Presentation Overview

● Project Motivation and Mission Objectives
● My Roles and Contributions
● Payload Design Overview
● Integration and Testing
● Future Work
Motivation and Mission Objectives

● First time demonstration of MEMS deformable mirror technology in space
● Mission critical for coronagraphic high contrast imaging
● Applications in
  ○ Laser Communication
  ○ Earth imaging from space
  ○ Direct imaging of Earth-like exoplanets
● Mission Objectives
  ○ On-orbit characterization of MEMS deformable mirror
  ○ Demonstrate on-orbit wavefront correction
  ○ Demonstrate on-orbit stellar PSF correction

LUVIOR Credit: L. Pueyo, M. N'Diaye, A. Roberge
My Project Roles and Contributions

- Concept of operations
- Sensor and wavefront correction software development
- Sensor/hardware characterization, calibration and testing
- Hardware assembly and integration
- Payload configuration and testing
Payload and Bus Overview
Launch Operations
Launch Vehicle: Virgin Orbit Launcher One
Orbit: ~500km mid-latitude inclination
Launch Date: Early 2019
Lifetime: ~1 year

Concept of Operations

Payload Ejection

Pre-Operation
System health checks
Sensor noise level measurements
Baseline images

Internal Operation (using 633 nm laser)
DM actuator test
Standard wavefront correction loop
Image plane wavefront correction

External Operation
External observation of stars
Standard wavefront correction
Image plane wavefront correction
Optical Layout

M: OAP Mirror
DM: Deformable Mirror
FM: Field Mirror
BS: Beam Splitter
L1: Imaging Sensor
R: Relay OAP Mirror
SHWFS: Shack-Hartmann Wavefront Sensor

32nd Annual Small Satellite Conference
External Operation
MEMS Deformable Mirrors

- Mirror surface
- Electrostatic pads for actuation
- Third layer
- Actuator Details
  - Actuator beam
  - Electrostatic pad
- 4.95mm

http://www.bostonmicromachines.com/low-actuator-count.html
DeMi’s Adaptive Optics System Layout

DeMi

BCT Bus

Payload

Bobby Holden (MIT)

Image Plane Sensor

BMC MEMS Mirror

SHWFS

www.pixelink.com

bluecanyontech.com/buses

32nd Annual Small Satellite Conference

Jennifer Gubner 12
3D Printed Model: First Iteration
3D Printed Model: Second Iteration
Optical Alignment Testing

M1

FM M2

Surface Error Map

0.549λ

-0.471λ

Interference Fringes
Aluminum Assembly: Third Iteration
Future Work

- More integration and optical alignment testing
  - Aluminum assembly integration
  - Refined optical alignment procedures
- Environmental testing and calibration of payload
- Lab demonstration of wavefront correctional capabilities
- Refinement of mission operations
- Future use on exoplanet imaging missions
Acknowledgements

- Professor Kerri Cahoy, Dr. Ewan Douglas, and the rest of the DeMi team
- DARPA
- Aurora Flight Sciences, a Boeing Company
- Dr. Anne Marinan
- SmallSat Judges and Organizers
Questions?
Backup Slides
Wavefront Sensing

- The payload shall measure low order aberrations to lambda/10 accuracy and lambda/50 precision
- The payload shall measure individual deformable mirror actuator wavefront displacements contributions to a precision of 12 nm (TBR)

**Plan:**

**Build a SHWFS around Thorlabs MLA150-5C-M:**
- measures ~3um WFE/actuator
- 150 um pitch
- 3.7mm effective f.l.
- Same array as used in Thorlabs CCD SHWFS used in lab:
  - Lambda/15 accuracy spec
  - Lambda/50 precision spec
  - 5.0um pixels (2x larger than planned CMOS pixels)
# BMC MEMS DMs

<table>
<thead>
<tr>
<th>Mirror</th>
<th>Ultra Compact Mini-1.5</th>
<th>Mini-3.5</th>
<th>Mini-5.5</th>
<th>Multi-3.5</th>
<th>Multi-5.5</th>
<th>Multi-SLM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actuator Count</strong></td>
<td>25 (5 across the active aperture)</td>
<td>32 (6 across the active aperture)</td>
<td>32 (6 across the active aperture)</td>
<td>140 (12 across the active aperture)</td>
<td>140 (12 across the active aperture)</td>
<td>140 (12 across the active aperture)</td>
</tr>
<tr>
<td><strong>Stroke</strong></td>
<td>1.5µm</td>
<td>3.5µm</td>
<td>5.5µm</td>
<td>3.5µm</td>
<td>5.5µm</td>
<td>1.5µm (SLM)</td>
</tr>
<tr>
<td><strong>Aperture</strong></td>
<td>1.2mm</td>
<td>2.0mm</td>
<td>2.25mm</td>
<td>4.4mm</td>
<td>4.95mm</td>
<td>3.6mm</td>
</tr>
<tr>
<td><strong>Pitch</strong></td>
<td>300µm</td>
<td>400µm</td>
<td>450µm</td>
<td>400µm</td>
<td>450µm</td>
<td>300µm</td>
</tr>
<tr>
<td><strong>Mechanical Response (10%-90%)</strong></td>
<td>&lt;40µsec</td>
<td>&lt;75µsec</td>
<td>&lt;100µsec</td>
<td>&lt;75µsec</td>
<td>&lt;100µsec</td>
<td>&lt;20µsec</td>
</tr>
<tr>
<td><strong>Approx Interactuator Coupling (+/-5%)</strong></td>
<td>15%</td>
<td>13%</td>
<td>22%</td>
<td>13%</td>
<td>22%</td>
<td>0%</td>
</tr>
</tbody>
</table>

http://www.bostonmicromachines.com/low-actuator-count.html
Shack-Hartmann Wavefront Sensor

CMOS Camera

- Used for
  - Imaging
  - Shack-Hartmann wavefront sensor
- Pixelink camera with some in-lab adjustments for payload compatibility
CONOPS: Internal Operation

3 modes of internal operation

1. DM Actuator Test
2. Standard Wavefront Correction Loop with the SHWFS
3. Image Plane Wavefront Correction with the Image Plane Sensor
CONOPS: External Operation

- External observation of stars or other astronomical objects to demonstrate imaging capabilities
Dem Optical Ray Trace
E. Douglas, MIT
DeMi’s MEMS Deformable Mirror Layout

Payload Computer

Deformable Mirror Driver

Deformable Mirror
Deformable Mirror Housing/Driver Comparison

Before

Deformable Mirror

Driver

Now