M2 & M3 Positioning Systems

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Introduction to CSA Engineering

An Employee–Owned Company

Founded in 1982 around core competencies in structural dynamics and vibration

Custom integrated systems

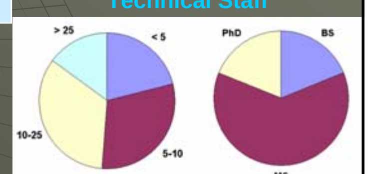
Engineering services, R&D and custom products for
Vibration suppression
Precision motion control

Products

Application Areas

- Launch vehicles
- Ground test systems
- Spacecraft
- Directed energy
- Optics
- Aerospace structures
- Semiconductor equipment
- Medical, automotive, etc.

Technical Staff



Experience (years)

Education (degree)

50 employees

Hexapods for Motion and Vibration Control

Functions: precision positioning, vibration isolation or motion simulation

Actuation: piezoelectric, electromagnetic, and motor-driven screws

Electronics and control: customized interfaces to user specifications

Scope of Work

- M2 Positioner Concept Design ("Baseline")
- M2 Integrated Positioner Concept Design
  - Positioner, Alignment System, and Nutation all in one system
- M3 Positioner Concept Design
  - Relative mirror alignment
    - Likely passive, one-time adjustment
    - Gravitational load constant
  - Beam direction to Naysmyth/Cassegrain foci
    - Active motion to any of four locations
- Investigation & Optimization of Hexapod Geometry for Best Resolution
- Reactionless Gimbal Support Design

Requirements for M2 Positioner

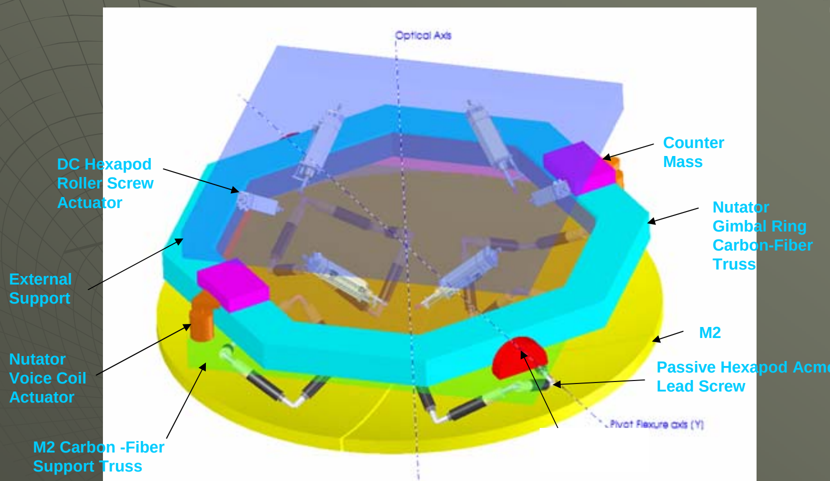
	Range	Precision	Speed
Focus	± 20 mm	18 µm	300 µm s^{-1}
Translation	± 10 mm	65 µm	150 µm s^{-1}
Tilt	± 0.5°	4.85 µrad	15°/hr

- 80kg mirror, Ø3.3m, 4 segments, "X" configuration
- +/-2.5 arcmin nutation @ 1 Hz; 100ms transitions
- Gravitational loading changes

