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# Proposal to Strengthening Laboratory Monitoring of Especially Dangerous Pathogens Using the PackBot 510 Robotic System in Post-Combat Areas of Ukraine, 2023 – 2025

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_____

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Committee Chair

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An abstract of
A thesis submitted to the Faculty of the
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## Abstract

Proposal to Strengthening Laboratory Monitoring of Especially Dangerous Pathogens Using the PackBot 510 Robotic System in Post-Combat Areas of Ukraine, 2023 – 2025

By Mayya V. Abdullayeva

**Background**: On February 24, 2022, the sovereign country of Ukraine was invaded by the Russian Federation. Artillery fire, mining of 30% of the country, and the destruction of Nova Kakhovka dam has resulted in the dispersal and contamination of especially dangerous pathogens such as anthrax spores from 10,000 animal burial sites, cholera and other infectious pathogens into water supply systems and the Black Sea. There is a current need to prevent potential mortality among 14.5 million people living in post-war territories by strengthening the laboratory monitoring of these pathogens.

**Objective:** Strengthen laboratory monitoring by the implementation of PackBot510 Robotic Systems.

**Methods**: Through the implementation of the PackBot 510 robotic systems, samples will be safely collected to monitor soil, water, and air.

**Results:** Increased capacity for safely monitoring the spread of especially dangerous pathogens and other infectious agents in the post-combat territories of Ukraine.

**Conclusion:** Implementation of the PackBot 510 will facilitate monitoring by safely collecting especially dangerous pathogens and other infectious agents in a target population of 14.5 million people living in potentially contaminated and heavily mined post-combat territories; establish a cadre of trained personnel; and ensure collaboration between targeted, relevant partners.

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**Table of Contents**

## Acronyms and Abbreviations

| | |
|---|---|
| MoHU | Ministry of Health of Ukraine |
| WHO | World Health Organization |
| USAID | United States Agency for International Development |
| SAM | Small Arm Manipulator |
| RF | Russian Federation |
| UNHRO | United Nation Human Rights Office |
| RCDCP | Regional Centers for Disease Control and Prevention |
| USES | Ukrainian State Emergency Service |
| MoU | Memorandum of Understanding |
| ISO | International Standards Organization |
| US | United State |
| DoD | Department of Defense |
| DTRA | Department of Threat Reduction |
| USSR | Union of the Soviet Socialist Republic |
| *B. anthracis* | Bacillus Anthracis |
| V. *cholerae* | Vibrio cholerae |

## Chapter 1. Introduction

### 1.1 Background

Full-scale invasion by Russian Federation (RF) troops into the territory the sovereign state of Ukraine on 24 February 2022 has had catastrophic consequences. [1] Russian armed forces carried out indiscriminate artillery shelling of the infrastructure of cities and villages, including residential buildings, hospitals, schools, nuclear and thermal power plants, and burial places for people and animals. [1] As of January 2023, the United Nation Human Rights Office (UNHRO) recorded about 6,919 civilians killed, 11,000 injured, more than 14,5 million people fled the country, and 6.5 million became internally displaced [2, 3].

The explosion by the occupiers of the dam of the Kakhovka hydroelectric power station led to ecocide not only in the Kherson region, but also in the southern territory of Ukraine. As a result of this terrorist act, 55 people and more than 883 million wild animals were drowned. In the temporarily occupied city of Mariupol, there is also a shortage of drinking water, running water, and sewage treatment plants, which can lead to outbreaks of dangerous diseases. [4]

In the liberated territories of Ukraine, the Regional Centers for Disease Control and Prevention (RCDCP) conducted continuous monitoring of water, air, and soil for the presence of biological pathogens. [5] Even though the country has a national program for the epidemiologic surveillance of the spread of diphtheria, tetanus, poliomyelitis, and cholera, vaccination of children and adults

was suspended due to complications associated with hostilities and migration of the population. [6, 7, 8]

According to the Ukrainian State Emergency Service (USES) about 30% of the territory in Ukraine is mined, which corresponds to eight thousand square kilometers in scale. [9]

In the current situation, there is a huge need to prevent potential mortality among 14.5 million people living in post-war territories and to strengthen laboratory monitoring of especially dangerous pathogens such as Bacillus *anthracis (*B. *anthracis)* and Vibrio *cholerae (*V. *cholerae)* using PackBot 510 robotic systems. [10]

**1.2 Problem Statement**

In Ukraine, there is now a huge need for constant virological and bacteriological monitoring of environmental samples for the detection of dangerous infectious pathogens collected in the post-combat territories. However, this does not provide security for more than 14.5 million people living in areas where active hostilities are taking place. To improve laboratory monitoring of especially dangerous pathogens by improving the quality of sampling, as well as preventing the potential death of laboratory employees who manually collect biological samples, it is necessary to provide laboratories with transport PackBot 510 robotic systems that will quickly and efficiently collect and test biological samples of soil, water, and air from potentially mined areas.

### 1.3 Objectives

The objective of our project is to strengthen laboratory monitoring of especially dangerous pathogens through the implementation of the PackBot 510 robotic system.

The current, active hostilities make it difficult to monitor especially dangerous pathogens in Ukraine. The spread of pathogens is especially enhanced in the bombed and adjacent territories of burial grounds for animals that died from especially dangerous infections. About 30% of the post-combat areas are mined now, which makes laboratory monitoring of these pathogens difficult.

The implementation of the PackBot 510 robotic system is critical as current conditions makes laboratory monitoring of these pathogens difficult and dangerous for the entire population living in these areas, as well as for laboratory specialists who risk being killed by hand collecting soil, water, and air samples in post-combat areas, reducing the time required for testing and preventing the further spread of pathogens. [11] Currently, Ukraine does not have the ability to monitor especially dangerous pathogens in mined areas, which makes it difficult to identify and prevent the spread of especially dangerous diseases by state control bodies and ministries.

