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<b>14. ABSTRACT</b> The International X-ray Observatory (IXO) will require mandrel metrology with extremely tight tolerances on mirrors with up to 1.6 meter radii. Metrology on these shapes using conventional interferometry is difficult. A system that could perform in-situ metrology on the polishers may be ideal. Error budgets for the IXO mirror segments are presented. A potential solution is presented that uses a voice-coil controlled gauging head, air bearings, novel probes, and temperature control.					
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# In Situ Metrology for the Corrective Polishing of Replicating Mandrels

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NASA Phase I Contract NNX10CD72P

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Mirror Technology SBIR/STTR Workshop  
Boulder, CO  
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The Challenge: Develop an instrument for the process-intermittent metrology of the IXO mandrels to control the corrective polishing process

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- Extremely tight tolerances
- Very large radii (to 1.6 m)
- Unsuitable for interferometry
- Radii too large for on-center polishing or metrology
- Ultimate need to provide in-situ metrology on the polisher(s) for rapid process control

Our solution: Develop a dedicated metrology **instrument using a “virtual axis of rotation”**

# Mandrel Sizes for IXO

	<b>Inner Ring</b>	<b>Middle Ring</b>	<b>Outer Ring</b>
<b>Azimuthal Span of Each Module (degrees)</b>	<b>30</b>	<b>15</b>	<b>15</b>
<b>Number of mandrels</b>	<b>286</b>	<b>230</b>	<b>206</b>
<b>Radius of Each Module</b>	<b>372-693 mm</b>	<b>740-1110 mm</b>	<b>1156-1605 mm</b>
<b>Polished chord width of Slab Mandrels</b>	<b>255-475 mm</b>	<b>310-470 mm</b>	<b>500-700mm</b>
<b>Clear Aperture length</b>	<b>200 mm</b>	<b>200 mm</b>	<b>200 mm</b>
<b>Mandrel polished length</b>	<b>275 mm</b>	<b>275 mm</b>	<b>275 mm</b>

# Error budget for individual forming mandrels for IXO

Mandrel Surface Parameters		Error Allocation for either Primary or Secondary (assuming perfection for the other)		RSS Contribution to HPD (arcsec)	Cumulative HPD (arcsec)
		Numerical Value	Unit		
Radius	Average Radius	10.00	μm	0.2	0.2
	Radius Variation	0.20	μm	0.1	0.2
Cone Angle	Average Cone Angle	0.50	arcsec	0.7	0.8
	Cone Angle Variation	0.40	arcsec	0.7	1.0
Axial Sag	Average Sag	0.05	μm	0.5	1.1
	Sag Variation	0.05	μm	0.2	1.1
Axial Figure	Low Frequency Figure (200mm-20mm)	5.00	nm	0.4	1.2
	Mid Frequency Figure (20mm-2mm)	2.00	nm	0.9	1.5
	High Frequency Figure (2mm-0.002mm)	NA	nm	NA	1.5

# A 3 Phase Approach:

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- Phase 1: Develop a conceptual design
- Phase 2: Develop a stand-alone metrology system
- Phase 3: Integrate the metrology and manufacturing systems

