MZA Associates Corporation

High Energy Laser Weapon Systems (HELWS)

Beam Control Systems (BCS)

Capabilities Overview

May 2026

Distribution A: Approved for Public Release

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- Information about certain DoD programs in which MZA is involved is sourced from prior publicly released documents.

MZA Delivers Tri-Service Directed Energy Solutions

MZA's beam control solutions are deployed in Army, Navy, and Air Force HEL weapons

MZA Associates Dayton, OH

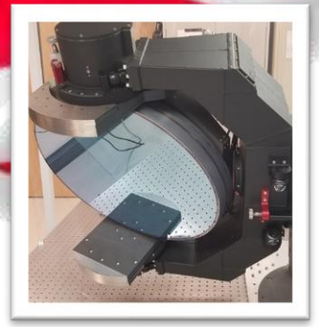
- Design, CFD, FEM
- Flight test transition
- Wave-optics simulation

MZA Associates Albuquerque, NM

- Hardware manufacturing
- Beam stabilization
- Integration and testing

Active Optical Systems, LLC Albuquerque, NM

- Adaptive Optics
- Deformable Mirrors
- Wavefront Sensors



MZA-McCarter La Porte, TX

- Large optics
- Precision machining

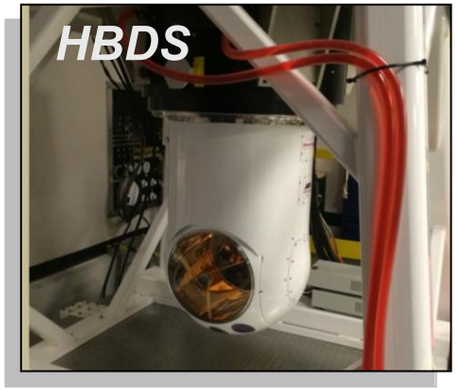
- *Beam Directors*
- *Beam Control Systems*
- *Adaptive Optics*
- *Fire Control Systems*
- *Line-of-Sight Stabilization*
- *Acquisition Tracking & Pointing*
- *Atmospheric Sensors*
- *Decision Aids*

Directed Energy Weapons Development Builds up Small Business Industrial Base

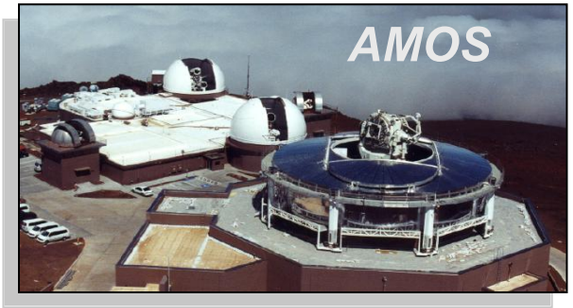
MZA is a world leader in the modeling, analysis, and development of directed energy and imaging systems

- Beam control and imaging systems
- Adaptive optics design and implementation
- Atmospheric and aero-optical effects
- High energy laser systems engineering
- Target signatures and vulnerability
- High speed target tracking
- Laser communications
- LADAR/LIDAR applications
- Deformable mirrors and wavefront sensors

MZA's modeling and analysis software has been used on nearly every major HEL program over the past 30 years.



WaveTrain



Introduction

- MZA specializes in the modeling, simulation, and analysis (MS&A), design, development, engineering, and testing of advanced optical and control systems for High Energy Laser Weapon Systems (HELWS) and advanced surveillance systems (ISR).
- MZA has provided more than thirty years of support to a broad range of US Department of Defense (DoD) research organizations and provides some of the most formidable capabilities in the concept development, analysis, modeling, systems engineering, manufacturing, integration and test of HELWS.
- MZA's staff consists of some of the world's experts in the fields of advanced beam control analysis and design, beam control component and system development, aero-optical and aero-mechanical effects, atmospheric propagation, and laser engagement analysis.
- No other single organization of any size provides comparable breadth and depth of engineering, analysis, manufacturing, and test capabilities for HELWS beam control systems.

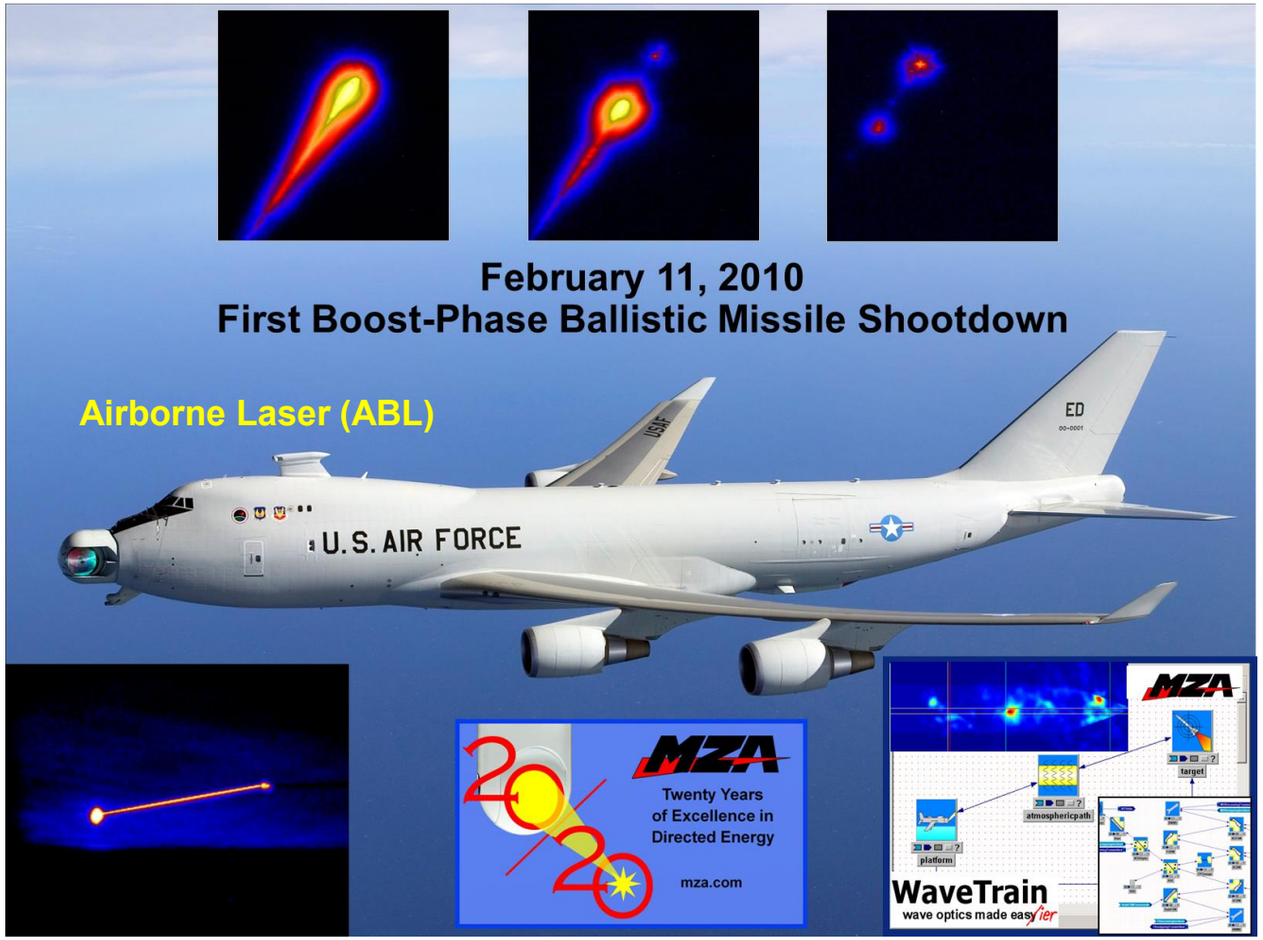
MZA's Core Capabilities

- **Laser Weapon & Optical Sensing Modeling & Simulation**
  - WaveTrain - Integrated physics-based simulation
  - Atmospheric and aero-effects modeling
  - Beam control and propagation scaling models
  - Systems engineering models
  - Laser device modeling
- **Laser System Design, Development, Integration & Testing**
  - High Energy Laser (HEL) beam control and line-of- sight (LOS) stabilization
  - Target acquisition, tracking, and beam pointing (ATP)
  - Laboratory and field test and experimentation
  - Atmospheric turbulence characterization and profiling
  - Aero-effects characterization and mitigation
- **Adaptive Optics & Beam Control Hardware**
  - High-speed tracking and wave front compensation sensors and control devices
  - High Power Deformable Mirrors (HPDMs) and Fast Steering Mirrors (HPFSMs)
  - Real-time and distributed control systems
  - Optical telescopes and beam directors
  - Experimental optical measurement devices
  - Atmospheric measurement and characterization devices
  - Large high-power optic fabrication

Airborne Laser Laboratory (ALL) & Airborne Laser (ABL)

First air-to-air laser shoot down in 1983

MZA staff contributed to the development of the beam control systems of the two most significant airborne achievements in High Energy Laser Weapon Systems (HELWS).



