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ENERGY,
INSTALLATIONS,
AND ENVIRONMENT

JUL - 6 2018

MEMORANDUM FOR ASSISTANT SECRETARY OF DEFENSE (RESEARCH AND ENGINEERING)

SUBJECT: Department of Defense Research, Development, Testing and Evaluation Requirements for Vector and Pest Management, Fiscal Years 2018-2022

The Armed Forces Pest Management Board (AFPMB) has completed the Department of Defense Research, Development, Testing and Evaluation (RDT&E) Requirements for Vector and Pest Management, Fiscal Years 2018-2022 (attached) per Department of Defense (DoD) Instruction 4150.07, "DoD Defense Pest Management Program."

The mission of the DoD pest management program is to ensure that Service members and DoD installations have the most effective disease vector and pest surveillance and control capabilities to prevent adverse effects on personnel, weapons systems, infrastructure, equipment, and the environment. To achieve this goal, capability gaps must be consistently and systematically identified and addressed to ensure the DoD has the very best tools and techniques available to maintain the highest level of military readiness.

In 2014, the AFPMB established a capabilities working group of Component subject matter experts to assess gaps in the DoD vector and pest surveillance and management tool box for risk assessment and mitigation capability areas. The DoD RDT&E vector and pest management requirements are based on the results of this assessment.

The intent of the Research Requirements Report (attached) is to provide DoD and other federal agencies that execute RDT&E programs with the DoD's consistent and actionable requirements for improved vector and pest management capabilities to protect Service members, equipment, infrastructure, and the environment. The requirements consider the need for interoperability between assessment and management systems and a coordinated acquisitions approach for the development of new capabilities.

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Lucian Niemeyer

Attachment:
As stated

# Department of Defense

# Research, Development, Testing and Evaluation (RDT&E) Requirements

# for

# Vector and Pest Management, FY18-22

**April 24, 2018**

The Armed Forces Pest Management Board
Office of the Deputy Assistant Secretary of Defense
(Energy, Installations and Environment)

## ACKNOWLEDGEMENTS

This report was prepared by the following members of the Armed Forces Pest Management Board (AFPMB) directorate staff with additional inputs provided by the AFPMB committees: CDR Daniel E. Szumlas, Dr. Gabriela Zollner, Dr. Doug Burkett and CPT Erica Lindroth. The AFPMB is a directorate within the Office of the Assistant Secretary of Defense (Energy, Installations and Environment) that recommends policies and procedures, provides guidance, and coordinates the exchange of information related to pest management throughout the Department of Defense (DoD).

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## Introduction

Throughout history, vector-borne diseases have contributed significantly to the morbidity and mortality of Department of Defense (DoD) Service members during military operations. During World War II, the US military suffered more than 500,000 cases of malaria as well as a forced evacuation of Tonga and New Guinea due to lymphatic filariasis that cost the US an estimated $100 million. More recently, vector-borne diseases such as malaria, dengue fever, and leishmaniasis have negatively impacted Operation Enduring Freedom and Operation Iraqi Freedom, and will likely continue to affect future operations. Diseases such as malaria, dengue, and Zika virus continue to pose a significant threat to our deployed forces, while Lyme disease is the most common vector-borne disease among Service members. Personnel utilizing training areas on many installations are at risk of acquiring a vector-borne illness, which impacts our readiness.

After decades of research, only two Food and Drug Administration (FDA) licensed vaccines exist for vector-borne diseases (i.e., Yellow fever and Japanese encephalitis). Chemoprophylaxis and/or therapeutics are available for only a small number of vector-borne diseases, leaving the use of personal protective measures and vector control as the only means to protect Service members. Increasing pesticide resistance, loss of U.S. Environmental Protection Agency (EPA) registered public health pesticides, and continuing worldwide missions leave the DoD with decreasing options for effective vector and pest management. Many current vector control products and application methods are inadequate to control vector species that pose the greatest threats to our Service members at home and abroad.

The mission of the DoD pest management program is to ensure that Service members and military installations have the most effective disease vector and pest surveillance and control capabilities to prevent adverse effects on personnel, weapons systems, supplies and equipment, and the environment. To achieve this goal, capability gaps must be identified and addressed to ensure the DoD has the very best tools available to maintain the highest level of military readiness.

## Research Requirements

This document identifies the Research, Development, Testing and Evaluation (RDT&E) requirements (henceforth termed "**research requirements**") for DoD vector and pest management based on critical capability gaps previously identified by the Armed Forces Pest Management Board (AFPMB). The term **vector** is defined as arthropods capable of transmitting disease pathogens, and research priority is given to those groups (i.e., mosquitoes, phlebotomine sand flies, ticks and filth flies) that have high military relevance due to the disease pathogens they transmit in areas where DoD Service members are at greatest risk. The term **pest** includes all other organisms that may adversely affect readiness and military operations, damage real property, supplies, equipment or vegetation; or organisms

that are otherwise undesirable (e.g., bed bugs, rodents, snakes, and invasive animal and plant species).

