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THESIS

APPLYING INDUSTRIAL DESIGN BEST PRACTICES IN THE ACQUISITION OF SOLDIER EQUIPMENT

by

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March, 2002

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APPLYING INDUSTRIAL DESIGN BEST PRACTICES IN THE DEVELOPMENT OF SOLDIER EQUIPMENT

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requirements for the degree of

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ABSTRACT

Too often a piece of equipment is delivered which, though functional, is unusable. The computer provides us an excellent example of this phenomenon in our daily life. There are so many features on most computers that we will never understand them all, we will never use all the features, and what is worse, the excess features confuse the user and may even make accomplishment of the core task more difficult.

The goal of any designer should be to develop a piece of equipment that facilitates the accomplishment of a task and is a pleasure to use. These criteria must be the overriding consideration of the developer whenever they acquire a new system or piece of equipment. System designers today are better trained and have more resources at their disposal than perhaps any designers in any time in history. What's more, designers today have design media, such as software, which provide unique opportunities to make incredibly effective pieces of equipment to facilitate the accomplishment of virtually any task.

Certainly military program managers are concerned with the acceptance of the equipment they field. However, undesirable equipment is still in our inventory, such as some of the radio systems, and certain features on military vehicles. This thesis examines why a good design is critical and explores the best ways the program manager can apply industrial design best practices in the development of soldier equipment.

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I. INTRODUCTION

Design is not just about pretty colors and pleasing curves. It's about understanding what your customers really want (Ref. 20).

A. WHY DO WE CARE ABOUT INDUSTRIAL DESIGN?

Industrial Design is the professional discipline that adds value to the manufacturing process by making people want to use a product. Industrial designers are integrators (Ref. 50). Industrial designers express concepts that embody all relevant design criteria determined by the group (Ref. 65). They organize and package products in a way that the customer finds attractive and pleasing. "The industrial designer's unique contribution places emphasis on those aspects of the product or system that relate most directly to human characteristics, needs and interests" (Ref. 65).

Industrial Design is essential in the commercial marketplace where product differentiation is essential. Commercial firms realize that the only value they can add to most products is through a better, more attractive design. The automobile, for example, has very little new technology from brand to brand and year to year. The principle way to differentiate products is through the application of industrial design (Ref. 50). Industrial Design certainly adds to the bottom line, but it can add other tangible benefits as well.

Improving operator performance, evoking positive emotion, and reducing training burden are benefits that are attractive to both the commercial marketplace and the military.

Good design **improves operator performance**. Improved performance leads to greater mission accomplishment and fewer mistakes. These benefits are attractive for almost any task, in particular commercial aviation and military operations.

Good design **evokes positive emotion**. Emotion inspires confidence in a product. If the design is applied to a well-engineered piece of equipment, operators are more likely to use the equipment and its capabilities rather than discard it. These benefits are essential when trying to introduce a process change within an organization. For example, if the United Parcel Service were to introduce a new piece of equipment to improve its tracking process for packages, the drivers would be more likely to implement the change if the equipment facilitates the task and is attractive to use.

Good design **reduces training burden**. Users will be interested in a good design. If the design is attractive and intuitive, users will volunteer their time to learn more about the product and how they can use the product in accomplishing their tasks (Ref. 33).

The military already realizes that there is benefit to making the soldier feel good about his equipment (Ref. 33). In the military, the term for feeling good about the equipment is called "soldier acceptance". For example, Tabasco™ brand hot-sauce is put into the field rations because the soldiers feel better about their meal when it is included. Presently, the US Army is considering a complete change of uniform if for no other reason, the soldier will feel more like a soldier if he likes his uniform (Ref. 2). These same considerations extend to other equipment as well, such as rifles, helmets, boots and vehicles.

However, even though the military realizes the importance of soldier acceptance, often the military does not know how to integrate all the competing requirements to get what it wants: performance and soldier acceptance.

The purpose of this thesis is to examine how the military can use Industrial Design "best practices" to help procurement officials acquire equipment that performs and is accepted by the soldier.

B. RESEARCH SCOPE.

In searching for best practices, this research covers the spectrum of institutions, which develop, teach, and utilize industrial design: academia, industry, and Department of Defense (DoD) Human Factors. Research then discusses one group of the military that can benefit from incorporating the best practices of industrial design: Program Managers.

1. Academia.

Industrial design is taught at many different levels. At the most basic level, industrial design is taught in design clinics or workshops. At a more formal and involved level, industrial design has a standard curriculum, with accredited degrees earned at the baccalaureate, masters and doctoral levels. The Art Center in Pasadena, California is the leading industrial design institution in the United States. Additionally, there are several private authors, who are also university professors, who have written significant design guides that shape the academic view of industrial design. These authors include Stuart Pugh and Donald Norman.

2. Industry.

Often the cutting edge of design is not in academia, but in the workplace. Industry crosses the bridge from academic theory to the challenges of application. David Kelly, a Stanford Design Professor, is also a successful entrepreneur. Robin Peng, Principal of Design Engine (a Utah design company), is also an instructor and industry leader. It is industry that defines the current best practices in industrial design and should be considered a reliable measure of what works.

3. Human Factors.

The Department of Defense (DoD) has a number of subject matter experts who spend their time considering only the human factors aspects of system design. The Human Factors Engineering Tri-service Advisory Group (HFETAG), made up of human factors professionals, meets semi-annually to discuss their specialty and share their perspectives on what is important to the military community and what the future in military procurements will be as they relate to the human factors field. Despite this wealth of knowledge available within the DoD, it is the opinion of some experts that human factors advice and expertise is not incorporated into programs to the greatest extent possible (Ref. 56).

4. Program Managers.

In the United States military, program managers are ultimately, responsible for incorporating all of the system requirements into one package. Program managers must find the best balance of cost, schedule and performance, which will satisfy the material requirement of the service they represent. There seems to be different degrees of commitment to "soldier acceptance" within the community of program managers. While some program managers are driven strictly by performance, others recognize the fact that in addition to performing, for a product to be truly successful, the user must accept it.

C. RESEARCH QUESTIONS.

1. What is the value added of a good design?
2. What are indicators of customer dissatisfaction with a product?
3. What is the cost/waste associated with a bad design?
4. What are academic industrial design principles?
5. What are commercial industrial design principles?
6. Are there different design principles for hardware and software?
7. What is an example of a well-designed piece of hardware?
8. What is an example of a well-designed piece of software?
9. How are commercial firms organized to produce well-designed items?
10. What process do commercial firms employ to pursue a good industrial design?
11. What causes industry reluctance to adopt an attractive, usable design? Are there cultural issues?
12. What, if any, are the government design principles?
13. What information, related to soldier acceptance and design considerations, is available to program managers?
14. Do program managers use human factors information available to them?
15. How do program managers weight human factors requirements and soldier acceptance in the development of soldier equipment?
16. What causes government reluctance to adopt usable designs? Are there cultural issues?
17. How can a program manager ask for a good design?
18. How does a program manager assess the ability of a firm to produce a good design?
19. How does a program manager evaluate a product to ensure it is usable?

D. RESEARCH METHOD.

The methodology used in this thesis research consisted of the following steps: Conducting a literature search of books, magazine articles, and other library information resources. Conducting interviews with academic experts in the area of industrial design looking for principles of usable design, methods of good design and examples of good design. Conducting interviews with industrial experts in the area of industrial design looking for principles of usable design, methods of good design and examples of good design. Conducting interviews with government officials, to include Program Managers and Department of Defense; Human Factors experts, looking for principles of usable design, methods of good design and examples of good design. Conducting a survey of the costs of a bad design. Assemble facts, identify and analyze the issues. Make recommendations, oriented toward Program Managers, which will help them when specifying a product and evaluating a product for usable design.

E. THESIS ORGANIZATION.

The remainder of this thesis consists of chapters on background, findings, analysis and synthesis and finally conclusions and recommendations. I will build a case for user acceptance of the product and then examine whether or not program managers are using the best processes and tools available to procure equipment that will be accepted by the soldier.

The background information orients the reader to the definitions and concepts of industrial design, such as the definitions of performance, usability, aesthetics and the experience. Professional organizations that use industrial design and military organizations are outlined. Additionally, commercial and military product examples assist in the understanding of the scope of application for industrial design within the military.

The findings are collected from academia, industry, DoD Human Factors professionals and program managers. Findings include the cost of a bad design, design principles, the means of identifying user requirements, how the design organization is structured and the design process.

The analysis and synthesis portions of the thesis seek to identify currently acceptable design practices, as well as innovative processes, which the military could employ in the acquisition of equipment. Analysis focuses on the impact of bad design, the feasibility of employing industrial designers and the expected benefits of industrial design best practices, which program managers can utilize to increase soldier acceptance of equipment.

The conclusion provides recommendations to program managers on how they can design a good product, what type of processes should be used to develop good products, what to look for in product design, and other recommendations of how program managers can increase acceptance of their products by the user community.

F. EXPECTED BENEFITS OF THIS THESIS.

It is in the interest of the entire acquisition system to field only that equipment that -- by design -- enhances the soldier's ability to perform his/her duties. By applying industrial design best practices, the military will field equipment that meets its performance requirements. The newly designed equipment will also *improve operator performance, evoke positive emotion* in the user, and *reduce the training burden*. It can be argued that these benefits are worth the associated costs. A soldier is not likely to use a piece of equipment that is confusing, tedious, or unappealing (Ref. 33). When equipment is not used, money spent on its design and procurement is wasted. Money is only well spent when the soldier accepts and uses the equipment. Industrial design can help make the best use of the acquisition budget and give soldiers what they really want and need.

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II. BACKGROUND

Industrial Designers provide vision that shapes new technology into easily understood product solutions (Ref. 68).

A. INTRODUCTION.

Military program managers are concerned with the acceptance of the equipment they field. However, undesirable equipment is still in our inventory, examples being some of the radio systems, and certain features on military vehicles. The objective of this thesis is to ensure that program managers are aware of why a good design is critical and what the current "best practices" are in order to field desirable equipment. The ultimate objective is to change the status of human factors engineering within the acquisitions field, so that a good design is, if not the most important criteria, one of the top two considerations for system development.

B. THE GOAL OF DESIGN.

The goal of any designer should be to develop a piece of equipment, which facilitates the accomplishment of a task and is a pleasure to use (Ref. 45). These two criteria must be the overriding consideration of the developer whenever acquiring a new system or piece of equipment.

System designers are better trained and have more resources at their disposal than at any time in history. What's more, designers today have design media, such as software, which provide unique opportunities to make incredibly effective pieces of equipment to facilitate the accomplishment of virtually any task.

However, manufacturers today are sometimes overwhelmed by “engineering” considerations. In the 15 January 2001 edition of *U.S. News & World Report*, the magazine’s feature article was titled *“Overwhelmed by Tech”* The underlying theme is that designers of a firm make a usable product for the public, then the engineers of the same firm add features to increase functionality, thereby rendering the product overly complex and undesirable.

For some design practitioners on the cutting edge, design is still an art. However, good, usable design is a science. In *The Design of Everyday Things*, Donald Norman lists several guiding design principles, --such as visibility, a good conceptual model, good mappings and feedback-- which are easy to use and apply. In addition Norman lists seven principles for transforming difficult tasks into simple ones. Norman’s ideas are intelligent, compelling and easy to employ, wherever there is concern for a usable design.

C. WHAT IS INDUSTRIAL DESIGN?

“Industrial design is the professional service of creating and developing concepts and specifications that optimize the function, value and appearance of products and systems for the mutual benefit of both the user and the manufacturer” (Ref. 65).

Industrial design is both an art and a science. While the ultimate aim of industrial design is to create, through art, a desire to use a product, the approach to creating that desire is scientific. Industrial designers understand technical processes, manufacturing requirements, marketing and legal parameters (Ref. 65). Industrial design emphasizes good design; it emphasizes functionality (Ref. 50).

Industrial designers are inventors (Ref. 50). Industrial designers design everything from Ferraris to toasters. Industrial designers dream up products, presenting to manufacturing clients their vision of what a certain product should look like (Ref. 62).

Industrial designers are not engineers. Engineering rigor is different from design rigor. Any type of engineering is a partial design input, which does not add to the final product unless it is applied appropriately for the product. Designers are interested in total design, the integration of the partial design inputs. Unless all the elements of design are properly integrated, the product may fail in the marketplace (Ref. 52).

Industrial designers are integrators (Ref. 50). Industrial designers often work as part of a developmental group. They apply their principles in a process to integrate the elements of a good design to create a cohesive, attractive product. "Industrial designers are trained to prepare clear and concise recommendations through drawings, models and verbal descriptions" (Ref. 65). Industrial designers also create ideas using materials like clay and modeling foam to show what a product should feel like (Ref. 62).

