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COST BENEFIT ANALYSIS OF THE NAVY 2-PIECE FLAME RESISTANT UNIFORM

December 2018

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This research used afloat uniforms of the United States Navy to explain the costs and benefits of implementing the Navy 2-Piece (PC) flame-resistant uniform. This study examined the history and characteristics of Navy afloat uniforms. It analyzed benefits and costs of implementing the new flame-resistant 2-PC uniform as an additional at sea uniform along with the current improved flame-resistant variant (IFRV) coveralls. The research concluded that even though course of action (COA) 3 (Status Quo) produces the lowest cost, the improved flame-resistant coverall does not provide the versatility and capability that the 2-PC uniform offers sailors to operate in all climates, environments, and workspaces on a daily basis. In comparison to the flame-resistant coverall, the 2-PC has no limitations and delivers the advantages of being deckplate-driven, improving the quality of life and work, satisfying all communities, and offering a better fit and more comfort. COA 2 has a net benefit of -$85,174,785.00, which is not a viable choice as it does not deliver any benefits. Our study has concluded that COA 1 would be the best option, because it will produce a net benefit of $20,637,638.00 while providing numerous non-monetized benefits to our sailors.

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COST BENEFIT ANALYSIS OF THE NAVY 2-PIECE FLAME RESISTANT UNIFORM

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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

2-PC	Two-piece, 2-Piece
ASTM	American Society for Testing Material
B	Benefit
C	Cost
CBA	Cost-Benefit Analysis
CIRCULAR A-94	CBA Guidelines and Discount Rates Federal Programs
COA	Course of Action
E-6	Navy First Class Petty Officer
E-7	Navy Chief Petty Officer
FRV	Flame-Resistant Variant
GQ	General Quarters
IFRV	Improved Flame-resistant Variant
IPT	Integrated Product Team
NAVADMIN	Naval Administrative Message
NAVSAFECEN	Naval Safety Center
NCTRF	Navy Clothing Textile and Research Facility
NEXCOM	Navy Exchange Command
NFPA	National Fire Protection Association
NPV	Net Present Value
NSB	Net Social Benefit
NWU	Navy Working Uniform
OMB	Office of Management and Budget
OPNAV	Office of the Chief of Naval Operations
OPTAR	Operation Target
OSHA	Occupational Safety and Health Administration
PBI	Polybenzimidazole
PV	Present Value
TTP	Thermal Protective Performance
USFF	U.S. Fleet Forces
USS	United States Ship

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I. INTRODUCTION

A. PROBLEM STATEMENT

The commander of the U.S. Fleet Forces (USFF) in 2012 stated, "The safety of our sailors remains a paramount concern and top priority" (Navy Live, 2012). There are currently 120,000 operational fleet sailors deployed at any time around the world, working in highly dangerous environments where the risk of fire hazards is increasingly prevalent. However, opposing views were present in 1996, when the vice chief of Naval Operations eliminated the flame-resistance requirement for the dungaree and khaki uniforms of shipboard personnel. A fleetwide flame-resistant uniform was considered an unsustainable requirement due to problems with the uniforms, the unlikely occurrence of major shipboard conflagrations, and funding concerns. The top priorities for working uniforms shifted from safety to sailors' desire for improved functionality, comfort, and less maintenance.

Even though modern ships have better firefighting capabilities, they present more fire hazards; significantly more high-voltage equipment is used today in conjunction with continuing trends toward reducing manpower. Prior to 2014, NAVSAFECEN Advisory 6–11 stated that there were no uniforms in the Navy seabag designed for sustained firefighting. However, fires are often discovered by sailors wearing the flammable Navy working uniform (NWU) and utility coverall, and their trained response is to take immediate action to extinguish or contain the fire and set boundaries until relieved by a properly equipped fire party. Based on these realities and in response to safety concerns over the lack of flame protection from Navy afloat uniforms, the USFF rapidly introduced the flame-resistant variant (FRV) coverall in 2014. In light of the safety implications, the speed of implementation took precedence over product quality, durability, appearance, and comfort. This led to significant dissatisfaction with FRV coveralls throughout the fleet.

In early 2015, an improved flame-resistant variant (IFRV) coverall was designed to address deficiencies in the FRV coveralls, evaluate alternative fire-resistant fabrics, and provide low voltage arc flash resistance. The IFRV is created from an inherently flame-resistant, tri-fiber fabric blend. The tri-fiber fabric weighs significantly less than the FRV

fabric and provides improved moisture-wicking management. The IFRV was designed to provide increased comfort, durability, and safety (offering arc flash protection) from the original FRV. The results from the IFRV wear test were overwhelmingly in support of the IFRV coverall as the preferred prescribed at-sea uniform. In January 2017, Admiral Phil Davidson, commander USFF, declared the authorization of the "IFRV coverall as an approved fleet organizational clothing item to replace the FRV coverall" (U.S. Fleet Forces, 2017). The IFRV coverall provides adequate protection from shipboard hazards under all normal steaming conditions in designated working environments; however, the climate modularity and wear restrictions of the current design remain a top concern among many fleet sailors. A professional-looking, flame-resistant uniform that can be worn both afloat and ashore, including transit to and from work and out in town, is strongly desired.

B. RESEARCH QUESTION

In order to answer the fleet's demand, this study uses a cost-benefit analysis (CBA) approach to identify and analyze the potential costs and benefits, advantages and disadvantages of implementing a 2-PC flame-resistant uniform to all afloat sailors.

Primary research question: What are the costs and benefits to the Navy implementing a 2-PC flame-resistant at-sea uniform that can be worn on and off the ship? If so, what is the net benefit?

C. PURPOSE

The purpose of this project is to investigate if there will be benefits to the Navy implementing a 2-PC flame-resistant uniform as organizational clothing. This is accomplished by performing a CBA that evaluates the IFRV coverall against the 2-PC fire-resistant uniform. Chapter III covers the details of our methodology. For the sake of this study, we examine three potential courses of action (COA), defined as follows:

- COA 1: The IFRV coverall and a 2-PC flame-resistant uniform are both prescribed at-sea uniforms
- COA 2: A 2-PC flame-resistant uniform replaces the IFRV coverall as the only prescribed at-sea uniform

- COA 3: Status Quo (IFRV coveralls are the only prescribed at-sea uniform)

Our study has found that even though COA 3 (Status Quo) produces the lowest cost, the IFRV coverall does not provide the versatility and capability that the 2-PC uniform offers sailors to operate in all climates, environments, and workspaces on a daily basis. In comparison to the FRV coverall, the 2-PC has no limitations and delivers the advantages of being deckplate-driven, improving the quality of life and work, satisfying all communities, and offering a better fit and more comfort. COA 2 has a net benefit of -$85,174,785.00, which is not a viable choice as it does not deliver any benefits. Our study has concluded that COA 1 would be the best option, because it will produce a net benefit of $20,637,638.00 while providing numerous non-monetized benefits to our sailors.

D. ORGANIZATION

Chapter I of this thesis begins with a brief introduction, the purpose of the research, and introduces the current functional U.S. Navy uniforms. Chapter II goes into detail on the background and history of Navy afloat uniforms, flame-resistant fabrics, and shipboard clothing. The focus of the study is on the functionality and safety of afloat working uniforms and clothing for the Navy. Chapter III contains a literature review of briefs and reports by the Navy Safety Center, Occupational Safety and Health Administration, USFF, Navy Exchange Command (NEXCOM), and the Navy Clothing Textile and Research Facility (NCTRF). Chapter IV describes the methodologies utilized in this study, specifically CBA, and discusses the results, Chapter V describes the impediments and non-monetized benefits. Finally, Chapter VI provides a conclusion with answers to the research questions and recommendations from the findings.

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II. BACKGROUND

A. HISTORY OF U.S. NAVY AFLOAT UNIFORMS

The Chief of Naval Operation's vision for the 21st Century Navy is "A Navy in which sailors are afforded a set of uniforms which present a professional appearance which recognizes naval heritage and offers versatility, safety, ease of maintenance, and storage, comfort, utility and cost-effective" (Navy Personnel Command, 2017). The U.S. Navy possesses an arsenal of uniforms for its sailors, ranging from formal dinner attire to dirty work coveralls, with each item serving a particular function and having an appropriate time to wear. A great deal of the attention in this paper will be devoted to the U.S. Navy's afloat working uniform. The Navy describes working uniforms as functional attire worn to perform work that would excessively soil the clothing or inappropriate for the specific task at hand. These uniforms are required for wear at sea and in industrial workplaces ashore. In July 2010, the NWU Type I and coveralls became the official working uniforms for afloat platforms. The FRV coverall replaced them as the prescribed afloat uniform in 2014. In 2015, this uniform was updated to the IFRV coverall.

The "Navy's iconic uniforms are steeped in tradition and practicality with roots as far back as the Continental Navy and the 18th-century British Navy" (Rayburn, 2016). The uniforms' designs are the byproduct of a sailor's physical, geographical, and technical environment. The birth of the U.S. Navy commenced in the early days of the American Revolution with the Continental Congress establishing a naval force on October 13, 1775, but not seeing the first official uniform until 1817. From their inception, "military uniforms were created to distinguish their civilian counterparts or from service members belonging to a different group or military" (Rayburn, 2016). The war department authorized "enlisted sailors wear blue jackets and trousers, red vest with yellow buttons and a black hat" (History of U.S. Navy Uniforms, n.d.). Uniform regulations were not vigorously enforced at that time, however, as funding was sparse, and the little money available was being used to expand and maintain its evolving fleet. Additional and unique challenges the Navy encountered while developing and implementing a uniform included logistic issues, salty conditions, and diverse climates (Rayburn, 2016).

"According to Naval History and Heritage Command, uniform items issued to enlisted Sailors reflected their surroundings and the work they did" (Rayburn, 2016). Most articles in the enlisted sailor's seabag fulfilled a practical purpose beyond being a standard uniform item, such as the Dixie cup, black neckerchief, and bell-bottoms (Rayburn, 2016). The Dixie cup replaced the "flat hat" and white sennet straw hat; it was written into uniform regulations in 1886. The high-domed, low-rolled brim cover was initially made from wedge-shaped pieces of sail canvas but eventually replaced by cheaper, more comfortable cotton (Kirkpatrick, 2018). It holds some practical applications as a flotation device, to dewater a space, and to protect one's face from rain or waves. In the event a sailor fell overboard, it could turn into a flotation device by opening the cover all the way, holding it over the head with both hands, and quickly moving it in a downward motion to water level. The air captured in the cover could hold a person up for some time. Another practical use is the ability to scoop out water from a flooded space or boat. Lastly, the brim flipped up to allow for protection from the rain and waves; the water from both could be collected in the top of the cover. It quickly came to symbolize the Navy and became an icon among sailors. All enlisted service members, from the newest recruit to the saltiest veteran, share a direct link to the past when wearing a Dixie cup. It holds a special meaning and legacy.

"Bell-bottoms, another classic and timeless naval uniform, were implemented in the early 1800s to differentiate Sailors from civilian clothing styles. Perhaps unintentionally, bell-bottoms proved extremely useful and practical" (History of U.S. Navy Uniforms, n.d.). The wide-leg design at the bottom of the pants provided a utility and safety benefit. They allowed sailors to easily roll the trouser leg above the knee to keep their legs dry when conducting shipboard tasks such as scrubbing the decks or when landing a small boat. In landing a small boat, a sailor would swiftly roll up the pant leg before jumping into the shallow water to pull the boat onto the beach (U.S. Navy Uniform Traditions and Origins, n.d.). Lastly and critically, the trousers could be used as a life preserver in the water to prevent drowning. sailors could quickly remove their pants while still wearing their boots. In case they were forced to abandon ship or tossed overboard, the ends of the legs could be knotted and air put in them to make a temporary flotation device (U.S. Navy Uniform Traditions and Origins, n.d.).

Neckerchiefs were a frequently worn item for the men operating on ships as they were widely used as convenient sweat rags and collar fasteners. A neckerchief could be worn around the forehead or neck. Some men used one to protect their jackets from being soiled from greasy hair in the days when pigtails were fashionable. Most neckerchiefs were black, as it was practical and did not readily show dirt or grease (U.S. Navy Uniform Traditions and Origins, n.d.). They could also be utilized as a battle dressing in emergencies. The Navy recognized the beneficial use issued "a standard-issue neckerchief with a square knot in 1817" (History of U.S. Navy Uniforms, n.d.).

