Wearable Physiological and Cognitive Sensors System (WPCSS)

Capability Needs Statement (CNS)

15 June 2023

(U) EXECUTIVE SUMMARY

U.S. Indo-Pacific Command (INDOPACOM) requires an early warning capability to maintain optimal cognitive and physical performance at all echelons and operational domains, specifically to sustain the high operational tempo of ongoing global competition. Along with a commensurate decision support system, this capability will mitigate the risk of a strategically disruptive event as a result of high tempo stressors, austere environments, naturally occurring illness, and chemical, biological, radiological, and nuclear (CBRN) exposures.

The INDOPACOM mission environment is mobile, multi-domain and flexible. Persistent high tempo operations, austere environments, infectious diseases, and CBRN events pose threats to warfighter physical and cognitive performance throughout INDOPACOM Theater. The current approach to measure warfighter physiology and cognition level is reactive at best and can delay countermeasures for many days. Bio-threat insults to the Force therefore may go undetected for extended time. The result is decreased force readiness, strategic mission risk, increased costs with deployed and garrisoned forces, and possible loss of life.

A Wearable Physiological and Cognitive Sensors System (WPCSS) closes this gap by buying decision space to take action for countermeasures and allowing for a proactive approach. The WPCSS **monitors** physiology and cognition, **predicts** increased risk of impairment due to an additional stressor like CBRN exposure, high tempo operations and/or austere environment, **alerts** to an impairment in performance, and **mitigates** impairment of individual and successive units by providing results to first line medical supervisors and up to the service component and combatant command levels for tactical decision making. The WPCSS is a threat-agnostic warning system. In this way, WPCSS provides days of notice by monitoring clinical signs in advance of symptom development and before an operator's mission performance degrades, a communicable disease spreads, or an individual becomes a casualty. When deployed at scale, enterprise-level trend analysis of WPCSS information will provide early warning of force vulnerability. These capabilities increase warfighter readiness and enhance force-wide resiliency when preparing, executing, and recovering from high tempo operations in austere and garrison environments. A holistic WPCSS includes sensors, algorithms, data transmission architecture and information fusion to affect timely decisions. The priority of effort should be on the data transmission architecture in a JADC2 Mission Partner Environment. Second priority is developing sensor interface and system lexicon standards to enable ready adoption of different current and future sensor technologies without having to rework the WPCSS. Decision support and information fusion should roll up to the Component and Combatant Command level.

A WPCSS provides software algorithms and use artificial intelligence and machine learning (AI/ML) capabilities to analyze data from a suite of wearable sensors and monitors for theater-specific threats. A series of software-defined interfaces and storage solutions governs the connection from devices to the AI/ML algorithms. Algorithm outputs integrate into joint common operating pictures to provide early warning of threats from expeditionary, austere, garrison and CBRN environments at tactical to strategic levels. The WPCSS system operates in all environments found throughout the Indo-Pacific Theater, to include land, sea, and air domains. It will integrate directly with command and control networks already operating throughout the INDOPACOM user base.

A WPCSS will increase the physical and cognitive **readiness, performance,** and **resiliency** of warfighters before, during, and after high-tempo operations in expeditionary and garrison environments. Aggregating data into actionable information will enhance decision support from tactical through strategic levels provide battlespace awareness and deliver vital decision space for commanders.

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1. OPERATIONAL CONTEXT / THREAT SUMMARY

"In preparation for future conflict, the DoD is prioritizing the multi-domain threat posed by our adversaries, by focusing on strengthening Indo-Pacific deterrence. The Pacific Deterrence Initiative (PDI) is based on joint warfighting concepts which highlights modernizing and strengthening DoD's presence; improving logistics, maintenance, and pre-positioning; carrying out exercises, training, and experimentation; improving infrastructure; and building defense capabilities of allies and partners in the Indo-Pacific region. This includes investments in INDOPACOM priorities."[1] The PDI improves INDOPACOM posture to dominate in great power competition. As its main mission in this competition, "INDOPACOM ensures a free and open Indo-Pacific region in collaboration with our allies and partners. INDOPACOM deters adversary aggression across its area of responsibility (AOR), which encompasses about half the earth's surface, by protecting the Homeland and being ready to fight to win in armed conflict. INDOPACOM's mission is to implement a combat credible deterrence strategy by focusing on posturing the joint forces to win *before* fighting while being ready to fight and win, if required."[2]

To win in a great power competition, the future mission environment shall be mobile, flexible and multidomain. INDOPACOM Service Component Commands' operations will be geographically distributed across all domains. They will employ a mission partner environment (MPE) to enable command and control as well as information sharing with allies and partners. The chronic high operational tempo (OPTEMPO) of great power competition requires persistent warfighter and senior leader engagement to project forces, build security cooperation and partner nation capacity to ensure a free and open Indo-Pacific theater. The INDOPACOM warfighter will face numerous inhospitable conditions that can impair physical and cognitive performance, thereby risking optimal performance in sustained high OPTEMPO (Fig. 1, Appendix A). In turn, this poses a threat to a mobile and flexible joint force. First, high tempo operations require complex schedules with extended periods of little to no sleep. The effects of sleep deprivation include impairments in situational awareness, decision-making and physical abilities. This physiological and cognitive drain is compounded by operations in an AOR that has multiple time zones. The warfighter also faces many austere environments that can impair physical and cognitive performance, such as: heat, cold, high altitude/hypobaria/hypoxia, water immersion, diving/hyperbaria/hyperoxia, confinement/high carbon dioxide, and acceleration/centrifugal forces.

