for military engineers has increased and spurred the escalated employment of contractors, this balance has shifted towards Engineering Management and the oversight functions it entails. The purpose of this research, then, is to explore this "shift" of military engineers away from technically oriented work towards managerial and the resulting transformation it incurs on corresponding organizational knowledge base.

For this research, knowledge base is defined as the compilation of knowledge, skills, and abilities that must be acquired to achieve a specific capability. Knowledge base is attained through formal training and informal on-the-job training programs and maintained through continued experience. Therefore, the shift away from technical work alters the level of experience gained by military engineers and thus creates implications on the organization's technical capability, or technical knowledge base. Likewise, the shift also impacts managerial capability, or management knowledge base. The combined impact on technical and management knowledge bases comprises the transformation.

It is important to elucidate the differences and definitions of technical and managerial knowledge bases. Technical knowledge base is defined by the knowledge, skills, and abilities commensurate with a professional Civil Engineer occupation. Typical tasks associated with this include technical design, drafting, and inspecting (U.S. Department of Labor, 2010a). Management knowledge base is defined by the knowledge, skills and abilities commensurate with an Engineering Manager. The typical tasks associated with this occupation include coordinating and directing projects, interacting with clients, and performing administrative functions (U.S. Department of Labor, 2010a). The relationship between the two knowledge areas could be considered hierarchical; Engineering Managers are one step above Civil Engineers.

Research Objectives

Using these definitions of technical and managerial knowledge bases, this research examines the changing nature of the military's knowledge base and the underlying causes contributing to it, including what has been called a reliance on expeditionary contractor support (Singer, 2004; Congressional Budget Office, 2008; Government Accountability Office, 2008). To do this, an understanding of the system in which Air Force Civil Engineers operate must be understood, which represents the first research objective.

> **Research Objective #1:** Utilize the unique approach of System Dynamics to build and validate a model of the Air Force Civil Engineer officer career field and how it is used to complete current mission objectives.

System Dynamics is a tool used to model the behavioral trends within a complex system over time. In this research, it will be used to understand how garrison and expeditionary mission requirements change over time and the career field's reaction to fulfilling them. As previously mentioned, Air Force Civil Engineers fill both regular and additional operational requirements, relying on contractors to manage the excess. Therefore special emphasis will be placed on the points within the model which decide how resources are divided and training is aligned, such as policy, structure, and training. The second research objective relates these key points transforming knowledge base.

> **Research Objective #2:** Through system analysis, determine the factors giving rise to the transformation of knowledge and the endogenous leverage points to minimize it.

There are two approaches to the knowledge transformation; it's either acceptable or unacceptable to some degree. While such a decision is reserved for Air Force Civil Engineer career field leadership, this research assumes the transformation is not completely acceptable and explores the system's endogenous leverage points that, when exploited, can alter the transformative behavior. Additionally, because expeditionary contractors can be costly, tedious, and often reduce the inherent flexibility and reliability required (Singer, 2003; Palmby, 2006; Verkuil, 2007), the model will also address the expeditionary contractor reliance. Utilizing the leverage points of Research Objective #2 to explore alternative changes (such as organizational structure, force balance, or policy) and then make career field recommendations is the intent of the third research objective.

> **Research Objective #3:** Develop a framework to compare the affects of these leverage points and explore alternative policies (career field structure, new training policy, etc.) and their associated trade-offs to meet current and future mission requirements.

The Cold War era career field structure and training regime utilized today is long overdue for revision (Barnett, 2005). The current structure is optimal for short duration, high intensity, state versus state conflict; conversely, the United States is currently involved in long duration, low intensity, state versus non-state combat operations (Addison, 2008). To say that the current structure and training is not optimal is presumptive, as many aspects coincide very well with current mission requirements. However, because of the immense transformations to modern warfare over the past four decades there is a significant possibility of an alternative structure emerging that is more suitable. Therefore, career field structure and training will be particularly reviewed in conjunction with expeditionary contractors.

Scope

The scope of the research and subsequent recommendations is limited to the Air Force Civil Engineer officer career field at the functional level. It does not address staff level operations as those are considered administrative functions whose primary purpose is to support functional level activities. Similarly, a model is a simplification of a real world system and as such it is impossible to account for every subtle nuance. Therefore, this research was aggregated to a macroscopic level concerning how garrison and expeditionary mission requirements are accomplished. As such, recent Civil Engineer squadron reorganization efforts (Eulberg, 2008b) and other details within the unit level organization have no impact on the model. The model does, however, address the macroscopic factors affecting those individual organizations.

II. Literature Review

A Brief History of Air Force Civil Engineers

Air Force Civil Engineers have a long history originating back to World War I as a small unit of the Army Signal Corps, later transferring into the Army Air Corps. The Air Corps recognized the necessity of specialized engineers before World War II and in 1940 began training a small handful of men to form the 21st Engineer (Aviation) Regiment. These engineers were to be instructed on how to construct, conceal, maintain, and defend airfields. The success of the unit and commencement of the war landed the 21st as a parent unit to over 100,000 engineers serving in every theater. Their excellence was evident as the first airstrip was completed in Normandy within 15 hours of forces landing during the D-Day operation (Hartzer, 2008).

As the Air Force became its own service, construction services were eventually handed from the Army Corps of Engineers to the AF Director of Civil Engineering (now known as the Air Force Civil Engineer) and engineer services at air installations came under the responsibility of the Base Civil Engineer. However, following a series of mini-crises in the 1960's (Lebanon, Berlin, Cuba), it became apparent the Air Force needed to develop a deployment platform for engineers responding to wartime emergencies. This led to the formation of Prime BEEF (Base Engineer Emergency Force) and RED HORSE (Rapid Engineer Deployable Heavy Operational Repair Squadron, Engineer) squadrons, first employed in Southeast Asia during the Vietnam conflict. The Prime BEEF units were organized out of existing Base Civil Engineer units to build, operate, and maintain forward air bases while RED HORSE was created for the sole purpose of large-scale contingency construction (Hartzer, 2008).

This organizational structure proved extremely successful not only in Southeast Asia, but also in subsequent robust Cold War training programs and the first Gulf War. Because of this early success, it has remained as the organizational structure employed today despite the change to modern, irregular warfare. To later understand these changes, it is first necessary to gain an appreciation of these two units, their similarities and differences, and the original intent of each.

Prime BEEF

Prime BEEF units were created as a way to organize Base Civil Engineer squadrons to provide the capability to quickly respond to worldwide emergencies. This ability to go anywhere anytime is essential in today's era of globalization where the enemy does not exist as a set entity in a specific location. Prime BEEF's mission varies between its two major work environments: in-garrison and expeditionary. In-garrison, Prime BEEF units operate within the Base Civil Engineer squadron tasked with performing SRM (sustainment, restoration, and modernization), O&M, (operation and maintenance), planning and development, and minor construction; hence Prime BEEF units are located at nearly every active Air Force installation worldwide, providing valuable garrison training opportunities. In the expeditionary environment, Prime BEEF units are organized around small-scale contingency construction and installation operation and maintenance; the difference being a short-term contingency focus rather than long-term sustainment operations now going on twenty years in Iraq. However, as the wars in Iraq and Afghanistan protract into what some have dubbed the "Long War", Prime BEEF engineers are found performing expeditionary work that was traditionally reserved for permanent, garrison locations (National Museum of the USAF, 2008a).

Because Prime BEEF units do not include the personnel or equipment for heavy construction, major construction in-garrison is provided by contractors. This immediately creates a garrison dependency on contractors while providing Prime BEEF engineers with the opportunity to develop construction management skills. In the expeditionary environment, heavy construction is generally handled by RED HORSE; though in recent years civilian contractors have been increasingly utilized because of the increased requirements for more permanent construction and nation building efforts.

RED HORSE

RED HORSE units differ from Prime BEEF units in that they are self-sustaining and accountable to no specific operating location. These units are comprised of a much wider span of personnel and capabilities; heavy equipment and maintenance, food service, contracting and medical to name a few. This breadth of capability allows greater flexibility in completing a much larger scope of work, such as large scale construction, runway repair, and concrete batch or asphalt plants. Unlike Prime BEEF units, RED HORSE units are considered an expeditionary theater asset and therefore play no part in regular installation sustainment; they are only located at four active Air Force installations but report directly to higher headquarters rather than these installations' leadership.

Recent demand for RED HORSE engineers in support of the wars in Iraq and Afghanistan has created an extremely high deployment tempo, even requiring Prime BEEF personnel to augment RED HORSE teams. Additionally, due to a limited engineer capability in sister-services these Air Force engineers are consistently deploying to do everything from Army motor pool construction to Marine beddown. However, RED HORSE operations are not limited to the contingency setting. Because of their capability, RED HORSE aides in humanitarian projects in areas throughout the United States and abroad and conducts in-garrison training projects to hone their wartime skills at AF installations worldwide (National Museum of the USAF, 2008b).

RED HORSE and Prime BEEF engineers underwent one final transformation in the 1990s. Despite multiple involvements around the world in areas such as Somalia, Haiti, Saudi Arabia, Kuwait, Bosnia, and Turkey, the career field saw a 42 percent reduction in total force (47% for military) and a consolidation of the 26 specialty codes to just 13 (Hartzer, 2008). As the soviet threat disappeared, there came a push to downsize the force with the simultaneous goal of maintaining current readiness levels. Thus, a “reengineering” or “lean” revolution spilled over from the private sector into the government and forced engineers to “do more with less" - the accepted battle cry of Civil Engineers in the 21st century.

Current Situation

Immediately following the terrorist attacks of September 11th, 2001, Air Force civil engineers responded by deploying more than 2,000 personnel to 13 bases in support of Operation Enduring Freedom (OEF) on top of the hundreds of military personnel already supporting Operations Northern and Southern Watch. Two years later, with the beginning of Operation Iraqi Freedom (OIF), engineers deployed over 4,500 additional personnel to establish 12 new bases and expand all 10 existing bases in the region.

Combined with maintaining the home station mission, OEF and OIF have set a high standard for the 15,000 Air Force Civil Engineers to maintain.

The AEF (Air Expeditionary Force) Cycle, originally designed as a structured deployment process to give airmen a sense of predictability, has since become inadequate for engineers. Instead of the intended 120 day, four-to-one dwell deployment cycle (four 120 day cycles at home to one cycle deployed), engineers became formally classified as an "enabler" in January 2007 with deployment cycles shifting to 180 day, two-to-one dwells. Then, in 2009 Civil Engineer officers moved into the highest classification – one-to-one dwells. According to the Air Force Civil Engineer, of the 15,000 active duty personnel more than 3,900 are deployed at any one time with 62% percent of those serving in roles that are traditionally filled by members of other services (Beyers, 2010). This has helped place nine of the thirteen Civil Engineer specialties, including officers, in the "stressed" category - meaning there are insufficient trained personnel to fill critical positions supporting the expeditionary (deployed) and garrison (home station) missions.

Doctrine and the New Mission

During the Vietnam and subsequent Cold War years the strategic military focus was on containment operations defined by high-intensity, short-duration state-on-state armed conflict against an enemy with rational, political or ideological motives. Conversely, today's wars in Iraq and Afghanistan are low-intensity, long duration state versus non-state combat operations against an enemy with irrational, religious motives (Addison, 2008); or, Irregular Warfare. In the words of former President John F. Kennedy (1962), "This is another type of war…it requires…a whole new kind of strategy, a wholly different kind of force, and therefore a new and wholly different kind of military training."

The U.S. Air Force defines Irregular Warfare as “a violent struggle among state and non-state actors for legitimacy and influence over the relevant populations” (AFDD 2-3, 2007). By definition, legitimacy and influence are the main objectives that must be achieved and Nagl (2002) identified two archetypes to accomplish this: the Hearts and Minds and the Cost Benefit Theories. While the latter focuses on raising the insurgents’ costs associated with waging the rebellion (and thus outweighing the benefit), the Hearts and Minds theory attempts to win the popular support of the nation through security, reconstruction, economic development, and governance. The Hearts and Minds strategy, in parallel with AFDD 2-3, requires counterinsurgency forces to be involved with the local population to erode insurgency support and thus render irrelevant the opposing military forces. A key component to this, then, is accomplished through rebuilding the nation's government and infrastructure; or, Nation Building.

The concept of Nation Building is not new, with roots dating back to the Marshall Plan in post-World War II Europe. Similarly, the U.S. is currently spending millions of dollars on rebuilding schools, hospitals, infrastructure, and security in the impoverished nations of Iraq and Afghanistan through Provincial Reconstruction Teams (PRTs). The stated mission of the PRTs are to "help provincial governments with: developing a transparent and sustained capability to govern, promoting increased security and rule of law, promoting political and economic development and providing provincial administration necessary to meet the basic needs of the population" (Department of State, 2008).

Not only do Air Force engineers fulfill these reconstruction positions to rebuild the country, but traditional contingency construction roles must be fulfilled as well. The protracted approach that is indicative of IW requires a long-term strategy for victory and extended forward basing of troops. Thus, combatant commander demand for Prime BEEF and RED HORSE engineers has increased considerably as operations on two fronts (OEF and OIF), doubled mission requirements, and prolonged operational requirements of what some call the "Long War" (Addison, 2007) challenge the Civil Engineer career field.

It is apparent the Civil Engineer career field cannot carry on with these requirements without significant stress to the career field and assistance from civilian contractors. The ad hoc solution being currently employed hinges on the heavy reliance on contractors to handle work military personnel are under-resourced to accomplish. This dependency carries with it myriad of potential problems.

Contractor Reliance

Defense contracting in recent years appears to parallel the changes other industries are experiencing in the era of globalization: a shift from manufacturer to service provider (Palmby, 2006). The key component empowering this transformation is the use of outsourcing. In general, outsourcing is aimed at increasing the flexibility, effectiveness, and efficiency of an organization by streamlining operations toward the core mission or specialty of the organization (Kelty, 2005). According to the A-76 Circular (2003) which lays the foundation for proper government outsourcing procedures, "The longstanding policy of the federal government has been to rely on the private sector for needed commercial services. To ensure that the American people receive maximum value for their tax dollars, commercial activities should be subject to the forces of competition." While this seems rational and advantageous in the garrison environment, the initiative can act very differently in the contingency setting.

Despite the intentions of outsourcing, objective and subjective assessments of contractor performance in Iraq reveal the intended goals of the initiative are not necessarily being met (CBO, 2008 & Singer, 2003). While the use of civilians by the U.S. military dates back to Revolutionary War, the current conflicts mark an increasing trend in their employment; as of 2008 U.S. Central Command reported the number of contractors had surpassed military personnel in the Iraqi theater (CBO, 2008). The following year, the same milestone was met in Afghanistan. This quantitative increase in reliance raises concerns over qualitative issues.

Former U.S. Secretary of Defense Donald Rumsfeld stated in a December 5, 2005 speech that “I personally am of the view that there are a lot of things that can be done for a short time basis by contractors…any idea that we shouldn't have them I think would be unwise." However, David Graff, commander of the Defense Contract Management Agency, in a September 30, 2008 letter about KBR (one of the largest construction contractors in Iraq/Afghanistan) rebuffed that contractors were "not sufficiently in touch with the urgency or realities of what was actually occurring on the ground. Many within the Department of Defense have lost or are losing all remaining confidence in KBR's ability to successfully and repeatedly perform." And according to the Government Accountability Office (1995), “We cannot convincingly prove nor disprove that the results of federal agencies' contracting out decisions have been beneficial and cost-effective." So what do these contradictions mean?

The problem existing today is the lack of empirical research detailing performance of civilian contractors in wartime scenarios; the Department of Defense states they are necessary yet simultaneously criticizes their performance. Nearly all information currently held on expeditionary civilian contractors consists of anecdotal criticism on cost and quality. The lone standing comprehensive report was issued by the Special Inspector General for Iraq Reconstruction in 2008, which listed numerous quality violations by contractors; however, their success and mission enhancement were not included. Additionally, government agencies have failed to look at the impact of expeditionary contractors on mission reliability and long-term organizational goals (McPeak & Ellis, 2004). These are questions currently without answers and because the military, and civil engineers in particular, rely on contractors to accomplish the expeditionary mission (Singer, 2004; Congressional Budgeting Office, 2008; & Government Accountability Office, 2008), finding those answers are critical to identifying if contractors are truly worthwhile.

Total Force Application

The National Military Strategy directs the nation's military to be capable of sustaining operations for two major theaters of war simultaneously; a feat that would prove extremely costly if exclusively met with active duty forces (Department of Defense, 2008). Instead, the military operates in a Total Force concept, integrating active duty, reserve, National Guard, civilians, and even contractors from all branches into an interdependent force, available when needed and stood down when not. This organization is "consistent with the pre-Cold War model of force structure and is expressly designed with flexibility, efficiency, effectiveness, and economy in mind" (Palmby, 2006).

Outsourcing is intended to allow the military to "fulfill home-base requirements with civil-service or private-industry personnel, thus freeing military troops for deployed operations" (Palmby, 2006). However, the Congressional Budget Office (2008) reported 80,000 base support and 30,000 construction personnel working on contracts in Iraq for the Department of Defense (out of a total of 190,000 contractors). Questions as to whether these contractors are also part of the Total Force are important issues to consider. For example, when an airman separates to join a private firm contracted by the government is it a matter of retention or a lateral move within the same organization (Kelty, 2005)? For the purposes of this research contractors who are integrated into the military to provide a specific technical capability or service *are* a part of the Total Force, while those hired on a contract to provide a product are not. Under this definition, many expeditionary contractors such as those providing infrastructure maintenance would be considered part of the Total Force.

Using this definition of a Total Force civilian contractor, Table 1 below describes specifically the current disbursement of the Total Force in the Air Force Civil Engineer career field broken down by major command. It is interesting to note the overall total shows the career field is only 35% military, down from 41% in 2007 (Eulberg, 2007). Part of this can be attributed to A-76 actions in Air Education and Training Command, but the overall effect is part of a much larger push to civilianize and contract out traditional garrison engineering roles that are not military essential.

Table 1: Civil Engineer career field Total Force manning by command (Eulberg, 2008a).

Command	Military	Civilian	Contractor	% Military	% Civilian	% Contractor
ACC	3,802	2,279	2,003	47.0%	28.0%	25.0%
AETC	1,776	2,627	2,040	27.0%	41.0%	32.0%
AFMC	218	1,564	2,183	6.0%	39.0%	55.0%
AFSOC	482	208	158	57.0%	24.0%	19.0%
AFSPC	1,105	1,350	800	33.0%	42.0%	25.0%
AMC	2,197	1,231	1,100	49.0%	27.0%	24.0%
PACAF	2,829	3,378	2,290	33.0%	40.0%	27.0%
USAFE	2,164	2,318	2,115	33.0%	35.0%	32.0%
DRUs	555	950	2,055	15.0%	27.0%	58.0%
AD Totals	15,128	15,905	14,744	33.0%	35.0%	32.0%
ANG/AFR	14,146	1,007	301	91.0%	7.0%	2.0%

Army Case Study

The perfect example of reliance on expeditionary contractors can be found in the U. S. Army. The Army, slightly different than Air Force Civil Engineering, is split into a public works section (the U.S Army Corps of Engineers) and combat engineer brigades. At the end of the Cold War, massive troop reductions swept through the Department of Defense and in an attempt to maintain a sufficient level of front-line infantry personnel vast numbers of Army military engineers were moved to the reserve component. The Corps of Engineers now currently operates with 34,000 civilians and only 650 military personnel (U.S. Army Corps of Engineers, 2009). Combat engineers similarly took drastic cuts and while "the Army is attempting to reduce our deployed footprint by maximizing use of host-nation and contract engineers, this plan directly threatens the need for our current number of combat-heavy battalions" (Lindsay, 2000).

As these changes in the Army took effect, requirements continued in areas such as the Balkans. To meet these demands, the Army supplemented military with contractors and in 1992 fully initiated the Logistics Civilian Augmentation Program (LOGCAP) to create a standing contract source to meet mission requirements as they arose (U.S. Army Corps of Engineers, 2009). LOGCAP has now awarded over $25 billion to KBR alone for their work supporting Iraq and Afghanistan since 2001. Additionally, LOGCAP just started a new 10 year, $150 billion dollar contract in September 2008. To bring this spending into comparison, the Army pays $500,000 per day for approximately 1200 contractors to operate Bagram Air Base (West, 2009); a job that could be done by military personnel for almost half the price according to the Congressional Budget Office (2008).

In addition to complaints about contractor costs is the issue of reliability and flexibility. A squadron of military personnel is highly reliable: committed to the organization, flexible to changing military needs without requiring extensive documentation or added costs, can generally perform quality control on themselves, and can construct today and defend tomorrow if needed. How reliable is an engineer team as a whole when the entire contract force at an operating base could decide the situation is too dangerous for them, such as the 2004 banning of Philippine citizens from Iraq by the Philippine government? While there is no specific measure to gauge civilian reliability, the risks must nevertheless be weighed by military leaders.

As the reliance on expeditionary contractors continues, organizations (such as the Corps of Engineers) enter a reinforcing cycle that forces further and further reliance on others as their technical knowledge base erodes away. As mentioned previously, 62% of current Air Force Civil Engineer deployments are to sister services; almost all of which are in capacities that would normally be filled by Army engineers. Air Force Civil Engineers are very good at conducting installation sustainment operations (a task that has risen in importance as counterinsurgency strategies utilize a Forward Operating Base construct to project personnel into local communities), making their services invaluable in both Iraq and Afghanistan (Beyers, 2010). While Air Force Civil Engineers may be a long road away from reaching a similar situation as the Army, it serves as a reminder and lesson for what can happen from one small change in organizational structure. It is because of this the Air Force Civil Engineer career field will be modeled to analyze potential alternative solutions.

Knowledge Delineation

Knowledge is defined by the Oxford English Dictionary as (i) expertise and skills acquired by a person through experience or education; the theoretical or practical understanding of a subject; (ii) what is known in a particular field or in total; facts and information; or (iii) awareness or familiarity gained by experience of a fact or situation. For the research presented herein, knowledge represents the collective body of information related to a specific field that can be acquired through experience or education. The specific fields of concern are technical and managerial knowledge in the Air Force Civil Engineer officer career field. To define the specific knowledge of these fields, the Occupational Information Network (O*NET) was used.

The O*NET is a comprehensive system sponsored by the US Department of Labor and is designed to describe occupations based on data gathered over six decades, including more than 1,100 specific descriptions of different occupational titles. Specifically, it includes data on the mix of knowledge, skills, and abilities that are needed to perform the variety of activities and tasks associated with each occupation. Researchers use it as a guide for defining specific occupational information and have validated it as a sound research tool (Liu, Spector, & Jex, 2005 and Jeanneret & Strong, 2003).

Accordingly, O*NET was used to compare the knowledge of the technical and managerial work areas in the Air Force Civil Engineer career field. The technical side is represented by the occupation of Civil Engineers whereas Engineering Managers represent the managerial side. While many of the technical specialties among Air Force Civil Engineers include more engineering disciplines such as electrical and mechanical engineers, those technical specialties of the civil engineer are closely related and provide a baseline for comparison. A description of the tasks associated with each occupation is shown in Table 2. Additionally, Table 3 highlights the two occupations' knowledge components with disparities highlighted in red.

Table 2: Tasks for Civil Engineers and Engineering Managers (O*NET, 2010).

Civil Engineer	Engineering Manager
Manage and direct staff members and the construction, operations, or maintenance activities at project site.	Coordinate and direct projects, making detailed plans to accomplish goals and directing the integration of technical activities.
Provide technical advice regarding design, construction, or program modifications and structural repairs to industrial and managerial personnel.	Consult or negotiate with clients to prepare project specifications.
Inspect project sites to monitor progress and ensure conformance to design specifications and safety or sanitation standards.	Present and explain proposals, reports, and findings to clients.
Estimate quantities and cost of materials, equipment, or labor to determine project feasibility.	Direct, review, and approve product design and changes.
Test soils and materials to determine the adequacy and strength of foundations, concrete, asphalt, or steel.	Review and recommend or approve contracts and cost estimates.
Compute load and grade requirements, water flow rates, and material stress factors to determine design specifications.	Prepare budgets, bids, and contracts, and direct the negotiation of research contracts.
Plan and design transportation or hydraulic systems and structures, following construction and government standards, using design software and drawing tools.	Perform administrative functions such as reviewing and writing reports, approving expenditures, enforcing rules, and making decisions about the purchase of materials or services.
Analyze survey reports, maps, drawings, blueprints, aerial photography, and other topographical or geologic data to plan projects.	Analyze technology, resource needs, and market demand, to plan and assess the feasibility of projects.
Prepare or present public reports on topics such as bid proposals, deeds, environmental impact statements, or property and right-of-way descriptions.	Confer with management, production, and marketing staff to discuss project specifications and procedures.
Direct or participate in surveying to lay out installations and establish reference points, grades, and elevations to guide construction.	Recruit employees, assign, direct, and evaluate their work, and oversee the development and maintenance of staff competence.

Table 3: Knowledge components for Civil Engineers and Engineering Managers (O*NET, 2010).

Civil Engineers	Engineering Managers
Engineering and Technology — Knowledge of the practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services.	**Engineering and Technology** — Knowledge of the practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services.
Design — Knowledge of design techniques, tools, and principles involved in production of precision technical plans, blueprints, drawings, and models.	**Design** — Knowledge of design techniques, tools, and principles involved in production of precision technical plans, blueprints, drawings, and models.
Building and Construction — Knowledge of materials, methods, and the tools involved in the construction or repair of houses, buildings, or other structures such as highways and roads.	**Computers and Electronics** — Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming.
Mathematics — Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications.	**Mathematics** — Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications.
Physics — Knowledge of prediction of physical principles, laws, their interrelationships, and applications to understanding fluid, material, and atmospheric dynamics, and mechanical, electrical, atomic, and sub- atomic structures and processes.	**Administration and Management** — Knowledge of business and management principles involved in strategic planning, resource allocation, human resources modeling, leadership technique, production methods, and coordination of people and resources.
Transportation — Knowledge of principles and methods for moving people or goods by air, rail, sea or road, including the relative costs and benefits.	**Physics** — Knowledge of prediction of physical principles, laws, their interrelationships, and applications to understanding fluid, material, and atmospheric dynamics, and mechanical, electrical, atomic, and sub- atomic structures and processes.
Administration and Management — Knowledge of business and management principles involved in strategic planning, resource allocation, human resources modeling, leadership technique, production methods, and coordination of people and resources.	**Customer and Personal Service** — Knowledge of principles and processes for providing customer and personal services. This includes customer needs assessment, meeting quality standards for services, and evaluation of customer satisfaction.
Customer and Personal Service — Knowledge of principles and processes for providing customer and personal services. This includes customer needs assessment, meeting quality standards for services, and evaluation of customer satisfaction.	**Production and Processing** — Knowledge of raw materials, production processes, quality control, costs, and other techniques for maximizing the effective manufacture and distribution of goods.
Public Safety and Security — Knowledge of relevant equipment, policies, procedures, and strategies to promote effective local, state, or national security operations for the protection of people, data, property, and institutions.	**Personnel and Human Resources** — Knowledge of principles and procedures for personnel recruitment, selection, training, compensation and benefits, labor relations and negotiation, and personnel information systems.

As illustrated, Civil Engineers and Engineering Managers have many overlapping knowledge components. Of the three disparities for Engineering Managers, only

‘Personnel and Human Resources’ is unique to the Engineering Management occupation; ‘Production and Processing’ and ‘Computers and Electronics’ are common knowledge components to other engineering disciplines such as mechanical and electrical engineering, which is logical considering engineering management roles may encompass elements of all disciplines of engineering. However, the seven common knowledge components do suggest that technical knowledge and management knowledge contain a common core knowledge set.

