Designing Biosecurity Concentration for Interdisciplinary Majors

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***Abstract*—This manuscript deals with the design and expansion of a highly successful cybersecurity program in a minority serving university through contemporary education and training methods in biosecurity for students who major in other disciplines, such as biological systems engineering and biotechnology. The key efforts will focus on curriculum development by means of a hands-on laboratory-based instruction as well as research-based technological development for biosecurity. This is accomplished by collaborative work involving two academic departments, namely, Computer & Information Sciences (CIS), and Biological Systems Engineering (BSE). The product is a cross-disciplinary concentration in biosecurity leading to a professional certification, which is ideal for undergraduate students and professionals with a biology background. Although this approach is modelled for a minority serving university, it can be replicated in other institutions of higher learning as well.**

Keywords—Biosecurity; biosafety; cybersecurity; information assurance; active learning

I. Introduction

Intentionally releasing of harmful viruses, bacteria, or other microorganisms that can cause severe illnesses or lethal to people, livestock, or crops is termed as bioterrorism. Among others, the anthrax causing bacteria Bacillus anthracis has known to be the most likely agent used in such an attack involving bioterrorism or biological warfare. Currently real-time non-invasive spectroscopic and microscopic identification of surface, sub-surface and air-borne pathogens, with a resolution high enough to classify the subspecies and endospores in real-time for food and bio-safety as well as bio-security applications is highly challenging. This challenge in hand limits the education and training in the area of bio-security, especially from the real-time identification and monitoring perspective.

According to National Academy of Sciences (NAS) in the United States, biosecurity is defined as “security against the inadvertent, inappropriate, or intentional malicious or malevolent use of potentially dangerous biological agents or biotechnology, including the development, production, stockpiling, or use of biological weapons as well as outbreaks of newly emergent and epidemic disease”. Therefore, biosecurity can be achieved only if scientists, security engineers, information security professionals, policy makers, and law enforcement officials work together and co-operate in developing such solutions.

Currently, real-time food and bio-safety as well as bio-security applications are highly challenging. That is true with real-time non-invasive spectroscopic/microscopic identification of surface and sub-surface pathogens, with a resolution high enough to classify the subspecies and endospores. This paper provides the framework to offer a new academic concentration, namely “biosecurity”, in order to train minority students in monitoring and responding to threats to natural and agricultural environments.

In order to address the above-mentioned needs a collaborative curriculum development work was done to produce trained professionals in Biosecurity and the key components of it is presented in this manuscript in Sections II, III and IV as follows. Section II presents an overview of identifying the need for biosecurity. The proposed hands-on labs are introduced in Section III. It is based on those principles of active learning. The methodology for design curriculums and the hands-on labs implementation details are described in Section IV. The final section provides an overview of the study results and conclusions.

II. Identification of the Need

Biological agents were used as weapons in warfare dates back to thousands of years. The contagious nature of plague was understood by the Hittites of Asia Minor in 1500 B.C. They sent plague victims into enemy lands. Ancient armies catapult diseased corpses into fortresses to spread diseases and contaminate the wells from which the enemies drink water [1].

Over millenniums, scientific research and development as well as medical advances have provided deeper understanding of the different modes of pathogenesis (the mechanism by which a pathogen infects) and our immune system responses. These scientific advancements resulted in the development of vaccines and cures. On the flip side, they also have led to the development of biological weapons by enhancing some of the most destructive microbial agents known to humans.

Anthrax was one among the weaponized bacterial agent developed nearly a century ago, by both the German and Japanese armed forces. The United States, Russia (The Soviet Union) and the United Kingdom are among the countries that followed this biological arms race. The Biological Weapons Convention of 1972 and the Geneva Protocol outlawed biological weapons. As a result, several nations have ended their research of biological weapons and destroyed their stockpiles. Nonetheless, the threat remains and the need to be able to detect such threats early is critical in saving lives of innocent people.

