Alabama Research and Development Enhancement Fund
Quarterly Report
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Background

The Alabama Innovation Act (AIA) was established by Legislative Act #2019-404 and became effective June 6, 2019. The Act designated the Alabama Department of Economic and Community Affairs (ADECA) as the state agency to establish and administer the Alabama Research and Development Enhancement Fund (ARDEF) Program.

The purpose of the ARDEF Program is to encourage new and continuing efforts to conduct research and development activities within the state. The Fund is designated to receive appropriations from the legislature, or from the receipt of gifts, grants, or federal funds to be expended for the purpose of increasing employment opportunities, products and services available to the citizens of Alabama.

Overview of 2020 Program Year

Projects Funded Under 2020 Round One Grant Period

Applicant	Amount
Auburn University – Removal of Per- and Polyfluoroalkyl Substances (PFAS) in Water and Landfill Leachate in Alabama	$193,960.00
Auburn University – Knitting Micro-Resolution Mosquito Bite Blocking Textiles	$868,145.00
Auburn University – Advanced Biosensors from Forestry Products and Agricultural Resources	$245,864.77
HudsonAlpha Institute for Biotechnology – Advancing Genomic Health in Community Clinics and Employee Wellness Settings	$969,409.00

Auburn University – Removal of Per- and Polyfluoroalkyl Substances (PFAS) in Water and Landfill Leachate in Alabama

This project aimed to remove and destroy the so-called forever chemicals, per- and polyfluoroalkyl substances (PFAS), from Alabama water and landfill leachate. PFAS have been detected in chemical manufacturing wastes and landfill leachate in Alabama and have caused some serious cases of drinking water contamination in the state. Ongoing health concerns and regulatory development associated with PFAS are threatening the sustainable development of the Alabama economy and business. The goal of this research was to develop an innovative "Concentrate-&-Destroy" technology to cost-effectively remove and degrade PFAS in water and landfill leachate. The new remediation technology will provide the affected industries and water utilities with a powerful remediation means to mitigate the PFAS-related issues, thereby assuring sustainable development of the economy and the wellbeing of Alabama citizens.

Within this quarter, our research focused on enhancing the effectiveness of Bi/TNTs@AC for treating perfluorooctanoic acid (PFOA) spiked in an Alabama landfill leachate. The preliminary results revealed great potential of Bi/TNTs@AC for selective adsorption of PFOA in the leachate and subsequent photocatalytic destruction of pre-adsorbed PFOA on the solid particles. Moreover, we found that the photocatalytic degradation can be further enhanced through the addition of persulfate or ferric iron during the photodegradation stage.

Auburn University – Knitting Micro-Resolution Mosquito Bite Blocking Textiles

Insects transmit crippling diseases to humans. Nearly a half-million people die of malaria each year. In Alabama, citizens encounter Dengue and Zika virus invasions as well as a multitude of encephalitis variants. The worse vector-borne diseases are transmitted in the hottest climates like Alabama, and it is uncomfortable to wear the thickest clothing. This project will research different textile and weave patterns to create clothing that is cool in heat and capable of blocking mosquito bites and develop prototypes based on this research. Beyond the prototype phase, research will be done to measure the effectiveness this product will have on the Alabama economy.

By this quarter, we have successfully completed Aims 1 and 2 of the proposal and are in the final stages of completing Aim 3. We have reached a highly comfortable blocking prototype. Our focus is now shifting to development of a manufacturing pipeline of final garments utilizing our newest designs. We will continue to optimize for comfort, but at this point we feel that we have reached a marketable item. We are moving our knitting laboratory into a local Auburn industry partner's location to facilitate final completion of a robust manufacturing and retail pipeline.

Auburn University – Advanced Biosensors from Forestry Products and Agricultural Resources

The main goal of this project is to utilize Alabama's forestry products and agricultural resources for extracting cellulosic nanomaterials (CNM) by using these nanomaterials in advanced biosensing. As timber production and other agricultural products are essential for the economy in Alabama, these materials are a great resource for obtaining cellulosic nanomaterials.

Outstanding laboratory facilities along with the support from ADECA are enabling scientific knowledge contributions and revalorization of agricultural and forestry waste products as biosensors. Trees and crops contain tiny materials known as cellulose nanomaterials (CNMs). Developing new applications for CNMs could enable forestry and crop waste to provide additional economic benefits for Alabama citizens. An Auburn University research team is exploring using CNMs from cotton, soybean hulls, and wood to produce sensors for the detection of allergens and water contaminants. Thus far, the team has shown that CNMs can be used to absorb carbofuran which is a common pesticide. They have also shown that CNMs can be used to absorb beta-lactoglobulin, a milk allergen. In ongoing work, they are improving the chemistry to make sensors that cannot only absorb multiple species but also selectively detect the materials of interest (analytes). The long-term goal of this work is to have a family of portable CNM sensors that can be used by citizens to test for water contaminants and food allergens.