Perhaps more importantly, given the overlap, the technical knowledge may serve as a necessary prerequisite for the successful performance of engineering management roles. The Bureau of Labor Statistics’ *Occupational Outlook Handbook* (2010a) suggests, “strong technical knowledge is essential for engineering managers who must understand and guide the work of their subordinates and explain the work in non-technical terms to senior management and potential customers. Therefore, most managers have formal education and work experience as an engineer, scientist, or mathematician.” The handbook goes on to emphasize the importance of technical experience as the stepping-stone to managerial roles. This creates an interesting dynamic in relation to the knowledge transformation of the Air Force Civil Engineer career field. If knowledge and experience in a technically oriented occupation is a precursor to success in a managerially oriented occupation, then what happens if that experience is reduced due to shifting mission requirements (i.e. increased contractors requiring more oversight)? That is a question perfectly suited for a System Dynamics methodology.

The System Dynamics Approach

Most engineered systems are designed with the implicit goal of achieving predictable effects and to do it efficiently (Shelley, 2009). However, we are often not afforded the luxury of designing a system but instead must create an understanding of the systems already in operation in the world around us. So in order to analyze the Total Force system at work in the Air Force Civil Engineer career field, the System Dynamics paradigm offers the opportunity to create this understanding. In System Dynamics, a given behavior is used to generate the system's underlying framework. Within this real-world representative framework, endogenous system structures of relationships and closed loop feedbacks generate a dynamic perspective which can be understood mechanistically.

Using the System Dynamics paradigm is beneficial for a number of reasons. Modeling makes it possible to replicate the Civil Engineer officer career field and "test" various Total Force structures and their resultant performance without affecting current operations. It can be used as an on-going tool to explore system behavior in new and uncertain situations, planning for future contingencies and gaining an understanding of expected reactions.

System Dynamics is a simple, five step process consisting of conceptualizing, building, formulating, testing, and implementing the model. First, the modeler must conceptualize the unstructured and complex to create a mental model of the system. This mental model includes displaying a reference mode, which is generally an observed, unwanted behavior that intrigues the initiation of the modeling process. It is this reference mode that is dynamic (not system state), affected by and effecting other components of the model; the system components are what cause the reference mode behavior. Utilizing the reference mode and basic system definitions from conceptualization, the second step begins iteratively building endogenous cause-effect interactions to create a system of causal, closed feedback loops, either compensating or reinforcing.

Once this causal-loop diagram is conceptualized, the third step of formulation can begin. Here, the cause-effect relationships represent a system of flows that change component values over time (hence the dynamic perspective). These relationships are then represented as written mathematical equations which can be simulated using software. The simulations are part of the fourth step, which is testing of the model. Multiple simulations, tests, and validations allow an iterative process from steps one and two to help refine the model into an accurate representation of the real world. The fifth and final step is then only to implement the model, using it to enact policy variations and test hypotheses about the system.

Here lies the inherent value of System Dynamics; a well understood and validated real-world representative system that provides insight into the system's behavior, not possible otherwise. By identifying the behaviors of the Air Force Civil Engineer Total Force system, representing them through cause-effect relationships and gaining intuition about the system's behaviors, new force structures, balance, and policies can be explored to make more efficient use of scarce resources to better meet operational mission requirements.

III. Methods

The following chapter introduces the concept of System Dynamics and how it uniquely provides an appropriate methodology for analyzing the Air Force Civil Engineer career field's knowledge base erosion. System Dynamics, first developed by Jay W. Forrester in the 1960's, is "a methodology for studying and managing complex feedback systems" (System Dynamics Society, 2010). The methodology consists of five steps which will be covered shortly, but first it is important to understand what makes System Dynamics unique.

System Dynamics is set apart from other methodologies by the "System Dynamics Paradigm," which consists of four characteristics (Shelley, 2009). The first characteristic is a dynamic perspective, meaning rather than focusing on a specific system state, System Dynamics is committed to analyzing the system's behavior over time. Because of this focus on behavior, traditional statistical analysis of model outputs against real-world data is inappropriate; instead, a qualitative analysis relating behavior is used. The second characteristic is the system as cause, meaning the behavior creating the dynamic perspective arises from the causal structure within the system rather than external to the system. While often systems fail given a specific external input, System Dynamics is not concerned with changing that input but instead strengthening the system by looking internally at an endogenous viewpoint to correct problematic behavior. The third characteristic is a closed loop perspective, meaning the system is represented by a set of closed, causal feedback loops where most variables are endogenous to the system. Feedback refers to the relationship between X and Y where not only does X affect Y but

Y also affects X, though perhaps indirectly. It is impossible to study the relationship of X to Y and Y to X independently and make accurate predictions of system behavior, only when the system as a whole is accounted for (including feedback) can appropriate conclusions be reached. This concept compliments the second characteristic (system as cause) as problematic behavior is traced to specific feedback loops endogenous to the system. The final characteristic of System Dynamics is operational thinking. As will be explained further shortly, System Dynamics begins as a “mental model” which is observable, real-world behavior. This behavior is then reconstructed in the model to create cause-and-effect relationships where all variables also represent real-world counterparts. This mechanistic view enables the comparison of system behavior to real-world behavior and the exploration of “what-if” scenarios.

Built on these foundational characteristics, the System Dynamics methodology consists of five steps: Problem Identification, Development of Causal Logic, Model Formulation, Model Simulation and Validation, and Policy Generation and Implementation (Shelley, 2009; with modifications). The following sections cover these five steps, using Air Force Civil Engineer *Technical Knowledge Base* as a small demonstration for the overall process.

Step 1: Problem Identification

Problem identification is the visual recognition of a real-world issue requiring attention, investigation, and correction. This visualization comes in the form of a mental model of an operational system and some problematic result occurring within it. The problem is evidenced by a behavior called a Reference Mode, which is a notional representation of system behavioral patterns over time, either historical or hypothesized. For example, in chapters one and two the problem of an eroding technical knowledge base in the Air Force Civil Engineer career field was identified. This behavioral pattern can be expressed graphically, as shown in Figure 1. The desired behavior is a steady increase to some target level; however, the observed behavior is degradation and subsequent steady state at a much lower level, hence the problem.

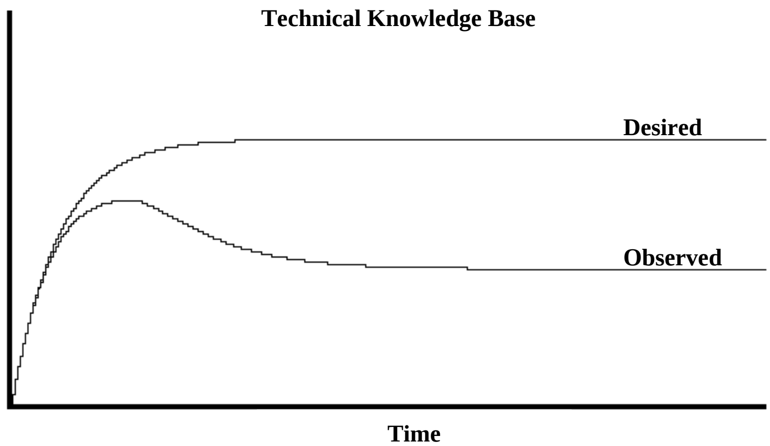


Figure 1: Reference Mode Diagram for *Technical Knowledge Base*.

It is important when graphing the reference mode or any other behavior using a System Dynamics methodology is to express it in terms of a smooth behavior. A common mistake is to include all aspects of real-world data (peaks, valleys, etc.) and attempt to perfectly recreate that output in the system model. In System Dynamics, extraneous noise should be eliminated to uncover the underlying behavioral response. This allows analysis of long-term behavioral trends not as easily found or predicted using statistical analysis of historical data.

The second half of the problem identification step is the recognition of other important variables whose values define the current state of the system. These variables, called stocks (or state variables), are influenced directly by in-flows and out-flows, meaning the stocks represent an accumulation of these flows, their history, and combinations. A stock, combined with its flows, creates an infrastructure which produces a dynamic behavior. This behavior is called a Virgin Behavior and provides the basic building blocks for the model. Virgin Behaviors are different than Reference Modes. As mentioned, a Reference Mode is a problematic behavior produced from the system, whereas a Virgin Behavior is the individual stock's behavior when isolated from the system. For example, given Figure 1 the plot labeled "observed" is the Reference Mode while "desired" represents the Virgin Behavior.

Virgin Behaviors are generally classified into one of ten standard behavioral categories. While the exact rate and value of the behavior may vary, the underlying infrastructure they generate is the same. Some common reference mode behaviors are displayed in Figure 2.

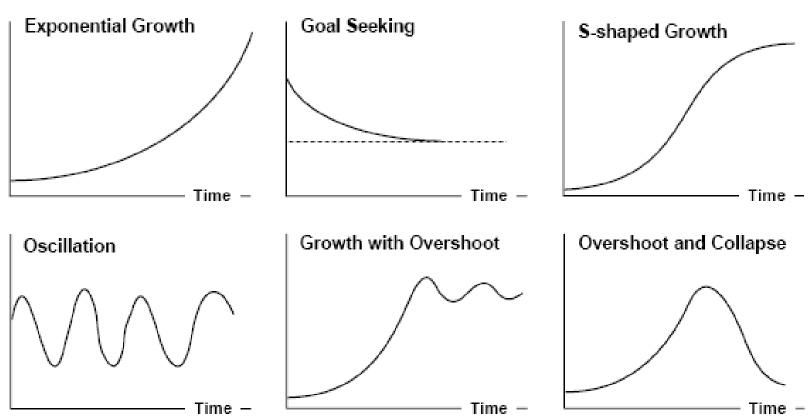


Figure 2: Common Reference Mode Diagrams (Sterman, 2000).

For example, the forthcoming model includes a stock named *Expeditionary Nation Building Mission* representing a changing requirement for a technically centered Air Force Civil Engineer workload. The Virgin Behavior of this stock is S-shaped; requirements begin small as the conflict begins, then builds rapidly as a military strategy converges on winning support of the local population, then levels off at some required level (graphical representation shown in Figure 3). While this stock is not immediately tied to the *Technical Knowledge Base* problem, its value defines the current state of the system and its Virgin Behavior represents underlying cause and effect relationships.

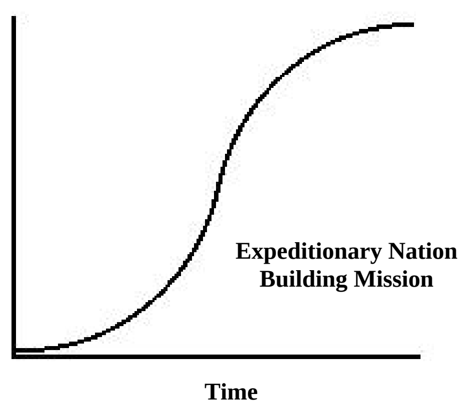


Figure 3: Virgin Behavior of *Expeditionary Nation Building Mission*.

Step 2: Development of Causal Logic

The second step in the System Dynamics methodology is to convert the Virgin Behaviors into their appropriate cause and effect relationship structure, then connect the system components together to create a Causal Diagram of feedback loops. Returning to Figure 1 and the Virgin Behavior of *Technical Knowledge Base* in the Civil Engineer career field, Figure 4 illustrates the causal structure corresponding to the behavior. The structure is called Approach to Steady State, as named for its illustrated behavior. The flow titled *Increasing Knowledge Base* represents various internal system entities adding to the *Technical Knowledge Base* stock. Conversely, the flow *Decreasing Knowledge Base* takes away from the stock. However, *Decreasing Knowledge Base* is influenced by the current level of *Technical Knowledge Base*. Think of it rationally, if an individual has X amount of information retained, they will lose it at some rate Y. However, if the same individual increases their knowledge to X*2, retaining that level of knowledge will be more difficult causing the rate of decrease (Y) to happen more rapidly (not necessarily Y*2, however). This is the premise behind the Approach to Steady State, where the causal loop created by *Decreasing Knowledge Base* prevents *Technical Knowledge Base* from spiraling out of control; it compensates.

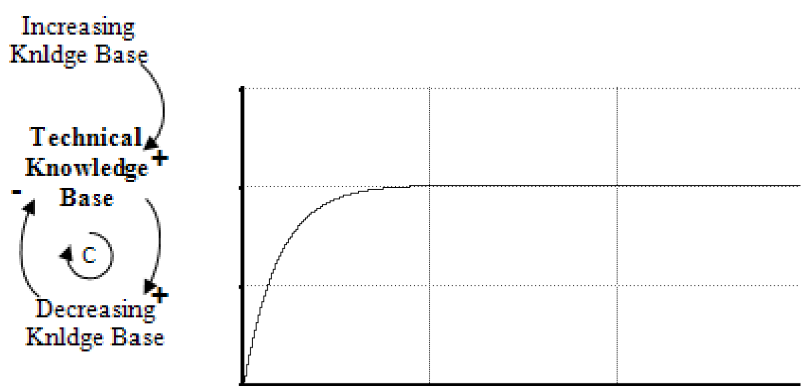


Figure 4: Causal Diagram and Virgin Behavior for *Technical Knowledge Base*.

All causal loops work within a system work to either reinforce or compensate. A Reinforcing Loop creates perpetual growth, often sending the system spiraling out of control. Conversely, as shown in Figure 4, a Compensating Loop works to balance system behavior and inhibit intensification of actions. There are many examples of these phenomena in the real world, including compounding interest (reinforcing) and a thermostat (compensating). These loops often work in conjunction, for example while population growth (births) is reinforcing, a second causal loop for population decline (deaths) is simultaneously compensating to keep the system stable.

The procedure of converting the Virgin Behaviors into a causal structure culminates with their interconnection to create multiple feedback loops, and ultimately the system itself. This process follows an intuitive approach, matching causal and effect relationships with known influence. As these connections are made, the system begins to take shape as connections reveal reinforcing or compensating loops that have formed. The actions of these loops, particularly the reinforcing loops, also provide insight to potential areas of concern – instability – within the model.

Step 3: Model Formulation

Equipped with the Causal Diagram for the system, the next step of System Dynamics modeling is formulating causal relationships into mathematical relationships that extend and elaborate the initial model into a mechanistic format, called a Flow Diagram. This process proceeds much like Step 2, first at the individual stock level and gradually making intra-system connections. During this process the modeler continuously checks model performance to ensure the operational behavior being built matches the previously determined Virgin Behavior and makes intuitive sense conceptually. Model validity, discussed further later, is built throughout this process as behavior is recognized and accepted as accurate and the completed model correctly displays the original Reference Mode behavior.

However, when building the Flow Diagram (and the Causal Diagram) great care must be taken to maintain the appropriate level of depth and breadth of detail included. System Dynamics models must be aggregated to a level that appropriately provides a level of detail unhampered by intricate details. At the same time, the model must be broad enough to cover a suitable boundary for the system without stretching too far. As previously mentioned, the modeling process begins with a mental model of the system; this generally lies at point A of Figure 5. This mental model is commonly narrowly focused and highly detailed. The challenge of System Dynamics then is to aggregate the mental model as highly and simplistically as possible, then bring back the appropriate level of detail and breadth that is appropriate (point B) while avoiding "the dangers."

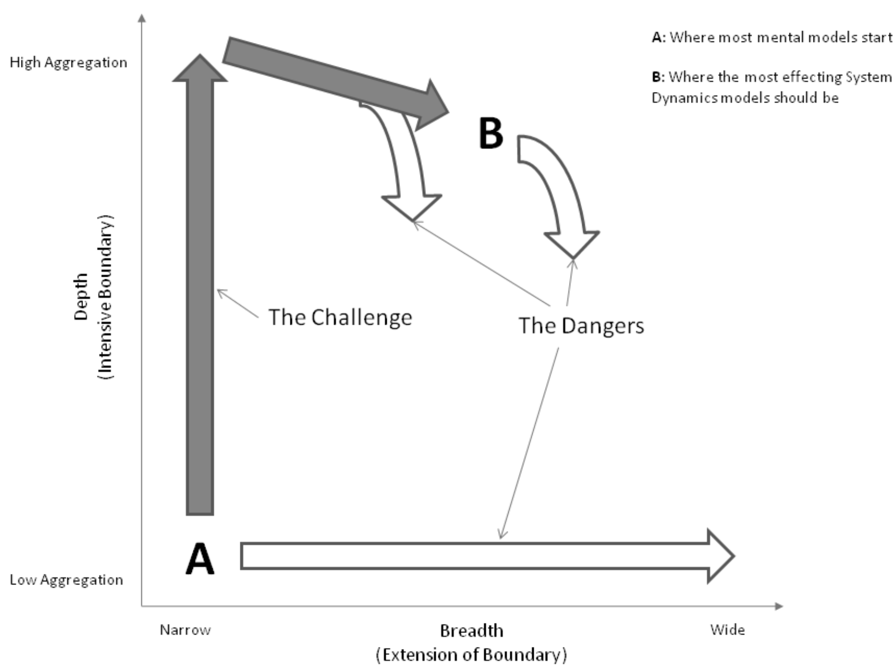


Figure 5: Model aggregation for System Dynamics modeling (IThink, 2001).

While formulating the Flow Diagram, there are some additional rules to follow. All mathematical relationships must comply with the logic represented in the Causal Diagram. However, iteration is a key component to the System Dynamics methodology; as formulation uncovers further clarification, causal relationships can be revisited for adjustment. These adjustments should not arise simply to "force" behavior to match desired performance, but instead to improve the model and thus build confidence in its accuracy. Additionally, the entire process with iterations should be continuously communicated and confirmed with a client or expert to also gain confidence. Continuing with the example, Figure 6 depicts the flow diagram for *Technical Knowledge Base*.

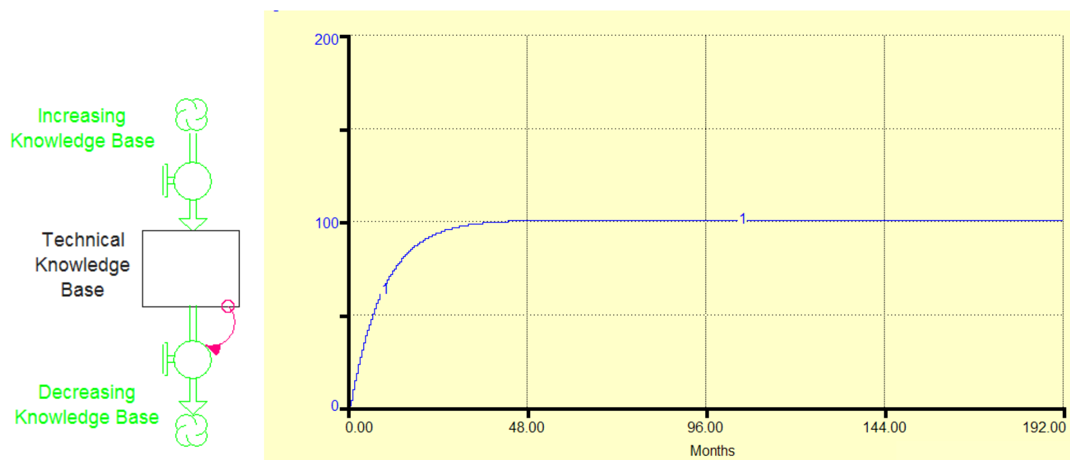


Figure 6: Flow Diagram and behavior of *Technical Knowledge Base* simulated in STELLA 9.

Step 4: Model Simulation and Validation

With the model fully formulated mathematically into a Flow Diagram, it is now ready for simulation and validation. However, simulation at this point has occurred numerous times throughout the iterative modeling process to observe behavior and validate the system structure. The simulation now should reflect hypothesized Reference

Mode behavior. Unexpected behavior should be identified and checked for possible flaws in the model or a realization of actual system behavior other than hypothesized that provides better insight to the system's behavior.

At this point, the validity of the model must be addressed. Validation of a System Dynamics model "is the process of establishing confidence in the soundness and usefulness of a model" (Shelley, 2009). Confidence is the appropriate criterion strictly because there is no absolute proof of correctness in System Dynamics. The validity is always in respect to a specific modeling purpose. The confidence is not gained through a single test, but rather accumulated gradually throughout the iterative modeling process and through passing multiple validation tests. The very nature of System Dynamics warrants tests not generally acceptable to other modeling endeavors and likewise tests for other models are inappropriate for System Dynamics. For example, a long-standing conflict exists concerning the feasibility of statistical validation of model output against real-world data. This is generally not possible because System Dynamics is concerned with comparing model *behavior patterns* with real-world *behavior patterns*, not prediction of specific data points at a specific time.

There are multiple formal tests used in System Dynamics to gain confidence (and thus validity). These tests fall into two categories: test of model structure and tests of model behavior. The following is a list of the tests and a brief explanation of each (Forrester & Senge, 1980):

Tests of Model Structure:

- Structure Verification Test: a comparison of model structure directly with the structure of the real system to verify a real-world representation.
- Parameter Verification Test: a test to ensure formulation parameters correspond conceptually and numerically to real life.

- Extreme Conditions Test: identification of stocks to which each rate equation depends and manipulation to maximum and minimum plausible values to demonstrate effect; this identifies structural flaws and enhances usefulness in the normal operating range. This test is generally considered the most important.
- Boundary Adequacy Test: a test for appropriate aggregation and inclusion of all relevant structure.

Tests of Model Behavior:

- Behavior Reproduction Tests: a test to ensure behavior is a consequence of model structure.
- Behavior Anomaly Test: tracing anomalous behavior back to the structural cause to reveal a flaw or identify unpredicted behavior in the real system, thus building confidence.
- Boundary Adequacy Test: different from its structural counterpart, this test conceptualizes additional structure which might influence behavior.
- Behavior Sensitivity Test: a test to seek plausible sets of parameter values that cause behavior test to fail; confidence is built as these values cannot be found.

These tests build confidence in the model's utility as a simulation tool of the real-world system. Validation as a whole process works to gain insight into the model's infrastructure to gain an understanding that builds confidence in the methodology.

Step 5: Policy Generation and Implementation

The final step of the System Dynamics modeling process is to generate feasible solutions in the form of policies that address the Reference Mode behavior. To generate these policies, it is important to identify the reinforcing loops and key components causing the unwanted behavior. These areas can then be used as leverage points, the point of intervention by an artificial policy. The policies generated should be simple in design, feasible in nature, measureable in qualitative impact on system behavior, and effective. However, often a single solution will not completely rectify the Reference Mode, requiring further search into the trade-offs of each potential policy solution.

Armed with a thorough understanding of the system, a full confidence in the model's utility as a simulation tool, and a detailed inventory of potential policy solutions and corresponding implications, a solution can be chosen and implemented in the real-world. The research presented here presents recommended solutions to provide guidance for implementation by senior career field leadership and sheds light into further studies for more other specific policy generation. The next chapter walks through these five steps of model development, searching for that library of potential policy solutions.

IV. Analysis and Results

The previous chapters of this research have established a theoretical framework of the situation faced by the Air Force Civil Engineer officer career field and demonstrated the practical application of a System Dynamics methodology to gain insight into the system in operation. This chapter will now integrate that foundation into the implementation of a working model to not only demonstrate the issues seen currently but also create a platform for exploring various alternatives to alter Civil Engineer knowledge transformation. As discussed in Chapter 2, technical knowledge serves as a prerequisite to managerial knowledge, making it the focus point of the research. Therefore, the initial modeling will focus solely on the technical knowledge side of the Civil Engineer officer career field. The five step modeling process of the System Dynamics methodology outlined in Chapter 3 provides the outline for this chapter.

Step 1: Problem Identification

As discussed in Chapter 3, the general modeling process starts by examining the Reference Mode behavior and determining what model elements are necessary to describe the system at any given time; or, what are the stocks. Identifying these stocks and determining their Virgin Behavior provides the baseline for assembling the model. The stocks identified as necessary to this model and their Virgin Behaviors are summarized in Table 4.

Table 4: Model stocks and Virgin Behaviors.

Model Element	Virgin Behavior
Expeditionary Nation Building Mission	S-Shaped
Expeditionary Base Operations Mission	S-Shaped
Garrison Civilians & Contractors	Goal Seeking
Expeditionary Military Technical	Goal Seeking
Expeditionary Military Management	Goal Seeking
Expeditionary Contractors	Goal Seeking
Expeditionary Contractor Efficiency	Goal Seeking with First-Order Drain
Training Policy	Goal Seeking
Technical Knowledge Base	Approach to Steady State
Garrison Military	No Natural Behavior
Garrison Mission Requirement	No Natural Behavior

The first elements identified are the *Expeditionary Nation Building Mission* and *Expeditionary Base Operations Mission* (also known as Forward Operating Base, or FOB operations). These two entities represent the two distinct missions faced by civil engineers in the expeditionary environment, both of which require significant personnel, resources, and time. However, the stocks represent only the technical aspect of the mission to be accomplished; for the purposes of this model management functions are not included here. The S-Shaped behavior of these stocks represent the initial gradual mobilization of forces in response to conflict initiation, which then leads to a rapid increase until leveling off at some steady state commensurate with conflict requirement. As an example, at the start of the Iraq invasion of Spring 2003 it took six months for the full American military force to occupy Iraq, which was done slowly initially as planning and mobilization occurred, followed by a rapid flood of forces into the country. This Virgin Behavior is represented in the causal diagram shown in Figure 7.

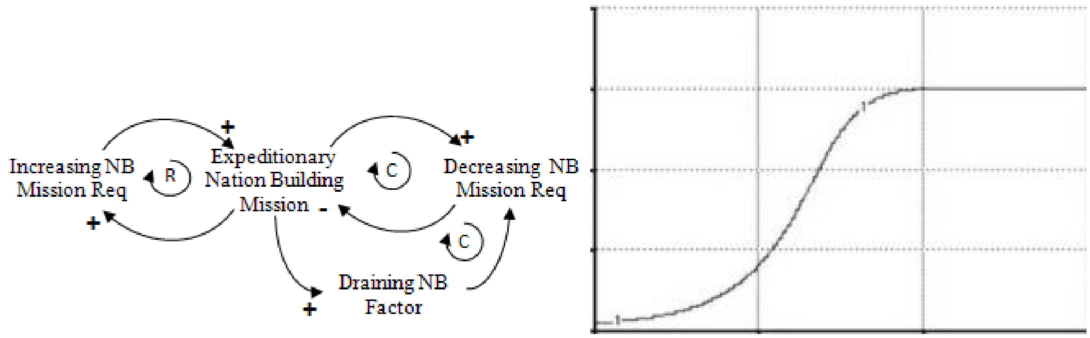


Figure 7: Causal Diagram and graph of Virgin Behavior of S-Shaped Structure.

The next Virgin Behavior to introduce is Goal Seeking, used by six of the eleven stocks in this model (*Garrison Civilians & Contractors*, *Expeditionary Military Technical*, *Expeditionary Military Management*, *Expeditionary Contractors*, *Expeditionary Contractor Efficiency*, and *Training Policy*). A Goal Seeking structure is characterized by a given goal for a specific stock which is compared to the current stock level, producing a gap. This gap is then closed by an increased flow into the stock at a given time constant. As the gap decreases the stock inflow too decreases, leveling the stock at a steady state equal to the goal. For example, given a time constant of ½, for each time unit the stock inflow would equal one half of the current gap; thus a goal of ten and current stock level of zero would close the gap by five the first time unit, 2.5 the second time unit, 1.25 the next, and so on until the stock level reaches the goal of ten. This behavior is seen every day in investing, manufacturing, and retail. The Virgin Behavior is shown in the causal diagram in Figure 8.

