White Paper

Data From Wearables:

Emerging Technology and Emerging Challenges

ATARC Data Interoperability Working Group

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Advanced Technology Academic Research Center

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On behalf of the Advanced Technology Academic Research Center, I am proud to announce the release of the 2023 White Paper titled **"Data From Wearables: Emerging Technology and Emerging Challenges"**, authored by the members of the **Data Interoperability Working Group**.

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Disclaimer: This document was prepared by the members of the ATARC Data Interoperability Working Group in their personal capacity. The opinions expressed do not reflect any specific individual nor any organization or agency they are affiliated with, and shall not be used for advertisement or product endorsement purposes.

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1 Introduction

In a March 2022 White Paper titled, “Warfighter Health: Leveraging AI for Improved Healthcare Delivery”, the Advanced Technology Academic Research Center (ATARC) Data Interoperability Working Group outlined a range of data interoperability factors affecting the ability of the Department of Defense to effectively utilize Artificial Intelligence (AI) technologies to improve military force readiness and informed situational awareness and decision making related to warfighter health. This white paper builds on prior research, industry perspective, as well as governmental stakeholders critical, with the intent to initiate real, informed discussion of the integration of wearables technology from a dual use commercialization and larger organizational integration perspective from small to large enterprise solutions. Our primary focus on the use of personal wearables to support military readiness is a result of industry engagement, programmatic and commercial research, as well as stakeholder and end user engagement, with the intent to expand upon the following topics as we engage more stakeholders across the wearables technologies communities of practice. We will discuss some of the highlights and explore several of the legal/ethical, technical, cultural, and training challenges that organizations are facing.

Opportunities Summary:

- Opportunity to conduct longitudinal studies.
- Opportunities for industry, academic, and government collaboration via defense innovation focused working groups, exercises, and joint collaborative events, fusing varying perspectives into a streamlined vision of the art of possible for data interoperability.
- Data persists, no longer need to continually conduct baselines as military members move; important data is not lost to local storage.
- Individual readiness (physical fitness, sleep, cognitive ability) can inform personnel assignments in near real time.
- Data can cue specialists to individual needs and provide personalized recommendations.
- Readiness can be aggregated to provide Commanders with dashboard views of units.
- Medical providers have access to data generated before a medical event to help identify root causes or trends.

Health or healthcare or system data is a representation of clinical illustration in its most raw form, whether collected remotely or in a designated set formal parameter. In warfighter health equivalent, active or inactive, the same rendition of collection, analysis, and interpretation rests with the participants of the event. Privacy, sweat equity and technology transfer intellectual property protection rights are all embedded in the requirements of the process that involves its acquisition, processing, storing, and transaction.[1] Healthcare data privacy makes its rank even more substantial than other type of privacy as it is speared by Hippocratic Oath cloth compliance of the human health sector which carries unique commodity value unparalleled by other commodities.[2] Data ownership rests on full disclosures, agreement and release by all parties involved and will incorporate protective privacy of individual(s) reference as healthcare sector participants in open market systems transact the data. Personal wearables equivalate same type of data collective means as in healthcare facilities collective modalities and require comprehensive like disclosures, adapted formulations, private or local drive option of hold/ save versus shared cloud, and choice of parties by the individual producing the data to identify and designate with specified rights to data, including expert contributions. This further includes but is not limited to expert subject matter healthcare experts who further interpret, modify, release and apply said data to retain appropriate rights for renumeration of transacting said data and value-based proposition initiated from respective know how, intellectual, academic and experienced contribution.[3]

Advancements in (bio)sensing technologies, the proliferation of consumer and research-grade wearable devices, and developments in artificial intelligence are driving efforts in academia, industry, and government alike to develop next-generation digital medicine platforms.[4] Wearable technology promises novel modes for (near) continuous, remote health monitoring outside the clinic and the prediction or timely identification of health conditions.[5] As these platforms evolve and mature, so too must federal agencies in the way data is gathered, analyzed and stored. There are important considerations to make with regards to evaluating, testing, and/or deploying wearable technologies. Here, we will briefly explore what wearable technology is and potential benefits for federal agencies, how data is collected and analyzed from wearables, and best practices for managing and storing wearables data with an eye on interoperability with federal systems.