This project is focused on using Alabama's forestry and agricultural products such as wood, cotton, and soybean hulls as sources of an exciting nanomaterial called cellulose nanocrystals (CNC). Cellulose nanocrystals are found in all biomass. Their high strength, large specific surface area, and natural organic chemistry make them exciting for a range of applications. We are focused on developing sensors to improve water safety and the health of Alabama citizens. This quarter we continued our work on modifying CNCs extracted from wood to enable them to be used to detect pesticide residues in water and presented results at conferences. We are also exploring other sources of CNC and the detection of food allergens such as milk allergen (β-lactoglobulin). We are using laboratory tools such as Quartz Crystal Microbalance with Dissipation (QCMD) and Surface Plasmon Resonance (SPR) to validate our approach. So far, we have increased the stability

of the CNC when exposed to water and demonstrated analyte absorption. Our current focus is on increasing the selectivity of the detection and understanding the differences between agricultural and forestry derived CNC's. Auburn University's outstanding laboratory facilities and the support from ADECA are helping the research team continue to gain insights on how an exciting material hiding in our abundant forestry and agricultural resources can be transformed to enable Alabama citizens to detect contaminants and allergens in their water and food.

HudsonAlpha Institute for Biotechnology – Advancing Genomic Health in Community Clinics and Employee Wellness Settings

Genomic medicine is a form of precision medicine that uses approaches customized to each patient to treat disease and optimize prescription medicine based on a genetic profile. This project will test and develop a genomic health complete delivery system for Alabama patients and physicians at healthcare systems and community hospitals with limited expertise in genomics. This system includes 1) Partnering with Auburn University to develop community-based models for health programs, 2) Refining and optimizing the process including insuring access by rural and underserved areas, and 3) Developing the health IT infrastructure needed to fully integrate genetic test reporting and education into an electronic health records system. The proposed development of new products and services will result in improved health outcomes for Alabamians, opportunities for employers to increase competitiveness and reduce costs, and modernization of health care in an equitable way for Alabama communities, large and small, regardless of socioeconomic status.

The HudsonAlpha project continues to work with partners across the state of Alabama to provide genetic testing as an employee wellness benefit. Genetic results provided as part of this project include pharmacogenetics, to inform the selection and dosing of medications, as well as risk for certain diseases such as cancer and cardiac conditions. Program impact is assessed through the analysis of de-identified test results as well as follow-up participant surveys. This past quarter we have begun work towards the collection of data directly from partner sites describing how they have implemented the workplace genetic testing program, challenges that have arisen, and factors that have contributed to project success. Data disseminated through the HudsonAlpha project will provide valuable insight into the clinical and personal utility of genetic testing in the context of employee wellness.

Projects Funded Under 2020 Round Two Grant Period

Applicant	**Amount**
University of Alabama in Huntsville – Alabama Business Resiliency and Sustainability Index and Roadmap	$746,104.00
University of Alabama in Huntsville – Rural Employment and the Need for an Alabama Irrigated Acreage Survey, Demand Estimate and Forecast	$172,073.00
University of Alabama at Birmingham – A Comprehensive Data Science Software Toolkit to Improve Alabama's Mobility Planning for Serving Businesses and Vulnerable Populations	$394,926.00
Auburn University – Design, Fabrication and Testing of Novel Medical Facemasks to Prevent COVID-19	$75,374.00

Auburn University – Formaldehyde Paper-based Device (PAD) for a Cost-efficient Detection of Formaldehyde Emissions from Wood Panels	$247,142.00
University of Alabama at Birmingham – Commercialization of Small Diameter Artificial Vascular Graft for an Animal Trial	$906,458.00
Bashan Institute of Science – Exploring the Use of Cellulose Fibers as Microcapsules for Plant Growth-promoting Bacteria (PGPB) Inoculants	$7,500.00

University of Alabama in Huntsville – Alabama Business Resiliency and Sustainability Index and Roadmap

Recent events, such as the global COVID-19 pandemic, are having detrimental impacts on companies throughout Alabama, including the products and services they provide and the citizens they employ. Other impactful events that can occur may include the sudden loss of a major customer or supplier, a natural disaster, or even a diminishing source of skilled labor. The objective of this project is to research potential impacts on businesses and organizations across several business sectors to develop and deploy a comprehensive Resiliency and Sustainability Index and Roadmap (RSIR) model. The RSIR can be further tailored to fit each business sector and individual organization. Additionally, the UAH team will directly support businesses in the customization and implementation of their RSIR along with assistance in developing the ability to execute the roadmap and plan should the need arise.

