Homeland Defense & Security
Information Analysis Center

Wearables for Physiological Monitoring and the DoD

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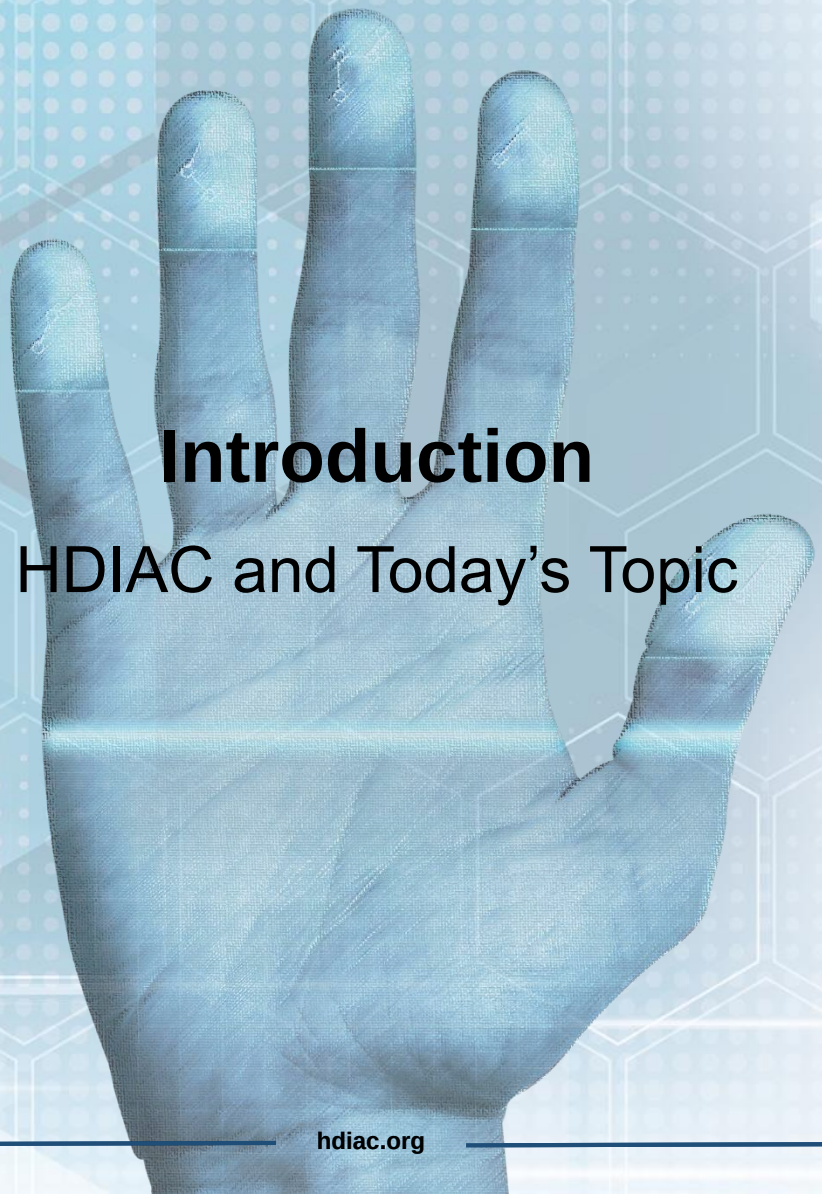
March 22, 2018



Introduction

HDIAC and Today's Topic

HDIAC Overview

What is the Homeland Defense & Security Information Analysis Center (HDIAC)?

One of three Department of Defense Information Analysis Centers

Responsible for acquiring, analyzing, and disseminating relevant scientific and technical information, in each of its eight focus areas, in support of the DoD and U.S. government R&D activities

HDIAC's Mission

To provide authoritative, responsive solutions by generating, acquiring, processing, analyzing, and disseminating relevant information and analysis to our customers

HDIAC Overview

HDIAC Subject Matter Expert (SME) Network

HDIAC SMEs are experts in their field(s), and, typically, have been published in technical journals and publications.

