“Predictive Health Management (PHM) for Human Assets – Military Perspective"

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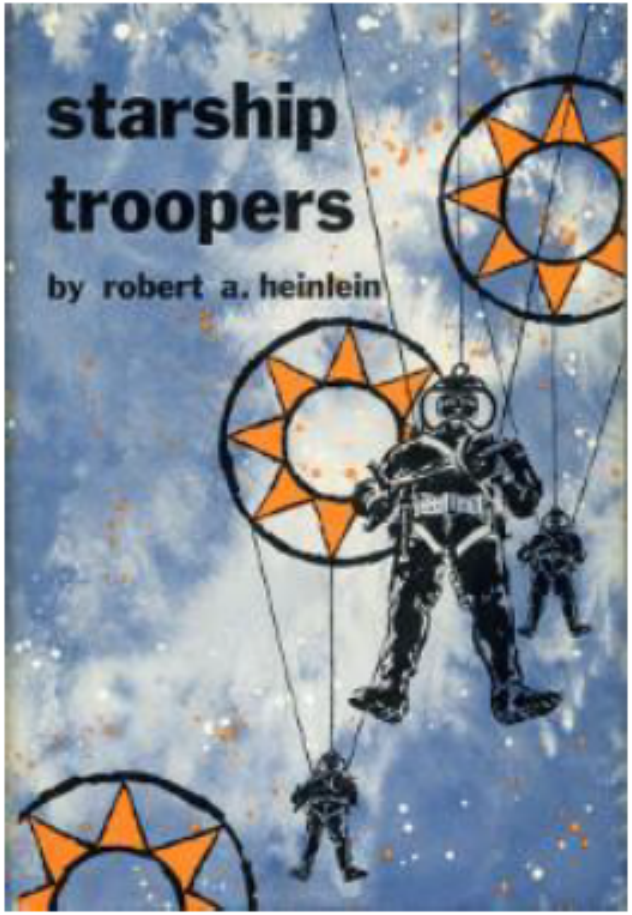

Robert Heinlein's 1959 book "Starship Troopers" provided a scientific concept of wearable physiological monitoring that inspired earlier Army research
First Edition cover]

Physiologic Status Monitoring
Key Partners

- US Army (USARIEM, MIT Lincoln Lab)
- US Navy (NHRC, ONR)
- US Marine Corps (School of Infantry-East, Marine Exp Rifle Squad))
- US Air Force (AFRL)
- DARPA (AugCog, Det & Comp Analysis of Psych)
- Combating Terrorism Technical Support Office (CTTSO)
- NSF (Nanosystems Engineering ResCntr: ASSIST)
- NASA (LifeGuard at NASA AMES)
- NIH/VA (Rehab & Behav syx with cognition/mood)
- International (Norway, Australia, France, UK, Germany)
- NATO Panel (HFM RTG-260; Enhancing Warfighter Effectiveness with Wearable BioSensors & Phys. Models)

PEO Soldier Mission
The Soldier: Center of Our Strength

PEO SOLDIER MISSION

"DEVELOP, ACQUIRE, FIELD AND SUSTAIN AFFORDABLE INTEGRATED STATE OF THE ART EQUIPMENT TO IMPROVE SOLDIER DOMINANCE IN ARMY OPERATIONS TODAY AND IN THE FUTURE"

http://www.peosoldier.army.mil/aboutus/mission.asp

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USARIEM
Warfighter Health & Performance

U.S. ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

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BIOPHYSICS & BIOMEDICAL MODELING DIVISION

MISSION

Develop biomedical models and networked physiological sensor systems that enable Soldiers to predict and counter health threats from physical challenges, protective ensembles, non-agent chemical exposure, and extreme environments.

BIOMEDICAL MODELING AND SIMULATION

RESEARCH DIVISIONS

- Biophysics & Biomedical Modeling (BBMD)
- Military Nutrition (MND)
- Military Performance (MPD)
- Thermal & Mountain Medicine (TMMD)

http://www.usariem.army.mil/index.cfm/about/divisions/bbmd.

U.S. Army
Research Institute of
Environmental Medicine
Natick, Massachusetts

TECHNICAL NOTE NO. TN16-2
DATE March 2016
ADA 630 142

REAL TIME PHYSIOLOGICAL STATUS MONITORING (RT-PSM): ACCOMPLISHMENTS, REQUIREMENTS, AND RESEARCH ROADMAP

The FUTURE *of* WEARABLE TECH

Working Soldiers to failure is a costly mistake, and until recently it's been anybody's guess at what temperature and exertion rate a given Soldier would max out. But now, wearable, chest-based sensors (far more accurate and informative than current wrist-worn models) can tell when a Soldier is nearing cardiac and temperature limits—protecting Soldiers, preventing heat casualties and generating data to help predict how Soldiers will perform under new environmental conditions.

by Dr. Reed W. Hoyt and Dr. Karl E. Friedl (COL, USA Ret.)

