Establishment of a Biomanufacturing Pipeline to Support Alternative Manufacturing of Chem-Bio Defense Materials and to Secure Supply Chain Resiliency

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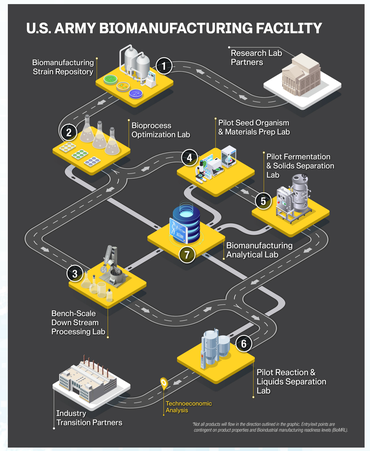
INTRODUCTION

The U.S. Army Biomanufacturing facility at the Combat Capabilities Development Command Chemical Biological Center (DEVCOM CBC) has been undergoing modernization and expansion efforts to harness biomanufacturing innovation to enable the creation of new materials and bolster supply chain resiliency for the Department of Defense (DOD). The facility is operated by an interdisciplinary team of biologists, chemists, and engineers to provide a single site for the storage, optimization, and scale-up of organisms that generate DOD and chem-bio defense relevant materials. Biomanufacturing development seeks to generate complex products and materials from basic feed stocks, such as sugars, by genetically optimizing internal bioprocesses of bacteria, yeasts, and other microbes. The primary function of the renovated facility is to transfer processes developed by our collaborators into a viable process at the pre-industrial pilot manufacturing scale. The facility achieves this through different steps of development to include bioprocess optimization, validation, scale-up, and separation/purification of the product.

Organisms that have been engineered to produce a desired compound are stored within our repository and can be transferred into our biomanufacturing pipeline. The titers and yields of desired products are validated and optimized at the small scale to produce the target materials in high quantities and with low projected costs. This capability is supported by recent acquisition of high-throughput fermentation equipment including the AMBR 250 and BioLector XT systems. The optimized processes are transferred into our pilot-scale fermentation lab and scaled up through a series of bioreactors to 1000-liter scale, during which the fermentation is monitored through an array of process sensors measuring oxygen availability, substrate consumption rates, and time. Following fermentation, the fermentation contents undergo downstream processing (DSP). Beginning at bench-scale the mixtures containing the organism, feedstocks, and the desired material undergo separations, isolations, and purifications to retrieve the material at high yield and purity. The bench-scale level of this down-stream processing effort provides procedural information and allows for multiple methods to be tested for efficacy without wasting material. It also allows for the gathering of important data such as heat generation, reaction thermodynamics, temperatures, pressures, and material purity, all which aid in the safe and efficient scale up of the DSP operations. After an effective DSP operation is developed at bench-scale, the process is scaled up to the pilot scale and utilized to process the large-scale fermentations. Following successful application of the purification techniques, the developed processes can then be utilized to manufacture material in-house or transferred to an industrial sized manufacturing facility. The U.S. Army Biomanufacturing Facility has provided a new and efficient capability within the DOD for chem-bio protective material manufacturing, both strengthening the supply chain against shortfalls in starting material and intermediate availability and creating the opportunity to reach new frontiers of novel materials only achievable using biomanufacturing methodologies.



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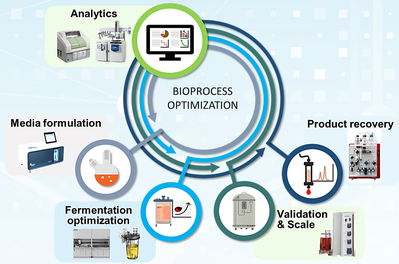
BIOPROCESS OPTIMIZATION LAB

- This lab is focused on conducting bioprocessing fermentation studies at small scale to save valuable time and resources while mitigating risks.
- The lab utilizes formulation and process optimization to increase product yields and titers prior to scaling

Key enabling infrastructure:

- BioLector XT: Designed for high throughput plate-based formulation optimization
- AMBR 250: Designed for process optimization of (12) 250 mL reaction vessels simultaneously
- BioFlo 320: Single unit bioreactor for scale-up of fermentations to 3 L for process validation.