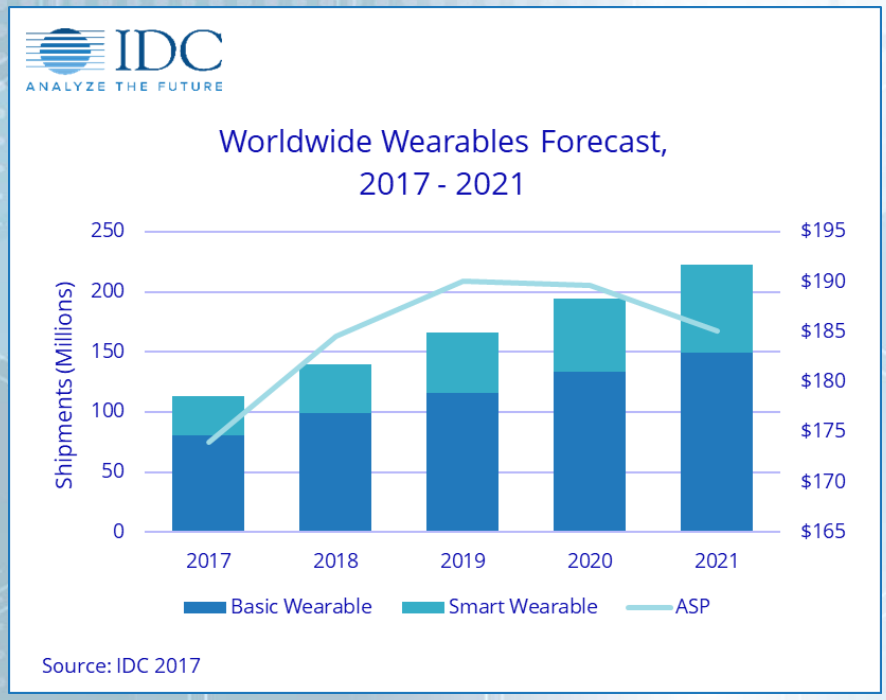
SMEs are involved in a variety of HDIAC activities

- Authoring HDIAC Journal articles
- Answering HDIAC Technical Inquiries
- Engaging in active discussions in the HDIAC community
- Assisting with HDIAC Core Analysis Tasks
- Presenting webinars

If you are interested in applying to become a SME, please visit HDIAC.org or email info@hdiac.org.

Why Wearables? Why Now?

"The Department of Defense (DoD) has an opportunity to leverage the substantial investment by the commercial sector in wearable technologies to improve the readiness of the deployed and training Warfighter and to support decisions and actions in response to operating in a threat environment." [1]



1. Hirschberg, D. L., Samuels, A. C., Rosenzweig, C. N., Lux, M. W., Emanuel, P. A., Miklos, A. E., . . . Brooks, J. R. (2016). Assessment of Wearable Technology for Integrated Decision Support (Rep. No. ECBC-TR-1377). Aberdeen Proving Ground, MD: U.S. Army Edgewood Chemical Biological Center, U.S. Army Research, Development and Engineering Command.
2. IDC. (2017, December 20). Worldwide Wearables Forecast, 2017-2121 [Figure]. Retrieved from https://www.idc.com/getdoc.jsp?containerId=prUS43408517. *(Released)*

Overview: Wearables and Soldier Performance

- Physical/Fitness Performance
- Medical Assessments
- Mental Health
- Rehabilitation
- Educational Methods
- Sports and Athletic Training

Overview: Wearable Technology Research for the DoD

- Human-subjects Research for Wearable Technologies
- Sensors for Physiological Data
- Smart Clothing
- Neurocognitive Data
- Management of Wearable Data

Introduction

Sandia National Laboratories

Prepared by: Sandia National Laboratories, Livermore, California, 94550

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Energy

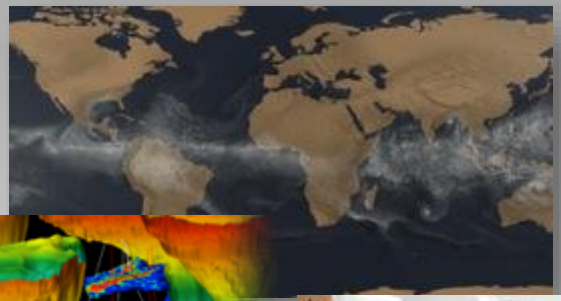
Sandia National Laboratories

Energy Research

ARPAe, BES Chem Sciences, ASCR, CINT, Geo Bio Science, BES Material Science

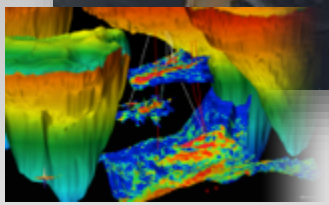
Climate & Environment

Measurement & Modeling, Carbon Management, Water & Environment, and Biofuels



Nuclear Energy & Fuel Cycle

Commercial Nuclear Power & Fuel, Nuclear Energy Safety & Security, DOE Managed Nuclear Waste Disposal