Key Design Issues & Parameters

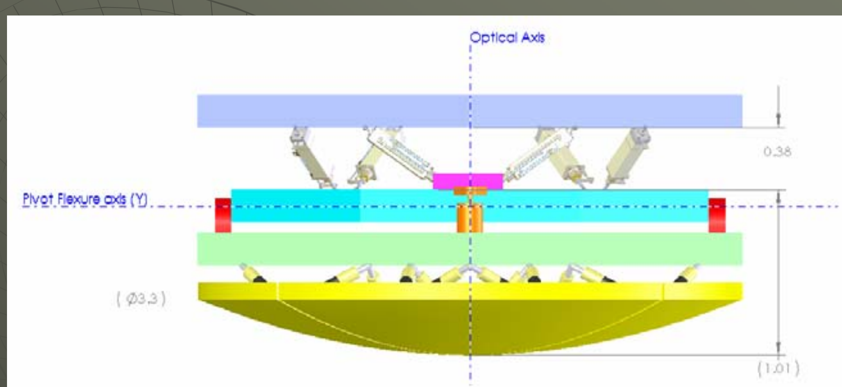
- Actuator Type & Resolution
- Geometry/Nodal Positions
- Reactionless Design
- Passive Alignment of 4 Segments
- Nutation Actuators
- Athermal or Zero-CTE Design

Baseline M2 Positioner Design



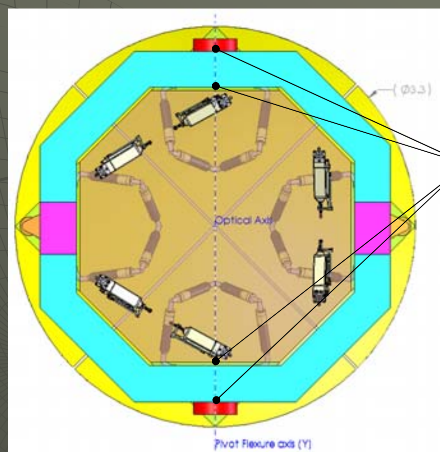
- Low bandwidth positioning hexapod (sub-Hertz) w/ roller screw actuators
- Nutation achieved with voice coil actuators (2 per nutation axis)

Baseline M2 Positioner Design – Side View



- Passive hexapods used for initial alignment of each mirror segment
- Reactionless design using gimbal ring (1 axis shown, 2 axis possible)

Baseline M2 Positioner – Top View

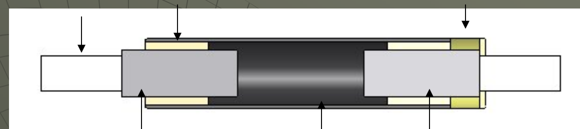


Baseline M2 Positioner: Estimated Resolution

Axes – Resolution Spec µm / µrad	Average Resolution µm or µrad	Standard Deviation µm or µrad	Maximum Step µm or µrad
X - 65.0	65.0	1.66	67.6
Y - 65.0	65.0	1.86	69.4
Z - 18.0	18.0	1.36	18.6
Ox - 4.85	4.84	0.567	7.29
Oy - 4.85	4.84	1.26	8.41
Oz - N/A	9.60	2.84	11.7

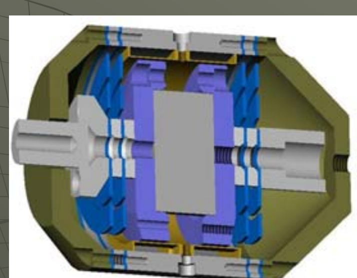
- Assumes 3-micrometer resolution actuators and a commanded step equal to the resolution specification
- 40 simulated moves using MATLAB
- 80mm stroke roller screw actuators
- 1 µrad is approximately 0.2 arcseconds

Baseline M2 Positioner: Alignment Hexapod



- ACME lead screw struts are manually adjusted
- 20 TPI effective pitch
- Up to 1.3 micron resolution
- 8.3 kg
- Flexure kinematic joints

