An Approach for the Enhancement of Military Combat, Performance and Personal Protective Equipment for Ground Troops

by

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Abstract

From the Revolutionary War to the war in Iraq, individuals in this country have stood in order to protect their family, friends and beliefs. Though there are no certainties in life, people are bound to protect their ideals and way of life and as Americans we leave this task to our soldiers. The soldiers that serve in the United States military are becoming overburdened with an ever increasing amount of equipment to use, maintain, carry and account for. This rise, however, leads to increasing weight with a greater complexity of use brought about by the number of individualized pieces of equipment, which decreases mobility, agility and a soldier's range of motion. Unfortunately all of these problems stem from the equipments inability to appropriately account for human factors associated with the soldier.

The purpose of this thesis is to create an approach that will be used to design, evaluate and re-design equipment with military applications. The approach will be designed to provide an effective method for re-designing or creating a new piece of equipment that centers around the Marine, with the intent of effectively increasing the soldier's operational capabilities by focusing on superior human factor integration while unifying the individual pieces of equipment by simplifying the number of individual pieces of gear by addressing product semantics associated with the equipment. The information that follows will provide individuals, contractors and non or governmental

agencies with the knowledge to design and create future equipment with military applications that offer our soldiers increased lethality without sacrificing protection.

Acknowledgments

I would like to begin by giving thanks to God for his continual guidance throughout my life. I would also like to thank my mother and father. A son could not have asked for a more loving, supportive and encouraging set of parents. It has been my mother's determination and my father's scarifies that have allowed me to have the opportunity to reach this academic milestone. I would also like to recognize my brother for always pushing me to achieve more and to never settle for mediocrity. I want to thank my sister who continues to teach me patience and to never forget my family. I would also like to thank the professors and staff of the industrial design department at Auburn University for the roles they have played in my growth as a designer.

In closing I would like to thank Huckleberry Starnes, Major Hestermen, Major Jeffrey Dyal, Sergeant Fountain, members of the NROTC program and the friends I have made while attending Auburn University. Rabindranath Tagore said "The depth of friendship does not depend on the length of acquaintance". Though I have been at Auburn for but a short time, I feel that I have made friendships that will last a lifetime.

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List of Abbreviations

ACAT	Acquisition Category
ALLICE	All-Purpose Lightweight Individual Carrying Equipment
APECS	All Purpose Environmental Clothing System
DoD	Department of Defense
DRR	Design Readiness Review
ESAPI	Enhanced Small Arms Protective Inserts
ICE	Infantry Combat Equipment
ILBE	Improved Load Bearing Equipment
MOLLE	Modular Lightweight Load Carrying Equipment
MTV	Modular Tactical Vest
NETT	New Equipment Training Teams
OTV	Outer Tactical Vest
PASGT	Personal Armor System Group Troop
PDR	Preliminary Design Review
PPE	Personal Protective Equipment
R&D	Research and Development
RMS	Reliability, Maintainability and Supportability
SAPI	Small Arms Protective Inserts
SDD	System Design and Demonstration

SDOE	System Design for Operational Effectiveness
T&E	Test and Evaluation
USMC	United States Marine Corps

Chapter 1: Introduction to the Problem

1.1 Problem Statement

The study will encompass the creation of an approach that will seek to enhance the human factor considerations of current equipment with military applications. The focus of the approach is to be used to create products that specifically benefit individuals who use this equipment in order to overcome past, present and future unseen obstacles with their equipment. United States soldiers are constantly having to overcome obstacles, which are life threatening. Developing new equipment that gives our troops the edge over the enemy without decreasing their own abilities is a priority. New technology is constantly being adapted by the military to gain an edge over the opposition. Over the course of this project, I will create an approach utilizing my industrial design knowledge to develop, analyze and create criteria form which new designs are to be based.

Unfortunately, the current state of the procurement process of the United States military has evolved over time. In theory this means that the current system is a direct result of all of the lessons learned in the past 200 years. In practice, however, the underlining process as it stands has become cumbersome, and the results as they pertain to current use are uncertain because the lessons learned which served as the foundation of the process are by definition from past conflicts. As a result of this the process may not anticipate the new and continual changes in terrain, conflict or operation. In addition an equally critical issue is that the procurement of equipment lacks a user-centered component, meaning that the end users, in this case the soldiers, operational needs are not adequately represented during the initial development of equipment. From this core issue stems additional problems which lead to newly designed equipment for the military having initial faults before deployment, occurring from the undervaluing of human factors and aesthetics. Because of this, problems such as weight, cumbersome equipment, unnatural operating systems and an inability of equipment to work with multiple systems are a continual problem. In order to overcome these flaws, a true design approach much be instilled which addresses the needs of the Marine before the needs of the equipment. By taking into account fundamental industrial design philosophy, which is to design for the end user, the aim is to ensure that the individuals who use the equipment are not hindered or negatively affected by the designs. Therefore, examining and analyzing the potential of Industrial Design in order to fuse soldiers and their equipment together into a flawless entity will give soldiers a greater opportunity to overcome future obstacles.

This document will consist of four distinct phases. First, the document will begin by researching aspects that influence the design of military equipment. These aspects include soldier feedback, the evolution of equipment and the need of more protection, the acquisition, distribution and deployment time of equipment. Second, I will develop an approach that will allow an individual to design equipment with military applications. This process will be used to design, develop, re-design and evaluate military equipment with the intent of enhancing the system of equipment used by soldiers in order to improve their operational capabilities and effectiveness. These enhancements will serve to better suit the natural and basic needs of the soldier while maintain the needs of current and future engagements. Third, I will test the approach by applying it to a piece of military equipment and then developing a new product from the formula provided by the design approach. Lastly, I will test the new design by creating a prototype and evaluate the design on its performance and ability to meet specified criteria as well as testing the design's ability to enhance the soldiers' capabilities.

1.2 Need of Study

We find ourselves with increasingly complex problems which are answered with science fiction-type conclusions. Difficulties with equipment use are created when the interactions between two or more systems are not accounted for. This then creates friction between these systems which can then effect the time and ease of use of one or more of these items. Equipment can then have negative effects on the soldier due to their inability to be used properly when these systems come together on the soldier. Designs are also being created to satisfy a single need instead of understanding and dealing with problems that may arise from the designed solution thus affecting the soldier and additional equipment. The obstacles the gear seeks to overcome takes the forefront of the new design solutions while the basic needs of the person are becoming less of a concern. This brings us to the present state of military equipment, which is being designed without consideration of user needs. As a result of this situation soldiers have to conform to the restrictions and limitations of the equipment instead of the gear complementing the individual soldier's natural movements and capabilities.

Currently designed equipment suffers from a detachment from the solider. Because of this detachment, these designs do not fully succeed and allow the soldier to operate to the fullest potential of their abilities. Due to how these individual items are designed they are ineffective in the fact that multiple pieces of equipment that have to work with one another can become a hindrance. Through the influence of a designed approach, a designer will have the ability to offer the soldier the most appropriate and effective equipment.

"We search incessantly for new ideas, new methods, and new materials. We are not content to stand still or to accept present processes as the final word. If we are to progress, we must constantly evaluate the status quo, and if what it stands for is no longer valid, we must abandon it" (Dreyfuss, 1955, Designing for People).

1.3 Objectives of Study

The objective of this document is to study the consistent problems faced by military equipment. The research will identify the standards and criteria equipment must meet. The study will also research the current process by which equipment is developed.

- Research equipment criteria.
- Research current equipment flaws that lead to modifications by the end-user.
- Develop a process which outlines how to design and evaluate equipment with the intention of increasing human interface.
- Use developed process to create a piece of equipment.

1.4 Definition of Key Terms

Active Duty - Full-time duty in the active military service of the United States. This includes members of the Reserve Components serving on active duty or full-time training duty, but does not include full-time National Guard duty.

Approach March - Advance of a combat unit when direct contact with the enemy is imminent. Troops are fully or partially deployed. The approach march ends when ground contact with the enemy is made or when the attack position is occupied.

Assault Load - The load needed during the actual conduct of the assault. It will include minimal equipment beyond water and ammunition. From the human factors perspective, the maximum assault load weight will be that weight at which an average infantry Marine will be able to conduct combat operations indefinitely with minimal degradation in combat effectiveness.

Approach March Load - The load necessary for the prosecution of combat operations for extended periods with access to daily re-supply. The approach march load is intended to provide the individual infantry Marine with the necessities of existence for an extended period of combat.

Battle Injury - Damage or harm sustained by personnel during or as a result of battle conditions.

Casualty - Any person who is lost to the organization by having been declared dead, whereabouts unknown, missing, ill or injured.

Combat Survival - Those measures to be taken by service personnel when involuntarily separated from friendly forces in combat, including procedures relating to individual survival, evasion, escape and conduct after capture.

Combat Zone - That area required by combat forces for the conduct of operations.

Existence Load - The load taken from the point of origin into the assembly area. The existence load, for planning purposes, will be intended to support the individuals from their pack when immediate re-supply is impossible.

Frequency of Use Principle - The most frequently used items should be in the most accessible locations.

Guerrilla Warfare - Military and paramilitary operations conducted in enemy-held or hostile territory by irregular, predominantly indigenous forces.

Function Principle - Items with similar functions should be grouped together.

Importance Principle - The most important items should be in the most accessible locations.

Interoperability - The compatibility of components with standard interface protocols to facilitate rapid repair and enhancement/upgrade through black box technology using common interfaces.

Maintainability - The ability of a system to be repaired and restored to service when maintenance is conducted by personnel using specified skill levels and prescribed procedures and resources.

Modularity - Packaging of components such that they can be repaired via remove and replace action rather than on-board repair.

Metaphor - Ways to express the meaning of form with implications, allowing designers to appropriate a feature from one domain and transfer it to the new product.

Military Acquisition - A management process dealing with a nation's investments in the technologies, programs and product support necessary to achieve its national security strategy and support its armed forces. Its objective is to acquire products that satisfy specified needs and provide measurable improvement to mission capability at a fair and reasonable price.

Mobility - A quality or capability of military forces which permits them to move from place to place while retaining the ability to fulfill their primary mission.

Outgrowth - A natural development, product, result or natural consequence of development.

Obstacle - Any obstruction designed or employed to disrupt, fix, turn or block the movement of an opposing force, and to impose additional losses in personnel, time and equipment on the opposing force. Obstacles can exist naturally, be man-made or a combination of both.

Obstacle Clearing - The total elimination or neutralization of obstacles.

Pace - For ground forces, the speed of a column or element regulated to maintain a prescribed average speed.

Performance Evaluation - The plan for evaluating whether the metrics and any other measures identified to guide the acquisition have been achieved. These measures shall include the thresholds for cost, schedule and performance for the acquisition of a service.

Protection - Preservation of the effectiveness and survivability of mission-related military and nonmilitary personnel, equipment, facilities, information and infrastructure deployed or located within or outside the boundaries of a given operational area.

Protective Clothing - Clothing especially designed, fabricated or treated to protect personnel against hazards caused by extreme changes in physical environment, dangerous working conditions or enemy action.

Prototype - A model suitable for evaluation of design, performance and production potential.

Reliability - The ability of a system to perform as designed in an operational environment over time without failure.

Risk - Probability and severity of loss linked to hazards.

Risk Management - An assessment of current and potential technical, cost, schedule and performance risks and the plan for mitigating or retiring those risks.

Self Assemble - Used to describe processes in which a disordered system of pre-existing components forms an organized structure or pattern as a consequence of specific, local interactions among the components themselves, without external direction.

Systems Design - Defining the hardware and software architecture, components, modules, interfaces and data for a system to satisfy specified requirements. It also includes requirements analysis, system design, implementation, documentation and quality assurance.

Simile - Ways to provide the meaning of form with obvious symbols or texts.

Small Arms – A term used by armed forces to denote infantry weapons an individual soldier may carry. Small arms refer to handguns or other firearms less than 20 mm in caliber, and including heavy machine guns (typically .50 caliber or 12.7 mm in U.S. service).

Sequence of Use Principle - Items that are commonly used in sequence should be laid out in the same sequence.

Techniques - Non-prescriptive ways or methods used to perform missions, functions or tasks.

Theater - A large geographic area in which military operations are coordinated.

Target - An entity or object considered for possible engagement or other action.

Unconventional Warfare - A broad spectrum of military and paramilitary operations normally of long duration, predominantly conducted through, with or by indigenous or surrogate forces who are organized, trained, equipped, supported and directed in varying degrees by an external source. It includes, but is not limited to, guerrilla warfare, subversion, sabotage, intelligence activities and unconventional assisted recovery.

1.5 Literature Review

1.5.1 Overview

During World War II industrial designers came into their own, creating design solution and products to help win the war, such as the Walkie-Talkie and two-way FM radio invented by Galvin Manufacturing, later called Motorola, Inc. "Out of the era of so-called streamlining, the designer learned a great deal about clean, graceful arcs and ugly corners that not only spoiled good honest lines but interfered with efficient operation" (Dreyfuss, 1955, Designing for People). However, these new design principles were not implemented into Personal Protective Equipment. Instead the core of the designs focused solely around the function of the equipment and not the individual user. "We bear in mind that the object being worked on is going to be ridden in, sat upon, looked at, talked into, activated, operated, or in some other way used by people individually or en masse. (Dreyfuss, 1955, Designing for People)" Pertaining to military equipment, the designers must consider how the soldier will interact with the equipment and how these interactions can be enhance to improve the capabilities of the Marine. Even with the advancement of robotic and unmanned devices, a human being has to interact and control it; nothing can replace the human component and as such should be the primary focus of any design. "We begin with men and women and we end with them" (Dreyfuss, 1955, Designing for People). Considerations of human factors as it pertains to the soldier should be considered at the forefront of any design, as well as confirming that the integration of these human factors are present throughout the development process. The military generally stands at the forefront of design and innovation. Daniel Sarewitz, co-director of the Consortium for Science, Policy and Outcomes, says "The military is always looking for technological advantage against its enemies". This is a necessity to ensure that our troops are given a significant edge over the opposition to ensure victory. As it stands the United States has the largest military budget in comparison to other countries and world powers. This budget allows the United States government to provide our military forces with the resources necessary to establish, maintain and secure national security. A portion of this budget goes towards the development of equipment. The military does not have an unlimited amount of funds and when equipment is constantly redesigned shortly after its production and deployment, These funds are essentially wasted.

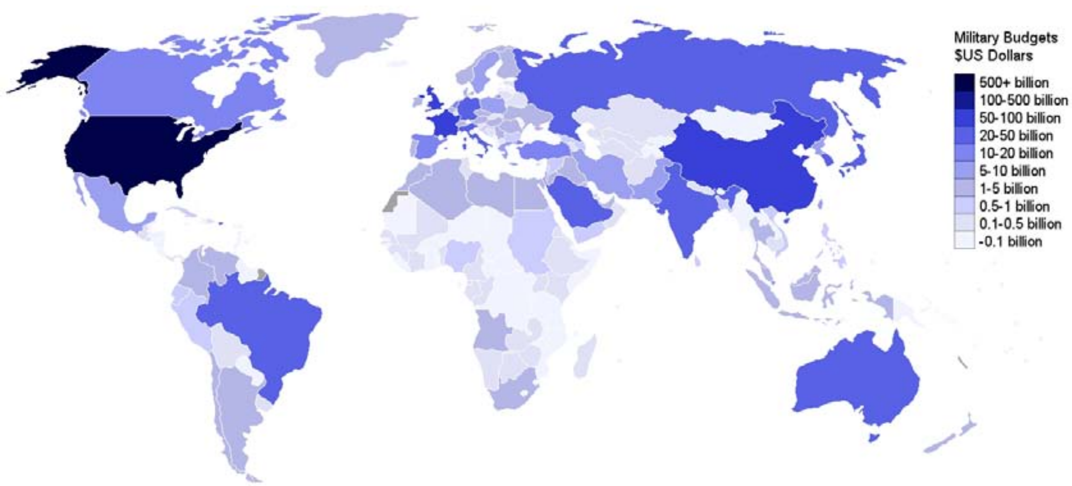

Figure 1: World Military Budget in US. Dollars

Designers play an integral role in this cycle because it is our responsibility to ensure that these new devices and equipment interact comfortably with the user while meeting required performance and production criteria. “We search incessantly for new ideas, new methods, and new materials. We are not content to stand still or to accept present processes as the final word. If we are to progress, we must constantly evaluate the status quo, and if what it stands for is no longer valid, we must abandon it" (Dreyfuss, 1955, Designing for People). With these advancements and continual growth it is important to create useful items that can work with current and future models of equipment. This is important because the time between development and integration is not immediate. Along with this, new articles of equipment may conflict with existing equipment in a manner that often leads to one of the items being disregarded. "Too often a piece of equipment is delivered which, though functional, is unusable" (Dreyfuss, 1955, Designing for People). With this continual growth and constant re-development, the creation of new equipment, as well as allowing a single item to have several different functions, causes clutter and overcrowding of equipment to a point of being unmanageable. Here the risk of over- complicating equipment for the soldier comes into play, and if one function is damaged it could potentially affect other functions, inevitably making the item unusable.

"Today more and more design problems are reaching insoluble levels of complexity… these problems have a background of needs and activities which is becoming too complex to grasp intuitively…The intuitive resolution of contemporary design problems simply lies beyond a single individual's integrative grasp" (Bar-Cohen, 2006, Biologically Inspired). To combat this, designers should seek solutions that are progressive in taking advantage of the technological capabilities that were not present 30 years ago, yet functional enough to be implemented with the soldier; it is possible to take a piece of equipment and continually build upon each generation, so that the latest model is a culmination of aspects that benefit the soldier and the equipment only increasing in its ability to increase the lethality of the Marine. This type of design thinking should be adopted in military designs in an effort to stop equipment from dealing with the same issues. “Make the model as simple as possible but not simpler” (Zatsiorsky, 2002, Kinetics of Human Motion). The focus placed into a single design should be in the elimination of unnecessary parts. Having a model function at a maximum level, while using relatively fewer parts to manufacture, will reduce cost, weight, clutter and assembly confusion for the soldier. But these decisions should be based on reason, analyzing and factoring in mission specific aspects necessary to optimize the soldier’s ability to complete operations successfully and effectively. Along with simplifying designs, equipment must also be intuitive; there should not be much, if any, confusion on the soldier’s behalf about how a piece of equipment functions. “Because of their intuitive characteristics, the use of biologically based rules allows for the making of devices and instruments that are user-friendly and humans can figure out how to operate them with minimal instructions”(Benyus, 1997, Innovation Inspired by Nature). The goal is to take a piece of equipment and design it around basic human factors as well as basic military movements, such as working with the proper firing stance. Designers must make sure that the equipment’s operations are so straightforward that few if any instructions are necessary and an individual will instinctively know how to operate and use the design.

Personal protective equipment has evolved without the input of the user; changes instead overcome a small number of problems, while forgetting the original aspects of the previous design. The design of the equipment generally takes one step forward and two steps back. The previous models should not be forgotten but used a foundation to build upon. The design should continually manage to overcome the original presented problems while solving new and unforeseen ones. “Tracing the evolution of technology over generations of products, one can observe numerous instances of designs being encapsulated into modules, and those modules being used as standard higher-level building blocks elsewhere” (Bar-Cohen, 2006, Biologically Inspired). I believe in this idea, taking a design and breaking it down to its simplest form which can continually build upon itself as well as taking the simplest design and having it perform its desired objective but being able to act as a starting point for an even more advanced design. Within the DoD acquisition process, there is very little initial focus on the evaluation of the aspects which concern the individual who uses the equipment. This is a vital flaw that should be addressed but the reality of the situation lies in the final cost. From production to materials and technology, every aspect is reviewed to ensure cost of the equipment is within order. However, each year the government spends millions of dollars reevaluating and designing new equipment because of the flaws based around basic human factors and operational usage of the equipment. “No soldier worth his salt is afraid of sleeping cold for a night or two. No good man will become mutinous if he has to go hungry for a day. Not one would collapse of shame if enemy wire ripped out the seat of his pants and he couldn’t get another pair immediately. But you would think that the life of the American nation depended on not letting any of these things happen to a single man in uniform” (Marshall, 1950, The Soldiers Load). Marines operate with the equipment they are provided and any complaints with their equipment is swiftly meet with the determination of completing their operations no matter the condition of their equipment. It is the duty of the design to ensure the equipment used by soldiers will only increase their capabilities. If a more intuitive design approach was implemented and used in conjunction with the acquisition process, human factor based difficulties would be examined and accounted for during the initial development process, thus eliminating the constant cycle of rapid re-design and development.

1.5.2 Internet Research Material

Through the use of the internet, I managed to find a multitude of websites that are used specifically to store documents, articles, data and information on equipment, engagements, processes and procedures pertaining to the military.

1.5.3 Printed Research Material

The printed material I found did not mainly came in the form of books, but rather documents released from the United States Government, more specifically, the Department of Defense. These documents, though helpful in gaining knowledge and insight, did not, however, go over an actual process used for designing or evaluating equipment. The document explaining the acquisition process for the DoD outlined their process for acquiring new equipment, but the information presented is lacking in the area pertaining to the design and of equipment during this process. Unfortunately, I was unable to find any books that specifically outlined, from an industrial designer's point of view, the aspects required to develop equipment with military applications.

1.6 Assumptions

In this study, information from secondary sources such as books, journals and internet sources will be used. It is assumed that the information collected from the sources is factual and presented with as little bias as possible. It is assumed that none of the equipment currently being used by the military was purposely designed to be problematic or ineffective. The project will also feature input from primary sources such as designers and United States Marines. It is assumed that all of the information from these sources is factual based on accurate research with the intent of improving the final outcome of the study.

1.7 Scope and Limits

The scope of this study includes United States service men and women who have served a tour during the war on Iraq or other hostile conflicts and have firsthand experience with the most currently issued military equipment. The study will cover how soldiers must adapt and conform their abilities within the limitations and constraints of their issued equipment. It will also cover how soldiers must continually and significantly re-train in how to use equipment from each redesign. However, the study will not include military weaponry.

The limits of this study are as follows.

- The study will include the current process by which military equipment is evaluated and designed.
- A design approach that will improve the creation and redesign of military equipment will be developed through the writing of this document.

- Prototype testing is limited to a pre-prototype model that will show form and basic use.
- The final model is purely conceptual and will need further development to become a military certified piece of equipment.

1.8 Procedures and Methods

Procedure One:

Research the current military equipment evaluation process.

Method: Research the standards the equipment must meet in order to function in the field.

Analyze collected data.

Draw conclusions.

Procedure Two:

Research the current standard issued military equipment.

Method: Research the currently issued equipment and its predictors and identify the modifications between each re-design.

Analyze collected data.

Draw conclusions.

Procedure Three:

Research the main factors that contribute to the continual redesign of military equipment.

Method: Speak with United States Marines that can identify the problems soldiers face when interacting with the equipment and examine documents and military equipment journals.

Analyze collected data.

Draw conclusions.

Procedure Four:

Research equipment that has been specifically designed with the intention of improving human factors.

Method: Review the “results” of the equipment with specifically designed features to enhance human interface and ease of use and analyze what factors lead to the increased performance of the equipment.

Procedure Five:

Categorize information into groups of factors that cause the design of equipment to be continually problematic, based on but not limited to mobility, functionality, flexibility, weight, bulk, interface and protection.