Early MZA

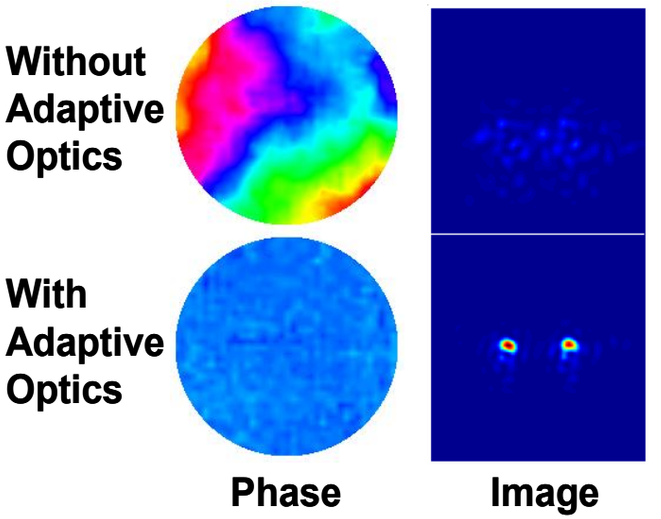
MZA started out in 1991 as a company that specializes in modeling and analysis of atmospheric propagation and atmospheric wavefront compensation.

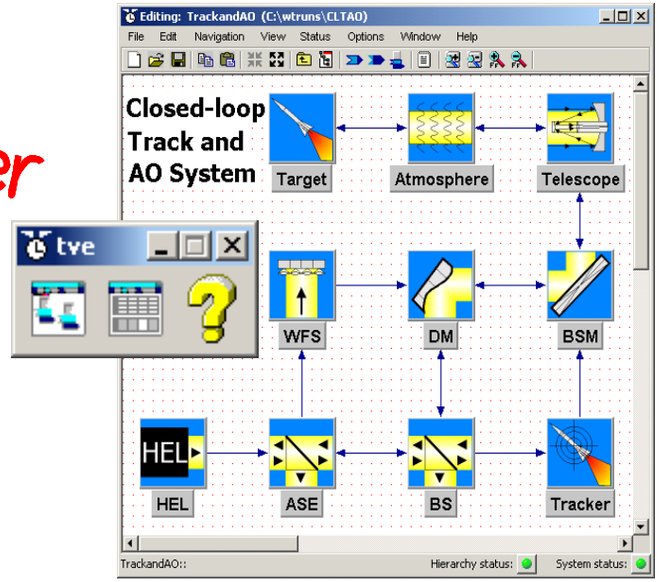
WaveTrain

wave optics made easy*ier*

The Challenge of Wave Optics Simulation

Wave optics simulation is a crucial technology for the design and development for advanced optical systems. Until now it has been the sole province of a handful of specialists because the available codes were extraordinarily complicated, difficult to use, and they often required supercomputing resources.





The Solution is WaveTrain

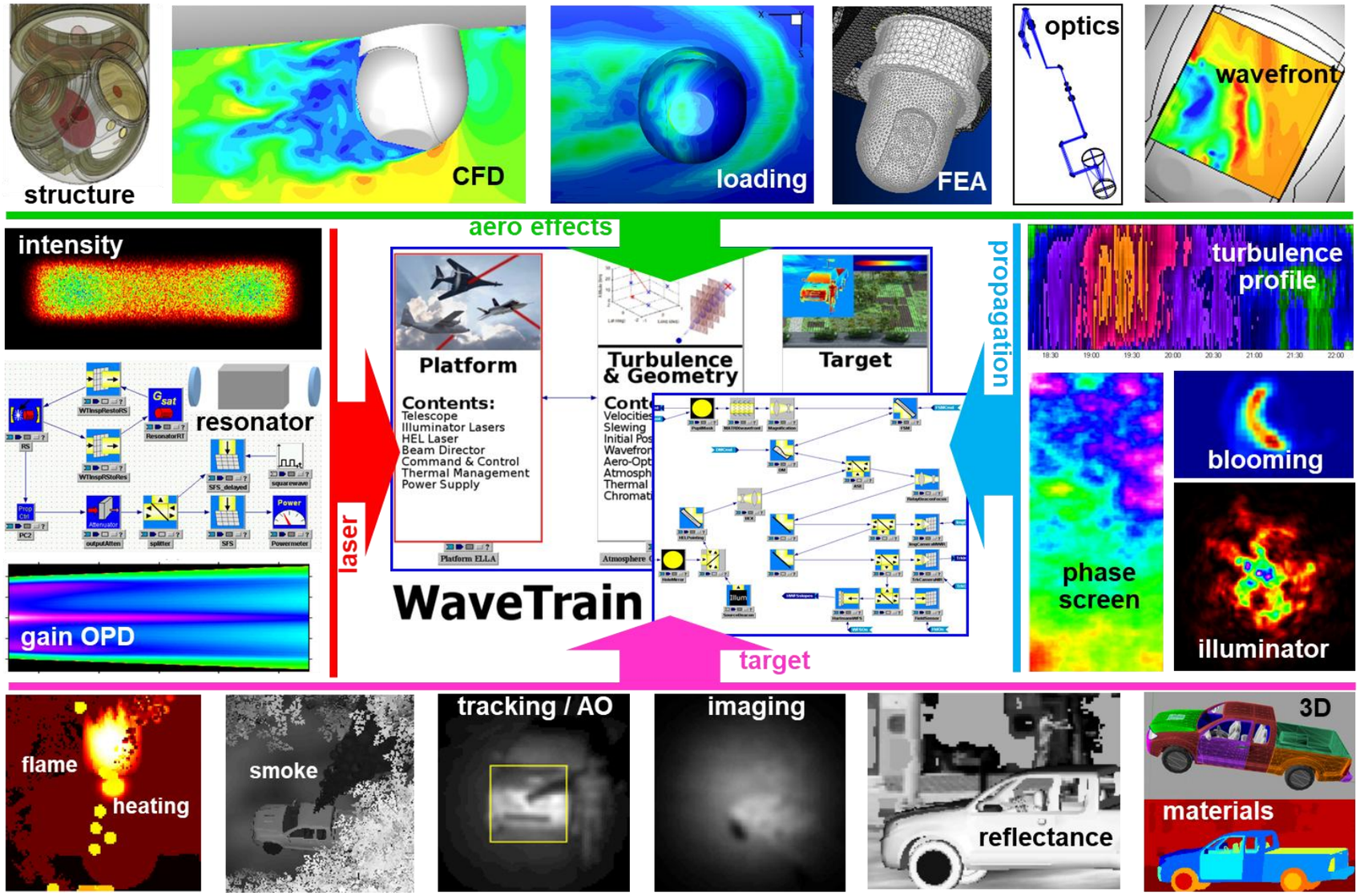
WaveTrain puts the power of wave optics simulation on your PC. Through an intuitive connect-the-blocks visual programming environment, you can assemble beam lines, control loops, and complete system models, including closed-loop adaptive optics (AO) systems.

