Tech Talk

Secure Wearable Technology for Early Illness Detection and Analysis

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RTI INTERNATIONAL

Background

- Readiness is a top priority for military services
  - Disease and nonbattle injury (DNBI) are the leading causes of morbidity during wars and military operations
  - In 2019, 15.8 million limited duty days were recommended for more than 188,000 Active Component Soldiers (Pre-COVID)
  - December 2019 COVID-19 detected in China

"We know more about our trucks than we do about our Soldiers"

LTG (RET) PATRICIA HOROHO, FORMER US ARMY SURGEON GENERAL

- Measures of readiness historically are self-reports
  - Self reports are often inaccurate
  - Self reports are often after a Service member is ill or injured with no chance for prevention

DoD Wearables

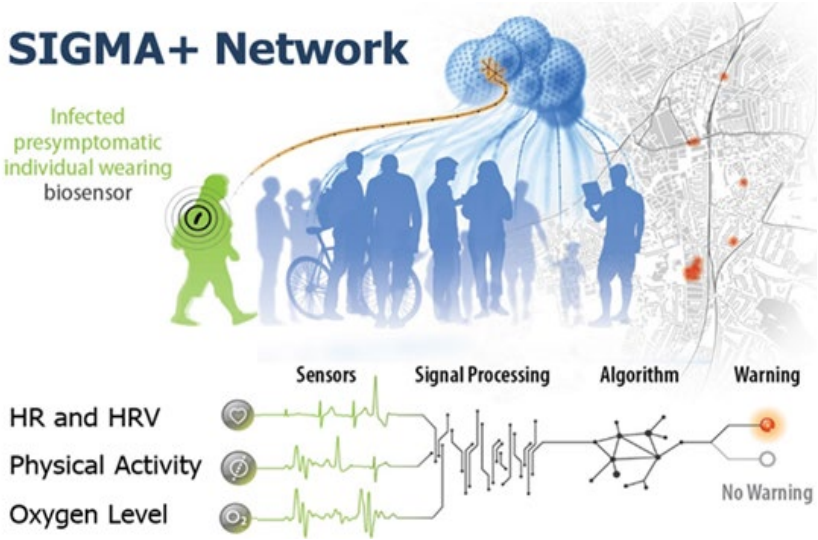
- Multiple DoD organizations funding wearables work
  - Joint Program Executive Office for Chemical, Biological, Radiological and Nuclear Defense (JPEO-CBRND)
  - Defense Innovation Unit (DIU)
  - Defense Threat Reduction Agency (DTRA)
  - US Special Operations Command (SOCOM)
  - US Army Medical Research & Development Command (MRDC)
  - US Army Combat Capabilities Development Command (CCDC)
  - Office of Naval Research (ONR)
  - Air Force Research Laboratory (AFRL)
  - **Defense Advanced Research Projects Agency (DARPA)**
- Multiple use cases
  - Psychological Health Status
  - Cognitive Health Status
  - **CBRN exposures**
  - **Infectious Diseases/Respiratory Illness**
  - **Mild Traumatic Brain Injury (mTBI)**

SIGMA+ Wearables: Goal and Approach

Goal: automated system of wearable biosensors that provides presymptomatic warning of **viral respiratory illness**