Method: Design an approach, with consideration of the previously mentioned factors, for designing equipment with military applications. This approach will be suitable for any military branch and issued equipment.

Procedure Six:

Apply the approach to a specific piece of equipment and redesign.

Method: Prove the feasibility of the approach by creating a piece of equipment that improves interoperability, a soldier's mobility, and the interface of the equipment. Create a document that visually and verbally explains the problem, definition and feed for research study, design implications and design solution example.

1.9 Anticipated Outcome

The anticipated outcome for this project is to provide research in order to identify aspects of military equipment that hinder soldiers' effective use of the equipment. From the information gathered on the current military development and evaluation standards, factors can be identified that lead to the design of ineffective equipment. The study will also discover what design aspects increase equipment interoperability, protection mobility and user interface. The information gathered from the research will assist in developing a guideline that specifies how to research and design equipment with military applications that will become increasingly simplified with a greater ability to work with current equipment while positively increasing human interface without subsequently affecting other equipment or sacrificing protection. Furthermore, a prototype will be produced according to the requirement of the guidelines. The prototype will be derived from concept sketches and then made into a physical model.

Chapter 2: Introduction to Research

2.1 Overview

Napoleon Bonaparte once said that “An army marches on its stomach, but an army also performs on the functionality of its equipment.” The evolution of military equipment changes with the needs, difficulties and specifications of the engagement at that particular time. The equipment is also influenced by the available technologies, materials and needs of the soldiers during the engagement. At the same time, equipment evolution is also moved forward and influenced by the enemy’s tactical techniques and offensive capabilities, which include but are not limited to weapons, machinery, firepower and technology. This chapter will outline the evolution of Personal Protective Equipment and the factors that influenced each design. This chapter will also review the acquisition process used for the procurement of equipment.

2.2 Evolution of Ground Troop Equipment

Shortly after World War II, the development of equipment with the potential to reduce fatal wounds and casualties was the primary responsibility of the Army Quartermaster Corps. They were assigned the task of developing helmets, body armor and additional armored clothing worn by soldiers. Before any development was undertaken, the Department of the Army’s Operations Research Office conducted a study in order to ascertain information pertaining to the value of the use of armor for soldiers engaged in active combat. This evaluation of the use of armor for ground troops was initially seen as inauspicious due to the excessive weight of available and standard models. Unfortunately this is a trend that continues to hinder the designs of military ballistics protection. It is the struggle of protection or mobility as it was in 1947: offering a soldier more protection often means adding additional weight and therefore improving mobility means decreasing weight and thus limiting protection. With this concern in mind, the Quartermaster Corps developed a new vest that took advantage of new technologies available at the time and utilized flexible laminated nylon. This materials innovation was lightweight and flexible. The fibers of the nylon were able to trap the jagged fragmentations of low-velocity missiles, which caused the majority of combat-inflicted wounds. Testing of the nylon vests revealed that it was superior to steel in stopping fragments of exploding missiles. In 1948 the first laminated nylon body armor was developed. This first generation flak jacket was made up of two fully laminated pieces, a front and back armor, with a groin apron attached. This design was also a first to be designed around an identified problem for ground troops which the main concern was protection from shrapnel but was faulted in its singular objective. The vest showed that the armor deflected approximately 65 percent of all types of missiles, 75 percent of all fragments, and 25 percent of all small-arms fire. The armor reduced torso wounds by 60 to 70 percent, while those inflicted in spite of the armor's protection were reduced in severity by 25 to 35 percent.

This design was very similar to the World War II vest, armor and apron, and two years later in 1950 the Army nylon armor was redesigned as a one-piece vest. This would be the flak jacket model used as the forerunner and foundation behind all modern flak vest designs, from Korea to Vietnam to today. Though developed in the Korean War, the M1951 vest was used for most of the Vietnam War. Minimal upgrades were made to it with the introduction of the M1952, M1955 and M1969. However, these designs were not looked on as favorable by the soldiers because of their restrictive nature and the lack of protection they offered. The protective collars were also rejected by soldiers because they interfered with the issued helmets. This is a clear example of the soldiers and basic human factors not being included in the actual design as well as other components of the soldiers' gear not influencing the design of the vest. These problems could have potentially been avoided if looked at prior to the design and development of the vest.

Throughout the Vietnam War, soldiers, however, were not protected from small arms fire or shrapnel which led to the death of many soldiers. These deaths could have potentially been avoided if basic human factors were taken into account, making the equipment more suitable and bearable to wear. Due to this oversight, the vests worn during the engagement were often discarded because they were designed without the considerations of the environment and the soldiers using the equipment. The total number of people who were recorded killed during the Vietnam War is 58,193. Out of this number, 18,518 died from small arms and gun fire, and an additional 8,456 died from multiple fragmentary wounds. It was also documented that 1,207 soldiers died from drowning suffocation. From these numbers it is evident that around 45% of the casualties from Vietnam were caused by small-arms fire. We can presume that with some form of ballistics protection that better suited the engagement, the number of casualties could have potentially been reduced.

In 1964, early in the Vietnam War, soldiers used the M1956 Light Weight Load Carrying Equipment, which was re-designed from the World War II web gear in 1956.

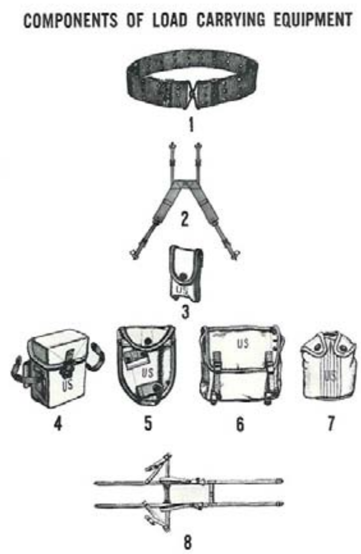

Figure 2: Components of Load Carrying Equipment

The eight components that made up the LCE /LBV consisted of individual equipment belt, suspenders, field pack, entrenching tool carrier, ammunition cases, canteen cover, first aid case/ compass pouch and sleeping bag carrier. The material used to make this equipment was the same cotton used in WWII. The M1956 used All-Purpose Individual Carrying Equipment clips to replace the M1910 hooks. This system was used for only a short period of time due to its poor performance in the tropical conditions of Southeast Asia, and a redesign of the system was issued. In 1967 the new design was implemented and distributed to the troops in Vietnam. The M1976 Individual Load- Carrying Equipment was similar to its predecessor in an effort to allow equipment between the two systems to be interchangeable.

Figure 3: M1967 Modernized Load Carrying Equipment

The main difference in the designs was the introduction of new material, which included nylon and resistant materials that were more suitable to the natural environment conditions of the engagement. The conditions the new material combated were wetness, heat and mildew. Velcro was also used to replace LTD fasteners and zippers that were the current insufficient and expensive means of securing the equipment to the soldier. In addition to these changes, all brass and steel components of the system were replaced with aluminum or plastic in an effort to reduce weight, rust and eventual breaking of parts. These changes in the equipment can also be credited to the advancement of new technologies and materials. For the second time during Vietnam, another design would be produced to address continual and additional problems during the conflict.

The All-Purpose Lightweight Individual Carrying Equipment was implemented in 1974. ALICE was designed to allow a soldier to carry more equipment. The loads of equipment it would hold were broken down into two sections, a fighting and existence load. ALICE was also designed with the ability to be used in every type of environment and withstand hot, temperate and cold climates. This was the first in this series to address the possibility of this system being used in multiple types of environments and future engagements. This system also was the first to combine two pieces of equipment to create a singular functioning system that could also work as individual pieces. ALICE also allowed a soldier to carry all of the equipment, food, and supplies necessary to maintain and complete the operation, called existence load. The existence load was comprised of a frame, lower back strap, waist strap, shoulder strap, cargo shelf, large combat pack, cargo tie down, medium combat pack, and field pack.

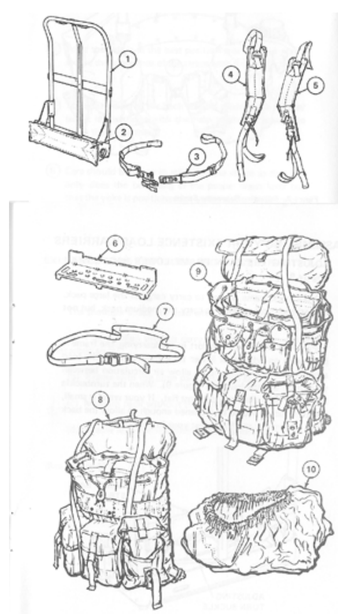

Figure 4: All-Purpose Lightweight Individual Carrying Equipment

The ALICE system's second load type was fighting. This was a system equipped with the first "quick – release" function that would detach the existence load from the fighting load. The fighting load was comprised of the basic equipment necessary to complete an operation in an effort to increase soldier mobility and agility. This load consisted of a belt, small arms case, suspenders, entrenching tool, canteen, and field first aid dressing.

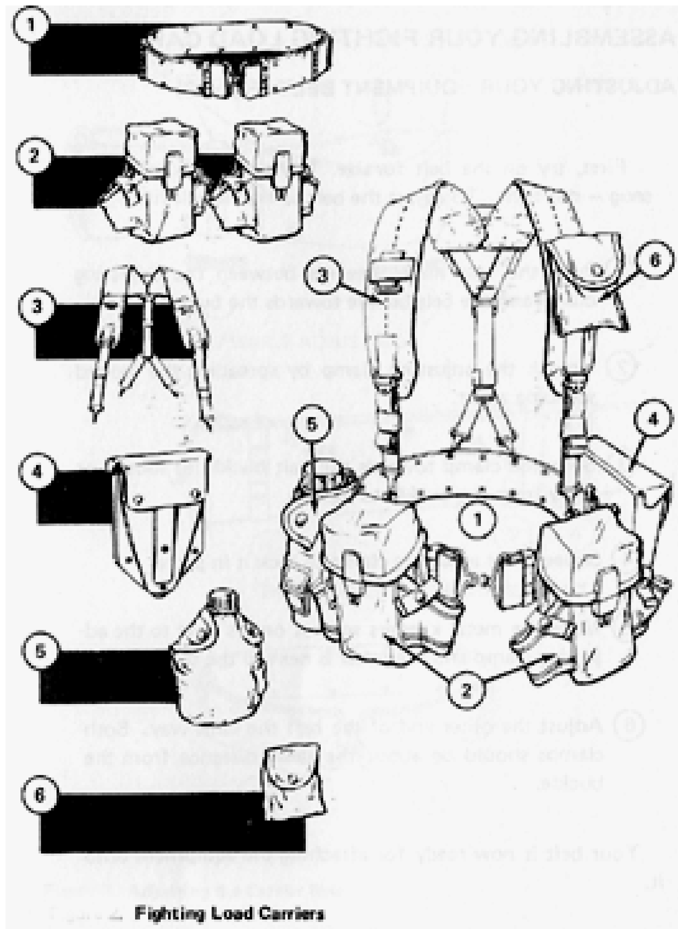

Figure 5: ALICE Fighting Load Carrier

The first real advancement in equipment for ground troops came after the Vietnam War with the introduction of Kevlar and ceramic materials in the late 1970's and early 1980's.

With this development, the newly designed vests, known as Personal Armor System for Ground Troops or PASGT, were the first armor system for ground troops that were actually bullet proof, unlike its predecessors, which merely deflected bullets and only offered minimal protector from shrapnel. The PASGT was designed to protect the upper torso of the body and was water repellent. The inner and outer cover, shoulder pads and front closure flap of the vest were also made to be water repellant. The PASGT vest has improved ability to stop or slow down fragments, compared to the nylon vest of the Vietnam War. It dramatically reduced the number of lethal wounds from conventional exploding and improved conventional munitions. The PASGT vest decreased the number of casualties due to fragmentation by 18 to 53 percent. The PASGT vest was also superior to its predecessor in terms of its camouflage properties and comfort. This vest was the first to have woodland camouflage print on the outside and olive green on the inside. Eventually a three- and six- color desert camouflage covers were issued for the PASGT in addition to the standard woodland camouflage. PASGT inadvertently provided a superior fit and wearer comfort because it was more flexible due to both the materials used and the vest design. The Kevlar ballistic filler in the back was made in four sections; the three upper back sections slid over each other and over the lower back section to allow for any changes in body dimensions associated with various movements. The shoulder pads with elastic webbing and snaps allowed more freedom of upper arm movement, and compatibility with the other clothing and individual equipment was increased. A feature that was taken out of the design allowed the vest to operate with Interim Small Arms Protective Over-Vest. The combination allowed this system to stop 7.62-mm rounds. However, the combined weight of the two systems was 25.1 pounds, considered too much by most soldiers. Again we come to the issue of sacrificing protection for mobility. This vest was deemed too heavy for the average soldier to wear, yet in later designs this opinion is reversed.

Unfortunately all of these designs discussed had only one primary function, which was to allow soldiers to secure and carry equipment or offer ballistics and shrapnel deflection or protection. From here the next evolution in the development of equipment for soldiers was the introduction of the interceptor vest; this was the first piece of equipment unique in its own right, because it combined the primary functions of the flak jacket and load bearing equipment. This combination allowed a soldier to secure limited amounts of equipment, which include grenades and ammunition, onto the vest while offering ballistic protection from small arms fire and shrapnel and being able to be used in conjunction with the ALICE pack. The interceptor vest allowed more protection than the previous PASGT vest while weighing around ten pounds less. The interceptor vest was used during the early stages of the war on terrorism. The vest is constructed from the SAPI or small-arms protective inserts. The vest was additionally equipped with removable throat and groin protectors. While the vest alone could stop a 9 mm pistol round, with the combination of the SAPI the vest was able to stop larger rounds while being more lightweight. This would be the first generation vest to implement the use of ceramic plates as a means of ballistic protection. The new interceptor body armor was worn by soldiers and Marines in Iraq and Afghanistan. The Interceptor body armor became an effective and highly valued piece of gear in the global war on terrorism. The vest was also the first to utilize a new system of securing equipment, known as MOLLE webbing, which was applied to the front and back of the vest. The vest came with removable neck and crotch protection attachments and was designed to work with all current and future anticipated load carrying equipment. Even with these advancements the vest had major problems. With the addition of the MOLLE webbing, soldiers were able to attach equipment to their chest and perform their operations. However, the front opening of the vest was equipped with the MOLLE attachments and due to the weight of the added equipment the vest would continually open. Due to this fact, the only way to compensate for this problem was to avoid placing equipment on the front vest flap, which decreased the area to secure equipment. The vest also did not provide adequate protection from ballistics and shrapnel. The new ceramic plates were only inserted on the front and back of the vest, leaving the sides of the torso exposed. Due to this placement of SAPI plates, if a bullet entered from an unprotected area, bullets would often bounce back between the plates, causing greater damage. Another problem was the ceramic plates themselves. Once a plate is hit, it is structurally damaged and will not work as effectively if struck a second or third time. Then soldiers are left with a plate that is not working at its maximum efficiency until it is replaced. Additional problems pertained to the loss of circulation in the arms in situations where soldiers had to wear the Interceptor Body Armor with the ALICE pack or the Load Bearing Vest instead of the MOLLE pack for which it was designed. Complaints about interceptor body armor accumulated. The vest was still too heavy, too hot and too cumbersome.

From these problems came the rapid development of the Outer Tactical Vest in an attempt to address these major concerns. The main focus of the OTV was to offer soldiers increased ballistics protection. This was achieved by the addition of side protection inserts called side-SAPI plates to overcome the lack of protection offered, but the side-SAPI plates pushed soldiers' arms out and away from their bodies in an unnatural position. The OTV was also being used as a load bearing device, but its original design did not intend for it to be used in such a way. Because of the additional weight of items being attached to the vest, it would continually open up on Marines. The OTV was then quickly redeveloped to overcome these problems, leading to the creation of the Modular Tactical Vest.

The MTV was created as an interim solution during an acquisition process in 2006 and 2007. The Interceptor Multi-Threat Body Armor System in conjunction with the Outer Tactical Vest was not performing to its desired standards. The OTV was not designed to carry equipment and additional armor during USMC missions, but was being used that way. Due to this failure, a design was sought after for body armor with integrated load-bearing capability to meet the need for USMC operations. An accelerated development and acquisition effort was undertaken with the result of the USMC Modular Tactical Vest (MTV). This was to replace the Interceptor and OTV vest, and the cost was about $600 each. The MTV continued with the use of Small Arms Protective Insert (SAPI) Ballistic Protection Plates from the previous OTV armor but developed a new ceramic plate known as Enhanced Small Arms Protective Insert or ESAPI. All of the Marines deployed to Iraq and Afghanistan were issued this vest, and it is currently in use as of 2010. The initial reaction to the design changes were favorable, in comparison to the Interceptor, but complaints mounted that MTV was too heavy and cumbersome, the recurring problem faced by vest development. It caused discomfort when pulling it on or off over the head, and fatigue and exhaustion quickly set in for soldiers on dismounted patrol in the heat from the environment as well as being too constrained in their natural and trained military movements. Development of an Improved Modular Tactical Vest or IMTV was undertaken in 2008 in an effort to re-design and attempt to address the areas of concern with the MTV. The acquisition of this vest was scheduled in 2009 with a delivery and integration date of 2010.

Throughout the evolution of equipment for ground troops, the problems are relatively the same. An overview of the problems are a lack of mobility, over- or underestimation of protection needs which increases weight and diminishes mobility, inconsistencies with acceptable weight requirements, comfort, accessibility modularity, scalability, miscalculation in the environmental effects on the designs and type of engagement. There is also a lack of communication between the user and the designer. Many problems could have potentially been avoided by taking into account the direct concerns and opinions of the soldiers. Coupled with these problems is the lack of an actual design approach or evaluation within the acquisition process.

For the design of the first military flak vest, mobility was at the core. These vests were light weight, and the use of equipment that would add weight was quickly dismissed. Twenty-five pounds was an unacceptable weight, by military standards, for the average soldier to wear just 30 years ago, yet the acceptable weight has increased to a back-injuring 40 pounds with equipment on. The increase in the weight of equipment has occurred primarily due to improved ballistics protection. This increase was integrated into the designs but created equipment that became uncomfortable for soldiers to wear over periods of time and interfered with basic movements. The material selections often conflicted with the environment of the engagement. The past designs also have not taken into account the type of engagement. A downfall in the design of new equipment is the lack of representation of the soldiers. There is not a readily available publicized system where Marines can give their thoughts, opinions and concerns on the equipment soldier's use.

2.3 Acquisition of Equipment

The government is acquiring equipment that generally does not complement the soldier but rather hinders their abilities in one way or another. I believe this is because of the disconnection between the users and the designers, which leads to human factors having a decreasing influence in the overall design and not being reflected in the equipment. This is due to the increase of functions taking greater importance while human factors are having to step back in order to allow for these new functions to operate. Due to the inadequate nature of the equipment, billions of dollars are wasted on trying to solve problems which could have been addressed by ensuring certain factors are continually present and accounted for in the designs prior to the procurement of equipment. There should be a set design approach that bidding companies and contractors could use as the foundation for designing equipment and for the DoD to use as a reference chart to make sure certain aspects are always considered and present within new designs. This would potentially eliminate equipment flaws that are a clear result of the lack of influence from and consideration of the users. This would strengthen the ergonomics of the designs as well as allow companies to ensure that Marines are the focus of the design and every other aspect is a reflection of them. In addition, this approach could be added within an appropriate phase of the acquisition process. Working in conjunction with the other phases and elements of the acquisition process would strengthen the overall process, also allowing the individuals to understand, ensure and acquire the best equipment for the particular needs of the time.

The military acquisition process deals with the investments of the nation, which include programs, technologies and product support that are necessary for achieving the national security strategy as well as supporting the nation's armed forces. The objective of this process is to acquire products that satisfy specific needs and to provide measurable improvements to mission capabilities at a fair and reasonable price. The modern, ever-evolving military acquisition process is a blend of management, science and engineering disciplines that work within the context of the nation's laws and regulation framework to produce military material and technology.

The acquisition process consists of elements that serve as the body for the seven phases. These phases are then divided into milestones.

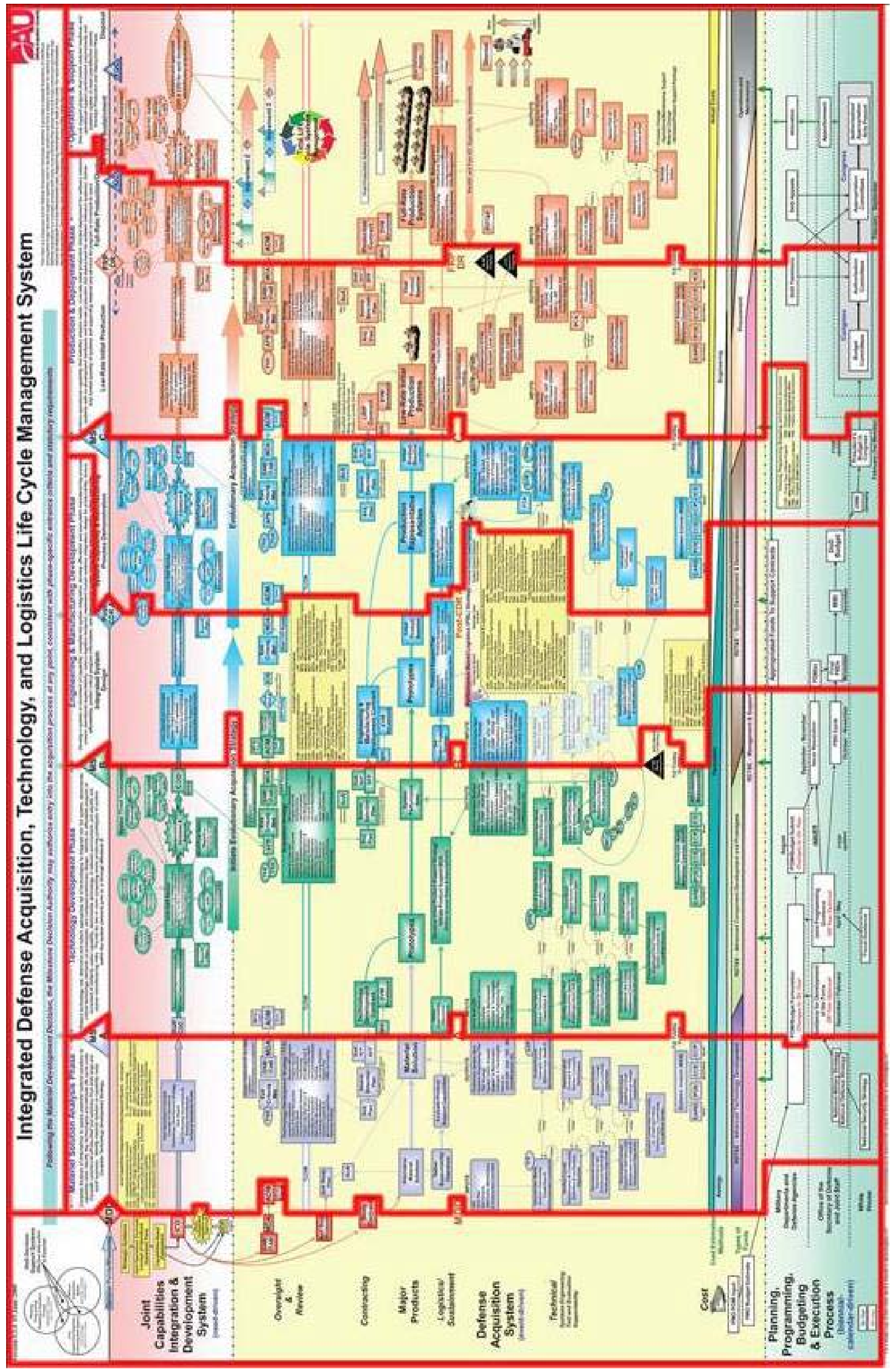

Figure 6: Integrated Defense Acquisition Process

The first stage is the concept exploration phase. It deals with the decision support system, which is comprised of planning, programming, budgeting and execution processes.

