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Life Cycle Logistics Group

A Commercial IOTV Cleaning Study

By Kailim Willie Yung, Jason Sellazzo, and Norm Fanning

NOTICES

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A commercial cleaning trial was conducted to evaluate the viability of Traditional Wet Laundering, Computer-controlled Wet Cleaning, Liquid CO_2 Cleaning and Solvair® Cleaning in cleaning soiled Improved Outer Tactical Vests (IOTV). Computer-controlled Wet Cleaning coupled with the use of LANADOL® AVANT and AKTIV detergents was found to be most effective while preserving the key functionalities of the vest.

This report outlines the methodology, results and conclusions of the study. It also provides the Business Case Analyses (BCA) on the economics of these four commercial cleaning technologies and on the financial benefits of Computer-controlled Wet Cleaning versus the current practice of "Discard and Replace".

As a result of the study, a Maintenance Action Message (MAM) was published on October 26, 2009 authorizing the use of Computer-controlled Wet Cleaning as an interim solution to clean soiled IOTVs.

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VESTS ECONOMICS LAUNDRY OPERATIONS CLEANING DETERGENTS COMMERCIAL CLEANING EQUIPMENT PROTECTIVE EQUIPMENT BODY ARMOR BUSINESS CASE ANALYSES LAUNDER IOTV (IMPROVED OUTER TACTICAL VEST) COMPUTER-CONTROLLED					
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PREFACE

This report outlines the IOTV commercial cleaning trial we conducted. The report is divided into two parts: 1) the main portion of the report which describes the methodology, the results and conclusions of the trial, and 2) the appendix section which provides the Business Case Analysis (Part 1 & Part 2) and the procedures and reference information regarding Computer-controlled Wet Cleaning, the recommended interim IOTV commercial cleaning solution.

SUMMARY

Due to ongoing contract difficulties, there has been a severe shortage of IOTVs to supply to the Soldiers. In the meantime, large quantities of soiled IOTVs are being returned from the field. Existing technical publications caution machine washing the IOTV garments for fear that improper cleaning and drying methods and conditions could damage the garments, making them unfit for use. Therefore, there is a critical need to develop and standardize a commercial cleaning method to clean the soiled IOTV garments as a depot level maintenance procedure to help relieve the shortage situation.

This study was initiated to address these needs. As a first step, we conducted a market study assessing various commercial cleaning methods. From the market study, we narrowed the choice of our investigation to four technologies: Traditional Wet Laundering, Computer-controlled Wet Cleaning, Liquid CO_2 Cleaning, and Solvair® Cleaning.

The commercial cleaning trial was conducted at a professional cleaner, Chesley the Cleaner, in Nashville, TN. We chose to work with this cleaner because they have the ability to conduct all four of these cleaning technologies in-house as well as the appropriate experience and expertise. Ninety soiled IOTV samples were collected from the CIF at Fort Campbell for the commercial cleaning trial. They were divided into 9 groups consisting of 10 samples each, and all were classified into 3 soiling levels: lightly soiled, medium soiled and heavily soiled. The samples were washed three times under eight treatment conditions using the four technologies with and without prewash spot cleaning. In all cases, the soft ballistic inserts were removed from the vest prior to washing. New Cordura® fabric, elastic and MOLLE strapping materials were included as standard control samples. The cleaned garments were returned to the Textile Test Lab in Natick for testing. The Yoke and Collar samples were sent to HP White Laboratory for ballistic testing.

Among the four technologies evaluated, Computer-controlled Wet Cleaning offers the best performance in terms of cleaning and preserving the key functional characteristics of the garment. The Cordura® fabric showed minimal shrinkage and no deterioration in tensile and abrasion resistance characteristics. Color fading and decline in camouflage properties are not directly attributable to washing and are mostly caused by everyday use of the garment. Yoke and Collar ballistic test results (V50 17 grain fragment test) also showed no deterioration in performance.

Further market studies revealed that Computer-controlled Wet Cleaning is well established in the marketplace. There are over 250 professional commercial cleaners in the U.S. which offer Computer-controlled Wet Cleaning. Economics data of our commercial trial also showed that the associated capital investment and operating costs are moderate.

A Maintenance Action Message (MAM) was published on 26 October 2009 disseminating Computer-controlled Wet Cleaning as the cleaning procedure for the soiled IOTVs at the depot maintenance level.

1. Background and Scope

Due to ongoing contract difficulties in sourcing the Improved Outer Tactical Vest (IOTV), there is a severe shortage of supply to meet the deployment needs. In the meantime, large quantities of soiled IOTVs have been returned to the Central Issue Facilities (CIF) by the Soldiers as they complete their tour. Many of these IOTVs are heavily soiled and are not suitable for reissue without proper cleaning. The existing equipment technical manual and maintenance and care instructions specify not to machine wash the IOTV. This was because of the concerns that a wide variety of cleaning methods, conditions and detergents are employed in the laundering industry, and improper cleaning can damage the vests, making them unfit for use. As a result, there is a critical need for the ARMY to develop a viable commercial cleaning method for the soiled IOTVs to help relieve the shortage situation. This study was initiated to address this critical need.

Because of the urgency of producing an interim commercial cleaning solution, we focused our initial effort on evaluating various commercial cleaning methods. As a first step, we conducted a market study identifying and assessing various commercial laundering methods. From this list, we eliminated several technologies because of the pollution and health risks they present, and narrowed our choice to four potential cleaning technologies: Traditional Wet Laundering, Computer-controlled Wet Cleaning, Liquid CO_2 Cleaning, and Solvair® Cleaning.

This report discusses the commercial cleaning trial of these four technologies and their results. In the second phase of this project (not covered in the current report), we will look into improving the field cleaning method for IOTV.

2. Methodology

2.1 Market Research

An initial market study of various commercial laundering methods employed by the laundry industry was conducted via the internet. Through this study, we identified the following technologies: Traditional Wet Laundering, Computer-controlled Wet Cleaning, PERC Dry Cleaning, Liquid CO_2 Cleaning, Solvair® Cleaning, Hydrocarbon Cleaning and Silicone Liquid Cleaning. **Tables 1 and 2** summarize the findings about each technology and our initial assessment of their viability.

From this list, we eliminated PERC Dry Cleaning, Hydrocarbon Cleaning and Silicone Liquid Cleaning because of the pollution and health risks they present, efficacy issues, etc.

Table 1

An Overview of Laundry Methods

	Traditional Wet Laundering	Computerized Wet Cleaning	PERC Perchloro Ethylene	Liquid CO2	"Solvair" Improved Liquid CO2	Hydro-carbon	Green Earth
Cleaning Agent	Water	Water	Organic Solvent	Liquid CO2	Liquid CO2 + Glycol Ether (DPnB)	Petroleum Based Solvents	Silicone Liquid
Machines	Traditional Washer & Dryer	Modern Computerized Washer & Dryer	Traditional Dry Cleaning Equipment	Modern High Pressure Cleaner	Solvair	Modified Dry Cleaning Machine	Modified Dry Cleaning Machine
Availability	Wide Spread	250+ Shops	35,000 + Shops	35 Shops	Latest Technology 10 Shops in US	Unknown	600-700 Shops
Heat	Cold, Warm & Hot Wash Cycles	Precise Temperature Control, Residual Moisture Content Sensor	120F +	None	None	120F +	120F +
Residual Chemical Odor	None	None	Strong	None	None	Slight	None , Prone To Mildew & Micro-organism Growth

Table 2

An Overview of Laundry Methods

	Traditional Wet Laundering	Computerized Wet Cleaning	PERC Perchloro Ethylene	Liquid CO2	"Solvair" Improved Liquid CO2	Hydro-carbon	Green Earth
Pollution	No	No	Hazardous Chemical, VOC	No	Glycol Ether Bio-degradable	Ground Water Contamination	No
Worker Risk	No	No	Suspected Carcinogen, High Risk	No	Low	Flammable, Explosive	Low Risk
Cleaning Actions & Effects	Vigorous Mechanical Action, Effective for Water-based Stains, Susceptible to Shrinkage	Gentle Cycle, Suitable for Delicate Materials, Effective Detergency for Water-based and Oily Stains	Excellent for Oily Stains	Low Shrinkage, Excellent for Oily Stains, Less Effective for Water-based Stains	High Solvating Power, Low Shrinkage, Effective for Oily Stains		
Cost	Medium Investment ($35-40K), Low Operating Cost	Low Investment ($20-25K), Medium Operating Cost	Medium ($0.5-$0.7 per lb)	High Investment ($125K+), Medium Operating Cost	High Investment ($150K+) & Operating Cost		

2.2 Contracted Cleaner

Through our market research, we identified a commercial cleaner in Nashville, TN, Chesley the Cleaner, which possesses the four relevant technologies (Traditional Wet Laundering, Computer-controlled Wet Cleaning, Liquid CO_2 Cleaning and Solvair® Cleaning) in house. We also learned that Chesley the Cleaner was not only an experienced commercial cleaner but also an expert consultant to the laundry industry. As Chesley uniquely met our needs, we contracted Chesley to collaborate with us in conducting the IOTV cleaning trial at their facility.

2.3 Sampling

We solicited the cooperation of Ft. Campbell to allow us to sample the soiled IOTVs there, because of its close proximity to Nashville – where Chesley the Cleaner is located – and the availability of soiled IOTVs at their Central Issue Facility (CIF).

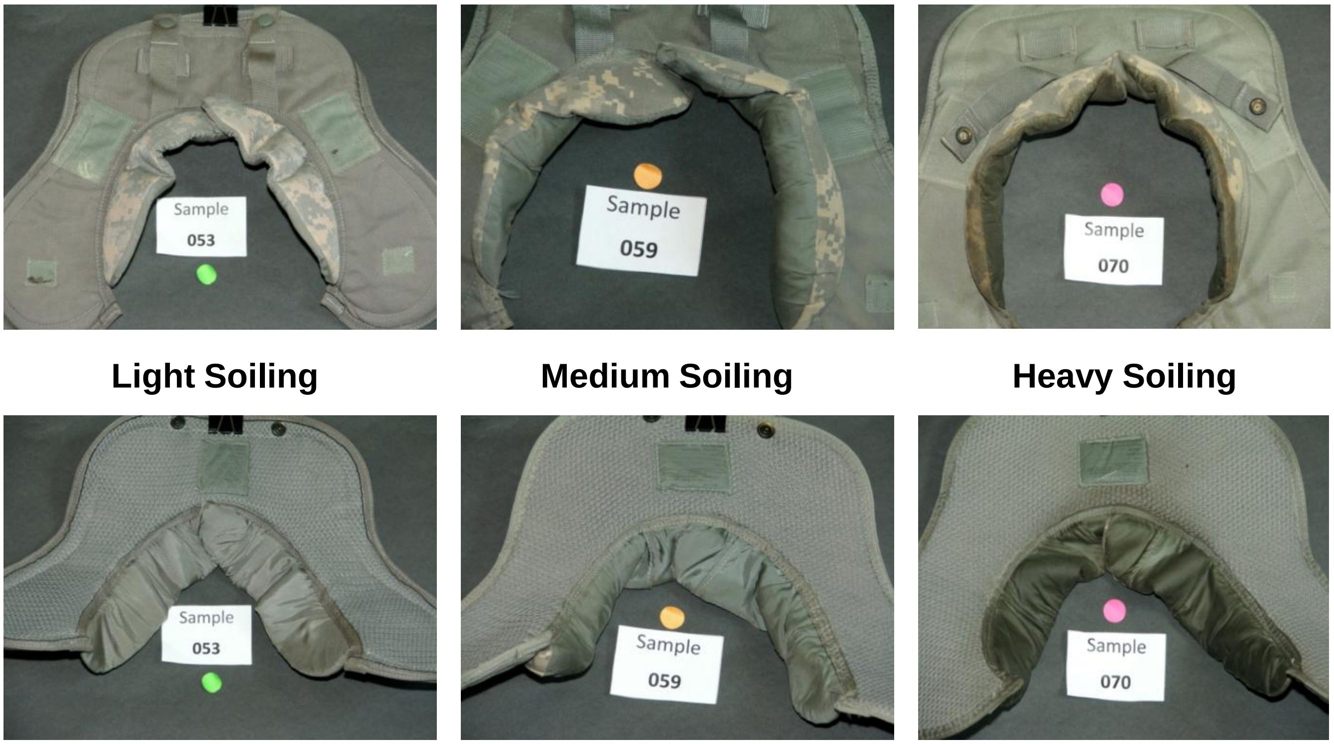
We first examined 250 IOTV samples and, based on their soiling level, classified them into three groups: lightly soiled, medium soiled and heavily soiled. We found that approximately 60% of the samples belonged to the lightly soiled category, 30% to the medium soiled category and 10% to the heavily soiled category.

Out of these 250 IOTVs, we selected 90 samples divided into 9 groups of 10 IOTVs each, with each group consisting of 6 lightly soiled samples, 3 medium soiled samples and 1 heavily soiled sample, thus representing the soiling distribution of the larger population.

Photographs in **Table 3** exemplify the three soiling levels. The two photographs on the far left represent the lightly soiled level, the middle two represent the medium soiled level, and the two on the far right represent the heavily soiled level.

Table 3

Soiling Level Classifications



In conjunction with the IOTV samples, new fabric and component materials were also included in the trial to serve as baseline control samples in order to distinguish the effects of normal wear and tear (as experienced by the IOTV samples during use) from those of laundering.

Before washing, each IOTV was disassembled into individual components. The release cable and ballistic inserts were removed from the front and back carriers and the lower back protector and set aside. **Table 4** shows the component items which were subject to washing.

Table 4

Item #	Picture		Item Name	Washable
	Front View	Back View		
1			IOTV Front Carrier	Yes
2			IOTV Back Carrier	Yes
3			Right External Side Plate Carrier	Yes
4			Left External Side Plate Carrier	Yes
5			Right Internal Waistband	Yes

Item #	Picture		Item Name	Washable
	Front View	Back View		
6			Left Internal Waistband	Yes
7			Back Yoke/Collar Assembly	Yes
8			Front Yoke/Collar Assembly	Yes
9			Groin Protector Carrier	Yes

Item #	Picture		Item Name	Washable
	Front View	**Back View**		
10			Lower Back Protector Carrier	Yes
11			Front Ballistic Insert	No
12			Back Ballistic Insert	No
13			Lower Back Protector Ballistic Insert	No

Item #	Picture		Item Name	Washable
	Front View	Back View		
14			Groin Protector Ballistic Insert	No
15			Cable Release Assembly	No
LEGEND: Black Circle –	Indicates recommended location to pin tracking ID tag or label. Pin to MOLLE straps at mark.			

The components of each garment (disassembled from the vest) were identified with an ID number and were kept in a separate perforate laundering bag to avoid possible mix-ups and maintain product traceability.

Straight lines of predetermined lengths were marked with indelible ink on the vest materials, the new fabric and component samples; lengths were measured after each wash cycle. Photographs of the components were taken prior to cleaning and after each wash cycle.

The cleaned IOTV garment samples were returned to Natick for physical testing and the Yoke and Collar samples were sent to HP White Laboratory in coordination with Dr. James Zheng and Mr. John Glisson for ballistic testing.

2.4 Design of Experiment & Sampling Matrix

The commercial cleaning trial conducted is statistically a 4 x 2 randomized block experimental design consisting of two variables: 1) the four cleaning technologies, and 2) with and without spot cleaning. There are a total of 8 treatments with 10 IOTV samples per treatment. Each IOTV sample was cleaned three times using one of the four treatment methods. An additional set of 10 soiled IOTVs were included without cleaning as the baseline control samples for comparison purposes.

In addition to the vest samples, new fabric and component samples were also cleaned in order to isolate the effects of wear and tear from cleaning.

Table 5 shows a more detailed breakdown of the samples and the treatment descriptions.

Table 5

Treatment	Laundering Method (3 Cycles)	Use of Prewash Spot Cleaner	No. of IOTV (3 Soil Levels)*	No. of Fabric & Component Samples
1	Traditional wet laundering with cold water & low temp machine drying	Yes	10	3-6 (1-2/cycle)
2	Traditional wet laundering with cold water & low temp machine drying	No	10	3-6 (1-2/cycle)
3	Computer-controlled wet laundering & low temp machine drying	Yes	10	3-6 (1-2/cycle)
4	Computer-controlled wet laundering & low temp machine drying	No	10	3-6 (1-2/cycle)
5	Liquid CO_2 laundering & room air drying	Yes	10	3-6 (1-2/cycle)
6	Liquid CO_2 laundering & room air drying	No	10	3-6 (1-2/cycle
7	Solvair® laundering & room air drying	Yes	10	3-6 (1-2/cycle)
8	Solvair® laundering & room air drying	No	10	3-6 (1-2/cycle)

9	Unwashed soiled samples (baseline control)	NA	10	NA
10	New fabric and component materials	NA		3
Total Samples			**90**	

* 6 lightly soiled, 3 medium soiled and 1 heavily soiled samples

2.5 Equipment and Process Descriptions

2.5.1 Traditional Wet Laundering

Equipment Manufacturer:

Washer:

UniMac Company, Inc.
Shepard Street
PO Box 990
Ripon, WI 54971-0990
Web Site: http://www.unimac.com
Tel: (800) 587-5458

Dryer:

Wascomat Company, Inc.
461 Doughty Blvd.
Inwood, New York 11096
Tel: (516) 371-4400
Fax: (516) 371-4204
Web Site: http://www.wascomat.com

Equipment Model & Description:

Washer:

UW65PV
UNIWASH Machine
65 Pounds (Dry Garment Weight) Capacity
Variable Speed
WE-6 Micro-computer Control Module

Dryer:

TD75 RMC
Commercial Dryer with Residual Moisture Control
75 Pounds Capacity

Laundering & Drying Conditions:

<u>Laundering</u>

Water Level:	Medium (174 liters)
Volume of Cylinder:	300 liters
Wash Speed:	40 RPM
Rinse Speed:	70 RPM
Extract Spin Cycle Speed:	523 RPM
Water Temperature during Wash Cycle:	135 degrees F
Water Temperature during Rinse Cycle:	100 degrees F
Wash Load:	10 IOTV Samples*

*(Each in a separate laundering bag)

<u>Drying</u>

Residual Moisture Level:	5% (in the dried garment)
Acceptable Moisture Range:	5-7%
Air Temperature:	180 degrees F
Garment Temperature:	110 degrees F (maximum)
Approximate Cycle Time:	20 minutes

Chemicals Used:

Table 6 Traditional Wet Laundering Detergents

Supplier	**Product Trade Name**	**Function**	**Application Stage**	**Amount**
Phoenix Supply – Paragon	RELEASE	Detergent	▪ Prewash ▪ Main (Alkaline) Wash ▪ Acid Wash	1.5 oz
	TREND	Laundry Brightener (Hydrogen Peroxide)	• Main (Alkaline) Wash	3 oz

	SUBDUE	Sour Wash	• Acid Wash	6 oz
	BUILDER PLUS	Alkaline Wash	• Alkaline Laundry Builder	6 oz

Chemical Supplier Contact Info:

Phoenix Supply
Paragon Products
5330 Dividend Drive
Decatur, GA 30035
Tel: 770-981-2800

2.5.2 Computer-controlled Wet Cleaning

Manufacturer of Equipment:

Washer:

Wascomat Laundry Equipment
461 Doughty Blvd.
Inwood, New York 11096
Tel: (516) 371-4400
Fax: (516) 371-4204
Web Site: http://www.wascomat.com

Dryer:

Wascomat Laundry Equipment
461 Doughty Blvd.
Inwood, New York 11096
Tel: (516) 371-4400
Fax: (516) 371-4204
Web Site: http://www.wascomat.com

Equipment Model & Description:

Washer:

EXSM-230C
High Extract Solid-Mount Washer
65 Pounds (Dry Garment Weight) Capacity
300 G-Force
Clarus® Wash Cycle Control

Dryer:	TD75 RMC Commercial Dryer with Residual Moisture Control 75 Pounds Capacity

Cleaning and Drying Conditions:

Cleaning

Water Level During the Prewash & Wash Cycles:	110 liters
Water Level During the Rinse Cycle:	141 liters
Volume of Cylinder:	280 liters
Wash Motor Speed:	30 RPM
Drain Motor Speed:	41 RPM
Rinse Speed:	30 RPM
Extract Spin Cycle Speed:	400 – 690 RPM
Water Temperature during Wash Cycle:	104 degrees F
Water Temperature during Rinse Cycle:	104 degrees F
Wash Load:	5 IOTV Samples*

*(Each in a separate laundering bag)

Drying

Residual Moisture Level:	5% (in the dried garment)
Acceptable Moisture Range:	5-7%
Air Temperature:	180 degrees F
Garment Temperature:	110 degrees F (maximum)
Approximate Cycle Time:	20 minutes

Chemicals Used:

Table 7 Computer-controlled Wet Cleaning Detergents

Supplier	Product Trade Name	Function	Application Stage	Amount
Kreussler Company	Lanadol Avant	Pre-spotting Agent	▪ Prewash ▪ Main Wash	360 ml 120 ml
	Lanadol Aktiv	Detergent	• Main Wash	240 ml

Chemical Supplier Contact Info:

GERMANY
KREUSSLER & CO. GMBH.
RHEINGAUSTR: 87-93
65203 WIESBADEN
GERMANY
Tel: 0049 0 611 9271 0
Fax: 0049 0 611 9271 111

USA
KREUSSLER INC.
8426 Sunstate Street
USA/TAMPA FL 33634
Tel: 001 813 884 1499
Fax: 001 813 884 1599
Web Site: http://www.kreussler.de/

2.5.3 Liquid CO_2 Cleaning

Manufacturer of Equipment: **GeneSys Cleaning System**
Alliance Laundry Systems
Shepard Street
Ripon, Wisconsin, 54971-0990
Tel: 920-748-4375
Contact Person: Susan Miller

Equipment Model & Description:

GeneSys GD30D001
GeneSys CO_2 Drycleaning Machine
30 pounds Dry Weight Capacity

Process Steps and Cycle Time:

Table 8. Liquid CO_2 Process Steps and Cleaning Cycles

Step	Description	Cycle Time (Total Cycle Time: 20 min)
1	Purge air from the wash wheel	1 minute (repeat 2 to 3 times)
2	Transfer 75 psi CO_2 gas into the wash wheel	
3	Open valve from CO_2 storage tank to equalize the pressure between the storage tank and wash wheel at 250 – 300 psi	
4	Pump 30 gallons of liquid CO_2 into the wash wheel and increase pressure to 500 – 600 psi, 32 RPM	
5	Wash garments at 550 to 900 psi pressure; re-circulate liquid CO_2 through filter and rotating wheel	8 minutes
6	Drain liquid CO_2 from wash wheel to machine storage tank	
7	Recover CO_2 gas and decompress the wash wheel to the storage tank until 100 psi	
8	Recover CO_2 gas and decompress the wash wheel to the purge tank until 30 psi	
9	Vent CO_2 gas and open wash wheel door	

Wash Load: 5 IOTV Samples*
*(Each in a separate laundering bag)

Drying: No machine drying – Liquid CO_2 cleaned garments were dried indoor upon reaching atmospheric pressure

Chemicals Used:

Table 9. Liquid CO_2 Spot Cleaning Agent

Supplier	Product Trade Name	Function	Application Stage	Amount
Kreussler Company	Clip COO	Pre-spotting Agent	▪ Hand apply on soiled area of garment before wash	Variable

No detergent was added to the liquid CO_2 machine during wash.

Chemical Supplier Contact Info:

GERMANY
KREUSSLER & CO. GMBH.
RHEINGAUSTR: 87-93
65203 WIESBADEN
GERMANY
Tel: 0049 0 611 9271 0
Fax: 0049 0 611 9271 111

USA
KREUSSLER INC.
8426 Sunstate Street
USA/TAMPA FL 33634
Tel: 001 813 884 1499
Fax: 001 813 884 1599
Web Site: http://www.kreussler.de

SOURCE OF LIQUID CO_2
Volunteer Welding Supply
815 5th Ave S
Nashville, TN 37203 – 4609
(615) 256-5658

2.5.4 Solvair® Computer-controlled Wet Cleaning

Manufacturer of Equipment:	**Solvair® Cleaning System** 184 Shuman Blvd. Suite 420 Naperville, IL 60563 518 221 4745 Contact Person: Robert Joel
Equipment Model & Description:	Solvair® Cleaning System 30 pounds Dry Weight Capacity

Machine Operations:

Wash Load:	5 IOTV Samples* *(Each in a separate laundering bag)
Drying:	No machine drying – Solvair® cleaned garments were air dried indoor after each cleaning cycle See Appendix X.12

Chemicals Used:

Table 10. Solvair® Cleaning Chemicals

Supplier	Product Trade Name	Function	Application Stage	Amount
Dow Chemical	DOWANOL DPNB Glycol Ether	Cleaning Solvent	▪ 1st Cleaning Cycle	100% 30 gallons
Volunteer Welding Supply	Liquid CO_2		▪ 1st through 4th Rinse Cycles	30 gallons

Chemical Supplier Contact Info:

Dow Chemical
Dow Ashman Center
4520 Ashman Street
P.O. Box 1206
Midland, Michigan 48642
Tel: 800-447-4369
Web Site: http://www.dow.com

Volunteer Welding Supply
815 5th Ave S
Nashville, TN 37203 – 4609
(615) 256-5658

3. Results and Discussions :

3.1 Cleanliness

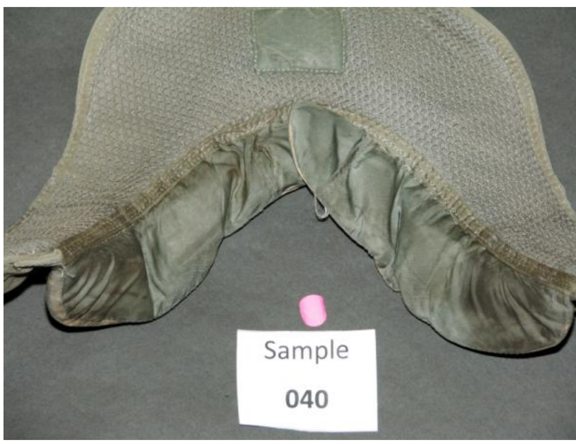
Based on the appearance of the IOTV samples before and after cleaning, Computer-controlled Wet Cleaning is most effective in cleaning the garments among the four technologies tested. It is followed by Traditional Wet Laundering, then Solvair®, then Liquid CO_2 cleaning. After the first wash using Computer-controlled Wet Cleaning, the vests appear substantially cleaner and smell much fresher.

The Yoke and Collar subassemblies are typically the dirtiest among all IOTV components. As an illustration of the cleaning effects of Computer-controlled Wet Cleaning, photographs below show the Yoke and Collar subassemblies before and after the first wash cycle.

Rear Y&C – Before Washing

Rear Y&C – After 1 Wash

Rear Y&C – Before Washing



Rear Y&C – After 1 Wash

Front Y&C – Before Washing

Front Y&C – After 1 Wash

Front Y&C – Before Washing

Front Y&C – After 1 Wash

3.2 Physical Testing

3.2.1 Shrinkage (Tables 11 – 18)

Shrinkage measurements were performed on the Cordura® material on the vests and on the new fabric samples (received from BAE, Point Blank and Glen Raven), as well as on the elastic band and MOLLE webbing samples after each wash cycle through each of the eight treatment conditions. Shrinkage (%) was calculated as follows:

% Shrinkage = (Length Measured after Each Wash Cycle – Original Length)/Original Length x 100%

Tables 11 through **18** compile the statistical results from the raw data for each cleaning method and condition.

Table 11. Shrinkage Statistical Data
Traditional Wet Laundering with Prewash Spot Cleaning

		After 1 cycle	After 2 cycles	After 3 cycles
Vest	Average Cordura® Shrinkage	0.1%	-1.0%	-0.7%
	Standard Deviation	2.2%	1.4%	1.9%
BAE Fabric	Average Shrinkage	-1.1%	-1.4%	
	Standard Deviation	0.4%	1.7%	
PB Fabric	Average Shrinkage	-0.5%	-1.6%	
	Standard Deviation	0.9%	0.9%	
Glen Raven FR Fabric	Average Shrinkage	-1.3%	-1.4%	-2.3%
	Standard Deviation	1.7%	0.7%	0.9%
Elastic Band	Average Shrinkage	-5.6%	-8.7%	
	Standard Deviation	1.2%	2.5%	
MOLLE Webbing	Average Shrinkage	-4.4%	-4.6%	-6.3%
	Standard Deviation	0.3%	0.4%	1.0%

Table 12. Shrinkage Statistical Data
Traditional Wet Laundering without Prewash Spot Cleaning

		After 1 cycle	After 2 cycles	After 3 cycles
Vest	Average Cordura® Shrinkage	-0.4%	-0.5%	-0.7%
	Standard Deviation	0.7%	1.3%	1.3%
BAE Fabric	Average Shrinkage	-1.1%	-2.1%	
	Standard Deviation	0.7%	0.7%	
PB Fabric	Average Shrinkage	-0.2%	-1.2%	
	Standard Deviation	1.1%	1.0%	
Glen raven FR Fabric	Average Shrinkage	-0.8%	-1.8%	-1.9%
	Standard Deviation	0.9%	0.9%	1.0%
Elastic Band	Average Shrinkage	-5.6%		
	Standard Deviation	0.0%		
MOLLE Webbing	Average Shrinkage	-4.2%	-4.9%	
	Standard Deviation	0.1%	0.9%	

Table 13. Shrinkage Statistical Data
Computer-controlled Wet Cleaning with Prewash Spot Cleaning

		After 1 cycle	After 2 cycles	After 3 cycles
Vest	Average Cordura® Shrinkage	1.6%	-0.3%	0.7%
	Standard Deviation	1.3%	2.0%	1.7%
BAE Fabric	Average Shrinkage	-1.9%	-2.2%	
	Standard Deviation	0.6%	1.7%	
PB Fabric	Average Shrinkage	-1.2%	2.3%	
	Standard Deviation	1.9%	4.2%	
Glen Raven FR Fabric	Average Shrinkage	-1.2%	-0.7%	-2.5%
	Standard Deviation	0.9%	1.5%	1.3%
Elastic Band	Average Shrinkage	-3.5%		
	Standard Deviation	0.7%		
MOLLE Webbing	Average Shrinkage	-3.9%	-4.7%	
	Standard Deviation	0.5%	1.0%	

Table 14. Shrinkage Statistical Data
Computer-controlled Wet Cleaning without Prewash Spot Cleaning

		After 1 cycle	After 2 cycles	After 3 cycles
Vest	Average Cordura® Shrinkage	0.2%	-0.8%	-0.6%
	Standard Deviation	0.7%	1.0%	1.3%
BAE Fabric	Average Shrinkage	-1.0%	-0.9%	
	Standard Deviation	0.8%	0.2%	
PB Fabric	Average Shrinkage	-0.1%	1.0%	
	Standard Deviation	0.2%	2.5%	
Glen Raven FR Fabric	Average Shrinkage	0.0%	-0.8%	-1.2%
	Standard Deviation	0.4%	0.8%	0.5%
Elastic Band	Average Shrinkage	-3.2%		
	Standard Deviation	0.4%		
MOLLE Webbing	Average Shrinkage	-3.7%	-4.2%	
	Standard Deviation	0.9%	0.9%	

Table 15. Shrinkage Statistical Data
Liquid CO_2 Cleaning with Prewash Spot Cleaning

		After 1 cycle	After 2 cycles	After 3 cycles
Vest	Average Cordura® Shrinkage	1.0%	0.5%	0.7%
	Standard Deviation	1.2%	1.2%	0.9%
BAE Fabric	Average Shrinkage	-0.2%	0.5%	
	Standard Deviation	0.3%	0.9%	
PB Fabric	Average Shrinkage	-0.3%	-0.4%	
	Standard Deviation	0.3%	0.5%	
Glen Raven FR Fabric	Average Shrinkage	-0.5%	-0.9%	-0.6%
	Standard Deviation	0.3%	0.1%	0.4%
Elastic Band	Average Shrinkage	-3.6%		
	Standard Deviation	0.5%		
MOLLE Webbing	Average Shrinkage	-2.0%	-1.0%	
	Standard Deviation	0.7%	3.0%	

Table 16. Shrinkage Statistical Data
Liquid CO_2 Cleaning without Prewash Spot Cleaning

		After 1 cycle	After 2 cycles	After 3 cycles
Vest	Average Cordura® Shrinkage	0.1%	-0.3%	0.7%
	Standard Deviation	0.9%	1.4%	1.7%
BAE Fabric	Average Shrinkage	-0.5%	-0.8%	
	Standard Deviation	0.4%	0.2%	
PB Fabric	Average Shrinkage	-0.2%	-0.3%	
	Standard Deviation	0.3%	0.3%	
Glen Raven FR Fabric	Average Shrinkage	-0.8%	-1.4%	-1.0%
	Standard Deviation	0.4%	0.4%	1.2%
Elastic Band	Average Shrinkage	-3.6%		
	Standard Deviation	0.5%		
MOLLE Webbing	Average Shrinkage	-2.1%	-2.7%	
	Standard Deviation	0.1%	0.2%	

Table 17. Shrinkage Statistical Data
Solvair® Cleaning with Prewash Spot Cleaning

		After 1 cycle	After 2 cycles	After 3 cycles
Vest	Average Cordura® Shrinkage	-1.1%	-1.1%	-0.7%
	Standard Deviation	0.7%	1.4%	1.4%
BAE Fabric	Average Shrinkage	-1.8%	-0.4%	
	Standard Deviation	2.7%	0.5%	
PB Fabric	Average Shrinkage	-0.4%	-0.5%	
	Standard Deviation	0.8%	0.3%	
Glen Raven FR Fabric	Average Shrinkage	-0.9%	-0.8%	-1.0%
	Standard Deviation	0.3%	0.2%	0.4%
Elastic Band	Average Shrinkage	-3.0%		
	Standard Deviation	0.8%		
MOLLE Webbing	Average Shrinkage	-2.7%	-2.8%	
	Standard Deviation	0.3%	0.0%	

Table 18. Shrinkage Statistical Data
Solvair® Cleaning without Prewash Spot Cleaning

		After 1 cycle	After 2 cycles	After 3 cycles
Vest	Average Cordura® Shrinkage	0.1%	0.1%	0.6%
	Standard Deviation	0.6%	1.1%	1.2%
BAE Fabric	Average Shrinkage	-0.8%	-0.7%	
	Standard Deviation	0.5%	0.5%	
PB Fabric	Average Shrinkage	-0.4%	-0.7%	
	Standard Deviation	0.6%	1.1%	
Glen Raven FR Fabric	Average Shrinkage	-0.6%	-1.4%	-1.7%
	Standard Deviation	0.4%	0.5%	0.3%
Elastic Band	Average Shrinkage	-3.0%		
	Standard Deviation	0.9%		
MOLLE Webbing	Average Shrinkage	-2.0%	-3.0%	
	Standard Deviation	0.8%	0.3%	

The implications of these data are as follows:

- The Cordura® face fabric material of the vest exhibits minimal shrinkage (<1%).
- The elastic waist band and MOLLE webbing materials are more susceptible to shrinkage (3-6% range) than the Cordura® fabric.
- Traditional Wet Laundering results in the highest shrinkage among the four cleaning technologies.
- Liquid CO_2 and Solvair® Cleaning cause the least amount of shrinkage because no heat is used in these processes.
- Computer-controlled Wet Cleaning, due to its more gentle cleaning action and residual moisture content drying control, results in lower shrinkage rate than Traditional Wet Laundering.

Aside from the specific nature and composition of the materials, the extent of shrinkage is also highly sensitive to the process conditions, e.g., temperature of the process, degree of drying, etc. Therefore, care must be exercised to control the process to alleviate excessive shrinkage. Excessive shrinkage will not only create difficulties in reassembling the IOTV components, but will also cause mis-fit between the ballistic inserts and/or the ballistic plates with the carriers.

3.2.2 Tensile Properties (Charts 1–4)

Strip tenacity of the Cordura® material cut out from the vests and from the new fabric materials, both after three cycles of cleaning, were tested in both the warp and filling directions on the Instron tensile tester per ASTM D5035 test method. Test results compiled in **Charts 1–4** show a 95% confidence range for each laundering method versus the control unwashed sample.