Any discussion of the current market for wearables technologies requires a fundamental understanding of how all of our smart watches, sensors, smart clothes, and other devices talk to each other, or artificial intelligence (AI), machine learning (ML), and how it scales to become Internet Of Things (IoT)- the ‘wizard of Oz’ technology which enables us to better understand

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[1] CC Cotca. International Standardization Organization, Japan Osaka Meeting. Resolution Proposal on Data Collection Devices in Dentistry & Dental Settings

[2] CC Cotca, et.al. International Electrotechnical Commission. SEG 12. Bioconvergence Standardization Committee & Digital Twins Subject Matter Presentation & Regulatory Recommendation

[3] CC Cotca, C3 Think Tank. 360healthcareTM. White Paper (https://c3thinktank.org/white-papers)

[4] Steinhubl, S. R., Wolff-Hughes, D. L., Nilsen, W., Iturriaga, E. & Califf, R. M. Digital clinical trials: creating a vision for the future. npj Digit. Med. 2, 1–3 (2019); Ku, J. P. & Sim, I. Mobile Health: making the leap to research and clinics. npj Digit. Med. 4, 1–4 (2021); Seifert, A., Hofer, M. & Allemand, M. Mobile Data Collection: Smart, but Not (Yet) Smart Enough. Front Neurosci 12, (2018)

[5] Dunn, J., Runge, R. & Snyder, M. Wearables and the medical revolution. Personalized Medicine 15, 429–448 (2018)

the metrics of how we function, think, and feel. Internet of Things (IoT) is a somewhat ubiquitous, and frankly, intimidating concept to most. Simply put- Internet of things describes how physical objects with sensors, with processing ability, software and other technologies, are able to connect and share data with other devices and systems. As the number of devices, share of data increases, so too will the interoperability of varying devices and applications, due to their better ability to communicate via artificial intelligence and machine learning.

2 Wearables

Wearable devices can be worn or attached to clothing or the body and contain a variety of sensors that can be used to track and monitor information, such as heart rate, blood oxygen concentration, location/mobility, and activity level, or be utilized in optimizing performance in warfighter scenarios such as high noise environments with the use of an intra-oral removable device. Popular types of consumer wearables include fitness trackers, smart watches, and augmented reality glasses. Although these are designed with the intended purpose of allowing individuals to monitor and track their own health, many consumer wearable device platforms are being used for medical research. Popular commercial platforms with research support include Fitibit/Fitabase, Garmin, Apple (Apple Watch and HealthKit), Oura Ring, and Samsung (Galaxy Watch and Samsung Health), among others.

These consumer wearables and associated apps provide a range of health and wellness services and support for conducting studies. Less general purpose, research or clinical grade wearables are often tailored to very specific use cases and geared towards answering research questions or in guiding medical treatment. Examples include continuous glucose monitors (CGM) (e.g. Abbott) or patches that attach to the skin and measure cardiac vital signs (e.g. VitalPatch).

Related to wearables are the continuous development of Remote Patient Monitoring (RPM). While RPM is largely provided by clinicians and considered as regulated medical devices, it's worth noting a gradual convergence of wearables and RPM technology in the future.

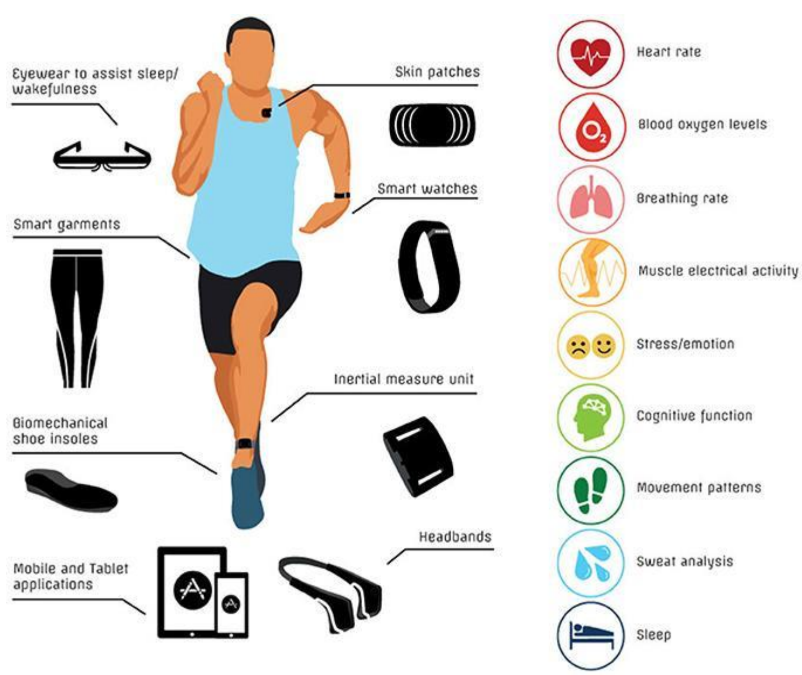

Figure 1: Summary of wearable technologies and associated biometrics that can be monitored. Adapted from Peake, Kerr, & Sullivan (2018) Frontiers in Physiology 9:743 doi:10.3389/fphys.2018.00743. Copyright Peake, Kerr, & Sullivan 2018