Nearly two decades ago, letters containing anthrax powder (i.e., lyophilized spores of the *Bacillus anthracis* – the bacterial agent that causes anthrax) were sent to U.S. Senate offices and media outlets. It was reported that 22 people were infected and five were killed in those attacks [2]. Among the different modes of transmission followed by anthrax, inhalation is considered to have the highest mortality (100 per cent, 75 per cent with medical treatment), and it is easy to spread the bacterial spores in the air making it a viable mode of attack in a biological warfare. In Gruinard Island, anthrax weaponization experiments conducted by the British forces in 1942, resulted in the need for two hundred and eighty tons of formaldehyde to decontaminate after nearly 45 years. The Soviet Union accidentally killed 66 people by releasing airborne anthrax. The last known aerosolized human trials of anthrax were conducted by the Japanese in the early 1980s in a facility dedicated for biological warfare in Manchuria [3]. Over the years, several biological weapons development programs have research and development more virulent forms of anthrax. In meanwhile vaccines were also developed for the same. But administering vaccines on a national scale would require a significant threat and/or mass exposure.

Although we were successful in eradicating the smallpox disease from the world and we have not heard of a natural infection of smallpox since 1977, several copies of virulent smallpox are still kept in government laboratories around the world. World Health Organization has approved some stores of smallpox for medical research purposes in Russia and the United States [4], but there may be several secret stockpiles existing in several countries. Smallpox is classified as a Category a bioweapon by the Centre for Disease Control in the United States. It has a high mortality rate (30%) and it can be airborne. Despite the successful development of vaccine for smallpox, only medical and military personnel are vaccinated, mainly before a scheduled travel to areas of potential risk [5]. Thus, small pox as a bio-weapon can wreak havoc among innocent civilians.

Infected fleas typically transmit the bubonic plague. It can also be transmitted by contact with infected bodily fluids. This also has a very high mortality (70%), within 24 hours [6]. In 1940, Japan dropped sacks of bubonic plague infected fleas into China from airplanes. Given today’s technological advancement, an aerosolized version of it is highly feasible.

Tularemia (*Francisella tularensis*) is a category A biological weapon and it spreads very rapidly between animal hosts and humans and it is especially virile in aerosol form. Among others, Canada, Britain, the United States, and the Soviet Union tried to weaponize tularemia after the Second World War [7].

Clostridium Botulinum toxin, which causes the deadly botulism, even in extremely small concentrations was released as an aerosol against several political targets, by the Japanese cult Aum Shinrikyo in 1990.

The recent outbreaks of *Ebola* virus, which causes one of the fatal viral haemorrhagic fevers, marked by copious bleeding, present opportunities for developing the same as a biological weapon.

Therefore, it is imperative that research and education is essential to produce trained highly qualified personnel in the area of bio-security to ensure safety and security of the United States against possible bio-terrorism attacks in the future.

III. Hands-on Labs

As described earlier in Section 1, the non-availability of necessary equipment for enhanced biosecurity applications limits our ability to educate and train future generations of students. While a handful of courses and training programs existing there, they are mostly at the graduate level and require at least two years.

The current methods of detecting and mitigating such attacks follow tedious pathways. The detection of an anthrax attack in the United States can happen in two ways: 1) A nationwide monitoring system setup for detecting anthrax could detect it as soon as it is released; or 2) it may be detected in the emergency room by the doctors after receiving an unusual pattern of patients. Then the doctors might order lab tests, which could take days before confirming anthrax. But this could get more complicated if a concoction of pathogenic endospores and/viruses are used as a biological weapon.

High energy radiations like x-rays and gamma rays ionize the material through which it passes, especially if the object is of biological in nature. In order to make pictures of an object without affecting it adversely the energy level of the radiation used to make such pictures must be low. The image of any object we get is nothing but its optical signature and in the hyperspectral range these optical signatures are supposed to be unique for different molecules that would be detected in a hyperspectral image taken with a nanoscale resolution [8].