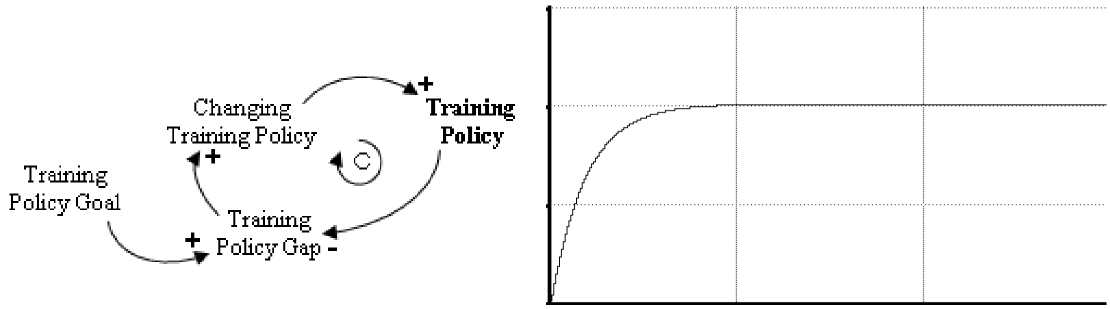


Figure 8: Causal Diagram and graph of Virgin Behavior of Goal Seeking Structure.

The stocks with Goal Seeking structures are listed and defined as follows:

- *Expeditionary Contractors*: the number of contractors needed in addition to *Expeditionary Military Technical* to meet the *Total Expeditionary Mission Requirement*; these contractors' focus is on technical work, not management.
- *Expeditionary Military Technical*: the number of military personnel operating in the expeditionary environment on the technical mission.
- *Expeditionary Military Management*: the number of military personnel operating in the expeditionary environment on the management mission.
- *Garrison Civilians & Contractors*: the number of civilian and contractor personnel working to meet *Garrison Mission Requirements*.
- *Training Policy*: the percent of garrison time each *Garrison Military* individual devotes to the *Expeditionary Training Program*.
- *Contractor Efficiency*: the level of effectiveness maintained by *Expeditionary Contractors* in performing technical tasks. (Units are work/person/time.)

The last of the six stocks represented by a Goal Seeking structure (contractor efficiency) exhibits dual characteristics. *Expeditionary Contractor Efficiency* reacts to an efficiency goal, but also exhibits a natural First Order Drain. This characteristic is not hard to imagine when put into context of traditional human behavior. When an individual learns something (or in this case becomes efficient at it), there will be a natural atrophy of that knowledge over time unless some action is taken to prevent it. This is the premise behind the hit television show "Are You Smarter Than A Fifth Grader," a show which faces adults against fifth graders answering elementary school level questions.

The children almost inevitably win because they have been practicing the knowledge while the adults have let it erode over time. A causal diagram of the Virgin Behavior for a First Order Drain is shown in the causal diagram in Figure 9.

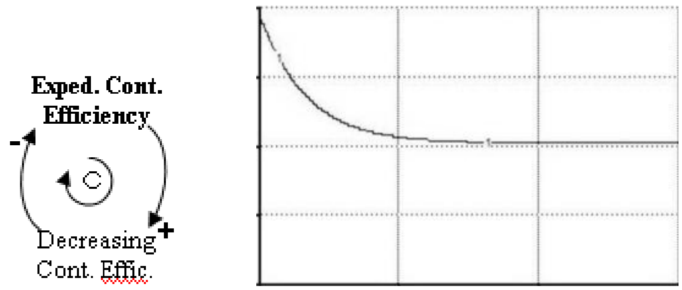


Figure 9: Causal Diagram and graph of Virgin Behavior of Draining Structure.

Similar to a first order drain is the last Virgin Behavior structure, the Approach to Steady State. While the structure is similar to a First Order Drain, the behavior is identical to Goal Seeking. By adding an inflow to the stock used in the First Order Drain example, the drain no longer dominates the behavior but instead only determines the level of the steady state. More specifically, an Approach to Steady State structure has a constant input and a drain that is dependent upon the current stock level. As the stock level gets higher, the drain pulls more from the stock. Eventually the inflow level will equal the outflow, leaving the stock at a steady state. A more detailed causal diagram and Virgin Behavior is shown in Figure 10.

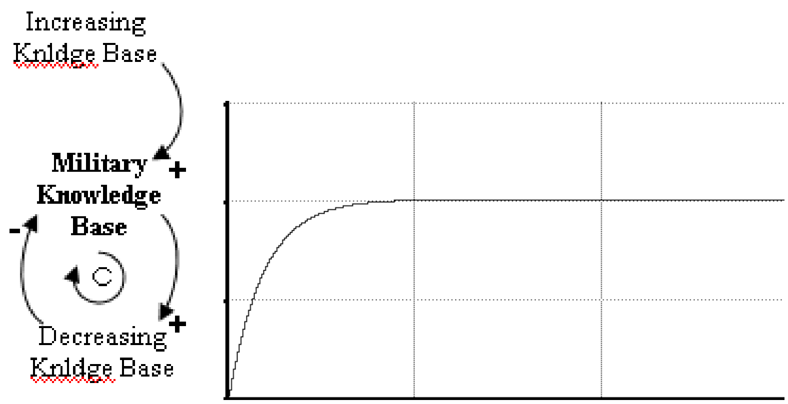


Figure 10: Causal Diagram and graph of Virgin Behavior for Approach to Steady State Structure.

Lastly, *Garrison Military* and *Garrison Mission Requirement* do not demonstrate independent Virgin Behavior. *Garrison Military* operates as a pool of resources for deployment and training purposes, thus not displaying any individual characteristics. Conversely, *Garrison Mission Requirements* is held at a constant for the purposes of the model under the assumption this mission load will not decrease over the course of the simulation period. However, it is coded as a stock for policy implementation later in this study.

Step 2: Development of Causal Logic

Given the Virgin Behaviors of the individual stocks, a foundation is laid to iteratively build the causal diagram showing individual influence factors in the model. The causal diagram depicts which entities affect each other and the direction of their effect (positive or negative). Figure 11 shows the compilation of the Virgin Behaviors previously discussed with the exception of *Expeditionary Military* both *Technical* and *Management*, whose Goal Seeking structure will be built in the forthcoming iterative steps. (For reference purposes, note that all stocks are labeled with bold font, circled C's are compensating loops, circled R's are reinforcing loops, and starting with Figure 12 all new components appear in red.)

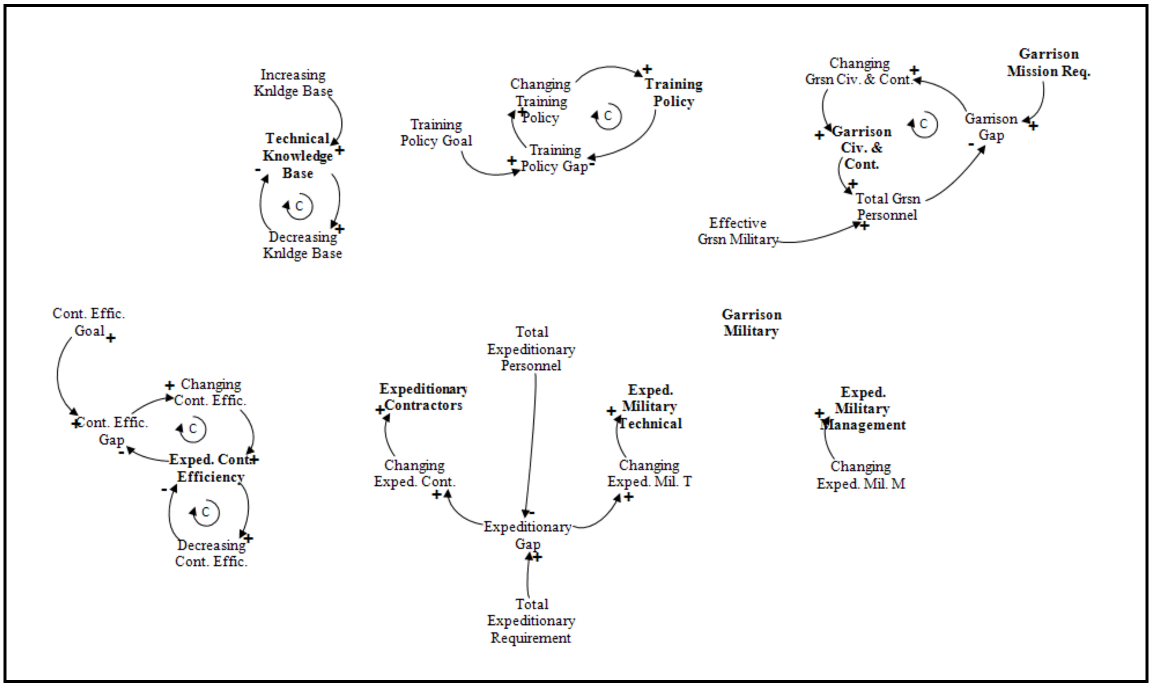


Figure 11: Causal Diagram showing Virgin Behaviors of individual stocks.

The first set of influences to illustrate is the completion of the Goal Seeking structure for *Expeditionary Contractors* and *Expeditionary Military Technical*. These two stocks are driven by a goal of completely meeting the *Total Expeditionary Mission Requirement*, which is a sum of the *Expeditionary Nation Building Mission* and *Expeditionary Base Operations Missions* outlined previously. This requirement is then compared to the *Total Expeditionary Personnel* to create a single gap that drives the increase of both contractor and military stocks. However, the *Total Expeditionary Personnel* is not simply the number assigned to that mission; those individuals are operating at a specific efficiency at any one time with the highest possible value of one. For example, contractors completing a task for the first time will not perform at the highest efficiency because of a learning curve; however, with experience that efficiency will rise. So the *Total Expeditionary Personnel*, then, is the sum of the contractor and military personnel multiplied by their respective efficiency. Note that for military the efficiency is a function of the *Technical Knowledge Base,* per the previous definition. Completing the complementary Goal Seeking structures also creates two compensating loops, discussed previously as bringing stability to the system.

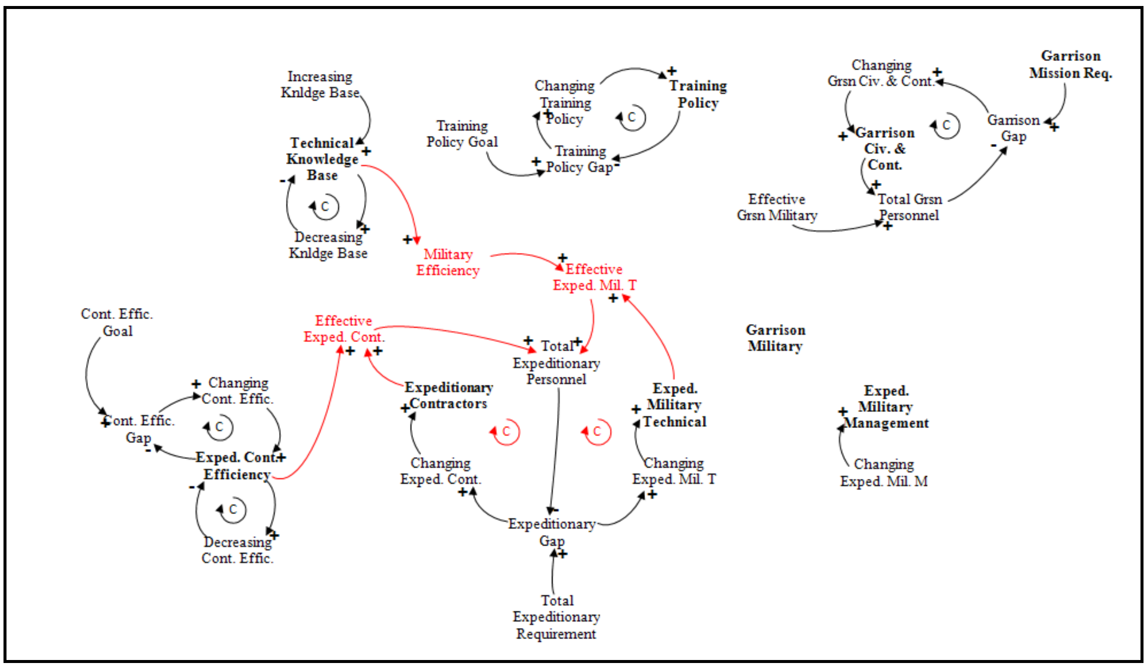


Figure 12: Causal Diagram added closing the causal Goal-Gap loops for *Expeditionary Contractors* and *Expeditionary Military Technical.*

The next step is to identify how the *Expeditionary Gap* is divided between the military and contractors. Closing the entire value of the gap on both the contractor and military sides results in increasing personnel at a rate of double the current gap. Therefore, a factor titled *Contractor Preference* is created in Figure 13 to compare the efficiency of military personnel to that of contractors, thus deciding how the gap is split. If contractors are better at performing the expeditionary mission, they will receive a higher percentage of the gap, and thus higher increase in personnel. Conversely, if military personnel perform the job more efficiently, the larger workload will shift to them. The total preference of military and contractors is always equal to one, ensuring the integrity of the gap is maintained. In the flow diagram, a time constant is also used to further detail the increase and/or decrease in contractors and military.

The second factor introduced in Figure 13 is *Expeditionary Contractor Experience*. As mentioned with the First Order Draining structure, there is a natural atrophy of efficiency if no action is taken to maintain it. The act of maintaining knowledge (or in this case efficiency) comes through continued practice and experience. Therefore, as *Expeditionary Contractors* are being utilized, the effect of the drain on *Expeditionary Contractor Efficiency* is decreased. Notice that the addition of this factor creates two reinforcing loops (in addition to two reinforcing loops from the previous factor). As previously discussed, reinforcing loops create instability within the system as causal effects spiral out of control. As an example, follow the circular influence from *Expeditionary Contractor Experience* that, when increased, decreases the drain on *Contractor Efficiency*, which increases *Contractor Preference*, which increases *Expeditionary Contractors*, and then further increases *Expeditionary Contractor Experience*. This loop, uncontrolled, can have serious repercussions throughout the system.

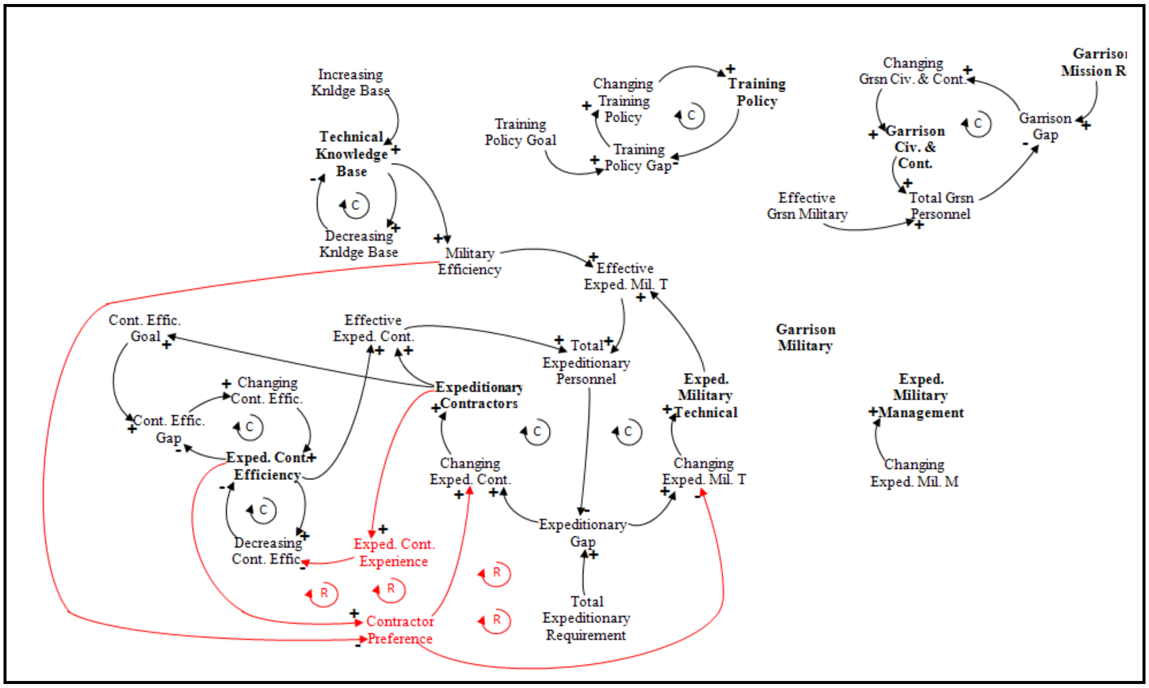


Figure 13: Causal Diagram adding *Contractor Experience* and *Contractor Preference*.

The final influence added to the *Expeditionary Military Technical* is a *Propensity to Deploy* in Figure 14. As the *Deployment Tempo* increases for military, there comes a point where the tempo goes over sustainable measures, typically targeted at fifty percent of personnel deployed. Therefore, as tempo nears the breakpoint the propensity decreases. This addition provides a compensating loop to help stabilize the system; however the second influence added in Figure 14 creates two reinforcing loops and one compensating loop. This influence, *Military Deployment Experience*, works the same as the *Expeditionary Contractor Experience* previously displayed in Figure 13.

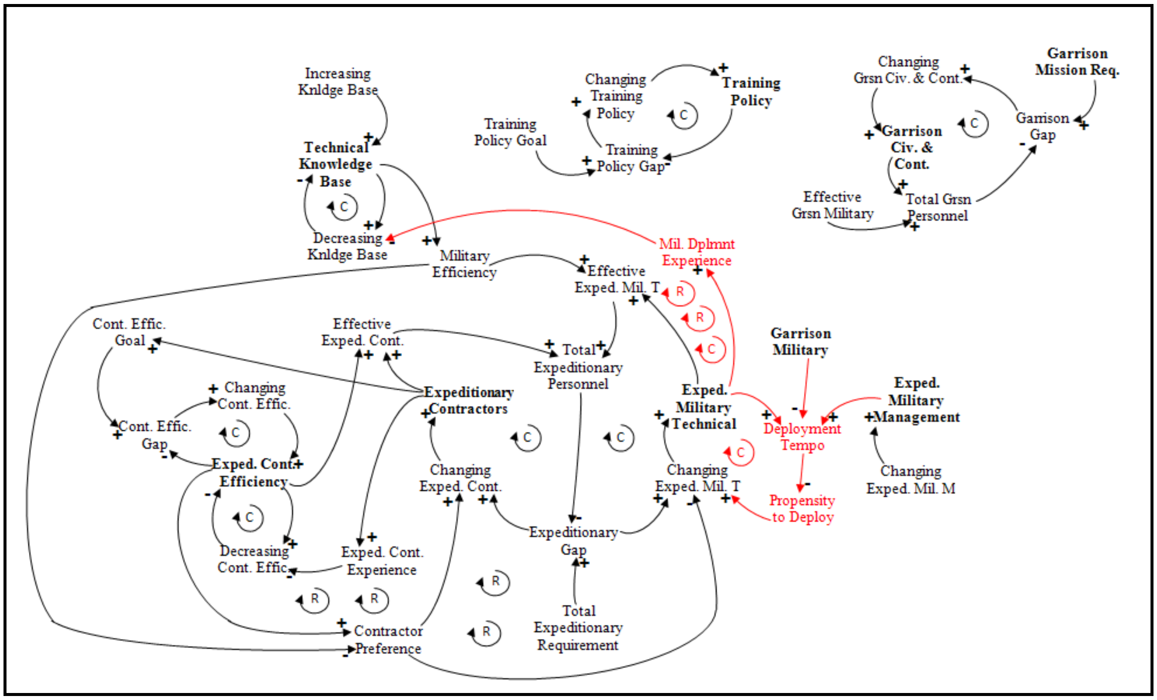


Figure 14: Causal Diagram adding *Military Deployment Experience*, *Deployment Tempo*, and *Propensity to Deploy*.

The next step of iteratively building the model moves into the realm of *Garrison Military* and *Training Policy*. The *Training Policy* represents the percent of garrison military efforts that are devoted to the *Expeditionary Training Program*. This *Expeditionary Training Program* is what builds the *Technical Knowledge Base* to allow operations to continue efficiently. The compliment (one minus the *Training Policy*) is then dedicated to performing the *Garrison Mission Requirement*. It is important to note that the *Expeditionary Training Program* represents a multitude of training venues, including formal classroom training, informal on-the-job training in garrison, and the actual Prime BEEF (expeditionary) training program. Also introduced is the *Contractor Ratio*, a simple ratio of contractors per *Total Expeditionary Personnel*. This provides a baseline for the *Expeditionary Work Shift*, which represents how work requirements shift from nearly purely technical when the military is performing tasks to much more managerial oversight when more contractors are involved. This shift in work then determines the number of *Expeditionary Military Management* required for proper oversight and quality control.

The *Expeditionary Work Shift* and *Garrison Gap* also influence the *Training Policy Goal*. As the *Garrison Gap* grows larger, garrison civil engineer commanders sacrifice the *Expeditionary Training Program* for meeting strict requirements set forth by their leadership, with the *Garrison Gap* being exacerbated by decreased levels of military personnel due to deployments. Follow the influence loop: an increased *Garrison Gap* decreases the *Training Policy Goal*, which decreases the *Training Policy,* which decreases *Technical Knowledge Base*, which decreases *Military Efficiency*, which increases the *Expeditionary Gap*, which increases *Expeditionary Military Technical* deployments, which decreases *Garrison Military,* which decreases *Total Garrison Personnel* and increases the *Garrison Mission Gap* further; another reinforcing loop. Similarly, an increased *Expeditionary Work Shift* decreases the *Training Policy Goal*, which decreases the *Training Policy* and continues through the loop similarly until the work shift increases further as well. These two factors combine to produce five new reinforcing loops and only one compensating loop, as shown in Figure 15.

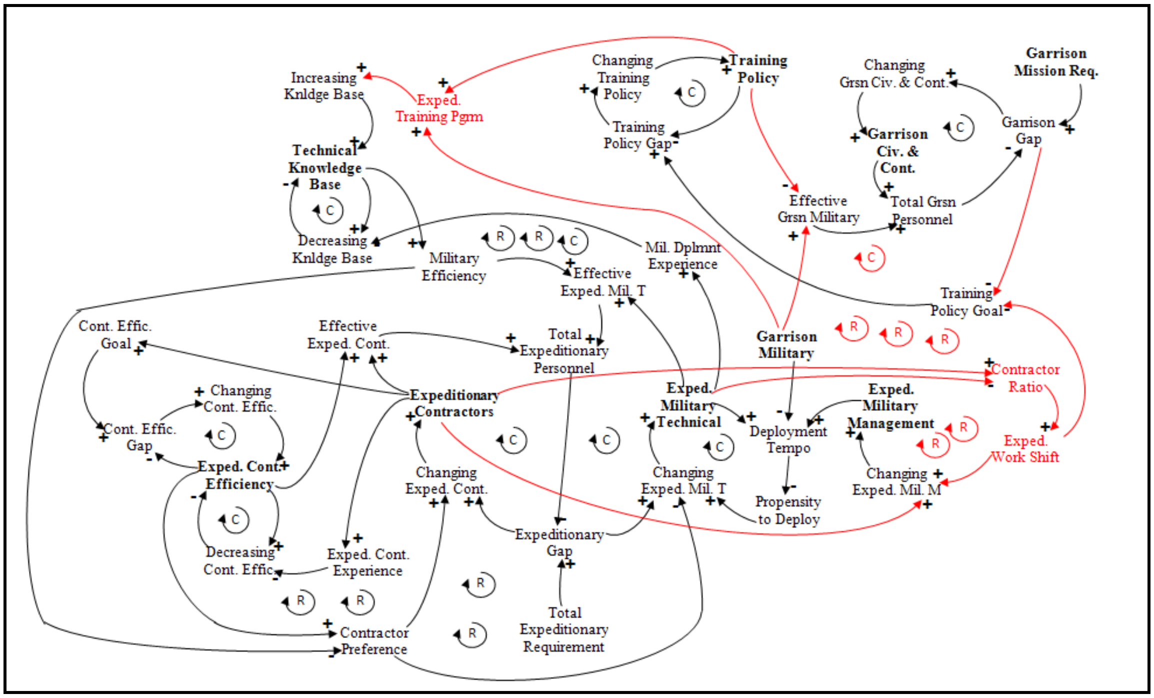


Figure 15: Causal Diagram adding *Work Shift* and *Expeditionary Training Program.*

The final step to complete the model causal diagram incorporates influence on *Garrison Military*, bringing it within the system boundary (rather than an external input). The influence is simple: as personnel are deployed to the *Expeditionary Military Technical* and *Expeditionary Military Management* they must be removed from the *Garrison Military* stock. This influence, along with the complete depiction of the influence diagram is shown in Figure 16. The last influence added, while simple, increases the number of reinforcing loops in the model by five to a total of nineteen, while compensating loops are severely outnumbered at eleven. This proves the model in question is severely unsteady and susceptible to erratic behavior, providing a baseline for proceeding forward with the second step of the modeling process: model formulation.

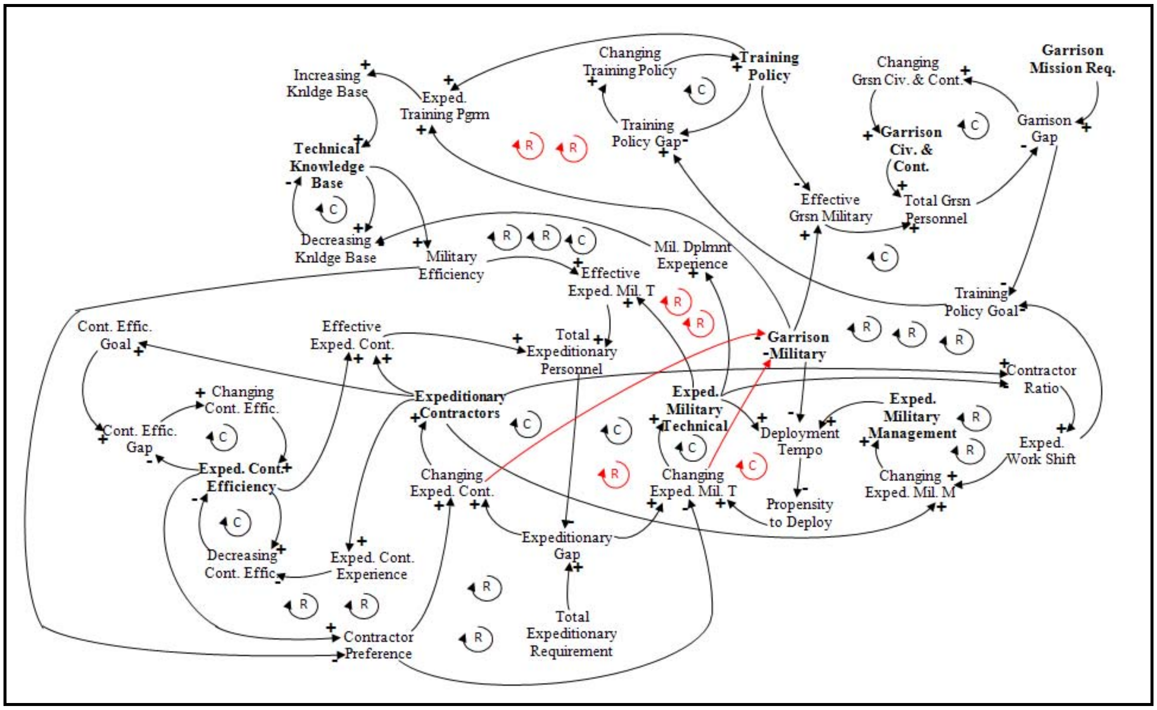


Figure 16: Causal Diagram, final model.

Step 3: Model Formulation

The process of implementing the influence diagram through flow diagram simulation is done with System Dynamics software. STELLA® (version 9.0.2, by ISEE, Inc) is used for this study because of its widespread acceptance among System Dynamics proponents and immediate availability (Richmond, 2004). This section will convey the logical development and implementation of the causal relationships into graphical representations of systemic behavior.