Among these four charts, the vertical axis is the breaking load in pounds and the horizontal axis represents the nine laundering conditions which we tested, which are:

Wet Laundering + Spot Cleaning	1
Wet Laundering	2
Computer Wet Cleaning + Spot Cleaning	3
Computer Wet Cleaning	4
Liquid CO_2 + Spot Cleaning)	5
Liquid CO_2	6

Solvair® + Spot Cleaning	7
Solvair® Cleaning	8
Control (Dirty/ Uncleaned IOTVS)	12

Chart 1. Vest Warp Direction Strip Tenacity (95% Confidence Range)

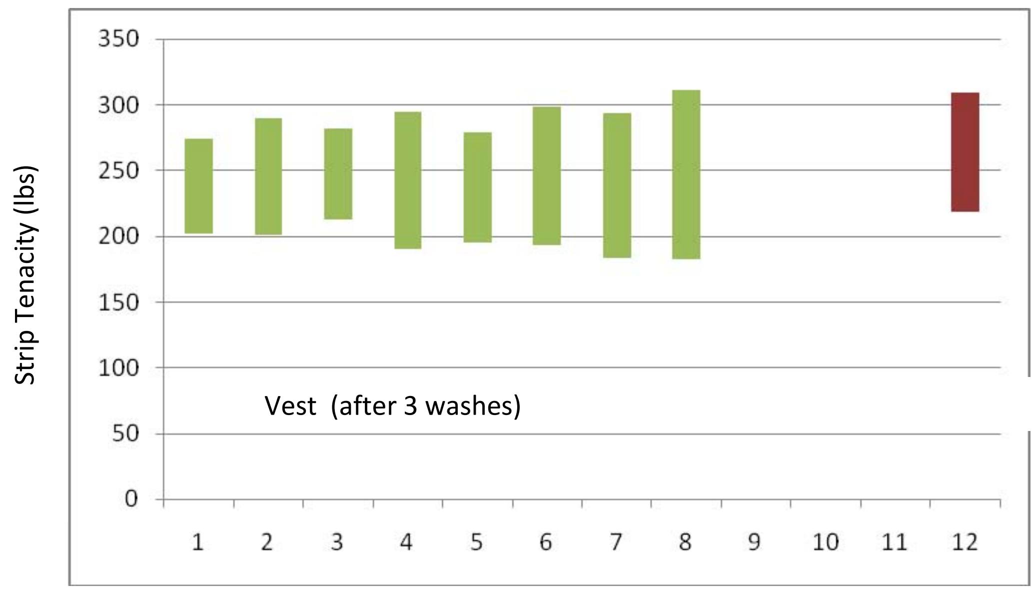


Chart 2. Vest Filling Direction Strip Tenacity (95% Confidence Range)

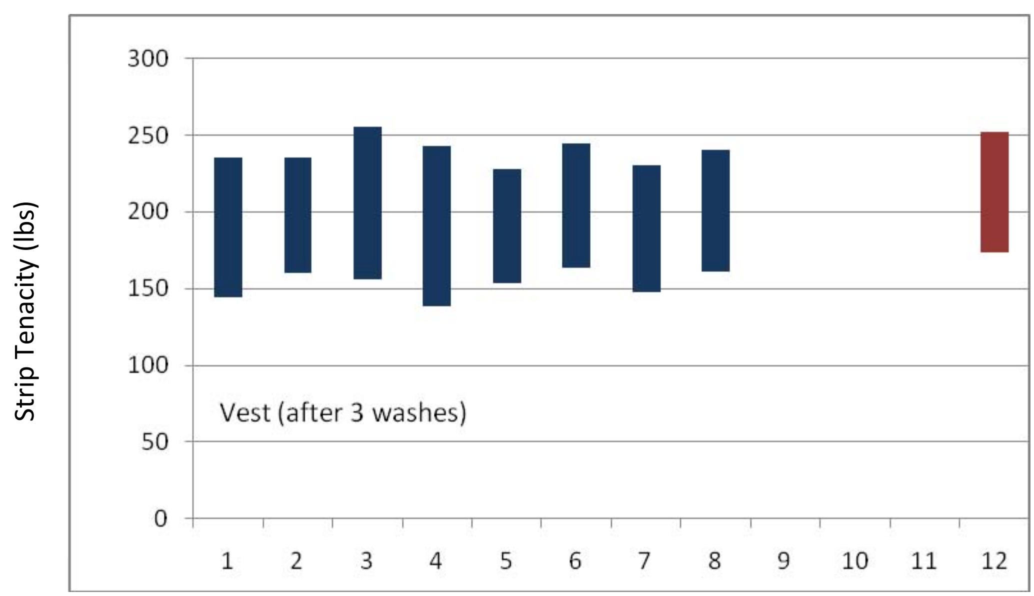


Chart 3. BAE Fabric Warp Direction Strip Tenacity (95% Confidence Range)

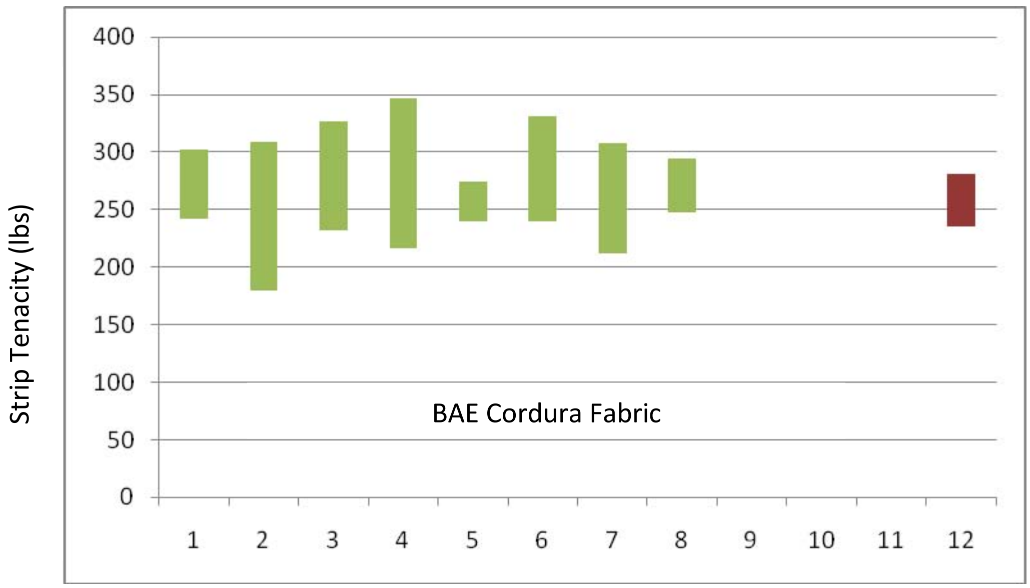
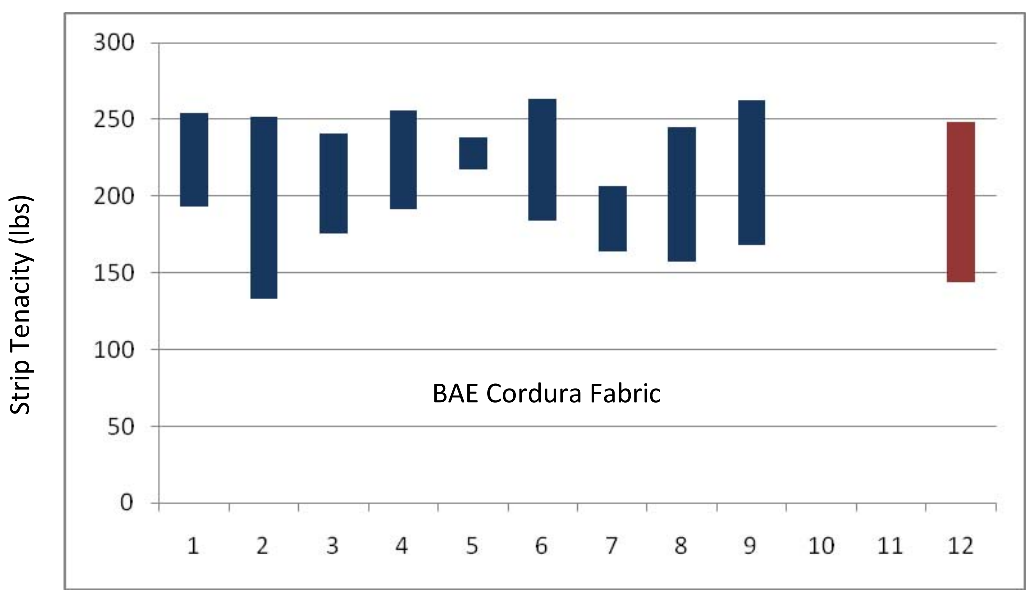


Chart 4. BAE Fabric Filling Direction Strip Tenacity (95% Confidence Range)



The implications of these tensile data are as follows:

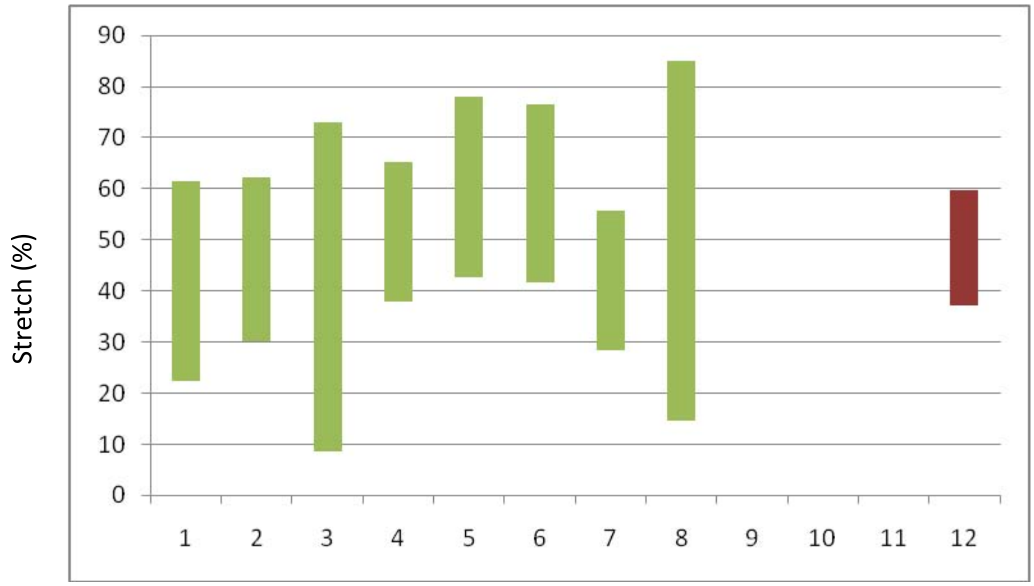
- The 95% confidence range of each laundering condition overlaps each other and with the control un-cleaned IOTV sample, implying little or no significant difference among the various conditions.
- As compared with the control un-cleaned vest sample, there appears to be no deterioration in strip tenacity as a result of laundering.

3.2.3 Waist Band Stretch and Elastic Recovery (Chart 5–7)

The effects of laundering on the stretch characteristics of new elastic waist band material were determined per ASTM D3107, whereby a standard weight (2 pounds) was attached to a given length of the elastic band and the stretched lengths were measured. A lower stretch % would indicate that the elastic material has a higher elastic modulus. Recovery, on the other hand, measures the ability of the elastic band to recover to its original length when the load is removed. A higher stretch recovery would mean the elastic band retains more of its elastic characteristics.

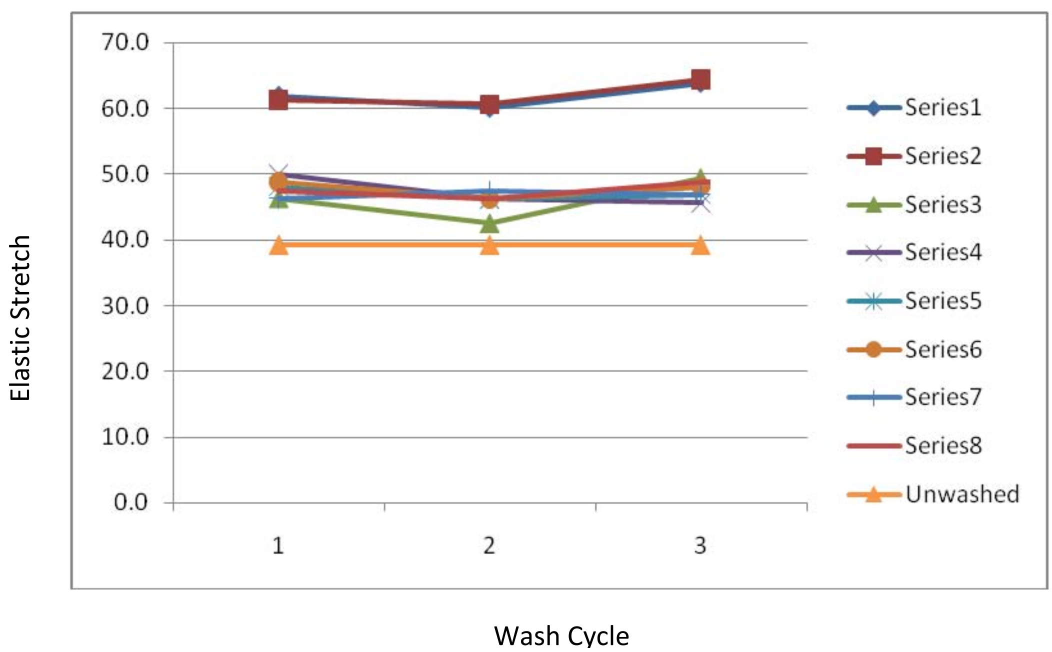
Charts 5 and 6 show the 95% confidence range of the stretch characteristics of new elastic bands after three wash cycles versus an unwashed elastic band sample, and the specific stretch behavior after each wash cycle, respectively.

Chart 5. Waist Band Material Stretch Characteristics after 3 Wash Cycles



Again the horizontal axis in **Chart 5** shows the same eight laundering conditions plus the control unwashed elastic sample (condition #12).

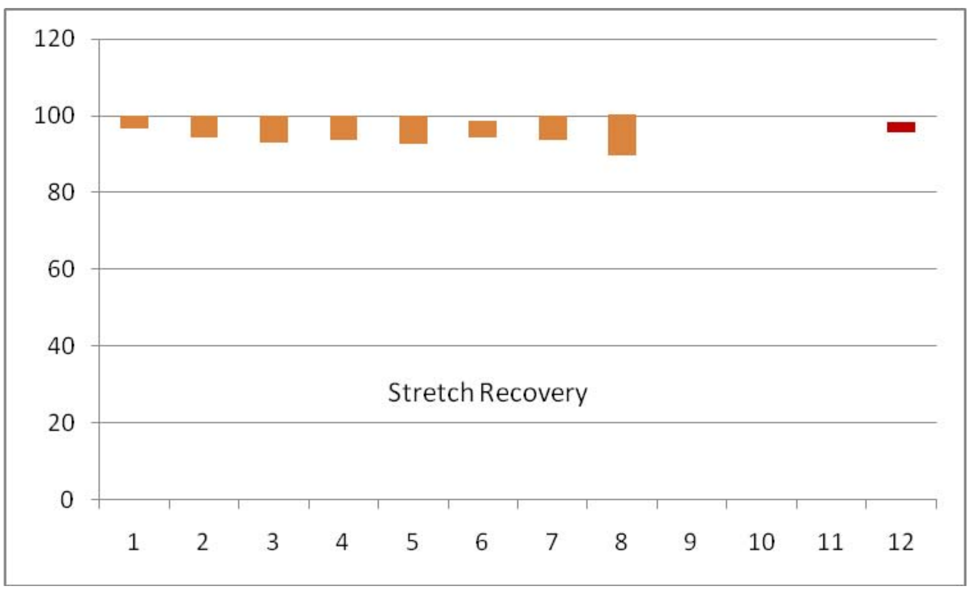
Chart 6. Elastic Stretch Characteristics after Each Wash Cycle



As compared with the unwashed elastic sample, laundering seems to have relaxed the elastic material so that it becomes more stretchable after washing. Although we have only conducted three wash cycles for each laundering condition, the data does not suggest that the trend of material relaxation would continue with more wash cycles. It appears that after one wash, the elastic material might have already reached its equilibrium relaxation state.

Chart 7 shows the recovery characteristics when the load is removed. All elastic samples exhibit a 95% confidence range between 90 to 100% recovery although laundering seems to have increased the variability and thus the confidence range. That may be due to some variations on how the elastic material responds to the laundering conditions.

Chart 7. Stretch Recovery after 3 Wash Cycles
95% Confidence Range



3.2.4 Abrasion Resistance

Abrasion resistance of the Cordura® fabric was measured on the Tabor Abrasion Tester per ASTM D 3884 for 1,000 cycles. During cycling and at the end of 1000 cycles, the samples were examined frequently to note any noticeable wear. Out of 120 samples, only 1 sample marginally failed. The failed sample was one that had been cleaned three times with Solvair® Cleaning and with Spot Cleaning.

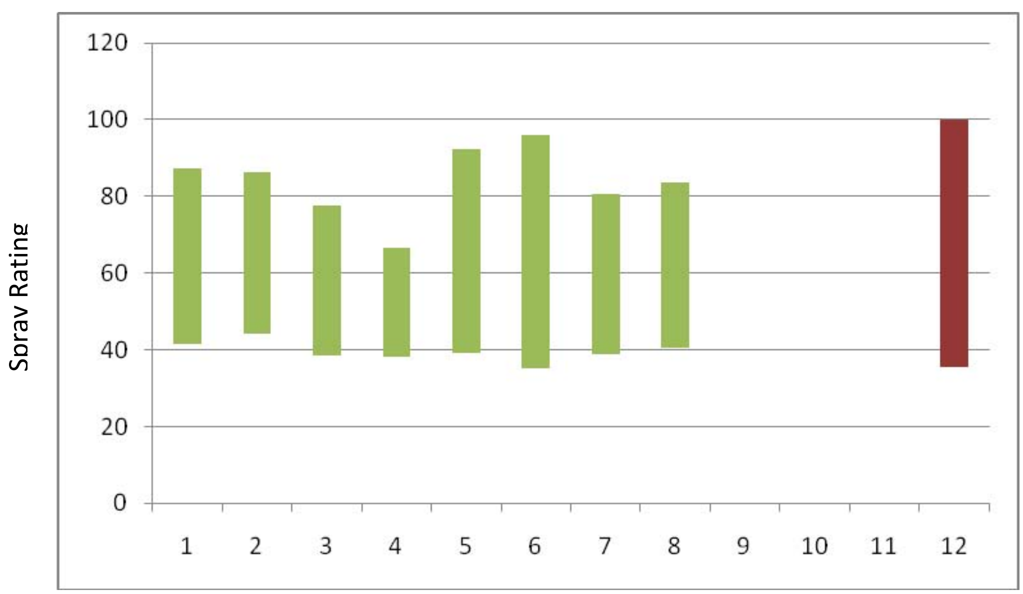
3.2.5 Water/Oil Repellency

Water repellency of the Cordura® fabrics cut from the vests and from new fabric pieces after three washes were determined by Spray Test (AATCC 22) and Hydrostatic Resistance Test (AATCC 127).

