

Senior Design Team 5



Sensor Test Team:

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Sponsored by:
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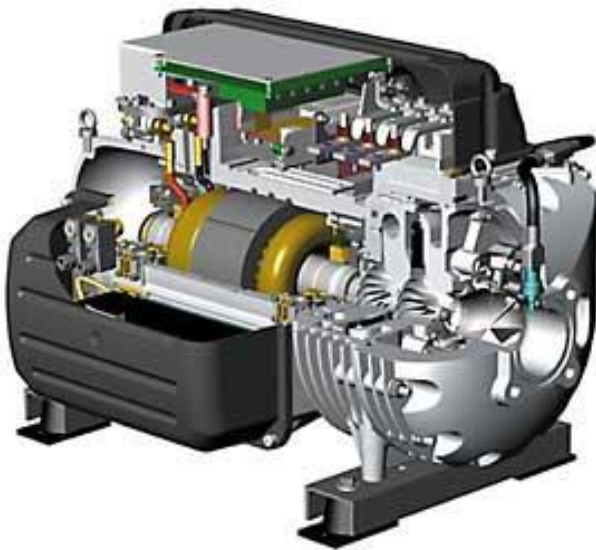
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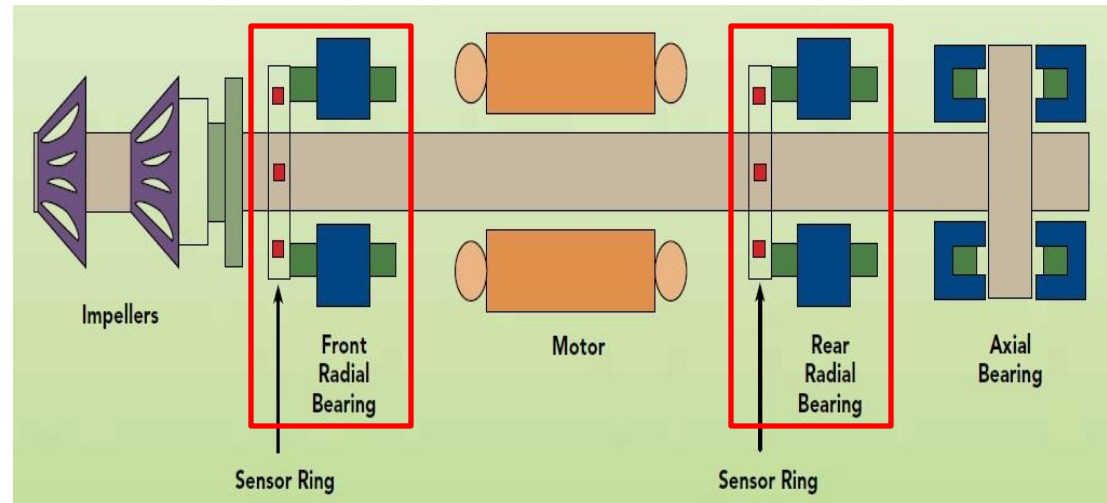
Overview

- Introduction
- Problem Statement
- Objectives
- Design Approach
- Design Concept
- Assembly
- Testing
- Expenditures
- Future Recommendations
- Summary

Introduction



Turbocor's Compressor



Internal view of compressor

- Compressors used in HVAC systems for large scale structures.
- Compressor shaft spins in a magnetic field (virtually no friction).
- 30,000 rpm, keep shaft in rotation position.

Problem Statement

- Current testing fixture
 - Inaccurate and unreliable
 - Only tests in the X-Y directions, and does not test Z
 - Backlash