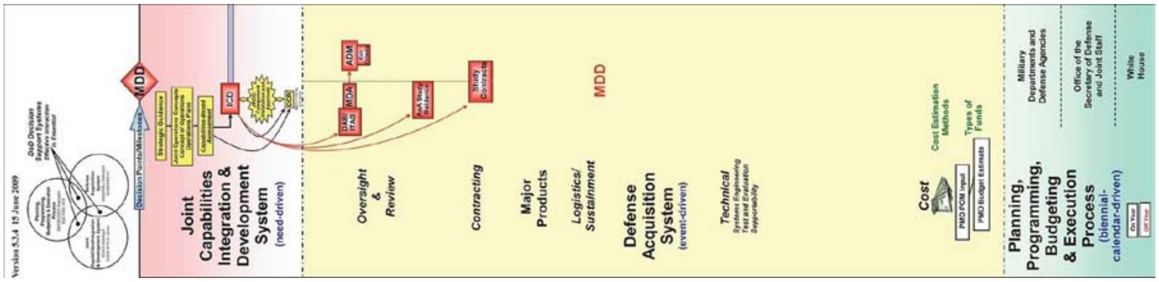

Figure 7: Phase One

The next phase is the material solution analysis phase. This pertains to the complete analysis of alternatives to assess potential material solutions to capability needs. Identification of key technologies and estimation of life cycle costs are reviewed or established. Consideration is given to commercial off-the-shelf solutions from other organizations that meet specific needs. It is within this that material solutions are identified to meet capability needs.

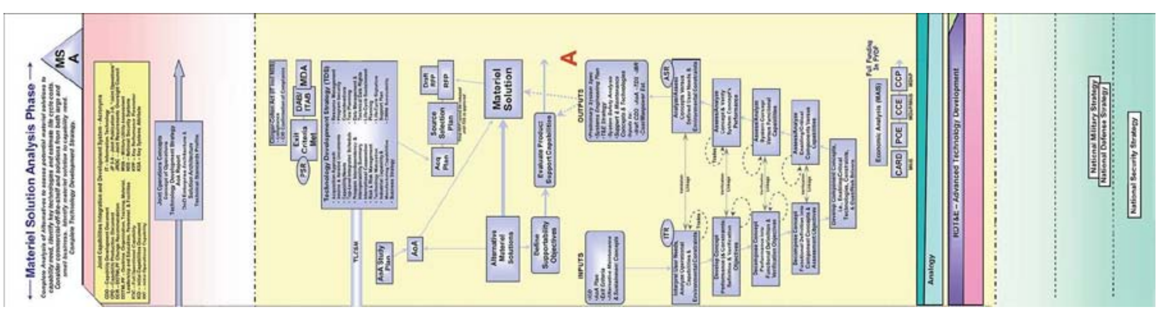

Figure 8: Phase Two

The third phase is the technology development phase. The purpose of this is to reduce the technology risks and to determine the appropriate set of technologies to integrate into full systems. It is also within this phase to demonstrate critical technology elements on prototypes and to complete preliminary designs. This phase continues to identify affordable programs or increments of militarily useful capabilities, demonstrate technology within relevant environments as well as identify and assessment of manufacturing risks.

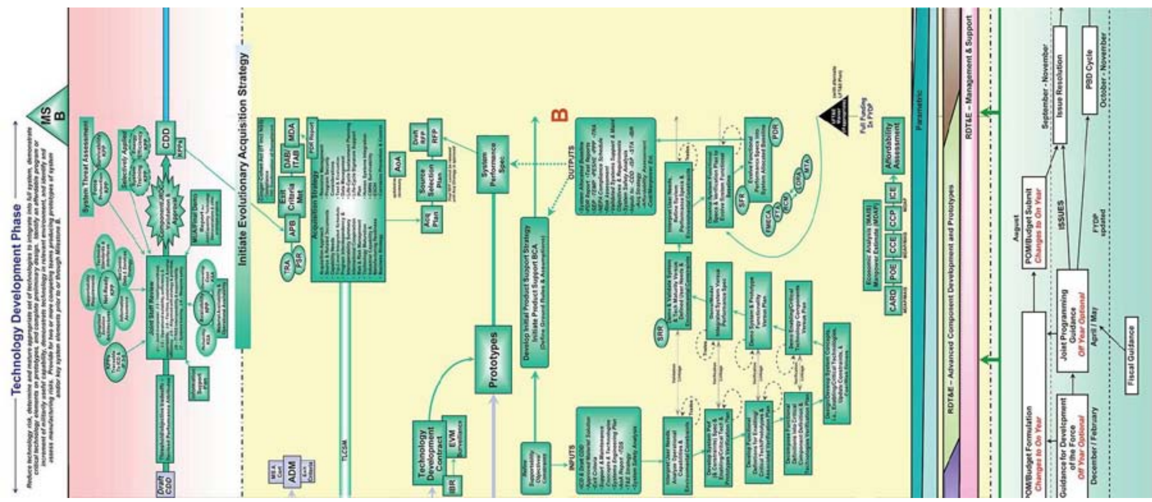

Figure 9: Phase Three

The fourth phase is the engineering and manufacturing development phase. Here individuals are to develop a system or increments of capability. This section is for complete full system integration and development of an affordable and executable manufacturing process. It is to ensure operational supportability and the reduction of logistical footprints as well as the implementation of human systems integration. It also means to ensure that items are designed producibly and affordably. Within this phase equipment must demonstrate system integration, interoperability, safety and utility.

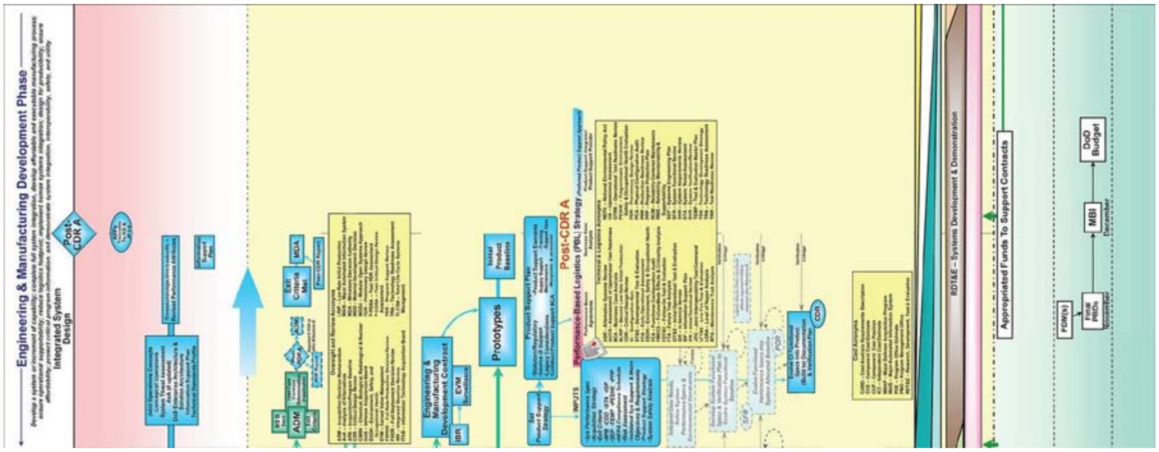

Figure 10: Phase Four

The next phase is the system capability and manufacturing process demonstration. This phase is intended to demonstrate the product in its environment.

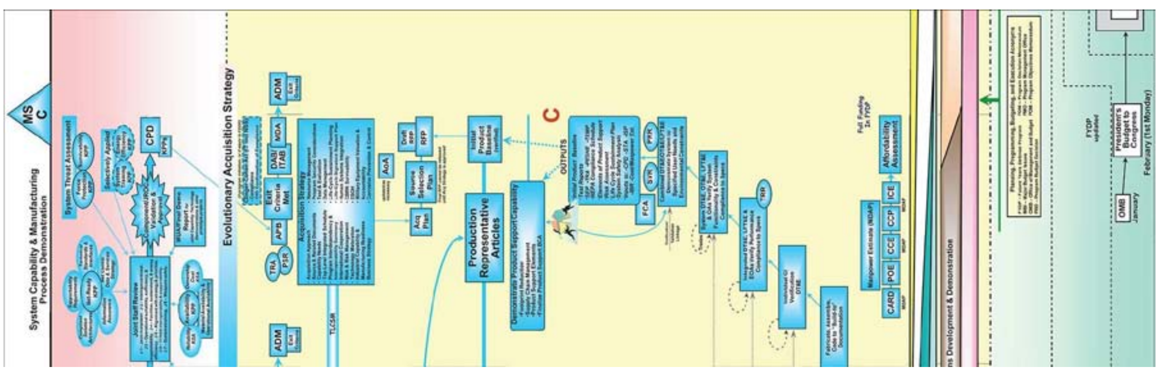

Figure 11: Phase Five

The next phase is the production and deployment phase. This phase must achieve operational capabilities that satisfy the needs of the specific mission. Low rate initial production and full rate production must be calculated and determined. Delivery of fully funded quantities of systems and supporting material and services for programs must also be established.

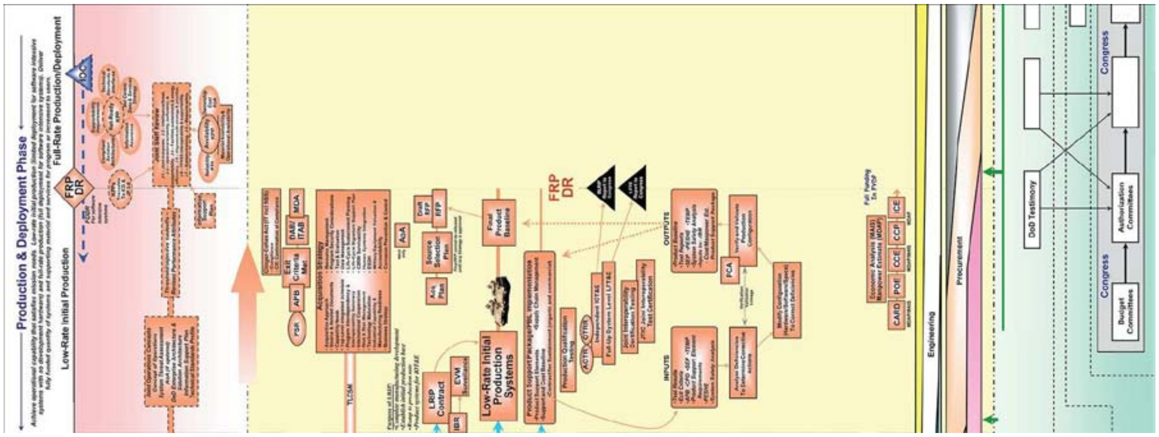

Figure 12: Phase Six

The final phase is the operations and support phase. Here the execution of support programs that meet materiel readiness and operational support performance requirements are evaluated. Systems that sustain in the most cost-effective manner will move forward. This phase also looks at the life cycle of sustainment as well as the disposal of the item.

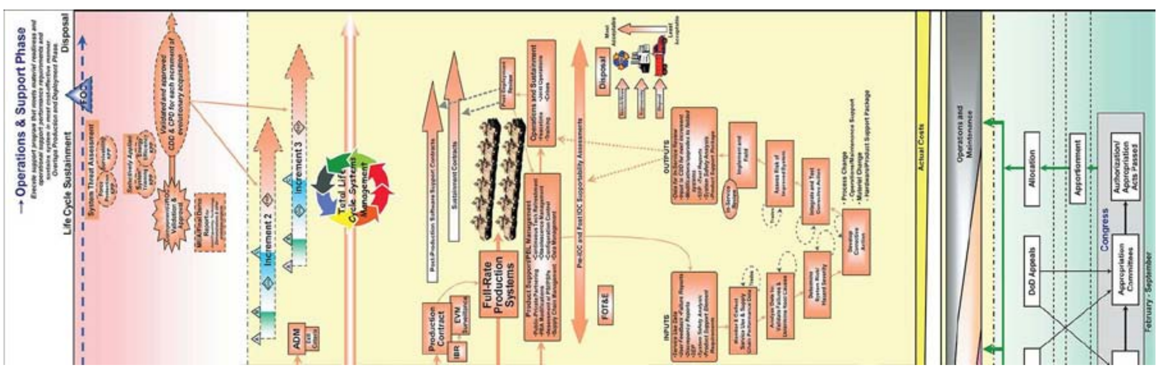

Figure 13: Phase Seven

Overall the acquisition process is an evolving framework that is used as a framework for the development and acquiring of equipment and products. It is a system that takes into account the specific needs of the time and can be selectively used to best accommodate those needs. It is rare that a product actually goes through the entire system. Depending on the specific needs, the item at hand can be placed into a specific milestone if deemed necessary. The entire process does not happen overnight, but rather over the course of a year or more depending on the situation. However, for example, if there is an immediate need for a specific piece of equipment, the process can and will be tailored to offer the best solution within a relatively short time. This means the item will skip certain milestones and phases in order to produce results more quickly.

Chapter 3: Design Approach

3.1 Overview

This section will deal with the design and development of equipment with military applications. This section outlines and details an approach created in order to design equipment that takes into account, but is not limited to, the operational, functional, environmental and tactical aspects as well as human factors and assimilates these aspects to create equipment that is better suited for soldiers to perform at their maximum potential. Once this information is acquired, it will serve as the foundation for the design, which will serve to eliminate known and potential future unknown problems with the equipment. This approach is also intended to be integrated within DoD's Acquisition process. This design approach would serve as an additional element within the system to evaluate the designs of contractors during the bidding process as well as functioning as the foundation for the different contractors, companies and designers during their design process to ensure that the necessary factors needed in order to ensure the functional, human and operational aspects of the equipment are present throughout the design approach. This approach would also allow multiple companies to design different aspects of equipment and promote interoperability throughout future military designs.

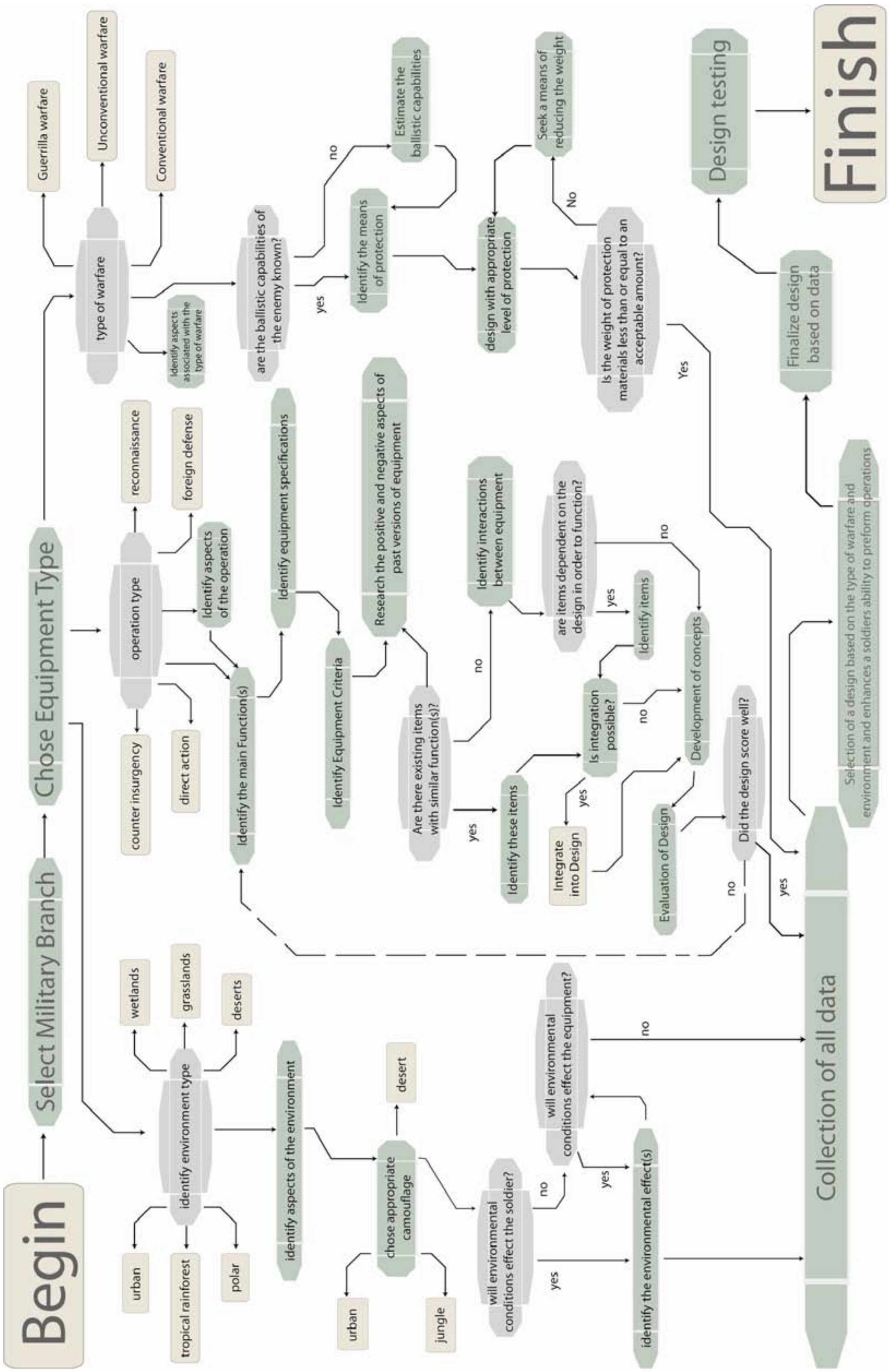

Illustration 1: Flow Chart of Design Approach

3.2 Previous Model Research

The approach begins by identifying the evolution of the equipment under review. This allows the designer to visually understand problematic aspects and outdated technologies that may continue to be in use. This section will also benefit the designer by demonstrating what aspects did and did not carry over to the current system. In conjunction with this, it is essential to understand the purpose of the aspects that were carried over or changed in order to maintain the equipment's core purpose or function. This section will contain two previous and current models. These steps will also stand to identify the similarities and differences between the models. These differences can be, but are not limited to, new technologies and materials, size, weight and core function.

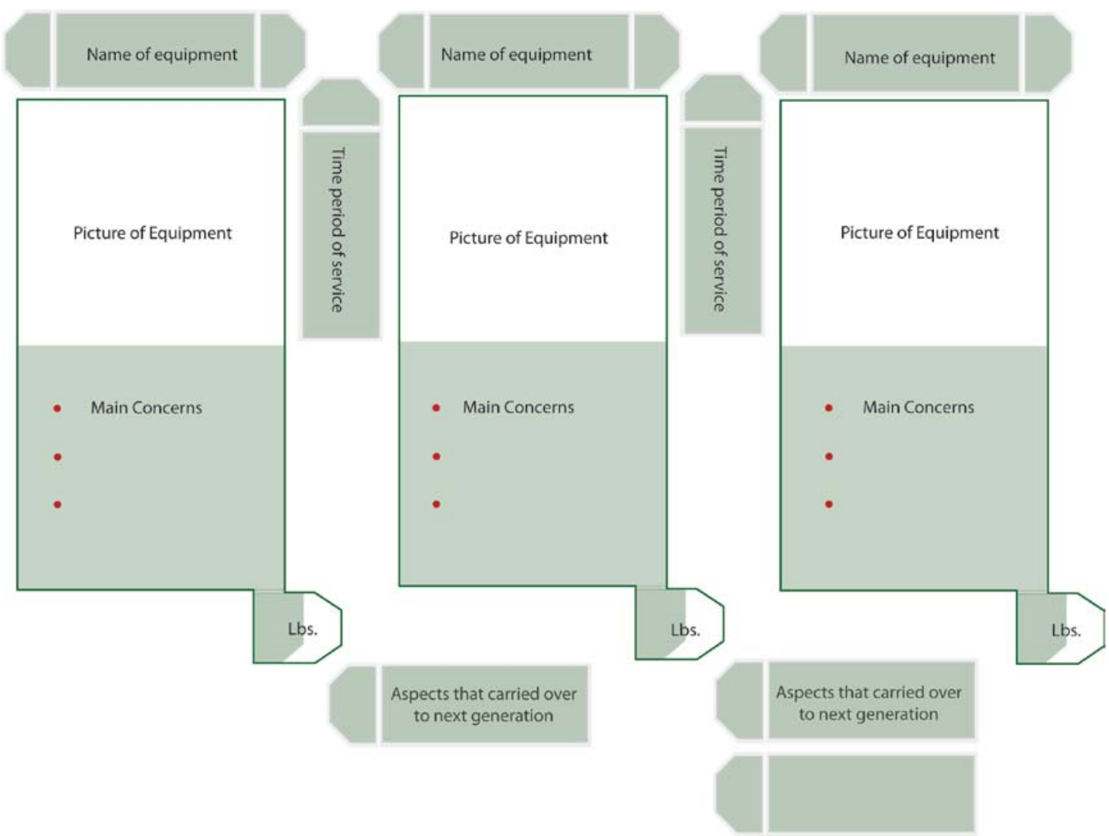

Illustration 2: Demonstration of Previous Model Chart

3.3 Equipment Analysis

The next step in the approach will be broken into two parts. The first portion will identify why the equipment is under review and the problems that lead it to its current state of redevelopment or need of development. This section will detail the initial presented problems that the equipment must address and solve. The section portion will identify the equipment specifications. This information will be divided into four categories: dimensions, materials, integrated technologies, location and weight.

