AWARD NUMBER: W81XWH-17-C-0238

TITLE: Complete and Resilient Documentation (CARD) for Operational Medical Environments

PRINCIPAL INVESTIGATOR: Kuang-Ching Wang, PhD

CONTRACTING ORGANIZATION: Clemson University
Clemson, SC 29634

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Sponsored Programs
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Clemson, SC 29634-0001

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13. SUPPLEMENTARY NOTES

14. ABSTRACT
In response to the HITI HFEHRI solicitation for research to demonstrate and validate hands-free electronic health record data entry solutions that will operate reliably in noisy operational environments, alleviate disruption of care for documentation, and prevent loss of documentation, this project studies a system-oriented approach to meet these objectives with a platform aimed to enable resilient hands-free data collection, preserve complete documentation through stages of care, and present timely information useful for the medical operation.

15. SUBJECT TERMS
Battlefield, Hands-free, Electronic health record, Documentation, Operational environments, Medical Workflow, Stages of care, Speech recognition, Noise, GPU, Deep learning, Neural network, Video, Simulation

16. SECURITY CLASSIFICATION OF:

a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON USAMRMC
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1. INTRODUCTION:

In response to the HFEHRI (Hands-Free Electronic Health Record Data Entry Initiative) solicitation for research to demonstrate and validate hands-free electronic health record data entry solutions that will operate reliably in noisy operational environments, alleviate disruption of care for documentation, and prevent loss of documentation, this project studies a system-oriented approach to meet these objectives with a platform aimed to enable resilient hands-free data collection, preserve complete documentation through stages of care, and present timely information useful for the medical operation.

2. KEYWORDS:

Battlefield
Hands-free
Electronic health record
Documentation
Operational environments
Medical
Workflow
Stages of care
Speech recognition
Noise
GPU – Graphics processing unit
Deep learning
Neural network
Video
Simulation

3. ACCOMPLISHMENTS:

What were the major goals and objectives of the project?

The project has the following four specific aims:
- Medical Workflow Studies – By conducting focus group interviews, EMS simulation drills, and identifying medical workflow driven performance metrics for CARD, this aims to inform the CARD platform design goals and assessment methods.
- Platform Development – By integrating camera and data storage to GPU-based embedded computer, developing deep-learning based speech recognition and video analysis software with focus on military operation conditions, and integrating with DoD's digital medical data platforms (TCCC card and Cerner EHR), this aims to create an extensible, prototype for CARD and to demonstrate the complete technology workflow from creating training data sets to identifying performance enhancement methods.
- Assessment – This assesses performance of the technology, the quality of recorded clinically relevant data in the TCCC format, and the level of acceptance by EMS professionals in simulated medical operations.

- Roadmap Development – This aims to derive recommendations of a technology maturation roadmap for the CARD technologies.

a. **What was accomplished under these goals?**

The project was originally planned with a two-year duration. While a 6-month no-cost extension was requested and granted to explore further developments in the speech and video analysis works, and henceforth pushing back the planned medical simulation drill #2, the majority of the proposed work has been completed by the composition of this year 2 annual report.

For medical workflow studies, we completed all focus groups, two simulation drills (#1 and #1.2), developed metrics and processes for assessments.

For platform development, the proposed CARD platform is fully implemented and we continue to enhance the speech and video algorithms, the training methodology for persistent enhancements, and added utilities for efficient launch and operation of the active CARD units with a monitoring dashboard.

For assessment, we have concluded assessing the CARD speech recognition software alongside several state-of-the-art open source speech recognition software. We have also completed a complete process to evaluate the end-to-end data entry performance assessment, together with full insights of performance of individual modules of the system. We have scheduled the next simulation drill to take place on 12/2/2019.

For roadmap development, we have begun discussion with potential DoD partners to devise a plan to formally assess the technology readiness level of CARD and, accordingly, the technology maturation roadmap.

What opportunities for training and professional development has the project provided?
Nothing to report.

How were the results disseminated to communities of interest?
The results have been presented at multiple conferences, including abstracts at MHSRS 2017, 2018 and a full paper at INTERSPEECH 2019.

What do you plan to do during the next reporting period to accomplish the goals?
In the remaining six months, efforts will focus on:
- Publication of speech technology study
- Natural language processing for error-tolerant post-processing into TCCC card
- Military-centric training method for video analysis software
- Drill #2 execution, performance assessment, and EMS personnel interviews
- Discussion with partners on next steps

Gantt Chart for year 2 and the 6-month extension:

	Y2Q1	Y2Q2	Y2Q3	Y2Q4	Y3Q1	Y3Q2
Specific Aim I- Medical Workflow Studies						

Task	Y2Q1	Y2Q2	Y2Q3	Y2Q4	Y3Q1	Y3Q2
Task 1.3: Qualitative Assessment						
Quality assessment instrument design		█	█			
Survey execution and analysis					█	
Specific Aim 2- Platform Development						
Task 2.2: Speech Recognition & Video Digest						
Video digest	█					
Cerner integration	█	█	█			
Publication of speech technology study		█	█	█	█	
Natural Language Processing study			█	█		
Video Analysis study			█	█		

Task	Y2Q1	Y2Q2	Y2Q3	Y2Q4	Y3Q1	Y3Q2
Specific Aim 3 – Assessment						
Task 3.1: Technology Assessment						
Platform benchmarking	█	█	█			
Drill #2 design and preparation	█	█	█	█		
Drill #2 execution					█	
Task 3.2: Workflow and EHR Assessment						
Qualitative Survey of workflow quality	█	█				
Specific Aim 4 – Roadmap Development						
Platform Usability and gaps assessment			█	█	█	█
Roadmap development			█	█	█	█

4. IMPACT:

What was the impact on the development of the principal discipline(s) of the project?