In this quarter, the RISR discussion handouts have evolved and adapted based on the customer experience. The assessment materials have been further simplified to effectively accommodate any industry. The assessments utilizing the revised handouts reduced the total assessment time by 13% while still maintaining effective discussions.

Outreach strategies and materials continue to adapt and grow based on customer feedback. Over the last quarter, the majority of outreach has been through direct contact and social media. Over 140 business owners expressed interest. Six new companies have been recruited during this period as part of the full engagement schedule. There are a total of nine companies engaged in the execution portion of the program to date and represent the majority of targeted NAICS and much of the State's geography.

University of Alabama in Huntsville – Rural Employment and the Need for an Alabama Irrigated Acreage Survey, Demand Estimate and Forecast

As irrigated agriculture develops in our rural communities, it is imperative Alabama has the tools and data needed to ensure water resources are available for sustainable economic development. The goals of this project are to update the existing manual center pivot irrigation survey completed by UAH for the years to include 2017 and 2019 and develop a state-specific machine-learning framework from multiple sources of remote sensing products to efficiently and semi-autonomously identify the irrigated areas in Alabama to include all irrigated land such as golf courses and other irrigation system types beyond just center pivots. This information will be used to update the report "Estimates of Future Agricultural Water Withdrawal in Alabama", produced by the Water Resources Center, Auburn University for OWR in 2017. The result will include updated estimates as well as methodologies utilizing more recent urban growth and land use change data. The results and outcomes of this project will support the Alabama Department of Economic and Community

Affairs (ADECA) Office of Water Resources (OWR) to accurately analyze and forecast water use across the State.

During the third quarter of 2022, the team finalized the 2021 center pivots mapping, concluded the machine learning study, and compiled feedback from the irrigation projection study. The results show that while the rate of increase declined from 2017-2019, the 2021 data show a renewed statewide increase by 5,951 acres overall. It can be seen that the increases are mostly present in the Pickwick-Wheeler and the Perdido-Mobile basins, while the Wiregrass region saw a slight decline, on average. We have concluded the final assessment of the accuracy of the ML approach compared to the 2015 and 2017 pivot mapping. The customized product has increased the overall accuracy significantly for Alabama compared to National level products; however, the product still struggles with low recall rates that currently limit the application of the product as compared to the manual mapping technique.

Lastly, field experts were surveyed across the state to evaluate the 2040 projected irrigation report. In the Choc-Pea region, most field experts agreed with the proposed scenarios. In the Perdido-Mobile and Pickwick-Wheeler regions, most field experts agreed with the proposed scenarios. However, they noted land use changes due to increasing urban development and housing. This potential increase in development pressures may take prime farmland and current irrigated acres out of production resulting in the model prediction being higher than the actual value.

University of Alabama at Birmingham – A Comprehensive Data Science Software Toolkit to Improve Alabama's Mobility Planning for Serving Businesses and Vulnerable Populations

This project focuses on the development of a comprehensive data science software toolkit to support transportation planning for Alabama's businesses and vulnerable populations. Research activities include: (i) use of transportation user surveys and open data source collection to build a web-based data portal for mobility analysis in Alabama; (ii) development of agent-based urban transportation simulation models, and employment of machine learning techniques for transportation forecasts; and (iii) use of the developed tools to study scenarios that address pressing mobility needs in Alabama. Examples include (1) building a COVID-19 simulator to explore how various business reopening strategies affect the population's mobility and hence the virus spread; and (2) studying the impact of shared mobility services such as Uber/Lyft/Via, Zyp BikeShare stations and dockless electric scooters on local traffic congestion, transit use; and accessibility and mobility of vulnerable populations. The project will provide helpful recommendations to transportation policymakers about transportation initiatives that can help Alabamians, including economically and physically disadvantaged ones, to gain access to jobs and critical amenities in an equitable and efficient manner.

During the reporting period of July to September 2022, the team has successfully published their work on transportation simulation for the Birmingham region integrated with Uber services in the prestigious ACM SIGSPATIAL 2022 conference. Building on top of this work, the team is expanding the modeling of Uber services to investigate the impacts of UberPool on traffic operations. This is a prospective study since the Uber app currently does not support UberPool for the Birmingham region, though it has been made available in big cities such as San Francisco. In real life, the UberPool service allows riders heading in the same direction to choose to share a ride. This allows one vehicle (Uber) to accommodate more than one trips thus holding promise towards

