The CAO has enjoyed a rich history of optical and opto-mechanical design and fabrication since its inception. We have developed NASA flight hardware, refurbished military hardware and supported return to flight. And we have been involved in some of the most interesting and rewarding projects.

Here is a sample of some of our recent collaborative efforts.
GiGA pixel camera
Current System: Flight Test in Springfield, IL

Six inch resolution
The NASA X-Ray Calibration Facility (XRCF)

For UAH testing of the JWST

Modified to test JWST mirror segments.
JWST SBMD/NMSD Testing

Cryogenic testing led, conducted and analyzed by CAO.
WAVE: Response to Columbia Accident Investigation Board

A Collaboration with NASA MSFC to design and build a telescope on a mobile platform to observe the Shuttle launch as never seen before.
Laser – Powered Flight

A collaboration of UAH, NASA to demonstrate wireless transmission of power

the first ever flight

powered solely by laser power.

Potential use:
- 100Kft cell phone “floating tower”
- Short range areal survey
Adaptive Optics

Assisted National Solar Observatory (NSO)

with the analysis and testing of adaptive optics (AO) and of multi-conjugate adaptive optics (MCAO) for the Advanced Technology Solar Telescope (ATST).
ATST Triple Fabry-Pérot Étalon Tunable Filter

Zemax lens design of optics supporting triple F-P in telecentric mounting configuration.

Evolutionary algorithm developed at CAO for optimization of triple etalon system.
Thin Disk Laser
Technology licensed by inventor Dr. Adolf Giesen

A collaboration of UAH and NASA to design, analyze, fabricate and assemble working TDL

First group in US to achieve lasing. System transferred to CAO for student research. We have hosted three teams of Mechanical Engineering students.
Automatic Target Recognition Technology

- Target scene searching
- Region of interest tracking
- Low latency target tracking (ms)
- Real time aim point selection
- Target-relative Shift invariance
- Range and rotation invariants built into optical filters
- Range relative accuracy increase
A first FTL creates the spectrum of the input scene (P1) at P2, 
FTL1\{g\} => G
A matched filter, H, is placed in plane P2
A second FTL creates the FT of the product of the matched filter 
and the FT of the input scene.
\[ P3 = \text{FTL2}\{G \times H\} \]
Cross correlation of g and h
If \( G^* = H \), the result is a bright correlation peak which moves 
with the motion of the input.
OPTICAL CLASSIFICATION / IDENTIFICATION PROCESSING PARADIGM

Application example

- INPUT TO SLM
- FLASH IMAGE FFT
- OSP
- FILTERING
- HAZARD CORRELATION AND TRACKING
- SAFE ZONE
- CMDR VIDEO OVERLAY

Lidar Scan

3D Map

landing site flash image

NANO SECONDS

UAHuntsville

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE
OPTICAL MODELING
CRITICAL COMPONENTS OF OPTICAL DESIGN/MODELING/FABRICATION

AN EFFECTIVE OPTICAL DESIGN HAS TO:

- Efficiently use desired science performance requirements
- Establish system level optical specifications from those requirements
- Optimize optical system designs
- Develop optical element alignment and fabrication tolerances
- Fiducialize reference surfaces for ease of alignment
- Account for heat loading of optics in the system
- Validate models with hardware experiments
- Verify opto-mechanical constraints for fabrication
- Develop ergonomic cost effective mechanical structures for optics

The UAH THIN DISK LASER IS A GOOD EXAMPLE OF OUR OPTICAL MODELING

DIODE ARRAY REDIRECTION
- Control of the beam parameter product
- Efficient homogenizer tube launch
- Monitor irradiance at optical element surfaces

OPTICAL PUMP CAVITY
- Complex set of turning mirrors
- Delacite alignment to parabola
- Parabola to disk BPP requirements
THE TDL IS A VERY COMPLEX LASER DESIGN

THE TDL HAS NUMEROUS TOLERANCING ISSUES

MODELING ACHIEVED WITH PHOTON ENGINEERING’S FRED
- NON SEQUENTIAL MODEL
- RIGEROUS, NOT A RAY TRACE PROGRAM

MODEL VALIDATED AS BUILT LASER

ANCHORED MODEL WAS USED FOR TOLERANCE STUDIES

LASER BUILT AND PERFORMED AS PREDICTED

TDL Bench unit designed to:
Anchor models
Establish requirements and tolerances
Scale the output power
Flight Qualification issues
DIODE ARRAY DESIGN AND MODELING
-REDUCING FACTORY BPP

COMPLEX OPTICAL PROBLEM:
• BPP TOO BIG FOR LASER
• HOW TO BEST MEET REQUIREMENT

Total power = 286W
\( \lambda = 940 \text{ nm} \)
425.5 mm*mrad
Need 232mm*mrad

BPP = 425.5
Array Bar
Array = 7 Bars
251 Watts max

Single emitter

\( \phi = 3 \text{ mm} \)
\( \alpha = 70 \text{ mrad} \)

BPP = 212.8
Dense array

Design results
\( \phi \alpha = 212.8 \)

\( f = 3 \text{ mm} \)
\( a = 70 \text{ mrad} \)
\( f \alpha = 212.8 \)

Total power = 286W

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\( f \alpha = 212.8 \)
TOLERANCING AND ANCHORING OPTICAL DESIGN MODELS