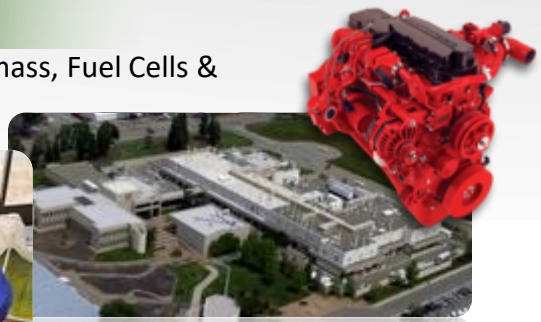


Renewable Systems & Energy Infrastructure

Renewable Energy, Energy Efficiency,
Grid and Storage Systems

Transportation Energy & Systems

Vehicle Technologies, Biomass, Fuel Cells & Hydrogen Technology



Global and Homeland Security

Sandia National Laboratories

Global Security

Remote Sensing and Verification

Homeland Security Programs

WMD Counterterrorism and Response

Homeland Defense and Force Protection

Cyber and Infrastructure Security

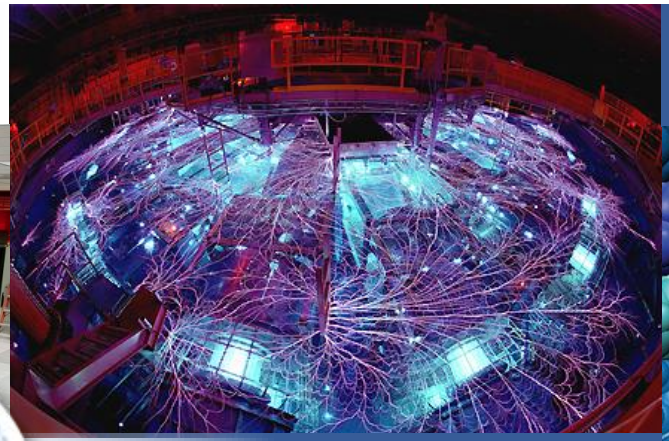
Our Research Framework

Strong research foundations play a differentiating role in our mission delivery

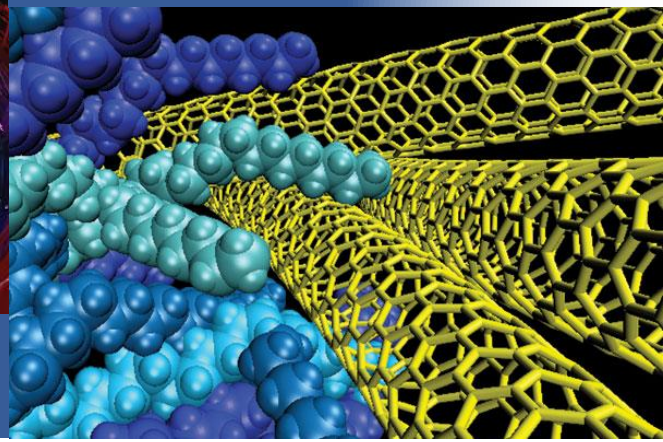
Sandia National Laboratories

Computing & Information Sciences

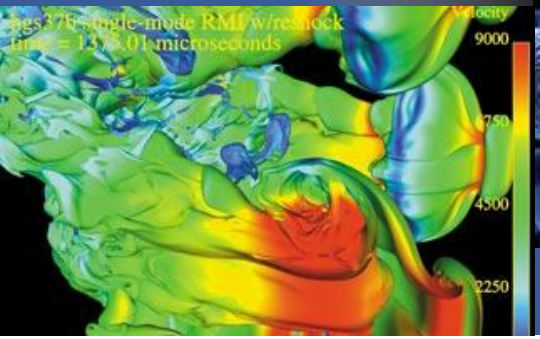
Radiation Effects & High Energy Density Science