Impact on state-of-the-art understanding of speech recognition technology challenges for battlefield environment:

- Deep look into the question "is state-of-the-art speech solutions, either academic or commercial, ready for the battlefield?"
    - o Produced systematic benchmarking of two most advanced open source neural network-based speech recognition software by Mozilla (Deep Speech, end-to-end deep learning) and John Hopkins University (Kaldi, hybrid deep learning) with respect to battlefield noise of different types and intensity and concluded severe performance degradation with battlefield noise.

- Build foundations for DoD's long-term success in speech recognition competencies:
    - o Produced systematic assessment and analysis of speech recognition correctness's dependencies on algorithms, processing, and data (training).
    - o Derived approach to systematically assess specific speech recognition enhancement actions with measurable performance impacts
    - o Developed modular enhancement methods to enable persistent performance enhancement for hybrid deep-learning based speech recognition.

- Build foundations for DoD's long-term success in video analysis competencies:
    - o Integrated video analysis software for object and action analysis in recorded video.
    - o Explored systematic process for DoD to continuously enhance video analysis with contents reflecting DoD operation needs and priorities.

- The research expects significant impacts in:
    - o Commercial, Civilian and Military
        - – Commercial development in key technologies
        - – Synergistic use in civilian EMS, homeland security and disaster recovery
        - – New companies or consortium of companies on standard based integrated platform, from variety of data capture devices, mobile app, to cloud solutions
        - – Integration with telemedicine, enhance the care and survivability of service members
        - – Establish understanding of battlefield readiness of state-of-the-art technology
        - – Establish foundations for long-term success for DoD speech recognition competencies

    - o Academic
        - – Speech recognition, natural language understanding, and video analysis in battlefield settings is a rich area for academic research
        - – Large scale, distributed data collection (speech, video, sensors) and aggregation into individual patient data is a rich area of research

What was the impact on other disciplines?
Nothing to Report

What was the impact on technology transfer?
Nothing to Report

What was the impact on society beyond science and technology?
Nothing to Report

5. CHANGES/PROBLEMS:
Changes in approach and reasons for change

In the previous quarters, we made a strategic decision to execute an additional drill to confirm the impact of noise towards speech recognition performance, including the corresponding noise level for the "performance cliff" and the causes for different types of errors. In the January 2019 IPR meeting, review members observed that multiple projects all confirmed the same drastic impact by noise, but none has had a conclusive approach towards addressing it. In addition, common observations were made about how state of the art speech software is lacking in its vocabulary when it comes to military and medical language (similarly observed by the Clemson and CERDEC teams). Comments were also made on the unclarity of how to bootstrap deeper investigation into the potential rich information in recorded video from these solutions. These findings provide valuable insights for the Clemson team in our execution plan for the rest of the project:

- Our approach has been, from the onset, focused on long-term extensibility. Our goal was clearly set to identify the most critical aspects for the success of speech and video-based data entry in the battlefield and to identify methods that can support persistent improvement to its performance. The consensus on the need for better noise tolerance and a better language model matching military and medical operations is critically valuable.
- Our focus towards video integration has been on assuring its extensibility. The consensus is that it is more important to have a flexible platform to explore potential use cases based on flexible user inputs than to have a fixedly designed video solution.

Based on these reasonings, we have decided to make the best use of the rest of the project time, including a recently requested 6-month extension, to present a roadmap that will avail a much clearer expectation for mid-term and long-term achievable speech and video capabilities for DoD. This is not really a change, since it is in line with our original plan and goals; nonetheless, it adds significant clarity to our execution focus based on facts not available before.

Actual or anticipated problems or delays and actions or plans to resolve them

The challenges seen in speech recognition software have already extended the needed testing and development time to: 1) produce a systematic deep-look study of the noise impacts and resolutions, and 2) plan for an additional drill study to incorporate specific medical terms. While this delayed the original intended schedule, we believe this is a required step that will give us valuable guidance to the needed steps towards a robust technology development plan. Due to the decision of the extra drill, and the observed extent of speech recognition challenges, it was determined that more time was needed to develop a speech recognition software, including a long-term extensible workflow. That resulted in a later date expected for drill #2, as well as opportunities for more technical work on completing a long-term plan for speech and video analysis. Hence, the 6-month no cost extension was requested. We plan to complete the proposed extended scope in time.

Changes that had a significant impact on expenditures

The delay in personnel spending has caught up with a significantly larger team now, and that delay has given us the leverage to have this larger team to spend an additional six months working on a few high value investigations if we are approved for doing so.