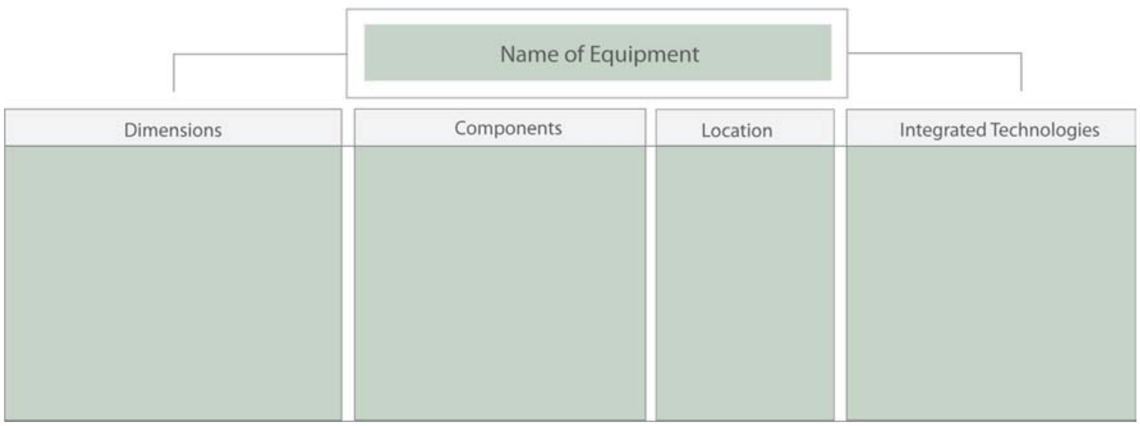

Illustration 3: Demonstration of Equipment Analysis Chart

3.4 System Overview

Within this section the designer will outline the systems that are created when individual pieces of gear come together and then used by the Marine and the equipment under review. This overview of the system is to allow the designer to recognize and identify where the item fits within the system in relation to the other components and in regards to the Marine. This will be represented with the use of a hierarchical tree. This step will also assist in recognizing all of the components, items and parts that come together to create a single piece of equipment and facilitate the understanding that individual pieces of USMC equipment never work as a single system, but with multiple items that constantly affect one another that create a much larger system that constantly affect one another.

Illustration 4: Demonstration of the System Overview Chart

This chart will also serve to improve understanding of where the equipment fits within other systems while visually showing equipment dependencies and vital components that affect the system's ability to operate properly. It is important to realize that any changes in one area of the equipment will resonate through the entirety of the system. It is necessary to understand the role of the equipment that is being redesigned or developed within these systems and recognize that any modification will begin a positive or negative domino effect toward another area, which will lead to the designs' success or failure.

3.5 Operational Research

The design must include research on aspects that directly affect the equipment and the users. These aspects should be used in an effort to create equipment that will directly enhance the soldier during the specific engagement. These aspects include information about the type of war being fought, the hostile combatants, environmental aspects, the type of terrain and the effects each will potentially have on soldiers and equipment. Another aspect which must be researched is the ballistic capabilities of the enemy. Knowing this information, the designer can tailor the design specifically for the engagement in order to enhance the soldiers' ability to complete their operations.

A main concern with the creation or redesign of equipment is that the user's input is far too often overlooked. It is when an overwhelming number of complaints about equipment are realized after a significant amount of time that gear goes under review and then redesigned if deemed necessary. The problem lies in the fact that the only real contribution soldiers can make about the redesign of the equipment is in the form of a complaint, due to their lack of input to begin with. It is imperative that the soldiers' opinions and concerns be taken into consideration with the redesign or creation of new equipment; therefore the information gathered from this portion should resonate throughout the entire design.

Research gathered from this sage should be tailored to the specific needs of the equipment in order to confirm or discover problems that may or may not have been addressed. This primary research will come from individuals with firsthand experience with the equipment. This should include members of the United States military with combat experience with the gear. This research should also include focus groups, again with individuals who have served in a military conflict with experience with the equipment under review.

Another form of research should come from information collected by others, then studied by those who will be redesigning or creating new equipment. This information pertaining to the equipment should come from but is not limited to published texts, documents and media reviews. Information can also be obtained from journals and internet sites dedicated to military equipment.

3.6 Function Identification

With the identification of functions, the designer is able to recognize the main and sub-functions as well as associated problems of the equipment that will be redesigned or developed. This will be accomplished with the use of a function hierarchy chart, where a chart is created listing the equipment's primary function. The sub-branches are added, which detail the secondary and tertiary functions, to which additional sub-branches can be added if necessary. With the creation of each branch, any problems caused by the functions should be listed. This hierarchy establishes a precise order of functions in which to observe the order of importance for each function while redesigning or developing equipment. The main function of the equipment should be at the forefront of the design, while the sub-branches are important in that they should not impede the main function's ability to operate. Analysis of the chart will identify problems or overlapping functions within this hierarchy as well as inconsistencies between the main function of the equipment and the sub-branches. The focus of the design should complement and enhance the main function. Essentially, two charts will be created; the first chart will deal with the current equipment that is being redesigned, or developed. The second chart will only deal with the main and sub-functions pertaining to the new model.

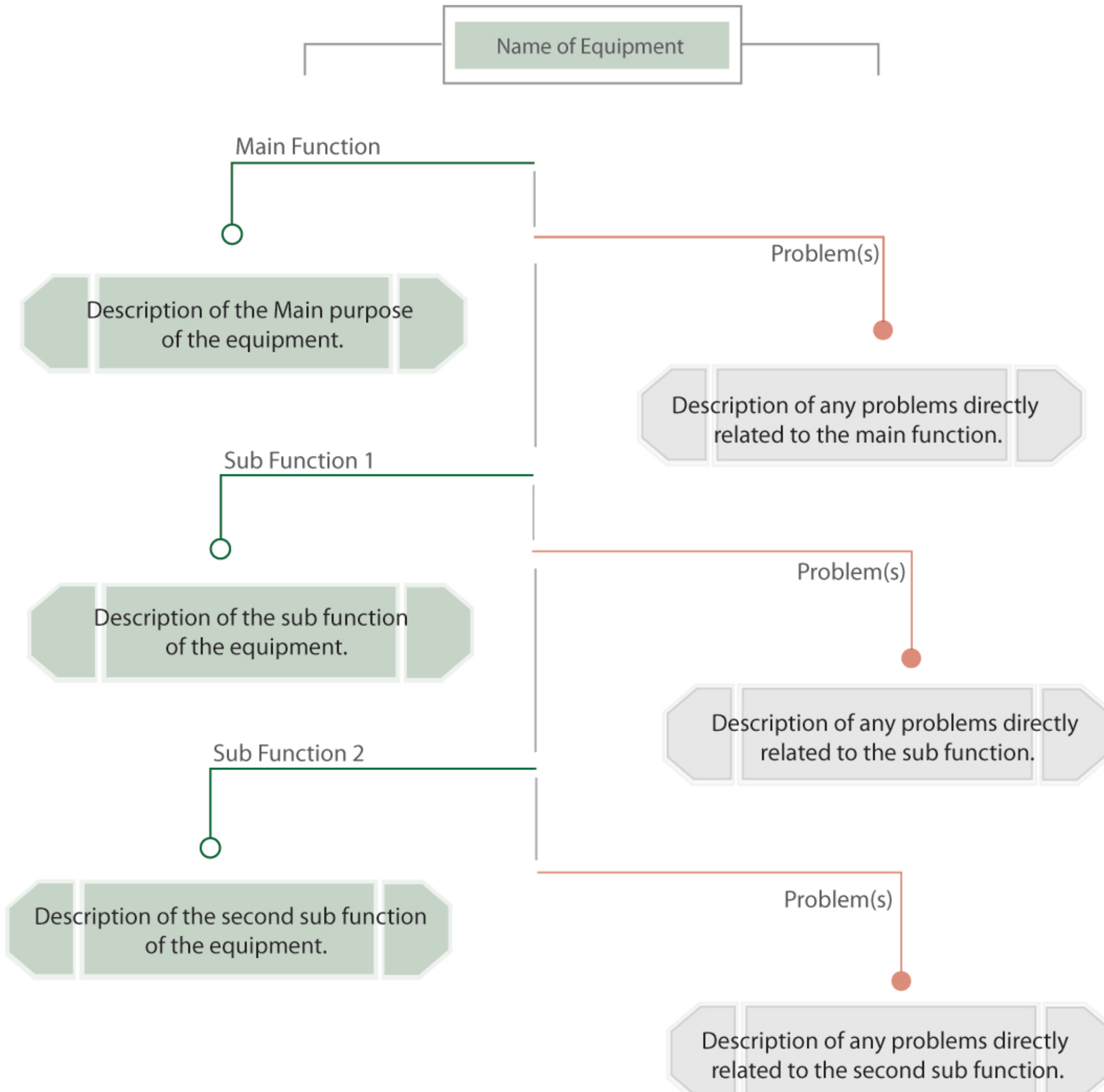

Illustration 5: Demonstration of Function Identification

In order to combine pieces with similar functions, simplifying and decreasing the number of individual pieces a soldier must carry, connections should be established between equipment functions.

3.7 Close Proximity Interactions

The intent of this section is to identify all of the interactions created by the equipment being redesigned or developed. This will be done with the use of an interaction matrix. The chart is to contain the main piece of equipment, as well as all of the gear that interacts with or is dependent on the main piece of equipment to function. The chart will then numerically rank the frequency and proximity of interaction on a scale of one to five, one being the lowest and five being the highest. The pieces of equipment a soldier must wear and carry can overlap or are worn within a few inches of one another. The intent of this section is to understand the relations and frequency of interaction between the user and other equipment. This knowledge will be used to ensure that items with a high interaction rate complement and function seamlessly with one another. It is also used to recognize the dependencies of equipment in order to continue or change that relationship in future designs without damaging the interaction and function of the equipment. Two separate areas will be under review, one being the interaction between the equipment. The second area will focus on the interactions between the equipment and the user. This second section will be comprised of the head, torso, hands, legs and feet. It will include the equipment's frequency and ease of use with details about the location of the equipment in relation to the body part it will interact with.

Equipment	1	2	3	4	5	6	7	8	9	10	Totals
	0										
		0									
			0								
				0							
					0						
						0					
							0				
								0			
									0		
										0	

Illustration 6: Demonstration of Close Proximity Interaction Chart

3.8 Performance Criteria

This section is comprised of the information obtained from the previous sections and any criteria created by the DoD. The performance criteria chart is a culmination of information based on the technical needs of the equipment as well as the researched operational and Marine-based needs. This chart will then serve as the foundation for which concepts and ideation of designs will be established. Through the use of this approach, a designer identifying the parameters of the equipment that is being redesigned or developed will go beyond the military standards and specifications regulated by DoD. This will assist in the creation of equipment that is continually striving to enhance the current state of USMC equipment in order to increase lethality and operational abilities. Illustration 7 illustrates these standards and the level to which the equipment must succeed.

			Concept / Equipment Identification		
			Parameters	Required Performance Criteria	Concept / Equipment Specifications
Human Factors	Aesthetic	1			
		2			
		3			
	Physical	4			
		5			
		6			
Technical Factors	Internal	7			
		8			
		9			
	External	10			
		11			
		12			

Illustration 7: Demonstration of Performance Criteria Chart

This chart will consist of human and technical factors. It will then be broken down into physical, aesthetic, external and internal factors.

3.9 Concept Generation

These steps focus on the creation of criteria for design and the development of ideas and concept sketches. These ideas should be within military standards and guidelines as well as the design criteria set forth by the designer from previous research completed on the equipment. Also during this creation phase an underlying focus should be on the main aspects presented during the equipment analysis section. In conjunction with these criteria and aspects, increased mobility and the reduction of weight should also be a main consideration within any and every design.

3.9.1 Function Streamlining

The next step is to research the possibility of revising the equipment function chart in an effort to simply equipment functions by eliminating or integrating unnecessary or overlapping functions of the equipment. This is done by creating a function innovation matrix. This chart will enable the designer to develop new solutions to a failing function or possibly integrate existing functions in an effort to increase the simplicity and functionality of a piece of equipment.

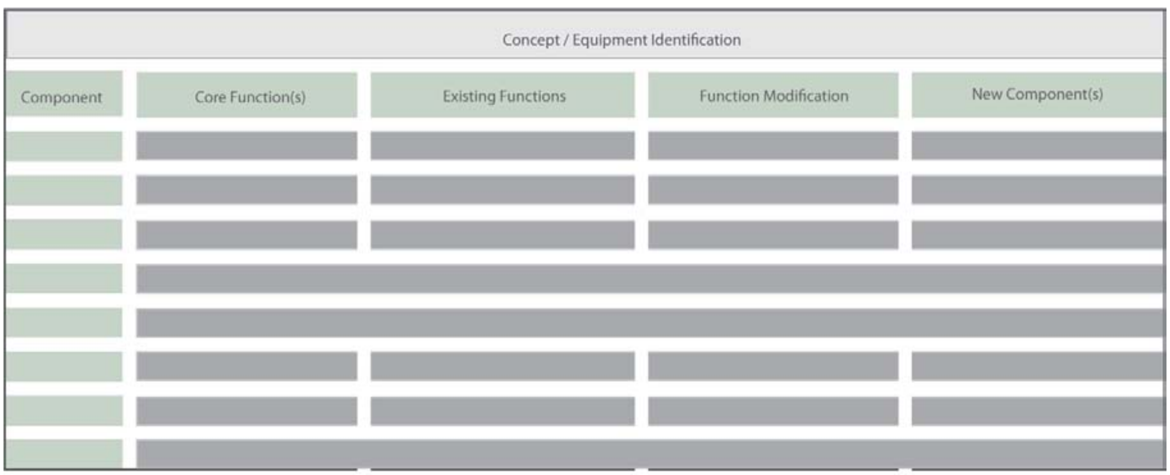

Illustration 8: Demonstration of Function Streamlining Chart

3.9.2 Function Alternatives

Once these initial steps are completed, the designer can begin to develop design concepts based on the performance criteria. These concepts should include but are not limited to the criteria created by the designer. During this stage the designer should create a morphological matrix in order to organize alternative solutions methodologically.

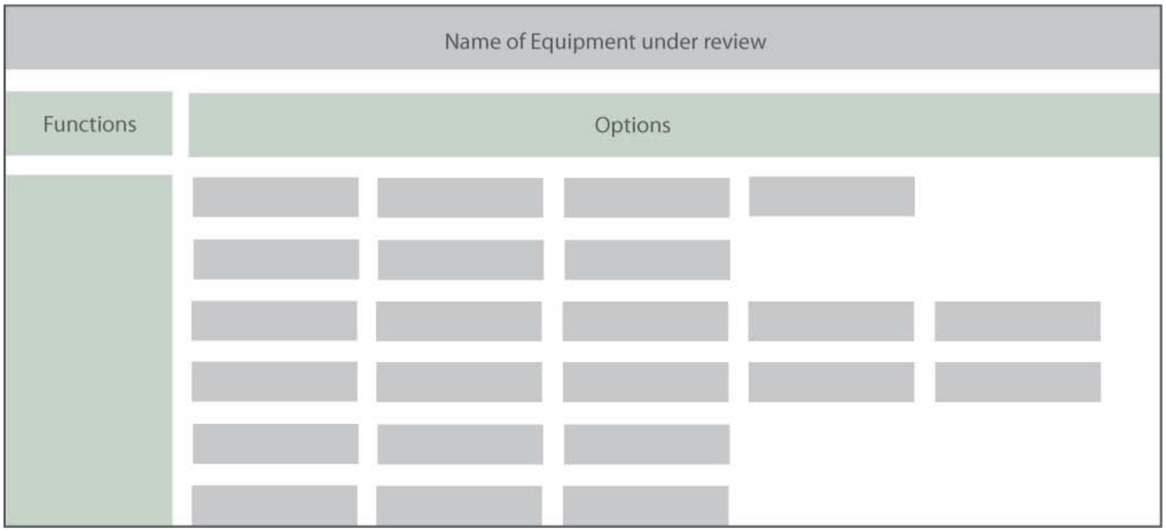

Illustration 9: Demonstration of Function Alternative Chart

The designer should use this chart in order to possibly combine equipment functions to simplify the design, as well as take into consideration the possibility of new technologies and materials which could potentially increase protection and decrease weight and complexity. These concepts should consist of idea sketches, computer and 3D pre-prototype models to display form and basic use. From here the designer will choose the solution that best meets the necessary military standards as well as the criteria set forth in the initial stages.

3.10 Sketching and Development

After all of the information and data has been collected, the creation of design concepts can begin. These concepts will encapsulate all of the aspects researched and will include, but are not limited to, sketches, computer models and pre-prototypes.

3.11 Design Evaluation

The testing done in this phase is to offer support in choosing a concept based on the results from a performance criteria evaluation chart. Each concept will be evaluated with this evaluation system, and the concept which satisfies all of the needs to the greatest extent will go though as the final concept, which will be made into a pre-prototype for additional testing under the guidelines outlined by the DoD, T&E process.

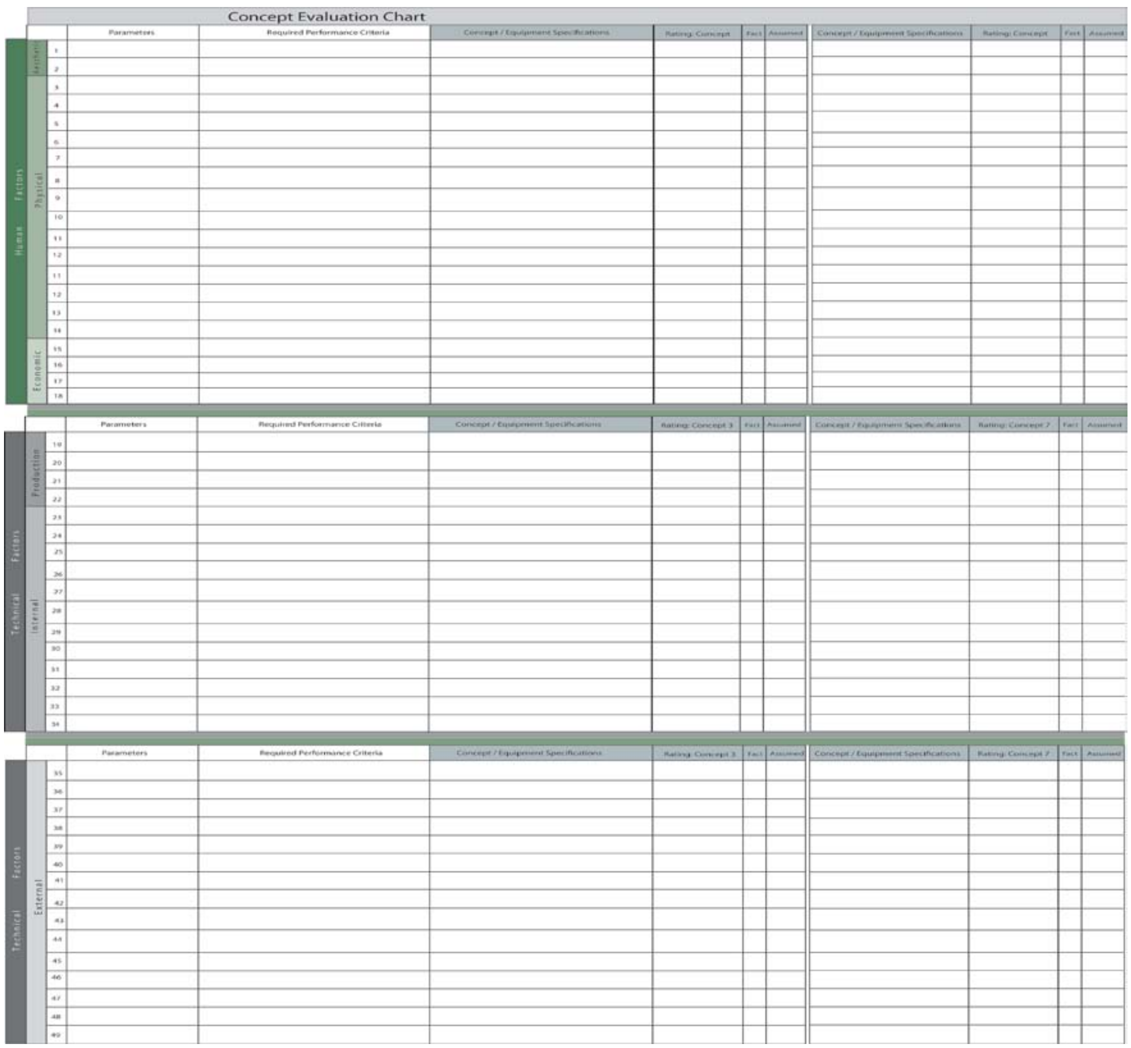

Illustration 10: Demonstration of Performance Criteria Evaluation Chart

After a concept is chosen as the best possible solution, a pre-prototype can be made in an effort for the designer to create a series of controlled simulated scenarios in which to pre-evaluate the designed solution before the pre-prototype undergoes the T&E process. Additional testing of the equipment should be done specific to the standards put forth by the DoD. These tests may include but are not limited to ballistic, environmental and extreme temperature testing. If the solution fails to meet the military standards or criteria set forth by the designer, the reason for failure must be established, and the concept should be recycled back into an earlier stage of the design process appropriate to resolve the problem.

3.12 User Guide

Another aspect to be addressed with design considerations is the sequence of use. The designer must create the method in which the equipment will be assembled and used. This new sequence of use should reflect the changes made to the equipment. This guide should also illustrate each functioning piece and the proper method of use to assemble and properly configure the equipment.

Illustration 11: Demonstration of Proper Assembly

In addition to showing how to correctly assemble the equipment, illustrations and pictures should be used to demonstrate incorrect methods of assembly.

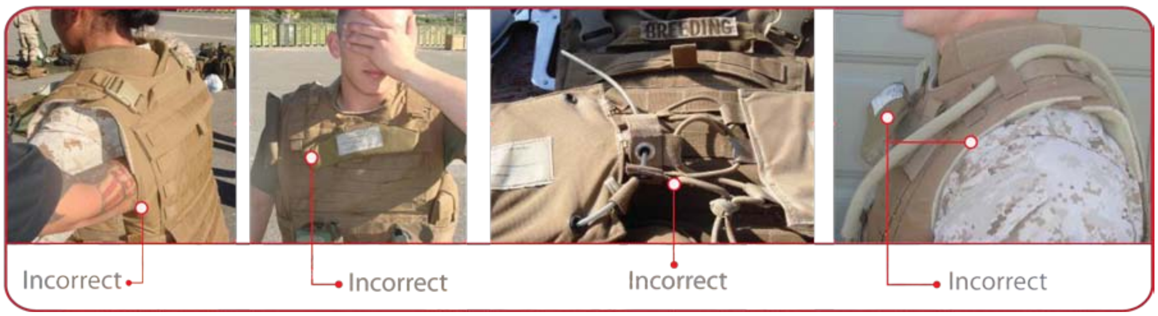

Illustration 12: Demonstration of Improper Assembly

In closing, by using the approach outlined above, a designer will have the information necessary to create equipment for military applications that will continually go beyond the standard criteria and previous versions. The approach will have taken the Marine to the forefront of the design and enhanced the operational capabilities of their equipment and by doing so increased the Marines ability to complete USMC operations. This process will also aid in a designer's ability to make a single piece of equipment work independently as well as in an integrated system to increase the simplicity and interoperability of the gear.