Of these two tests, the Spray Test is a subjective comparison test. In the Spray Test, a known amount of water was sprayed onto the fabric material held at an incline from a predetermined distance below the spray head. After spraying, the pattern of water penetration as shown on the fabric sample was compared with the AATCC standards. Based on the size of the wetting area, a rating from 0 to 100 was assigned to the tested sample. 0 means complete wetting whereas 100 means no wetting at all.

Chart 8 below shows the IOTV Cordura® fabric's 95% confidence spray rating range after three washes for the eight test laundering conditions along with the control unwashed vest face fabric material (Condition #12).

Chart 8. IOTV Face Fabric Spray Rating (after 3 washes)
95% Confidence Range



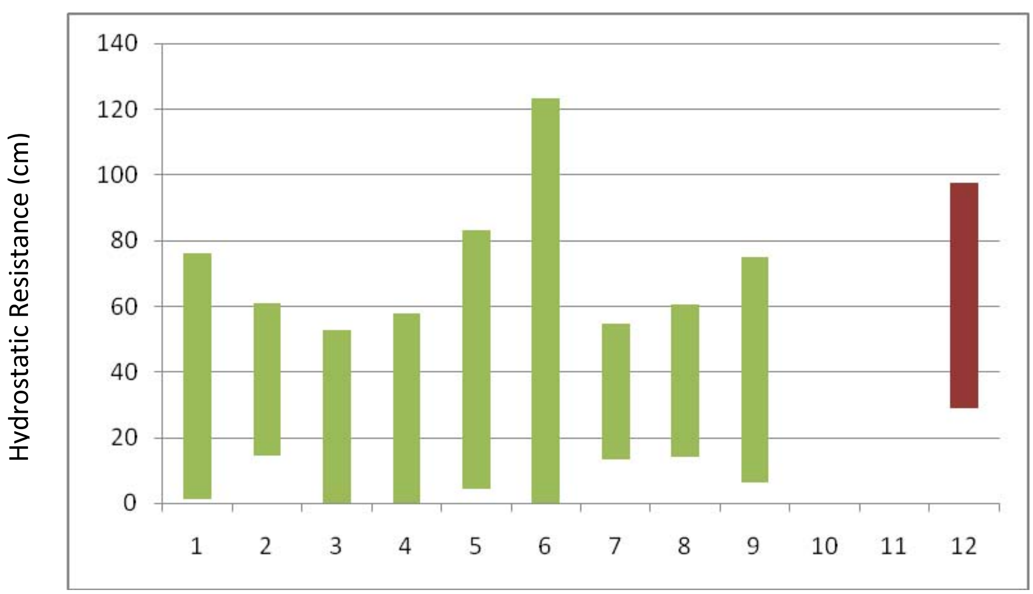
In addition, we also determined the spray rating of some unwashed new fabric pieces. They were found to have a spray rating of 100, showing no trace of wetting.

The implications are as follows:

1) The substantial differences in the spray ratings between the unwashed new fabric material and the cleaned vests suggest that wear and tear of the garments combined with cleaning have contributed to the deterioration of the Cordura® material on water repellency.
2) The effects of laundering alone on the spray ratings are less than definitive due to the smaller differences between the washed and unwashed IOTV samples and to the fairly large standard deviations.

On the other hand, the differences in hydrostatic head between the vests cleaned by various methods and the unwashed vest, as shown in **Chart 9**, are more pronounced.

Chart 9. IOTV Face Fabric Hydrostatic Resistance (95% Confidence Range)
Test Method: AATCC 127



The oil repellency attribute appears to be more sensitive to the vest's prior use history and laundering than water-repellency. Many unwashed vest samples could not survive the oil repellency test even with Oil #1, the oil with the highest surface tension (AATCC-118 Test Method).

The good news is that with some laundering processes such as computer-controlled wet cleaning, it is possible to reapply the water/oil-repellent finish to the vests being washed. The reapplication of water/oil repellent finish not only can preserve the garment's repellent characteristics but also could improve the ease of future cleaning. It is perhaps worth further investigation.

3.2.6 Camouflage Characteristics (Night Vision Goggle Screening/IR Reflectance)

With the increased use of night vision goggles in war fighting, the camouflage characteristics of Soldier OCIE items such as clothing require not only the material blends in with the surrounding in visible light but also in the low light and near-IR spectrum.

The vests in our test were first visually observed and photographed before and after washing. Many of them were found to have faded in color prior to washing due to normal wear or prior laundering history. We suspected that some vests might have been cleaned improperly with detergents that contain bleach before they were turned into the CIFs.

Most vests, however, still showed good color breakouts between different colors, Gray, Green and Sand, in the Universal Camouflage Pattern both in visible light and in night vision goggles. From the night vision test vest samples, we selected the most faded samples for the more detailed IR Reflectance Spectral tests.

The IR tests confirmed that many of these vests have fallen outside the original IR spectral specifications. On the other hand, the IR spectral results of the new fabric control test samples (after three washes) showed that they are still very much within specifications.

Charts 10–11 exemplify the IR Spectral results of a vest that has fallen outside the original IR spectral specifications (highlighted in yellow).

Chart 10. IR Reflectance
(Vest sample cleaned three times by Traditional Wet Laundering)

Near IR Wavelength (nm)	Desert Sand 500 Min	Desert Sand 500 Max	Desert Sand 500 Actual	Urban Gray 501 Min	Urban Gray 501 Max	Urban Gray 501 Actual	Foliage Green 502 Min	Foliage Green 502 Max	Foliage Green 502 Actual
600	28	40	33.70	12	26	26.64	8	18	36.51
620	30	42	35.12	14	26	27.83	8	18	38.09
640	34	48	36.81	14	28	28.46	8	20	39.96
660	38	56	39.83	14	30	30.10	10	26	43.30
680	44	60	47.29	18	34	36.76	10	26	51.80
700	46	66	55.70	24	38	43.83	12	28	62.51
720	48	68	59.52	26	42	47.19	16	30	68.80
740	48	72	60.87	30	46	48.18	16	30	71.48
760	50	74	61.44	32	48	48.66	18	32	73.01
780	54	76	61.79	34	48	48.89	18	34	73.51
800	54	76	57.85	34	50	49.89	20	36	70.38
820	54	76	60.82	36	54	50.63	22	38	72.69
840	56	78	61.43	38	54	49.75	24	40	73.60
860	56	78	62.09	40	56	50.11	26	42	75.14

Chart 11. IR Reflectance (Vest sample cleaned three times by Solvair® Cleaning)

Near IR Wavelength (nm)	Desert Sand 500 Min	Desert Sand 500 Max	Desert Sand 500 Actual	Urban Gray 501 Min	Urban Gray 501 Max	Urban Gray 501 Actual	Foliage Green 502 Min	Foliage Green 502 Max	Foliage Green 502 Actual
600	28	40	33.41	12	26	25.00	8	18	21.27
620	30	42	34.89	14	26	26.12	8	18	22.30
640	34	48	36.51	14	28	26.61	8	20	22.83
660	38	56	39.49	14	30	27.95	10	26	24.22
680	44	60	47.35	18	34	34.01	10	26	30.05
700	46	66	56.72	24	38	40.11	12	28	37.05
720	48	68	61.91	26	42	42.76	16	30	40.64
740	48	72	63.88	30	46	43.60	16	30	42.12
760	50	74	64.97	32	48	44.13	18	32	42.40
780	54	76	65.62	34	48	44.36	18	34	42.08
800	54	76	62.01	34	50	44.40	20	36	40.99
820	54	76	65.07	36	54	43.82	22	38	41.69
840	56	78	66.10	38	54	43.48	24	40	41.69
860	56	78	67.02	40	56	44.80	26	42	41.40

Chart 12. IR Reflectance
(New Cordura® fabric sample cleaned three times by Computer-controlled Wet Cleaning)

Near IR Wavelength (nm)	Desert Sand 500		Desert Sand 500	Urban Gray 501		Urban Gray 501	Foliage Green 502		Foliage Green 502
	Min	Max	Actual	Min	Max	Actual	Min	Max	Actual
600	28	40	37.32	12	26	21.70	8	18	13.58
620	30	42	38.04	14	26	22.30	8	18	14.09
640	34	48	38.44	14	28	22.95	8	20	14.76
660	38	56	40.29	14	30	25.33	10	26	16.74
680	44	60	45.94	18	34	30.77	10	26	20.94
700	46	66	52.08	24	38	36.24	12	28	24.79
720	48	68	55.60	26	42	39.09	16	30	26.56
740	48	72	57.24	30	46	40.39	16	30	27.33
760	50	74	57.81	32	48	40.94	18	32	27.65
780	54	76	58.42	34	48	41.50	18	34	27.94
800	54	76	55.22	34	50	40.97	20	36	27.59
820	54	76	55.47	36	54	40.07	22	38	26.63
840	56	78	58.26	38	54	41.32	24	40	27.39
860	56	78	58.16	40	56	40.78	26	42	29.14

What these charts show is that normal wear of the vests has more of a deteriorating effect on the camouflage properties than laundering. If laundering is conducted properly with the correct method and under the right conditions, it alone does not contribute to significant camouflage pattern degradation.

3.2.7 Yoke and Collar Ballistic Performance

The ballistic panels inside the Yoke and Collar are an integral part which cannot be removed from the subassemblies before washing. It is, therefore, important to determine how laundering would affect their ballistic performance. As Dr. James Zheng and Mr. John Glisson recommended, nine sets of cleaned Yoke and Collar samples from each laundering method (front and back, after three washes) along with another group of unwashed Yoke and Collar control samples were sent to HP White for fragment (17 grain) ballistic testing.

V50, the velocity at which 50% of the fragments penetrate through the Yoke and 50% do not, was determined**. Charts 13** and **14** show the V50 95% confidence lower limits of the Yoke and Collars cleaned by Traditional Wet Laundering and Computer-controlled Wet Cleaning.

Chart 13. 95% V50 Lower Confidence Limit
Yoke and Collar Samples made by Point Blank

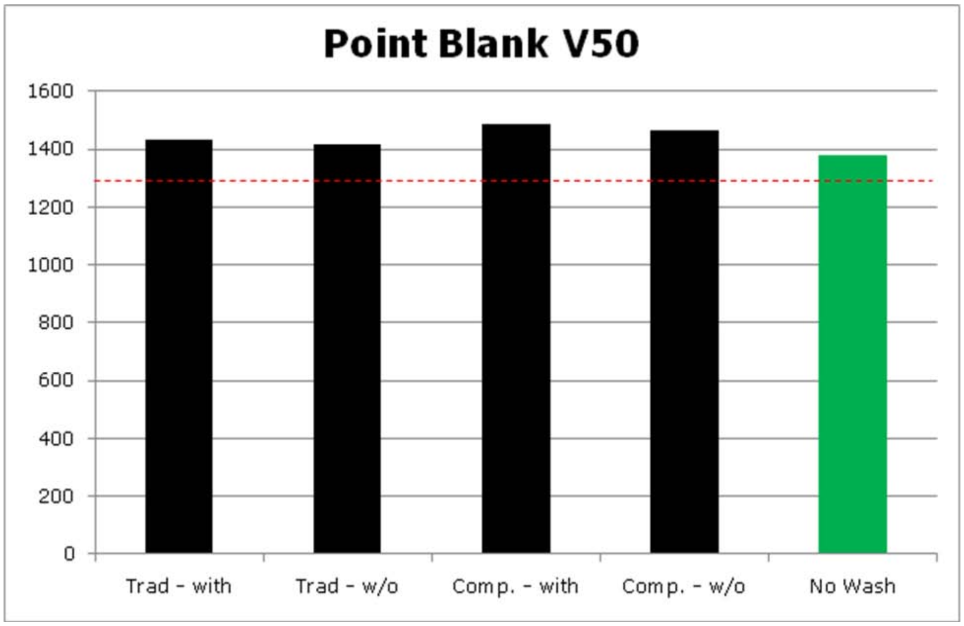
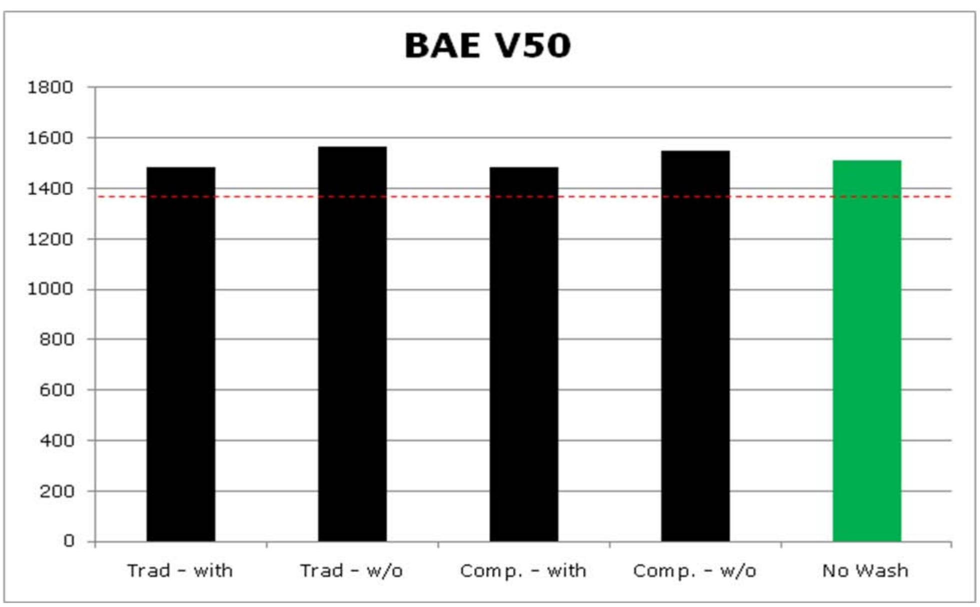


Chart 14. 95% V50 Lower Confidence Limit
Yoke and Collar Samples made by BAE Specialty Defense



No adverse effects were seen on the V50 fragment ballistic properties of the Yokes and Collars as a result of traditional or computer-controlled wet cleaning.

3.2.8 Flame Resistance

As the Cordura® face fabric material used for the next generation IOTV is going to be changed to a Flame Retardant material, we were interested in finding out how the various laundering methods may affect the fabric's flame resistance characteristics. An excursion trial was therefore conducted to determine the effects of laundering on the flame resistance characteristics of a Flame Retardant Cordura® fabric material (supplied by Glenn Raven), whereby the flame retardant characteristics were imparted as a coating.

Chart 15 shows the average "After Flame" and "Char Length" measurements (Test Method ASTM D6413) of this FR fabric after one, two and three cleaning cycles by each of the eight cleaning treatments.

Chart 15. Flame Resistance Characteristics

Cleaning Method	After Flame (sec)		Char Length (inch)	
	Warp	Filling	Warp	Filling
Wet Laundering + Spot Cleaning	3.89	1.86	2.83	3.30
Wet Laundering	2.32	5.54	2.83	3.60
Computer Wet Cleaning + Spot Cleaning	0.00	0.20	3.30	3.38
Computer Wet Cleaning	0.50	2.39	3.47	3.93
Liquid CO_2 + Spot Cleaning	4.63	33.57	4.43	7.17
Liquid CO_2	20.11	49.94	6.63	6.97
Solvair® + Spot Cleaning	40.43	49.13	7.67	8.53
Solvair® Cleaning	76.18	16.50	9.47	6.15
New FR Fabric without Washing	0.61	1.57	4.07	4.10

It is apparent from the data that the FR characteristics as illustrated by the After-Flame period and the Char Length were impaired to varying degrees by the cleaning treatments. Among the eight cleaning treatments, Solvair® Cleaning has the most drastic adverse effects on After Flame and Char Length and Computer-controlled Wet Cleaning has the least. Nonetheless, this points to the fact that the FR coating applied to the fabric is not permanent in nature and it deteriorates through cleaning.

4. Conclusions and Recommendations:

4.1 Conclusions:

Among the four commercial cleaning technologies explored, Computer-controlled Wet Cleaning offers the best balance in performance and cost. It surpasses Traditional Wet Laundering, Liquid CO_2 and Solvair® Cleaning in terms of effectiveness while preserving the key functional attributes of the vests, e.g., ballistic performance, strength, near IR camouflage, shrinkage, and water and oil repellency.

Computer-controlled Wet Cleaning requires the least capital investment (approximately $25K), and is moderate in terms of operating costs. Computer-controlled Wet Cleaning is well established in the market and is offered by over 250 professional cleaners in the United States.

After one wash cycle with Computer-controlled Wet Cleaning, most, if not all, lightly soiled IOTV garments (60% of the samples) became quite clean and had a refreshing scent. The medium soiled garments (30%) also looked reasonably clean after one wash. The heavily soiled garments (10%), particularly the yoke and collar subassemblies, may require a second wash cycle.

The detergents supplied by Kreussler Company used in Computer-controlled Wet Cleaning are superior in performance and are an essential part of the specification.

4.2 Deliverables

The deliverables as a result of this study are as follows:

- Specify Computer-controlled Wet Cleaning and Kreussler detergents as the interim commercial cleaning solution for the soiled IOTVs (already completed).
- Disseminate the IOTV interim commercial cleaning solution as a depot level maintenance procedure (completed via MAM, Control Number: MA 10-007 dated October 26th, 2009).

4.3 Recommendations:

Recommendations for future Interceptive Body Armor (IBA) garment material cleaning research:

- Conduct a follow-up short trial to optimize the Computer-controlled Wet Cleaning process conditions and the cleaning configurations of the IOTV components.
- Once the conditions and configurations have been optimized, conduct another trial to extend the wash cycle test to determine the end point criterion when the garment should no longer be washed.
- Determine the effects of Computer-controlled Wet cleaning (up to 10 cycles) on the ballistic performance of the soft ballistic panels;
- Upgrade the equipment capabilities of a mobile laundering container system (LADS) to clean soiled IOTVs.
- Validate the Computer-controlled Wet Cleaning procedures for commercial cleaning of OTVs and Plate Carriers.
- Investigate the feasibility and benefits of reapplying the water/oil repellent finish to the garments during the cleaning cycles.
- Develop the hand field cleaning procedures for IOTV, OTV and plate carrier using the AVANT and AKTIV detergents.
- Develop the sourcing for the detergents and acquire the initial buy of the detergent.
- Identify and evaluate potential non-destructive methods and tools to test ballistic performance of soft ballistic panels.

