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| REPORT DOCUMENTATION PAGE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                   |                                | Form Approved OMB NO. 0704-0188                          |                                                          |                                                   |
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| 1. REPORT DATE (DD-MM-YYYY)<br>01-11-2012                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                   | 2. REPORT TYPE<br>Final Report |                                                          | 3. DATES COVERED (From - To)<br>1-Feb-2005 - 31-Jan-2012 |                                                   |
| 4. TITLE AND SUBTITLE<br>Novel Materials Design and Fabrication for Army Needs                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                                | 5a. CONTRACT NUMBER<br>W911NF-05-1-0039                  |                                                          |                                                   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |                                | 5b. GRANT NUMBER                                         |                                                          |                                                   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |                                | 5c. PROGRAM ELEMENT NUMBER<br>206023                     |                                                          |                                                   |
| 6. AUTHORS<br>Dr. Christine W. Cole, Dr. Deborah K. Lickfield                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                   |                                | 5d. PROJECT NUMBER                                       |                                                          |                                                   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |                                | 5e. TASK NUMBER                                          |                                                          |                                                   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |                                | 5f. WORK UNIT NUMBER                                     |                                                          |                                                   |
| 7. PERFORMING ORGANIZATION NAMES AND ADDRESSES<br>Clemson University<br>Office of Sponsored Programs<br>Clemson University<br>Clemson, SC 29634 -5702                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                   |                                | 8. PERFORMING ORGANIZATION REPORT NUMBER                 |                                                          |                                                   |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)<br>U.S. Army Research Office<br>P.O. Box 12211<br>Research Triangle Park, NC 27709-2211                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |                                | 10. SPONSOR/MONITOR'S ACRONYM(S)<br>ARO                  |                                                          |                                                   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |                                | 11. SPONSOR/MONITOR'S REPORT NUMBER(S)<br>47149-CH-CDP.2 |                                                          |                                                   |
| 12. DISTRIBUTION AVAILABILITY STATEMENT<br>Approved for Public Release; Distribution Unlimited                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                   |                                |                                                          |                                                          |                                                   |
| 13. SUPPLEMENTARY NOTES<br>The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |                                |                                                          |                                                          |                                                   |
| 14. ABSTRACT<br>This project included 5 sub-projects: High Strength Barrier Seams for Shelters, Outer Tactical Vest Patterns, Improved OTV patterns, Textile-based options for Reduced Helmet Weight, and Canine Footwear (Dog Booties). Each sub-project represented an Army need for improved materials and fabrication design.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                   |                                |                                                          |                                                          |                                                   |
| 15. SUBJECT TERMS<br>seams, barrier seams, IOTV, patterns, stitchless seams, dog booties                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                   |                                |                                                          |                                                          |                                                   |
| 16. SECURITY CLASSIFICATION OF:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                   |                                | 17. LIMITATION OF ABSTRACT<br>UU                         | 15. NUMBER OF PAGES                                      | 19a. NAME OF RESPONSIBLE PERSON<br>Christine Cole |
| a. REPORT<br>UU                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | b. ABSTRACT<br>UU | c. THIS PAGE<br>UU             |                                                          |                                                          | 19b. TELEPHONE NUMBER<br>864-646-8454             |

**Report Title**

Novel Materials Design and Fabrication for Army Needs

**ABSTRACT**

This project included 5 sub-projects: High Strength Barrier Seams for Shelters, Outer Tactical Vest Patterns, Improved OTV patterns, Textile-based options for Reduced Helmet Weight, and Canine Footwear (Dog Booties). Each sub-project represented an Army need for improved materials and fabrication design.

