The NIST Dual Parallel Cantilever MEMS Scale Micro Positioner

Dr. Nicholas G. Dagalakis, Dr. Jason Gorman

Mr. Sebastien Bergna

NIST/MEL Intelligent Systems Division

Gaithersburg, MD

nicholas.dagalakis@nist.gov, Tel.: (301) 975-5845

Defense Manufacturing Conference '04

TECHNICAL SESSION I:

MICRO/NANO MANUFACTURING

MONDAY, 29 NOVEMBER 2004

Presentation Objectives

Discuss the possible application of precision micro/nano devices as lightweight distributed sensors for terrain mapping, construction automation, space optical communications and other similar applications

Outline

- List of Contributors
- Motivation
- Micro/Nano Scale Devices
- Why Use Compliant Mechanism Structures
- Planar Dual Parallel Cantilever Micro-Positioners
- 6D Dual Parallel Cantilever Micro-Positioners
- Optical Spacecraft Communications
- Distributed Micro Scanner Arrays
- Conclusions

List of Contributors

Dr. Jason Gorman

Mr. Sebastien Bergna

Dr. John Kramar

Dr. Andras Vladar

College and HS Students

RPI/CAT Participants

Prof. Harry Stephanou

Dr. Woo Ho Lee

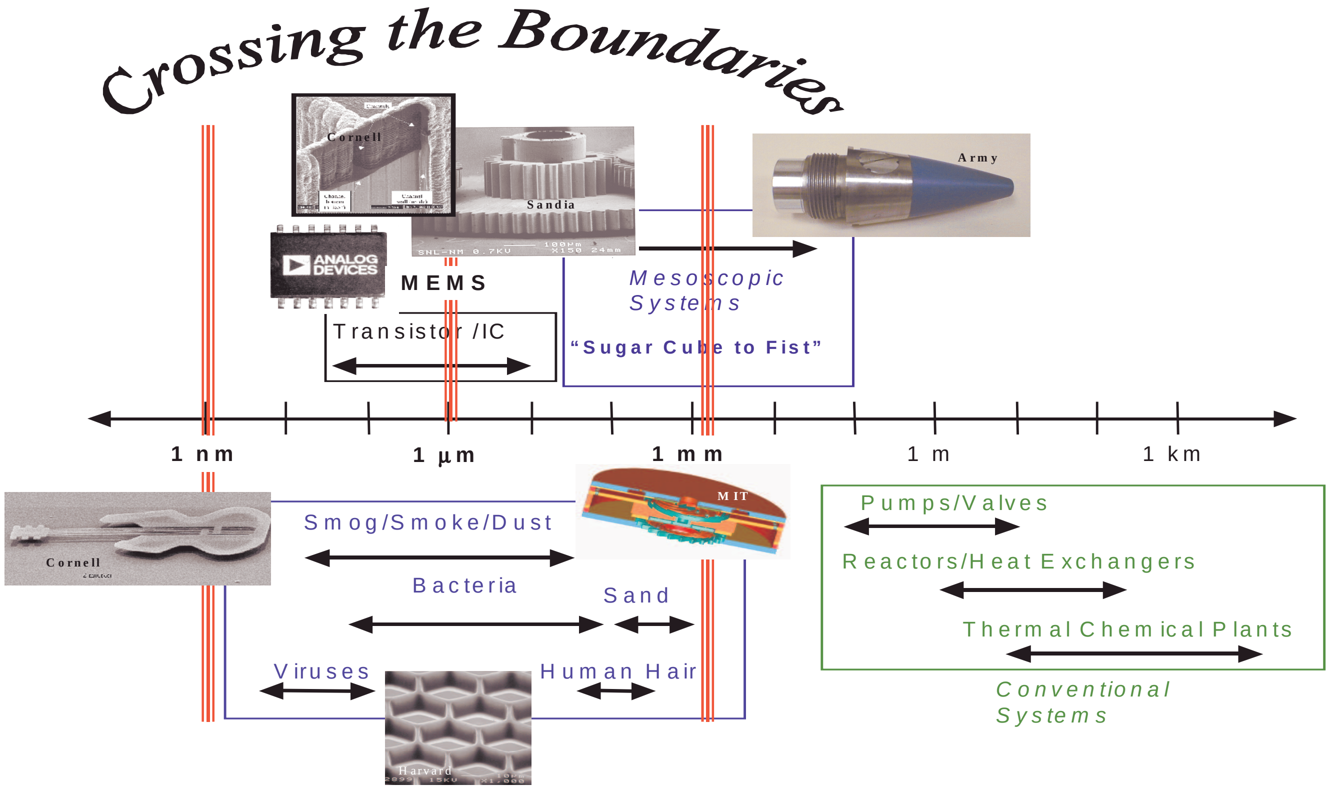
Prof. John Wen

Dr. Byoung Hun Kang

Motivation

- NIST/MEL/ISD Robot Mobility Project
- NIST/BFRL Construction Automation
- ARL LADAR Work
- JHU/APL/SD Spacecraft Optical Communication
- NASA/GSFC Robot Sensors
- High Precision Micro/Nano Devices for Nano Manufacturing

Micro/Nano Scale Devices



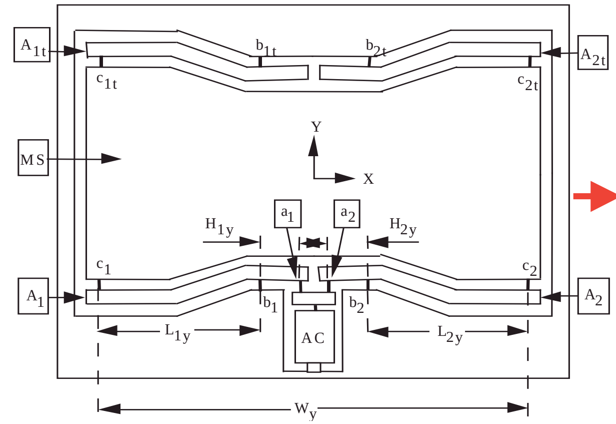
Kevin Lyons
Manufacturing Engineering Laboratory

Why Use Compliant Mechanism Structures with Embedded Sensors Aligned to the Actuators