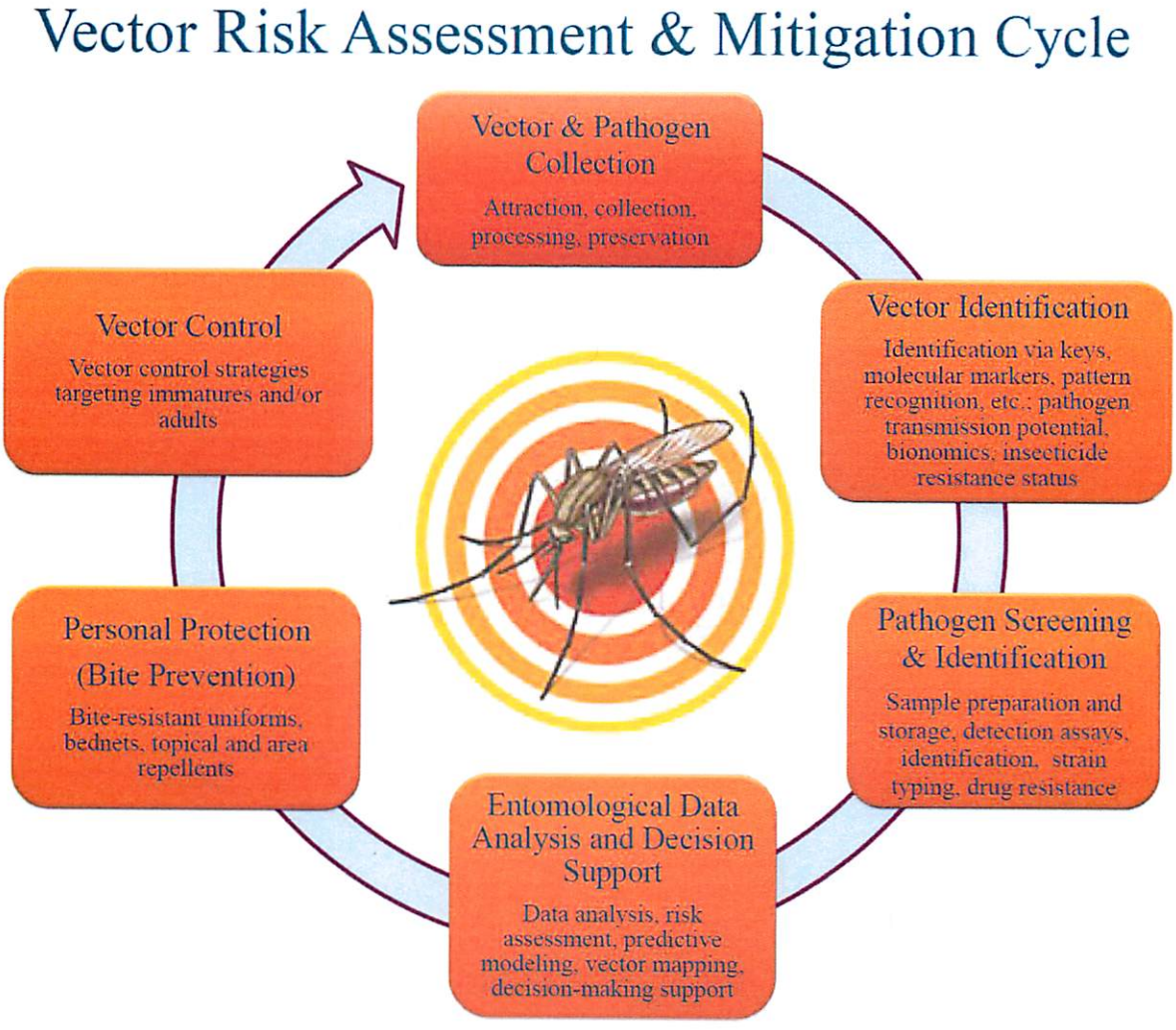
The research requirements for vector management are outlined in **Section 1**, and the research requirements for pest management are outlined in **Section 2**. The capabilities developed in response to the research requirements will be incorporated into DoD integrated pest management (IPM) programs which strive to use an effective and environmentally sensitive approaches to pest management. Each capability area consists of a short description, an operational requirement, current state of the capability and identified research requirements. The following factors are of utmost importance when developing solutions to capability gaps: (1) the potential to reduce disease transmission; (2) the prevalence and incidence of the vector or pest threat to Force readiness as well as the geographic extent of the problem; (3) benefits to the health and morale of Service members and their dependents; (4) logistical impact on military operations; and (5) the time and resources required to develop the capabilities to meet the research requirements, including associated training and lifecycle costs. Individual research requirements are part of one or more systems, and interoperability with other systems must be considered when developing any new technology or product. For example, topical insect repellents are one part of the DoD Personal Protection System, which in turn is part of a system of personal items Service members must carry with them into the field. Finally, working in close cooperation with the Armed Forces Pest Management Board (AFPMB) and within the DoD Acquisitions framework is highly encouraged.

This document, including subsequent versions, will be provided to DoD and other federal agencies that execute RDT&E programs leading to improved vector and pest management capabilities that protect Service members, equipment, facilities, and the environment. DoD research programs include, but are not limited to: the Military Infectious Diseases Research Program (MIDRP) Program Area U (Vector Identification & Control); the Deployed Warfighter Protection (DWFP) Research Program; Defense Medical Research & Development Program (DMRDP; also known as the "DHP 6.7 Research Program"); Strategic Environmental Research & Development Program (SERDP); Small Business Innovative Research (SBIR); and, Small Business Technology Transfer (STTR) programs. **Appendix 1** summarizes the DoD vector and pest management requirements, identifies standing committees of the AFPMB Council with expertise and responsibility for the identified requirements, and lists potential DoD funding programs. **Appendix 2** provides more information about these DoD programs, including websites for more information about specific programs.

## SECTION 1. VECTOR MANAGEMENT

### Background

An integrated approach employing multiple capabilities is necessary to minimize the negative impact of pests and disease vectors on DoD operations. At the broadest level, the tools used in IPM operations fall into either risk assessment or risk mitigation capability areas. The following six key capabilities in the figure below comprise the main categories for research requirements and illustrate the continuing iterative cycle of vector risk assessment and risk mitigation tasks from one capability area to the next to monitor the effectiveness of vector management strategies and eliminate the risk of vector-borne disease transmission.



The risk assessment of medically important vectors and their pathogens refers to the use of surveillance techniques and tools that enable the collection of whole arthropod specimens, pathogens, or their nucleic acids (e.g., environment DNA or eDNA or use of DNA/RNA-preserving filter paper cards to collect vector saliva containing both vector and pathogen nucleic acids) for the purpose of vector and pathogen identification as well as any other vector characteristics of interest (e.g., insecticide resistance). Vector surveillance includes components of the Vector Identification and Pathogen Detection capabilities that detect and measure relevant vector and pathogen characteristics important to vector control and disease prevention (e.g., vector identification, vector insecticide resistance potential, pathogen detection and identification, pathogen drug resistance potential, etc.), which can also integrate into a data management system that interfaces with a bioinformatics platform. Risk mitigation refers to the analysis of surveillance data and the use of decision support algorithms that can be used to inform vector control decisions and disease mitigation strategies.

