NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

SEQUOYAH FOREIGN LANGUAGE TRANSLATION SYSTEM – BUSINESS CASE ANALYSIS

by

Wing Shan Shirley Ong

December 2007

Thesis Advisor:	Dan Nussbaum
Second Reader:	Kevin Squire

Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** December 2007	**3. REPORT TYPE AND DATES COVERED** Master's Thesis	
4. TITLE AND SUBTITLE Sequoyah Foreign Language Translation System – Business Case Analysis		**5. FUNDING NUMBERS**	
6. AUTHOR(S) Wing Shan Shirley Ong			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000		**8. PERFORMING ORGANIZATION REPORT NUMBER**	
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A		**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.		**12b. DISTRIBUTION CODE**	

13. ABSTRACT (maximum 200 words)

Sequoyah, which is the Department of Defense (DoD)'s Program of Record for automated foreign language translation, is to identify current and developing technologies to meet warfighter requirements for foreign language support. Sequoyah aspires to have MLT capability embedded in other systems, such as Soldier as a System (SaaS) and Future Combat System (FCS), so as to provide automated capability to meet the warfighters' foreign language translation needs when a human linguist is unavailable.

The purpose of this thesis is to analyze the potential cost savings and benefits of utilizing MLT systems as a complement to the host nation linguists required to be hired to support military operations. This thesis will develop a Business case for the following purposes:

- Analyze the best circumstances in military operations that MLT systems can be used to complement human linguists or when human linguist is not available.
- Determine the comparative costs of MLT system vs. host nation linguists using techniques from the field of cost estimation.

Although the use of computers is very prevalent in today's society, they simply cannot replace human beings in performing some of the tasks that require thinking and understanding. Bar-Hillel, an early machine translation researcher, used a seemingly simple sentence "The box is in the pen" to point out that "to decide whether the sentence is talking about a writing instrument pen or a child's play pen, it would be necessary for a computer to know about the relative sizes of objects in the real world… The point is that accurate translation requires an understanding of the text, which includes an understanding of the situation and an enormous variety of facts about the world in which we live." Hence, this study does not advocate replacing human linguists with MLT systems but rather to explore the circumstances that MLT systems can be used to complement host nation linguists or when there is no linguist available.

14. SUBJECT TERMS Business Case Analysis, Sequoyah, Machine Language Translation System, Advanced Concept Technology Demonstration			**15. NUMBER OF PAGES** 91
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

SEQUOYAH FOREIGN LANGUAGE TRANSLATION SYSTEM – BUSINESS CASE ANALYSIS

Wing Shan Shirley Ong
Civilian, Defence Science & Technology Agency, Singapore
B.Eng., National University of Singapore, 2002

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
December 2007

Author: Wing Shan Shirley Ong

Approved by: Dr. Dan Nussbaum
Thesis Advisor

Dr. Kevin Squire
Second Reader

Dr. James Eagle
Chairman, Department of Operations Research

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

Sequoyah, which is the Department of Defense (DoD)'s Program of Record for automated foreign language translation, is to identify current and developing technologies to meet warfighter requirements for foreign language support. Sequoyah aspires to have MLT capability embedded in other systems, such as Soldier as a System (SaaS) and Future Combat System (FCS), so as to provide automated capability to meet the warfighters' foreign language translation needs when a human linguist is unavailable.

The purpose of this thesis is to analyze the potential cost savings and benefits of utilizing MLT systems as a complement to the host nation linguists required to be hired to support military operations. This thesis will develop a Business case for the following purposes:

- Analyze the best circumstances in military operations that MLT systems can be used to complement human linguists or when human linguist is not available.
- Determine the comparative costs of MLT systems vs. host nation linguists using techniques from the field of cost estimation.

Although the use of computers is very prevalent in today's society, they simply cannot replace human beings in performing some of the tasks that require thinking and understanding. Bar-Hillel, an early machine translation researcher, used a seemingly simple sentence "The box is in the pen" to point out that "to decide whether the sentence is talking about a writing instrument pen or a child's play pen, it would be necessary for a computer to know about the relative sizes of objects in the real world… The point is that accurate translation requires an understanding of the text, which includes an understanding of the situation and an enormous variety of facts about the world in which we live."[1] Hence, this study does not advocate replacing human linguists with MLT systems but rather to explore the circumstances that MLT systems can be used to complement host nation linguists or when there is no linguist available.

[1] DiploFoundation. *Machine Translation*. Retrieved October 23, 2007 from http://www.diplomacy.edu/Language/Translation/machine.htm

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

I would like to personally thank Professor Dan Nussbaum, Professor Kevin Squire, and COL (Ret) Edward Lesnowicz for their excellent support, encouragement, and guidance towards the completion of this thesis. Without their support, I would not have been able to complete this thesis.

I would also like to thank Dr. Edward Cerutti, and Dr. Gao Yuqing for their valuable advice on machine language translation matters; Mr. Jurgen Sottung for the information on Defense Language Institute Foreign Language Centre (DLIFLC); and CPT (Ret) Rodney Githens for the information on contract linguists.

Most importantly, I would like to express my heartfelt gratitude to my husband, David, for his encouragement and support.

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

Sequoyah, which is the Department of Defense (DoD)'s Program of Record for automated foreign language translation, is to identify current and developing technologies to meet warfighter requirements for foreign language support. Sequoyah aspires to have MLT capability embedded in other systems, such as Soldier as a System (SaaS) and Future Combat System (FCS), so as to provide automated capability to meet the warfighters' foreign language translation needs when a human linguist is unavailable.

The purpose of this thesis is to analyze the potential cost savings and benefits of utilizing MLT systems as a complement to the host nation linguists required to be hired to support military operations. This thesis will develop a Business case for the following purposes:

- Analyze the best circumstances in military operations that MLT systems can be used to complement human linguists or when human linguist is not available.
- Determine the comparative costs of MLT systems vs. host nation linguists using techniques from the field of cost estimation.

Although the use of computers is very prevalent in today's society, they simply cannot replace human beings in performing some of the tasks that require thinking and understanding. Bar-Hillel, an early machine translation researcher, used a seemingly simple sentence "The box is in the pen" to point out that "to decide whether the sentence is talking about a writing instrument pen or a child's play pen, it would be necessary for a computer to know about the relative sizes of objects in the real world… The point is that accurate translation requires an understanding of the text, which includes an understanding of the situation and an enormous variety of facts about the world in which we live."[2] Hence, this study does not advocate replacing human linguists with MLT systems but rather to explore the circumstances that MLT systems can be used to complement host nation linguists or when there is no linguist available.

[2] DiploFoundation. *Machine Translation*. Retrieved October 23, 2007 from http://www.diplomacy.edu/Language/Translation/machine.htm.

Based on literature review on existing MLT technology and Subject Matter Expert (SME) judgment and experience, MLT systems can outperform host nation linguists in terms of credibility, deployability, translation speed, and consistency. In addition, MLT systems have the capability to meet translation requirements with large numbers of Linguistic Point of Presence (PoPs). However, host nation linguists can provide an unmatched capability in terms of Interagency Language Roundtable (ILR) level and cultural awareness. MLT systems also take a longer process to add additional language modules, making them unsuitable for time-sensitive missions.

Based on current state-of-the-art translation technology, the author recommended that MLT systems be used to support less complex translation requirements with ILR level 2 and below, where communications are mostly in the form of simple questions and answers. With the users trained so as not to exceed the capabilities of MLT systems, the following military missions are found to be the best circumstances that MLT systems can be used to complement host nation linguists:

- Coalition Compound Checkpoint.
- House Search.
- Emergency Medical Diagnosis.
- Maritime Warning and Interdiction.

The amount of time and money required to be invested in the development of MLT systems is dependent on factors like function, language pairs, and missions to be supported. To decide if MLT system is a worthwhile investment from an economic point of view, the author recommended finding the investment breakeven point by comparing the Net Present Value of Life Cycle Cost of MLT systems with that of human linguists. The study developed breakeven points for the development cost of MLT system under a variety of assumptions and found that annual cost of contract linguist is the most critical factor. In no case did these “ceiling” costs exceed $6M for the category of CAT I Local National contract linguist, which indicates that a MLT system faces a very difficult hurdle in displacing host nation linguist from an economic point of view. Together with the qualitative benefits derived, the estimated maximum allowable development cost of a MLT system will facilitate informed decision by decision makers.

I. INTRODUCTION

A. PURPOSE OF THE STUDY

The purpose of this study is to analyze the potential cost savings and benefits of utilizing Machine Language Translation (MLT) systems as a complement to the host nation linguists required to be hired to support military operations. With the ever soaring need for language translation, there is a shortfall in the number of available qualified linguists to support military operations.[3] Sequoyah, which is the Department of Defense (DoD)'s Program of Record for automated foreign language translation, is to identify current and developing technologies to meet warfighter requirements for foreign language support.[4] This thesis will develop a Business case for the following purposes:

- Analyze the best circumstances in military operations that MLT systems can be used to complement human linguists or when human linguist is not available.
- Determine the comparative costs of MLT systems vs. host nation linguists using techniques from the field of cost estimation.

B. WHAT IS MACHINE LANGUAGE TRANSLATION (MLT)

MLT is the use of computers to automate some or all of the process of translating from one natural language to another. The problem of automatically producing a high-quality translation of an arbitrary text from one language to another is far too hard to automate completely, but certain simpler translation tasks can be addressed with current computational models. In particular, MLT systems often focus on (1) task for which a rough translation is adequate, (2) tasks where a human post-editor can be used to improve MLT system output, and (3) tasks limited to small sublanguage domains in which fully automatic high quality translation is achievable.[5]

---

[3] GlobalSecurity.org. *Language and Speech Exploitation Resources (LASER)*. Retrieved October 14, 2007 from http://www.globalsecurity.org/intell/systems/laser.htm.

[4] Edward A. Cerutti & CW4 (Ret.) Tim Hunter. (2005). *Sequoyah Foreign Language Translation System Analysis of Alternatives (AoA) Final Report*.

[5] Daniel Jurafsky & James H. Martin. (2000). *Speech and Language Processing: An Introduction to Natural Language Processing, Speech Recognition, and Computational Linguistics*. First Edition, Prentice-Hall.

As the first stage in a complete translation process, an MLT system can produce a draft translation that can be fixed up in a post-editing process by a human linguist, and thus expedite the overall translation process. This model of MLT usage is effective, especially for high volume jobs and those requiring quick turn-around. Weather forecasting is an example of a sublanguage domain that can be modeled completely enough to use raw MLT output even without post-editing. This domain has a limited vocabulary and only a few basic phrase types. Hence, ambiguity is rare, and the senses of ambiguous words are distinct and easily disambiguated based on local context.

MLT can generally be reduced to text-to-text (T2T) translation since speech-to-text (S2T), text-to-speech (T2S), and speech-to-speech (S2S) translations almost always use T2T translation as an intermediate step. The difficulty of translating from one language to another depends a great deal on how similar the languages are, and in all speech processing systems, including MLT systems, language translation can be considered at four levels. Details of the four levels are explained in Appendix A and outlined below:[6]

- Word for word translation – despite the common misconception about translation, simple "word-for-word" relation do not normally exists between any two languages.
- Syntax-directed translation – translate from parse tree in one language to parse trees in other languages.
- Semantic translation – use semantic information to aid in translation of data in one representation or data model to another representation or data model.
- Higher level analysis, e.g., discourse.

Traditionally, MLT systems adopted step by step approach to directly translate from one language to another, i.e., first mapping words, then rearranging the grammar and adding articles/particles etc. However, the progress and accuracy of statistical machine translation, in which computers essentially learn new languages on their own

[6] Daniel Jurafsky & James H. Martin. (2000). *Speech and Language Processing: An Introduction to Natural Language Processing, Speech Recognition, and Computational Linguistics*. First Edition, Prentice-Hall.

using statistical analysis[7] instead of being "taught" the languages by bilingual human programmers, has recently surpassed that of the traditional machine translation programs used by Web sites like Yahoo and BabelFish.

1. Complexities with Speech-to-text Translation

MLT systems may occasionally produce incorrect pronunciation and thus introduce the problem of speech synthesis. However, this problem is not significant as adding speech into MLT system introduces another set of difficulties, i.e., speech recognition. Speech recognition can generally be characterized as:

- Small vocabulary, speaker independent system, e.g., domain specific systems like airline reservations. These systems are quite accurate with small difficulties recognizing unusual accents.
- Large vocabulary, speaker dependent systems like general speech recognizers trained with one speaker. A single speaker often trains the system up front by reading some standard text, and the system tweaks a generic speech model to better match the nuance of that speaker. These systems give generally good performance.
- Large vocabulary, speaker independent systems. People speak with a variety of grammar rules and accents, so understandably these systems give generally poor performance. Syntax modeling, while useful, is much more difficult than with written documents because of the variation in inputs. Ontologies can be used to model semantics, which might aid in transcription, but may also restrict the vocabulary.

Similar to T2T translation, speech recognition also faces the same problem with semantics and context, such as cultural and immediate surroundings. In addition, all the above speech recognition systems do suffer from problems with background noise, i.e., accuracy diminishes considerably with noise.

[7] Compare two simple phrases in Arabic: "rajl kabir" and "rajl tawil". If a computer knows that the first phrase means "big man", and the second means "tall man", the machine can compare the two and deduce that rajl means "man", while kabir and tawil mean "big" and "tall" respectively. Phrases like these, called "N-grams" (with N representing the number of terms in a given phrase) are the basic building blocks of statistical machine translation.

2. Types of Language Translation Technologies

Language translation technologies can generally be categorized and described by the way they function, such as "S2S" or "T2T", "One-way" or "Two-way", and "Phrase-based" or "Free-flowing".

a. "S2S" vs. "T2T"

As the name suggested, S2S is translation of verbal communication between people who do not speak each other's language. It is typically initiated by a voice speaking in source language into a microphone input, and the resulting target language translation is produced audibly via an audio device such as a speaker. T2T is translation of written, printed, or electronic text, and it is initiated and produced via text, such as on a computer keyboard and screen.[8]

b. "One-way" vs. "Two-way"

One-way translation is translation from a source language into a target language while two-way translation is translation from a source language into a target language and from a target language back into the source language. Two-way translator obviously has more utility than a one-way translator, which is only suitable for simple and inflexible situations, but it also leads to a significant increase of technological challenge.

c. "Phrase-based" vs. "Free-flowing"

Phrased-based translation relies on speech recognition software to identify specific speech input in the source language and match is to a pre-recorded phrase in a target language. The input can be the phrase itself or a simple command that stands for the phrase. Free-flowing translation uses computer processing to translate any words or sets of words from a source language input into another language with equivalent meaning.

[8] Susan LaVonne Marshall. (Mar 2005). *Concept of Operations (CONOPS) for Foreign Language and Speech Translation Technologies in a Coalition Military Environment.* Master's Thesis, Naval Postgraduate School.

C. NEED FOR MACHINE LANGUAGE TRANSLATION SYSTEMS

Across the full spectrum and throughout all phases of military operations, there are an extensive number of enduring missions that have translation and interpretation requirements. The DoD Operational Community deploys Joint forces worldwide. Most often, units deploy with insufficient numbers of human linguists needed to support existing mission requirements. Foreign language support in the continental United States via reach-back is equally lacking.

The U.S. Army Intelligence Center (USAIC) conducted a series of analyses, including a Functional Area Analysis (FAA), Functional Needs Analysis (FNA), and Functional Solutions Analysis (FSA) that revealed a need for language translation technology to assist in meeting a significant shortfall in the number of available linguists to support military operations. According to findings of the study conducted by Battelle Memorial Institute, the Army must rely on over 11,000 contract linguists to support Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF).[9]

Joint forces are increasingly becoming coalition forces and there are many exercises being conducted annually with coalition partners where English is not the primary language of communication. Hence, language capability becomes essential in supporting military operations and the need for human language translation will continue to outrace the availability of human linguist. As the technologies become more capable, MLT systems can and should increasingly fill this gap.