reducing the number of vehicles on the roadway. In this reporting period, we have finetuned the Demand Responsive Transit (DRT) extension of MATSim to take our synthetic population travel plans generated in our SIGSPATIAL work, which integrates the Uber ride demand data that were generated respecting the trip distribution from our Uber driver survey conducted previously. The DRT extension simulates a request for Uber service dynamically and makes decisions based on the simulation state. An agent (traveler) submits a trip request and waits for a vehicle. The dispatching algorithm manages the movement of Uber vehicles and travelers' requests and matches Uber vehicles with rides. For picking up a second passenger, an acceptable waiting time threshold can be defined. We have conducted extensive experiments comparing the different scenarios with or without UberPool, and preliminary results show that the total number of trips in the study network was reduced as a result of the introduction of UberPool services, and that greater improvements were materialized for UberPool operating as door2door service. During the reporting period, we also continued our efforts to secure field data from the micromobility pilot deployment by Veo in Birmingham in an effort to enhance our models. We were successful in negotiating the release of one year's worth of data. The database will provide detailed information for 2021 e-scooter and e-bike trips in Birmingham.

Auburn University – Design, Fabrication and Testing of Novel Medical Facemasks to Prevent COVID-19

One of the most effective ways to prevent viral spread of the Coronavirus is to use face masks and respirators. Available reusable face masks are often not as effective as single-use coverings, which are costly and environmentally irresponsible. Currently, there is limited knowledge available on the performance of fabrics used in masks. Filtration efficiencies as a function of aerosol particulate sizes in 10 nm to 10 μm range are relevant for respiratory virus transmission but lack evaluation. The purpose of this research was to develop novel face masks to fight the pandemic based on scientific and engineering principles. In this research, novel medical face masks were designed, produced, and tested to reduce the spread of COVID-19 while improving on deficiencies present in currently used textile reusable face coverings. The project incorporates additive manufacturing, computer aided design (CAD), third party testing of both Bacterial Filtration Efficiency (BFE) and differential pressure measurements, and laser-visualization tools for illuminating leakage.

This project resulted in a textile face mask design with enhanced capabilities as compared to other textile masks currently available on the market. Through the employment of various testing methods, including bacterial filtration efficiency, breathability, initial filtration efficiency, laser leakage illumination, and performance testing, various mask iterations were evaluated and improved to perform better. Different engineering methods were utilized, including textile engineering, additive manufacturing, and laser imaging, all to construct a device with the capability of reducing the spread of COVID-19 or another disease if a pandemic such as COVID-19 were to occur again.

This research project ended May 15, 2022.

Auburn University – Formaldehyde Paper-Based Device (PAD) for a Cost-Efficient Detection of Formaldehyde Emissions from Wood Panels

Formaldehyde emission can be toxic to people depending on the time of exposure coupled with formaldehyde concentration. This level of exposure is generally not high in forest products because

companies that make indoor products currently measure formaldehyde through quality control techniques. Companies also use safe adhesives ("glues") by partnering with their suppliers. Nevertheless, these companies are regulated to federal standards such as the California Air Resources Board (CARB) to ensure this safety. To assist with the more expensive and laborious methods in CARB, this project endeavors to create a relatively cheap paper-based sensor that changes color based on formaldehyde exposure. Such a product can help to reinforce the safety of our forest products while maintaining the jobs of our many Alabamians.

The project entitled "Formaldehyde paper-based device (PAD) for a cost-efficient detection of formaldehyde emissions from wood panels" focuses on the development of a prototype of a paper-based device (PAD) for measuring formaldehyde concentration in air. The ultimate goal of the project is to develop an accessible, rapid, accurate analytical tool for the determination of formaldehyde in the air at concentration levels below 1 ppm.

During the third quarter of 2022, our team focused on validating the formaldehyde sensor prototype. For the validation of the prototype, we compare the results obtained by the image analysis of the scanned sensor with the results obtained by the ASTM-D6007 standard test method. Our team performs at least three replicates per target concentration of formaldehyde in the air. The validation of the sensor must be completed in the following quarter.

University of Alabama at Birmingham – Commercialization of Small Diameter Artificial Vascular Graft for an Animal Trial

The goal of the project is to finalize the development of an artificial vascular graft for surgical implantation. The graft has relevance to the current COVID-19 pandemic in that numerous patients are reporting kidney infections and blood clots. UAB has been working on this project since 2007 and has reached a point where funds are needed for an animal trial. Once this graft has been validated through this process, we plan to market it to a biomedical implant company to set up a division in Alabama or to establish a spin off company for the production and distribution. This graft has the potential for an estimated $50 million in annual sales based on conservative estimates of the number of surgical interventions that could use the implant in an unmet market and lead to a number of jobs for highly skilled workers in the State of Alabama.