For more information:
wavetrain@mza.com
www.mza.com
(505) 245-9970

MZA Associates Corporation

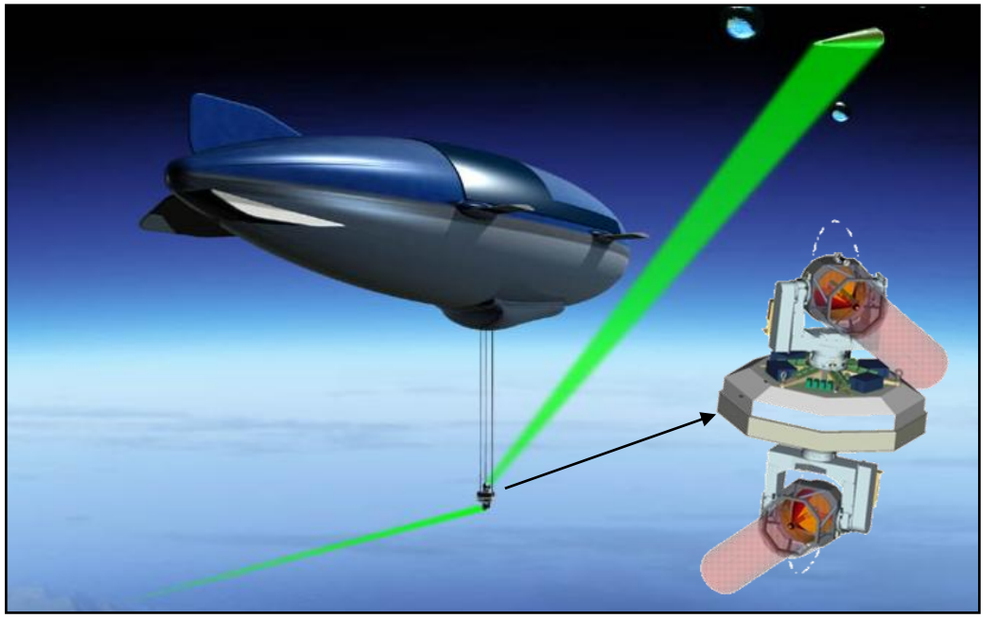
Integrated End-to-End Isomorphic Modeling

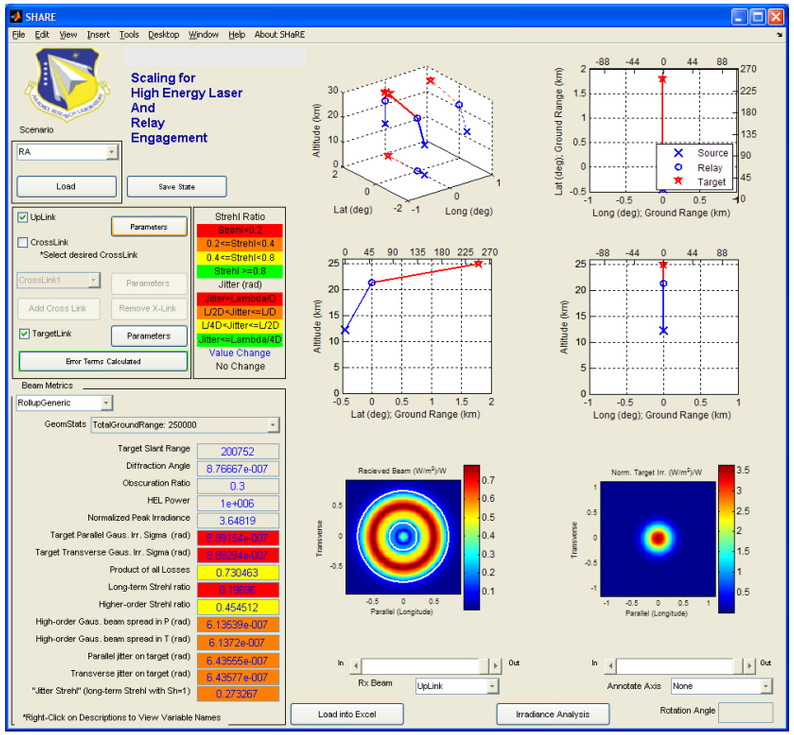
MZA has created the most sophisticated and detailed models of HELWS ever developed.



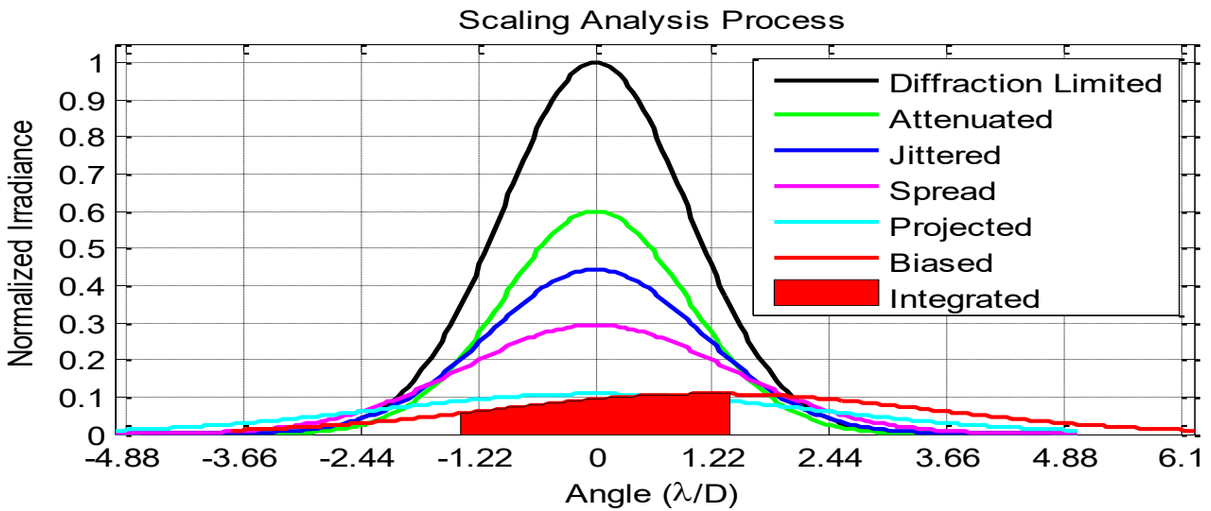
SHaRE - Scaling Codes

As the industry's problem set evolved, MZA established additional modeling capabilities.





Engagement modeling using SHaRE.



Atmospheric Characterization and Compensation

MZA developed sophisticated data acquisition and analysis systems to conduct ground-breaking atmospheric characterization and compensation experiments.

Differential-tilt technique for saturation-resistant profiling of atmospheric turbulence

Matthew R. Whiteley and Donald C. Washburn

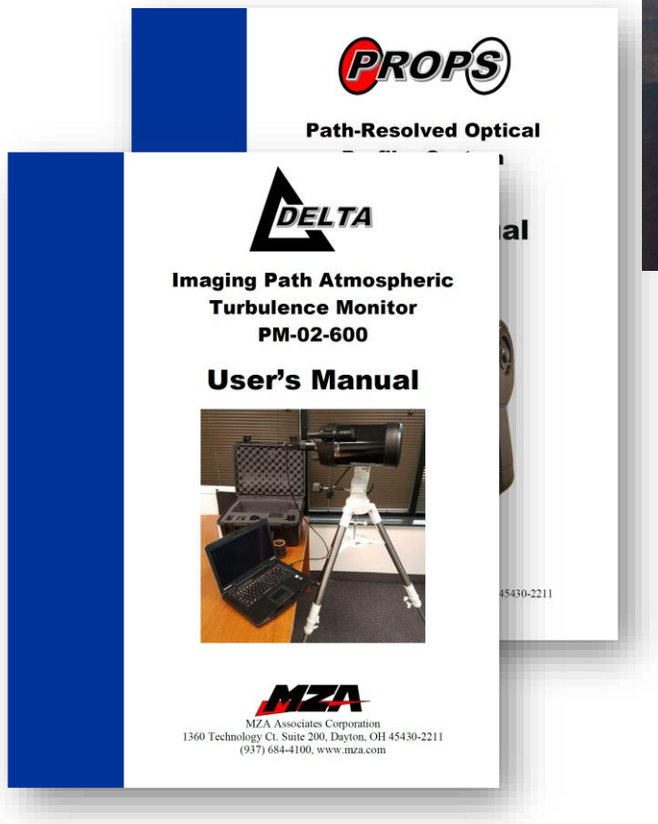
Air Force Research Laboratory, Directed Energy Directorate,
3550 Aberdeen Avenue SE, Kirtland Air Force Base, New Mexico 87117-5776