The NWU was designed to offer the same level of protection when worn for general use in the shipboard environments, replacing both the working utilities for E-6 and below and the wash khakis for E-7 and above (Chief of Naval Operations, 2012). The NWU Type I rollout began in December 2008. They were not made of treated or inherent fire-retardant or flame-resistant material and are not meant to be a firefighting uniform (Chief of Naval Operations, 2012). These blue camouflage uniforms were introduced in 2008 and were flaunted for not showing stains or signs of wear and tear. However, the Navy listened as complaints about the "aquaflage" (NWU) grew from fleet sailors. The NWUs were uncomfortable, put sailors at risk against fire, flame and arc flash hazards, and failed to simplify the seabag. They are no longer authorized for wear aboard afloat platforms at sea and will be phased out by 2019 (Faram, 2018). In December 2016, the USFF authorized the IFRV coverall as the prescribed at-sea uniform for all afloat sailors. Presently, the new IFRV coverall is phase replacing the first flame-resistant at-sea coverall, FRV coverall.

The uniforms of today's sailors have united both practicality and tradition to adhere to the current environment and to honor naval heritage. As fondly as many sailors reminisce on uniforms of the past, the Navy has a reputation "of changing to adapt to new environments" (Rayburn, 2016) and challenges or to implement improvements and enhancements. Numerous uniform variations have transpired leading to the NWU and flame-resistant coveralls worn today.

B. U.S. NAVY FLAME-RESISTANT UNIFORMS

Fire-retardant clothing requirements are specified in the Naval Ships' Technical Manual and further directed by the Type Commanders. The Navy provides organizational clothing to those watchstanders and sailors that need additional protection against fire hazards in environments such as engineering spaces, on the flight deck, and an element damage control teams. The afloat organizational protective clothing variants include an array of fire-retardant and arch flash protection coveralls as well as flight suits for aviation personnel. Firefighting ensembles are additionally provided to sailors specifically assigned to combat a fire (Chief of Naval Operations, 2012). Flame-resistant fabrics "ignite with difficulty, burn slowly when set on fire, and most importantly, self-extinguish when the heat source is removed" (Watson, 2014). Flame-resistant fabrics are produced through one of two methods: "fabrics are made from inherently FR fibers, or a non-FR fabric is chemically treated to provide FR properties and protection" (Watson, 2014). Producing an article of clothing to contain inherent or treated flame-resistant fabrics is easy; the challenge arises when striving to balance the flame-resistant fabrics with comfort, durability, and economic factors (Watson, 2014).

1. Treated Flame-Resistant Fabrics

Treated fabric begins as cotton fiber, which is inherently flammable (Adams, 2016). Cotton fiber will not protect the wearer when "exposed to flame, extreme heat, molten metal, hot liquids, or arc flash" (Watson, 2014). A common procedure to make "cotton more durable and cheaper is blending it with nylon or polyester—a plastic-based fiber that is also inherently flammable and could meld to the wearer's skin if exposed to a flash fire or electric arc" (Watson, 2014). "These blends are often produced with 88% cotton fiber and 12% nylon or polyester, which is where the term 88/12 comes from. Once the cotton or cotton blend fabric is made, it is treated with a flame-retardant chemical finish" (Adams, 2016). In addition, "treated flame-resistant fabrics are created by adding a chemical treatment to the fibers before they are woven or knitted into a fabric" (Watson, 2014). Both applications prevent the previously flammable fibers from igniting. "Many chemically

treated fabrics state that the protection lasts for the life of the garment with proper care" (Adams, 2016). However, the chemical additive may not be permanent

The phrase "proper care" is imperative and should be advertised and adhered to in all chemically treated, flame-resistant fabrics.

> Failing to follow the care instructions could put the wearer at risk of degrading the transparent layer of protection. Certain ingredients found in home laundry products (like chlorine bleach and boosters that use hydrogen peroxide additives) can interfere with the fire-extinguishing properties. If chlorine bleach, a non-compliant detergent, or the wrong temperature is used with a treated fabric, the wearer could be at elevated risk of injury without even knowing. (Adams, 2016)

Advantages and Disadvantages

Advantages

Enhanced comfort. "Workers want to wear organic fibers like cotton or 88/12 blends because they are lightweight, comfortable, and flexible even after they are chemically treated" (Watson, 2014).

Flame-resistance protection mechanism. "When exposed to a direct flame, some treated fabrics rely on a chemical reaction to extinguish the flame. This reaction is triggered by the heat of the fire and the amount of time the fabric is exposed to the flame. Other treated fabrics char as their form of protection or off-gas to prevent combustion" (Watson, 2014).

Inexpensive alternative. Treated fabrics have a tendency to be less expensive upfront because of the shorter shelf-life. "This can be a primary driver when choosing personal protective clothing" (Watson, 2014).

Disadvantages

Shelf-life. New innovations in finishes have assisted in extending the duration of treated fabrics, contingent that proper laundering procedures are obeyed. However, treated fabrics will eventually diminish. In addition, they are highly susceptible to damage if laundered with "chlorine bleach, the combination of hydrogen peroxide (oxygen bleach)

with hard water, or exposure to oxidizing chemicals in the workplace" (Watson, 2014). However, a wearer cannot identify degraded FR properties in fabric by the naked eye.

Weight and Comfort. Treated fabrics are often heavier than inherently flame-resistant fabrics. More mass between the wearer and the hazard indicates more protection. Unfortunately, "with increased protection (i.e., weight) come trade-offs in comfort. Treated garments, once regarded for their maximum comfort levels, may contribute to additional heat strain at heavier weights" (Watson, 2014).

2. Inherently Flame-Resistant Fabrics

The properties of inherently flame-resistant fabrics are considered permanent and inseparable, as the fiber's structure is non-flammable. "All pieces and parts of the fabric remain indefinitely flame-resistant" (Adams, 2016). "Flame-resistant fabrics are made of fibers in which these properties result from the polymer backbone and can never be worn away or washed out" (Watson, 2014). The flame resistance "will not wash or wear out, although proper care is always encouraged. For example, using chlorine bleach with an inherently flame-resistant fabric might fade the appearance and reduce the strength of the material, but it will remain flame-resistant" (Adams, 2016).

Advantages and Disadvantages

Advantages

Greater thermal protection. Inherently flame-resistant fabrics "consistently have a higher thermal protective performance (TPP) scores than treated fabrics. The TPP rating is a measurement of a protective garment's thermal insulation performance against convective and radiant heat exposure. A garment's TPP score is two times the number of seconds it takes for a second-degree burn to occur when exposed to a 2.0 cal/cm^2 flame and radiant heat source. The higher the TPP rating, the higher the level of protection provided by the garment" (Watson, 2014).

Permanent protection: The flame-resistance properties of these fabrics will not wash or wear out, thus resulting in a higher upfront price while providing long-standing value. Inherently flame-resistant fibers are "typically more expensive than treated fibers,

but the effectiveness of the thermal protection during the garment's lifetime may allow more expensive clothing to be worn for a longer time span. The higher upfront price can be justified over the long term when its durability extends the life of the garment" (Watson, 2014).

Improved comfort: In an effort to enhance comfort levels, protective clothing manufacturers using inherently flame-resistant fibers have developed more "flexible and lightweight options for extreme environments" (Watson, 2014). These garments are also designed with "increased breathability and improved moisture management" (Watson, 2014). However, this will also generate a significantly higher upfront price to provide both comfort and thermal protection.

Disadvantages

Higher cost. As stated earlier, "inherently flame-resistant fabrics tend to be more expensive than treated fabrics. However, the higher initial price can be acceptable over the long run as its durability prolongs the shelf life of the garment" (Watson, 2014).

3. Coveralls

Before 2014, flame-resistant uniforms or organizational clothing were not supplied to all afloat personnel but authorized for specific shipboard ratings, environments, and events. There were three types of flame-resistant coveralls available to shipboard sailors: damage control coveralls, low voltage 12 cal/cm^2 arc-resistant electric coveralls for electricians, and FRV coveralls. All three coveralls are constructed using treated, 100% cotton fabric, which has poor dimensional stability, colorfastness, and durability.

Damage Control Coveralls

Damage Controlmen, emergency response and fire party teams, and engineers are authorized to don fire-retardant coveralls for conducting specific jobs, working in particular environments (machinery spaces), and during events such as fires or floods. Damage Controlmen and emergency response and fire party teams wear a red version of these coveralls, while engineers don a navy blue version. The preferred damage control coverall is the commercially sourced Carhartt and Bulwark brand. The Bulwark Excel-FR

Arc-Rated Coveralls are made from treated, 9 oz. twill, 100% cotton blend fabric. It provides full-body, neck-to-wrist coverage.

> The essence to its safety feature is in the Excel-FR fabric, which has an arc thermal protective value of 10.6 calories/cm2 HRC 2. It also meets National Fire Protection Association (NFPA) 2112 standards. An arc rating designates how much heat a fabric can stand without causing burns on the skin; these Bulwark coveralls are flame-resistant. (Working Person's Store, n.d.)

Electrician's Coveralls

The Navy's Electrician's Mates are "responsible for the operation of a ship's electrical equipment, including the electrical power generation systems, lighting systems, electrical equipment, and electrical appliances" (Powers, 2018). Compared to other environments, the potential for electrical shock aboard ships is heightened due to the presence of hazards such as high-powered equipment, unstable workspaces, and saltwater. Since the ship's electronic/electrical systems are ungrounded, personnel and equipment may easily become a path to ground, resulting in injury or death (Department of Navy [DoN], 2017).

As a result of the hazardous environment and work, the Navy issued special, protective attire to electricians: low voltage 12 cal/cm^2 arc-resistant electric coveralls. Electricians are authorized to wear these coveralls at all times and mandated to wear then when working with "electronic and electrical equipment that poses a risk from arc flash, a fast-moving, high-intensity electrical fire that can prove deadly" (DoN, 2017). Electricians are the only sailors issued these specific protective organizational coveralls.

Flame Resistant Variant (FRV)

In 2014, USFF directed that the FRV be issued to all afloat sailors as the only prescribed underway uniform. It offers an enhanced "level of protection for all sailors against shipboard flame and flash hazards while providing consistent functionality in a variety of daily shipboard environments" (U.S. Fleet Forces, 2014). The FRV is constructed from a treated, "100% cotton fabric using the same design pattern as the existing utility coverall" (U.S. Fleet Forces, 2013).

> NCTRF has validated the FRV's capability to safeguard sailors. The FRV qualified in all flame-testing requirements, and the flame-resistant properties did not degrade with wear or laundering for the serviceable life of the coverall When worn with appropriate battle dress attire and preventative, the FRV supplies sailors with significant levels of "protection against a variety of flame and flash fire hazards associated with shipboard operating conditions. It was not designed to replace or serve as a firefighting ensemble but is an effective, flame-resistant underway uniform intended for general shipboard use. (U.S. Fleet Forces, 2013)

The FRV is prescribed solely as an underway uniform that is not designed or intended for wear off the ship or ashore. "The FRV is not to be used in place of organizational clothing mandated for specific operational environments such as flight decks or while performing work on electrical systems that require arc flash protection" (U.S. Fleet Forces, 2013). At the time, this new flame-resistant clothing, available to all shipboard sailors, offered a significantly upgraded level of protection to the wearer, although opportunities for improving the model were identified early on.

Improved Flame-Resistant Variant (IFRV)

In 2015, an IFRV coverall wear evaluation was initiated to address deficiencies in the FRV coveralls and evaluate alternative fabrics that provide low voltage arc flash resistance. The initial focus of the IFRV coverall effort was to evaluate improved flame-resistant fabrics. The IFRV coverall was wear tested on three platforms and received overwhelming and consistently favorable feedback. The lighter, more breathable, and more durable fabric has been universally perceived positively. Additionally, the IFRV coverall's inclusion of arc flash protection has positioned it to supersede all three of the previously mentioned coverall designs.

Its inherently flame-resistant properties allow the IFRV fabric to self-extinguish when exposed to an open flame. The system-level tests performed by the NCTRF included "exposure to a standard flame ignition source of 12 seconds" (Faram, 2017), and the flame went out within two seconds. The tests also proved that the IFRV fabric maintained the same level of protection even after 50 shipboard laundering cycles. An additional level of protection is the inclusion of arc flash protection, which is a significant improvement from the FRV. In December 2016, USFF approved the IFRV coverall as accepted fleet

organizational clothing to replace the current FRV coveralls. The USFF is currently working with NEXCOM and the Defense Logistics Agency to oversee the implementation, management, and acquisition plan of phasing in the new model. The transition from the FRV to the IFRV coverall began in 2018.

2-PC Flame-Resistant Shipboard Uniform

Due to strong demand from the fleet, USFF has endeavored to pilot a safe, functional, professional at-sea 2-PC organizational clothing variant that can also be worn during operational assignments ashore and on or off base (U.S. Fleet Forces, 2017). The 2-PC is designed to provide the wearer the same level of protection (flame, flash, and arc flash protection) and enhanced features (lightweight, comfortable, and durable) but adds versatility by allowing any sailor to work any job in any shipboard workspace and looking professional enough to wear off the ship and out in town. Three variants have been developed: one for officers and two for enlisted sailors. The officers' variant will be all khaki (similar in design to the wash khaki and working khaki), and the enlisted sailors' variant will be either solid navy blue or light blouse with dark trousers. All fabrics are made from inherently flame-resistant fiber blends and Berry Compliant, which requires DoD to use appropriated funds for the procurement of clothing materials produced in the U.S.

