MZA 20/20

Program Summary

MZA Associates Corporation

Airborne Laser Experiment (ABLEX) for High Altitude Laser Propagation

Early planning and development of the Airborne Laser (ABL) concept in the early 1990's addressed the practicality of performing sufficient atmospheric compensation of a high energy laser at long ranges in order to deliver lethal fluence on boosting targets. Of key interest at the time was whether the then-current understanding of the propagation of coherent light through very long paths through the upper atmosphere was sufficient and whether the models of such propagation were accurate enough to predict the performance of the system. The Air Force Research Laboratory (AFRL) undertook several experiments to characterize upper atmospheric propagation and to anchor wave-optics models that would eventually allow accurate prediction of the ABL's beam on target. ABLEX, the Airborne Laser Experiment, was the first of the major atmospheric characterization efforts undertaken to answer these questions. MZA was a key contributor to the data analysis and the anchoring of wave-optics models to this landmark experiment.

1. ABL and ABLEX

In response to the need for boost-phase defense against ballistic missiles, the Air Force developed the ABL concept, in which a megawatt class chemical oxygen-iodine laser (COIL) weapon carried aboard a modified Boeing 747 would be used to attack and destroy tactical ballistic missiles shortly after takeoff from hundreds of kilometers away. This concept presented many significant technical challenges related to the size and power of the laser system required, the requirement to integrate it onto an airborne platform, and the extreme precision required in pointing and tracking and beam control[1]. AFRL conducted ABLEX to characterize the effect of scintillation on the propagation of coherent light, establish an upper-bound on the efficacy of phase-only compensation, and to anchor the wave-optics modeling algorithms to be used in the design the ABL.

2. MZA's Role

During the ABLEX flights of January 1993, a pulsed laser beam was propagated between a transmitter and a receiver aircraft flying at high altitudes[2,3]. In these experiments, the scintillation patterns resulting from propagation through atmospheric turbulence were recorded.

---

[1] In February 2010 the ABL team led by the Missile Defense Agency (MDA) conducted a successful "shoot-down" demonstration, in which the ABL engaged and destroyed a boosting missile in flight, and then a short time later engaged a second missile. The prime contractor the program, the Boeing Company, was supported by major subcontractors Lockheed Martin for development of the beam control system and Northrop Grumman for the COIL laser device. The acronym for the ABL has since been changed to ALTB for Airborne Laser Test Bed. (http://en.wikipedia.org/wiki/Airborne_laser)

[2] Lawrence D. Weaver and Robert R. Butts, "ABLEX high-altitude laser propagation experiment", Proc. SPIE 2120, 30 (1994). (http://dx.doi.org/10.1117/12.177697)

[3] Robert R. Butts and Lawrence D. Weaver, "Airborne laser experiment (ABLEX): theory and simulations", Proc. SPIE 2120, 10 (1994). (http://dx.doi.org/10.1117/12.177690)

From these patterns, the fundamental performance limits of phase-only adaptive optics systems were determined. MZA developed algorithms to compute the Strehl ratios that would have been obtained by perfectly compensating the phase of the transmitted beam for atmospherically-induced aberrations. The results established that there were no fundamental physics limits that would prevent a phase-only adaptive optics (AO) system from providing sufficient atmospheric compensation for an effective ABL system. In other words, an effective ABL system could be built with then-current AO technology.

MZA won its first competitive contract in December 1992, and as a newly-formed organization, ABLEX was one of the first major projects to which it contributed. Prior to MZA's engagement, the ABLEX experiment had been designed and built and very soon after MZA was brought on, the experimental flights were flown. So MZA's involvement in the experiment was primarily that of data management, analysis, and anchoring to wave-optics simulation.