D. RESEARCH METHODOLOGY, LIMITATIONS, AND ASSUMPTIONS

To develop a Sequoyah Business Case, the author conducted a literature review on business case writing and recommend an analytic structure for performing business case analysis. For qualitative analysis of MLT systems' strengths and limitation, the author conducted a literature review on existing machine language translation technology and interview Subject Matter Expert (SME) for their judgment and experience. In addition, the author performed a cost comparison between MLT systems and host nation

[9] Hampson E., Jones T., Strictland M. (2007). *Determination of the Army's Requirement for a Cadre of Professional Linguists at Level 3/3/3.* Battelle Memorial Institute.

linguists to quantify the benefits of utilizing MLT systems from an economic point of view. Finally, results of the Sequoyah business case analysis is to be reported with relevant recommendations for decision makers.

The comprehensiveness of business case analysis presented in this thesis was limited by the data available to the author.

The following assumptions were made during the conduct of the analysis:

- A Command, Control, Communications, and Computers (C4) enterprise will exist to support Sequoyah down to the individual user and that additional language modules, language module updates, and language support will be available through the Global Information Grid (GIG).
- Adequate linguistic resources will be available for the preparation of language modules, i.e., translation sets, dictionaries and mission sets, for each strategically relevant language.
- Offensive Information Operations (IO), including Computer Network Attack (CAN), Computer Network Exploitation (CNE), Electronic Warfare (EW), along with cyber-terrorism, constitutes a significant threat to Sequoyah hosted information, information systems, and communications links. However, a threat to Sequoyah is also a threat to the network and systems associated with that network. This study assumes that such threats will be countered through network security systems and procedures.
- For this analysis, Interagency Language Roundtable (ILR) descriptions are used to describe the Translation Level Capability required to satisfy a given translation/interpretation requirement. The ILR descriptions for speaking and reading may be found in Appendix B.[10] While ILR is meant to apply to a human linguist's proficiency levels (written and oral), the assumption is made that a MLT system that can achieve the ILR level required to accomplish the translation task will be capable of satisfying that task.
- Language Translation Software can be integrated into a C4 enterprise so as to meet all classifications requirements. Linguists, on the other hand, must be individually screened for security clearances.

[10] Edward A. Cerutti & CW4 (Ret.) Tim Hunter. (2005). *Sequoyah Foreign Language Translation System Analysis of Alternatives (AoA) Final Report*.

II. BACKGROUND

A. JOINT CAPABILITY TECHNOLOGY DEMONSTRATION PROCESS

1. Advanced Concept Technology Demonstration (ACTD)

Budget constraints, significant changes in threats, and an accelerated pace of technology development have challenged the ability of Component Commanders (COCOMs) to respond adequately and rapidly to evolving military needs. Part of the DoD response to these challenges has been to initiate the Advanced Concept Technology Demonstration (ACTD) program in early 1994 to get new technologies into the hands of the warfighter as quickly as possible.

The ACTD program is designed to assist the DoD acquisition process to adapt to today's economic and threat environments. ACTDs identify significant military needs and match them to mature technologies or technology demonstration programs which are maturing key technologies in order to solve important military needs. These technologies are then combined and integrated into a complete military capability to provide decision makers an opportunity to understand fully the operational potential offered by a proposed new military capability before making an acquisition or sustainment decision.

This goal is met by developing fieldable prototypes of the proposed capability and providing those prototypes to the warfighter for evaluation of that capability. The warfighter evaluates the capability in real military exercises and at a scale sufficient to assess fully military utility. During the ACTD, the warfighter also evolves the broad statement of need, which existed at the start of the ACTD, into a definitive set of operational requirements that can support a follow-on acquisition. At the completion of the ACTD, the prototypes used in the evaluation process are left with the warfighter to provide an interim capability or, in some cases, to fulfill the total, current need.[11]

[11] Gadala E. Kratzer. (October 2005). *A Methodological Approach For Conducting A Business Case Analysis For The Advanced Technology Ordnance Surveillance (AOTS)*. Master's Thesis, Naval Postgraduate School.

2. ACTD/JCTD Transition Process

Beginning in FY 2006, a new ACTD business process had been initiated to take the successful ACTD program and update it to meet the DoD's transformational goal of becoming capability vice threat based in its focus. The program will be referred to as the Joint Capability Technology Demonstration (JCTD) program. The JCTD program will include many of the positive aspects of the ACTD program, but will be revamped to meet the defense challenges of the 21st century. The new process will integrate the ACTD program with the new Joint Integration and Development System (JCIDS) developed by the Joint Chiefs of Staff (JCS).

The DoD estimated a three to five year transition period from the current ACTD process to the improved JCTD program. Eventually, JCTDs will replace ACTDs, providing an even faster process that focuses on joint and transformational technologies that are initiated in Science and Technology (S&T) and carried through the difficult transition stage, sometimes referred to as the "S&T valley of death".

The new JCTD business model includes a Defense Acquisition Executive (DAE) pilot program which will take a limited number of "joint peculiar" JCTDs past milestone B, through engineering and manufacturing, and into procurement, followed by initial sustainment - a "cradle to grave" approach. The piloted program envisions using joint acquisition activities like the Joint Precision Strike Demonstration (JPSD) program office, or even U.S. Special Operations Command (USSOCOM), to provide the necessary acquisition compliant and program management functions. The DAE pilot program will give overall programmed oversight of JCTDs that are deemed uniquely joint/combined, i.e., capability directly supports more than one Military Service, and/or transformational. The new JCTD demonstration model will specifically address congressional concerns and recommendations made by the General Accountability Office (GAO) regarding ACTD program.[12]

[12] Advanced Systems & Concepts. (October 14, 2006). *Joint Capability Technology Demonstration (JCTD)*. Retrieved August 17, 2007 from http://www.acq.osd.mil/jctd/index.htm.

B. SEQUOYAH FOREIGN LANGUAGE TRANSLATION SYSTEM

In March 2001, U.S. Army Pacific Command (USARPAC) identified Language Translation Deficiencies through a Statement of Need to Headquarters Training and Doctrine Command (HQ TRADOC). On 30 April 2001 TRADOC directed USAIC to take the lead for this task. A TIER I Integrated Concept Team (ICT) Charter for MLT was approved by LTG Jordan on 25 January 2002.

In November 2001 the Sequoyah – Foreign Language Translation System (hereafter referred to as Sequoyah) ICT completed the Mission Needs Statement (MNS) and the Mission Needs Analysis (MNA) in accordance with TRADOC Pamphlet 71-9 and Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 3170. The MNS and MNA were staffed and approved through TRADOC agencies and were forwarded to the Assistance Deputy Chief of Staff for Combat Developments (ADCSDEV) (Mr. Allan Resnick) in Feb 02. The MNS was approved and forwarded to Deputy Chief of Staff (DCS) G8. Subsequently, USAIC was directed to rewrite the MNS into the new Initial Capabilities Document (ICD) format and to produce a Mission Area Analysis (MAA).

In June 2003, HQ TRADOC directed that USAIC remain in the lead and approved its request to work with the Joint Forces Command (JFCOM) to continue the Sequoyah effort at the Joint level.

On 3 Sep 04, HQ TRADOC directed USAIC to conduct an Analysis of Alternatives (AoA) for Sequoyah. On 1 Oct 04, the Army Intelligence Master Plan (AIMP) was contracted to conduct the Sequoyah AoA.[13]

1. Sequoyah Analysis of Alternatives

The AoA, conducted by USAIC in July 2005, addressed the identification of DoD requirements for language translation which formed the basis for determination of Measures of Performance (MOPs) that were utilized to compare the 5 alternatives considered in AoA, namely:

[13] Edward A. Cerutti & CW4 (Ret.) Tim Hunter. (2005). *Sequoyah Foreign Language Translation System Analysis of Alternatives (AoA) Final Report*.

- Base case. Military, government, contract, and host nation linguists as currently used in all mission support roles.
- Alternative 1. Government off-the-shelf (GOTS) language translation systems and devices such as the FALCon, DARPA Phraselator, FORUM/TRiM, S-MINDS, and Harmony.
- Alternative 2. Commercial off-the-shelf (COTS) language translation systems such as the International Business Machines (IBM) ViaVoice®, Ectaco's Partner UT-203®, the Franklin Translator®, LingoTalk®.
- Alternative 3. An amalgamation of means and devices such as Language cards, billboard placards, detainees, local language Standard Operating Procedures (SOP), linguist support, and teaching rudimentary English to local nationals.
- Alternative 4. Incremental development of a two-way speech and text translation software module for each language designated a priority within DoD. Modules will be interoperable and compatible with future DoD automated systems.

The AoA concluded that linguist and MLT systems are complementary in nature. While MLT systems, as configured under Alternative 4, provide a militarily useful capability that can be readily deployed to address low level requirements, linguists provide an unmatched capability in terms of Interagency Language Roundtable (ILR) level and cultural awareness. Hence, MLT systems can enable non-linguists when a linguist is unavailable, and can provide triage services to ensure that critical translation requirements are brought to a linguist to be properly executed.

Furthermore, linguists can be grouped into three categories: uniformed linguists, cleared linguists (native/heritage linguists with a security clearance), and host nation linguists that are hired in the Area of Operations. The latter category, while it provides the greatest number of linguists, also has the greatest number of drawbacks. These include trustworthiness and security issues, reliable attendance, as well as the lack of English skills. The executive summary of Sequoyah AoA final report may be found in Appendix C.

III. SEQUOYAH BUSINESS CASE ANALYSIS

A. WHAT IS BUSINESS CASE ANALYSIS (BCA)

A Business Case Analysis (BCA) is an important financial tool that helps decision makers to evaluate alternative approaches and to decide on the allocation of scare resources. It is a structured and systematic methodology that examines and compares the cost and benefits of alternatives on a level playing field. BCA is an all-purpose, commonly used term and is also known by other titles, such as Cost-Benefit Analysis, Economic Analysis, Cost-Effectiveness Analysis, and Cost-of-Ownership Analysis, among others.[14]

The BCA framework is an iterative process that is updated as the business and mission environment changes. It consists of the following elements:

- State objectives of the action being considered.
- Specify assumptions and constraints.
- Identify possible alternatives including status quo.
- Estimate costs and benefits of each alternative.
- Conduct sensitivity, uncertain and risk analysis.
- Draw conclusion and make recommendations.

The ability to make a good decision for the acquisition of a technology and capability is largely dependent on the ability to conduct a sound and reliable BCA, which is an unbiased and objective analysis of the financial consequences of the various alternatives. It is based on facts, reasonable assumptions, and sound financial principles with its conclusion traceable whenever possible. Hence, a sound and reliable BCA will aid decision makers in enhancing the war fighting capability of the forces and prevent unnecessary waste of valuable resources on peripheral capabilities.

[14] Hang Sheng Lim. (December 2006). *A Methodological Approach For Conducting A Business Case Analysis For The Joint Distance Support and Response (JDSR) Advanced Concept Technology Demonstration (ACTD)*. Master's Thesis, Naval Postgraduate School.

The BCA structures the assessment by providing necessary information concerning the scope, alternatives considered, estimated costs and Return on Investment (ROI), and risks necessary for decision makers to make an informed funding decision for the investment/project. Each BCA will be different depending on its application. However, a BCA structure should include the following as a minimum:

- Introduction. It presents the objectives addressed by the subject of the case, and all the options, including the status quo, considered to achieve the objective.
- Assumptions and Methods. Outlines the rule for deciding what belongs in the case, and what does not, along with the critical assumptions.
- Business Impacts. The main business case results.
- Sensitivity and Risk Analysis. Shows how results depend on the important assumptions ("what if"), as well as the likelihood for other results to surface.
- Conclusions and Recommendations. Recommends specific actions based on business objectives and the results of the analysis.

A BCA methodology can be described as a 4-phase process shown in Figure 1.

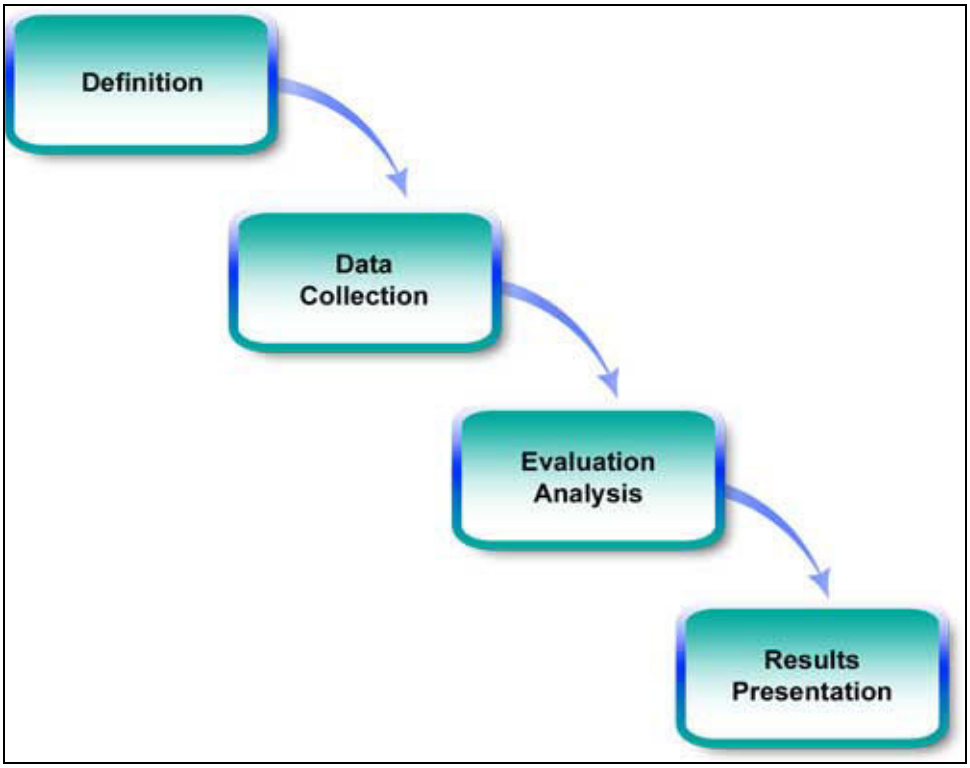

Figure 1. The Business Case Analysis Process (From: Ref. ACC 2004)

1. Definition

In Phase 1, the objective and scope of the analysis is defined along with the assumptions and constraints. Potential alternative solutions, including preserving the status quo, are also explored and determined for the analysis.

2. Data Collection

In phase 2, a plan is created for data collection. The plan will specify the types of data required, the potential data sources, and the approaches to obtain these data. In situations where the required data are not available, an estimate is made with the approach for calculating the estimate clearly explained and documented. Upon the completion of data collection, the data is examined for consistency and anomalies.

3. Evaluation Analysis

The actual BCA computation occurs in this phase. Each alternative is compared against the baseline, which is the status quo, to determine the one that offers the best value. It is also important that the risks associated with each alternative are examined along with the potential risk mitigation strategies for each identified risk. In addition to risk analysis, a sensitivity analysis must also be conducted. Sensitivity analysis aims to provide insights to the BCA results if the input parameters change or if assumptions change or are proven invalid.

4. Results Presentation

In this phrase, the BCA results are summarized into appropriate graphs and tables for presentation to the decision makers. The presentation should include key information outlined in phases 1, 2, and 3. Last but not least, the conclusion and recommendations for a suitable course of action are made with respect to the objectives defined in phase 1.

B. CAN MLT SYSTEMS FILL THE GAP

On a national scale, there are many political and military issues associated with human language translation. The DoD requires human language translation capabilities in a wide range of languages to support coalition/joint task force headquarters and tactical

or routine field operations. However, most often, units deploy with insufficient numbers of human linguists needed to support existing mission requirements as the need for human language translation exceeds the availability of linguist. Anyone who has ever traveled to a foreign country and felt the pain of not being able to communicate with the local populace would understand the problem.

1. Currently Fielded or Tested MLT Systems

The idea that human language translation can be carried out by technology and machines is appealing. However, in the 21st century, human machine language translation is still a great challenge for technology. Nonetheless, as the technologies become more capable, performance of state-of-the-art MLT systems has made significant improvement over the years. Some of the currently fielded or tested MLT systems are listed as follow:

a. Broadcast Transcription and Translation (BTT)

The BBN Broadcast Monitoring System supports S2T translation of television broadcasts in Arabic, Spanish and Chinese by automatically transcribing real-time audio stream and translating it into English.[15] Both the transcript and translation are searchable and synchronized to the video, providing powerful capabilities for effective retrieval and precise playback of the video based on its speech content. With this revolutionary system, users can sift through vast collections of news content in other languages efficiently. Intelligence products for strategic or tactical use are developed with language translation and data storage integrated with analyst tools to correlate information.