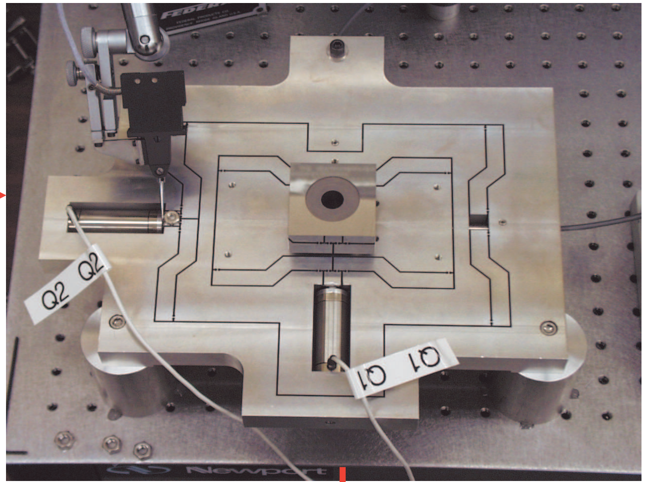
- Mechanical backlash and play
- Dynamic and static friction (stiction)
- Abbe errors
- Cosine errors
- Hysteresis

Planar Dual Parallel Cantilever Micro-Positioners

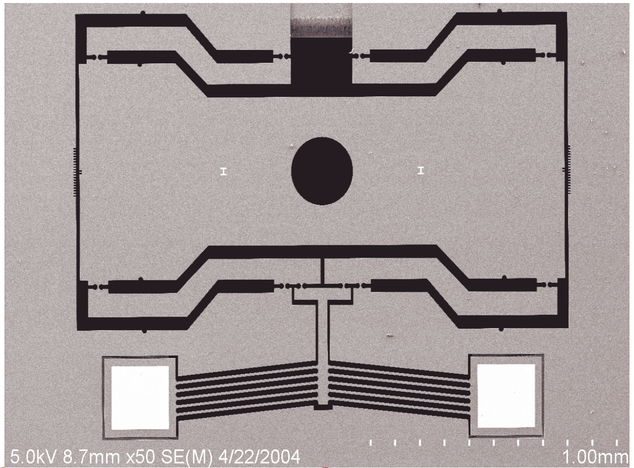
1D Parallel Cantilever Biaxial Design

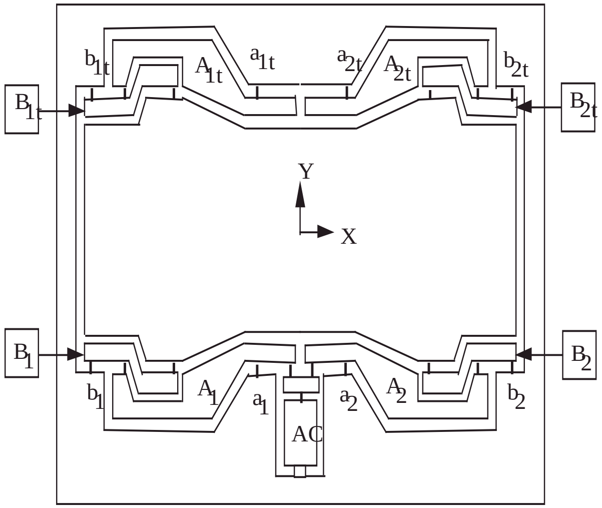


2D prototype (vs. #1)



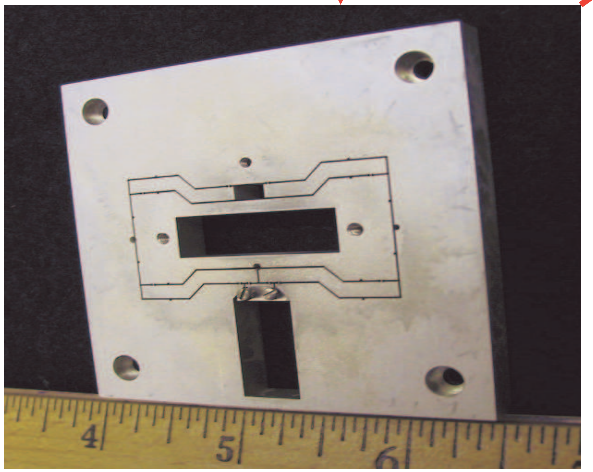
1D Si MEMS prototype (vs. #1)





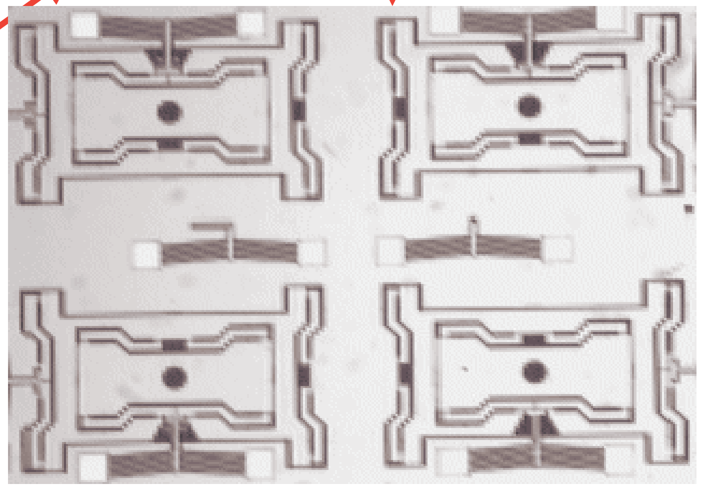
1D Folding Cantilever Design

(Higher Gain, Smaller size)