The process to identify gaps in DoD disease vector control programs was initiated in 2015, when the AFPMB established a capabilities working group (CAP WG) to identify gaps in DoD disease vector control programs based on vector-borne disease threats identified in the US Army's Surgeon General memo, "Infectious Disease Threats to the US Military Prioritization Panel Results" (14 Jan 2015) and the Defense Intelligence Agency study report, "Naturally Occurring Infectious Disease Threats to Deployed U.S. Forces" (6 May 2011). The CAP WG focused on vectors of primary importance, including mosquitoes (vectors of malaria, dengue, chikungunya, Zika and yellow fever pathogens), phlebotomine sand flies (leishmaniasis), ticks (Lyme disease and other tick pathogens), and filth flies (diarrheal diseases). In collaboration with the AFPMB Council, the CAP WG assessed the current DoD surveillance and control tool box against the identified major vector groups and six key capability areas to characterize gaps. To identify potential solutions, the CAP WG followed the Joint Capabilities Integration Development System (JCIDS) which considers solutions within the eight DOTMLPF-P categories: doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy. The resulting Vector Centric Capability Gap Working Group Report of 9 August 2016 ("CAP GAP Report") summarized the gaps identified and served as an AFPMB source document to develop Requirements in the present document IAW DoD acquisition policy.

In the CAP GAP Report, each capability area within a vector category was assigned a color code and descriptive assessment of its operational effectiveness. Tools determined to provide a current solution without a need for further development or improvement, are coded green. In comparison, tools that have not been evaluated by the DoD, with partial effectiveness, or where no capability exists, are coded red. Any tools that show promise but do not have a National Stock Number (NSN) or need further improvement and evaluation are considered yellow. Throughout this section, **field expedient** capabilities refer to those capabilities immediately available to preventive medicine assets (i.e., technicians) at the point of action or in the field (see *Roles of Medical Care* in Field Manual 4-02). Generally, risk assessment capabilities should result in actionable data within 72 hours or sooner depending on the operational

need. Personal protection applies to all medical roles of care, including Role 1 (i.e., unit-level medical care); all other capabilities pertain to Role 2 (i.e., medical treatment facility [MTF] operated by an area support squad), Role 3 (i.e., MTF staffed and equipped to provide care to all categories of patients) and Role 4 (e.g., medical care in U.S.-based hospitals). **Users** refers to entomologists, public health officers, environmental science officers, preventive medicine technicians, installation pest management coordinators, installation environmental services, pest control operators and other associated DoD personnel who use these capabilities to prevent vector-borne disease transmission. Table 1 summarizes the current state of all capability areas for the high priority vector groups.

**Table 1.** Capability Gap Assessment Summary for Vector Management.

| Main Diseases or Pathogens | Vectors | Capability Area | | | | | |
|---|---|---|---|---|---|---|---|
| | | Risk Assessment | | | Risk Mitigation | | |
| | | Vector and Pathogen Collection | Vector ID | Pathogen ID | Data Analysis & Decision Support | Vector Control | Personal Protection |
| Dengue, Zika, Chikungunya, Yellow fever, etc. | *Aedes aegypti* | Amber | Green | Amber | Red | Amber | Red |
| Malaria | *Anopheles* | Amber | Red | Amber | Red | Amber | Red |
| West Nile fever, encephalitis | *Culex* | Green | Red | Green | Red | Green | Red |
| Lyme disease, Rocky Mountain spotted fever, anaplasmosis, ehrlichiosis, Tick-borne encephalitis, tularemia, etc. | Ticks | Amber | Red | Red | Red | Amber | Amber |
| Leishmaniasis | Sand flies | Amber | Red | Amber | Red | Amber | Red |
| Diarrhea | Filth flies | Amber | Amber | Red | Red | Amber | N/A |

## Vector & Pathogen Collection

**Definition:** The collection of medically important vectors and vector-borne pathogens refers to the use of techniques and tools that enable the collection of whole specimens or their nucleic acids to characterize the vector and pathogen threat.

**Operational Requirement:** Collect specimens to determine the presence of vectors, estimate their relative population levels, establish action thresholds for control measures, and evaluate the efficacy of implemented control measures. Screen specimens for pathogens and characterize the disease threat.

**Current State:** There are many different methods and sampling devices available for collecting vectors and pests. The effectiveness of existing sampling devices varies due to differences in species bionomics, geographic location and collection site, as well as any attractants (e.g., chemical and/or luminescent) that are used. Many devices require power sources (such as batteries) that are logistically cumbersome and usually require daily charging. Standard operating procedures (SOPs) for processing and storing collected specimens for future testing are lacking.

**Vector and Pathogen Collection Requirements:**

BASIC AND APPLIED RESEARCH

- Conduct systematic studies of vector bionomics to increase fundamental knowledge and understanding of behavior and ecology of medically relevant vectors in order to implement effective surveillance and control.
- Determine insecticide resistance status of medically important vector species.
- Develop SOPs that do not require a cold chain for the processing, storage and shipment of collected specimens for vector and pathogen molecular testing.

ADVANCED TECHNOLOGY DEVELOPMENT

- Perform comparative evaluation of existing technologies that are used to collect specific vector groups (e.g., *Anopheles* mosquitoes).
- Assess commercially available attractants or combinations of attractants that can be used interchangeably for the collection of whole vector specimens (or their nucleic acids) across multiple genera of medically important vectors, including other biting arthropods whose status as vectors of human pathogens is unknown.
- Assess existing power sources (e.g., battery technologies, solar cells, nanocrystal sources, etc.) that are light-weight, durable, long-lasting and that can be integrated into the collection system that meets DoD shipping requirements, and that are compatible with other military pest management products that require power sources (currently battery-operated requiring external charge).