[15] BBN Technologies. *BBN Broadcast Monitoring System*. Retrieved October 6, 2007 from http://www.bbn.com/solutions_and_technologies/data_indexing_and_mining/bbn_broadcast_monitoring_system.

b. Coalition Chat Line Plus (CCL+)

CCL+ is embedded Microsoft capability to collaborate and share electronic documents with coalition and ally nations in T2T translation that is bi-directional and nearly instantaneous. It supports English and European languages.

Figure 2. BBN Broadcast Monitoring System (From: Ref. Edward A. Cerutti 2007)

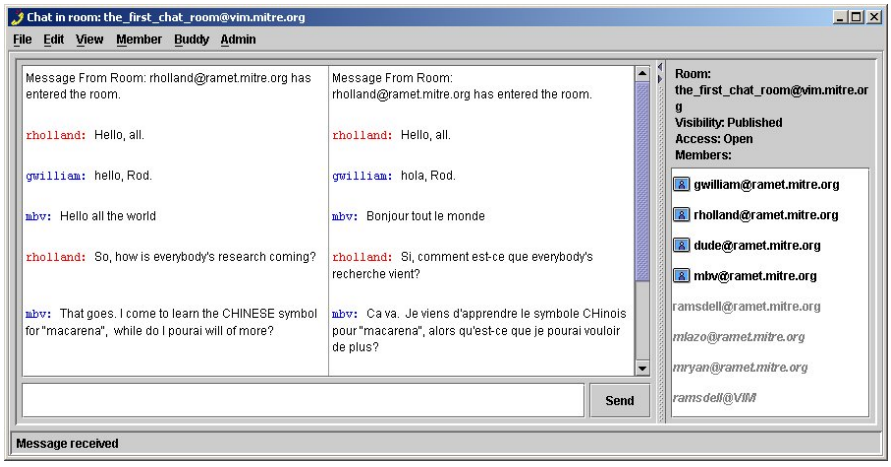

Figure 3. Coalition Chat Line Plus (From: Ref. Edward A. Cerutti 2007)

c. Document Exploitation (DOCEX) and Deployable Harmony DOCEX System (DHDS)

DOCEX uses advanced technology to improve the ability to organize, translate, and analyze captured information in virtually all formats and many languages.[16] When information is quickly processed it becomes easier to find and use key data for intelligence, law enforcement and homeland defense. Hence, it enables the DoD to focus their limited linguistic resources on documents that have the highest probability of containing value. The DHDS system integrated the DOCEX system into the Harmony[17] databases of languages. The systems are deployed in both Iraq and Afghanistan to translate documents to meet tactical needs.

d. Forward Area Language Converter (FALCon) and Personal Digital Assistant-Basic Language Translation Services (PDA-BLTS)

FALCon is an Optical Character Recognition and machine translation system integrated on a portable computer for translation foreign languages documents. It provides the Military Intelligence Community a quick and reliable way to translate and analyze captured documents. FALCon can translate up to 47 languages including Arabic and Asian languages and is being used in both Iraq and South West Asia.[18]

BLTS is a hardware and software suite designed to assist users in identifying and interpreting foreign language documents or other items of interest for further intelligence exploitation. The BLTS allows personnel to photograph or scan documents and transmit them to a laptop computer for immediate conversion or translation and back again to the soldier. The PDA-BLTS gives the user a handheld,

[16] CACI Ever Vigilant. *Document and Records Management – Document Exploitation*. Retrieved October 7, 2007 from http://www.caci.com/business/systems/doc_mgt/doc_manage_docex.shtml.

[17] Harmony is the DoD's and the Intelligence Community's media exploitation database. It is the single, comprehensive bibliographic reference for all available primary source foreign technical and military documents and their translations.

[18] Defense Update. (January 27, 2005). *Commander's Digital Translator*. Retrieved October 7, 2007 from http://www.defense-update.com/products/t/translators.htm.

wireless system that they can use to capture and translate document images to determine the importance of captured foreign language documents.[19]

e. IBM MASTOR

Multilingual Automatic Speech-to-Speech Translator (MASTOR) system enables real-time, interpersonal communication via natural spoken language for people who do not share a common language. It currently has bidirectional English-Iraqi Arabic and English-Mandarin translation capabilities on unconstrained free-form natural speech input with a large vocabulary (over 30,000 words for each direction) in multiple domains, including travel, emergency medical diagnosis and defense-oriented force protection and security. MASTOR runs in real-time on a laptop, and has also been ported to a handheld PDA, with minimal performance degradation.[20]

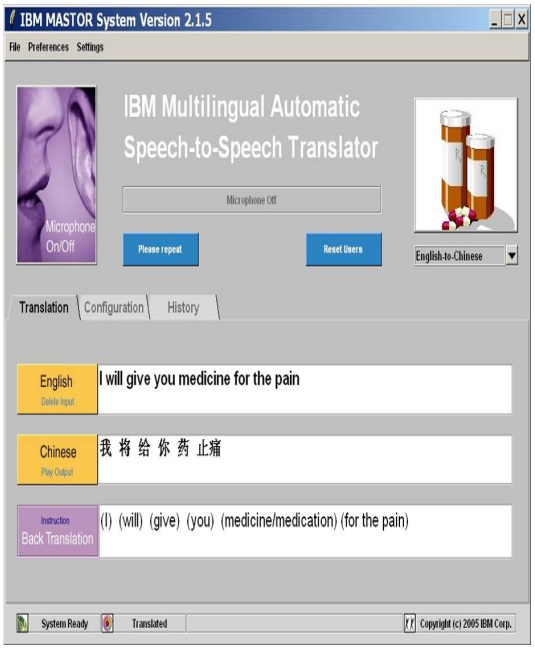

Figure 4. MASTOR - GUI for S2S in Medical Domain (From: Ref. IBM)

[19] Mobile Information Technologies. *Basic Language Translation System (BLTS) V1*. Retrieved October 7, 2007 from http://www.essworld.net/pdfs/MIT_BLTSv1.pdf.

[20] International Business Machines (IBM). *Speech-to-Speech Translation*. Retrieved October 7, 2007 from http://domino.watson.ibm.com/comm/research.nsf/pages/r.uit.innovation.html#sfeedback.

f. IraqComm

SRI's IraqComm is a mobile device allowing soldier basic 2-way S2S foreign language communication. Its vocabulary of 40,000 words in English and 50,000 in Iraqi Arabic is designed to enable soldiers or medics to converse with civilians in a limited range of settings such as military checkpoints, door-to-door searches or first-aid situations. After a soldier speaks into a microphone and the words are collected and analyzed by speech-recognition software. The laptop screen then shows the phrase as the computer heard it. If the software has misheard some words, speaker can choose from a list of other likely phrases before the software performs the translation.[21]

Figure 5. IraqComm (From: Ref. Edward A. Cerutti 2007)

g. P2 Phraselator

Phraselator, which is IraqComm's predecessor, is a handheld, S2S, one-way, phrase-based language translation device. It takes an input phrase by pushing a Push-To-Talk button and speaking into the microphone on top of the device or via the touch screen with a stylus, matching the input with its corresponding translated phrase, and plays that phrase in the selected target language through a built-in speaker. The phrases are designed to prompt responses that can be conveyed using gestures such as nodding one's head, holding up a number of fingers, pointing to something, or writing

[21] Kate Greene. (August 23, 2006). *How to Talk Like an Iraqi*. Retrieved on October 8, 2007 from http://www.technologyreview.com/read_article.aspx?id=17350&ch=infotech&a=f.

something down on paper.[22] While useful, Phraselator has drawbacks. The number of possible phrases is limited, and it cannot translate phrases into English, resulting in a conversation that relies heavily on gestures.

h. PocketTerp

PocketTerp is a PDA based speech device developed by the Rapid Equipping Force (REF).[23] It allows user to prerecord translations for specific phases with voice print recorded that can be recalled. The system can be programmed to hold hundreds of phrases and is reprogrammable in the field.[24] PocketTerp is currently not fielded in significant numbers.

Figure 6. The P2 Phraselator (From: Ref. Edward A. Cerutti 2007)

[22] Susan LaVonne Marshall. (Mar 2005). *Concept of Operations (CONOPS) for Foreign Language and Speech Translation Technologies in a Coalition Military Environment*. Master's Thesis, Naval Postgraduate School.

[23] REF is an organization that takes its operational guidance from the G-3 and reports directly to the Vice Chief of Staff of the Army. It has a broad mission to rapidly increase mission capability while reducing risk to Soldiers and others.

[24] U.S. Army Rapid Equipping Force. Retrieved October 14, 2007 from http://www.ref.army.mil/textonly/default.html.

i. Speaking Multilingual Interactive Natural Dialogue System (S-MINDS)

S-MINDS is a portable S2S translation system that both translates and transcribes. S-MINDS provides two-way speech translation in multiple languages, including Korean, Japanese, and Spanish. Additional languages can be added at short notice. It is interactive in that S-MINDS enables a conversation between two persons; the speakers alternate speaking in their respective languages and the system recognizes, translates and plays back their dialogue. S-MINDS consists of a handheld notebook, together with a noise-canceling, hands-free microphone. With speaker-independent speech recognition no voice training is necessary. S-MINDS comes with a Rapid Interview Translation editor that allows the user to add new modules or topics in almost any new language in a matter of hours with the help of a linguist.[25]

Figure 7. Navy Corpsman Conducting Medical Screening of ROK Marine using S-MINDS (From: Ref. U.S. Marine Corps Forces Pacific Experimentation Center 2004)

[25] U.S. Marine Corps Forces Pacific Experimentation Center. (August 2004). *Machine Language Translation Systems Demonstration and Assessment Report.* Retrieved October 14, 2007 from http://www.languagerealm.com/Files/usmc_mt_test_2004.pdf.

j. Voice Response Translator (VRT)

The VRT is a S2S human language translation device that uses strictly pre-recorded phrases. It provides a one-way voice translation capability for crowd control, or directive type applications in an operational environment. A voice recognition algorithm recognizes a user's voice with near 100 percent accuracy even in high background noise environments; however, this algorithm does require individualized training for each user's speech pattern. Each device will retain up to eight different user voice profiles. The VRT holds approximately 1000 15-word phrases and can support multiple languages in one unit. It is compact and weighs approximately one pound. The design allows for hands-free, eyes-free operation.[26]

Figure 8. U.S. Marine Military Policeman Demonstrating VRT (From: Ref. U.S. Marine Corps Forces Pacific Experimentation Center 2004)

[26] U.S. Marine Corps Forces Pacific Experimentation Center. (August 2004). *Machine Language Translation Systems Demonstration and Assessment Report.* Retrieved October 14, 2007 from http://www.languagerealm.com/Files/usmc_mt_test_2004.pdf.

2. Strengths of MLT System vs. Host Nation Linguists

MLT system is a long way from being able to replace human linguist, or it may never do so. Despite so, MLT systems have been used around the world in view of the offered advantages. The SYSTRAN translation system is used to power both Google translate and AltaVista's Babel Fish.[27] Global Translations, a translation agency in the United States, has been developing specialized dictionaries for machine translation of tenders for telecommunications companies. In the context of defense applications, MLT systems can outperform host nation linguists in the following aspects:

a. Credibility – Ability of a Language Translation System to Provide Credible, i.e., not Intentionally Misleading, Two-Way Translation of Voice and Text

Host nation linguists, who are usually hired locally and require vetting, are the most abundant resource pool but their credibility is rated poorly. Being local nationals, these host nation linguists first loyalty is probably to the host nation or ethnic group, not to the U.S. military. Some interpreters, for political or personal reasons, may have ulterior motives or a hidden agenda. Hence, the types of information host nation linguists can overhear are limited.[28]

Unlike human linguist, MLT systems have no potential for bias or hidden agenda. Hence, they were evaluated as being highly credible in Sequoyah AoA Final Report.

b. Deployability – Ability to Deploy a Language System to Support All Missions When/Where Language Translation Capabilities are Required within a Specified Time Frame

Compared to MLT systems, acquisition of host nation linguists required long lead time as the contractor cannot begin the in-country hiring process until there is a

---

[27] Wikipedia, the free encyclopedia. *Machine Translation*. Retrieved October 20, 2007 from http://en.wikipedia.org/wiki/Machine_translation.

[28] Headquarters Department of the Army. (December 2006). FM 3-24 CounterInsurgency. Retrieved October 21, 2007 from https://atiam.train.army.mil/soldierPortal/atia/adlsc/view/public/23285-1/FM/3-24/FM3_24.pdf

stable and permissive environment.[29] This leads to its lower rating in deployability. In addition, from the study conducted by Battelle Memorial Institute, Commanders agreed that in many cases, contract linguists are able to hold their units hostage and offered the following comments about contract linguists:[30]

- They refuse to support certain missions with little or no consequence.
- The contractor responsible for contract linguist management is seldom seen.
- Many contract linguists are physically unable to operate at the required OPTEMPO.

The above shed some lights on the problems associated with deployment of host nation linguists. On the other hand, MLT systems would be readily available for deployment so long as the units are assigned the required number of MLT systems with the appropriate language modules and mission sets to support their missions. MLT systems also have an added advantage over host nation linguists who are at risk of being targeted by adversary during deployment to the area of operation as well as during mission.

c. Translation Requirement Fill – Ability of Language Translation Solutions to Satisfy Tasks with Large Number of Linguistic Points of Presence (Pops)

MLT systems provide the capability to meet majority of the less complex translation requirements where there were large numbers of Linguistic PoPs, defined as points in space where speech and/or text translation support is required. With limited number of linguists assigned to the units, host nation linguists comparatively fared poorly in this aspect. In addition, most of the military operations require linguist teams to be able to support 24 hour operations, so a minimum of four linguists per team is

[29] Edward A. Cerutti & CW4 (Ret.) Tim Hunter. (2005). *Sequoyah Foreign Language Translation System Analysis of Alternatives (AoA) Final Report*.

[30] Hampson E., Jones T., Strictland M. (2007). *Determination of the Army's Requirement for a Cadre of Professional Linguists at Level 3/3/3*. Battelle Memorial Institute.

necessary.[31] This aggregates the problem of limited number of linguists to meet translation requirements both in space and time.

d. Translation Speed – Number of Words Per Minutes that a T2T, S2T, T2S, or S2S System is Capable of Translating

From commercial point of view, the primary advantage of MLT systems is translation speed as time is equivalent to money. Similarly for military applications, fast translation speed could lead to operational advantages. The translation speed for average human, whether S2S or T2T, is slow. S2S translations will take place at less than a conversational pace. The average human translator can translate approximately 30 to 60 words of text per minute.[32] The MLT T2T translation capability is significantly faster than that of host nation linguist, though the translations are much less precise on anything above ILR level 2. For example, DOCEX is able to distill useful intelligence from multilingual sources eight to ten times faster than traditional manual methods, thereby enabling the Intelligence units to focus their limited linguistic resources on documents that have the highest probability of containing value.[33]

e. Consistency – Ability of a Language Translation System to Give Consistent Translation

MLT systems have a better memory that is unmatched by human translators. It can store translated documents and re-use phrases that have already been translated, resulting in highly consistent translation throughout missions. Provided that MLT systems give an accurate translation, consistent translation is certainly desirable

3. Limitations of MLT Systems vs. Host Nation Linguists

With the above strengths, MLT systems can deliver good results when dealing with very predictable technical texts, which never go beyond the expected domain of

---

[31] Hampson E., Jones T., Strictland M. (2007). *Determination of the Army's Requirement for a Cadre of Professional Linguists at Level 3/3/3*. Battelle Memorial Institute.

[32] Edward A. Cerutti & CW4 (Ret.) Tim Hunter. (2005). *Sequoyah Foreign Language Translation System Analysis of Alternatives (AoA) Final Report*.

