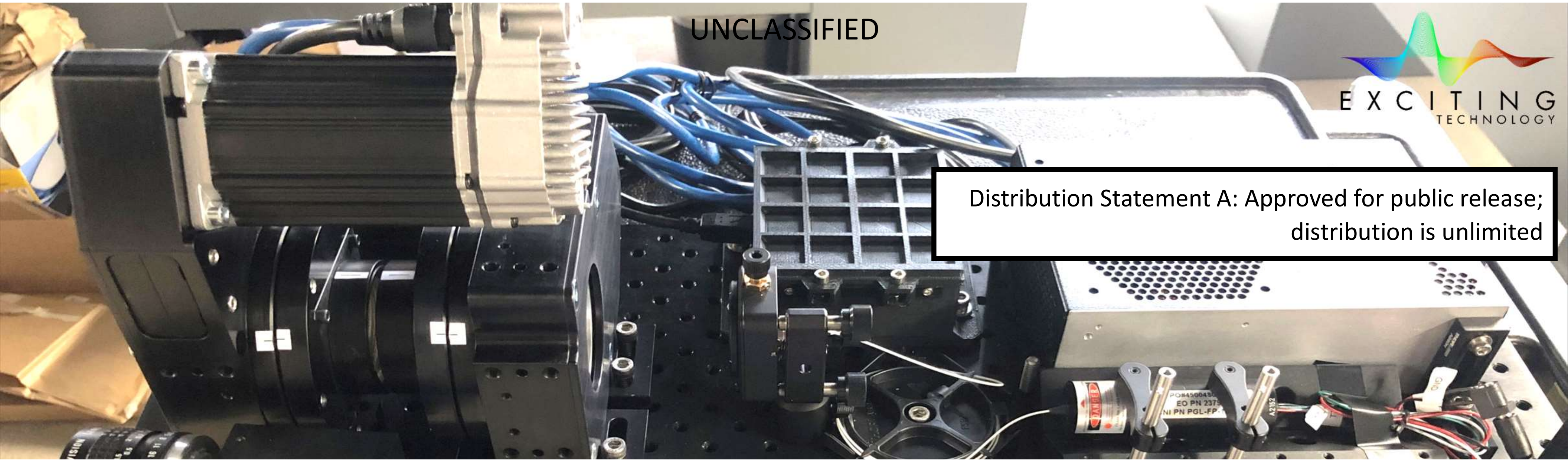

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Development of a beam steering device for LiDAR-based spacecraft hazard avoidance and landing missions

Presented by: **Anna Gnacek**
Dr. Paul McManamon, Eddie Ruff, Alexander Cain, and Dr. Farzin Amzajerdian

Military Sensing Symposium, Active EO Systems
Advanced Systems and Technologies
May 16th, 2024

Overview

6-month NASA SBIR program to design and build a beam steering demonstration to be used for lunar landing missions and investigate the optical path to space ruggedization.

Topics

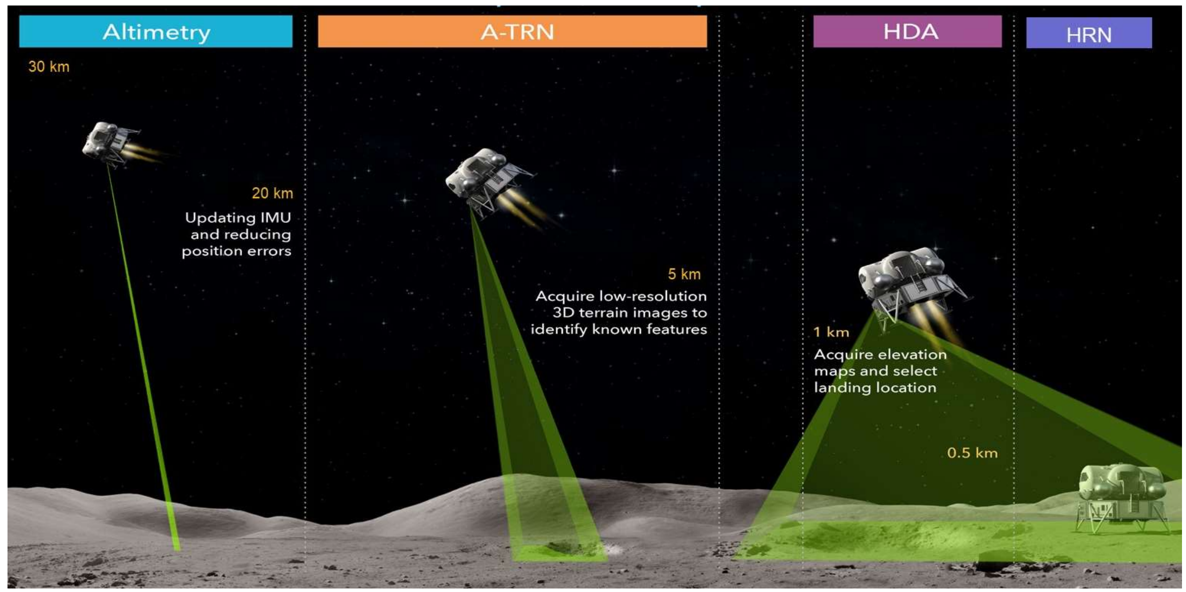
- Space Application
- Beam Steering Technologies
- Optical Design
- Breadboard Build and Preliminary Results
- Military Applications