OPERATIONAL SYSTEM DEVELOPMENT

- Develop a field expedient, light-weight, and compact system or capability, preferably a single product, with an integrated power source that can be used in any situation (i.e., location, environment, dust, rain, temperature) to collect all medically relevant vectors and their pathogens. The system may integrate with components that detect and measure all relevant vector and pathogen characteristics important for accurate vector identification and control. Vectors and pathogens should be identified within 72 hours of collection and further characterized immediately or processed and stored for future analyses. Ideally, the system components should integrate with a data management system that interfaces with a bioinformatics platform.

## Vector Identification

**Definition:** Vector identification refers to the techniques and tools used to identify collected specimens to the appropriate taxonomic level required to implement control. Depending upon the vector, operational environment, personnel capability, and medical roles of care 1-4, vectors may be identified to family, genus, or species level.

**Operational Requirement:** Entomologists and preventive medicine assets identify vector species to characterize potential threats and make informed decisions regarding appropriate risk mitigation measures to protect personnel. Vectors must be identifiable at the point of collection. Those performing vector identification must be able to do so without internet connectivity or advanced entomological or laboratory training. Mosquitoes, sand flies, and ticks should be identified to species level to acquire enough information about their biology, ecology and disease transmission potential to inform appropriate risk mitigation methods. Filth flies should be identified to family or genus level.

**Current State:** Vectors are identified using taxonomic keys and specialized equipment (e.g., microscopes) or techniques (e.g., microscope slide preparation) necessary to prepare specimens. Identification of many vectors to species level is labor intensive, time consuming, and often inaccurate depending on previous vector identification training. Molecular identification tools via genetic markers or sequencing are available for some important vectors but require significant laboratory capability and training (currently available only in well-established laboratories). Field expedient, efficient and accurate vector identification tools are needed.

**Vector Identification Requirements:**

IDENTIFICATION TOOLS AND SYSTEMS

- Conduct basic research into the systematics and taxonomy of militarily relevant vector groups (particularly *Anopheles*) to create resources such as keys that enable field preventive medicine technicians to accurately identify vectors.

- Using all available taxonomic information, develop field expedient identification systems (e.g., mobile software applications or other media) that are accessible to PM assets across the range of military operations.
- Develop machine learning and novel algorithms or systems that can identify vectors by sight, sound, chemical, molecular and/or other means.
- Develop field expedient capability for vector identification using genetic and/or molecular markers and that require minimal training and resources. This capability may be designed to integrate as a modular component of an operational vector/pathogen collection and/or pathogen identification system, and link to a data management system that interfaces with a bioinformatics platform.
- Develop training tools for use with new and existing identification systems.
- Develop field expedient capability to identify and characterize insecticide resistance phenotypes and genotypes in vector populations.
- Develop SOPs to process and store sample specimens for future analyses if field expedience is not desirable or possible within 72 hours of specimen collection.

REFERENCE COLLECTIONS AND DATABASES

- Build and maintain accurate vector specimen collections and databases to develop next generation identification capabilities.
- Develop current DoD vector species databases and mapping tools that are not only sensitive to spatial and temporal changes, but also track species movement and population size fluctuations.
- Develop reference genomic databases to facilitate molecular vector identification.

## Pathogen Screening and Identification

**Definition:** Pathogen screening refers to the techniques, tools and methods used to determine if vectors are infected with pathogens that are capable of causing disease in humans (e.g., screen for flaviviruses, *Plasmodium*, *Leishmania*, etc.). Pathogen identification refers to the techniques, tools and methods used to identify pathogens to an appropriate level (e.g., serotype for Dengue viruses) to best inform specific disease threats to humans.

**Operational Requirement**: Accurately identify vector-borne pathogens of military importance in a timely fashion (e.g., within 72 hours of collection) at the point of collection. New tools and protocols therefore should be field expedient to inform leadership of new or changing disease threats. Information about pathogens detected in vectors may elevate disease risk levels and hence provide critical medical intelligence to support force health protection decision making across the Combatant Commands.

**Current State:** Field expedient pathogen screening and identification capabilities are extremely limited. Deployed units have few options to transport vector and pathogen specimens to laboratories for subsequent identification, and when accomplished, results are often unavailable in time to inform vector control decisions. Rapid diagnostic assays

(i.e., dipstick tests) are available for some pathogens (e.g., *Plasmodium*, *Leishmania* and several viruses), but these are costly and have limited (~2 year) shelf lives. There are no standardized pathogen detection tools or protocols available across the DoD Enterprise.

**Pathogen Screening and Identification Requirements:**

PATHOGEN/VECTOR BIONOMICS

- Determine the competence of vectors to become infected with and/or transmit pathogens to animal hosts.
- Study vector-pathogen interactions to identify weaknesses which may be targeted or utilized to mitigate pathogen threats to human health.
- Determine the extent to which filth flies are able to mechanically transmit pathogens to Service members in operational environments.
- Develop strategies to monitor vector populations for current and emerging pathogens.

PATHOGEN SCREENING AND IDENTIFICATION TECHNOLOGIES

- Develop field expedient pathogen detection capability that does not require a cold chain and has a minimal logistics footprint.
- Develop training tools for new and existing pathogen detection methods.
- Develop capability to identify pathogens to species or strain. This capability may be designed to include the identification of insecticide resistant vectors and drug resistant pathogens, integrate as a modular component of an operational vector/pathogen collection and/or vector identification system, and link to a data management system that interfaces with a bioinformatics platform.
- Develop capability to identify multiple pathogens accurately and simultaneously within vectors, including the capability to simultaneously distinguish closely related pathogens (e.g., among flaviviruses or *Plasmodium* spp.).
- Develop integrated capability to simultaneously identify arthropods and pathogens of military importance.

BIOINFORMATICS TECHNOLOGIES

- Develop a stand-alone analysis platform for pathogen identification using appropriate reference genomic databases for coordinated access among all DoD laboratories and other DoD assets worldwide.
- Develop search and matching algorithms to identify vectors and pathogens using reference databases.

## Entomological Data Analysis & Decision Support

**Definition:** Entomological data analysis & decision support refer to an information technology capability that accepts, stores and analyzes surveillance data acquired from different surveillance sources to produce medical intelligence and/or actionable vector management information via decision tree algorithms to inform disease mitigation strategies needed for effective vector-borne disease prevention and control programs.