Additionally, INDOPACOM warfighters are vulnerable to an array of external threats and naturally occurring threats from CBRN events, environmental contaminants, and infectious and emerging disease. Disease non-battle injuries (DNBI), such as respiratory and gastrointestinal infections, heat injuries, musculoskeletal injuries and dermatologic conditions, reduce mission readiness. Non-invasive early detection of DNBI and early indicators of infection or systemic injury can reduce the impact of DNBI's by allowing for earlier treatment, thereby reducing the use of local higher level care and medevacs. Most recently, the effects of an infectious disease were evident during the FY20 SARS COV-2 pandemic when 85 INDOPACOM exercises and significant engagements were cancelled, and all travel stopped. These threats increase mission complexity, risk mission success, place strain on healthcare resources, risk the health and life of the warfighter, reduce joint force readiness and resiliency, and ultimately disrupt INDOPACOM force projection.

Current capabilities to maintain peak physical and cognitive performance in a persistent high OPTEMPO are insufficient or non-existent. Traditionally, there are two ways in which impaired warfighter physical or cognitive performance is identified:

1) Observation: a warfighter feels ill enough to alert someone and seek medical attention, or a first line leader observes the impairment and sends the warfighter to seek care, and
2) Testing: biological assays and chemical sensors specifically designed to detect a known library of chemical and biological agents or medical diagnoses are used.

The process is reactive – time is lost while symptoms develop, emerge and are recognized as an admitted problem, and time is further lost while samples are collected and tested for known agents. In the case of highly contagious threats of unknown origin, there is no assay or sensor to detect it before a widespread event occurs. Overall, this approach is untenable to sustain effective physical and cognitive performance in a persistent high OPTEMPO (Fig. 2). Collectively, this puts INDOPACOM forces and missions at a significant risk.

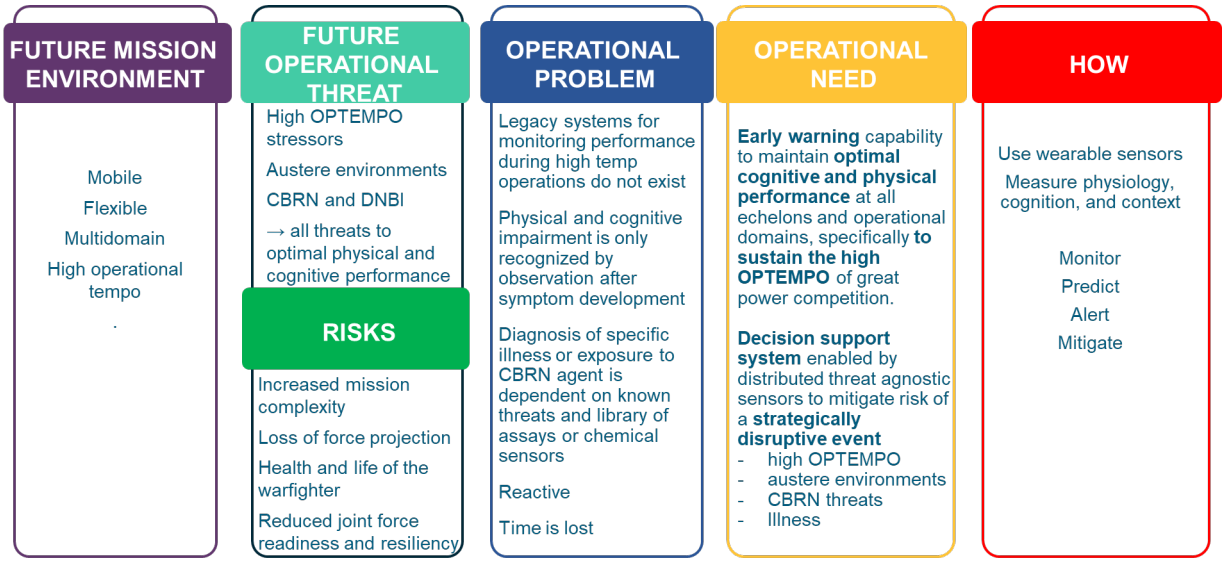

Figure 2. Summary of future mission environment, operational threats, risks, operational problem, operational need, and how the need will be addressed.

2. CAPABILITIES NEEDED

The overall operational need is for an early warning capability to maintain optimal cognitive and physical performance at all echelons and operational domains specifically to sustain the high operational tempo of ongoing great power competition. Along with a commensurate decision support system, this will mitigate the risk of a strategically disruptive event as a result of high tempo stressors, austere environments, CBRN threats and Disease Non-Battle Injury (DNBI).

The WPCSS early warning capability will assess physiological and cognitive performance for warfighters and their units. Additionally, the WPCSS will feed data in real or near-real time to an integrated indications and warning knowledge system at the service component and combatant command levels. This capability will be wearable, meaning the physiological and cognitive sensors will be worn on/in the body, and the wearer will not be tethered by wires to a monitor, data logging device or power source. The wearer will remain completely ambulatory and able to perform all physical activities in all environments as they normally would. This new capability will address two gaps: 1) the inability to monitor clinical signs across INDOPACOMs force structure before the development of symptoms and/or performance degradation, 2) the need to detect known and unknown CBRN threats, and 3) to maintain cognitive and physical resilience under prolonged operational conditions. This required capability aligns with Joint Requirements Oversight Committee Memorandum 098-20, dated 17 Dec 2020.