Space Application: Flash LiDAR

NASA LaRC Multifunction Flash LiDAR System for Lunar Landings

- High-resolution surface elevation maps

Decent and Landing Phases



Active during decent and landing phases:

- Altimetry
- Terrain Relative Navigation (TRN)
- Hazard detection and avoidance (HDA)
- Hazard Relative Navigation (HRN)

Space Application: Flash LiDAR

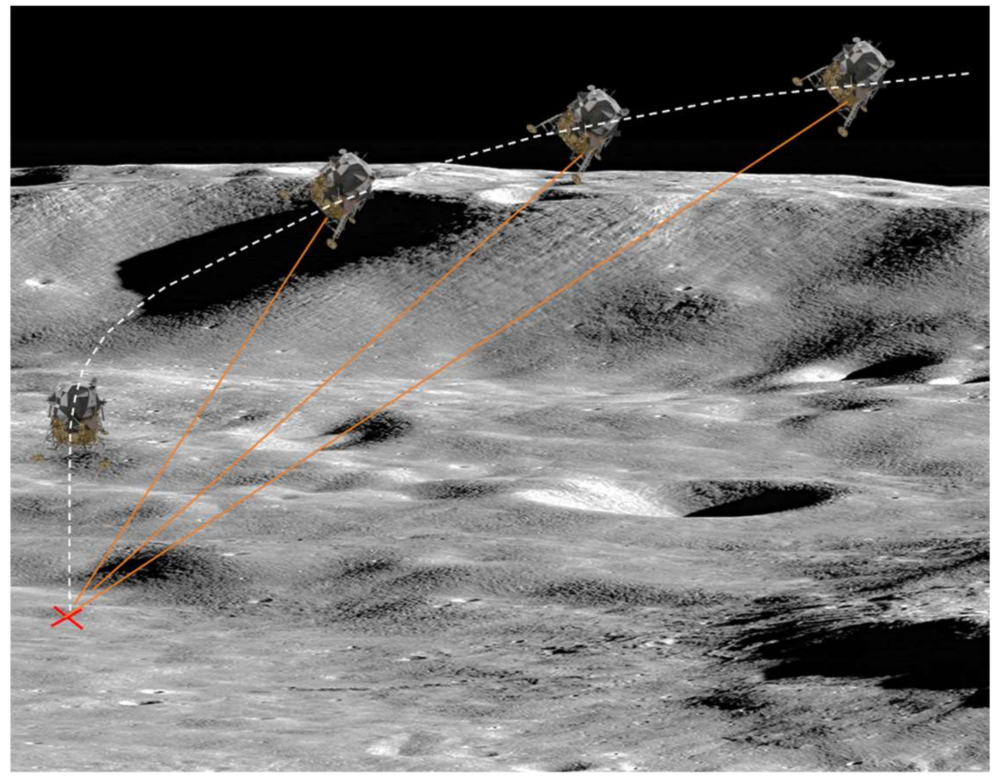
During decent, NASA uses super resolution techniques to:

- Endure platform vibrations
- Eliminate the need for very high precision pointing.

Remaining Beam Steering Needs (HDA)

- Vehicle attitude changes, >10° FoR
- Steering speeds accommodate FR
- Path to space qualification
- Keep 5cm-7.5cm aperture
- Minimal footprint

HDA Phase to HRN Phase



Beam Steering Technology

Mechanical Examples

- Gimbals
- Risley Prisms
- Fast Steering Mirrors
- Mirrored Galvanometer
- Mirrored Polygons
- Lenslet Arrays
- MEMS

Non-Mechanical Examples

- Liquid Crystals
- Optical Phased Arrays
- Polarization Gratings

Beam Steering Needs

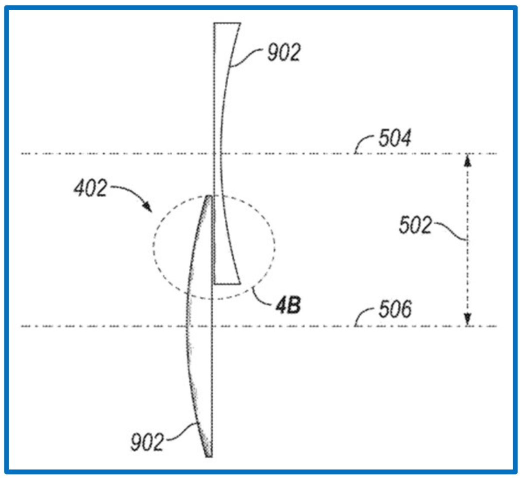
- Wide angle steering without large physical footprint
- Improved functionality, performance, and C-SWaP compared to existing technology
- Integrate with existing Flash Lidar system
- Reliable in space