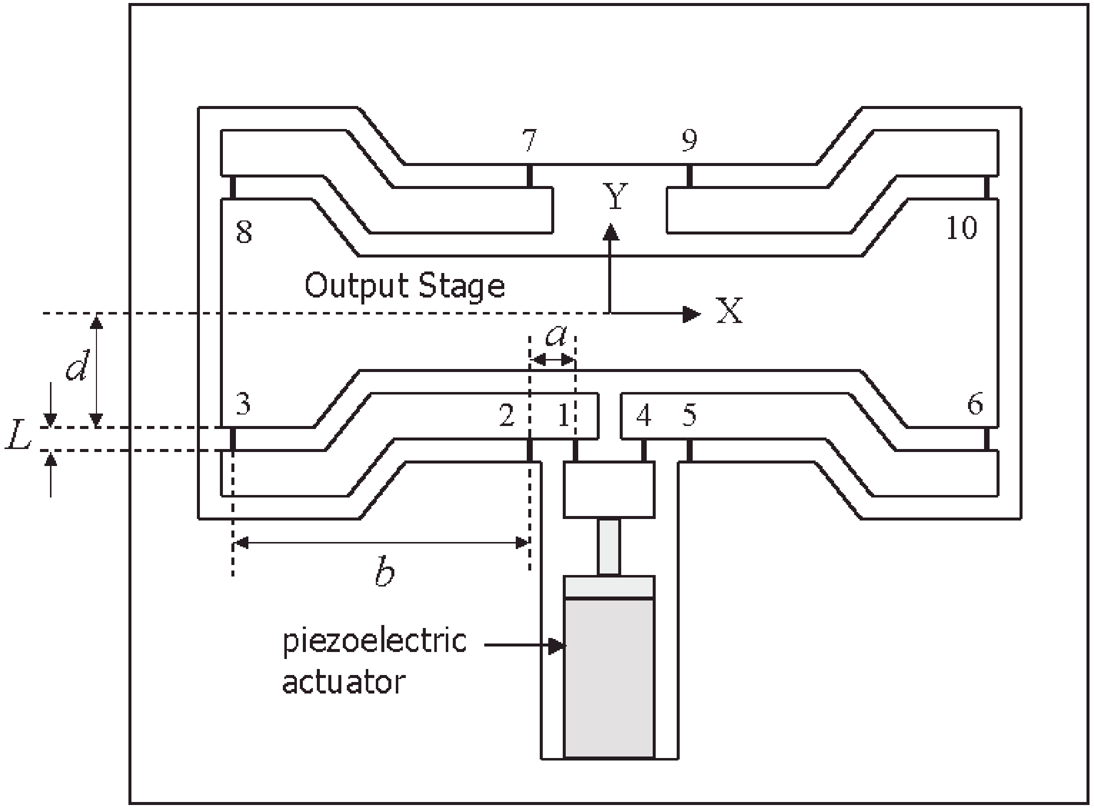
1D Credit Card Prototypes made from

Aluminum, Steel, Invar, Beryllium-Copper, Ti alloy

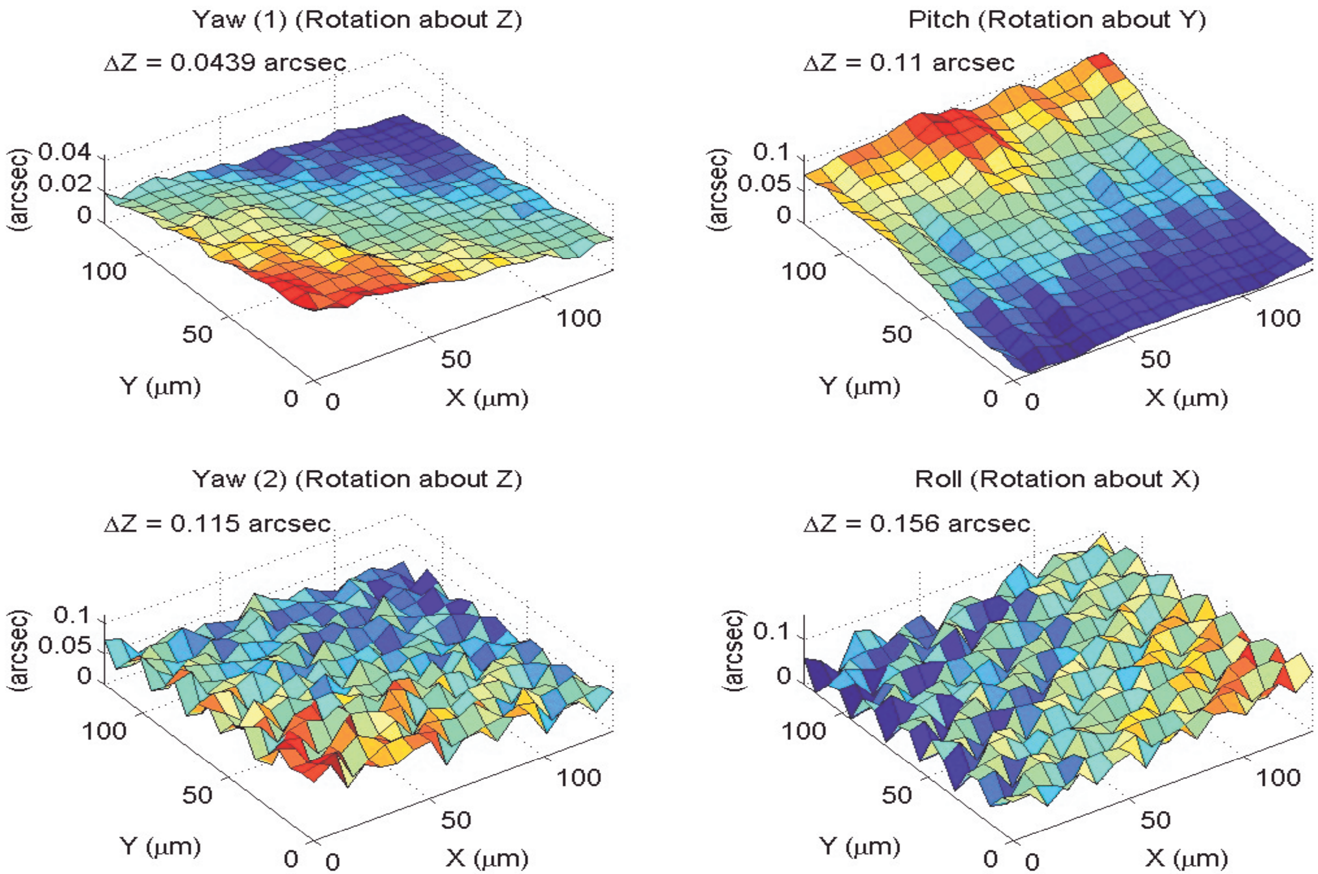


Array of 2D Si MEMS prototypes (vs. #2)

Planar Micro Positioner Schematic of Y Axis



Macro Scale Planar Micro-Positioner Angular Deviation Test Results



1 arcsec = 4.845 µrad
1 arcsec = 0.277 mdeg

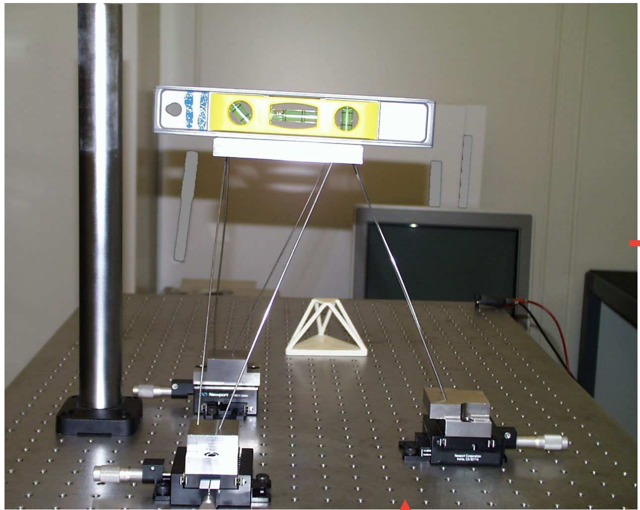
Maximum rotational errors of the second generation macro scale Dual Parallel Cantilever Planar Micro-Positioner over a range of motion of 130 mm by 130mm