Specifically, our objectives are to: 1) identify post-combat areas most relevant for monitoring of especially dangerous pathogens; 2) monitor especially dangerous infectious pathogens in post-combat areas using laboratory personnel trained in sample collection using the PackBot 510 robotic system, as well as process and test samples; and 3) establish a long term, trained specialists of

laboratory and research staff to frequently analyze and report ongoing results to project partners for monitoring especially dangerous pathogens in targeted, post-combat areas of Ukraine.

### 1.4 Aims

Aim 1. Assess the current availability and limitations of the use of robotic systems for monitoring highly dangerous infectious pathogens in Ukraine;

Aim 2. Implement and utilize the PackBot 510 robotic systems in the diagnostic laboratories of Ukraine for remote sampling of especially dangerous pathogens in the post-combat territories; and

Aim 3. Evaluate the effectiveness of monitoring of especially dangerous pathogens carried out using a robotic system to make the necessary adjustments.

### 1.5 Approaches

Aim 1. Memorandum of Understanding will be signed by ministry partners; the creation of a working group to coordinate implementation; determine availability of the robotic systems; determine the five main post-combat territories and laboratories; and develop the data entry SOP and program.

Aim 2. Pre-test the PackBot 510 robotic system; pilot sample collection; project implementation and the collection of samples from post-combat areas.

Aim 3. Complete training of laboratory specialists on PackBot 510 robotic systems; prepare an equipment maintenance plan as specified; follow International Standards Organization (ISO) 15189, laboratory standards and in-

country regulations when handling samples and use comparative standard controls.

### 1.6 Significance

The results of this investment will be monitoring of a target population (14.5 million people living in a post-combat area contaminated by mines and other unexploded ordinance), to potential exposure from especially dangerous pathogens; the implementation of a PackBot 510 robotic systems with the ability to quickly and safely collect especially dangerous pathogen samples; training personnel; and critical collaboration among partners.

### 1.7 Charitable Purpose

This grant will fund the implementation of five PackBot 510 robotic systems in the post-combat areas of Ukraine to strengthen the laboratory monitoring of especially dangerous pathogens.

### 1.8 Organizational Capacity

Organizational capacity to conduct this work is ensured by collaboration with the United State Department of Defense/Threat Reduction Agency (U.S. DoD/DTRA). This organization brings significant experience working in 35 countries in the area of biodefense, including Ukraine, through the detection of especially dangerous pathogens. The State Service of Ukraine for Food Safety and Consumer Protection will be responsible for environmental sample testing. The Ministry of Health will be responsible for monitoring especial dangerous pathogens on human health in the post-combat areas of Ukraine. The Department of Defense for the safety and security of all project personnel in the

post-combat areas. All partners will be involved in all activities carried out within the framework of this project.

**1.9 Beneficiaries**

The direct beneficiaries of this project will be 14.5 million people who live in Ukraine in a post-combat area contaminated by mines and other unexploded ordnance. Indirect beneficiaries will be residents of Ukraine living in regions bordering post-combat territories. The ability to quickly and safely collect samples in post-combat areas will strengthen monitoring of the spread of especially dangerous pathogens, quickly eliminate outbreaks, and save lives.

**1.10 Critical Relationships**

Critical relationships include partnerships with Health Ministry of Ukraine, U.S. Department of Defense/Threat Reduction Agency with the State Service of Ukraine for Food Safety and Consumer Relationships as well as the Ministry of Health and Ministry of Defense, with each having assigned duties and roles. Critical to this project will be a Memorandum of Understanding to ensure compliance of all parties to country rules and that all activities are carried out within the framework of the project. The responsibility will be the implementation of the PackBot 510 robotic systems, coordinating the activities between all partners, and ensuring all deliverables are met.

The duties of the Health Ministry of Ukraine will include the following:

a) create a working group to coordinate the project and support its implementation;

b) provide information to support the implementation of this project on

the website of the Ministry of Health;

c) assist in the implementation of project assignments;

d) sampling and testing by laboratory specialists;

e) collection of results, analysis, preparation of reports and their publication on the website of the Ministry of Health.

The duties of the Ministry of Defense of Ukraine will provide access to post-combat territories in Ukraine and assist in the implementation of project assignments.

The duties of the U.S. Department of Defense / Threat Reduction Agency responsibilities will include the following:

a) compliance with country rules as described in the Memorandum of Understanding;

b) inform the Ministry of Health and Defense about the activities carried out within the framework of the project;

c) provide targeted funding for the project;

d) provide training to laboratory professionals using the PackBot 510 robot for sample collection and analysis;

e) obtain and provide a report on the project and results to all stakeholders and prepare a final report on the use of funds and a research report conducted for the Ministry of Health.

**1.11 Partner Communication**

This project outlines the minimal staff and other requirements for its implementation in Ukraine. One of the most critical issues will be the necessity to

establish regular and ongoing communication with the U.S. Department of Defense / Threat Reduction Agency as the funding agency as well as all other partners. In an active, war-time environment, conditions are fluid and can change at any time. The establishment of an alert system will be associated with the U.S. Department of Defense / Threat Reduction Agency to ensure all expectations are being met with the safety of all personnel and a coordinated response among all partners. This includes developing a contingency plan should a “stop work” order is initiated as well as a plan that makes provisions for all personnel in the event of a worst-case scenario.