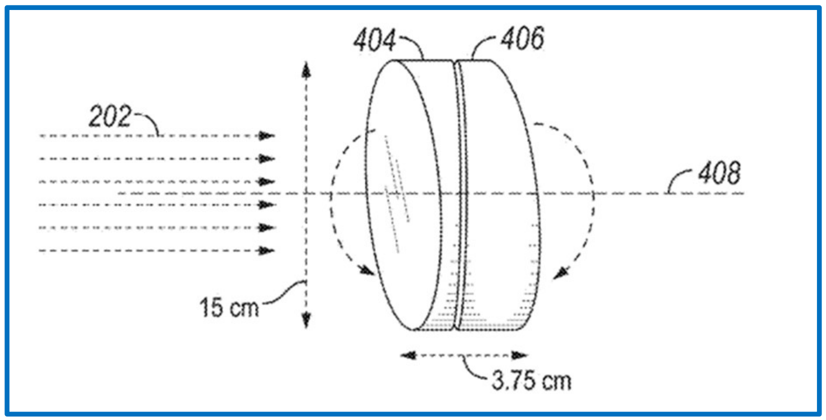
Optical Design

Combines optical principles of <u>decentered lenses </u>and mechanical principles of <u>rotating wedge prisms</u>.

(1) Lens segments cut from the decenter lens pair

(2) Lens segments rotated independently to change relative displacement of the two lenses





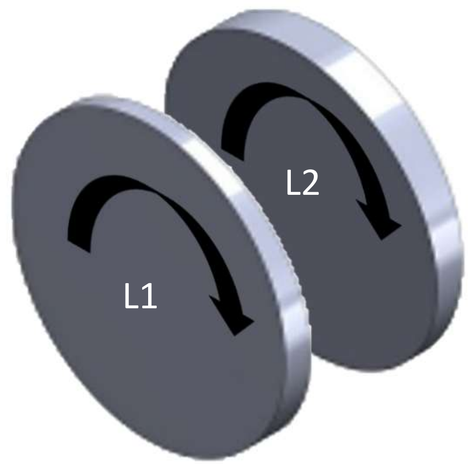
U.S. Patent Nov. 21, 2023 Sheet 4 of 38 US 11,822,205 B2

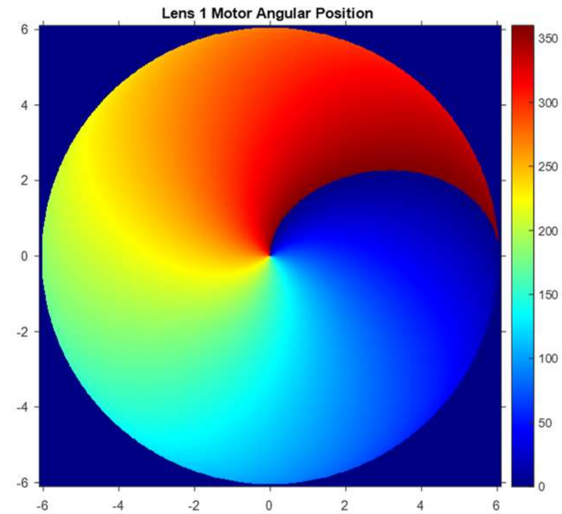
We see light is deflected and expanded simultaneously

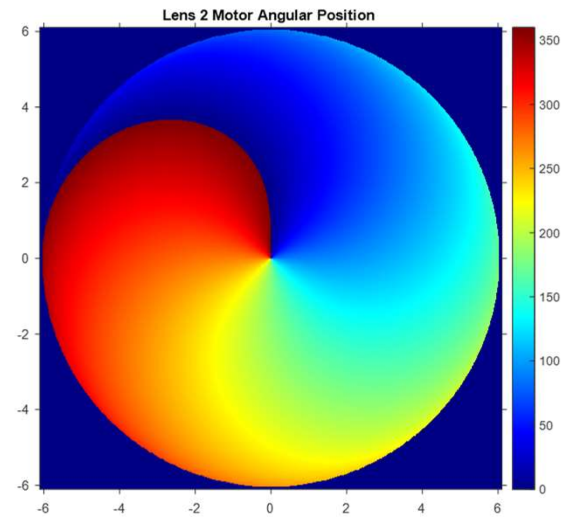
Optical Design

- Steering from relative angular positions of L1 and L2.
- All steering positions within ±6° in Az and El
- Only 12° FoR, but design potential much wider

Optical Specification	
Input Type	Fiber
AR Coating Wavelength	1.060µm
Field of Regard	±6.05°
Exit Aperture Diameter	50mm
Beam Divergence	~30mrad
Diffraction Limit	21.2 µrad
Mechanical Specifications	
Rotary Accuracy	327 µrad
Rotary Repeatability	174 µrad
Rotary Max Speed	1,300 rpm
Dimensions (w/o fiber)	7.2"x 7.2" x5"