Starting the model formulation process requires identifying the framework of general requirements for the model simulation. This framework includes determining the scenario to be simulated along with the length and time interval of the simulation. Remaining consistent with historical trends and projections from military analysts, the scenario utilized for this simulation consists of a state versus non-state military intervention rather than full scale, state on state, near-peer warfare (Barnett, 2005). This type of warfare, typically characterized by some type of counterinsurgency, is estimated to average ten years in duration (Nagl, 2002). This projection of warfare scenario and duration provide the starting point for replicating real world behavior in the model. Therefore, a sixteen year window will be used for the simulation, expressed in terms of months, producing a simulation range of zero to 192 months. Sixteen years was chosen to fully encompass timeframes before, after, and during the conflict simulation. However, many of the simulations do not include a conflict end, instead focusing on behaviors produced during the conflict. It is also important to reiterate that although the model is formulated in terms of months it is inappropriate to analyze it in terms of the exact timescale, but rather in terms of systemic behavior over the short, medium, and long term horizons.

Using this framework and keeping in mind the aforementioned value of behavioral analysis over statistical analysis, the modeling process continues by translating the Virgin Behavior of the individual components (stocks) into flow diagrams and incrementally connecting the elements in the same manner as previously done with the causal diagrams. The intent is to implement each system element as an accurate reflection of real-world behavior, ensuring all aspects are real, logical, and appropriate to the system.

As with the causal diagram, development of the flow diagram begins with the individual stocks and their infrastructure to demonstrate individual Virgin Behaviors. The first stocks to operationalize are the two system inputs, the *Expeditionary Nation*

Building Mission and *Expeditionary Base Operations Mission*. These two stocks are a representation of current mission requirements from the technical domain, expressed in units of personnel. As discussed in Step 2, their Virgin Behavior takes the form of an S-shaped curve where requirements first start small and begin growing more rapidly as operations intensify, eventually slowing to some steady state level appropriate for the given conflict. However, these two requirements differ in their inception. The *Expeditionary Base Operations Mission* begins when the first combat boots hit the ground and is generally proportional to the number of foreign personnel present. However, the *Expeditionary Nation Building Mission* lags behind as the bulk of technical engineering work cannot be accomplished satisfactorily until security has taken hold. Furthermore, the level of requirements between the two differs as well. While military strategists argue whether the appropriate counterinsurgency strategy consists of a Hearts and Minds versus a Cost Benefit approach, the one overarching understanding is that defeating a counterinsurgency requires boots on the ground (FM 3-24, 2006). To sustain a high number of military personnel and operate expeditionary airfields requires an increased technical engineer capacity. Figures are not available for exactly what percentage of deploying personnel are being utilized for Nation Building versus Base Operations, but a conservative estimate would put Nation Building around three quarters the work load of Base Operations. Figures 17 and 18 illustrate the flow diagrams for these two stocks with the operational Virgin Behavior for the model.
(Note: all flow diagrams are color coded with stocks being black, flows being green, converters (mathematical calculations and constants) being blue, and a few noteworthy

mathematical representations in orange. All ghosts, or stock shadows, are represented with the same color, albeit a lighter shade.)

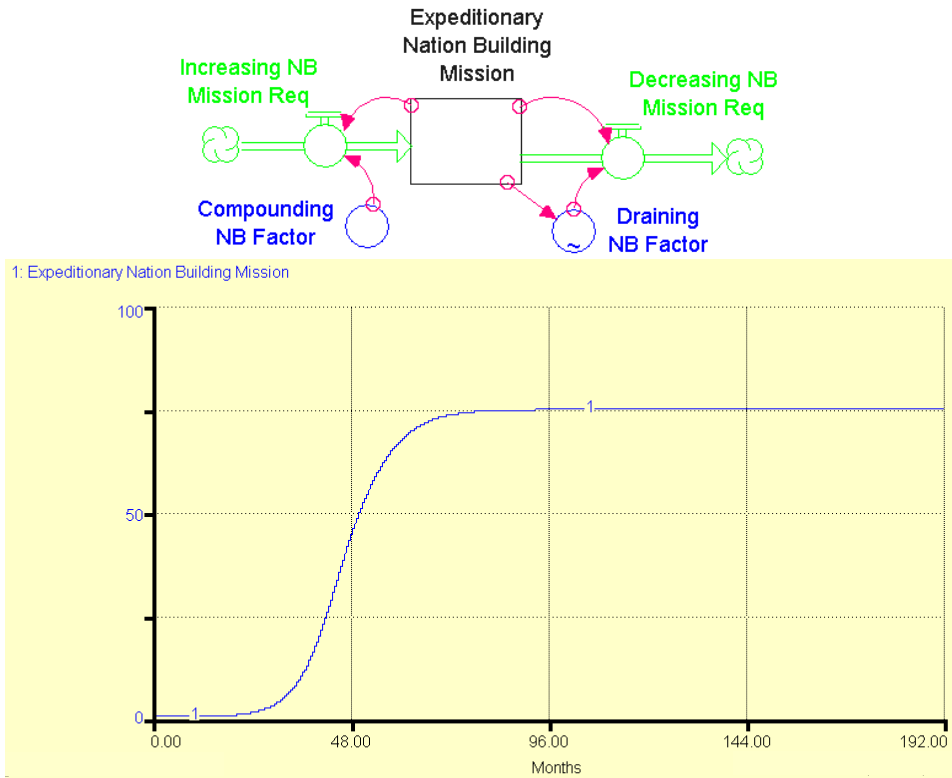


Figure 17: Flow Diagram and behavior of *Expeditionary Nation Building Mission* simulated in STELLA.

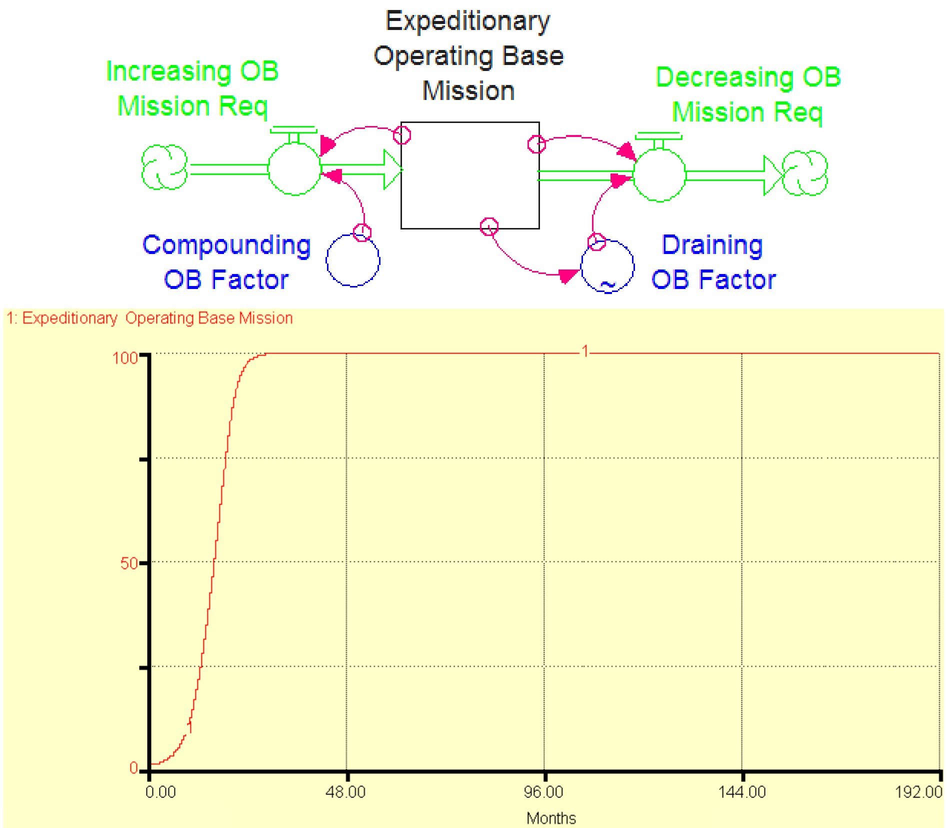


Figure 18: Flow Diagram and behavior of *Expeditionary Base Operations Mission* simulated in STELLA.

Moving forward with the main portion of the model, the next piece of infrastructure to bring to life is the *Technical Knowledge Base* stock. Knowledge base is gained through both formal and informal training (*Expeditionary Training Program*) and retained through repetition (*Deployment Experience*). The Virgin Behavior's infrastructure was tailored to produce a steady-state *Technical Knowledge Base* level of 100, allowing it to be a straightforward representation of *Military Efficiency*. *Deployment Experience* acts as the draining factor, lowering the rate with more experience and raising it when there is little experience. The complete flow diagram and resulting graphical behavior is shown in Figure 19.

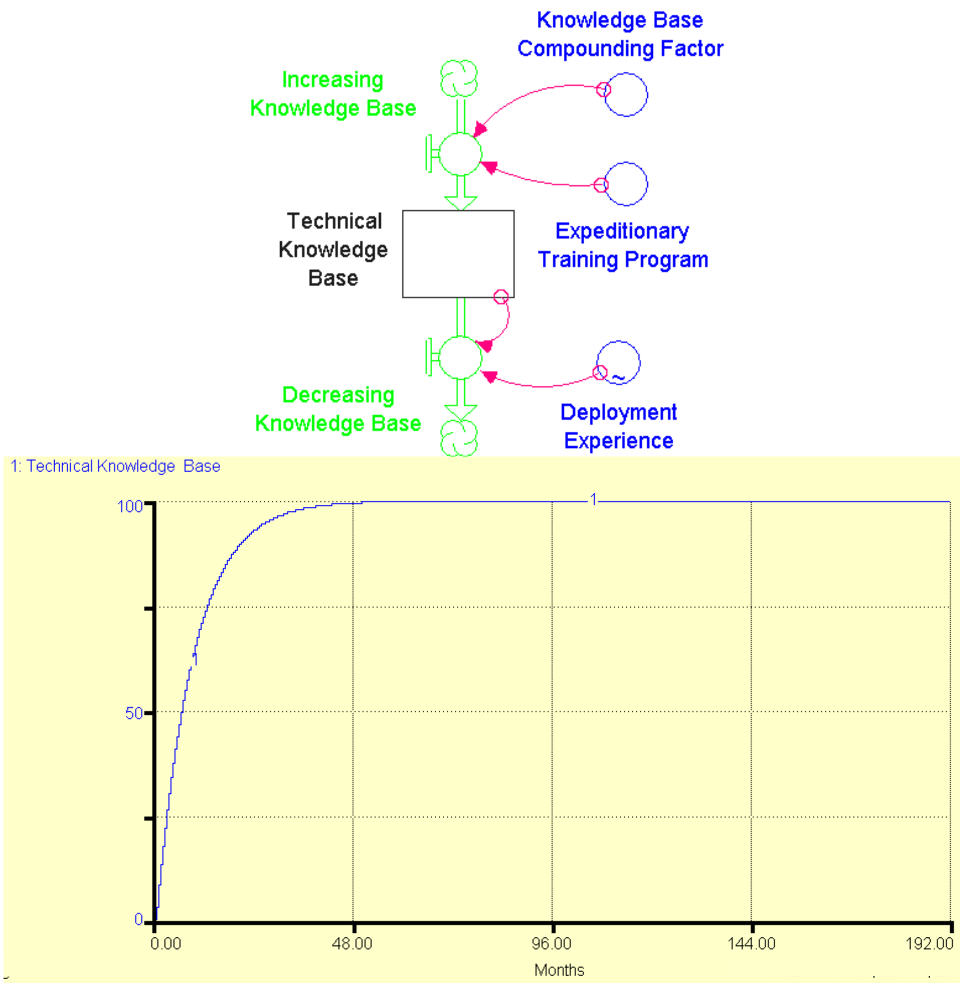


Figure 19: Flow Diagram and behavior of *Technical Knowledge Base* simulated in STELLA.

The remaining six stocks were all identified as having a Goal Seeking structure. For brevity, *Training Policy*, *Garrison Civilians & Contractors*, and *Expeditionary Contractors* will not be discussed further, but their flow diagrams with resulting graphical output are available in Figures 20, 21, and 22 respectively.

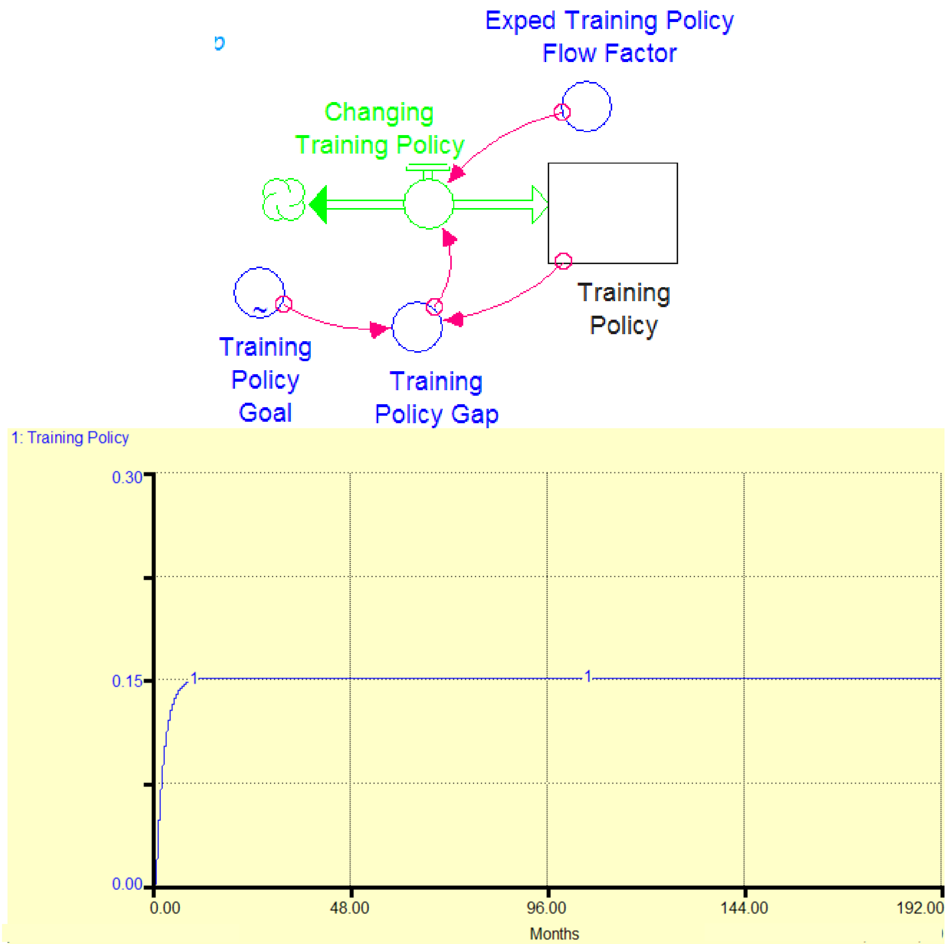


Figure 20: Flow Diagram and behavior of *Training Policy* simulated in STELLA.

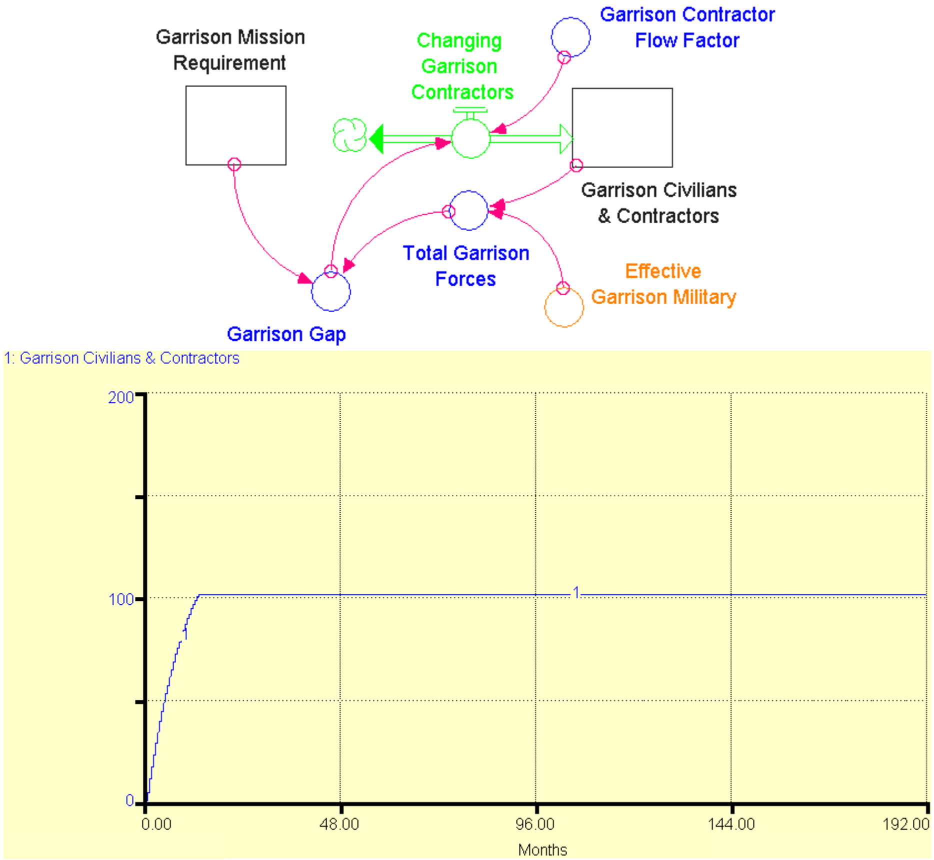


Figure 21: Flow Diagram and behavior of *Garrison Civilians & Contractors* simulated in STELLA.

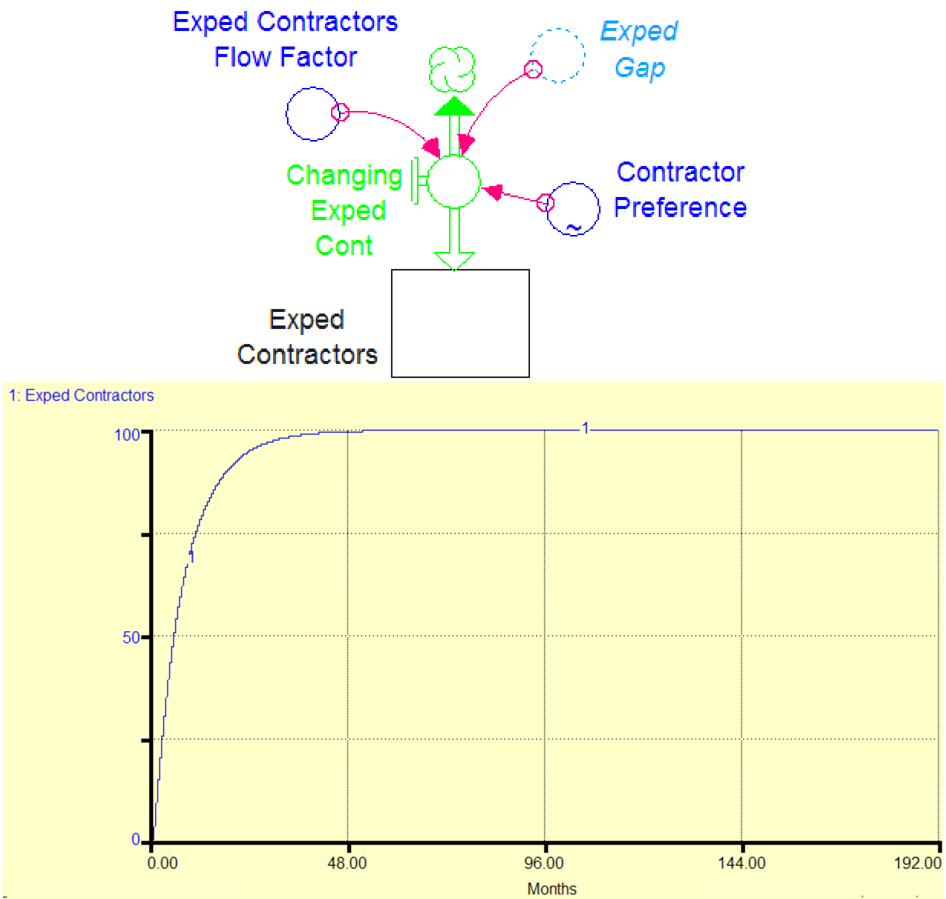


Figure 22: Flow Diagram and behavior of *Expeditionary Contractors* simulated in STELLA.

The remaining stocks to focus on are *Expeditionary Contractor Efficiency*, *Expeditionary Military Technical*, and *Expeditionary Military Management*. The first consists of the typical goal seeking structure with an added first-order drain. The concept is simple. *Expeditionary Contractors* are striving to reach an efficiency goal or maximum performance level as any individual or organization would. However, because of the previous ties of *Technical Knowledge Base* for military members with efficiency, there is an assumption being made that efficiency is dependent on knowledge, which dissipates over time. Therefore, the same draining structure utilized for the military applies here to contractors. The resulting combination of goal seeking infrastructure with a first-order drain (a combination quite common in System Dynamics) is displayed in Figure 23.

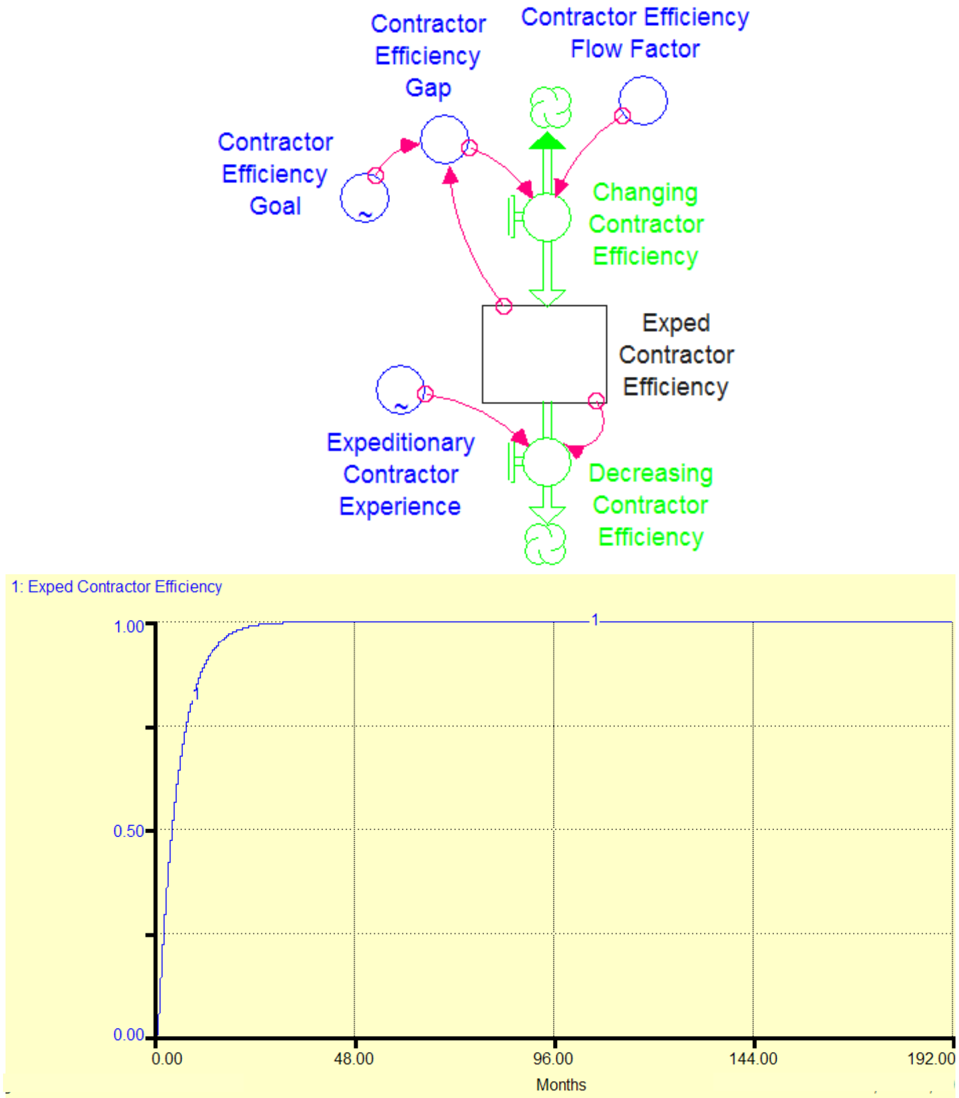


Figure 23: Flow Diagram and behavior of *Expeditionary Contractors Efficiency* simulated in STELLA.

In the model being presented, it is impossible to display the flow diagram for the final two stocks individually without visually losing the implications they have on one another. *Expeditionary Military Technical* and *Expeditionary Military Management* are individual stocks operating in separate goal-seeking structures, however they both draw from a common supply of personnel, creating complex relationships between them. Figure 24 exhibits their flow diagram with resulting behavior.

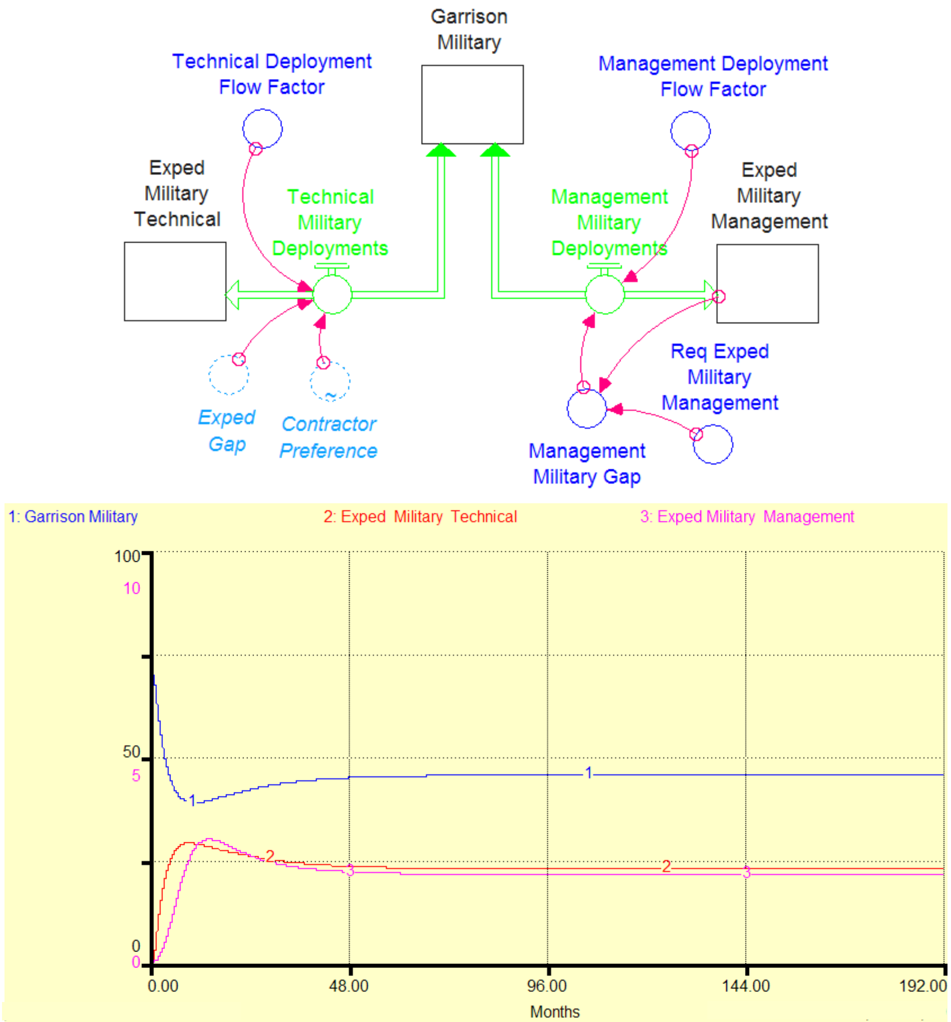


Figure 24: Flow Diagram and behavior of *Expeditionary Military Technical*, *Expeditionary Military Management*, and *Garrison Military* simulated in STELLA.