[33] CACI Ever Vigilant. *Document and Records Management – Document Exploitation*. Retrieved October 7, 2007 from http://www.caci.com/business/systems/doc_mgt/doc_manage_docex.shtml.

discourse. When the translation task at hand is complicated, MLT systems performance is degraded due to the following limitations:

a. Translation Level Capability – Ability of a Language Translation System to Render Consistent Two-Way Translations at a Level Based Upon the ILR Description

Lincoln Laboratory Massachusetts Institute of Technology (MIT), Department of Brain and Cognitive Sciences and Defense Language Institute Foreign Language Centre (DLIFLC) conducted an experiment designed to measure human readability of machine generated text. This three part experiment focused on S2T and T2T translation. The results of their experiment showed that the current state-of-the-art MLT technologies can achieve an ILR score of between 1+ to 2 in S2T and 2 to 2+ in T2T translation. These results indicated that MLT systems have the capability to accomplish vast majority of tasks with low level translation requirement, i.e., ILR level 2 or less. On the other hand, those host nation linguists who possess the required linguistic ability in English have the potential to achieve an unmatched high ILR score of 5, which is high enough to meet any translation requirement.[34]

b. Extensibility – Ability of a Translation System to Add Additional Language Modules

It is impossible for one-fit-all solution, so MLT systems are designed for selected language pairs within certain domains. The process to add new languages to a MLT system takes time and the timeline for developing a new language is similar to that of training a new linguist.[35] Hence, MLT systems are unable to meet time sensitive translation requirements that call for development of a new language.

Host nation linguists have an advantage over MLT systems and even military linguists for contingency operations. Support for Operation Joint Endeavor (OJE), the initial peacekeeping operation in Bosnia-Herzegovina, began in December 1995. Prior to that mission, the Army had very little need for Serbian-Croatian linguists,

[34] Edward A. Cerutti & CW4 (Ret.) Tim Hunter. (2005). *Sequoyah Foreign Language Translation System Analysis of Alternatives (AoA) Final Report*.

[35] Ibid.

and was caught unprepared for the large requirement of OJE. The U.S. Army Europe (USAREUR) linguist support contract enabled the Army to acquire approximately 500 Serbian-Croatian linguists in a relatively short amount of time.[36]

c. Versatility – Ability of a Translation System to Deal Adequately with Various Complexities of Language

One of the biggest limitations of MLT systems is their inability to deal adequately with the various complexities of language that humans handle naturally: ambiguity, syntactic irregularity, multiple word meanings and the influence of context. A classic example is illustrated in the following pair of sentences: "Time flies like an arrow" and "Fruit flies like an apple". A computer can be programmed to understand either of these examples, but not to distinguish between them. A computer translation is similar to a translation done by a human without a deep knowledge of the target language. Alan Melby, professor of linguistics at Brigham Young University, points out that "Being a native or near-native speaker involves more than just memorizing lots of facts about words. It includes having an understanding of the culture that is mixed with the language. It also includes an ability to deal with new situations appropriately. No dictionary can contain all the solutions since the problem is always changing as people use words in unusual ways."[37]

4. Areas of Application of MLT Systems

The potential scope of use for MLT systems is dictated by their capabilities and limitations. In view of their limitation in translation level capability, MLT systems alone would not be able to address high level translation requirements that need linguists at ILR level 3 and above. Based on the analysis conducted by Battelle Memorial Institute (Figure 9), missions with the greatest need for linguists at level 3 are Human Intelligence

[36] Hampson E., Jones T., Strictland M. (2007). *Determination of the Army's Requirement for a Cadre of Professional Linguists at Level 3/3/3*. Battelle Memorial Institute.

[37] DiploFoundation. *Machine Translation*. Retrieved October 23, 2007 from http://www.diplomacy.edu/Language/Translation/machine.htm

(44%), Command and Staff (42%), Document Exploitation (40%), Coalition Liaison (39%), Signals Intelligence (37%), Civil Affairs (36%), Media Exploitation (30%), and Psychological Operations (30%).[38]

In the same study, it was found that a large percentage of some missions do not require linguists at ILR 3, and some can be performed by soldiers with as little as ILR 0+ proficiency. These missions included Perimeter Security/Gate Guard (66% at level 0), Convoy Escort (62%), Military Police (56%), Training (55%), Humanitarian (48%) and Combat Fire Team (48%). MLT systems lend themselves best to these low level and straightforward translation requirements, where communications are mostly in the form of simple questions and answers. In addition, these translation requirements often require large number of Linguistic PoPs. With feedbacks from SME, the following military missions are found to be the best circumstances that MLT systems can be used to complement host nation linguists. There is also opportunity for MLT systems to provide a bridge when no linguist is available or the number available is insufficient within these missions.

[38] Hampson E., Jones T., Strictland M. (2007). *Determination of the Army's Requirement for a Cadre of Professional Linguists at Level 3/3/3*. Battelle Memorial Institute.

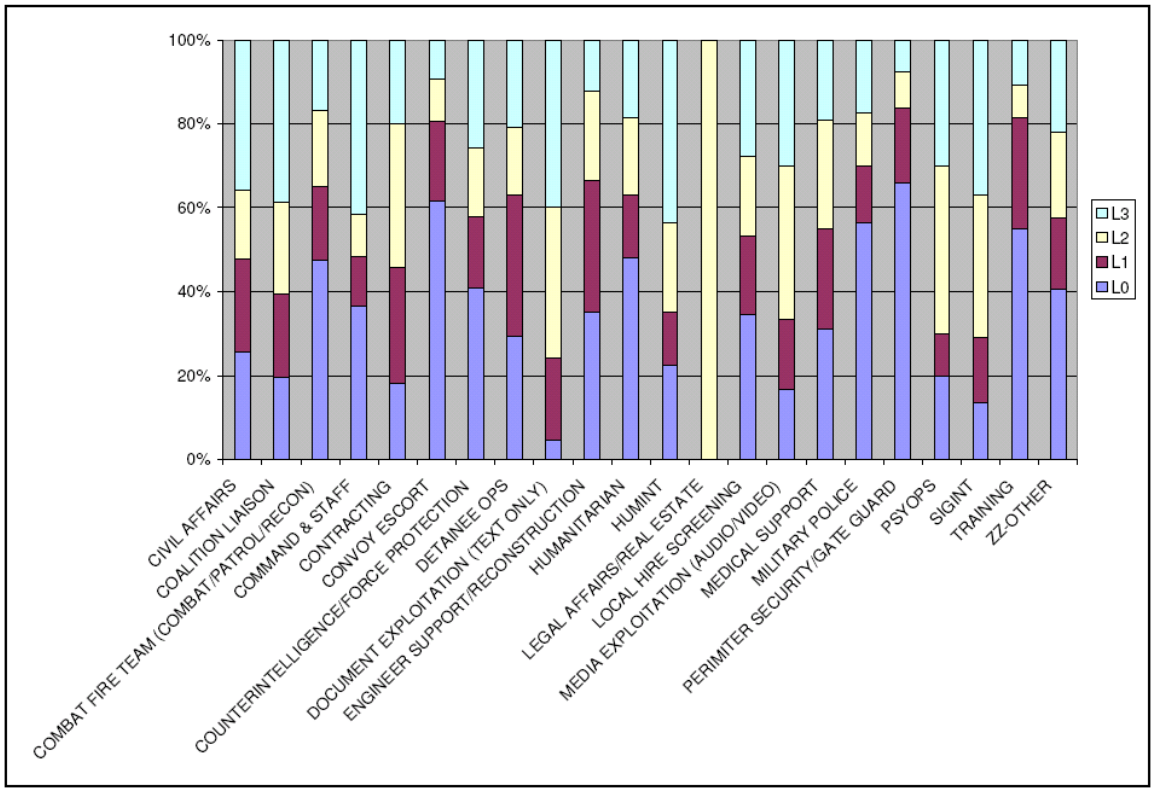

Figure 9. Operational Linguist Missions – Proficiency Level Requirements (From: Ref. Battelle Memorial Institute 2007)

a. Coalition Compound Checkpoint

With Joint forces increasingly becoming coalition forces, it is not uncommon for coalition forces to build or establish a physically enclosed compound in a foreign country. Coalition personnel who stand guard at the gate are responsible for ensuring that no unauthorized persons enter the compound and that the subjects are searched for weapons. Hence, the guard can expect to be approached face-to-face by foreign national subjects who may or may not speak English. Depending on the threat situation of the host country, there may be additional security concerns related to insurgency activity and the guards may seek to find out information from potential informants.

This mission involves mostly straightforward and repetitive situations, where a soldier equipped with MLT system would be able to handle. For example, a soldier can pre-record the most used phrases relating to checkpoint activities in a P2

Phraselator, like "*raise your hand if you understand*", "*do you have an appointment here?*", "*I must search you*" and "*are you carrying any weapons?*" Any expected replies can be visually expressed by body gestures, compliant behaviour, or writing something down on paper. In this way, the guard enabled by a MLT system can screen the general crowd to identify subjects that need the attention of human linguists. If the guard were equipped with a two-way S2S MLT system like MASTOR or IraqComm, he would be able to communicate with subjects effectively even when host nation linguist is not available.

b. House Search

This mission is for a small coalition force to search a neighborhood of homes for weapons caches and insurgent activity. It is a highly tactical mission with great potential for bodily harm. Similar to checkpoint operation, house search involves straightforward and repetitive situations where the soldiers need to explain their intention to the homeowners and broadcast standard directions for them to follow. Hence, soldiers enabled by MLT systems would be able to carry out the mission without support from host nation linguists who will be at risks of being targeted during the mission. For example, soldiers can give voice commands like "*House search*" as input to a Voice Response Translator which will then broadcast the associated pre-recorded phrase, "*Please open your doors and remain outside in your yard until the search is complete. When the Marines arrive at your house, the homeowner can walk them through the search. We are not here to harm anyone. Our goal is to increase security in the area. Thank you for your cooperation.*" in the target language. With VRT allows for hands-free, eyes-free operation, the soldiers' operational readiness will not be affected.

c. Emergency Medical Diagnosis

This mission could be part of the disaster relief operation in an area where a natural disaster has occurred and humanitarian workers are trying to communicate with the local population to render assistance. Many locals are expected to arrive at a field refugee-type site everyday to seek food, water, and medical care. In order for relief workers to perform medical triage, they need to communicate with the locals to diagnose

and assess the nature and seriousness of their wounds. Different from checkpoint operations and house search, replies expected from the locals involved more than body gestures. Hence, the relief workers need to be equipped with two-way S2S MLT systems, such as MASTOR to perform basic conversation with the locals. This allows efficient classification and prioritization of casualties as large number of Linguistic POPs is required to support the mission, and the limited pool of human linguists may not be able to satisfy the requirement.

d. Maritime Warning and Interdiction

This mission can be envisioned to be in a harbor where small vessels are approaching U.S. Navy ships. Maritime warning involves mostly straightforward and repetitive situation as the soldiers do not have close face-to-face contact with foreign national people. The soldiers only need to be equipped with one-way S2S MLT systems like a P2 Phraselator pre-recorded with a list of appropriate phrases to conduct the mission effectively. As for a full blown Maritime Interdiction Operation that includes boarding, the soldiers can communicate with the foreign locals using a two-way S2S MLT system.

C. EVALUATING THE INVESTMENT POTENTIAL OF MLT SYSTEMS

Based on above qualitative analysis, there is certainly potential scope to utilize MLT systems to complement host nation linguists or when there is no linguist available. However, there is no one-fit-all solution, and each MLT system is designed for selected language pairs within certain domains. Whenever there is a need to add new languages to a MLT system, the process involved takes time and money. Hence, there is a need to explore the viability of utilizing MLT systems from an economic point of view.

1. Cost of Human Linguists

There are currently two types of human linguist available to support military operations, i.e., military and contract linguists. All military linguists are DLIFLC trained linguists who will have a minimum proficiency of ILR level 2 upon completion of the basic instructional program. Subsequent programs and follow-on courses help the

students attain Level 3 proficiency. Foreign languages are categorized from I (easiest) to IV (hardest), based on the difficulty native speakers of American English may have in learning a foreign language:[39]

- Category I: French, Italian, Portuguese, and Spanish.
- Category II: German, Romanian.
- Category III: Greek, Hebrew, Persian-Farsi, Polish, Russian, Serbian and Croatian, Tagalog, Thai, Turkish, Ukranian, and Vietnamese.
- Category IV: Arabic, Chinese-Mandarin, Japanese, and Korean.

In view of the difference in difficulty level associated with each Language Difficulty Category (LDC), length of basic course increases with LDC, as tabulated in Table 1. In addition, difficulty in achieving higher levels of proficiency increases exponentially, as shown in Figure 10. According to former DLI Chancellor, Dr. Raymond Clifford's research, summarized in *Foreign Language Program Characteristics and Likely Exit Proficiency of Motivated Students*, 4,800 hours of instruction plus study time is required to reach an expected exit proficiency of 3 for an LDC IV language.[40] Table 2 listed the length of instruction plus study time required for a motivated student to reach ILR level 3 for other LDC languages.

LDC	Length of DLIFLC's Basic Program
I	26 weeks
II	35 weeks
III	48 weeks
IV	64 weeks

Table 1. Length of DLIFIC's Basic Instructional Program

[39] Defense Language Institute Foreign Language Center. (2007). *General Catalog 2006-2007*. Retrieved October 25, 2007 from http://www.dliflc.edu/academics/academic_affairs/DLIFLCcatalog2006-07.pdf

[40] Hampson E., Jones T., Strictland M. (2007). *Determination of the Army's Requirement for a Cadre of Professional Linguists at Level 3/3/3*. Battelle Memorial Institute.

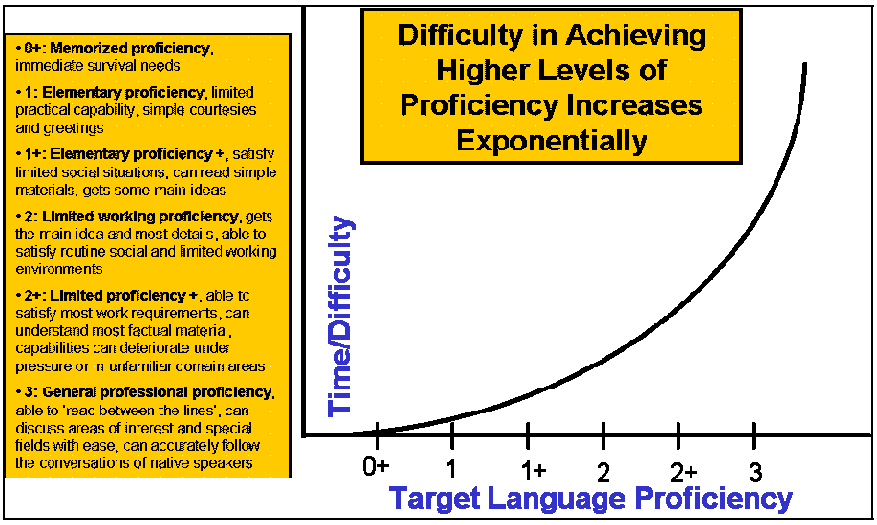

Figure 10. Graph of Language Proficiency vs. Time/Difficulty

LDC	Length of Instruction Plus Study Time Required
I	1600 hours (40 weeks)[41]
II	2000 hours (50 weeks)
III	3200 hours (80 weeks)
IV	4800 hours (120 weeks)

Table 2. Instruction and Study Time Required for Motivated Student to Reach ILR Level 3

There are approximately 3,500 students in the resident educational programs at the Presidio of Monterey at any given time.[42] With the assumption that all students are attending basic program and an estimated total annual funding for DLI, training cost per student-week is approximated. Table 3 listed the estimated cost to train a military linguist to an ILR proficiency level 2, i.e., complete basic program. With an assumed post-DLI education at the Army standardized training planning cost of $30/hour (rounded

[41] In general, instruction in DLIFLC is conducted for six hours a day, five days a week. Hence, assume 40 hours per week (6 hour/day plus 2 hours study time).

[42] Defense Language Institute Foreign Language Center. (2007). *General Catalog 2006-2007*. Retrieved October 25, 2007 from http://www.dliflc.edu/academics/academic_affairs/DLIFLCcatalog2006-07.pdf

up) for students beginning at ILR level 2,[43] the training cost per student to increase from ILR level 2 to level 3 is estimated. Table 3 listed the estimated cost to train a military linguist up an ILR proficiency level 3. Details, including sources of the estimation, are explained at Appendix D.