Underlayers being tested with the 2-PC include a long sleeve, moisture-wicking undershirt that provides no-melt, no-drip, flame-resistant protection; climate modularity; and significantly reduces the bulk of current uniforms. The underlayers will provide flame-resistant, moisture-wicking, and anti-microbial capabilities to increase comfort and improve dexterity. This is the key feature that will increase sailors' ability to operate in all climates, environments, and workspaces. The 2-PC, when worn de-bloused (flame-resistant underlayer and trousers), will allow sailors to work and perform in all spaces and operations where the FRV and IFRV are not authorized, such as on the flight deck during flight operations.

Fire Fighting Ensemble

Firefighting ensembles are provided for sailors specifically assigned to combat a fire. The ensemble consists of a lightweight, one-piece, fire-protective garment with an

outer shell, inner fire-retardant thermal liner, vapor barrier and enhanced water repellency. It provides protection against, heat, smoke, hot steam, hot liquid to a limited degree, and short duration flame and flash exposure. “It is certified to NFPA 1971, Standard on Protective Ensemble for Structural Fire Fighting” (Maritime DC & PPE Information Center, n.d.)

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III. LITERATURE REVIEW

A. UNIFORM CATEGORIES

The United States Navy currently has thirty-three different uniforms. Navy uniforms are classified into three main categories: seabag uniforms (government uniforms), non-seabag uniforms (commercial uniforms), and organizational clothing. OPNAV 41 determines seabag uniform requirements and manages associated policies. Seabag uniforms, also referred to as government uniforms, are issued to enlisted sailors at boot camp and officers at officer candidate school or the equivalent commissioning source. Enlisted sailors receive an annual clothing replacement allowance, while officers are required to budget appropriately from their base pay to replace worn uniforms. The Defense Logistics Agency funds the research, development, test, and evaluation (RDT&E) for new seabag uniforms. Once the RDT&E phase is complete, Navy Exchange uniform stores sell them at cost throughout their 111 uniform stores as well as their online store (U.S. Fleet Forces, personal communication, July 19, 2018). Figure 1 shows a summary of the phases a Navy seabag uniform goes through.

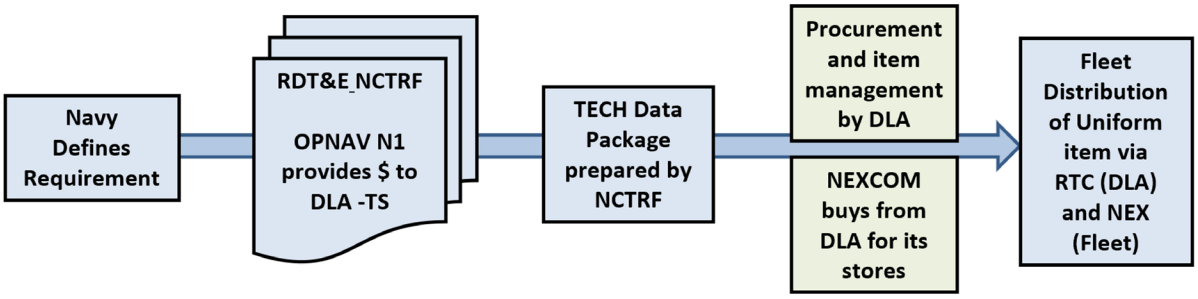

Figure 1. Summary of the phases a Navy seabag uniform goes through. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

OPNAV 41 also determines non-seabag uniform requirements and manages their associated policies. However, purchasing non-seabag uniforms is not mandatory. The

RDT&E for new non-seabag uniforms is funded by NEXCOM. Once the RDT&E phase is complete, Navy Exchange uniform stores sell them at cost plus a retail markup (U.S. Fleet Forces, personal communication, July 19, 2018). Figure 2 shows a summary of the phases a Navy non-seabag uniform goes through.

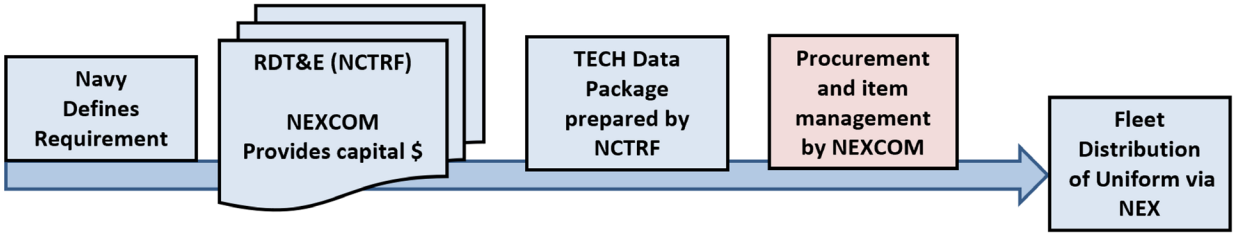

Figure 2. Summary of the phases a Navy non-seabag uniform goes through. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

The final category of uniforms, organizational clothing, is managed at the fleet level by individual unit commands. Each command has the autonomy to determine their individual needs and requirements for organizational clothing. Unit commands are also responsible for dictating the manner of wear and other policies. Organizational clothing is uniforms that are loaned to sailors. These uniforms are part of a unit's inventory, which means that sailors are required to return them upon transfer or when the uniforms are no longer serviceable. In most cases, units' supply departments are responsible for the inventory and issuance of organizational clothing. Supply departments can either procure required organizational clothing from the Navy stock system or buy it from commercial vendors. Figure 3 shows a summary of the phases an organizational uniform goes through.

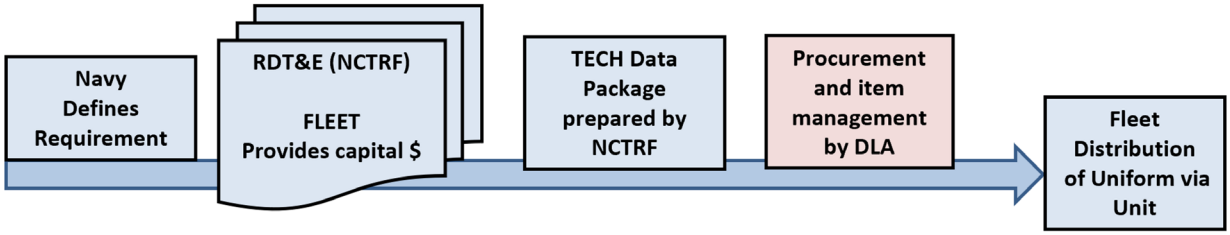

Figure 3. Summary of the phases an organizational uniform goes through. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

B. CURRENT AFLOAT UNIFORMS

Operational sea commands currently have at least five different uniforms being worn throughout their decks—six if the ship is flight-capable. These uniforms include the NWU Type I, and both FRV and IFRV coveralls. The remaining three are job-specific uniforms issued as organizational clothing to sailors who work in the associated fields. These uniforms included engineering coveralls (being replaced by the FRV coverall), electrician coveralls, and flight deck clothing (flight suites). The majority of sailors onboard Navy ships will not wear these job-specific uniforms but instead be required to wear the official underway uniform. Following is a comprehensive review and timeline of the Navy's modern underway uniform from 2004 to present day.

1. Navy Working Uniform (NWU) Type I

The NWU Type I, illustrated in Figure 4, was designed in late 2004 and was launched by the Navy in 2008.

Figure 4. Navy's modern underway uniform from 2004 to present day. Source: Military.com (2016).

It was designed to replace the seven assorted styles of working uniforms at the time. The uniform's permanent press, maintenance-free, cotton blend, and 50/50 nylon would later be the reason for its demise (Foutch, 2006). It was originally intended for shipboard use but relinquished those duties when multiple private tests revealed that the uniform was highly flammable.

The NCTRF conducted an impromptu flame-resistant test in in Natick, MA during September of 2012. Their report concluded that when exposed to fire, the NWU Type I will burn intensely, describing how "the cotton fibers in its 50/50 cotton/nylon blend burn while the nylon fibers 'melt and drip'" (*Military Times*, 2013). The report also warned that

"If this sticky, molten material came in contact with skin it would contribute to increased burn injury" (*Military Times*, 2013). These results came to no surprise to top Navy officials, who voiced that the NWU Type I uniform was never meant to be flame-resistant. However, these same officials had previously stated the opposite. The *Military Times* reported that "the new findings appear to contradict the Navy's own guidance when the uniforms were introduced. In 2005, uniform officials said NWUs met 'fire-retardant standards' and could withstand 'intense heat without causing injury'" (*Military Times*, 2013). Many active-duty sailors were extremely surprised that the Navy would send them to sea in a uniform that was unsuitable and inherently dangerous (*Military Times*, 2013): "CAPT Rothschild wrote in an email, 'I had no idea that the uniform was so dangerous in a fire. Quite frankly, I am extremely disappointed in Navy leadership that they did not conduct this type of testing before adopting the uniform; or if they did, that they proceeded with approving it for shipboard use'" (*Military Times*, 2013).

The Navy's decision to design and distribute a flammable working uniform was not the safest, but it was in accordance with current policies at the time: "The requirement (for a flame-resistant uniform) was dropped for Navy working uniforms in 1996, when the Navy was developing a successor to the unpopular but traditional dungarees-and-chambray shirt combination that had been used since World War II" (*Military Times*, 2013). Dropping the requirement for a flame-resistant working uniform was seen by many sailors as a leadership fail. It is well known that throughout history, Navy ships have experienced fires aboard their gray hulls that have killed sailors and left ships severely crippled. "Devastating fires raged on carriers Forrestal and Enterprise, the frigate Stark, and in the past four years, aboard the carrier George Washington, dock landing ship Whidbey Island and the drydocked attack submarine Miami" (*Military Times*, 2013). The Navy saved $12M in 1996 by dropping the flame-resistant requirement for its afloat uniforms (*Military Times*, 2013).

While the findings of the evaluation done by the NCTRF came as no surprise to the high-ranking Navy officials who led the NWU Type I project, the results directly contradicted previous statements those same high-ranking officials had made about the uniforms' safety. "Indeed, the new findings appear to contradict the Navy's own guidance

when the uniforms were introduced. In 2005, uniform officials said NWUs met 'fire-retardant standards' and could withstand 'intense heat without causing injury'" (*Military Times*, 2013).

> The test conducted by the NCTRF was part of a larger electrical safety review. Engineers hung 3-by-12-inch strips of NWU material alongside strips of flame-resistant Army and Marine uniforms, exposed them to flames for 12 seconds, and observed the results. The Army and Marine combat uniforms did not burn after the flame was removed, experienced no melting, and were only charred for three or four inches. However, the NWUs ignited. The entire strip burned, nylon fibers melted, all material samples totally consumed by robustly burning flames,' the observers noted in their report, adding that the uniform burned for longer than 60 seconds after the flame was removed. (*Military Times*, 2013)

Navy uniform officials have yet to reveal if the NWU went through a flame test prior to its implementation as an official seabag uniform.

The NCTRF's report sparked reactions from top Navy officials. The first was the formation of the Organizational Clothing Working Group (U.S. Fleet Forces, personal communication, July 19, 2018). The group's research and diligent work was responsible for providing the commanders of the USFF and United States Pacific Fleet with the necessary data for the Shipboard Organizational Clothing Update Press Release on May 30, 2013. The announcement promised, "within the next nine months, the Navy will develop and deliver a hybrid coverall combining the designs of the existing nylon/cotton coverall currently sold in the Navy Exchange with the flame-resistant material of the current repair-locker coverall. The hybrid coverall will be available for all sailors as organizational clothing" (U.S. Fleet Forces, personal communication, July 19, 2018).

The Navy held true to its promise. The Shipboard Clothing Working Group was initiated in July of 2013 with the primary task of determining the suitability of wearing the NWU Type I at sea. The Shipboard Clothing Working Group was successful in delivering a new FRV coverall to the fleet. In January of 2015, the first FRV coveralls were distributed to the USS BATAAN and the USS GEORGE H.W. BUSH (U.S. Fleet Forces, personal communication, July 19, 2018). Additionally, the Navy announced in August of 2016 that

the NWU Type I would be replaced by the NWU Type III starting October of that year. This announcement marked the end of the NWU Type I for good.

