Phase I Project Summary

Firm: Michigan Aerospace Corporation
Contract Number: NNX10CE68P
Project Title: Molecular Air Data Clear Air Turbulence Sensor “MADCAT”

Identification and Significance of Innovation: (Limit 200 words or 2,000 characters whichever is less)

Clear air turbulence (CAT), often referred to as "air pockets," is attributed to Kelvin-Helmholtz instabilities at altitudes generally above 18,000ft, often in the absence of any visual cues such as clouds. CAT most often occurs when there is a temperature inversion and wind shear through the layer, and is associated with strong horizontal temperature gradients and vertical velocity gradients. CAT can form from atmospheric waves as well as mountain waves. Atmospheric waves can form between any two layers that have significantly different densities and wind speeds. Clear-air turbulence typically occurs at high altitudes (7,000-12,000 meters/23,000-39,000 feet) and can be potentially dangerous for commercial and military aviation. Mountainous terrain can also be a cause of severe turbulence. Michigan Aerospace Corporation (MAC) has designed an instrument, the Molecular Air Data and Clear Air Turbulence (MADCAT) system, capable of providing not only a look-ahead capability to predict clear air turbulence but also provide a full air data solution (airspeed, angle of attack, angle of sideslip, pressure and temperature) at high altitude. The design is based on technology already demonstrated in-flight, including the ability to measure airspeed, angle of attack and angle of sideslip.

Technical Objectives and Work Plan: (Limit 200 words or 2,000 characters whichever is less)

The Phase I Objectives were the following:

Objective 1: Determine the performance specifications and instrument constraints to provide an in-flight CAT hazard detection system

Objective 2: Determine the capability and performance of the proposed MADCAT system

Objective 3: Develop the necessary design augmentation to enhance the current air data system design to add the capability of simultaneously measuring range-resolved measurements of winds ahead of the aircraft at fine enough resolution to resolve turbulence, wind shear and gusts.

The Work Plan included the flowing tasks:

Task 1: Requirements Analysis: to establish the baseline requirements for the MADCAT instrument.

Task 2: Sensor Performance Trade Studies: to determine the capability and performance of the proposed sensor as well as an estimate in cost, size, weight and power based on the requirements that were refined under Task 1.

Task 3: System Design: to augment our current design of the optical air data system for long range capability to detect and quantify turbulence and wind gust ahead of the aircraft platform.

Task 4: Demonstration Plan for Phase II: to develop a demonstration plan to be implemented under a phase 2 contract.

Technical Accomplishments: (Limit 200 words or 2,000 characters whichever is less)

Measuring vertical flow velocity associated with CAT using Doppler shift is difficult because of the weak projection of the vertical velocity component on the laser line of sight. However, CAT manifests itself also by horizontal gusts, ramp patterns in the velocity field and temperature/density gradients, phenomena measurable using direct detection molecular Doppler, even at long ranges (> 5 km). Trade

studies were conducted to determine the specifications of the long rage lidar for the detection of CAT patterns in the velocity and density fields at long ranges, with a range resolution of less than 70 m. The lidar uses direct detection of molecular and aerosol backscatter, enabling operations up to 80,000ft in altitude. An engineering model was designed to verify the performance of the proposed solution to measuring CAT and develop fast and accurate algorithms. The components of the engineering model were chosen for performance, weight and size, such that the tests results represent that of the flight instrument. The components include the light source, transmitter, receiver and processor.

NASA Application(s): (Limit 100 words or 1,000 characters whichever is less)

NASA has been active in detection of CAT for decades. This instrumentation will open new possibilities for additional experimental research and characterization of CAT. MADCAT will allow NASA aircraft the benefit of having a clear-air turbulence warning system and an optical air data system in one package, suitable for general use by NASA aircraft as well as for flight research concerning clear-air turbulence and scientific studies of atmospheric processes. Ground-based research uses include measuring wind speed and direction along with air temperature and density while also detecting and characterizing turbulence; this could find use in large wind tunnels and near airports.

Non-NASA Commercial Application(s): (Limit 200 words or 2,000 characters whichever is less)

Clear-air turbulence represents a significant hazard and passenger-comfort issue, and the proposed MADCAT system will be very useful for commercial aircraft not only as a turbulence-warning solution, but also as an air data system that is more reliable than current speed-sensing technologies. Information on winds near aircraft, if downlinked and compiled, will be of significant value to weather forecasters, especially from aircraft flying over areas (oceans, etc.) where balloon radiosonde releases and other wind measurements are sparse or non-existent; the National Weather Service lists the lack of more comprehensive wind-profile data as a major unmet data need for accurate, longer-range forecasts. Turbulence detection with wind speed and direction data will find ground-based uses for wind farms (to detect approaching turbulence, gusts and direction changes, allowing corrective action) and for the military (in artillery and other munitions delivery and in the airdrop of supplies).

Name and Address of Principal Investigator: (Name, Organization, Street, City, State, Zip)
Dr. Dominique Fourguette, Michigan Aerospace Corporation, 1777 Highland Dr., Suite B, Ann Arbor, MI 48108

Name and Address of Offeror: (Firm, Street, City, State, Zip)
Michigan Aerospace Corporation, 1777 Highland Dr., Suite B, Ann Arbor, MI 48108