- ❖ Projected Expenditure: $1,644,510   Actual Expenditure: $1,159,717.58 @ 8/31/19
- ❖ Anticipated adjustments on remaining periods – None

Burn Rate
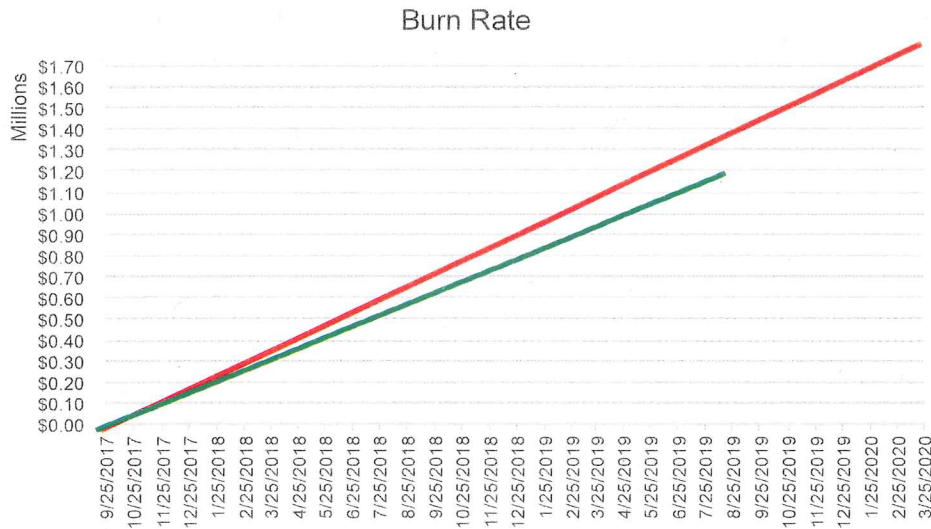
Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents:
Nothing to Report

Significant changes in use or care of human subjects:
Nothing to Report

Significant changes in use or care of vertebrate animals:
Nothing to Report

Significant changes in use of biohazards and/or select agents:
Nothing to Report

6.PRODUCTS:

Publications, conference papers, and presentations

Journal publications
Nothing to Report

Books or other non-periodical, one-time publications
Nothing to Report

Other publications, conference papers, and presentations
- Ju Lin, Sufeng Niu, Zice Wei, Xiang Lan, Adriaan J. van Wijngaarden, Melissa C. Smith, Kuang-Ching Wang, "Speech Enhancement Using Forked Generative Adversarial Networks with Spectral Subtraction", in Proceedings of INTERSPEECH 2019, Graz, Austria, Sep. 15~19, 2019.

Website(s) or other Internet site(s)
Nothing to Report

Technologies or techniques
Nothing to Report

Inventions, patent applications, and/or licenses
Nothing to Report

Other Products
Nothing to Report

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS
What individuals have worked on the project?

Provide the following information for: (1) PDs/PIs; and (2) each person who has worked at least one-person month per year on the project during the reporting period, regardless of the source of compensation (a person month equals approximately 160 hours of effort). If information is unchanged from a previous submission, provide the name only and indicate "no change."

Name: — *Kuang-Ching Wang (no change)*
Project Role: — *Principal Investigator*
Research Identifier: — *0000-0002-5675-7104*
Nearest person month worked: — *2.25*
Contribution to Project: — *Dr. Wang is responsible for all aspects of the research study.*

Name: — *Ronald Gimbel (no change)*
Project Role: — *Co-PI*
Research Identifier: — *0000-0001-8185-4013*
Nearest person month worked: — *1.0*
Contribution to Project: — *Dr. Gimbel supports Dr. Wang and Dr. Griffin in qualitative research, co-coordinating drill #1, and communication with the Palmetto Health Emergency Medicine team.*

Name: — *Sarah Griffin (no change)*
Project Role: — *Investigator*
Research Identifier: — *0000-0003-4820-3985*
Nearest person month worked: — *1.0*
Contribution to Project: — *Dr. Griffin will lead focus groups and interviews to glean insight on operational medical workflow.*

Name: — *Melissa Smith (no change)*
Project Role: — *Investigator*
Research Identifier: — *0000-0003-0798-8536*
Nearest person month worked: — *1.0*
Contribution to Project: — *Dr. Smith and her graduate students will lead technology enablement activities.*

Name:	Minjae Woo (no change)
Project Role:	Graduate Student
Nearest person month worked:	12
Contribution to Project:	Mr. Woo supports Drs. Gimbel and Griffin in activities related to the proposed qualitative research, statistical analysis and outcome analysis, and issues related to the drills and workflow. The student will also develop the basic model that controls simulation of battlefield noise.

Name:	Caleb Linduff (no change)
Project Role:	Graduate Student
Nearest person month worked:	12
Contribution to Project:	Mr. Linduff will focus on platform integration and support Dr. Wang in the area of how to integrate the data into the Cerner electronic health record.

Name:	Qing Wang
Project Role:	Graduate Student
Nearest person month worked:	12
Contribution to Project:	Mr. Wang will support Dr. Smith's work on video and speech recognition.

Name:	Ju Lin (no change)
Project Role:	Graduate Student
Nearest person month worked:	12
Contribution to Project:	Mr. Lan will support Dr. Smith's work on video and speech recognition.

Name:	Snigdhaswin Kar
Project Role:	Graduate Student
Nearest person month worked:	12
Contribution to Project:	Mr. Kar will support Dr. Wang's work on benchmark experiments and publication.