The WPCSS will (Fig. 3, Appendix B):

- *monitor* baseline physiology and cognition as well as contextual environmental conditions (e.g., air temperature, humidity, altitude, body movement, etc.),
- *predict* increased risk of impairment due to a stressor like austere environment, CBRN exposure or high operational tempo,
- *alert* to current impairment in performance or an impending impairment (observed in physiology but not yet observable in performance) due to a stressor like CBRN exposure, illness, high tempo operations or austere environment, and
- *mitigate* impairment of the individual and force by providing actionable information for tactical, operational and strategic decision support.

Consequently, this capability will move from the purely reactive legacy system of **detect and protect** to a proactive system of **predict and perform**. Early intervention is needed before a widespread event occurs, an operator's mission performance degrades, a communicable disease spreads, or an individual becomes a casualty. A distributed, threat-agnostic early indication and warning capability will afford commanders days of advanced warning of the risk of impaired warfighter performance and of an emerging threat. At the first-line leader level the WPCSS will provide warnings of individual warfighter acute performance degradation. It will provide valuable decision space to shape maneuver, logistics, and other combat support operations to deliver appropriate threat and medical countermeasures. This threat-agnostic detection and warning system will share data with defense intelligence and defense health agencies. Working in conjunction, threat-agnostic physiological and cognitive sensors and legacy threat-specific detectors will provide a comprehensive alert system. Warfighters will have a robust human performance and threat monitoring system needed for high tempo operations, and the force will succeed and dominate in high tempo, austere and CBRN environments of today.

Whereas the capability need is for a holistic WPCSS, including sensors, algorithms, data transmission architecture and information fusion to affect timely decision support; the priority of effort is the transmission architecture and information fusion at the Component and Combatant Command level. Wearable sensor and algorithm technology development are ongoing through defense, industry and academic research, and development efforts. Estalishing the operational and garrison data architecture developed in a joint service construct, along with the commensurate information fusion and knowledge management, will enable defense acquisition managers to define lexicon, interface and key performance standards. Wearable device and algorithm developers will align their products to these standards to more readily integrate into the DOD WPCSS ecosystem. Lastly, this priority will enable periodic spiral improvements over time without requiring major rework to the underlying operational data management operating system.

2.1. Capability Area 1: Monitor physiology and cognition and contextual environmental conditions

This capability will provide data from a WPCSS to monitor physiology and cognition and monitor environmental conditions for context. This information is the foundation for assessing warfighter performance and deviations from optimal state. Capabilities will include:

- Physiological monitoring: Devices/sensors and algorithms to monitor physiology and physical stress (e.g., cardiorespiratory function, ventilation, metabolism, cerebral hemodynamics, circulatory function, thermoregulation, skeletal muscle function, hydration, fatigue, acid-base balance, etc.).
- Cognitive monitoring: Devices/sensors and algorithms to monitor cognitive resilience, speed and stress (e.g., memory, executive function, learning, reaction time, vigilance, etc.), sleep deprivation, and concussion.

- Contextual environmental monitoring: Devices/sensors and algorithms to monitor ambient conditions (e.g., air temperature, humidity, barometric pressure, altitude, water temperature if immersed, breathing air gas concentrations (e.g., oxygen and carbon dioxide), body movement, talking, body position, etc.). These data will be utilized further in Capability Area 2 to assess if given the context, physiological and cognitive responses are normal or are abnormal, signaling a possible exposure to CBRN agents or other health anomalies (electromagnetic insult), for example.

2.2. Capability Area 2: Predict increased risk of physical or cognitive impairment due to physiological, cognitive, environmental, CBRN or high OPTEMPO stressors

This capability will provide AI/ML capabilities based on data from WPCSS (Capability Area 1) at the individual level to predict if the risk of physical or cognitive impairment is greater than normal should the warfighter be exposed to additional stressors, including those from austere environments (e.g., heat/cold, hypoxia/hypercapnia, hyperbaria/diving, immersion in water, hypobaria/altitude, acceleration/centrifugal forces, vibration, low visibility, etc.), CBRN exposure, illness, injury, sleep deprivation, dehydration, fatigue, or cognitive load. This capability will also predict in real-time the operational and logistical status of warfighters. Capabilities will include:

- Readiness Prediction: Algorithms to assess and predict warfighter readiness for operations in environments with additional stressors such as potential CBRN threats, high tempo operations stressors and austere environments.
- Acute Performance Degradation Prediction: Algorithms to predict impending acute performance degradation, either physically or cognitively, for any reason should the present workload be continued.
- Response Operations Performance Prediction: Algorithms to predict the ability of the warfighter to effectively perform during response operations that may require donning PPE (e.g., contagious medical environments, CBRN operations, firefighting, arctic/cold exposure, etc.).
- Response Operations Recovery Prediction: Algorithms to predict the ability of warfighters to physically and cognitively recover following response operations and their readiness to resume operations.
- Illness and Disease Susceptibility Prediction: Algorithms to predict increased risk of illness and/or infection from emerging or existing infectious disease or biological warfare agents.
- Illness/Injury Prediction from Austere Environments: Algorithms to predict warfighter condition in extreme environments (e.g., risk of heat illness, cold injury, hypothermia, decompression sickness, oxygen toxicity, acute mountain sickness, high altitude cerebral or pulmonary edema, hypercapnia, g-force induced loss of consciousness, dehydration, etc.).
- Illness/Injury Prediction from DNBI: Algorithms to predict warfighter health from DNBI (e.g., gastrointestinal infections, respiratory infections, musculoskeletal injury, etc.).