LDC	Estimated Cost to Train Student (FY06$k)	
	ILR Level 2	ILR Level 3
I	45	81
II	60	99
III	82	165
IV	110	255

Table 3. Estimated Cost to Train Military Linguist to ILR Level 2 and Level 3

The Department of the Army's primary contract vehicle for supplying linguist services to combatant commanders is the Translator/Interpreter Services support contract managed by the U.S. Army Intelligence and Security Command (INSCOM). Contract linguist requirements are divided into four categories based on security clearance:

- Category (CAT) I Foreign National: Heritage speakers and no formal language training must be provided. Poor English skills are what usually bring down their proficiency rating. No security clearance required.
- CAT I U.S. Citizen: Heritage speakers and no formal language training must be provided. Poor English skills are what usually bring down their proficiency rating. No security clearance required.
- CAT II U.S. Citizen: Heritage speakers and no formal language training must be provided. Poor English skills are what usually bring down their proficiency rating. SECRET clearance required.
- CAT III U.S. Citizen: Heritage speakers and poor English skills are what usually bring down their proficiency rating. TOP SECRET clearance required with special background investigation for Special Compartmented Information (SCI) access.

[43] Hampson E., Jones T., Strictland M. (2007). *Determination of the Army's Requirement for a Cadre of Professional Linguists at Level 3/3/3*. Battelle Memorial Institute.

By contract, all CAT I and II linguists require ILR level 4 to level 5 proficiency in the target language, in all modalities (reading, listening, speaking, and writing), and ILR level 2+ in English. CAT III linguists require a level 3 in the target language and native proficiency in English.[44] The primary factors determining the cost to hire contract linguist are language, location, mission, and the number of people willing to provide the service. As a reference, Table 4 listed the current annual cost for each linguist under the Titan/L3 INSCOM contract.[45]

Category of Contract Linguist	Annual Cost (FY07$K)
CAT I Local National	13 – 15
CAT I U.S. Citizen	205 – 215
CAT II U.S. Citizen	289 – 297
CAT III U.S. Citizen	312 – 316

Table 4. Annual Cost to Hire one Contract Linguist

Comparing to the cost to train and retain military linguists, it is generally more cost efficient to hire contract linguists at CAT I Local National, whereas it is not the case for other categories of contract linguist. However, there are extenuating issues beyond cost that may outweigh the cost factor. These issues include:

- Credibility of contract linguists.
- Security issues.
- Inability or unwillingness of many contract linguists to support combat missions.
- Lack of English skills.
- Management flexibility or flexibility of outsourcing – ability of the DoD to surge or adjust downward its capability in any particular language.

[44] Hampson E., Jones T., Strictland M. (2007). *Determination of the Army's Requirement for a Cadre of Professional Linguists at Level 3/3/3*. Battelle Memorial Institute.

[45] Provided by CPT (Ret) Rodney Githens, North Carolina Army National Guard, G-2 Army.

- Core competency – whether the Services consider foreign language translation capability as a core competency.

2. MLT Systems Investment Breakeven Point

Time and monetary effort required to be expended to develop a MLT system differ depending on many factors such as function, language pairs, and missions to be supported. For example, Asian languages, in general, are more difficult than Romance or Germanic languages as there are more local dialects and the syntax and grammar is very different. In addition, a S2S MLT system is more difficult to develop than a T2T MLT system due to the problems faced with speech recognition as outlined in Chapter I. If that is the case, when will the investment be worthwhile from an economic point of view? To answer this question, the author proposes to find the investment breakeven point by comparing the Net Present Value (NPV) of Life Cycle Cost (LCC) of MLT systems with that of human linguists. Appendix E gives the definition and formula of NPV.

For purpose of illustrating the methodology, the following assumptions are made for the hypothetical scenario:

- The MLT systems have a life cycle of 10 years.
- It costs $15k per year to hire one host nation linguist during the 10 years of life cycle of MLT systems.
- Four host nation linguists are required to support one 24-hours operation, while one MLT system suffices.
- A discount rate of 5% is used for computing NPV, in accordance with the current 10-year US Treasury note rate.
- Cost to develop the MLT system is $X.
- Operation & Support (O&S) cost per year for MLT system is estimated as 10% of development cost.
- Production cost per MLT system is estimated as 10% of development cost.
- There are Y numbers of simultaneous operations with translation requirement per year.

NPV of LCC of host nation linguists (HNL) and MLT systems are calculated as follows:

$$(\text{NPV LCC})_{\text{HNL}} = \frac{\$60Yk}{1.05} + \frac{\$60Yk}{1.05^2} + \ldots + \frac{\$60Yk}{1.05^{10}}$$
$$= \frac{\$60Yk\left(\frac{1}{1.05} - \frac{1}{1.05^{11}}\right)}{1 - \frac{1}{1.05}}$$

$$(\text{NPV LCC})_{\text{MLT}} = \$X + \$0.1X\left(Y - 1\right) + \frac{\$0.1XY}{1.05} + \frac{\$0.1XY}{1.05^2} + \ldots + \frac{\$0.1XY}{1.05^{10}}$$
$$= \$0.9X + \$0.1XY + \frac{\$0.1XY\left(\frac{1}{1.05} - \frac{1}{1.05^{11}}\right)}{1 - \frac{1}{1.05}}$$

For MLT system to be a worthwhile investment, $(\text{NPV LCC})_{\text{MLT}}$ must not be more than $(\text{NPV LCC})_{\text{HNL}}$, i.e., $(\text{NPV LCC})_{\text{MLT}} \leq (\text{NPV LCC})_{\text{HNL}}$. Figure 11 shows the relationship between maximum allowable development cost of MLT system and number of simultaneous operations with translation requirement per year. Due to the lower production cost of MLT system compared to the cost of a human linguist, its investment breakeven point increases with the number of operations per year, this clearly illustrated the financial advantage of MLT system over host nation linguist in this range of cost.

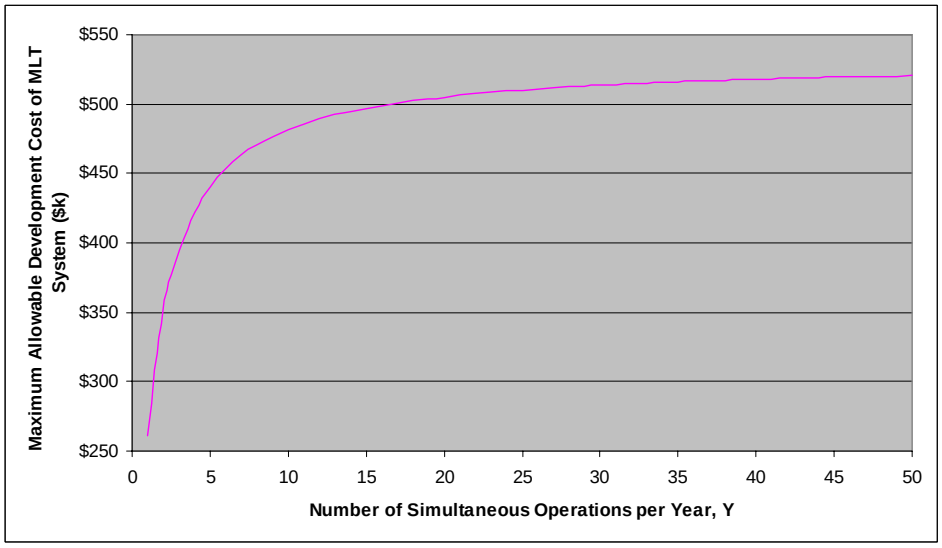

Figure 11. Graph of Maximum Allowable Development Cost of MLT System vs. Number of Operations per Year

The above approach can be adjusted and applied to other scenarios with different parameters. It is important to note that the methodology does not consider non-monetary benefits gained by using MLT systems instead of host nation linguist. In addition, the point that host nation linguist can address cultural aspects with ease is not considered as it is a value that is difficult to quantify at this point.

D. SENSITIVITY ANALYSIS

Sensitivity analysis is a process to understand uncertainty in a model by changing significant input parameters of the model one at a time and notes the changes in model output. The objective of a sensitivity analysis is to identify critical inputs of the model and how their variability impacts the result. This is particularly important in investments where a change of say 10% in an input can make the project unprofitable. For the purpose of this study, a sensitivity analysis was conducted by varying the following factors:

- Life cycle of MLT system – This factor was varied from 10 to 20 years.
- Discount rate – This factor was varied from 5% to 10%.
- Production cost of MLT system – This factor was varied from 10% to 30%.
- Annual cost of contract linguist – This factor was varied from $15k to $315k.

Figure 12 shows the analysis of varying the life cycle of a MLT system. From the figure, the maximum allowable development cost of a MLT system increases as its life cycle lengthens, reaching a maximum of $548k for 20 years of life cycle with 50 operations per year. The increase is expected as annual O&S cost of MLT system is lower than the annual cost to hire host nation linguist.

Figure 13 shows the analysis of varying discount rate used in computing NPV of LCC. From the figure, the maximum allowable development cost of MLT system decreases with discount rate, with a minimum of $228k for discount rate of 10% with 1 operation per year.

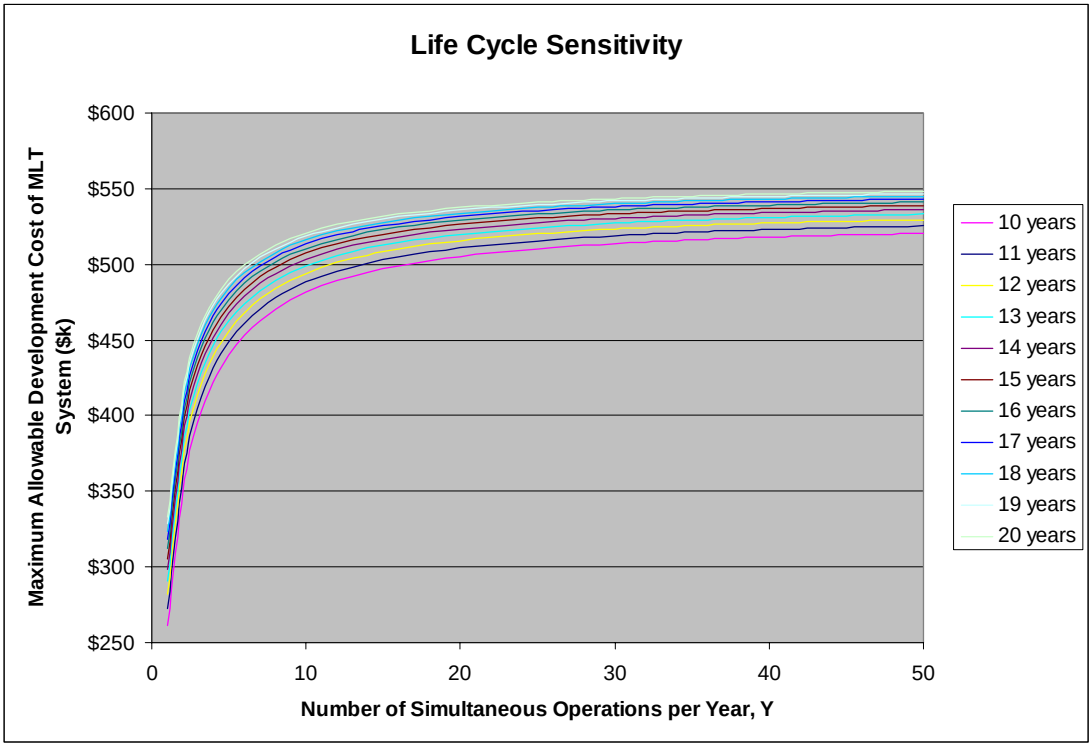

Figure 12. Life Cycle Sensitivity

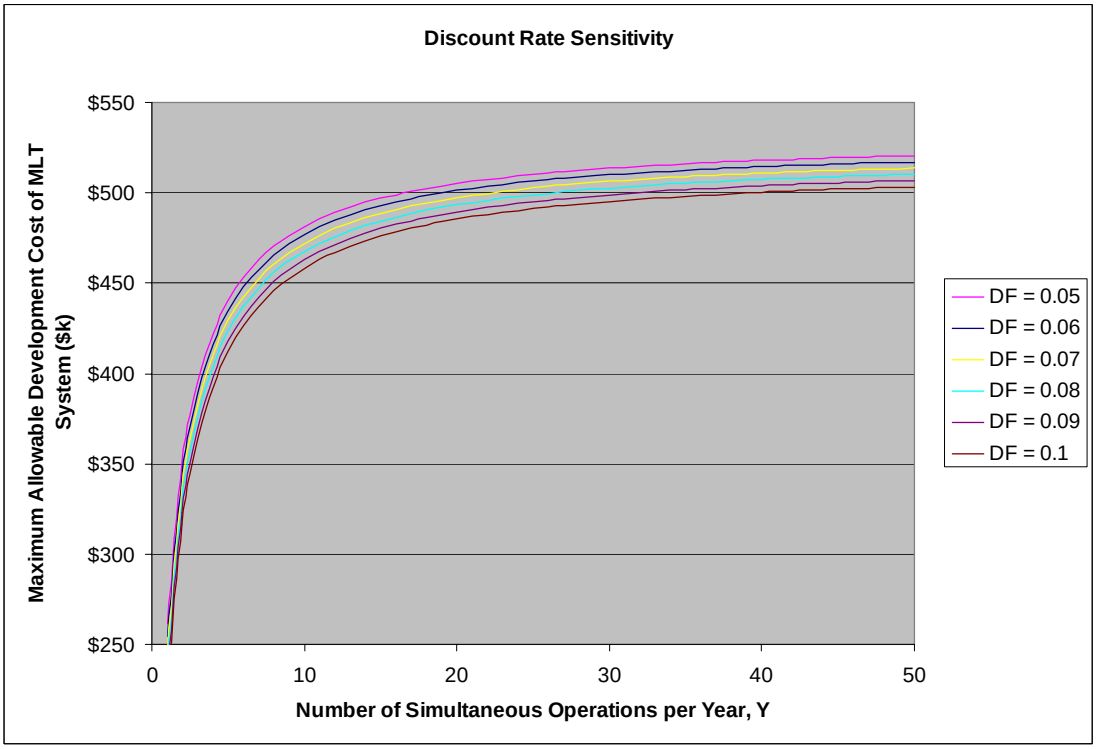

Figure 13. Discount Rate Sensitivity

Figure 14 shows the analysis of varying production cost of a MLT system. From the figure, the maximum allowable development cost of MLT system decreases with production cost. The decrease is expected since the advantage of MLT system over host nation linguist will be reduced as the production cost of a MLT system increases.

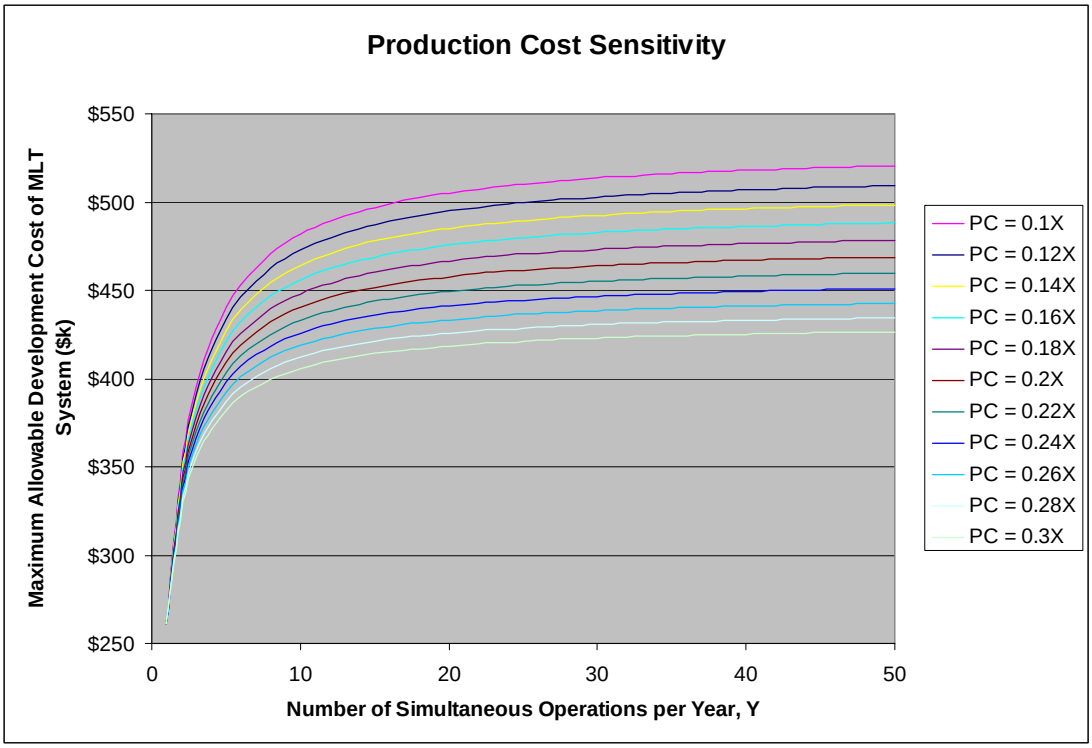

Figure 14. Production Cost Sensitivity

From Figure 15, which shows the analysis of varying annual cost of contract linguist, maximum allowable development cost of MLT systems increases with the annual cost of contract linguist. Hence, the higher the cost to hire contract linguists to support a mission, the more worthwhile is the investment on MLT systems. At an annual cost of $315k, which corresponds to the annual cost to hire one CAT III U.S. Citizen contract linguist, the maximum allowable development cost of MLT system increases to $10,930k for 50 operations per year.