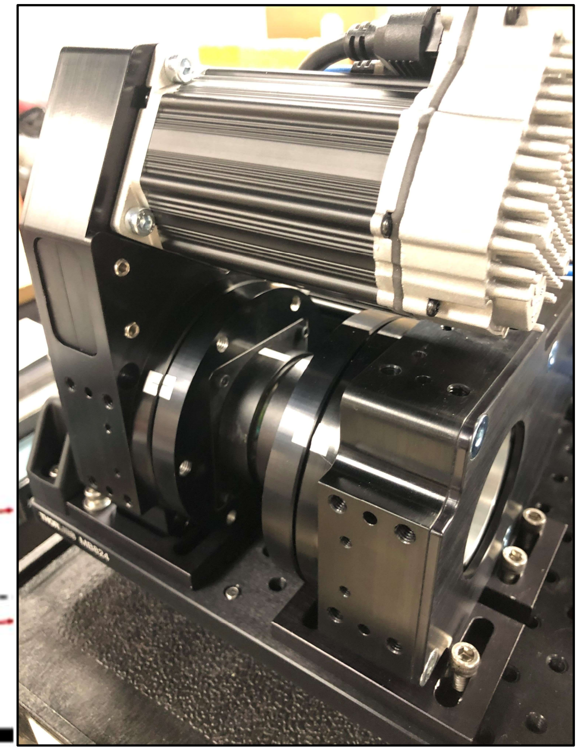




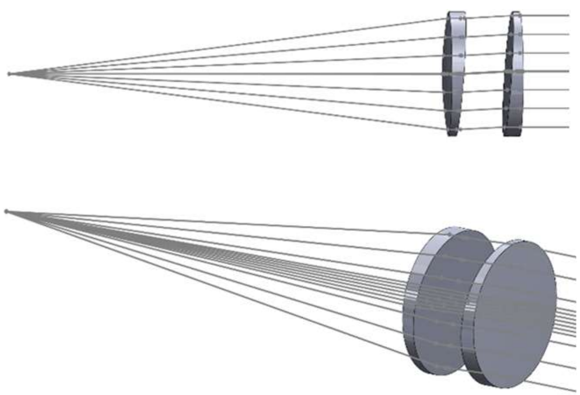
Opto-mechanical Design

- Only require two lenses to meet specifications
- Lens are small, but stages are large due to availability