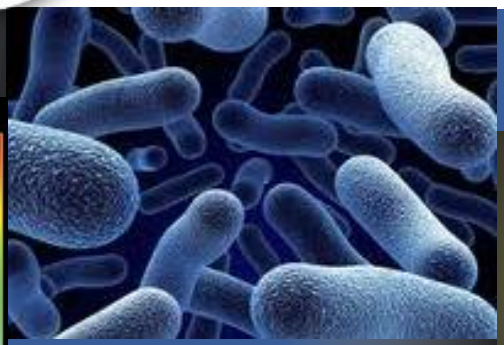
Materials Sciences



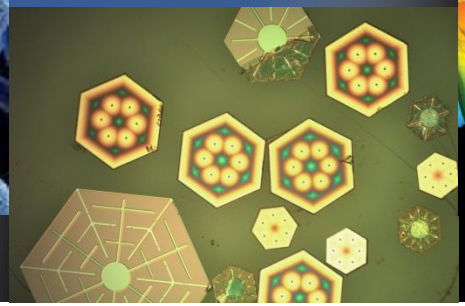
Engineering Sciences



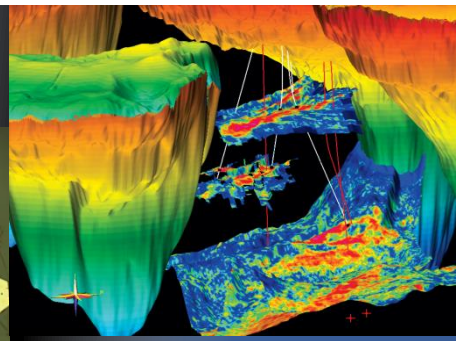
Bioscience



Nanodevices & Microsystems



Geoscience



Wearable Technologies and the DoD

The Problem

Chem-bio threats are used against military and civilian populations

Potential solution is to leverage advances in wearable technologies

Summary of historical attacks using chemical or biological weapons

compiled by Wm. Robert Johnston
last updated 5 December 2017

The following table summarizes known historical instances of the use of chemical or biological weapons, in reverse chronological order. The listing is limited to events after 1900 (while there were some earlier instances of chemical/biological warfare, these instances were generally of very limited effectiveness). Note that some incidents are disputed, and casualty figures in some cases are very uncertain. Events included:

- **use in warfare:** multiple attacks within a war are grouped together.
- **use by terrorists:** includes attacks with larger numbers of casualties.
- **other:** several criminal incidents and accidental chemical releases are included because of their significance.

Sources are provided following the table.

http://www.johnstonsarchive.net/terrorism/chembioattacks.html

date	location	attacker	agent	affected pop	casualties	description
21 - 27 Oct 2016	near Mosul, Iraq	Islamic State militants	sulfur	civilians, soldiers	**2 killed**, 1,500 injured	sulfur mine set on fire, producing widespread sulfur dioxide plumes
8 Mar 2016	Taza, Kirkuk, Iraq	Islamic State	blistering agent	civilians	**1 killed**, 600 injured	attack on town; fatality was 3-year-old child
23 Jan 2015	between Mosul, Iraq, and Syrian border	Islamic State militants	chlorine	Kurdish soldiers	~30 injured	truck bomb with chlorine-filled tanks used against troops
Sep - Oct 2014	Duluiya and Balad, Iraq	Islamic State militants	chlorine, possibly mustard gas	Iraqi and Shiite soldiers	40 injured	bombs with chlorine-filled cylinders used against defending troops
27 Mar - 22 Apr 2014	Syria--Damascus, Kafr Zita in Hama, and Talmenes in Idlib	Syrian military suspected	chlorine, others	civilians	**104 killed**, 200 injured	chlorine bombs used on civilians in two towns
21 Aug 2013	Damascus suburbs, Syria	Syrian military	sarin nerve gas?	civilian urban areas	**1,429 killed** (including 426 children), 2,200 injured	rockets with chemical agents fired at about 12 areas in suburbs south and east of Damascus, targeting rebel-held areas
19 Mar - 13 Apr 2013	Syria--Damascus, Al-Otaybeh, Khan al-Assal, Adra, Aleppo, Sheikh Maqsoud, and Saraqeb	Syrian military?	multiple chemical agents?	rebel soldiers and civilians	**at least 44 killed**, 76 injured	multiple attacks, mostly blamed on Syrian government; Syrian government accuses rebels of the attacks
Apr 2012 - Jun 2013	Afghanistan--Takhar province (9), Sar-e-Pul province (4), others	Islamist terrorists	pesticides?	schoolchildren	1,952 injured (including 1,924 children)	23 poison attacks on girls' schools, some cases of water poisoning
Mar 2012 - Apr 2013	Afghanistan	Islamist terrorists	rat poison?	police, other civilians	**53 killed**, 40 injured	9 attacks involving poisoning of food at police stations/academies
Apr - Aug 2010	Afghanistan--Kabul (6), Kunduz (4), others	Islamist terrorists	pesticides?	schoolchildren	672 injured (including 636 children)	20 gas attacks on girls' schools
11 Mar 2007	Iraq	Islamist terrorists	mustard gas	U.S. soldiers	2 injured	failed improved explosive device using chemical weapon artillery shells

1. Johnston, W. R. (2017, December 5). Summary of historical attacks using chemical or biological weapons. Retrieved from http://www.johnstonsarchive.net/terrorism/chembioattacks.html.