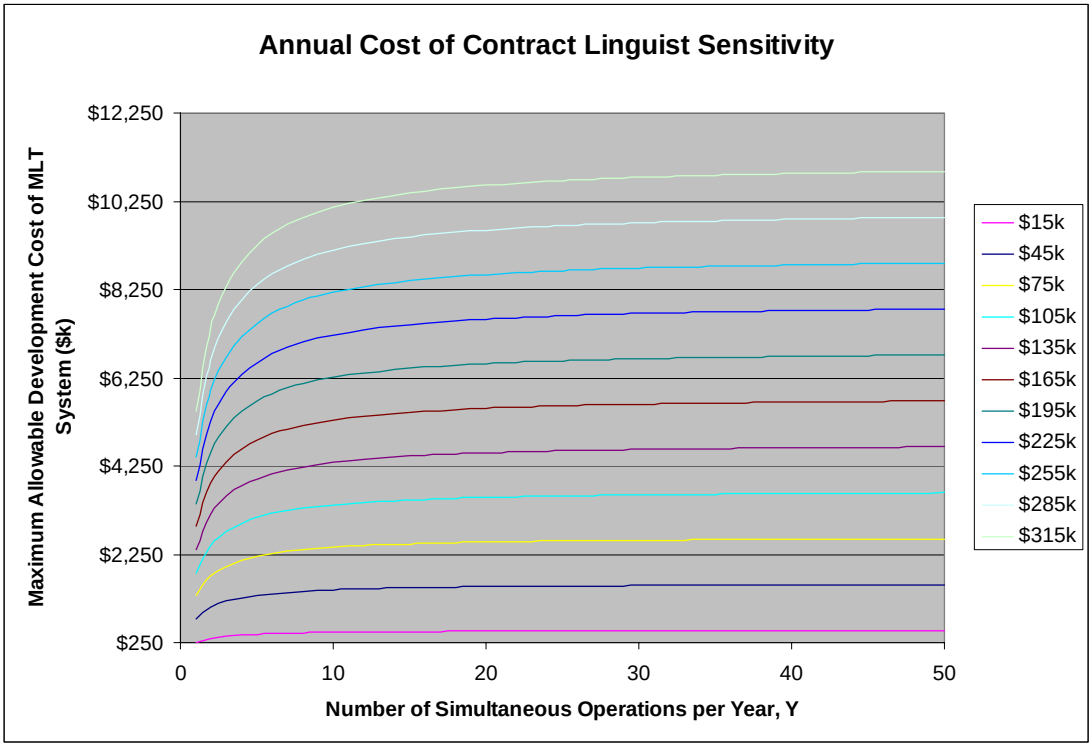

Figure 15. Annual Cost of Contract Linguist Sensitivity

Based on above sensitivity analysis results, it is noted that annual cost of contract linguist is the most critical factor as its variability causes the greatest impact. For the category of CAT I Local National contract linguist, it is observed that in no case did the maximum allowable development cost of MLT system exceed $6M, which indicates that MLT system faces a very difficult hurdle in displacing host nation linguist from an economic point of view.

IV. CONCLUSION AND RECOMMENDATIONS

Although the use of computers is very prevalent in today's society, they simply cannot replace human beings in performing some of the tasks that require thinking and understanding. Bar-Hillel, an early machine translation researcher, used a seemingly simple sentence "The box is in the pen" to point out that "to decide whether the sentence is talking about a writing instrument pen or a child's play pen, it would be necessary for a computer to know about the relative sizes of objects in the real world… The point is that accurate translation requires an understanding of the text, which includes an understanding of the situation and an enormous variety of facts about the world in which we live."[46] Hence, this study does not advocate replacing human linguists with MLT systems but rather to explore the circumstances that MLT systems can be used to complement host nation linguists or when there is no linguist available.

Based on literature review on existing MLT technology and SME judgment and experience, MLT systems can outperform host nation linguists in terms of credibility, deployability, translation speed, and consistency. In addition, MLT systems have the capability to meet translation requirements with large numbers of Linguistic PoPs. However, host nation linguists can provide an unmatched capability in terms of ILR level and cultural awareness. MLT systems also take a longer process to add additional language modules, making them unsuitable for time-sensitive missions.

Based on current state-of-the-art translation technology, it is recommended that MLT systems be used to support less complex translation requirements with ILR level 2 and below, where communications are mostly in the form of simple questions and answers. With the users trained so as not to exceed the capabilities of MLT systems, the following military missions are found to be the best circumstances that MLT systems can be used to complement host nation linguists:

- Coalition Compound Checkpoint.
- House Search.

[46] DiploFoundation. *Machine Translation*. Retrieved October 23, 2007 from http://www.diplomacy.edu/Language/Translation/machine.htm

- Emergency Medical Diagnosis.
- Maritime Warning and Interdiction.

The amount of time and money required to be invested in the development of MLT systems is dependent on factors like function, language pairs, and missions to be supported. To decide if MLT system is a worthwhile investment from an economic point of view, it is recommended to find the investment breakeven point by comparing the Net Present Value of Life Cycle Cost of MLT systems with that of human linguists. The study developed breakeven points for the development cost of MLT system under a variety of assumptions and found that annual cost of contract linguist is the most critical factor. In no case did these "ceiling" costs exceed $6M for the category of CAT I Local National contract linguist, which indicates that MLT system faces a very difficult hurdle in displacing host nation linguist from an economic point of view. Together with the qualitative benefits derived, the estimated maximum allowable development cost of a MLT system will facilitate informed decision by decision makers.

APPENDIX A. FOUR LEVELS OF LANGUAGE TRANSLATION

The difficulty of translating from one language to another depends a great deal on how similar the languages are in their vocabulary, grammar, and conceptual structure. In general, language translation can be considered at the following four levels:

A. WORD FOR WORD TRANSLATION

Word for word translation does not generally work as words sometimes do not translate directly. For example, rather than a single word, one-to-many or many-to-one mappings are required, or there are multiple meanings of words, or explanation of concepts required cultural or other context. In addition, word order, and more generally syntax, can differ significantly from language to language.

B. SYNTAX-DIRECTED TRANSLATION

As noted above, syntax can differ from one language to another. Syntax-directed translations is to translate from one parse tress, suitable for describing a phrase in the source language, into another parse tree, suitable for describing a sentence in the target language. Figure 16 suggests the basic idea.

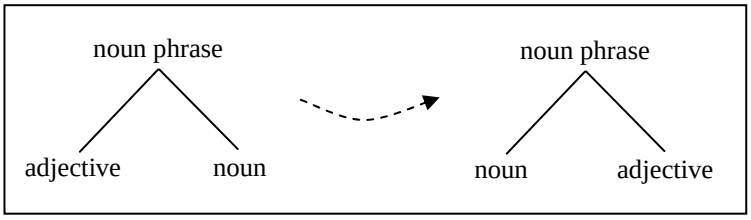

Figure 16. A Simple Translation that Reorders Adjectives and Nouns (From: Ref. Daniel Jurafsky 2000)

Syntax translation is better than word for word translation, but it will have difficulty when dealing with ambiguous sentences and it still does not handle context or meaning.

C. SEMANTIC TRANSLATION

One problem with word for word and syntax translation is that they require a distinct set of translation rules for each pair of languages. This is clearly suboptimal for translation systems employed in multilingual environments. Hence, an alternative is to treat translation as a process of extracting the meaning of the input and then expressing that meaning in the target language. This type of translations may use a lingua franca, which essentially tries to capture semantic information. A lingua-franca usually consists of one or more ontology, which represent domain-specific concepts existing in both languages. However, creating ontology is time consuming and difficult, and it may be difficult to cover all possible concepts. In addition, mapping from text or parse trees to the lingua franca is still difficult.

D. HIGHER LEVEL ANALYSIS, E.G., DISCOURSE

Instead of analyzing at the word or isolated and unrelated sentence level, discourse is about collocated, related groups of sentences.

APPENDIX B. INTERAGENCY LANGUAGE ROUNDTABLE (ILR) DESCRIPTIONS FOR SPEAKING AND READING

The following descriptions of proficiency levels 0, 1, 2, 3, 4, and 5 characterize spoken-language use. Each higher level implies control of the previous levels' functions and accuracy. The designation 0+, 1+, 2+, etc. will be assigned when proficiency substantially exceeds one skill level and does not fully meet the criteria for the next level. The "plus-level" descriptions, therefore, are subsidiary to the "base-level" descriptions.

A skill level is assigned to a person through an authorized language examination. Examiners assign a level on a variety of performance criteria exemplified in the descriptive statements. Therefore, the examples given here illustrate, but do not exhaustively describe, either the skills a person may possess or situations in which he/she may function effectively.

Statements describing accuracy refer to typical stages in the development of competence in the most commonly taught languages in formal training programs. In other languages, emerging competence parallels these characterizations, but often with different details.

Unless otherwise specified, the term "native speaker" refers to native speakers of a standard dialect.

"Well-educated," in the context of these proficiency descriptions, does not necessarily imply formal higher education. However, in cultures where formal higher education is common, the language-use abilities of persons who have had such education are considered the standard. That is, such a person meets contemporary expectations for the formal, careful style of the language, as well as a range of less formal varieties of the language.

These descriptions may be further specified by individual agencies to characterize those aspects of language-use performance which are of insufficient generality to be included here.

A. SPEAKING

1. S-0 No Proficiency

Unable to function in the spoken language. Oral production is limited to occasional isolated words. Has essentially no communicative ability.

2. S-0+ Memorized Proficiency

Able to satisfy immediate needs using rehearsed utterances. Shows little real autonomy of expression, flexibility, or spontaneity. Can ask questions or make statements with reasonable accuracy only with memorized utterances or formulae. Attempts at creating speech are usually unsuccessful.

Examples: The S-0+'s vocabulary is usually limited to areas of immediate survival needs. Most utterances are telegraphic; that is, functors (linking words, markers, and the like) are omitted, confused, or distorted. An S-0+ can usually differentiate most significant sounds when produced in isolation, but, when combined in words or groups of words, errors may be frequent. Even with repetition, communication is severely limited even with persons used to dealing with foreigners. Stress, intonation, tone, etc. are usually quite faulty.

3. S-1 Elementary Proficiency

Able to satisfy minimum courtesy requirements and maintain very simple face-to-face conversations on familiar topics. A native speaker must often use slowed speech, repetition, paraphrase, or a combination of these to be understood by an S-1. Similarly, the native speaker must strain and employ real-world knowledge to understand even simple statements/questions from the S-1. An S-1 speaker has a functional, but limited proficiency. Misunderstandings are frequent, but the S-1 is able to ask for help and to verify comprehension of native speech in face-to-face interaction. The S-1 is unable to produce continuous discourse except with rehearsed material.

Examples: Structural accuracy is likely to be random or severely limited. Time concepts are vague. Vocabulary is inaccurate, and its range is very narrow. The S-1 often speaks with great difficulty. By repeating, such speakers can make themselves

understood to native speakers who are in regular contact with foreigners but there is little precision in the information conveyed. Needs, experience, or training may vary greatly from individual to individual; for example, S-1s may have encountered quite different vocabulary areas. However, the S-1 can typically satisfy predictable, simple, personal and accommodation needs; can generally meet courtesy, introduction, and identification requirements; exchange greetings; elicit and provide, for example, predictable and skeletal biographical information. An S-1 might give information about business hours, explain routine procedures in a limited way, and state in a simple manner what actions will be taken. The S-1 is able to formulate some questions even in languages with complicated question constructions. Almost every utterance may be characterized by structural errors and errors in basic grammatical relations. Vocabulary is extremely limited and characteristically does not include modifiers. Pronunciation, stress, and intonation are generally poor, often heavily influenced by another language. Use of structure and vocabulary is highly imprecise.

4. S-1+ Elementary Proficiency, Plus

Can initiate and maintain predictable face-to-face conversation and satisfy limited social demands. The S-1+ may, however, have little understanding of the social conventions of conversation. The interlocutor is generally required to strain and employ real-world knowledge to understand even some simple speech. An S-1+ may hesitate and may have to change subjects due to lack of language resources. Range and control of the language are limited. Speech largely consists of a series of short, discrete utterances.

Examples: An S-1+ is able to satisfy most travel and accommodation needs and a limited range of social demands beyond exchanges of skeletal biographic information. Speaking ability may extend beyond immediate survival needs. Accuracy in basic grammatical relations is evident, although not consistent. May exhibit the commoner forms of verb tenses, for example, but may make frequent errors in formation and selection. While some structures are established, errors occur in more complex patterns. The S-1+ typically cannot sustain coherent structures in longer utterances or unfamiliar situations. Ability to describe and give precise information is limited. Person, space, and

time references are often used incorrectly. Pronunciation is understandable to natives used to dealing with foreigners. Can combine most significant sounds with reasonable comprehensibility, but has difficulty in producing certain sounds in certain positions or in certain combinations. Speech will usually be labored. Frequently has to repeat utterances to be understood by the general public.

5. S-2 Limited Working Proficiency

Able to satisfy routine social demands and limited work requirements. Can handle routine work-related interactions that are limited in scope. In more complex and sophisticated work-related tasks, language usage generally disturbs the native speaker. Can handle with confidence, but not with facility, most normal high-frequency social conversational situations including extensive, but casual, conversations about current events, as well as work, family, and autobiographical information. The S-2 can get the gist of most everyday conversations but has some difficulty understanding native speakers in situations that require specialized or sophisticated knowledge. The S-2's utterances are minimally cohesive. Linguistic structure is usually not very elaborate and not thoroughly controlled; errors are frequent. Vocabulary use is appropriate for high-frequency utterances, but unusual or imprecise elsewhere.

Examples: While these interactions will vary widely from individual to individual, an S-2 can typically ask and answer predictable questions in the workplace and give straightforward instructions to subordinates. Additionally, the S-2 can participate in personal and accommodation-type interactions with elaboration and facility; that is, can give and understand complicated, detailed, and extensive directions and make non-routine changes in travel and accommodation arrangements. Simple structures and basic grammatical relations are typically controlled; however, there are areas of weakness. In the commonly taught languages, these may be simple markings such as plurals, articles, linking words, and negatives or more complex structures such as tense/aspect usage, case morphology, passive constructions, word order, and embedding.

6. S-2+ Limited Working Proficiency, Plus

Able to satisfy most work requirements with language usage that is often, but not always, acceptable and effective. An S-2+ shows considerable ability to communicative effectively on topics relating to particular interests and special fields of competence. Often shows a high degree of fluency and ease of speech, yet when under tension or pressure, the ability to use the language effectively may deteriorate. Comprehension of normal native speech is typically nearly complete. An S-2+ may miss cultural and local references and may require a native speaker to adjust to his/her limitations in some ways. Native speakers often perceive the S-2+'s speech to contain awkward or inaccurate phrasing of ideas, mistaken time, space, and person references, or to be in some way inappropriate, if not strictly incorrect.

Examples: Typically an S-2+ can participate in most social, formal, and informal interactions; but limitations either in range of contexts, types of tasks, or level of accuracy hinder effectiveness. The S-2+ may be ill at ease with the use of the language either in social interaction or in speaking at length in professional contexts. An S-2+ is generally strong in either structural precision or vocabulary, but not in both. Weakness or unevenness in one of the foregoing, or in pronunciation, occasionally results in miscommunication. Normally controls but cannot always easily produce general vocabulary. Discourse is often incohesive.