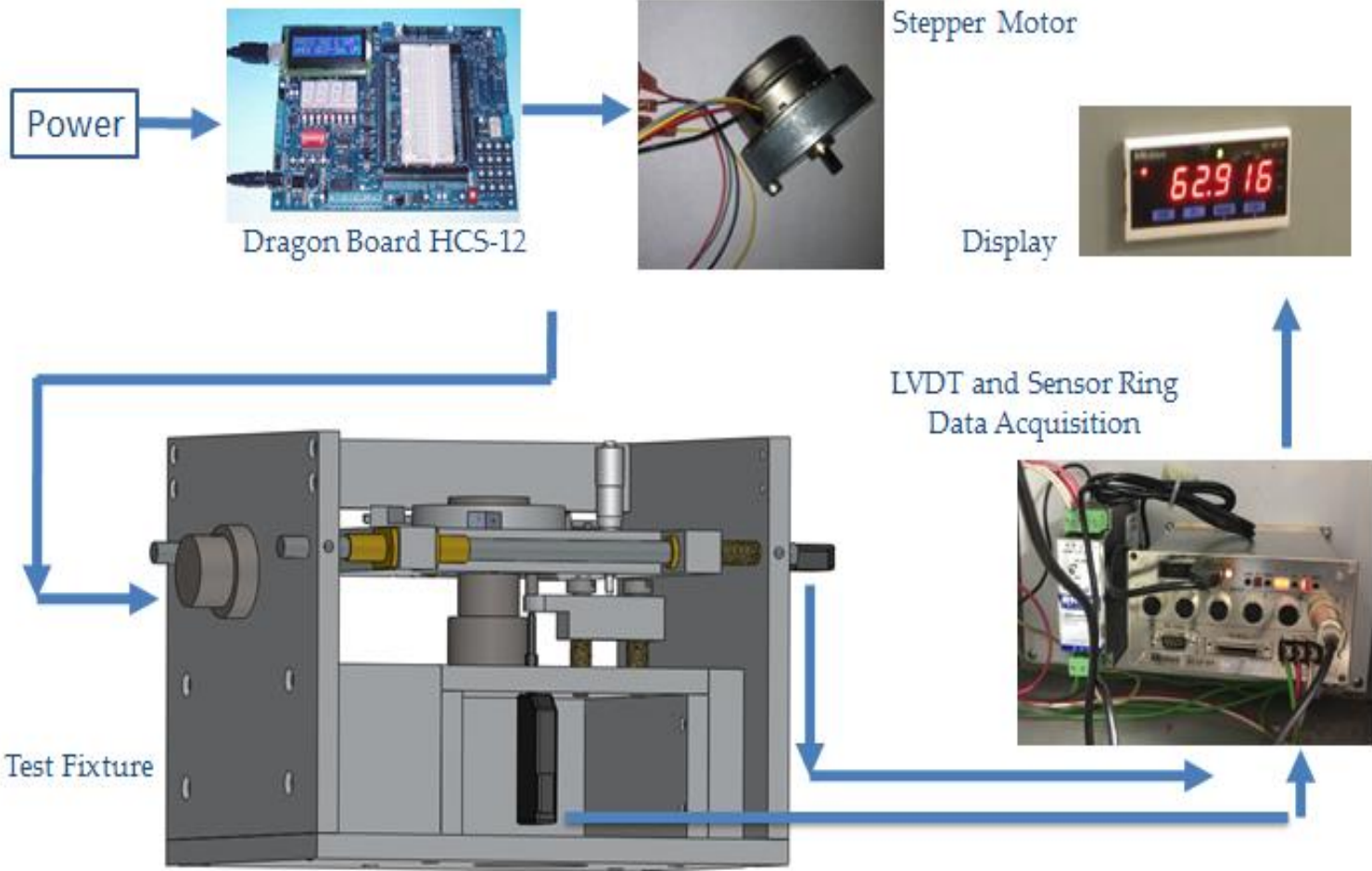
Objectives

- Design new test fixture to use in production line
 - 400 microns total displacement in X-Y
 - 500 microns total displacement in Z
 - Minimal backlash
 - Test X-Y-Z sensors
 - Semi-automated

Design Approach

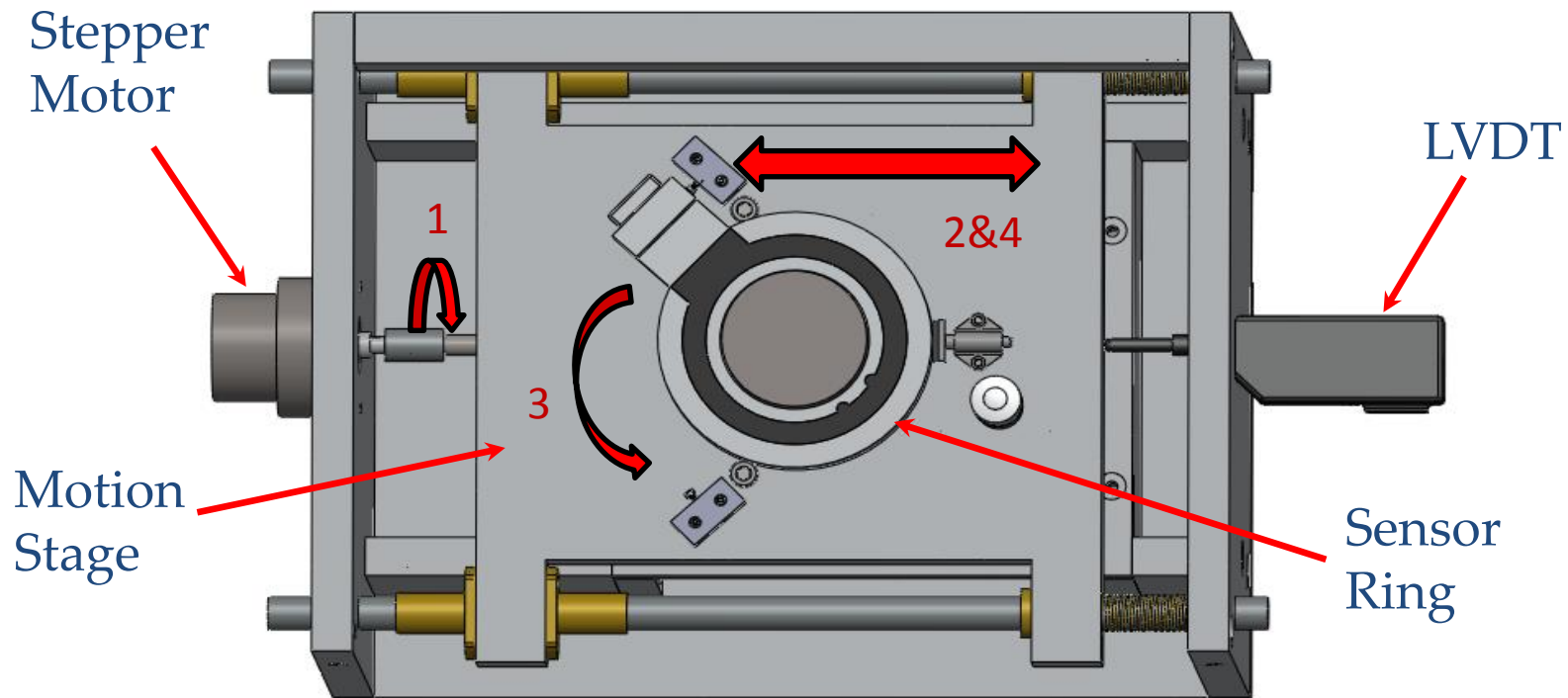
- Use stepper motor to actuate
 - Rotation to linear displacement
- LVDTs
 - Record displacement
 - Accurate for microns measurement