## Chapter 2. Literature Review

### 2.1 Background

Ukraine was the center of the first East Slavic state, Kyivska Rus, which in the 10th and 11th centuries was the largest and most powerful state in Europe (Figure 1). [32]


Figure 1. Ukraine map showing major cities as well as parts of surrounding countries and the Black Sea. *The World Factbook 2021*. Washington, DC: Central Intelligence Agency, 2021. https://www.cia.gov/. [32]

Although Ukraine gained independence in 1991 with the collapse of the USSR, democracy and prosperity remained elusive. The legacy of state control has stalled privatization and civil liberties efforts. Ukraine has strongly resisted the Russian invasion since 2022, which has destroyed infrastructure and created a humanitarian crisis. The population of Ukraine before the war was estimated at 43,306,477; the current total population is now 14,500,000. The total area of the country is 603,550 sq. km; land: 579,330 sq. km and water 24,220 sq. km. [12]

### 2.2 Current Situation in Ukraine

The full-scale invasion of Ukraine by the Russian Federation began February 24, 2022. [1] There has been indiscriminate shelling of civilian populations as well as burial sites of animal sites that died of anthrax after the Russian army was forced from Kharkiv. Sumy and Kherson found that 30% of the territory of Ukraine is mined (Figure 2). [5, 33]

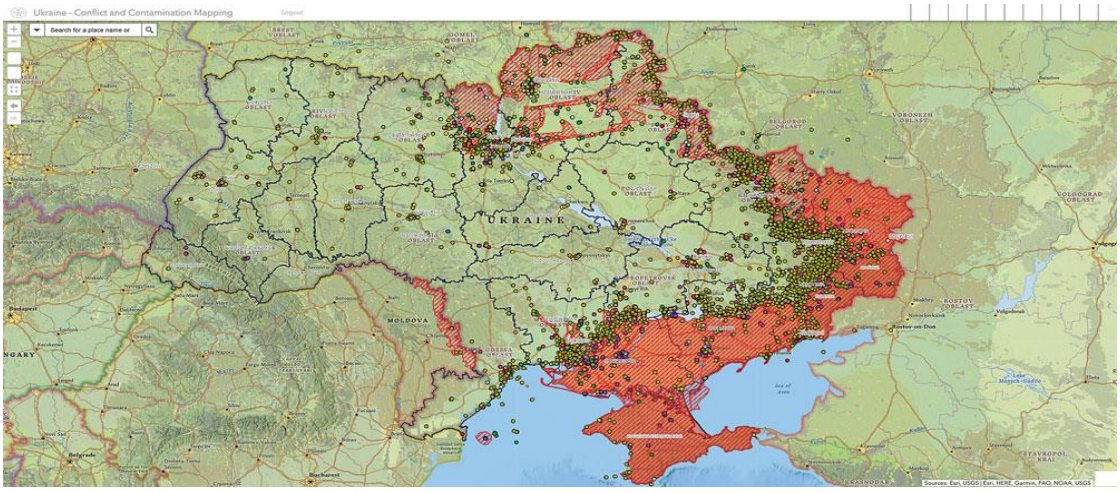



Figure 2. HALO's conflict and contamination map as of 26 September 2022. Each dot corresponds to a unique event involving EO and the colors represent a different category based on HALO's project objectives. JOURNAL, CISR (2022) "The Journal of Conventional Weapons Destruction Issue 26.2 & 26.2," *The Journal of Conventional Weapons Destruction*: Vol. 26 : Iss. 1 , Article 1. Available at: https://commons.lib.jmu.edu/cisr-journal/vol26/iss1/1. [33]

There is presently a shortage of drinking water and sewage treatment facilities and other critical infrastructure which has been destroyed. This has resulted in the spread of diphtheria, tetanus, poliomyelitis, cholera, and other dangerous diseases. [6] This situation is further complicated by the migration of populations and the suspension of vaccination for adults and children. [7, 8] The situation was further exacerbated by the shelling of about 10,000 animal burial grounds which has spread soil contamination with anthrax spores in the liberated and occupied territories. [13,14] Demining is not just slow, it is also expensive. The World Bank estimates that demining Ukraine, which costs between $2 and $8 per square meter, will cost $37.4 billion over the next 10 years. [2] The United States has committed more than $95 million to Ukraine's demining, according to a 2023 State Department report. After 100 days of war, Ukraine's health system is under severe pressure and many countries are hosting displaced Ukrainians, to help meet the escalating health needs. War has shattered lives and communities and imperiling the short- and long-term health of Ukraine's people. The war has increased the need for healthcare while reducing the system's ability to provide services, particularly in areas of active conflict. Some health facilities have been destroyed, while others have been overwhelmed by people seeking care for trauma and injuries resulting directly from the war. [15]

Politically, Ukraine sees the demands clearly. Land will have to be returned over an exchange for Peace. With Russia, there is only lip service to the criminality of a of its invasion of a sovereign country and ambiguity with respect to the consequence of it. Also, reparations for Ukraine must be made through the

seizure of Russian state assets. This may increase the cost of the war to Russian and help end it. The pitfalls of concessions for peace are that ceding territory to an aggressor with maximalist demands — that Ukraine abandon not just claims to its own land, but its independence and desire for a future free of Russian state influence. This imparts a lesson: that war works and that the invader is just. Instead of lasting peace, critics of such proposals maintain that they will effectively serve as a temporary freeze, allowing a battered Russian military to regroup and try for more in the near future. [15]

### 2.3 Existing Problem of Dangerous Pathogens in Ukraine

#### 2.3.1 Anthrax

Anthrax is a serious, notifiable, non-contagious, toxin-mediated zoonosis. It is caused by Bacillus *anthracis* (B. *anthracis*), a globally distributed, gram-positive, spore-forming bacterium that has been classified as a category “A” biological agent that poses a massive destructive threat to human health and safety if used in bioweapons. [16] The spore form of this organism can survive in the environment for many decades. [16] Humans exposed to anthrax spores develop either cutaneous, gastrointestinal, or inhalational types depending on route of exposure.