7. S-3 General Professional Proficiency

Able to speak the language with sufficient structural accuracy and vocabulary to participate effectively in most formal and informal conversations on practical, social, and professional topics. Nevertheless, an S-3's limitations generally restrict the professional contexts of language use to matters of shared knowledge and/or international convention. Discourse is cohesive. An S-3 uses the language acceptably, but with some noticeable imperfections; yet, errors virtually never interfere with understanding and rarely disturb the native speaker. An S-3 can effectively combine structure and vocabulary to convey his/her meaning accurately. An S-3 speaks readily and fills pauses suitably. In face-to-face conversation with natives speaking the standard dialect at a normal rate of speech,

comprehension is quite complete. Although cultural references, proverbs, and the implications of nuances and idiom may not be fully understood, the S-3 can easily repair the conversation. Pronunciation may be obviously foreign. Individual sounds are accurate; but stress, intonation, and pitch control may be faulty.

Examples: Can typically discuss particular interests and special fields of competence with reasonable ease. Can use the language as part of normal professional duties such as answering objections, clarifying points, justifying decisions, understanding the essence of challenges, stating and defending policy, conducting meetings, delivering briefings, or other extended, elaborate and informative monologues. Can reliably elicit information and informed opinion from native speakers. Structural inaccuracy is rarely the major cause of misunderstanding. Use of structural devices is flexible and elaborate. Without searching for words or phrases, an S-3 uses the language clearly and relatively naturally to elaborate concepts freely and make ideas easily understandable to native speakers. Errors occur in low-frequency and highly complex structures.

8. S-3+ General Professional Proficiency, Plus

Is often able to use the language to satisfy professional needs in a wide range of sophisticated and demanding tasks.

Examples: Despite obvious strengths, may exhibit some hesitancy, uncertainty, effort, or errors which limit the range of language-use tasks that can be reliably performed. Typically there is particular strength in fluency and one or more, but not all, of the following: has breadth of lexicon, including low- and medium-frequency items, especially socio-linguistic/cultural references and nuances of close synonyms; employs structural precision with sophisticated features that are readily, accurately, and appropriately controlled (such as complex modification and embedding in Indo-European languages); has discourse competence in a wide range of contexts and tasks, often matching a native speaker's strategic and organizational abilities and expectations. Occasional patterned errors occur in low frequency and highly complex structures.

9. S-4 Advanced Professional Proficiency

Able to use the language fluently and accurately on all levels normally pertinent to professional needs. An S-4's language usage and ability to function are fully successful. Organizes discourse well, employing functional rhetorical speech devices, native cultural references, and understanding. Language ability only rarely hinders him/her in performing any task requiring language; yet, an S-4 would seldom be perceived as a native. Speaks effortlessly and smoothly and is able to use the language with a high degree of effectiveness, reliability, and precision for all representational purposes within the range of personal and professional experience and scope of responsibilities. Can serve as an informal interpreter in a range of unpredictable circumstances. Can perform extensive, sophisticated language tasks, encompassing most matters of interest to well-educated native speakers, including tasks that do not bear directly on a professional specialty.

Examples: Can discuss in detail concepts that are fundamentally different from those of the target culture and make those concepts clear and accessible to the native speaker. Similarly, an S-4 can understand the details and ramifications of concepts that are culturally or conceptually different form his/her own. Can set the tone of interpersonal official, semi-official, and non-professional verbal exchanges with a representative range of native speakers (in a range of varied audiences, purposes, tasks, and settings). Can play an effective role among native speakers in such contexts as conferences, lectures and debates on matters of disagreement. Can advocate a position at length, both formally and in chance encounters, using sophisticated verbal strategies. Can understand and reliably produce shifts of both subject matter and tone. Can understand native speakers of the standard and other major dialects in essentially any face-to-face interaction.

10. S-4+ Advanced Professional Proficiency, Plus

Speaking proficiency is regularly superior in all respects, usually equivalent to that of a well-educated, highly articulate native speaker. Language ability does not

impede the performance of any language-use task. However, an S-4+ would not necessarily be perceived as culturally native.

Examples: An S-4+ organizes discourse well, employing functional rhetorical speech devices, native cultural references and understanding. Effectively applies a native speaker's social and circumstantial knowledge. However, cannot sustain that performance under all circumstances. While an S-4+ has a wide range and control of structure, an occasional non-native slip may occur. An S-4+ has a sophisticated control of vocabulary and phrasing that is rarely imprecise, yet there are occasional weaknesses in idioms, colloquialisms, pronunciation, cultural reference or there may be an occasional failure to interact in a totally native manner.

11. S-5 Functionally Native Proficiency

Speaking proficiency is functionally equivalent to that of a highly articulate, well-educated native speaker and reflects the cultural standards of the country where the language is natively spoken. An S-5 uses the language with complete flexibility and intuition, so that speech on all levels is fully accepted by well-educated native speakers in all of its features, including breadth of vocabulary and idiom, colloquialisms, and pertinent cultural references. Pronunciation is typically consistent with that of well-educated native speakers of a non-stigmatized dialect.

B. READING

1. R-0 No Proficiency

No practical ability to read the language. Consistently misunderstands or cannot comprehend at all.

2. R-0+ Memorized Proficiency

Can recognize all the letters in the printed version of an alphabetic system and high-frequency elements of a syllabary or a character system. Able to read some or all of

the following: numbers, isolated words and phrases, personal and place names, street signs, office and shop designations. The above often interpreted inaccurately. Unable to read connected prose.

3. R-1 Elementary Proficiency

Sufficient comprehension to read very simple connected written material in a form equivalent to usual printing or typescript. Can read either representations of familiar formulaic verbal exchanges or simple language containing only the highest frequency structural patterns and vocabulary, including shared international vocabulary items and cognates (when appropriate). Able to read and understand known language elements that have been recombined in new ways to achieve different meanings at a similar level of simplicity. Texts may include simple narratives of routine behavior, highly predictable descriptions of persons, places or things; and explanations of geography and government such as those simplified for tourists. Some misunderstandings possible on simple texts. Can get some main ideas and locate prominent items of professional significance in more complex texts. Can identify general subject matter in some authentic texts.

4. R-1+ Elementary Proficiency, Plus

Sufficient comprehension to understand simple discourse in printed form for informative social purposes. Can read material such as announcements of public events, simple prose containing biographical information or narration of events, and straightforward newspaper headlines. Can guess at unfamiliar vocabulary if highly contextualized, but with difficulty in unfamiliar contexts. Can get some main ideas and locate routine information of professional significance in more complex texts. Can follow essential points of written discussion at an elementary level on topics in his/her special professional field.

In commonly taught languages, an R-1+ may not control the structure well. For example, basic grammatical relations are often misinterpreted, and temporal reference may rely primarily on lexical items as time indicators. Has some difficulty with the

cohesive factors in discourse, such as matching pronouns with referents. May have to read materials several times for understanding.

5. R-2 Limited Working Proficiency

Sufficient comprehension to read simple, authentic written material in a form equivalent to usual printing or typescript on subjects within a familiar context. Able to read with some misunderstandings straightforward, familiar, factual material, but in general insufficiently experienced with the language to draw inferences directly from the linguistic aspects of the text. Can locate and understand the main ideas and details in material written for the general reader. However, persons who have professional knowledge of a subject may be able to summarize or perform sorting and locating tasks with written texts that are well beyond their general proficiency level. The R-2 can read uncomplicated, but authentic prose on familiar subjects that are normally presented in a predictable sequence which aids the reader in understanding. Texts may include descriptions and narrations in contexts such as news items describing frequently occurring events, simple biographical information, social notices, formulaic business letters, and simple technical material written for the general reader. Generally the prose that can be read by an R-2 is predominantly in straightforward/high-frequency sentence patterns. The R-2 does not have a broad active vocabulary (that is, which he/she recognizes immediately on sight), but is able to use contextual and real-world cues to understand the text. Characteristically, however, the R-2 is quite slow in performing such a process. Is typically able to answer factual questions about authentic texts of the types described above.

6. R-2+ Limited Working Proficiency, Plus

Sufficient comprehension to understand most factual material in non-technical prose as well as some discussions on concrete topics related to special professional interests. Is markedly more proficient at reading materials on a familiar topic. Is able to separate the main ideas and details from lesser ones and uses that distinction to advance understanding. The R-2+ is able to use linguistic context and real-world knowledge to make sensible guesses about unfamiliar material. Has a broad active reading vocabulary.

The R-2+ is able to get the gist of main and subsidiary ideas in texts, which could only be read thoroughly by persons with much higher proficiencies. Weaknesses include slowness, uncertainty, and inability to discern nuance and/or intentionally disguised meaning.

7. R-3 General Professional Proficiency

Able to read within a normal range of speed and with almost complete comprehension a variety of authentic prose material on unfamiliar subjects. Reading ability is not dependent on subject matter knowledge, although it is not expected that an R-3 can comprehend thoroughly subject matter which is highly dependent on cultural knowledge or which is outside his/her general experience and not accompanied by explanation. Text-types include news stories similar to wire service reports or international news items in major periodicals, routine correspondence, general reports, and technical material in his/her professional field; all of these may include hypothesis, argumentation, and supported opinions. Misreading rare. Almost always able to interpret material correctly, relate ideas, and "read between the lines," (that is, understand the writers' implicit intents in texts of the above types). Can get the gist of more sophisticated texts, but may be unable to detect or understand subtlety and nuance. Rarely has to pause over or reread general vocabulary. However, may experience some difficulty with unusually complex structure and low frequency idioms.

8. R-3+ General Professional Proficiency, Plus

Can comprehend a variety of styles and forms pertinent to professional needs. Rarely misinterprets such texts or rarely experiences difficulty relating ideas or making inferences. Able to comprehend many sociolinguistic and cultural references. However, may miss some nuances and subtleties. Able to comprehend a considerable range of intentionally complex structures, low frequency idioms, and uncommon connotative intentions; however, accuracy is not complete. The S-3+ is typically able to read with facility, understand, and appreciate contemporary expository, technical, or literary texts that do not rely heavily on slang and unusual idioms.

9. R-4 Advanced Professional Proficiency

Able to read fluently and accurately all styles and forms of the language pertinent to professional needs. The R-4's experience with the written language is extensive enough that he/she is able to relate inferences in the text to real-world knowledge and understand almost all sociolinguistic and cultural references. Able to "read beyond the lines" (that is, to understand the full ramifications of texts as they are situated in the wider cultural, political, or social environment). Able to read and understand the intent of writers' employment of nuance and subtlety. An R-4 can discern relationships among sophisticated written materials in the context of broad experience. Can follow unpredictable turns of thoughts readily in, for example, editorials, conjectural, and literary texts in any subject matter area directed to the general reader. Can read essentially all materials in his/her special field, including official and professional documents and correspondence. Recognizes all professionally relevant vocabulary known to the educated non-professional native, although may have some difficulty with slang. Can read reasonably legible handwriting without difficulty. Accuracy is often nearly that of a well-educated native reader.

10, R-4+ Advanced Professional Proficiency, Plus

Nearly native ability to read and understand extremely difficult or abstract prose, a very wide variety of vocabulary, idioms, colloquialisms, and slang. Strong sensitivity to and understanding of sociolinguistic and cultural references. Little difficulty in reading less than fully legible handwriting. Broad ability to "read beyond the lines" (that is, to understand the full ramifications of texts as they are situated in the wider cultural, political, or social environment) is nearly that of a well-read or well educated native reader. Accuracy is close to that of the well-educated native reader, but not equivalent.

11. R-5 Functionally Native Proficiency

Reading proficiency is functionally equivalent to that of the well-educated native reader. Can read extremely difficult and abstract prose: for example, general legal and technical as well as highly colloquial writings. Able to read literary texts, typically including contemporary avant-garde prose, poetry, and theatrical writing. Can read

classical/archaic forms of literature with the same degree of facility as the well educated, but non-specialist native. Reads and understands a wide variety of vocabulary and idioms, colloquialisms, slang, and pertinent cultural references. With varying degrees of difficulty, can read all kinds of handwritten documents. Accuracy of comprehension is equivalent to that of a well-educated native reader.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX C. EXECUTIVE SUMMARY OF SEQUOYAH AOA FINAL REPORT

A. BACKGROUND

The US Army Intelligence Center conducted a series of analyses, including a Functional Area Analysis (FAA), Functional Needs Analysis (FNA), and Functional Solutions Analysis (FSA) that revealed a need for language translation technology to assist in meeting a significant shortfall in the number of available linguists to support military operations. Those analyses, as well as the Sequoyah Foreign Language Translation System (hereafter referred to as Sequoyah or S-FLTS) Initial Capabilities Document (ICD), provide the foundation and impetus for this Analysis of Alternatives (AoA). This AoA provides combat and materiel developers an understanding of current language technology capabilities, as well as metrics that may be used to assess those capabilities. The AoA has been conducted in order to support the Milestone Decision Authority (MDA) for a Milestone A decision. The specific Study Issues addressed in this AoA are as follows:

- Issue 1: Analyze the missions and type units to be supported by a foreign language translation system in the Current and Future Force Brigade Combat Team (BCT) and Unit of Employment (UE) within a Joint Operating Environment (JOE), to include use of coalition, multinational, and allied forces.
- Issue 2: Determine the requirements for speech and text foreign language translation capabilities to support the following tasks:
  - (1) Provide language support for medical and chaplain services for non-English speaking personnel.
  - (2) Support refugee and displaced civilian resettlement.
  - (3) Support enemy prisoner of war and civilian internment mission.
  - (4) Conduct criminal investigation.
  - (5) Communicate with non-English speaking Forces and Agencies.
  - (6) Conduct Psychological Operations (PSYOP).
  - (7) Conduct Civil Affairs (CA).
  - (8) Support Combat Operations and Patrols.

- Issue 3: Determine the ability of each study alternative to support interpretation, document translation, data conversion, and technical analysis of captured enemy material.
- Issue 4: Determine the ability of each study alternative to support communication with host nation personnel and thereby provide opportunities to avoid confrontations and gather information.
- Issue 5: Determine the requirements and risks that evolve from potential solutions with a requirement for a central database and network capability to house and distribute language software modules to user units.
- Issue 6: Determine the cost of each alternative.

B. SEQUOYAH ALTERNATIVES

The alternatives considered are as follows:

- Base Case. Military, government, contract, and host nation linguists as currently used in all mission support roles.
- Alternative 1. Government off-the-shelf (GOTS) language translation systems and devices such as the FALCon, DARPA Phraselator, FORUM/TRIM, S-MINS, and Harmony.
- Alternative 2. Commercial off-the-shelf (COTS) language translation systems such as the International Business Machines (IBM) ViaVoice®, Ectaco's Partner UT-203®, the Franklin Translator®, and LingoTalk®.
- Alternative 3. An amalgamation of means and devices such as Language cards, billboard placards, detainees, local language Standard Operating Procedures (SOP), linguist support, and teaching rudimentary English to local nationals.
- Alternative 4. Incremental development of a two-way speech and text translation software module for each language designated a priority within DoD. Modules will be interoperable and compatible with future DoD automated systems.

C. STUDY METHODOLOGY

Analysis for Study Issues 1 and 2 commenced with an extensive literature search. This included researching applicable Joint and Service tasks, Sequoyah Operational and Organizational (O&O) tasks, Sequoyah architecture documentation, lessons learned from Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF), and previous Integrated Concept Team (ICT) decisions. Missions and units requiring translation

support were determined, as well as the specific tasks and required translation functions (e.g. speech to speech [S2S], text to text [T2T], etc.).

For Study Issues 3 and 4, in order to assess the ability of the Alternatives to support analysis of captured enemy material and host nation communications, a troop to task list was prepared and the performance of each Sequoyah alternative evaluated against individual tasks using eleven separate Measures of Performance (MOP). Composite performance scores were determined for each alternative based upon MOPs that were weighted using a rank-order analytical approach. Performance scores were determined for each Alternative against all requirements, against requirements that involve analysis of captured enemy material (Study Issue 3), and requirements that address communications with host nation personnel (Study Issue 4). Subject Matter Expert (SME) and user validation of specific translation requirements and evaluations of Alternatives against requirements was conducted at a Language Translation Map Exercise (MAPEX).