Name:	Prabodh Kumar Mishra
Project Role:	Graduate Student
Nearest person month worked:	12
Contribution to Project:	Mr. Mishra will support Dr. Wang's work on benchmark experiments and publication

Name:	Karen Edwards (no change)
Project Role:	Research Associate
Research Identifier:	0000-0003-3584-0328
Nearest person month worked:	1.2
Contribution to Project:	Mrs. Edwards assisted with regulatory/IRB approvals from Palmetto Health and Clemson University as well as the approval from the HRPO

military secondary review board. She will assist with various reports and logistical items.

Name:	*William Gerard, MD (no change)*
Project Role:	*Co-Investigator*
Nearest person month worked:	*1.0*
Contribution to Project:	*Dr. Gerard oversees all aspects of the study at Palmetto Health System*

Name:	*Stephen Shelton, MD (no change)*
Project Role:	*Investigator*
Nearest person month worked:	*1.0*
Contribution to Project:	*Dr. Shelton works alongside Dr. Gerard and the Emergency Department physicians at Palmetto Health System.*

Name:	*Kelly Hawsey, RN (no change)*
Project Role:	*Investigator*
Nearest person month worked:	*1.0*
Contribution to Project:	*Mrs. Hawsey assists with logistics of the study at the Palmetto Health System site.*

Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?
Nothing to Report

What other organizations were involved as partners?
   Organization Name: Palmetto Health System
   Location of Organization: Columbia, South Carolina
   Partner's contribution to the project:
   Financial support: n/a
   In-kind support: n/a
   Facilities: *Project staff use the partner's facilities for project activities.*
   Collaboration: *Partner's staff work with project staff on the project*
   Personnel exchanges: *Project staff and/or partner's staff use each other's facilities, work at each other's site.*
   Other: n/a

8.SPECIAL REPORTING REQUIREMENTS
   COLLABORATIVE AWARDS: n/a
   QUAD CHARTS: Appendix D

9. APPENDICES:

APPENDIX A - Simulation Drill #1-2 Photographs

Hospital scenario with amputee patient

Transport scenario with concussion patient

Conversation among two medics and one patient

Two medics with two injured patients

APPENDIX B – Plan Highlights for Simulation Drill #2 on December 2, 2019

Simulation drill #2 will be the last drill before this project concludes. It will consist of the following components and emphases:

- Full CARD solution on the NVIDIA TX2-based embedded platform
- Full Kaldi/TensorFlow based speech recognition software with speech enhancement, medical language model, preliminary NLP post-processing, and TCCC card entry
- Monitoring dashboard with live streamed status and speech, video, and TCCC outputs of all (6) active TX2 platforms
- Extended medic scripts covering more data fields in the TCCC card
- Tests under multiple conditions: 1) high vs. low vs. no noise, 3) single vs. multiple speaker, 4) regular vs. speed-up pace of speech
- Improved video camera attachment to medics and recording of point-of-injury surroundings

The drill will be accompanied by interviews with EMS personnel.

Slide 1

DHA

Complete and Resilient Documentation (CARD) for Operational Medical Environments

September 24, 2019

Slide 2

DHA — **Project Information**

- ❖ Organization / key partners / institutes: Clemson University
- ❖ Award #: W81XWH-17-C-0238
- ❖ Award Mechanism: Contract
- ❖ Solicitation: BAA, Health Information Technologies and Informatics Hands-Free Electronic Health Record Data Entry Initiative (HFEHRI)
- ❖ Principal Investigator: Kuang-Ching Wang, PhD
  - ❖ Key Sub-Awards: Bill Gerard, MD (Palmetto Health System)
- ❖ Total Cost/Budget: $1,644,510
- ❖ Period of Performance: 9/25/17- 3/24/20
- ❖ Grants / Contract Officer Representative: Dr. Prem Yadav
- ❖ Grants / Contract Specialist: Jeanette Wolfe
- ❖ Related government funding: n/a

Slide 3

DHA — **Quad Chart**

Study/Product Outcome/Aim(s)

Our objectives are:
- Identify the medical workflow and information needs of battlefield medics and air transport nurses caring for wounded warriors in an operational environment.
- Develop the platform for hands free EHR data documentation robust to this environment.
- Develop natural language processing solution for multi-stage information extraction.
- Develop systematic assessment instruments based on medical workflow efficacy.

Approach

The research targets long-term feasibility of hands-free documentation of injury in operational environments from two fronts: Medical and Technological.

☐ On the medical front:
- Focus groups/interviews
- Simulation drills (battlefield, en route, field hospital care)

☐ On the technology front:
- Platform for flexible integration (recording devices, compute devices, and EHR)
- Decoupled recording and processing + persisted performance improvement

Timeline and Cost

Activities	CY	17	18	19	20
Medical Workflow Studies					
Platform development					
Assessment					
Roadmap development					
Estimated Budget ($K)		$41k	$697k	$719	$208

Goals/Milestones

CY17-19 Goals – Medical Workflow, Platform Development, Qualitative Assessment
☐ Focus Groups, Drill #1a, #1b
☐ Platform integration
☐ Speech Recognition & Video Digest
☐ Workflow Assessment

CY19-20 Goals – Roadmap Development
☐ Natural Language Processing for recognized speech post processing to TCCC card
☐ Video Classification
☐ Drill #2

Comments/Challenges/Issues/Concerns
- Speech recognition under noise is challenging and continues to be actively researched. Techniques for "error tolerance" is critically needed.
- Video contains rich insights but is under explored – A chicken-and-egg problem.