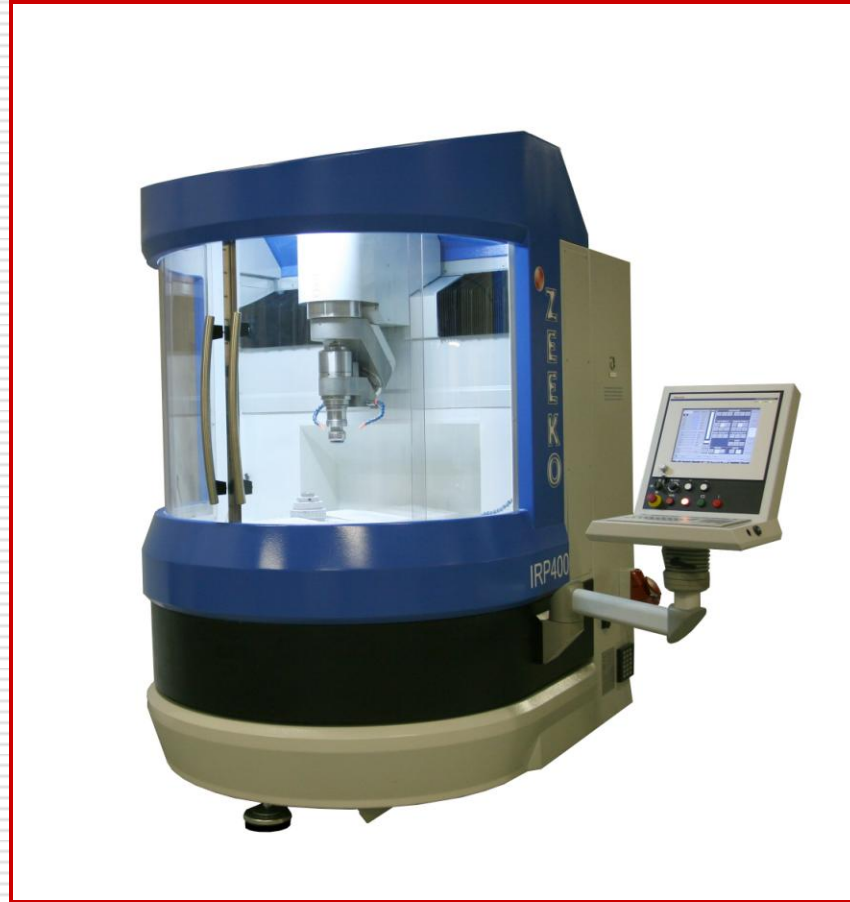
# Phase 1 Work Plan

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- ❑ Establish a detailed specification for the instrument
- ❑ Develop a conceptual design for metrology equipment
- ❑ Create an error budget for metrology equipment
- ❑ Develop a plan to combine polishing and metrology equipment
- ❑ Prepare a final report and a project plan for Phase 2 of the SBIR

# Zeeko IRP 400

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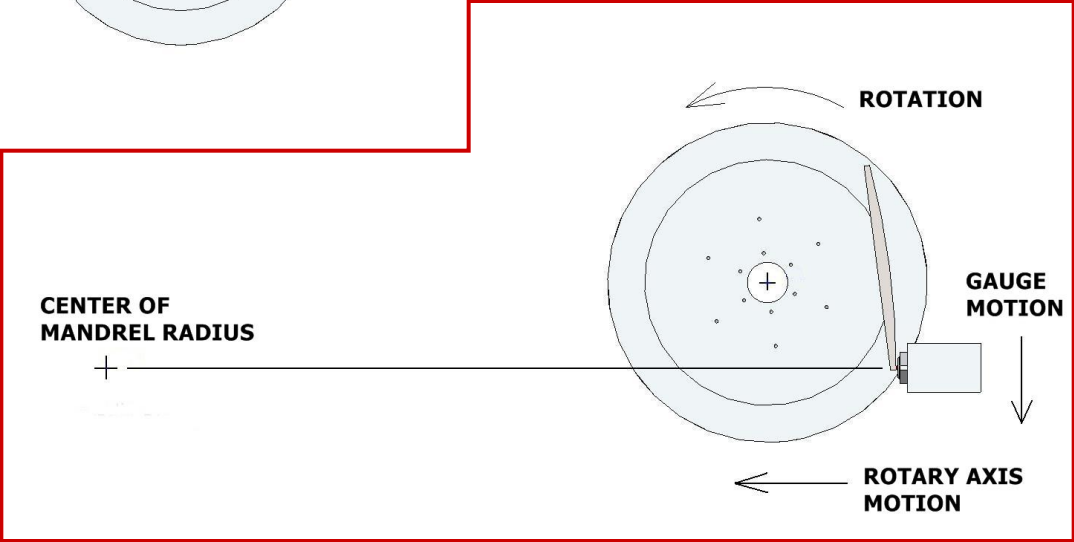
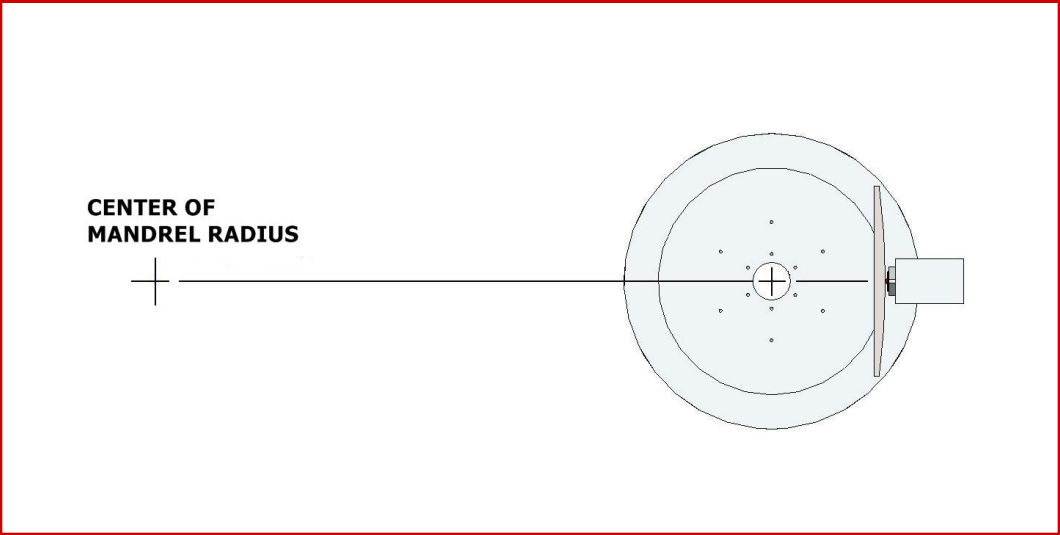