The methodology for addressing Study Issue 5 was to determine the networking and database requirements for each alternative. Once these requirements were determined, discussions with SMEs on the vulnerabilities of similar systems that rely on networks and databases, and/or are comprised of software-based systems was researched to determine the risks to Sequoyah Alternatives.

Costing for Sequoyah Alternatives was conducted by the Training and Doctrine Command (TRADOC) Analysis Center located at White Sands Missile Range (TRAC-WSMR). Input into the cost analysis was provided by the Army G-2 staff (on linguists), vendors and SMEs.

D. RESULTS

A total of 69 requirements (tasks) for translation and interpretation support were determined based on analysis of Joint, Service, and Agency tasks as well as operator and SME input. While translation support is required from strategic down to tactical levels, it was determined that by far the greatest amount of support is required at the tactical level where uniformed members of the Armed Services come in contact with host nation

personnel. It was further determined by operators and SMEs that many of these exchanges can be handled at an Interagency Language Roundtable (ILR) level of fluency of 1 or less for S2S interpretation interactions and ILR 2 for T2T translation tasks.

1. The Base Case

This includes linguists as currently employed, provides translation (T2T) and interpretation (S2S) capabilities up to and including ILR level 5. Human linguists provide a combination of translation capabilities with cultural expertise which is impossible to match through automated means. Category II and III (SECRET and TOP SECRET respectively) Contract linguists as well as military linguists provide credible support; host nation contract linguists (Category I local hire) may not. The challenge with the Base Case is providing support (numbers of linguists) to handle the extensive requirements for linguists in today's environment where exchanges with host nation personnel occur on a continuous basis with coalition and U.S. military personnel.

2. Alternative 1 (GOTS systems) and Alternative 2 (COTS Systems)

These two Alternatives are closely related. Virtually all GOTS systems consist of COTS systems which have been packaged to make them more suitable for a military environment. Empirical studies have shown that T2T translation systems provide support at ILR level 2 or less, and that speech to text (S2T) translation systems operate at less than ILR level 2. GOTS and COTS systems, as currently configured, provide a one way speech translation capability. A two way S2S translation capability does not exist except for very limited circumstances; thus, these Alternatives are not considered effective in meeting DoD's translation and interpretation requirements. Alternative 1 and 2 do however provide the capability for support at any number of Linguistic Points of Presence (POP), defined as points in space where speech and/or text translation support is required.

3. Alternative 3

This Alternative consists primarily of printed products. It provides a credible capability that can be readily distributed to any number of locations. However, it is

unable to support any level of linguistic capability beyond ILR 0+, and can barely support one-way text to speech (T2S) interactions. While in some situations graphics cards provide utility, they do not facilitate any exchanges beyond basic pointing and yes or no exchanges. Therefore, Alternative 3 by itself is not deemed capable of meeting DoD's translation and interpretation requirements.

4. Alternative 4

This is an Incrementally Developed System (IDS). It was structured based on Alternative 1 with an added S2S interpretation capability within strictly defined mission sets (domains). This S2S capability is assessed to have a minimum level ILR level 1+ capability. The T2T capability is assessed to have a level ILR 2 or less (as with Alternatives 1 and 2). Modules are structured so that they are downloadable and upgradeable through connection to the network. Alternative 4 is deemed effective in meeting DoD's lower level (ILR 2 or less) translation and interpretation requirements. Furthermore, this Alternative does provide the capability for support at any number of locations (large numbers of Linguistic PoP).

5. Costing and Performance

The results of plots of the performance scores for all Alternatives and their corresponding costs over a 20 year period are shown in the following figure. Alternatives that plot in the lower right portion of the graph are preferred. It is important to note that the maximum performance score is 100 and that costs are provided in FY06 constant $M.

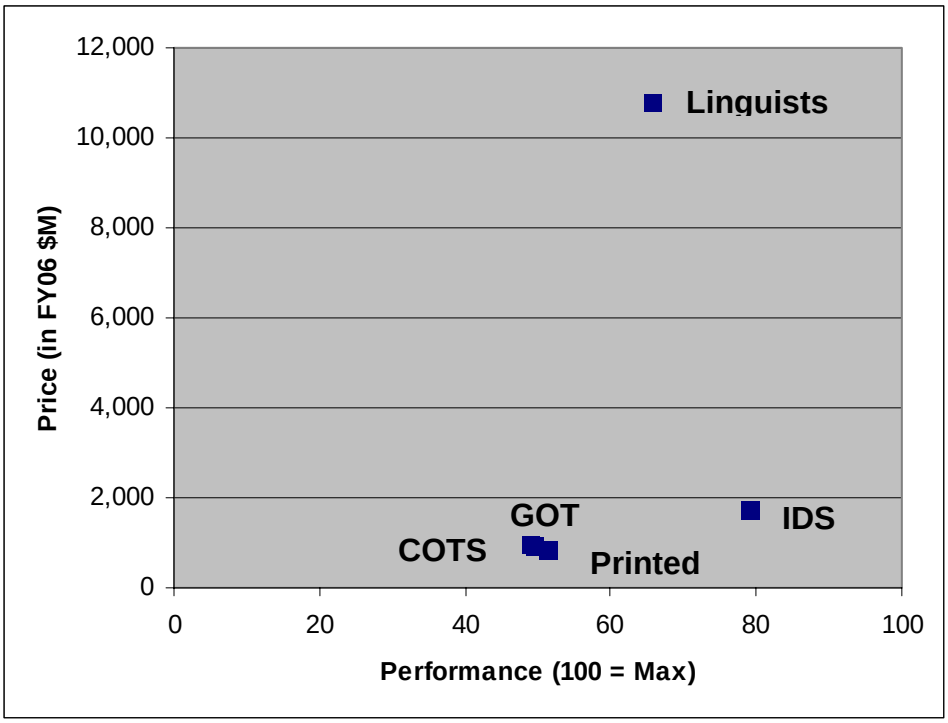

Figure 17. Plots of Performance Scores for all Alternatives and their Corresponding Costs over a 20 year Period (From: Ref. Edward A. Cerutti 2005)

E. CONCLUSIONS AND RECOMMENDATIONS

Linguists provide an unmatched capability in terms of ILR level and cultural awareness. While they can be augmented by host nation contract hires, there are insufficient numbers of linguists to address the full scope of translation requirements to support our Armed Forces. Machine Language Translation (MLT) systems, as configured under Alternative 4 (Incrementally Developed System with two way S2S capability) on the other hand, provide a militarily useful capability that can be readily deployed to address low level requirements. Thus linguists and MLT systems are complementary in nature. MLT systems can enable non-linguists when a linguist is unavailable, and can provide triage services to ensure that critical translation requirements are brought to a linguist to be properly executed. Furthermore, MLT systems are relatively affordable. The cost of their development and maintenance is a fraction of the overall annual cost for linguists.

APPENDIX D. ESTIMATED COST TO TRAIN MILITARY LINGUIST

Estimated cost to train military linguist up to ILR level 2:

Information gathered:

1. According to FY2006, National Defence Authorization Act - Budget Request from Dept of Army, DLI annual budget in **2006** is **$59 million**
2. There are approximately **3,500 students** in the resident educational programs at the Presidio of Monterey campus at any given time
3. There are 23 basic courses for 4 Language Difficulty Categories (LDC) from I (easiest) to IV (hardest)
4. Four basic courses on **LDC I** language takes **26 weeks** each to finish
5. Two basic courses on **LDC II** language takes **35 weeks** each to finish
6. Thirteen basic courses on **LDC III** language takes **48 weeks** each to finish
7. Four basic courses on **LDC IV** language takes **64 weeks** each to finish
8. Each basic course is designed to take the students up to an ILR proficiency Level 2 in listening & reading comprehension, speaking ability

Assumptions made:

1. Annual fundings for DLI's **Infrastructure** is **$500k**
2. 3,500 students are made up of **1,750 Army officers** with rank **O-3** and **10 years** of services, and **1,750 Army enlisted** with rank **E-5** and **10 years** of services
3. Cost/training week for linguist in LDC I language = Cost/training week for linguist in LDC IV language
4. Cost/training week for linguist does not differ across domains
5. **Fringe** is **25%** of basic salary and **Allowance** is **35%** of basic salary
6. All 3,500 students are taking basic courses

Cost Components	Unit cost ($/month)	Number of students	Amount ($mil/year)
1. Annual Budget			59
2. Military Personnel Appropriation (MPA)			
a. O-3			
- Basic Salary	4982.7	1750	
- Fringe (25% of B.S.)	1245.675		
- Allowances (35% of B.S.)	1743.945		
TOTAL			167.41872
b. E-5			
- Basic Salary	2551.5	1750	
- Fringe (25% of B.S.)	637.875		
- Allowances (35% of B.S.)	893.025		
TOTAL			85.7304
3. Infrastructure			0.5

Total annual fundings for DLI	$312.65	mil
Annual student load	3500	stduents
Training Cost per student - week	$1,717.85	
Cost to train a linguist in LDC I language (ILR level 2 or higher)	**$44,664.16**	
Cost to train a linguist in LDC II language (ILR level 2 or higher)	**$60,124.83**	
Cost to train a linguist in LDC III language (ILR level 2 or higher)	**$82,456.91**	
Cost to train a linguist in LDC IV language (ILR level 2 or higher)	**$109,942.55**	

Estimated cost to train military linguist up to ILR level 3:

Information gathered:

1. Number of hours of instruction plus study time to reach ILR level 3 is based on Dr. Clifford's research summarized in Foreign Language Program Characteristics and Likely Exit Proficiency of Motivated Students.
2. Extracted from Hampson E., Jones T., Strictland M. (2007). Determination of the Army's Requirement for a Cadre of Professional Linguists at Level 3/3/3. Battelle Memorial Institute.

Assumptions made:

1. Rate of post-DLI education assumed at the Army standardized training planning cost of $30/hour (rounded up)
2. Basic course hours are calculated by multiplying the number of weeks by 40 (6 hours/day plus 2 hours study time)
3. Linguist's pay and allowances is in-between that of O-3 and E-5

Language Difficulty Category	Basic Course Hours	Supplemental Hours	Cost/Hour	Total Training Cost
I	1040	560	30	**$16,800**
II	1400	600	30	**$18,000**
III	1920	1280	30	**$38,400**
IV	2560	2240	30	**$67,200**

Pay and Allowance per student-week	**$1,391**
Cost to train a linguist in LDC I language (ILR level 3 or higher)	**$80,937.17**
Cost to train a linguist in LDC II language (ILR level 3 or higher)	**$98,988.77**
Cost to train a linguist in LDC III language (ILR level 3 or higher)	**$165,366.65**
Cost to train a linguist in LDC IV language (ILR level 3 or higher)	**$255,034.58**

APPENDIX E. NET PRESENT VALUE (NPV)

Net Present Value (NPV) of an investment is defined as the sum of present values of the annual cash flows. Annual cash flows are the net benefits (revenues minus costs) generated from the investment during its lifetime. As this thesis is comparing NPV of Life Cycle Cost (LCC), annual cash flows are the costs spent at the end of each year. These cash flows are discounted or adjusted by incorporating the uncertainty and time value of money. An investment with the smaller NPV of LCC is a better option. The formula for calculating NPV is as follows:

$$NPV = \sum_{t=0}^{n} \frac{CF^t}{(1+k)^t}$$

where

t – time of the cash flow

n – life cycle of investment

k – discount rate

CF^t – cash flow at time t

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

Acquisition Community Connection (ACC). (2004). *Business Case Analysis (BCA)*. Retrieved October 27, 2007 from https://acc.dau.mil/CommunityBrowser.aspx?id=32524.

Advanced Systems & Concepts. (October 14, 2006). *Joint Capability Technology Demonstration (JCTD)*. Retrieved August 17, 2007 from http://www.acq.osd.mil/jctd/index.htm.

BBN Technologies. *BBN Broadcast Monitoring System*. Retrieved October 6, 2007 from http://www.bbn.com/solutions_and_technologies/data_indexing_and_mining/bbn_broadcast_monitoring_system.

CACI Ever Vigilant. *Document and Records Management – Document Exploitation*. Retrieved October 7, 2007 from http://www.caci.com/business/systems/doc_mgt/doc_manage_docex.shtml.

Christopher John Farah. (2003). What's Next: From Uzbek to Klingon, the Machine Cracks the Code. Retrieved May 24, 2007, from http://www.nytimes.com/2003/07/31/technology/circuits/31next.html?ex=1180968985&ei=1&en=03cef2fbef441e4e.

Daniel Jurafsky & James H. Martin. (2000). *Speech and Language Processing: An Introduction to Natural Language Processing, Speech Recognition, and Computational Linguistics*. First Edition, Prentice-Hall.

Defense Language Institute Foreign Language Center. (2007). *General Catalog 2006-2007*. Retrieved October 25, 2007 from http://www.dliflc.edu/academics/academic_affairs/DLIFLCcatalog2006-07.pdf

Defense Update. (January 27, 2005). *Commander's Digital Translator*. Retrieved October 7, 2007 from http://www.defense-update.com/products/t/translators.htm.

Edward A. Cerutti & CW4 (Ret.) Tim Hunter. (2005). *Sequoyah Foreign Language Translation System Analysis of Alternatives (AoA) Final Report.*

Edward A. Cerutti & Tracy Blocker. (Jan 2007). *SEQUOYAH Foreign Language Translation System*. Presentation Slides, U.S. Army Intelligence Center.

Gadala E. Kratzer. (October 2005). *A Methodological Approach For Conducting A Business Case Analysis For The Advanced Technology Ordnance Surveillance (AOTS)*. Master's Thesis, Naval Postgraduate School.

GlobalSecurity.org. *Language and Speech Exploitation Resources (LASER)*. Retrieved October 14, 2007 from http://www.globalsecurity.org/intell/systems/laser.htm.

Hampson E., Jones T., Strictland M. (2007). *Determination of the Army's Requirement for a Cadre of Professional Linguists at Level 3/3/3*. Battelle Memorial Institute.

Hang Sheng Lim. (December 2006). *A Methodological Approach For Conducting A Business Case Analysis For The Joint Distance Support and Response (JDSR) Advanced Concept Technology Demonstration (ACTD)*. Master's Thesis, Naval Postgraduate School.

Headquarters Department of the Army. (December 2006). FM 3-24 CounterInsurgency. Retrieved October 21, 2007 from https://atiam.train.army.mil/soldierPortal/atia/adlsc/view/public/23285-1/FM/3-24/FM3_24.pdf

International Business Machines (IBM). *Speech-to-Speech Translation*. Retrieved October 7, 2007 from http://domino.watson.ibm.com/comm/research.nsf/pages/r.uit.innovation.html#sfeedback.

Kate Greene. (August 23, 2006). *How to Talk Like an Iraqi*. Retrieved on October 8, 2007 from http://www.technologyreview.com/read_article.aspx?id=17350&ch=infotech&a=f.

Mobile Information Technologies. *Basic Language Translation System (BLTS) V1*. Retrieved October 7, 2007 from http://www.essworld.net/pdfs/MIT_BLTSv1.pdf.

Susan LaVonne Marshall. (Mar 2005). *Concept of Operations (CONOPS) for Foreign Language and Speech Translation Technologies in a Coalition Military Environment*. Master's Thesis, Naval Postgraduate School.

U.S. Army Rapid Equipping Force. Retrieved October 14, 2007 from http://www.ref.army.mil/textonly/default.html.

U.S. Marine Corps Forces Pacific Experimentation Center. (August 2004). *Machine Language Translation Systems Demonstration and Assessment Report*. Retrieved October 14, 2007 from http://www.languagerealm.com/Files/usmc_mt_test_2004.pdf.

Wikipedia, the free encyclopedia. *Machine Translation*. Retrieved October 20, 2007 from http://en.wikipedia.org/wiki/Machine_translation.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Dr. Dan Nussbaum
   Naval Postgraduate School
   Monterey, California

4. Dr. Kevin Squire
   Naval Postgraduate School
   Monterey, California

5. Dr. Edward A. Cerutti
   Army Intelligence Master Plan
   Falls Church, Virginia

6. Ms. Teresa Gayle
   Office of the Secretary Defense
   Washington, District of Columbia

7. Mr. Jurgen Sottung
   Defense Language Institute Foreign Language Center
   Monterey, California

8. Mr. Glenn H. Nordin
   U.S. Department of Defense
   Washington, District of Columbia