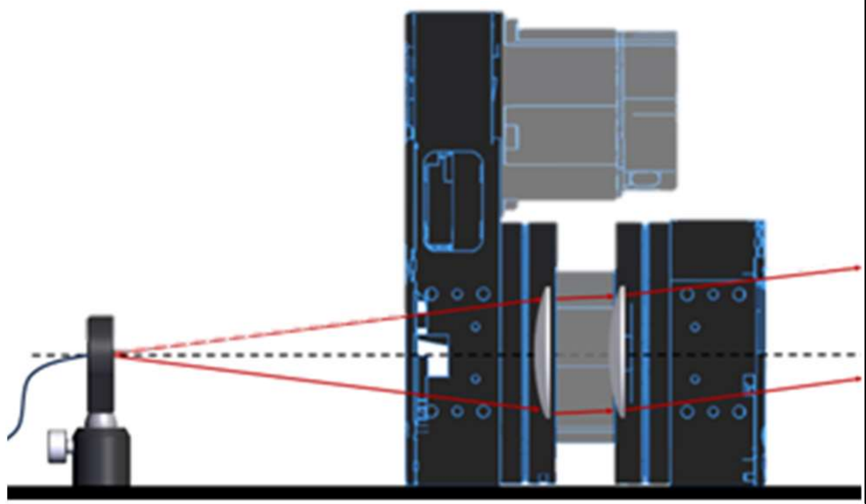
Build



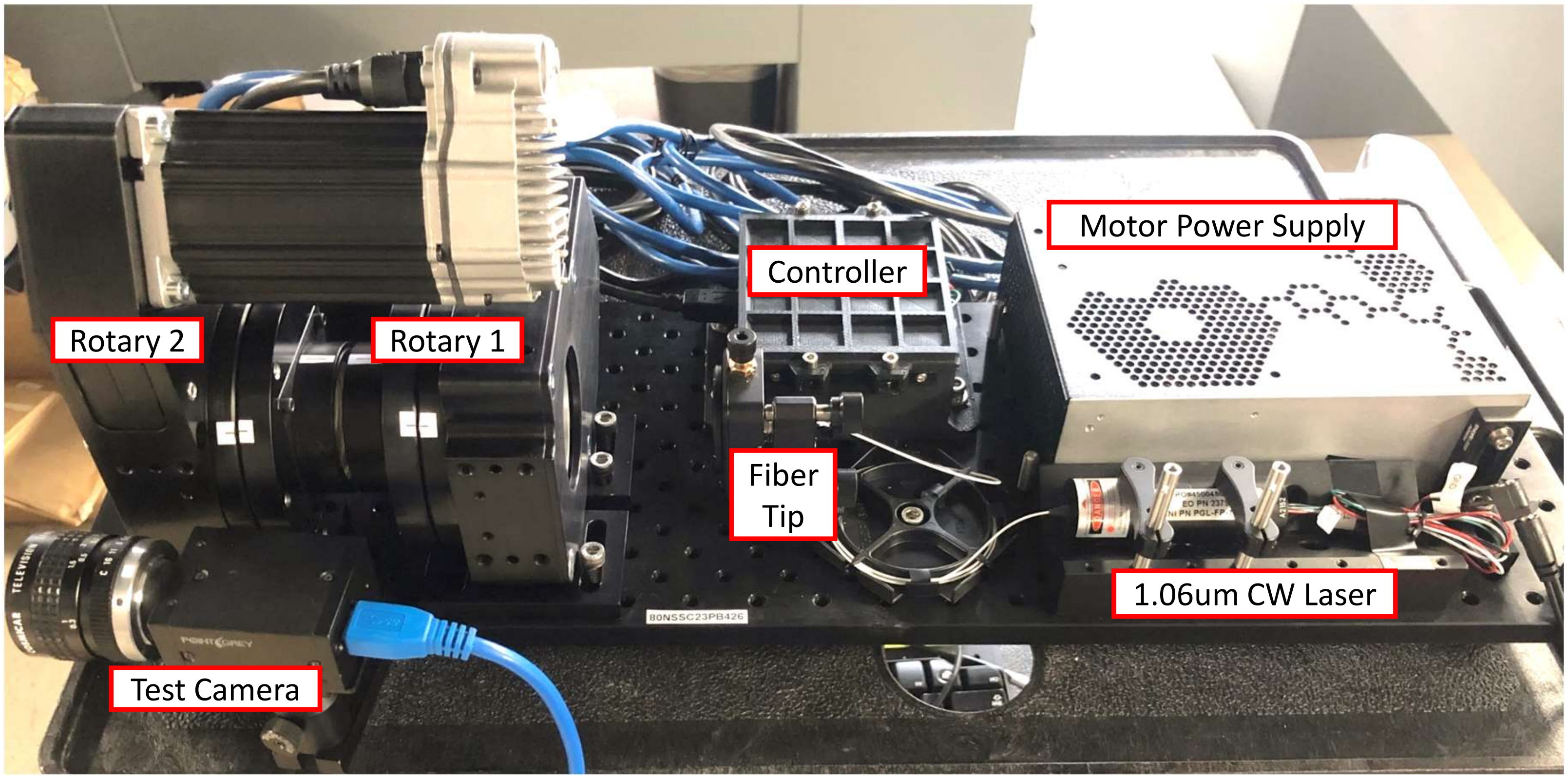
Optics



Concept



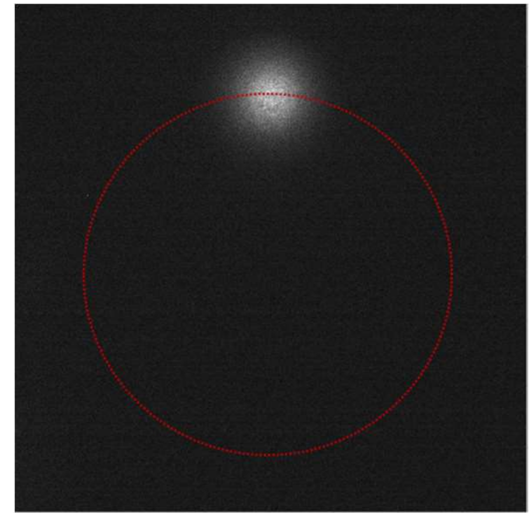
Breadboard Demonstration Unit

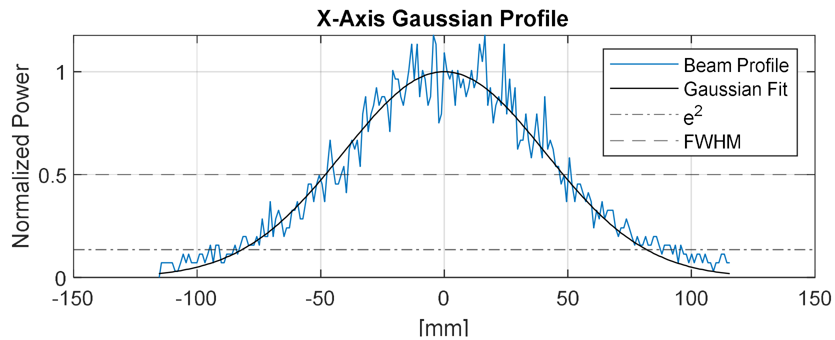


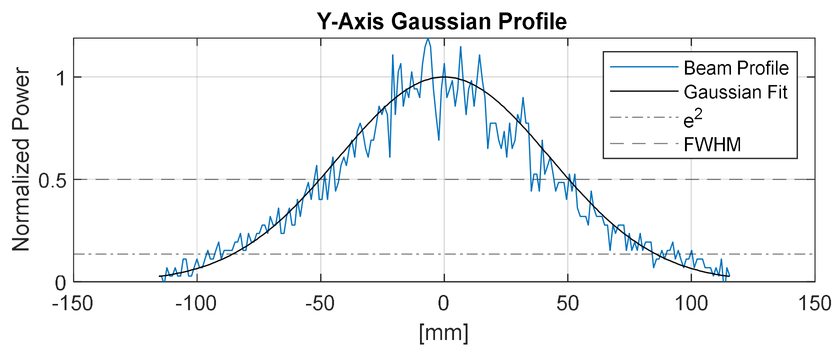
Optical Design Performance

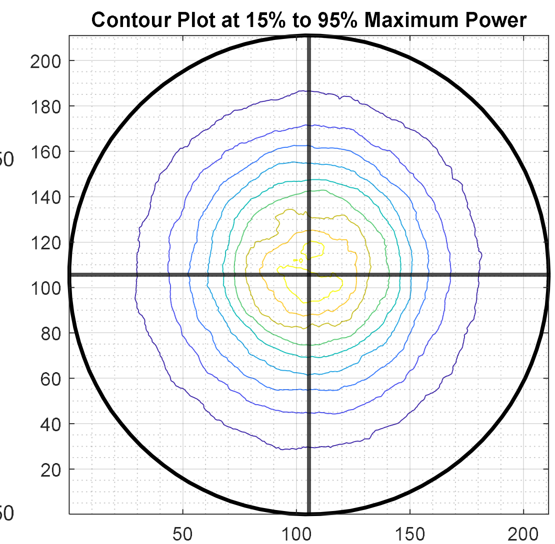
Maintains Beam Shape and has Magnification

- Profiles for 6° steered beam.
- Gaussian fit
- At maximum angle, no visible aberrations, coma, or compression
- Beam divergence ~30mrad