**Operational Requirement:** There is an operational need for vector management decision support that includes collection and analysis of information obtained on multiple vectors and vector-borne diseases, and integrated into a single computational tool. The tool must allow users to compile, manage and access entomological and pathogen surveillance data obtained using standard operating protocols (SOPs) and integrated into a surveillance data management system that is coordinated jointly among the Services.

**Current State:** The AFPMB previously maintained Disease Vector Ecology Profiles (DVEPs) which summarize unclassified literature on medically important arthropods, vertebrates and plants that may adversely affect troops in specific countries or regions of the world, focusing on the epidemiology of arthropod-borne diseases and the bionomics and control of disease vectors. However, these DVEPS are outdated. In addition, several U.S. Government and Non-Governmental Organizations (e.g., Smithsonian Institution and the Worldwide Insecticide Resistance Network, respectively) manage a number of disparate systems, some of which can produce distribution risk maps of vectors and/or pathogens in select regions.

**Decision Support Tool Requirements:**

STANDARDIZE TESTING & EVALUATION METHODS

- Develop SOPs for the testing and evaluation of vector surveillance and control methods, as well as to evaluate the efficacy of personal protective measures and vector control tools used against insecticide susceptible and insecticide resistant field vector populations.

DATA MANAGEMENT, DATA SHARING AND SAMPLE SHARING ACROSS THE DoD ENTERPRISE

- Leverage an existing or develop a new integrated, dedicated, unclassified vector and pathogen surveillance data management system on a DoD network that is coordinated jointly among the Services, centralized in one location and globally accessible.
- Develop SOPs to improve data sharing across the DoD medical community.
- Develop capability to systematically update existing reports (e.g., DVEPS), technical guides and databases to ensure that up-to-date DoD

entomological intelligence is maintained.

DECISION SUPPORT TOOLS

- Develop standardized algorithms to assess the entomological efficacy of vector control programs.
- Develop models and algorithms that establish vector population and pathogen infection thresholds required to prevent disease transmission. For example, develop capability to determine to what level a vector population must be reduced to prevent pathogen transmission and disease incidence. Important variables include vector species and population levels, biting rates, pathogens present, pathogen infection levels, intrinsic and extrinsic incubation rates, temperature, etc.
- Develop data collection and analysis capability that incorporates surveillance data, actionable information on target vector species including bionomics and associated vector pathogens, and with the capability to produce vector/pathogen risk maps and standardized/customized reports. An ideal tool will utilize all available data and predictive algorithms to characterize vector-borne risks and inform which vector control strategies (including pesticide and application equipment) are needed.

## Personal Protection

**Definition:** Personal protection includes any capability that individuals can use to prevent bites from vectors. Examples include Personal Protection Measures (PPM) such as insecticide-treated clothing and bednets, as well as topical and spatial repellents.

**Operational requirement**: Protect Service members from being bitten by vectors.

**Current State**: The current state of our personal protection system includes permethrin treated uniforms (both factory and unit treated), topical repellents applied to the skin, and permethrin treated bed nets, all of which are affordable and effective tools. However, due to low end-user acceptability, poor compliance, and/or increasing prevalence of insecticide resistance, deployed Service members remain at risk of being bitten by vectors and acquiring vector-borne pathogens.

**Personal Protection Requirements:**

BASIC RESEARCH

- Conduct epidemiological studies to inform our understanding of the relationship between bite prevention and true protective efficacy as defined by zero disease incidence. Establish evidence-based threshold and objective bite prevention levels to understand the relationships among pathogen infection level, vector biting rate,

and transmission risk to provide baseline information for actionable vector control decisions.
- Characterize the mathematical relationship between the laboratory-controlled "arm in cage" vector bite test and biting rates that occur under semi-field and field conditions.
- Develop overarching SOPs to test PPM in laboratory, semi-field and field scenarios to evaluate uniform and repellent products.

NOVEL BITE PROTECTION CAPABILITIES

- Develop bite protection capability which provides protection for personnel when they are not wearing a combat uniform. The ideal capability will have high user acceptability and/or be passive, requiring only limited or no human intervention.
- Characterize the conditions and interactions affecting the efficacy of spatial repellents (e.g., volatile repellent chemicals) to reduce vector contact or vector bites to determine: (i) the levels of bite prevention; (ii) chemical concentrations and physical distance from the chemical point source needed for effective bite prevention; (iii) the required duration of effective bite prevention; and (iv) which environmental conditions are most important (i.e., temperature, humidity, air movement, etc.) to optimize effective bite prevention.

PROTECTIVE TEXTILES

- Develop clothing (e.g., uniforms) that protect personnel from biting arthropods for the serviceable life of the uniform.
- Develop alternatives to pyrethroid insecticides for use on clothing and bednets with efficacy against vector species with known insecticide resistance.
- Develop protective bednet systems with better air flow and high user acceptability for use in hot and humid environments.

INSECTICIDE RESISTANCE

- Characterize insecticide resistance in vector populations (i.e., detect and measure prevalence and intensity) and determine if resistance is operationally and/or epidemiologically important in terms of adversely affecting vector population control or bite protection methods that rely on insecticides.
- Determine insecticide resistance thresholds (i.e., prevalence, intensity, mechanism) that require changes to the operational vector control strategy (i.e., switch insecticide, change control method, target different life stage, etc.) and to manage insecticide resistant vector populations.
- Evaluate the effectiveness of arthropod repellents (e.g., permethrin, etofenprox, deltamethrin, etc.) on uniforms and bednets to prevent bites from mosquitoes of all medically important genera.

## Vector Control

**Definition:** Vector control refers to the use of pesticides, equipment and methods to reduce the number of vectors in an area to levels that eliminate the risk of pathogen transmission to Service members.