Army AL&T Magazine, January-March 2016; www.asc.army.mil

Concept for physiological monitoring systems

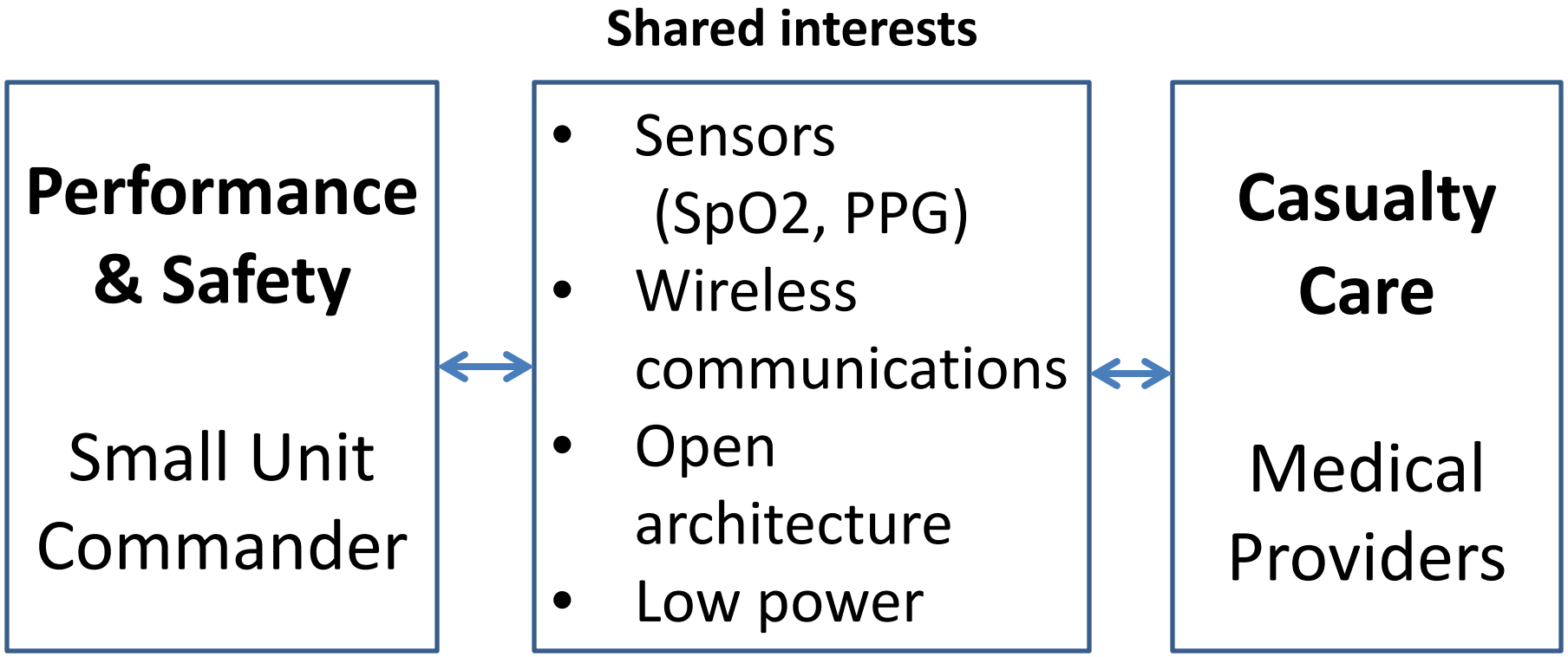
Continuum of monitoring: transition from performance to triage