Budget Expenditure to Data
Projected Expenditure: $1,644,510
Actual Expenditures: $1,159,717.58 @31AUG2019

Slide 4

DHA — **Scientific Overview**

- ❖ **Purpose:** This research project addresses one common perception of hands free electronic health record data collection for the operational environment
  - ❖ Hands free data entry requires speech recognition, but …
  - ❖ It is impossible to ever be usable in the field with all the noise, movement, and harsh elements
- ❖ **Methodology**
  - ❖ Decoupled recording and recognition
    - ❖ Robust recording in the field + Just in time speech recognition + perpetual archive
  - ❖ Medical leads the way
    - ❖ Focus group studies with EMS physicians, helicopter transport nurses with prior military medical experiences + EMS drills + systematic quality assessment
  - ❖ Platform for integration
    - ❖ All components are evolvable: Data input devices, compute HW/SW, storage, EHR interface
    - ❖ Resilience and usability rooted in platform design and data lifecycle
    - ❖ Focus on system architecture & data interfaces, instead of individual component performance
    - ❖ Creation of military-oriented training data set for speech and video recognition
- ❖ **Expected Outcomes**
  - ❖ **Medical workflow** and requirements
  - ❖ **CARD platform** prototype hardware and software + process for persistence enhancements
  - ❖ **Assessment** instruments and results

Slide 5

DHA — **Scientific Overview (Continued)**

- ❖ **Hypothesis(es) / Research Question**
  - ❖ The key objective for the solution is two-fold
    - ❖ Complete and resilient documentation (CARD)
    - ❖ Timely data that enhances medical workflow
  - ❖ The key concerns for the solution differ based on roles of care
    - ❖ Point of injury (medics) – record, confirm correct capture
    - ❖ Transport/en route care (nurses) – record further, confirm correct capture, communicate advance stats downstream
    - ❖ Field Hospital (physicians) – review assessment and treatment history since point of injury
  - ❖ Recorded data can be in multiple forms linked to a patient's EHR record
    - ❖ Original audio/video recording
    - ❖ Structured text data via speech recognition and natural language understanding
    - ❖ The former assures complete and resilient documentation. The latter assures useful enhancement to medical care
  - ❖ Speech & video recognition performance can be persistently improved given
    - ❖ A sizeable archive of recordings for training deep-learning based software
    - ❖ Decoupled "human-audit" and "re-train" process using the archive.

- ❖ **Specific Aims / High Level Objectives**
  - ❖ Aim 1: Medical Workflow
    - ❖ Identify requirements and operational conditions from physicians and nurses
    - ❖ Study medical rescue standards and deviations in operational environments
  - ❖ Aim 2: Platform
    - ❖ Integrate, end-to-end, cameras, GPU compute devices, storage, to Cerner EHR
    - ❖ Develop and integrate speech recognition, video digest solutions
    - ❖ Explore a multitude of data interface and management options
  - ❖ Aim 3: Assessment
    - ❖ Experienced physician/nurse/EMS drills
    - ❖ Surveys for workflow efficiency
  - ❖ Aim 4: Technology roadmap development

Slide 6

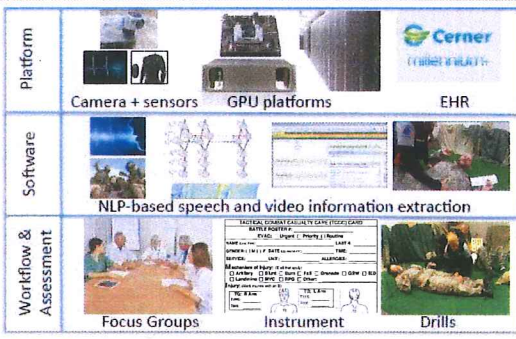**DHA** — **Research Design / Methods**

Platform: Camera + sensors | GPU platforms | EHR (Cerner)

Software: NLP-based speech and video information extraction

Workflow & Assessment: Focus Groups | Instrument | Drills

Slide 1: Research Design / Methods

DHA

Research Design / Methods

Focus Group & Drills
- **Objectives:**
  - Focus groups with EMS, transport nurses, ED physicians → Needs & requirements
  - Battlefield rescue drills in sim center → A/V recording for S/W dev & testing
- **Approach:**
  - 6 focus groups, total 26 participants
  - 2+1 drills: 3 trauma types x 3 stages x 2 medics x 1 soldier, scripted speech
- **Findings:**
  - Focus group: multiple speakers, multiple patients, chaotic conditions, need of on/off control
  - Drills: 6+ hrs recording, multiple noise levels

Platform Design
- **Objectives**
  - Not to reinvent the wheels
  - Identify unique challenges
  - Propose and validate near- and long-term improvement strategies
- **Principles**
  - Examine holistically, end-to-end
  - Analyze incisively, modular
  - Long term persistent enhancement
  - Open integration
- **Approach**
  - Systematic, modular performance analysis (varied noise, S/W and H/W components)
  - Open source, modular S/W (instead of end-to-end black-box)

Slide 2: Research Design / Methods — Speech Recognition

DHA

Research Design / Methods
Speech Recognition

Slide 3: Research Design / Methods — Video Analysis

DHA

Research Design / Methods
Video Analysis

Slide 4: Results to Date (Highlights)