High Level Flow Chart



Design Concept

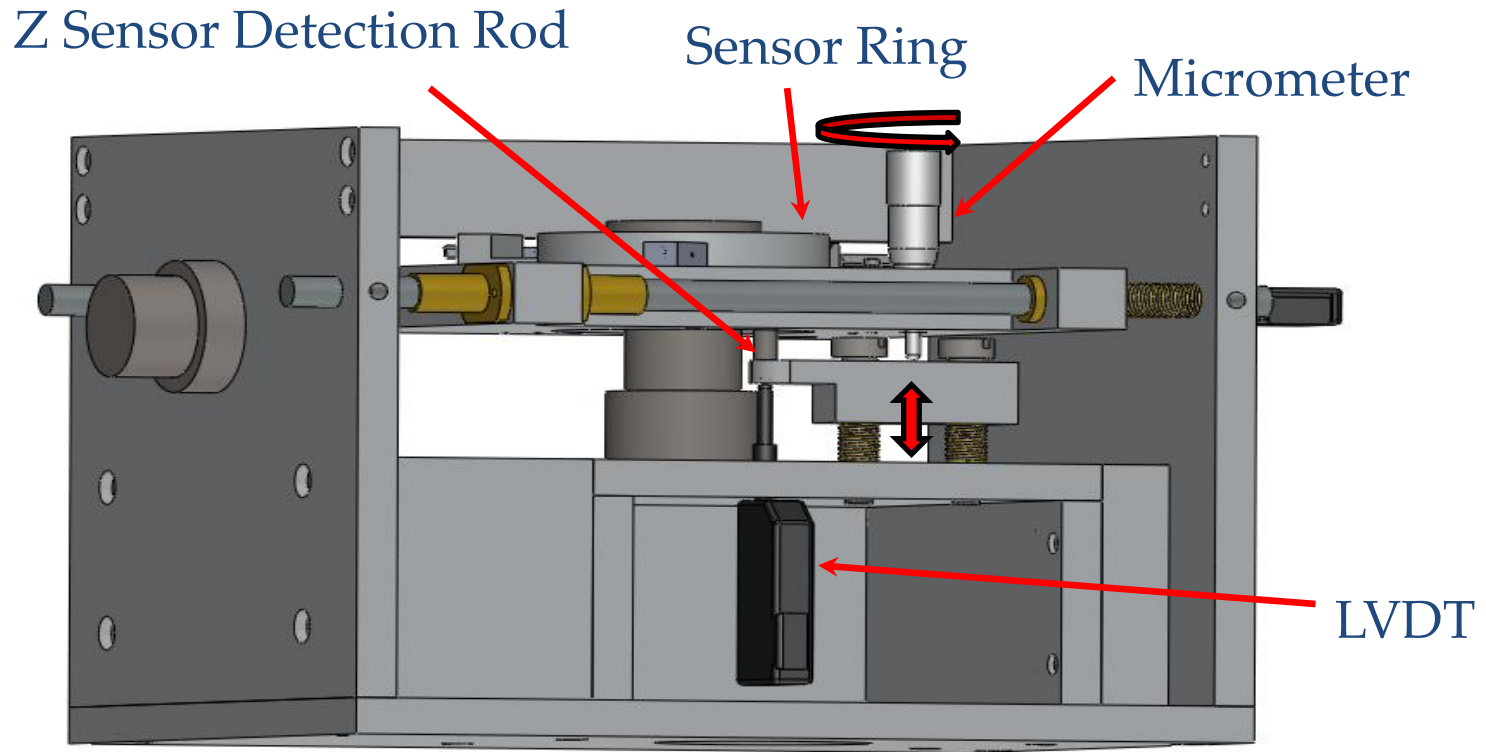
- 2-D approach to 3-D problem
 - X and Y sensors tested using same axis of movement
 - Sensor ring is rotated to achieve independent displacement