Monitoring requirements and functions

Applications of Real Time Physiologic Status Monitor (RT-PSM) technologies

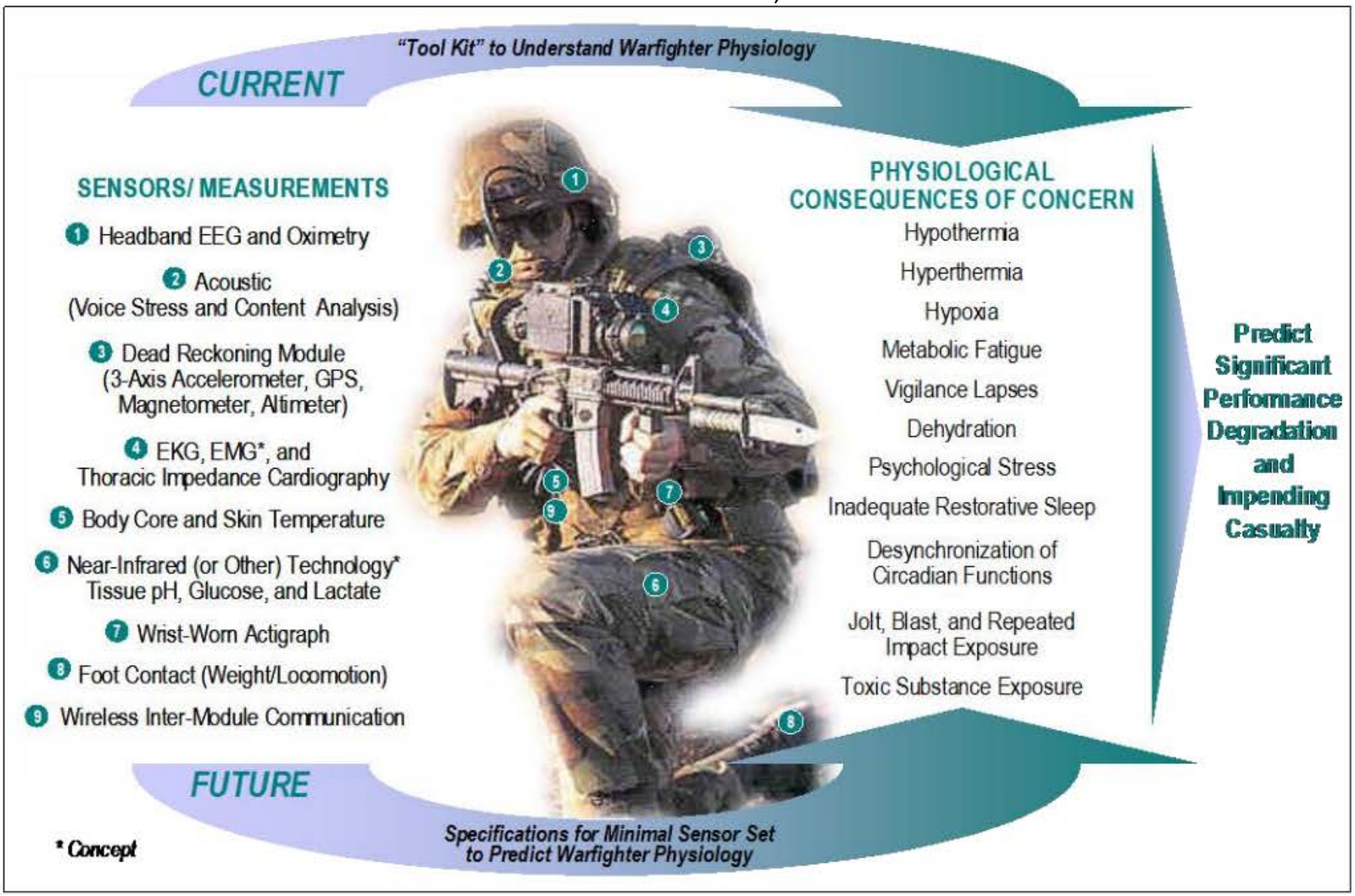
- **Goal: provide actionable information for safety & performance**
  - dismounted route-planning decision support tools
  - performance and safety monitoring in high-risk chemical & biological threat environments requiring full protective gear
  - performance & safety training for individuals and small-unit leaders