The goal-gap structure for *Expeditionary Military Management* can be clearly seen in the diagram presented; however, the goal-gap structure for *Expeditionary Military Technical* is not immediately evident because the entities referenced are in other parts of the model. It is important to note the model begins with a specific number of military personnel in-garrison; utilization of those personnel towards expeditionary tasks has a special dynamic. If there are excess personnel, there are no problems. However, when personnel shortages arise (which is inevitable) there must be some determining factor to decide which mission will receive personnel and which will not: technical or management. The priority was given to the management function. While this may not happen in real life, the following logic supports that decision: if there is a personnel shortage the stop-gap is the addition of more contractors, who require more oversight, requiring more management positions. It would be suboptimizing not to take those personnel from the technical side and move them into a management role, thus multiplying their expeditionary impact (multiple contractors versus the individual). Of course, this shift is not physically seen in daily expeditionary operations; however, the slow shift of this burden has accumulated over time, especially throughout the past eight years of combat operations in Southwest Asia. This concept of shifting work requirements is expressed in the model as an *Expeditionary Work Shift*, impacting the model in two separate areas: the *Training Policy Goal* (displayed in Figure 24) and *Required Expeditionary Military Management* displayed in Figure 25. At its heart, the work shift is a function of the percentage of expeditionary personnel who are contractors, expressed as the oversight requirements on a graphical scale. This clearly impacts the required number of *Expeditionary Military Management* and also indirectly influences the *Training Policy Goal*. The training goal (expressed as technical training, not managerial) can be driven down when work shifts away from technically oriented work, having an indirect impact on *Technical Knowledge Base*.

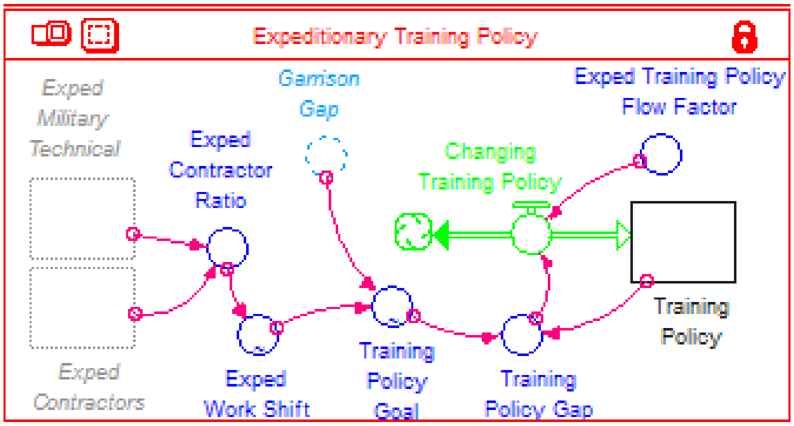


Figure 25: Flow Diagram of *Training Policy* displaying *Expeditionary Work Shift.*

A second factor influencing the *Training Policy Goal* is the *Garrison Gap*. As high deployment tempos create shortages in garrison personnel to accomplish the *Garrison Mission Requirements*, garrison squadron commanders are forced to cut or forgo portions of the *Expeditionary Training Program*; a devastating impact on *Technical Knowledge Base*. The remainder of the influences being operationalized from the Causal Diagram into the Flow Diagram are unambiguous and can be seen as part of the final Flow Diagram model displayed in Figure 26, with Table 5 listing the factors used. It is this model that will be carried into Step 4 of the System Dynamics methodology: simulation and validation.

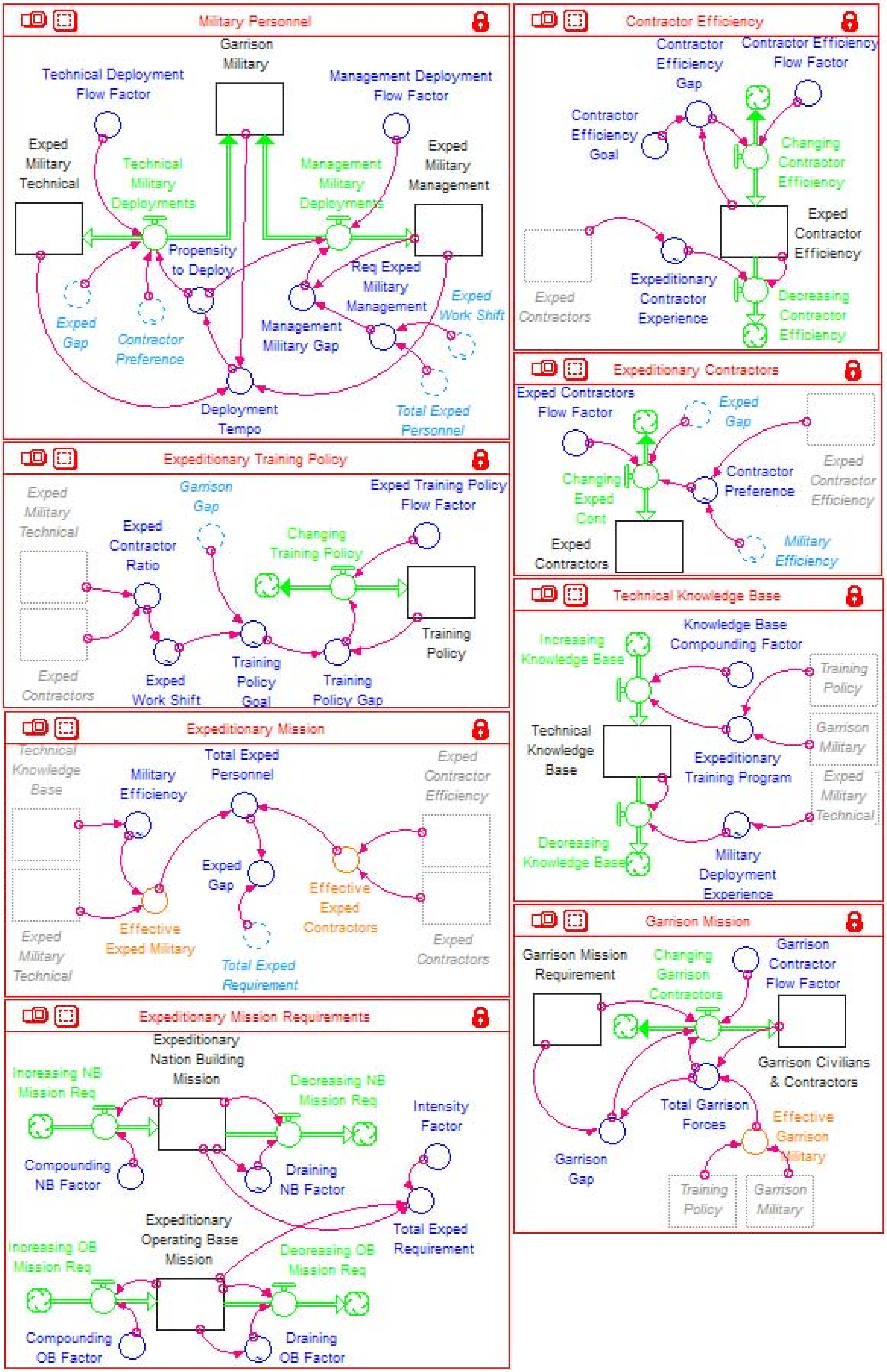


Figure 26: Flow Diagram, full model.

Table 5: Names, values, and units of coefficients used in the Flow Diagram.

Coefficient Name	Coefficient Value	Coefficient Units
Management Deployment Flow Factor	0.50	1/month
Technical Deployment Flow Factor	0.50	1/month
Expeditionary Training Policy Flow Factor	0.50	1/month
Compounding NB Factor	0.35	1/month
Draining NB Factor	0.20	1/Person*month
Compounding OB Factor	0.50	1/month
Draining OB Factor	0.25	1/Person*month
Intensity Factor	0.50	- Unitless -
Garrison Contractor Flow Factor	0.10	1/month
Knowledge Base Compounding Factor	0.50	Efficiency/Person*month
Expeditionary Contractors Flow Factor	0.40	1/month
Contractor Efficiency Flow Factor	0.20	1/month

Step 4: Model Simulation and Validation

With the Flow Diagram complete, a final view of the resulting *Technical Knowledge Base* behavior can be demonstrated. However, although Step 4 of the System Dynamics methodology is labeled simulation, throughout Step 3 numerous intermediate simulations where processed to aid the iterative construction of the model. Step 4, therefore, is simply the final simulation which either confirms or refutes the hypothesis. The model behavior for *Technical Knowledge Base* is shown in Figure 27, clearly representing the Reference Mode behavior presented in Figure 1. The remaining challenge to Step 4 then is to subject the model to validation testing and identify the characteristics of the model infrastructure and relationships that give rise to the demonstrated Reference Mode.

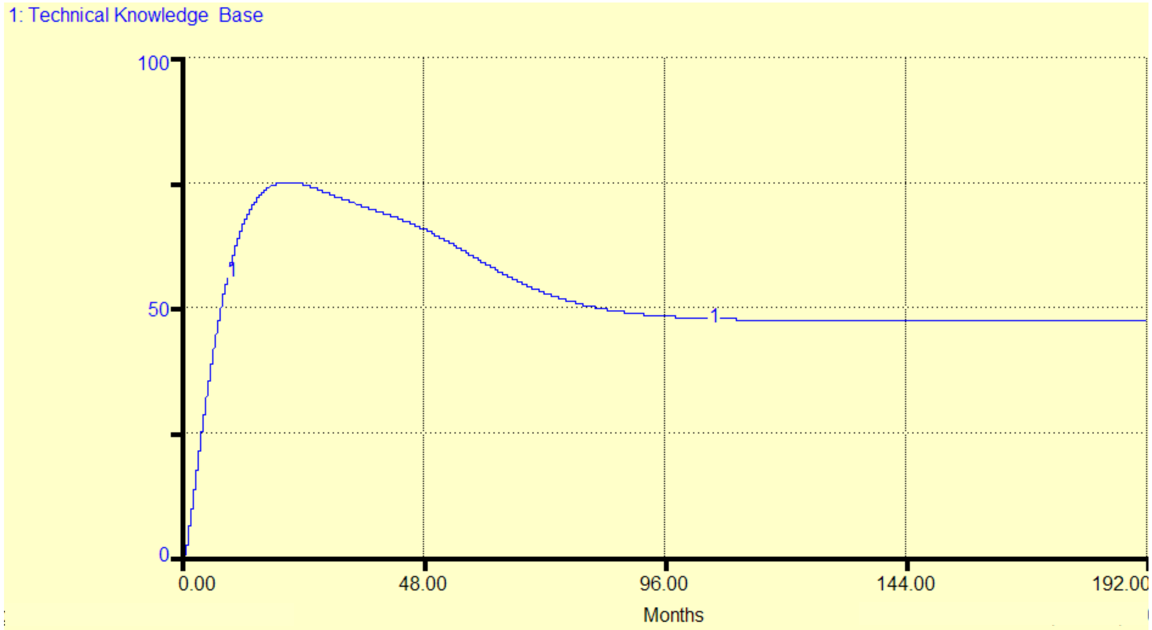


Figure 27: *Technical Knowledge Base*, as simulated from the final model.

With the operational model producing an accurate representation of the Reference Mode, it is now ready to continue building confidence in the model through the validity tests introduced in Chapter 3. Many of these tests are iterative in nature, being accomplished throughout the modeling process (Structure Verification Test, Parameter Verification Test, Behavior Anomaly Test, and Behavior Reproduction Test); however a few key tests will be discussed in detail.

The first key test accomplished after the final simulation is the Extreme Conditions Test, considered by many to be the most important validation test (Shelley, 2009). This test involves manipulating levels of stocks to which rate equations depend, demonstrating the effect and giving insight to possible structural flaws. Throughout the testing there were no surprises as the model reacted extremely appropriately to all stock levels used. As an example, *Training Policy* is a key stock influencing the inflow of

Technical Knowledge Base and when changed from minimum (zero training) to maximum (only training), the resulting action on *Technical Knowledge Base* is exactly as expected. Similarly, Figure 28 displays the reaction of *Technical Knowledge Base* to varying levels of *Total Expeditionary Requirement*; again we see an appropriate resulting behavior, increasing confidence in the accuracy of the model.

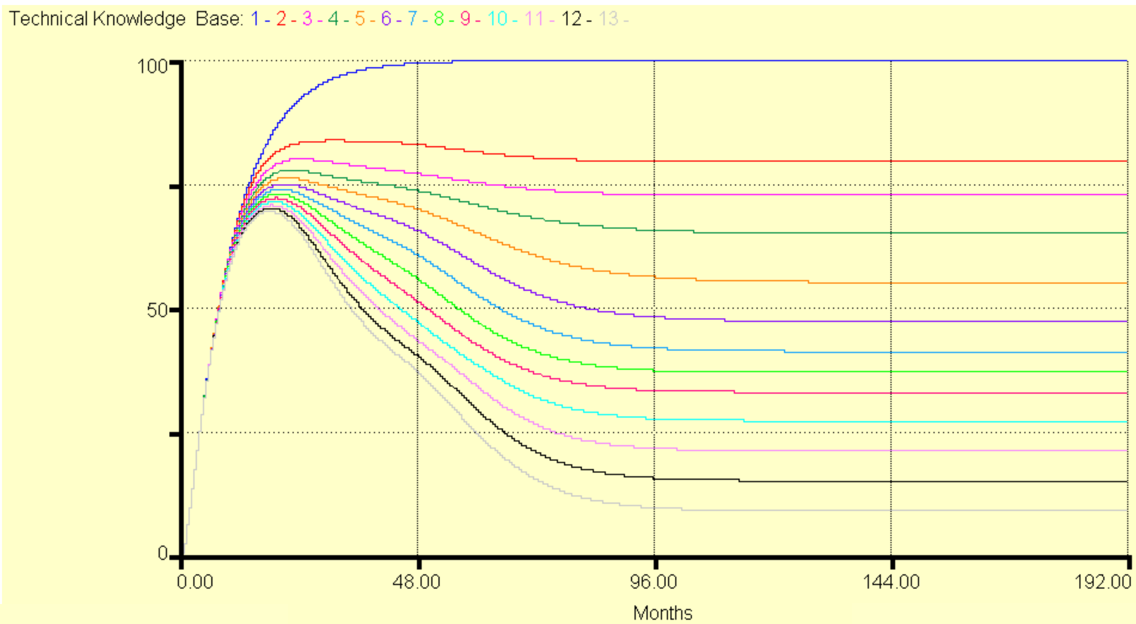


Figure 28: *Technical Knowledge Base's* reaction to varying levels of *Expeditionary Mission Requirement.*

The Boundary Adequacy Test was also assessed throughout model formulation and again upon conclusion. This test looked at various entities within the model to test if their inclusion was significant to the model's purpose. For example, when the model was going through a long and rigorous iteration phase the idea of incorporating turnover into the model was introduced. After discussion and preliminary simulation it was decided not to be included because it would aggregate the model to a level incommensurate with the goal of solving the Reference Mode behavior; the impact was minimal. All of the entities included in the current model are significantly tied to the operational relationships in the model, showing the model's boundary is adequate and again building confidence.

The final noteworthy validity test is the Behavior Sensitivity Test, which tests parameter values looking for levels causing behaviors to fail. The results of this test showed impact on behavior intensity; however, the behavioral trends remained intact. Again, the inability to find parameter values that cause major system failures builds confidence that the model being used is valid and appropriate for the purposes of assessing *Technical Knowledge Base* within the Civil Engineer career field and exploring potential solutions to reverse the Reference Mode behavior.

The final part of Step 4 in the System Dynamics methodology identifies those endogenous areas of the system where solutions can be implemented. The first and obvious entity impacting Knowledge Base is the *Training Policy*. Because this policy directly affects increasing *Technical Knowledge Base*, it can immediately be identified as crucial to reversing current trends. Another entity identified through structure is *Expeditionary Military Management*. It may not seem as evident, however there is one pool of military personnel divided between *Garrison Military*, *Expeditionary Military Technical*, and *Expeditionary Military Management*. While the first two directly impact *Expeditionary Knowledge Base, Expeditionary Military Management* does not directly influence knowledge base at all. This means military personnel residing in the *Expeditionary Military Management* arena are not contributing to maintaining knowledge base. The implications of this will be further discussed in Step 5, along with other areas identified by Civil Engineer career field representatives as potential solution areas, also called leverage points.

Step 5: Policy Generation and Implementation

The following section will explore several leverage points in order to demonstrate potential solutions to the problem of an eroding technical knowledge base. However, first it is necessary to clarify that it is not the intention of this research to explore all of the possible alternatives or determine the optimal solution sets. Instead the research is interested in identifying potential solution areas and exploring some of the benefits and detriments of those areas. Further research will be recommended in Chapter 5 to further reinforce the findings of the model developed during this study.

However, before presenting the findings of Policy Generation, during the data gathering process a structural flow in the model was found. The version of the model that was being used attempted to operationalize deployments on an individual level; it needed to be aggregated to the organizational level. The problem presented itself when attempting to implement a Garrison Work Reduction policy that would free military personnel from garrison obligations in favor of training and deployments. However, *Expeditionary Military Technical* would not react as expected to this change. What was happening was due to military members being on a conveyer while contractors were in a reservoir. A reservoir is the traditional function of a stock; a supply that is increased and decreased according to its structural in-flows and outflows. A conveyer similarly takes inflows, however these flows are then held in the conveyer for a designated period of time then automatically released as an out-flow. Therefore, the deployment cycle was not only fighting to close the *Expeditionary Gap* but also working to replace those personnel coming off the conveyer (returning from deployments). This coupled with the internal bifurcation of the gap between contractors and military created a favor towards contractors that, over time, resulted in military falling off and contractors taking the entire workload. See the Figure 29 for the graphical display of the military's behavior.

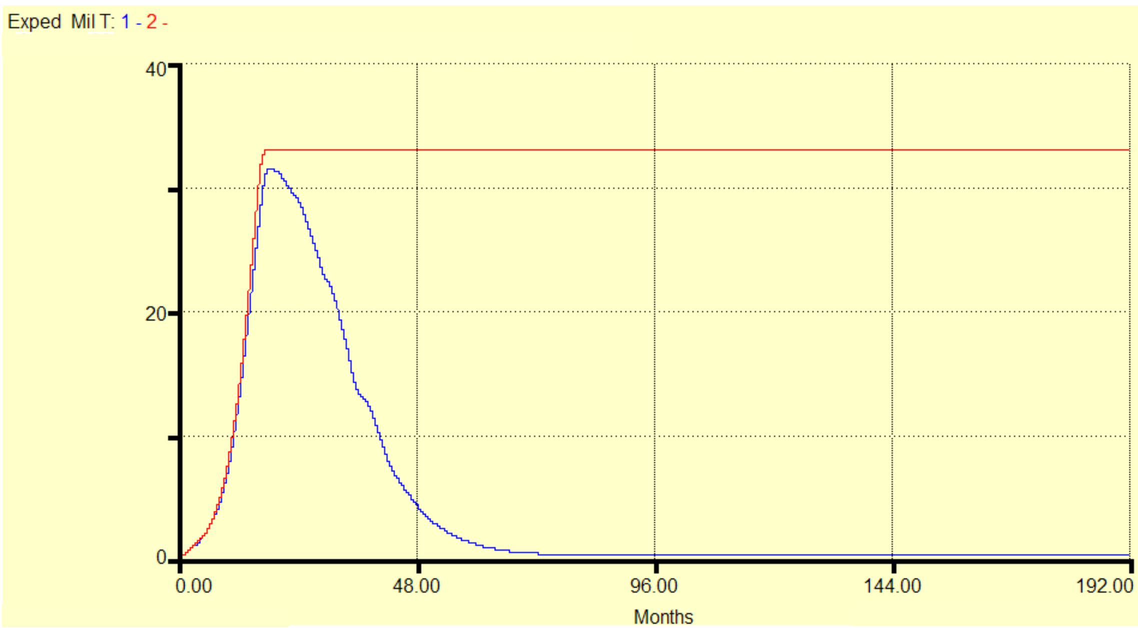


Figure 29: Behavior of *Expeditionary Military Technical* before the correction (blue line) and after (red line).

To further explain how this behavior is being produced mechanistically, consider the following scenario: a gap requirement of 100 personnel is split 90% to military and 10% to contractors; met immediately it is brought to zero. However, because the military are on a conveyor processing at two time units, those 90 personnel will flow out of the conveyer after 2 time units and the gap which was previously eliminated is now at 90 (note that because the contractors are in a reservoir, they never decrease – or "redeploy" – until the gap is negative). So now the gap of 90 is again split 90%/10% to military and contractors bringing the total to 81 military and 19 contractors. Six time units later the entire process repeats itself changing the balance to 73 military and 27 contractors, then 65 military and 34 contractors, then 59 military and 41 contractors, and so on. In mathematics, this is known as a limit (when a certain entity approaches a certain number but never actually fully gets to it); the military approach zero while the contractors, in this example, approach 100.

To correct the model, the conveyor used in the military deployment-cycle was changed to a reservoir, a previously used outflow eliminated, and *Technical Military Deployments* was made into a biflow. There were no changes made to the actual formulations of the flows, however there was a significant change made to the behavior of Expeditionary Military Technical as seen in Figure 29. No longer fighting against the redeployment, this stock's infrastructure is now free to respond to the *Expeditionary Gap* alone and creates a behavior in-line with what we would expect to see (and what is currently being seeing in Iraq and Afghanistan).

This change also had minor changes elsewhere in the model, which unfortunately required data collections to be re-accomplished. However, through finding this formulation error confidence can be further built that the model is valid. The two entities affected by this change were *Expeditionary Military Management* and *Technical Knowledge Base.* First, there was a slight decrease in the total number of Expeditionary Military (Management) created because the Expeditionary Mission Requirement which was formerly completed exclusively by contractors was now shared by military, who require less oversight. The overall change (~15% decrease) is not considered significant and the overall behavior is unchanged, which is the focus of the analysis (see Figure 30).

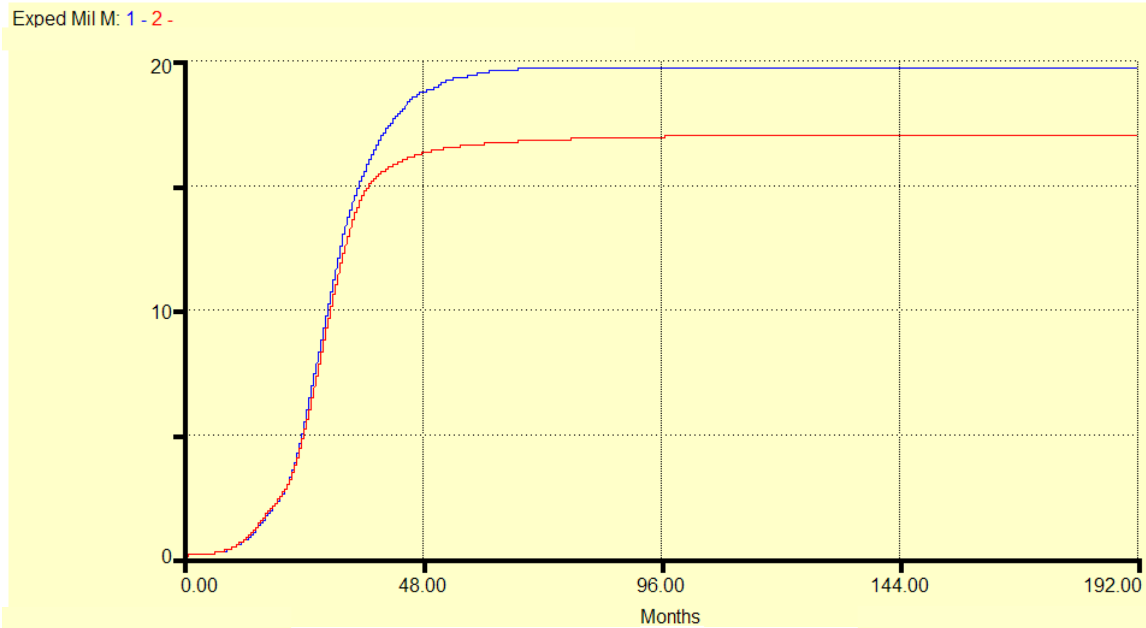


Figure 30: Behavior of *Expeditionary Military Management* before the change (blue line) and after (red line).

The second entity changed and most important is *Technical Knowledge Base*. The changes are shown in Figure 31 and are quite acceptable, even to the point of building more confidence. The final level of knowledge base erosion and behavioral pattern are exactly the same; the only change is the time it takes for the steady state level to be reached (144 months versus 80). This can be directly attributed to the higher levels of Expeditionary Military Technical and relates perfectly to the results seen in Contractor Policy #2 (where this error was found, to be explored shortly). In those results, controlling the level of bifurcation of the gap between contractors and military had no change in the final level of knowledge base, only how long it took to get there (as we see here).

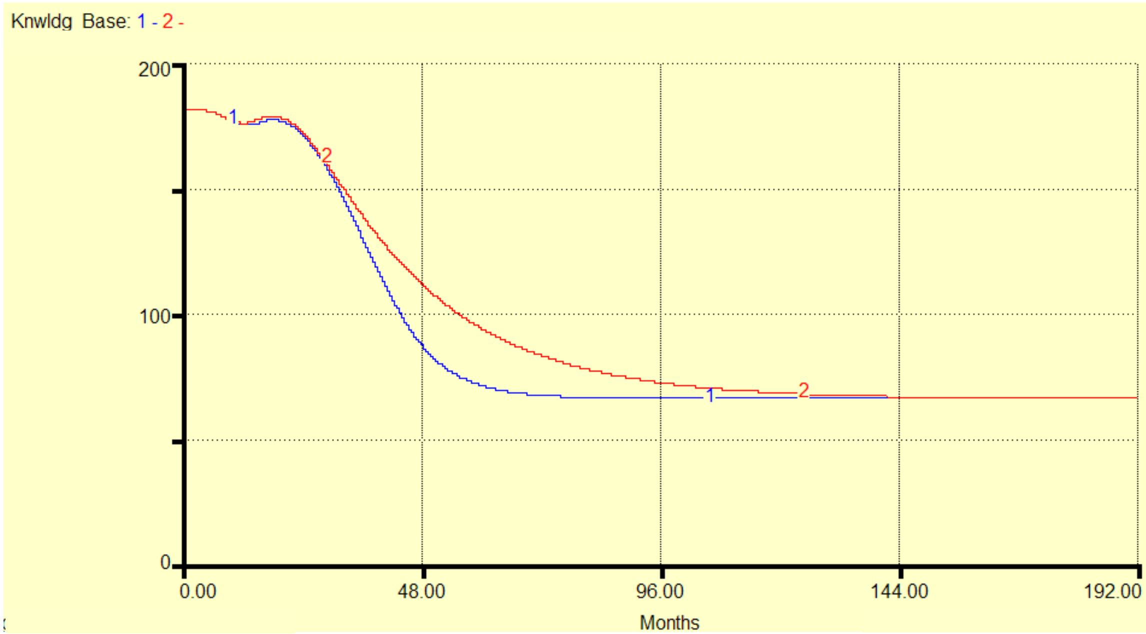


Figure 31: Behavior of *Technical Knowledge Base* before the change (blue line) and after (red line).

Though the change made here has already been incorporated throughout the entirety of the research presented, it represents the importance of iteration throughout the System Dynamics methodology process. Confidence is built with each iteration and leads to a final model that can provide pathways to potential Reference Mode solutions. The following sections identify those areas where various policies can be generated to do so.