The overwhelming majority (95%) of naturally occurring anthrax cases in humans are cutaneous, with an incubation period of 1 – 5 days. The context of the ongoing Russian invasion of the country should alert local authorities and international donors to the importance of discerning between bacteriological outbreaks of natural and unnatural causes. Ukraine is surrounded by seven

endemic countries, among them Russia, Romania, and Moldova, which are listed among the countries with a high number of registered cases in Europe. Data from the Public Health Center of the Ministry of Health of Ukraine and the SSUFSCP for anthrax cases in humans registered the highest number between 1999 and 2000 with 35 cases registered. According to the Ministry of Heath of Ukraine, there are more than 13,500 foci in Ukraine where anthrax may occur, as there are biothermal pits and cattle burial grounds with anthrax-infected animals buried. Thus, anthrax may occur anywhere in Ukraine. Anthrax in wartime Ukraine requires increased public health surveillance (PHS) - global biosecurity. [17] Currently, the shelling randomly throughout the territories where some of these pits or burial grounds are located has spread soil contaminated by spores. [13,14] Russian troops have reportedly been infected with anthrax after excavating a cattle burial site while digging defensive trenches in southern Ukraine. [18, 19] The difficulty of monitoring especially dangerous pathogens lies in the fact that Ukraine is now the most mined country in the world. It will take decades to make the environment safe.

### 2.3.2 Cholera

Cholera is an acute diarrheal infection caused by ingestion of food or water contaminated with the bacterium V. *cholerae*. Cholera remains a global threat to public health and is an extremely virulent disease that can cause severe acute watery diarrhea. It takes between 12 hours and 5 days for a person to show symptoms after ingesting contaminated food or water. [20] Cholera affects both children and adults and can kill within hours if untreated. Most people infected

with V. *cholerae* do not develop any symptoms, although the bacteria are present in their faces for 1-10 days after infection and are shed back into the environment, potentially infecting other people. [21]

Ecological disaster triggered by the collapse of the Nova Kakhovka dam has become a global problem as severely contaminated waters flow into the Black Sea. Flood waters raging through the lower Dnipro River valley brought with them sewage, oil, chemicals and possibly anthrax from animal burial sites. At least two anthrax burial places are in the temporarily occupied territories, Russia has been accused of deliberately blasting the main concrete barrier. [22] Approximately 100,000 people affected downstream, 50,000 hectares of forests have been flooded while 20,000 animals and 10,000 birds were “under threat of imminent death”. [23]

Ukraine's health ministry is preparing for an outbreak of waterborne diseases such as cholera following the huge release of water caused by the destruction of the Nova Kakhovka dam in the country's Kherson region. So far, the epidemiologic situation is stable, and only have isolated cases of intestinal diseases caused by the consumption of unwashed fruits and vegetables. Nevertheless, preparations for an outbreak are underway. The Ukrainian government has prepared over 220 beds for possible infected patients and supplied hospitals with all the needed medicines and vaccines to treat patients in case the outbreak happens. [24]

### 2.4 Technical Application of the PackBot 510 Robotic Systems

The PackBot 510 is a multi-mission tactical mobile robot, designed to be used in dangerous missions in high-threat battlefield scenarios. The robot can perform biological surveillance and detection and is easily configured by the operator based on the mission needs. The robotic system is man-portable, easy-to-use, compact, featuring a modular design, incorporating an array of sensors and interchangeable payloads. It can be deployed in less than two minutes and operates under all weather conditions. The machine is also fitted with a small arm manipulator (SAM) featuring a camera for manipulation, interrogation, and inspection (Figure 3). [25, 26, 34]

Figures 3. The Next Generation PackBot 510 with Hazmat kit. Adapted from PackBotfinal "iRobot® PackBot® 510 with EOD Kit" by ©2007 iRobot Corporation, 2020, Ag2link.com. https://www.ag2link.com/wp-content/uploads/2020/01/PackBotfinal.pdf. Copyright 2020 by Ag2link.com [34]

The robotic system also has an assist package that facilitates semi-autonomous functionality and enhanced situational awareness. It also incorporates a variety of communications systems and multiple high-resolution cameras to capture real-

time imagery and video. Sensors and a Hazmat kit that can be used to detect biological materials. The 510 PackBot robot is powered by rechargeable batteries, which provide continuous power for more than four hours. The robotic system has a wireless teleoperation interface and sensors provide high resolution and accuracy and can build a map of the surrounding environment (Figure 4). [25, 26, 34]


Figure 4. Portable Command console and Hand Controller for the iRobot PackBot 510. Adapted from PackBotfinal "iRobot® PackBot® 510 with EOD Kit" by ©2007 iRobot Corporation, 2020, Ag2link.com. https://www.ag2link.com/wp-content/uploads/2020/01/PackBotfinal.pdf. Copyright 2020 by Ag2link.com [34]

The ground-based systems are uniquely fitted for the required task(s), such as sample collection. The robotic systems include manufacturer training and technical support to ensure selection of the appropriate collection system and software. [26, 27]

## Chapter 3. Methods

### 3.1 Memorandum of Understanding

Critical to this project will be a Memorandum of Understanding to ensure compliance of all parties to country rules and that all activities are conducted within the framework of the project. At minimum, it will describe each partner agency; state the purpose of the Memorandum of Understanding; and clearly describe the roles and responsibilities each organization or agency. The roles and responsibilities will align with project goals, objectives, and target outputs; it should also identify the staff responsible for completing the specific responsibilities and reporting requirements; describe how the collaboration/partnership benefits the project and describe the resources each partner will contribute to the project. It clearly will define how the parties will work together and establish expectations. The goal is to achieve a clear and mutual understanding of the collaborating partnerships.

### 3.2 Project Design

The invasion of Ukraine by the Russian Federation is considered a “special military operation.” As a result, the ability to execute and implement a project of this type will be done under highly stressful working conditions, requiring the ability for immediate change and adjustments. At the start of the project, the effective use of a Working Group(s) approach will be used to develop, optimize, and implement the project design. This method can be most effective to rapidly respond to the ever-changing working landscape created by combat conditions. It can utilize structured groups that leverage the expertise and capabilities of all

project participants and partners. This includes brainstorming for the solution of complex tasks; plan and manage time; refine understanding through discussion and explanation; give and receive feedback on performance; challenge assumptions; share diverse perspectives; hold one another accountable; and maintain a path forward under all conditions.