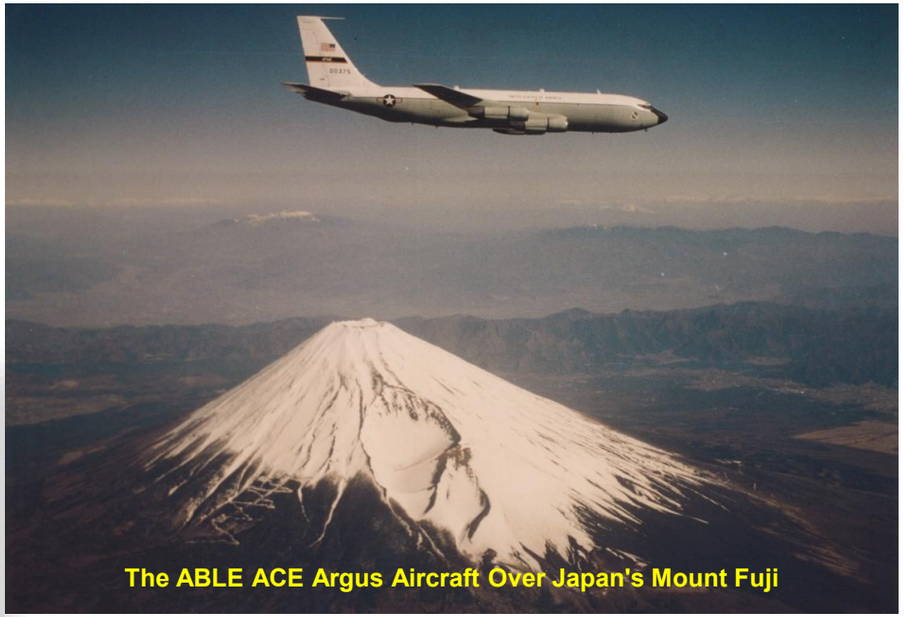
Approved for public release; distribution unlimited

ABSTRACT

A technique for profiling of C_n^2 over an atmospheric propagation path is proposed, developed and analyzed. The technique employs differential-tilt measurements to arrive at statistics which have unique weighting functions over the propagation path. These weighting functions are computed theoretically and used to derive a reconstructor matrix for C_n^2 values throughout the path to be applied to an appropriate set of differential-tilt statistics. A candidate optical system is presented, and the performance of the profile reconstructor is analyzed. This study indicates that the relative error in the C_n^2 estimates is approximately 5%. The relative error in estimating key atmospheric parameters such as the Fried parameter, isoplanatic angle, and the Rytov parameter from the reconstructed profiles is approximately 3%. The noise gain for estimating atmospheric parameters is less than 0.2 for all parameters considered.

Keywords: differential tilt, turbulence profiling, atmospheric characterization





The ABLE ACE Argus Aircraft Over Japan's Mount Fuji

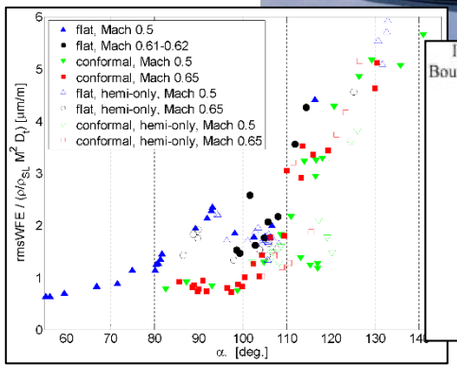
The North Oscura Peak Facility on WSMR

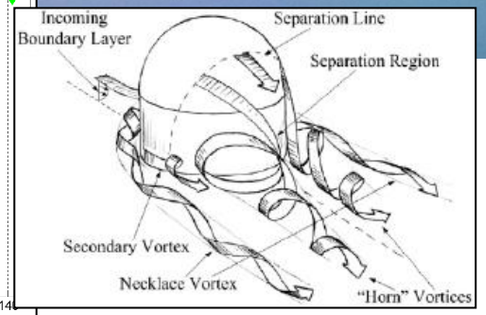
Aero-Effects Characterization and Mitigation

MZA helped to design, instrument, and conduct ground-breaking aero-effects characterization and compensation experiments.

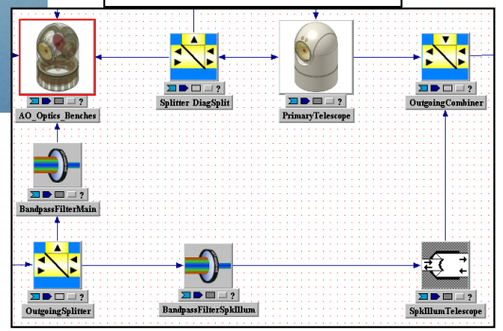
(See SPIE Optical Engineering, July 2013 and Aero-Optical Effects, Physics, Analysis, and Mitigation, by Gordeyev, Jumper, and Whiteley)