Industrial design is in its infancy (Ref. 50). Hal Hendrick, in his Presidential Address at the 40th Annual Meeting of the Human Factors and Ergonomics Society, lamented the fact that private organizations and the government are not taking advantage of the potential of the human factors community (Ref. 30). Industrial design is less likely to be used by engineering companies. It is more likely to be used by entertainment companies (Ref. 50). In fact, some manufacturers think of industrial design as form over function (Ref. 21), when in fact the opposite is true; form follows function (Ref. 50).

D. ELEMENTS OF GOOD DESIGN.

N. Rain Noe, in an article titled "*What is ID and why should I care?*" says the goal of the industrial design profession is to make a product attractive and to make the product not be a pain in the neck (Ref. 45). Noe presumes that the product should also perform its designated task. A truly good product or system facilitates task accomplishment and is a pleasure to use. Facilitating task accomplishment is measured by performance and usability, ease of use. Attractiveness makes the product a pleasure to use. Finally, the aim of industrial design is to provide the user with a fulfilling experience. Products can be a bunch of "stodgy crap" that clutters, or a "hyper-cool" collection of objects that subtly enhance you life (Ref. 45). Nothing is accomplished by making a defective piece of equipment look good; this would lack integrity and waste resources.

1. Performance.

Industrial design starts with a sound design which allows the newly designed equipment to perform the required task. Form should always follow function (Ref. 50). "Success in the marketplace requires total design rigor and engineering rigor or the highest order – never one without the other (Ref. 52)." However, it should be noted that pure functionality is not enough.

2. Usability.

Good design is usable and intuitive. The design must facilitate task accomplishment through a clear conceptual model; the design enhances the understanding of task achievement. However, all too often usability is not considered at the initial design stage. Usability problems are more likely due to poor design than a problem with the user (Ref. 46).

3. Aesthetics.

Aesthetics refers to shape, form, texture and color (Ref. 52). Industrial designers integrate already sound concepts into an attractive package. Industrial designers are often retained for consultation on how to improve a client's image (Ref. 65). "Design also makes a difference in, say, the car market. An automobile is probably the most important kind of design object that you buy. If you look at what makes a person buy one car vs. the other, it's all the subjective stuff." (Ref. 20)

4. The Experience.

In the end, design is not about a product, design is about an experience a company has to offer. The experience can be related to a product or a service. (Ref. 20). "Nobody wants a toaster, or an iron, or an ironing board. What people want is toast, and pressed shirts (Ref. 45)." Sturridge tells an interesting story from 1984 about the struggle with designing products,

> *"Xerox's* Palo Alto research laboratory spent 30 work years wrestling with the problem of user friendliness. At the end of the day it concluded that things are best left the way they are. The machine must mirror the way things are done now and not attempt to improve on them…the gadgets that are friendly are the ones that make the user feel conceptually that he is doing the same as he did before the electronics intervened (Ref. 51)."

E. PROFESSIONAL ORGANIZATIONS.

Professional organizations associated with industrial design as it relates to military procurements are the academic community, industry, DoD Human Factors, and the program managers. There is an established community of industrial design professionals within academia and industry, who teach and practice good design. Within DoD, there is a nucleus of Human Factors professionals who understand the ergonomic issues, which are ultimately related to industrial design. They offer advise to product developers and help guide design. Finally, there are program managers, who understand the systems engineering process, but may know nothing about industrial design. The common thread of these communities is that they each want the end user to be pleased with the product they produce.

1. Academia.

The Universities and the training centers, which formulate design philosophy and educate design professionals, define academia. Education can range from workshops to a formal curriculum, presenting degrees from the baccalaureate level to a PhD. However, different design schools have different approaches to design education (Ref. 65).

Regardless of philosophical design differences, all industrial designers are educated to anticipate the psychological, physiological and sociological factors that influence and are perceived by the user. Essential competencies include a basic understanding of how things work, how things can be made to work better, how things are made, why things look good or bad, and how ideas can be presented using common tools of the profession (Ref. 65).

The industrial design community is committed to proper education and professional excellence and has a structured curriculum to ensure the appropriate rigor of industrial design education. For example, the University of Canberra Industrial Design Department has listed the top 10 skills for emerging industrial design graduates (Ref. 62):

a. Fast and fluid ability to sketch and freehand draw.
b. Good model making ability.
c. Must know vector based software, such as Freehand or Illustrator 7 and a Raster based package, such as Photoshop or Photostyler.
d. 3D modeling skill in one high-end package.
e. 2D CAD skills in Autocad and Microstation.
f. Self-starters with good presentation and interpersonal skills, and report writing. Industry experience is a bonus.

g. Excellent appreciation of form and the interaction of positive and negative space.
h. Portfolios with a clear progression of the idea from fluid sketch to detailed sketch to 3D model.
i. A solid understanding of the product development process and how ID fits with marketing is a bonus.
j. Time management skills, which are compatible with a consulting type operation.

Industrial design is a rigorous pursuit. In the article, *The Framing of a Practice-Based Ph.D. In Design*, Norman, Heath and Pedgley, of Loughborough University in the United Kingdom, clearly outline the serious and professional view that academics take toward the profession of industrial design. Requirements for a Ph.D. in industrial design include designing artifacts, which includes analysis or evaluation of the process with the aim of making the most effective processes available to the design community (Ref. 47).

While there is a wealth of knowledge available, this thesis focuses on the work of two individuals whose work influences design thought and the design industry, Donald A. Norman and Stuart Pugh. Norman is the author of *The Design of Everyday Things.* Pugh is the author of *Total Design.*

2. Industry.

The industrial design community is worldwide and spans disciplines from concepts development to prototype production.

Industrial designers are part of the human factors community. A visit to industrial design web sites, such as *ideo.com* illustrate how industrial designer incorporate the empirical elements of ergonomics into their products and services. However, industrial designers are not only interested in the physical aspects of ergonomics, but also the psychological aspects. Industrial designers consider the entire product experience from the macro to the micro level (Ref. 64).

Industrial designers often work in a consultation role. Usually, the marketing department of a commercial firm investigates user requirements. Results of the marketing analysis are brought to the industrial designer, who will integrate the customer's requirements into an attractive design. However, the customer can directly approach an industrial design firm with a project, especially when the project involves the redesign of an existing article (Ref. 50.)

An attractive facet of industrial design firms is the ability to produce a design in a very short turn-around time. Industrial designers employ the latest technology. This technology is able to convey the design concept effectively. Often the data is in a digital format, which can be transmitted worldwide via the Internet. The designer and customer can have instant communication about the ongoing design (Ref. 50). In addition to graphical representations, industrial designers can make full-size and scale models of designs using new technologies, such as the *ThermoJet 2000*; by *3D Systems*. The Thermojet 2000 can fashion an artifact out of a polymer substance using a computer-guided laser. Almost instantly, the customer can hold the design in their hand (Ref. 1).

Industrial designers are dedicated to innovation in the product and the process. Companies like *Doblin*, of Chicago, focus on developing insights into the unstated needs and desires of their clients and then designing a solution. Doblin's client list is evidence of the value of design to successful companies. Doblin clients include, *Aetna Insurance, Alamo Rent a Car, Amoco Oil, Clorox, Hallmark, JCPenny, Motorola, McDonalds, Pillsbury, Royal Dutch Shell, SAS Scandinavian Airlines, Sears, Texas Instruments, Whirlpool* and *Xerox*, just to name a few (Ref. 63).

While there are many design firms, this thesis focuses on two companies which have a solid understanding of the commercial industrial design market and are competitive in the industry: *Design Engine* of Salt Lake City, Utah and *Ideo* of Palo Alto, California.

Robin Peng established Design Engine in 1990s. Robin is a graduate of the *Art Center* in Pasadena, California. He worked for several years in the Detroit auto industry before deciding to open his own studio. His studio designs every conceivable product from bicycles, to *Matchbox* cars, to handheld computers for students and video games. Design Engine has won distinction for its innovative designs: in particular, an especially innovative passenger seat for a roller coaster. During an interview in June 2001, Robin, (who incidentally loves military equipment) expressed some reservation about the application of industrial design principals to military equipment. Because industrial design is primarily used to differentiate a product in the commercial market, he was skeptical that the military would be interested in applied industrial design. He was not convinced that the military had an interest in making a product attractive for the user.

The Palo Alto firm Ideo is known for designing eye-catching objects, such as the *Apple* mouse, the *Palm V*, *Nike* sunglasses, and *Oral-B's Squish Grip* toothbrush for kids. They also apply their philosophy to architecture, cognitive psychology, interior design, cultural anthropology and linguistics. Ideo designs environments, services and experiences (Ref. 57). David Kelly, CEO of Ideo, believes that design is not just about pretty colors and pleasing curves. Design is really about understanding what customers want. "If you can make your product or service meet (the customer's) needs, they'll come running" (Ref. 20). Ideo provides innovation and design services from strategy and concept development to engineering and production (Ref. 64).

3. Human Factors.

Industrial designers are part of the human factors community, but not everyone in the human factors community is an industrial designer. For this research, the body of human factors knowledge should be considered as a critical resource for industrial designers and program managers in the development of equipment. The benefits of the human factors profession are exactly the same benefits contributed by industrial designers.

Human factors professionals are interested in the human-technology relationship, sometimes called the man-machine interface. Human factors professionals investigate how the user perceives the design of a product and how the product design enhances or inhibits human performance.

Human factors professionals are interested in improving the quality of life, including health, safety, comfort, usability and productivity (Ref. 30). "It would be wrong to assume that the technological forest that surrounds one has no effect on the citizen of a technological civilization." (Ref. 43) It is essential that we consider the effect of product design on humans when humans are an integral part of a system, such as a pilot of an airliner. If designers make no consideration for the user, then the user is merely a stage prop or a spectator (Ref. 43). It is this understanding of the importance of the user that is the foundation of human factors work.

The Department of Defense appreciates the need for human factors engineering and has dedicated professional organizations to that aim. The Department of Defense recognizes the critical importance of the human as a vital element of the total system. Paragraph 4.3.8 of DoD 5000.2-R states:

> "A comprehensive management and technical strategy for human systems integration shall be initiated early in the acquisition process to ensure that: human performance; the burden the design imposes on manpower, personnel, and training (MPT); and safety and health aspects are considered throughout the system design and development process. (Ref. 28)"

The fundamental human factors effort within the Army is a concept known as MANPRINT.

> "MANPRINT (Manpower and Personnel Integration): The comprehensive technical effort to identify and integrate all relevant information and considerations regarding the full range of manpower, personnel, training, human factors engineering, system safety, health hazards, and soldier survivability into the system development and acquisition process to improve individual performance, total system performance, and reduce the cost of ownership throughout the entire life cycle of a system (Ref. 28)."

Human factors considerations are mandated by regulation.

> "AR 602-2, Manpower and Personnel Integration (MANPRINT), the Army's Human Systems Integration Process for Systems Acquisition. AR 602-2 is the basis for establishing effective integration of manpower, personnel, training, human factors engineering, health hazards, system safety, and soldier survivability considerations into the acquisition of Army Materiel, Information, or Clothing and Individual Equipment (CIE) systems. It prescribes policies and assigns responsibilities for the Army Manpower and Personnel Integration (MANPRINT) Program. The MANPRINT Program influences the design of systems and associated support requirements so that developmental, nondevelopmental, and modified systems can be operated, maintained, and supported to improve total system performance and reduce costs of ownership by focusing on the capabilities and limitations of the human (Ref. 28)."

The Army makes many subject matter experts available to the Program Manager to help with MANPRINT considerations (Ref. 29).

a. Functional Proponent (FP) and/or Combat Developer (CD) or TRADOC System Manager (TSM)
b. Program/Project/Product Manager (PM)
c. Army Research Laboratory -- Human Research and Engineering Directorate (ARL-HRED)
d. U.S. Total Army Personnel Command (PERSCOM), Deputy Chief of Staff for Operations (DCSOPS), Force Integration Division, MPT Domain Branch
e. Training and Doctrine Command (TRADOC) Supporting Proponent School
f. Army Research Laboratory - Survivability\ Lethality Analysis Directorate (ARL-SLAD)
g. U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM)
h. U.S. Army Signal Command (for AIS)
i. U.S. Army Safety Center (for materiel systems)
j. U.S. Army Operational Test and Evaluation Command (OPTEC)

Although the program managers have human factors professionals at their disposal, human factors considerations are not always implemented as often as the human factors community would like (Ref. 56).

4. Program Managers.

Military program managers procure virtually every kind of system from tanks to combat boots. This thesis focuses on program managers that develop personal equipment, that is, equipment that comes in direct contact with the soldier.

Every program manager must balance many competing priorities. The aim of every program should be to produce a product that performs and is a pleasure to use. However, in managing the major program risks; cost, schedule and performance, the program manager might decide that human factors considerations may be traded away in order to satisfy other program risk areas. If not managed carefully, product performance can be sacrificed in the attempt to meet other program goals. Because of the very competitive nature of military programs, it is imperative that program managers find the most economical way to meet the program requirements.