Biomedical monitoring – distinct research objectives & regulatoty requirements

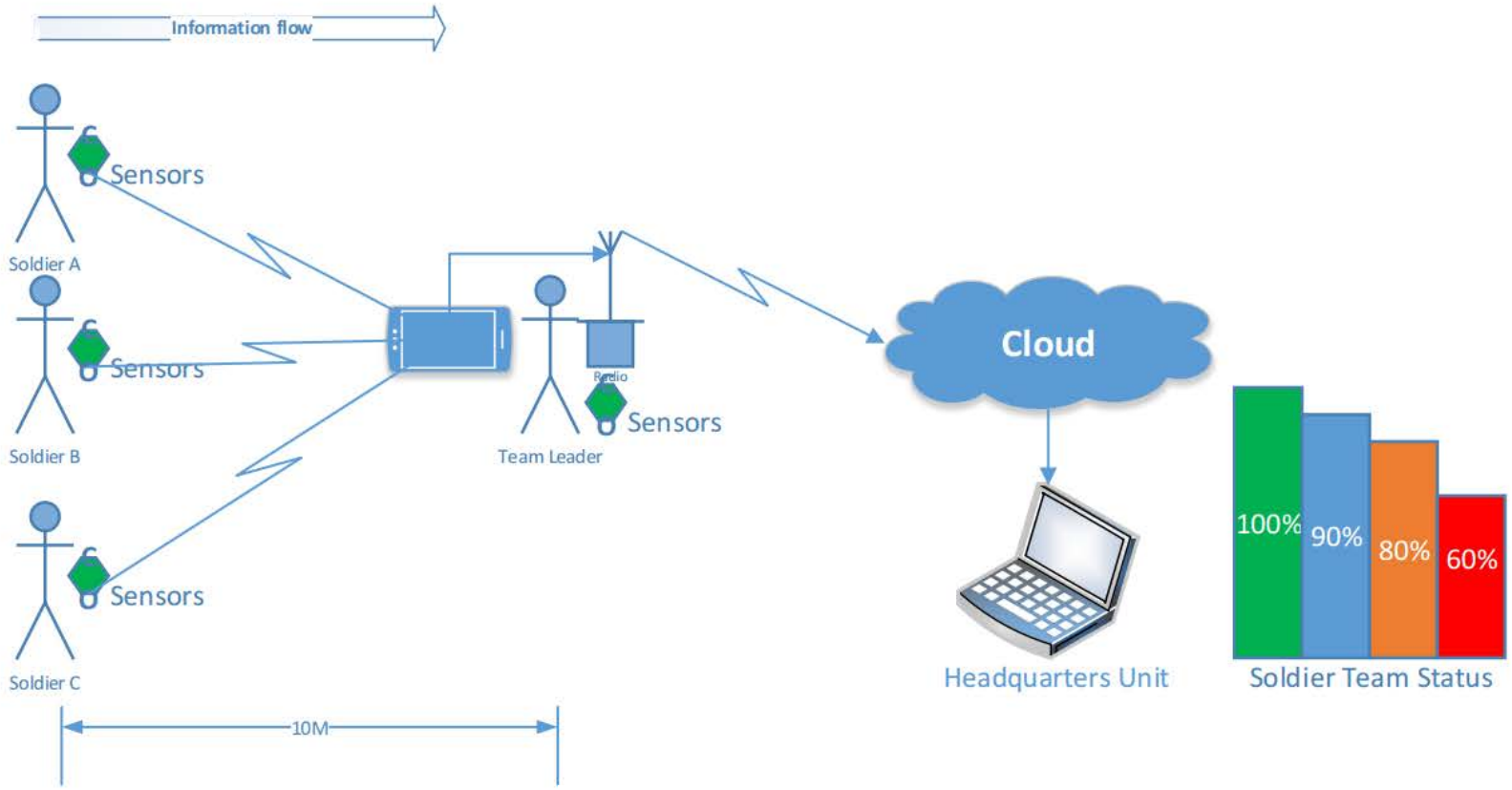


Early concept of wearable sensor data fusion to predict physiological outcomes of relevance to military training and operational environments

Source: Karl Friedl & Janet Reece, 1999



Unit Level Physiological Status Monitor Schema



Warfighter Physiological Status Monitor – Initial Capability (WPSMIC) 2004-2006, led by USARIEM. The primary objective was to create a wearable system that includes sensors, data processing and algorithms, and local area network communications.

Eyewear

Eye Movement Monitor

Early seizure warning, chemical Exposure, fatigue, data read-out, GPS

Smart Textiles

Energy & Flexible Displays

Thin flex batteries, flexible solar panels

Smart "Keychains"

Environmental Monitoring

Air quality, temperature, humidity & Ozone, radiation, electromagnetic Feedback, nitrates in food, luminosity (UVA, UVB), GPS location

Smart Tattoos

Medical & Environmental Sensing

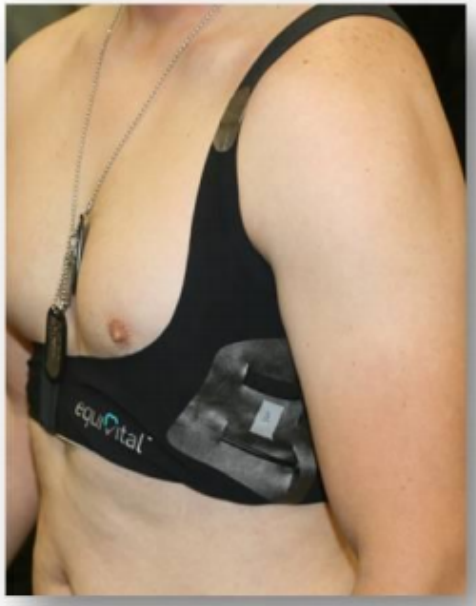
Blood o2, temperature, EEG, ECG and EMG, vibrating alerts, voice commands