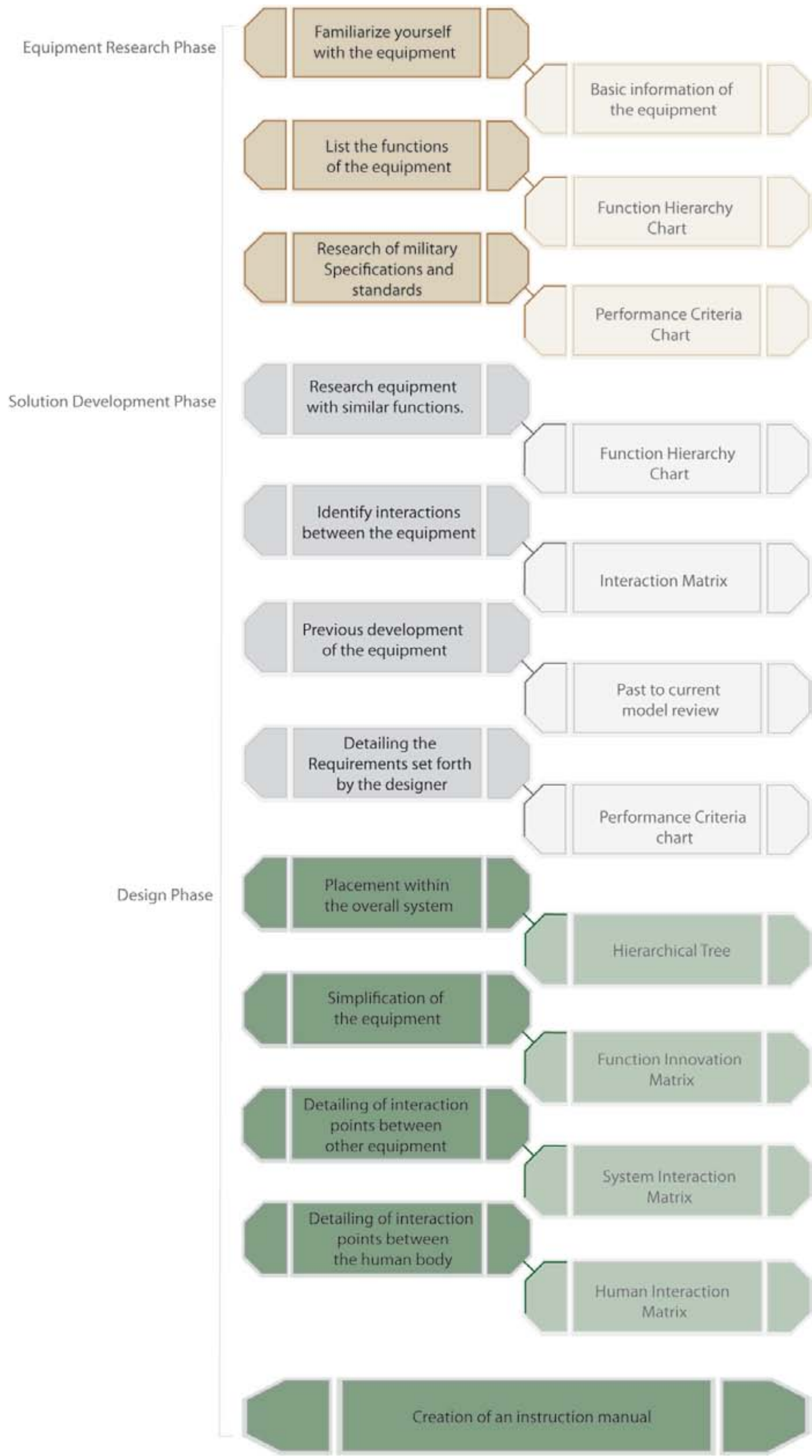

Illustration 13: Design Approach Phase Outline

Chapter 4: Implementation of Design Approach

4.1 Overview

This chapter will focus on the implementation of the created design approach in order to assist in the development of equipment with military applications. This guide will be the basis for creating equipment that addresses the main concerns of the selected gear. The equipment that will be the target of focus is the current USMC-issued flak jacket, the "Modular Tactical Vest (MTV)". The intent of this section is to redesign the MTV by dissecting, analyzing, and addressing current, past, and future concerns.

4.2 Previous Model Research

The first generation vest, the interceptor, was designed with dual primary functions, which included load bearing capabilities and offering ballistics protection. This vest offered minimal protection from ballistics and presented soldiers with an area to secure items onto this vest with the introduction of MOLLE webbing. This webbing consisted of a series of straps that run horizontally across the vest, allowing the Marine to equip items necessary to complete USMC missions.   This new webbing was to replace and eliminate the use of metal fastening clips. During the mid 90's, the interceptor was deemed inadequate due to its inability to adequately protect from shrapnel and larger caliber ballistic rounds. In addition the vest had difficulties staying closed when items were added onto the MOLLE webbing. From these problems the second generation vest, the outer tactical vest was developed. The OTV sought to offer a greater amount of ballistics protection, while it continued to use the MOLLE webbing. The OTV was not specifically designed to carry the increasing equipment load of Marines. Because of this, the vest also had difficulties staying closed with the addition of equipment being placed on the MOLLE webbing. The additional protection that was offered with the OTV included neck and groin protection, but it did not offer sufficient side ballistic protection. Due to operational difficulties and increased hostile ballistics fire power, the vest needed an upgrade, which resulted in the modular tactical vest. Aspects of the OTV that carried over into the third generation vest, the MTV, was its overall resemblance to the OTV which was favored by Marines, the continued use of MOLLE webbing, neck and groin protection, and the use of SAPI inserts. Unlike the OTV, the MTV's primary function was the increase of load bearing capabilities. Its sub-function was ballistics protection because the ballistics protection offered by the OTV was carried over to the MTV. The MOLLE webbing completely covers the vest and offers maximum space for storage. Another aspect added to the MTV was the addition of ESAPI plates for further ballistics protection in areas that were susceptible on the OTV. These changes have also considerably changed the weight over the generations.

In each generation, the primary focus of the equipment has changed. The interceptor had a dual role of ballistics protection and securing equipment to the soldier. The OTV vest focused on ballistics protection, while offering minimal load bearing capabilities but was primarily being used by Marines for load bearing. The current MTV was designed to first focus on the ability to adequately secure equipment and second to continue to offer the same level of ballistic protection as the OTV. These changes in focus have also led to the extreme inflation of the vests' weight, which is one of the main concerns of the user.

The information gained from this section which is to be included in the new design consists of the sufficient protection from IEDs and shrapnel. The ability to carry mission critical equipment, shares a resemblance to previous equipment, and the vest has the ability to close securely with the addition of equipment.

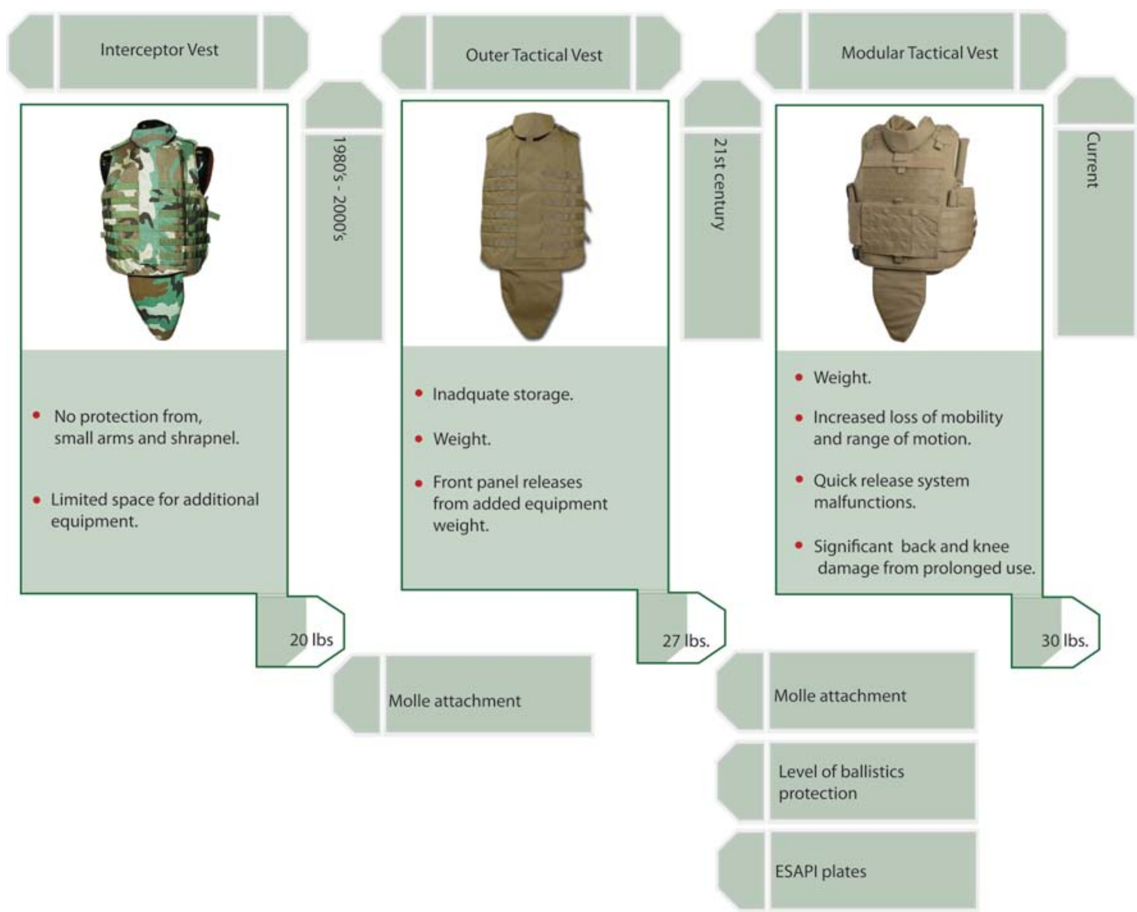

Illustration 14: Previous Model Research Chart

4.3 Analysis of Equipment

The MTV was integrated into the USMC as a Urgent Statement of Need in order to surmount the inadequacies of the OTV while dealing with new tribulations faced during Operation Enduring Freedom and Operation Iraqi Freedom, or OEF and OIF. The amount of protection offered by the MTV increased greatly but in turn amplified the weight of the equipment while decreasing Marines' mobility. An overview of the MTV shows the problems lie in its hindrance of mobility; significant weight; and numerous secure, release and attachment points offered by the vest. The MTV weighs around 30 pounds with the addition of ESAPI plates and Kevlar inserts. This extreme weight supported by a soldier over long periods of time leads to fatigue, lower back problems and most importantly a significant loss of mobility. With the addition of ESAPI plates and their positioning on the side of the torso and the MOLLE webbing configuration throughout the entire vest, the bulk and overall size of the vest severely limits soldiers' range of movement and ability to perform simple trained tasks or move efficiently. These tasks must then be modified in order to work around the additional bulk of the soldiers' equipment. Lastly, the amount of equipment soldiers must carry is increasing at a dramatic rate. This equipment, its placement and its attachment is leading to congestion, clutter and an inability to properly wear and remove the vest. In using the created design approach, the focus will be to reduce these problems, as well as any other inadequacies discovered while using the approach. These factors will be taken into consideration in order to find a solution that will best resolve these issues in order to create a vest that is better suited for USMC operations.

The information gained from this section which is to be included in the new design consists of the operational accuracy of the equipment, reduction of bulk and overall size, better fit, and increased ESAPI plate development.

4.4 Equipment Specifications

The MTV is the currently issued vest used by the USMC. The general sizes are small, medium, large and extra-large. The small size has a back piece measuring a back piece measuring 19 inches in width by 16.25 inches in height and a front piece measures 21.50 inches in width by 13 inches in height. As the size increases, the pieces increase by one inch in width and height. When worn, the vest is meant to offer protection for the torso. The components that make up the MTV include throat protector, yoke and collar, base vest, lower back protector and groin protector. Other technologies used by the MTV include ESAPI plates and the MOLLE webbing system. The total weight, including the ESAPI plates, is roughly 30 pounds.

Illustration 15: Equipment Specification Chart

4.5 System Overview

The flak jacket is part of a military super-system know as personal protective equipment or PPE. It is part of a system that attempts to work together to protect the soldier during hostile engagements and from enemy ballistics. This system consists of a helmet, blouse, back pack, gloves, trousers and footwear. From this system we examine the flak jacket and the sub-system of parts that come together to make the flak jacket. The sub-system for the flak jacket is derived from a neck protector, yoke, collar, lower back protector, groin protector and a vest. Going one step further, the focus of the redesign centers on the vest, and the components that allow the vest to function are analyzed. These components include ESAPI plates, MOLLE webbing, Kevlar inserts, and Velcro strapping and fastening clips.

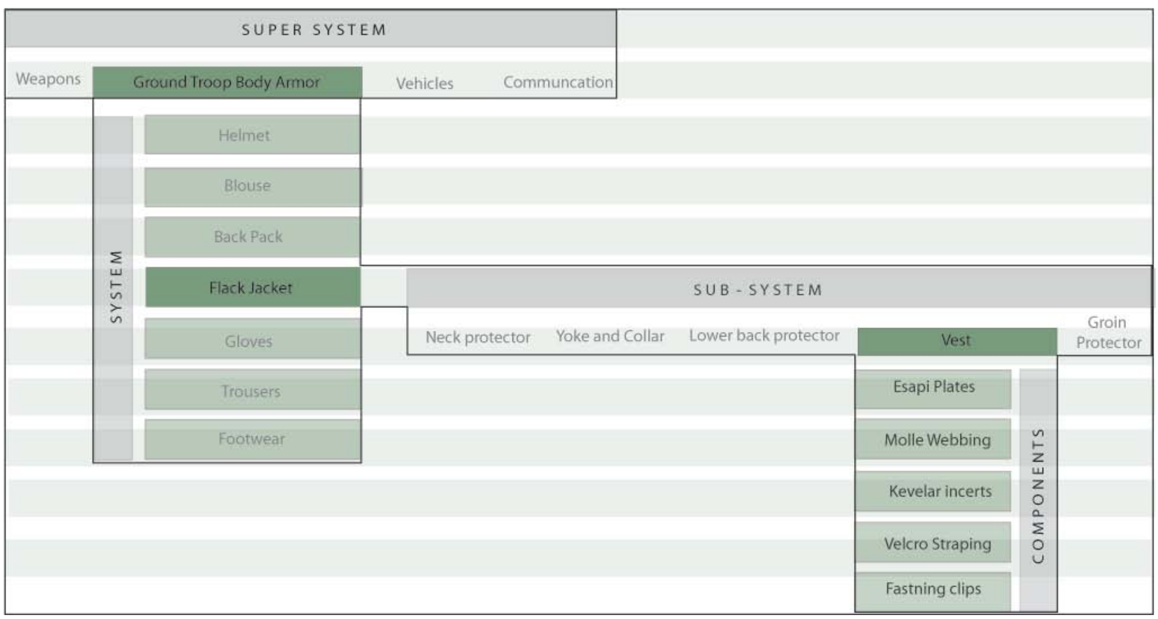

Illustration 16: System Overview Chart

The information gained from this section which is to be included in the new design consists of the removal of ESAPI plates and the exploration in the use of shear-thickening fluid or STF. The removal of the ESAPI plates will affect the vest in a significantly positive way by reducing the weight of the vest and offering more range of motion for soldiers and additional space for equipment. This removal will not negatively affect the other components of the vest or the items in the sub-system.

4.6 Operational Research

The MTV was designed to increase soldiers' load bearing capabilities while continuing to offer the same amount of protection the OTV gave from ballistic threats faced during OEF and OIF. The new design will focus on prevailing over the shortcomings of the MTV for OIF as well as looking ahead to future conflicts. Iraq is mostly desert; mild to cool winters with dry, summers and a terrain that consists of mostly broad plains. Frequent naturally occurring hazards are dust and sandstorms. Areas of military operations are conducted in rural urban areas, and the type of war being fought now is a counterinsurgency. The soldiers are fighting against plainclothes operatives, which means the hostile combatants do not wear protective equipment and thus are extremely mobile. The ballistic capabilities of the combatants include small arms ammunition to 7.62 mm rounds as well as projectile and explosive devices. Surveys and interviews were not used with this specific design. Additional research and information pertaining to the individuals who use the equipment was gathered from government documents made public, as well as from equipment reviews placed in military websites and magazines. The information gathered from these reviews specified the weight of 35 pounds or more was unacceptable because the equipment load inhibits the soldiers from being able to close with and engage a hostile combatant. It is also noted that the bulk of the equipment increases the time it takes to get in and out of transport vehicles and buildings. In addition, the weight of the equipment induces back pain and can cut off the blood circulation to the arms, causing numbness.

The information gained from this section which is to be included in the new design consists of the consideration of heat and urban terrain. The equipment needs to allow for greater mobility and agility in order to pursue plainclothed operatives. Increased protection from IEDs and the reduction of injuries caused by ballistic impacts.

4.7 Function Identification

The main function and purpose of the MTV is to offer the soldiers increased load bearing capabilities, and the sub-function is the continuation of ballistics protection to stop small arms fire and shrapnel. Over the years, there has been a significant increase in the amount of protection offered by the vest. Due to this increase in protection, the weight of the vest has increased significantly, which leads to quicker fatigue, severe lower back problems and decreased travel speed and mobility. This sub-function, also reduces a soldier's range of motion, due to the increased bulk by the addition of ESAPI plates. Simple tasks, such as the ability to properly fire a weapon, must be modified in order to account for this lack of range of motion. The MTV is a vital and unique piece of equipment. Its main function is to offer greater load bearing capabilities for items used during USMC operations. The sub-function is to offer significant ballistic protection to the soldier. The hierarchy of functions as it currently stands needs to be reversed. It should be noted that the main and sub-functions of the OTV and MTV have switched places. The OTV's main function was to offer protection from ballistics fire, whereas the current MTV's main focus is the increase in load bearing capabilities, and the sub-function is the continuation of ballistics protection from the OTV. But the main problem of the MTV is that its current design focuses too heavily on ballistic protection while less consideration is given to the effects caused by the equipment because of this increase.

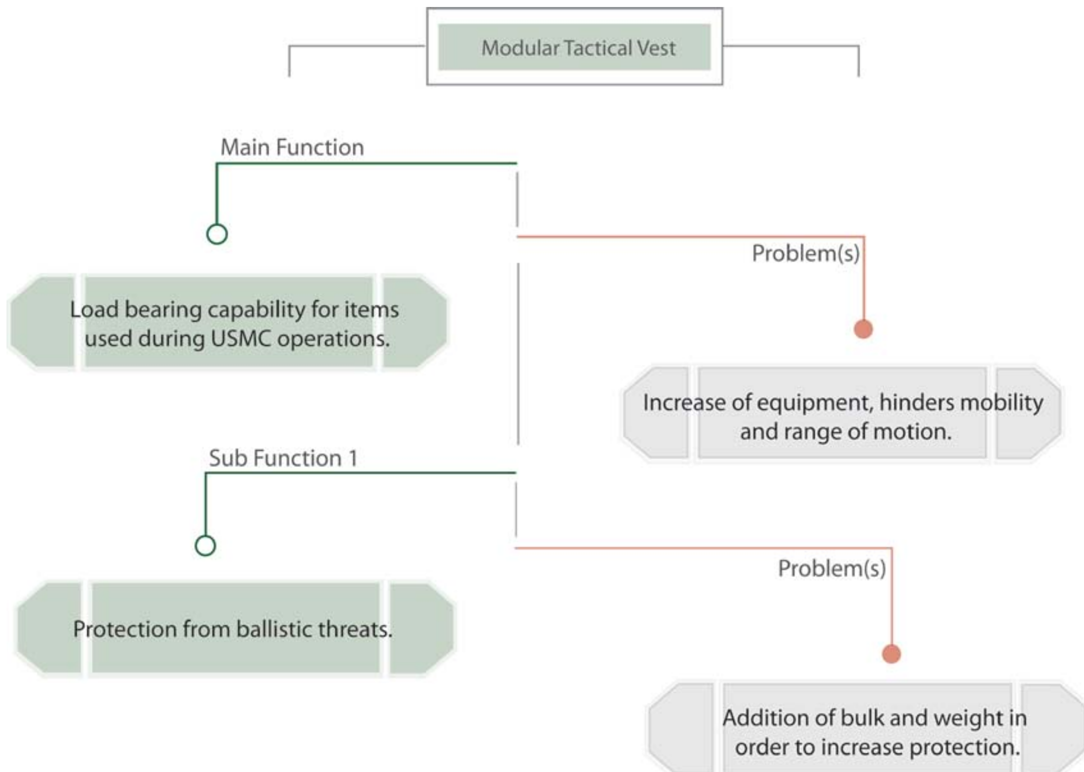

Illustration 17: Function Identification Chart (a)

The information gained from this section which is to be included in the new design consists of switching the main and sub-functions of the equipment. The new design will now focus on ballistics protection while concentrating on reducing the bulk and weight of the vest. A potential problem could be providing inadequate ballistics protection. The sub-function will be load bearing capabilities, with a concentration on minimizing the amount of equipment able to be stored on the vest to mission critical items only. A potential problem could be the exclusion of necessary equipment due to the reduction equipment storage.

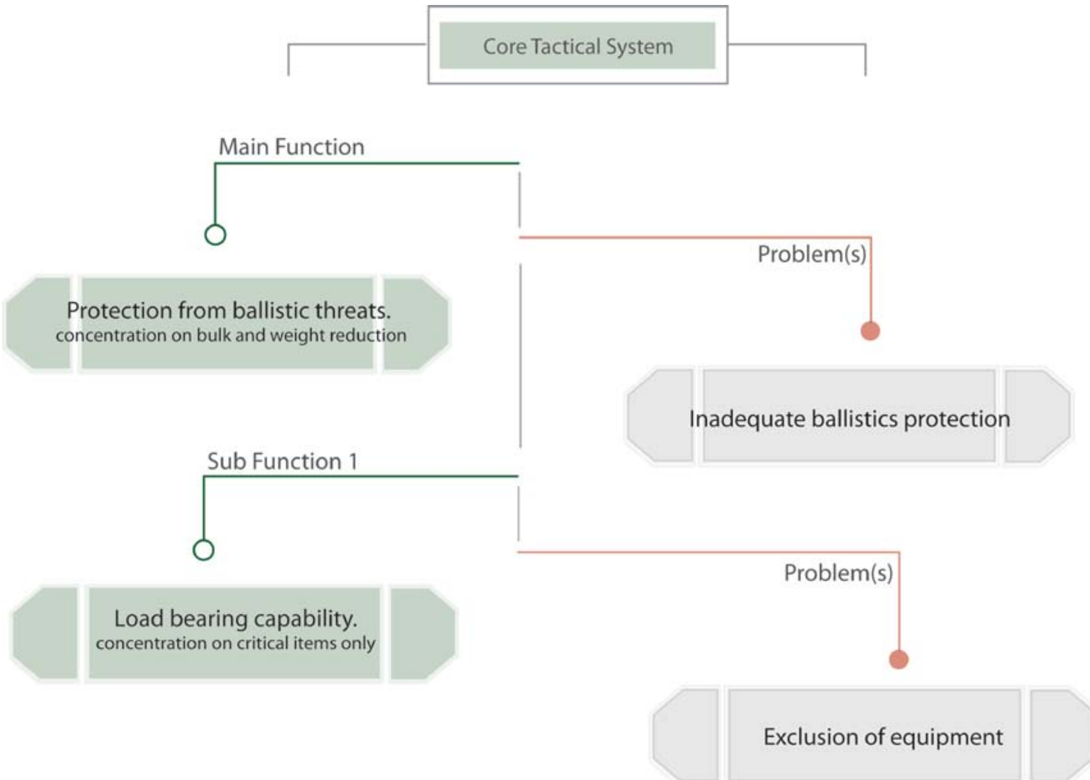

Illustration 18: Function Identification Chart (b)

4.8 Close Proximity Interaction

The tactical vest is a vital piece of equipment that serves as the foundation for the series of equipment used by the USMC. As the foundation, the tactical vest interacts and is within close proximity of a multitude of equipment that is currently dependent on the vest in order to have a location to operate. The vest is used to secure, organize, separate, combine and to ultimately unify the equipment used by the USMC. Depending on the duties of soldiers, their equipment must change accordingly. Even so, there are certain components that transcend individual duties and are used by every soldier. These items include the combat helmet, ballistic vest (MTV), Marine Corps combat utility uniform (MCCUU), load bearing equipment (LBE) and boots. The pieces of equipment found specifically on the vest and within close proximity to one another includes pop-up (Flare), rifle magazine, first aid kit, cat-turnik and radio.