**Operational Requirement**: Prevent pathogen transmission through safe and effective vector control operations.

**Current State:** Vector control programs can be effective at controlling vectors, but only when operations are adequately resourced and properly conducted. Significant knowledge and logistical constraints prevent implementation of sustained, effective vector control operations in the field. While several insecticides to control vectors are available, oftentimes they are ineffective due to detrimental environmental conditions, lack of knowledge of vector activity or resting behaviors, inability to find and treat larval breeding sources, faulty equipment, or pesticide applicator error. The decline in EPA registered public health pesticides exacerbates the problem and leaves DoD with few vector control tools. Therefore, the DoD lacks a sustainable system to reliably and effectively control vectors to an epidemiologically relevant level across the spectrum of operations.

**Vector Control Requirements:**

BASIC RESEARCH

- Determine to what population density or level (e.g., based on trap numbers or larval sampling criteria) that larval and adult vector populations must be reduced in order to prevent pathogen transmission.
- Develop new area-wide integrated methods to control vectors to an epidemiologically relevant level (see above bullet) that are reliable and sustainable across the spectrum of operations.
- Determine the best practices for effective control of vectors using currently available tools. For example, determine what combinations of current control capabilities (i.e., insecticides, repellents, insecticidal baits, trapping systems, etc.) effectively reduce vector populations to levels that reduce the risk of disease transmission and that are operationally sustainable (i.e., cost-effective, long storage under austere conditions).
- Determine best practices for effective control of adult vectors when larval source management is not an option (examples include container-breeding *Aedes* mosquitoes, phlebotomine sand flies and filth flies).

PUBLIC HEALTH INSECTICIDES

- Develop and/or evaluate new vector control capabilities and active ingredients (particularly alternatives to pyrethroids), synergists, and formulations for vector control with a focus on chemistries that are more effective and efficient (e.g., higher bite protection at lower doses, faster knockdown, longer duration of efficacy, etc.), have greater target specificity, improved environmental profiles (e.g., less toxic or

dangerous to non-target organisms such as fish or pollinators, etc.), improved sustainability (i.e., lower cost, smaller weight and cube, etc.), and greater potential to prevent, overcome or manage insecticide resistant vectors, than the current available tools.

INSECTICIDE RESISTANCE

- Develop capability to characterize insecticide resistance (i.e., detect, measure prevalence and intensity, determine resistance mechanism) within vector populations to insecticides in different classes (e.g. pyrethroid, carbamate, organophosphate) and determine the extent to which insecticide resistance compromises effective vector control.
- Develop best practice program guidelines for insecticide resistance management and prevention.

APPLICATION EQUIPMENT

- Develop capability to autonomously deliver pesticides safely, effectively and efficiently to control medically important vector species.

## SECTION 2. PEST MANAGEMENT

### Background

The DoD requires land, air and water resources to conduct mission essential testing, training, and operational activities. These readiness activities are commonly compromised by invasive species, nuisance wildlife and urban pests associated with buildings or other structures. Plant and animal pests impact infrastructure and cause lost training days due to encumbered military training lands, reduced navigation and security through loss of line-of-sight for installation perimeters and water ways and loss of water navigation and access. Pests impose high management costs from adversely impacted landscapes and ecosystems through lost biodiversity and hindered conservation efforts for threatened and endangered species. Costly invasive species such as brown tree snake (BTS) in Guam significantly impact military operations due to imposed 100% cargo inspections and through expensive mitigation associated with predation and recovery efforts of endangered wildlife. Likewise, other non-native species such as Invasive grasses (e.g., cheatgrass), thistles and other noxious weeds have altered fire ecology on training ranges which limits personnel and equipment movement and live fire exercises due to wildfire risk. In addition, servicemember health and safety is adversely affected by species that bite, sting, wound, or serve as allergens. Bed bugs impact readiness through degradation of morale, interrupted sleep patterns and costly control methods.

This section highlights research requirements to develop new or improved pest management capabilities to address relevant pest management issues impacting DoD installations and military readiness. Many of the research requirements described below are not unique to DoD, as these issues impact other government agencies and the private sector. DoD commonly collaborates with and relies on other agencies and entities to help solve our most important pest management challenges.

### Invasive Species

**Definition:** An '**Invasive species**' is defined as a non-native organism in a particular ecosystem whose introduction causes or is likely to cause economic or environmental harm, or harm to human, animal, or plant health. Invasive species may be either animals or plants and require significant resource expenditure to maintain DoD mission readiness.

**Operational Requirement**: The DoD is responsible for management of 25 million acres across 525 installations and requires high quality testing and training landscapes to conduct mission activities. Invasive species and unwanted terrestrial and aquatic vegetation adversely impact the DoD's testing and training missions and ability to maintain force health and security, therefore the capability to manage such pests is paramount to maintaining DoD's force health, security and readiness.

**Current State:** Most DoD installations have abundant natural resources and have regionally significant and resource-draining invasive species and vegetation management issues that adversely impact military readiness and training.

**Invasive Species Requirements:**

INVASIVE ANIMALS

- Suppress / eradicate Brown Tree Snake (BTS) on Guam with an emphasis on developing:
    - Landscape level suppression/eradication methods that include improvements to the acetaminophen baited mouse aerial drop system (ADS), baits and bait tubes, interdiction techniques, population and control modelling and improved trapping efficacy.
    - Artificial BTS bait.
    - Permanent multi-species barriers to prevent re-infestations.
    - Portable BTS barriers for storing equipment during transport for exercises.
    - Early detection and rapid response capabilities.
- Develop capability for the sustainable control and management of invasive animal species impacting military operations in Pacific areas of operation (e.g., coconut rhinoceros beetle, little fire ant and other predatory ants, Formosan termites, invasive rat species, cats, feral hogs, Philippine deer, etc.).
- Develop capability for sustainable and landscape level management of invasive aquatic animals that impede water transport, infrastructure, force health and safety, and threatened and endangered species and species at risk (e.g., zebra and quagga
- Develop capability for the sustainable control of organisms found in ship ballast water and on ship hulls.
- Develop capability to control the biocontrol-resistant strain of coconut rhinoceros beetle (*Oryctes rhinoceros*) in Hawaii and Guam.
- Also see Nuisance Wildlife section below.