During the third quarter of 2022, the results of the last survivable animal trial have shown that during the 20-day implantation period, blood flow was lost through the graft due to a collapse in the graft in the area where it has the greatest bend. This occurred due to a separation of the outer 3D printed layer which supports the nanostructured fiber internal layer. We are currently working on a new coating material which will hold these two layers together in a more durable manner. There is also an ongoing learning process between the surgical team and the engineering team regarding the procedure for implantation which will greatly improve as the process is repeated and methodology is improved. We are planning the next survivable study as soon as the new coating has been prepared.

Bashan Institute of Science – Exploring the Use of Cellulose Fibers as Microcapsules for Plant Growth-Promoting Bacteria (PGPB) Inoculants

Inoculation of plants with plant growth-promoting bacteria (PGPB) that enhance the yield of crops and growth performance of environmental plants is an old practice. Two main factors control the

success of inoculation—effectiveness of the bacteria and application technology. If the suspensions of bacteria are inoculated into the soil without a proper carrier, the bacteria population declines rapidly. These unprotected inoculated bacteria must compete with the often better-adapted native microflora and withstand predation by soil microfauna. Consequently, a major role of formulation of bioinoculants is to provide a more suitable microenvironment, combined with physical protection for a prolonged period to prevent a rapid decline of introduced bacteria. This project explored the feasibility of using cellulose fibers as carriers, to improve survival and enhance the PGPB viability.

This research project ended March 15, 2022.

Overview of 2022 Program Year

Projects Funded Under 2022 Grant Period

Applicant	Amount
The University of Alabama – Innovative Wood-Concrete Composite Structural Elements for Resilient Modular Building and Transportation Structures	$341,679.00
Auburn University – Advanced Liquid Transportation Fuels from Co-Liquefaction of Forest Biomass and Waste Plastics	$727,677.00
Auburn University – Novel Biotechnology that Converts Agricultural and Municipal Waste into Bioplastics	$294,008.00
HudsonAlpha Institute for Biotechnology – Next Generation Crops for a Diverse Alabama Agricultural Economy	$968,365.00
The University of Alabama in Huntsville – Versatile Training to Provide an Agile, Advanced Manufacturing Workforce in Alabama	$603,206.00
Auburn University – Polymer Smart Machines	$268,353.00
University of North Alabama – Surface Plasmon Resonance-based Biosensors	$10,353.33
Auburn University – Novel and Sustainable Feed Binder from Soybean Hulls	$300,432.00
The University of Alabama at Birmingham– Amputation	$700,000.00
The University of Alabama at Birmingham – Pneumococcal Vaccine	$635,926.67

The University of Alabama – Innovative Wood-Concrete Composite Structural Elements for Resilient Modular Building and Transportation Structures

This research project focuses on the development of innovative materials and construction techniques that can help improve the sustainability and resilience of Alabama building and transportation infrastructure. The overall research goal of this project is to develop innovative hybrid structural building elements using fiber reinforced concrete and laminated wood materials (traditional lumber and/or bamboo); and characterize their performance under several loading conditions. As part of this research, we will develop two types of hybrid elements and perform large-scale testing of these elements whereby they will be subjected to mechanical and impact loading (representing expected debris impact during a tornado event). We will also investigate the acoustic and thermal performance of these elements to understand their energy efficiency for building applications. The novel and validated structural elements can provide opportunities to attract new industries and supply chains related to prefabricated building systems.

We continued the literature review on the CLT-concrete composite construction during this quarter. Few of gaps in the literature related to interface preparation and moisture transfer potential of the UHPC-to-CLT interfaces were identified. We also performed an analysis of experimental data from UHPC-CLT panel tests and have developed a worksheet to predict the capacity of UHPC-CLT composite specimens' structural capacity. We also performed Mechanical characterization of UHPC material.

Additionally, we have added the second PhD student to work on the project. He is working on the state-of-art Bamboo panel manufacturing. He also identified potential test setups that we can use to evaluate the thermal and noise performance of these composites.

Auburn University – Advanced Liquid Transportation Fuels from Co-Liquefaction of Forest Biomass and Waste Plastics

The main goal of this project is to advance economic development in Alabama (and the nation) through reinvigoration of our natural resource-based industries and to establish new industries based on advanced liquid fuels from woody biomass grown in the state and the waste plastics collected from our local cities. Woody biomass prevalent in Alabama will be co-liquefied with waste plastics using a pyrolysis technology, which will then be subjected to hydrogen treatment to produce jet- and diesel- fuels. The funding from the Alabama Innovation Fund will be used to overcome technical barriers faced in converting woody biomass to biofuels and waste plastics recycling. The research will be focused on developing: (i) a process that would require lower capital and operating cost for biomass liquefaction; (ii) catalysts for the production of jet- and diesel-fuels; and (iii) a pathway for recycling waste plastics for the production of liquid fuels along with woody biomass. The team will leverage existing infrastructure and expertise at the Center for Bioenergy and Bioproducts at Auburn University.