DHA

Results to Date (Highlights)

- **Platform integration**
  - Completed – Camera + video capture unit + TX2 GPU board + software + battery
  - Cerner integration – completed with local sandbox

- **Speech recognition**
  - Completed
  - Working on performance improvement workflows – language model, NLP
  - Metrics: general word error rate, medical word error rate

- **Video classification**
  - Working on open source video classification software: YoLo v3, DenseCap
  - Focus on new image training workflow

Slide 5: Results to Date (Dashboard)

DHA

Results to Date (Dashboard)

Slide 6: Results to Date (Video Analysis)

DHA

Results to Date (Video Analysis)

- Language model training + NLP post processing

Ground Truth	Old Language Model	New Language Model
... primary and secondary survey airway has been patent he is tachypneic with good he has a heart rate in the one thirties with **palpable radial pulses bilaterally** he has been alert he is allergic to penicillin and takes **Adderall** for his A.D.H.D. no other medical history or surgeries so our last.	... primary and secondary serve and everybody's been paid me to get that was good he has a heart rate and the one thirties **operating a false bilateral** even alert he's allergic to benefit olympic **that are all** whereas a. d. h. d. no automatically after a certain race or last.	... primary and secondary survey everybody's been paid me to get that was good he has a heart rate and the one thirties **palpable radial pulses bilaterally** even alert he's allergic to benefit olympics **adderall** whereas a.d.h.d. no automatically or surgeries or last.

- Video classification
  - Video demo!
  - Focus on training workflow and data set

Acquisition Overview

DHA

- COST
  - What is the Money($) spent to date? $1,159,717.58 @ 8/31/19
  - Is burn rate on schedule? Yes
  - Have you spent too much or too little; and why?
    This project is financially on track.

- SCHEDULE
  - Is the project on schedule, behind schedule, what delays?
    This project is on schedule with the 180-day no-cost extension.

- PERFORMANCE
  - What tasks have you successfully completed on your SOW?
    - 82% of proposed tasks have been completed.
    - Remaining: Natural language processing for speech post processing, Video analysis for object detection, final drill, roadmap development
  - What tasks are at risk? There are no tasks at risk.

GANTT Chart

DHA

	Y2Q1	Y2Q2	Y2Q3	Y2Q4	Y3Q1	Y3Q2
Specific Aim I- Medical Workflow Studies						
Task 1.3: Qualitative Assessment						
Quality assessment instrument design		■	■			
Survey execution and analysis					■	
Specific Aim 2- Platform Development						
Task 2.2: Speech Recognition & Video Digest						
Video digest	■					
Cerner integration	■	■				
Publication of speech technology study		■	■		■	
Natural Language Processing study			■	■		
Video Analysis study			■	■		

Updated as of: 8/31/2019

GANTT Chart

DHA

	Y2Q1	Y2Q2	Y2Q3	Y2Q4	Y3Q1	Y3Q2
Specific Aim 3 – Assessment						
Task 3.1: Technology Assessment						
Platform benchmarking	■	■	■			
Drill #2 design and preparation	■	■	■			
Drill #2 execution					■	
Task 3.2: Workflow and EHR Assessment						
Qualitative Survey of workflow quality	■	■				
Specific Aim 4 – Roadmap Development						
Platform Usability and gaps assessment			■	■	■	
Roadmap development			■	■	■	

Updated as of: 08/31/2019

Tasks In Progress & Future Tasks

DHA

Specific Aim 1 – Medical Workflow Studies
Task 1.3: Qualitative Assessment
- Final drill assessment
- Final drill survey

Specific Aim 2 – Platform Development
Task 2.2 – Speech Recognition & Video Digest
- Publication of speech study
- Natural Language Processing
- Video Analysis

Specific Aim 3 - Assessment
Task 3.1 – Technology Assessment
- Final drill assessment

Specific Aim 4 – Roadmap Development
- Platform usability and gaps assessment
- Roadmap development

Budgetary Update

DHA

- Budget Expenditure to-date:
  - Projected Expenditure: $1,644,510   Actual Expenditure: $1,159,717.58 @ 8/31/19
  - Anticipated adjustments on remaining periods – None

- Speak to expected vs. actual burn rates
  - Are you spending money too fast or too slow, and why? This study is financially on track.

Burn Rate

Contracting Overview

DHA

- HIGHLIGHT tasks that have deviated from original proposal or SOW.
  - A 180-day extension has been approved (extended completion date in March 2020)

DHA — **Technical Overview**

❖ TRL / KRL

The CARD platform and its speech and video analysis technologies currently fall within TRL 2-4. It's current focus is on the refinement of the core technologies and its operational concepts.