3 Data Pipeline

3.1 Data Collection

Collecting, analyzing, and extracting actionable insight from wearable tech data is a complex process requiring specialized hardware, software, and analytic tools. Raw data (e.g. triaxial acceleration) is collected from sensors (e.g. accelerometer) integrated into the device at a certain sampling frequency. Data is then transferred off the device to the cloud and/or local storage solution. Commercial solutions typically offer the ability to download an individual's data from their cloud via Application Programming Interfaces (APIs), providing programmatic integration with other systems (e.g. EHRs).

3.2 Size, Weight, Power: Low swAp Considerations

Size, weight, and power (low swAp) are also key considerations when discussing data collection in varying environments from a bandwidth and connectivity view, as well as electronic warfare and cybersecurity lenses. Increasingly, wearable technologies have expanded from the commercial and defense perspectives, to include not only the physiological monitoring of individuals, as well as the larger conditions we sensing and monitoring of their environment. As wearable technologies are further integrated in forward operating, remote, far edge, or remote telemedicine/telehealth locations, bandwidth and connectivity becomes increasingly significant, as signature management is critical in these environments to protect warfighters, operators, and forward operating sites/bases, in example.

This inclusion of wearables capabilities/adjacencies, from the multi domain perspective, further enables warfighter and industrial situational awareness, health, as well as industrial/ commercial risk identification, mitigation, and signals management/threat detection. Table 1 below summarizes features and capabilities provided by various wireless technologies.

Table 1: Comparison of various wireless standards[6]

Wireless Standard	**Range** (meters)	**Data** (Mbps)	**Bandwidth** (GHz)	**Power Consumption**	**Applications**
Bluetooth	100	1-3	2.14	2.5-100 mW	Short range, control and monitoring
ZigBee	10-100	0.250	2.4/868/915	30 mW	Low power consumption & data rates applications

[6] Table sourced and modified from Bhelkar and Shedge, doi: 10.1109/ICATCCT.2016.7911963

Wireless Standard	**Range** (meters)	**Data** (Mbps)	**Bandwidth** (GHz)	**Power Consumption**	**Applications**
WiMAX	15,000	75	2.3/2.5/3.5	-	Provides internet facility for mobile devices
Wi-Fi	5000	1-450	2.4/2.5	-	Wireless networking and data exchange
IrDA	1	0.1 - 1	-	-	Not suitable for wireless health monitoring
MICS	2	0.5	0.402/0.405	25 µW	Low data rate, not preferred

Table 2: Sensors commonly found in wearables and measured data

Sensor Type	**Measured Data**
3 axis accelerometer gyroscope	Movement (translation/rotational) and position of body (type, intensity of physical activities)
Optical heart rate	Heart rate in beats per minute and heart rate variability
Pulse oximeter (light-based)	Blood oxygen saturation
Temperature	Body or skin temperature
Skin electrodes	Electrocardiograms (i.e. electrical impulses of heart)
GPS Magnetometer Compass	Precise location and bearing from which various metrics can be derived (e.g. distance traveled, environmental exposures)
Piezoresistive or piezoelectric	Breathing rate per unit time
UV sensor	UV index (intensity of ultraviolet light)
Electrodermal	Changes in electrical activity measured on skin, related to stress levels

Sensor Type	Measured Data
Ambient light	Measures intensity of light form which other bio-markers (e.g. sleep time and duration) can be derived

3.3 Data Processing

Raw data from sensors, like those in Table 2, must be processed to yield physiologically and behaviorally relevant metrics. These metrics are often referred to as digital biomarkers[7], digital endpoints[8], or digital clinical measures[9]. For example, multi-step algorithms (e.g. noise filtering, data transformation) are applied to raw accelerometer data to calculate step count as a digital biomarker for physical activity. Digital biomarkers, like intensity of physical activity, may combine multiple data streams like accelerometer and heart rate data to improve accuracy. Other notable digital biomarkers include sleep duration, sleep quality, daily distance traveled, resting heart rate, among a myriad of others. It is important to note that digital biomarkers and their underlying algorithms must undergo rigorous verification and validation[10] prior to operational or clinical use and while progress continues along these lines there remains important questions about generalizability of methods/algorithms and how to leverage data from multiple sources.