This research is not meant to critique the performance of the program offices. On the contrary, the programs selected for study are examples of new products, which embody the same user satisfaction objectives of the industrial design community. This thesis looks at these programs to compare the way in which industrial designers and the military develop and acquire quality equipment.

F. SYSTEMS ADDRESSED IN THE THESIS.

The impact of the human-system interfaces is ubiquitous. "Even in bed, the human is functioning within a habitation system that contains machines like the refrigerator, stove, telephone, heater, water closet and so on." (Ref. 43) There are many products that could be included in this research. However, the systems considered here provide a good basis for research and are representative of what academia, industry and the military consider examples of good design.

1. Commercial Products.

In the commercial market, sales are an excellent measure of product design. Design may be independently evaluated outside of the market place, but the market seems to indicate which designs are the best and rewards the producer with a return. To succeed in the market, a product or service must be designed explicitly to meet the needs of human users, no matter how excellent the product is in technical terms (Ref. 10).

The *Apple Newton* was a good concept, but it was a bad product. It did not have the “killer technology” and was clunky to use. However, the same concept was used a few years later in the *Palm Pilot*, which is an example of excellent design. The *Palm Pilot* has better technology, but more importantly, it had the user in mind. Palm Pilot has been an extraordinary success because of properly applied industrial design principles (Ref. 20).

The Industrial Designers Society of America distinguishes excellent designs in a number of fields annually. In 1999, gold winners included the *VW Bettle* and *BMW 3 Series* for Transportation. For Business and Industrial products, the gold winners were the *iMac*, the *Palm Pilot*, and the *PowerShot Forward Action Staple Gun*. For Consumer Products, the gold winners were the *Gillette Sensor* for Women Razor, the *Motorola TalkAbout SLK Two-Way Radio*, the *Nike Triax Sportswatch*, the *OXO Good Grips Kitchen Tools*, and the *Sony Playstation*. The *Nokia 6100 Series* phone and the *BabyBjorn Baby Carrier* were silver winners. The *Digital Satellite Receiving System* was a bronze winner. For furniture, the gold winner was the *Aeron Chair*. And for medical and scientific equipment, the *Acuson Sequoia 512 Ultrasound System/C256 EchoCardiography System* (Ref. 66).

This list of design winners illustrates two points. First, popularity and good design go together. American consumers should recognize many of the products on the list. Not only were they popular in 1999, but also they are still popular products two years later. Second, the breadth of industrial design spans the trivial commercial items to the critical life-saving technologies. And, although the entertainment community readily accepts industrial design, its application is no less important in engineering fields.

2. Military Products.

In the military, there are no commercial sales to indicate user satisfaction with a product. Instead of sales, the military evaluates the "soldier acceptance" of products. Soldier acceptance is measured through panels of soldiers, called "user juries" (Ref. 33). Two systems which have had great success in user juries are the *Delta Force Land Warrior* trainer and the *Land Warrior* system.

These products are used as examples because they are currently under development, and they are systems with intimate human machine interface. These are the kind of systems that can benefit most from industrial design best practices.

a. Delta Force Land Warrior.

Delta Force Land Warrior is a computer simulation. The Delta Force Land Warrior project was developed by TRADOC Analysis Center-Monterey, out of a need for the office of PM Soldier to have a training tool to ease the testing and evaluation process involved with the introduction of the Land Warrior system.

Delta Force Land Warrior was designed to replicate the heart of the Land Warrior system, the Soldier Computer Interface (SCI). Soldiers can then use the simulation to evaluate the next generation of software for the Land Warrior system.

> "The Land Warrior SCI provides the situational awareness in the form of maps with soldier position icons, messaging functions to send messages between soldiers, and weapon video feed to the helmet mounted display (Ref. 47)."

Delta Force Land Warrior is also known as the Dismounted Simulation & Acquisition System (DSAS). PM Soldier particularly wanted the DSAS to be able to evaluate the ease of use of the computer system by the user and other interfaces, as well as an ergonomic evaluation of the soldier input devices.

b. Land Warrior.

Land Warrior is a system of equipment worn by the soldiers for combat operations. The aim of Land Warrior is to develop a holistic integrated weapon system (Ref. 71). Land Warrior gives the individual soldier the best information technology equipment an infantryman has ever had. The equipment gives him unprecedented capabilities by employing mature technologies to enable him to navigate, communicate, and engage the enemy and control troops, as he never has before.

> "The LW Program establishes the Infantry soldier as an Army's singularly unique weapons platform. The LW is first and foremost a soldier. However, the LW soldier is equipped, trained, and employed as a unique weapons platform. This is a major shift in the culture and capability of the individual Infantry soldier. As a weapons platform, the LW achieves overmatch of potential enemy soldiers through use of fully integrated, state-of-the-art subsystems. LW system facilitates dynamic flow of battlefield information and actively supports solider-level integration into the digitized battlefield (Ref. 36)."

The Land Warrior system is a particularly relevant example. In May of 1988 the Land Warrior program failed many of its measures of technical performance when tests demonstrated that it hindered soldier performance (Ref. 71). In December 1999 the GAO reported that, "The Land Warrior Program has not resolved technical and human factor problems that may render the system ineffective" (Ref. 25). The survival of the Land Warrior project was put on the line, based upon the user acceptance or lack of acceptance. In an amazing turnaround, Land Warrior received the 1999 Army MANPRINT Achievement Award for significant system improvements, to include interface with the soldier (Ref. 71).

> "The integration challenge will reap the most benefit and we must continue to address the entire soldier as an integrated system and consider cost, weight, power and balance together as the soldier trade space (Ref. 69)."

Land Warrior is a system which integrates all of the infantryman's vital information into a computer controlled, head mounted display. The Land Warrior information technology gadgets are the computer/radio/GPS, the helmet and the weapon components.

(1) The Computer/Radio/GPS. The computer/radio/GPS component is the heart of Land Warrior. The component integrates the helmet and weapon sensors, with voice and digital communications, planning, messaging and warnings to the soldier. The information system also stores the report formats and complex military orders. The soldier navigates through the system via a tool called the System Control Module, which moves a cursor on the visual display.

To help with communication, every soldier will have a radio capable of secure transmission up to 1.3 kilometers; every infantryman will be able to talk to every other nearby infantryman and to armor systems, artillery and aircraft. All soldiers will share voice transmissions, digital reports and still frame video in real time. Leaders will have slightly more powerful radios, capable of transmissions up to 5 kilometers.

To aid navigation, every soldier will have an integrated GPS which receives a military signal. The computer will be able to store this information, which the soldier can reference. By looking at his visual display, the soldier will know where the enemy is, where he is and where his buddies are: no more map and compass, no more hopeful searching in the night.

(2) The Helmet. The helmet is the most intimate piece of equipment for the soldier. He will receive all of his information through its integrated video display. The helmet also incorporates the audio headset and microphone, day/night image intensifiers and laser detectors.

(3) The Weapon Components. The weapon is standard issue, designed to accommodate several components, the Close Combat Optic, the Thermal Weapon Sight, the Multi-Function Laser, the Daylight Video Sight and the Multi-Function Laser.

The Close Combat Optic is a red-dot sight, used to quickly acquire and engage targets while keeping both eyes open.

Thermal weapons sights, linked to the head mounted display, will show the soldier an enemy hidden by rain, fog, and smoke, darkness or dense foliage.

The Daylight Video Sight captures standard visual images and can enhance the soldier's natural vision.

Images collected by the thermal and video sights are integrated into the helmet-mounted display. Both sights can be used for targeting and engaging the enemy, or they can be used to capture video information for reference or transmission.

Because the images from the weapon sights are remotely linked to the helmet, the soldier can fire on a target without aiming the weapon from his shoulder. He can aim from around a corner or from over his head and still hit a target. All sights will be more accurate than traditional iron sights at greater ranges, out to 550 meters.

The Multi-Function Laser can determine the range and direction to a target. Before Land Warrior, ranging a target was almost always a guess. The Multi-Function Laser can give the proper range to a target to within $\pm$ 5 meters and direction to the target with an accuracy to $\pm$ 10 mils, out to a distance of 2500 meters.

Land Warrior's power supply is a 4.2-pound lithium-manganese dioxide cell which lasts for 16 hours.

III. FINDINGS

Design itself is an activity, not a subject in the traditional sense like mathematics or physics (Ref. 52).

A. INTRODUCTION.

Findings were collected from academia, industry, human factors professionals and program managers. Findings cover the value of design, the design principles, identifying user requirements, the design team and describes the design method/process.

Data collection included a literature review and interviews with several industrial designers, human factors experts and military personnel. The interviews took the form of a free-form discussion whenever possible, while addressing the research questions which were applicable to the area of expertise of the person being interviewed.

B. THE VALUE OF DESIGN.

1. The Cost Of Bad Design.

Design principles are attainable, but not often well applied. Costs of bad design range from theoretical to catastrophic.

Death and destruction are the worst. In the book *Set Phasers on Stun and Other True Tales of Design, Technology, and Human Error,* Steven Casey recounts chapter after chapter of the consequences of poor design. In *Phasers*, the consequences are not just poor maintainability or user disappointments; the results of bad design are death and destruction of millions of dollars of property (Phasers). Badly engineered products can kill and maim (Ref. 52). Examples of design disasters include:

a. During a medical treatment, Voyne Ray Cox, 33, was killed by a lethal dose of 25,000 rads of high-energy radiation because the computer gave the operator imprecise information.

b. The supertanker *Torrey Canyon* runs aground on Pollard Rock, spilling 31 million gallons of crude oil because the ship's captain mistakenly disconnects the ship's rudder from the wheel on the helm, via the computer controls.

c. Union Carbide kills 2,500 residents of Bhopal, India when methyl isocyanate escapes from the plant into the atmosphere. Design shortcomings make it impossible for the engineers monitoring the plant to correctly assess the situation in time to avert disaster.

d. Northrop test pilot David Barnes is killed in his F-20, *Tigershark* jet fighter when his g-suit is unable to protect him from the high g-forces encountered during test maneuvers. He loses consciousness and crashes into the forest.

Some designers consider the moral consequences of their designs. In the current age of information technology, the design affects people's minds directly. During the industrial revolution, technology may have had undesirable effects, such as the danger of awkward machinery while at work. However, with information technology, the effects are ubiquitous, direct and subtle (Ref. 43).

In the military, the cost is measured in a variety of ways. If a soldier is issued a piece of equipment, but cannot figure out how to use it, does not like it, or finds it tedious to work with, the equipment will likely not be used. A mounted soldier might take equipment along if he is required to, but is unlikely to actually use the equipment. A dismounted soldier might not take the equipment at all because the weight makes his work harder. The dismounted soldier is only likely to take along equipment that he feels adds to his mission (Ref. 33).

Commercially, loss of market share and opportunity is part of the cost of bad design. Ideo founder David Kelly tells us that design is not everything: it is just one aspect of doing business. However CEOs suddenly see the value of a good design when customers lust after their product (Ref. 20).

Perhaps a better indicator of what is lost by a bad design is the value of what is gained by a good design.

2. The Value Of Good Design.

Systems are designed to solve problems. However, all too often, the developed system creates new problems. Typically, there is a low level tension between the machine and the human user. For the military, one human-machine pair can have far-reaching, life and death consequences, so it is especially important to reduce the interface tension. Developers can reduce the low level tension and avoid many potential problems through appropriate design (Ref. 43).

Good design takes into account innate human variability and unpredictability. Traditional engineers are continually surprised by the behavior of operators and users, which can result in accidents, possibly with heavy costs. Engineers tend to blame "human error" in such cases. Human factors experts say that a better integration of behavioral knowledge into engineering, operations, and training could avoid most catastrophes (Ref. 10).

The benefits of design can also be measured from an economic standpoint of managers and workers. Management benefits from increased productivity and reduced costs. Workers benefit from increased safety, health, comfort, usability of tools and improved quality of life (Ref. 30).