5. Acknowledgement:

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Lastly, thanks are also extended to Mr. Jim Haley, Director of Logistics at Ft. Campbell, and his CIF team for assisting us in collecting the soiled IOTV samples for our cleaning trial, and the RDEC textile material laboratory staff f for performing various tests on the materials for us.

LIST OF SYMBOLS, ABBREVIATIONS, AND ACRONYMS

BCA	Business Case Analysis
CIF	Central Issue Facility
CO_2	Carbon Dioxide
IOTV	Improved Outer Tactical Vest
IR	Infra Red
MAM	Maintenance Action Message
MOLLE	Modular Lightweight Load-Carrying Equipment
NPV	Net Present Value
PERC	Perchloro Ethylene
Y&C	Yoke and Collar

APPENDIX

A. Business Case Analysis

Part 1: Technology Selection - An IOTV Commercial Cleaning Study

EXECUTIVE SUMMARY

Economic data of the four (4) cleaning technologies, namely, Computer-controlled Wet Cleaning, Traditional Wet Laundering, Liquid CO2 Cleaning and Solvair® Cleaning, derived from the Improved Outer Tactical Vest (IOTV) Commercial Cleaning Study are presented and analyzed in this BUSINESS CASE ANALYSIS.

Traditional Wet Laundering is the most economical among these four (4) processes. It is followed by Computer-controlled Wet Cleaning, Liquid CO2 Cleaning and Solvair® Cleaning. However, in terms of cleaning performance and ability to retain the desirable functional properties of the IOTV, Computer-controlled Wet Cleaning surpasses the other cleaning methods. As performance is of critical importance, Computer-controlled Wet Cleaning is selected as the "Best Value" commercial cleaning method for soiled IOTVs.

Based on the process economics of Computer-controlled Wet Cleaning and the business practice of the commercial laundering industry, the fair market price of cleaning an IOTV (which includes disassembling, cleaning, reassembling, inspection, and packing) is estimated to be in the range from $11.14 to $16.45, ex-works at the contractor location. With gained experience, improved productivity, new IOTV wash configuration, and economy of scale, the operating cost is expected to improve, and the fair market price could ultimately be reduced to $10.88, ex-works, per IOTV.

BUSINESS CASE ANALYSIS

Part 1 – Technology Selection

An IOTV Commercial Cleaning Study

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Business Case Analysis

Part 1: Technology Section

An IOTV Commercial Cleaning Study

A.1 Introduction

Presently, deployed Soldiers are provided with an Improved Outer Tactical Vest (IOTV) for protection against small arms and fragmentation. When the deployment is complete, Soldiers are to turn in their IOTVs. Many of these returned IOTVs are very dirty and are unsanitary for re-issue without proper cleaning. While in the U.S. during training, Soldiers are required to wear their IOTVs as well.

Due to ongoing contracting difficulties, there has been a severe shortage of supply of IOTVs to meet Soldiers' needs. To help relieve the shortage situation, we undertook a cleaning study in 2009 examining the viability of cleaning the soiled IOTVs using commercial cleaning technologies.

The objective of this Business Case Analysis (BCA) is to analyze the economics of the four (4) IOTV commercial cleaning technologies which we investigated so as to determine the best value approach to clean the soiled IOTVs.

More specifically, this BCA covers the economics (processing cost and capital investment) of Computer-controlled Wet Cleaning, Traditional Wet Laundering, Liquid CO2 Cleaning and Solvair® Cleaning as derived from our IOTV Commercial Cleaning Study. The performance aspects of these technologies were reported separately in a technical report entitled "A Commercial IOTV Cleaning Study."

Prior to undertaking the IOTV Cleaning Study, General Repair Procedures for Individual Equipment (TM 10-8400-203-23) and Manufacturer's Use and Care Procedures precluded the use of any machine cleaning method due to the concern that a wide range of equipment and conditions is used in the laundering industry and improper machine cleaning can damage the functional properties of the garment. The only available option to the Central Issue Facilities (CIFs), therefore, is to replace the damaged or heavily soiled IOTV components.

A.2 Methods and Assumptions

A.2.1 Methods

An initial market study of various commercial laundering methods employed by the laundry industry was conducted via the internet. Through this study, the following technologies: Traditional Wet Laundering, Computer-controlled Wet Cleaning, PERC Dry Cleaning, Liquid CO_2 Cleaning, Solvair® Cleaning, Hydrocarbon Cleaning and Silicone Liquid Cleaning were identified. **Table A-1** summarizes the findings about each technology and our initial assessment of their viability.

TABLE A-1. COMMERCIAL GARMENT CLEANING TECHNOLOGIES

	Traditional Wet Laundering	Computerized Wet Cleaning	PERC Perchloro Ethylene	Liquid CO2	"Solvair" Improved Liquid CO2	Hydro-carbon	Green Earth
Cleaning Agent	Water	Water	Organic Solvent	Liquid CO2	Liquid CO2 + Glycol Ether (DPnB)	Petroleum Based Solvents	Silicone Liquid
Machines	Traditional Washer & Dryer	Modern Computerized Washer & Dryer	Traditional Dry Cleaning Equipment	Modern High Pressure Cleaner	Solvair	Modified Dry Cleaning Machine	Modified Dry Cleaning Machine
Availability	Wide Spread	250+ Shops	35,000 + Shops	35 Shops	Latest Technology 10 Shops in US	Unknown	600-700 Shops
Heat	Cold, Warm & Hot Wash Cycles	Precise Temperature Control, Residual Moisture Content Sensor	120F +	None	None	120F +	120F +
Residual Chemical Odor	None	None	Strong	None	None	Slight	None , Prone To Mildew & Micro-organism Growth
Pollution	No	No	Hazardous Chemical, VOC	No	Glycol Ether Bio-degradable	Ground Water Contamination	No
Worker Risk	No	No	Suspected Carcinogen, High Risk	No	Low	Flammable, Explosive	Low Risk
Cleaning Actions & Effects	Vigorous Mechanical Action, Effective for Water-based Stains, Susceptible to Shrinkage	Gentle Cycle, Suitable for Delicate Materials, Effective Detergency for Water-based and Oily Stains	Excellent for Oily Stains	Low Shrinkage, Excellent for Oily Stains, Less Effective for Water-based Stains	High Solvating Power, Low Shrinkage, Effective for Oily Stains		

PERC Dry Cleaning, Hydrocarbon Cleaning and Silicone Liquid Cleaning were subsequently eliminated as viable candidates because of the pollution and health risks they present, efficacy issues, etc., and the scope of our cleaning study was narrowed down to the four technologies: Traditional Wet Laundering, Computer-controlled Wet Cleaning, Liquid CO2 Cleaning, and Solvair® Cleaning.

A commercial cleaner in Nashville, TN, Chesley the Cleaner, was awarded the contract to collaborate with us in conducting the IOTV cleaning trial. The economic data used in this analysis comparing the four (4) cleaning technologies was supplied to us by Chesley the Cleaner based on our cleaning trial. It includes the direct variable costs (labor, materials, energy, and repair) and the equipment depreciation cost. Sales, General & Administrative (SGA) costs and profit margins are not included.

As the four (4) types of cleaning equipment have different drum sizes and have different capacity ratings, the wash load was adjusted to fit each equipment size. Ten (10) IOTV garments per load were washed by Traditional Wet Laundering, whereas five (5) IOTV garments per load were washed by Computer-controlled Wet Cleaning, Liquid CO2 Cleaning and Solvair® Cleaning.

The wash drum and hence the load size of Liquid CO2 and Solvair® Cleaning technologies is very much limited to the present capacities, because of the high pressure (>700 psi) at which these technologies operate, whereas larger size Computer-controlled Wet Cleaning equipment is commercially available.

Although the per item cleaning costs derived from the trial as shown in **Tables A-2 and A-3** appear more in favor of Traditional Wet Laundering versus Computer-controlled Wet Cleaning due to its large load size, the reality is that the use of a larger Computer-controlled Wet Cleaning machine does not result in any significant savings because as the drum size increases, proportionally more detergents will be required and the operating costs will similarly increase. The investment cost of a larger Computer-controlled Wet Cleaning machine is also almost proportional to the rated capacity. Therefore, the per item cost derived from the trial is still valid for comparison purposes among these four (4) cleaning technologies.

A.2.2 *Assumptions (Applied To All Four Processes)*

- Labor cost was set at $10/hour for direct labor. The actual labor rate may vary depending on the locations.
- Costs of detergents were based on the manufacturer's list price without taking into consideration of possible volume discount.
- Equipment depreciation cost was calculated based on straight line depreciation over ten (10) years running 4,000 cleaning cycles per year.
- Equipment repair cost was based on Chesley's experience.

A.3 Business Impacts

While cost considerations are one of the driving factors in the choice of a viable commercial technology to clean soiled IOTVs, the more critical consideration is performance. The chosen technology must demonstrate effectiveness in cleaning the soiled IOTVs without degrading their functional characteristics such as tensile properties, ballistic performance, camouflage characteristics in visible light and near IR spectrum, material shrinkage, color fading, etc.

Results of our cleaning trial showed that among the four (4) technologies studies, Computer-controlled Wet Cleaning is most effective in cleaning soiled IOTV garments without degrading the desirable functional characteristics of the garment. It is followed by Traditional Wet Laundering, Solvair® Cleaning and Liquid CO2 cleaning. Details of the trial results are reported in a Technical Report entitled "A Commercial IOTV Cleaning Study" and are, therefore, not repeated in this BCA.

TABLE A-2. COMPUTER-CONTROLLED WET CLEANING PROCESS ECONOMIC DATA

		Amount Used	Cycle Cost	Per Item Cost
Washer	65# Washer/ $14,864	1/40,000 (.000025)	$0.37	$0.07
Dryer	75# Dryer/ $6,855	1/40,000 (.000025)	$0.17	$0.03
Aktiv	24kg/$200.40 ($.0835/10ml)	240ml	$2.00	$0.40
Avant	24kg/$181.20 ($.0755/10ml)	480ml	$3.62	$0.72
Water/Sewer	.0188 per Gal	643 Liters (170 Gal)	$3.20	$0.639
Energy			$0.37	$0.074
Direct Labor	Cost per Load: 0.167 x hourly wage	$10/hour *	$1.67	$0.334
Repair & Maintenance Labor	Cost per Load: 0.006 x hourly wage	$10/hour *	$0.06	$0.012
Repair Parts			$0.12	$0.024
			$11.59	$2.317

** may vary according to location*

TABLE A-3. TRADITIONAL WET LAUNDERING PROCESS ECONOMIC DATA

		Amount Used	Cycle Cost	Per Item Cost
Equipment Cost (Depreciate over 10 years/4,000 cycles a year)				
Washer	Washer/ $14,864	1/40,000 (.000025)	$0.37	$0.037
Dryer	75# Dryer/ $6,855	1/40,000 (.000025)	$0.17	$0.017
Additive Cost				
Builder +	$185.00/15 Gal ($.096/oz)	6oz	$0.58	$0.058
Subdue	$189.95/15 Gal ($.099/oz)	6oz	$0.59	$0.059
Trend	$189.25/15 Gal ($.098/oz)	3oz	$0.29	$0.029
Release	$391.99/15 Gal ($.204/oz)	1.5oz	$0.31	$0.031
Water/Sewer	.0188 per Gal	1566 Liters (414) Gal)	$7.78	$0.778
Energy			$0.37	$0.037
Direct Labor	Cost per Load: 0.167 x hourly wage	$10/hour *	$1.67	$0.167
Repair & Maintenance Labor	Cost per Load: 0.006 x hourly wage	$10/hour *	$0.06	$0.006
Repair Parts			$0.12	$0.012
			$12.32	$1.232

** may vary according to location*

TABLE A-4. LIQUID CO_2 CLEANING PROCESS ECONOMIC DATA

		Amount Used	Cycle Cost	Per Item Cost
Equipment Cost (Depreciate over 10 years/4,000 cycles a year)				
CO_2 Machine	$150,000	1/40,000 (.000025)	$3.75	$0.750
Additive Cost				
Clip COO	24kg/$200.40 ($.0835/10ml)	80ml	$0.67	$0.134
CO_2 Cost	$.25/ lb	15 lbs	$3.75	$0.750
Energy			$0.83	$0.166
Direct Labor	Cost per Load: 0.083 x hourly wage	$10/hour *	$0.83	$0.166
Repair & Maintenance Labor	Cost per Load: 0.13 x hourly wage	$10/hour *	$1.30	$0.260
Repair Parts			$0.58	$0.116
			$11.71	$2.342

** may vary according to location*

TABLE A-5. SOLVAIR® CLEANING PROCESS ECONOMIC DATA

		Amount Used	Cycle Cost	Per Item Cost
Equipment Cost (Depreciate over 10 years/4,000 cycles a year)				
CO_2 Machine	$150,000	1/40,000 (.000025)	$3.75	$0.750
Additive Cost	No additive			
Filters	$750 for 500 loads	1/500	$1.50	$0.300
CO_2 Cost	$.25/ lb	15 lbs	$3.75	$0.750
Energy			$0.83	$0.166
Direct Labor	Cost per Load: 0.083 x hourly wage	$10/hour *	$0.83	$0.166
Repair & Maintenance Labor	Cost per Load: 0.26 x hourly wage	$10/hour *	$2.60	$0.520
Repair Parts			$0.75	$0.150
			$14.01	$2.802

The more significant aspect of the cleaning study is that we have now identified a commercial cleaning method capable of cleaning soiled IOTVs to help relieve the shortage situation and the considerable cost benefits it brings versus discarding and replacing the soiled IOTV components. The economic analysis comparing "Commercial Cleaning" versus "Discarding and Replacing" soiled IOTVs will be reported separately in BCA Part 2 entitled "Benefits of Cleaning Soiled IOTVs versus Discard and Replace."

The economic data reported in this report is more for documentation purposes. It provides also the basis to determine the fair market price to clean a soiled IOTV.

It should be noted that the costs reported in the previous tables (**Table A-2 through A-5**) cover only the cleaning procedures. They do not include the steps and hence the costs of disassembling the IOTVs, identifying the components, inspection, reassembly, packaging and transportation. Hands-on experience showed that it takes approximately eight (8) minutes to disassemble the components and approximately 30 minutes to reassemble the clean components into an IOTV, inspect and pack.

Table A-6 below shows the estimation of a fair market price of the complete service to disassemble, identify, clean, reassemble, inspect, and pack an IOTV garment using Computer-controlled Wet Cleaning.

TABLE A-6. COMPLETE SERVICE MARKET PRICE ESTIMATION
(Computer-controlled Wet Cleaning Technology)

Computer-controlled Wet Cleaning:	$2.32
Disassembly Direct Labor (8 minutes @$10/hour):	$1.34
Reassembly, Inspection & Packing (30 minutes @$10/hour):	$5.00
Miscellaneous (Labels, Polybags, Markers, Pins etc.):	$0.15
Total:	$8.81
Gross Profit Margin:	30%
Fair Market Price Estimate (Per IOTV):	$8.81/(1-30%) **$12.59**

A.4 Sensitivity Analysis

As the fair market price hinges on many variables such as: 1) cost of detergents, 2) detergent usage, 3) labor wage, 4) productivity, and 4) gross margin expectation, a sensitivity analysis of the fair market price (**Table A-7)** is conducted based on the following scenarios :

1) Reduction of Detergent Cost by $20% (as a result of Volume Purchase)
2) Increase Usage of Detergents with the Extended Wash Cycle (AKTIV: 480 ml, AVANT: 600 ml)
3) Labor Wage Increase by $20% (e.g., TN vs. CA)
4) Increase the Wash Load to 6 IOTVs/load
5) Improvement of Productivity in Disassembling, Reassembling, Inspecting and Packing (15% improvement as a part of the learning curve and new wash configuration)
6) Gross Profit Margin Expectation (25%) – Note: the average gross profit margin for the laundering industry is about 30%
7) Gross Profit Margin Expectation (35%)
8) Worst Case (combining Scenario #2, #3, and #7)

TABLE A-7. EFFECTS ON THE FAIR MARKET PRICE ESTIMATE BASED ON THE ABOVE DESCRIBED SCENARIOS

	Baseline	Scenario #1	Scenario #2	Scenario #3	Scenario #4	Scenario #5	Scenario #6	Scenario #7	Worst Case
Cleaning									
Washer/Dryer Depreciation	$0.108	$0.108	$0.108	$0.108	**$0.090**	$0.108	$0.108	$0.108	$0.108
Aktiv	$0.401	**$0.321**	**$0.802**	$0.401	**$0.334**	$0.401	$0.401	$0.401	**$0.802**
Avant	$0.725	**$0.580**	**$0.906**	$0.725	**$0.604**	$0.725	$0.725	$0.725	**$0.906**
Water/Sewer	$0.639	$0.639	$0.639	$0.639	**$0.533**	$0.639	$0.639	$0.639	$0.639
Energy	$0.074	$0.074	$0.074	$0.074	**$0.062**	$0.074	$0.074	$0.074	$0.074
Direct Labor	$0.334	$0.334	$0.334	**$0.401**	**$0.278**	$0.334	$0.334	$0.334	**$0.401**
Repair Maintenance Labor	$0.012	$0.012	$0.012	$0.012	**$0.010**	$0.012	$0.012	$0.012	$0.012
Repair Parts	$0.024	$0.024	$0.024	$0.024	**$0.020**	$0.024	$0.024	$0.024	$0.024
Total Cleaning Cost	$2.317	$2.091	$2.899	$2.383	**$1.931**	$2.317	$2.317	$2.317	$2.965
Disassembly, Reassembly, Inspection & Packing	$6.333	$6.333	$6.333	**$7.600**	**$6.333**	**$5.333**	$6.333	$6.333	**$7.600**
Miscellaneous	$0.150	$0.150	$0.150	$0.150	$0.150	$0.150	$0.150	$0.150	$0.150
Total Complete Service	$8.800	$8.575	$9.382	$10.133	$8.414	$7.800	$8.800	$8.800	$10.715
Fair Market Price Estimate	**$12.571**	**$12.250**	**$13.403**	**$14.476**	**$12.020**	**$11.143**	**$11.733**	**$13.538**	**$16.485**

Given the estimates derived from the sensitivity analysis, the fair market price (ex-works) for the complete service of disassembling, cleaning, reassembling, inspection and packing an IOTV should range from $11.14 to the worst case of $16.48. Many of the scenarios are very probable, e.g., the detergent supplier has offered future Government Cleaning Contractors a volume discount of 22.5% on direct sales and 10% on distributor sales, and the new wash configuration (without complete disassembly) plus gained experience is expected to reduce the labor time involved in handling, identifying, disassembling and reassembling the IOTV.