2. Flame Resistant Variant (FRV) Coverall

In response to the NCTRF's 2013 report on the flammability of the NWU Type I, the Navy mandated fire-retardant uniforms for sailors underway (*Navy Times*, 2018). This knee-jerk reaction resulted in the fleet outfitting all its sailors at sea with FRV coveralls. This new uniform, shown in Figure 5, was to be organizational clothing; sailors would not have to buy them but would borrow from the command during their time aboard.

Figure 5. Flame Resistant Variant (FRV) Coverall. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

The coveralls were comprised of 100% treated cotton. The USFF gave a description of the FRV coverall in its official Flame-Resistant Variant Coverall and Rollout plan.

FRV Coverall review:

> The FRV coverall is made from a Flame retardant treated 100% cotton fabric using the same design pattern as the existing utility coverall. The Navy's Clothing and Textile Research Facility has demonstrated the FRV's ability to protect sailors. The FRV passed all flame and flash fire testing requirements and the flame resistance properties did not degrade with wear or laundering for the serviceable life of the coverall. (COMUSFLTFORCOM NORFOLK VA, 2013)

The FRV coverall was subjected to multiple American Society for Testing and Materials (ASTM) evaluations, the two most important being ASTM D6413-13: Standard Test Method for Flame Resistance of Textiles (Vertical Test); and ASTM F1390-13: Standard Test Method for Evaluation of Flame Resistant Clothing for Protection against Fire Simulations Using an Instrumented Manikin (U.S. Fleet Forces, personal communication, July 19, 2018). The FRV coveralls had to meet strict requirements associated with ASTM D6413-13. These requirements include: self-extinguishment within two seconds of flame exposure, no more than five inches of charred material after flame exposure, and no melted or dripping material as a result of flame exposure (U.S. Fleet Forces, personal communication, July 19, 2018). Evaluation ASTM D6413-13 mandates that after being exposed to flame, the coverall material must self-extinguish to increase the user's chance of survivability and decrease the severity of any burn injuries (U.S. Fleet Forces, personal communication, July 19, 2018).

Evaluation ASTM F1390-13 is a system-level test performed using an instrumented manikin. "The manikin is equipped with 123 skin sensors uniformly distributed over the entire body, minus the hands and feet" (U.S. Fleet Forces, personal communication, July 19, 2018). The manikin is dressed in the FRV coverall and positioned to be fully engulfed in flames from eight burners, simulating a flash fire scenario (U.S. Fleet Forces, personal communication, July 19, 2018). All sensors are interconnected to a data acquisition system. Burn data is collected through a burn prediction model, and the predicted area and location of the sensors which received burn injuries are graphically displayed (U.S. Fleet Forces,

personal communication, July 19, 2018). Burns are categorized as no burn, first-degree, second-degree, and third-degree. A total of 12 FRV coveralls were tested. Three FRV coveralls were home-laundered once, three were shipboard-laundered once, three were home-laundered 50 times, and the final three were shipboard-laundered 50 times (U.S. Fleet Forces, personal communication, July 19, 2018). In accordance with ASTM F1390-13, none of the twelve FRV coveralls that were evaluated may have more than a 25% total burn injury prediction (threshold) or 15% (objective) including second-degree and third-degree burns during a 3-second exposure at 2.0 cal/cm^2/sec heat flux (U.S. Fleet Forces, personal communication, July 19, 2018). Figure 6 shows before, during, and after visuals of a system-level test being conducted in accordance with ASTM F1390-13.

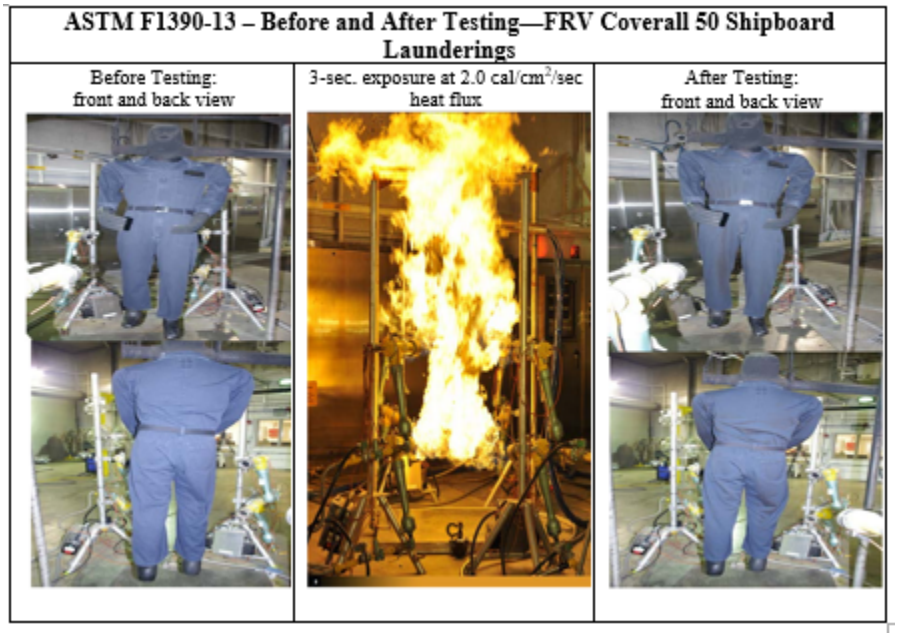

Figure 6. Before, during, and after visuals of a system-level test. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

Figure 7 illustrates the test results of both the 50 home and 50 shipboard laundered FRV coveralls. The flash fire protection test for the FRV group comprised of the 50 home launderings resulted in a 2.18 percent prediction of 3rd degree burn injuries and 11.73 percent prediction of 2nd degree burn injuries. The combination of both 3rd and 2nd degree

burn injuries is below the threshold and objective requirements associated with ASTM F1930. The results for the 50 shipboard launderings group were similar. The shipboard laundering group yielded a .89 percent prediction of 3rd degree burn injuries and 9.16 percent prediction of 2nd degree burn injuries (U.S. Fleet Forces, personal communication, July 19, 2018). Both conditions passed the threshold and objective requirements.

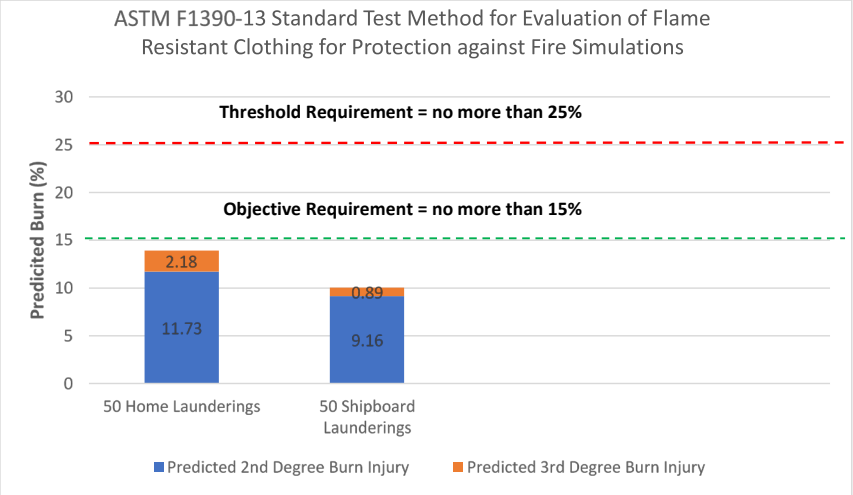

Figure 7. Illustrates the test results of both the 50 home- and 50 shipboard-laundered FRV coveralls. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

While the FRV coverall did provide sailors with flame-resistant protection, it "failed to meet an appropriate standard for durability, climate modularity, and did not provide protection against arc flash" (U.S. Fleet Forces, personal communication, July 19, 2018). The FRV coverall was riddled with issues because of its rushed implementation. Getting the required sizes and quantities (three for each sailor onboard) to each ship proved to be an impossible task. Many of the popular sizes were backordered for months at a time, resulting in ships going pier to pier to borrow from one another sometimes only hours before setting sail on deployments. A fleet survey conducted between April 25 - May 21, 2014 to assess fit, durability, overall satisfaction, and comfort concluded overwhelmingly

that sailors were dissatisfied with multiple aspects of the FRV coverall and the FRV coverall all together. The survey had a total of 1,454 respondents across eight different ships, of whom 76% were male and 24% were female (U.S. Fleet Forces, personal communication, July 19, 2018). A few of the survey's highlights follows.

- Significant issues with wrinkling and color change (e.g., fading) identified
- Moderate issues with shrinkage (expected)
- Fit was "just right" for 38% of respondents, "too large" for 42% of respondents, and "too small" for 18% of respondents
- Significant issues with tearing, snagging, and fraying were identified
- 59% of respondents were either "very dissatisfied" or "moderately dissatisfied" with the FRV coveralls
- The majority of respondents (68%) were dissatisfied with the comfort of the FRV coverall in hot environments
- Many quality issues were noted throughout the free-response portions of the survey (e.g., zippers failing or not sewn in garment; loose seams; Velcro wearing out; belt loops coming off) (U.S. Fleet Forces, personal communication, July 19, 2018)

This dissatisfaction led to the third phase of the Navy's modern NWU saga, the IFRV.

3. Improved Flame-Resistant Variant (IFRV) Coverall

"The approval of the IFRV as a fleet organizational clothing item to replace the legacy FRV coverall was announced in early January 2017 after the completion of a series of afloat wear tests. The IFRV, shown in Figure 8, addresses comfort and durability issues found with the original FRV coverall" (U.S. Fleet Forces, personal communication, July 19, 2018).

Figure 8. Improved Flame-Resistant Variant (IFRV) Coverall. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

The Navy began the IFRV project by outlining specific objectives it wished to accomplish through the implementation of an improved variant of the FRV coverall. These objectives included identifying alternative flame-resistant fabrics with increased dimensional stability, colorfastness, and durability compared to the 100% cotton used in the FRV model (U.S. Fleet Forces, personal communication, July 19, 2018). The Navy wanted to qualify two different fabric blends and evaluate whether a utility or flight suit design was more practical for sailors. The main safety improvement from the FRV to the IFRV was protection against arc flash. An arc flash is defined as a "phenomenon where a flashover of electric current leaves its intended path and travels through the air from one conductor to another, or to ground. The results are often violent and when a human is in close proximity to the arc flash, serious injury and even death can occur" (OSHA, n.d.). While arc flashes do not frequently occur, they do pose a real threat to sailors at sea. For this reason, electrician's mates and other personnel dealing with electrical systems have

been required to wear special coveralls while preforming high-voltage verification and maintenance checks in the past. The IFRV currently provides every sailor aboard with this protection in addition to meeting the flame-protection standards imposed by ASTM D6413-13 and ASTM F1390-13. The IFRV evaluation process was very similar to the FRV in that it included surveys (mid- and post-deployment), focus group feedback, and discussions from type commander leadership (U.S. Fleet Forces, personal communication, July 19, 2018).

The Navy tested and eventually qualified two fabric blends. Fabric B (Springfield Dual Hazard) consists of a 48% Lyocell, 40% Modacrylic, 12% Para Aramid blend. This blend is approximately 50% more expensive than comparable weights of 100% flame-resistant cotton but has a superior appearance and colorfastness after laundering (U.S. Fleet Forces, personal communication, July 19, 2018). Furthermore, Fabric B has an almost a 300% longer wear life on top of improved breathability and moisture management which will contribute to keeping sailors cooler, drier, and more comfortable (Navy Clothing and Textile Research Facility, 2015). Fabric C (Tencate Tecasafe® Plus 700A) consists of a 48% Modacrylic, 32% Lyocell, and 20% Para Aramid blend. Fabric C is approximately 85% more expensive than comparable weights of 100% flame-resistant cotton with all the same additional benefits as Fabric B (U.S. Fleet Forces, personal communication, July 19, 2018).

The Navy then contracted 50 coveralls of each design (utility and flight suit). Each lot included both fabric options. Once system level testing was complete for both design options, the Navy contracted and distributed 2,200 of each design to sailors for operational testing during pre-deployment and deployment phases. Each participant was issued four sets of coveralls: two utility and two flight suits in either Fabric B or Fabric C. Participants were geographically located in San Diego, CA and Norfolk, VA. The utility design is unisex and costs approximately $85 per unit, while the flight suit design cost $120 per unit and is sized by gender. (U.S. Fleet Forces, personal communication, July 19, 2018).

The results from the IFRV wear test were unanimous: sailors reported major improvements from the original FRV. Satisfaction rates for appearance, durability, and

comfortability were all 85% or higher (U.S. Fleet Forces, personal communication, July 19, 2018). Detailed survey results for the IFRV coverall wear test are contained in Figure 9.