AAOL flight data

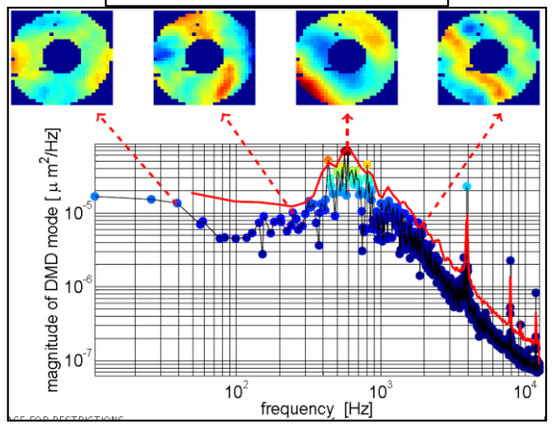




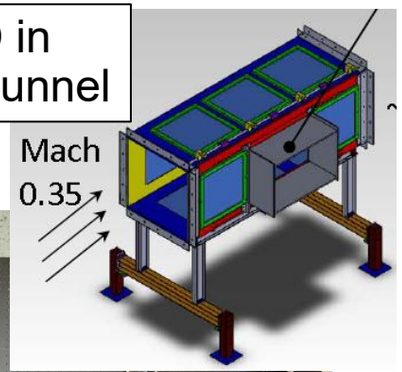
Wave-Optics Simulations

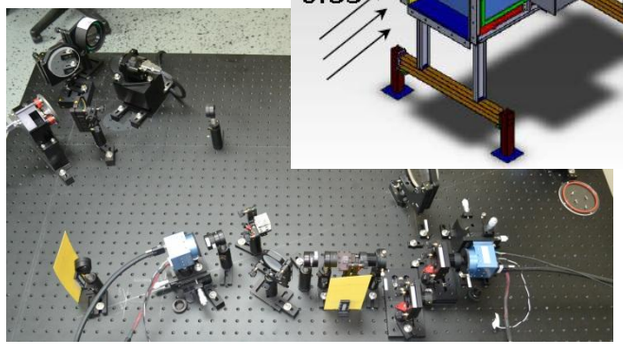


Dynamic Mode Decomposition

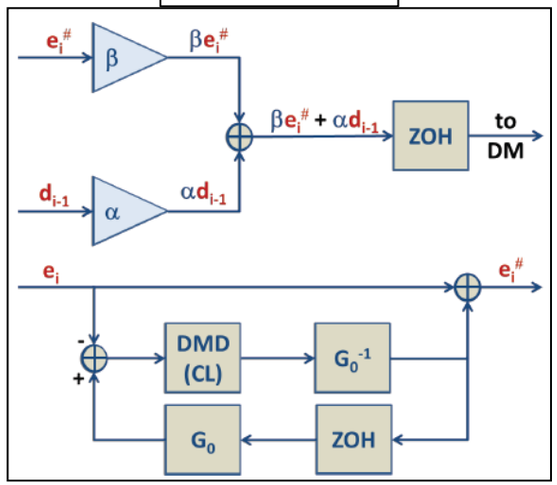


AFIT AO in UND wind tunnel

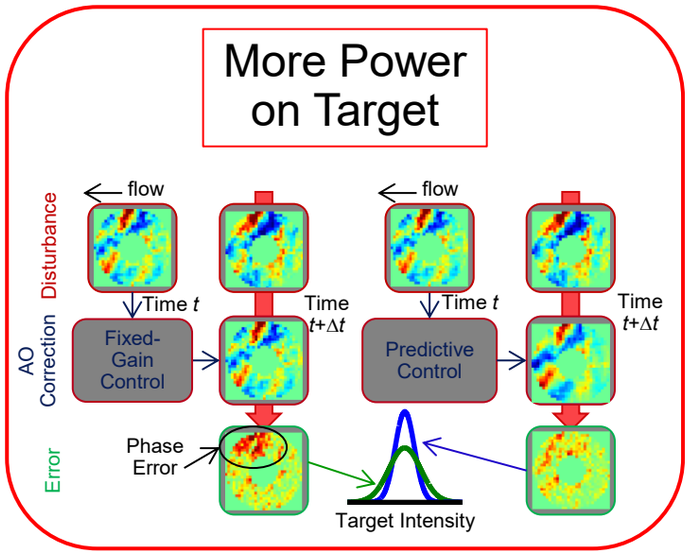




Predictive Control

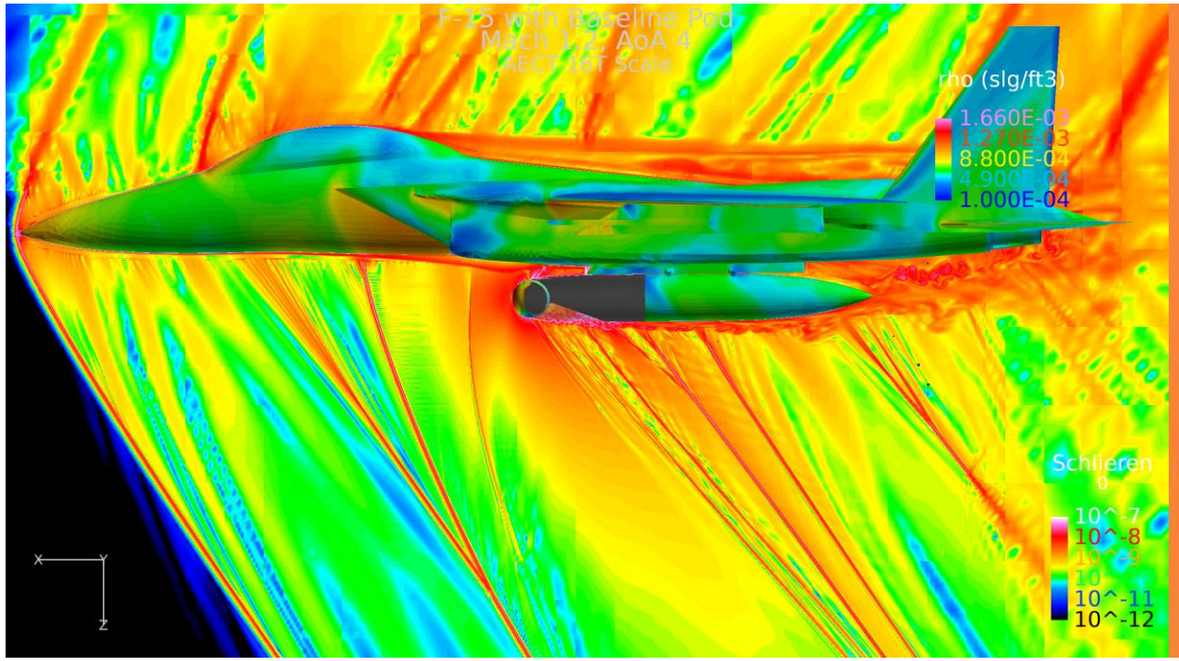


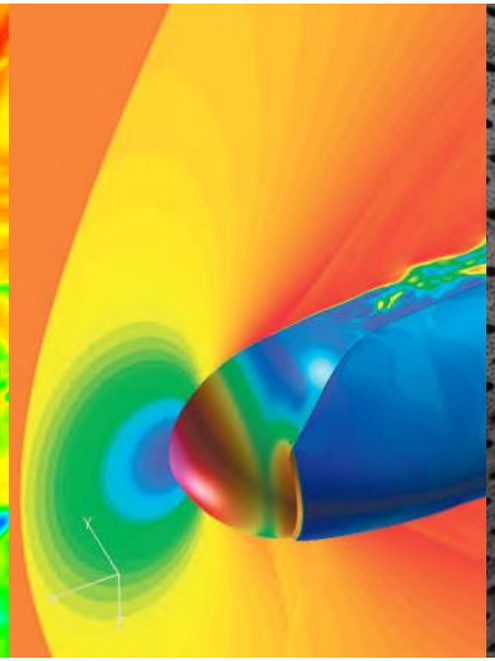
More Power on Target

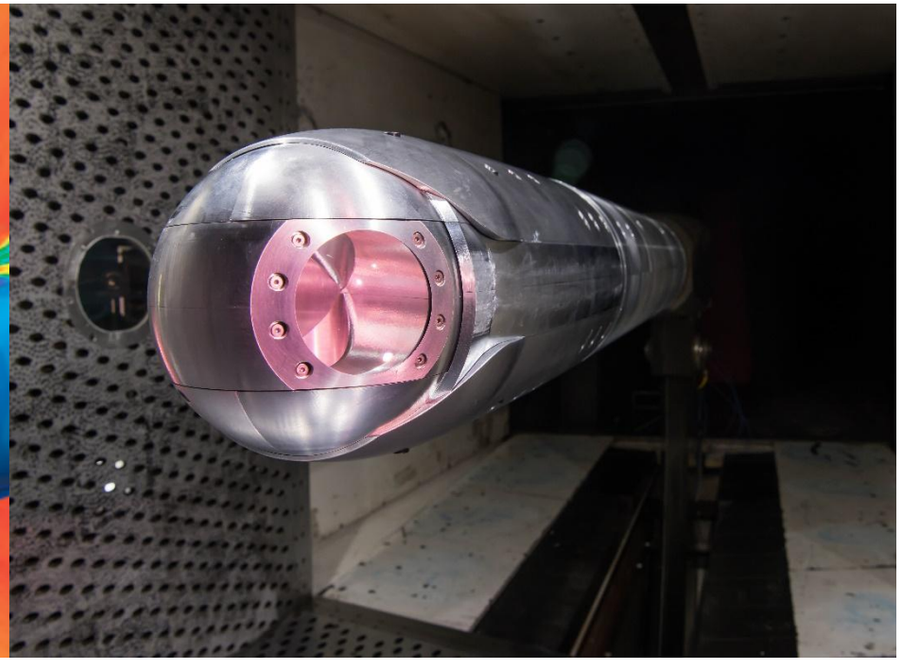


Aero-Effects CFD and Wind Tunnel Testing

- MZA has worked with AEDC and DARPA to analyze the effects associated with transonic and supersonic flow around HELWS turrets.
- The goal is to understand the aero-effects disturbances and to develop techniques to mitigate their effects on HELWS systems.







https://www.arnold.af.mil/News/Article-Display/Article/2715543/aedc-tests-directed-energy-system-in-wind-tunnel/

Compact Beam Control Systems

MZA added innovative engineering to our modeling and analysis expertise to advance the goal of building more compact and deployable beam control systems.

Othela

Optimized Tactical High Energy Laser Architecture

Addressing a high priority need identified by the Air Force Research Laboratory, MZA undertook the challenge to develop lightweight compact beam directors for high power laser applications.

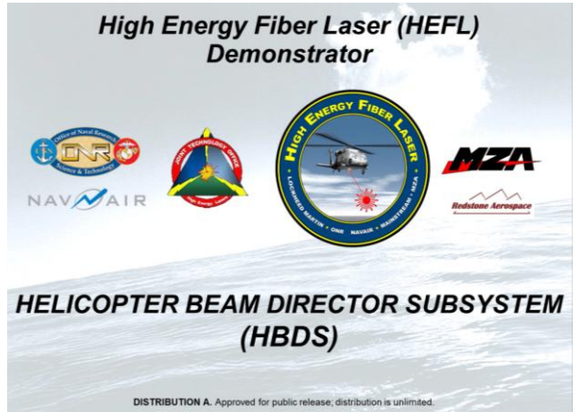
The result has been the development of MZA's Othela line of beam directors that utilize the latest technologies in opto-mechanical materials, gimbals, optical coatings, and sensors to reduce the number of high power optics in order to institute on-gimbal beam control concepts.