External Training Policy

The first area to explore is the *Training Policy*; it has a few interesting aspects as it stands in the model (reference Figure 26 for an illustration). First, *Training Policy* is set at a steady state of .15 in the model which, if each unit follows training program regulations, is the minimum required level (AFI 10-210, 2009). Hence, *Training Policy* is the sole driver for *Increasing Knowledge Base* and at a level of .15 maintains that base at its steady state value of 100. Second, *Training Policy* changes as a function of the current policy with the *Training Policy Goal*. This goal is a graphical function that increases and decreases in accordance with the *Expeditionary Work Shift* and the *Garrison Gap* (shown in Figure 32). As the *Expeditionary Work Shift* increases, the goal decreases (i.e. more work is being performed in the *Expeditionary Military Management* mission, hence training programs respond by shifting training to other than technical topics). Likewise, as the *Garrison Gap* increases, the goal decreases (i.e. there are not enough people to perform the garrison mission, so the training program will be sacrificed to the immediate needs of the squadron commander). Therefore, any external policy inserted will attempt to increase *Training Policy*, the key driver in maintaining knowledge base. However, as the *Expeditionary Work Shift* and *Garrison Gap* decrease the *Expeditionary Policy Goal* below the steady state (.15), this results in a competition of the artificial policy against the endogenous causal structure.

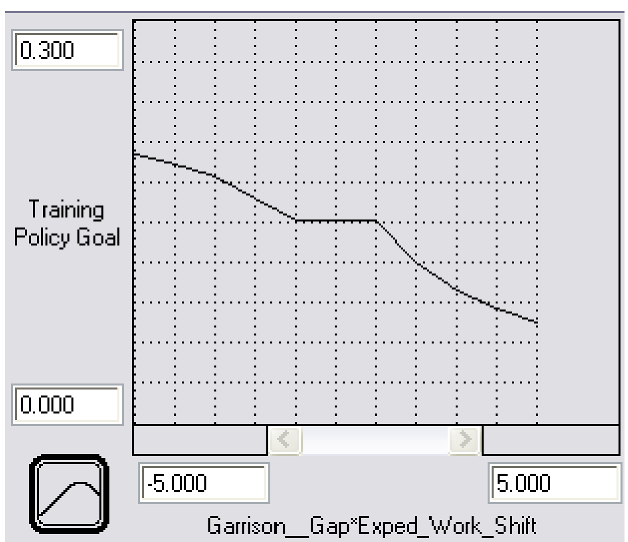


Figure 32: Graphical Function defining *Expeditionary Policy Goal* as a function of *Expeditionary Work Shift* and *Garrison Gap*.

A variety of options are available to attempt policy intervention for the *Training Policy*, but for the research here two options and their combination will be used. The first option is a straight-forward rule bolstering of *Training Policy* if ever it falls below the steady state level of .15. The policy, dubbed *External Training Policy #1* consists of using if-then logic so that whenever training drops below .15, it forces additional training into the system commensurate with how far below .15 it currently is(formulated as: *External Training Policy* = .15 - *Training Policy*).

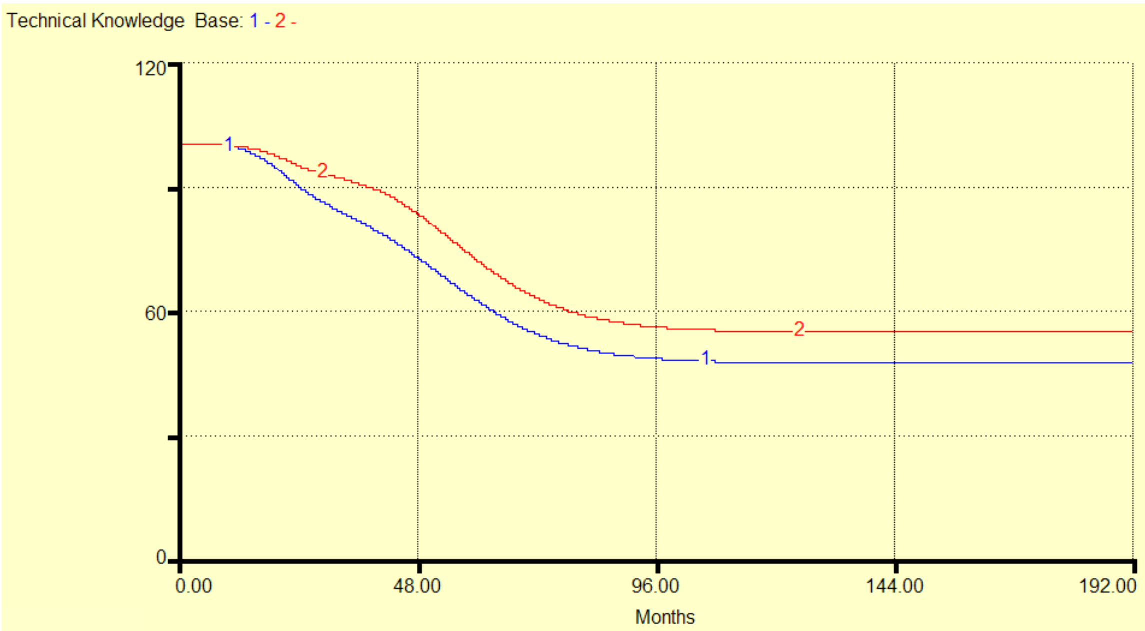


Figure 33: Impact of *External Training Policy #1* on *Technical Knowledge Base*.

The results of this policy are shown in Figure 33 with line 1 representing no policy and line 2 representing the additional policy. Though this policy eases the loss of knowledge base, it does not bolster it to acceptable levels; it could, however, be used later in conjunction with other policies. What's happening in both *External Training Policy #1* is a battle between the external policy and the *Policy Goal*, which is controlled by the

Work Shift and *Garrison Gap*. To influence the *Training Policy* effectively, the influence of these two units must be dropped to simulate a hard-line policy in maintaining current training levels despite *Garrison Mission Requirements* and *Expeditionary Work Shift*.

This shift in thinking brings the intervention tactics to the root of the problem, addressing multiple negative reinforcing loops. Therefore the next artificial policy, *External Training Policy #2*, removes the causal influences of *Expeditionary Work Shift* and the *Garrison Gap* altogether, setting the *Training Policy* at a constant level of .15 (the steady state value). This representative of career field leadership standing up to make expeditionary training a priority investment over garrison requirements and making an effort to remain technically oriented despite the shift in work to managerial roles in the expeditionary environment. The results are seen in Figure 35 with trace one being no policy, trace two being *External Training Policy #1* and trace three being *External Training Policy #2*.

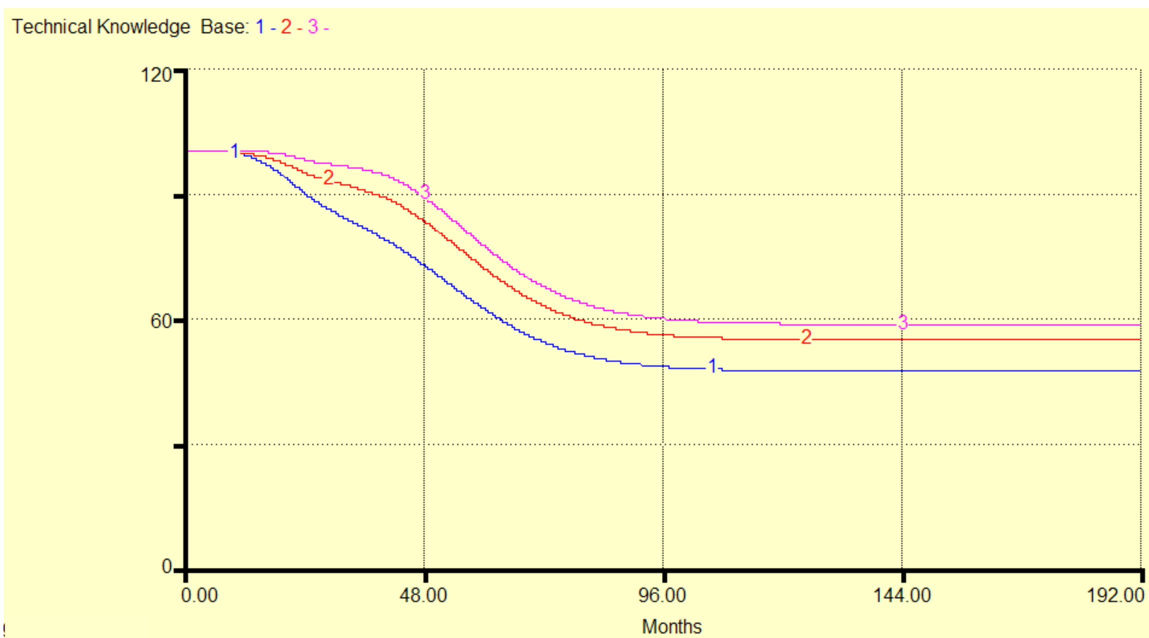


Figure 34: Impact of *External Training Policy #2* on *Technical Knowledge Base*.

Additionally, Figure 35 takes *External Training Policy #2* one step farther by increasing that steady-state level for multiple simulations. In *External Training Policy #3* the first trace is no external policy at all, the second is a steady state level of .15, and the remaining traces step that value by .05 each, finishing on trace seven with a steady state value of .40. It is obvious that higher, unhindered levels of training does increase knowledge base, but there are other entities involved here impacting the erosion.

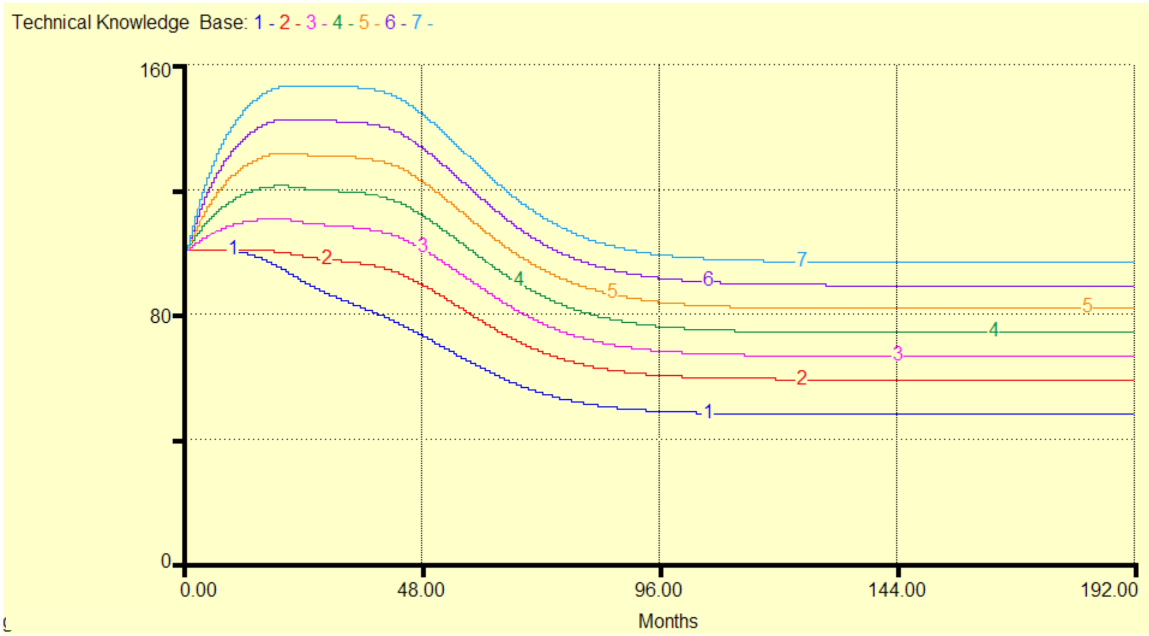


Figure 35: Additional impact of *External Training Policy #3* on *Technical Knowledge Base*.

To summarize the External Training Policy, other than increasing training levels by multiple factors there is no single solution to solving the knowledge base problem; changing the *Training Policy* alone is not enough. However, key to allowing changes in training requires addressing the influences of *Garrison Gap* and *Expeditionary Work Shift*. Finally, these policies begin to point towards the chief factor creating the knowledge erosion: *Expeditionary Military Management*. These personnel are effectively taken out of the loop of contributing to *Technical Knowledge Base* (either through training in garrison or by technical experience while deployed). However, these assignments are part of the mission requirement and therefore completely necessary; the indications of an impasse.

<u>Garrison Work Reduction</u>

The second area to explore in the model is the *Garrison Mission Requirement*, starting with its characteristics (reference Figure 26 for a flow diagram illustration). The Garrison Mission Requirement is expressed in terms of a stock, though it remains static throughout the model; this was done simply to draw attention and recognize it as a valuable entity defining the model performance. Despite the model simulating a 12 year time frame, there is no reason to assume the garrison requirement will change significantly. However, the Air Force Civil Engineer in recent years has laid the foundations for a plan to reduce the garrison physical plant (square footage of buildings) by 20 percent by the year 2020 (Eulberg, 2008b). This *Garrison Workload Reduction* initiative, then, is designed to simulate such reductions and analyze the impact of various reduction levels.

The *Garrison Mission Requirement* is completed by *Garrison Civilians & Contractors* and *Garrison Military* similar to its expeditionary counterpart. Military do not react to *Garrison Mission Requirements* directly, however if the *Garrison Gap* grows it cuts *Expeditionary Training*, which is taken off the top, freeing military personnel to accomplish the required garrison work. *Changing Garrison Contractors* is a bi-flow which represents the plus-up and drawdown of contractors in reaction to military deployment and redeployment. This flow is sometimes evident with temporary contractors, but other times veiled as units simply utilize simple contractors more, such as IDIQ (indefinite delivery, indefinite quantity), SABER (Simplified Acquisition of Base Engineer Resources), and IMAs (Individual Mobilization Augmentee). The bi-flow does not attempt to meet a specific target, but instead a target range defined as 80-95% of mission requirements. Therefore, if manning drops below 80% contractors will be hired, and conversely if it rises above 95% contractors will not be renewed (cut). Because contracts take time, the time constant here is representatively low (.2).

Keeping these settings in mind, the first iteration of *Garrison Mission Reduction Policy* consists of decreasing the Garrison Mission Requirement from zero to 35 percent reduction in increments of 5 percent. The resulting impact on *Technical Knowledge Base* is shown in Figure 36. While it is evident there are minor improvements in knowledge base retention, the gains are not commensurate with desired performance and are only temporary. However, there were significant changes in the level of *Garrison Civilians & Contractors* used, with levels dropping sharply with increased workload reductions (shown in Figure 37). The originally formulated bi-flow reduced *Garrison Civilians & Contractors* if ever the supply of garrison forces exceeds 95 percent of the requirements. This formulation defeats the purpose of the attempted policy, and therefore must be reconciled. The intent of the policy is to free military members from the higher garrison workload, allowing increased levels of technical training. Properly implemented, the proposed policy would not allow *Garrison Civilians & Contractors* to decrease.

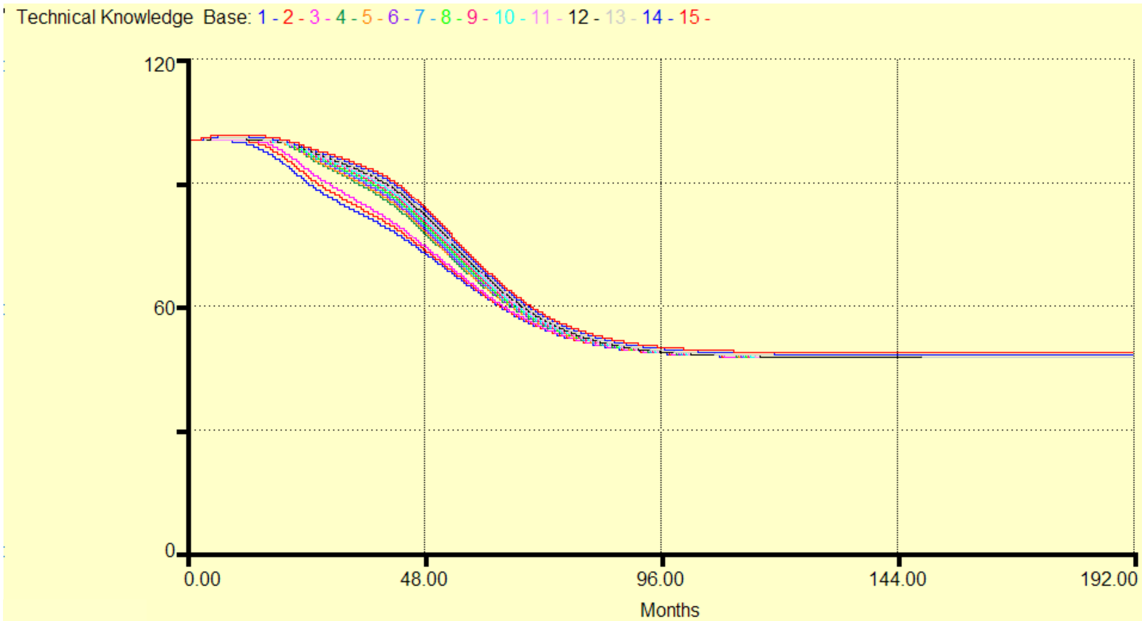


Figure 36: Impact of *Garrison Mission Reduction Policy #1* on *Technical Knowledge Base*.

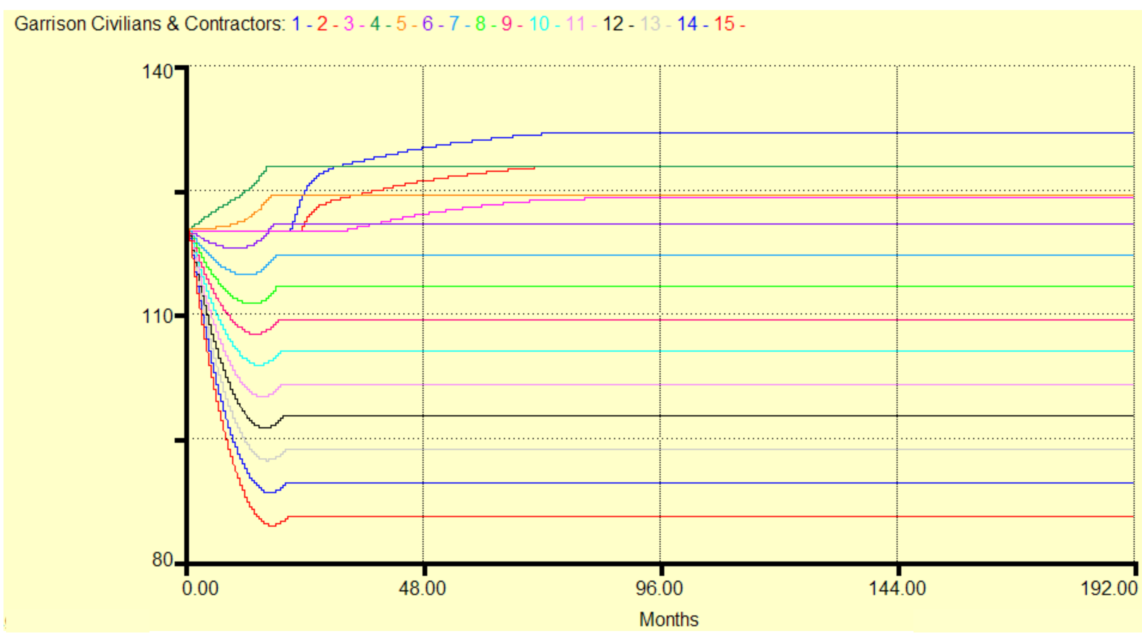


Figure 37: Impact of *Garrison Mission Reduction Policy #1* on *Garrison Civilians & Contractors*.

To rectify this error, *Garrison Mission Reduction Policy #2* did nothing more than eliminate the 95 percent cap being imposed. The results, shown in Figure 38, display the expected improvement from this correction. By not allowing *Garrison Civilians & Contractors* to decrease (yet allowing increase if necessary), there is sufficient personnel in-garrison to result in a zero or negative garrison gap. Because the *Garrison Gap* is one of the factors driving the *Training Policy*, bringing the garrison workload down is crucial to maintaining the minimum steady-state training policy. However, it should be noted there are multiple methods for accomplishing this. For example, increasing the number of *Garrison Civilians & Contractors* would also do the same. The underlying function here is the pre-determined level of manning. As previously discussed, *Garrison Civilians & Contractors* only increase when the gap is greater than 20 percent; this is a reflection of the real-world where many bases do not receive additional military personnel until manning is below 80 percent.

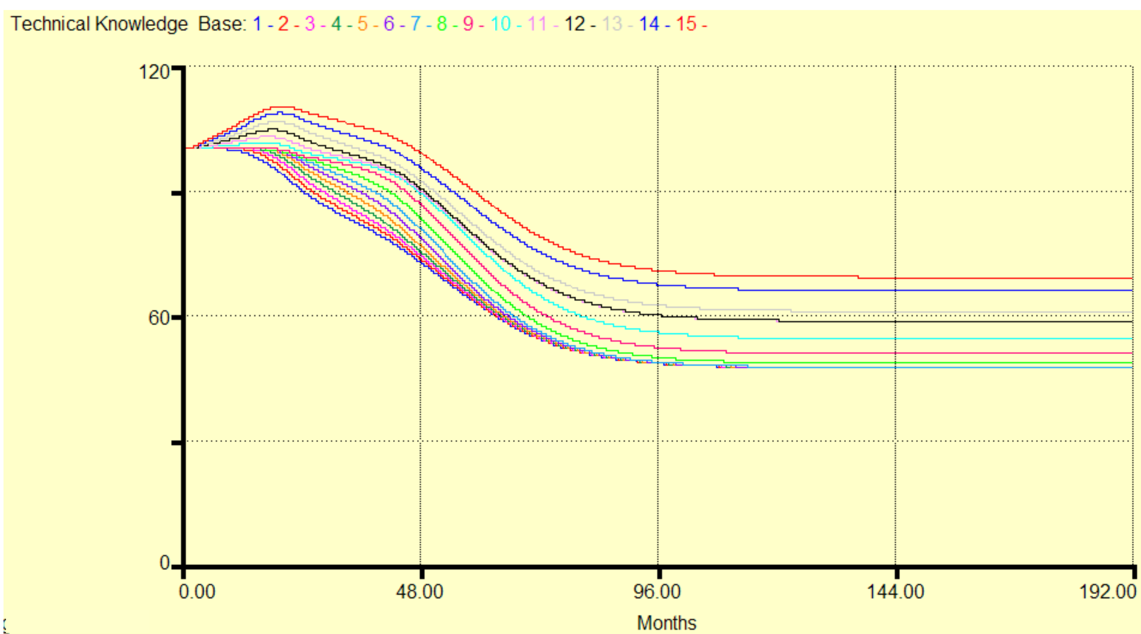


Figure 38: Impact of *Garrison Mission Reduction Policy #2* on *Technical Knowledge Base*.

To summarize the *Garrison Workload Reduction Policy*, workload reduction alone cannot fix the problem of *Technical Knowledge Base* erosion, however it does make notable contributions toward its reversal above the 20 percent level. Similar to the external training policy experiments, the policy efforts here focus on allowing more training to increase knowledge base. However, there again are additional factors significantly weighing on the erosion.

Expeditionary Contractor Policy

The next area of the model to explore is the *Expeditionary Contractors*. As contractors increase, the *Contractor Ratio* creates the *Expeditionary Work Shift* which drives the decrease in *Training Policy* and also is the determining factor for the level of *Expeditionary Military Management*. *Expeditionary Contractors* are driven by the *Expeditionary Gap* with *Contractor Preference* dictating what portion of the gap will be met by the contractors (shown in Figure 39). There are two ways to approach the introduction of a policy for contractors, by limiting the amount of contractors using the *Contractor Ratio* or artificially weighting the *Contractor Preference* to largely favor military.

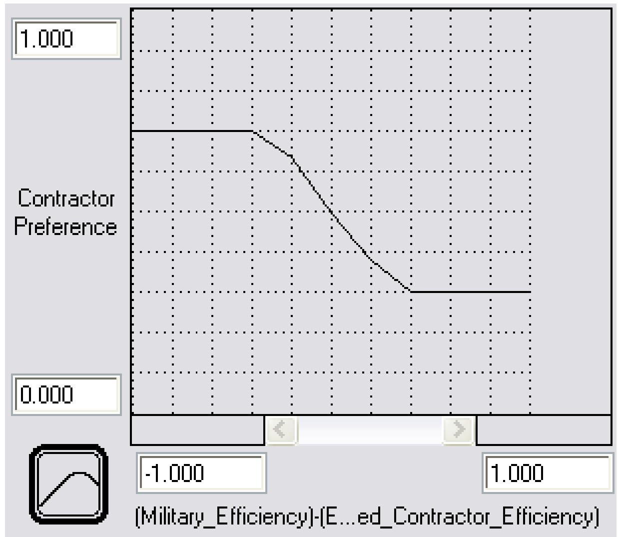


Figure 39: Graphical Function defining *Contractor Preference* as a function of *Expeditionary Contractor Efficiency* and *Military Efficiency*.

For *Expeditionary Contractor Policy #1*, the *Contractor Ratio* is brought to the *Changing Expeditionary Contractor* bi-flow to be used to limit contractor contribution to 50% contribution toward the mission (i.e. military must accomplish 50% or more of the expeditionary mission). The results, seen in Figure 40, are good but have major drawbacks. *Technical Knowledge Base* loss is cut significantly, however the *Expeditionary Gap* rockets up to 39% of *Expeditionary Mission Requirements* compared to zero before the policy introduction (Figure 41). While this policy is conceptually sound, the results show it is unrealistic in a real world scenario; deployed commanders simply would allow it. The Office of Management and Budget (2008) reported there are equal numbers of contractors and military in the Iraqi and Afghan theaters, but they also report that approximately two thirds of those work in civil engineer related fields. Therefore, a realistic scenario for limiting contractors would probably be closer to 70 to 80 percent, which yields only minor improvements.

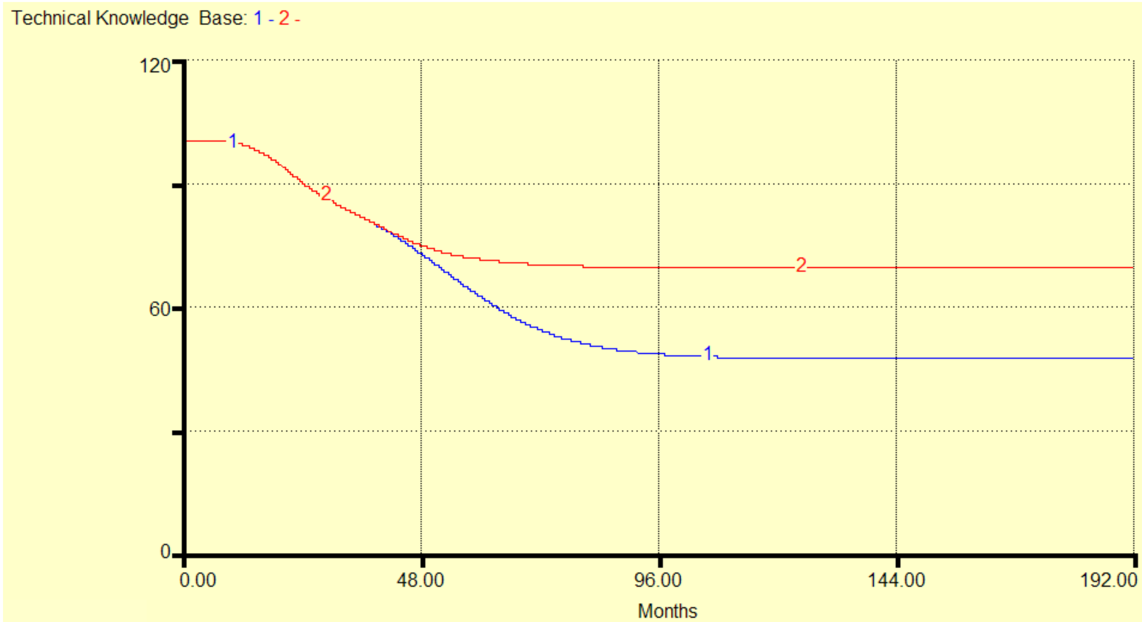


Figure 40: Impact of *Expeditionary Contractor Policy #1* on *Technical Knowledge Base*.