In the commercial world, "(Industrial design) is important because how much your product pleases the customer is going to determine how quickly you'll be able to ramp up your sales. Good design can provide the kind of buzz, the kind of word of mouth you need for a successful product." (Ref. 20) People will pay a premium for good design. The *Palm V*, which is sleek and beautiful, outsells the *Palm III*, which has exactly the same functionality (Ref. 20). Other examples of the value of good design include:

a. The office supply store, *Staples*, redesigned their website to be more user friendly. In one business quarter, Staples boosted repeat customers by 67% and experienced an 80% increase in traffic. There was a 31% decline in users that fell off of the page. Most importantly, Staples sales were up 491%, with continuing growth (Ref. 73).

b. *Human Factors International* (HFI) is a commercial firm that specializes in website design. *Dell Computer* had *HFI* help redesign their website, to improve the customer experience in hopes of selling more computers. Within weeks of the redesign, customer satisfaction increased 12%, demonstrating a positive correlation between the website redesign and value added (Ref. 52).

c. Industrial design can solve problems with products. If a product has problems with sales, usability, or manufacturability, industrial designers can redesign a problem product to meet the needs of the user (Ref. 7).

d. The Government-University-Industry Research Roundtable identified several advantages of understanding human behavior, which translates into designing systems and products based on this understanding. Specifically, the benefits included:

i. Vastly more accurate market forecasts;

ii. Improved educational techniques;

iii. Automated systems more tolerant of human error;

iv. Information technology tailored to the user's cognitive and perceptual capabilities;

v. Improved financial technologies;

vi. Better understanding of how humans interact with natural environments;

vii. Better strategies for improving public health;

viii. Improved public goods (Ref. 10).

e. Redesign of kit components for the C-141 aircraft saved $2 million in installation costs and reduced operation weight for 200 aircraft over a 35-year life span (Ref. 30).

f. Improved operator seating for a lumber loader saved $65,000 annually for a one-time investment of $6,900. Leg protectors for loggers saved the South African forest industry $4 million annually (Ref. 30).

g. A forge shop manipulator was redesigned to have an ergonomically designed cabin and overall better workplace design; vibration and noise were reduced. As a result operator sick leave dropped from 8% to 2%, productivity improved, and maintenance costs dropped by 80% (Ref. 30).

Unfortunately, the human factors community has done a poor job of documenting and advertising the cost-benefits of good ergonomics (Ref. 30).

Good design process, which leads to a good design, is superior in terms of cost effectiveness and manpower efficiency and satisfies needs in a cost effective, safe and elegant manner. Concentration on simplicity leads to enhanced quality at lowest cost. Simplicity also leads to better reliability (Ref. 52).

There are some program offices within the military that realize the benefit of making the soldier feel good about his equipment. PM Land Warrior insists that soldier acceptance is an essential part of the success of the equipment (Ref. 33).

C. DESIGN PRINCIPLES.

Most modern systems are fantastically complex. It is not possible to design a system of any complexity without a method of organization (Ref. 43). Understanding the design principle is the best starting point of any project.

So just what is a design principle? A principle is a basic truth, law, or assumption and a rule or law concerning the functioning of natural phenomena or mechanical processes (Ref. 61). While there are fads and trends in every school and industry, only the principles remain true over time. This research attempts to identify those truths that the different design communities use to guide their approach to product development.

With few exceptions, design principles are interchangeable for hardware, software and even organizational processes.

1. Academia.

Design is an activity (Ref. 52). The principles that guide design cover the development of the product from the first concepts to the final production and use. The principles can be detailed, making them good for describing the attributes of a specific artifact. The principles can also be broad, which make them good for describing the process and relationship of the designers and the design team. Good design principles embody all of the applied sciences – from the process to the product (Ref. 52).

Donald Norman describes in detail the attributes of a specific artifact. In his book *The Design Of Everyday Things,* Norman outlines principles, which designers must apply in order to simplify a problem and make a product that is useful. Norman gives us *Seven Principles For Transforming Difficult Tasks Into Simple Ones*:

a. Use both knowledge in the world and knowledge in the head. If the user knows how to use the product, don't include every bit of information in the design; let the user utilize his knowledge in the head. If the product or task is complex, make the information available to the user through the design of the product.
b. Simplify the structure of tasks. Do not add unnecessary steps into task accomplishment.
c. Make things visible: bridge the gulfs of execution and evaluation. Let the user see what it is that you want him to do.
d. Get the mappings right. Do not make the function of a product invisible. There must be a cause and effect relationship.
e. Exploit the power of constraints. Don't make it possible for a user to do something they should not do.
f. Design for error. Expect users to do the unpredictable and expect mistakes.
g. When all else fails, standardize. Make all designs for a particular task exactly the same. Electrical wall sockets are a good example. Through standardization, many problems of design variation and interface problems are avoided.

These seven principles lead into Norman's *Principles For Good Design*:

a. Visibility: Make key elements visible to the user. Give the user a clue as to what they are meant to do.

b. A good conceptual model: The product should give clues to its use through its design. For example, a door that is pushed should not have a handle that you can pull.

c. Good mappings: Let the user see the relationship between their action and the desired outcome. The manipulation of the product should seem logical to the operation of the product.

d. Feedback: The product should immediately tell the user if it is being used correctly or incorrectly.

In *Total Design*, Stuart Pugh outlines thirteen principles, which bridge the gap between the design and manufacturing communities. These principles may seem to relate better to a program manager than Norman's principles from an overarching perspective.

a. The user need/customer requirement/voice of the customer is paramount to the success or failure of the product.

b. All facets of business need to be involved in, and interact with, the design core in parallel and not sequentially – the design team.

c. To satisfy the user need, rigorous systematic working is required throughout the design core using modern methods that are both dependent and independent of the technology or product.

d. A product's status needs to be assessed accurately before starting any new design.

e. Within systematic working, a cyclical process of synthesis/analysis/synthesis is necessary, brought to a satisfactory conclusion by the appropriate methods.

f. The most up-to-date elements of engineering, based on sound engineering principles, must be used as appropriate.

g. Total design teams must be multi-disciplinary, with sufficient expertise within the team, and sufficient diversity of expertise.

h. Consideration must be given to a wide range of alternatives without prior commitment to any particular alternative.

i. The design team must repeatedly scrutinize and test the information and reasoning on which a design is based.

j. People performance is critical to total design performance.

k. Engineering principles are a vital subset of total design; they influence but do not necessarily relate directly to the user need.

l. To minimize the cycle time for completion of the design core (to minimize process losses), systematic working with modern methods and aids is required.

m. Total product quality is only achievable through total design (Ref. 52).

2. Industry.

David Kelly believes that the majority of people are not design savvy. However, he believes that human values "hit you in the face eventually" and designers become more interested in them. Kelly does not have a list of principles. Instead he seems to embody a philosophy of design, spending at least half of the money on the fit to the user, ("the subjective stuff") and spending the rest on the "technological stuff." Kelly's rational is that lawyers are expensive, compared to designers. When the customer is really important, the designer must spend a lot of time on the customer. A technologically based product may not be as focused on the customer. It will be a product which the customer is happy to have regardless of how well it works. In this case, the company must spend more time implementing the product than designing it (Ref. 20).

Design Engine believes, above all, that form follows function (Ref. 50). You always need the functionality. “Industrial design is not just making something look pretty, it is making something work” (Ref. 7). The goal of the designer is the same as the producer, to make something that works. Good industrial designers ask themselves, “How can we make the product intuitive?” Styling is important because it gives the product an edge in the market. Even an existing product (i.e., old technology) essentially becomes “new” after a redesign. For example, in the military, redesigning the GPS would make the product more appealing to soldiers (Ref. 7).

3. Human Factors.

In his book, *The History of Human Factors and Ergonomics,* David Meister evaluates effects of the system concept on human factors ergonomics. Meister assumes that the system concept is the foundation of human factors ergonomics. The system concept provides the essential framework for human factors considerations:

a. The system approach accounts for the human element of the system and justifies the application of the human factors and ergonomics disciplines.

b. The human-machine system is a unique phenomenon.

c. Professionals who are honestly committed to the systems approach, must consider every human factors problem.

d. The system approach requires ergonomic considerations at every level.

e. Human factors cannot be considered in an isolated way. The interaction of humans and machines must be considered within the context in which it will be operating.

f. Organization of the system is essential in evaluating human factors.

g. The human model provides the basis for system design; the system must conform to the human.

h. The system must account for human variability.

i. Human factors ergonomics must be a top priority if systems are to be developed properly (Ref. 43).

The Government-University-Industry Research Roundtable believes that the principles of behavioral science and human factors must be integrated to create product that solve real world problems (Ref. 10).

The Government believes that "Human Factors engineering is an integral part of the systems engineering process. In order to assure mission success, all factors that affect the system performance and readiness must be considered. In fact, people are a significant part of the operational system in every case" (Ref. 13). Government, human factors design principles come in the form of usability-based standards such as MIL-STD-1472, *Human Engineering Design Criteria for Military Systems, Equipment and Facilities.* Guidance from this publication and complementary publications clearly identifies the challenges and the aims of human factors considerations.

> "The capabilities and limitations of the system operators and maintainers always place constraints on systems that must be considered during the development process. A comprehensive management and technical strategy for human systems integration must be initiated early in the acquisition process to ensure that human performance, safety, manpower, personnel and training issues be considered throughout the system design and development process. The objective of the human factors engineering critical process is to establish acceptable compatibility between the system and the people who operate, maintain, and support it. To insure system objectives are met and personnel safety is considered, human factors engineering must be integrated into all phases of systems engineering: design, manufacture, test, and support (Ref. 13)."

United States Air Force guidance accounts for the capabilities and limitations of the operator, maintainer, trainer, and other support personnel (Ref. 13):

Human Factors	Human Characteristics
Anthropometrical Factors	Human Physical Dimensions, Body Posture, Repetitive Motion, Physical Interface
Sensory Factors	Hearing, Vision, Touch, Balance
Cognitive Factors	Mental Ability, Skills, Decision Making, Training Requirements
Psychological Factors	Human Needs, Attitudes, Expectations, Motivations
Physiological Factors	Human Reactions to Environments, Strength (lifts, grip, carrying, etc.), Endurance

The following paragraph is an excellent summary of the design beliefs and principles common among DoD professionals. The example relates to software, but applies equally to hardware.

> "The human interface is of vital importance in automated information systems (AIS). If feasible, the AIS being acquired should be compatible with other systems in the organization, and operation of both software and hardware should be user friendly. This will reduce the amount of training required to operate the system. In addition, the human factors engineer must ensure that, internally, the AIS is consistent. For example, functions should be standardized across screens (e.g., "exit" is always used to leave a window) and buttons should be placed in the same position relative to each other (e.g., "exit" always appears as the last button on the right-hand, bottom portion of the window and "cancel" always appears as the next to last button) (Ref. 28)."

More understanding of human factors principles and resources can be found at URL: http://dtica.dtic.mil/hsi/srch/hsi11.html.

> "DoD 5000.2-R (Paragraph 4.3.8) requires that a comprehensive management and technical strategy for human systems integration (HSI) be initiated early in the acquisition process. MANPRINT (Manpower and Personnel Integration) is the Army's implementation of HSI. The program was established in 1984, and the ultimate goal is to place the human element (functioning as individual, crew/team, unit and organization) on equal footing with other design criteria. MANPRINT's goal is to optimize total system performance. This is achieved by the continuous integration of seven human-related considerations (known as MANPRINT domains) with the materiel component of the total system and with each other, as appropriate (Ref. 28)."

The seven MANPRINT domains include Manpower, Personnel Capabilities, Training Development and Delivery, System Safety, Health Hazards, Soldier Survivability and Human Factors Engineering (HFE).

> "The goal of HFE is to maximize the ability of an individual or crew/team/organization to perform at required levels by eliminating/avoiding design-induced difficulty and error. Human factors engineers work with systems engineers to evaluate human-system interfaces to ensure they are compatible with the capabilities/characteristics of the target audience. Materiel systems should be designed using sound human factors engineering principles. Illumination, color, placement of controls, and quick and easy access to components for maintenance, built-in test equipment and self-diagnostics: these are but a few of the issues that must be considered in designing or acquiring a new system (Ref. 28)."

4. Program Managers .

The program manager must have the "buy-in" of the soldier. This seems to be a prevailing attitude among current Army programs. Certainly, the Delta Force Land Warrior and the Land Warrior program offices believe that it is important for the soldier to "accept" his equipment (Ref. 33).

The Delta Force Land Warrior goal was to design a product with the proper look and feel, ease of use, and functionality. COL Jette, PM Soldier had told the design team that he wanted something soldiers would accept (Ref. 33).

Land Warrior was a foundering system at one time. In 1998 it had become the focus of some rather unpleasant criticism from the GAO. As a strategy to recover, PM Soldier COL Jette adopted a new philosophy, and Land Warrior received the Army MANPRINT Achievement Award in 1999.

> "In November 1998, the PM Soldier Systems embarked on a strategy and philosophy to transition to a COTS and GOTS open architecture hardware, software and interfaces to take advantage of the commercial and consumer marketplace with innovative and "nimble" companies. Understanding that commercial and consumer contractors are structured to produce products economically, the ultimate goal is to produce a Land Warrior system much like Dell produces its computer systems for the consumer marketplace (Ref. 69)."

The program manager may specify his design principles, but it is the contractor that makes the principles a reality in the product. It is important to examine the principles of the design firm that designs and makes the equipment for the soldiers.

A consortium of companies, each with their own specialty, makes the components of the Land Warrior system. This researcher interviewed officials with two of the companies, *Pacific Consultants LLC*, the designer and *PEMSTAR*, the manufacturer. Pacific Consultants LLC is the "design house" for Land Warrior. When developing a product, Pacific tries to find a balance in four areas: weight, space, power, and balance (Ref. 3).