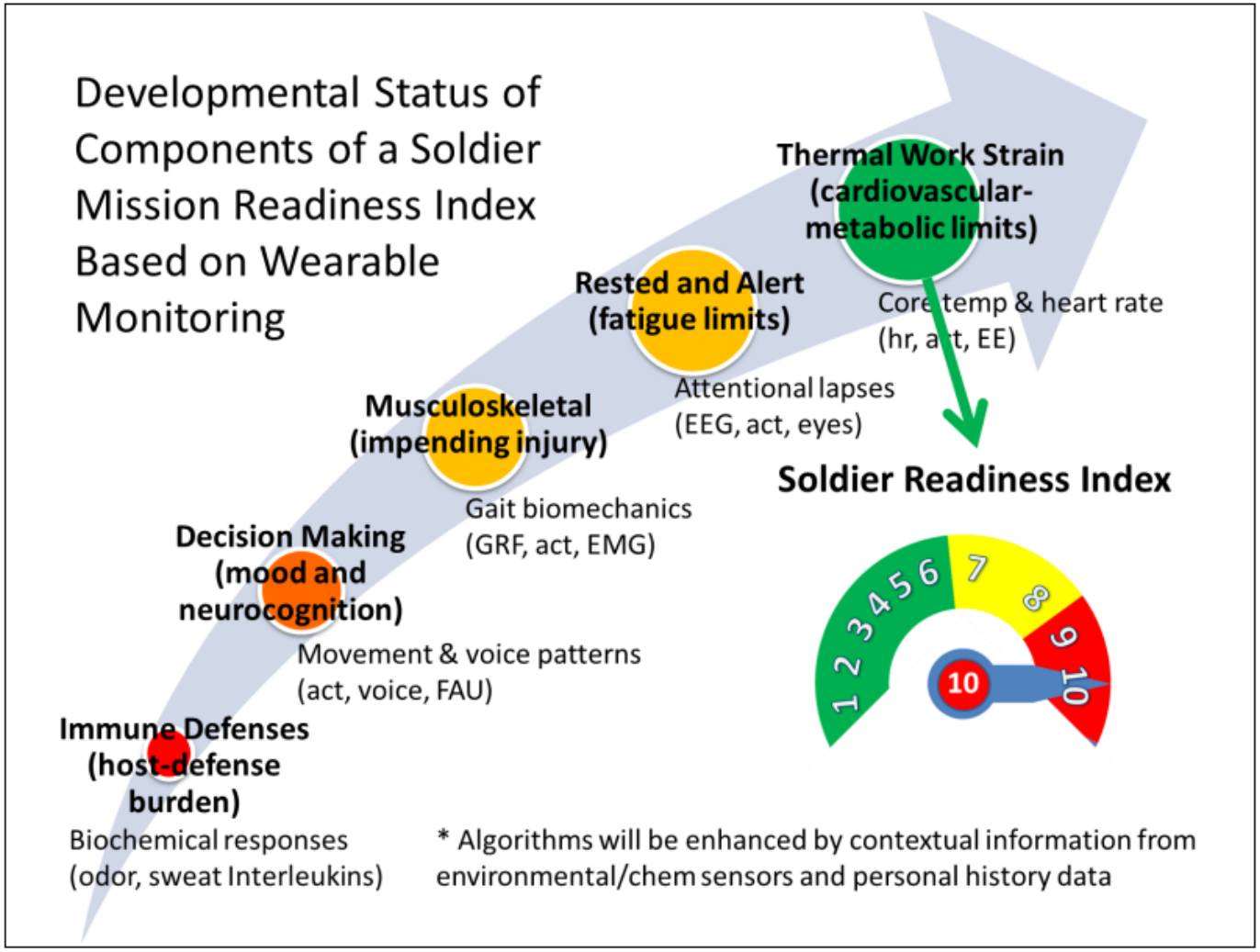
Wearables

Biometric data:

Cardiac monitoring, temperature decreased performance warning, GPS seizure warning, pulse ox , accellerometer

In 2006, an FDA 510k certified, chest worn system, the Equivital EQ01 (Hidalgo, Ltd.) became an important field research tool for remote physiological data acquisition.





Examples of RT-PSM

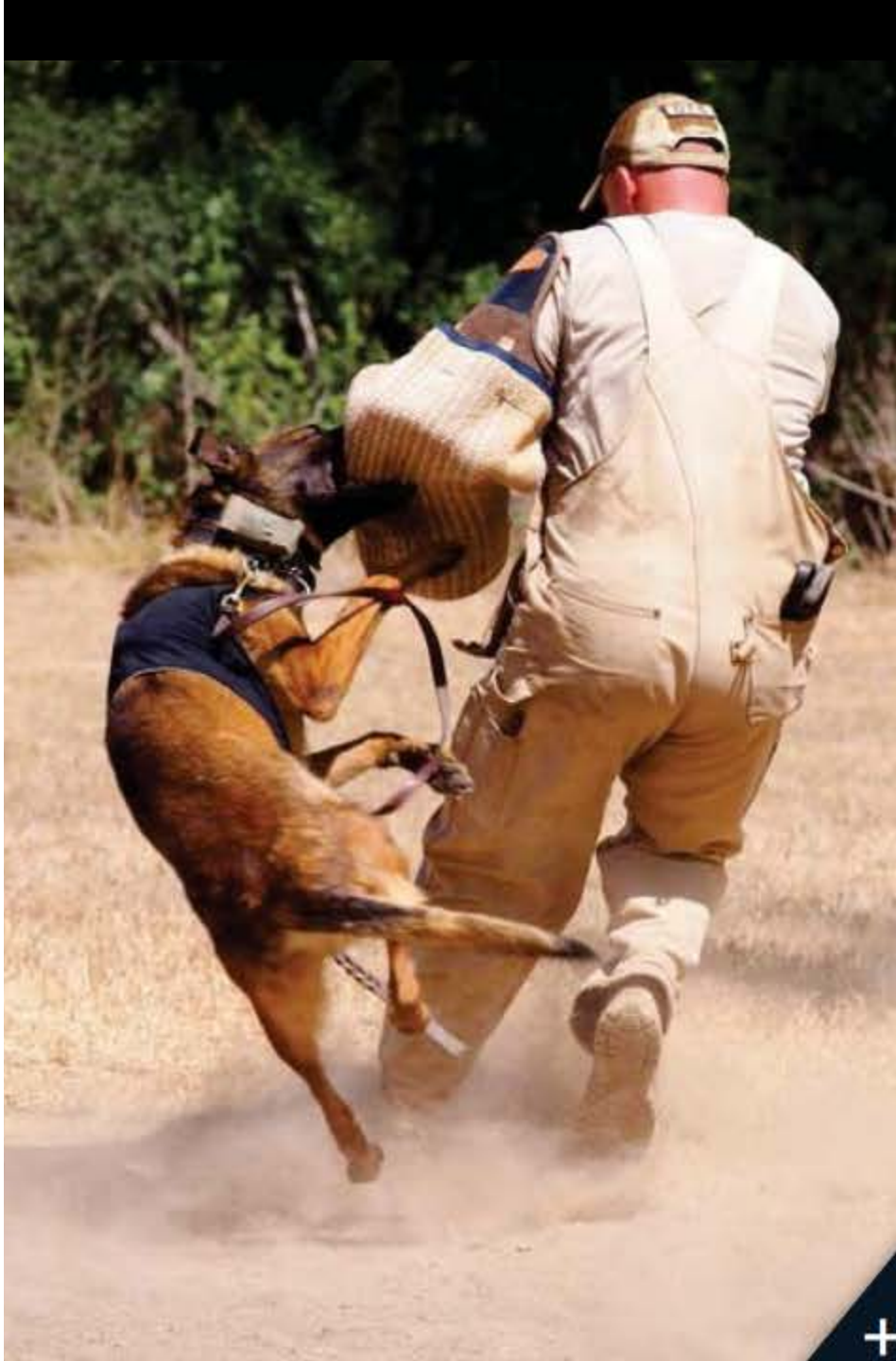
- Army National Guard (ARNG) Weapons of Mass Destruction Civil Support Teams (WMD-CSTs) train and respond to emergency events in full chemical, biological, radiological, nuclear and explosive protective gear
  - Chest-mounted physiological sensors provide work- and heat-strain data to downrange team members and to leaders at a command post
- Marine Expeditionary Rifle Squad “Gruntworks,” (human systems integration center,Marine Corps Jungle Warfare Training Center, Camp Gonsalves, Okinawa, Japan)
  - wearable sensors to quantify human thermal or work strain during field evaluations of new jungle uniforms