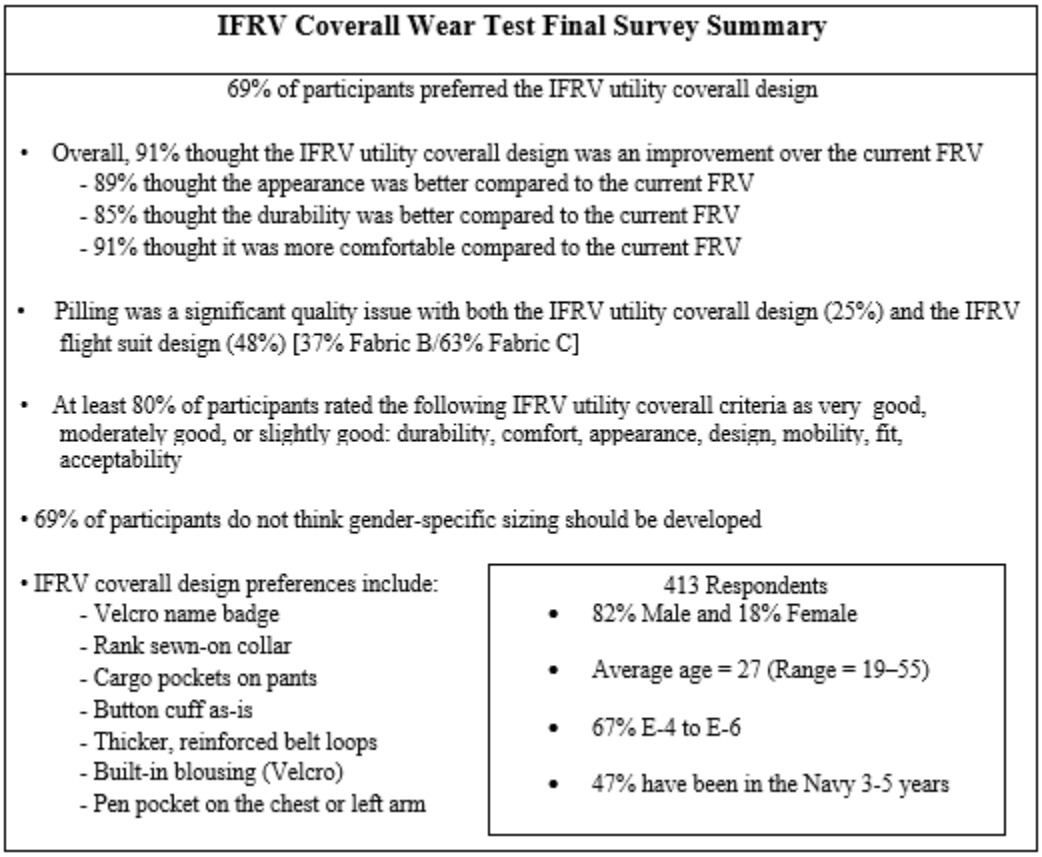

Figure 9. Detailed survey results for the IFRV coverall wear test. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

In addition to being a fan favorite for sailors, the IFRV is a safer coverall. Both Fabric B and C, passed ASTM D6413-13 and ASTM F1390-13, making the IFRV certified flame-resistant (U.S. Fleet Forces, personal communication, July 19, 2018). Furthermore, the IFRV passed ASTM F1959: Standard Test Method for Determining the Arc Rating of Materials for Clothing. The IFRV has an arc thermal protective value exceeding the minimum 8 calories/cm^2 (U.S. Fleet Forces, personal communication, July 19, 2018).

The final IFRV prototype was the utility design. It gave sailors better flame-resistant protection for longer (9 months vice 6 months), arc flash protection, and a more comfortable but durable fit. The USFF also made design modifications to implement valid recommendations that resulted from the wear test (U.S. Fleet Forces, personal communication, July 19, 2018). These design modifications included adding an additional pen pocket on the left chest pocket, thicker and reinforced belt loops, reinforced pockets, built-in Velcro blousing on trousers, cargo pockets on legs with Velcro closures, and a cell phone pocket (U.S. Fleet Forces, personal communication, July 19, 2018). At last, the Navy developed an underway uniform that provides exceptional protection and incorporates recommendations from the fleet. "The new coveralls will mark a final resolution to an embarrassing chapter for the Navy that began in 2012, when startling internal tests discovered the blue-and-gray NWUs quickly caught fire when exposed to heat and would 'burn robustly until completely consumed'" (*Navy Times*, 2018). Depending on the vantage point taken, the IFRV was the end of the saga or only the beginning.

C. NEW UNIFORM PROPOSAL: TWO-PIECE (2-PC) FLAME-RESISTANT UNIFORM

The final IFRV survey reported a recommendation that Navy uniform officials have strongly supported: a more professional-looking 2-PC afloat shipboard uniform that could be authorized for off-base wear. While the IFRV was being wear tested, the USFF created the 2-PC Integrated Product Team (IPT) (U.S. Fleet Forces, personal communication, July 19, 2018). Enlisted sailor and officer 2-PC prototypes are shown in Figure 10.

Figure 10. 2-PC Uniform. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018

The main goal of the 2-PC IPT was to use feedback from the deckplate and focus groups in developing a 2-PC uniform that would fit a new, condensed selection of afloat uniform options (U.S. Fleet Forces, personal communication, July 19, 2018). The Navy's working uniform convergence plan is illustrated in Figure 11.

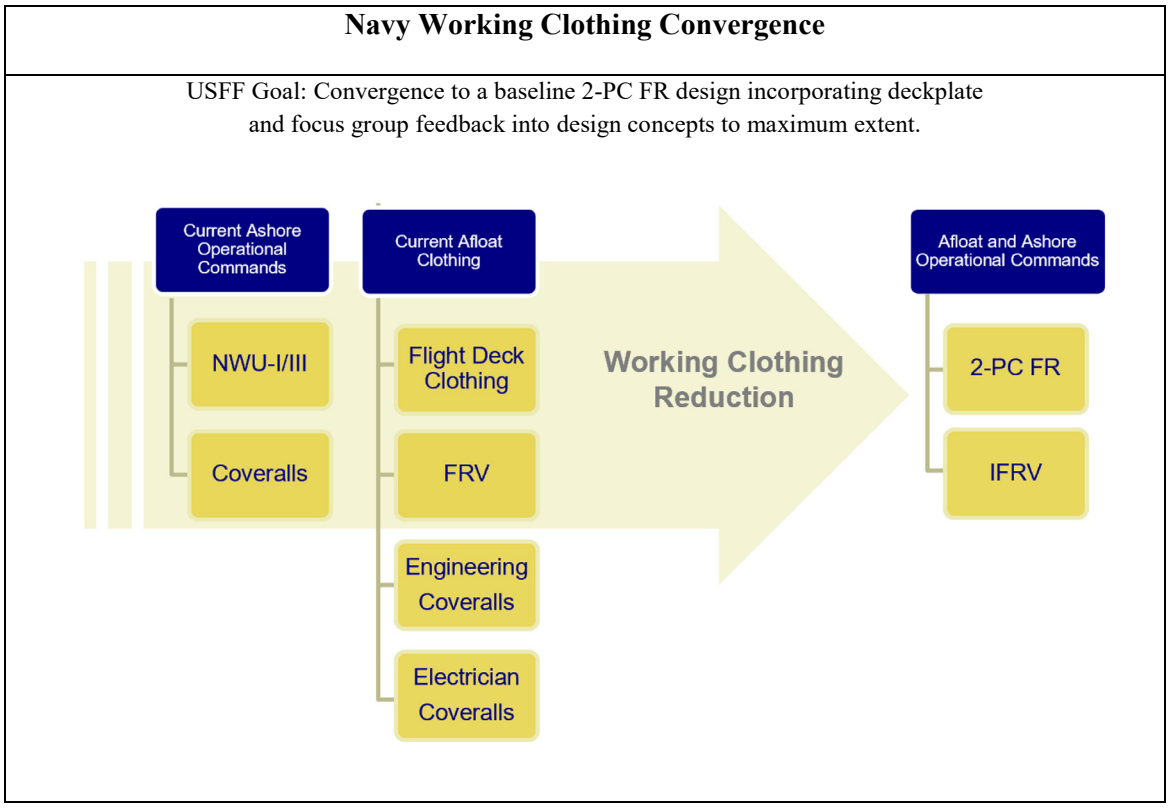

Figure 11. Navy's working uniform convergence plan Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

Focus group feedback was elicited and received from both the deckplate and senior leadership levels. The purpose of this information was to help the USFF develop 2-PC prototypes that incorporated sailor-driven design features. Feedback from the two groups was divided into three different subcategories: performance, design, and manner of wear. A breakdown of the deckplate-level focus group feedback received by the USFF is presented as follows:

Performance

- Climate modularity remains a concern

Design

- The use, application, and durability of pockets are an important design feature
- Trouser blousing should accommodate for general quarters (GQ)
- Sewn-on name tags and insignia are preferred
- Male/female and athletic/classic cut options should be offered
- E-7 and above favor a wash khaki-like tuck-in style
- E-6 and below are split between an over-blouse and tuck-in variant of a single color if color fastness can be ensured
- Blouse: permanent press finish, short and long sleeve variants, ability to roll sleeves
- Trousers: flexible waist bands, belt loops large enough to support use of a riggers belt, pen and cargo pockets, and built-in Velcro for blousing

Manner of Wear

- Manner of wear should be expanded to include wear on the base and in transit
- Ballcaps should be authorized as appropriate headwear
- Sailors should not be required to blouse when in working spaces
- Will not replace use of coveralls for dirty work nor on submarines (U.S. Fleet Forces, personal communication, July 19, 2018)

The focus group feedback received from senior leadership was similar but went into more detail for each subcategory.

Performance

- Climate modularity
- Comfort and suitability for routine shipboard work

Design

- Application of an anthropometric sizing study to uniforms suggested
- Velcro should be used to attach name tags and insignia
- Two designs favored: service khaki variant and NWU Type III variant
- Solid color favored (khaki for E-7 and above; blue for E-6 and below) if color fastness ensured
- Blouse: short and long sleeve variants; long sleeves allow for "smart" looking roll up
- Trousers: straight-legged, capable of blousing, adjustable side waist tab, large belt loops to support use of a riggers belt, variation in pocket numbers and placement
- Permanent press favored
- Dryfire-style moisture-wicking jerseys preferred
- Female uniform should be available in over blouse and tuck-in (service khaki variant)

Manner of Wear

- Manner of wear should be expanded to include wear on the base and in transit
- Ballcaps should be designated as appropriate headwear (alternate - garrison cover)

- Comfort and suitability should be improved by allowing sailors to add layers or de-blouse in extreme climates and challenging work environments
- A range of black maritime boots (slip-on, lace-up, 4-, 6-, and 8-inch heights) preferred (U.S. Fleet Forces, personal communication, July 19, 2018)

Focus groups were also conducted to determine what colors of shirts and trousers would be worn by deckplate and senior-leadership service members. Additionally, design characteristics such as belt loops, number of exposed buttons, and pockets were also driven by survey results (U.S. Fleet Forces, personal communication, July 19, 2018). Figures 12 and 13 depict proposed 2-PC uniform designs for E-7 and above based on focus group feedback.