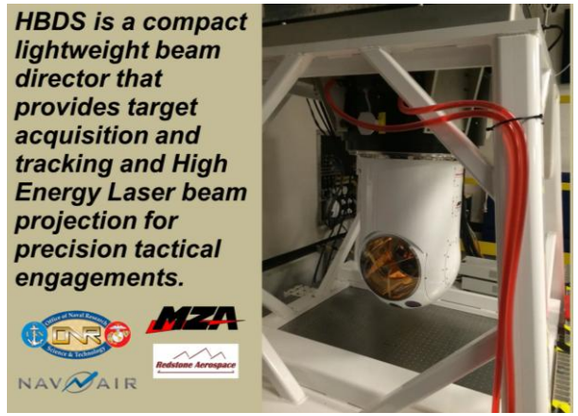
- **Integrated on-gimbal beam control systems.**
- **Line-of-site stabilization and wave front compensation.**
- **< 1 cubic meter in volume**
- **< 500 lbs.**
- **Designed for high power laser applications.**
- **On-axis and off-axis telescope designs.**

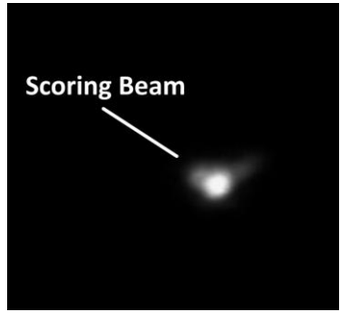
High Energy Fiber Laser (HEFL)
Helicopter Beam Director System (HBDS)

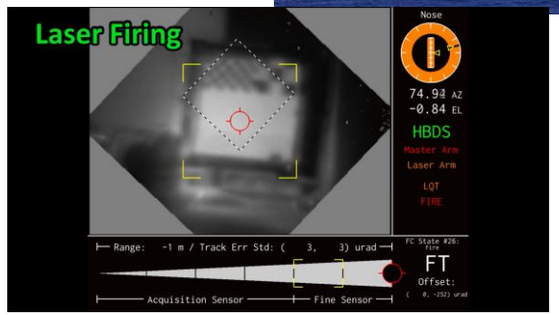
See the video at: https://www.youtube.com/watch?v=Bqc4YCVcJ9g&feature=youtu.be

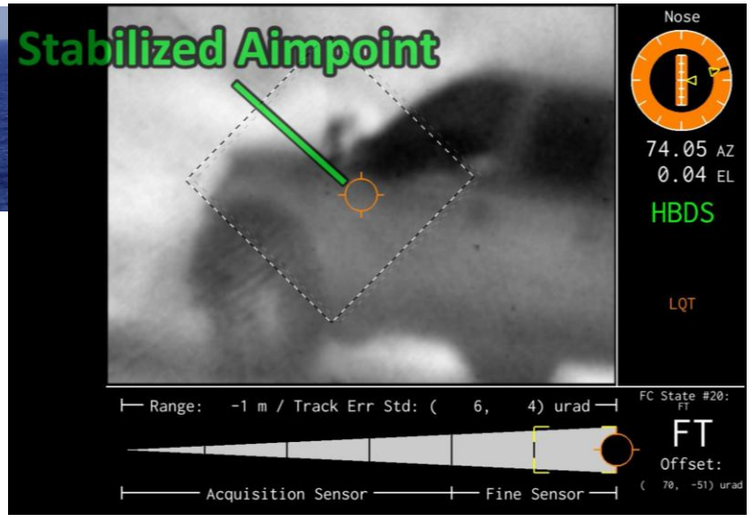
MZA customized Othela to create the most compact lightweight airborne HEL beam control system ever built.







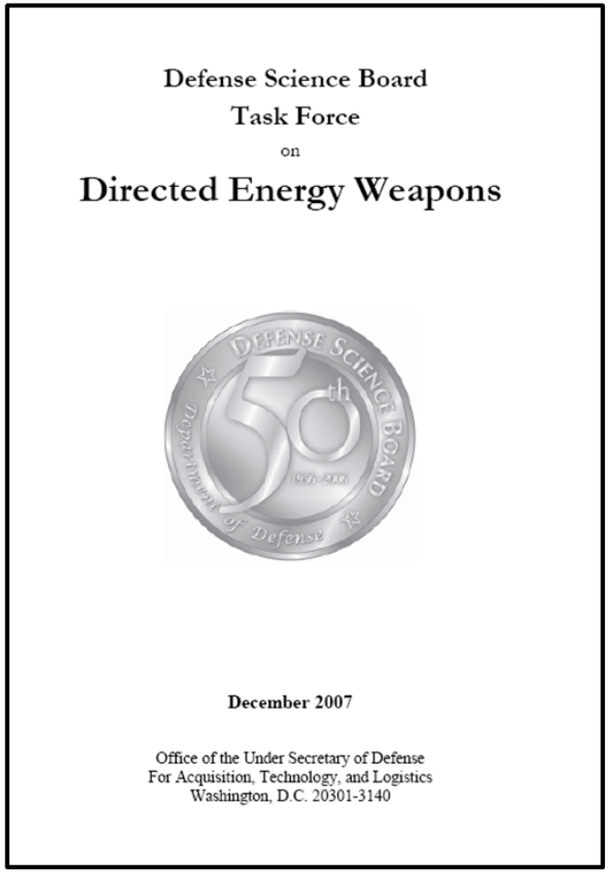




https://www.youtube.com/watch?v=Bqc4YCVcJ9g&feature=youtu.be

Expanding the Industrial Base for HELWS

In 2007, the US Defense Science Board (DSB) recognized that there were very limited options to meet the adaptive optics needs of the HELWS industry.



Defense Science Board
Task Force
on
Directed Energy Weapons

December 2007

Office of the Under Secretary of Defense
For Acquisition, Technology, and Logistics
Washington, D.C. 20301-3140

- The lack of directed energy production programs or the serious prospect of significant production programs has jeopardized the supporting industrial base. There is essentially one U.S. vendor capable of supplying deformable mirrors.
  - *The Deputy Secretary of Defense should direct the military departments to provide overall vision and strategic plans for developing relevant directed energy capabilities that can provide visibility into the likely future business case for sustaining directed energy industry capabilities.*
- The nation's technical capabilities in HEL components and sub-systems are thin and have, in some cases, atrophied. The situation in large high-power optics and beam control is particularly fragile depending on a single vendor at best.

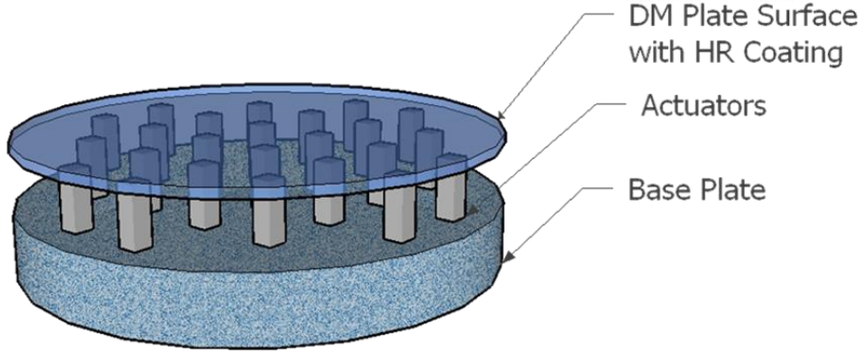
  USD (AT&L) should direct a survey of laser component capability and produce a plan for sustaining access to the required capability.

MZA and AOS have stepped up to this challenge. We are now the second US provider of high power deformable mirrors. We have also significantly improved the state-of-the-art in beam control systems engineering.