Test steps numbered in red

Design Concept

- Z sensor tested independently

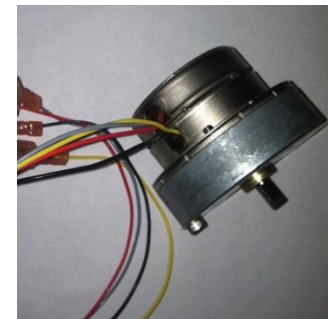


Stepper Motor

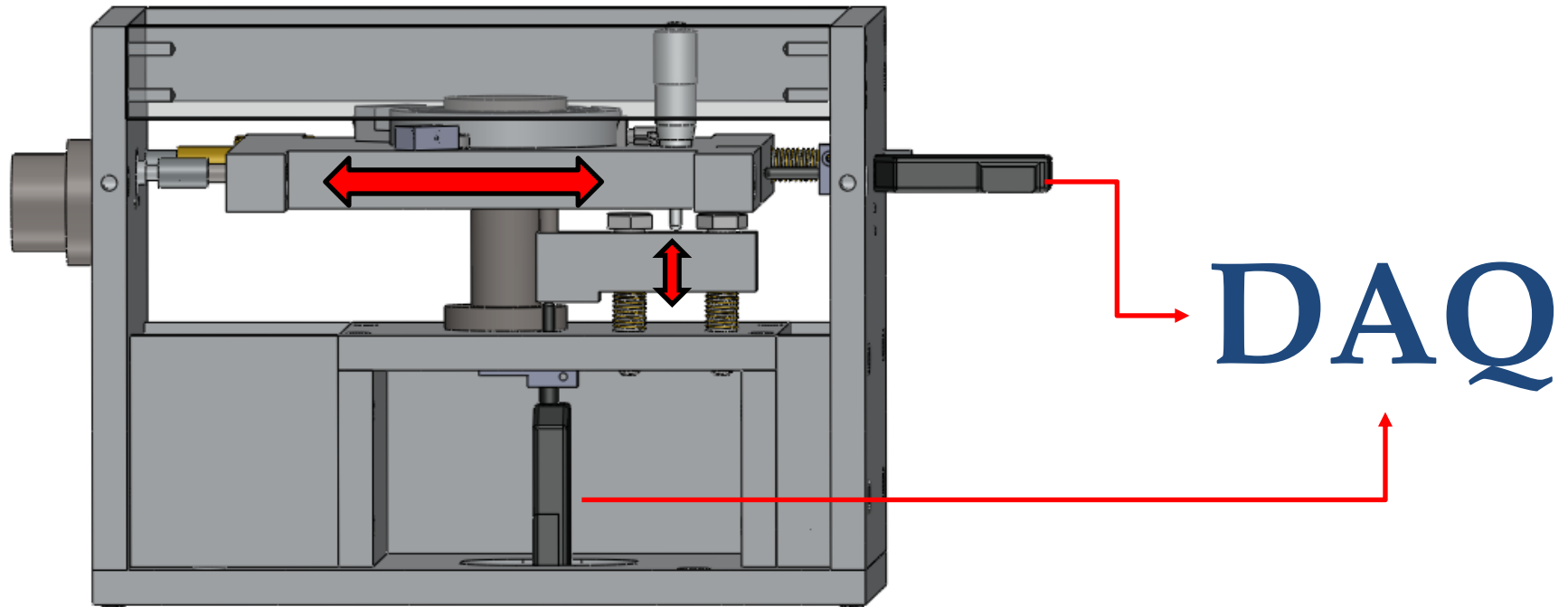
- Portescap™ custom-made geared motor for Danfoss
 - 0.25° per step
 - Coupled to 3/8 – 24 drive screw
 - Provides excellent motion resolution: 0.735 μm/step
 - 136° of total motor rotation
 - 400μm total lateral displacement
- Controlled by HCS-12 Dragon Board