❖ Entrance and Exit criteria

To advance the CARD solution beyond TRL 4, key criteria may include:

- Validation of usage scenario in accurate tactical conditions and workflows
- Validation of critical metrics and acceptance thresholds per tactical standards

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DHA — **Deliverables**

Deliverables & Data Requested	Details/Format	Data Rights	Delivery Schedule
Quarter #1 Technical Progress Report and Quad Chart	A brief description of overall progress to date for the reporting period 9/26/17-12/25/17	Full access	12/25/17
Quarter #2 Technical Progress Report and Quad Chart	A brief description of overall progress to date for the reporting period 12/26/17-3/25/18	Full access	3/25/18
Quarter #3 Technical Progress Report and Quad Chart	A brief description of overall progress to date for the reporting period 3/26/18-6/25/18	Full access	6/25/18
Annual Progress Report and Quad Chart	A brief description of overall progress to date for the reporting period 9/26/17-9/25/18	Full access	9/25/18; REVISED 11/19/18
Quarter #5 Technical Progress Report and Quad Chart	A brief description of overall progress to date for the reporting period 12/26/18-3/25/18	Full access	3/25/19
Quarter #6 Technical Progress Report and Quad Chart	A brief description of overall progress to date for the reporting period 3/26/19-6/25/19	Full Access	6/25/19

DHA — **Anticipated Impact**
as an Outcome of Research

❖ The research expects significant impacts in:

❖ Commercial, Civilian and Military
- Commercial development in key technologies
- Synergistic use in civilian EMS, homeland security and disaster recovery
- New companies or consortium of companies on standard based integrated platform, from variety of data capture devices, mobile app, to cloud solutions
- Integration with telemedicine, enhance the care and survivability of service members
- Establish understanding of battlefield readiness of state-of-the-art technology
- Establish foundations for long-term success for DoD speech recognition competencies

❖ Academic
- Speech recognition, natural language understanding, and video analysis in battlefield settings is a rich area for academic research
- Large scale, distributed data collection (speech, video, sensors) and aggregation into individual patient data is a rich area of research

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DHA — **Transition Strategies**

CARD Inception:

Clemson team

⟹

CARD Refinement:

Clemson team
+
Gov. partners
(e.g., TATRC)

⟹

Tech Transfer:

Clemson team
+
Company

Military & academic research in speech, NLU & clinical info extraction & use in operational environments

Civilian applications for emergency medicine & homeland security

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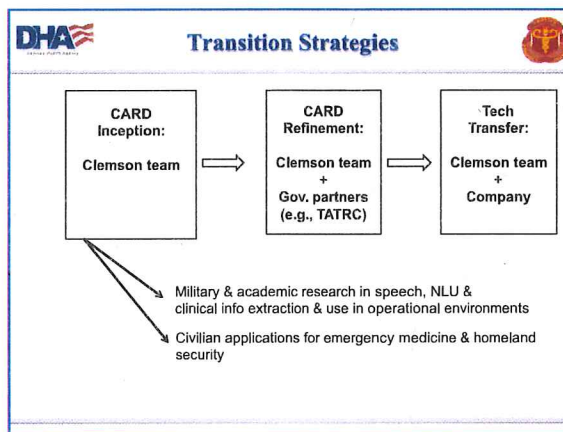
DHA — **Summary/Conclusions**

❖ As it completes the Q8 (Y2Q4), the project is on track on all proposed tasks.

❖ The anticipated outcomes and their status/outlook are as follows:
- CARD Platform completed - A/V capture, speech recognition, NLP speech post processing, video classification
- 3rd simulation drill scheduled for Dec. 2

❖ The project's aim is not a point product. Instead, its aims are on:
- Confirmation of the CARD concept's clinical opportunities and challenges
- Development of the platform's architecture and interfaces
- Demonstrating the extensible nature of the platform components
- Assessing the CARD design's impact to the medical workflow

DHA — **BACK-UP SLIDES**

10/17/19

BACK-UP SLIDES

BACK-UP SLIDES

Original Dataset
- 260 hours of Switchboard Data
  - Distributed by Linguistic Data Consortium (LDC)
  - 2,400 two-sided telephone conversations among 543 speakers (302 male, 241 female)
- 500 hours of Common Voice Data
  - Freely and publicly available

Noise Injection
- 14 types of battlefield related noises
- Selected from Signal Processing Information Base Noise Database
- For a unique yet realistic output, randomize:
  - Number of noises added to each speech file
  - Type of noise
  - Starting point of noise
  - Power level of noise

Dataset #1 — 780 Hours
- Gunshots and other noises occurring intermittently.
- Different noises each having a duration of 5s.

Dataset #2 — 780 Hours
- Continuous battlefield related background noise from tanks, jets, helicopters, etc.
- Mixed with intermittent gunshot noise.

BACK-UP SLIDES

Speech Input → Waveform
Acoustic model → Acoustic feature extraction → Acoustic features
Word lexicon → Word selection → Words
Grammar → Sentence-level matching → List of words
Transcription output

BACK-UP SLIDES

Unknown Medical Words — CMU's Sphinx Knowledge Base Tool — Dictionary/Lexicon of new medical words with their Phonemes

Language model created from medical words

Current Language Model → New merged language model

New merged dictionary

New Phonemes found? — Yes → Train Acoustic Model again — No

List of existing Phonemes from Switchboard

Current Dictionary

SRILM Toolkit
Compile the new lexicon (L.fst)
Compile the new grammar (G.fst)
Current HCLG graph
Reassemble/Construct new HCLG graph (HCLG.fst)

LEGEND
- New inputs to be supplied
- Inputs from the existing model
- Intermediate inputs/outputs
- Final outputs from the new model

Process for creating new language model and HCLG.fst from new unknown medical words

BACK-UP SLIDES

New language model results comparison

Ground Truth	Old Language Model	New Language Model
... primary and secondary survey airway has been patent he is tachypneic with good he has a heart rate in the one thirties with **palpable radial pulses bilaterally** he has been alert he is allergic to penicillin and takes **Adderall** for his A.D.H.D. no other medical history or surgeries so our last.	... primary and secondary serve and everybody's been paid me to get that was good he has a heart rate and the one thirties **operating a false bilateral** even alert he's allergic to benefit olympic **that are all** whereas a.d.h.d. no automatically after a certain race or last.	... primary and secondary survey everybody's been paid me to get that was good he has a heart rate and the one thirties **palpable radial pulses bilaterally** even alert he's allergic to benefit olympics **adderall** whereas a.d.h.d. no automatically or surgeries or last.