### 3.3 PackBot 510 Robotic System Phases of Implementation

Phases of implementation will include:

a) pre-testing of the PackBot 510 robotic systems;

b) pilot sample collection;

b) project implementation;

c) safe collection of samples remotely from post-combat areas.

Remote-controlled robotic systems have been used to detect dangerous bacteria in water, air, and soil samples. [25] The main aim of this type of robotic system to safely collect and identify biological threats. [25, 26, 27]

### 3.4 Personnel and Training

The project will be carried out by 18 employees; 14 are permanent and four are temporary contractors. Ten employees of Ukrainian laboratories will be trained to work with laboratory robotic systems and sample collection. The training will be conducted by two U.S.-based engineers specializing in robotic systems. The project in Ukraine will be managed by the Project Manager and the full data analysis and final presentation will be conducted by the principal investigator.

The training of laboratory specialists will be done by PackBot 510 U.S.-based engineers who will also provide a training plan and standard operating procedure for the trainees.

**3.5 Sample Size**

The minimum volume of soil will be determined by the overall objective, site conditions, and tests conducted. Bulk density, moisture content, and impurities will be adjusted on site (e.g., moist, or dry soil, debris, or stones) to determine the amount and number of samples collected. Pathogens may be deposited and distributed on surface soil at greater concentrations in the top few meters (e.g., 0 – 30 cm) to meet the minimum soil volume required for testing. The number of samples collected will depend on the study objective.

**3.6 Sample Collection**

Sample collection for pathogens will be done in various environmental media (soil, surface, liquid, and aerosols). This sampling process will be conducted with discreet soil samples or composites (e.g., the number of replicates, test species per replicate, volume of soil per test). Soil is a natural body comprised of solids (minerals and organic matter), liquid, and gases occur on the land surface. After samples have been collected, they will be returned to the laboratory and immediately stored and remain undisturbed to mimic field conditions until tested. Composited soil samples will be tested as soon as possible and will not be frozen as freezing and thawing can disrupt soil structure and could influence biological activity. [28, 30]

### 3.7 Sample Testing

B. *anthracis* can be isolated from a soil sample taken from 50 cm depth at the place of mass burial. The sample can be identified on characteristic growth on special nutrient plates or by anthrax - typical beaten – egg-white effect appeared when growth of the colony was lifted with an inoculation loop. These colonies were inoculated on columbia agar with the addition of 5 % defibrinated sheep blood and incubated for 24 hours at 37 °C. Also, DNA is extracted for qPCR testing using standard methods. [29] Soil sample processing protocols can be divided into two general types: indirect and direct. There are two requirements for successful indirect isolation of B. *anthracis* from soil samples: dissociate the spores from the soil particles and physically separate the free spores from the soil particles. Adding an aqueous carrier medium to a soil sample creates a sample slurry for easier manipulation. [30]

### 3.8 Data Analysis of Samples Collected

Samples collection will be analyzed based on the capability and capacity of the PackBot 510 systems as compared to historical data.

### 3.9 Monitoring and Evaluation

#### 3.9.1 Inputs

Working with the Health Ministry of Ukraine, we will identify the five post-combat areas territories and laboratories to deploy the PackBot 510 and pilot test and assess the current availability and current limitations of the use of robotic systems for monitoring highly dangerous infections in Ukraine. We will sign a “Memorandum of Understanding” with Ukrainian Ministry of Health and the

Ministry of Defense. We will determine the availability and biological modification of the robotic systems.

At the first stage of the project, we will evaluate the monitoring of especially dangerous pathogens carried out using the PackBot 510 robotic systems to make changes and necessary adjustments. Production and delivery of robotic systems may be delayed for a period of three to four months, as assembly of robots will only start after prepayment, and this is also due to high demand for this technology. The project will employee 18 employees; 14 are permanent and temporary contractors and two are U.S.-based engineers specializing in robotic systems. The project will be managed by the project Manager and the full data analysis will be done by the principal investigator. Facilities for training of laboratorians must in a safe and secured area. The project will be submitted to the U.S. Department of Defense / Threat Reduction Agency. It is designed for two years at a cost of $1,000,0000 U.S. dollars. This will include: the salaries of six employees and ten trainees; five PackBot 510 robotic systems; local and international business trips, lodging, *per diem*, equipment, and consumables. The cost of vehicles used for the transportation robotic systems and rent of offices will not be included, since it will be already paid by our partner.

**3.9.2 Outputs**

A working group will be created with the Health Ministry of Ukraine and the State Service Ukraine for Food Safety and Consumer Protection to coordinate the project and support its implementation of project assignments. A signed “Memorandum of Understanding” with Ukrainian Ministry of Health of Defense

will support the delivery and implementation of the PackBot 510 robotic systems for the remote sampling of water, soil, and air for especially dangerous pathogens. Eighteen trained employees will work with the laboratory robotic systems and sample collection. The project will be managed in Ukraine by the in-country program manager. Data analyses and timely reporting of results/indicators and project updates to all partners will be submitted by the principal investigator. A training facility for the safe and secure training of all personnel will be established and an approved budget will cover the cost of salaries of employees, trainees, five PackBot 510 robotic systems, local and international business trips, lodging, *per diem*, equipment, and consumables.

### 3.9.3 Outcomes

1. Assess the current availability and current limitations of the use of robotic systems for monitoring especially dangerous infectious pathogens in Ukraine;

2. Implementation and utilization of the PackBot 510 robotic systems in diagnostic laboratories in Ukraine for remote sampling of especially dangerous pathogens in post-combat territories;

3. Constantly evaluate the effectiveness of monitoring of especially dangerous pathogens carried out using a robotic system to make the necessary adjustments, if necessary.

### 3.9.4 Impact

Utilize evidence-based data to strengthen monitoring of especially dangerous pathogens through the implementation of PackBot 510 robotic systems. These pathogens present a threat for the entire populations living in

these post-ware areas as well as for the laboratory specialists who risk being killed by hand collecting soil, air, and water samples, and reduces the time required for testing and preventing the spread of pathogens.