Pacific's aim is to make a system that is lethal, effective and suitable, within the four guiding principles. However, Pacific relies on feedback from PM Soldier to validate the design and provide constructive criticism. With this in mind, off-the-shelf technology drives much of the design. Politics also influences the design outside of the principles of Pacific. The very nature of a consortium arrangement requires that everyone compromise (Ref. 3).

PEMSTAR is the parent company of Pacific and manufactures the designs that Pacific produces. PEMSTAR is less interested in rapid innovation and more interested in reaching stable points in the design process so that production can go ahead (Ref. 21).

PEMSTAR seems skeptical of industrial design, fearing and attitude of form over function, which might be more suitable for commercial products. PEMSTAR believes design isn't as important when you are producing for a captive audience. However, PEMSTAR also acknowledges that military equipment should have a high-tech 'look' and maybe it should even look fierce (Ref. 21).

D. IDENTIFYING USER REQUIREMENTS.

Products are developed for users. Given a choice, a user will only use a product that they find helps them to complete any given task; such as a user who needs to open a bottle would likely use a bottle opener. The user's need is defined as a requirement. Each design community develops products according to the requirements of the user. However, each community has a different approach to identifying user requirements, which leads to different degrees of success.

1. Academia.

Proper design specifications can only be derived through full descriptions of the operational procedure, described by the user. This description is necessary in order to develop an evaluation matrix, which will lead to development of a successful product (Ref. 52). Pugh does not believe that this "front-end" of design is handled at all well (Ref. 52).

Often, user needs are represented by market research. Unfortunately, "market researchers are not taught to analyze situations so that they provide a comprehensive PDS suitable to control the activity of the design core." The best designers know what to look for and how to identify omissions in the market research (Ref. 52).

Pugh identifies a myriad of types of information needed at the market investigation/user need stage. Essential to the user, but not so much related to the market or manufacturing, are needs analysis and matrix analysis. Needs analysis is concerned with establishing the true needs of the customer. This analysis can be accomplished through suitably structured questionnaires, interviews, observations and discussions (Ref. 52).

> "If an experienced designer is asked to design something with [a] less than comprehensive product design specifications, he will almost, without thinking, fill in the gaps based on his experience and feelings; if these happen to be at variance with the true user needs, he will be designing to the wrong base (Ref. 51)."

Matrix analysis is an excellent method for the marketplace. A matrix is developed, which compares the product features desired with the availability of the features in the marketplace. The popularity of each feature is considered, and provides a basis for preparation of product design specifications (Ref. 52).

Pugh identifies 31 elements of a product design specification. Every element must be considered, at least on the first iteration of the design. Among the elements are performance, aesthetics and ergonomics.

Performance must be fully defined and objectives established. Successful design teams pay great attention to establishing performance objectives that are attainable. Many clients are amazed at the incredible cost of products written directly from performance specifications. However, it is not useful to over-specify (Ref. 52). There must be a balance between too much and too little specification.

Aesthetics, appearance and finish are difficult to specify, but, if done incorrectly, lead to many complaints afterwards. If the appearance of the product is not considered early, the final configuration "just happens". The visual performance is always first; the physical performance comes later (Ref. 52).

Ergonomics address the man-machine interface in all its aspects. The aim of well-applied ergonomics is to design a product which is a delight to use. The only way to know what the customer will really enjoy is to ask him (Ref. 52).

2. Industry.

Industrial design firms are often employed as a subcontractor by other firms to enhance products. The marketing departments of the client firms collect and provide user requirements to the industrial designer (Ref. 50).

David Kelly incorporates the identification of user requirements into his design process. He believes that interviewing only one user doesn't do much good. It is more important to interview ten. However, Kelly doesn't believe that the designer gets much more out of interviewing 1,000 users than he would from just interviewing just the ten (Ref. 20).

Design Engine most often uses marketing requirements. However, through market awareness, they try to anticipate the design trends of the future. Design Engine tries to anticipate what the user wants, even if the user isn't completely aware of what will work (Ref. 7).

Design Engine tries to help the user establish a design language. A design language is a commercial trademark, which comes through in the look of the product. For example in car styles, the styles become the design language. Design language helps to establish a product and win market share. Once a design language is established, it helps the producer to sell related products. *Lego*^{TM} is a good example of how design language has been established. *Mission to Mars* becomes a product line within the larger market of building blocks (Ref. 7).

3. Human Factors.

Identifying the needs of the user is actually done in two ways: first, by interviews and an understanding of human needs; secondly, through observing the user in the situation. The Human Engineering Research Laboratory can apply both of these methods to assist the user.

Requirements are developed through an understanding of the specific tasks to be performed and the related hazards. Human factors professionals will examine records, conduct interviews, and make observations of the situation. Finally, they will develop cost-effective solutions that work using sound ergonomic principles (Ref. 8). For example, the U.S. Army has worked with BC Research, Inc., an ergonomics firm, to develop a standard for the health hazard of mechanical shock and repeated impact in Army vehicles (Ref. 8).

4. Program Managers .

Program managers rely on the government requirements generation process. Once a material need is identified, the user writes requirements for the product. In the case of Land Warrior, the user also has experts from the Human Engineering Research Lab in Aberdeen, Maryland at his disposal to assist in writing requirements. The requirements are written based on empirical information and mission specific information (Ref. 35).

PEMSTAR has a practical approach to satisfying the user – they give the user what the he asks for. The government brings its requirements to PEMSTAR and PEMSTAR makes the product. Benefits to PEMSTAR are revenue and the possibility of commercial applications of its product. Pacific produces prototypes to specifications and makes corrections based on feedback from the program office (Ref. 3). However, giving the user what they want does not mean that the most economical process is followed (Ref. 21).

One of the typical aspects of government contracts is a requirement to find a unit price before the product is actually designed. Usually, PEMSTAR would not fix a unit price early in the program. Consequently, PEMSTAR must mark-up the unit price to cover uncertainties in the program. This price is then fixed for that portion of the contract. In a normal commercial contract, PEMSTAR would offer the customer a choice of cost reduction or increased functionality as production progresses. This choice still may be possible in future blocks of the Land Warrior system (Ref. 21).

E. THE DESIGN TEAM.

The design team is the organization that integrates the user requirement and develops the product. Some design teams are very small while others are very large. However, each has the same goal in mind: make the best product for the user. The design team is not necessarily the core group of the entire project. Instead, the design team is part of the larger program team or may work independently in a consulting role.

1. Academia.

Design, above all else, must be a team activity (Ref. 52). Non-engineers should always be included on design teams to help prevent misdirected engineering effort. Non-engineers are very helpful in generating ideas through analogy, brainstorming, attribute listing, checklists, inversion and combination. These methods for creating ideas are obvious to psychologists, but not obvious to many engineers (Ref. 52). Pugh recommends that the total design effort should become even more rigorous as the engineering effort increases on a project (Ref. 52). It is essential that every team member see how his or her partial design discipline fits into the overall effort (Ref. 52).

There must be space dedicated for the design activity. The design environment should have room for six to eight people, plenty of wall space, and it must be furnished to allow the designers to collect and portray their ideas (Ref. 52).

Design teams are more productive than individuals. However, it is important to emphasize the best of individuals and groups together. Individuals often best generate concepts, but the concept selection and enhancement is often best performed in groups (Ref. 52).

The design team must have a leader to ensure that the proper documentation occurs and that the design process is applied in a disciplined way. Occasionally a strong-willed individual will try to force through a failed concept based on emotion. It may be necessary to control the questioning of concepts and move forward (Ref. 52).

2. Industry.

At Design Engine, the team varies in size depending on the type of project, the money involved, the size of the project, and where the customer wants to take the project. The design team is never composed of just industrial designers. The size of the team is flexible and may change as the project progresses (Ref. 7).

The design team always has a team leader to prioritize work. In iteration after iteration, the team meets together to discuss concepts and to capitalize on individual work, in order to narrow the design concept into the product. Communication is the most important thing for the team. The working area facilitates the progress of the project. At Design Engine, tables are arranged in a circle to enhance communication among the designers (Ref. 7).

3. Human Factors.

DoD prescribes that a MANPRINT working group will be formed to provide the Combat Developer, the Functional Proponent, the Program Manager, and the Materiel Developer with subject matter expertise in MANPRINT-related functional disciplines to ensure that MANPRINT is fully integrated in the systems acquisition process. The MANPRINT Working Group should be established prior to Milestone 0 (Ref. 40).

The composition of the MANPRINT working group varies with the program, but the team members must include subject matter experts in each of the seven domains of MANPRINT. However, even this focus may be too narrow. Because MANPRINT interacts extensively with other disciplines, it may be necessary to consult with individuals in other areas (Ref. 40).

Once the group has been established, a draft MANPRINT Working Group charter should be prepared and distributed to members for comment and approval. The charter should define the purpose, membership, objectives, and procedures of the group. This charter defines responsibilities in order to ensure understanding and promote a feeling of ownership (Ref. 40).

The MANPRINT working group then develops the System MANPRINT Management Plan (SMMP). The System MANPRINT Management Plan (SMMP) is the documented foundation for further work (Ref. 6).

Ideally, many of the members of the MANPRINT Working Group will transition over to the MANPRINT Working IPT as the program progresses. This transition allows for continuity in the MANPRINT program (Ref. 40).

4. Program Managers.

TRAC Monterey develops its own Delta Force Land Warrior product. Through their own innovation and the help of some software designers, the personnel from TRAC Monterey meet in small groups with the soldiers to resolve design issues.

At the Land Warrior office, a civilian, Dr. Jerry Krueger, heads the Land Warrior MANPRINT IPT (Integrated Product Team). Dr. Krueger advises PM Soldier on the MANPRINT aspects of the Land Warrior system. In addition to Dr. Krueger's 'in-house' advice, teams of human factors specialists from the Human Engineering Research Laboratory, in Aberdeen, Maryland support the user. These teams help the user write requirements and evaluate prototypes (Ref. 35).

The PEMSTAR focus is on manufacturing. Its teams are oriented toward production and not design.

Pacific Consultants LLC has an impressive operation. Pacific can rapidly design and artifact and produce a prototype. However, it was not apparent that anyone on the staff had any human factors expertise. Likewise, there did not appear to be anyone with industrial design training on the staff. There were conference rooms, but most of the work was done in separate offices within the building complex, and not in one design area.

F. THE DESIGN METHOD/PROCESS.

Each design community has its own method or process, which it applies to develop and produce a product.

1. Academia.

A structured approach greatly enhances design performance (Ref. 52). This research has never found a design professional who does not subscribe to this belief. Pugh emphasizes that the design effort must be up front.

> "By design, the work has concentrated on the front-end of the product design core, up to and including detail design with the main emphasis tapering off after the detail stage, although parallels have been drawn with manufacturing process design. It is the author's view that it is in the front-end area where much rhetoric and exhortation has been expended over many years, with little positive results in tangible terms (Ref. 51)."

Pugh calls his total design method the Product Delivery Process (PDP) where he can interlink technology-independent methods (Ref. 52). Pugh's PDP follows a design core with six stages. Each stage has a technique or method to be applied, which yields a result and corresponding benefits.

a. The Market is the first stage of the design core. In this stage the designer applies information and competitive analysis, parametric analysis, and Product Design Specifications (PDS) as an integrator. PDS becomes the workspace for the entire design project. PDS is refined as the stages of the design core progress. The aim of this stage is to understand competition, technology and markets.

b. Specification is the second stage of the design core. The designer applies techniques like Dr. Genichi Taguchi's Quality Function Deployment (QFD), which is considered the "voice of the customer". The Product Design Specification (PDS) is formed in this second stage and it is here that real customer requirements and constraints are identified (Ref. 52).

c. Concept Design is the third stage. Concept generation and selection matrices are developed. The use of QFD matrices is an excellent method to design a concept. The aim is to develop invulnerable concepts in shorter time frames.

d. The fourth stage is Detail Design. This stage employs optimization techniques, like Taguchi's design of experiments or parameters and QFD matrices. The aim is to develop better components and to prepare for manufacturing.

e. Manufacturing is the fifth stage. Pugh gives examples of Just In Time Delivery, Statistical Process Control and QFD matrices. The aim of this stage is quality control and reduced inventory.

f. The final stage is to Sell. Again, the designer must verify that the product produced is what the customer actually wants. If this is the case, commercial firms will realize profits through sales.

The purpose for each of the stages is to directly benefit the customer, the company and the employees. Once the product is sold, the ultimate benefit will be customer satisfaction. The design professional follows the core design stages systematically, resisting the temptation to start engineering without developing the specifications (Ref. 52).