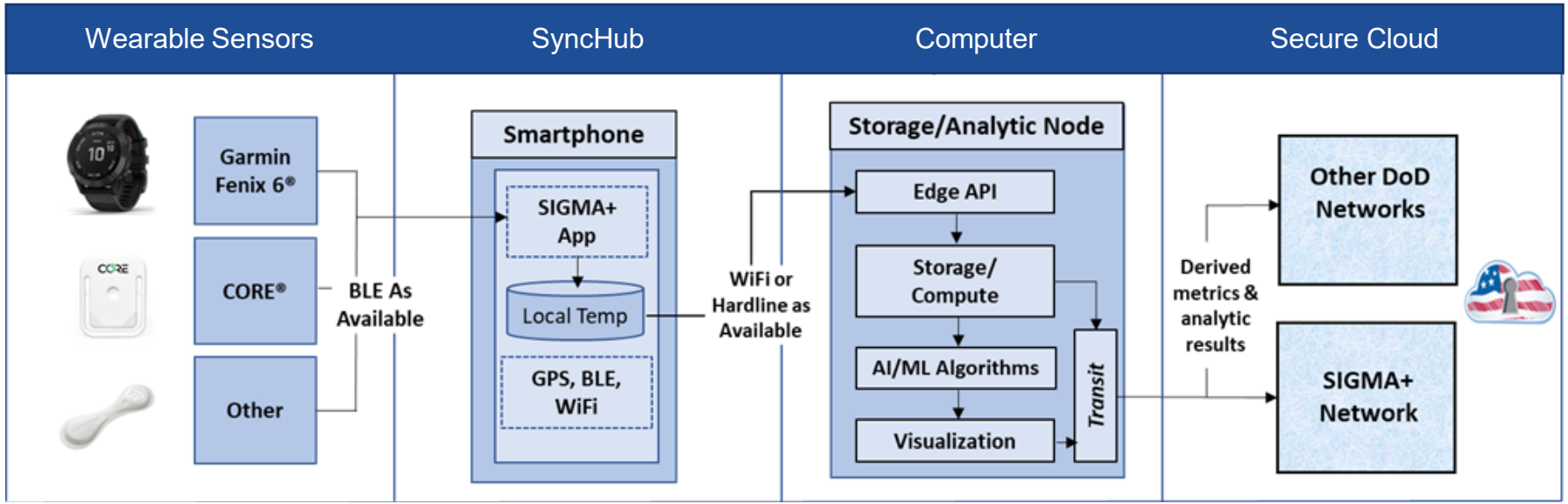
Approach: monitoring of heart rate (HR), HR variability (HV), blood oxygen level, and physical activity

Output: ML algorithms for early detection of respiratory infections -› alerts to individual and at SIGMA+ network level



Supported by the Defense Advanced Research Projects Agency (DARPA)

SIGMA+ Wearables Architecture

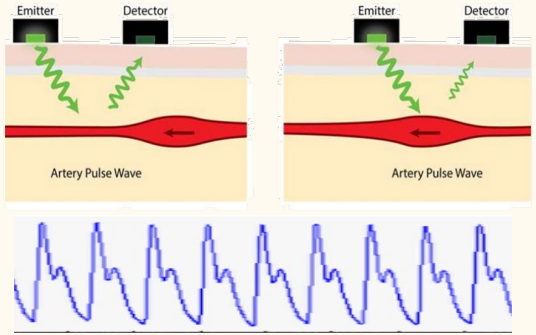


- Can be used in field with no internet connectivity
- Secure operation - data are never transmitted to non-DoD cloud servers

Wearables: Some Examples

Garmin Fenix 6

- Heart rate monitor, PPG technique
- PulseOx sensor for blood oxygen level



Polar H10

- ECG technique

GreenTEG Core

- Core body temperature

- Various form factors

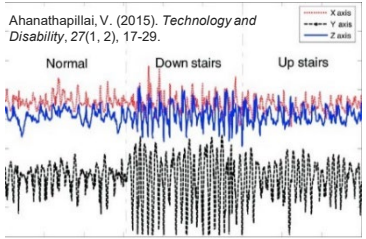
PPG *(photoplethysmography) is an optical technique that senses blood volume changes in the artery (i.e., pulse rate).* ***ECG*** *(electrocardiography) measures the heart's electrical activity (i.e., heart rate). ECG is considered the gold standard measurement technique for HR/HRV, but PPG is more convenient for long-term measurements.*

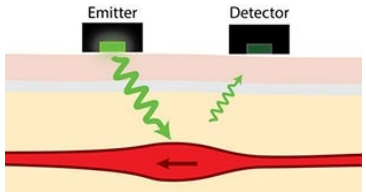
Custom SIGMA+ App for Data Collection

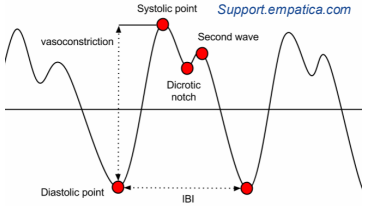
- Acquires data from watch and transfers data to designated DoD endpoint
- Android and iOS compatible
- Collected dataset includes **each interbeat interval (IBI)** with ms accuracy
- Links to symptom and contextual information surveys
- Collects GPS coordinates (at census track resolution) to enable monitoring of geolocation