2.3. Capability Area 3: Alert to impairment in performance due to a stressor like high tempo operations, CBRN exposure, illness or austere environment

This capability will provide alerts of graded severity based on Capability Area 2 for the predicted risk of impairment or the presence of impairment, physically or cognitively. Alerts will be provided for the susceptibility of contracting an infectious disease and alerts to CBRN exposure, infection and injury. Alerts will inform the warfighter and inform at the service command level. Capabilities will include:

- Blast and Concussion Detection: Algorithms to measure direct blows and accumulated blast hazard on the body caused by the kinetic delivery of munitions containing chemical, biological, or

radiological hazards and the air blast at the periphery of a nuclear weapons detonation. Algorithms will alert to possible concussion and traumatic brain injury.

- Acute Performance Degradation Alerts: At the individual warfighter level, deliver warnings to the device wearer and first line leader or medic of risk of performance degradation, impending degradation and current degradation.
- Emerging Threat Detection**:** Algorithms to analyze interactions among multiple variables from continually monitoring individual physiological baselines to identify infectious disease and CBRN exposure-related emergent cases with risk of disease progression; provide an early warning at an individual level of potential threat exposure and warning that the warfighter is more susceptible to contracting communicable disease stemming from a biological event.
- CBRN Exposure Alerts: Algorithms to detect health anomalies associated with exposure to CBRN hazards, which include chemical warfare agents, toxic industrial chemicals, pharmaceutical-based agents, biological toxins, and radiation doses elevated enough to cause acute radiation syndrome.
- Environmental Contaminant Alert: Algorithms to detect exposure to environmental hazards, such as hazards emitted from burn pits and off gassing chemicals, fuel, dust, and water-borne contaminants. Algorithms to predict impaired performance as a result of this exposure.
- Alerts for Illness/Injury from Austere Environment: Algorithms to alert to performance-impairing and possibly life-threatening changes in physiology and cognition in extreme environments (e.g., hyper/hypothermia, dehydration, decompression sickness, high altitude cerebral and pulmonary edema, electromagnetic insult, etc).
- Illness Prediction and Disease Susceptibility Alerts: Algorithms to inform of impending illness, possibly before the development of symptoms or measurable performance degradation.

2.4. Capability Area 4: Mitigate impairment of the individual and force by providing actionable information for tactical, operational and strategic decision support

The WPCSS will provide actionable information about the physiological and cognitive status of the warfighter on an individual level. When deployed at scale, unit and enterprise-level WPCSS data analysis will provide early warning of impaired units that may pose significant risk to mission, maneuver and force projection. Additionally, alerts of emerging illness or unknown CBRN threats could be investigated for timely confirmation and counter-measure response. These capabilities will increase physical and cognitive readiness and enhance force-wide resiliency when preparing, executing, and recovering from persistent high tempo operations with CBRN threats and/or austere environments. This capability is needed to enable dynamic and resilient force flow into and around the INDOPACOM AOR to perform missions under the INDOPACOM Theater Campaign Order and various associated operational plans. In tactical and operational environments, ashore, aloft, undersea and afloat, this new capability will need to be compliant with cyber and operational security requirements, as well as D-DIL communications environment requirements.

The new capability must function within the MPE under a Joint All-Domain Command and Control (JADC2) architecture. Each service component has their respective command and control management architectures that roll up information from tactical to operational units and then into the combatant command strategic level architecture. Capabilities will include:

- Tactical Data Integration: Raw WPCSS data and/or post-processed information will be brought in from locally managed networks to cloud-hosted joint environments for further analysis and long-term storage. The joint cloud environment will provide users with a set of tools to visualize WPCSS data, inform commanders, and recommend follow-on actions related to warfighter readiness and

performance. This allows for the ability to pre-emptively make operational and tactical decisions before performance degradation occurs to prevent it, delay it, or be prepared for when it happens.

- Networking and Cybersecurity: WPCSS data and fused information management need to work within Defense Information Systems Agency network and personal data privacy and cybersecurity frameworks. Device data transfer interfaces into the service component command and control architectures need to be standardized to allow for periodic hardware replacements without compromising the software interoperability or data analytic algorithms and resulting outputs. Architecture synchronization is critical to support tactical readiness and establish a set of common and multi-use wearable devices, integrate a streamlined joint network architecture, and develop data visualization and decision support tools to enable the use of person-worn sensor capabilities in operational environments. Network infrastructure must also be developed in conjunction with hardware, software, and firmware requirements to create a whole-of-force tactical network.
- Interoperability with Allies and Partners: In the current operational environment, namely the competition phase, INDOPACOM forces enjoy a relatively uncontested communications and logistics environment. In this current environment, the WPCSS will rely on relatively standard forms of data transfer, largely within U.S. command and control architectures. Future environments likely will be conflict or foreign support mission-based environments, where data and information management will need to be interoperable with allies and partners, at a minimum the Five Eyes Alliance (FVEY).
- Command, control, communication, computers and intelligence (C4I): The capability needs to include command and control information interfaces to carry sensor data from point of detection to point of decision support in a coalition MPE. This type of system will act to ingest actionable information from WPCSS and process this information into service component and combatant command decision support systems and common operation pictures.
- D-DIL Environment: WPCSS will function at the local tactical level in the event of a D-DIL environment. When communications are restored, WPCSS data integration to the cloud environment will be resumed, retroactively sending all data recoded during the degraded communications time period. If possible, predictions and alerts will still be available to the individual if the data cannot get to the cloud environment.
- Enterprise Bio Analysis: Enterprise-level analysis to inform optimal deployment of diagnostics, therapeutics, and non-medical countermeasures, and subsequent management for not only initiating patient treatment, but also for preventing contamination of medical personnel, equipment, and facilities. The capability will track and limit disease spread and, at the enterprise level, inform risk assessments and guide diagnostic and countermeasure development[3, 4].
- Contact Tracing and Proximity Logging: Digital log of warfighter to warfighter interactions will include distance, duration, activity and environmental context of when the interaction occurred. Combined with diagnosis of disease after exposure to CBRN hazards, this log supports accelerated contact tracing and rapid implementation of the desired operational response. Identifies both high and low risk individuals for continued CBRN response operations[5].
- Casualty Tracking and Personnel Recovery Monitoring: Monitor and track warfighters with severely impaired performance from austere environments, illness/injury and CBRN exposure to alert and inform medical staff receiving injured warfighters and prepare for decontamination, segregation and treatment.