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**Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:**

**(a) Papers published in peer-reviewed journals (N/A for none)**

| <u>Received</u> | <u>Paper</u> |
|-----------------|--------------|
|-----------------|--------------|

**TOTAL:**

**Number of Papers published in peer-reviewed journals:**

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**(b) Papers published in non-peer-reviewed journals (N/A for none)**

| <u>Received</u> | <u>Paper</u> |
|-----------------|--------------|
|-----------------|--------------|

**TOTAL:**

**Number of Papers published in non peer-reviewed journals:**

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**(c) Presentations**

**Number of Presentations:**      0.00

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**Non Peer-Reviewed Conference Proceeding publications (other than abstracts):**

Received

Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

---

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received

Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

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(d) Manuscripts

Received

Paper

TOTAL:

Number of Manuscripts:

---

Books

Received

Paper

TOTAL:

Patents Submitted

A Method of Joining Two or More Substrates with a Seam (US and EPO)

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Method of Joining Two or More Substrates with a Seam (US)

## Patents Awarded

A Method of Joining Two or More Substrates with a Seam (EPO)

Method of Joining Two or More Substrates with a Seam (US)

## Awards

### Graduate Students

| <u>NAME</u>            | <u>PERCENT SUPPORTED</u> | Discipline |
|------------------------|--------------------------|------------|
| Katelyn Howay          | 1.00                     |            |
| <b>FTE Equivalent:</b> | <b>1.00</b>              |            |
| <b>Total Number:</b>   | <b>1</b>                 |            |

### Names of Post Doctorates

| <u>NAME</u>            | <u>PERCENT SUPPORTED</u> |
|------------------------|--------------------------|
| <b>FTE Equivalent:</b> |                          |
| <b>Total Number:</b>   |                          |

### Names of Faculty Supported

| <u>NAME</u>            | <u>PERCENT SUPPORTED</u> | National Academy Member |
|------------------------|--------------------------|-------------------------|
| Christine W. Cole      | 0.10                     |                         |
| Deborah K. Lickfield   | 0.20                     |                         |
| <b>FTE Equivalent:</b> | <b>0.30</b>              |                         |
| <b>Total Number:</b>   | <b>2</b>                 |                         |

### Names of Under Graduate students supported

| <u>NAME</u>            | <u>PERCENT SUPPORTED</u> |
|------------------------|--------------------------|
| <b>FTE Equivalent:</b> |                          |
| <b>Total Number:</b>   |                          |

### Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

|                                                                                                                                                                                                                          |      |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| The number of undergraduates funded by this agreement who graduated during this period: .....                                                                                                                            | 0.00 |
| The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:.....                                                    | 0.00 |
| The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:.....           | 0.00 |
| Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):.....                                                                                                                                  | 0.00 |
| Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:.....                                                                                      | 0.00 |
| The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense .....                                                                            | 0.00 |
| The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: ..... | 0.00 |

**Names of Personnel receiving masters degrees**

|                        |
|------------------------|
| <u>NAME</u>            |
| Katelyn Howay          |
| <b>Total Number:</b> 1 |

**Names of personnel receiving PHDs**

|                      |
|----------------------|
| <u>NAME</u>          |
| <b>Total Number:</b> |

**Names of other research staff**

|                        |                          |
|------------------------|--------------------------|
| <u>NAME</u>            | <u>PERCENT SUPPORTED</u> |
| Sara Betts             | 0.20                     |
| Robert Bennet          | 0.30                     |
| <b>FTE Equivalent:</b> | <b>0.50</b>              |
| <b>Total Number:</b>   | <b>2</b>                 |

**Sub Contractors (DD882)**

**Inventions (DD882)**

## 5 A Method of Joining Two or More Substrates with a Seam

Patent Filed in US? (5d-1) Y

|                                           |   |
|-------------------------------------------|---|
| Patent Filed in Foreign Countries? (5d-2) | Y |
|-------------------------------------------|---|

Was the assignment forwarded to the contracting officer? (5e) Y

Foreign Countries of application (5g-2): Germany, Gr Britain, Sweden, Spain, Italy

5a: Christine W. Jarvis

5f-1a: Clemson University

5f-c:

|         |    |       |
|---------|----|-------|
| Clemson | SC | 29633 |
|---------|----|-------|

5a: Christine W. Jarvis

5f-1a: Clemson University

5f-c:

|         |    |       |
|---------|----|-------|
| Clemson | SC | 29633 |
|---------|----|-------|

## Scientific Progress

Title: "High Strength Barrier Seams for Shelters"

Sub-projects

High Strength Barrier Seams for Shelters

Outer Tactical Vest patterns OTV

Improved OTV patterns IOTV

Textile-based options for Reduced Helmet Weight

Canine Footwear

Personnel

PI – Christine W. Cole, Ph.D.