2. Industry .

David Kelly (the CEO of Ideo) uses a design method that is excellent, well tested and leads to good design:

a. Understand: Understanding means knowing the state of the art and understanding the marketplace. Understanding includes market research and talking with experts. It is essential to meet people and know what they do.

b. Observe: David Kelly says this phase is often skipped. In this phase, designers figure out how the user will use the product. However, this step cannot be conducted using focus groups, because focus group members tend to want to please the designer; saying what they think the designer wants to hear. Instead, it is crucial that the designer observe the user and the product or similar products and reach objective conclusions about where the product causes the user problems and then design in a way to fix those problems.

c. Visualize: This is the prototype stage. It is better to build prototypes and show them to people than trying to "intellectualize" the specifications on paper. The prototype should be "crummy"; made out of cardboard and cheap materials. The user will then feel free to suggest major changes, which will give the designer the answers he needs to make the product.

d. Evaluate and refine: Repeat the visualization process, making the refinements that the user recommends. There is no end to the cycle until the deadline when the solution must be implemented.

e. Implement: Get the product to the market place. Use the market place as a testing ground, and expect to make product No. 2, No. 3, and No. 4.

The process is time intensive. Time and effort can range from one day for one person to six months for ten people. Everyone will be tempted to cut corners. However, no part can be done in a cursory way. It is possible to get 70% of the knowledge the designer needs with very little effort. The risk of skipping a phase is that the product will not match the market.

At Design Engine, the design process is from start to finish (Ref. 7). Design Engine's product development process covers seven steps, up to the product testing.

a. Identify Customer Needs. Industrial Designers work closely with marketing and engineering to identify customer needs. Industrial designers participate in focus group study.

b. Develop Target Product Specification. Design Engine develops target product specifications for hardware, software, --desired features and target performance. At this point, Design Engine asks a few critical front end questions:
   (1) Have we prioritized the project goals?
   (2) Did we achieve good product specification?
   (3) Did we stay within the budget?
   (4) Have we identified and defined all project responsibilities for our team?
   (5) Can we meet the deadline?

(6) Is our project schedule in writing?

c. Develop product platform and market positioning. Define product category and point of entry. Important marketing questions at this point include:

(1) What is the message?

(2) Who is the target audience?

(3) Is the market willing to accept the product?

d. Generate Core Product Concept. This stage is the initial project introduction meeting. Industrial designers generate multiple concepts in accordance with the specification prescribed. Industrial designers work in cooperation with engineering and address both hardware and software issues. The group arrangement, for a small product, is a hardware group, a software group and the industrial design group.

e. System level design. The engineering team narrow down the concepts from industrial designers then selects a final approach and industrial designers refine the most promising approach. Industrial designers can quickly develop and generate the proposed architecture and refine product's styling and function.

f. Management makes an evaluation of the proposed system.

g. Detail design. Industrial designers select a final concept and work with engineers so that changes do not create ergonomic or aesthetic problems. Industrial designers work closely with marketing and engineers to solve any design conflicts. Finally, industrial designers are responsible for packaging the product once most of the engineering details have been addressed. Industrial designers complete product documentation and choose materials. Engineering will define product specifications and assign product tolerances.

Industrial designers are committed to the steps of the process but are flexible in how the steps are carried out. Senoir design professionals negotiate the design plan with their clients. Younger designers execute the commercial design method/process, but only under the close supervision of more experienced design supervisors. This arrangement allows young designers to develop innovative solutions while the senior designers ensure process integrity (Ref.7).

3. Human Factors.

The human factors effort is meant to be non-stop throughout the development process. The MANPRINT Working Group is able to get advice from many subject matter experts, including the U.S. Army Research Laboratory -- Human Research and Engineering Directorate (ARL-HRED).

ARL-HRED is responsible for conducting a Human Factors Engineering Domain Assessment, which will assist the user and the program office. The assessment reviews the status of human factors engineering the program approaches a milestone decision. The major purpose is to identify any design flaws that might prevent the system from passing into the next phase of the acquisition lifecycle. The assessment will also identify issues that might enhance system performance (Ref. 29).

The contractor is expected to incorporate human factors considerations into the design and manufacture of the hardware or software.

> "The contractor shall plan and implement a Human Factors Program to insure the satisfaction of system objectives and personnel safety of the operator and maintainer. The contractor shall perform user and machine analyses and trade studies to include trade-offs among the hardware, software, skill levels, safety, training, personnel, and life cycle costs; ensure manpower, personnel training and logistics support information is derived from early human engineering analyses; and verify through test and evaluation that trained personnel can safely and effectively operate, maintain and control the system in its intended operational environment (Ref. 13)."

4. Program Managers.

Program managers are committed to the systems engineering approach for product development (Ref. 49). This approach is systematic and allows the program manager to consider all the essential elements of the process and incorporate solutions at the optimal time in the program.

On both the Delta Force Land Warrior simulation and Land Warrior, an iterative approach of design, test-fix-test has emerged. This is an iterative process where the user gets to see a prototype of the product, and make comments which can then be incorporated into the design. The redesign is again evaluated until the product is acceptable.

This design process is incorporated in the systems engineering model, which is meant to account for all aspects of procurement. The IPT for MANPRINT makes an assessment of the MANPRINT domains within Land Warrior (Ref. 35). Below are some of the issues, which the IPT must consider:

a. *Operational Suitability (OS)* The degree to which a system can be placed satisfactorily in field use with consideration being given to availability, compatibility, transportability, interoperability, reliability, wartime usage rates, maintainability, safety, human factors, manpower supportability, logistic supportability, natural environmental effects and impacts, documentation, and training requirements (Ref. 26).

b. *Soldier-Machine Interface (SMI)* Considerations through system analysis and psychophysiology of equipment designs and operational concepts ensure they are compatible with capabilities and limitations of operators and maintainers (Ref. 26).

c. *Man-Machine Interface* Degree of compatibility between the user (individual) and the equipment being used (Ref. 26).

The IPT for MANPRINT submits its assessment of the man-machine interface issues to PM. The PM then incorporates the MANPRINT issues into the program.

The military employs a "User Jury" to evaluate software design. A "user jury" at Fort Bragg, North Carolina tested Delta Force Land Warrior. The "user jury" consisted of military subject matter experts, both users as well as computer programmers from the contractor. For the most part, the soldiers loved the system. Most of the appeal had to do with the commercial grade visualization of the military system. In obtaining the visualization necessary, little of the required performance was compromised (Ref. 33). However, some changes did have to be made. As the jury recommended changes, the contractor would reprogram the software to give the user what they wanted. This process was iterative until the software met an acceptable level of performance from both the users and the computer programmers (Ref. 48).

Land Warrior has been pleased with its results so far and sees itself as a cutting edge program. The program takes advantage of the commercial marketplace to produce a Land Warrior system much like Dell produces computer systems. Additionally, the program office and the contractor see that Land Warrior can be applied to other areas of society. Firefighters, forest rangers, medical support personnel, police and maintenance technicians may eventually use Land Warrior technologies (Ref. 5).

Land Warrior uses a series of "fightability assessments" to determine the nature of the man-machine interface (Ref. 35). One of the most significant assessments to date was the Joint Contingency Force – Advanced Warfighting Experiment in September 2000 at Fort Polk, Louisiana (Ref. 5). The program manager and the contractor get feedback on the design during these assessments.

There are problems with user feedback --it is rare and often biased. As discussed earlier, users often don't tell contractors what they really think, or they only tell contractors what they think contractors want to hear. A better way to collect useful information is for company professionals to observe the user with the product. However, PEMSTAR and Pacific usually do not make their own assessments of users with the equipment. It is possible that both PEMSTAR and Pacific could do a better job of assessing user satisfaction if they got to evaluate the user with the equipment (Ref. 21). Apparently, specialists from the Human Research Engineering Laboratory make MANPRINT evaluations and pass the results to the program office, leaving PEMSTAR and Pacific out of the loop (Ref. 35).

Once feedback is received, the contractor can propose a different solution. Pacific showed the researcher several iterations of Land Warrior components. Pacific had taken advantage of the latest stereo-lithography techniques to produce rapid prototypes for evaluation. Each was a concept that had been evaluated and rejected by the Program Office, until an acceptable model was chosen for further development (Ref. 3).

IV. ANALYSIS AND SYNTHESIS

The ultimate customer is the soldier – my son or daughter, your son or daughter – who will judge our efforts with their lives and mission accomplishment. This is a sacred trust, which will not be compromised.

- Army Test and Evaluation Command

A. INTRODUCTION.

Research has shown that everyone, in this study, involved in the design or acquisition process really has the user's best interest in mind. I truly believe that everyone involved in this research is doing everything they can to make the best product possible. However, I think there are instances, for whatever reason, that not all 'best practices' are use in the acquisition of soldier equipment.

The analysis and synthesis looks for trends within the data, or for innovative processes, which the military could employ in the acquisition of equipment. The analysis and synthesisattempts to discover the impact of bad design, the feasibility of employing industrial designers and the expected benefits of industrial design best practices, which program managers can utilize to increase soldier acceptance of equipment.

Much of the analysis and synthesisis drawn from anecdotal data. Although the opinions vary, themes emerge in principles and processes, that concur with the stated desire of designers and program managers.

B. ANALYSIS AND SYSTHESIS OF THE VALUE OF DESIGN.

"It is professionally impossible to give an opinion of any value about a design without knowing its origins – the PDS" (Ref. 52). However, because we can investigate the origins of design, it is possible to place a value on design. Analysis of design is subjective only if you do not understand the objective of the designer.

For a design to add value, the design must be created around the need of the user. Design that is not oriented toward the user will go to waste. Given a choice, a soldier will pick a design that suits his needs best, even if that equipment is unauthorized personal equipment in the place of equipment that is issued. For example, many soldiers prefer to use the *Garmin* global positioning system instead of the military system. The soldiers prefer the size, weight and usability of the *Garmin*. While it is true that the Garmin doesn't use the military signal and is therefore susceptible to jamming or spoofing by the enemy, soldiers are willing to take a risk in performance for the convenience of using a more user friendly piece of equipment (Ref. 23).

Soldiers tolerate poor designs, but only because they are a captive audience. However, tolerance doesn't mean the soldier will actually use the equipment. If a soldier is issued a poorly designed piece of equipment, he may never use it. In the early development of the Land Warrior system, there were elements included which the soldiers did not use. The original design included a mouse for soldiers to input information into the computer. Almost no one used the mouse during the initial week of training. Recommendations were to omit or modify the mouse (Ref. 36).

The soldier may give the 'appearance' of using the equipment by taking it along to field exercises for accountability purposes. Mounted soldiers can easily carry excess equipment on their vehicles. Dismounted soldiers are more likely not to take the equipment along at all because they have to carry it. Equipment that is never used is a waste of time, money, and other resources (Ref. 33).

There is no real way to determine what the soldier will use and/or like unless the soldier is included in the design process. For example, in evaluating five designs for field gloves, the soldiers selected the gloves with loops by which the gloves could be hung on a hook. All other things being equal, the one attribute that really mattered to the soldiers were the loops (Ref. 22). However, this attribute made a significant difference to the soldiers, setting the gloves apart as a quality design.

Design quality refers to the inherent value of the product in the marketplace. The design dimensions include: performance, features, reliability, durability, serviceability, human response, aesthetics, and reputation (Ref. 12). Industrial design does not try to optimize every inherent value of design, but it will benefit the military in three ways. It will improve operator performance, evoke positive emotion in the user, and reduce the training burden associated with the piece of equipment.

The true value of the design is the experience it provides to the user. This research has shown that everyone in the acquisition process wants the user to have a positive experience with his or her product. However, in the fast paced acquisitions world, positive experience may not be enough to change the culture of government acquisitions.

1. Improved Operator Performance.

Good design improves operator performance. Staples attributed much of its 491% increase in sales to the ability of customers to use the Staples website more easily (Ref. 73). The South African forest industry saved $65,000 annually by improving the operator seating on a lumber loader, reducing mistakes and increasing productivity (Ref. 30). As demonstrated by these experiences, good design leads to commercial success because the users can actually use the product. There is no reason to believe that this is not also true for military equipment.

Operator performance is enhanced by attractive and intuitive design. The user will examine the product closely because the user finds the product appealing. The design will accentuate the functional elements of the design that the user is meant to notice. Because the essential elements are accentuated, the item becomes more intuitive to use. Because the item is more intuitive, the operator will make fewer mistakes, leading to improved operator performance.

Performance is also enhanced because design accounts for the human variability and unpredictability (Ref. 10). This enables workers to modify their workspace to optimize their comfort, which leads to improved performance. For example, in the data included, improved operator seating for a lumber loader saved $65,000 annually for a one-time investment of $6,900. The major improvement was the positioning of the operator. The operator could see the operation much better. This change led to increased productivity and decreased down time due to repairs, which had to be made to the machine because of operator accidents. In another case, a forklift was completely redesigned using the ‘human-centered’ approach: it was designed around the operator’s needs, maximizing comfort. It has been a huge success in the marketplace (Ref. 30).