The project aims to produce transportation fuels using biomass and non-recyclable waste plastics. During this quarter, the Recipient performed a two-stage hydrotreatment process using noble and transition metal catalysts. The mild-hydrogen treatment at 150℃ was conducted in which carbonyl and carboxyl functional groups in pyrolysis oil were transformed into alcohols, and the bio-oil was stabilized. The second stage hydrotreatment was performed at 400℃ for 5h using unsulfided bimetallic cobalt-molybdenum (CoMo) catalysts on two supports (biochar and alumina) to hydrotreat a blend of pyrolysis bio-oil (upgraded from the 1st stage) with carinata oil and poultry fat. In summary, pyrolysis oil blended with poultry fat and hydrotreated using biochar support catalysts was more successful in hydrodeoxygenation activity and in improving overall bio-oil quality compared to alumina supported catalyst and with carinata oil.

In the next quarter, the Recipient will (i) finalize two-stage hydrotreatment of pyrolysis oil with carinata and poultry fat work for publication; (ii) complete the analysis of mixed plastic liquefaction work; and (iii) continue working on characterizing bio-oils produced using different biomass types.

Auburn University – Novel Biotechnology that Converts Agricultural and Municipal Waste into Bioplastics

Alabama is one of the top agricultural producing states in the U.S., with annual agricultural exports exceeding $1 billion. As a result, there is a significant amount of organic wastes produced in the

state, and Alabama ranks 14th among all states in terms of biogas generation potential from organic waste through anaerobic digestion (AD). These organic wastes represent an underutilized renewable feedstock for biofuel and biochemical production. This project aims at researching and assessing the economic feasibility of converting organic wastes into bioplastics. Specifically, the project will develop and optimize a prototype of a patent-pending biotechnology that enables the conversion of organic wastes into bioplastics, and to assess its technical and economic feasibility at scale through techno-economic analysis (TEA). In the proposed technology, a microalgae-methanotroph coculture will be cultivated in a novel patent-pending circulation coculture biofilm photobioreactor (CCBP) to convert biogas (both methane and carbon dioxide) derived from organic wastes into microbial biomass while simultaneously recovering chemicals from AD effluent to produce treated clean water. The produced mixed microbial biomass can be economically processed to produce high-value bioplastics that are in rising demand. The project will advance the progress of the patent-pending biotechnology towards commercialization, which has potential to create many new jobs in the State of Alabama.

During the third quarter of 2022, the project team worked on constructing a bench-scale CCBP with improved features, including airtightness, improved biofilm-growing substratum attachment to the chains, and an ultrasonic mist generator. In addition, the project team developed a novel screening station capable of conducting nine parallel screening experiments simultaneously.

HudsonAlpha Institute for Biotechnology – Next Generation Crops for a Diverse Alabama Agricultural Economy

The HudsonAlpha ADECA/ARDEF project, in collaboration with Auburn University Crop, Soil and Environmental Science and Pathology Departments, and Alabama A&M Winfred Thomas Agricultural Research Station will develop a pilot pipeline to import and test new crop varieties that could be deployed by Alabama farmers. We will connect the advanced agronomy crop research at Alabama Land Grant Institutions to the advanced plant genetic and genomic science expertise at HudsonAlpha. For two crops, barley and beans, the team will bring in diverse germplasm, plant and evaluate cultivars to advance in additional trials. Barley will be tested as an overwinter crop for a spring harvest in Northern and Southern Alabama and dry beans will be tested as a summer crop in North Alabama. The team will evaluate disease, environmental, and weed pressure and other important agronomic traits for a crop to be successful in our challenging farming climate. As part of the goals, the partners will focus on increasing economic awareness of local barley and beans, connecting into existing educational and career development frameworks, and partnering with end users for brewing and food applications to increase the value of these Alabama crops. As this project develops, the teams will work with local farmers who are interested in planting alternative crops and engage stakeholders in workshops to discuss the science of next generation crop development to expand partnerships and apply this strategy to more crops useful for Alabama. With this newly developed research and collaborative infrastructure to bring in additional crop options, we can take control of the future of Alabama farming by optimizing the genetics and germplasm for Alabama, train new scientists in advanced plant science, open up new economic development in agriscience, and expand the current impact of local food and beverage industries.

During the third quarter of 2022 for this project, we have made substantial progress to grow Alabama local barley and beans. We were able to demonstrate that barley grown over winter 2021/22 in Alabama has the quality to go to malting and eventual brewing. Based on this field

season, we have developed a plan for larger scale production of successful varieties to have substantial material that can go to malting and be shared with brewery partners. To move forward the goal of growing local beans, we have planted a 48-bean trial at Alabama A&M University over the summer and are preparing for harvesting, quality assessment, and tasting. We have performed outreach activities to local growers and the winter planting of barley will now include 3 grower partners to test cultivars in a range of locations. This will complement the field station production at Auburn University and Alabama A&M University.