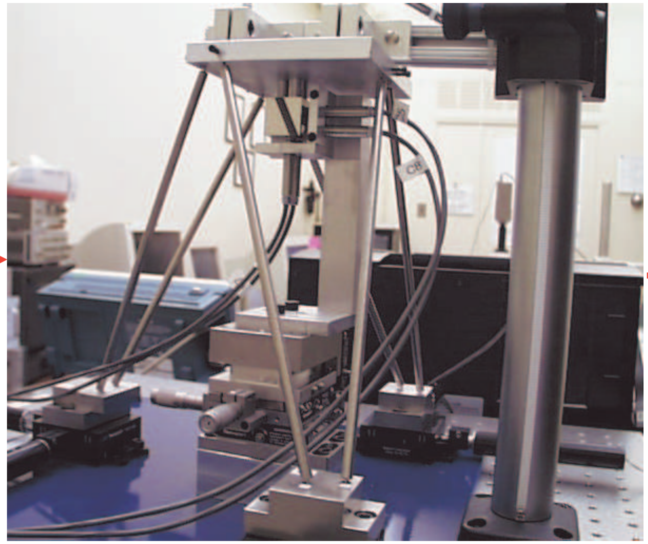
About the Z axis: 0.115 arcsec = 0.557 μrad = 0.031 mdeg

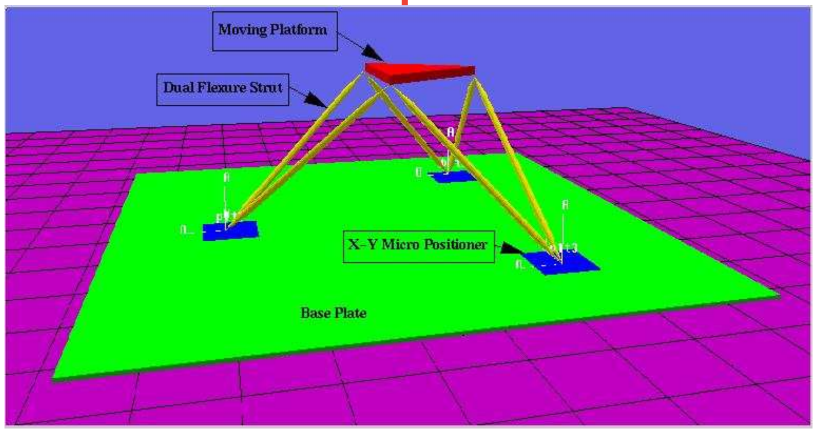
About the Y axis: 0.110 arcsec = 0.532 μrad = 0.030 mdeg

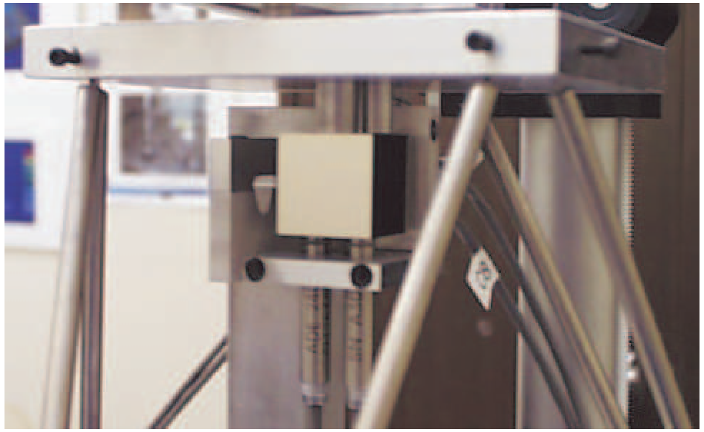
About the X axis: 0.156 arcsec = 0.755 μrad = 0.043 mdeg