Equipment	1	2	3	4	5	6	7	8	9	10	Totals
Combat Helmet	0	1	1	0	0	0	1	1	0	0	4
Ballistic Vest (MTV)	1	0	5	5	5	5	5	5	5	0	36
Pop-Up (Flare)	1	5	0	1	1	1	1	3	2	0	15
Rifle Magazine	0	5	1	0	1	1	1	2	2	0	13
First Aid Kit	0	5	1	1	0	1	1	2	2	0	13
Cat- Turnik	0	5	1	1	1	0	1	2	4	0	15
Radio / Communication Device	1	5	1	1	1	1	0	2	3	0	15
Load Bearing Equipment	1	5	3	2	2	2	2	0	4	0	21
Marine Corps Combat Utility Uniform(MCCUU)	0	5	2	2	2	4	3	4	0	4	26
Boots	0	0	0	0	0	0	0	0	4	0	4
Human Elements											
Head	5	1	0	0	0	0	4	3	0	0	13
Torso	0	5	5	5	5	5	4	5	5	0	39
Arms	0	2	2	2	2	2	2	2	2	0	16
Hands	2	4	4	4	4	4	4	4	4	3	37
Legs	0	1	0	3	1	1	1	1	5	0	13
Feet	0	0	0	0	0	0	0	0	0	5	5

Illustration 19: Close Proximity Interaction Chart

Analyzing the chart and focusing on the “Totals” column, the designer is able to see the levels of interaction between the equipment. In particularly, vest has the highest total, meaning any changes made to it will affect a greater amount of equipment within the system. Here is an opportunity to simply and enhance the current system. Each of the listed equipment between the total score of 13-15 is currently a separate entity, randomly placed on the vest by the Marine. At the same time, that equipment is not specifically meant for the Marine to use but for another individual to use for the soldier. If a soldier is hurt, the person who is offering assistance uses the injured soldier's equipment. From this a problem arises due to the personal placement of this gear. A soldier has to search in order to find where the injured Marine secured the first aid kit. Creating a vest with these pieces already integrated would allow for more space to secure other gear while increasing interoperability and streamlining the vest to a degree.

The information gained from this section which is to be included in the new design consists of creating concept ideas that give close attention to not impeding the actions of these areas so as to not slow down or lessen the interactions with these areas and the equipment. In addition, the MCCUU scored the second highest on the chart, yet it does not currently have a significant function. The new design will incorporate functionality with the MCCUU.

4.9 Performance Criteria

From the researched information gathered from the approach so far, the next step is the creation of a list of parameters the new design must meet in order to be considered a success. This chart is derived from not only the researched information but any criteria set forth prior to the start of the design set forth by the DoD. Because this is a test of my approach there are not a set of parameters given which this vest must meet. The performance criteria chart will also include the relevant parameters established by the past equipment models. The MTV did not have a list of performance criteria, but instead it had a series of Key System Attributes, which consisted of area of coverage, weight distribution, weapon shouldering, simplicity and increased mobility. These factors will be used in conjunction with the parameters that were derived from my design approach.

Flak Jacket Parameters

Factors	Category	#	Parameters	Required Performance Criteria
Human Factors	Aesthetic	1	Color of Equipment	appropriate for engagement
Human Factors	Aesthetic	2	Visual Appearance	intimidating
Human Factors	Physical	3	Adjustability	must allow for personal adjustment
Human Factors	Physical	4	Assault Pack Interaction	must function with in-use assault pack(s)
Human Factors	Physical	5	Ergonomic Fit	must fit the soldier comfortably
Human Factors	Physical	6	Equipment Comfort	able to be worn over long periods of time
Human Factors	Physical	7	Firing Posture Compatibility	ready, standing, kneeling, sitting, prone
Human Factors	Physical	8	Flexibility	allow for movement
Human Factors	Physical	9	Hydration System Compatibility	work with vest or on its own
Human Factors	Physical	10	Mobility	agility and movement unaffected
Human Factors	Physical	11	Modularity	personal customizing of equipment
Human Factors	Physical	12	Protection Adjustment	single level of protection
Human Factors	Physical	11	Sizes	small, medium, large
Human Factors	Physical	12	Stability	non-movement of vest, armor, pouches
Human Factors	Physical	13	Weapons Management	drop holster
Human Factors	Physical	14	Weight of Equipment	Less than 40 lbs
Human Factors	Economic	15	Advertisement	web sites, magazines, trade shows
Human Factors	Economic	16	Equipment Cost	moderate
Human Factors	Economic	17	Production Cost	moderate
Human Factors	Economic	18	Repair Cost	moderate

Illustration 20: Performance Criteria Chart (a)

Flak Jacket Parameters				
			Parameters	Required Performance Criteria
Technical Factors	Production	19	Assembly Method	automated and manual
		20	Color Application	digital print
		21	Production Process	textile manufacturing
		22	Storage	warehouse
	Internal	23	Fabric Requirements	nylon, cotton
		24	Integrated Technologies	ballistic protection
		25	Interoperability	function similar to other branches of equipment
		26	Hydration System	camel back
		27	Packaging Materials	water resistant fiberboard
		28	Resistances	fire, water, weather
		29	Thread Material	nylon, cotton, polyester
		30	Ventilation	Breathable
		31	Vest Material	acceptable for desired effect
		32	Weapon Compatibility	ammunition access, firing posture shouldering capable
		33	Webbing Material	nylon
		34	Wiring Control	integration into vest

Illustration 21: Performance Criteria Chart (b)

Technical Factors	External	#	Flak Jacket Parameters: Parameters	Required Performance Criteria
		35	Cleaning of Equipment	machine / hand wash
		36	Durability	withstand long periods of active duty
		37	Emergency Detachment System	quick release
		38	Exposed Area, Protection	increased protection
		39	Groin Protection	shrapnel, ballistics
		40	Lower Back Protection	shrapnel, ballistics
		41	Major Artery Protection	shrapnel, ballistics
		42	Mission Specific Protection	modifiable levels of protection
		43	Modular Load Carrying Technology	MOLLE webbing
		44	Neck Protection	shrapnel, ballistics
		45	Number of Components	minimal
		46	Pouch Closures	closure security
		47	Rifle Support	three point sling
		48	Storage Pouches	quick and easy to mount
		49	Vest Secureness	improved means of closure

Illustration 22: Performance Criteria Chart (c)

4.10 Function Streamlining

Of the components of the MTV, the core function of the throat collar, vest, groin protector, ESAPI and Kevlar for ballistic protection. More specifically, the existing function of the throat and groin protectors and vest are meant to protect their respective areas. Functional changes that will be made in these areas will consist of the following. The throat collar will be less cumbersome to the soldier while firing weapons. A new complement added to the throat will be an adjustable attachment. The vest will be redesigned to increase flexibility and increase mobility. Flexible ballistic protection will be a new component added to the vest. The size of the groin protection will have the size decreased to reduce interference with leg movements. A protective groin plate and thigh protection will be added. Currently, the ESAPI plates and Kevlar use removable protection inserts. In the new design, the use of ESAPI plates will be discontinued, and replaced with STF covered soft armor. The Kevlar will become more modular by using smaller individualized inserts. The core functions of the remaining components of the MTV consist of locking and securing items. The MOLLE webbing will have the same existing function throughout the new designs. The Velcro at present is not a reliable means of securing the vest; this will be improved with the use of a downward interlocking Velcro attachment system. The existing locking system is the primary means of adjusting the equipment. The adjustment system needs to be able to function more quickly, and this will be done by using fewer attachment points and increasing the size of the clips to function better with the use of gloves.

Modular Tactical Vest (MTV)				
Component	Core Function(s)	Existing Functions	Function Modification	New Component(s)
Throat Collar	Ballistic Protection	Neck Protection	Less Cumbersome	Adjustable attachment
Vest	Ballistic Protection	Torso Protection	Additional Mobility & Flexibility	Flexible ballistics protection
Groin Protector	Ballistic Protection	Groin Protection	Decreased Size	Form fitting protector
ESAPI	Replaceable ballistics protection inserts		Discontinued use of ESAPI	Shear- thickening fluid (STF)
Kevlar	Replaceable ballistics protection inserts		Modular Inserts	Smaller Individual Kevlar inserts
Velcro	Attachment points	Secondary attachment point	Increased reliability	Downward interlocking attachment
Locking System	Adjustable attachment	Primary attachment point	Quicker fastening ability	Larger fastening buckles
Molle Webbing	Organization and securing of equipment			

Illustration 23: Function Streamlining Chart

4.11 Function Alternatives

Within the new designs, exploration of new ideas for protection, storage, intimidation, communication and display will be created. This area mainly pertains to areas less focused on in previous sections. These include the possible use of built-in and removable storage compartments. Looking into the area of intimidation, one possibility is to design the vest to be visually threatening or futuristic, even possibly incorporating high-intensity lighting or sound to deter or nullify potentially hostile threats. I will also look into the use of integrated personal communication devices as well as a display system built into the vest to show vital information pertaining to the soldier such as blood type and identification. I will also explore combining the hydration system with the flak jacket to reduce the amount of equipment the Marine needs to carry.