# Key Technologies and Principals

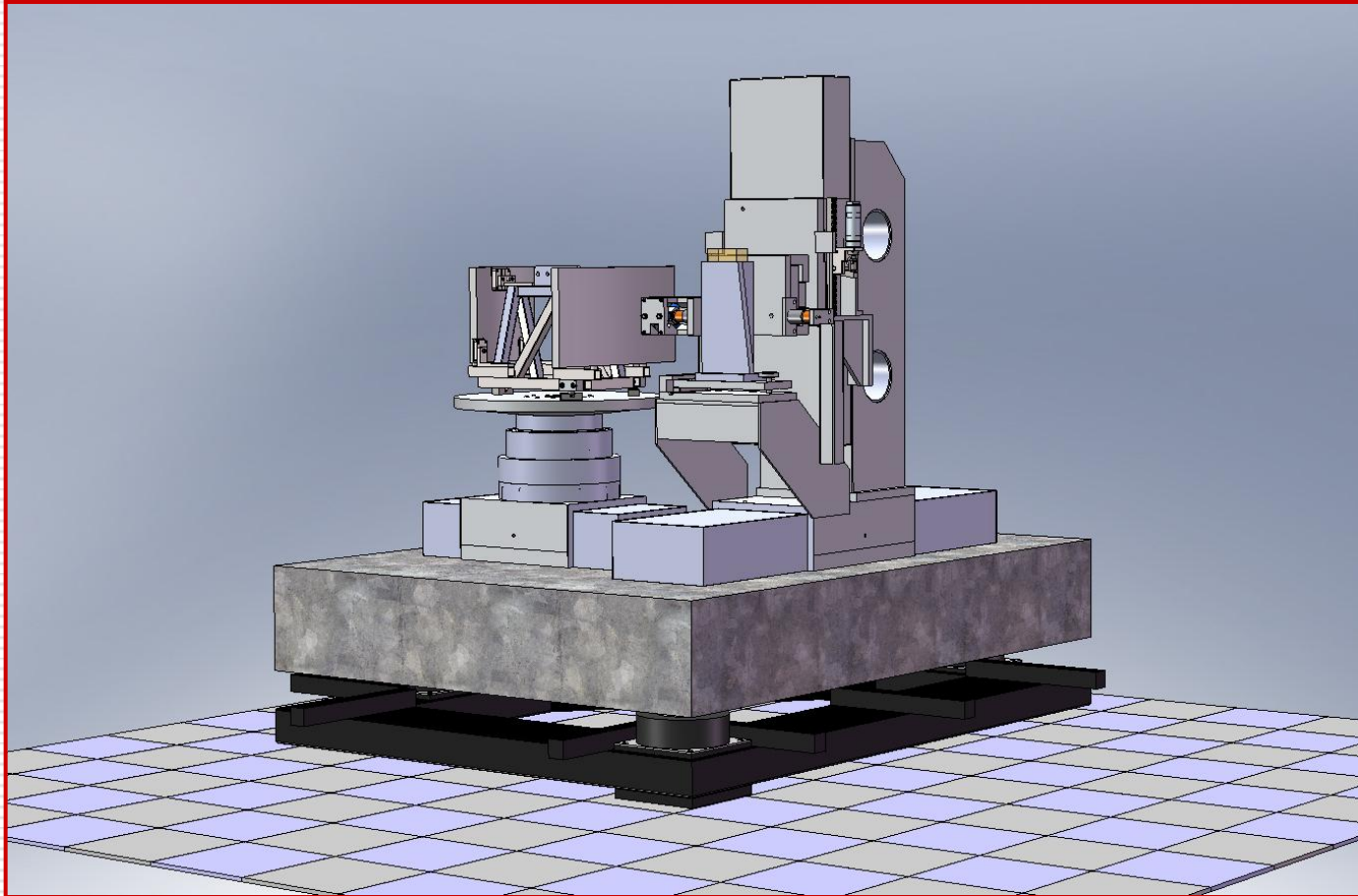
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- ❑ Extensive use of error budgeting as a design guidance tool
- ❑ The development of a novel contact voice-coil controlled gauging head, with dynamic range, resolution and uncertainty necessary to meet component metrology requirements
- ❑ The merging of an array of precision engineering principles and design elements including air-bearing components, a novel probe design, temperature control in a radical environment, and the integration of all of these technologies on a computer controlled machine to control the manufacturing process

