5.13 TASK 13
Contaminant Plume Identification, Estimation and Forecasting

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Task 13 Technical Requirements

This project will assemble and coordinate a multidisciplinary team at UCSD and LANL to investigate the problem of the identification, estimation, and forecasting of a major contaminant plume released into the atmosphere. The project will focus on how to coordinate a fleet of several small UAVs, each equipped with small payload (our target is less than 5 pounds) containing A) GPS, accurate enough to determine both local position of the UAV and wind velocity, B) MEMS-based sensors for rapid local detection of the contaminant in question (radioactive, chemical, bio), C) low-power communication links, both between vehicles and between at least one vehicle and the command center, and D) a modest amount of onboard computer power in order to do some onboard trajectory planning based on the information received.

The coordination of the vehicles in this fleet will be semi-autonomous, and controlled in a hierarchical manner from ground-based command and control center. This ground-based computer will gather and assimilate all data collected by the fleet into a detailed plume simulation and forecasting algorithm. The algorithm will produce a real-time state estimate of the plume extent and local flow velocity distribution. It will also provide accurate forecasts of plume dispersion for emergency responders. Finally, the algorithms will coordinate the fleet, instructing individual aircraft where to probe next in order to minimize the uncertainty of the plume location, extent, and the flow velocity estimates. This project will leverage emerging capabilities being developed at UCSD and LANL in several engineering fields including 1) Novel UAV designs, 2) data assimilation/forecasting of uncertain flow systems with adaptive observations, 2) multi-agent vehicle coordination and control strategies with hierarchical control algorithms, and 3) low-power coordination, communication, & control of semi-autonomous agents. The problem has direct applications in stockpile stewardship (DOE), homeland security (DHS), battlefield observations (DOD), and environmental (EPA) applications.

Task 13 Deliverables

	Task 13 - Deliverables	Due Date (days after contract award)
13.1	Design and numerical validation of control algorithms for tracking of a moving source of a diffusive contaminant plume in 3D. Submit report summarizing the algorithm	90
13.2	Experimental validation of control algorithms for boundary tracing using a single mobile robot; laboratory tests to be performed with a non-convex optical field composed of multiple light sources. Submit report	180

	summarizing the validation experiment	
13.3	Design and numerical validation of control algorithms for efficient mapping out of the entire 2D boundary surface of a diffusive spatially distributed plume in 3D with a static or slowly moving source, using a single vehicle. Deliverable: report progress in quarterly report	270
13.4	Experimental validation of control algorithms for coordinated swarming motion of a team of 3 or more mobile robots equipped with obstacle avoidance and bluetooth communication capabilities, demonstrating the ability to simultaneously track several light sources and to perform coordinated tracing of a curved boundary in a fraction of the time needed by a single vehicle. Deliverable: report progress in quarterly report	360
13.5	Define mission profile (range in distance and time and latitude), payload requirements (weight, sensor pods, etc), performance requirements (cruise speed, dash speed, stall speed, and hover??), autopilot/ground station needs, and other (vehicle size, launching, retrieval, etc). Work with UCSD and LANL to define parameter ranges. Deliverable: report progress in quarterly report	180
13.6	Perform review of industry vehicles to rank their ability accomplish mission. UCSD has compiled a database of over 350 current world-wide UAVs (aircraft, helicopters) that will be used to identify and rank vehicles meeting the previous needs. A few of these vehicles have filed (or are in the process of filing) for a FAA certificate of authorization. This information will also be included in the study, which along with the "sense and avoid hardware" will provide the basis for being able to fly in the national airspace. Deliverable: report progress in quarterly report	90
13.7	Review current military and science studies that are using multiple UAVs to perform their missions.	90
13.8	Conduct an autonomous flight demonstration using one (or two) UCSD UAVs. This demonstration will be defined by the UCSD/LANL team, but it will be expected to serve more as a data collection and analysis, This could be a vehicle flying through smoke above a fire to identify the GPS start and endpoint of the smoke as a function of altitude. Deliverable: report progress in quarterly report	360
13.9	A report will be submitted to LANL that summarizes the ability of existing commercial aircraft to accomplish the UCSD/LANL mission versus the need for a special vehicle.	270
13.10	Building on the standard and retrograde adjoint-based forecasting algorithms, implement and test our new retrograde Kalman framework on the Lorenz and Kuramoto-Sivashinsky models. Discuss findings in quarterly report.	90
13.11	Obtain a large-scale atmospheric (3D) plume code from LANL and learn how it works. Provide status in quarterly report.	90
13.12	Develop an adjoint solver for the UCSD spectral DNS/LES turbulent channel flow code named diablo. Discuss progress in quarterly report.	90

13.13	Demonstrate the retrograde Kalman framework in the analysis of a contaminant released behind a mobile pollutant source in 2D without convection. Discuss findings in quarterly report.	90
13.14	Extend item 13.13 to include convection. Discuss findings in quarterly report.	180
13.15	Study the viability of using automatic differentiation tools to develop the discrete adjoint of the LANL plume code, in order to build upon it our data assimilation and adaptive observation algorithms for atmospheric plumes. Discuss findings in quarterly report.	180
13.16	Using diablo, demonstrate viability of our new forecasting algorithms in controlled 3D computational experiments in which we can tune at will the complexity of the truth model and the fidelity of the estimation model. Describe findings in quarterly report.	270
13.17	Downselect either the lab code or an appropriate modification of the home-built turbulence code as the core computational model for the remainder of this study; write a detailed report describing the steps remaining before flight test.	360
13.18	Radio communications: review of intermediate-range communication technologies and network interfaces (1 to 5 km) for use with the potential UAV candidates identified in 13.6. Evaluation of design tradeoffs in non-line-of-sight beamforming and antenna steering capabilities. Report progress in quarterly report.	270
13.19	Design platform and i/o interfaces including integrated orientation sensors. Report progress in quarterly report.	180
13.20	Localization strategy using assisted GPS or local radios that are compatible with the platform chosen. Report progress in quarterly report.	180
13.21	Network design: design network topology to support energy-efficient ad hoc network formation. Report progress in quarterly report.	90
13.22	Detailed report outlining architectural design and design tradeoffs related to communications networking and platform. Report progress in quarterly report.	360