Thermal-strain monitoring testing with a prominently displayed numeric readout (USARIEM)

(Photo by Dr. Mark Buller, USARIEM)

A military working dog wears a real-time physiological status monitor (RT-PSM) chest sensors and a collar-worn acoustic sensor to detect panting frequency.

(Photo by Anthony Karis, USARIEM)



Soldier Readiness Scores

near-term components

Thermal-Work Strain

Need to know when a soldier is reaching limits of work performance in hot environments

Applications: encapsulated soldiers; route/mission decision aid; individualized predictions in IET training

TRL 7 National Guard Bureau implementing first version for WMD-CSTs

Alertness

Need to know when a soldier's attention is lapsing with micro-sleeps and reduced situational awareness

Applications: sentry and monitoring duties; night convoy drivers

TRL 5 Demonstrated methods to monitor alertness in the field but need to be less intrusive and more comfortable for continuous use, and higher reliability of measures

Musculoskeletal

Need to know who is beginning to fail in loaded patrolling based on gait changes and ground reaction forces

Applications: decision support tool for load distribution within squads in IET and in operations

TRL 4 Concepts for gait and lower extremity biomechanics measures to predict impending injury

Soldier Readiness Scores

long-term components

Neuropsychological

Need to know who may be in distress based on changes in mood, cognition, and stress levels

Applications: pre-mission screening tool for “not mission ready” individuals; screening tool following head impact, trauma, or psychological stress

TRL 5 Physiological markers (movement patterns, voice analyses, eye gaze, and facial expressions) are predictive for depression and mild cognitive impairment

Physiological Stress/Host Defense Responses

Need to identify early signs of incapacitation from environmental exposures such as air pollution and infectious agents to sustain performance and implement protective measures

Applications: decision support tool for performance decrements (e.g., reduced lung volume) in MOUT; activation of protective measures and/or early treatment)

TRL 4/5 System for outward looking ozone/particulate sensors and inward looking respiratory changes has been demonstrated; routine ambulatory cardiorespiratory measures have been used to predict Marburg virus infection ahead of usual diagnostics