Unfortunately, the non-ionizing (low energy) band of the electromagnetic spectrum does not possess such high-resolution capability to be able to make pictures at the nanoscale. This is where the ability of the Hyperspectral Photon Scanning Tunneling Microscopy (HPSTM) to detect and display surface characteristics at the nanoscale can be exploited to perform various imaging operations beyond the capability of the non-ionizing band of the electromagnetic spectrum. The fact that an electrically conductive surface is not needed is a major advantage for using HPSTM for biological applications. Thus, biological samples can be imaged without coating them in gold or another conductive metal. In addition to the above-mentioned advantage, HPSTM can be easily coupled with techniques such as photoluminescence, absorption, and Raman spectroscopy to measure optical properties of the samples.

Quantum optics provides a transformative platform for the photonic manipulation by confining of the electromagnetic field into smaller regions that are well below the diffraction limit [9]. This enables ubiquitous applications of this technique in various fields [10], including but not limited to optical metamaterials [11], nano-photonics [12], [13], biochemical sensors [14] and antennas for nano-scale light transmission and reception.

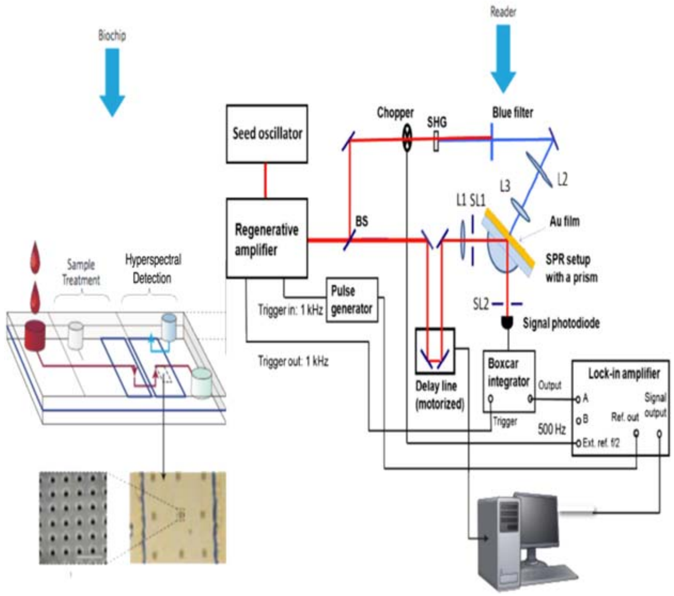

Fig. 1. Schematic of the bench-top equipment design.

Therefore, it is necessary to custom fabricate a laboratory scale hyperspectral microscopy/spectroscopy equipment prototype using 3D printing techniques. This bench-top prototype can be used test the functionality and fine tune design parameters. Using the deliverables obtained from objective, a bench top apparatus will be built following the schematic shown in Fig. 1, wherein the hyperspectral signatures of biological material will be detected using nano-gratings.

The state of the art nano-fabrication lab available at the National High Magnetic Field Laboratory will be used along with the 3D printer procured in the project to build a portable prototype. Perform field testing of the equipment to ensure functionality in different environments. The equipment thus fabricated will be tried in an outdoor environment to assess its robustness and reliability in real-world conditions.

IV. Curriculum Design

The concentration involved innovative approaches to both education and research. The courses developed would involve a hybrid hands-on and classroom/online teaching approach. The courses "Introduction to Computer Applications" and "Introduction to Data Mining" will be developed as a stand-alone module that can be taught fully online as long as the students have access to the appropriate software. "Introduction to Biosecurity" course would be required at least short-term physical presence for hands-on training. The concepts taught in the curriculum are presented in Fig. 2 which portrays the overall integration of basic knowledge of this track.

Multiple physical and computational models will be used to teach the above-mentioned concepts. Existing models can be purchased and modified. New models created from parts. Fig. 3 shows the series of progressively more engaging exposures by which students move from the state of being aware of the existence of instances of biosecurity to varying degrees of competence (can use, can adapt, can create).