6D Dual Parallel Cantilever Micro-Positioners





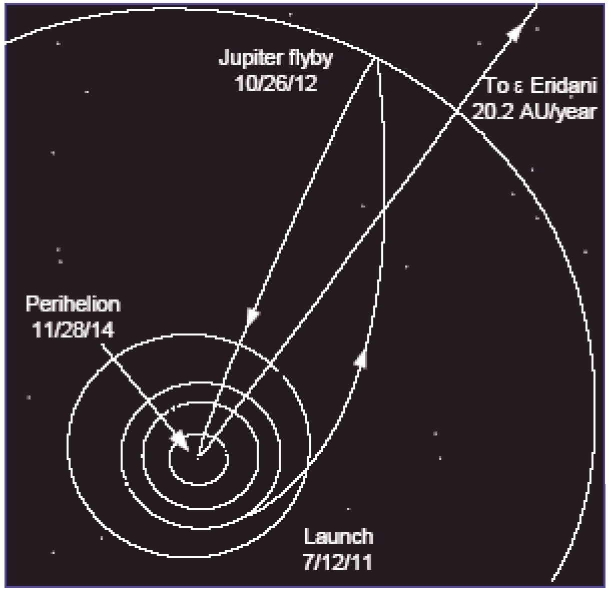


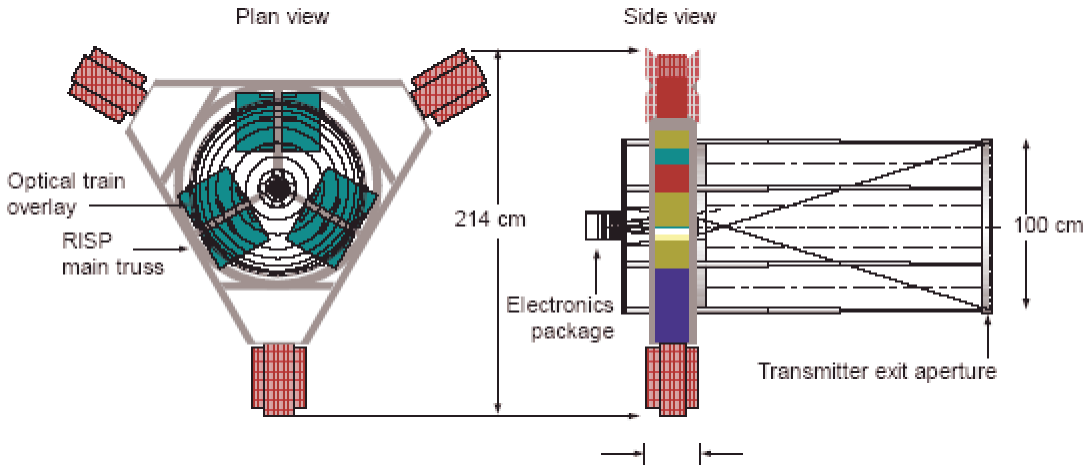


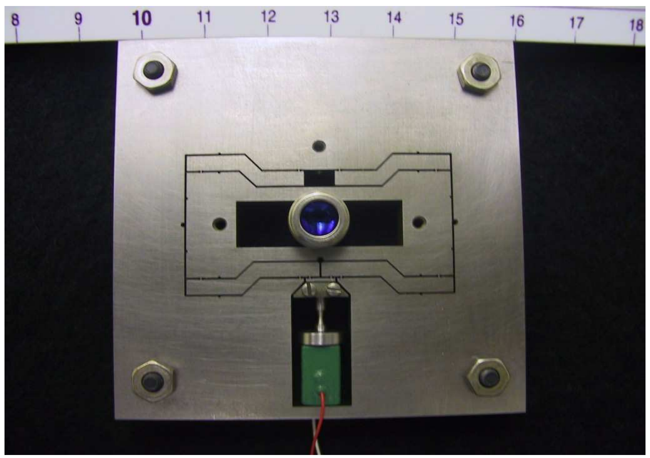
Uniqueness of Technology

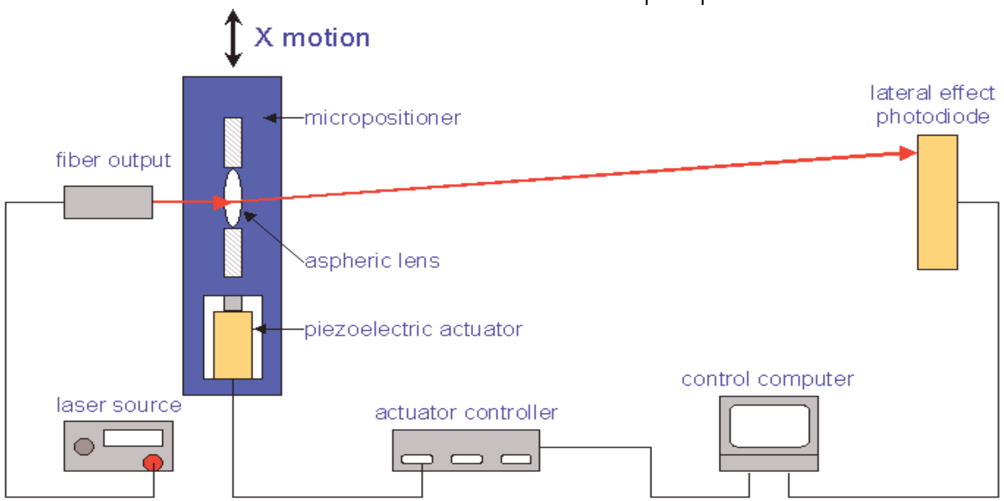
1. The cantilever transmission design allows a wide range of gain selection.
2. The 2x2 dual parallel cantilever biaxial design virtually eliminates cross talk and angular deviation errors.
3. An integrated cantilever adjustable stop mechanism protects the flexures from overloading.
4. The design allows for the placement of moving stage displacement (feedback) sensors, which are aligned with the axes of the actuators.
5. The planar micro positioner can have up to 3 degrees of freedom.
6. The basic planar 3D design can be extended to 4 and 6 degrees of freedom.
7. The 6D metrology sensor also acts as an over load protection and locking mechanism.

Optical and microwave communications system conceptual design for a realistic interstellar explorer