Improving operator performance is critical on the battlefield and it is essential to the life of the program. Every program must pass through operational testing. The idiosyncrasies of operational testing can be the death of a program, such as the testing problems experienced by SADARM. SADARM was tested by, what some believe, was an unprepared unit. The unprepared unit did not understand the system and was not able to optimally demonstrate the weapon system. Industrial designers probably could not have prevented SADARM’s problems. However, on many other systems such as Land Warrior, industrial designers can provide a design that even under-prepared users could operate effectively during testing.

2. Positive Emotion.

Industrial designer David Kelly believes that design represents the emotional part of the product. It includes how the user relates to the product and how the product resonates with the user. Emotion includes how the product looks, how easy it is to use, etc. (Ref. 20). This emotional element is really the aim of industrial design in the commercial market. Emotion inspires confidence in a product. If the design is applied to a well-engineered piece of equipment, operators are more likely to use the equipment and its capabilities rater than discard it. The military should be as interested in how the soldier feels about his equipment as any commercial firm.

One government contractor claimed, "design really wasn't important, when there is a captive audience." However, shortly afterward he said that "government products should look high-tech and maybe they should even look fierce" (Ref. 21), acknowledging the importance of the emotional element of product development.

Emotion is not just a term for commercial products. Air Force guidance accounts for the capabilities and limitations of the operator, maintainer, trainer, and other support personnel. These include psychological factors, such as human needs, attitudes, expectations, and motivations (Ref. 13).

Emotional benefits are essential when trying to introduce a process change within an organization. For example, if the United Parcel Service were to introduce a new piece of equipment to improve its tracking process for packages, the drivers would be more likely to implement the change if the equipment facilitates the task and is attractive to the user.

TRAC Monterey selected commercial products for their simulation because of the look. The look was essential to the success of the simulation. The computer program needed to realistically portray the soldier's environment. The one shortcoming of the commercial products was the physics behind the simulation (Ref. 49). There are elements of the simulation that are essential to the military but may not have been considerations of the game designers. However, Delta Force Land Warrior was able to work with computer programmers to change the product, thereby saving the look they found appealing and essential while adding the physics rigor that was required.

Creation of positive emotion cannot be underestimated. Positive emotion gives the user confidence in his equipment. Ultimately, if the equipment looks nice, but doesn't perform, the user will lose faith in his equipment. However, making a functional piece of equipment attractive will invite curiosity in the equipment. Appealing equipment will draw out the user's curiosity. Once the user discovers that the equipment is attractive and useful, the positive emotional bond will be cemented.

In early tests of the Land Warrior system, soldiers said that they felt like "guinea pigs" because the equipment was not well developed. Soldiers said they could not see the added value of the Land Warrior system (Ref. 36). Land Warrior has come a long way since that evaluation, but the lesson should not be lost. Unless the soldier feels considered in the design of the system, they will feel like guinea pigs long after the system has been designed, produced and fielded. This feeling will have a negative impact on the soldier's performance.

PM Soldier understands that the key to success of Land Warrior is soldier acceptance. If the soldier doesn't accept the product, then the product will lose support and funding and die. TRAC Monterey, under the patronage of PM Soldier, is also very clear about the importance of soldier acceptance. Industrial designers are expert integrators that can design a product to evoke the positive emotion that program managers want to see in the soldiers.

3. Reduced Training Burden.

Good design reduces training burden. Users will be interested in a good design and will volunteer their time to learn more about the product and how they can use the product in accomplishing their tasks (Ref. 33). Soldiers who are attracted to products become curious and gladly inspect the design that they are given. TRAC Monterey found that soldiers liked the Delta Force Land Warrior simulation so much that they gladly gave up their free time to use the system. If the product is designed to be intuitive, which industrial designers will ensure, training will be less complicated and more effective, and training time will be reduced.

Research shows that industrial design can fix many fundamental problems with existing products. Industrial designers can make an unpopular product popular by changing its configuration to be more attractive to the user. Again, attractiveness is the element that commercial marketing offices employ to interest customers. Additionally, if the design principles are properly applied, then the equipment will also perform properly and be intuitive. However, it is the attractiveness that invites the soldier to discover the great performance of the new systems. Program managers add attractiveness to the product by employing industrial designers.

4. Cost Savings.

Unfortunately, detailed data on cost savings is not readily available, even from the industrial design firms. This means that an analysis to determine wheather there is a positive do not support an analysis which shows a correlation between dollars invested in design and dollars saved cannot be conducted. The variety of situations and the ability to assess dollar amounts is too varied to draw direct comparisons. However, the anecdotal evidence available shows a positive and dramatic return on investment. There is no evidence that the application of good, sound design ever killed anyone.

In virtually every case, employing sound design principles pays off with a positive return of investment. The benefits were in the form of increased productivity, fewer worker absences, fewer injuries, less turnover, less damage to equipment, and an improved quality of life. Wherever the user was made the center of the design, the benefits grew (Ref. 30).

Cases where new design may not pay off can be effectively modeled and prevented from being employed. For example, *NYNEX* had designed a new workstation for its toll assistance operators to decrease the amount of time an operator took to handle a call. An evaluation of the new system was made using the GOMS (goals, operations, methods and selection rules) model. Results showed that the new system actually increased average operator time by 4%. By not installing the new system, NYNEX saved $2.4 million (Ref. 30). The lesson is that only the use of ergonomic design principles allowed NYNEX to evaluate the cost and benefit of the design.

C. ANALYSIS AND SYNTHESIS OF DESIGN PRINCIPLES.

Products that the military acquires should fulfill three requirements, in this order: First, the product should be functional; actually doing the task it was invented to do. Second, the product must be intuitive, to reduce training time, and decrease mistakes. Third, the product must be attractive in weight, size, shape, and color, i.e., pleasing to the user. This attractiveness will evoke positive emotion, which in turn enhances the reduction of training time and improves performance. Ultimately, the best products will enhance task accomplishment rather than retard it. The best products will provide the best experience for the user.

Research shows that every dedicated acquisition and design professional uses a structured approach to design and employs design principles. However, in both the commercial world and in the military, there is a real misunderstanding of the benefits of good design, and a false assumption that design is easy to do. Hal Hendrick gives four reasons that some designs seem to miss the mark:

1. Bad ergonomics has tainted the entire ergonomics profession. It could be that an incompetent ergonomics professional designed a user-friendly product or process that did not turn out to be so user-friendly.
2. Many users consider themselves "experts" at ergonomics and believe that ergonomics is nothing more than common sense. This belief leads to an

attitude that says ergonomics is not something worth spending money on. Unfortunately, this attitude leads to some of the worst design mistakes, including death.

3. Ergonomics professionals may naively expect organizational decision makers to automatically support human factors/ergonomics because it is the right thing to do. However, the "right thing to do" is not often the reason decision makers do what they do. Decision makers must justify every step in the process, and good will is not enough.
4. Ergonomics professionals have done a terrible job of advertising the cost-benefits of good ergonomics. The good word about ergonomics has not gotten out to everyone. The economics of ergonomics is probably the most compelling reason to invest in human factors considerations (Ref. 30).

Additionally, some of the academic traditions of behavioral and social sciences are part of the problem (Ref. 10).

Research suggests that some military procurement officials understand design principles and their importance, but could do much better pursuing good design. Program managers, know that they want the soldier to "accept" the product, but they are not so sure of the design principles to use to get the soldier to accept the product. In fact, there is evidence of each of Hal Hendrick's four points in military programs.

Professionals from PM Soldier and TRAC Monterey were very skeptical of industrial design and ergonomics. Personnel at TRAC Monterey seemed doubtful that any design firm could actually produce what they wanted. This attitude seems to lead to Hendricks' second point: Everyone at TRAC Monterey was confident that they could identify and meet the user's needs with a design-fix-design approach to software development. Indeed, TRAC Monterey had some degree of success with this approach.

Obviously TRAC was impressed with the original work of commercial designers, when they looked at the first commercial software product, but they seemed reluctant to employ those same designers in the Delta Force Land Warrior project. In simulations, the military is often reluctant to use commercial practices, because they lack the physics based rigor to suit military requirements (Ref. 49). On the other hand, the military doesn't do the visualization piece as well as the commercial market (Ref. 49). This is a problem because lack of visualization is not attractive to the user. To put it more succinctly, "It's got to look cool." (Ref. 32) TRAC Monterey seemed to believe that there is no point in making a useful product that bores the user. However, TRAC Monterey did not employ a methodical approach based on best practices to win the user over.

The Land Warrior system also demonstrated many of the commercial design phobic traits of Delta Force Land Warrior. The primary design principle espoused by PM Soldier was the use of COTS, which is not really a design principle. Instead it is a strategy to infuse good design into military equipment and there are problems associated with this approach.

> "Acquisitions involving NDI/COTS pose unique challenges to the MANPRINT practitioner, because the ability to influence actual system design can be minimal. This is not to say, however, that MANPRINT does not play a role. In fact, MANPRINT issues (risks) and concerns should be a major determinant of whether an NDI/COTS solution is viable. Suitability to the aptitudes, knowledge and skills of the intended user population; the human-machine interface; and the ability of the NDI/COTS components to satisfy total system performance requirements are among the many MANPRINT considerations that should be addressed completely and early in the decision process, during market surveillance and market research (Ref. 39)."

Most of the great success of the Land Warrior system has been due to this COTS philosophy, but the program could do better by applying descriptive design principles into the acquisition process from start to finish.

Land Warrior's design principles really are a function of the design principles of the consortium of companies, which produce Land Warrior, Pacific LLC in particular. Research has shown that Pacific strives to optimize the mix of weight, space, power and balance. This philosophy becomes the default design principles of the Land Warrior system. This arrangement does not seem extraordinary until you consider that there are apparently no human factors or industrial design professionals employed by Pacific.

The program office relies on Pacific for design input as well as consultants from Aberdeen Proving Grounds, Maryland to assist with the human factors considerations. These consultants employ their extensive training in human factors to help write system requirements. The design principles of the factors community are well structured and prolific. The guidance available to the program office, as demonstrated by the data, is impressive. Virtually every conceivable design criteria is accounted for in one way or another. The office of PM Soldier Electronic Equipment was content that the information provided by the user's representative in Fort Benning, Georgia, represented the soldier's needs well. However, the guidance of the human factors professionals is only useful if it finds its way into the program.

Even if the consultants for Aberdeen were used, their design principles cannot be faithfully reproduced by a contractor, if this contractor has not been involved in the design process. For example, PEMSTAR, the manufacturer of the Land Warrior system, was convinced that a designer would only make the product look pretty and would take away from its performance. This behavior could be evidence that the PM's office is comfortable with the military approach to design and has not considered bringing in a commercial designer in the way a commercial firms currently do.

There was no evidence that human factors considerations were an overriding consideration of the project. This lack of emphasis on human factors could be due to an absence of design influence in the program, or it could be that the objective of the program is not a human centered design, but simply an effort to introduce a capability into the field now, despite some major design issues.

Whatever the objective really is, research indicates that the consistent attention of an industrial designer can integrate technology quickly, in a way that is pleasing to the soldier, especially when the design process is the integration of existing technologies.

The technology that makes up the Land Warrior system comes from the commercial market, the perfect arena for industrial designers.

Best commercial practices include user-centered design and form that follows function. Academic guidance is even more specific and useful to designers in military programs. The military does not share a similar approach to design principles. Military equipment seems to get its style from the design principles of the contractor, which can vary from project to project.

D. ANALYSIS AND SYNTHESIS OF THE USER REQUIREMENTS PROCESS.

It is pointless to make a product that the user does not desire. To achieve this end, best commercial practices involve the designer with the user at the very beginning of the program. Research shows that every segment of design professionals agrees that the best policy is to ask the user what he wants.

There are several ways to define requirements for the user. All designers agree that interviews are essential. It is critical to really understand what experience the user wants to have, then the designer can help create that experience. In the commercial world, trained industrial designers interview users to identify the most desirable traits of the proposed product. In the military, trained professionals interview users, however the degree to which the interviewer understands design can vary. If a program manager wants a product that pleases the user he must use trained professional designers. As the data show, aesthetics, appearance and finish are difficult to specify but, if done incorrectly, lead to many complaints afterwards (Ref. 52). Therefore, trained personnel must be employed to address the element of aesthetics, because users will have trouble telling you what they want, but they know what they like when they see it.

The only proper way to define the requirements is to consider them in the context of the soldier, namely usability, maintainability, reliability, and supportability (Ref. 28). This idea leads to the best practice of building prototypes early and observing the user with the product. This is an essential best practice in defining requirements because users are more honest in their actions than in their words.

In the commercial world, marketing departments often, but not always, collect information related to user desires. Often, the industrial design firm will conduct research itself. This practice does not appear to be a habit adopted by program offices.