- Measured DIODE RESHAPING
- ENABLES:
  - REFINED OPTICAL TOLERANCING
  - BROAD BAND COATING DESIGN
  - SCALABILITY STUDIES
  - PERFORMANCE PREDICTIONS
  - OPTICAL COMPONENTS
  - MULTIPLE DIODE ARRAYS
  - OPTICAL INTENSITY LOADING
  - IGS FORMATING FOR CAD
  - THERMAL LOADING ESTIMATES
  - STRAY LIGHT

- PUMP CAVITY MISALIGNMENT

DIODE RESHAPING
## Select Programs Worked on by Current CAO Staff

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<tr>
<td>Orbiting Wide-Angle Fresnel Lens</td>
<td>IR Detector Development/Modeling</td>
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The Spectacle Lens Image Mapper

• The Issue: Optical quality assessment methods have not kept pace with the increasing complexity of Progressive Addition Lenses (PALs).
• The Need: Objective measure of PAL image quality over the entire usable aperture of the lens.
• CAO developed & patented the Spectacle Lens Image Mapper for Johnson & Johnson Vision Products.

- Direct optical measurements on lenses.
- Mimics wearer geometry.
- Measures PSF at best-focus using high-resolution CCD.
- Fourier transforms PSF to MTF.
- Predicts lens-limited visual acuity.
- Also measures power, cylinder, & prism.
- Automatic test produces data over full aperture of lens.
The Steerable Laser Projector

CAO, working for Aegis Research, performed all optical & mechanical design (excluding WISP & WISP collimator) for this KHILS IR projector (Eglin AFB).
EOA AN/PSM-80 Collimator

Pentastar Electronics, Inc. - Collimator Development

- Materials selection by CAO
  - Light weight – 1 man portable
  - Versatile – 45 calibrations of 18 systems
  - Rugged – 365 day cal cycle
- Aluminum – Silicon (Vanasil)
  - High elastic strength
  - Low density
  - Machinable
  - Thermally stable fielded design
  - Low cost, non-toxic Be substitute
  - Prototype, process development by CAO
- Manufacturing process development
  - Optical – mechanical design of collimator
  - Precision casting process
  - Thermal treatment cycles
  - Coating process and surface preparation
- Unit still in production
Materials and Device Modeling

- Infrared Detectors--Parametric Modeling/Figures of Merit
  - Photoconductive
  - Photovoltaic
  - Blocked Impurity Band
- HgCdTe Heterojunctions/Detectors
- Multiple Quantum Well Detectors
- Electronic & Optical Properties of Quantum Confined Structure
- Electronic & Thermal Transport in Semiconductor Alloys
- Optical Waveguides
Significant Strategic Sensor Work

• AST Replacement Study

• MSX
  – Co-PI 1990 to 2001
  – Tech-transfer to MDA programs

• POST Calibration Chamber
  – Design, fabrication, test, & optical modifications
  – Calibration traced to NIST

• HALO - IRIS
  – Sensor performance tests
Optical Wide-angle Lens (OWL)

Instrument and large Fresnel optics developed at CAO along with the Physics department.

Earth-Viewing Satellite for the Highest Energy Cosmic Particles

OWL’s view area: ~1000 - 6000 km²

Wide-angle Fresnel Optics: FOV ~ 60° / unit to cover ~120° x 360°

Observable Energy Range: $10^{19} \leq E \leq 10^{22} + \text{eV}, \sim 10^3 - 4$

Nuclei per year greater than $10^{20} \text{eV}$

Angular resolution ~ 0.1°

Identify Topological Defects and/or Gamma Ray Bursts.

Watches earth’s night sky for air shower-flashes caused by energetic cosmic rays.

Led to the EUSO designs

Anticipate metrology work from EUSO
NASA Imaging X-ray Optics

Manufacturing R & D

- AXAF-S, SXI, HERO, Constellation X
- Replicated optics by electro-chemical processes
- Performance requires innovative materials
  - 3 – 4 Å finish
  - High quality figure
  - Low weight
  - Ultra-high elasticity
  - Low residual stress
- Nickel alloy development
  - Fine grain structure nickel
  - Nickel cobalt
  - Nickel cobalt phosphorous
- Electromechanical developments
  - Low stress replicated optics
  - High elastic strength alloys developed
Total Integrated Scatter Instrument

Part of the Optical Properties Monitor experiment. Flew on exterior of MIR from Apr 29 to Dec 26, 1997. Measured space environmental effects on various materials as a function of exposure time.
Support of NASA’s James Webb Space Telescope

- CAO led telescope optical design for pre-Phase A study & supports continuing optical design analyses.
- CAO supported alignment & phasing studies for segmented apertures using MSFC’s PAMELA test-bed.
- CAO led opto-mechanical modeling & analysis of one advanced mirror concept.
- CAO led optical testing of JWST technology-development mirrors at Marshall’s X-Ray & Cryogenic Facility (XRCF).
- CAO currently supporting preparations for testing flight PM segments at XRCF.
Cryogenic Large Optic Testing:

- Several large (0.5-2 m), lightweight (<15 kg/m²) mirror technology programs conducted. Vendors included Ball, Kodak, Goodrich, COI, & U of AZ.
- Materials: SiO₂, ULE, Be, SiC, Composite.
- XRCF at MSFC upgraded for optical testing of meter-class mirrors at cryo-temperatures (to 20 K).
- CAO led modification of facility.
- Main chamber is 7 m x 23 m. Also 1 m x 2 m chamber.
- CAO led optical testing of the mirrors.
- Instrumentation: Shack-Hartmann sensor, 2 instantaneous phase-shifting interferometers, diffractive nulls, 6-DOF hexapod, & 2 absolute distance meters.