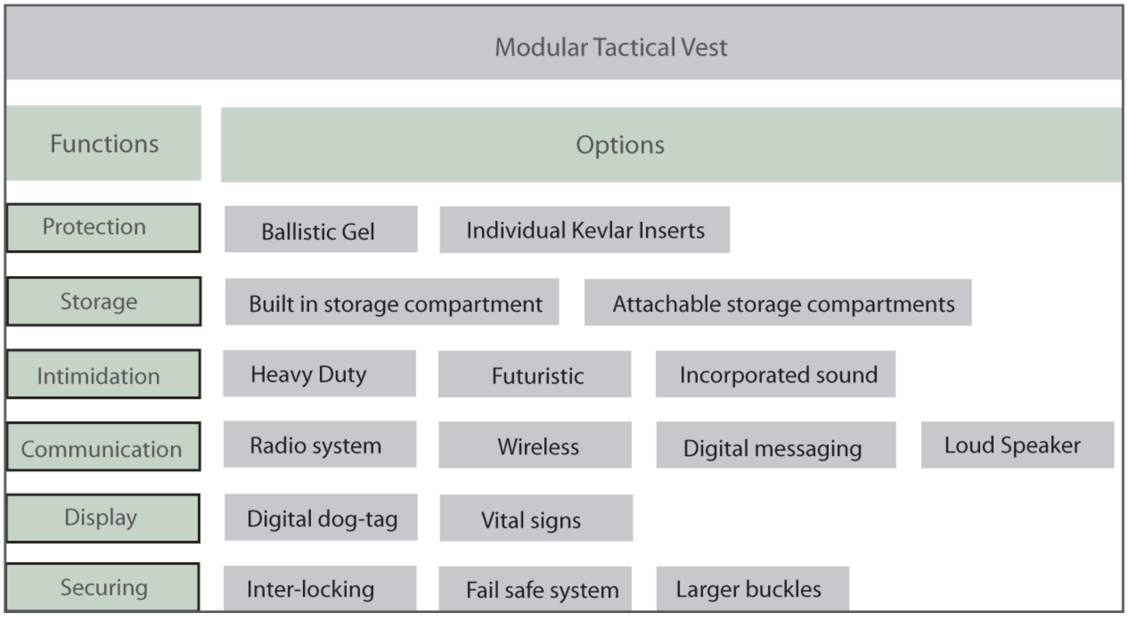

Illustration 24: Function Alternative Chart

4.12 Sketching and Development

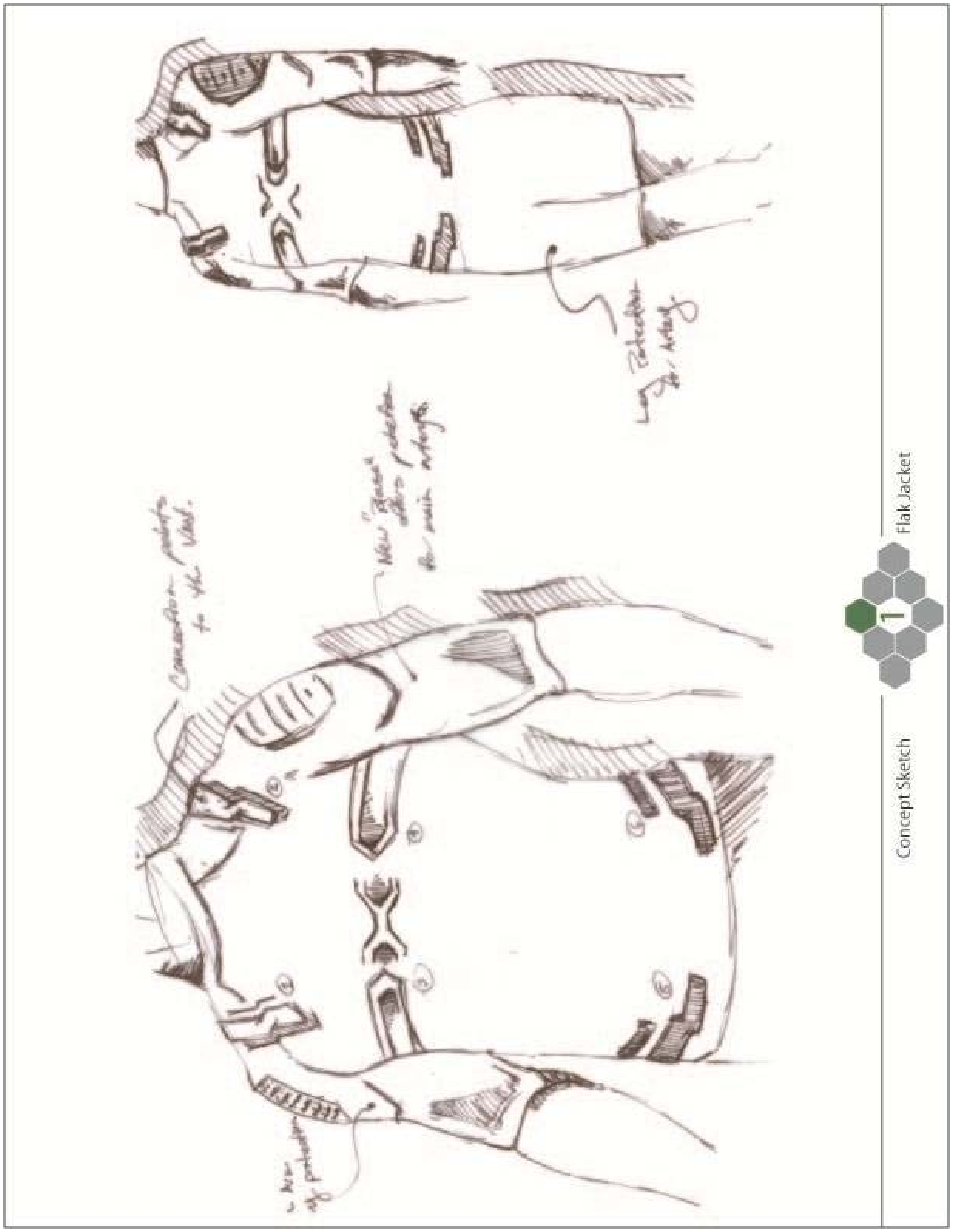

Illustration 25: Concept Sketch One

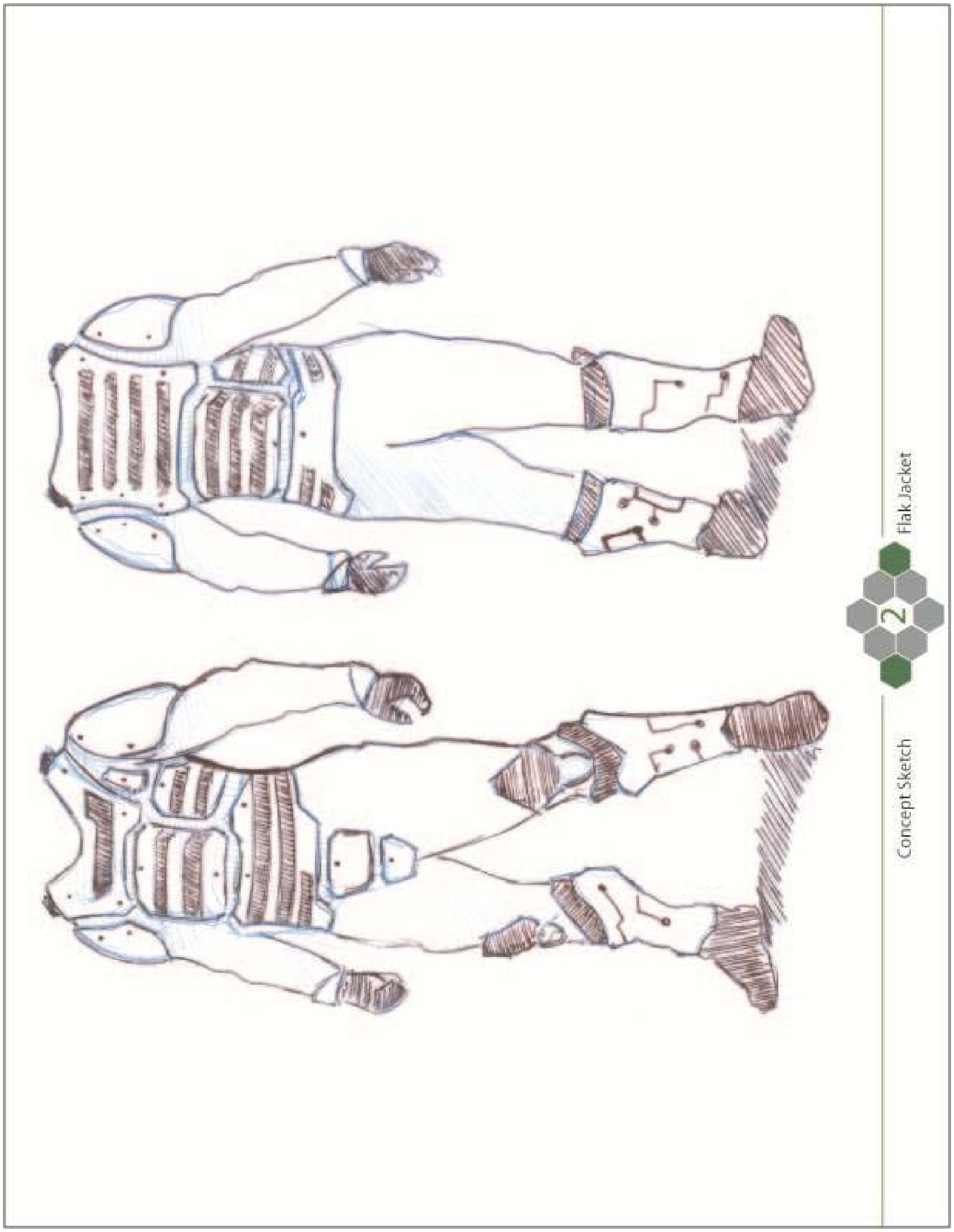

Illustration 26: Concept Sketch Two

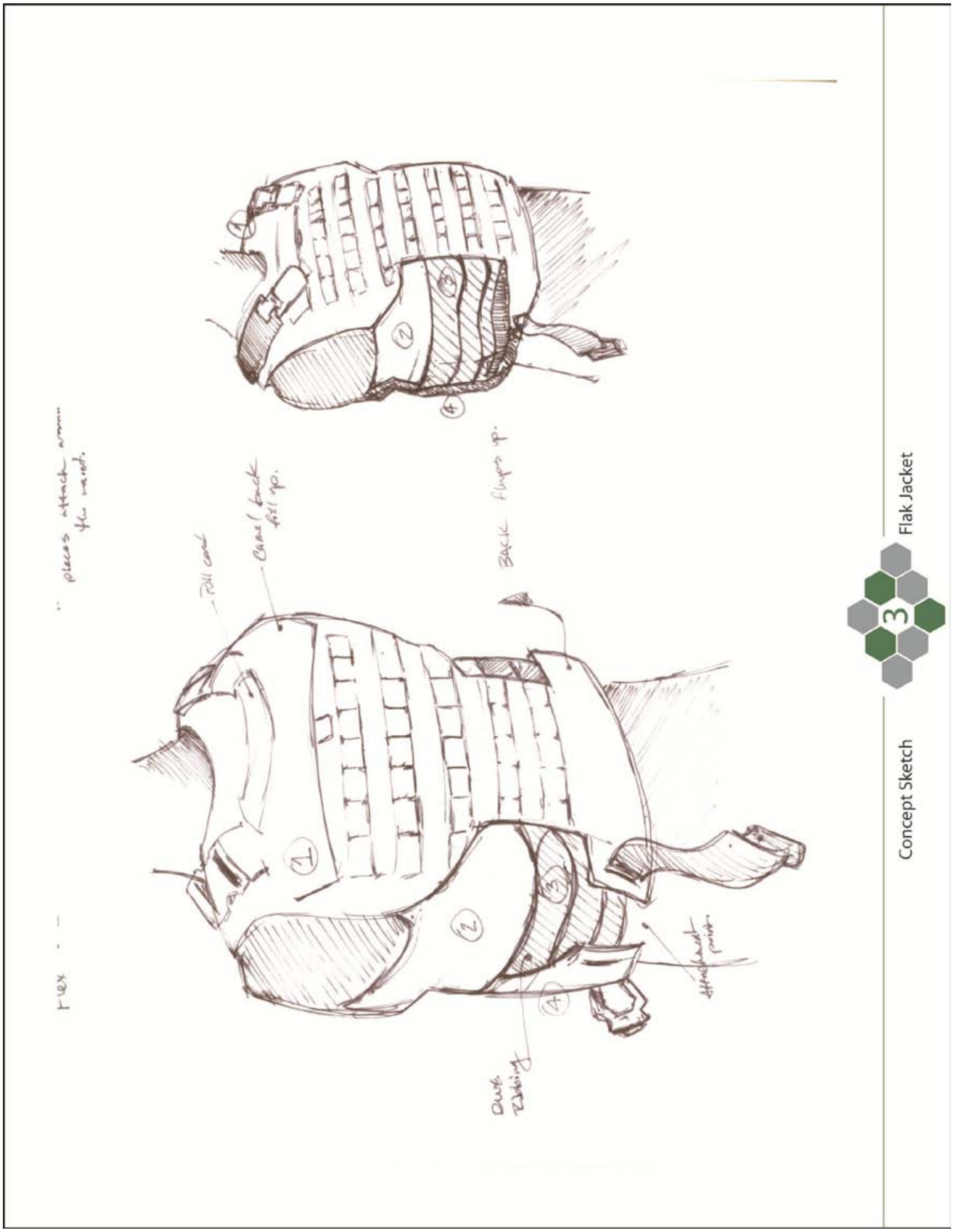

Illustration 27: Concept Sketch Three

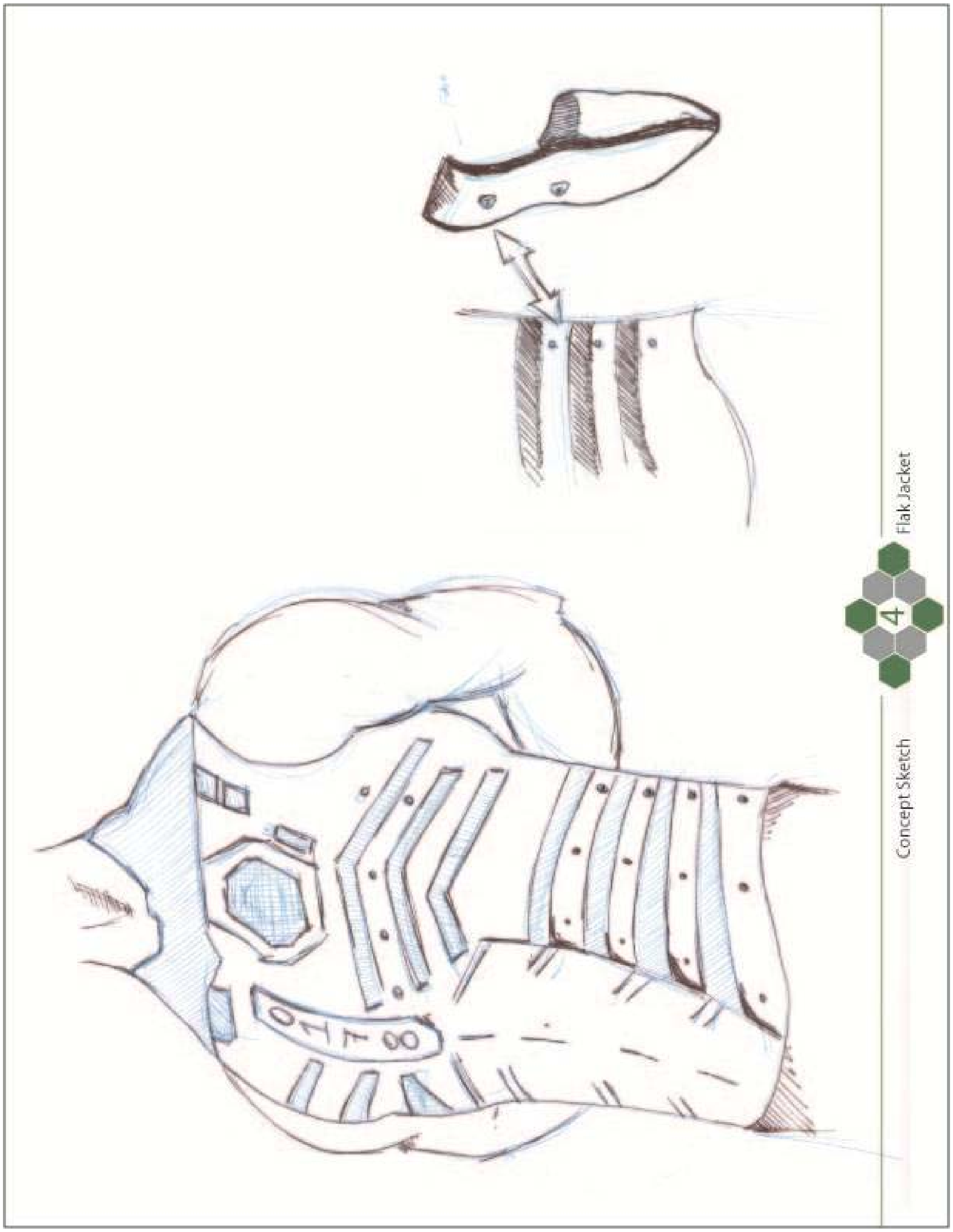

Illustration 28: Concept Sketch Four

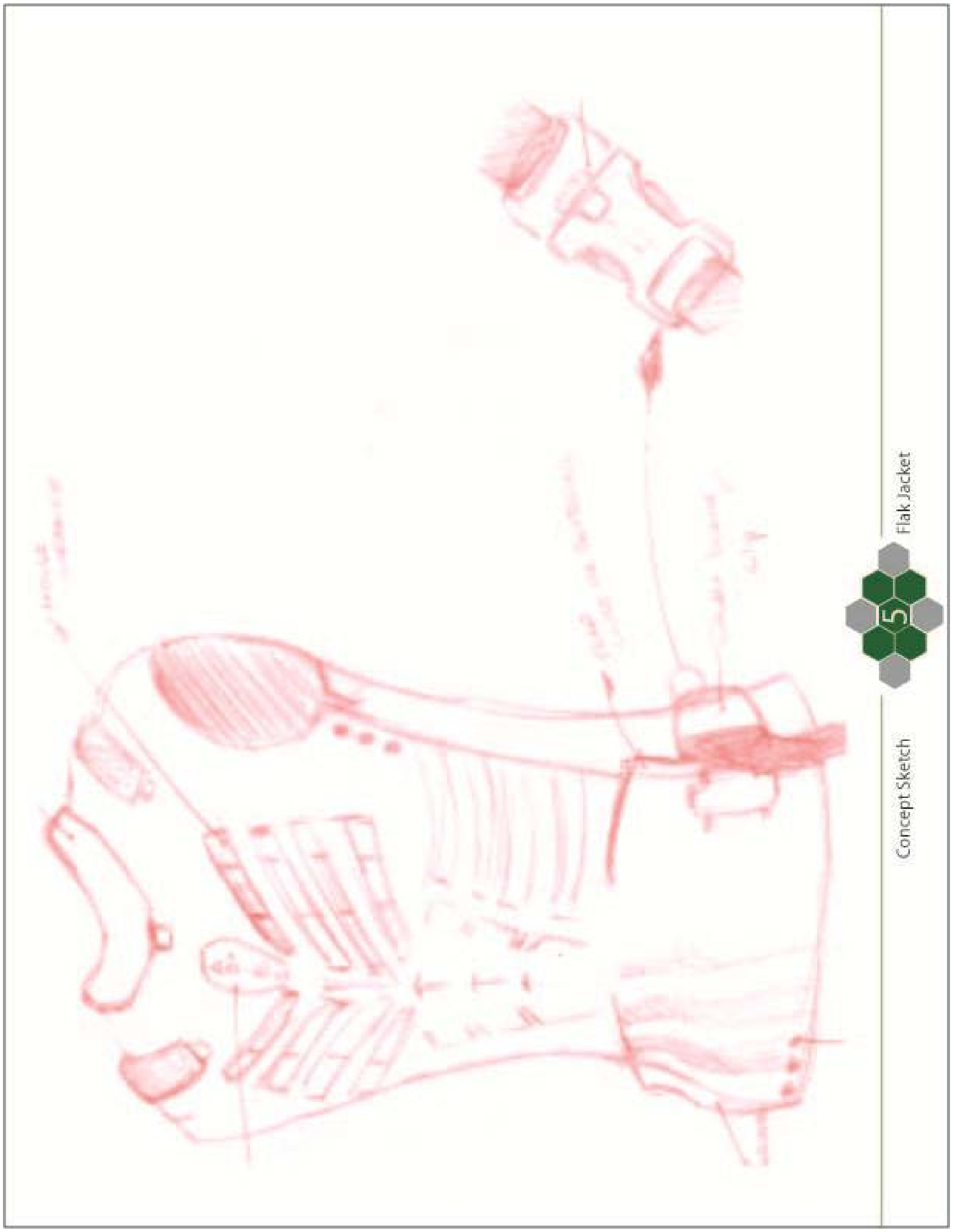

Illustration 29: Concept Sketch 5

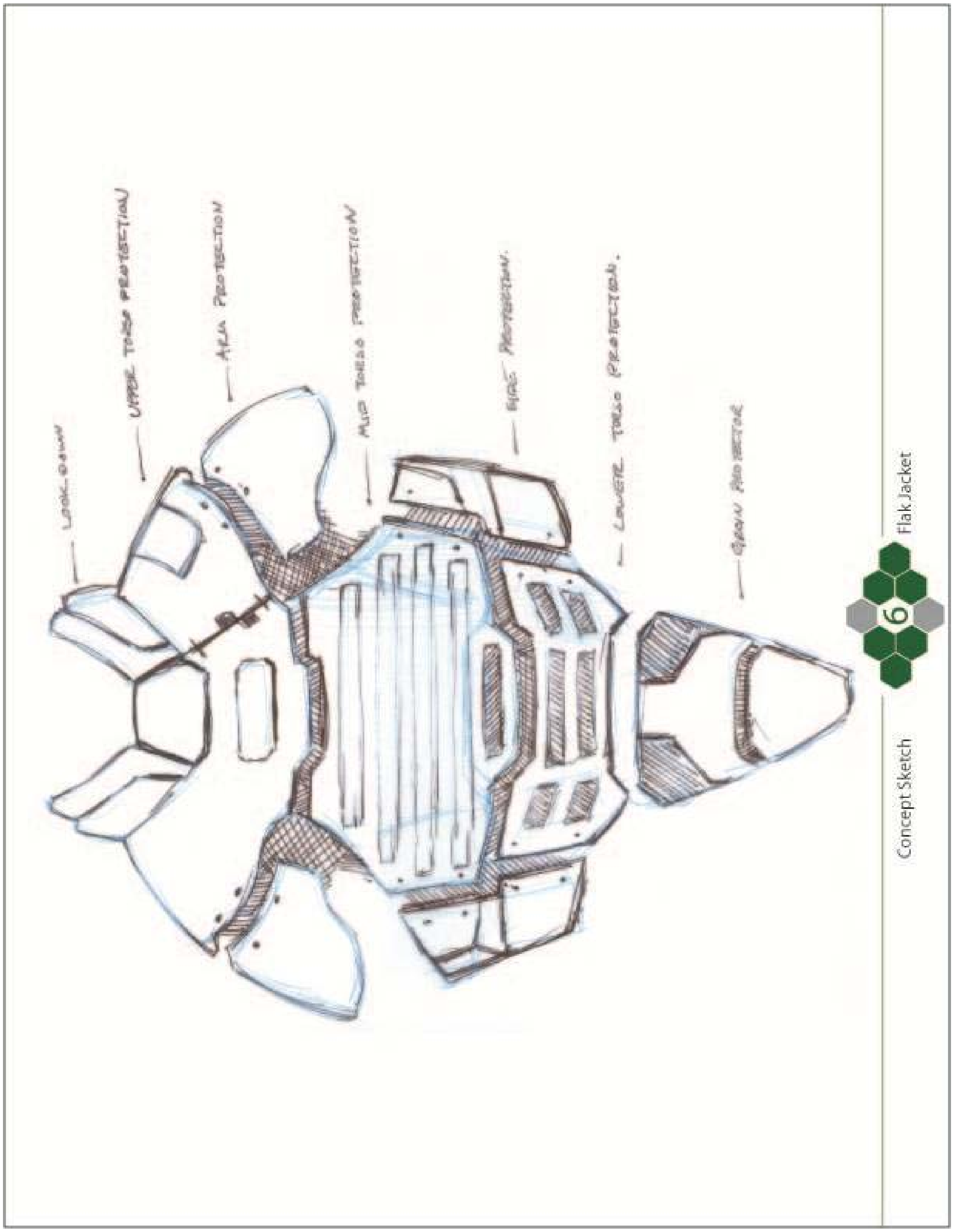

Illustration 30: Concept Sketch Six

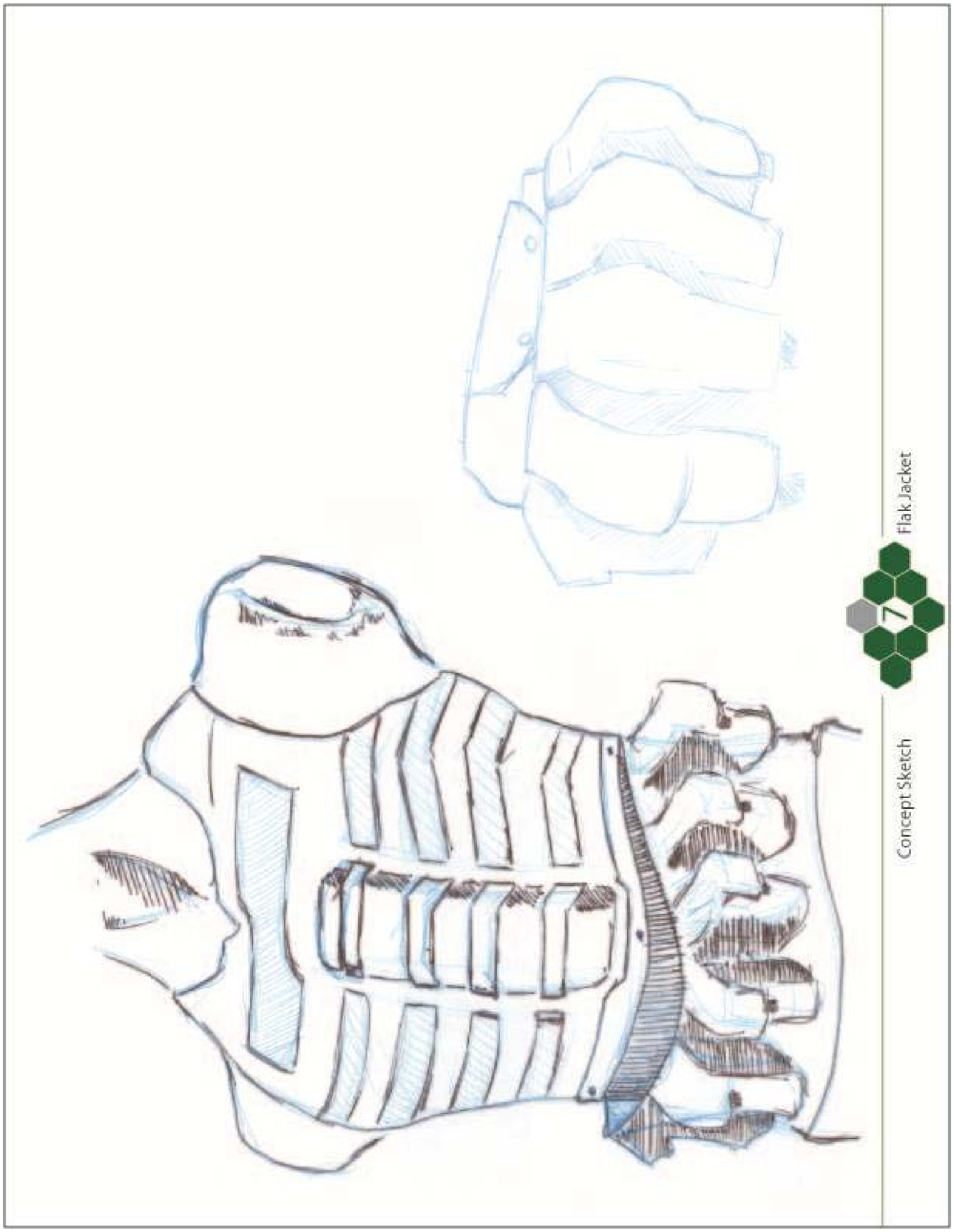

Illustration 31: Concept Sketch Seven

4.13 Design Evaluations

The performance criteria evaluation chart was used in this section to analyze the flak jacket design concepts created in the previous section. This was done in order to choose a design concept for further refinement and development. The top two concepts were placed within this chart and evaluated on how effectively or significantly they met the required performance criteria, outlined in Chapter 4.4 Equipment Specifications. Each design was evaluated on three major aspects, which were then broken into more detailed elements. These major aspects dealt with human, technical and production factors. Then these aspects were further categorized into aesthetic, physical, economic, production, internal and external factors.

The concepts that were chosen for this phase were three and seven from Chapter 4.11 Concept Sketches. The specifications for each concept were listed and evaluated against the required parameters in Illustration 32 to 34 from Chapter 4.9 Equipment Parameters. Each parameter was evaluated numerically on a scale from one through five, represented by a colored square. An evaluation score of three is represented by three colored squares. Next to the numerical evaluation there is an area in which to mark if the parameter is based on actual or educationally assumed information. Those parameters based on actual information are double the value of assumed information. With the growing concern with weight, mobility and flexibility for soldiers, those areas under the human factor section of the evaluation chart are to be tripled in their value. For example, under the performance criteria category for weight, if the design scores a five out of five and is based on factual information, its score will amount to 30 points. If the information was assumed it would score a 15 for that category.

Based on the performance criteria evaluation chart, concept three (see illustration 27) achieved the highest value with a combined score of 380 out of 570. Concept seven (see illustration 31) scored 361 out of 570. Concept three was chosen to move forward into refinement and serves as the base for the final design.

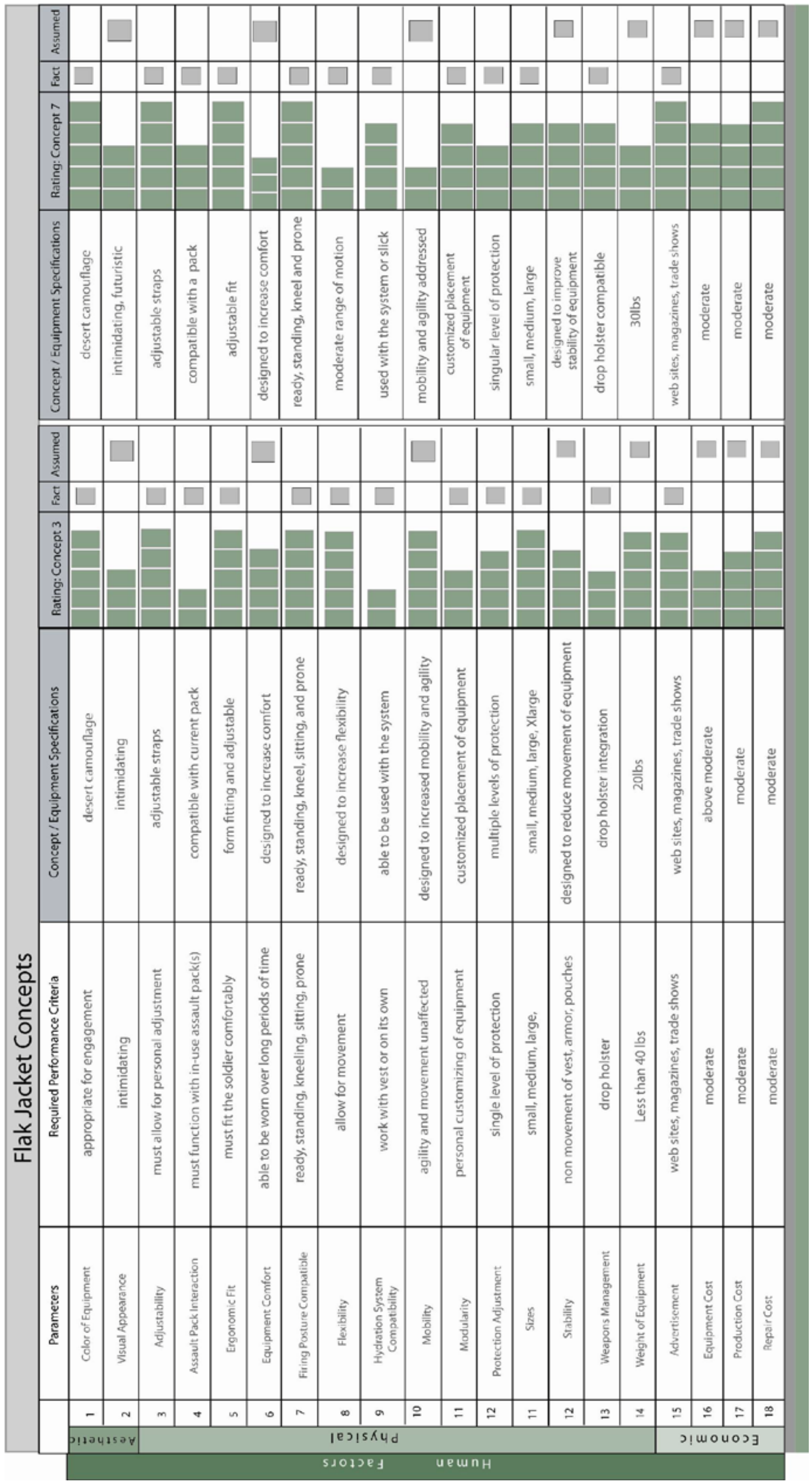

Illustration 32: Performance Criteria Evaluation Chart (a)

Factors		#	Parameters	Required Performance Criteria	Concept / Equipment Specifications	Rating: Concept 3	Fact	Assumed	Concept / Equipment Specifications	Rating: Concept 7	Fact	Assumed
Technical	Production	19	Assembly Method	automated & manual	automated & manual	5	■		automated & manual	5	■	
Technical	Production	20	Color Application	digital print	digital print	5	■		digital print	5	■	
Technical	Production	21	Production Process	Textile manufacturing	Textile manufacturing	4	■		Textile manufacturing	4	■	
Technical	Production	22	Storage	warehouse	packed flat, two in width, two in length and twelve in depth	4	■		24" in length 18" in width 15" in depth	5	■	
Technical	Internal	23	Fabric Requirements	nylon, cotton	nylon, cotton, and woven shear thickening fluid	5	■		nylon, cotton, plastic	5	■	
Technical	Internal	24	Integrated Technologies	ballistic protection	Shear thickening fluid	4	■		kevlar, ceramic plates	3	■	
Technical	Internal	25	Interoperability	function similar to other branches of equipment	multi operational	5		■	single unit based	3		■
Technical	Internal	26	Hydration System	camel back	camel back	4	■		camel back	5	■	
Technical	Internal	27	Packaging Materials	water resistant fiberboard	water resistant fiberboard	5	■		water resistant fiberboard	5	■	
Technical	Internal	28	Resistances	Fire, water, weather	Fire, water, weather	3		■	Fire, water, weather	3		■
Technical	Internal	29	Thread Material	nylon, cotton, polyester	nylon, cotton, polyester, shear thickening fluid	4	■		nylon, cotton, polyester, plastic	4	■	
Technical	Internal	30	Ventilation	Breathable	Breathable	3		■	Breathable	3		■
Technical	Internal	31	Vest Material	acceptable for desired effect	cloth, twill, cotton and nylon	5	■		cloth, twill, cotton and nylon	5	■	
Technical	Internal	32	Weapon compatibility	ammunition access, firing posture shouldering capable	designed to be compatible with the use of a weapon	4	■		designed to be compatible with the use of a weapon	4	■	
Technical	Internal	33	Webbing Material	nylon	nylon	5	■		nylon	5	■	
Technical	Internal	34	Wiring Control	integration into vest	secured through channels inside of the vest	2	■		secured by MOLLE webbing	5	■	