3. CAPABILITY PERFORMANCE ATTRIBUTES

Capability Area	Performance Measure	Target State
Monitor physiology, cognition, and contextual environmental conditions	Physiology: devices/sensors and algorithms to monitor cardiorespiratory function, ventilation, metabolism, energy expenditure, cerebral hemodynamics, circulatory function, thermoregulation, skeletal muscle function, hydration, fatigue, acid-base balance, gastrointestinal function Cognition: devices/sensors and algorithms to monitor resilience, speed, stress and concussion Environment: devices/sensors and algorithms to monitor ambient weather conditions, including microenvironments inside garments, location above or below sea level, water temperature, ambient air concentrations, body movement, talking, body position, tactical hazards and other battlefield threats	Examples are listed here so as not to preclude alternatives. Physiology: Heart rate, blood pressure, cardiac output, peripheral oxygen saturation, respiratory rate, tidal volume, minute ventilation, oxygen consumption, carbon dioxide production, glucose concentration, lactic acid concentration, blood pH, cerebral edema, cerebral oxygenation, cerebral blood flow, skin blood flow, skin temperature, body or core temperature, sweat rate, hematocrit, electrolyte concentration, force production, muscular fatigue, motor unit recruitment. Cognition: memory, executive function, learning, reaction time, vigilance, presence, focus, attention, brain activity, perception, visuospatial disorientation, alertness Environment: air temperature, humidity, barometric pressure, water temperature, wind speed, breathing air gas concentrations (oxygen, carbon dioxide, carbon monoxide), 3-plane accelerometry, speech detection, visibility, sound triangulation, identification of friend or foe
Predict increased risk of physical or cognitive impairment due to physiological, cognitive, environmental, CBRN or high OPTEMPO stressors	Chemical warfare agent (CWA) and biological warfare agent (BWA) algorithms based on biomarkers and the aforementioned physiological metrics to detect emerging threats Performance algorithms to predict likelihood of or time to fatigue (slowing of performance), failure (inability to perform minimally acceptable functions), and clinically dangerous conditions.	Toxic industrial materials and toxic industrial chemicals, pharmaceutical based agents and traditional chemical and nerve agent response based on physiological metrics (O), non-traditional agents (T) for CWAs. Exposure detection 3 days prior to onset of symptoms (T). Ability to reliably detect and predict 2 days prior to onset of symptoms other biological pathogens relative to the physiological metrics listed above for BWAs (O). Rad/Nuc detection with at least 75% reliability (T) and greater or equal to 95% (O). Performance algorithms will include predicted outcomes such as maximum heart rate, heat stroke, cold injury, decompression sickness, high altitude illnesses, hypoglycemia, and clinically dangerous blood pressure, hypoxia, hypercapnia, oxygen toxicity, hypothermia, and dehydration.

Alert to impairment in performance due to a stressor like high tempo operations, CBRN exposure, DNBI/illness or austere environment	Alerts will be based on the above prediction algorithms.	Customizable alerts for both the individual as well as Service Command Leaders and medical personnel. May be absolute values of physiological and cognitive measures. May be categorized as red, yellow, green. May be set to alert at a specific predicted time to reach endpoint (illness, injury, decrement in performance).
Mitigate impairment of the individual and force by providing actionable information for tactical, operational and strategic decision support	Architecture synchronization: Hardware shall be person worn technology that integrates wearable AI/ML algorithm capabilities and hardware into the tactical internet, which includes existing and emerging tactical internet hardware assets and the common operating environment. Network and cybersecurity: measures will span end-to-end for the network architecture from hardware to data visualization and will utilize an array of network interfaces such as: Bluetooth Low Energy, WiFi, 5G, Satellite and ultra-low power wireless standards. The system will have alternatives to be effective in D-DIL environment. Tactical integration: Geographical location and blue force tracking, tactical chat and two-way communication from Brigade level to Platoon and Squad level as well as on afloat platforms. Geo-fencing shall be created using virtual geographic boundaries based on AI/ML algorithms to support tactical troop movements.	The hardware, firmware, and software will function seamlessly with Army, Navy, Marine and Air Force tactical networks. There will be limited to no (5% = T and; 0% = O) latency and synchronization errors for reliable data inception, batch-processing, and data visualization for all personnel utilizing a WPCSS platform to inform decision making. The architecture will have 95% (T) and 100% (O) connectivity, reliability, and data transmittal across the network. The architecture will have alternative options so as to function in a D-DIL environment. Tactical or D-DIL communications option from delayed data download and sharing shall be an option for units. The Privileged Session Manager shall be designed with an open architecture that is scalable to allow insertion of future capabilities (T=O).