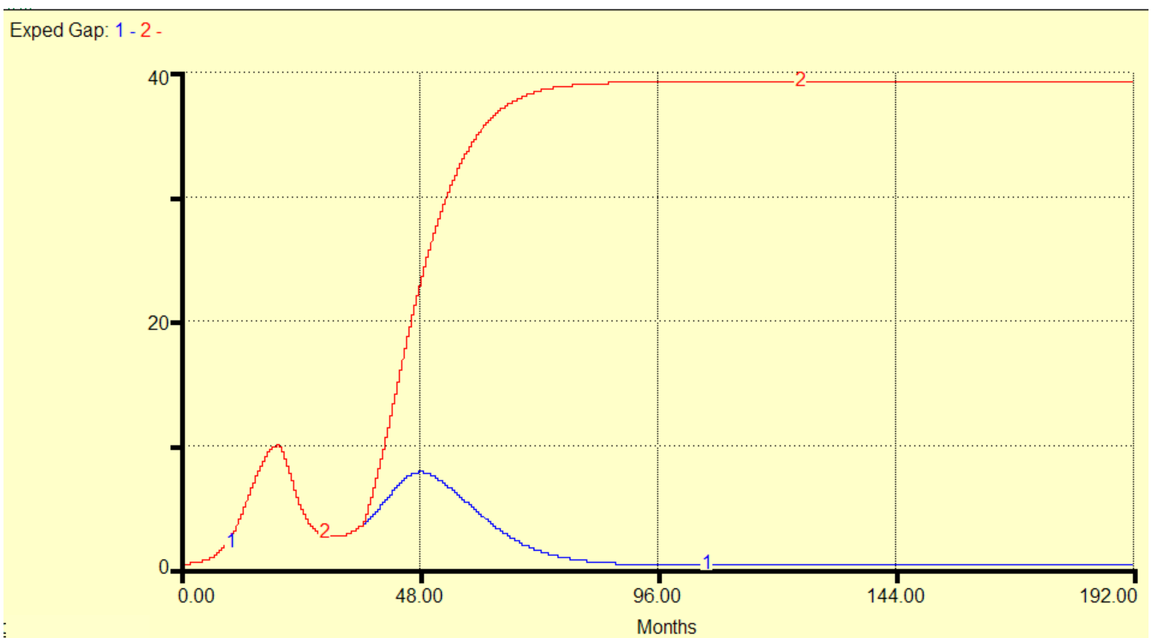


Figure 41: Impact of *Expeditionary Contractor Policy #1* on *Expeditionary Gap*.

The second contractor policy focuses on the *Contractor Preference*, artificially intervening to impress a military bias. Removing efficiency's influence, in this policy

Contractor Preference is set as a constant, varying from 100 percent of the gap to contractors down to zero percent. The resulting behavior of *Technical Knowledge Base* (Figure 42) indicates this policy has no significant impact; the only change being the speed knowledge base eroded. The only exception when *Contractor Preference* is set to zero (no contractors at all), there is significant knowledge base retention. The logic behind this behavior lies in the value of the *Expeditionary Mission Requirement* and the *Propensity to Deploy* for military personnel. Due to rotation requirements, military are stopped short of deploying more than 50 percent; however, mission requirements are higher than the number of deployable personnel. Therefore, military will remain at the maximum operational tempo while contractors continue to increase to meet mission requirements, albeit slower due to the lower *Contractor Preference*.

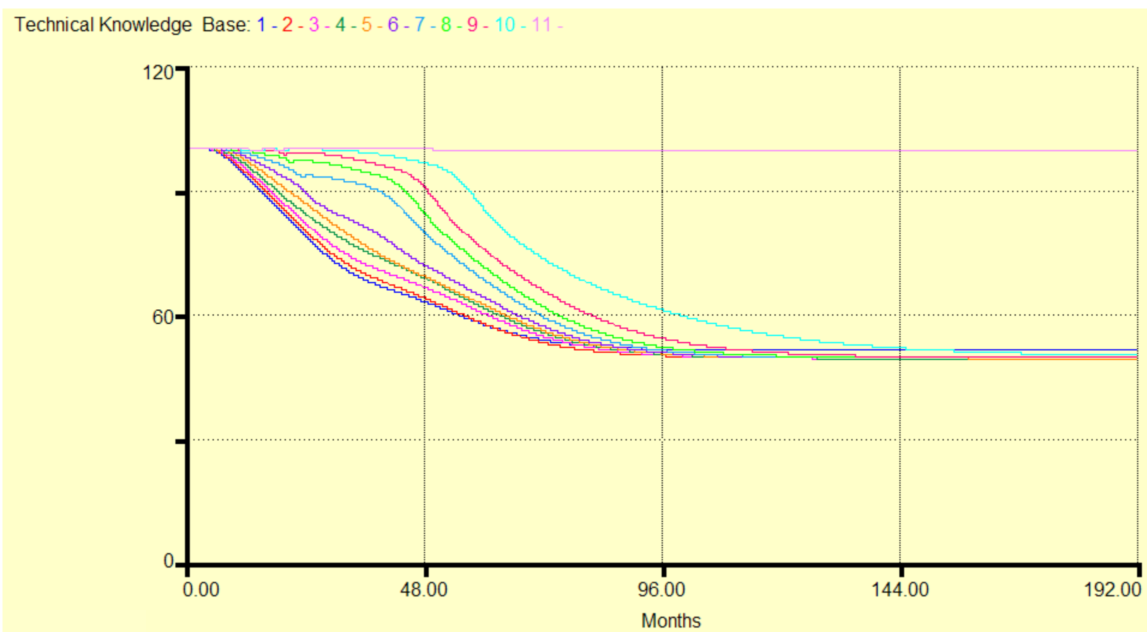


Figure 42: Impact of *Expeditionary Contractor Policy #2* on *Technical Knowledge Base*.

To summarize the *Expeditionary Contractor Policy,* there is no significant advantage to implanting policy in this area. Results showed that although progress to prevent *Technical Knowledge Base* erosion is possible, it comes at a significant cost to the *Expeditionary Gap*, a sacrifice commanders in the field will not easily or willingly take. However, there are unseen benefits to this policy that could supersede the costs. As discussed in Chapter 2, issues with contractors such as cost, reliability, and knowledge base retention are also factors with appeal on the decision. Furthermore, it is possible this policy could perform better when coupled with other initiatives, such as the *Garrison Work Reduction*.

<u>Career Field Structure Policies</u>

Over the years there have arisen many different suggestions for restructuring the Air Force Civil Engineer career field or fundamentally changing the way tasks are completed; all for the sake of improving operations to better meet current and future mission requirements. This section is aimed at looking at some of them, many of which will utilize combinations of policies already explored (i.e. *Garrison Work Reduction*, etc.).

The first policy is *Civil Engineer Civilianization,* which relieves military personnel from garrison responsibilities, giving that workload exclusively to *Garrison Civilians & Contractors* (with a few exceptions). This frees military to be dedicated solely to training purposes while in-garrison; the typical Army unit construct. There are many variations of this proposal (Addison, 2008) which include allowing military to perform “training projects” that not only accomplish training goals but concurrently contribute to the garrison workload. However, for implementation in the present model this aspect is irrelevant because the focus (*Technical Knowledge Base* erosion) relies only on the level of technical training being accomplished, not who is accomplishing the garrison workload. Some of the strengths of this plan are increased training levels which will boost *Technical Knowledge Base* production. However, the plan fails to account for the daily maintenance aspect of the current setup; garrison military currently performs a significant amount of installation maintenance, a crucial aspect of knowledge base that would be lost. Additionally, this plan requires significant adjustments to civilian and military personnel authorizations and therefore potentially significant funding.

To implement this civilianization policy, two main changes are made to the model: *Garrison Mission Completion* is effectively severed from the system and *Expeditionary Training Policy* is bolstered significantly. *Garrison Military* no longer impact mission completion and thus likewise the *Garrison Gap* no longer impacts the *Expeditionary Training Policy Goal*. Also, the *Training Policy Goal* is increased to 40 percent to appropriately reflect the new garrison mission emphasis on training; a very conservative value. The impact of this policy on *Technical Knowledge Base* is shown in Figure 43, with trace one being before implementation and trace two after. The results show near perfect long-term retention of knowledge base, making this solution look promising and potentially even lucrative if garrison military can achieve training levels higher than 40 percent (which should be effortless given training as the main mission).

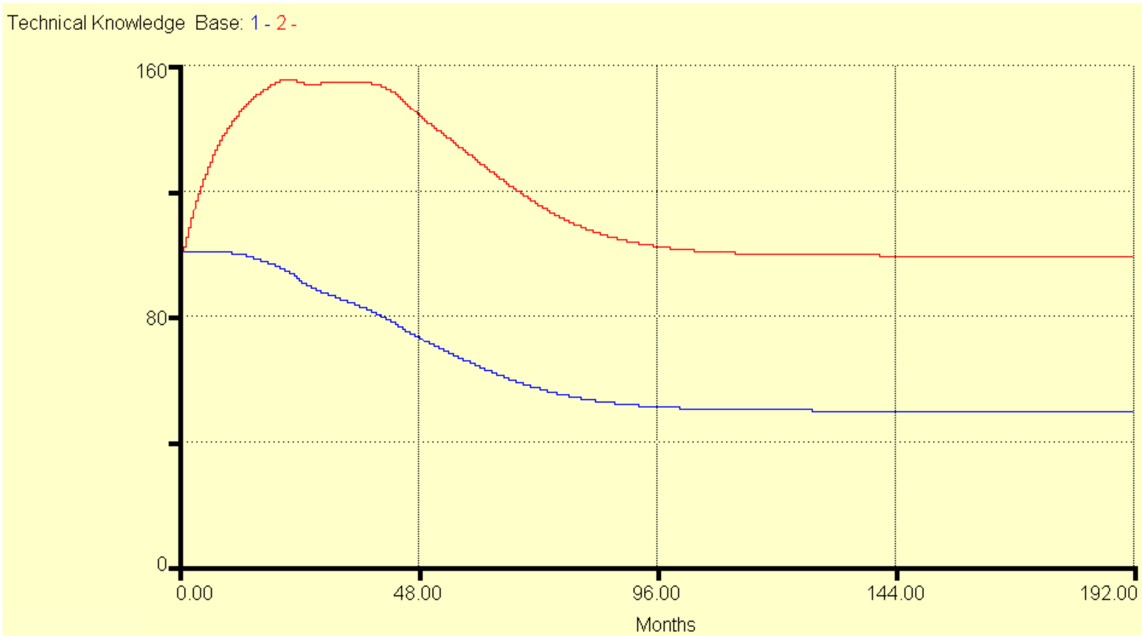


Figure 43: Impact of *Civil Engineer Civilianization* on *Technical Knowledge Base*.

The second structural policy change comes from the works of Thomas Barnett, a military strategist famous for advocating a bifurcation of lethal, high intensity military operations (Leviathan force) from the nation building function which includes police, engineers, and civil affairs (System Administrator force). Following a similar roadmap, civil engineers could also be bifurcated into a technical core used for rapid deployment and support for a Leviathan force and non-technical core focused on managing nation building initiatives involving numerous organizations and contracted personnel. The former would maintain that *Technical Knowledge Base* while the latter foregoes such training in favor of managerial competencies such as construction management. The strength of this proposal lies in its structure, inherently nurturing the traditional technical knowledge while allowing transformation to occur where it is needed. The career field already has a structure similar to this in place, RED HORSE and the Air Force Civil

Engineer Support Agency act as the hotbed for technical knowledge while Prime BEEF teams traditionally cover a broader range of tasks including managerial duties.

Although the Air Force Civil Engineer career field already has the natural bifurcation of personnel, there are inherent problems preventing the full benefits from being realized. Because the military culture includes rotating military personnel every two to four years, those individuals containing technical knowledge from a specific position are replace by others who may not immediately possess the same level of expertise (knowledge base). For example, a Captain sitting in the Pavement Evaluations section at AFCESA may hold a significant level of knowledge base; however, when that individual must be replaced in three years the replacement rarely immediately possesses that same knowledge base level, but rather must build it over time. It is this inefficiency which is addressed in the second structural policy, called *Career Field Bifurcation*.

In the model used for *Career Field Bifurcation*, the *Garrison Military* stock is divided into two separate pools; one for the technical mission and the other for the management mission. This represents a specialization of the forces into these two separate categories, utilizing the technical personnel to fulfill *Expeditionary Military Technical* requirements and likewise management personnel for the *Expeditionary Military Management* requirements. To accomplish the split, it was necessary to duplicate the *Propensity to Deploy* and *Ops Tempo* so each side could operate independently. As for the *Effective Garrison Military*, the technical pool does not contribute while the management pool contributes fully (100 percent). And finally, the *Expeditionary Training Policy* was set to 40 percent for the technical side and ignored for the management side (no impact on results). Figure 44 illustrates the behavior of

Technical Knowledge Base in reaction to this policy when split evenly. Trace one is the original results, which is worse than the baseline performance; however there is one important unaccounted factor. Trace one and all previous model outputs expressed *Technical Knowledge Base* in terms of a collective, career field level entity. However, because the number of personnel contributing to that level was cut in half, the pot needed to represent knowledge base per person, vice the career field. Therefore, trace two made this correction and demonstrates much healthier progress.

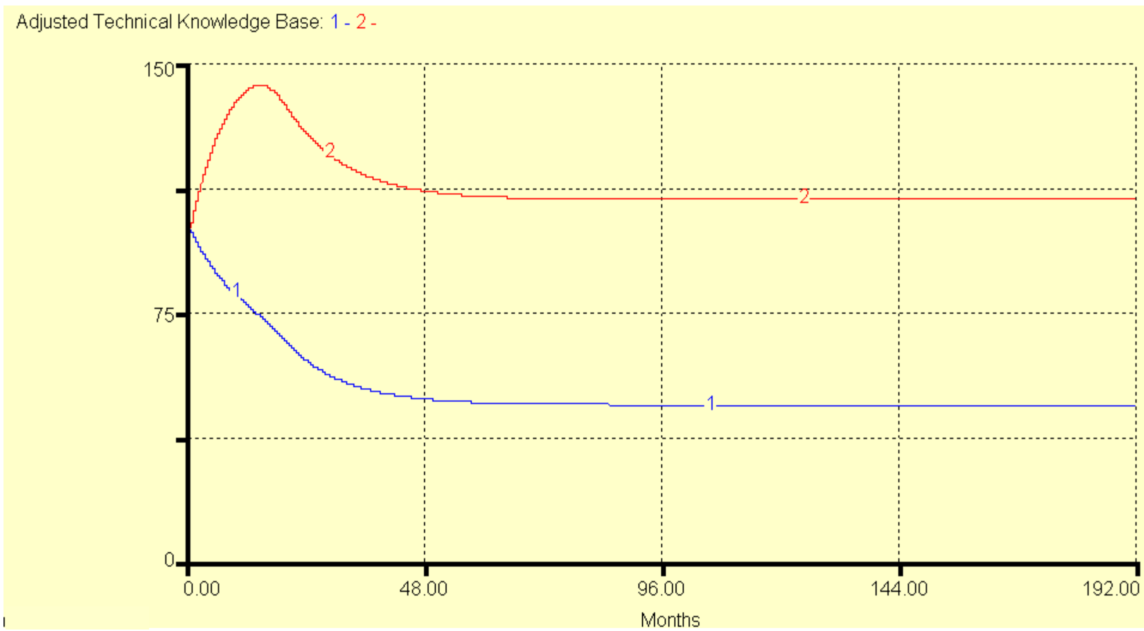


Figure 44: Impact of *Career Field Bifurcation* on *Technical Knowledge Base*.

The final change implemented was a policy allowing the deployment of civilians. Although the Civil Engineer career field already practices this, the levels of deployments are extremely low, especially in comparison to their civil engineer counterparts in the Army who deploy large numbers of civilians from the Corps of Engineers. The policy used here utilized civilians when military resources had been exhausted, effectively adding an additional pot of personnel to draw from. The results need not be shown as there was no change to the value or behavior of *Technical Knowledge Base* from this policy. However, each garrison civilian utilized proportionally decreased the number of *Expeditionary Contractors*. Therefore, in sufficient quantities civilian deployments could solve many of the problems posed by contractors, as discussed in Chapter 2 (i.e. reliability, cost, flexibility, etc.).

To summarize the endeavors of Step 5 in the System Dynamics methodology, several leverage points in the model were identified to potentially provide an avenue for mitigating the erosion of *Technical Knowledge Base*. Those areas are summarized in Table 6. Across the top are the five different variations made to the model to create the desired policy (solution). Training Policy is used twice, once as the minimum training level currently required by Air Force regulations (approximately 15 percent of garrison work hours) and the second as the worst-case scenario for *Expeditionary Training Policy* should the *Garrison Mission Requirements* be removed. Garrison Workload Reduction is used at the 20 percent reduction level (the career field goal) and the Expeditionary Contractor Limit is set to ensure contractors make up less than 75 percent of expeditionary forces. The final entity, Career Field Bifurcation, splits the 70 units of military personnel with 30 going to the technical side and 40 to the managerial side.

The vertical options listed show each of the areas identified, the possible combinations, and the specific structural and procedural changes explored. Each is marked to represent which policy on the horizontal axis was utilized and a numerical measure of the steady-state value of *Technical Knowledge Base* displayed for comparison purposes. Further combinations of the structural changes with the other additional policies were accomplished but were omitted due to insufficient effect.

Table 6: Summary of policies implemented and resulting steady-state values of *Technical Knowledge Base* and *Management Knowledge Base*.

	Training Policy (.15)	Training Policy (.40)	Garrison Workload Reduction (20%)	Exped. Cont. Limit (75%)	Career Field Bifurcation (30T/40M)	TKB @ t=192	MKB @ t=192
Option #1: Do Nothing						49	61
Option #2: Minimum Training	X					60	75
Option #3: Maximum Training		X				99	125
Option #4: Garrison Work Reduction			X			52	65
Option #5: Contractor Limits				X		56	69
Option #6: #'s 2 & 4	X		X			60	75
Option #7: #'s 2 & 5	X			X		69	86
Option #8: #'s 4 & 5			X	X		63	78
Option #9: #'s 2, 4 & 5	X		X	X		69	86
Option #10: Civilianization		X	X*			99	125
Option #11: Bifurcation		X	X**		X	109	142
Option #12: Deploy Civilians						50	63

* The Garrison Workload Reduction used here is 100 percent.
** Garrison Military Technical don't support the garrison mission.

The results found here provide significant insight into the knowledge base transformation. The next chapter will further discuss the findings and issues of Civil Engineer career field knowledge sustainability. From this discussion, recommendations can be made for potential courses of action and their associated advantages and disadvantages. Additionally, further research areas will be proposed to follow the progress of this research.

V. Discussion and Conclusions

The model developed investigated the transformation of knowledge within the Air Force Civil Engineer career field and assessed the consequences associated with that transformation. The results provide senior career field leaders an understanding of the causal relationships and resulting behaviors that affect future sustainability. However, the ultimate decision must be made by those leaders, identifying the risks and judging whether the current course is acceptable. The following discussion identifies those risks and makes candid recommendations based on the results. However, the fundamental assumption is the overall degradation of knowledge resulting from the transformation is undesirable for the Civil Engineer career field.

Through the modeling process, training and experience, expeditionary contractors, and career field structure have emerged as significant system attributes. However, in analyzing them it is important to remember the model serves only as a representation of the system's behavior; it's inappropriate to expect definitive values from this or any other System Dynamics Model. Instead, to truly value the results attention must be placed on understanding the system's infrastructure through the causal relationships, which give the model its characteristic behavior and value.

The Concept of the Technical Loop

The first issue centers on the concept of a technical loop. This loop captures how the garrison military mission and the expeditionary technical engineering mission contribute positively to the technical knowledge base of the officers through training and experience. If military personnel remain within these two missions, there is zero degradation of technical knowledge. Yet, as the officers deploy more frequently to fill managerial tasks, they do not gain this same technical experience (i.e. they are outside the technical loop) which, over time, degrades the overall level of both technical and managerial knowledge.

Under scenarios with no or relatively few expeditionary requirements, the increased benefit of experience from performing technical tasks while deployed outweighs the comparatively smaller losses from personnel outside the technical loop supporting managerial tasks. However, under heavy operational demands the amount of managerial tasks crosses a threshold, removing enough military members from the technical loop such that normal steady state levels of technical knowledge are no longer attainable; there are simply too many personnel removed from the technical loop. This same concept holds true for the management side as well only in reverse. Despite this, the gains in managerial knowledge through increased managerial expeditionary tasks cannot be sustained because the ability to perform these roles is contingent on a strong technical base that is no longer being groomed through technical experiences gained in garrison or deployed settings.

The technical loop creates a starting point for addressing the knowledge transformation issue. While experience gained reaches a maximum as the operation tempo reaches 50%, the home station training program is an area with significant potential to assist maintaining technical knowledge levels. This degradation could be ameliorated by maximizing the organization’s training program, bringing the technical and management knowledge levels back to the original steady state levels, and actually increasing the latter. Civil Engineer leadership has this within their control and is currently pursuing changes to reinvigorate the expeditionary training program. For example, a new Prime BEEF initiative was recently introduced to involve young officers with the technical details of managing construction projects at home station (Beyers, 2010). However, as defined in chapter 4 the training program includes expeditionary training, formal classroom training, and garrison on-the-job training; the new initiative addresses only the first of these three, but advances in the latter two are similarly viable.

Therefore, the first major recommendation is to reshape home station training programs to create a formalized “Technical Track”. This track could include technically oriented assignments to organizations such as RED HORSE, the Air Force Civil Engineer Support Agency (AFCESA), and the Air Force Center for Engineering and the Environment (AFCEE); a formalized, standardized, and robust training regimen through the Civil Engineer School; and the new Prime BEEF initiative. Another area is professional licensure. Engineers in the Navy are required to attain licensure as a Professional Engineer at around four to six years of service; it is required for promotion to Lieutenant Commander, O-5. Instituting a similar program in the Air Force Civil Engineer career field would not only bolster technical knowledge, but provide the technical baseline necessary for managerial knowledge as well.

The Concept of Contractor Policy

While the training program is something that can be controlled by career field leadership, the second discussion topic swings to the opposite side of the pendulum. The area of expeditionary contractor use is complex: nearly every anecdotal news story and a comprehensive report from the Special Inspector General of Iraq Reconstruction (2008) show significant difficulties (regarding cost, quality, and integrity) when working with expeditionary contractors. However, one fact is certain, the United States Department of Defense (and military engineers specifically) cannot accomplish their mission without the support of expeditionary contractors (GAO, 2008); the operational demand is too high, the military capabilities are limited in scope and size, and the military organization is not structured for such a massive undertaking as rebuilding an entire country. The National Guard and Reserves were originally designed as a surge capacity in times of war, but as operations in Iraq and Afghanistan extend into the ninth year regulations governing Guard and Reserve forces restrict their continued use (Title 10 Regulations). This, combined with a shift in attitude around the turn of the century toward a pro-government outsourcing policy, has created the contractor reliance seen today (GAO, 2008).

Reliance on expeditionary contractors has additional risks besides knowledge transformation. Reliability, retention, and cost are all factors weighing heavily on the effectiveness of expeditionary contractors. While there is a lack of formal literature specifically citing Expeditionary Contractors as unreliable, as non-combatants there always exists the risk of hostile activities hindering performance. For example, in 2004 the government of the Philippines banned tens of thousands of foreign working citizens from Iraq after a worker was captured by terrorists. Five years later, the Iraqi government is still pleading for the ban to be lifted, although reports say there are more than 6,000 Philippinos working in Iraq despite the ban (Gulf News, 2007). But the question exists, what would be the result if this happened on a mass scale? The risk remains beyond the reaches of the Civil Engineer career field, but it must be managed.

One way to manage the risk is to utilize the garrison civilian workforce. By deploying civilians the required number of contractors could be reduced, but the results from the model demonstrate only minimal improvements. The solution also comes with disadvantages, such as the loss of continuity at the garrison location and, if deployments are non-voluntary, the potential to have a drop in retention of qualified civilian personnel. However, the Air Force already deploys some personnel and further research could explore the feasibility of increasing the program scale to that of the extensive Army program, thereby making it effective in reducing contractors.

The Concept of Restructuring

While the first issue highlighted a concern nearly completely in the career field's control and the second issue is nearly completely out of its control; the area of structure lies somewhere between. Many formal and informal proposals for Air Force Civil Engineer structure have been made over the years (Addison, 2007; Katzer, 2002; Taylor, 1983), with a base-level reorganization implemented in 2008 (Eulberg, 2008). However, the recent reorganization and many of the proposals fall short of the aggregation level suggested in this model; the two aggregate structural changes explored through this model are civilianization and bifurcation. Civilianization is the removal of military personnel from the garrison mission while bifurcation was the separation of the career field into technical and managerial cores. The model results showed both alternatives effectively reversed the overall degradation of knowledge, with bifurcation producing results roughly ten percent better.

The recommendation from the structural simulations is to work a pseudo-bifurcation strategy. Civilianization and complete bifurcation as it was intended by Barnett's (2005) *The Pentagon's New Map: Blueprint for Action* are multi-year, labor intensive reorganizations with a complete overhaul to the strategic purpose of military engineers. However, the "Technical Track" suggested from the technical loop concept is a good beginning for a pseudo-bifurcation. By creating a program allowing young officers an opportunity to focus on their technical skills, significant gains can be accomplished throughout both technical and managerial knowledge areas.

The Concept of Personnel

The last discussion area pertains to the level of personnel. The initial knee-jerk reaction is to increase Air Force military engineers to meet the higher demand. However, it is important to remember that 62 percent of Air Force Civil Engineer deployments are to augment sister services. Increasing Air Force engineers will cost more, require increased authorizations, and result in excess personnel at the end of the conflict. An alternative solution is to bolster the surge capacity internal to the Guard and Reserve components. However, regulations governing their use constrain the extent to which this may address the concern. Reserve components can only deploy twice per conflict within a five year period (per Title 10 Regulations) and the typical counterinsurgency lasts an average of 10 years (Nagl, 2002); military policies are incongruent with current mission requirements. Based on this incongruence, something must be changed to align policy with practice. The benefit of a change such as this to the Air Force includes a reduction in sister service support, easing contractor requirements. However, as The Air Force Civil Engineer stated in June 2009, it's a joint fight and we all must contribute.

Suggested Future Research

Throughout the research and System Dynamics method, the goal has been to identify the knowledge transformation in the Air Force Civil Engineer career field and provide information and potential solutions for career field leadership to appropriately assess the situation and make candid decisions. However, the research cannot explore every aspect of knowledge transformation and opened more questions about the career field's future. These provide opportunities for additional research to further the understanding of this topic. One recommendation is to focus solely on the sustainability issues associated with expeditionary contractors. The impact expeditionary contractors have on retention, career field sustainability, and reliability is largely unknown; this is an important topic with extensive implications. Another continuation of the research is in the area of Civil Engineer officer development. Because the model was aggregated to the entire officer corps, progressive development of officers throughout their career was not included but could provide further details on how a "Technical Track" could be implemented.

Conclusion

The Air Force Civil Engineer career field is experiencing a transformation of their core knowledge. Extended operations in Iraq and Afghanistan combined with unprecedented use of expeditionary contractors are shifting the roles that Civil Engineers fill – from technical tasks towards more managerial tasks. Unfortunately, the experience and knowledge gained through the technical tasks are the precursor to successfully fulfilling the managerial roles. This transformation, then, results in an overall degradation of the engineer's knowledge base. It is up to career field leadership to recognize this transformation and decide whether action is necessary to protect the technical base. If so, this research presents multiple methods to counter the anticipated technical knowledge erosion, namely through increased training programs and a "Technical Track" to groom young officers for success as they advance to higher organizational levels.