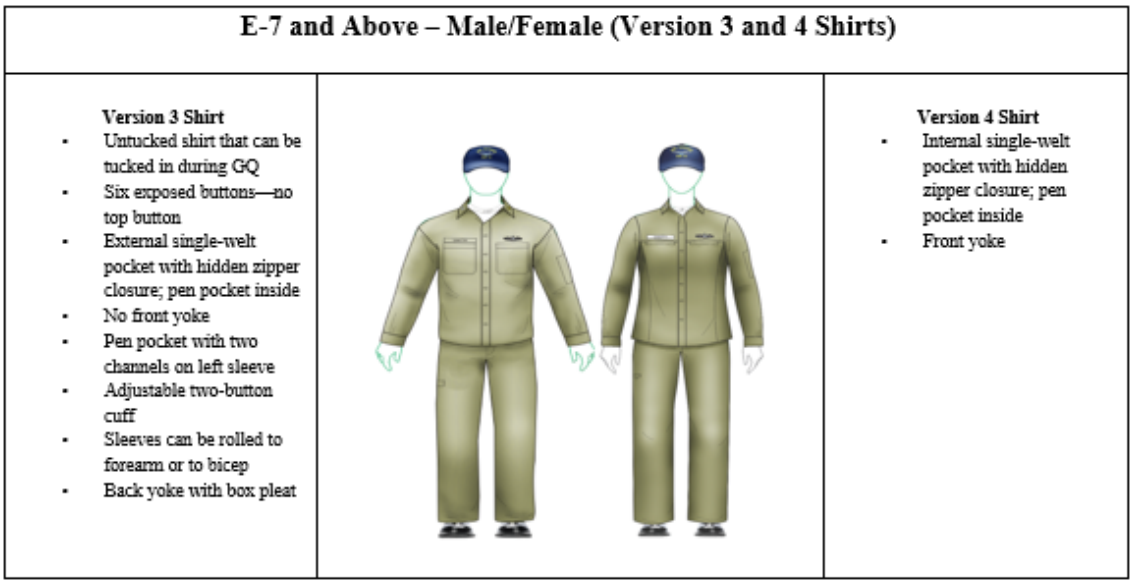

Figure 12. Proposed 2-PC uniform designs for E-7 and above based on focus group feedback. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

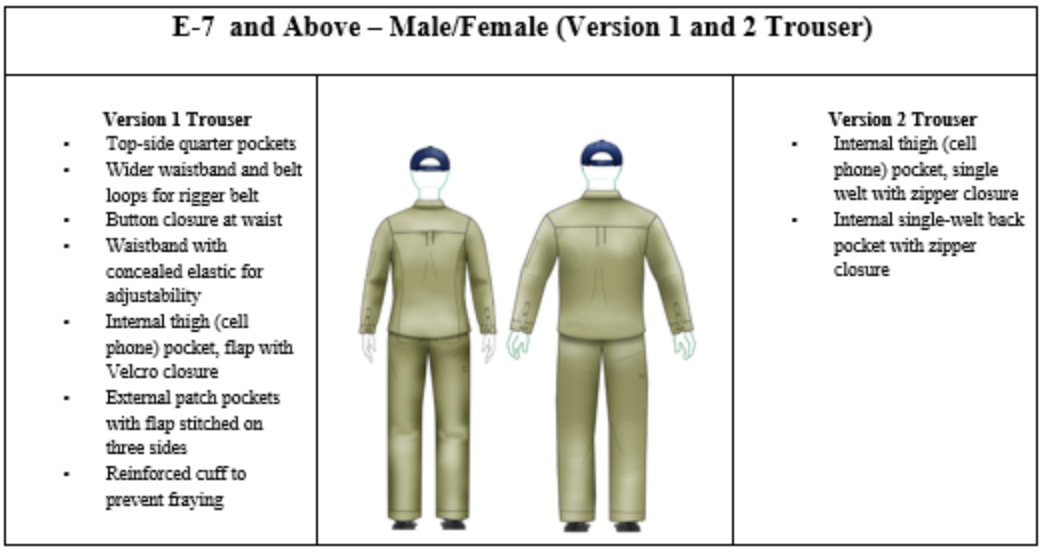

Figure 13. Proposed 2-PC uniform designs for E-7 and above based on focus group feedback. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

Focus group feedback yielded four different shirt variations and two different trouser variations for E-6 and below. Figures 14, 15, and 16 illustrate these designs.

E-6 and Below - Male/Female (Version 1 and 2 Shirts)

Version 1 Shirt

- Untucked shirt that can be tucked in during GQ
- Covered six-button placket - no top button
- External patch pockets with internal pen pocket, flap with Velcro closure
- No front yoke
- Pen pocket with two channels on left sleeve
- Adjustable two-button cuff
- Sleeves can be rolled to forearm or to bicep
- Back yoke with box pleat

Version 2 Shirt

- Dark blue shirt
- Front yoke

Figure 14. Variations of shirts, versions 1 and 2. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

E-6 Below – Male/Female (Version 3 and 4 Shirts)

Version 3 Shirt

- Untucked shirt that can be tucked in during GQ
- Six exposed buttons – no top button
- External patch pockets with internal pen pocket, flap w/ Velcro closure
- Front yoke
- Pen pocket with two channels on left sleeve
- Adjustable two-button cuff
- Sleeves can be rolled to forearm or to bicep
- Back yoke with box pleat

Version 4 Shirt

- Dark blue shirt
- No front yoke

Figure 15. Variations of shirts, versions 3 and 4. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

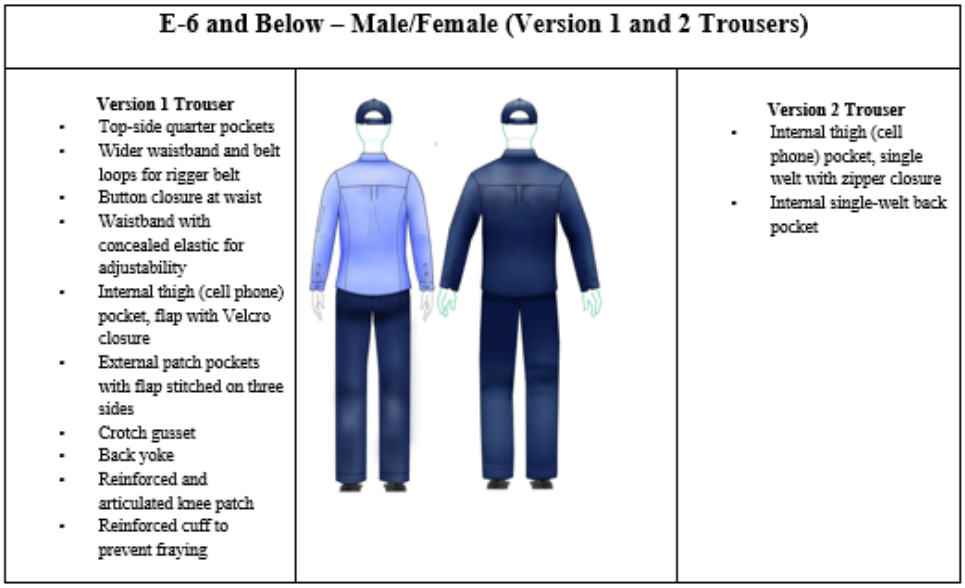

Figure 16. Variations of trousers, versions 1 and 2. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

1. Two-Piece (2-PC) Focus Group Survey Results (Pre-wear Test)

A 2-PC focus group survey was conducted once the design prototypes had been developed. The survey concluded that overall, 84% of the 287 participants supported a 2-PC flame-resistant variant for use afloat, ashore on operational commands, and off-base (U.S. Fleet Forces, personal communication, July 19, 2018). Detailed survey results follow.

E-7 and above:

Male participants

- 80% supported a 2-PC flame-resistant khaki variant.
- 72% favored an untucked shirt over tucked.

Female participants

- 88% supported a 2-PC flame-resistant khaki variant.
- 83% favored an untucked shirt over tucked.

E-6 and below:

Male participants

- 83% supported a 2-PC flame-resistant variant.
- 82% favored an untucked shirt over tucked.
- 74% favored a solid navy blue uniform over a light blue shirt with dark blue trousers.

Female participants

- 86% supported a 2-PC flame-resistant variant.
- 86% favored an untucked shirt over tucked.
- 71% favored a solid navy blue uniform over a light blue shirt with dark blue trousers. (U.S. Fleet Forces, personal communication, July 19, 2018)

2. Future Considerations

The Navy 2-PC flame-resistant afloat uniform could mark the end of a disappointing uniform saga that started in 2004. The Navy is currently conducting wear tests for the 2-PC with the expectation of delivering units to the fleet as soon as possible. Preliminary wear test feedback indicates that sailors enjoy the convenience of the 2-PC uniform and that its functionality and design remain among the most highly rated attributes for a quality working uniform (U.S. Fleet Forces, personal communication, July 19, 2018). The inception of an untucked, 2-PC uniform authorized for commutes and off-pier activities could be the type of innovative thinking the Navy needs. The sailors themselves will always remain the best weapon system in the Navy's arsenal, so it is fitting that the Navy provide its sailors with the best and most innovative uniform. Just like the flame-resistant uniforms that came before the 2-PC, the Navy will have to develop appropriate under and outer garments that meet ASTM standards. Most importantly, however, will be deciding whether the 2-PC uniform is organizational clothing or a seabag item. It is worth stating that "the Navy does not have a sea-going uniform in the seabag, that it views going to sea—the primary job of the Navy" (Kurtz, 2018).

IV. METHODOLOGY

A. COST-BENEFIT ANALYSIS (CBA) MODEL

Due to the nature of the proposed 2-PC fire-resistant uniform, we used CIRCULAR A-94 to conduct Cost-Benefit analysis. According to CIRCULAR A-94, CBA is the recommended technique for the official economic analysis of government programs. Cost-benefit analysis is the organized process of equating benefits and costs in assessing the attractiveness of a program. Cost-benefit analysis is a recognized government method for making well-informed choices on the usage of society's uncommon resources. It tries to answer questions if a project is worthy, the best measure of the project, and the applicable restraints (Mishan & Quah, 2007).

> In CBA, we try to assess all of the costs and benefits to society as a whole which includes the social costs and the social benefits. For this reason, some experts refer to CBA as social cost-benefit analysis. The collective value of a policy is measured by its net social benefits (NSB), sometimes only referred to as the net benefits The NSB equivalents the social benefits (B) minus the social costs (C): NSB = B − C. (Boardman, Greenberg, Vining, Weimer 2011, p. 21)

1. Steps of Cost-Benefit Analysis (CBA)

Boardman et al. (2011) provide a detailed explanation of the steps of a CBA.

(1) Specify the set of alternative projects.

In Step 1 we require to specify the set of alternative projects. In our study, we are looking at the different available alternatives to the Navy for 2-PC uniform to analyze the best alternative.

(2) Decide whose benefits and costs count (standing).

In this step, the analyst decides who has standing in the project. Whose benefits and costs must be taken into consideration.

(3) Identify the impact categories, catalog them, and select measurement indicators.

> Step 3 requires the analyst to recognize the physical impact categories of the proposed alternatives, catalog them as benefits or costs, and specify the measurement indicator of each impact category. Although this list of impact categories appears comprehensive, critics might argue that some relevant impacts were omitted. However, the CBA perspective is interested only in project impacts that affect the utility of individuals with standing. Impacts that do not have any value to human beings are not counted. (Boardman et al. 2011, p. 27)

(4) Predict the quantitative impacts over the life of the project.

The fourth step is to measure the impacts in a specific period. To monetize means to value in dollars. The cost and benefits are discounted to find present values (PV). When projects have impact over multiple years, the cost and benefits that happen in different years should be aggregated.

(5) Discount benefits and costs to obtain present values.

> In CBA, the PV is obtained by discounting future benefits and costs relative to present benefits and costs. Discounting has nothing to do with inflation, although inflation must be considered. A cost or benefit that occurs in a year (t) is calculated for its PV by dividing by the social discount rate (s). For example, suppose a project has a life of n years, and let B and C denote the benefits and costs, respectively, in year t. The present value of the benefits, PV(B), and the present value of the costs, PV(C), of the project are, respectively. (Boardman et al. 2011 p. 31)

$$PV(B) = \sum_{t=0}^{n} \frac{B_t}{(1+s)^t}$$

$$PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1+s)^t}$$

(6) Compute the net present value of each alternative.

> The net present value (NPV) of an alternative equals the difference between the PV(B) and the PV(C): NPV = PV(B) − PV(C). The basic decision rule for a single alternative project (relative to the status quo) is simple: adopt the project if its NPV is positive. In short, the analyst should recommend proceeding with the proposed project if NPV = PV(B) - PV(C) > 0. This will indicate that the benefits of a project exceed its costs: PV(B) > PV(C).

When there is more than one alternative to the status quo and all the alternatives are mutually exclusive, then the rule is slightly more complicated: select the project with the largest NPV. This rule assumes that at least one NPV is positive. If no NPV is positive, then none of the specified alternatives are superior to the status quo, so the status quo should stay in place. (Boardman et al. 2011, p. 32)

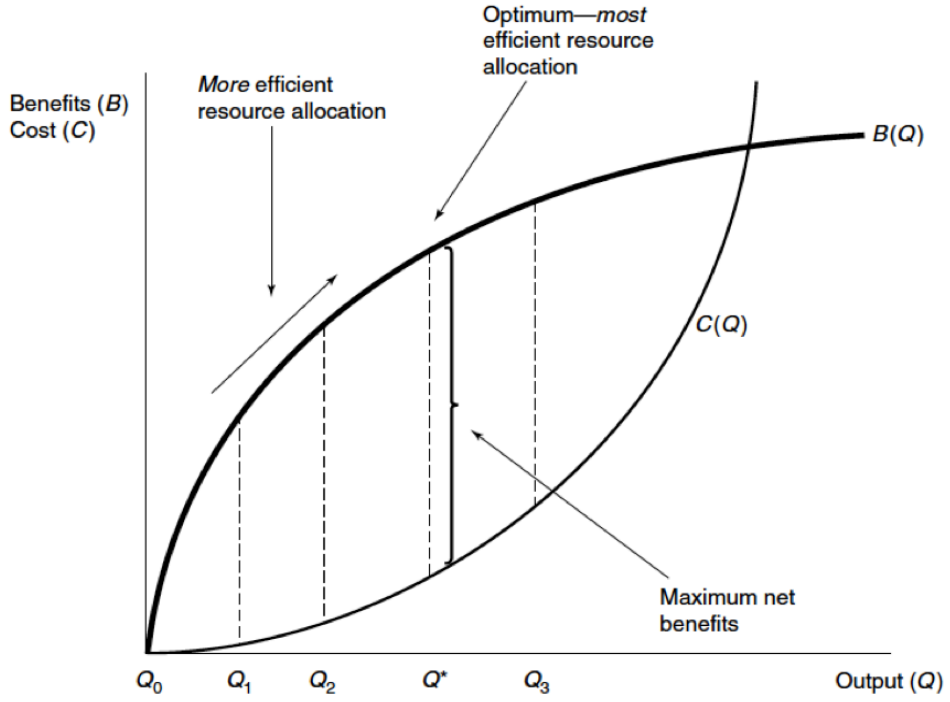

Figure 17. CBA seeks more efficient resource allocation. Source: Boardman, Greenberg, Vining, and Weimer (2011).