The University of Alabama in Huntsville – Versatile Training to Provide an Agile, Advanced Manufacturing Workforce in Alabama

The overall goal of the proposed institutional collaboration is to assist in the transition of Alabama from a low-labor-cost manufacturing state to a leader in the research and development of next generation manufacturing sciences. To meet this goal, our primary objective is to expedite trans-disciplinarily, inter-disciplinarily, and multi-disciplinarily training of Alabama for entering the industrial and government workforces and contributing to the implementation and advancement of the emerging manufacturing technology through Additive Manufacturing.

During the third quarter of 2022, a load frame has been ordered for mechanical evaluation of printed specimens with additional quotations being obtained for other equipment for expanding our Additive Manufacturing Laboratories. Student teams from the University of Alabama in Huntsville (UAH) and Calhoun Community College (CCC) have developed a documentation system to track vital information on builds and have developed parameters for printing of 316L. The parameter development and documentation are critical to companies' efforts to qualify and certify additive manufactured components.

Auburn University – Polymer Smart Machines

This project aims to research and develop the foundational building blocks of polymechatronics, which will enable the realization of 3D printable polymer smart machines. The research and development includes designing, fabricating, modeling, and characterizing piezopolymer versions of traditional mechanical and electrical building blocks such as actuators, sensors, energy harvesters, energy storers, and analog & digital circuit elements. Conventional 3D printed structures do not actuate or compute. However, if successful, the proposed project will lead to the first 3D printable smart machines that can actuate and compute without the need of externally-manufactured actuators and circuits. Compared to traditional devices, polymer smart machines are expected to be less expensive, easier to manufacture, biocompatible, recyclable, use less energy, operate over a larger range of temperatures, offer new functionalities, and be more environmentally friendly. Such attributes are expected to enable a wide spectrum of novel mechatronic components and products for consumers.

Our progress over the last quarter includes advancements in composite structures, finding the best laser polymerization scanning parameters, verifying recipes for piezo and conductive polymers, and determining how to align multiple 3D printed structures. As for composite structures, we appear to be the first to use the Nanoscribe to 3D print a structure that is comprised of more than one material. Our latest structures are comprised of a piezoelectric dielectric polymer and a conductive polymer. Both types of polymers are needed to create 3D-printable actuators for the

first time. Our piezopolymers are mixtures of PVDF, and our conductive polymers are mixtures of silver nanoparticles.

Regarding fabrication parameters, the complexity of designs has advanced from simple structures that were made to understand optimal laser scanning parameters to useable s-drive designs. Such parameters include the speed of raster-scanning, laser power, size of focal point, and structure-to-structure stitching. Such parameters yield tradeoffs between speed of fabrication to structural toughness. Regarding piezo-polymer recipes, we are exploring practical wight-percent ratios of photopolymerizable resin and PVDF with respect to polymerization and piezo constant measurement. Regarding conductive-polymer recipes, we are exploring the practical weight-percent ratios of silver nanoparticles and photopolymerizable resin with respect to polymerization and conductivity measurement. And regarding 3D printing alignment, when printing structures that are composed of more than one type of material, it is important to align the second structure to the geometry of the first structure such that both structures seamlessly combine into a single structure.

Although alignment is common in the semiconductor industry, alignment in 3D printing has not been a significant necessity because most structures have been made using a single material. To address this issue, we have found a way to repeatedly align our most recent 3D printed structural designs.

University of North Alabama – Surface Plasmon Resonance-based Biosensors

Biosensors are devices that convert a biological response into an electrical signal; and, they are increasingly prevalent across multiple industries including (i) food industry to check and verify the quality of the vegetables, fruits and meat, (ii) medicine and health industry to diagnose biological samples for diseases, ailments etc., and (iii) monitor safety industry to identify harmful chemicals. The current state of biosensors' sensitivity is often limited to minute concentrations of the molecules/agents under testing, usually in the range of 5 ng/mL. Due to this limitation, the biosensor output may lead to a failed detection and/or recognition that might cause harm to life.

A novel technique will be used to enhance the sensitivity of the biosensors based on the principle of surface plasmon resonance (SPR). Numerical investigations have suggested that this novel technique can improve the sensitivity by at least 5-fold, which facilitates easier detection of biomolecules in concentrations not possible using other biosensors. Upon building and successful testing of the SPR sensor system with regular glucose samples, the plan is to detect cow milk allergy agent and Staphylococcal enterotoxin B (SEB), which are important biomolecule agents in the food industry. The proposed biosensor setup can also be used for medical diagnostics.