4. INTEROPERABILITY

The WPCSS platform will operate in all environments found in the Indo-Pacific Theater, to include land, sea and air domains (Fig. 4). WPCSS platforms will integrate directly with C2 networks already operating throughout the INDOPACOM user base (Appendix C). WPCSS will also function at the local tactical level in a degraded or denied environment.

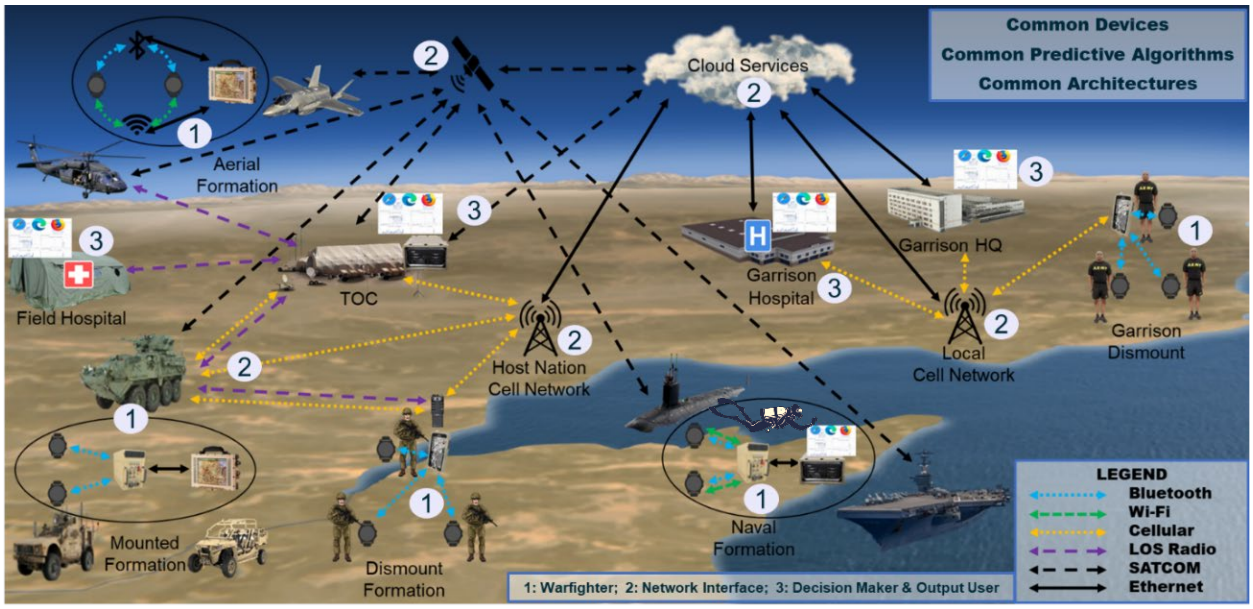

Figure 4. High-level operational concept graphic (OV-1) of notional wearable physiological and cognitive sensor system (WPCSS)

The program will develop a Joint Wearable Physiological and Cognitive Sensors Digital Engineering Database to develop and govern interfaces and data for the program. The database will include joint service mission architectures (Dept. Of Defense Architecture Framework), select mission and mission engineering threads, and will include model-based systems engineering tools supported by wearable capabilities. As of 2022, Table 1 lists the primary service-specific command and control (C2) systems in which the WPCSS data must flow. The WPCSS Program will provide common components/capabilities across the services and will integrate with JADC2 in a MPE to enable interoperability with allies and partners in INDOPACOM region. The program will leverage as many current or to-be fielded communications and computing assets as possible. Data from WPCSS will be paired with existing end-user devices the warfighter already uses.

Table 1. Network interfaces detailed in the Joint Wearable Physiological and Cognitive Sensors Digital Engineering Database

Joint	Domain	Network / System
Army	Land – Dismounted	Nett Warrior (including Android Tactical Assault Kit, ATAK) IVAS (Integrated Visual Augmentation System) JBC-P (Joint Battle Command-Platform) COE (Common Operating Environment) (Mobile/Handheld, Sensors)
	Land – Mounted	JBC-P COE (Mobile/Handheld, Mounted, Sensors)
	Land – Installation	COE (Command Post)
	Air	Electronic Flight Bags
Marine Corps	Land – Tactical	JTCW (Joint Tactical Common Operational Picture Workstation) JBC-P
Navy	Sea	Project Overmatch CANES (Consolidated Afloat Networks and Enterprise Services)
Air Force	Air	Advanced Battle Management System
SOCOM	All	MPU5 radios and ATAK
	Land – Installation	Smartabase
Medical	All	Joint Operational Medical Information System (JOMIS)
CBRN	All	CBRN Support to Combat Support Command and Control (CSC2)
FVEY	All	MPE compliant system (to be determined)

5. REQUIREMENTS MANAGEMENT

INDOPACOM will manage requirements for the WPCSS system using four main information products co-developed with Joint Program Executive Office - Chemical, Biological, Radiological and Nuclear Defense (JPEO-CBRND) (

Table 2). Each product will be updated frequently based on lessons learned from user feedback events, value assessment outputs, and science and technology transition schedules.