(7) Perform a sensitivity analysis.

Boardman et al. (2011) explain sensitivity analysis

A sensitivity analysis is an integral part of the CBA. There may be some uncertainty about the predicted impacts and their monetized value; sometimes analysts are not confident about the number of lives saved or the dollar value of a statistical life. The discount factor is another essential part of a sensitivity analysis. The analyst may also be unclear about the proper social discount rate and the applicable level of standing. The sensitivity analysis tries to deal with such doubts. There are practical limits to extent of a sensitivity analysis; every assumption in a CBA can be diverse. In practice, one has to use best judgment and focus on the most significant assumptions (Boardman et al. 2011, p33).

(8) Make a recommendation.

The analyst should, in most cases, advocate approval of the project with the largest NPV. However, these are only projected values. "A sensitivity analysis, which is not demonstrated in detail, might recommend that the alternative with the largest theoretical NPV is not realistically the best alternative in all circumstances. Finally, it is critical to note that analysts make recommendations, not decisions. Decisions are reserved for the political and bureaucratic environment" (Boardman et al. 2011).

B. DATA ANALYSIS

In order to begin the data analysis, the COAs must be declared. Our research team came up with three different COAs (Course of Actions), which we will analyze and make a recommendation based on which alternative results in the most benefits.

1. Course of Action (COA) Options

For the sake of this study, the COA options are defined as follows:

- COA 1: Both IFRV coveralls and the 2-PC flame-resistant uniform are prescribed as at-sea uniforms
- COA 2: The 2-PC flame-resistant uniform will replace IFRV coveralls as the only prescribed at-sea uniform
- COA 3: Status Quo (IFRV coveralls are the only prescribed at-sea uniform)

2. Assumptions

- The 2-PC flame-resistant uniform will be organizational clothing and no uniforms are returned to stock
- Uniform cost data is provided by the USFF
- Nine-month phased replacement occurs
- 120,000 operational sailors will receive the 2-PC uniform

- Four lives will be saved per year with flame protection from arc flash
- 50 injuries will be prevented due to the 2-PC flame-resistant uniform
- There will 50 major injuries prevented with the 2-PC flame-resistant uniform.
- The value of a statistical life is $9,600,000.00 (Rohlfs, Sullivan, & Kniesner, 2015; U.S. Department of Transportation, 2016)
- The value of a statistical injury is 18.9% of the value of a statistical life which equates to $1,814,400.00 (Rohlfs and Sullivan, 2013)
- The discount rate is 7% (OMB 2018)

3. Benefits

The objective of developing the 2-PC a professional-looking flame-resistant uniform that durable, lightweight, and comfortable. Two variants will be developed: one for officers and one for enlisted sailors. The officers' uniform will be khaki (similar in design to the wash khaki/working khaki), and the enlisted sailors' uniform will be solid navy blue. Feedback on design and fabric preferences from the IFRV wear evaluation will be utilized. There are many benefits of the 2-PC uniform, but it will be difficult to monetize every benefit for this research. The new 2-PC uniform is expected to be the required uniform in the fleet for many years. In our study, we will look at the cost and benefit for all three years. This decision is based on a review of the length of the time previous uniforms have been used before another version replaced them. The lower risk of death affects every sailor who will wear the 2-PC uniform, so that benefit will be applied over the life cycle of the project. There are monetary and non-monetary benefits of the 2-PC uniforms; the non-monetary benefits will be discussed in Chapter V. Monetized benefits are in Table 1.

Table 1. Monetized benefits table. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

Monetized Benefits Table			
Year One: 2019	**COA #1**	**COA #2**	**COA #3 (Status Quo)**
Lifesaving (4)	$38,400,000.00	$38,400,000.00	$38,400,000.00
Fatal injury saving (50)	$90,720,000.00	$90,720,000.00	$90,720,000.00
Total for 2019	$129,120,000.00	$129,120,000.00	$129,120,000.00
Year Two: 2020	**COA #1**	**COA #2**	**COA #3**
Lifesaving (4)	$38,400,000.00	$38,400,000.00	$38,400,000.00
Fatal injury saving (50)	$90,720,000.00	$90,720,000.00	$90,720,000.00
Total for 2020	$129,120,000.00	$129,120,000.00	$129,120,000.00
Year Three: 2021	**COA #1**	**COA #2**	**COA #3**
Lifesaving (4)	$38,400,000.00	$38,400,000.00	$38,400,000.00
Fatal injury saving (50)	$90,720,000.00	$90,720,000.00	$90,720,000.00
Total for 2021	$129,120,000.00	$129,120,000.00	$129,120,000.00
Total Benefits	**$387,360,000.00**	**$387,360,000.00**	**$387,360,000.00**

The total benefit for all COAs is $387,360,000.00. The Figure 18 shows the NPV of the total benefits in three year.

Net Present Value of the Benefits (Same for all COAs)			
Discount Rate	**7.00%**		
Year	**1**	**2**	**3**
Discount Factor	0.93	0.87	0.82
Undiscounted Cash Flow	129,120,000	129,120,000	129,120,000
Present Value	120,672,897	112,778,409	105,400,382
Net Present Value	**338,851,688**		
Discounted Value	8,447,103	16,341,591	23,719,618

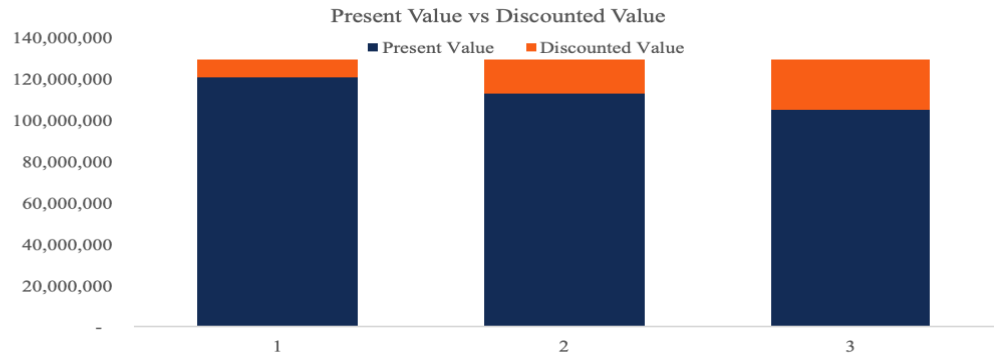

Figure 18. Net present value of the benefits. Adapted from U.S. Fleet Forces Command (2017).

After discounting the benefits by 7% (OMB 2018), the NPV of the benefits is $338,851,688.00. However, here are many other benefits of the 2-PC uniform that are harder to monetize which may play a significant role in decision making

4. Cost

The 2-PC uniform can be worn in any space on a ship or sub, while conducting any job, and is authorized for wear on and off the ship. The 2-PC costs $224 (flame-resistant Drifire jersey costs $50.99 and 2-PC costs $173) per set plus the $75 IFRV coveralls if they are kept as an at-sea uniform. Allowing sailors, the 2-PC in addition to the IFRV coverall would constitute added cost to the Navy and afloat commands. There will always be a need for a dirty-work coverall and a uniform that sailors can don quickly in response to causalities such as general quarters or man overboard, and the IFRV would satisfy those needs.

As organizational clothing, the command would be required to procure, manage, and issue the IFRV and 2-PC to all their sailors. The command would have to appropriately handle this cost in addition to all the other shipboard costs from their operational target funds. The USFF started research on 2-PC uniform in 2017. The initial cost for research and development of the 2-PC uniform appears in Table 2.

Table 2. The initial cost for research and development of the 2-PC uniform. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

Category	**Responsibility**	**FY17**	**FY18**	**TOTAL**
Labor	NCTRF	$100,000.00	$264,851.95	**$364,851.95**
Non-Labor	NCTRF	$160,305.00	$250,000.00	**$410,305.00**
Travel	NCTRF	$23,540.00	$32,459.00	**$55,999.00**
OVERALL PROGRAM TOTAL=		***$283,845.00***	***$547,310.95***	***$831,155.95***

According to our assumptions, 120,000 operational sailors will receive this 2-PC uniform, and the life of this uniform is nine months. There will be 180,000 uniforms required per year to satisfy this requirement. If three uniforms are issued to each sailor, there will be a total of 540,000 uniforms required per year. The total research and development (R&D) cost for 2017 and 2018 was $831,155.95.

Table 3. Cost table. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018.

Cost Table			
Year One: 2019	**COA #1**	**COA #2**	**COA #3 (Status Quo)**
R&D costs	$831,155.95.00	$831,155.95.00	$831,155.95.00
Recurring costs	$120,960,000.00	$161,280,000.00	$54,000,000.00
Total cost for 2019	$121,791,156.00	$162,111,156.00	$54,831,156.00
Year Two: 2020	**COA #1**	**COA #2**	**COA #3**
R&D costs	$0	$0	$0
Recurring costs	$120,960,000.00	$161,280,000.00	$54,000,000.00
Year Three: 2021	**COA #1**	**COA #2**	**COA #3**
R&D costs	$0	$0	$0
Recurring costs	$120,960,000.00	$161,280,000.00	$54,000,000.00
Total Costs	**$363,880,000.00**	**$484,671,156.00**	**$162,831,156.00**

To conduct our CBA, we need to find the NPV for our cost and benefits.

Net Present Value of the COA 1			
Discount Rate	**7.00%**		
Year	**1**	**2**	**3**
Discount Factor	0.93	0.87	0.82
Undiscounted Cash Flow	121,791,156	120,960,000	120,960,000
Present Value	113,823,510	105,651,149	98,739,391
Net Present Value	**318,214,050**		
Discounted Value	7,967,646	15,308,851	22,220,609

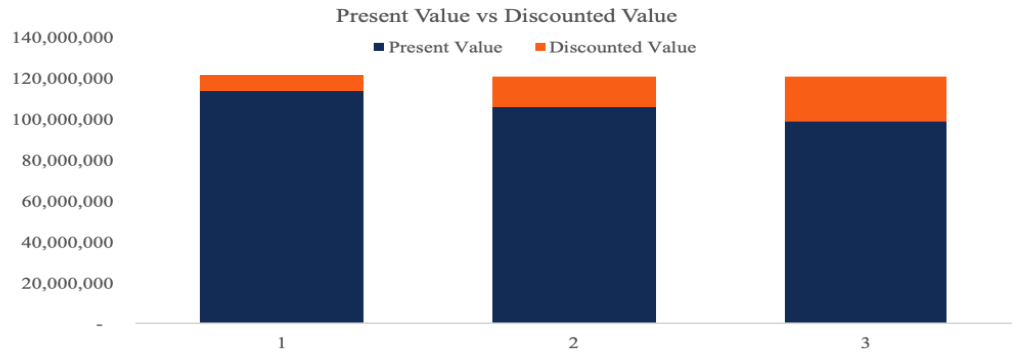

Figure 19. Net present value of COA 1. Adapted from U.S. Fleet Forces Command (2017).

There will be a cost of $121,791,156.00 cost in 2019, $120,960,000.00 in 2020, and $120,960,000.00 in 2021. The total cost of COA 1 will be $363,880,000.00. After applying the 7% discount rate, the total NPV for COA 1 will be $318,214,050.00. The Figure 19 shows the total NPV for COA 2.