Algorithms to derive digital biomarkers, like step count for example, are often maintained by companies as proprietary information and they are typically developed using data collected from a small population that may not appropriately translate to other populations or environments. This complicates the ability to control for systematic device-specific biases (e.g. comparing step count measured with a Fitbit to an Apple Watch) and comparisons across individuals when employing a 'bring-your-own-device' strategy to data collection and monitoring. In these situations, longitudinal **changes** in digital biomarkers measured for a single individual may be more appropriate as opposed to attempting to make inferences at a cohort level (e.g. physical fitness of a group). While downstream analyses may account for device-specific biases, another approach to data collection is to issue the same wearable devices to a cohort ensuring a fair comparison (i.e. normalization) is being made across the group.

[7] Coravos, A., Khozin, S. & Mandl, K. D. Developing and adopting safe and effective digital biomarkers to improve patient outcomes. npj Digit. Med. 2, 1–5 (2019)

[8] Landers, M., Dorsey, R. & Saria, S. Digital Endpoints: Definition, Benefits, and Current Barriers in Accelerating Development and Adoption. DIB 5, 216–223 (2021)

[9] Shandhi, M. M. H. et al. Recent Academic Research on Clinically Relevant Digital Measures: Systematic Review. Journal of Medical Internet Research 23, e29875 (2021)

[10] Goldsack, J. C. et al. Verification, analytical validation, and clinical validation (V3): the foundation of determining fit-for-purpose for Biometric Monitoring Technologies (BioMeTs). npj Digit. Med. 3, 1–15 (2020)

3.4 Data Analysis and Modeling

Digital biomarkers must be analyzed and assessed for associations with particular outcomes of interest. For example, the physical fitness of an individual, the early detection of COVID, the identification of individuals at risk for heat stroke. This can be done through a variety of statistical modeling methods, including, more recently, machine learning and artificial intelligence approaches. To establish clinical utility/validity it is important to assess the performance of developed models (e.g. accuracy, error rates, bias), which is typically done by a comparison with gold standard, benchmark data or assessing outcome rates before and after implementation. It is also important to be cognizant of the population and environment in which digital biomarkers and derived models were developed. Although a nascent field, progress continues to be made to integrate wearable technology and digital biomarkers into practice. In this regard, we refer to the Digital Medicine Society's Library of Digital Endpoints[11] for an extensive list of industry-sponsored clinical studies involving digital biomarkers across diverse health applications.

3.5 Data Storage

In order to ensure that wearable tech data is managed and stored securely, federal agencies tend to use specialized software and tools. These tools are designed to manage and store data in a secure and compliant manner. Additionally, these tools are designed to make it easy to access, analyze, and share data. The ability for data to be stored where it can also be read by a variety of modern applications becomes a key element of data storage platforms. Performant platforms that offer file and object protocols help enable data sharing through application level protocols (API's). These API's become the foundation for data sharing within government, academia and industry.

- ***Data categorization and storage-***How data will be categorized should be taken into account when determining where data is stored, cloud vs on premise. Department of Defense Impact Level 4 (DOD IL4) is a designation for data considered CUI (Controlled Unclassified Information). DOD IL4 is considered by many to be a minimum requirement needed for the storage of data in the cloud. This may be increased to IL6 if member locations or missions are classified in nature.
- ***Localized vs Cloud storage cybersecurity ramifications-*** Storing data locally or in the Cloud to comply with classification requirements has to be considered throughout the process. Data sets could also start in the cloud during the collection phase and then be processed, analyzed, locally as data sets grow. Hybrid Cloud solutions are an option for this style of workload as the mix of cloud and local elements can allow for greater adaptability.

[11] DiMe's Library of Digital Endpoints

- ***Data interoperability vs stovepipes and silos-*** Accounting for the former two points, the aggregating and parsing of data, when discussed from the lens of DoD, and larger federal government, data interoperability, is the tertiary component when discussing any form of future data sharing.

The Chief Data Officer Council, Data Sharing Working Group recommended in their Findings and Recommendations that a draft data-sharing infrastructure playbook be developed to guide agencies as they start to build data sharing infrastructure. They feel that a playbook will accelerate the data sharing capabilities and culture while providing successes, pitfalls, and lessons learned from those who have implemented similar infrastructure.[12]

3.6 Commercial & Industrial Health and Wellness: Use Cases and Special Considerations

As commercialization of wearable technology continues on its exponential growth path, understanding this as a fundamental baseline helps us to see the art of the possible- how can we, individually and collectively, unlock and leverage the power of data to better protect, support, and empower ourselves? Commercial markets have seen a boom in consumer through organizational adoption of wearable technologies to better protect employees, equipment, facilities, as well as begin to explore how AI/ML can be leveraged for situational, environmental awareness for better decision making.