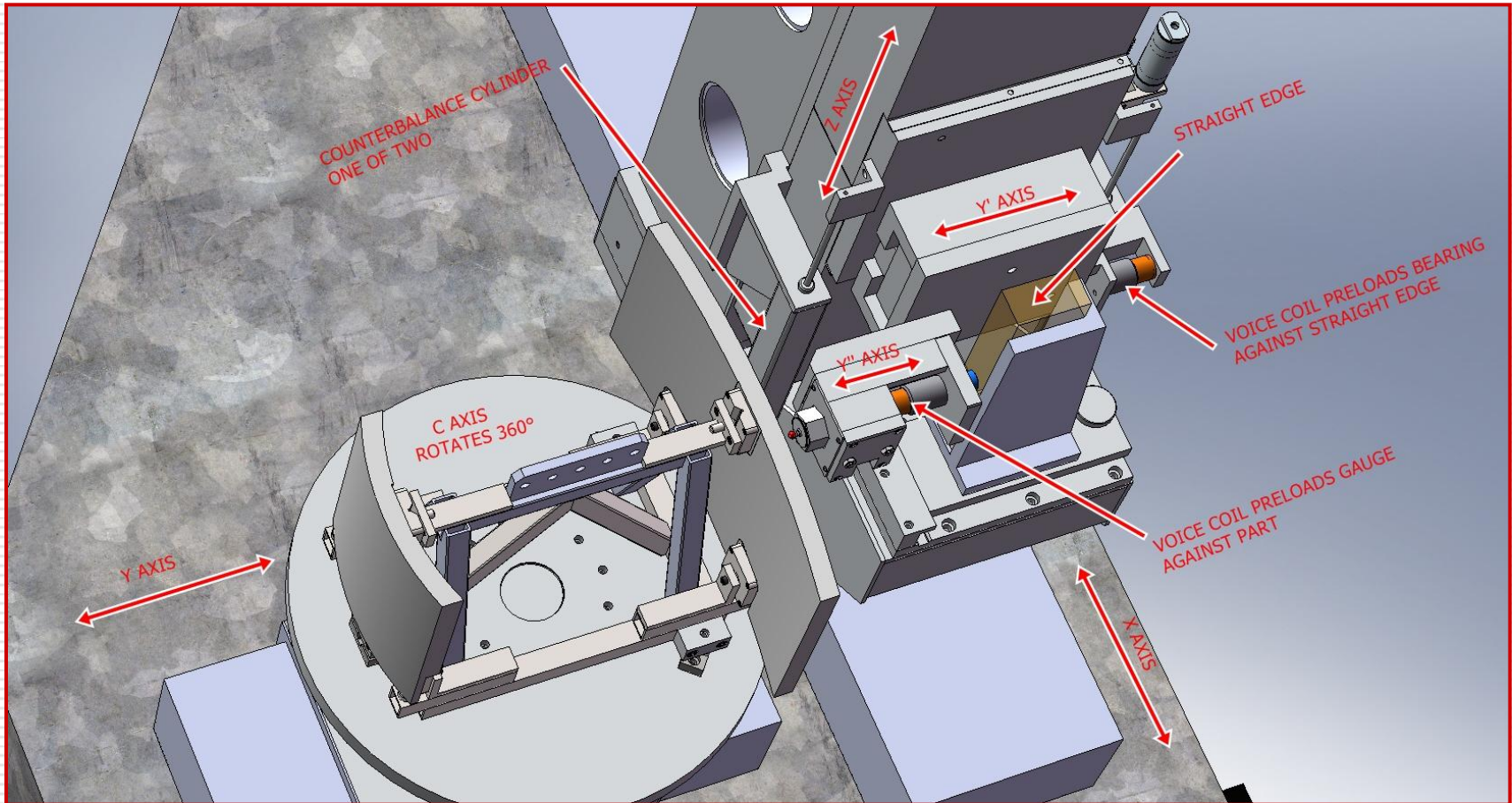
# How it Works



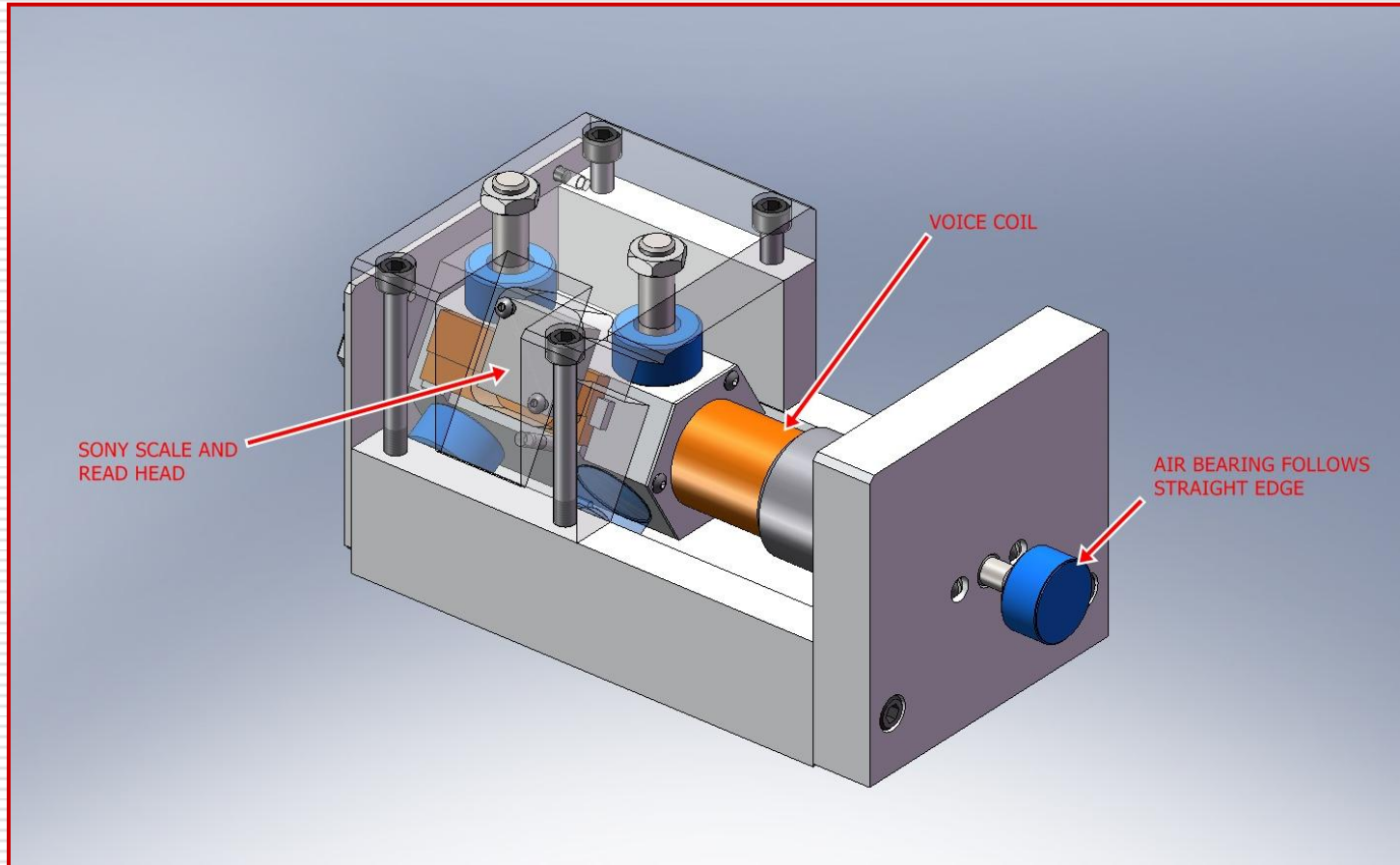
An overall perspective of the IXOMMM (without temperature enclosure)