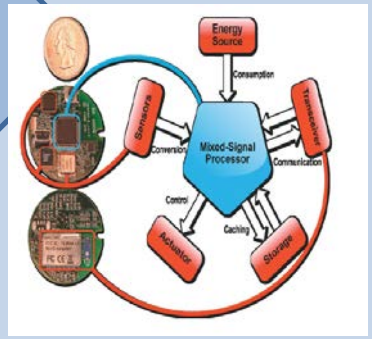
Platform Characteristics

Initial system

Wear-and-forget
noninvasive

Objective system

Body powered
implantable

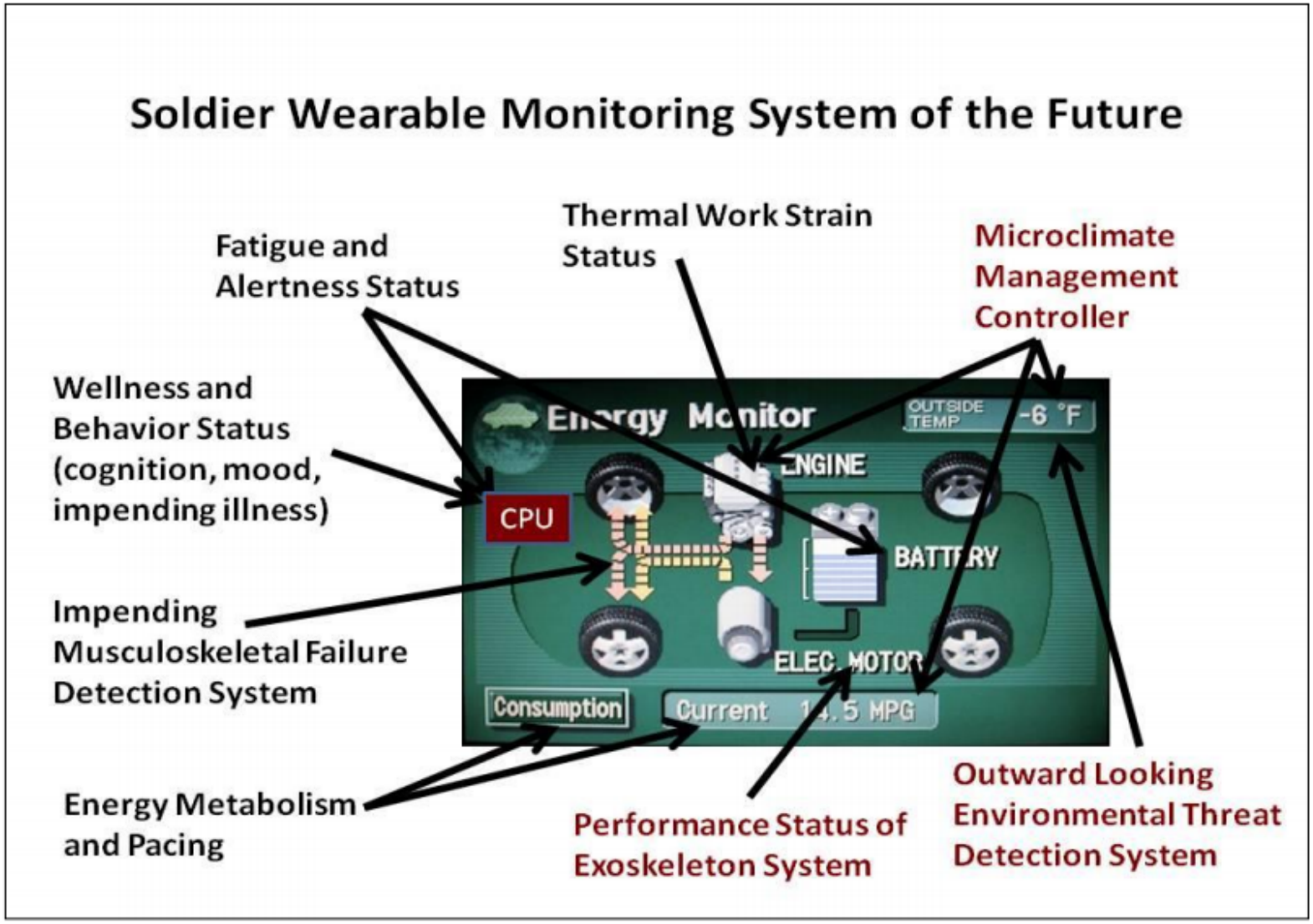


Future Gen system

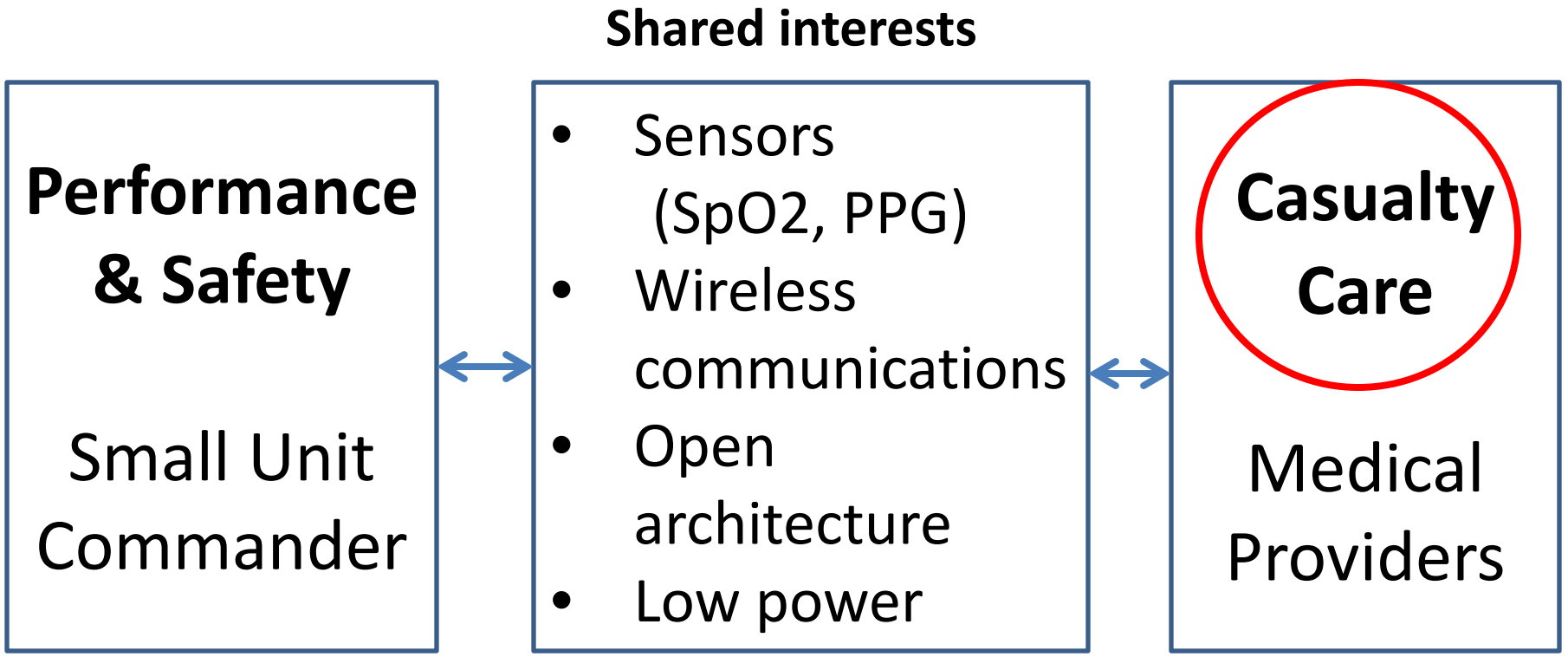
Brain-to-brain
sensing

Internet of Things
Contextually Rich Predictions

Notional Soldier dashboard of the future, similar to modern car displays.



Biomedical monitoring – distinct research objectives & regulatoty requirements



Battlefield Mobile Health Applications

Remote Patient Monitoring, Encounter Documentation, and Telementoring over Secure Mobile Tactical Networks

Guiding Research Principles

- Align research efforts with both Joint and separate service health services capability gaps.
- Adapt & integrate government or commercially developed technologies rather than develop new ones.
- Minimize size, weight, cost, and logistical support requirements.
- Implement medical applications on common user digital devices being developed, for line applications (operations, intelligence, and logistics).
- Maximize use of emerging organic joint tactical communications networks versus stand-alone medical networks.
- Evaluate prototype medical capabilities at field training exercises.

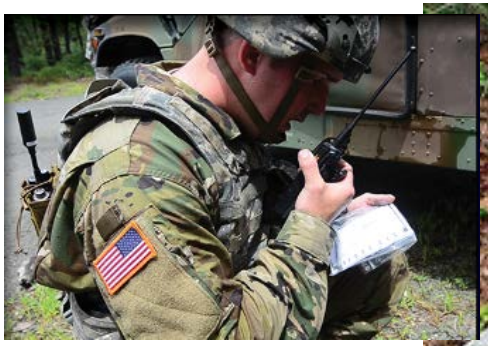
Capability Gaps

- **Gap #1**– Document combat casualty care at the points of injury (POI).
- **Gap #2**– Conduct patient medical monitoring at points of care (POC).
- **Gap #3**– Document care during evacuation.
- **Gap #4**– Provide telementoring/tele-consultation at Roles1-3 POI & POC.
- **Gap #5**– Provide Role 1 medic providers with decision support.
- **Gap #6**– Provide secure medical information exchange connectivity at points of injury and during pre-hospital evacuation within roles 1-3 medical treatment facilities.