Illustration 33: Performance Criteria Evaluation Chart (b)

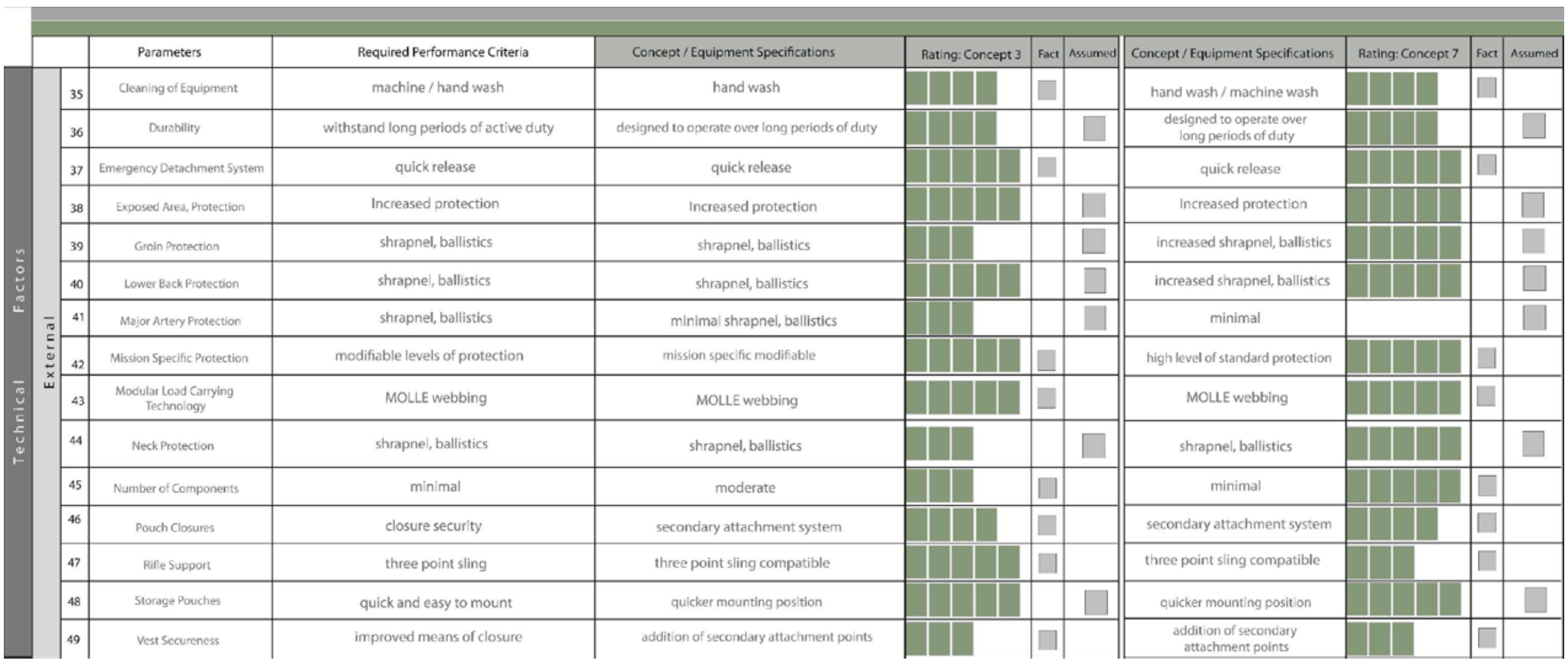

Illustration 34: Performance Criteria Evaluation Chart (c)

4.14 User Guide

A user guide for concept three will be presented in Chapter 5 following the refinement of the equipment. This guide will outline the sequence of use and proper method of assembly for the concept. The method in which the equipment will be assembled and used will be illustrated and coupled with brief descriptions detailing each step. This guide will also illustrate each functioning piece and the proper method of use.

4.15 Concept Refinement

Evaluation of the design ideas shows that concept three scored the highest and it will be refined and further developed. The design evaluation chart analyzes each concept, not simply to add validation, but to also show areas of weakness within each design. Concept number three, chosen as the final design for further development, was, however, weak and required adjustments in a few areas. The areas that scored lowest were placed back into specific sections of the process to increase their score. These areas included:

- Increasing the intimidation factor: Operational Research, Concept Development
- Hydration system integration: Interaction Matrix, Concept Development
- Better system for wire management: Alternative Solution, Concept Development
- Making the vest more breathable: Concept Development
- Reducing the weight: Operational Research, Concept Development
- Better protection for neck and vital arteries: Concept Development

Chapter 5: Final Solution

5.1 Introduction

After analyzing concept three (see illustration 27), which was chosen as the final design solution, and understanding the areas that require improvements, the concept was further reviewed by designers and USMC soldiers. The opinions, concerns and suggestions presented by the reviewers were addressed and represented within the final design and model. The improvements suggested were:

- Make the system mission specific.
- Turn the blouse into a uniform.
- Allow the camel back to attach to blouse if vest is off.
- Allow for a quick release function.

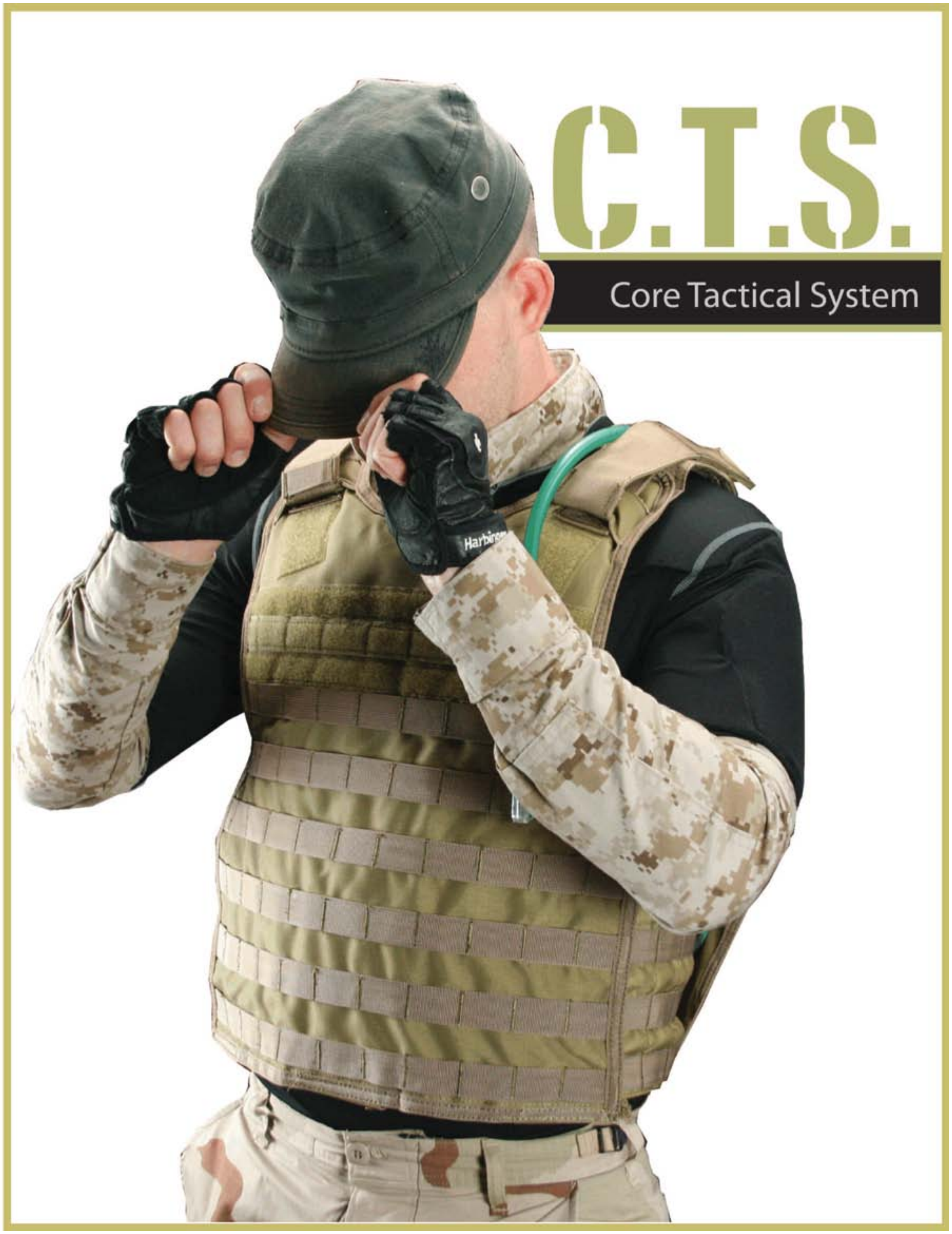

Illustration 35: Core Tactical System

Illustration 36: System Components

Illustration 37: Blouse and Trousers

Illustration 38: Hydration System

Illustration 39: Hydration System Bladder Outline

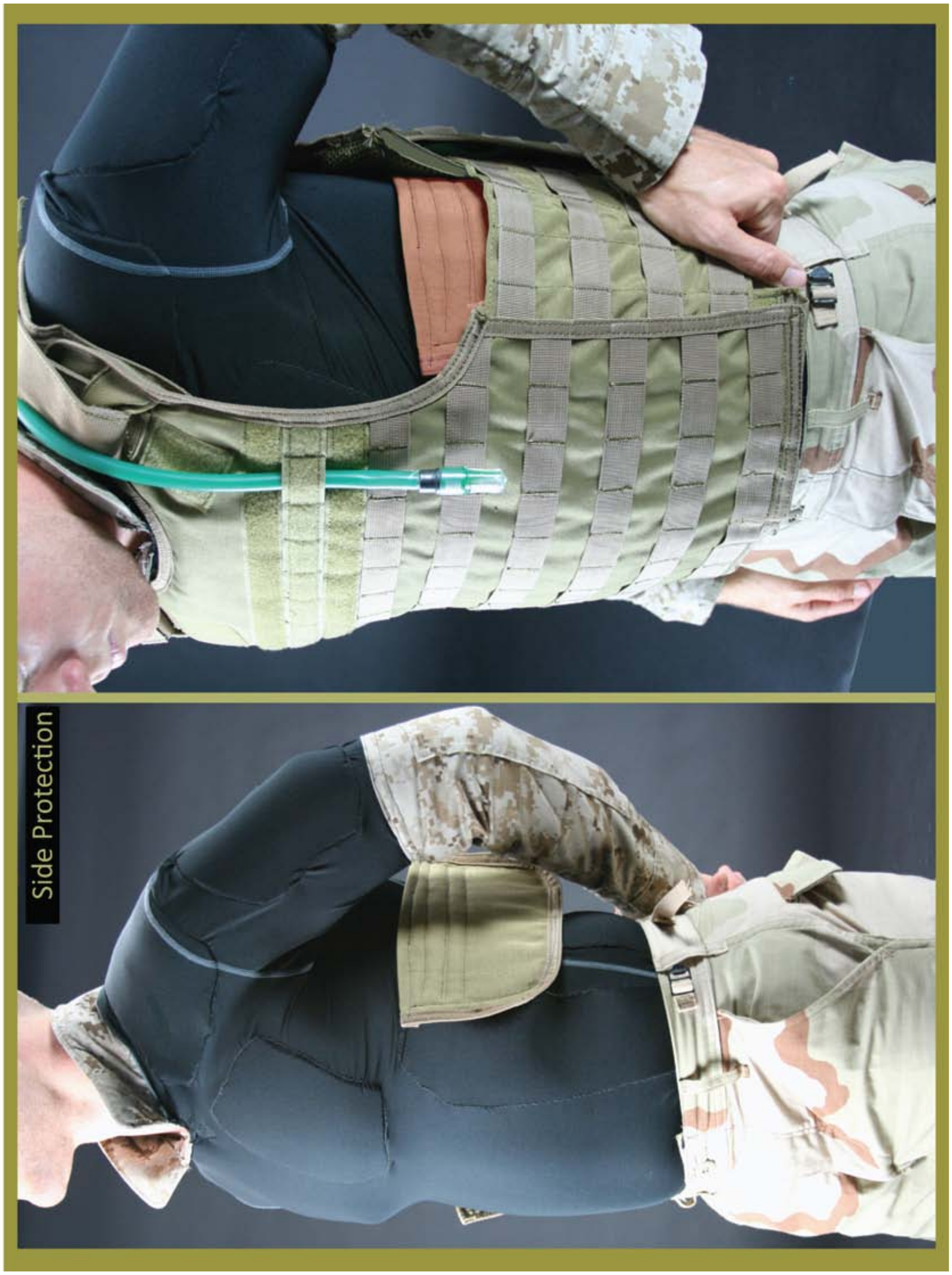

Illustration 40: Side Protection

Illustration 41: Straps

Illustration 42: Lookdown Collar

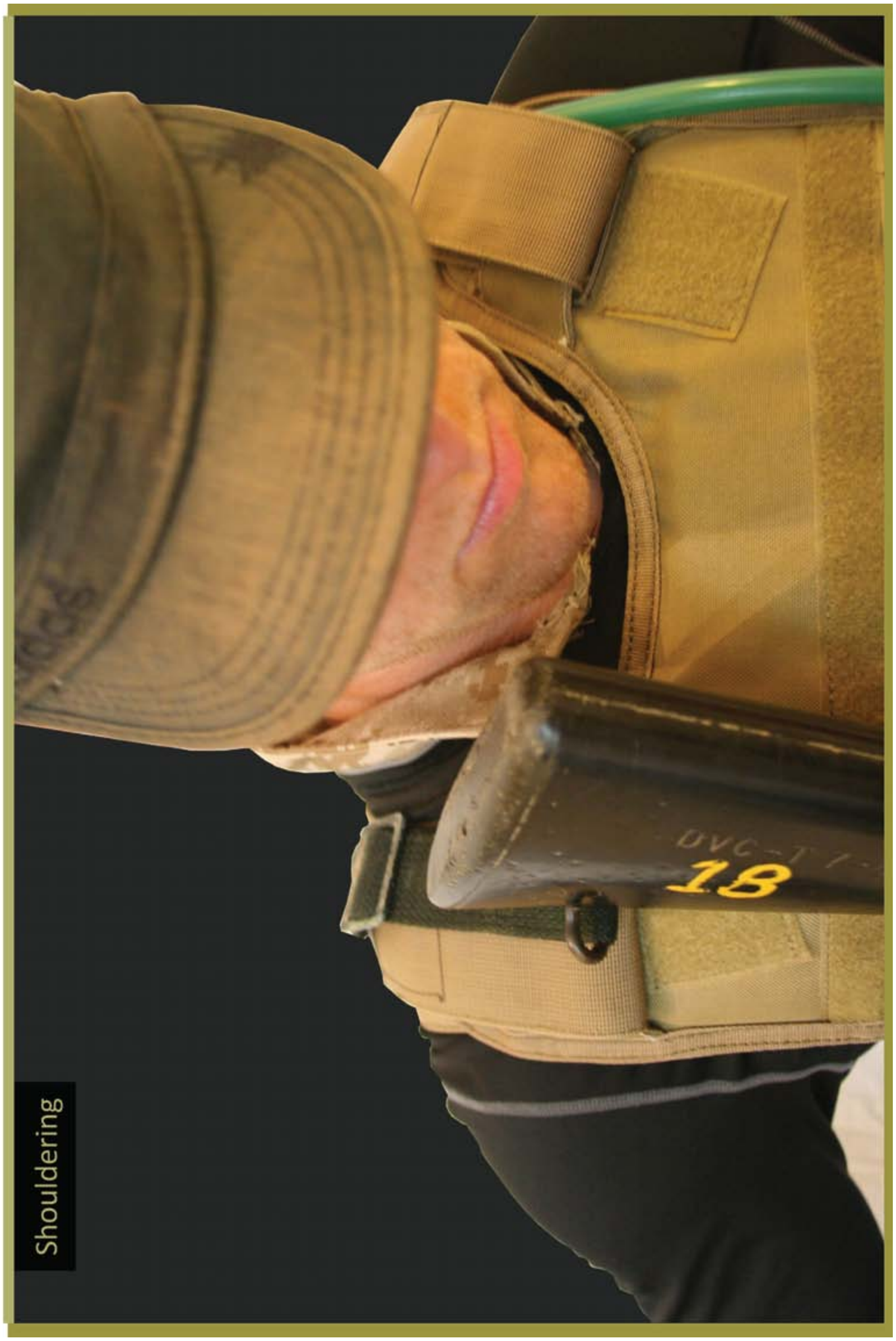

Illustration 43: Weapon Shouldering

Illustration 44: Complete View

5.2 User Guide

The following images will demonstrate the proper method of assembly for the Core Tactical System vest. The system is comprised of 19 steps, beginning with the system components and ending with the Marine wearing the fully assembled system.

Illustration 45: Assembly Phase One

Illustration 46: Assembly Phase Two

Illustration 47: Assembly Phase Three

Illustration 48: Assembly Phase Four

Illustration 49: Assembly Phase Five

Illustration 50: Assembly Phase Six

Illustration 51: Assembly Phase Seven

Illustration 52: Assembly Phase Eight

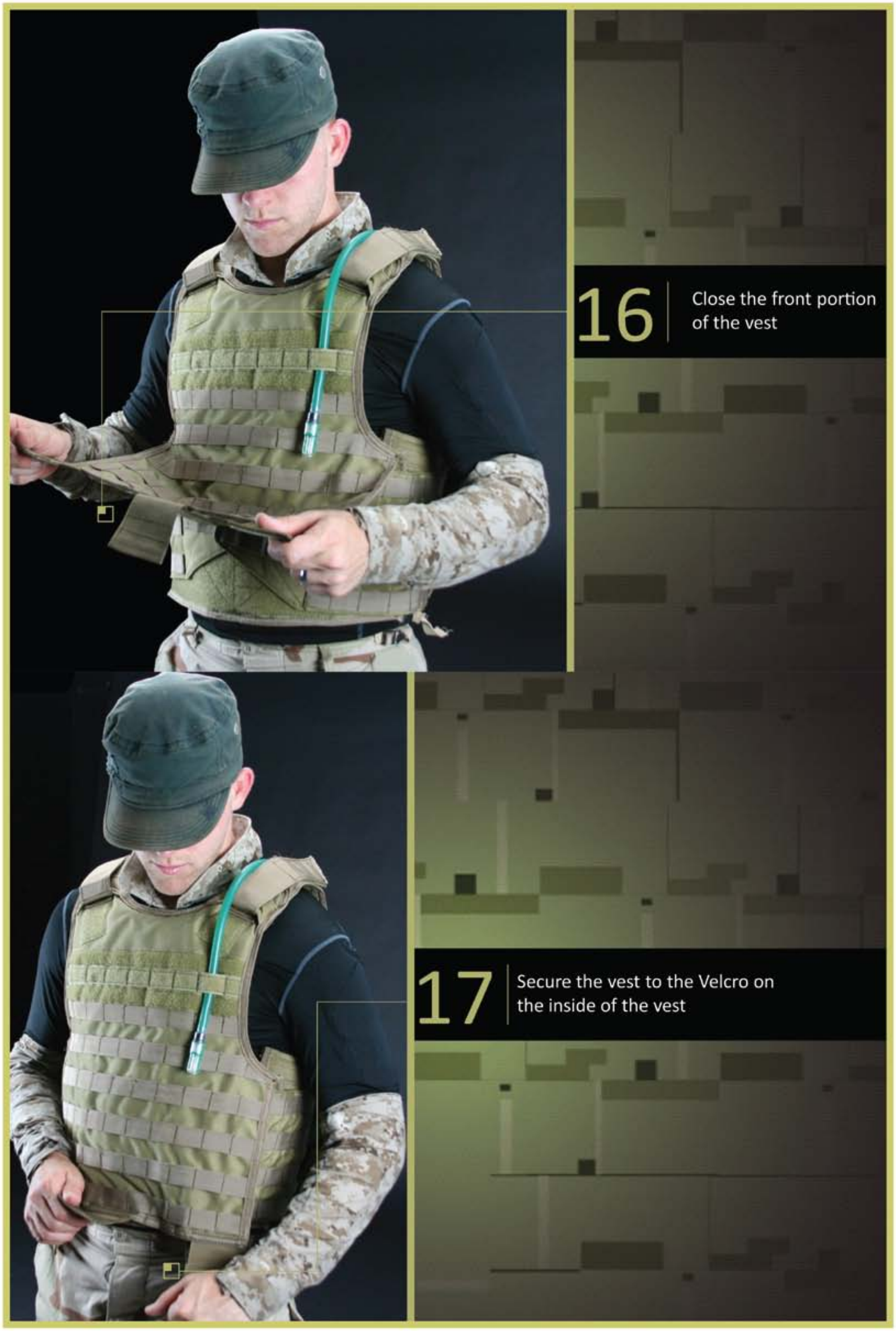

Illustration 53: Assembly Phase Nine

Illustration 54: Assembly Phase Ten

Chapter 6: Conclusion

6.1 Summary of Project

Chapter one of this thesis project began with the identification of a problem which stands as the foundation on which this document is based. The problem was the vast disconnect between soldiers, their equipment and the factors which influenced the outcome of past and current designs. After stating the need for this study, the goals were defined and an approach to which they would be accomplished was outlined.

Within chapter two, research was conducted which describes the evolution of military personal protective equipment and the acquisition process used by the DoD. The evolution of equipment outlined the reasons for each upgrade and acknowledged the problems within the designs which led to the redesigns. The outline of the acquisition process was reviewed to give a general understanding of the method used in acquiring equipment as well as detailing areas that need improvement, specifically those dealing with human and design factors.

Chapter three outlines the approach derived to design equipment with military applications. Each portion of this approach was explained in detail in an effort to improve understanding of individuals with limited or no prior experience and knowledge of the requirements of military equipment basic information in order to design equipment. This approach is to allow an individual to analyze and evaluate the validity of the equipment, design, or both.

Chapter four discussed, documented and applied the design approach. This phase implemented the use of charts, graphs, text and illustrations to reach a final design solution. Continuing to chapter five, the final solution was then refined with the suggestions and changes deemed necessary in the previous sections. The final solution was represented by illustrations and a pre-prototype model which demonstrated the functions.

6.2 Implications and Applications of Study

The approach was created for the use of individuals with limited or no military or design knowledge to develop equipment with military applications by focusing on soldiers as the base system and designing equipment around their needs and abilities, as well as concentrating on making equipment work as a system by increasing its ability to integrate with soldiers and increasing their lethality. With the lack of information currently available on PPE designs, it is my intent that others would use this document as a foundation and guide for their designs. This approach would not be used alone, but in conjunction with the designer's own methodology.

6.3 Recommendations for Future Study

Future studies are still necessary in other military areas outside of personal protective equipment. These areas include, but are not limited to, weapons, ballistics, vehicles and means of transport by land, sea, or air. It would also be practical and beneficial to expand on the psychological effects equipment can have on soldiers. Other future considerations should include designing for future engagements and preparing equipment to be equipped to handle specific types of theaters prior to the start of an engagement. This could potentially lead to a multitude of mission-specific equipment which could be distributed per conflict, instead of the current single item, which is meant to cover every type of theater and engagement.

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