# Axis nomenclature and critical components and details of the IXOMMM

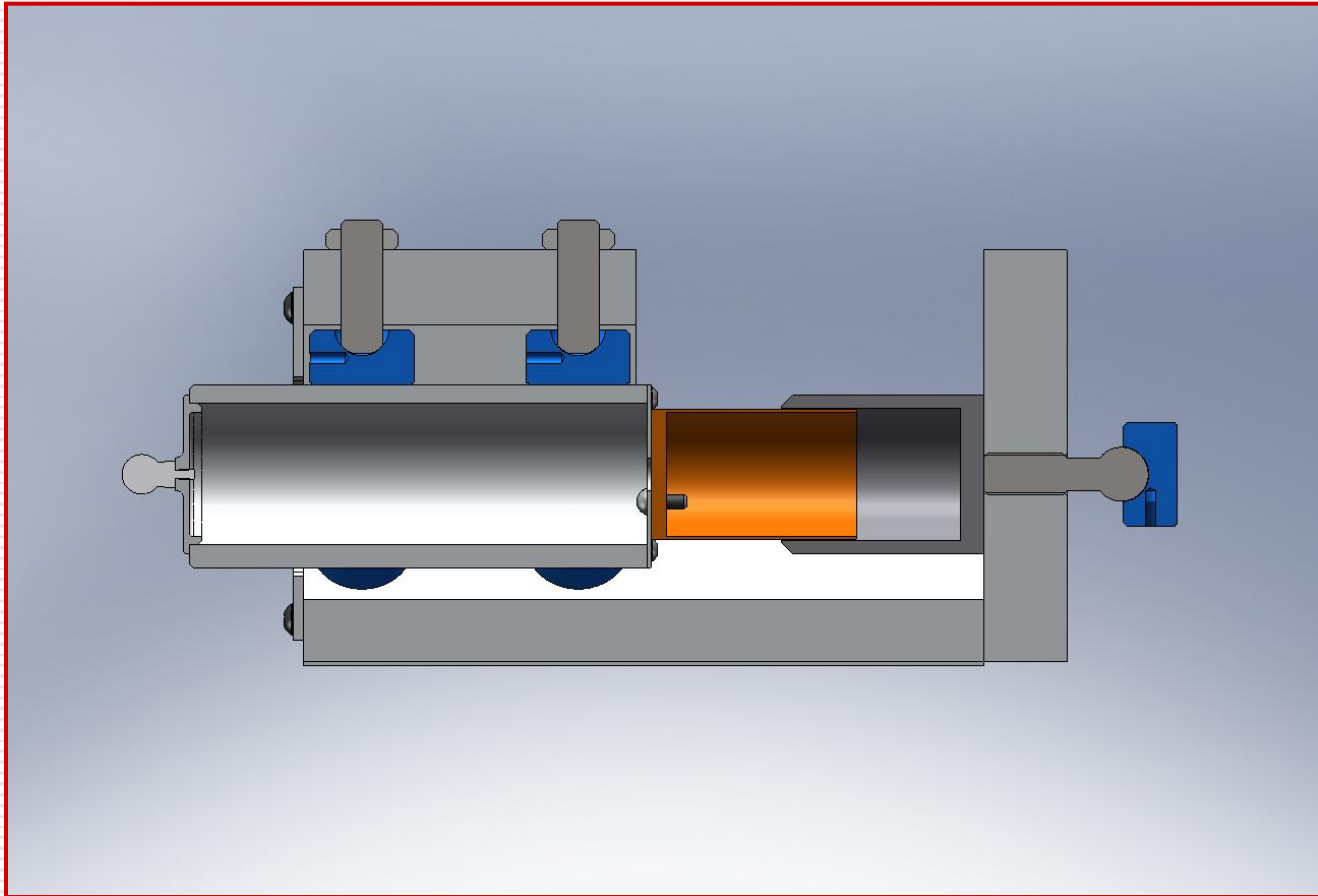


The gaugehead is actuated with a voice coil to provide a gauging range of 30 mm. Resolution is 53 pm, construction is principally Zerodur