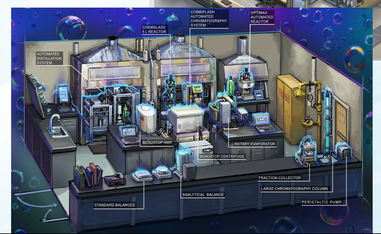
PILOT FERMENTATION LAB

- This lab is referred to as our "brewery" and is responsible for optimizing fermentation and solid separation operations.
- (2) 50 L, (1) 100 L, and (1) 1000L fermentation vessels are used for scale-up and validation.
- Additional fermentation support equipment is housed in this lab to support fermentation scale-up efforts.
- This lab is supported by a traditional biology lab used for the preparation of materials for fermentation scale-up and validation.

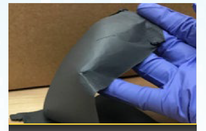
DOWNSTREAM PROCESSING LAB

- This lab is separated into our bench-scale downstream processing (DSP) lab and our "distillery", or large-scale DSP lab.
- The development of DSP methods at the bench scale is an essential step in safely and efficiently isolating the desired products.

- The bench-scale processes are validated and scaled up in our distillery utilizing techniques such as filtration, distillation, chromatography, and centrifugation.



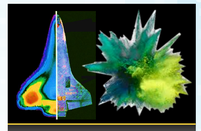
BIOMATERIALS FOR DEFENSE



MATERIALS IN DEVELOPMENT

Materials developed using Biomanufacturing can be utilized for DOD and CB Defense applications. These materials are currently in development at the DEVCOM CBC Biomanufacturing facility:

- Biocarbonized Nanofibers (BioCNFs)
- Biocement
- Cellulose
- Melanin



CRITICAL CAPABILITIES

Addresses critical operational gaps while increasing the supply chain resiliency across multiple domains. New materials with novel properties are created for applications such as:

- energetics
- fuels
- armor components
- optical materials
- biopolymers/fabrics

COLLABORATION

Service labs & industrial partners collaborate to scale-up high-performance materials that leverage prior research investments in synthetic biology.

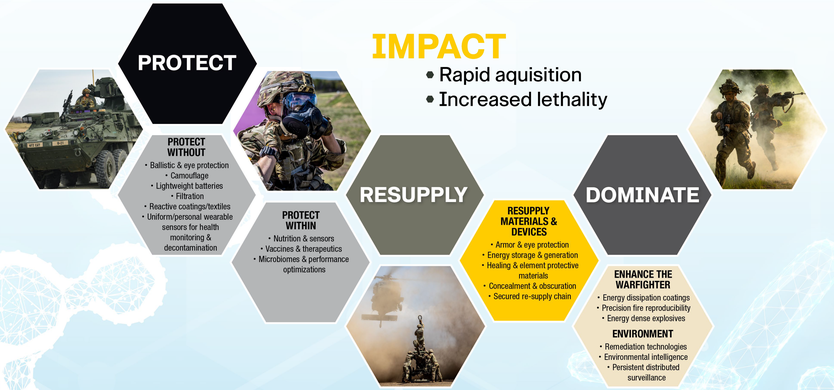
- DEVCOM CBC Produces kilogram quantities for field testing
- Pilot-scale fermentation and downstream processing at BioMRL 4-5
- Works with partners to transition to commercial scale

IMPACT

Rapid acquisition through increased prototyping and experimentation leads to materials that:

- are flexible and scalable
- are inexpensive
- are low energy/waste and toxicity
- increase lethality through high performance
- reduce logistical, weight, and thermal burden on the Soldier
- are domestically produced, breaking reliance on overseas suppliers

EXPECTED MILITARY VALUE



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