If we are to look at the likely scenarios (20% detergent price reduction, 15% productivity improvement, extended wash cycle, 6 IOTVs per wash load, 30% average gross margin expectation), the fair market price can optimistically be improved to $10.88, ex-works, per IOTV **(Table A-8)**.

TABLE A-8. OPTIMISTIC MARKET PRICE ESTIMATE

Cleaning	
Washer/Dryer Depreciation	$0.090
AKTIV	$0.538
AVANT	$0.604
Water/Sewer	$0.533
Energy	$0.062
Direct Labor	$0.278
Repair Maintenance Labor	$0.010
Repair Parts	$0.020
Total Cleaning Cost	$2.135
Disassembly, Reassembly, Inspection & Packaging	$5.330
Miscellaneous	$0.150
Total Complete Service	$7.615
Optimistic Market Price Estimate	**$10.878**

A.5 Risk Assessments

Aside from cost and performance, the other consideration in our selection of the cleaning technology is their availability. There are two (2) factors of availability which are of concern: one is the availability of Computer-controlled Wet Cleaning technology and the other the availability of the selected detergents.

As to the availability of Computer-controlled Wet Cleaning, our market research showed that there are more than 250 commercial cleaners in the U.S. which have the capabilities of offering Computer-controlled Wet Cleaning services. There are more than ten (10) equipment manufacturers which supply computer-controlled wet cleaning equipment. The technology is environmentally safe. As EPA or the state regulations tighten on the dry cleaning industry, it is expected that more and more cleaners would resort to the Computer-controlled Wet Cleaning process. Therefore, there is a very low risk of availability of Computer-controlled Wet Cleaning technology in the market place. Future contracted cleaners will require training on disassembling and reassembling the IOTV garments to meet Government specifications and the Government needs to provide oversight to ensure that appropriate quality control measures are in place to ensure compliance to specifications. Given the expected return on investment (comparing Cleaning with Discard and Replace) and the critical shortage of IOTVs, the resources needed for the implementation are more than worthwhile.

The specified detergents, AVANT and AKTIV, which we used with Computer-controlled Wet Cleaning, are manufactured by Kreussler Company. Kreussler's headquarters and manufacturing facility is located in Wiesbaden, Germany. It has a warehouse and sales office located in Tampa, FL to service North American sales. They also have a well entrenched distributor network (over 50 distributors) serving the cleaning industry in the U.S. The Sales VP of Kreussler assured us that there is plenty of production capacity to meet our projected needs. They are also willing to stock sufficient detergents in their Florida warehouse to anticipate surges of demand. Logistically, it appears that Kreussler has the desire and means in place to supply the needed detergents to our future contracted cleaners.

While there is some risk of depending on the supply of AVANT and AKTIV, the risk level is deemed low to moderate. To mitigate or reduce this risk level, it may be worthwhile to look into expanding future trials to cover other potential detergents and suppliers. The decision factors whether to undertake this investigation will depend on internal resource availability, future supply and demand of AVANT and AKTIV, and selected contractors will have to be monitored as we proceed into the operation phase.

A.6 Conclusions

- Computer-controlled Wet Cleaning is deemed to be the “Best Value” commercial cleaning method to clean soiled IOTVs. Computer-controlled Wet Cleaning offers the best technical performance and acceptable economics.
- The initial fair market price for an outside contracted cleaner to disassemble, clean (using Computer-controlled Wet Cleaning technology), reassemble, inspect and pack should range from $11.14 to $16.45, ex-works, per IOTV.
- With gained experience, the fair market price assuming the likely scenarios could be improved optimistically to $10.88, ex-works, per IOTV.

A.7 Acknowledgement

The authors would like to acknowledge the management of S-PSID, Life Cycle Logistics and PM-SPIE for their vision to initiate and sponsor the IOTV Commercial Cleaning Study. Special thanks are extended to Mr. Norm Fanning for his unwavering support and guidance through this project and editorial comments, the colleagues in the Life Cycle Logistics Team who have lent their assistance in conducting the cleaning trial, and to Mr. Sean O’Donoghue for reviewing and providing editorial comments to this report.

APPENDIX

B. Business Case Analysis

Part 2: “Clean” versus “Discard and Replace” - An IOTV Commercial Cleaning Study

EXECUTIVE SUMMARY

This Business Case Analysis (BCA) constitutes a part of our Improved Outer Tactical Vest (IOTV) Commercial Cleaning Study in which the viability of various commercial cleaning methods to clean soiled IOTV outer-shell materials and Yoke and Collar components is examined.

Economic data generated in this BCA comparing “Cleaning” versus “Discarding and Replacing” soiled IOTV outer-shell and Yoke and Collar components overwhelmingly favors our recommendation to clean and reuse the soiled components by Computer-controlled Wet Cleaning. The cost savings by cleaning soiled IOTV components in terms of Net Present Value (NPV) during the first three (3) year tour rotation cycle exceeds $131.4 million per year. The total NPV cost savings over a projected period of ten (10) years is as much as $1.029 billion.

Cleaning costs have very little impact to the outcome of the analysis. The variable that has significant impact is the service life of the IOTV garments. Opportunities exist to further increase the expected savings by extending the wash cycles of the IOTV outer-shell materials and the Yoke and Collar Assembly should be explored.

NOTE: This BCA and the associated Commercial Cleaning Study of IOTVs <u>did</u> <u>not</u> include the cleaning of the IOTV Soft Ballistic Inserts.

Business Case Analysis

Part 2 –"Clean" versus "Discard and Replace"

An IOTV Commercial Cleaning Study

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Business Case Analysis

Part 2 –“Clean” versus “Discard and Replace”

An IOTV Commercial Cleaning Study

B.1 Introduction

Presently, deployed Soldiers are provided with an Improved Outer Tactical Vest (IOTV) for protection against small arms and fragmentation. When the deployment is complete, Soldiers are to turn-in their IOTVs. Many of these returned IOTVs are very dirty and are unsanitary for re-issue without proper cleaning. While in the U.S. during training, Soldiers are required to wear their IOTVs as well.

Existing Technical Manual, Maintenance and Care Procedures, and Users Instructions preclude machine washing of soiled IOTVs due to the concern that a very wide range of cleaning methods, conditions and detergents are used in the commercial laundering industry, and improper cleaning can deteriorate the functional properties of the vests rendering them unfit for use to protect Soldiers. Therefore, the only previously authorized method to clean soiled IOTVs was by hand cleaning.

As hand cleaning is extremely labor intensive and its results highly variable, it is impractical to implement large scale cleaning by hand at the installation or Depot level. The only option left is to discard and replace the outer-shell and Yoke and Collar components of IOTVs when the vests become heavily soiled.

The discovery from our IOTV Commercial Cleaning Study that Computer-controlled Wet Cleaning can effectively clean soiled IOTVs without degrading their functional properties has opened up opportunities for the cleaning of soiled IOTVs as a sustainment maintenance procedure rather than discarding and replacing the soiled vest components.

The purpose of this BCA is to analyze the benefits of instituting cleaning soiled IOTV outer-shell and Yoke and Collar components by Computer-controlled Wet Cleaning versus the current method of Discard and Replace.

B.2 Methods and Assumptions

B.2.1 Tour Rotation Cycle and Timeline

This BCA assumes that once our Armed Forces have reached the desired level, Soldiers will take-on a three year rotation cycle, i.e., they will deploy down range for 1 year and return home for two years during which they will continue to receive field training to prepare them for their next combat tour. If Soldiers use their IOTVs routinely and actively as intended, it is expected that after each year the IOTVs will become heavily soiled. For analysis purposes, this BCA assumes a total time-line of ten (10) years (the currently projected service life of the vest's Soft Ballistic Inserts).

B.2.2 IOTV Requirements

Given the present engagements and the premise that each Solider should be provided with an IOTV for protection against potential mission threats, 966,000 IOTVs (including a 15% size tariff inventory float) will need to be acquired in the first year to meet deployment and training needs. From the second through the tenth year, we assume that each year we will need to replace or clean 630,000 outer-shell and Yoke and Collar components (i.e. IOTV without the Soft Ballistic Inserts), or 75% of the 840,000 IOTVs which are in use.

B.2.3 IOTV and Cleaning Costs

The contract price of a complete Gen 2 IOTV including all soft ballistic inserts is $879, and the cost of replacing the outer-shell and Yoke and Collar components of each IOTV is $492 **(Table B-1)**. These prices are assumed to be fixed for the ten (10) year period.

TABLE B-1. IOTV Gen II COMPONENT PRICE

(Ref: Contract # W91CRB-08-C-0147)

NAME	Quantity	Unit Price	Total Cost
Front, IOTV Carrier (Outershell), IOTV GEN II	1	$ 41.40	$ 41.40
Back, IOTV Carrier (Outershell), IOTV GEN II	1	$ 41.40	$ 41.40
Universal External Side Plate Carrier, IOTV GEN II	2	$ 33.19	$ 66.38
Universal External Side Plate Pouch, IOTV GEN II	2	$ 31.76	$ 63.52
Internal Waist Band, IOTV GEN II	2	$ 6.61	$ 13.22
Yoke & Collar Assembly, IOTV GEN II	1	$ 187.82	$ 187.82
Lower Back Protector Carrier (Outershell), IOTV GEN II	1	$ 8.40	$ 8.40
Groin Protector Carrier (Outershell), IOTV GEN II	1	$ 6.60	$ 6.60
Deltoid Protector Outershell, IOTV GEN II	2	$ 31.73	$ 63.46
IOTV w/o Soft Ballistic Inserts			**$ 492.20**

In the "Cleaning" scenario, the cleaning cost is estimated to be $12.59 for the IOTV components based on the fair market price estimate as reported in Part 1 of the BCA, IOTV Commercial Cleaning Study. As some components (e.g. side plate carriers, pouches and internal waist bands) are more susceptible to damage due to wear and tear, we are budgeting each year $143 per IOTV to replace these damaged parts.

As the administrative, freight, material handling, and storage costs between the scenarios of "Cleaning" and "Discard and Replace" are very similar, for simplicity of the comparison, these costs are not included in the analysis.

B.2.4 Net Present Value (NPV) Analysis

An annual inflation, dollar devaluation rate or interest rate of 5% is assumed in calculating the NPV of both scenarios over the projected period of ten (10) years in this analysis.

B.3 Business Impact

Not only does the discovery of a viable commercial cleaning method contribute to relieving the tight supply situation for the IOTVs, it also has huge life cycle cost benefits. Without the access to cleaning, the service life of an IOTV is limited by the length of time it can be worn before it gets too dirty and unsanitary. Most IOTVs would become very dirty after a year of active service.

As our cleaning trial was limited thus far to only the outer-shell materials (excluding the soft ballistic inserts) and the Yoke and Collar, this BCA compares the economics of "Cleaning" versus "Discarding and Replacing" just the outer-shell and Yoke and Collar materials.

TABLE B-2 below is the Net Present Value (NPV) expense outlay comparison between the "Cleaning" and "Discard & Replace" scenarios over a projected period of ten (10) years:

TABLE B-2. NET PRESENT VALUE COMPARION BETWEEN "CLEANING" AND "DISCARD & REPLACE"

Discard & Replacement Scenario										
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Quantity*	966,000	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**
Unit Purchase Price**	$879	**$492**	**$492**	**$492**	**$492**	**$492**	**$492**	**$492**	**$492**	**$492**
Total Cost	$849,114,000	$309,960,000	$309,960,000	$309,960,000	$309,960,000	$309,960,000	$309,960,000	$309,960,000	$309,960,000	$309,960,000
$ Devaluation Rate due to Inflation	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Net Present Value	$849,114,000	$295,200,000	$281,142,857	$267,755,102	$255,004,859	$242,861,771	$231,296,924	$220,282,785	$209,793,129	**$199,802,980**
TOTAL NET PRESENT VALUE	**$3,052,254,407**									
Average Net Present Value/Year (1st Rotation Cycle)		**$281,365,986**								

* Includes 15% Inventory Float in Initial Purchase in Year 1; replace 75% of 840,000 outer-shells (630,000) each year from the 2nd through 10th year

** Initial purchase Includes Front and Rear Vests, Yoke and Collar Assemblies, Side Plate Carriers, Internal Waistbands, Lower Back Protector and All Ballistic Inserts ($879); outer-shell materials and Yoke & Collar replacement purchase from 2nd through 10th year ($492)

Cleaning Scenario (Replacing the Complete Outer-shell Materials Every 3 Years)										
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Quantity*	966,000	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**
Unit Purchase Price**	$879	$12.59	$12.59	**$492**	$12.59	$12.59	**$492**	$12.59	$12.59	**$492**
Damaged Parts Replacement Cost		**$143**	**$143**		**$143**	**$143**		**$143**	**$143**	
Total Cost	$849,114,000	$98,021,700	$98,021,700	$309,960,000	$98,021,700	$98,021,700	$309,960,000	$98,021,700	$98,021,700	$309,960,000
$ Devaluation Rate due to Inflation	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Net Present Value	$849,114,000	$93,354,000	$88,908,571	$267,755,102	$80,642,695	$76,802,567	$231,296,924	$69,662,192	$66,344,945	**$199,802,980**
TOTAL NET PRESENT VALUE	**$2,023,683,977**									
Average Net Present Value/Year (1st Rotation Cycle)		**$150,005,891**								

As you will note from the tables, the total NPV outlays differ in favor of the "Cleaning" scenario by as much as **$1.029 billion** over the ten (10) year period. The average NPV savings **per year** via "Cleaning" from the 2nd through 4th year exceeds **$131 million**.

B.4 Sensitivity Analysis

As the premise and assumptions used in this BCA may vary, a sensitivity analysis is prepared based on the following scenarios:

Scenario #1: IOTV Outer-shell Components (including the Yoke and Collar Assembly) Service Life from three (3) to five (5) years **(Table B-3)**;

Scenario #2: 15% Higher Commercial Cleaning Price **(Table B-4)**;

Scenario #3: Annual Inflation/Dollar Devaluation Rate at 4% instead of 5% **(Table B-5)**; and

Scenario #4: $72 Repair and Replacement Cost of Damaged Components **(Table B-6)**.

TABLE B-3. EFFECTS OF IOTV COMPONENT SERVICE LIFE

Outer-shell 3 Year Service Life	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Quantity	966,000	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**
Unit Purchase Price	$879	$12.59	$12.59	**$492**	$12.59	$12.59	**$492**	$12.59	$12.59	**$492**
Damaged Parts Replacement Cost		**$143**	**$143**		**$143**	**$143**		**$143**	**$143**	
Total Cost	$849,114,000	$98,021,700	$98,021,700	$309,960,000	$98,021,700	$98,021,700	$309,960,000	$98,021,700	$98,021,700	$309,960,000
$ Devaluation Rate due to Inflation	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Net Present Value	$849,114,000	$93,354,000	$88,908,571	$267,755,102	$80,642,695	$76,802,567	$231,296,924	$69,662,192	$66,344,945	**$199,802,980**
TOTAL NET PRESENT VALUE	**$2,023,683,977**									
Average Net Present Value/Year (3 Years Life Cycle)		**$150,005,891**								

Outer-shell 4 Year Service Life	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Quantity	966,000	**630000**	**630000**	**630000**	**630000**	**630000**	**630000**	**630000**	**630000**	**630000**
Unit Purchase Price	$879	$12.59	$12.59	$12.59	**$492**	$12.59	$12.59	$12.59	**$492**	$12.59
Damaged Parts Replacement Cost		**$143**	**$143**	**$143**		**$143**	**$143**	**$143**		**$143**
Total Cost	$849,114,000	$98,021,700	$98,021,700	$98,021,700	$309,960,000	$98,021,700	$98,021,700	$98,021,700	$309,960,000	$98,021,700
$ Devaluation Rate due to Inflation	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Net Present Value	$849,114,000	$93,354,000	$88,908,571	$84,674,830	$255,004,859	$76,802,567	$73,145,302	$69,662,192	$209,793,129	**$63,185,662**
TOTAL NET PRESENT VALUE (9 years)	**$1,863,645,112**									
Average Net Present Value/Year (4 Years Life Cycle)		**$130,485,565**								

Outer-shell 5 Year Service Life	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Quantity	966,000	**630000**	**630000**	**630000**	**630000**	**630000**	**630000**	**630000**	**630000**	**630000**
Unit Purchase Price	$879	$12.59	$12.59	$12.59	$12.59	**$492**	$12.59	$12.59	$12.59	$12.59
Damaged Parts Replacement Cost		**$143**	**$143**	**$143**	**$143**		**$143**	**$143**	**$143**	**$143**
Total Cost	$849,114,000	$98,021,700	$98,021,700	$98,021,700	$98,021,700	$309,960,000	$98,021,700	$98,021,700	$98,021,700	$98,021,700
$ Devaluation Rate due to Inflation	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Net Present Value	$849,114,000	$93,354,000	$88,908,571	$84,674,830	$80,642,695	$242,861,771	$73,145,302	$69,662,192	$66,344,945	**$63,185,662**
TOTAL NET PRESENT VALUE (9 years)	**$1,711,893,968**									
Average Net Present Value/Year (5 Years Life Cycle)		**$118,088,373**								

As the service life of IOTV outer-shell components increases from three (3) to four (4) and five (5) years, the total outlay in terms of NPV during the ten (10) year period decreases from $2,024 to $1,864, and $1,712 billion, respectively….a total of $312 million NPV potential savings in ten (10) years. The average NPV outlay per year during each of their respective first service life cycle declines from $150.0 million for the three (3) year service life to $130.5 million for the four (4) year service life, and to $118.1 million for the five (5) year service life. It is obvious that the longer the outer-shell service life, the better is the economics.

In our Commercial Cleaning Study, each IOTV sample was cleaned three (3) times. At the end of the trial, very little physical degradation was observed as a result of cleaning. It appears that most IOTV outer-shell and Yoke and Collar components can be cleaned more than three (3) wash cycles.