Appendix A: Equations for Flow Diagram

List of Stocks:

- X_1: Expeditionary Nation Building Mission
- X_2: Expeditionary Operating Base Mission
- X_3: Expeditionary Contractor Efficiency
- X_4: Expeditionary Contractors
- X_5: Expeditionary Military Technical
- X_6: Expeditionary Military Management
- X_7: Garrison Military
- X_8: Garrison Civilians and Contractors
- X_9: Expeditionary Training Policy
- X_{10}: Technical Knowledge Base

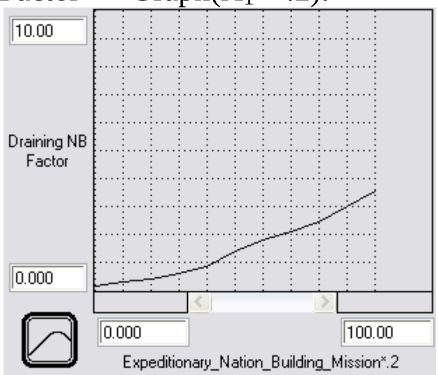
Expeditionary Nation Building Mission (X_1):

$$\frac{\partial X_1}{\partial t} = aX_1 - bX_1$$

where: $X_1(0) = 0.01$

a = Compounding Nation Building Factor = .35

b = Draining Nation Building Factor = Graph(X_1 * .2):



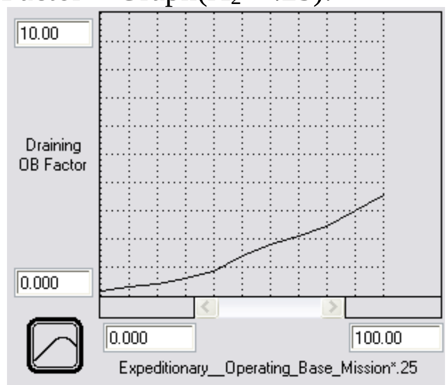
Expeditionary Operating Base Mission (X_2):

$$\frac{\partial X_2}{\partial t} = aX_2 - bX_2$$

where: X_2 (0) = 0.5

a = Compounding Operating Base Factor = .5

b = Draining Operating Base Factor = Graph(X_2 * .25):



Expeditionary Mission (Y):

Y = Total Expeditionary Requirement = a(X_1 + X_2)

where: a = Intensity Factor = .5

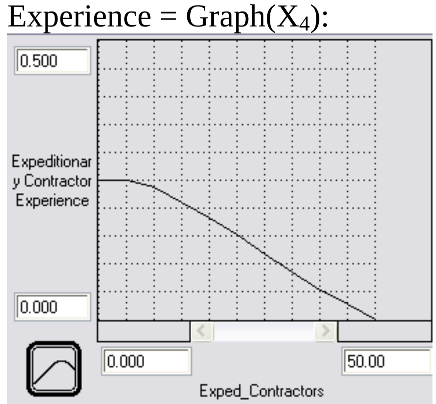
Expeditionary Contractor Efficiency (X_3):

$$\frac{\partial X_3}{\partial t} = a(1 - X_3) - bX_3$$

where: X_3 (0) = 0

a = Contractor Efficiency Flow Factor = .2

b = Expeditionary Contractor Experience = Graph(X_4):



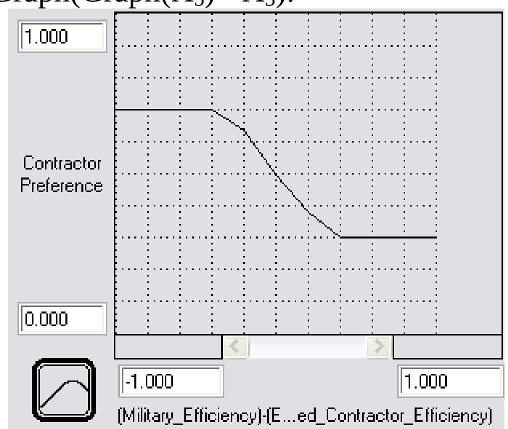
Expeditionary Contractors (X_4):

$$\frac{\partial X_4}{\partial t} = ab[Y - X_5 Graph(X_{10}) + X_3 X_4]$$

where: $X_4(0) = 0$

a = Expeditionary Contractors Flow Factor = .4

b = Contractor Preference = Graph(Graph(X_5) - X_3):



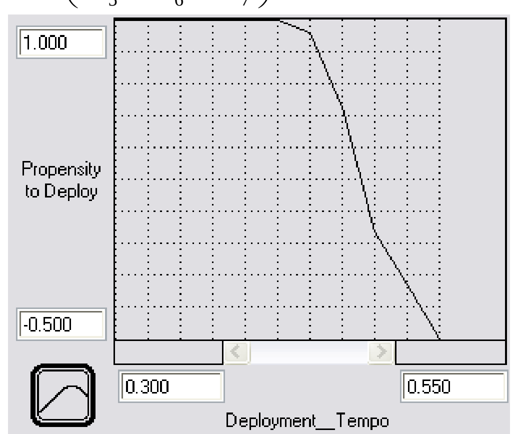
Expeditionary Military Technical (X_5):

$$\frac{\partial X_5}{\partial t} = ab[Y - X_5 Graph(X_{10}) + X_3 X_4] \times \{1 - Graph[Graph(X_5) - X_3]\}$$

where: $X_5(0) = .1$

a = Technical Deployment Flow Factor = .5

b = Propensity to Deploy = Graph$\left(\frac{X_5 + X_6}{X_5 + X_6 + X_7}\right)$:



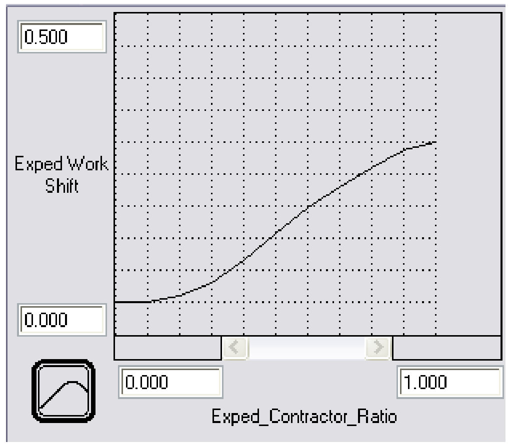
Expeditionary Military Management (X_6):

$$\frac{\partial X_6}{\partial t} = a[b(X_4 + X_5) - X_6]$$

where: $X_6(0) = 0$

a = Management Deployment Flow Factor = .5

b = Expeditionary Work Shift = $Graph\left(\frac{X_4}{X_4 + X_5}\right)$:



Garrison Military (X_7):

$$\frac{\partial X_7}{\partial t} = -\left(\frac{\partial X_5}{\partial t} + \frac{\partial X_6}{\partial t}\right)$$

where: $X_7(0) = 70$

Garrison Civilians and Contractors (X_8):

IF .8b < $(X_8 + X_7(1 - X_9))$ < .95b, Then: $\frac{\partial X_{8a}}{\partial t} = a\{b - [X_8 + X_7(1 - X_9)]\}$

Else: $\frac{\partial X_{8b}}{\partial t} = 0$

where: $X_8(0) = 120$

a = Garrison Contractor Flow Factor = .1

b = Garrison Mission Requirement = 200

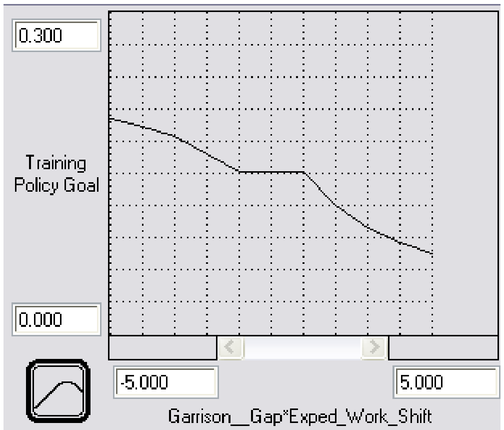
Expeditionary Training Policy (X_9):

$$\frac{\partial X_9}{\partial t} = a(b - X_9)$$

where: X_9 (0) = 0

a = Expeditionary Training Policy Flow Factor = .5

b = Training Policy Goal = Graph{ $[X_8 + X_7(1 - X_9)] \times Graph\left(\frac{X_4}{X_4 + X_5}\right)$ }:



Technical Knowledge Base (X_{10}):

$$\frac{\partial X_{10}}{\partial t} = X_7[aX_9 + b(1 - X_9)] - cX_{10}$$

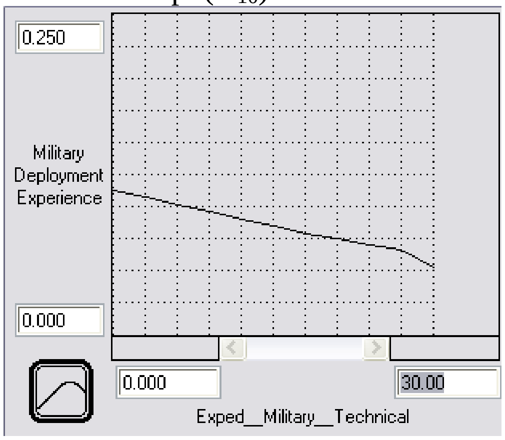
where: KB(0) = 0

IKB = X7 * X9 + (1 – X9) * X7 * .2 - X10*b

a = Knowledge Base Compounding Factor = .5

b = Military Garrison Experience Factor = .2

c = Military Deployment Experience = Graph(X_{10}):



Appendix B: Adding Management Knowledge Base

A revision was made to the model to include *Management Knowledge Base* and capture the link between technical and managerial knowledge within the engineering context. Specifically, an element entitled *Management Knowledge Base*, a representation of the core knowledge capabilities required to function in an Engineering Manager role, was included. Similar to the *Technical Knowledge Base* component, the Virgin Behavior and resulting structure is an approach to steady state. The Flow Diagram illustrating *Management Knowledge Base* is shown in Figure 45.

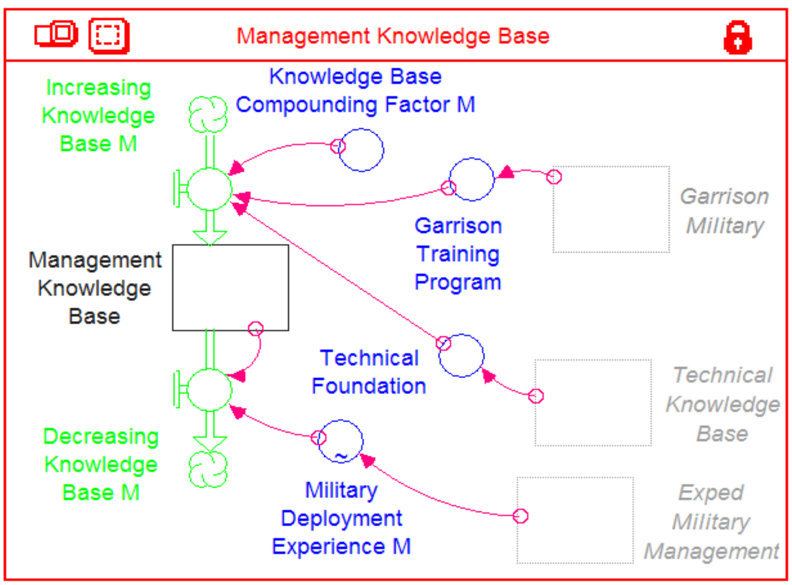


Figure 45: Flow Diagram of *Management Knowledge Base*.

As shown, there are two flows increasing and decreasing *Management Knowledge Base* consistent with a *Garrison Training Program* and deployment experience, respectively. There is, however, an influence not included the *Technical Knowledge Base* counterpart; the *Technical Foundation* which is a representation of the impact

Technical Knowledge Base plays (discussed in Chapter 2). As *Technical Knowledge Base* decreases, the ability to increase *Management Knowledge Base*, or the effectiveness of the *Garrison Training Program*, is similarly decreased. Finally, the steady-state level of *Management Knowledge Base* is set at a value of 100 given no *Expeditionary Mission Requirement*; the same as *Technical Knowledge Base*.

To understand the behavior of *Management Knowledge Base* within the system, it is first crucial to see and comprehend its behavior without the influence of the *Technical Foundation*. Figure 46 shows that under an expeditionary load, the *Work Shift* that creates a loss in *Technical Knowledge Base* similarly creates a gain in *Management Knowledge Base*. This is logical; as the work requirement shifts from technical to managerial, so will the experience and training, and in sum the balance of knowledge similarly shifts. Therefore, the behavior represents a shift in the balance of knowledge.

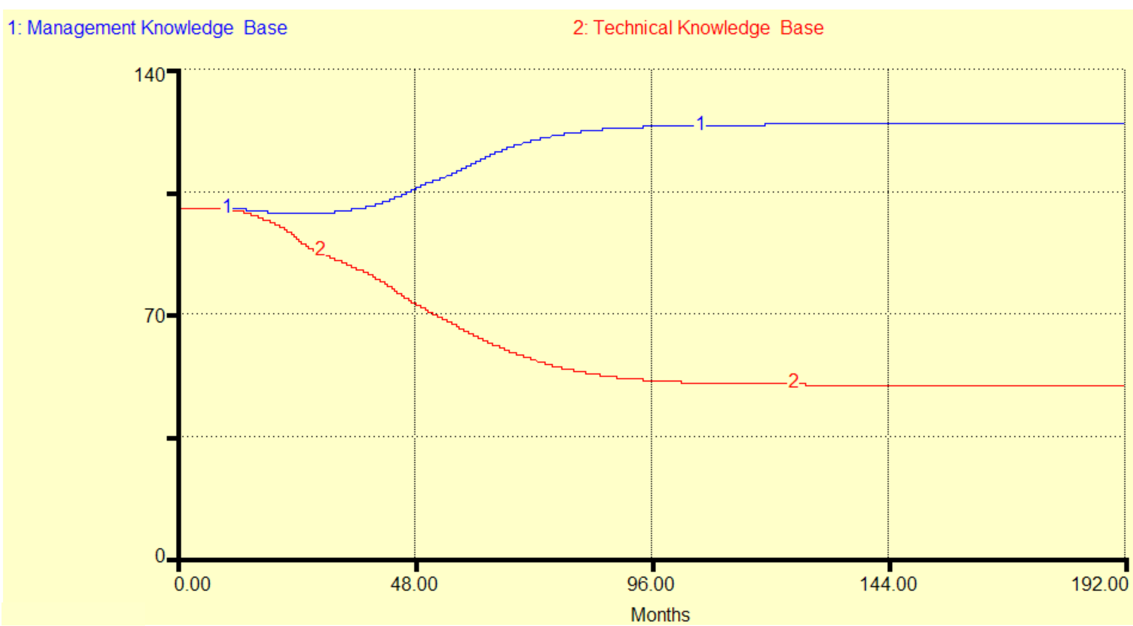


Figure 46: Behavior of *Technical* and *Management Knowledge Base* without the influence of *Technical Foundation*.

However, once the *Technical Foundation* is included, a very different behavior is perceived. Figure 47 demonstrates the once strong, increasing behavior of *Management Knowledge Base* is now eroding similarly to the *Technical Knowledge Base*. The explanation is simple: as *Technical Knowledge Base* erodes, the ability for *Management Knowledge Base* to increase is hindered, resulting in simultaneous knowledge erosion. Here lies the true threat if the *Technical Knowledge Base* erodes.

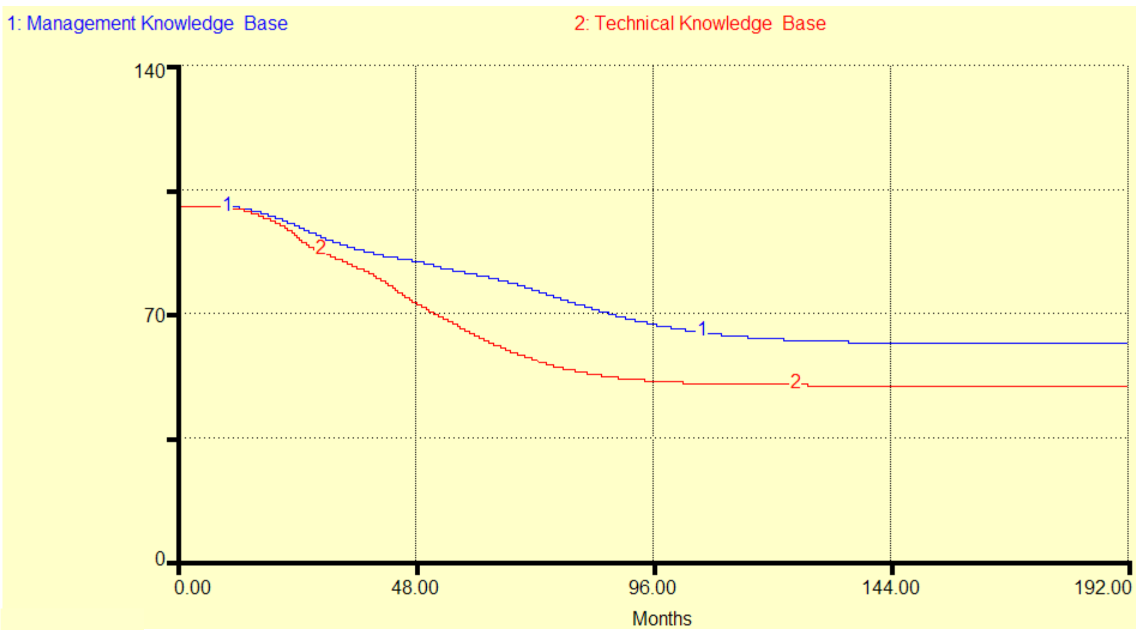


Figure 47: Behavior of *Technical* and *Management Knowledge Base* with the influence of *Technical Foundation*.

References

Addison, Michael. 2008. "Engineered for Victory: 21st Century Air Force Engineers." Presented to the Society of American Military Engineers, Scott Field Post, Scott Air Force Base, Illinois. May 28, 2008.

Air Force Personnel Center (AFPC). 2008. "Stressed AFS’s." http://ask.afpc.randolph.af.mil

Barnett, Thomas P.M. 2005. *Blueprint for Action: A Future Worth Creating*. New York: Penguin Group.

Beyers, Timothy A. 2010. Major General Timothy A. Beyers, The Air Force Civil Engineer. Address to Students, Air Force Institute of Technology. March 15, 2010.

Brown, Kendall. 2008. " The Role of Air Force Civil Engineers in Counterinsurgency Operations." *Air & Space Power Journal*. 22-2.

Congressional Budget Office (CBO). 2008. "Contractors' Support of U.S. Operations in Iraq." August 2008.

Department of Defense. 2008. "National Military Strategy." Washington, D.C. June 2008.

Department of State. 2008. "Provincial Reconstruction Team Fact Sheet." http://iraq.usembassy.gov/pr_01222008b.html

Department of the Air Force. 2009. “Prime Base Engineer Emergency Force (BEEF) Program.” AFI 10-210. Washington: HQ AFDDEC. June 26, 2009.

Department of the Air Force. 2007. "Irregular Warfare." AFDD 3-2. Washington: HQ AFDDEC. August 1, 2007.

Department of the Army. 2006. *Counterinsurgency Field Manual*. FM 3-24. Washington: HQ USA, 15 December 2006.

Eulberg, Del. 2009. "USAF: Enabling Air Force Priorities." *The Military Engineer*. 101-569: 85-87. May-June 2009.

Eulberg, Del. 2008a. "2008 Almanac." *The Air Force Civil Engineer*. 36-4.

Eulberg, Del. 2008b. "2008 United States Air Force Civil Engineer Strategic Plan." Published by the Office of the Civil Engineer, United States Air Force, Washington, D.C.

Eulberg, Del. 2007. "2007 Almanac." *The Air Force Civil Engineer*. 35-4.

Forrester, Jay W. and Senge, Peter M. 1980. “Tests for building confidence in system dynamics models.” *TIMS Studies in the Management Sciences.* 14, 209 – 228.

Government Accountability Office (GAO). 2008. “DoD’s increased reliance on service contractors exacerbates long-standing challenges.” Statement of David M. Walker, Comptroller General of the United States. GAO 08-621T. January 23, 2008.

Gulf News. 2007. “Philippine work ban in Iraq stays.” Posted April 23, 2007.

Hartzer, R.B. 2008. "Foundations for the Future: A Brief history of Air Force Civil Engineers." http://www.afcesa.af.mil/shared/media/document/AFD-070607-002.pdf, first accessed November 14, 2008.

Huffman, Ann H., Adler, Amy B., Dolan, Carol A., and Castro, Carl Andrew. 2005. “The impact of operations tempo on turnover intentions of army personnel.” *Military Psychology*. 17(3), 175-202.

IThink. 2001. *An Introduction to Systems Thinking*. Lebanon, NH: HPS Inc.

Jeanneret, P. Richard and Strong, Mark H. 2003. “Linking O*NET job analysis information to job requirement predictors: An O*NET application.” *Personnel Psychology*. 56(2), 465-492.

Katzer, Dee Jay. 2002. " Decision analysis with value-focused thinking as a methodology in structuring the civil engineer operations flight." Thesis, Air Force Institute of Technology, Air University, Wright-Patterson AFB, OH. March 2002.

Kelty, Ryan. 2005. "Military Outsourcing: A Case Study of the Effects of Civilianization on Sailors’ Retention Intentions." United States Military Academy. Submitted to the Inter-University Seminar on Armed Forces & Society, Chicago, IL. October 21-23, 2005

Lindsay, Kevin. 2000. “Engineers, Where Do We Go From Here?” *Engineer*. Fort Leonard Wood, MO. October 2000, 2-14.

Liu, Cong; Spector, Paul E.; and Jex, Steve M. 2005. “The relationship of job control with job strains: A comparison of multiple data sources.” *Journal of Occupational and Organizational Psychology*. 78, 325-336.

McPeak, Michael and Ellis, Sandra N. 2004. “Managing Contractors in Joint Operations: Filling the Gaps in Doctrine.” *Army Logistician*. Mar-Apr 2004.

Nagl, John A. 2002. *Learning to Eat Soup with a Knife: Counterinsurgency Lessons from Malaya and Vietnam*. Chicago: University of Chicago Press.

National Museum of the USAF. 2008a. "U.S. Air Force Fact Sheet: Prime BEEF." http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=1280

National Museum of the USAF. 2008b. "U.S. Air Force Fact Sheet: RED HORSE." http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=1306

Office of Management and Budget. 2003. "Circular Number A-76." Washington, D.C. May 29, 2003.

O*NET. 2010. *Occupational Information Network* (O*NET). Accessed from: http://online.onetcenter.org

Palmby, William G. 2006. "Outsourcing the Air Force Mission: A Strategy for Success." Walker Paper No. 4. Air University Press: Maxwell Air Force Base, Alabama.

Richmond, Barry. 2004. *An Introduction to Systems Thinking, Stella.* ISEE Systems. Accessed from: http://www.iseesystems.com

Rona, Roberto J.; Fear, Nicola T.; Hull, Lisa; Greenberg, Neil; Earnshaw, Mark; Hotopf, Matthew; & Wessely, Simon. 2007. “Mental health consequences of overstretch in the UK armed forces: first phase of a cohort study.” *British Medical Journal*. 335: 603-603.

Shelley, Michael L. Class handouts, EMGT 642, System Dynamics. School of Engineering and Management, Air Force Institute of Technology, Wright-Patterson AFB, OH. January 2009.

Singer, Peter W. 2004. “The private military industry and Iraq: What have we learned and where to next?” Policy Paper presented to Geneva Centre for the Democratic Control of Armed Forces. November, 2004.

Singer, Peter W. 2003. Corporate Warriors: The Rise of the Privatized Military Industry. Ithaca, NY: Cornell University Press.

Sterman, John D. 2000. *Business Dynamics: Systems Thinking and Modeling for a Complex World*, New York: Irwin/McGraw-Hill.

System Dynamics Society. 2010. “What is System Dynamics?” Accessed from: http://www.systemdynamics.org/what_is_system_dynamics.html

Taylor, Edwin S. 1983. “Base civil engineer organization: standardized versus flexible.” Thesis, Air Force Institute of Technology, Air University, Wright-Patterson AFB, OH.

U.S. Army Corps of Engineers. 2009. "The U.S. Army Corps of Engineers: A Brief History." Accessed from: http://www.usace.army.mil/History/Pages/Brief.aspx

U.S. Department of Labor. 2010a. "Engineering and natural sciences managers." *Occupational Outlook Handbook, 2010-11 Edition*. Bureau of Labor Statistics.

U.S. Department of Labor. 2010b. "Engineers." *Occupational Outlook Handbook, 2010-11 Edition*. Bureau of Labor Statistics.

Verkuil, Paul R. 2007. Outsourcing Sovereignty: Why Privatization of Government Functions Threatens Democracy and What We Can Do About It. New York: Cambridge University Press.

West, Christopher. 2009. Interview with author. June 4, 2009.

Vita

Biographical Sketch

First Lieutenant Gregory Ward graduated from Medomak Valley High School in Waldoboro, Maine. He then was accepted to Clarkson University in Potsdam, New York for his undergraduate studies on a four-year United State Air Force scholarship, where he graduated with a Bachelors of Science in Electrical Engineering. In May 2006 he was commissioned as a Second Lieutenant in the United States Air Force through the Air Force Reserve Officer Training Corps.

His first duty station was to the 375th Civil Engineer Squadron, Scott Air Force Base, Illinois where he was assigned the duties of Project Programmer and Readiness and Emergency Management Flight Commander. He was chosen to complete his Master of Science degree in Engineering Management at the Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio where he is expected to graduate in March 2010. Following his graduation, Lieutenant Ward will be assigned to the 52^{nd} Civil Engineer Squadron, Spangdahlem Air Base, Germany from where he will deploy for a 12-month rotation to Afghanistan serving with the U.S. Army Corps of Engineers.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 074-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From – To)*
03-2010	Master's Thesis	Nov 2008 - Mar 2010

4. TITLE AND SUBTITLE **Knowledge Transformation in the United States Air Force Civil Engineer Career Field: A System Dynamics Approach**	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Ward, Gregory J., 1Lt, USAF**	**5d. PROJECT NUMBER**
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S) Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Way WPAFB OH 45433-7765	**8. PERFORMING ORGANIZATION REPORT NUMBER** **AFIT/GEM/ENV/10-M13**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Intentionally Left Blank	**10. SPONSOR/MONITOR'S ACRONYM(S)**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Recent operations in Iraq and Afghanistan have brought the level of expeditionary contractors to historically unprecedented levels, altering the work composition for military engineers. The alteration has shifted emphasis from technical knowledge areas toward managerial knowledge associated with supervising the increased number of contractors. This research utilizes system dynamics modeling to analyze this shift in the United States Air Force Civil Engineer officer career field and resulting transformative effect on career field knowledge levels, both technical and managerial. The model is then tested with multiple external policy adjustments in the areas of career field structure, training, and operating policy.

Results indicate the shift from technical to managerial knowledge not only diminishes technical knowledge, but also hinders managerial knowledge which requires a strong technical foundation; this creates an overall degradation of both knowledge areas. Therefore, the external policies implemented focused on limiting technical knowledge loss. The recommended policy included a combination of additional technical training and bifurcation of entry-level officers to focus on core technical knowledge, simultaneously providing the foundation for successful managerial knowledge levels.

15. SUBJECT TERMS
Knowledge Transformation, Civil Engineer, System Dynamics

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
					Michael L. Shelley, ENV
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(Include area code)*
U	U	**U**	**UU**	126	937-257-3636

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18

	Form Approved *OMB No. 074-0188*