During this quarter, the noise in the SPR curve was reduced and the SPR curve for the gold-prism structure was obtained. Graphene layers (6-8) were deposited on a glass substrate (1 inch x 1 inch) and a glass slide (4 inch x 1 inch).

Auburn University – Novel and Sustainable Feed Binder from Soybean Hulls

The goal of this project is to establish a low cost, high value, and novel compound feed binder from soybean hulls (SBH), a co-product of soybean processing for oil and meal production. The specific objectives of this project are twofold: 1) to scale-up feed binder production to around 1.5

kg/hour and optimize process conditions for production; and 2) to scale-up shrimp feeding trials simulating shrimp farming operations at a commercial shrimp operation in West Alabama. Successful completion of this project will establish a high value and novel compound feed binder platform using 100% soy hulls that is ready for commercial scale productions and applications with significant economic and environmental benefits. It will significantly enhance competitive advantage of shrimp farmers in Alabama by reducing their feed costs. This will in turn improve employment opportunities in seafood farming and processing sectors, making more local seafood and services available to the citizens of Alabama. In addition, it will also significantly improve water quality by reducing leached nutrients.

In the last report, we described issues using the new equipment that was purchased and installed. During this quarter, we have resolved these issues by installing a heat exchanger and a vacuum condensation system. We have successfully produced 2 kg binder using the modified new equipment. Safety inspection of the new equipment went well in general but there is a concern of potential exhaust gas accumulation and extending a snorkel to the reactor is recommended. We are working on getting the extension done so that we can start the scale-up production, characterization, and optimization of the feed binder using the modified equipment.

University of Alabama at Birmingham – Amputation

Approximately 1.6 million people live with an amputation within the U.S., and amputation cases are expected to rise to approximately 3.6 million by 2050. 185,000 people have an amputation each year in the U.S., with a significant increase noted associated with COVID-19 infection. The conventional technology is unable to adapt to the dynamic residual limb as it atrophies over time and swells with heat or weight gain. Percutaneous osseointegrated prostheses (POP) are a promising development for the limb-prosthesis interface involving the direct skeletal attachment of the prosthetic device. Alongside the promising benefits of POP, significant risks are present at the bone-implant interface including superficial and deep infection, inflammation, insufficient osseointegration, lack of vascularization, and implant loosening. The main goal of this project is to develop the multifunctional nanomatrix coating on POP that can be clinically translated for improved osseointegration of prosthetics, and other types of orthopedic and dental implants in order to help promote healing and prevent infection.

The project has successfully started, recruited research staffs, and made progress to synthesize the multifunctional nanomatrix coating. During last period, this project has made a good progress including hands-on animal training, antibiotic release studies, antibacterial efficacy studies, and set up of reaction process for scale up.

University of Alabama at Birmingham – Pneumococcal Vaccine

Streptococcus pneumoniae is a leading cause of bacterial pneumonia and meningitis, resulting in more than 2 million pneumococcal infections and more than 6,000 deaths each year in the United States. Mortality rates are high especially in very young, elderly, and immunocompromised individuals. In Alabama, invasive *Streptococcus pneumoniae* represents a special concern to the State's aging population, as well as in the rural and economically deprived communities with limited access to routine health care. The currently available pneumococcal vaccines in clinic, *e.g.*, PPV23 and PCV13, have limitations. For example, PPV23 is not effective in children younger than two years old, the elderly, and immunocompromised individuals; and while PCV13 is

effective for children, it has limited serotype coverage (fewer than PPV23) and requires an inconvenient four-dose immunization schedule for infants and young children. Moreover, none of these clinical vaccines provide effective protection against *S. pneumoniae* serotype 3 (ST3), a significant cause of morbidity and mortality worldwide. In this project, we will develop enhanced PPV23 and PCV13 vaccines which can provide increased protection with reduced number of immunizations. The enhancement will be achieved by employing the potent new vaccine adjuvants recently discovered in the Principal Investigator's laboratory at UAB. Success of this project will benefit the citizens of Alabama and have broader positive impacts on global health as well.

During the third quarter of 2022, we conducted the planned *in vitro* opsonophagocytosis assay (OPA) analysis of the mouse serum samples collected in the second quarter. Based on the OPA results, we confirmed that our newly discovered saponin vaccine adjuvant significantly enhanced immune responses (antibodies and OPA titers) induced by a clinical pneumococcal vaccine. With addition of this new adjuvant to the clinical pneumococcal vaccine, the new vaccine formulation significantly enhanced the antibody responses against all the selected representative *S. pneumoniae* serotypes, including the most notorious and challenging serotype.