TABLE B-4. CLEANING PRICE EFFECTS

Cleaning Price: $14.48	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Quantity	966,000	**630,000**	**630000**	**630000**	**630000**	**630000**	**630000**	**630000**	**630000**	**630000**
Unit Purchase Price (Cleaning Price 15% Higher)	$879	**$14.48**	**$14.48**	**$492**	**$14.48**	**$14.48**	**$492**	**$14.48**	**$14.48**	**$492**
Damaged Parts Replacement Cost		**$143**	**$143**		**$143**	**$143**		**$143**	**$143**	
Total Cost	$849,114,000	$99,211,455	$99,211,455	$309,960,000	$99,212,400	$99,212,400	$309,960,000	$99,212,400	$99,212,400	$309,960,000
$ Devaluation Rate due to Inflation	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Net Present Value	$849,114,000	$94,487,100	$89,987,714	$267,755,102	$81,622,287	$77,735,511	$231,296,924	$70,508,400	$67,150,858	**$199,802,980**
TOTAL NET PRESENT VALUE	**$2,029,460,877**									
Average Net Present Value/Year (1st Rotation Cycle)		**$150,743,305**								
Cleaning Price: $12.59	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Quantity	966,000	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**
Unit Purchase Price	$879	**$12.59**	**$12.59**	**$492**	**$12.59**	**$12.59**	**$492**	**$12.59**	**$12.59**	**$492**
Damaged Parts Replacement Cost		**$143**	**$143**		**$143**	**$143**		**$143**	**$143**	
Total Cost	$849,114,000	$98,021,700	$98,021,700	$309,960,000	$98,021,700	$98,021,700	$309,960,000	$98,021,700	$98,021,700	$309,960,000
$ Devaluation Rate due to Inflation	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Net Present Value	$849,114,000	$93,354,000	$88,908,571	$267,755,102	$80,642,695	$76,802,567	$231,296,924	$69,662,192	$66,344,945	**$199,802,980**
TOTAL NET PRESENT VALUE	**$2,023,683,977**									
Average Net Present Value/Year (1st Rotation Cycle)		**$150,005,891**								

TABLE B-4 above shows the effects of increasing the commercial cleaning cost by 15% from $12.59 to $14.48 per IOTV garment. A 15% cleaning cost increase only increases the ten (10) year total NPV outlay by 0.29% and the average annual NPV outlay from Year 2 through Year 4 by less than 0.50%. Relatively, the comparison is insensitive to the price of cleaning.

TABLE B-5 shows the effects of decreasing the annual dollar devaluation/inflation rate to 4%. Reducing the inflation rate from 5% to 4% increases the NPV outlay by about 3% or $59 million during the ten (10) year period.

TABLE B-5. EFFECTS OF ANNUAL DOLLAR DEVALUATION/INFLATION RATE

4% Annual Inflation Rate	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Quantity	966,000	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**
Unit PurchaseCleaning Price	$879	**$12.59**	**$12.59**	**$492**	**$12.59**	**$12.59**	**$492**	**$12.59**	**$12.59**	**$492**
Damaged Parts Replacement Cost		**$143**	**$143**		**$143**	**$143**		**$143**	**$143**	
Total Cost	$849,114,000	$98,021,700	$98,021,700	$309,960,000	$98,021,700	$98,021,700	$309,960,000	$98,021,700	$98,021,700	$309,960,000
$ Devaluation Rate due to Inflation	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Net Present Value	$849,114,000	$94,251,635	$90,626,572	$275,553,311	$83,789,360	$80,566,692	$244,965,890	$74,488,436	$71,623,496	**$217,773,785**
TOTAL NET PRESENT VALUE	**$2,082,753,177**									
Average Net Present Value/Year (1st Rotation Cycle)		**$153,477,173**								

5% Annual Inflation Rate	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Quantity	966,000	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**	**630,000**
Unit Purchase Price	$879	**$12.59**	**$12.59**	**$492**	**$12.59**	**$12.59**	**$492**	**$12.59**	**$12.59**	**$492**
Damaged Parts Replacement Cost		**$143**	**$143**		**$143**	**$143**		**$143**	**$143**	
Total Cost	$849,114,000	$98,021,700	$98,021,700	$309,960,000	$98,021,700	$98,021,700	$309,960,000	$98,021,700	$98,021,700	$309,960,000
$ Devaluation Rate due to Inflation	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Net Present Value	$849,114,000	$93,354,000	$88,908,571	$267,755,102	$80,642,695	$76,802,567	$231,296,924	$69,662,192	$66,344,945	**$199,802,980**
TOTAL NET PRESENT VALUE	**$2,023,683,977**									
Average Net Present Value/Year (1st Rotation Cycle)		**$150,005,891**								

TABLE B-6. EFFECTS OF LOWER ANNUAL REPAIR COST ($72/IOTV)

Cleaning Scenario ($72 Damaged Parts Repair Cost and Replacing the Outer-shell Materials Every 3 years)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Quantity*	966,000	**$630,000**	**$630,000**	**$630,000**	**$630,000**	**$630,000**	**$630,000**	**$630,000**	**$630,000**	**$630,000**
Unit Purchase Price**	$879	**$12.59**	**$12.59**	**$492**	**$12.59**	**$12.59**	**$492**	**$12.59**	**$12.59**	**$492**
Repair Cost		**$72**	**$72**		**$72**	**$72**		**$72**	**$72**	
Total Cost	$849,114,000	$53,291,700	$53,291,700	$309,960,000	$53,291,700	$53,291,700	$309,960,000	$53,291,700	$53,291,700	$309,960,000
$ Devaluation Rate due to Inflation	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Net Present Value	$849,114,000	$50,754,000	$48,337,143	$267,755,102	$43,843,213	$41,755,441	$231,296,924	$37,873,416	$36,069,920	**$199,802,980**
TOTAL NET PRESENT VALUE	**$1,806,602,140**									
Average Net Present Value/Year (1st Rotation Cycle)		**$122,282,082**								

Cleaning Scenario ($143 Damaged Parts Replacement Cost and Replacing the Outer-shell Materials Every 3 years)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Quantity*	966,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000	630,000
Unit Purchase Price**	$879	**$12.59**	**$12.59**	**$492**	**$12.59**	**$12.59**	**$492**	**$12.59**	**$12.59**	**$492**
Damaged Parts Replacement Cost		**$143**	**$143**		**$143**	**$143**		**$143**	**$143**	
Total Cost	$849,114,000	$98,021,700	$98,021,700	$309,960,000	$98,021,700	$98,021,700	$309,960,000	$98,021,700	$98,021,700	$309,960,000
$ Devaluation Rate due to Inflation	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Net Present Value	$849,114,000	$93,354,000	$88,908,571	$267,755,102	$80,642,695	$76,802,567	$231,296,924	$69,662,192	$66,344,945	**$199,802,980**
TOTAL NET PRESENT VALUE	**$2,023,683,977**									
Average Net Present Value/Year (1st Rotation Cycle)		**$150,005,891**								

TABLE B- 6 above examines the effects of repairing the damaged parts instead of replacing them. Obviously as the outer-shell component repair and replacement cost per IOTV decreases from $143 to $72, it would favor the “Cleaning” scenario even more. By repairing the damaged components instead of replacing them, it could save an additional $28 million (NPV) per year from Year 2 through Year 4 and a total of $217 million (NPV) in the ten (10) year period.

B.5 Risk and Opportunity Assessments

As this analysis reveals, there is substantial savings in “cleaning” versus “discarding and replacing” soiled IOTV components. Even though the actual contracted cleaning price and interest rate may vary from the estimates we used in the analysis, they have very little impact to the comparison. The one variable that has the largest impact on the amount of savings is the service life of the outer-shell and Yoke and Collar components.

In our Commercial Cleaning Study, the IOTV samples (outer-shell and Yoke and Collar components without the Soft Ballistics Inserts) were washed three (3) times. As the economics improve drastically with the increase in service life, it would be more than worthwhile to conduct an extended wash trial to determine the final end point criteria for cleaning.

Other than the economic factors, the uncertainties or risks lie more on the implementation aspects of rolling-out the cleaning program, assuring the performance and quality of the contracted cleaners, coordinating the delivery orders, and managing the operations. However, these operational risk factors are expected to diminish with time as a part of the learning curve.

Further Cost Saving & Logistics Improvement Opportunities:

- Possibility of further cost savings by investigating the feasibility of cleaning the Soft Ballistic Inserts.
- Acquiring and establishing Computer-controlled Wet Cleaning capabilities in the field.

B.6 Acknowledgement

The authors would like to acknowledge the management of S-PSID, Life Cycle Logistics and PM-SPIE for their vision to initiate and sponsor the IOTV Commercial Cleaning Study. Special thanks are extended to Mr. Norm Fanning for his unwavering support and guidance through this project and editorial comments, Mr. Joe Rhodes for providing the IOTV parts NSN information, and to Mr. Sean O’Donoghue for reviewing and providing editorial comments to this report.

APPENDIX

C. Computer Controlled Wet Cleaning Reference Material

C. 1 What is Wet Cleaning:

Wet cleaning is a non-toxic, environmentally safe alternative to the solvent based dry cleaning, utilizing computer-controlled washing machines, biodegradable soaps, detergents and conditioners.

According to the Environmental Protection Agency (EPA), Wet Cleaning is the safest professional method of cleaning. It does not use hazardous chemicals; it does not generate hazardous waste, nor create air pollution, and reduce the potential for water and soil contamination. It uses the universal solvent - water - along with special computer-controlled machines such as the ones utilized by our cleaning trial contractor, Chesley the Cleaner (http://www.epa.gov/dfe/pubs/garment/wsgc/wetclean.htm).

Wet-cleaning offers several advantages, such as lowered costs for start-up capital, supplies, equipment and hazardous waste disposal, as well as less reliance on skilled labor.

A more detailed description of Computer-controlled Wet Cleaning is provided in the EPA Report (EPA744-K-96-002, May 1997) entitled "Wet Cleaning." Included in this report is also a list of professional clothes cleaning establishments with the ability to provide wet cleaning services.

C.2 Which Professional Cleaning Establishments Offer Wet Cleaning Services?

EPA published a report (EPA744-K-96-002) entitled "Wet Cleaning" in May 1997. In this report, it provides a list of over 120 professional cleaners and their contact information, which have the ability to provide wet cleaning services.

A more updated list has been compiled by NoDryClean.com and is accessible through their website: www.nodryclean.com/map/state.html.

C.3 Computer-controlled Wet Cleaning Equipment/Detergents

Although there is a diversity of professional wet cleaning equipment available in the market today, they all share many common features. Among them, computer-control and programmability are the essential components.

Anthony Star and Cindy Vasquez of Center for Neighborhood Technology (CNT) published a Wet Cleaning Equipment Report dated July 1999. In their report, it lists various Wet Cleaning Original Equipment Manufacturers, the models which they offer, wash load capacities, suggested equipment prices, as well as the detergents developed specifically for wet cleaning.   Apparent from the report is that computer-controlled wet cleaning is well established in the laundry industry and is a very viable cleaning technology which offers many advantages.

More details on the subject are accessible through the CNT website (www.cnt.org/wetcleaning/final-report/learned#technology).

APPENDIX

D. Computer-controlled Wet Cleaning Conditions and Procedures

D.1 IOTV Disassembly Procedures

NOTE

The order of disassembly is not important. Items may be disassembled in any expedient order.

1. Unsnap and remove the lower back protector and groin protector (Figure D-1.1).

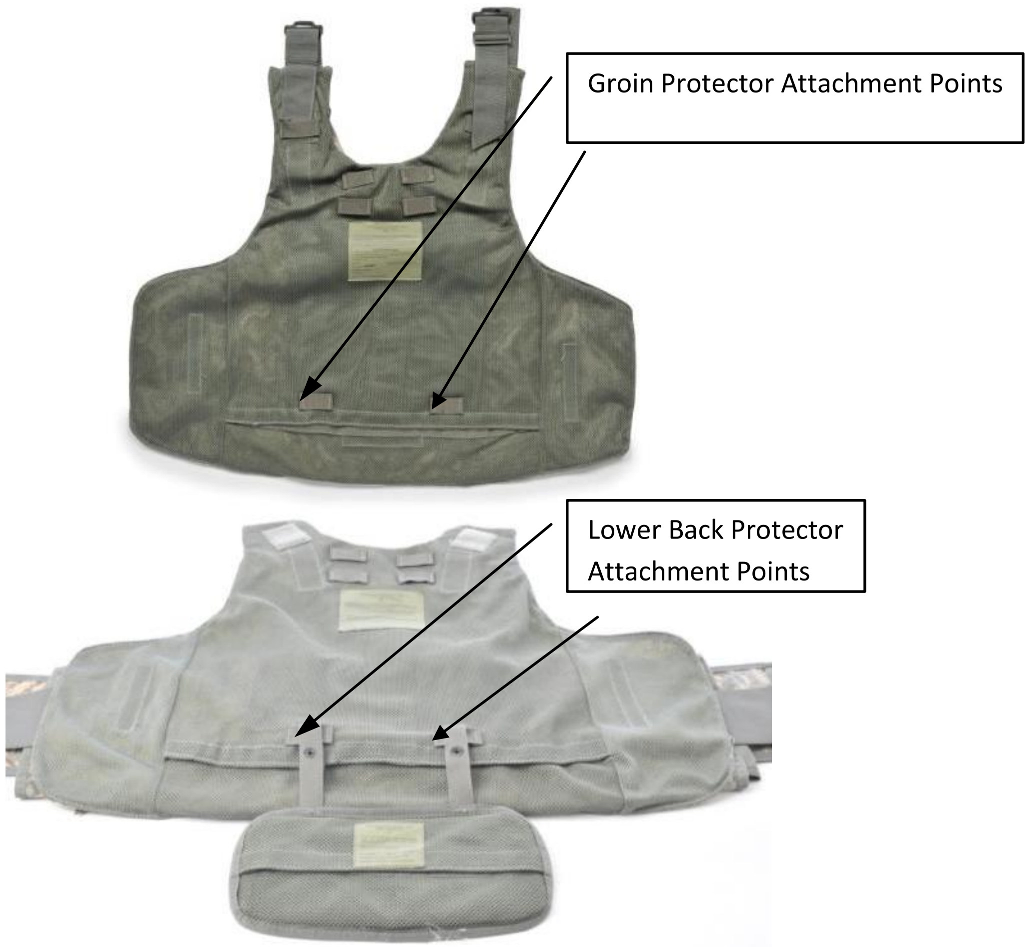

Figure D-1.1. Lower Back and Groin Protector Attachment Points.

2. Remove soft ballistic inserts from lower back and groin protector assemblies by separating the hook and pile tape fasteners on the carrier (Figure D-1. 2).

Figure D-1.2. Removing Soft Ballistic Inserts.

3. Unsnap and remove the front and back yoke/collar from vest (Figures D-1.3 and D-1.4).

Figure D-1.3. Removing Front IOTV Yoke and Collar Assembly.

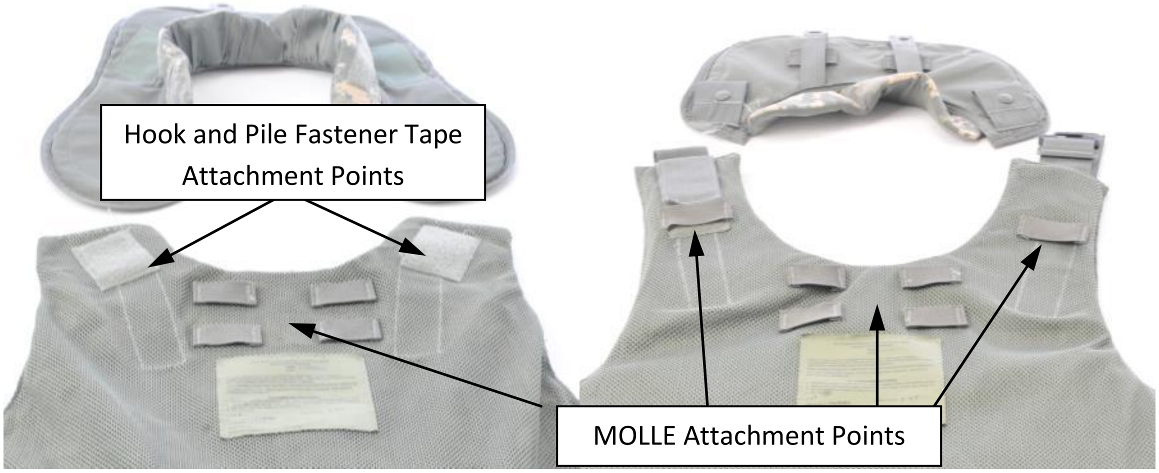

Figure D-1.4. Yoke and Collar Attachment Points.

4. Separate the front and back IOTV carriers by removing the quick release cable completely, and unsnapping and releasing the hook and pile fasteners on the left shoulder (Figure D-1.5).

Figure D-1.5. IOTV Quick Release.

5. Remove side plate carriers and internal waistband (Figure D-1.6).

Figure D-1.6. Removing Side Ballistic Carriers and Internal Waistbands.

6. Remove ballistic inserts from front and back IOTV carriers (Figure D-1.7).

Figure D-1.7. Removing Ballistic Inserts from Front and Back Carriers.

D.2 IOTV Cleaning Procedures

INITIAL SETUP

Equipment

- Washer: High Extract (300 G), 65-lb (dry) capacity, solid mount computer-controlled wet clean system, Wascomat® Model EXSM-230C or equivalent
- Dryer: Wascomat® Model TD75 RMC or equivalent

Materials

- Lanadol® Avant® Detergent
- Lanadol® Aktiv® Detergent
- Perforated Laundry Bag
- Suitable Personal Protective Gloves
- Laundry ID Tags or Wash-resistant Bar Code Label (human readable)
- Ventilated Plastic Bag for Storing Cleaned IOTV Components
- Plastic Bag for Storing Ballistic Inserts

Inspection Tool

- Temperature Measuring Instrument (70 °F – 200 °F capability, 1 °F accuracy)
- Textile Fabric Moisture Analyzer (0% – 15% moisture capability, 1% accuracy)

INTRODUCTION

The Improved Outer Tactical Vest (IOTV) consists of 15 individual components. Ten of the components are machine-washable using the instructions outlined below. The remaining five components consist of the soft ballistic inserts and the quick release cable. None of these items shall be machine washed. The laundry procedures outlined below apply to the items marked “Yes” in the Washable column in **Table D-2.1**.

Table D-2.1. IOTV Components.

Item #	Picture		Item Name	Washable
	Front View	Back View		
1			IOTV Front Carrier	Yes
2			IOTV Back Carrier	Yes
3			Right External Side Plate Carrier	Yes
4			Left External Side Plate Carrier	Yes
5			Right Internal Waistband	Yes

Item #	Picture		Item Name	Wash able
	Front View	Back View		
6			Left Internal Waistband	Yes
7			Back Yoke/Collar Assembly	Yes
8			Front Yoke/Collar Assembly	Yes
9			Groin Protector Carrier	Yes

Item #	Picture		Item Name	Wash able
	Front View	Back View		
10			Lower Back Protector Carrier	Yes
11			Front Ballistic Insert	No
12			Back Ballistic Insert	No
13			Lower Back Protector Ballistic Insert	No

Item #	Picture		Item Name	Wash able
	Front View	Back View		
14			Groin Protector Ballistic Insert	No
15			Cable Release Assembly	No

LEGEND:

Black Circle – Indicates recommended location to pin tracking ID tag or label. Pin to MOLLE straps at mark.