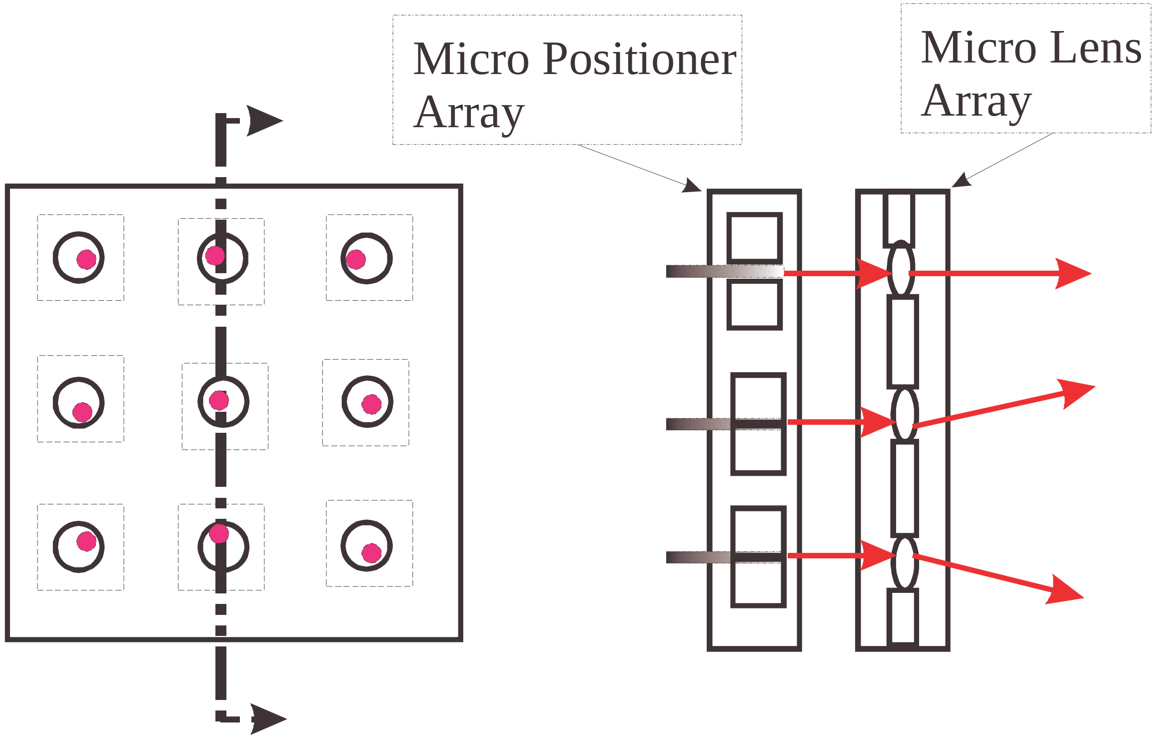




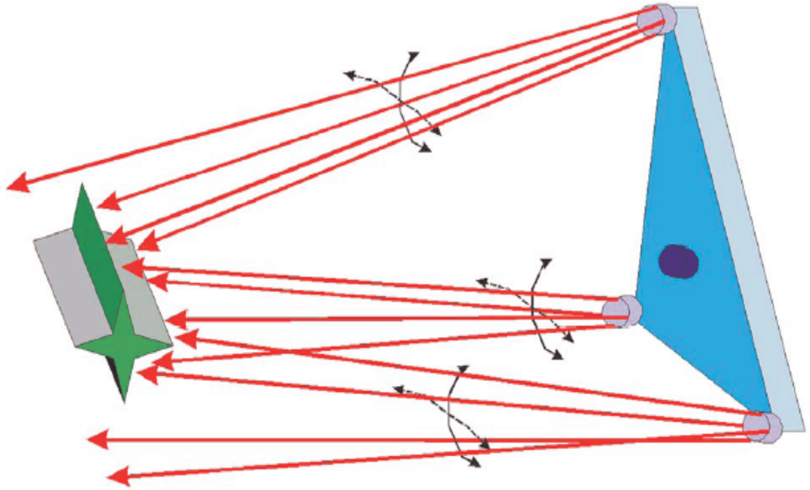




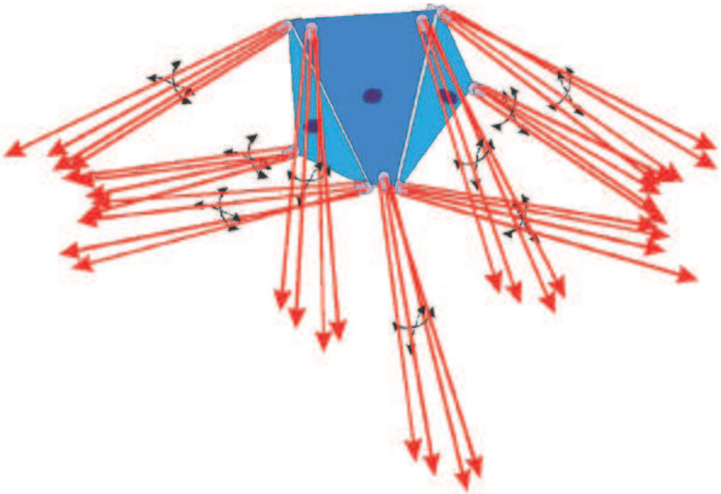
High Accuracy Steerable Laser Beam Micro-Arrays