The first software release documented in the WPCSS roadmap and RTM will become the program's minimal viable product (MVP). The JPEO-CBRND team will deliver the WPCSS MVP within 12 months of starting the program's execution phase. The MVP is an early version of the WPCSS software and will support the first round of user feedback events. It will evolve over future releases based on the analysis in the first value assessment. The MVP is designed to accelerate learning, shape future requirements, and inform on-going software design strategies.

Subsequent annual software releases will act as minimum viable capability releases (MVCRs). Each MVCR will support at least one user feedback event. INDOPACOM will analyze each MVCR's operational benefits, limitations, and opportunities in the value assessment. The WPCSS roadmap will document when the program will field a MVCR that is safe, secure, suitable, and supportable for initial warfighting operations.

Table 2. Wearable Physiological and Cognitive Sensors Requirements Management Information Products

Product	Author	Purpose
User Agreement	• INDOPACOM Product Owner • JPEO-CBRND	• Documents roles and responsibilities for the program • Identifies cadence of WPCSS user feedback events and establishes integrated product team structure • Approved by Operational Sponsor, Product Owner, Acquisition Authority, and JPEO-CBRND • Reviewed and updated annually as needed
WPCSS Roadmap	• INDOPACOM Product Owner • JPEO-CBRND	• Visually summarizes goals and features of each annual software release • Documents and prioritizes product backlog • Provides quarterly-level delivery schedule details for current and next fiscal year software releases • Updated annually
Requirements Traceability Matrix (RTM)	• JPEO-CBRND	• Digital database that captures lower-level user requirements needed to meet each software release • Documents threshold and objective metrics • Updated quarterly
Value Assessment	• INDOPACOM Product Owner • INDOPACOM Operational Sponsor • *(JPEO-CBRND support where needed)*	• Quantifies mission improvements provided by each annual software release based on lessons learned and observations form user feedback events • Informs and refines product backlog priorities and future software release investment areas • Published at least annually
Lower-level needs periodic update	• Requirements Integrated Product Team	• Periodically review, update and prioritize lower-level needs. Coordinate prioritization with software developers

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4. DoDD 6420.02, "DoD Biosurveillance," September 17, 2020
5. Joint Requirements Oversight Committee Memorandum 098-20, December 17 2020

APPENDIX A: EXAMPLES OF STRESSORS OR CONDITIONS THAT IMPAIR PHYSICAL AND COGNITIVE PERFORMANCE

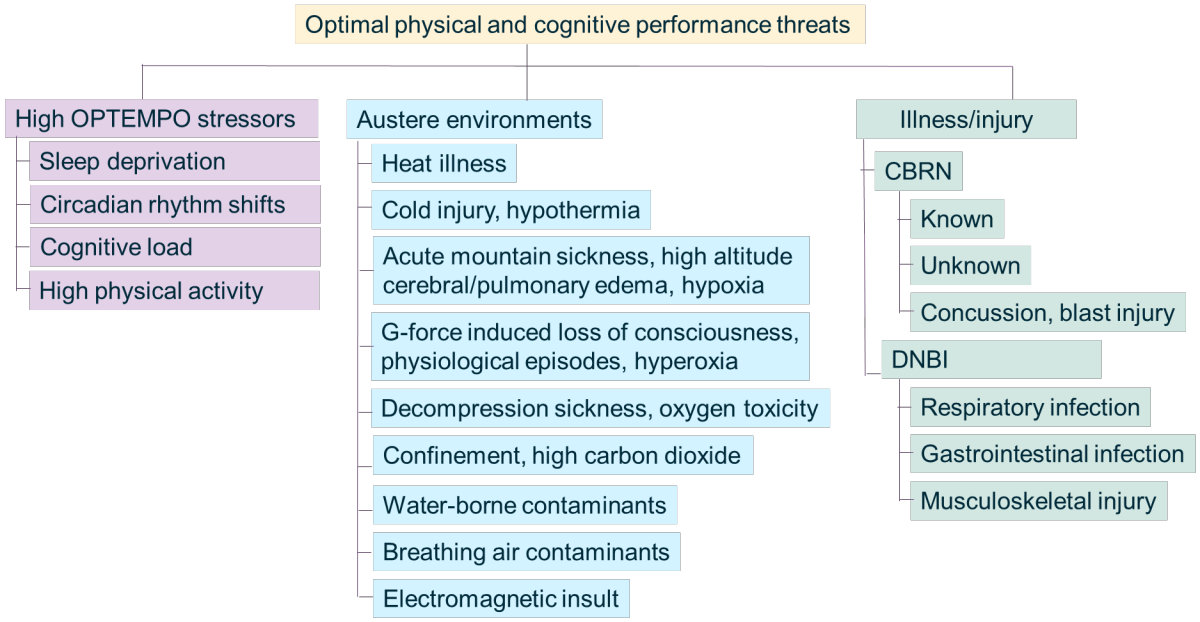

Figure 1. Examples of stressors and conditions that impair physical and cognitive performance.

APPENDIX B: CAPABILITIES NEEDED

Figure 3. Summary of capabilities needed.