Black Triangle – Indicates recommended location to place adhesive-backed ID tracking label.

Preparation for Cleaning

WARNING

Wear suitable protective gloves when handling soiled IOTVs.

NOTE

It is recommended that all component parts of an IOTV are tracked throughout the cleaning process so they can be reassembled properly. Tracking individual components and ballistic inserts will minimize risk of improper re-assembly and functionality.

1. If not already done, disassemble IOTV in accordance with Appendix A "Disassembly Procedures."
2. Inventory IOTV, ensuring all parts listed in **Table D.2.1** are present.
3. Record the size, manufacturer and lot number of each IOTV garment.

CAUTION

Do not pin or puncture any soft ballistic armor. Pins for ID tags shall only be placed on the MOLLE webbing and not through the nylon fabric.

NOTE

Laundry ID tags or labels shall be pinned to the washable IOTV components and cable release assembly. An adhesive-backed ID label shall be used for soft ballistic inserts.

4. Affix a traceable laundry ID tag or wash-resistant ID label with appropriate tracking information (i.e. information which can allow complete traceability to the original IOTV, customer order and any item information which might be provided with the order by the customer) on each component at locations shown in **Table D-2.1**.   Sample pinning locations shown in **Figure D-2.1**.

Figure D-2.1. Sample Tag Pinning Locations.

5. Place all soft ballistic inserts and quick release cable (**Table D-2.1**, Items 11 through 15) in a plastic bag, store the bag in an appropriate container and set aside until after wash. Each container shall hold the soft ballistic inserts of only one IOTV garment.
6. Inspect all washable components (**Table D-2. 1**, Items 1 through 10) for damage, defects, heavy soiling and stains. Note any damage or defects.

7. Wet the heavily stained and soiled areas with the undiluted spot cleaning solution (Lanadol® Avant®).
8. Place all washable components (**Table D-2.1**, Items 1 through 10) in a perforated laundry bag. Each laundry bag shall hold only one IOTV.
9. Identify the perforated laundry bag with a suitable laundry ID tag or label for tracking.

Washing Procedures

NOTE

> The cleaning conditions below are based on the Wascomat® Model EXSM-230C washer.
>
> Do not overload the wash cylinder. Do not exceed 50% of the rated capacity of the machine.
>
> The maximum load for a typical 65-lb machine is 5 IOTV garments.

Wash IOTVs inside the perforated laundry bags using the Wascomat® Model EXSM-230C washer or an equivalent computer-controlled, wet cleaning machine, using settings listed in **Table D-2.2** and detergents listed in **Table D-2.3**.

Table D-2.2. Process Cycle Program

Step	Process Description	Time
0	Head	
	• Buzzer at Program End	On
	• Motor Gentle Action On Time	00:05
	• Motor Gentle Action Off Time	00:10
	• Motor Normal Action On Time	00:10
	- Motor Normal Action Off Time	00:05
1	Prewash (1)	
	- Wash Time (min:sec)	08:00
	- Temperature (degree C)	40
	- Temperature Variability Range (degree C)	+/- 2
	- Second Fill Level (liters)	110
	- Cold Water	On
	- Hot Water	On
	- Fill Gentle	On
	- Heat Gentle	On
	- Wash Normal	On
	- Motor Speed During Filling (RPM)	20
	- Motor Speed During Heating (RPM)	20
	- Motor Speed During Wash (RPM)	30
	- Motor Acceleration (RPM/sec)	20

Step	Process Description	Time
	- Detergent Signal (Avant® @4 ml/sec)	01:30
2	Drain (1)	
	- Motor Normal	On
	- Drain Normal	On
	- Drain Time (min:sec)	1:00
	- Motor Speed During Drain Time (RPM)	41
	- Motor Acceleration During Drain (RPM/sec)	20
3	Main Wash (1)	
	- Wash Time (min:sec)	10:00
	- Temperature (degree C)	40
	- Temperature Variability Range (degree C)	+/- 2
	- Second Fill Level (liters)	110
	- Level Variability Range (liters)	+/- 10
	- Cold Water	On
	- Hot Water	On
	- Fill Gentle	On
	- Heat Gentle	On
	- Wash Normal	On
	- Motor Speed During Filling (RPM)	20
	- Motor Speed During Heating (RPM)	20
	- Motor Speed During Wash (RPM)	30
	- Motor Acceleration (RPM/sec)	20
	- Detergent Signal (Aktiv® @4ml/sec)	01:00

Step	Process Description	Time
	- Detergent Signal (Avant® @4ml/sec)	00:30
4	Drain (2)	
	- Motor Normal	On
	- Drain Normal	On
	- Drain Time (min:sec)	00:40
	- Motor Speed During Drain Time (RPM)	41
	- Motor Acceleration During Drain (RPM/sec)	20
5	Spin (1)	
	- Drain Normal	On
	- Extract Time (min:sec)	00:30
	- Extract Speed (RPM)	400
6	Rinse (1)	
	- Wash Time (min:sec)	02:00
	- Temperature (degree C)	40
	- Temperature Variability Range (degree C)	+/- 2
	- Second Fill Level (liters)	141
	- Level Variability Range (liters)	+/- 15
	- Cold Water	On
	- Hot Water	On
	- Fill Gentle	On
	- Heat Gentle	On
	- Wash Normal	On
	- Motor Speed During Filling (RPM)	20

Step	Process Description	Time
	- Motor Speed During Heating (RPM)	20
	- Motor Speed During Wash (RPM)	30
	- Motor Acceleration (RPM/sec)	20
7	Drain (3)	
	- Motor Normal	On
	- Drain Normal	On
	- Drain Time (min:sec)	00:40
	- Distribution Time (min:sec)	00:10
	- Motor Speed During Drain Time (RPM)	41
	- Motor Acceleration During Drain (RPM/sec)	20
8	Spin (2)	
	- Drain Normal	On
	- Extract Time (min:sec)	00:30
	- Extract Speed (RPM)	400
9	Rinse Repeat (1)	
	- Wash Time (min:sec)	01:00
	- Temperature (degree C)	40
	- Temperature Variability Range (degree C)	+/- 2
	- Second Fill Level (liters)	141
	- Level Variability Range (liters)	+/- 15
	- Cold Water	On
	- Hot Water	On
	- Fill Gentle	On

Step	Process Description	Time
	- Heat Gentle	On
	- Wash Normal	On
	- Motor Speed During Filling (RPM)	20
	- Motor Speed During Heating (RPM)	20
	- Motor Speed During Wash (RPM)	30
	- Motor Acceleration (RPM/sec)	20
10	Drain (4)	
	- Motor Gentle	On
	- Drain Normal	On
	- Drain Time (min:sec)	01:00
	- Distribution Time (min:sec)	00:20
	- Motor Speed During Drain Time (RPM)	41
	- Motor Acceleration During Drain (RPM/sec)	20
11	Spin (3)	
	• Drain Normal	On
	• Extract Time (min:sec)	00:30
	• Extract Speed (RPM)	690
12	End	

Table D-2.3. Approved Detergents.

Manufacturer	Product Trade Name	Function	Application Stage	Amount
Kreussler Company	Lanadol® Avant®	Pre-spotting Agent	▪ Prewash ▪ Main Wash	360 ml 120 ml

	Lanadol® Aktiv®	Detergent	• Main Wash	240 ml

Drying

CAUTION

Overheating and over-drying will result in damage to the IOTV that may not be readily apparent. Follow all directions carefully. The dryer must have proper temperature and residual moisture controls to assure conformance to the process and finished product specifications.

NOTE

Do not load dryer to more than 50% of rated capacity. The maximum load for a typical 75-lb machine is 6 IOTVs.

1. Dry the IOTVs in a drying machine capable of detecting the amount of residual moisture in the garment and automatically stopping the drying cycle when the garments reach the desirable residual moisture content (Wascomat® model TD75RMC or equivalent). The process conditions for the drying machine are located in **Table D-2.4**.
2. Upon completion of drying cycle, open one of the laundry bags and check the garment components for residual moisture level and temperature. Do not over-dry or over-heat the garment.
3. If residual moisture level is higher than the desirable range in **Table D-2.4**, extend the drying cycle time in small increments until the desirable residual moisture conditions are met.

Table D-2.4. Drying Process Conditions.

Condition	Setting/Measurement
Garment Residual Moisture Level	5 - 7%
Maximum Air Temperature	180 °F
Maximum Garment Temperature	110 °F
Approximate Cycle Time	20 minutes

Post-Cleaning Inspection

1. Inspect IOTV components for cleanliness.
2. If any of the components is not sufficiently cleaned (best commercial practices), repeat the cleaning and drying process.
3. If IOTV components are clean, allow items to acclimate to room relative humidity and temperature.
4. Once acclimated, regroup the clean washed components with the corresponding soft ballistic inserts and quick release cables that were previously set aside.
5. Check ID tag/label for each component and ballistic inserts to ensure that all items match to the original IOTV.
6. Inventory all items in accordance with **Table D-2. 1** to make sure there is no missing part. Note any discrepancies with inventory taken prior to washing.

ASSEMBLY

If required, assembly IOTV in accordance with instructions in Appendix B and then package in accordance with Packaging section. If assembly is not required, package in accordance with Packaging section.

PACKAGING

1. Place the matching bag of ballistic inserts and quick release cables, and all clean components belonging to the same IOTV in a separate, ventilated plastic bag. If IOTV is assembled, place in a single ventilated bag.
2. Identify the ventilated bag of IOTV or IOTV parts with a lot/serial code that is traceable to the specific customer order and any item information which might be provided with the order.
3. Return the cleaned IOTVs in the ventilated plastic bag to customer per order requirement.

D.3 ASSEMBLY

1. Install soft ballistic inserts in lower back, groin and deltoid protectors (**Figures D-3.1** and **D-3.2**).
    a. Lay the carrier on a flat surface with inner side (or side with label) facing up.
    b. Separate hook and loop seam and install soft ballistic insert with the label side facing up.
    c. Position ballistic insert inside the carrier, aligning the hook and loop tapes and ensuring the carrier material is smooth and flat after the installation.
    d. Re-seal seam of the insert pocket.

Figure D-3.1. Lower Back Protector Assembly.

Figure D-3.2. Groin Protector Assembly.

2. Install front and back ballistic inserts.

   a. Lay the carrier on a flat surface with inner side (or side with label) facing up (**Figure D-3.3**).

Figure D-3.3. Lay Carrier Flat.

   b. Lay the ballistic insert near the carrier and fold shoulder and side flaps toward the center of the insert (**Figure D-3.4**).

Figure D-3.4. Folding Soft Ballistic Inserts.

c. Separate hook and loop seam and install soft ballistic insert with the label side facing up.

d. Position ballistic insert inside the carrier (**Figure D-3.5**).

Figure D-3.5. Placing Ballistic Inserts in Carrier.

e. Unfold the ballistic insert inside the carrier. Flatten and smooth the ballistic inserts inside the carrier (**Figure D-3.6**). There should be no bunching, buckling or folds in the insert.

Figure D-3.6. Smoothing Ballistic Insert.

f. Align the hook and loop fastener tapes on the carrier with those on the insert. Refer to **Figure D-3.7** and match point A to point A. Continue through point D.

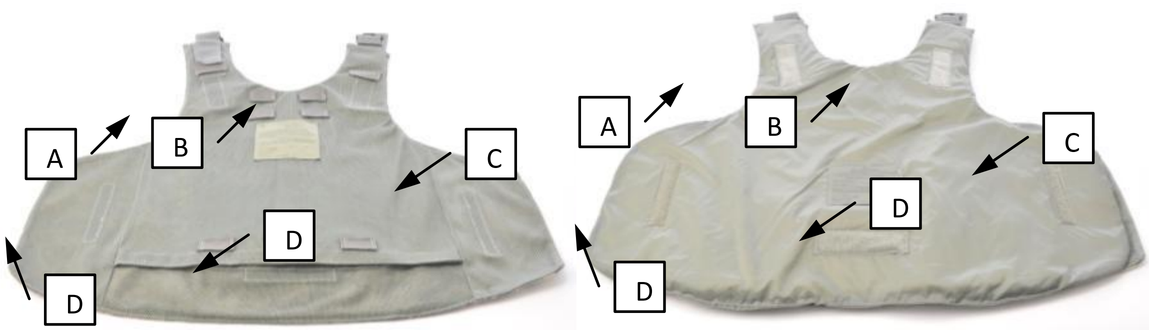

Figure D-3.7. Matching Hook and Pile Tape Fasteners.

g. Re-seal seam of the carrier (**Figure D-3.8**).

Figure D-3.8. Re-sealing Carrier.

3. Install quick-release cable assembly.

   a. Route the cables into the cable release handle pocket on the front carrier. Push the cables through the right shoulder channel and through the aft guide channel (**Figure D-3.9**).

Figure D-3.9. Routing the Quick Release Cable.

   b. Stow the webbing loop and the quick-release handle in the pocket and secure with the hook and loop patches inside the pocket (**Figure D-3.10**).

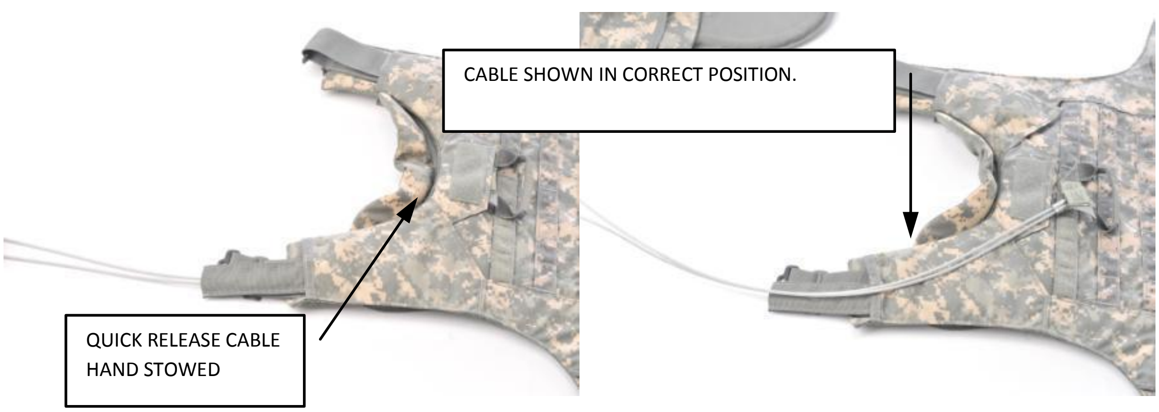

Figure D-3.10. Stowing Cable Release Handle.

4. Assemble the front and back carriers.
   a. Lay both back and front carriers on a flat surface with like shoulder together (right to right, left to left).
   b. Route the left shoulder of the front carrier into the left shoulder of the rear carrier (**Figure D-3.11**). Repeat for right side (**Figure D-3.12**).

Figure D-3.11. Shoulder Routing.

Figure D-3.12. Routing Right Shoulder.

c. Open the upper back flap on the back carrier. The buckle from the front carrier shoulder straps should now be in the back carrier.

NOTE

Strap loops and center cable guides may be tan in color to assist in cable routing.

d. For both shoulders, insert strap loops into the front carrier shoulder buckles (**Figure D-3.13**).

Figure D-3.13. Short Quick Release Cable Routing.

e. Route the short quick release cable through the right shoulder cable strap loop, the center cable guide and the left shoulder cable strap loop leaving the cable on the left side (**Figure D-3.13**).

f. Insert the end of the short cable into the cable guide on the left side of the rear carrier (**Figure D-3.14**).

Figure D-3.14. Stowing the Short Quick Release Cable.

g. Open the large flap on the back carrier and route the long quick release cable down through the opening at the top of the flap (**Figure D-3.15**).

Figure D-3.15. Routing of Long Quick Release Cable.

h. Secure upper back flap at hook and pile seam.

5. Install the internal waistbands and side plate carriers.

   a. Lay back carrier flat with label side facing down (**Figure D-3.16**).

Figure D-3.16. Lay Back Carrier Flat.

b. Route the 1-inch strap of the right internal waistband through the webbing loop and wing channel on the right side of the carrier. Repeat for left side (**Figure D-3.17**). Ensure the internal waistbands are flat and the labels are facing down (toward the carrier).

Figure D-3.17. Inserting Internal Waistbands.

c. Route the free end of the 1-inch webbing on the right internal waistband through the metal ring on the center webbing loop.

d. Route the end of the webbing back through the buckle leaving at least 2 inches of excess.

e. Route the right side plate carrier through the right wing channel, positioning the metal rings near the webbing loops. The label should be facing the carrier. Repeat for the left side.

Figure D-3.18. Install Side Plate Carriers.

f. Starting at the top center webbing loop, place the metal ring on the left side plate carrier over the top center webbing. Place the metal ring from the right side plate carrier over the center webbing.

Figure D-3.19. Side Plate Carrier Routing.

g. Place the metal ring from the left internal waistband over the middle webbing loop.

h. Place the metal ring from the left side plate carrier over the bottom center webbing. Place the metal ring from the right side plate carrier over the bottom center webbing.

i. Route the quick release cable through the center webbing loops from top to bottom.

Figure D-3.20. Routing Long Cable.

j. Place end of quick release cable in the retention pocket (**Figure D-3.21**).

Figure D-3.21. Stowing Long Cable.

k. Gather any loose straps and secure using elastic keepers.

l. Close back pocket and tuck the bottom of back flap up into the back flap pocket.

6. Attach yoke and collar assembly.

   a. Lay IOTV on a flat surface with the inside surface facing up.

b. Position the yoke collar on the carrier with label facing up.

c. Attach collar assembly to back carrier using standard MOLLE weave at both attachment points.

Figure D-3.22. Collar Attachment Sequence.

d. Mate hook and pile fasteners (back carrier) or snap side straps (front carrier) to complete attachment.

Figure D-3.23. Complete Collar Attachment.

7. Install groin protector and lower back protector (as required).

   a. Lay carriers on flat surface with interior facing up.

   b. Lay groin protector near bottom of front carrier with label facing up.

   c. Route straps on groin protector through loops and snap (**Figure D-3.24**).

   d. Lay the kidney protector near the bottom of the back carrier with label facing up.

   e. Route straps on kidney protector through loops and snap.

Figure D-3.24. Attaching Groin Protector.