3.7 Industrial IoT and Wearables

Morgan Reed, executive director of ACT | The App Association, which represents 5,000 app and information technology companies worldwide. Areas cited by Reed include:

Team communication. Apps that allow workers to communicate with each other without a phone or even the use of their hands. Smartwatch developers may want to stay away from this category. "Hands-free tasks limit watches because as much as it's technically hands-free information, you still have to be in a position to see where your wrist is," explains James Moar, a research analyst with Juniper Research.

Employee health and wellness. Companies have begun to take more interest in their employees' health, and wearables offer a way for them to do that. "Providing a dashboard would be an important application there," Moar says. "It would allow employees to benchmark their performance goals and also see how they're doing versus everyone else. That's been a big draw for fitness wearables in the consumer space and in the office; it could be used to boost camaraderie and competitiveness of employees using these devices."

[12] Federal CDO Council, Data Sharing Working Group, "Findings and Recommendations", page 5 Section 2C

Health and safety. Wearables, via sensor fusion, can be used to provide full physiological, environmental condition, and chemical/hazmat sensing and monitoring to promote personnel, facility, and infrastructure security. Sensors, integrated with wearables via IoT devices, perform functions such as air quality, chemical, hazardous materials, water quality, and noise conditions monitoring. These metrics inform real time health and safety monitoring, ensuring personnel and facilities are able to respond in real time to any environmental risk, as well as inform better organizational health, safety policy, and procedure.

“Increasing productivity and safety are two of the really big drivers for enterprise mobility in general, so wearables that contribute those things will be popular," says 451's Martin. Additionally, CBRNE sensor fusion at hazardous sites, such as nuclear power plants, could add an additional layer of protection via wearable technologies, by providing real time sensor fusion and monitoring of the individual’s exposure, environmental risk and contamination hazards, noise exposure, etc.

Core enterprise applications. Programs that allow wearables to manage processes or show micro-dashboards of critical information will also be needed by enterprises. "Companies have a lot of money invested in their heritage systems, so applications that allow wearables to connect to those systems will be a big opportunity," notes Juniper's Moar.

SOURCE:https://techbeacon.com/app-dev-testing/how-wearables-rise-industrial-internet-things-are-boon-developers

3.8 Consumer and Commercial Sports IoT and Wearables

The wearables sports market is dominated by three predominant trends, or ‘capability sets’, that address the nexus of data interoperability between consumers, professional athletes, environmental conditions, and larger organizational structure decision making to support player and team health and wellness. At the consumer level, sports wearables are used to measure, monitor, and track performance metrics related to physical performance, physiological response, and even conditions or hazards monitoring at both individual and group levels, inclusive of data interoperability functionalities that enable multi-app sensor tracking to inform overall individualized performance, an example being the AppleWatch and FitBit. Both devices represent the spectrum of more complex to more simplistic utilization of artificial intelligence, machine learning, and Internet of Things.

From an industry perspective, several national sports leagues, such as the National Football League, the National Basketball Association, and Major League Baseball, are utilizing wearables for sensing and monitoring of player performance and physiological state, with the additional inclusion of conditions monitoring, an example including pitch conditions prior to, and throughout, a match. There are wide opportunities to leverage wearables, as highlighted below in current Major League/ Professional Leagues initiatives for wearable technologies and sensor fusion to inform better player, team, and organizational performance supported by data, sourced via physiological and environmental sensing and monitoring, and supported by IoT.