STEM students are exposed to biosecurity in the foundational and discipline-specific courses they take. The extent of their exposures depends upon the maturity of using computer tools and the amount of security the instructor integrates into the course. Our students receive additional development from the tasks they do: funding and resources; working with a faculty member; making presentations and writing papers on biosecurity experiences; interacting with real-world problems. Thus, a seamless integration of teaching and research is accomplished. Fig. 4 presents the conceptual basis and framework for the research and educational activities. Integrating the novel research into teaching and hands-on-training the students will create increased student learning, retention and graduation rates. The bio-security certification course is one of those kinds in the country. It will open up new job avenues for students [15].

Fig. 2. Basic curriculum integration for biosecurity.

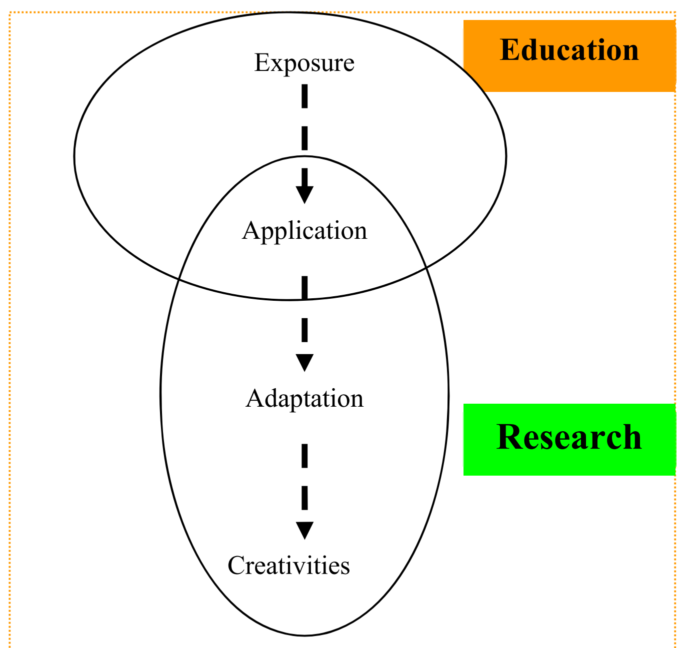

Fig. 3. Learning tree: from education to research.

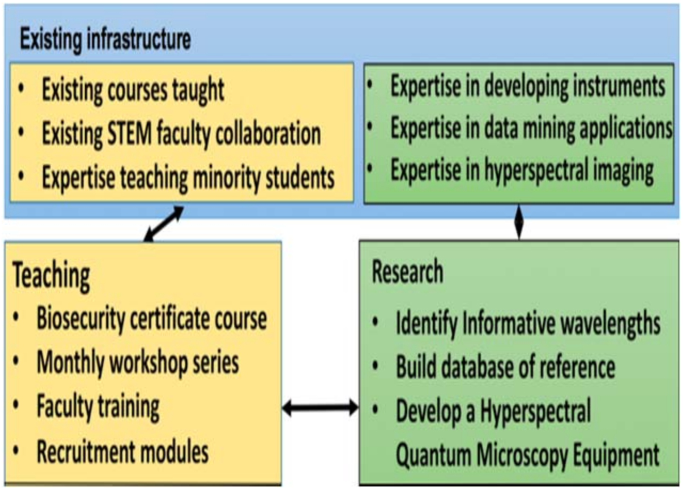

Fig. 4. Conceptual basis of the research and educational.

V. Conclusion and Future Work

The paper described activities involved in establishing a research informed undergraduate Biosecurity concentration at Florida A&M University (FAMU), and to broaden this awareness to other STEM students at this university as well. This concentration will expand diversity in three ways. First of all, it will expand opportunities for CIS and BSE undergraduate and graduate students. Secondly, the concentration will prepare FAMU students to proceed seamlessly into bio-security related workforce. Finally, the concentration will harness the strengths of cyber security program at CIS and biological engineering program at BSE to implement a synergistic inter-disciplinary experience that complement the respective disciplines [16], [17]. As a result, graduates will be even more highly marketable for employment or entry into further studies upon graduation.

In future, we would like to expand this concentration to students majoring in biological science and chemistry.

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