## Chapter 4. Deliverables

**Aim 1.** Assess the current availability and current limitations of the use of robotic systems for monitoring highly dangerous infectious pathogens in Ukraine.

*Deliverables:*

a) Final version of the SOPs;

b) Final version of data entry program;

c) Report of PackBot 510 robotic system implementation.

**Aim 2**. Implementation and utilization of the PackBot 510 robotic systems in the diagnostic laboratories of Ukraine for remote sampling of especially dangerous pathogens in the post-combat territories.

*Deliverables:*

a) Report of Pilot test results;

b) Issuance of Certificates of training to laboratory specialists;

c) Report of Results to the Ministry of Health weekly;

d) Report of Results to the Ministry of Defense every three months;

e) Report to the Department of Defense every three months;

f) Reports of the quantitative data analysis of the first half of the project.

**Aim 3.** Constantly evaluate the effectiveness of monitoring of especially dangerous pathogens carried out using a robotic system in order to make the necessary adjustments if necessary.

*Deliverables:*

a) Report of the PackBot 510 robotic systems validation;

b) Reports of final quantitative analysis;

c) Presentation of final report.

**4.4 Project Timeline**

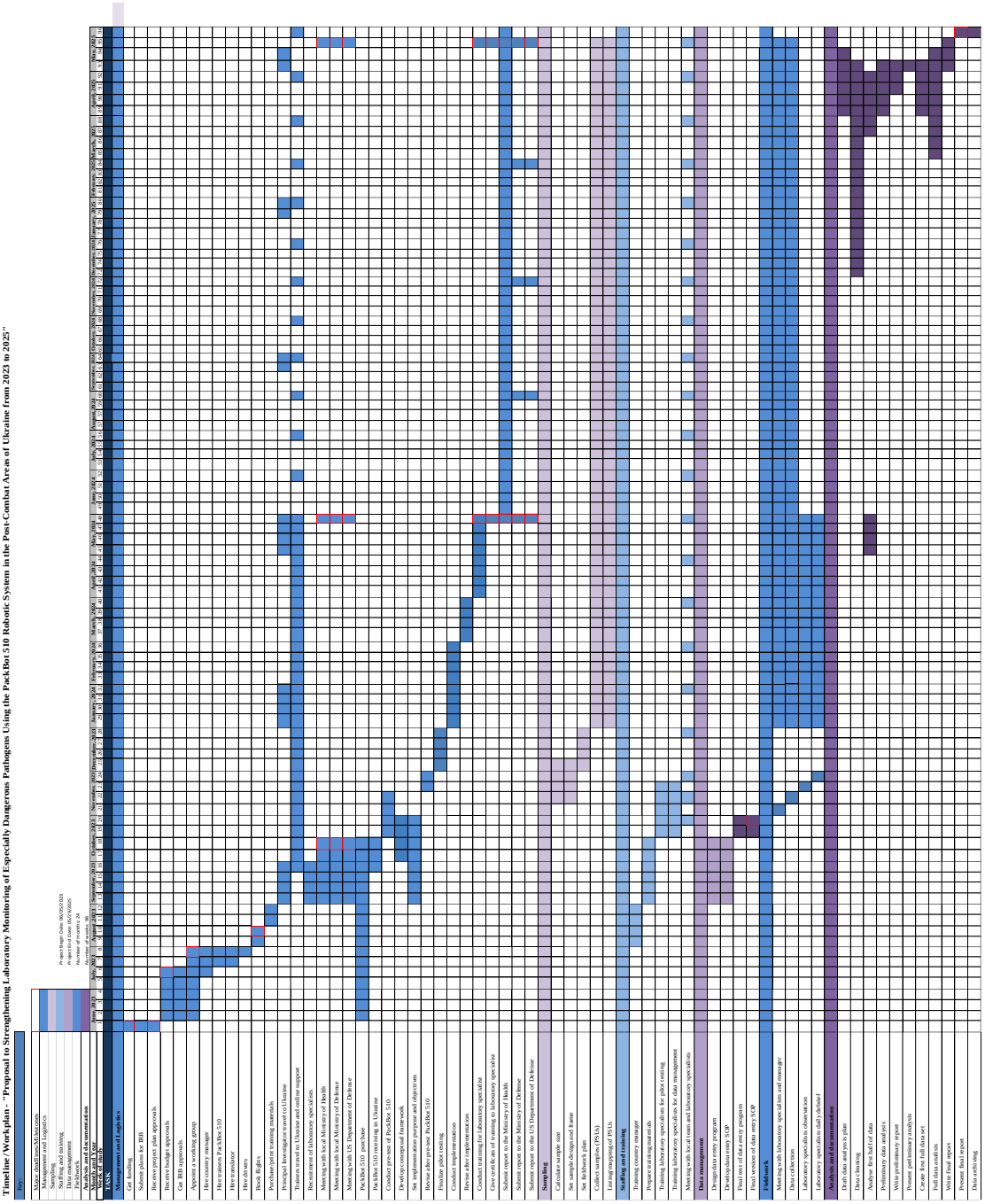
Aim 1. Assess the current availability and current limitations of the use of robotic systems for monitoring highly dangerous infectious pathogens in Ukraine. Activities will include purchase and delivery of the robotic system to reduce the likelihood of delay, hiring and training personnel, identifying laboratories, approved Memorandum of Understanding. The principal investigator will be carrying this out in coordination with the U.S. Department of Defense/Threat Reduction Agency, Ministry of Health, Ministry of Defense, and in-country manager.

Aim 2. Implementation and utilization of the PackBot 510 robotic systems in the diagnostic laboratories of Ukraine for remote sampling of especially dangerous pathogens in the post-combat territories. Activities will include training of laboratory personnel by U.S. based trainers, selection of five laboratories from post-combat areas, conduct pretest of the robotic system, collect data, and send test result to the Ministry of Health, Ministry of Defense, and the US Department of Defense/Threat reduction Agency.