INVASIVE PLANTS

- Develop capability for the sustainable landscape level control of invasive plant species and other vegetation impacting military operations in the Pacific areas of operation; e.g., mangroves (*Rhizophora mangle*), pickleweed (*Batis* spp.), Guinea grass (*Panicum maximum*) and fountain grass (*Pennisetum setaceum*).
- Develop capability for the sustainable landscape level control of invasive plants and noxious weeds, grasses and forbs that adversely influence troop and personnel movement, damage equipment, increase frequency and probability of wildfires, and unfavorably change ecosystem fire ecology (e.g., cheat grass and other invasive grasses, various invasive thistles, mustards, etc.)
- Develop capability for the sustainable landscape level control of invasive plant species and noxious weeds that hinder recovery efforts for populations of threatened and endangered species at risk.

- Develop capability for the sustainable landscape level control of invasive aquatic plants that impede water transport, infrastructure, force health and safety, and threatened and endangered species and species at risk (e.g., hydrilla, water lettuce, water hyacinth, etc.).
- Characterize the impact of invasive species and production of respiratory allergens (pollen), especially for herbicide (e.g., glyphosate) resistant plants such as ragweed.
- Characterize the force health implications associated with ideal tick, mosquito, and other vector refugia/microclimates created by invasive terrestrial plants (e.g., honey suckles, Japanese barberry, privet, autumn olive, porcelain berry, kudzu, etc.) or invasive aquatic plants (e.g., hydrilla, water lettuce, water hyacinth, etc.). Specifically, investigate the relationship between vectors, hosts, animal reservoirs and associated pathogens with the presence of invasive plant species.
- Develop capability for early detection and rapid response for invasive species.
- Develop cleaning and inspection SOPs for vehicles and equipment deployed overseas and between U.S. military installations.
- Develop capability and SOPs to rapidly clean equipment and vehicles to prevent movement or introduction of invasive species, noxious weeds and pathogens.
- Develop SOPs to control forest pests that increase wildfire potential, degrade training landscapes or impact threatened and endangered species.
- Develop capability (e.g., Unmanned Aerial Systems) for vegetation surveillance and management in operational environments.

## Feral Animals and Nuisance Wildlife

**Definition:** The management of feral animals and nuisance wildlife is defined as the management and removal of individuals or populations of specific species of native feral animals and other unwanted wildlife. Examples include feral swine / hogs, white tailed deer, coyotes and other canids, beavers, nutria and other rodents, brown tree snakes, nuisance birds, and other disruptive wildlife in and around airfields and training ranges.

**Operational Requirement:** Nuisance wildlife may interfere with military operations causing property damage, airstrike hazards, and vehicle and equipment damage. In addition, they may contaminate food and water and serve as pathogen reservoirs or create other human health and safety concerns. Some species such as feral swine also cause significant environmental damage via foraging activity, predation and habitat destruction that impedes threatened and endangered species recovery efforts.

**Current State:** The majority of DoD installations contain significant, expensive and often regional wildlife challenges and management short-comings that impact safety, health, the environment, and military readiness.

**Feral Animals and Nuisance Wildlife Requirements:**

- Develop capability for nuisance wildlife management, surveillance and control tools and technologies (e.g., exclusion, scare-tactics, control, trapping, relocation) in and around military airfields (e.g., Bird Airstrike Hazards [BASH]) and training lands (e.g., feral hogs, beaver, black bears and white tailed deer, birds). Some examples

include feral cats and dogs, feral swine/hogs, white tailed, bears, coyotes, beavers, nutria and other rodents, brown tree snakes, and birds and other wildlife in and around airfields.
- Improve capability for bird, bat and other wildlife exclusion and avoidance tools and techniques.

## Urban Pests

**Definition:** Urban pest management is defined as the sustainable management of unwanted pests in and around buildings and other structures, both in urban and non-urban areas.

**Operational Requirement:** Urban pests significantly impact military readiness. Global DoD operations, infrastructure, and force health are adversely impacted by stored product pests, wood-destroying organisms, building and household pests, rodents, birds, bats, horticultural pests and turf pests. Examples include cockroaches, bed bugs, ants, rodents and termites. DoD installations require the ability to quickly and efficiently detect and respond to pest problems to protect the health, morale, and welfare of Service members as well as DoD assets. The DoD needs additional cost effective and sustainable integrated application technologies, pesticides and management practices to address urban pest issues.

**Current State:** The vast majority of DoD installations contain significant, expensive, and often regional IPM challenges and management short-comings that impact military readiness.

**Urban Pests Requirements:**

- Develop capability for the surveillance and control (e.g., baits, pheromones, insecticides, exclusion, biocontrol, etc.) of bed bugs, cockroaches, ants, stored product and other urban pests that negatively impact military operations.
- Develop capability (e.g., baits, exclusion, surveillance, traps and other control measures) for the surveillance and control of urban commensal rodents (e.g., rats and mice), birds and bats.
- Develop capability for the detection of early, low-level bed bug infestations.
- Develop capability for the effective, rapid and sustained control of bed bugs.
- Develop capability (e.g., biocontrol, insecticides, exclusion, repellents, trap and kill, etc.) for the control of Formosan and other subterranean termites as well as other wood-destroying organisms.

## **Appendix 1.** Summary of Research Requirements.

| Capability Area | Requirement | AFPMB Committee | Potential Funding Sponsor |
|---|---|---|---|
| **Vector & Pathogen Collection** | Basic & Applied Research<br>Advanced Technology Development<br>Operational System Development | Equipment<br>Research<br>Medical Entomology | MIDRP<br>DHP 6.7<br>SBIR |
| **Vector Identification** | Identification Tools & Systems | Medical Entomology | MIDRP<br>DHP 6.7<br>SBIR |
| | Reference Collections & Databases | Medical Entomology | MIDRP<br>GEIS |
| **Pathogen Screening & Identification** | Pathogen/Vector Bionomics | Medical Entomology | MIDRP<br>GEIS |
| | Pathogen Detection & Identification Technologies | Medical Entomology | MIDRP<br>DHP 6.7<br>GEIS |
| | Bioinformatics Technologies | Medical Entomology | MIDRP<br>GEIS |
| **Entomological Data Analysis & Decision Support** | Standardize Testing & Evaluation Methods | Knowledge Management | MIDRP<br>GEIS |
| | Data Management, Data Sharing & Sample Sharing Across the DoD Enterprise | Medical Entomology<br>Knowledge Management | MIDRP<br>GEIS |