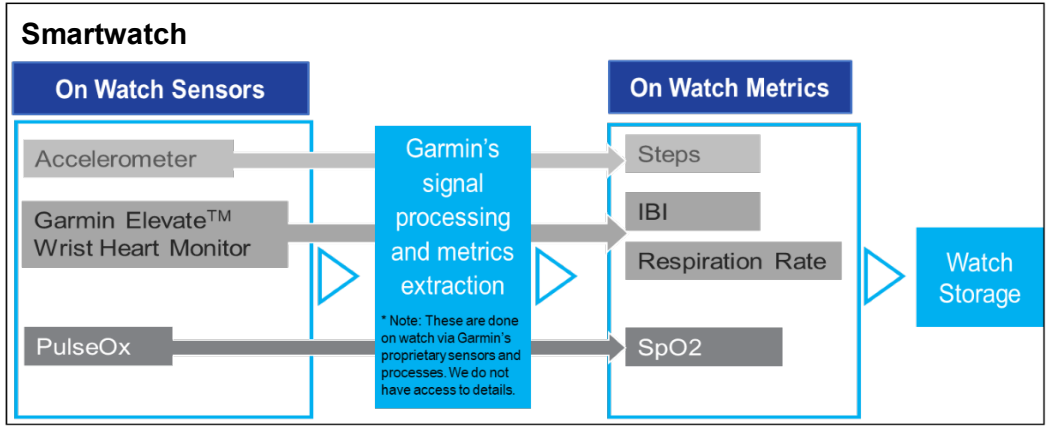
Simulated density of influenza alerts in Manhattan, New York; courtesy of JHU APL

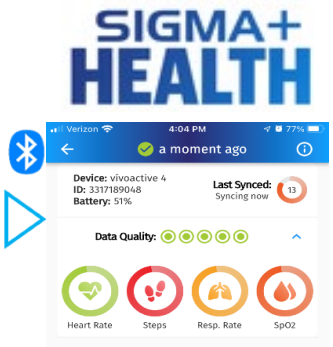
Data Processing Pipeline: Sensor Data



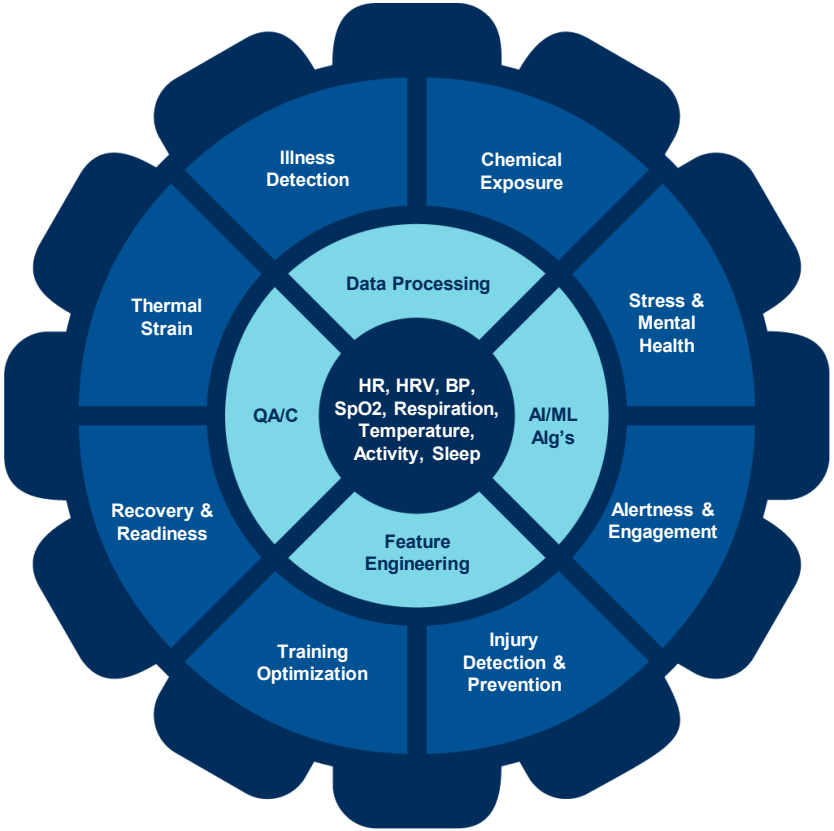








Metric	Unit	Frequency
Step count	steps/min	60s
Interbeat interval (IBI) *time between heart beats (inverse of heart rate)*	millisecond	with each beat
Respiration Rate	breaths/min	60s
SpO2	percent	60s