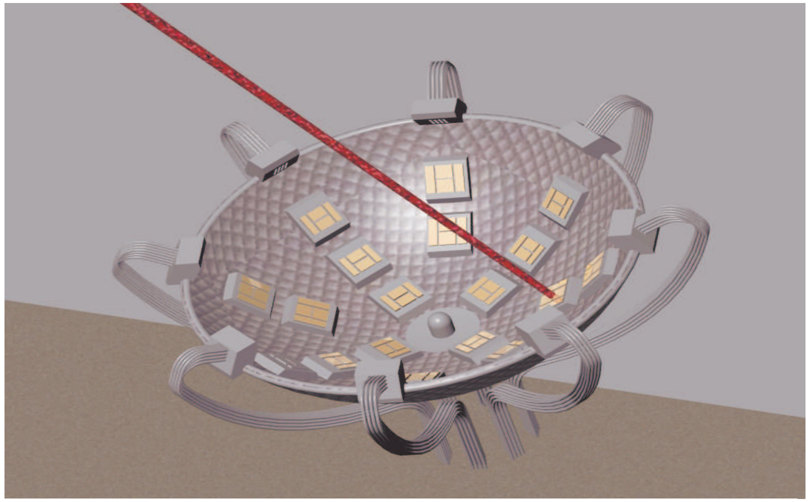
Distributed Micro Scanner Arrays



Multiple micro positioner scanners mounted on a triangular plate



Multiple scanner plates mounted on a convex frame

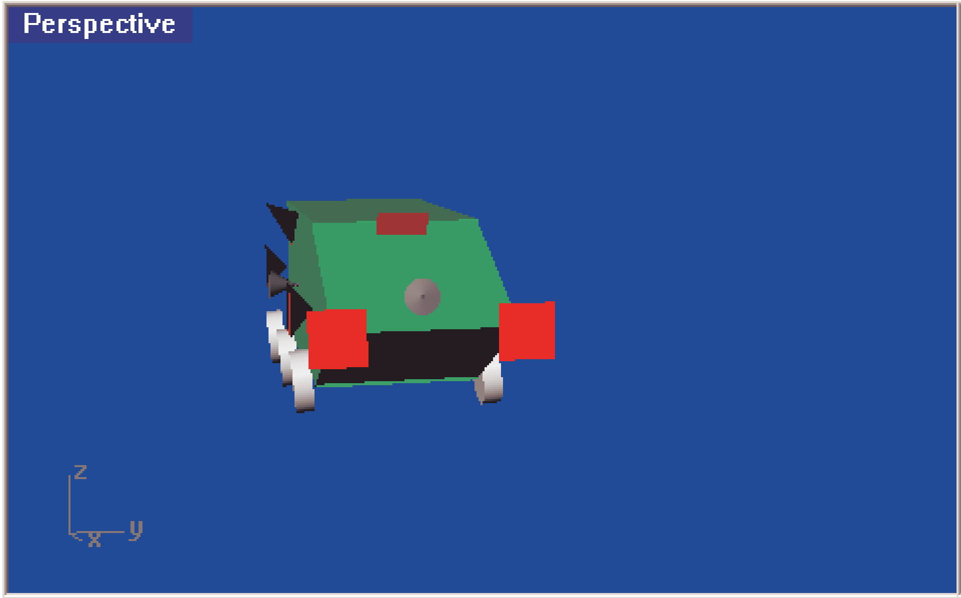


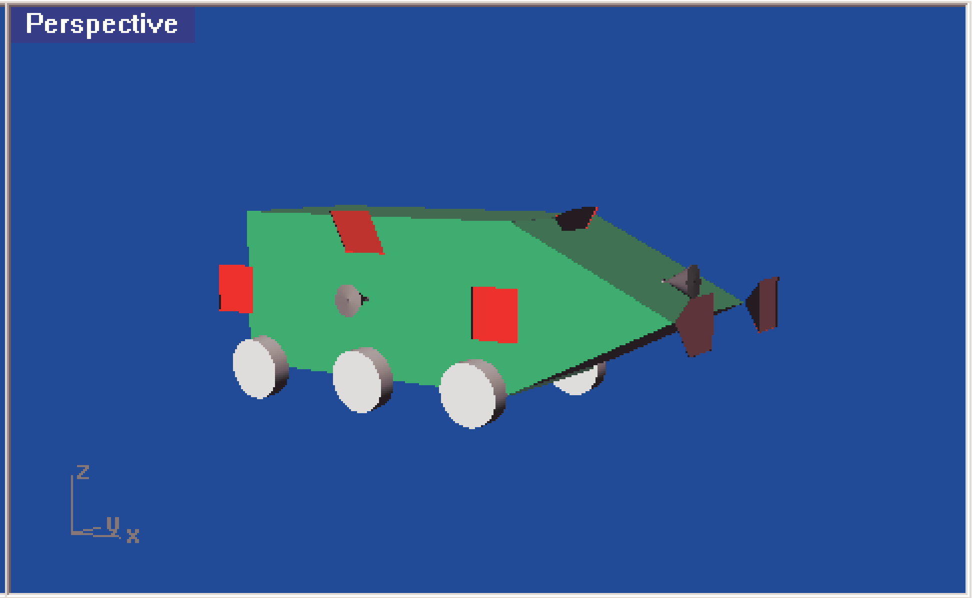
Micro-mirror array scanner concept under development at NIST

Schematic of a Military Vehicle Equipped with Distributed Arrays of Micro Scanners and LADAR Sensors

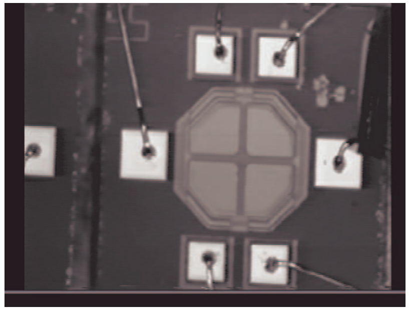
Each array contains wide angle scanners and agile fovea scanners.

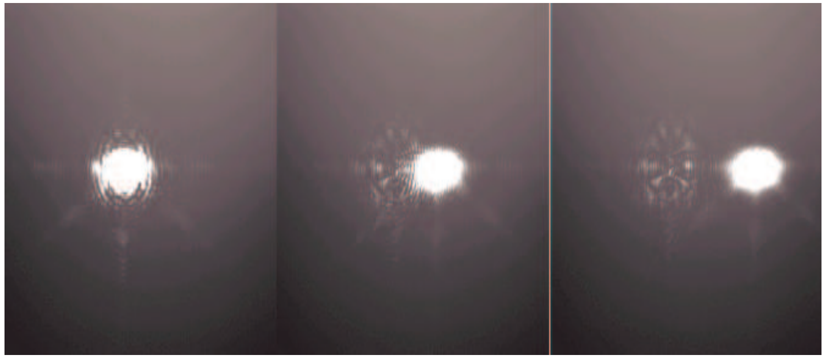
The red color pyramids in the figures depict the 2D angular scanning range of each array. The gray color cones depict LADAR sensors.