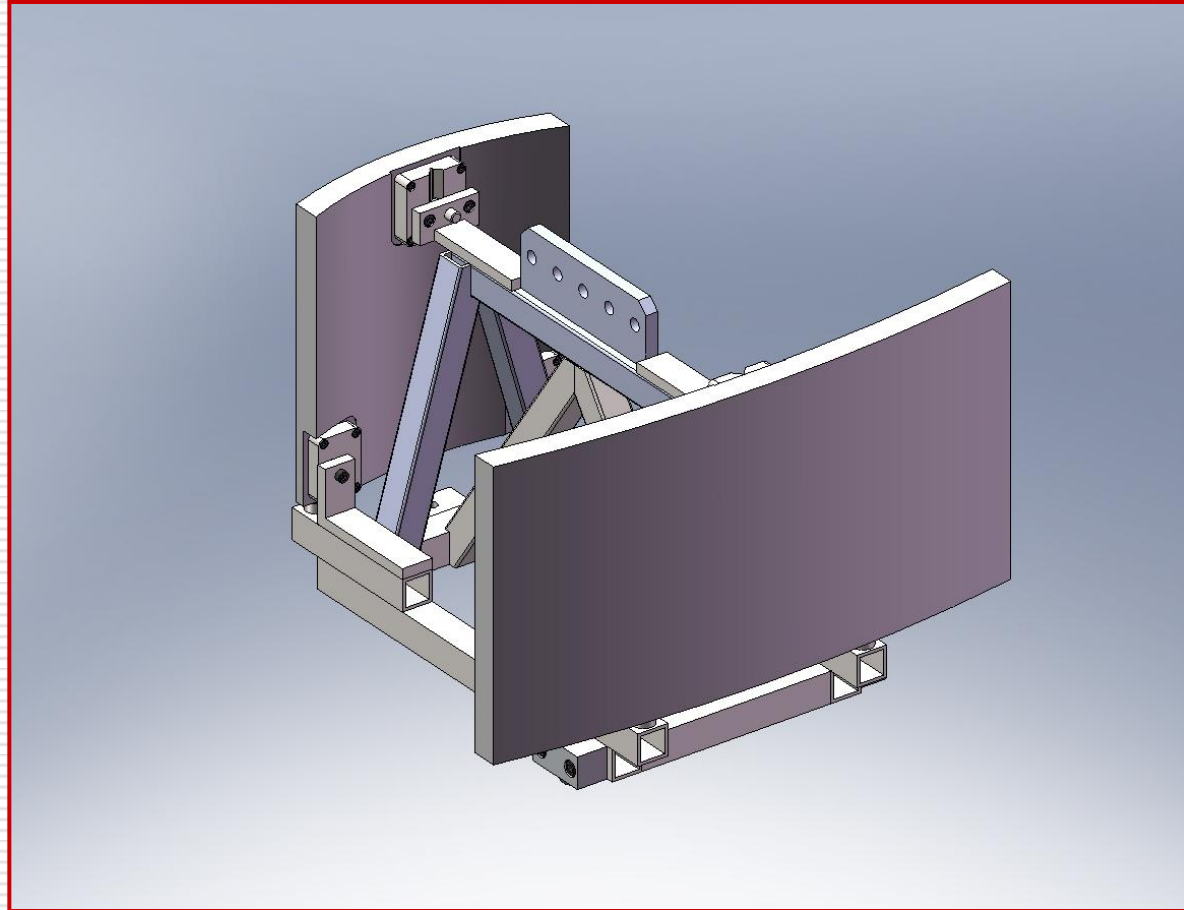


## Section view of the gaugehead

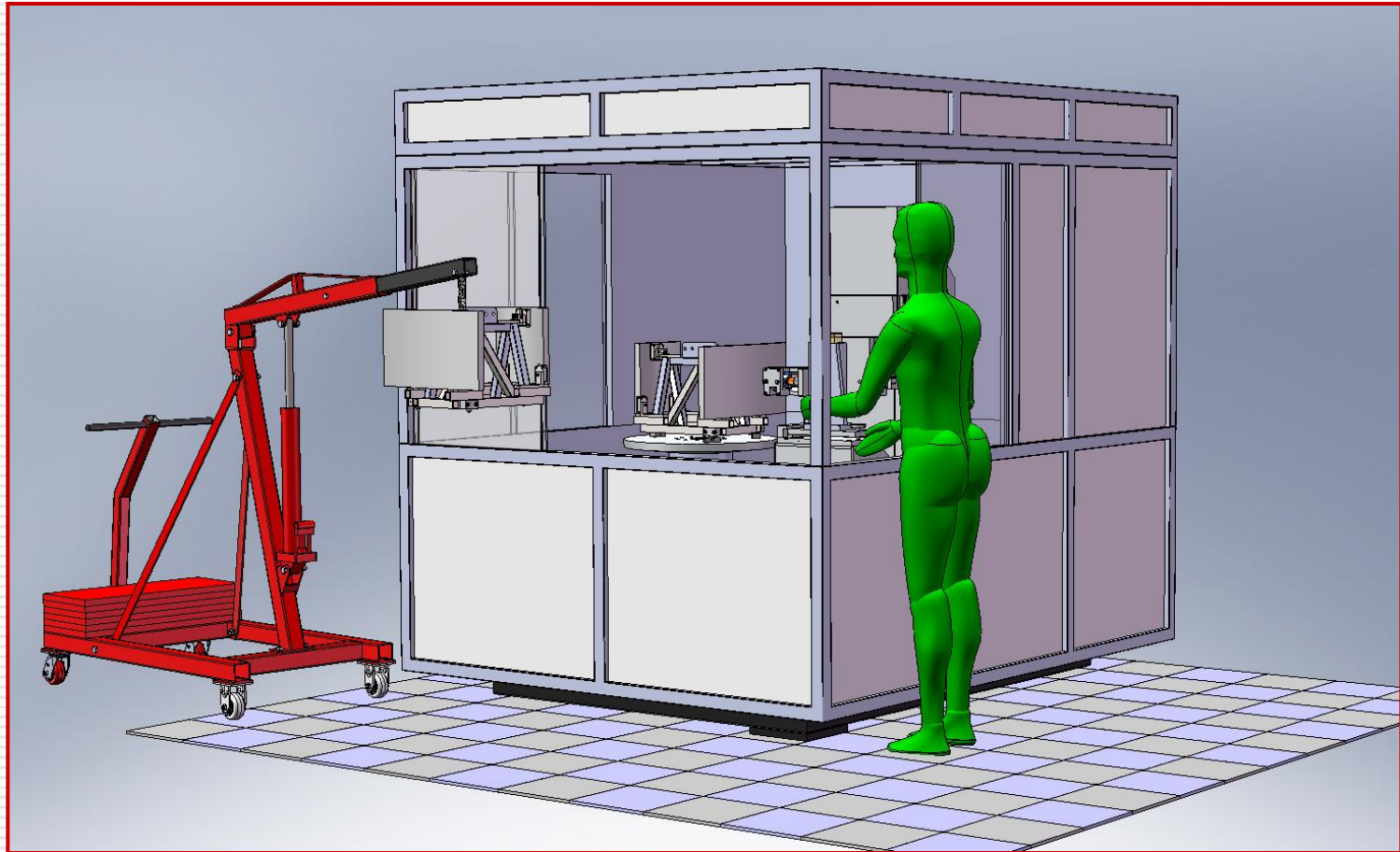
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Mandrel components are mounted kinematically to a frame, which is kinematically supported to the rotary table. The entire assembly can then be kinematically mounted on the polisher.



Temperature in the enclosure around the IXOMMM will be maintained within  $\pm 0.005^{\circ} \text{C}$ .



## Summary of current project status, Phase I work remaining

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- ❑ Conceptual design is 95% complete
- ❑ Error budget is in progress—and has been used as a tool to guide the design, materials selection
- ❑ Specification is complete, measuring process established
- ❑ Phase I work remaining: Completion of error budget, Final Report, Plan for Implementation (Phase II), Plan for integrating to polisher (Phase III)

## Acknowledgements

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