- **Gap #7** – Upload medical encounter documentation captured at points of injury and during casualty evacuation to soldier's permanent health record.

* *Gaps extracted & adapted from:*

- *JROC Rev 7.0, ICD for Theater Combat Casualty Care, 5 Oct 2007*
- *JROC Ver 1.0, Vol 1 ICD for Force Heath Protection, 24 Feb 2010*
- *Nomination & Rationale for Research Initiative – SMART Telemedicine at Point of Injury Research Project", 8 January 2012*

Medical Information Exchange at Point of Injury



Calling in 9-Line MEDEVAC Request

4G LTE Mobile Base Station in Squad MRAP

4G LTE Base Station mounted in Aerostat

NETT Warrior End User Device (EUD)

Medical Information Exchange during Ground MEDEVAC

NETT Warrior End User Device (EUD)

TEMPUS-pro Operational Telemedicine System

Medical Information Exchange during Air MEDEVAC

Flight medic data entry & telementoring from destination MTF

RT-2033 Wideband Network Waveform Radio

TEMPUS Pro Operational Telemedicine System

NETT Warrior End User Device (EUD)

Summary

- Remote Time Personal Status Monitoring **payoff** – obtain physiological data on Soldiers & Marines in training & operational environments under stressful conditions, not reproduced in the lab
- Over time, the RT-PSM datasets have guided changes in USMC work/rest doctrine
- A concerted R&D program is needed to develop a common wireless PSM infrastructure
- Integration of patient monitoring, encounter documentation, and tele-mentoring is feasible in the tactical environment.
- Reliable hands-free data entry methods is essential for effective medical information exchange during forward combat casualty care.
- Field exercise & evaluations are critical to validating the research strategies for adopting and adapting both commercial and GOTS technologies

Questions

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