Using Wearable Technologies in DoD Contexts for Chem-Bio Detection

- Wearables need to be able to withstand extreme environments
- The right data needs to be collected
- Wearables need to be able to provide useful data
- Data needs to differentiate between physical fatigue/health and chem-bio exposures
- Data needs to be processed and analyzed in real time

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- **Commercial-off-the-Shelf (COTS) fitness devices readily available:**
  - Sports watches, GPS tracking
  - Pulse oximeters
  - Wearable/temporary tattoos (EEG, ECG)
  - Electromagnetic generators
  - Smart clothing

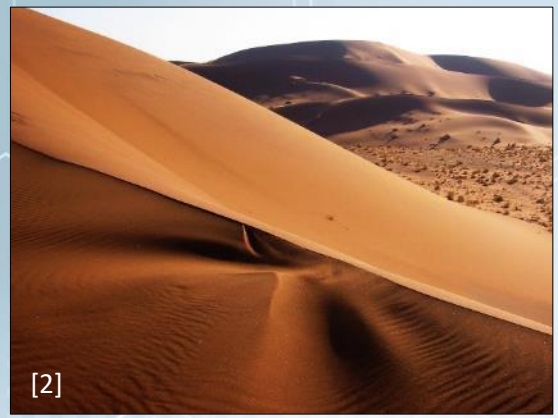
- **Advances are continually being made to improve devices, but not usually focused on extreme environments…**


[1]

1. Padilla, M. (n.d.) [Photograph]. Sandia National Laboratories.

- **For DoD contexts, wearables need to last**
- **Some wearable challenges…**
  - Proper fit/inhibition of movement
  - Signal
  - Battery life
  - Valid data
  - Device longevity
- **Devices need to last in harsh conditions**
  - Extreme temperatures
  - Dirt, grit, dust, sand
  - Extreme altitudes
  - Limited/no network connectivity
  - Limited power sources


[1]


[2]

1. Lamb, J. (n.d.). *White Mountain CA* [Photograph found in Wikimedia Commons]. Retrieved from https://en.wikipedia.org/wiki/File:White_Mountain_CA.JPG (Originally photographed 2004, June 10)
2. Schoch, T. (n.d.). *Namib Desert Namibia(2)* [Photograph found in Wikimedia Commons]. Retrieved from https://en.wikipedia.org/wiki/File:Namib_Desert_Namibia(2).jpg (Originally photographed 2003, August 29)

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Wearable sensors through fitness devices are the most common way to obtain **physiological data**

[1]

1. Adobe Stock

Wearable sensors collect **physiological data**

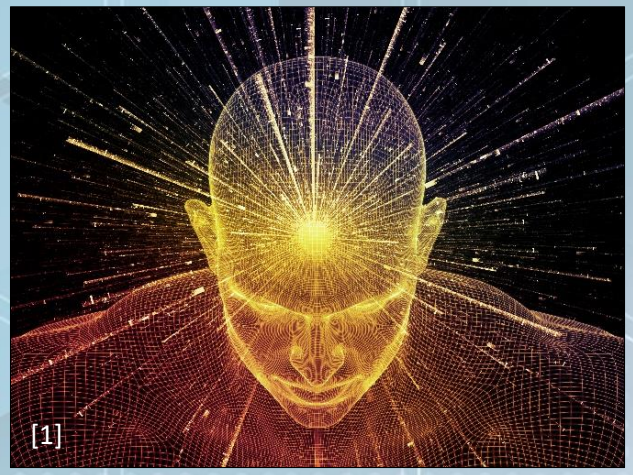
- Heart rate
- Heart rate variability
- Breathing rate
- GPS position
- Cadence
- Elevation
- Temperature (ambient + skin)
- Relative humidity


[1]

1. Adobe Stock

We have a limited snapshot of human performance

- Need advanced sensor development
- Smart clothing is more integrated but limited
- Need to quantify **neurocognitive** activity


[1]