Research indicates that the program office is confident with input of human factors professionals within the military. If human factors professionals from Aberdeen Proving Grounds are involved, then perhaps there is sufficient understanding of ergonomic requirements to write proper specifications. However, it does not appear that a designer is assigned to the project and stays with the project as it is actually produced. Apparently specifications are sent from the military to the design firm, Pacific Consultants LLC. As the data show, PEMSTAR makes what the user wants and Pacific produces prototypes based on specifications, waiting for feedback from the program office. The prototypes are produced and sent to Fort Benning for a "fightability assessment", which is a human factors evaluation of the prototypes. While this seems like a sound approach, there are no human factors professionals at PEMSTAR or Pacific. This gap, lack of ergonomic or industrial designer involvement, suggests that the program office assumes the contractors know enough about design to make a product the user will like. While this may be a correct assumption, this principle and process flies in the face of commercial best practices of design.

As a proxy for the user community as a whole, military members are in constant contact with the contractor, making recommendations as the product is developed. But in the absence of trained design professionals, one user's opinion may also bias the end product. In fact, military members believe that too often a core of influential personnel have too much influence over acquisitions, employment of equipment and regulations to the detriment of the military. It is not in the interest of the military or the acquisition process to allow any one individual to represent the user (Ref. 14).

Another reason to involve the same designer throughout the process is the historical problem that the military has with writing requirements, which lead to specifications. Even before acquisition reform we have had trouble writing requirements documents. We do not involve the right people. "The user is outclassed when writing requirements (Ref. 15)." The user often does not know what to ask for, or how to ask for it. For example, the user of Comanche requires the helicopter to make a trans-Atlantic flight. This one requirement results in ridiculous and unobtainable specifications (Ref. 15). In other programs, requirements can exceed the ability to produce them if the user is unfamiliar with design and production. There was no specific evidence that there were any problems on the Land Warrior program or with Delta Force Land Warrior. Problems in writing appropriate requirements tends to be a flaw inherent to the acquisition process in general.

The present acquisition policy demands that products be described in terms of minimum needs. However, minimum needs may not be useful. "If an experienced designer is asked to design something with a less than comprehensive PDS, he will almost, without thinking, fill in the gaps based on his experience and feelings; if these happen to be at variance with the true user needs, he will be designing to the wrong base" (Ref. 52). It is better to involve the designer from the beginning.

One last consideration that the government does not seem to acknowledge, but which may be beneficial, is the creation of a design language. Many commercial firms use design language effectively. Likewise, military products should also have a design language, which speak to the user to inspire confidence (Ref. 7). As previously discussed, the design language refers to the distinctive styling of a product that allows the consumer to associate a product design with the maker without even reading a label. Automobile styling is an excellent example. Almost every make of automobile has a distinctive front grill, so that whether the vehicle is a truck, a passenger car or a racing car, the public can immediately identify the maker strictly on the basis of its grill design.

Consumers will infer positive and negative attributes from the maker's previous designs to the current designs because of the design language. Design language helps a manufacturer with a reputation for building quality products sell future products more easily. The design language can help persuade the customer to accept or reject the product by appearance alone. It does not seem that anyone within the government had even considered the concept of a design language or the positive effect it could have on product acceptance. Use of an industrial designer would integrate this important element into the program.

E. ANALYSIS AND SYNTHESIS OF THE DESIGN TEAM.

The military, in theory, probably employs one of the most structured and best-trained design teams anywhere. Government adherence to the systems engineering process employs multi-disciplinary Integrated Product Teams (IPTs) throughout the acquisition process. However, if the IPT does not make the user a priority, then a well-balanced product will not be produced. The military employs the commercial best practice of employing non-engineers on the IPT.

As the data show, many members of the IPT will stay with the program as it progresses to ensure continuity. At TRAC Monterey, the team remained constant, and the same is true for PM Soldier.

The government is not using best commercial practices if it does not include industrial designers on the IPT. It is true that in many cases, a commercial company will specify what it wants an industrial design firm to produce. But it is also true that for complex acquisitions, the industrial designer needs to be involved early and consistently to produce the best product. Much of the feedback the designer, Pacific, received regarding product suitability was filtered through the program office. Only rarely did Pacific observe the user employing the equipment. PM Soldier does employ a civilian

PhD to oversee the MANPRINT IPT, but it was not clear how this individual influenced the prototypes that were being produced by Pacific for evaluation by the military.

F. ANALYSIS AND SYNTHESIS OF DESIGN METHOD/PROCESS.

Commercial best practices in the area of design process includes following a structured approach, emphasizing the design effort up front, involving the designer early and continuously in the procurement process and resisting the temptation of starting engineering without developing specifications.

> "Both now and in the future, man will engineer things. Unless these things are subject to the procedures an rigors of the total design process, they are likely to fail in the market place, either in part or in whole, particularly when subject to the pressures of competition (Ref. 51)."

The academic community gives an excellent outline of the design process. Pugh's total design approach integrates all technologies into a design framework. There is room for everyone in his total design approach. By adopting Pugh's approach, the program office does not limit creativity or opportunities, and the program manager can still follow a disciplined design process.

Design Engine's product development process demonstrates that the best practice is for the designer to be involved early and continuously. Guidance for the government states that the human factors effort is to be non-stop throughout the development process. The MANPRINT working group concept and military IPT process are structured perfectly to accommodate best commercial practices. Additionally, data show that guidance requires the contractor to plan and implement a Human Factors Program to insure the satisfaction of the system objectives and personal safety of the operator and maintainer. The programs included in this research do not seem to involve the contractor in the way the guidance specifies. Research is inconclusive as to how the commercial designer is able to incorporate human factors considerations in the design, without human factors personnel on the staff.

Industry data also emphasize the need for the designer to be involved in the entire process. One of David Kelly's five steps is the requirement to observe. The designer must see the user in his environment. Data show that this step is often skipped. Data from Pacific show that the commercial designer has little actual contact with the user, and relies on the program office to make observations. The Land Warrior program has employed a build-test-build approach, which is a best commercial practice. However, best practice in the commercial world includes the product designer in evaluation of the product. In fact, PEMSTAR and Pacific agreed that they could produce the product better if they had more access to the user.

With that said, the Land Warrior technology is indeed stunning. In fact Land Warrior and Delta Force Land Warrior were selected for examination because they have had such great success.

> "Senior DoD officials have recognized Land Warrior as a flagship of "out of the box" acquisition practices and is currently the subject of a "good news" DoD-wide GAO audit as the Army's single representative program for the Teaming category of Acquisition Reform Best Practices (Ref. 15)."

Pacific and PEMSTAR have a host of very talented people creating unprecedented designs. However, I did not meet anyone who spoke in terms of Norman's design principles. Despite that fact, Pacific has designed an amazing connector which Dr. Norman would be proud of. The program did seem oriented in the direction of Pugh's principles, at the corporate level, but lacked a complete industrial design rigor at the lower levels. Modern techniques like stereo-lithography are employed, but the expertise of industrial designers was absent.

Richard Newman is correct when he says that a formally designed system, such as the process the military uses, is a responsible method which mitigates many of the dangers of poor design (Ref. 43). However, it is not enough to have a formal system if you overlook the commercial best practices. The military may have become enamored with a process that does not produce the best design. The program manager must ensure that the process employed attains the desired level of customer satisfaction.

V. CONCLUSIONS AND RECOMMENDATIONS

"I think that people's unawareness of design forces them to continue purchasing crappy stuff because they don't realize that there's an alternative. As long as people keep purchasing products like that, as long as people seem not to care about and be aware of what their place looks like and works like, the world will remain filled with ugliness, and things that don't work properly" (Ref. 45).

A. INTRODUCTION.

The conclusion identifies the essential findings of the thesis research. The recommendations encourage program managers to consider employing industrial designers on their programs to increase acceptance of their products by the user community.

B. CONCLUSIONS.

1. A good design adds value.

A good design adds value by improving operator performance, evoking positive emotion in the user, reducing the training burden and providing cost savings. Good design provides the user with a positive experience. The user will accept a good design, capitalizing on the procurement effort.

2. Program managers want "soldier acceptance" of their equipment.

Acceptance of a product is not just a fringe benefit of the design, but is absolutely essential to program survival. Research shows that every program office wants to procure equipment that the soldier will want to use. This aim seems to have become the design principle of program offices. Logically, program managers should pursue the most effective and efficient way to procure a design that is technically sound and is pleasing to the user. Best commercial practices conclude that the use of industrial design professionals is the most effective and efficient path to an acceptable design.

3. Designers are not continuously involved in the military procurement process.

In an effort to procure products that are pleasing to the user, program offices employ their team of human factors consultants. Data show that program managers have excellent ergonomic resources available to them. However, the human factors consultants are not continuously involved in the procurement process. In the current process, the consultants ask for a product then evaluate the effort of the contractor. The contractors, in this research, have not been directly involved with the user and the contractor does not have human factors or industrial design professionals on staff. This method works, but because the designers are not involved with the contractor, the process takes too long and costs more than it should. Additionally, military ergonomic consultants may not be industrial designers and cannot replace the value added of industrial designers.

4. Industrial designers are expert at integrating the many aspects of a design into an acceptable product.

Industrial designers are expert at integrating the many aspects of a design, including ergonomics, into an acceptable product. As a best commercial practice, industry uses industrial designers to develop products for sale in the market place. Program managers currently do not incorporate industrial design professionals into the acquisition of soldier equipment. This research shows that the program office performs much of the duties of integration that an industrial designer should perform. If program managers do not use industrial designers, they are not using best commercial practices.

C. RECOMMENDATIONS.

1. Program managers should consider how improved operator performance, positive emotion, the reduction of training burden, and cost savings can be beneficial to program success.

If "soldier acceptance" is really an aim of the program, then the program office should recognize that a good design is the essential element that adds value for the user. Program managers should establish metrics that determine how operator performance is improved, how the soldiers feel about their equipment, how new equipment effects training requirements, and how these aspects affect cost savings. Well-designed equipment will make it easier for the soldier to accomplish his task, not more difficult. Well-designed equipment will enhance the soldier's experience. In turn, the soldier's positive experience will generate support for the program and improve chances of equipment success during testing and fielding.

2. In order to achieve a more predictable result and to avoid waste in the program, consistent design principles should be applied throughout the development of the system.

Program managers must define their own metrics for an acceptable design. Program managers can employ design principles outlined in this research, or they can employ program-unique principles, but they must have design principles. Program managers can even use the design principles of their contractors, but then they must ensure the contractor has the capability to incorporate those principles into the design. The contractor must be involved with the user early in the program and continuously. Whatever design professionals are used, they must be involved with the contractor at the time the prototypes are designed and maintain the integrity of the program manager's design principles.

3. Program managers must design products as if they were competing in a global, commercial equipment market.

Program managers design for a specific user, but program managers should never treat the user as a captive audience that must take what they are given. The program should make equipment that best meets the soldier's needs, and should care about the user's feeling for the equipment. This attitude of excellence should infiltrate the entire program from the user to the contractor.

4. The program must involve professional industrial designers early and continuously in the program.

As previously discussed, the military probably employs some of the most structured and best-trained design teams anywhere, which includes the commercial best practice of employing non-engineers on the design teams. However, these design teams do not currently seem to include industrial designers. Research shows that while there are many professionals who can integrate the requirements of a project, only professional industrial designers integrate projects from a user-centered approach and take into account the emotional element of design. Our findings clearly outline several methods to employ industrial designers into the program. For example, Design Engine is very specific about how they might be employed on a program. Duties and responsibilities are clear enough to understand how the industrial designers fit into a program and add value. The worst thing that can happen to a product is to over-engineer a product so that it is not usable. Industrial designers become the honest broker that retains the performance of the product, but also packages the product in such a way that it is not overwhelming and yet is attractive to the user. The program must employ industrial designers to gain the full benefit from a design opportunity.

D. AREAS FOR FURTHER RESEARCH.

1. How are user needs surveyed in the military?

Research indicates that the true requirements of the user may not be represented at the level of the contractor that can impact the design and waste time trying to test-fix-test until a desirable product is manufactured. Examination of the commercial best practices for identifying user requirements should be compared to the military approach for identifying user requirements.

2. What is the correlation between the investment and return?

Program budgets are tight. Program managers must carefully invest their resources where each dollar will create the maximum positive return for the program. Program managers are more likely to invest resources in activities when they can predict the outcome with some degree of certainty. While the involvement of industrial designers in the commercial world has been extremely profitable, program managers seem skeptical of involving industrial designers and industrial design firms in programs. Program managers might be more inclined to use industrial designers if they can better estimate the correlation of money invested by the program office and benefit received by the program.

3. What design language should the military use?

The concept of using a design language is powerful. Design alone can inspire confidence and acceptance of a product. More research should be conducted to determine which products inspire confidence in soldiers and which products soldiers try to avoid. This information could be obtained by an industrial design firm or a marketing firm. The information could be used to identify and develop products a design language that would inspire confidence and acceptance.

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