Testing and Evaluation of the Best Aircraft Turbulence (BAT) Probe for Airborne Research

Edward Dumas, Ron Dobosy, David Senn, Bruce Baker, NOAA/ATDD
Jim Anderson, Mark Witinski, David Sayres, Claire Healy, Jason Munster, Harvard University

Goal

A partnership between ARL, The Anderson Group at Harvard University's Chemistry Department, and Aurora Flight Sciences seeks to make flux measurements of H_2O, CO_2, and CH_4 over the Arctic tundra regions of Alaska and Siberia. The ARL-designed Best Aircraft Turbulence (BAT) probe will be carried aboard a Diamond Twin Star DA-42 aircraft, along with Anderson Group-developed gas concentration instrumentation. ARL will be performing data analysis and flux calculations in addition to measuring turbulence. The BAT probe is designed to measure 3-D turbulence at 50 Hz utilizing a hemisphere and nine pressure ports to measure pressure distributions around the hemisphere.

Approach

The BAT probe utilizes airflow around a hemisphere to measure horizontal and vertical winds, static air pressure, and air temperature at high-frequency. The BAT probe measures velocity of air with respect to the aircraft, and a GPS/INS system measures velocity of the aircraft with respect to Earth. By performing a vector sum of each component, the velocity of air with respect to Earth can be calculated.