1. Adobe Stock

Smart Clothing – E-textiles

- **Fabrics with electronics/interconnections woven into them; function to recognize the activity/physiological status and environment of the user to enhance performance:**
  - Heating/cooling
  - Physiological monitoring
- **Challenges and tradeoffs:**
  - Fit and flexibility
  - Stiffness
  - Ergonomic
  - Power consumptions
  - Autonomy
- **Additional development of advanced materials required to address challenges**


[1]


[1]


[1]

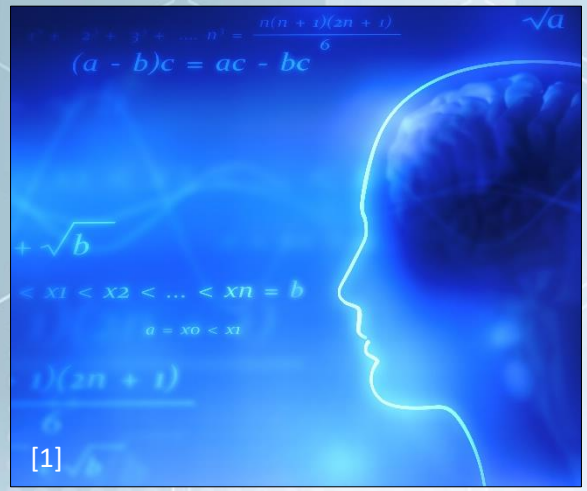
1. Adobe Stock

Neurocognitive Data

- **Neurocognitive data is cognitive function while performing or completing a task and focuses on and individuals ability to:**
  - Make decisions
  - Remember information
  - Maintain alertness
  - Respond to threatening stimuli

- **Focus of neurocognitive research:**
  - Wearable eye trackers (glasses)
  - Portable EEG

- **Benefits include:**
  - Identify health declines in real-time
  - Physical fatigue



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Using Wearable Technologies in DoD Contexts for Chem-Bio Detection

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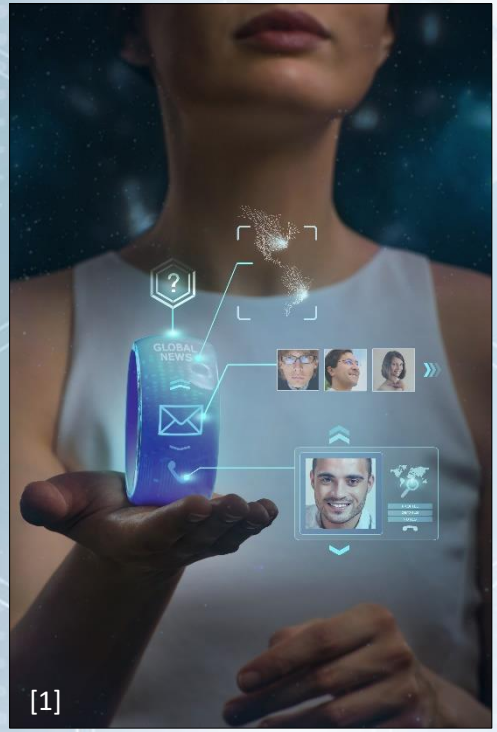
Ideally:

- **Data is collected from devices**
- **Data is analyzed**
- **Data is used for decision making**



[1]

We need to have data that measures what it says it measures.

We need to have data that tells us about human performance.

Data needs to be reliable.

Data should predict events before they are severe.

1. Adobe Stock

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How do human performance markers for physical fatigue/stress and chem-bio exposure differ?

Health event related to physical fatigue/stress

- ✓ Heat sensitivity
- ✓ Unfocused attention
- ✓ Coughing
- ✓ Lightheadedness
- ❑ Individual in a group is affected
- ❑ (e.g.) Change in HRV, more breaks, slower cadence

Health event relate to chem-bio exposure

- ✓ Heat sensitivity
- ✓ Unfocused attention
- ✓ Coughing
- ✓ Lightheadedness
- ❑ Whole group affected at about same time
- ❑ (e.g.)Change in HRV, less breaks, faster cadence

Use human-subjects research to understand differences

Health event related to physical fatigue/stress

- ✓ Heat sensitivity
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DoD Research for Wearable Technologies

Wearables at the Canyon for Health (WATCH)