Dragon Board HCS-12

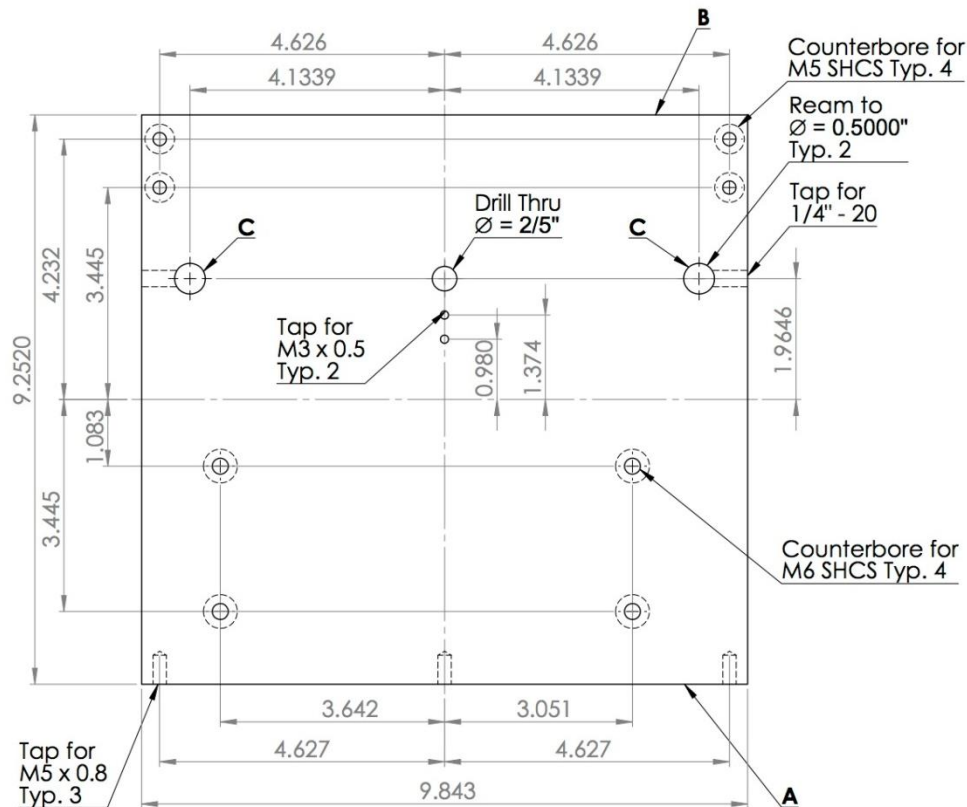


LVDT System



- LVDTs take displacement measurement
- DAQ displays displacement reading

Drawings & Tolerances

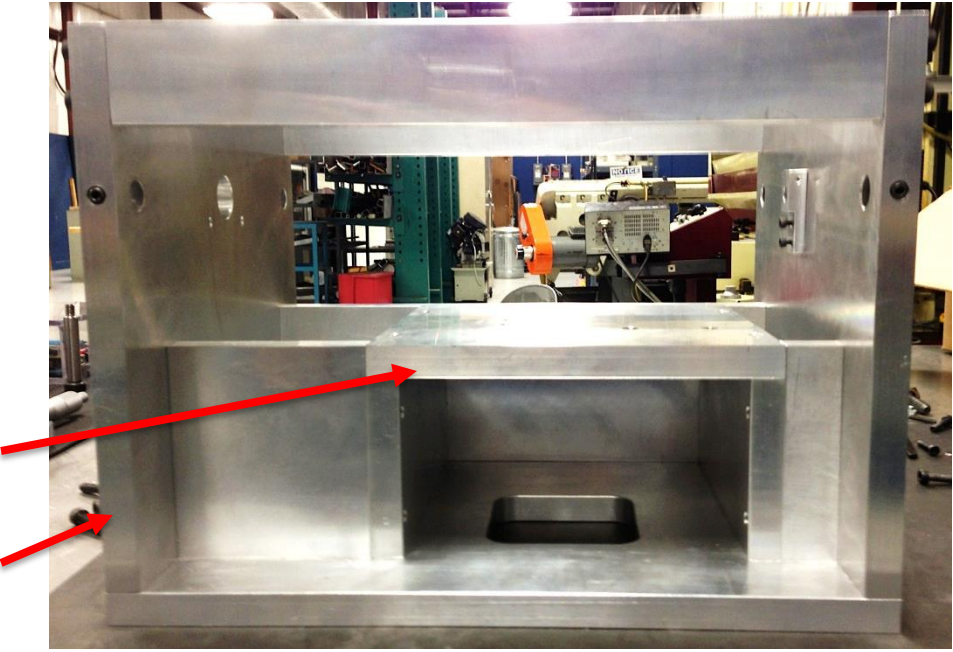
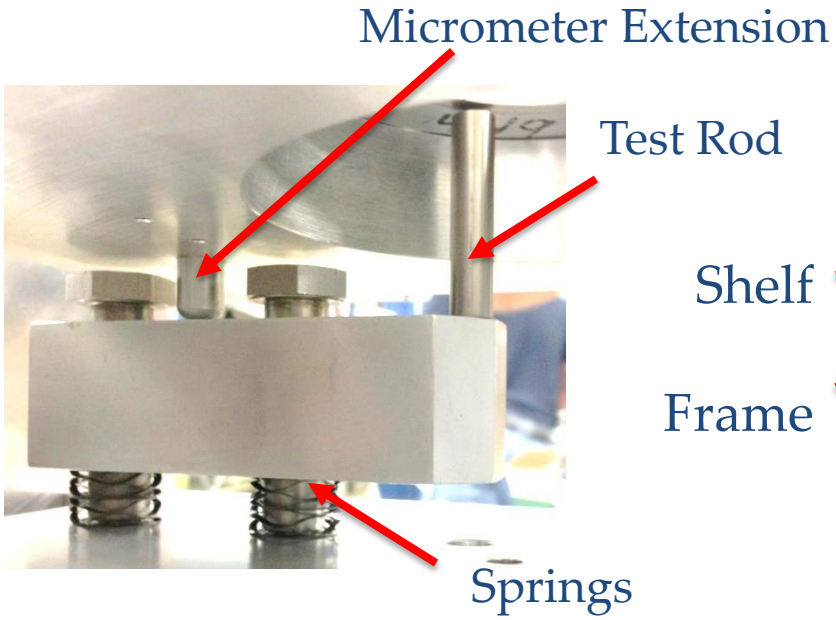


- Critical dimensions have tolerances of ± 0.00005 " (1.27 μm)
- Other dimensions have tolerances of ± 0.0005 " (12.7 μm)

A // B 0.0002"
C \perp A 0.0002"
C \perp B 0.0002"