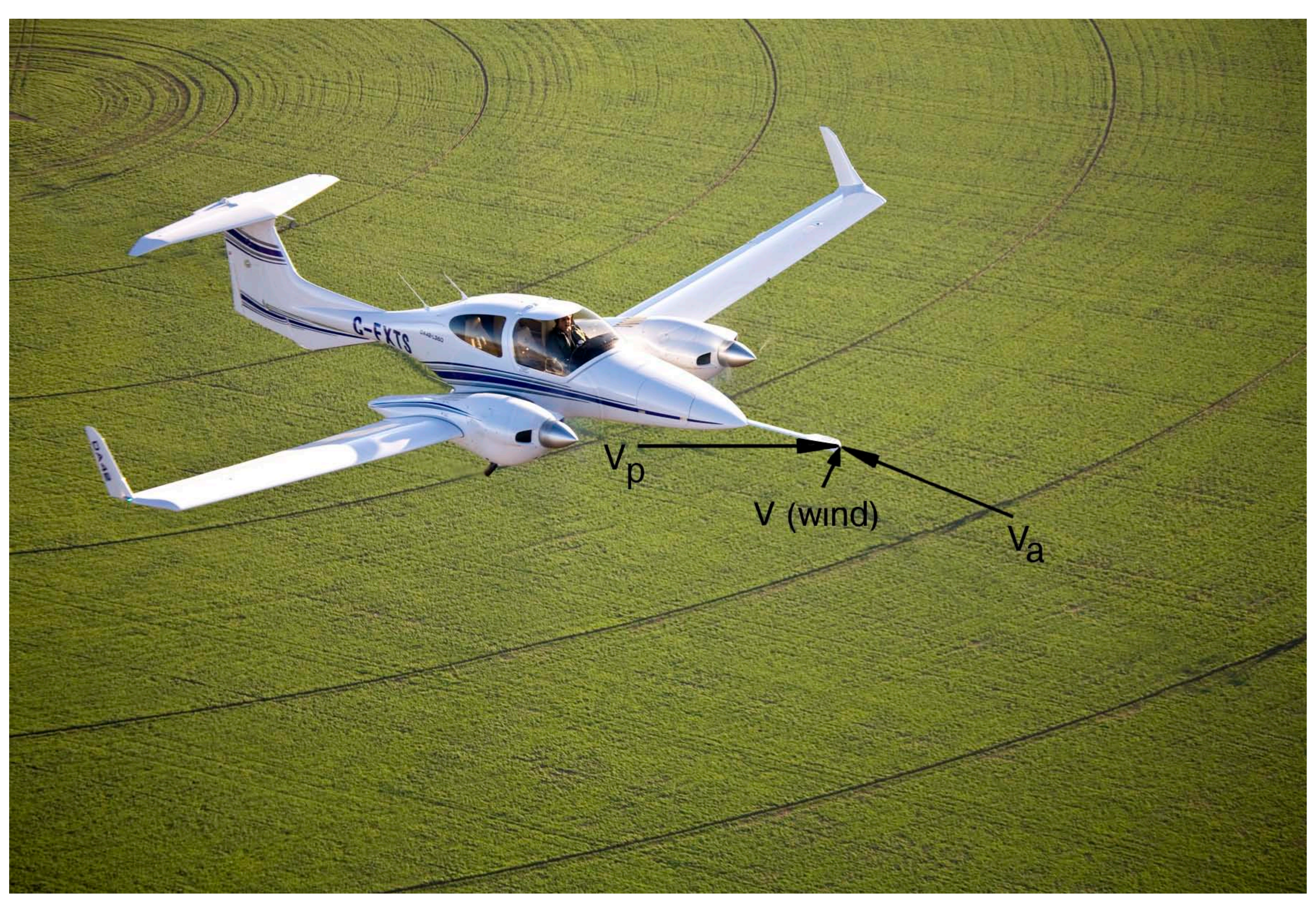
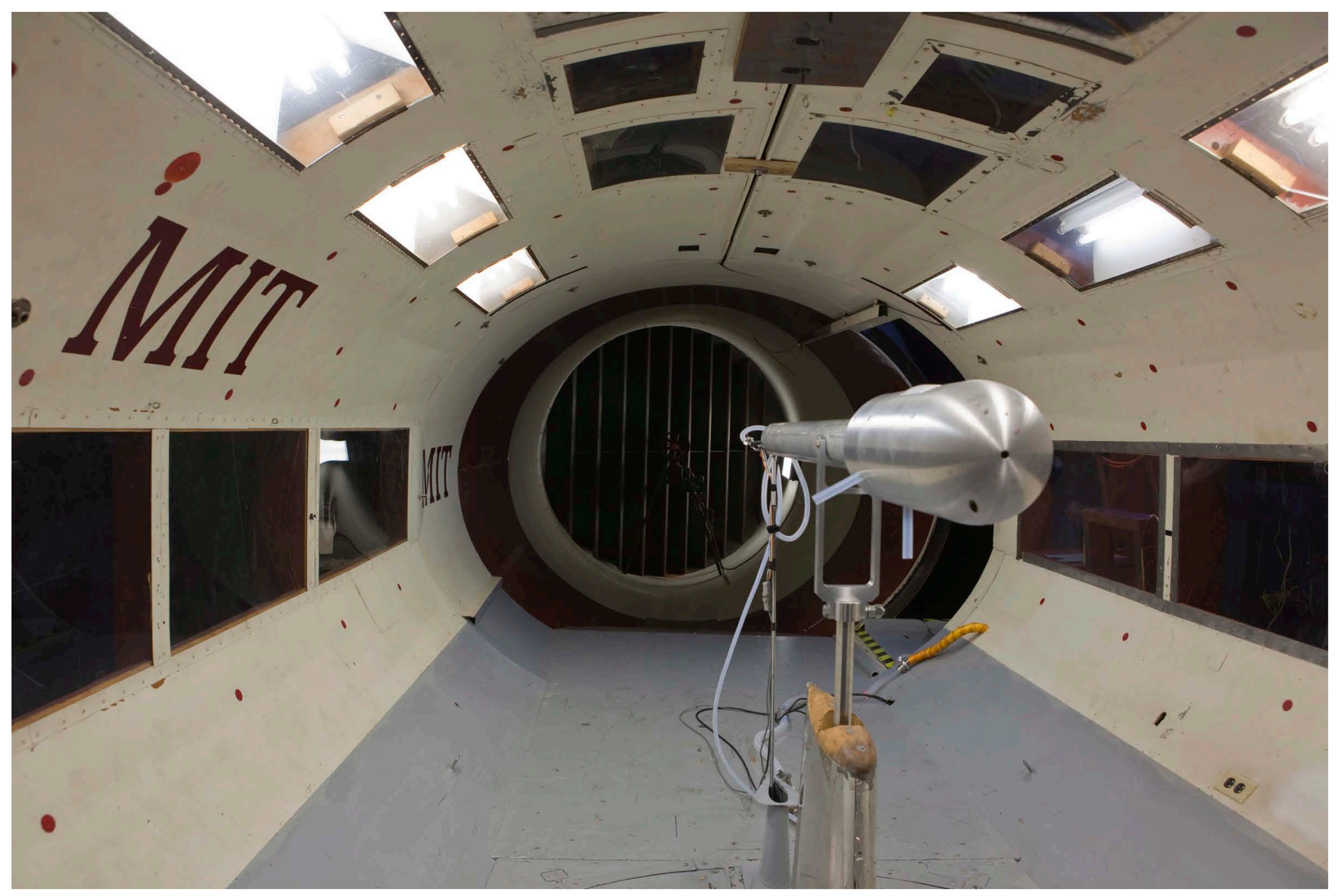


Diagram of BAT probe vector (Va) and the aircraft velocity vector (Vp). The resultant vector (V wind) is the sum of Va and Vp.