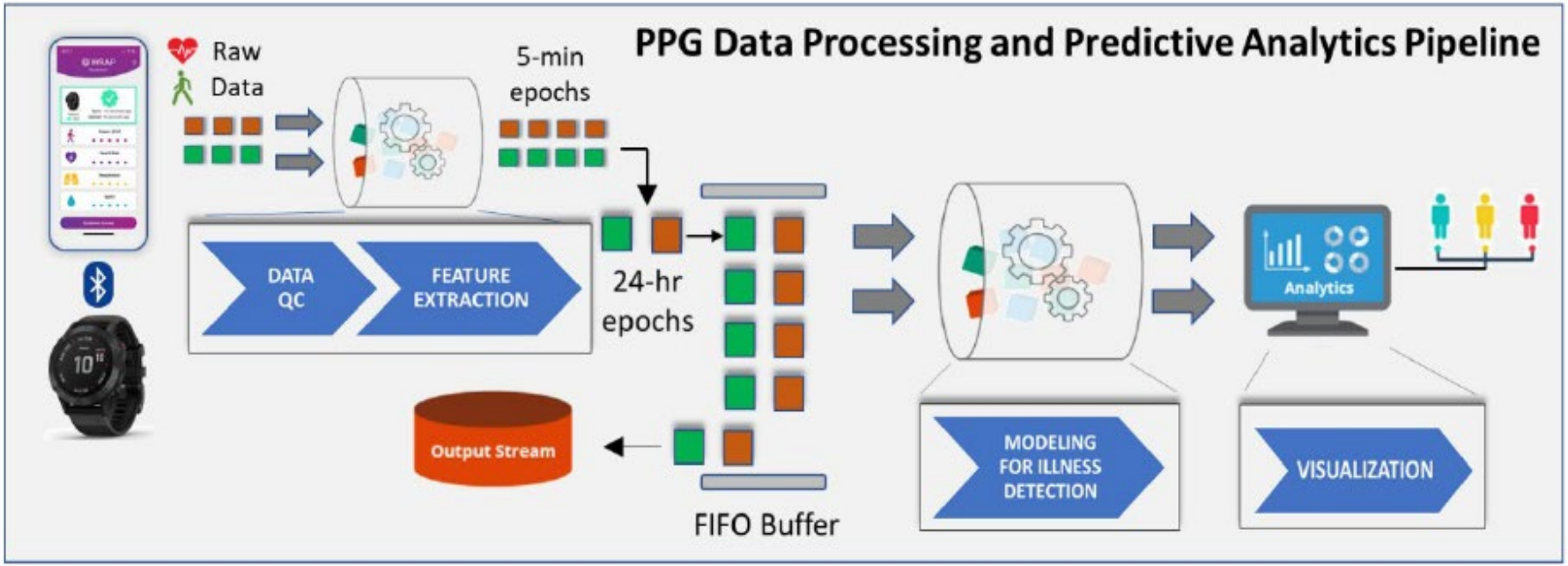


Algorithms and Applications

Because we can access **high fidelity metrics** such as IBI data, we can apply our own cleaning techniques and **calculate a variety of HR and HRV metrics** versus being confined to the vendor's choice. This allows our algorithms to be **device agnostic.**

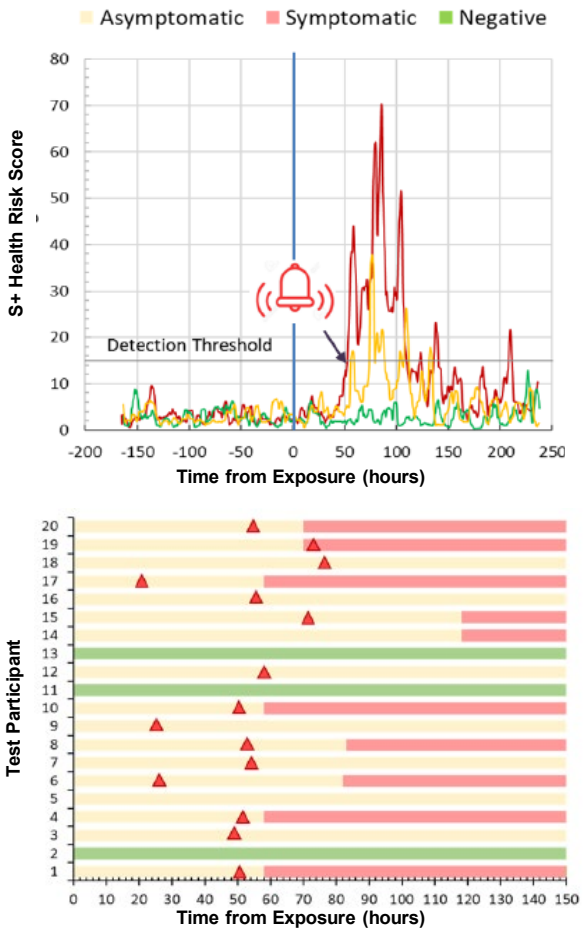
Data Processing: Metric Extraction and Risk Score Calculation