Assembly

- Frame and shelf
- Z-axis platform



Assembly

- Bearings
- Guide rods
- Sensor table components

Coupler &
Drive Screw

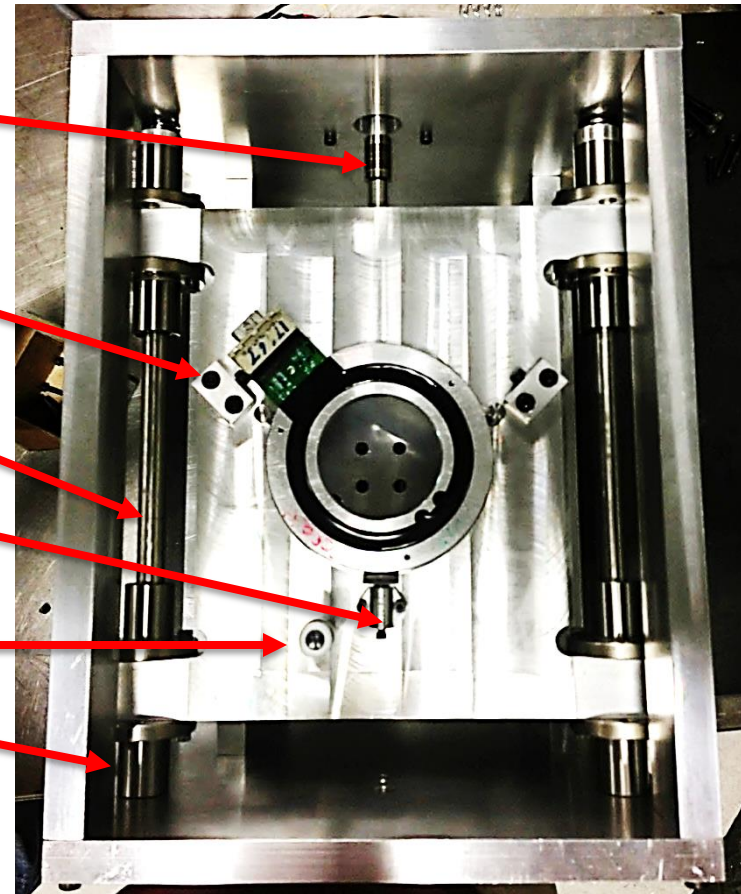
Position Blocks

Guide Rods

Plunger

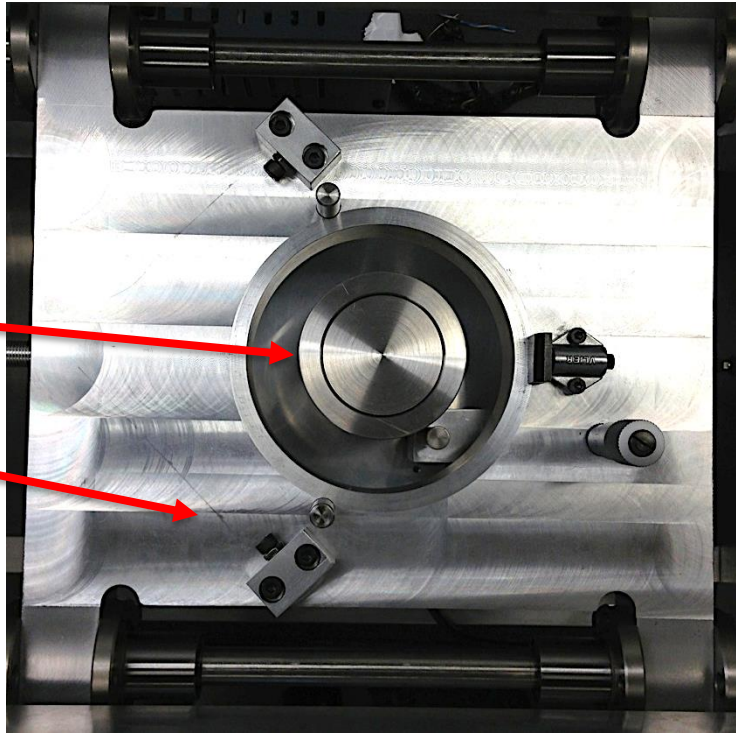
Micrometer

Bearings



Assembly

- Shaft
 - Transfer Ring
- LVDT



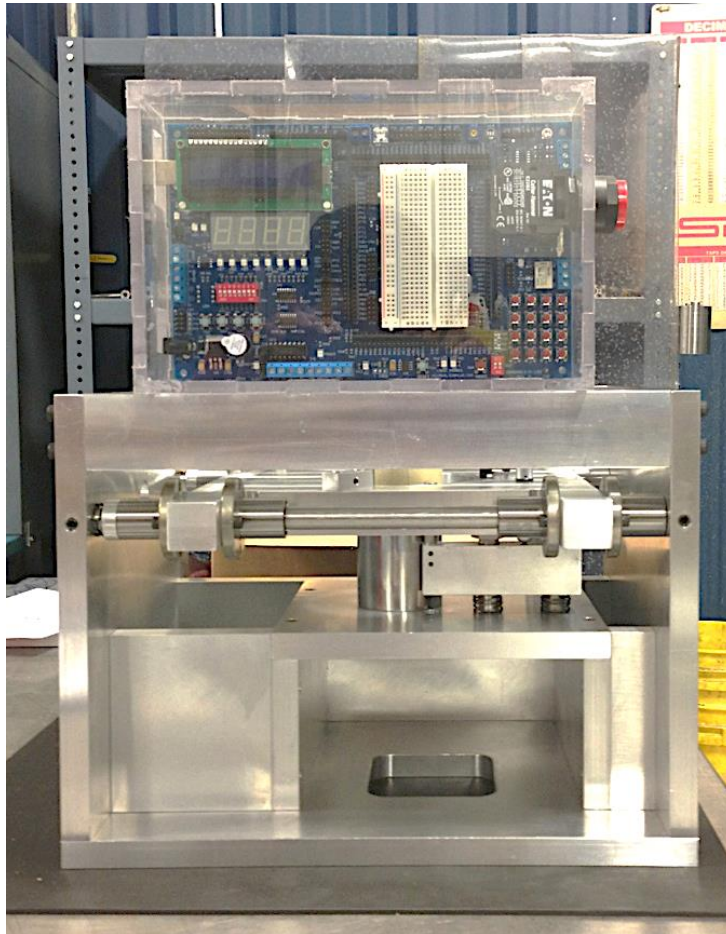
Sensor Table