Other Faculty – Deborah K. Lickfield, Ph.D.

Sara Betts

Graduate Student - Katelyn Howay

Staff – Robert Bennet

High Strength Barrier Seams for Shelters

Efforts on this part of the project were successful in producing barrier seams where the tensile strength of the seam exceeded that of the base materials. In each case the seam geometry was an overlap with a selected adhesive tape applied to all fabric surfaces within the seam gauge, with a combination of heat and pressure to set the seam. The successful candidate designs relative to strength were:

- ½" wide seam, Col-Pro MZ0067 (fabric) + Bemis #5250 polyester film
- 1" wide seam, St. Gobain Challenge X-22 (fabric) + Bemis #3405 polyurethane film
- 1" wide seam, St. Gobain Challenge X-CBNL (fabric) + Bemis #5250. polyester film

These same substrate materials were used to attach YKK barrier performance zippers. When tested for tensile strength, in all case, the base fabrics failed before the seam ruptured, confirming the efficacy of high strength joints produced by this method.

Prototypes of the seamed materials were tested at TNO labs in Netherlands against Mustard gas, VX, Lewisite, and Soman. With the exception of the Col-Pro MZ0067 prototype against Lewisite, all prototype seam samples showed a > 24 hour (limit of the test) breakthrough time against the selected agents. Later testing of the fabrics alone confirmed that the Col-Pro MX0067 fails against Lewisite at about 5 hours, therefore the failure of that prototype was not due to the seam.

Based on these final results, the St. Gobain Challenge fabrics combined with either of the Bemis films were determined to be suitable candidates for fabrication of shelters and other constructions where the seam would not fail on strength or against a CW challenge at a threshold level below that of the primary fabric used in the construction.

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IOTV

The work effort on the IOTV was specific to developing patterns according to specifications provided, and refining those patterns according to comments from the vest manufacturers. Ultimately 74 pattern pieces and 11 sizes, were delivered, including the deltoid protector.

Following an additional round of modifications to the shoulders, collars, and yolk designs paper patterns were supplied to vendors, along with technical support to contracting officer.

Helmet Weight Reduction

The helmet weight reduction task is directed toward textile/fabric solutions. A primary issue with physical systems which provide lift-support for the helmets is that most also contribute to constricted mobility of the wearer. While an initial prototype did not resolve that issue, a second design, featuring a soft, contoured foam collar and outer liners selected for breathability and good tactile properties, provided a more comfortable fit. Mobility restrictions with that prototype included confined chin-to-chest and lifted-chin motions. Those issues were addressed in modified prototypes which were accepted by ARO.

Additionally, a design for in-helmet impact absorption padding were investigated. These consisted of single layers of polystyrene beads which were captured between film layers to provide maximum flexibility/moldability. In-house testing indicated an improvement in rebound response when compared to the dual foam layer pads currently utilized in the ACH equipment.

## Canine Footwear

The project was a request of the Special Operations Group out of Fort Bragg, NC, to develop an improved dog bootie for the military work dogs in the Middle East. Among the required improvements were that the booties must be more robust, easy to don and doff, secure during operations, water resistant, and more ergonomic for the wearers. An initial survey of commercially available designs indicated that there were no viable options.

A novel design was developed, based on a soft, leather “moccasin” concept. Prototypes were fabricated using leather uppers and molded plastic soles with special lacing cords and locks. Final design modifications included the addition of a tongue to keep the front portion of the moccasin from riding down during activity, addition of a hard rubber sole, (source: Vibram,) fitted to the shape and size of a dog’s foot pad and replacement of tie laces with military spec shock cord to allow quick tightening and loosening.

Four (4) final prototypes which were submitted for evaluation. Twenty-one sets of the selected prototype were then manufactured and sent for trial. A primary response was a request for three (3) sizes – small, medium, large. Pending final costing approval, CAR expects to manufacture and ship 50 sets in each size.

## **Technology Transfer**