High Power Deformable Mirrors

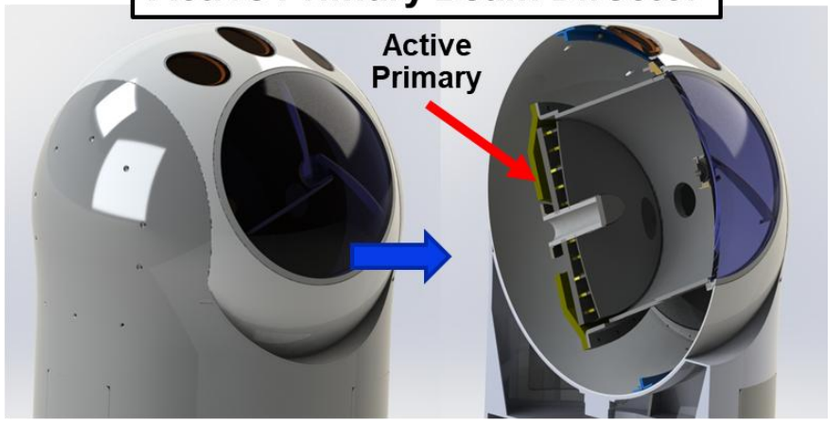
MZA became the world's second commercial provider of high-power deformable mirrors...

- 100 kW average power for up to 5 seconds over a 6 cm^2 area with < 1 deg. C temperature increase.
- Tested up to 250 kW CW.
- Rapid fabrication possible.
- More than 50 high power DMs delivered

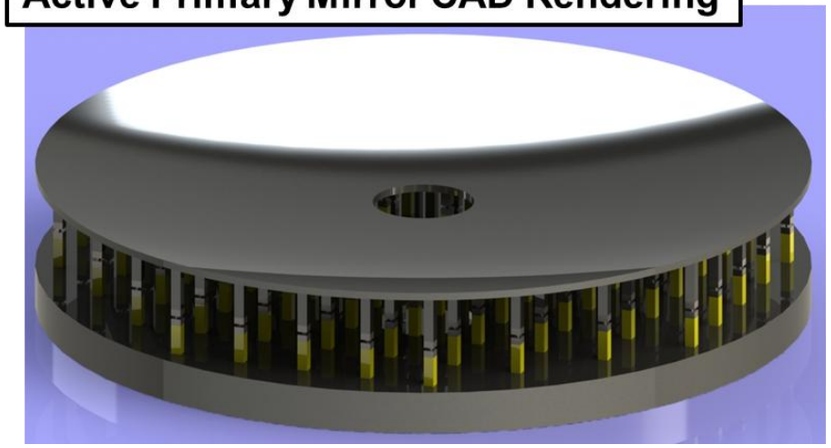


...and innovated even more.

Active Primary Beam Director



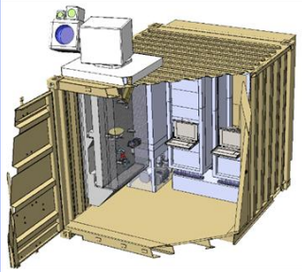
Active Primary Mirror CAD Rendering



MZA HELWS Beam Control Technology Transition to Military Systems

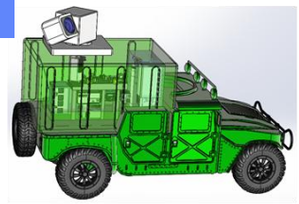
HELWS Concepts

Near-Term Deployable Low Cost C-UAS

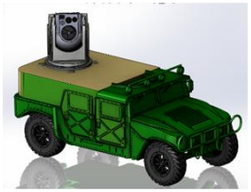


20 cm Class Apertures 3-10 kW applicable to C-UAS Missions

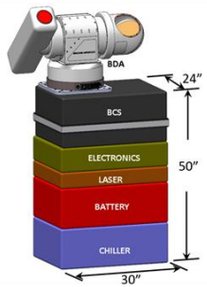
Near-Term Portable Low Cost C-UAS



Near-Term On-the-Move C-UAS



Small SWaP Modular On-the-Move C-UAS



< 1000 lbs suitable for numerous military vehicles

Scalable HELWS Architectures to address C-UAS and C-RAM for Ground, Maritime, and Flight Environments

50 cm Aperture 60-120 kW HEL

23 cm Aperture 28 kW HEL

30 cm Aperture 60-120 kW HEL

Future Objective Airborne HELWS

Rotary Wing HELWS Pod Architectures

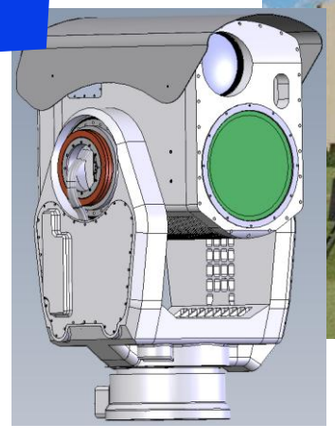
23cm / 28kW Helicopter Beam Director Subsystem

28kW High Energy Fiber Laser System

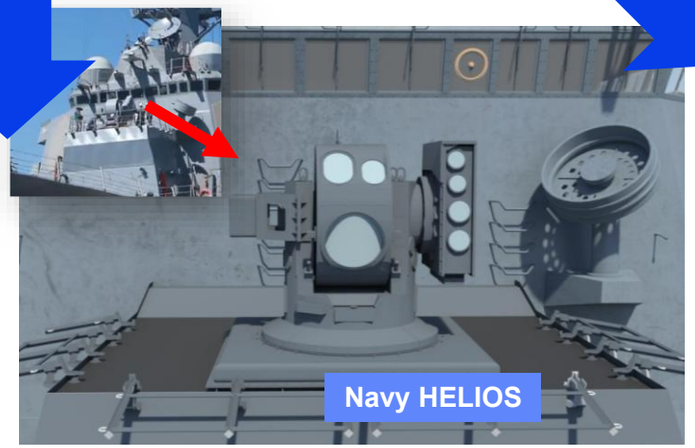
Navy/AFSOC AHEL

Army Valkyrie

Navy counter-UAS Scalable Beam Director



Navy ODIN



Navy HELIOS

MZA Developed the Beam Control System for HELIOS which is aboard the USS Preble

Image captures US Navy testing its new laser weapon: What to know about HELIOS

Eric Lagatta
USA TODAY

Published 9:26 a.m. ET Feb. 5, 2025 | **Updated 10:31 a.m. ET Feb. 5, 2025**

An incredible image buried deep in an annual military report released last month shows the U.S. Navy test-firing a high-powered laser weapon at a drone target from one of its warships.

The photo of the laser weapon in action was published in in January as part of a 2024 report released by the Office of the Director, Operational Test & Evaluation, which advises the Department of Defense on weapons systems.

The undated image shows the U.S. Navy testing a weapon system known as HELIOS from the USS Preble destroyer in the middle of the ocean. The demo was “to verify and validate the functionality, performance, and capability" of the laser weapon against an uncrewed aerial vehicle target, the report stated.

This undated image, published this month in the US Center for Countermeasures' annual report, shows warfighting laser technology being test-fired from the USS Preble destroyer in the middle of the ocean. *Department Of Defense*

What is the HELIOS weapon? The High Energy Laser and Integrated Optical Dazzler and Surveillance (HELIOS) is a weapon system developed by Lockheed Martin capable of engaging targets at the speed of light.

