## INNOVATING CROSS-DOMAIN SOLUTIONS TO DETECT EMERGING BIOLOGICAL THREATS

# ABACUS- Autonomous Bioaerosol Collection For Universal Sampling

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Small and mobile capabilities for detecting CBRNE hazards in real-time are necessary to counter our modern CBRNE threats. At the same time, miniaturized autonomous vehicles have significantly advanced in their range and capabilities. Our research utilized these emerging autonomous vehicles to sample CBRNE threats for detection and analysis, and how to coordinate vehicles' movements to optimize sample collection and hazard mapping.

In this research effort, several miniature autonomous vehicles, consisting of both quadcopter and ornithopter varieties, were evaluated in their aerosol collection capabilities. Methodologies were applied to advance aerosol collection efficiencies on their surfaces and incorporate location and environmental sensors for sample tracking. The key scientific advancement includes better understanding of particle-to-surface interactions and how to engineer an optimal adhesion substrate by using a novel combination of experimental and computational methodologies.

Initial tests performed included aerosolization of several particles sizes in the range of 1-10 µm, including fluorescent polystyrene latex spheres (PSLs), representative of an extreme hard surface particle to surface contact interactions, as well as a yeast and fluorescein solution, representative of extreme sticky particle to surface contact interactions to elucidate where the best surface sampling locations were on the drones. Particle collection "hot-spots" were identified, most notably at specific appendage sites. These locations were especially effective and versatile, as appendages are both easily customizable per CONOPs scenarios and detachable for the post-op sampling retrieval and/or analysis needs. Afterwards, versatile test rigs were fabricated to replicate the various flow fields associated with most foreseeable swarming drone platforms. These test rigs were then used to provide experimental data that was integrated into computational models developed in collaboration with Dr. Roseanna Zia (STC/University of Missouri) to assist in guidance for optimal methodologies for modifications of the COTS appendages to increase per-area collection sampling efficiency. Dr. Zia has existing mature computational models simulating a range of controllable substrate materials including: permeable membranes with highly tunable surface bonding forces, and embedded tortuous networks adjustable to capture and release macromolecules with a range of triggers, including solvent, temperature, pH, and salinity changes; and mechanical pressure. Models mimicked laboratory conditions and recommendations were made on alternative materials or surface conditions to catch-and-release target molecules.

Lastly, to ensure optimal sampling while flying multiple COTs drones simultaneously in close proximity to one another, it was imperative to coordinate their movements effectively to minimize collisions while maximizing aerosol sampling, i.e. development of a swarming algorithm for hazard mapping. Several mathematical models and algorithms already exist for route planning, serving as the starting point for the swarming algorithm. An outdoor demonstration was executed to simulate 'real world' environmental factors, using several COTs drones, the swarming algorithm, and refined sampling methodologies for capturing a simulated Bacillus atrophaeus (Bg) threat release scenario. Key outcomes of this effort include enhanced bioaerosol collector capability through complementary colloidal theory modelling, establishment of autonomous algorithm flying patterns for operating the vehicles, and the creation of a predictive database to guide the selection and utilization of any potential COTs drone for sampling and swarming.

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