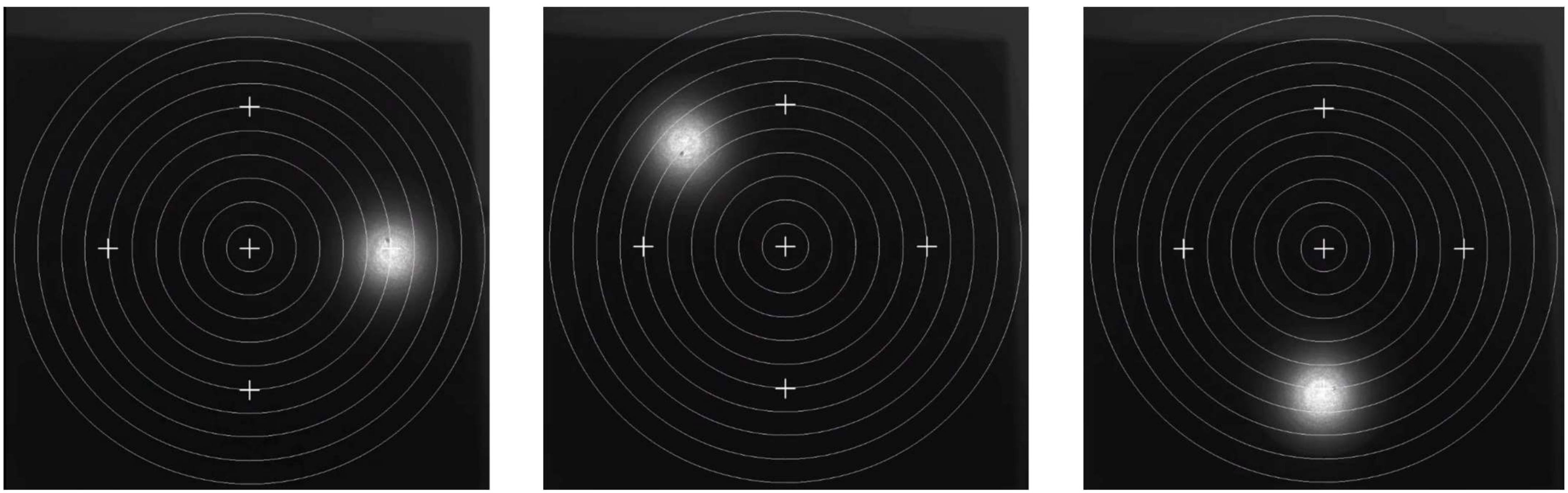






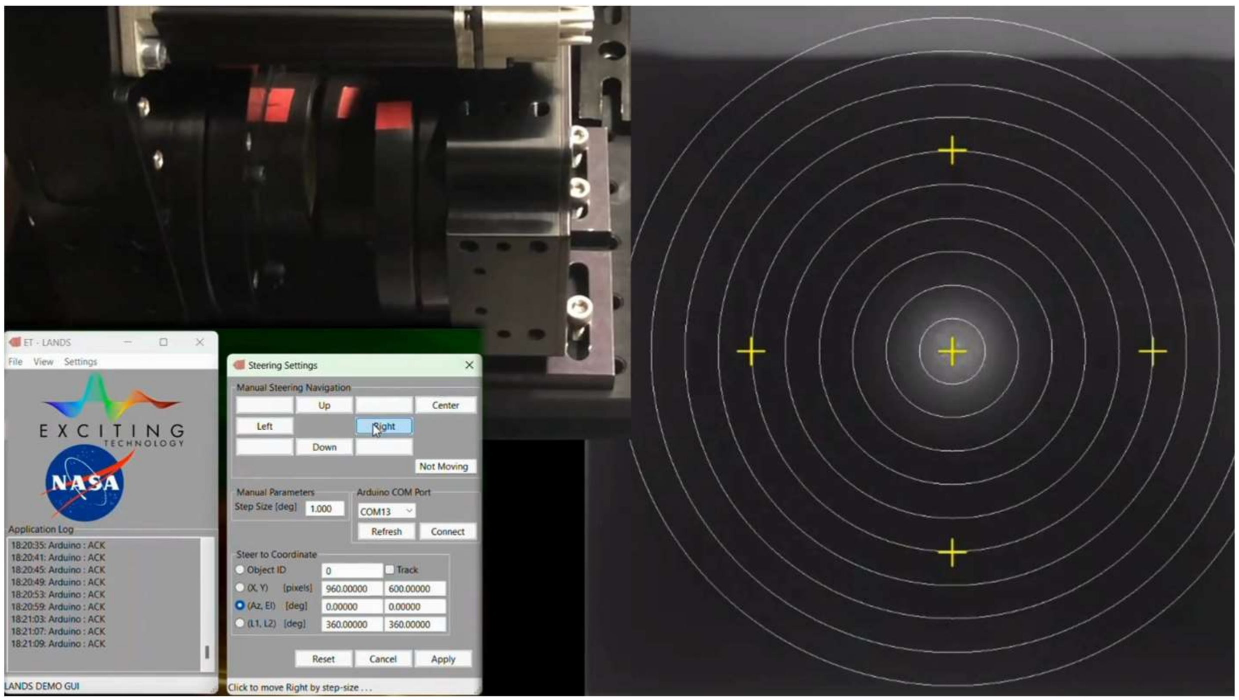
Demonstration Results

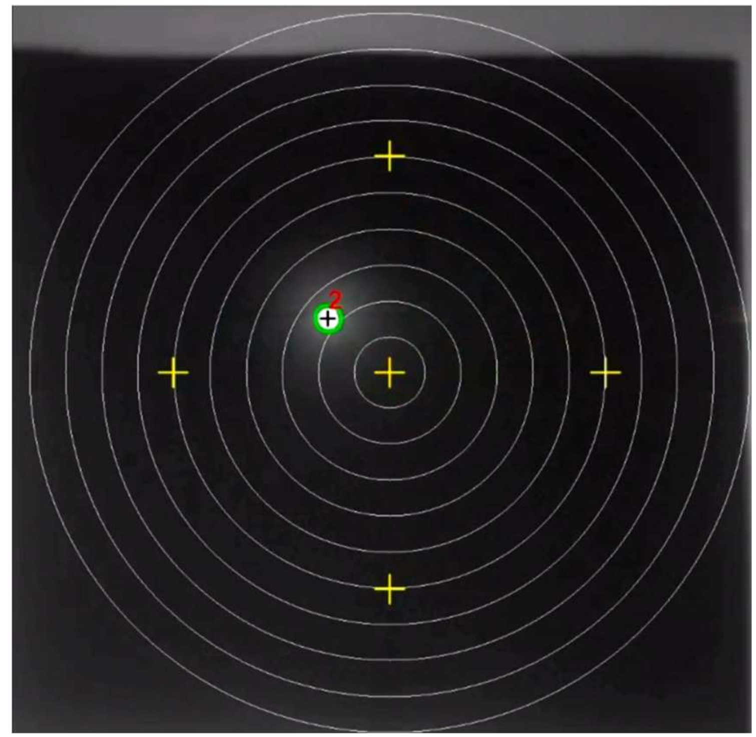
Slow, continuous scans through center



Demonstration Results

1° steps and object tracking





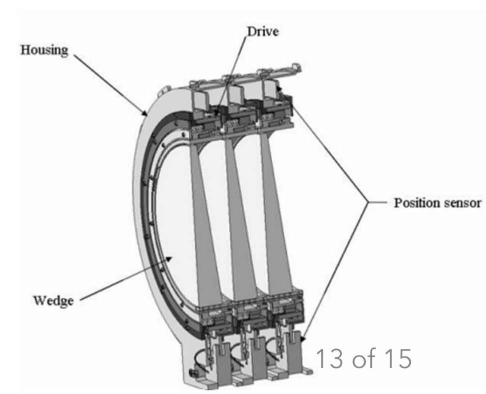
Replacing Higher C-SWaP Beam Steerers

Replacing Gimbals

- Conservative estimate of 30% reduction in SWaP while keeping existing instruments
- Conservative estimate >30% reduction in cost
- Reduce equipment in wind-stream
- Achieve wider angles with minimal design modifications