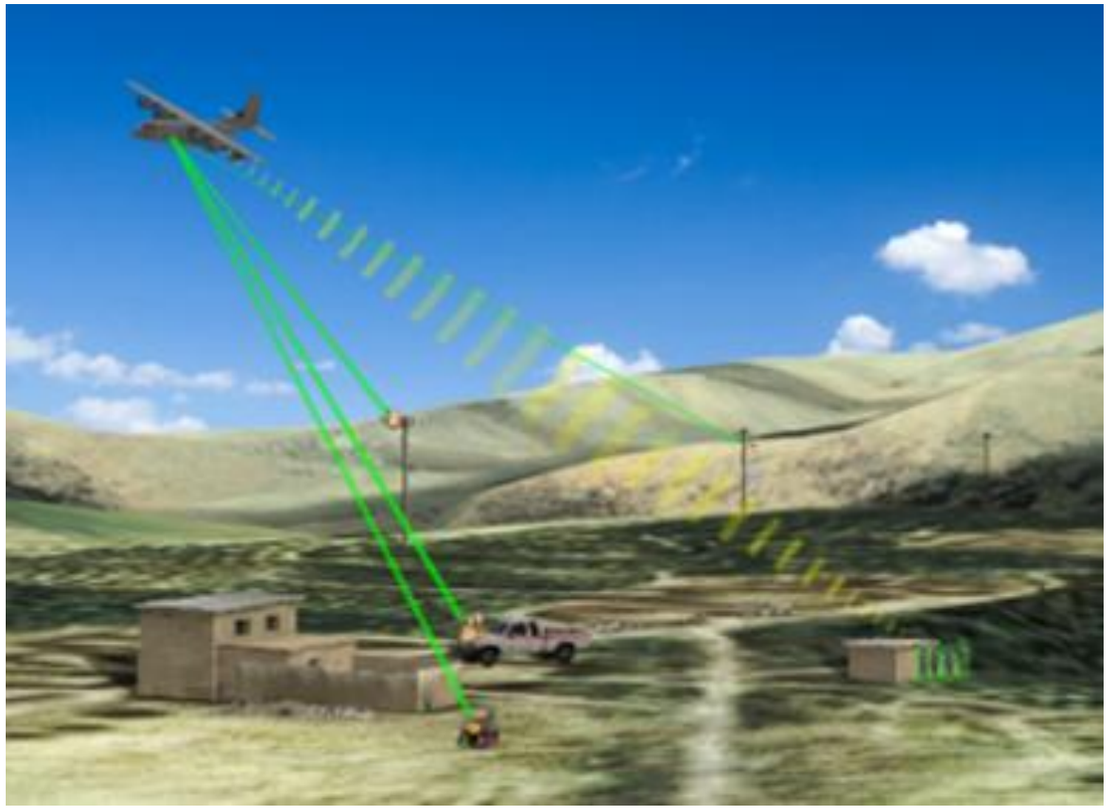
The system can destroy drones, watercraft and missiles by either melting or overheating them. The weapon not only can use a high-energy laser to destroy targets, but is designed to disrupt intelligence-gathering efforts and reconnaissance sensors from adversaries.

The Navy plans to continue testing HELIOS from the Preble, according to Naval News who first reported on the test. According to the annual report, the Department of Defense would also require new specialized test and training ranges to continue testing HELIOS.

- **See article at:** https://www.usatoday.com/story/news/nation/2025/02/05/us-navy-helios-laser-weapon-warship/78239697007/

Airborne High Energy Laser (AHEL)

- **MZA developed the beam control system for the Airborne High Energy Laser (AHEL), an integrated HELWS designed for the AC-130J Airborne Gunship.**

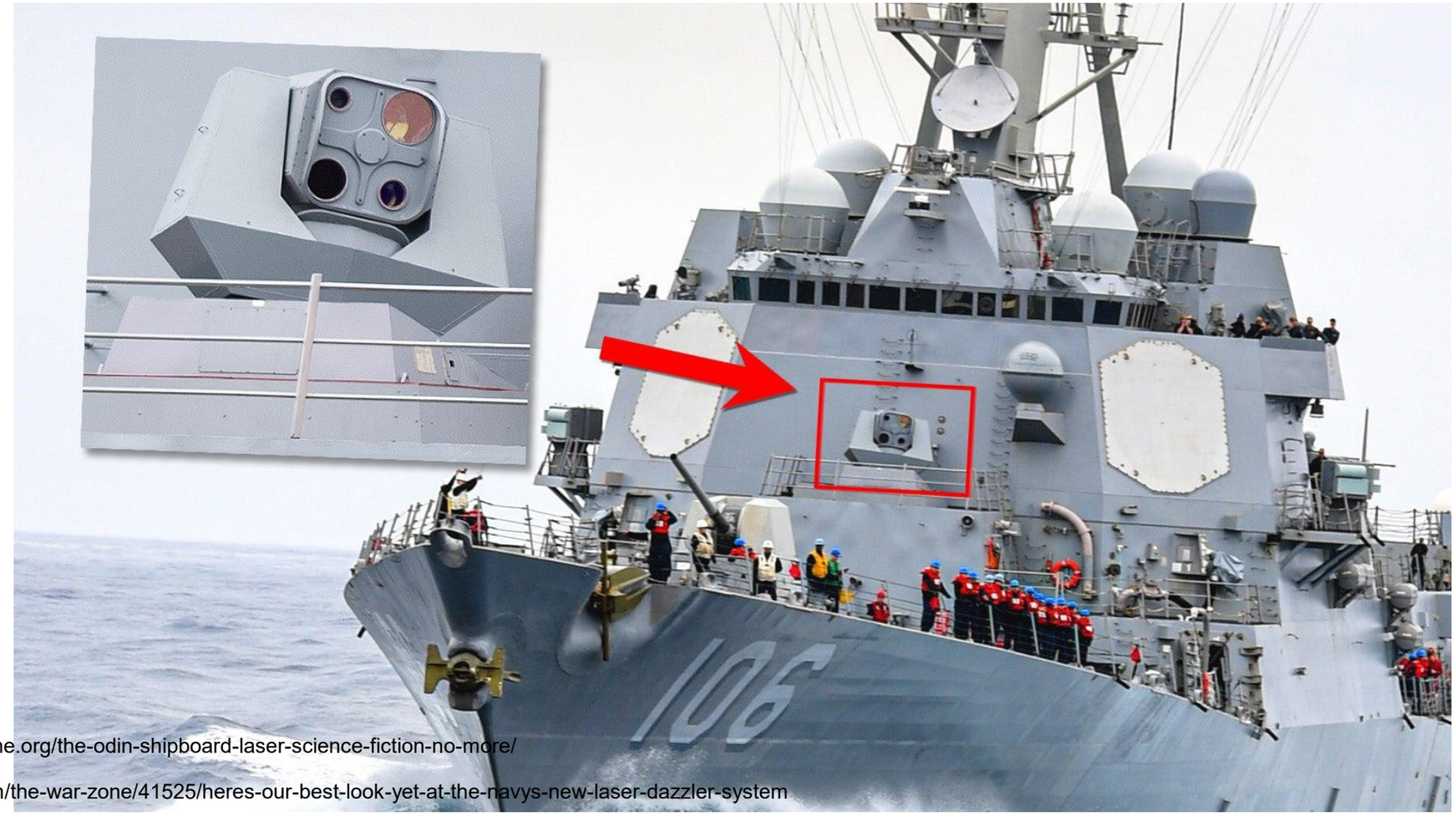


https://www.thedrive.com/the-war-zone/42673/the-ac-130j-gunships-first-solid-state-laser-weapon-has-arrived-for-testing

https://news.lockheedmartin.com/2021-10-07-Lockheed-Martin-Delivers-High-Energy-Laser-to-US-Air-Force-for-Flight-Testing-on-AC-130J-Aircraft

Optical Dazzling Interdictor, Navy (ODIN)

- **MZA helped to design and build the line-of-sight stabilization system for ODIN, and optical dazzler now placed on multiple US Navy vessels.**



https://seapowermagazine.org/the-odin-shipboard-laser-science-fiction-no-more/

https://www.thedrive.com/the-war-zone/41525/heres-our-best-look-yet-at-the-navys-new-laser-dazzler-system

https://www.youtube.com/watch?v=vDLSpRxKhMI

MZA Beam Control Products

- **Adaptive Optics**
  - High-Power Deformable Mirrors
  - High-Speed Shack-Hartmann Wavefront Sensors (WFS)
- **Line-of-Sight (LOS) Stabilization**
  - High-Power Fast Steering Mirrors (FSMs)
  - Alignment controllers
  - Inertially-stabilized alignment beams
- **Acquisition Tracking and Pointing (ATP)**
  - Visible, SWIR, and MWIR imaging systems
  - Automatic detection algorithms
  - Coarse tracking algorithms
  - Fine tracking algorithms
  - Aimpoint maintenance algorithms
  - Illuminator pointing
  - Laser range finder control
- **High Power Beamtrain Safety & Inspection**
  - Integrated visible, SWIR, and HWAS sensors.
- **Fire Control Systems**
  - Target cueing and beam director slew
  - Coordination of LOS Stabilizaton
  - Hand-over to optical tracking
  - Hard-Wired Abort Systems (HWAS)
- **Emerging Products**
  - Large high-power telescope optics
  - Large shared-aperture high-power beam directors

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