APPENDIX C: INTEROPERABILITY

WPCSS data for land-based units deployed in tactical dismounted or mounted settings will flow to a common data aggregator carried at the squad- or team-level. This aggregator is intended to be an end user device (EUD) fielded previously as part of another system. AI/ML algorithms will analyze WPCSS data on the aggregator and provide notifications to the squad or team lead in real-time. Post-processed information will flow to tactical operations centers (TOC) via a secure tactical radio connected to the EUD. The TOC will then pass WPCSS information as needed to local field hospitals.

Limited WPCSS information will flow from the TOC to joint cloud services because of bandwidth limitations. During or after deployments operators could upload WPCSS information from the EUD aggregator and/or TOC network server to joint cloud services for records management.

The data collection concept is similar for air operations, where each aircraft is outfitted with a vehicle-mounted data aggregator containing the fewest number of newly fielded items as possible. The aggregator will analyze WPCSS data and provide real-time notifications to the platform crew. The amount of post-processed information flowing off each aircraft to a TOC or similar command structure will be highly dependent on bandwidth availability.

For sea operations the system will be fully self-contained, with little to no WPCSS information flowing off sea-based assets in real-time. A data aggregator centrally located on the ship or submarine will capture, house, and analyze WPCSS data. Commanders and support staff will receive post-processed WPCSS information locally and in real-time. After deployments information could be downloaded to joint cloud services as bandwidth allows for records management.

Operations at garrison or installations will rely on a combination of commercial and military networks to capture and transport WPCSS data to joint cloud services. The data aggregator will likely be a personal or government-issued EUD with the potential to leverage existing networking hardware already in place at each installation. AI/ML algorithms will reside in the cloud with post-processed information flowing to several locations, to include garrison hospitals.

APPENDIX D: PRODUCT ROADMAP (EARLY FRAMEWORK)

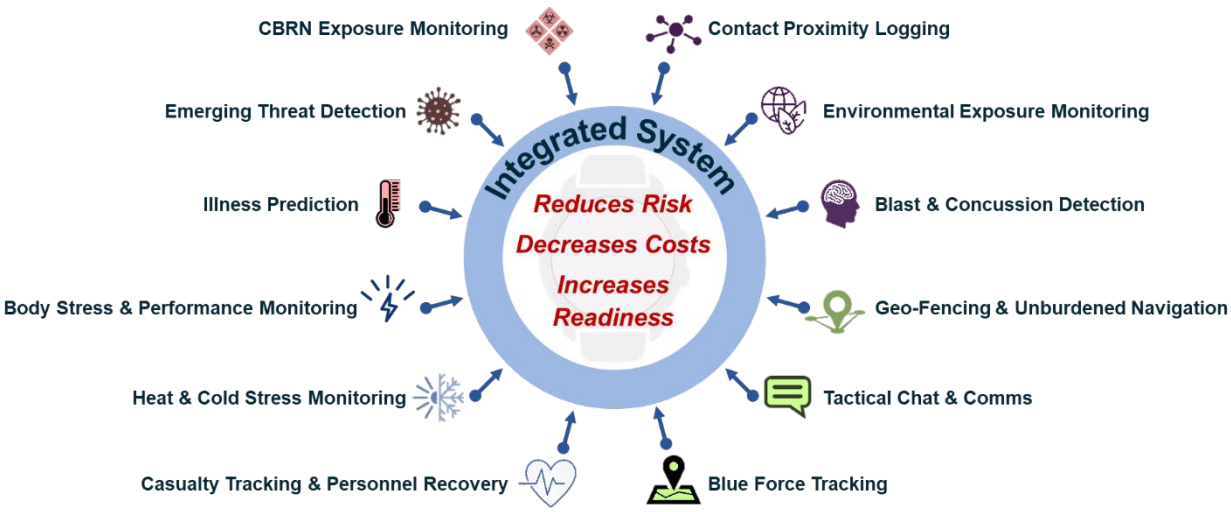

Figure 5. Wearable Physiological and Cognitive Sensors Information Ecosystem. Merging capabilities is a force multiplier. Capability integration unencumbers warfighters and increases user adoption.

APPENDIX E: ABBREVIATIONS

AI/ML	artificial intelligence and machine learning
AOR	area of responsibility (AOR)
ATAK	Android Tactical Assault Kit
BWA	biological warfare agent
C2	command and control
C4I	command, control, communication, computers and intelligence
CANES	Consolidated Afloat Networks and Enterprise Services
CBRN	chemical, biological, radiological, and nuclear
COE	common operating environment
CSC2	combat support command and control
CWA	chemical warfare agent
DNBI	disease non-battle injuries
DoD	Department of Defense
D-DIL	denied, degraded, intermittent, or limited bandwidth
EUD	end user device
FVEY	The Five Eyes Alliance
INDOPACOM	US Indo-Pacific Command
IVAS	Integrated Visual Augmentation System
JADC2	Joint All-Domain Command and Control
JBC-P	Joint Battle Command-Platform
JOMIS	Joint Operational Medical Information System
JPEO-CBRND	Joint Program Executive Office - Chemical, Biological, Radiological and Nuclear Defense
JTCW	Joint Tactical Common Operational Picture Workstation
MVCR	minimum viable capability release
MVP	minimal viable product
O	objective
OPTEMPO	operational tempo
PDI	Pacific Deterrence Initiative
PPE	personal protective equipment
RTM	requirements traceability matrix
T	threshold
TOC	tactical operations center
WPCSS	Wearable Physiological and Cognitive Sensors System