Accomplishments

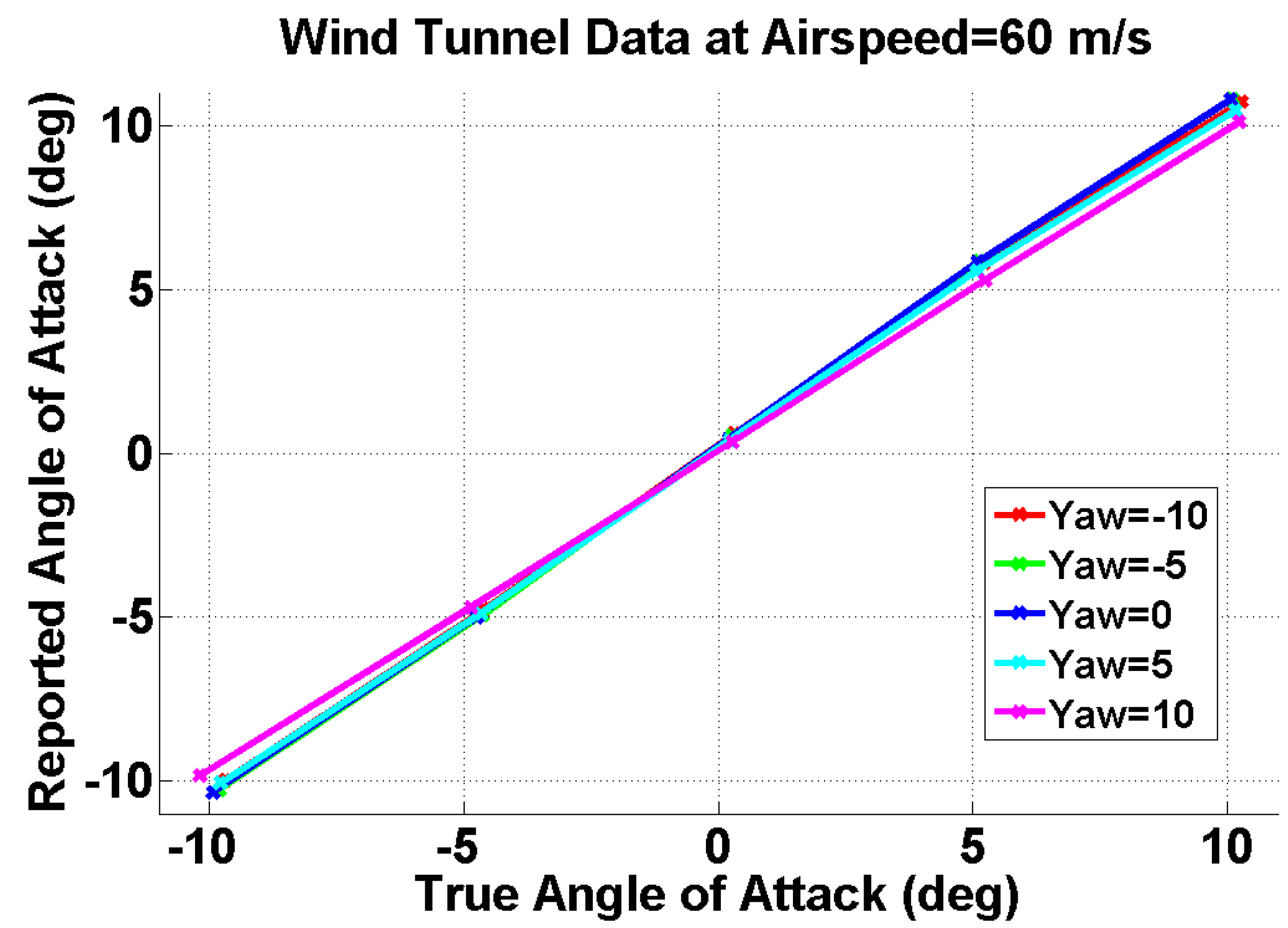
The BAT probe was tested in the Wright Brothers Wind Tunnel at MIT in April and October, 2010. The purpose of these tests was to verify the ability of the probe to measure angles of attack and yaw (sideslip), dynamic pressure, static pressure, and air temperature against a reference standard that simulates the actual conditions of flight. The MIT wind tunnel is a closed-return, continuous flow wind tunnel with a 3.0 m x 2.3 m elliptical test section that is 4.6 m long. The wind tunnel is capable of reaching speeds in excess of 62 m/s. It also provided the ability to position the probe over a range of ±10° in both pitch and yaw. This unique testing capability has allowed ARL to fully characterize the performance of the BAT probe.



The BAT probe mounted in the MIT Wright Brothers Wind Tunnel.

Indicators of Success

The first indicator of success is to determine the probe's ability to respond to changes in pitch and yaw angles. This was confirmed by changing the true angle of attack of the probe (the angle of the probe with respect to the horizontal) and recording the angle of attack reported by the probe while the yaw angle was held constant. This test was performed at the same flight speeds as the DA-42 aircraft, 60 m/s.



The true angle of attack of the probe (x-axis) versus the angle of attack reported by the probe (y-axis). Curves are shown for five constant angles of yaw.

The graph above shows excellent agreement between the true angle of attack of the probe and the angle of attack reported by the probe.

The wind tunnel test also allowed the uncertainty in the wind measurement of the probe to be measured. The maximum uncertainty in the vertical wind component was found to be 6%, which can be reduced significantly because the error is systematic.

Collaborators/Partners

- The Anderson Group, Harvard University, Chemistry Department
- Aurora Flight Sciences
- Massachusetts Institute of Technology

Future Direction

Field campaigns are planned for 2011, 2012, and 2013 in the Arctic regions of both Alaska and Siberia. Flux data of CO_2 and CH_4 will be measured using both the DA-42 aircraft and towers.