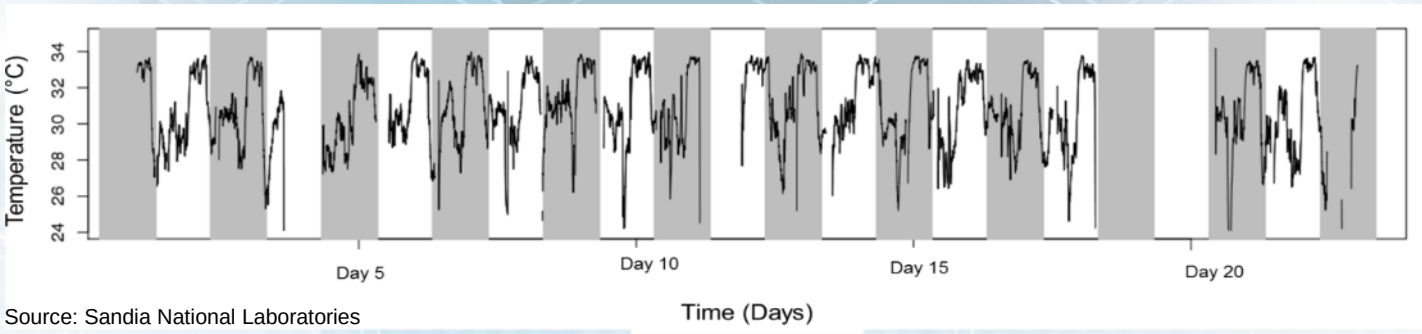
- **DoD funded through DTRA**
- **Hikers from South Rim to North Rim Grand Canyon**
- **Physical activity monitored by various wearable fitness devices**
- **Cognitive battery performed during hike**
  - Every 5 miles
- **Identify physiological, cognitive markers**
  - Health and task performance
  - COT device performance
  - Develop statistical models

Hikers are asked to complete a short cognitive battery before, during, and after the hike and wear a suite of fitness, wearable devices

1. [Photograph]. (n.d.). Sandia National Laboratories.

Infection and Altered Health Statuses

- **DoD funded through Naval Warfare Center**
- **Establish baseline physiological data – sleep patterns, heart rates, respiration, and body temp**
  - Impacted by cold, flu, etc.
  - Prolonged mission/operations
- **Goal: Develop an early warning system**
  - COTs biomonitoring accuracy to actual health/medical readiness
  - Security, performance, robustness, data security controls, reliability
  - Development of statistical algorithms



Source: Sandia National Laboratories

Microneedles as a Wearable Technology

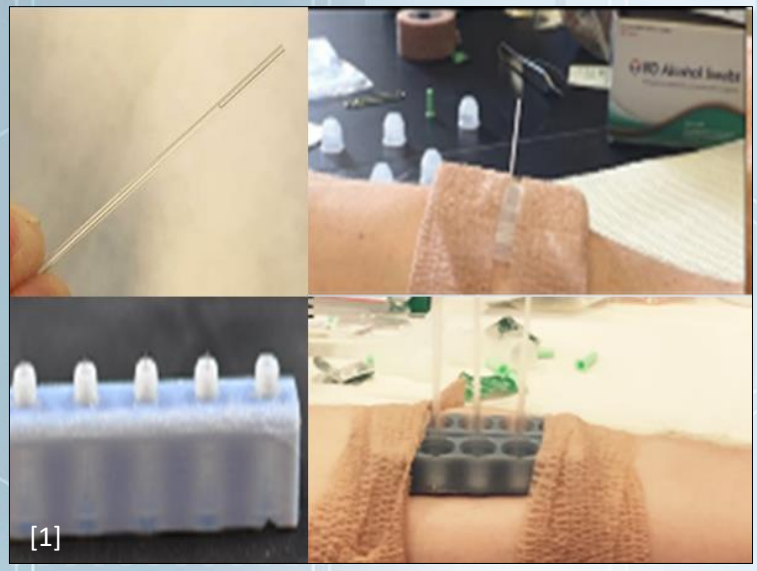
DoD funded through DTRA

Collect biological fluids in real-time (sweat, interstitial fluid [ISF])

- Light skin penetration
- Human chemistry and behavior
- Clinical monitoring and diagnosis

ISF highly similar to plasma and serum

Microneedles collecting ISF could be a proxy for blood in health monitoring



Development of microneedles as a wearable technology

1. [Photograph]. (n.d.). Sandia National Laboratories.