MAJOR LEAGUE BASEBALL	- Uses 3 wearables (Zephyr, Whoop, Motus) during live MLB games and training. - Takes 6-8 months to get new wearables approved.
NRL MASTERS / AFL	- Allows wearables (Catapult..) during live rugby games - Sharing with fans the GPS data, heat maps, HR of coaches and players
NASCAR	- Allow the use of wearables (Garmin, Misfit, Polar, Samsung, TomTom, Jawbone) during live races and training. - Has not allowed to show HR of drivers during live races yet.
EUROLEAGUE BASKETBALL	- Uses wearables to track GPS data, speed or players to track during live basketball games. Such data is not shared with fans on TV.
ATP WORLD TOUR / WTA	- ATP does not allow the use of HR sensors during live tennis games. But ATP did a first trial of biometric sensors on players at BNP Paribas in March 2017. - ITF allows the use of Babola Pay during live games.
NFL	- Uses Zebra's RFID tag and wearables (Catapult) during NFL game - Zebra shares live sensor data with broadcasters in real time..but NFL teams only get data 4 hours after the games. - Note: NFL PA signed a deal with Whoop that allows NFL players to sell their Whoop health data. Zebra just signed a deal with Kinduct for healthcare insights
NBA	- Does not allow the use of wearables during live NBA games, but only during training and D League - Launched an NBA wearable committee - NBA bans the use of wearable data during contract negotiation
MLS	- Uses wearables (Catapult..) during live MLS games. - Signed a deal with Cerner to collect health data of players. - 2 years ago Adidas had discussions with MLS to show wearable data (speed, acceleration..) as overlay on live TV.
NHL	- Allows the use of wearables during training, but not live NHL games.. - Works with STM to track puck, ice time, zone time, shots, distance, shot and player speed, puck trajectory, player travel and possession data, and show data on live TV.

SOURCES: https://www.theupside.us/p/upside-analysis-reflecting-on-wearable

4 Military Health Use Cases and Special Considerations

4.1 Defense Health Agency (DHA) Use Cases and Current Medical Wearable Technology

The Defense Health Agency (DHA) has also developed several wearables programs, projects, and initiatives, ranging from including the integration of several other wellness and pain management apps that include wearables data fusion with IoT devices.

DHA apps, some of which include wearables integration while others provide IoT device syncing, which are all available on the Apple App Store and on Google Play, and included in the Military Health System's App Portfolio. There is a potential opportunity to further integrate into a comprehensive wellness architecture via wearable technology, which can be seen from the larger context of DHA management of all DoD health data, warfighter healthcare, and a pioneer in novel approaches to sensing and monitoring, from JHRM burn pit victim monitoring, to stress monitoring and management tools. There is a further push to support veteran health, seen through ongoing dialogues, across branches, related to PTSD and TBI treatment using wearable technologies.

A few current DHA applications available, some with wearable technology, are listed here:

Breathe2Relax: This is a portable stress management tool which provides detailed information on the effects of stress on the body. It provides exercises to help with stress management, mood stabilization and anxiety management.

Pain and Opioid Safety: This app is for recording and measuring one's pain as well as a resource for information regarding opioids.

My Prosperity Plan: A tool to help you specify goals and to develop a plan to reach them with an objective to maximize your potential - personally, professionally, spiritually, and in your relationships.

MissionFit: Developed for the Air Force but available to anyone, this app offers a 12-week program of exercise routines along with a library of more than 90 exercises and detailed instructions with video, images and text. Users are guided through routines by navigating workout weeks, days and instructions.

Tactical Breather: This app can be used to gain control over physiological and psychological responses to stress. It employs repetitive practice and training toward a goal of gaining control your own heart rate, emotions, concentration, and other responses to your body during times of stress.

Positive Activity Jackpot: The app uses a behavioral therapy called "pleasant event scheduling," used to overcome depression and build resilience. It uses augmented reality technology to help users find nearby enjoyable activities and makes suggestions. Can't make up your mind? Pull the lever and the app's jackpot function makes a choice for you. SOURCE:

The Army's Holistic Health and Fitness (H2F) program presents a great example of the opportunities and challenges around warfighter data interoperability. H2F is the Army's primary investment in Soldier readiness and lethality, optimal physical and non-physical performance, reduced injury rates, improved rehabilitation after injury, and increased overall effectiveness of the Total Army.[13] Biometric data is essential to H2F's success. The Army notes, "Centralized collection and analysis of data from wearable technology, H2F personnel observation, and Soldier inputs or surveys allows coaches and mentors to set training goals, develop training programs, track the effects of training, and adjust training to improve performance. Examples of H2F biometric data points, or digital biomarkers, include sleep efficiency and duration, foot time, training intensity and duration, exercise heart rate, and power output."[14]

To achieve the access to a wide range of data from Soldiers and have that data persist across the lifecycle of a Soldier, the Army has turned to industry to leverage the capabilities of commercial Athlete Management Systems (AMS) to provide a scalable solution for collecting, managing, and analyzing a massive amount of data from disparate data sources. As this project progresses, the Army will be working through the opportunities summarized in this white paper. For situational awareness, additional representative use cases are provided in the table below along with brief descriptions and links to additional information.