LVDT

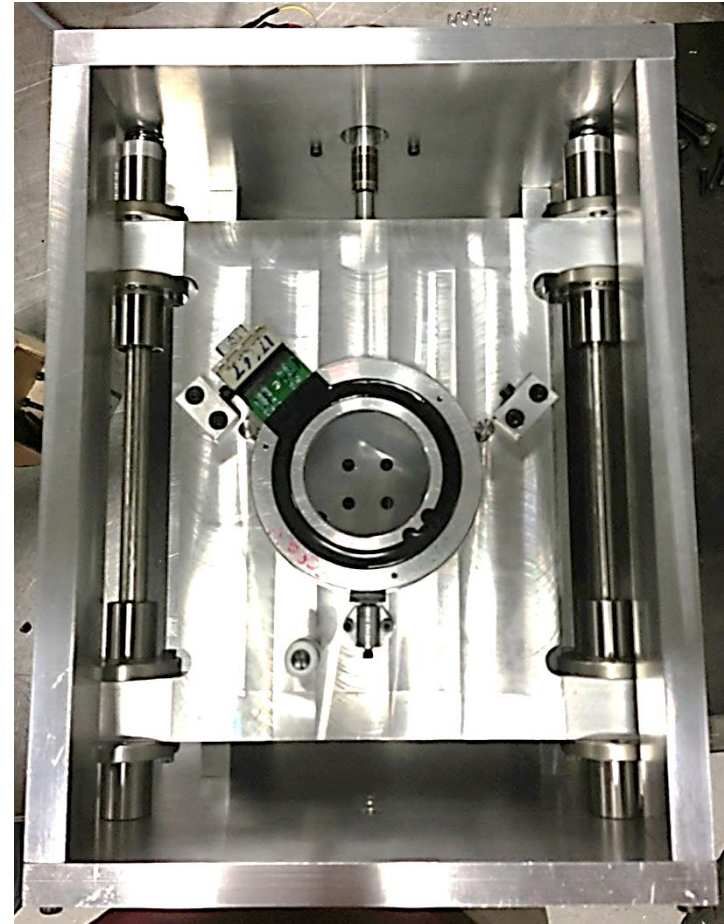
LVDT Clamp



Completed Test Fixture



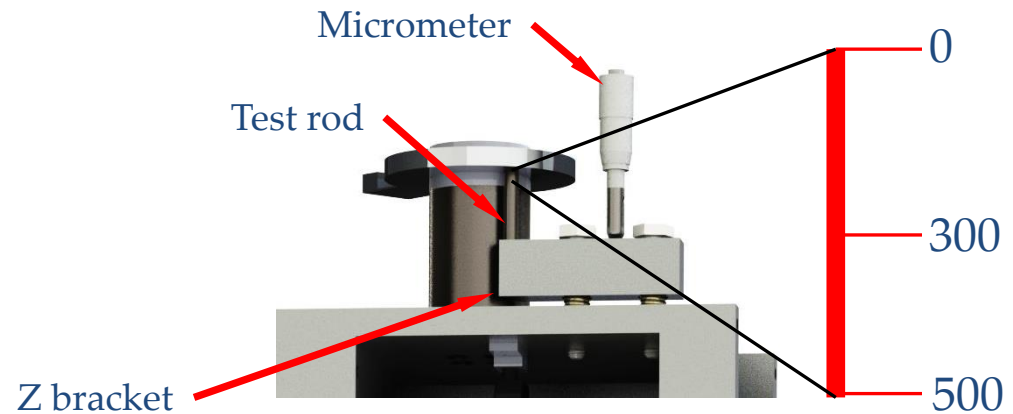
Side View



Top View

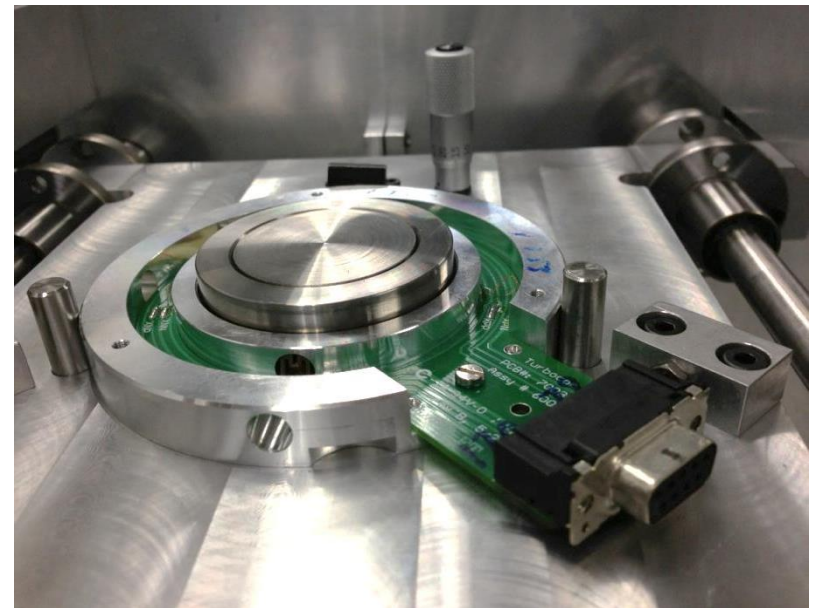
Testing

- LVDT testing
 - Accuracy
- Stepper motor calibration
 - Code tweaking
 - Number of steps
- Axial sensors
 - Three test positions
 - 0, 300, 500 μm
 - Dummy sensor