Net Present Value of the COA 2			
Discount Rate	**7.00%**		
Year	**1**	**2**	**3**
Discount Factor	0.93	0.87	0.82
Undiscounted Cash Flow	162,111,156	161,280,000	161,280,000
Present Value	151,505,753	140,868,198	131,652,522
Net Present Value	**424,026,473**		
Discounted Value	10,605,403	20,411,802	29,627,478

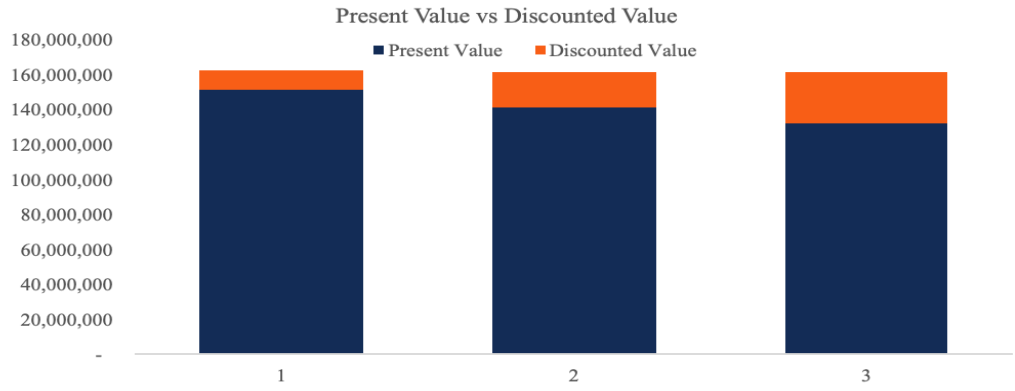

Figure 20. Net present value of COA 2. Adapted from U.S. Fleet Forces Command (2017).

There will be total of 720,000 2-PC uniforms required for COA 2, because the 2-PC will be the only prescribed uniform. In this COA, the IFRV coveralls will be discontinued. The total cost, including the R&D cost, will be $162,111,156.00. In 2020 and 2021, the cost of 2-PC uniform will be $161,280,000.00 each year. The total cost for COA 2 will be $484,671,156.00. The total NPV of COA 2 after the 7% discount rate will be $424,026,473.00. The figure 20 shows the total NPV for COA 2.

Net Present Value of the COA 3			
Discount Rate	**7.00%**		
Year	**1**	**2**	**3**
Discount Factor	0.93	0.87	0.82
Undiscounted Cash Flow	54,831,156	54,000,000	54,000,000
Present Value	51,244,071	47,165,691	44,080,085
Net Present Value	**142,489,848**		
Discounted Value	3,587,085	6,834,309	9,919,915

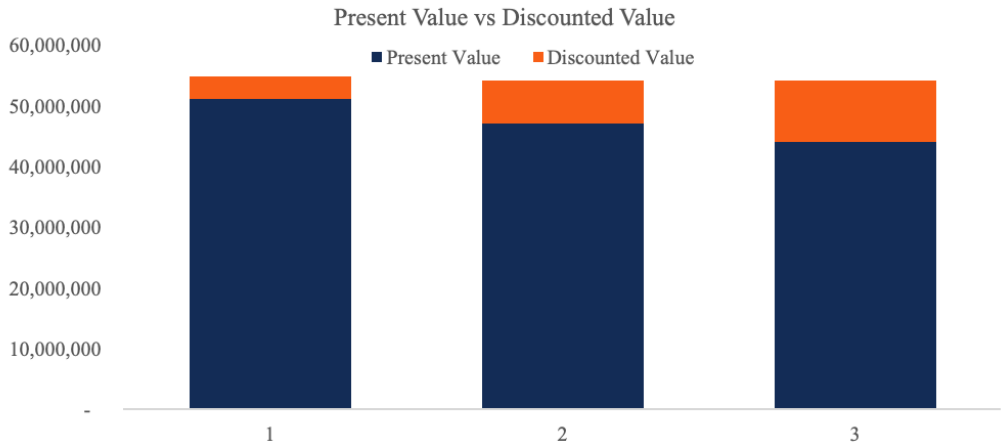

Figure 21. Net present value of COA 3. Adapted from U.S. Fleet Forces Command (2017).

There is no 2-PC uniform requirement for COA 3 because IFRV coveralls will be the only prescribed uniform in this scenario. The total cost for IFRV coveralls in 2019, including the R&D cost will be $54,831,156.00. In 2020 and 2021, the cost of 2-PC uniform will be $54,000,000.00 each year. The total cost for COA 3 will be $162,831,156.00 for three years. The figure 21 shows that the NPV for COA 3 is $142,489,848.00 for three years after the 7% discount rate.

C. COURSES OF ACTION (COA) COMPARISON ANALYSIS

In order to conduct a comparison of the costs and benefits for each COA, the research team created a table to describe benefits and costs as compared against the status quo.

Table 4. COA comparison. Adapted from U.S. Fleet Forces Command, personal communication, July 19, 2018

COA Comparison			
	COA #1	**COA #2**	**COA #3 (Status Quo)**
Total Benefits	$387,360.000.00	$387,360,000.00	$387,360,000.00
PV of Total Benefits (wit 7 % discount rate)	$338,851,688.00	$338,851,688.00	$338,851,688.00
Total Cost	$363,880,000.00	$484,671,156.00	$162,831,156.00
PV of Total Cost (with 7% discount rate)	$318,214,050.00	$424,026,473.00	$142,489,848.00
Net Benefits	**$20,637,638.00**	**$85,174,785.00**	**$196,361,840.00**

Although COA 3 (Status Quo) has the lowest cost, it does not provide the 2-PC uniform to sailors which is required to do their daily job. In comparison to the FRV coverall, the 2-PC has no limitations and delivers advantages of being deckplate-driven, improves the quality of life and work, satisfies all communities, and offers better fit and comfort. During the uniform survey, fleet forces found that there is a large demand for the 2-PC. Course of action 2 has net benefits of -$85,174,785.00 which would not be consider an acceptable choice by the Navy. Looking at all the COAs, COA 1 would be the best choice because it will provide net benefits of $20,637,638.00 while additionally providing many non-monetized benefits to our sailors.

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V. DISCUSSION

A. IDENTIFY IMPEDIMENTS

There are few of impediments to a 2-PC uniform. Analyzed in this paper are two weaknesses, as follows.

1. Management Complexity

The sizing specifics of the 2-PC will make its management as organizational clothing more difficult on afloat platforms. The supply officers on all afloat platforms are currently responsible for the management of the IFRV and would add the 2-PC into their inventory. Space and time are valuable commodities in this environment and adding this new uniform will take up a sizable portion of those resources. The supply department will have to reorganize its limited storage space to accommodate both uniforms and manage the ordering, procurement, and issuing of a new uniform consisting of two pieces that fit differently than the IFRV.

Fleet Forces N41 is currently working with OPNAV N41 to add the 2-PC to the seabag for sailors to procure and manage vice the afloat commands. This strategy has two benefits. First, it would alleviate the command's responsibility of managing another organizational uniform. Second, it would allow commands to cease in allocating their OPTAR funds on this uniform and instead use them for high-priority procurements for operational needs.

2. A New Paradigm for Organizational Clothing

The ability to wear the 2-PC both on and off the ship is a key feature that represents a departure from how the Navy traditionally views organizational clothing. Most Navy organizational clothing has been designated as dirty-work attire that lacks the professional, clean, and prideful appearance Navy uniforms exhibit. The 2-PC was designed based on current and historical naval uniforms. The purpose of this design strategy grants the 2-PC not only a professional appearance but, more importantly, the look of the uniform that

sailors wear and the public is familiar with. The sailors would be more comfortable and have more pride in wearing the 2-PC on base and out in town.

B. IDENTIFY NON-MONETIZED BENEFITS

There are many non-monetized benefits to the 2-PC flame-resistant uniform. Four non-monetized benefits are discussed in the following sections.

1. Deckplate-Driven

The 2-PC is the first uniform in naval history that was developed in response to an active request from fleet sailors and incorporated sailor feedback into the design. The Fleet Forces Flame-Resistant Clothing Program Team held multiple in-person focus groups with hundreds of fleet sailors from concentration areas in Norfolk, VA and San Diego, CA. The focus groups showcased the prototype uniform drawings and examined all the potential design features the uniform could possess. An overwhelming number of focus group participants supported the 2-PC uniform and discussed useful and functional design features that would complement all sailors in every job. The focus group participants felt like they had more ownership and pride in assisting with the design of this uniform (USFF, 2016). The participants took other sailors' rates, job specifics, and requirements into consideration. The discussions were very productive and confident, which aided in producing a safe, functional, professional-looking, flame-resistant at-sea uniform that sailors would be proud to wear on and off their ship or submarine.

2. Improves Quality of Life and Work

The 2-PC uniform is a safe, functional, and professional uniform that is designed to significantly reduce or eliminate unnecessary uniform changes as well as enhance climate modularity with flame-resistant layering. sailors are currently experiencing multiple clothing changes in the course of a typical workday with IFRV coveralls. All sailors have to wear either a non-flame-resistant uniform or civilian attire to and from the ship. Some sailors have to make subsequent uniform changes if they have an appointment on base or out in town. Aviation personnel working on the flight deck or in the hangar bay are not authorized to wear IFRV coveralls and must change into designated flight deck

clothing. The 2-PC makes these multiple uniform changes unnecessary as it can be worn off the ship, in all spaces on the ship, and while performing any job or task.

The key element that allows this to happen is the ability to de-blouse from the flame-resistant shirt to the flame-resistant, moisture-wicking, long-sleeve undershirt. The de-blousing option enables the sailors to work in all spaces of a ship. One example targets the aviation sailors that work on the flight deck and in the hangar bay. IFRV coveralls are not authorized for wear while operating in these two spaces. Currently, these sailors wear another type of organizational clothing called flight deck clothing, which consists of flight deck trousers and a long sleeve jersey. The 2-PC uniform, when de-bloused, is almost identical to the current flight deck uniforms and provides the same functionality while adding safety protection from flame and arc flash. De-blousing also enhances climate modularity by allowing all sailors to remove the outer long-sleeve shirt to be more comfortable while operating in hotter climates or hot spaces onboard the ship such as engineering spaces.

3. Satisfies all Communities

As previously mentioned, the limitations of the IFRV coveralls include the restrictions sailors have with not being allowed to wear them in every space and during certain events. The 2-PC uniform was designed to accommodate any sailor in perform any assigned task in any space onboard a ship or submarine. This uniform took into consideration all the job specifics from the aviation, surface, and submarine communities and implemented certain design features to prevent work-specific limitations and incorporate uniform requirements. The flame-resistant undershirt is what allows aviation and engineering personnel to work in their particular spaces and not introduce any foreign debris object concerns.

The in-person focus groups focused on these aspects of the uniform with all the personnel present representing their communities. The outcome of the focus groups is a functional uniform that took in all the communities' limitations and factors into the design and developed a single uniform which meets all the potential constraints and functionalities.

4. Better Fit and Comfort

"The NCTRF received information from Navy Personnel Research, Studies and Technology on the demographics of all sailors and were able to take a statistically valid sample of sailors based on race, gender, and age to ensure that the body measurements of all demographics are represented in today's Navy" (Sturkie, 2014). The 2-PC uniform is the first Navy uniform to incorporate this updated sizing data to improve the fit, appearance, and comfort of sailors' clothing. The 2-PC will better accommodate and fit today's sailor. The 2-PC uniform is also gender-specific and incorporates princess-cut seams to accurately and comfortably fit the female figure.

VI. CONCLUSION

The purpose of this project was to examine the potential benefits to the Navy using a 2-PC uniform as organizational clothing. We performed a CBA to evaluate the status quo IFRV Coveralls against the 2-PC uniform. The research team set out to answer the research question and asked if there are benefits to the 2-PC uniform. We determined that there are many possible monetized and non-monetized benefits to the 2-PC uniform. Added benefits for the 2-PC uniform include saving lives, preventing major injuries, being deckplate-driven, improving quality of life and work, satisfying all communities, and providing better fit and comfort. After analyzing three different possible COAs, the research team determined that COA 1, both IFRV coveralls and a 2-PC uniform as the prescribed at-sea uniforms, is the best option for the Navy because it will bring total net benefits of $20,637,638.00 while providing many non-monetized benefits to our sailors.

Course of action 2 is not a good option for the Navy, because there will be total of 720,000 2-PC uniforms required as the only prescribed uniform. In this COA, the IFRV coveralls will be discontinued. There will be $162,111,156.00 total cost including the research and development cost. In 2020 and 2021 the cost of 2-PC uniform will be 161,280,000.00 The total cost for COA 2 will be $484,671,156.00. The total NPV of COA 2 with 7% discount rate will be $424,026,473.00.

There is no 2-PC uniform requirement for COA 3 because according to status quo only IFRV covers will be the only prescribed uniform. The total cost for IFRV coveralls in 2019 will be $54,831,156.00 including research and development costs. In 2020 and 2021 the cost of 2-PC uniforms will be 54,000,000.00 each year. The total cost for COA 3 will be $162,831,156.00 for three years. Our team is recommending Navy to go with COA 1 because this is the best value added COA. It will bring total $20,637,638.00 net benefits to the Navy adding numerous other non-monetized benefits to our sailors**.**

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