Replacing Risley Prism Scanners

- Conservative estimate of 30% reduction in overall C-SWaP for same aperture and angles
  - Two rotaries vs. Three rotaries
  - Thinner optics (smaller motors)
- Better optical quality
- Benefits of vibration resilience

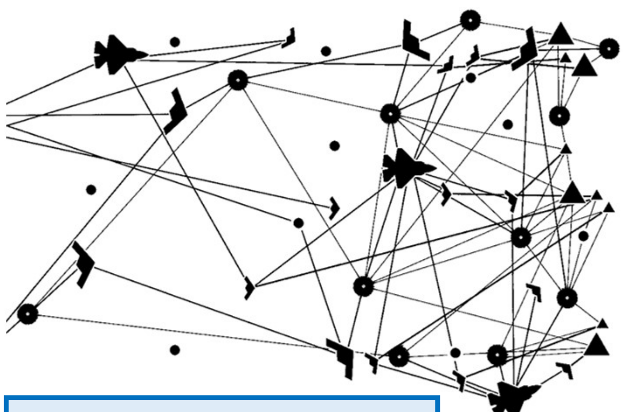


Military Applications

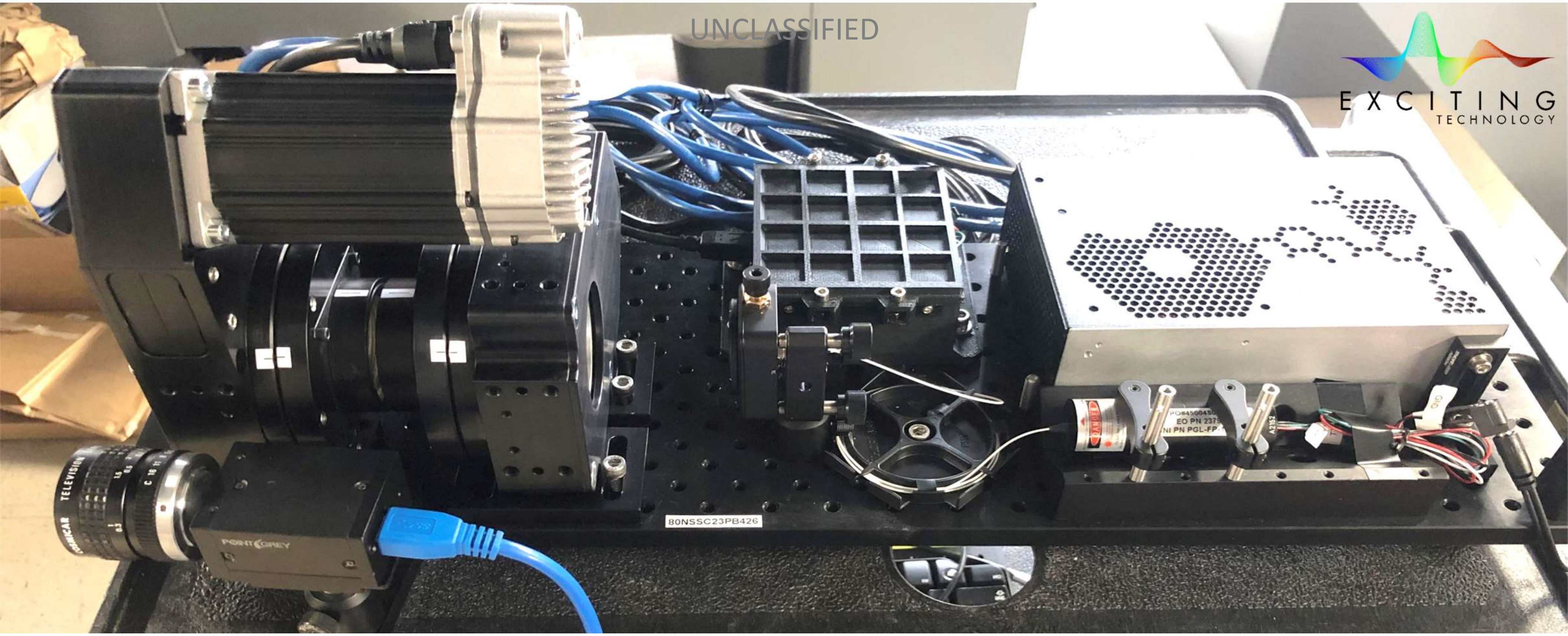
Applications requiring:

- Large aperture
- Wide angle
- Compact telescope
- Vibration resilience
- Maintained optical quality
- Low C-SWaP

Gimbal replacement on ISR Platforms and aircrafts



Low-cost steering for attritable, distributed platforms



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