BACK-UP SLIDES

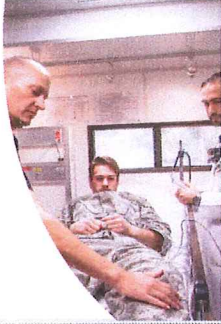|	Total n	Male n (%)	Female n (%)		Experience <10 years n (%)	Experience 10-20 years n (%)	Experience >20 years n (%)	Experience Unknown N (%)
EMS	6	5(83%)	1 (17%)		1 (17%)	1 (17%)	3 (50%)	1 (17%)
Transport Nurses	11	8 (73%)	3 (27%)		1 (9%)	2 (18%)	8(73%)	0 (0%)
ED Physicians	9	8 (89%)	1 (11%)		3 (33%)	2 (22%)	4 (44%)	0 (0%)
Total	26	21(81%)	5 (19%)		5 (19%)	5 (19%)	15 (58%)	1 (4%)

Slide 1

DHA — **BACK-UP SLIDES**

Focus Group Conclusions

Informed protocol needs for collecting and transmitting data

Suggests information (notes from audio & video) could be useful at multiple phases of care

Audio recognition sophistication for chaotic communication

Slide 2

DHA — **Regulatory Update**

- Palmetto Health System IRB Approval – 10/25/17
- Clemson University IRB Approval – 10/26/17
- HRPO Military Secondary Review Approval – 11/17/17

Slide 3

DHA — **Publication / Presentations**

Poster presentations/Publications/Articles

- Ju Lin, Sufeng Niu, Zice Wei, Xiang Lan, Adriaan J. van Wijngaarden, Melissa C. Smith, Kuang-Ching Wang, "Speech Enhancement Using Forked Generative Adversarial Networks with Spectral Subtraction", in Proceedings of INTERSPEECH 2019, Graz, Austria, Sep. 2019

- Griffin, S., Gimbel, R., Wang, K., Edwards, K., Gerard, W., Shelton, S., Hawsey, K. Complete and Resilient Documentation (CARD) for Operational Medical Environments: Knowledge Gained from Focus Groups Regarding the Use of GoPro® Equipment in Military and Civilian Medical Environments, 2018 MHSRS, Aug. 2018

- US Army News:

- Post and Courier:

- Clemson World:
- Clemson News:

Intended future Publications / Presentations

- A scientific manuscript regarding the systematic speech recognition study under battlefield noise and conversation conditions.

- A scientific manuscript regarding the focus group design, recruitment, interviews, transcription, analysis and operation recommendations will also be crafted.

Study/Product Outcome/Aim(s)

Our objectives are:
- Identify the medical workflow and information needs of battlefield medics and air transport nurses caring for wounded warriors in an operational environment.
- Develop the platform for hands free EHR data documentation robust to the environment.
- Develop natural language processing solution for multi-stage information extraction.
- Develop systematic assessment instruments based on medical workflow efficacy.

Approach

The research targets long-term feasibility of hands-free documentation of injury in operational environments from two fronts: Medical and Technological.

□ *On the medical front:*
   ○ Focus groups/interviews
   ○ Simulation drills (battlefield, en route, field hospital care)

□ *On the technology front:*
   ○ Platform for flexible integration (recording devices, compute devices, and EHR)
   ○ Decoupled recording and processing + persistent performance improvement

Timeline and Cost

Activities	CY	17	18	19	20
Medical Workflow Studies					
Platform development					
Assessment					
Roadmap development					
Estimated Budget ($K)		$41k	$687k	$716	$208

Platform — Camera + sensors — GPU platforms — EHR — Cerner

Software — NLP-based speech and video information extraction

Workflow & Assessment — Focus Groups — Instrument — Drills

Accomplishments: 1. focus groups with EMS personnel, 2. platform for A/V capture, speech recognition, and video analysis completed, 3. systematic noise impact study, 4. two medical drills, 5. NLP medical info extraction

Goals/Milestones

CY17-19 Goals – Medical Workflow, Platform Development, Qualitative Assessment
□ Focus Groups, Drill #1a, #1b
□ Platform Integration
□ Speech Recognition & Video Digest
□ Workflow Assessment

CY19-20 Goals – Roadmap Development
□ Natural Language Processing for recognized speech post processing to TCCC card
□ Video Classification
□ Drill #2

Comments/Challenges/Issues/Concerns
- Speech recognition under noise is challenging and continues to be actively researched. Techniques for "error tolerance" is critically needed.
- Video contains rich insights but is under explored – A chicken-and-egg problem.

Budget Expenditure to Date
Projected Expenditure: $1,644,510
Actual Expenditures: $1,159,717.58 @31AUG2019