- Machine learning model for translating high fidelity physiological data from wearable sensor into actionable information (e.g., risk of presymptomatic or asymptomatic illness)



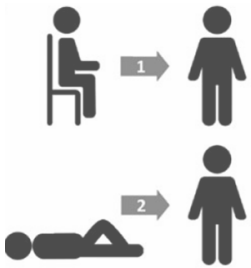
Early Illness Detection

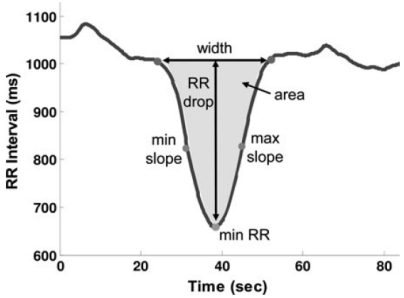
- Flu challenge study allowed us to quickly gather data on several sick individuals and precisely quantify detection time from illness exposure
  - Detected 16/17 positive individuals, including those who were asymptomatic, with no false positives
  - Most detected before symptom onset
- Refined this algorithm to work in real time with smartwatches and we are currently testing with several cohorts



Mild Traumatic Brain Injury

Developed a method using cardiac biomarkers for detecting mTBI within 72-hours post-injury that achieved **90% sensitivity and 69% specificity.**





Next Steps:

- Track recovery using the same biomarkers to objectively determine return to duty
- Extend to quantify the effects of repeated, sub-acute injuries
- Detect sub-acute injuries in 72-hours

FOCUS ON CLINICAL RESEARCH AND PRACTICE

Feasibility of Mild Traumatic Brain Injury Assessment Based on Cardiovascular Response to Postural Change

Russell, Katie N. MSSA; Preble, Edward A. PhD; Hegarty-Craver, Meghan PhD; Arrieux, Jacques P. MA; Cole, Wesley R. PhD; Choi, Y. Sammy MD; Grego, Sonia PhD; Rae Olmsted, Kristine MSPH; Gilchrist, Kristin H. PhD

Author Information

Journal of Head Trauma Rehabilitation: September/October 2020 - Volume 35 - Issue 5 - p E422-E428
doi: 10.1097/HTR.0000000000000582

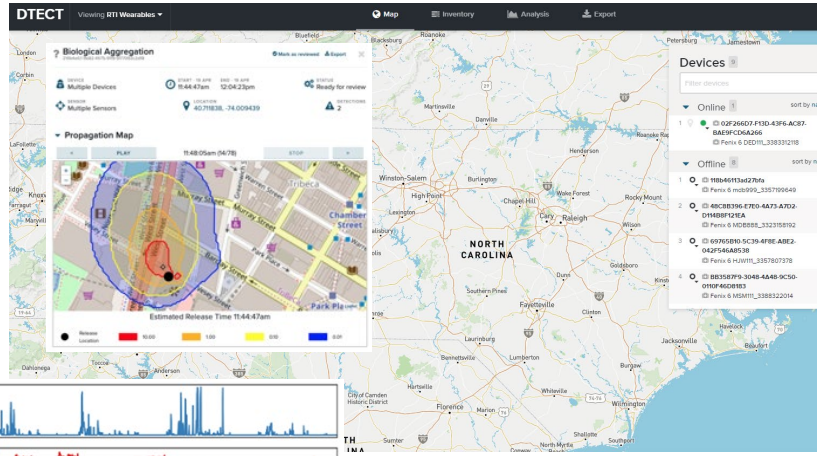
Russell, K. N., Preble, E. A., Hegarty-Craver, M., et al. 2020. *J. Head Trauma Rehabil.* **35**, 5, E422-E428.