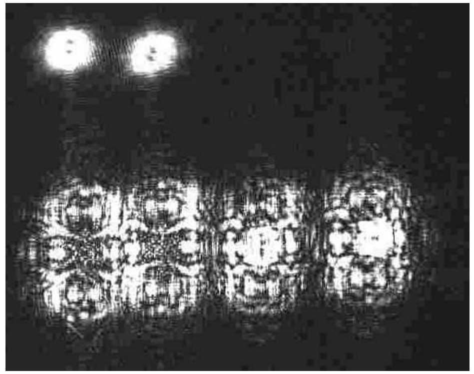


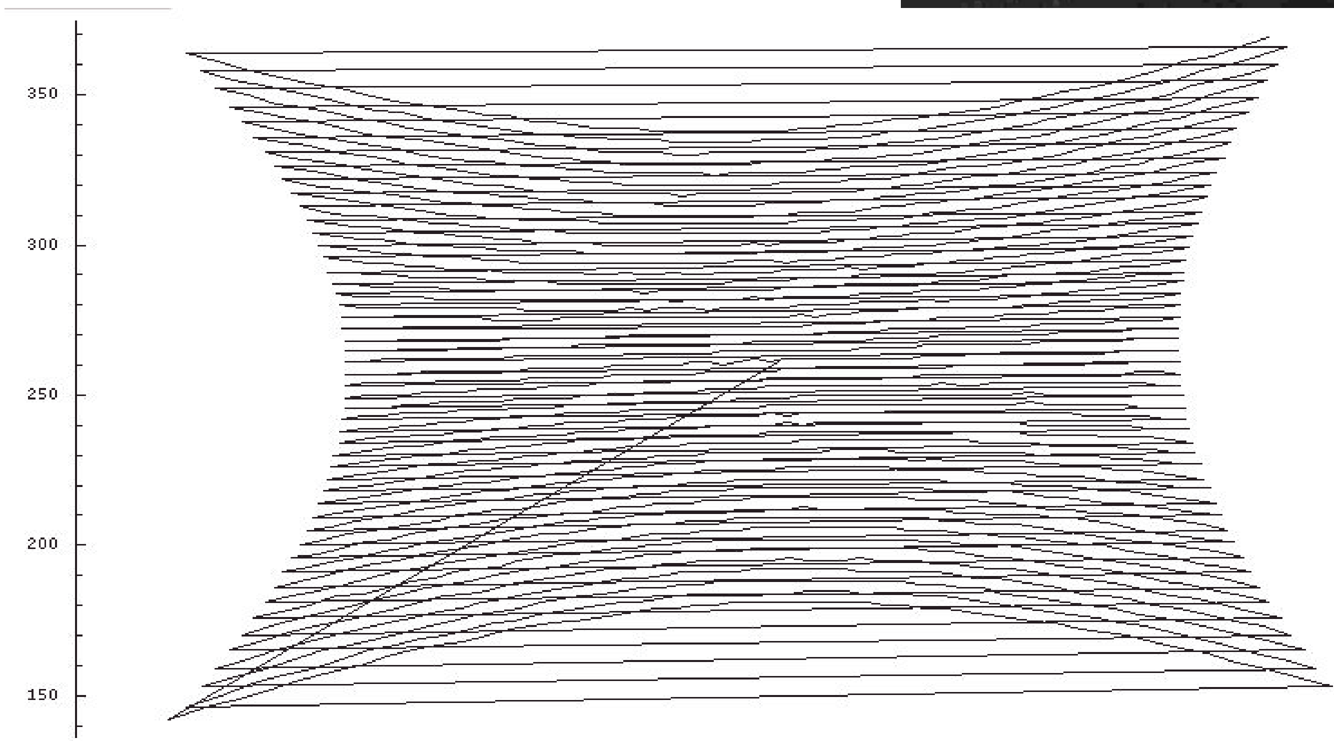


Scanning Micro Mirror Laser Beam Micro-Arrays







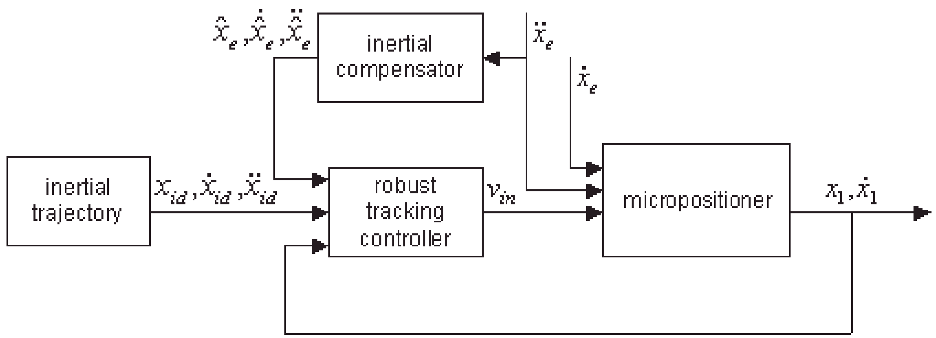


Disturbance Rejection Control

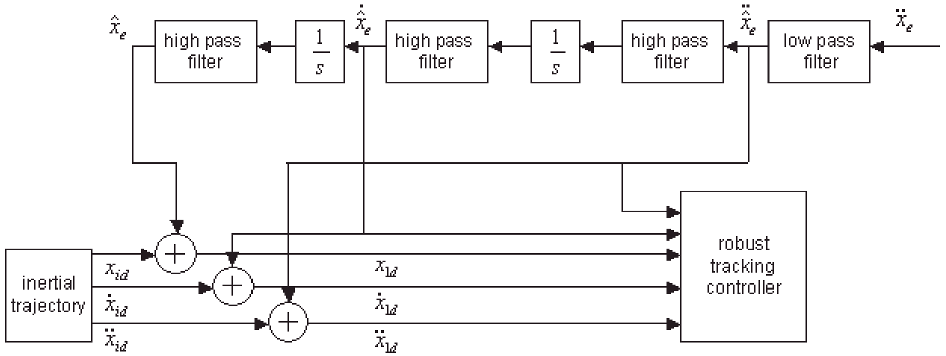
Proposed by Dr. Jason Gorman

- Base excitations from the interstellar explorer introduce inertial and Coriolis forces as well as relative motion within an inertial reference frame, which can severely degrade beam pointing and tracking performance
- The disturbance can be rejected using a sliding modes and base excitation estimation approach
- The relative motion errors can be compensated by an inertial motion estimator which updates the trajectory based on acceleration feedback

Closed-loop System



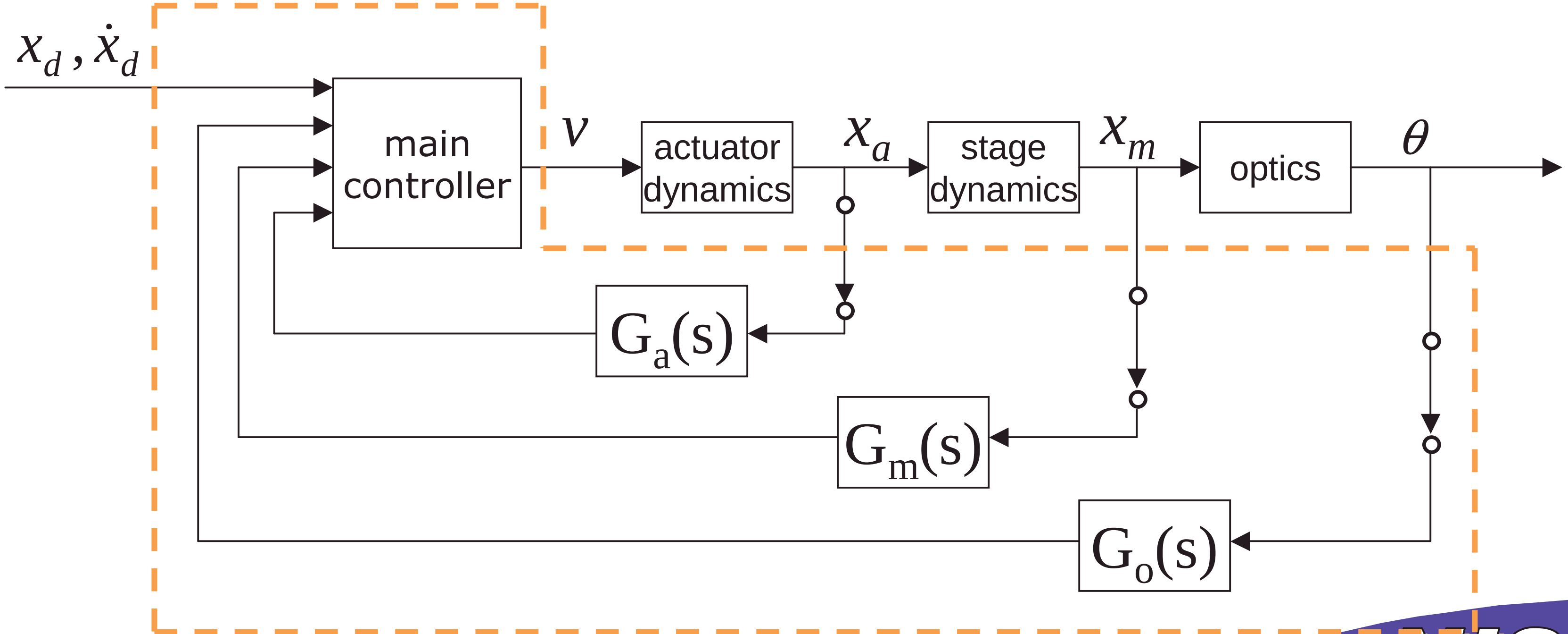
Inertial Compensator



Multi-Loop Control

Proposed by Dr. Jason Gorman

- Sensors provide measurements of the actuator displacement, x_a, micropositioner displacement, x_m, and beam angle, θ , with mixed resolution and bandwidth
- Multi-loop control utilizes all of the measurements, which provides robustness to unmodeled system uncertainty and fault detection for actuators and sensors
- Loops with detected faults can be opened and system stability can be maintained with remaining loops



Summary

- High Performance Dual Parallel Cantilever Positioners
- Macro, Meso, Micro/Nano Prototypes
- Deep Space Optical Communication
- High Performance Distributed Micro Scanner Arrays for Optical Communications, Mobile Robot Terrain Mapping and Construction Automation