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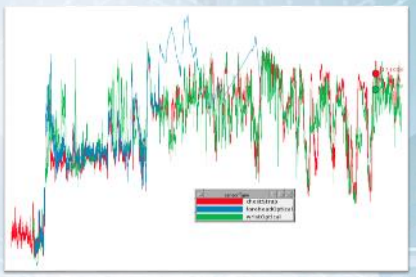
- **Data needs to be processed and analyzed in real time**

Research data is often downloaded and analyzed after physical activity

Innovative statistical models must be developed to appropriately analyze continuous, physiological data on human subjects

- PRESAGED uses real-time physiological data to predict the probability that a person was exposed to a pathogen, such as a virus or bacteria
- Build predictive models for military personnel in extreme environments

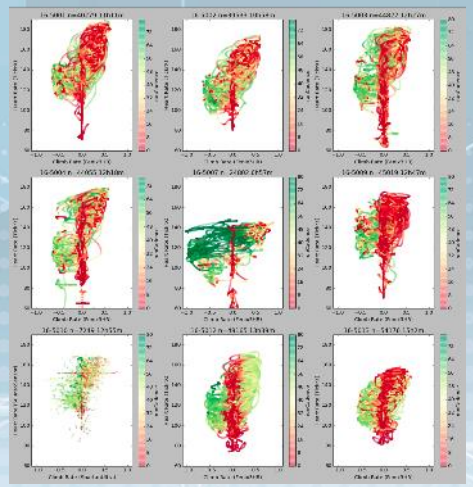
Example of Heart Rate Full Capture



- Forehead Optical starts well, but then drifts, then disappears. This is typical.
- Wrist optical is consistently fairly close but biased low. This is also typical.

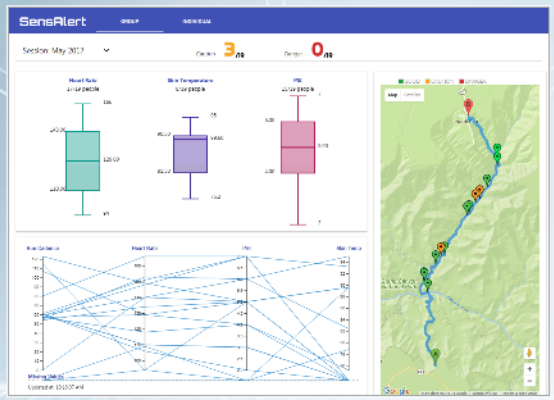
Source: Sandia National Laboratories

Individual Profiles – Heart Rate vs. Climb Rate



Source: Sandia National Laboratories

PNNL SensAlert Display for WATCH Data



Source: Pacific Northwest National Laboratory

Overall, need to make real-time decisions about humans by humans to further promote success in DoD mission contexts


[1]


[2]

1. FBI. (n.d.). *Intel Analysts*. Retrieved from https://multimedia.fbi.gov/?q=analyst&perpage=50&page=1&searchType=image (Originally photographed 2011, December 21)
2. Adobe Stock

Conclusion
&
Next Steps

Conclusion

- **Wearables need to be able to withstand extreme environments**
  - Harsh conditions: temperature, elements, network connectivity, etc.
- **The right data needs to be collected**
  - Not just a snapshot, but real-time
  - Not just a piece, but holistic data of human performance
- **Wearables need to be able to provide useful data**
  - Reliable, validated, accurately capture human performance
- **Data needs to differentiate between physical fatigue/health and chem-bio exposures**
  - Use of human-subjects studies
- **Data needs to be processed and analyzed in real time**
  - Build statistical models that are predictive of human performance

Next Steps

- Improving wearable technologies and human-subjects research to enhance soldier/human performance
- Improving validity/usefulness/security of data
- Improving robustness of devices in extreme environments, terrain, temperature, climate, and other factors
- Enhance soldier/human performance without distraction, added weight or discomfort
- Future DoD R&D that quantifies physiological, cognitive, and biological data with innovative wearable technology


[1]

1. Program Executive Office Soldier. (n.d.). *Soldier Maneuver Sensors*. Retrieved from https://www.flickr.com/photos/peosoldier/4996622259/ (Originally photographed 2009, September 3)

Thank You

Discussion, Questions, & Comments

HDIAC Services

Technical Inquiry Service

- HDIAC provides up to 4 free hours of information services:
  - Literature searches
  - Product/document requests
  - Analysis within our eight focus areas – Alternative Energy, Biometrics, CBRN Defense, Critical Infrastructure Protection, Cultural Studies, Homeland Defense and Security, Medical, Weapons of Mass Destruction

Core Analysis Task (CAT)

- Challenging technical problems requiring more than 4 hours of research can be solved by initiating a CAT:
  - Pre-competed, pre-awarded, contract vehicles
  - Work can begin on a project approximately two months after the statement of work has been approved
  - Cap of $500,000
  - Must be completed in less than 12 months

For more information: https://www.hdiac.org/technical_services