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|---|---|---|---|
| **Entomological Data Analysis & Decision Support (cont.)** | Decision Support Tools | Equipment<br>Medical Entomology<br>Knowledge Management | MIDRP<br>GEIS<br>DWFP |
| **Personal Protection** | Basic Research | Medical Entomology<br>Research<br>Personal Protection | MIDRP<br>DWFP |
| | Novel Bite Protection Capabilities | Research<br>Personal Protection | MIDRP<br>DWFP<br>DHP 6.7 |
| | Protective Textiles | Research<br>Personal Protection | Natick<br>DWFP |
| | Insecticide Resistance | Medical Entomology<br>Research<br>Personal Protection | Natick<br>MIDRP<br>DWFP |
| **Vector Control** | Basic Research | Equipment<br>Research<br>Medical Entomology | MIDRP<br>DWFP<br>DHP 6.7 |
| | Public Health Insecticides | Pesticides<br>Research | MIDRP<br>DWFP |

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|---|---|---|---|
| **Vector Control (cont.)** | | | DHP 6.7 |
| | Insecticide Resistance | Pesticides<br>Medical Entomology<br>Research | MIDRP<br>DWFP<br>DHP 6.7 |
| | Application Equipment | Equipment<br>Medical Entomology | DWFP<br>DHP 6.7 |
| **Invasive Species, Nuisance Wildlife and Urban Pests** | Invasive Animals | Installation & Operations Advisory | Legacy<br>SERDP<br>ESTCP |
| | Invasive Plants | Installation & Operations Advisory | Legacy<br>SERDP<br>ESTCP |
| | Feral Animals & Nuisance Wildlife | Installation & Operations Advisory | Legacy<br>SERDP<br>ESTCP<br>DWFP |
| | Urban Pests | Installation & Operations Advisory<br>Equipment<br>Pesticides<br>Med Entomol<br>Personal Protection | Legacy<br>SERDP<br>ESTCP |

**Appendix 2.** DoD and Federal Funding Programs.

The table below describes a selection of DoD and other Federal programs that may provide funding for vector and pest management projects. Funding announcements that are posted occasionally by Federal agencies (e.g. Centers for Disease Control, U.S. Agency for International Development, etc.) are not included below.

| Agency | Program | Topic | Website |
|---|---|---|---|
| Defense Health Agency (DHA) | Tick-Borne Disease Research Program (TBDRP) | Personal Protection<br>Vector Control<br><br>Landscape management | http://cdmrp.army.mil/tbdrp/default |
| | Defense Medical Research and Development Program ("DHP 6.7") | All vector management capability areas *(operational systems development)* | https://dmrdp.amedd.army.mil/login.jsf |
| | Deployed War-Fighter Protection Research Program (DWFP) | Personal Protection<br>Vector Control<br>*(advanced technology development)* | https://www.acq.osd.mil/eie/afpmb/dwfp.html |
| | Global Emerging Infection Surveillance and Response (GEIS) | Vector Surveillance<br>Pathogen Detection | https://www.health.mil/Military-Health-Topics/Health-Readiness/Armed-Forces-Health-Surveillance-Branch/Global-Emerging-Infections-Surveillance-and-Response |
| | Infectious Disease Clinical Research Program (IDCRP) | Personal Protection<br>Vector Control<br>*(in conjunction with clinical study,* | http://www.idcrp.org/ |

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|---|---|---|---|
| | | *e.g. epidemiological correlates of protection)* | |
| | Defense Malaria Assistance Program (DMAP) | Vector Surveillance<br>Pathogen Detection<br>Personal Protection<br>Vector Control<br>*(in conjunction with malaria clinical study)* | Website under construction<br><br>(POC: COL Mark Fukuda, USAMD-AFRIMS) |
| | Military Infectious Diseases Research Program (MIDRP) | Vector Surveillance<br>Vector Identification<br>Pathogen Detection<br>Personal Protection<br>Vector Control<br>*(basic & applied research)* | https://midrp.amedd.army.mil/ |
| Environmental Protection Agency (EPA) | EPA Research | Pesticide toxicology | https://www.epa.gov/research-grants/research-funding-opportunities |
| National Science Foundation (NSF) | National Science Foundation (NSF) | Personal Protection<br>Vector Control<br>*(all research)*<br><br>Invasive species management & control<br>*(landscape level)* | https://www.nsf.gov/funding/ |
| Office of the Secretary of Defense (OSD) | Strategic Environmental Research and Development Program (SERDP) & Environmental Security Technology Certification Program (ESTCP) | Invasive species management & control<br>*(landscape level)* | https://serdp-estcp.org/ |

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|---|---|---|---|
| Legacy | DoD Legacy Resource Management Program | Ecosystem management, habitat conservation, invasive species, military range sustainment | https://www.denix.osd.mil/cr/lrmp/home/<br><br>http://grantsoffice.com/GrantDetails.aspx?gid=36288 |
| Various DoD and Federal agencies<br><br>*(Air Force, DHA, Navy, NIH, OSD, USDA)* | Small Business Innovation Research (SBIR)<br><br>&<br><br>Small Business Technology Transfer (STTR) | All vector management capability areas<br><br>*(Topic Proposals only; funds go to industry/academia with option for DoD to provide unique materials or RDT&E facilities and services)* | Air Force: https://www.sbir.gov/node/1053877<br><br>DHA: https://health.mil/About-MHS/Defense-Health-Agency/Research-and-Development/Small-Business-Innovation-Research-Program<br><br>Navy: http://www.navysbir.com/<br><br>NIH: https://sbir.nih.gov/<br><br>OSD: https://www.acq.osd.mil/osbp/sbir/<br><br>USDA: https://nifa.usda.gov/program/small-business-innovation-research-program-sbir |