Representative use cases	**Devices**	**Description**
Rapid Analysis of Threat Exposure (RATE)[15],[16]	Garmin watch Oura ring	New system leverages wearable physiological monitoring and AI to assess likelihood or risk of becoming ill within 48 hours (even before noticeable symptoms develop). Developed as partnership between Defense Innovation Unit, Philips Healthcare, and the Defense Threat Reduction Agency.

[13] The US Army's System for Enhancing Soldier Readiness and Lethality in the 21st Century, October 2020
[14] Army Field Manual FM7-22, Paragraph 1-19
[15] https://breakingdefense.com/2022/05/time-to-start-operationalizing-wearable-technology-in-the-dod/
[16] https://www.nature.com/articles/s41598-022-07764-6.pdf?origin=ppub

Representative use cases	Devices	Description
Crew Readiness, Endurance, and Watchstanding (CREW)[17]	Smart ring and watch	Goal of the program is to monitor sleep, fatigue, and general health of Sailors and develop decision support system to identify individuals at high risk of fatigue. Stakeholders include the Naval Health Research Center's Warfighter Performance Dept., Commander, Naval Surface Forces, among others.
Space Force Holistic Health Assessment[18]	Testing Garmin watch, Oura ring, and 'bring-your-own-device' approaches	Platform leverages consumer wearables to comprehensively and longitudinally assess and promote physical fitness/activity, sleep, mental health, and balanced eating and sleeping habits. Decision support will allow command to identify individuals for which personalized intervention may benefit.
Heat strain in military trainees[19]	Multicomponent system: armband heart rate sensor, smartwatch, algorithm to estimate core body temp.	System continuously estimates core body temperature and determines risk level for heat strain, which is visually communicated to individuals via smartwatch as they train. Developed by Lincoln Laboratory Human Health and Performance Systems Group in partnership with the U.S. Army Research Institute of Environmental Medicine, sponsored by U.S. Army Medical Material Development Activity.
Physiological monitoring in extreme environments[20]	WHOOP Strap 3.0	Project uses a wrist- or arm-worn device to continuously collect biometric data from Alaska-based, U.S. Army paratroopers to better understand how military members deal with stress & strain in arctic and other extreme environments.

17 https://www.dvidshub.net/news/392795/uss-essex-first-ship-participate-crew-readiness-endurance-and-watchstanding-study

18 https://www.airforcetimes.com/news/your-air-force/2022/03/18/heres-the-space-forces-plan-to-ditch-annual-fitness-testing/

19 https://www.ll.mit.edu/news/new-device-detects-heat-strain-military-trainees

20 https://www.prnewswire.com/news-releases/whoop-partners-with-the-united-states-army-in-study-to-examine-stress-in-soldiers-301234688.html

5 Data Gathering

Military service members have significant variability where they could be located across the globe in pursuit of missions. This has an impact on the quality of data and the primary expected use of the data but the data may have multiple uses and impacts depending on sensors, storage, security and sharing.

5.1 Clinical Setting

Medical data has traditionally been gathered in a clinical setting or with medical devices transported to a patient’s home. This data has the highest known clinical quality and accuracy for medical diagnostic use when devices are used according to manufacturer's instructions and/ or when optimized by licensed physician or dentist to improve clinical outcome according to Hippocratic Oath Do No Harm and Responsibility to Improve Clinical outcome if it is identified.

5.2 In-Garrison/Home

Over the past few years, both commercial and military consumers of wearable technologies in the United States have become accustomed to increasingly diverse and device interoperable medical technology. Predominantly used in home environments, the majority of commercial users of wearable technologies have access to varying ranges of commercial connectivity, with some telecommunication companies offering 5G, or near real time sensing, data parsing, and monitoring. In military environments, however, there are varying levels of connectivity, which informs availability and scalability of wearable devices in technologies in low SwAp, disconnected, contested, or constrained environments. Additionally, technologies deployed in remote and austere environments are often ruggedized and deploy far edge technologies to communicate and collaborate on telemedicine related use cases, including search and rescue requiring aerial refueling, which all deploy data interoperability via wearable, synced with TAK devices, and distributed back to ‘hub’, to support real time decision making.

Some expect that there is/will be stable power, reasonable internet speed, sanitary conditions and personal privacy, even if only assured in an allocated bunk space, in all environments. However, some or all of these expectations may not be present for military members living on forward basing overseas where, dependent upon the assigned infrastructure, more austere living arrangements are not uncommon. At different stages in a military members career or whilst in training or exercises they may be technically ‘home’ but living and working in what most could term as quite austere or field conditions in group living arrangements.