Aim 3. Constantly evaluate the effectiveness of monitoring of especially dangerous pathogens carried out using a robotic system in order to make the necessary adjustments if necessary. In these activities we will conduct a

comparative quantitative analysis of the results obtained when sampling manually and using the PackBot 510 robotic system. If our method works, we will be able to expand the program and introduce such robotic systems in other regions of Ukraine. (Table 1)

Table 1. Timeline of Project Performers.



### 4.5 Human Participants in Project

This project does not require IRB approval because it does not meet the definition of a "human" or "clinical" study; a release letter will be received from Emory University.

### 4.6 Budget and Budget Justification

The project is designed for two years with a cost of $1,000,000 U.S. dollars. This includes the salaries of six employees and ten trainees, five PackBot 510 robotic systems, local and international business trips, lodging, *per diem*, equipment, and consumables. (Tables 2 and Table 3)

Table 2. Project Budget

dget for a project "Strengthening the laboratory monitoring of especially dangerous pathogens using the new PackBot 510 robotic system in the post-combat areas of Ukraine from 2023 to 202

| | Main Cost Categor | Sub-Cost Category | Item | Number | Amount of time | Unit name |
|---|---|---|---|---|---|---|
| 1 | Personel | Base Salary | | | | |
| | | | Principal Investigator | 1 | 24 | month |
| | | | In-country Manager | 1 | 24 | month |
| | | | Trainer - PacBot Robot (US-based) | 2 | 760 | hours |
| | | | Translator | 2 | 240 | hours |
| | | | Driver | 2 | 240 | hours |
| 2 | Travel | | | | | |
| | | International | Principal Investigator | 1 | 12 | trips |
| | | | Trainer - PacBot Robot (US-based) | 2 | 4 | trips |
| | | In-country | | | | |
| | | Taxi | Prinicipal Investigator | 1 | 48 | trips |
| | | | In-country Manager | 1 | 48 | trips |
| | | | Trainer - PacBot Robot (US-based) | 2 | 48 | trips |
| | | Public Transportation | | | | |
| | | | In-country Manager | 1 | 240 | e-tickets |
| | | | Trainer - PacBot Robot (US-based) | 2 | 40 | e-tickets |
| | | | Laboratory Specialists/Trainee | 10 | 120 | e-tickets |
| | | Personal Sim Card | | | | |
| | | | Principal Investigator | 1 | 1 | card |
| | | | In-country Manager | 1 | 1 | card |
| | | | Trainer - PacBot Robot (US-based) | 2 | 2 | card |
| 3 | Lodging | | | | | |
| | | Foreign Lodging | Principal Investigator | 1 | 12 | days |
| | | | Trainer - PacBot Robot (US-based) | 2 | 60 | days |
| | | | | | | |
| | | In-country Lodging | Laboratory Specialists/Trainee | 10 | 60 | days |
| | | | In-country Manager | 1 | 30 | days |
| 4 | Per Diem | | | | | |
| | | Foreign Per Diem | Trainer-PacBot 510 Robot (US-based) | 5 | 60 | days |
| | | | Principal Investigator | 1 | 12 | days |
| | | In-country Per Diem | Laboratory Specialists/Trainee | 10 | 60 | days |
| 5 | Equipment | | | | | |
| | | | PacBot 510 Robotic System | 5 | 1 | item |

Table 3. Budget Justification

| **Budget Item** | **Link** |
|---|---|
| Principal Investigator<br>This is a Ph.D. scientist and MPH student at the Rollins School of Public Health. She will be involved in preparing, coordinating and implementing this project and responsible for the statistical analysis of the received data, preparation of a full data analysis, final report and distribution to partners, cleaning and archiving of the data. Most of the work will be done online, in the US, but visits to Ukraine are also planned. | https://www.payscale.com/research/US/Job=Medical_Laboratory_Scientist/Hourly_Rate |
| Local Project Manager<br>The Local Project Manager will be responsible for the implementation of the project in Ukraine, namely the signing of documents allowing the work of our project with the Ministry of Health, Ministry of Defense, State Service of Ukraine for Food Safety and Consumer Protection as well as being responsible for hiring specialist, constant management and communication. | https://www.salaryexpert.com/salary/job/project-manager/ukraine/kiev |
| Trainers - PacBot 510 Robot (US-based)<br>Two American experts will travel to Ukraine to assemble the received robotics systems, adapt to use, help with pretesting sample collection and train 10 Ukrainian specialists on how to use the PackBot 510 to collect soil, water and air samples in post-combat areas. These specialists will stay in Ukraine for eight months. After returning to the US, they will continue to provide technical support for the project online until completion. | https://www.payscale.com/research/US/Job=Medical_Laboratory_Scientist/Hourly_Ratehttps://www.payscale.com/research/US/Job=Electrical_Engineer/Salary/519f2d1f/U.S.-Army-Corps-of-Engineers |
| Laboratory Specialists/Trainee<br>Ten specialists from five laboratories will be trained to use the PackBot 510 system to collect samples of highly dangerous pathogens in the post-combat area of Ukraine. For two months of training, all trainees will be paid a daily Per Diem. | https://aoprals.state.gov/web920/per_diem_action.asp?MenuHide=1&CountryCode=1113 |