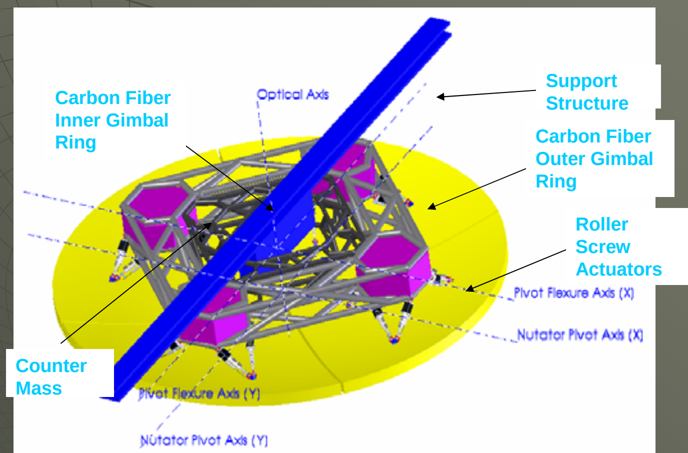
Baseline M2 Positioner: Nutation



- Voice coil actuator (2 units per nutation axis)
- Flexure-based return spring
- +/-1.5mm stroke
- +/-50N force
- CSA “SA10” or similar is adequate

CCAT Feasibility/Concept Study Review 17-18 January 2006

Integrated M2 Positioner Design



- 4 active hexapods replace 1 active + 4 passive hexapods
- Lighter payloads correspond to smaller struts, faster motion
- 2 axes of nutation using inner and outer carbon fiber gimbal rings

Integrated M2 Positioner: Resolution

Axes – Resolution Spec µm / µrad	Average Resolution µm / µrad	Standard Deviation µm / µrad	Maximum Step µm / µrad
X - 65.0	65.0	0.86	66.7
Y - 65.0	65.0	1.25	66.6
Z - 18.0	18.0	0.90	19.3
Ox - 4.85	4.84	0.95	6.71
Oy - 4.85	4.84	1.86	8.67
Oz - N/A	4.86	0.53	5.32

- Assumes 1 micrometer resolution actuator
- Uses similar analysis to baseline design

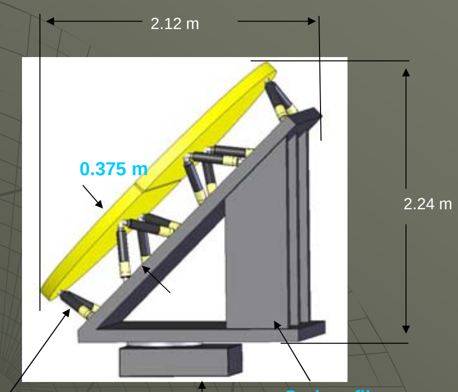
Baseline vs. Integrated M2 Positioner

	Baseline	Integrated
Actuator Count	8-10 Active, 24 Passive	24 Active
Actuator Mass	300 kg	60 kg
Kinematic Joints	60	48
Axes of Nutation	1, or 2 with add'l gimbal ring	2, relatively simple
Hex Actuator Resolution	3 micrometer	1 micrometer
Hex Actuator Force	1230 N	120 N
Hex Actuator Stroke	79 mm	70 mm
Hex Actuator Speed	~0.5 mm/s	75 mm/s
Support to Vertex Length	1.39 m	0.85 m
Alignment	6 manual mechanisms/panel	6 active actuators per panel
Risks	Accessibility, number of actuators & joints	Localized Actuator Wear, Coordinated Control of Segments

Requirements for M3 Positioner

- Support mirror segments
- Maintain Optical Alignment
- Rotate to direct telescope beam in any of 4 directions
- 10mm adjustment range
- 0.2 arcsec alignment with sky (5 arcsec rotation alignment)
- 180° rotation in 2 min
- 10^5 mirror rotations (lifetime)

M3 Positioner Design



Critical Risks/Cost Drivers

- Tip/Tilt resolution requirements require 1-3 micron actuator resolution
  - Mitigation: Single-strut qualification testing
- Nominal M2: Accessibility to passive hexapod for alignment
  - Mitigation: Additional development of installation/maintenance procedures
- Nominal M2: Large number of kinematic joints introduce compliance & deadband
  - Mitigation: Test program or opt for Integrated design
- Integrated M2: High frequency, low amplitude motion may cause actuator lubrication issues
  - Mitigation: 2-stage actuator or maintenance scheduling
- Integrated M2: Control of alignment of four mirror segments
  - Mitigation: Global control method
- 2 axes nutation may cause compliance, increase complexity
  - Mitigation: Additional design and review, or single-axis nutation