Common to all Services is that living standards vary by rank, with the most junior of staff commonly living in greater numbers and to more basic standards. This is typical in ships and barracks alike; however, such rank-related differentials reduce to a more common standard in forward operating environments.

5.3 Deployed Location – Forward Operating

While the Navy might have the most limited space in an at home environment, any service member knows deployment invokes changes that can be dramatically unexpected. One example includes warfighters engaged in expeditionary operations at forward operating bases and/or sites-often facing quickly shifting situational dynamics and combat scenarios, in austere, remote or constrained environments, and requiring distributed edge data collection via wearables sensor fusion, informing on-the-fly task configuration. Data collection of environmental conditions monitoring, exposure monitoring to chemicals and hazardous materials, and combat medic remote telemedicine informs better decision making for mission planning, warfighter health implications, and allows for the on-the-fly reconfiguration of telemedicine, even remote combat triage, in the field.

5.4 Quality of Metrics from Different Technologies

In an increasingly complex defense and commercial environment, novel approaches to utilization of data, as well as enablement of interoperability in near/ real time, are vital to future force design, military readiness, and war fighter health. Commercial markets are increasingly adopting, and utilizing, wearables and IoT technologies to further enhance, and improve, the daily lives, processes, and decision making that better informs how we as groups, as systems, as organizations, etc., perform.

The widespread use of artificial intelligence in government and the widespread uptake, increased usage of Artificial Intelligence (AI) is vital to consider regarding sensor data/wearables on the battlefield. AI has moved from the realm of Data Scientists solely to everyday end-users. Further, Artificial intelligence differentiation in bioconvergence systems and data utilization is key in optimal real-world scenarios.

Opportunities to share varying types of data-ie, data interoperability- across the DoD, and greater federal government, have been noted across various agencies, stakeholders, and end users. In recent months, DoD leadership, spearheaded by the CDAO, are driving the concept of Force Design 2030, which will allow for greater data collection, sharing, and monitoring, with the intent of near real time to deploy optimized and immediate situational and environmental awareness for warfighters, their partners, and leadership. The integration of wearables, and sensor fusion for warfighter health, are a common undercurrent of interest, as better physiological and conditions monitoring will further enhance multi-domain, telemedicine, nonprofit, and even transnational multinational corporations.

5.5 Integrity of Data Collection/ Ethical /Legal Implications

While it is important to ensure that the data is collected based on individual consent from the device owner, DOD personnel applications, however, are expected to be collected in a secure manner, as any breach of data can have serious consequences, particularly with respect to medical applications, or (as previously noted in 2019) may create an operational security (OPSEC) issue with individual service members. Some data collected are not inherently sensitive, though proprietary, like accelerometer data or noise level exposure data. Particular attention must be paid to ensuring protocols (e.g. encryption, limited access) are in place to protect sensitive data like GPS-based location data or voice recordings. There may also be a consideration for DOD to engage wearable providers to implement FISMA-compliant secure environments for wearable data for DOD personnel.

6 Conclusion

Wearable technology promises novel modes for near real time, continuous, and adaptive telehealth, and telemedicine, as well as medical sensing across a range of environments-remote, clinical, austere, disconnected, 5G enabled, and post-disaster. The integration of haptics, in combination with the utilization of augmented/virtual reality and point of need far edge computing, indicates wide range capabilities for telehealth and telemedicine, Medical sensing technologies support dual use capabilities, ranging from remote health monitoring outside the clinic and the prediction or timely identification of health conditions, or to providing real time Chemical, Biological, Radiological, Nuclear and Explosives (CBRNE) sensing and remote medical intervention for warfighters and operators in nuclear, hazardous, and/or contested combat zones.

Degraded communications, connectivity, cybersecurity, and environmental threats serve as primary challenges to efforts to integrate and fully field wearable technology platforms. Consumer privacy, protections, and information security are additional flashpoints, or challenges, to full commercial adoption and trust/acceptance of wearable technologies and fully integrated data interoperability. The commercial and defense sectors currently face a critical turning point regarding cybersecurity, data interoperability under a common data architecture, and force modernization. Wearable technologies highlight a critical point concerning data rights, data privacy and encryption, as well as the need for real-time sensing integration for mission-centric platforms that perform at the speed of competitive advantage.

Future considerations and extended recommendations will become available as these platforms evolve and mature. As these platforms evolve and mature, federal agencies look to adapt and improve the way data is gathered, analyzed and stored. There are important considerations to make with regards to evaluating, testing, and/or deploying wearable technologies, and how the wearables market will answer the call for enhanced cybersecurity, data sharing, to optimize defense and commercial sector health data interoperability.