| | |
|---|---|
| International travel<br>The Principal Investigator round trip from Atlanta to Kyiv and from Kyiv to Atlanta is necessary for the organization and implementation of the project in Ukraine; coordinating with partners and laboratory specialists and any other support required to ensure successful implementation of the projects. Until February 24, 2022, after this date, you must first fly to Warsaw, the capital of Poland, and then travel by train to Kyiv. | https://book.lufthansa.com/lh/dyn/air-lh/revenue/viewFlights<br>https://www.onetwotrip.com/ru/poezda/kiev_varshava |
| In-country travel:<br>Public transportation. Ukraine has a well-developed public transport system. Some employees within the country will be able to use public transport. Therefore, we provided all employees working in Ukraine with electronic travel tickets, for in country manager – 240 e-tickets, US trainers – 80 e-tickets, laboratory specialists – 1200 e-tickets. See Table 1. for additional information. | https://transport.kyivcity.gov.ua |
| Taxi. Taxi costs are also considered in our budget as it is possible for specialist to move to other cities where there is no wide access to public transport. | https://avangard-taxi.kiev.ua/tarifi |
| Foreign Lodging and Foreign Per Diem designed for three employees. | https://aoprals.state.gov/web920/per_diem_action.asp?MenuHide=1&CountryCode=1113 |
| In-country Lodging and In-country Per Diem designed for ten employees of our project. | https://www.budgetnyk.com.ua/article/ru/563-sutochnye-na-komandirovku-2022-kak-vyplachivat#anc_2 |
| Equipment: PackBot 510 Robotic System – 5 items, laptop – 4 items, printer – 1 item, hard drive storage – 1 item, STATA license – 1 program, anti-virus software – 1 program.<br>Consumables: paper – 20 boxes, pens – 40 items, cartridge for printer – 4 refills, facemask I-95 -1000 items, hand sanitizer - 40 bottles.<br>Other: internet access – 240 days. | https://epicentrk.ua/shop/flesh-pamyat-usb-sandisk-ixpand-drive-go-lightning-apple-128-gb-usb-3-1-green-sdix90n-128g-gn6ne.html<br>https://epicentrk.ua/shop/ruchka-round-stic-exact-sinyaya-bic.html<br>https://epicentrk.ua/shop/kartridzh-powerplant-hp-lj-p2050-canon-mf5850dn-ce505a-crg- 119-s-chipom-pp-ce505a-chernyy.html |

| | |
|---|---|
| Antivirus software program. | https://www.mcafee.com/en-us/antivirus.html?path=/en-us/for-home.html |
| The statistical software license STATA. | https://www.stata.com/order/new/dev/profplus/student-pricing |
| Face Masks<br>Today, face masks are not required in many public places in the US and Ukraine, but for employees to feel comfortable and be protected from the SARS-CoV-2 virus in the office and laboratories, we purchased 1000 masks. | https://epicentrk.ua/shop/mplc-maska-medichna-trisharova-z-zatiskom-sertifikovana-150-sht1eb74e40-1d9a-65de-9252-1153bff8a1c6.html |
| Hand Sanitizer<br>We purchased 40 bottles of hand sanitizer to use as needed. | https://nanocode.com.ua/sanitaizer-dlia-ruk-nano-sanitizer-nanocode-50-ml |
| Personal SIM card<br>A personal SIM card will be used by four of our employees in local phones and is required for each employee to maintain a permanent telephone and internet connection. A SIM card is bought once, and then its cost is replenished. We need 4 SIM cards. | https://kyivstar.ua/tariffs |
| Internet<br>The Internet will be recharged for 4 SIM cards. | https://prom.ua/p1103094554-bezlimitnyj-internet-sim.html |
| Exchange rate: 1 US Dollar = 36.58 Ukraine Hryvnia | https://www.oanda.com/currency-converter/en/?from=USD&to=UAH&amount=1 |

## Chapter 5. Discussion

The invasion of troops of the Russian Federation into the sovereign country of Ukraine has resulted in catastrophic consequences in the loss of human lives and the massive destruction of critical infrastructure. This includes the indiscriminate shelling of burial grounds with anthrax-infected animals buried plus the destruction of critical infrastructure (e.g., the Kakhovka Hydroelectric Power

Plant creating a potential outbreak from cholera and other waterborne pathogens). [4] The impact of this war has been daunting. The dispersal of highly resistant anthrax spores capable of lasting decades in the environment and contamination of water supplies resulting in outbreaks of waterborne diseases following the huge release of water throughout the Kherson Oblast as well as the surrounding regions will result in a global problem as severely contaminated waters flow into the Black Sea. Flood waters raging through the lower Dnipro River valley will bring sewage, oil, chemicals, and possibly anthrax from animal burial sites. At least two anthrax burial places are in the temporarily occupied territories. [22]

**5.1 Recommendations**

Ukraine is now the most mined country; it will not be safe for decades. The “clean-up” effort will require the need to ensure the safety of all workers involved. [2] To remediate the dissemination of these especially dangerous pathogens and other infectious agents throughout the country in non-combat areas, a PackBot 510 Robotic system will be used to implement a unique and novel approach to remotely collect samples and test areas for the presence of pathogens as well as ensure the safety of laboratorians tasked with ongoing monitoring. The end result will safely facilitate the return of refugees to non-combat territories of Ukraine.

**5.3 Risk Mitigation**

There are multiple risks associated with this project: 1) delay in the acquisition of the robotic system; 2) delays in the delivery of the robotic system;

3) working on the territory after the hostilities is potentially dangerous for the personnel collecting samples; 4) delay in the implementation of the Memorandum of Understanding among ministries.

To address these concerns we must do the following: 1) The contract will require on-time availability of the robotic system; 2) Use a single shipper will be used to deliver the robotic system working with partners in Ukraine; 3) Provide personnel initial robotic system training in non-combat areas; and 4) Utilize the U.S. Department of Defense/Thread Reduction Agency with the State Service of Ukraine for Food Safety and Consumer Protection and the Ministry of Defense and the Ministry of Health of Ukraine to ensure signing of the Memorandum of Understanding.

Additional risks to the project activities may include stolen supplies and/or equipment; bombing; and an active military presence to personnel and/or training participants. These concerns will be addressed as follows: provide a secure/locked area for the storage of supplies and equipment; provide an underground shelter training site for personnel and training participants.

**5.3 Conclusion**

Implementation of the PackBot 510 will facilitate monitoring by safely collecting especially dangerous pathogens and other infectious agents in a target population of 14.5 million people living in potentially contaminated and heavily mined post-combat territories; establish a cadre of trained personnel; and ensure collaboration among targeted, relevant partners.

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