The ABLEX scintillation patterns were recorded on then state-of-the-art high speed optical discs. MZA was responsible for extracting and organizing the data for calibration, image processing, and statistical characterization. MZA developed procedures to extract the data into a database which then allowed further classification and analysis. A particular challenge in processing the data was to ameliorate the effects of "jailbars," or vertical stripes in the image data caused by an mask placed in the optics which were intended to compensate for deficiencies in the sensor responsivity. The goal was to remove the effects of the jailbars without adversely affecting the resulting scintillation statistics. While a variety of approaches were considered, the method proposed by MZA, that of a sliding window average, which effectively amounted to a linear convolution operation, was determined to be the best way to maintain the proper statistics. MZA also developed background and non-uniform sensor responsivity compensation algorithms.

Image data from the ten flights were filtered for quality and divided into 177 segments according to flight conditions and spatial characteristics through a manual process that came to be known as the "Weaver filter," named after the late Dr. Larry Weaver[4], the AFRL program manager for ABLEX. MZA then performed the image processing and computed the ensemble statistics to create a comprehensive understanding of the data.

One of the primary goals of the ABLEX was to provide data which could be used to determine whether wave-optics propagation models properly represented the scintillation induced by the atmosphere on propagating light. MZA performed a series of wave-optics studies which showed that wave-optics calculations were quantitatively and qualitatively consistent with most phenomena observed during the ABLEX missions. This was an important finding since wave-optics models were to be used to establish the atmospheric compensation requirements for ABL.

---

[4] Dr. Lawrence D. (Larry) Weaver was the program manager for the ABLEX program. Throughout his long career with the Air Force Research Laboratory and its predecessors, Dr. Weaver made significant contributions to research and development of wavefront sensing, phased array, and atmospheric compensation. He continued to perform research on ABL-related technologies until his death in December 2007. Dr. Weaver was also a community activist who played a key role in the development of Albuquerque, New Mexico's west-side communities. (http://www.abqjournal.com/main/2011/04/30/riorancho/riorancho-news/paseo-extension-advocate-honored.html)

3. Summary and Acknowledgments

Drs. Larry Weaver and R. Russell Butts summarized the ABLEX experiment as follows,

> *"We conclude this discussion by noting that a rich set of atmospheric data was obtained from the ABLEX experiments. These data confirmed previous notions, based on the CLEAR 1 atmospheric turbulence model, that phase-only turbulence compensation can provide sufficient performance. The unresolved phenomenology issues (as opposed to engineering issues associated with the beacon, tracking, adaptive optics system design, etc., which were not an objective of ABLEX), are related to the variability of the atmosphere, and hence a more comprehensive definition of the turbulence model(s) is required. In addition, there are the uncertain transmission characteristics of the atmosphere over the slant paths of interests."*

and further offered the following acknowledgments,

> *"This work would not have been possible without the help and dedication of the many persons representing the following organizations: Logicon RDA who designed the receiver and transmitter packages, the Phillips Laboratory Flight Test Branch and the BDM Corporation who were responsible for the acquisition pointing system and the integration of the experiment onto the ARGUS aircraft, the Aeromet Corporation who were responsible for the integration of the transmitter on the Harp aircraft, Decade Optical Systems who provided the NdYAG laser source and kept it operating, Rockwell Power Systems who provided the laser diode beacons, MZA Associates who reduced the data, and the flight crew from the 4950th Test Wing who superbly coordinated the 200 km "mating dance" of ARGUS and Harp."*

While ABLEX represented an early milestone for the advancement of the ABL project, it also was key first-step for MZA's development into a leading organization in the modeling, analysis, and testing of directed energy and imaging systems.

MZA 20/20: Celebrating 20 years of technical excellence and service to the United States Armed Forces and looking forward with clear 20/20 vision.

MZA is commemorating its 20th anniversary through the MZA 20/20 initiative, part of which includes publishing a series of articles that provide an on-going retrospective of significant accomplishments that MZA has made to the industry throughout the company's history. This document was written by the staff of MZA to recognize one of those accomplishments. For more information about MZA Associates Corporation and its 20/20 initiative, visit the MZA website at www.mza.com.

MZA Associates Corporation
2021 Girard Blvd. SE, Suite 150
Albuquerque, NM 87106
voice: (505) 245-9970

Written by the staff of MZA Associates Corporation with various information taken from publicly-available summaries.

Current as of March 2012.