Polar H10 can stream HR data to a tablet or phone in real-time using Bluetooth.

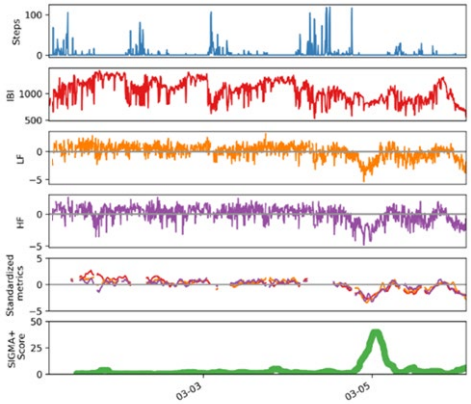
We have an app to walk users through the test and process the data.

SIGMA+ Field Demonstrations

- Integrating human sentinel capability into SIGMA+ network for CBRN detection
- Pilot wearables evaluations with SIGMA+ stakeholders
  - 40 participants, 8-week data collection
  - Test data collection architecture and evaluate data quality
- Field demonstrations in FY23
  - 100 participants, 12-month surveillance
  - Demonstration of algorithms for illness detection
  - Alerts to SIGMA+ network



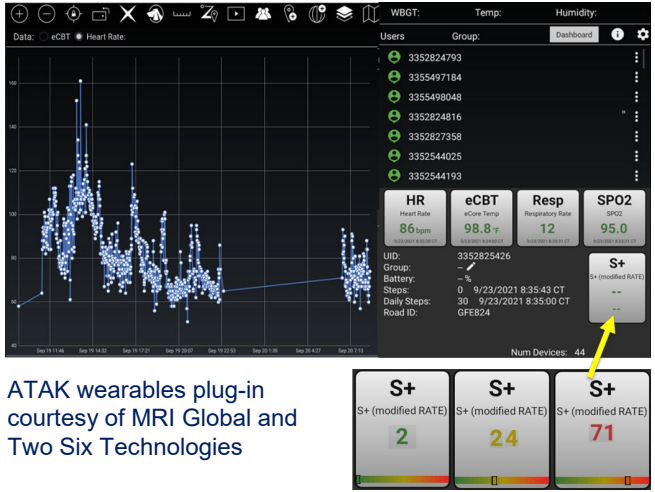
DTECT sensor visualization platform courtesy of Two Six Technologies



SIGMA+ wearables alert

DoD Demonstrations

- SIGMA+ demonstrated as local data collection and analytics (LDCA) architecture for simulated military scenarios
- Cyber-secure, closed-loop LDCA architecture operated with no internet connectivity
  - Situational awareness tool for garrison or tactical environments
  - Visualization integrated in DoD ATAK platform
- Incorporates health metrics including SIGMA+ risk score
  - Indicates deviation from individual's healthy baseline physiological metrics
  - Relevant to illness, CBRN exposure, or extreme fatigue (physical, heat strain)



ATAK wearables plug-in courtesy of MRI Global and Two Six Technologies

SIGMA+ Health Enables…

Secure, high-resolution data collection

- Real-time, raw data from best-in-class wearable sensors
- High-resolution data streamed independent of vendor cloud
- Secure cloud-based or local (no internet) data collection

Highly sensitive, predictive analytics

- Robust analytical models independent of vendor algorithms
- Metrics standardized to activity level, based on daytime and nighttime data
- SIGMA+ Health alerts every hour
  - Elevated SIGMA+ risk score = deviation from healthy baseline

NC-COMP

North Carolina
Center for Optimizing
Military Performance

- DoD recognizes the need to improve the health and performance of Service members (SM)
- NC-COMP is a “coalition of the willing” of over 40 academic, industry and DoD organizations working to unify & grow efforts in improving the health & performance of SM
- Kick-off was in September of 2021; currently applying for funding through a MRDC Other Transaction Authority (OTA)
- Wearables for objective measurement of health and performance underly many NC-COMP initiatives
- RTI and other NC-COMP members are collaborating to help deliver objective key readiness measures

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Discussion

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