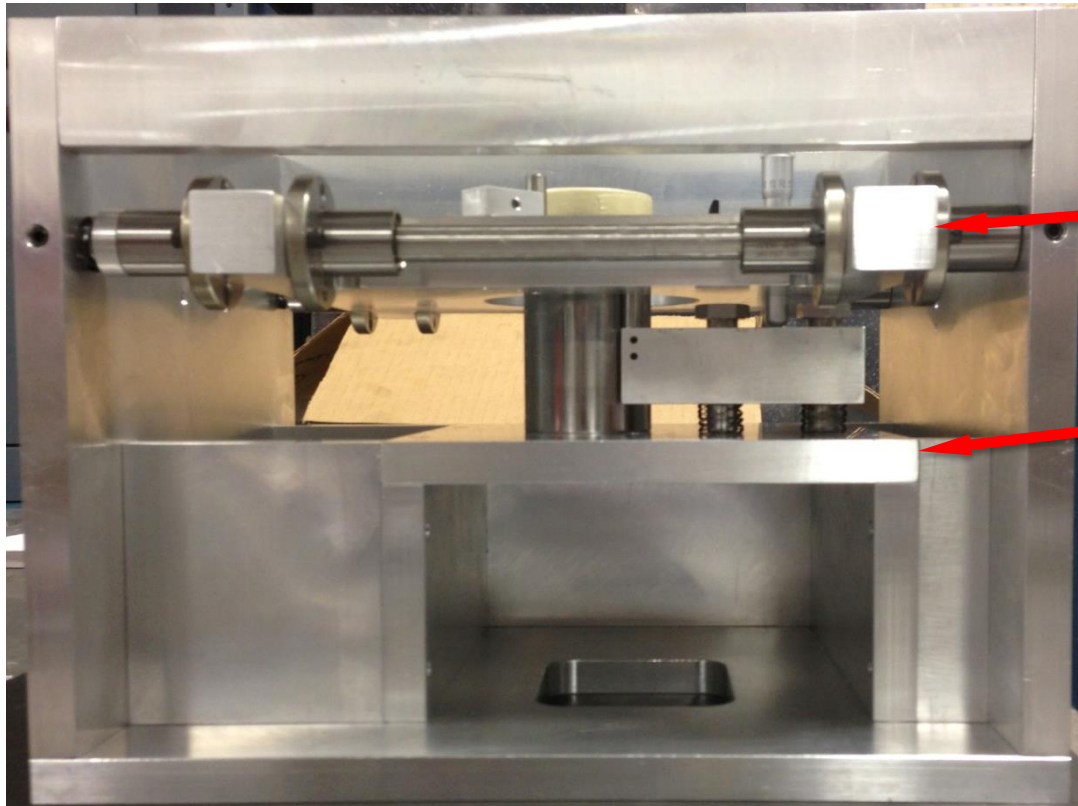
Testing

- Radial sensors
 - Center-position reading
 - Two extreme points in both X & Y
 - Determine sensitivity (V/mm)
 - Pass or Fail range



Challenges

- Machining for Perpendicularity

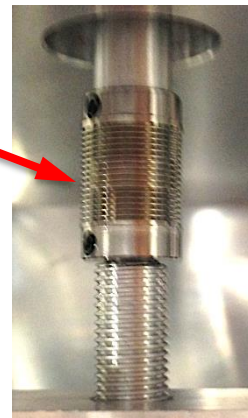
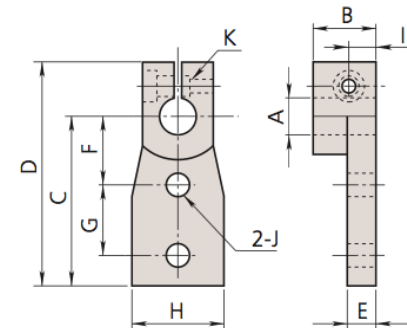
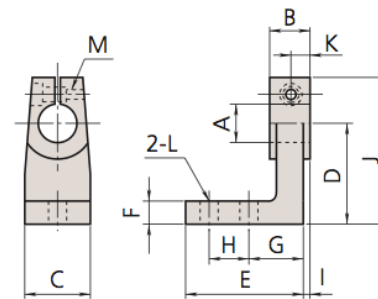
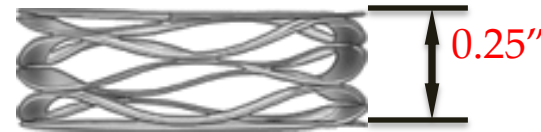


Testing Stage

Shaft Platform

Assembly Delays

- Reducing Backlash
 - Wave Form Springs
- Mitutoyo micro head clamps
- Bellows Shaft Coupler



Expenditures

Micrometer Head	8578A67	1	\$72.00	\$72.00
Spring Plunger	3351A13	1	\$7.94	\$7.94
10-24 Set Screws	92158A248	1	\$4.82	\$4.82
Compression Springs for Axial	9657K317	1	\$8.38	\$8.38
Linear Bearings	6483K53	8	\$30.80	\$246.40
AC to DC Converter	70235K96	1	\$16.56	\$16.56
Sleeve Bearings	9368T58	2	\$2.03	\$4.06
Springs for stage	9657K22	2	\$2.84	\$5.68
1/4-20 set screws	92158A417	1	\$5.50	\$5.50
3/8"-24 Threaded Rod (drive screw)	6516K21	1	\$7.90	\$7.90
#4-40 set screws	92158A119	1	\$3.93	\$3.93
1.5" Dowel Pins	97395A510	1	\$14.56	\$14.56
8-32 cap screws	91251A196	1	\$12.48	\$12.48
M4 x 0.7 Jam Nuts	93935A325	1	\$4.69	\$4.69
High load compression springs	1561T34	2	\$11.07	\$22.14
M3 Shcs screws	91290A124	1	\$5.15	\$5.15

Expenditures

Al 6061 5/8" thick 10" width 6' length	1614T973	1	\$237.13	\$237.13
Al 6061 1" thick 10" width 1' length	8975K103	1	\$86.09	\$86.09
303 SS Rod	88915K223	2	\$29.34	\$58.68
18-8 SS Shoulder Bolts	94731A480	2	\$21.19	\$42.38
Al 6061 Rod	8974K731	1	\$24.62	\$24.62
Bellows Shaft Coupler	59925K91	1	\$80.28	\$80.28
Grade 2 Titanium Rod	89145K169	1	\$17.49	\$17.49

LVDT	DONATED	2	\$600.00	\$1,200.00
STEPPER MOTOR	DONATED	1	\$28.00	\$28.00
MACHINING	DONATED	36	\$20.00	\$720.00
DRAGON BOARD HCS-12	DONATED	1	\$169	\$169

Total Spent	\$988.86
Overall Total	\$3,105.86

Future Recommendations

- Improve the precision of the Z mechanism by increasing the travel of the testing rod
- Add automation for the axial sensor and sensor ring rotation
 - Additional stepper motors

Summary

- Developed a production test fixture for sensor ring testing
- Eliminated any assumptions in testing
- Drastically reduced backlash in the system
- Assembled test rig and successfully tested components for production

Special Thanks



- Kevin Lohman
- Julio Lopez
- Ranjan Mahadevan
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- Dr. Lin Sun

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- Dr. Oscar Chuy

Questions?