RHIC 56 MHz SRF Cavity Tuner Design Overview

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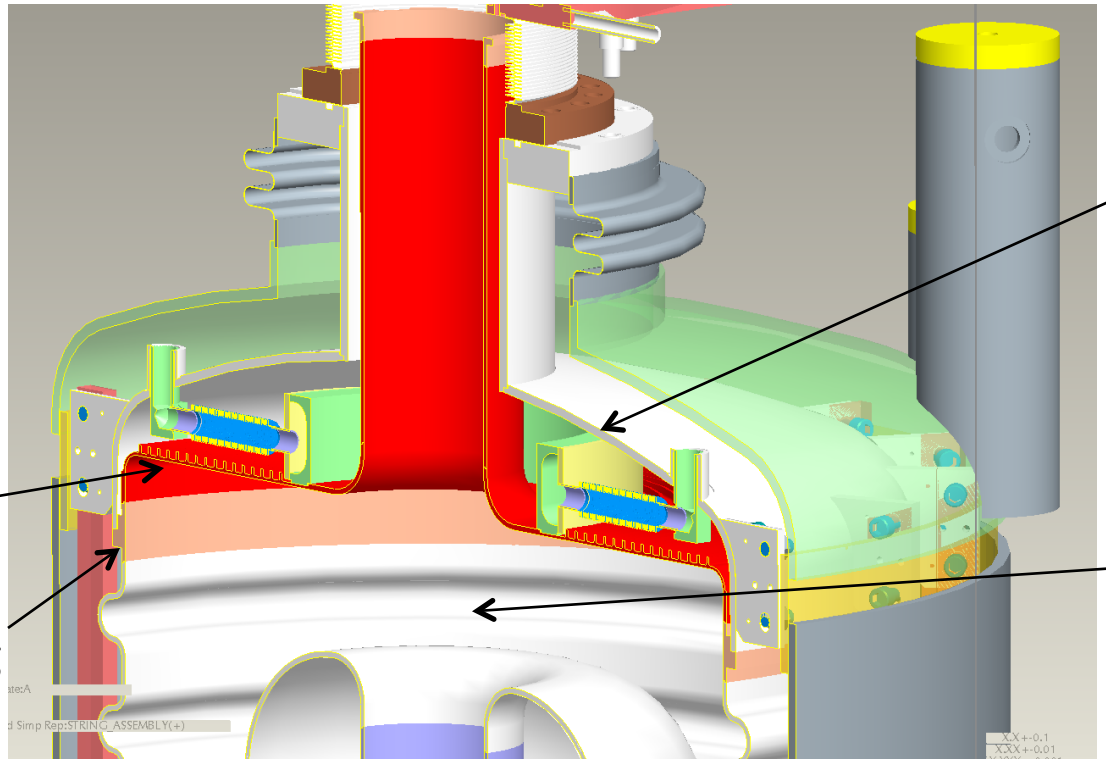
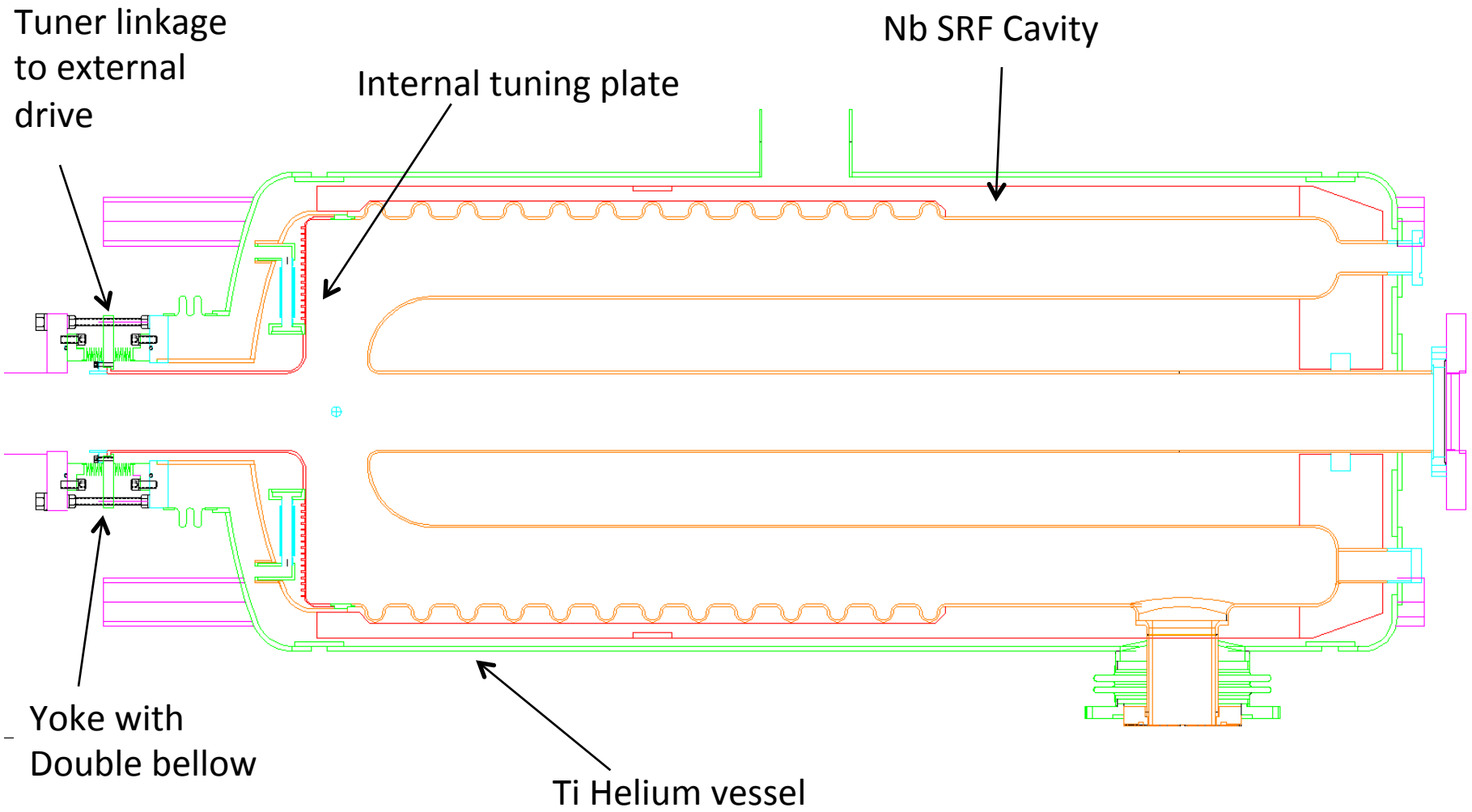
Mechanical Tuning of RF Cavity Resonance Frequency

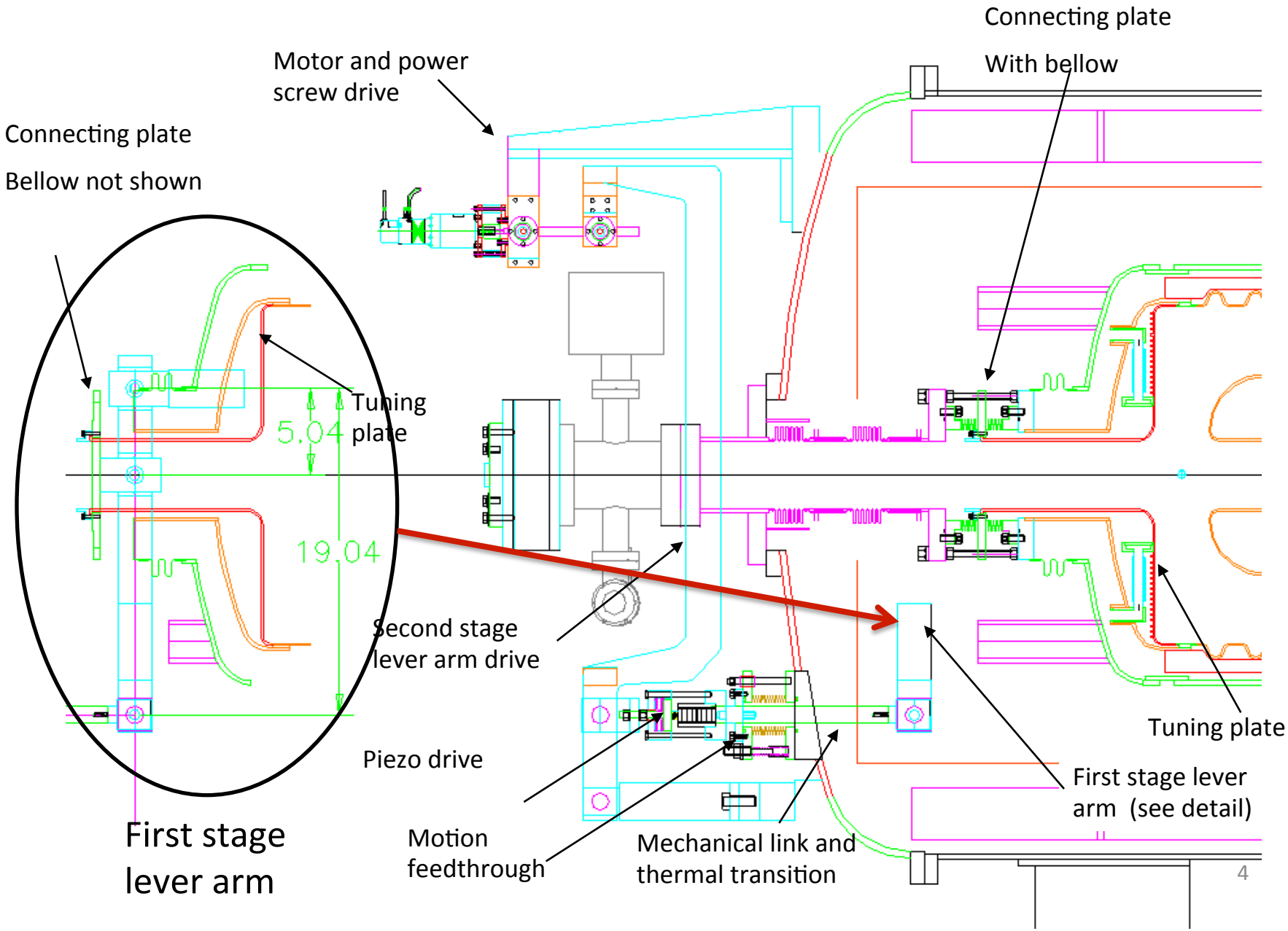
The mechanical tuning of the RF cavity resonance frequency is achieved by pushing or pulling the upper part of the SRF cavity (tuning plate) to change the gap distance of the SRF cavity. A tuning mechanism mounted on the helium vessel will provide both fast and slow tuning for the SRF cavity to change its fundamental resonance frequency. The tuner plate is an internal structure of the RF cavity vessel. A pressure head is outside the tuner plate to take helium pressure. The tuner plate is free from helium or vacuum pressure.



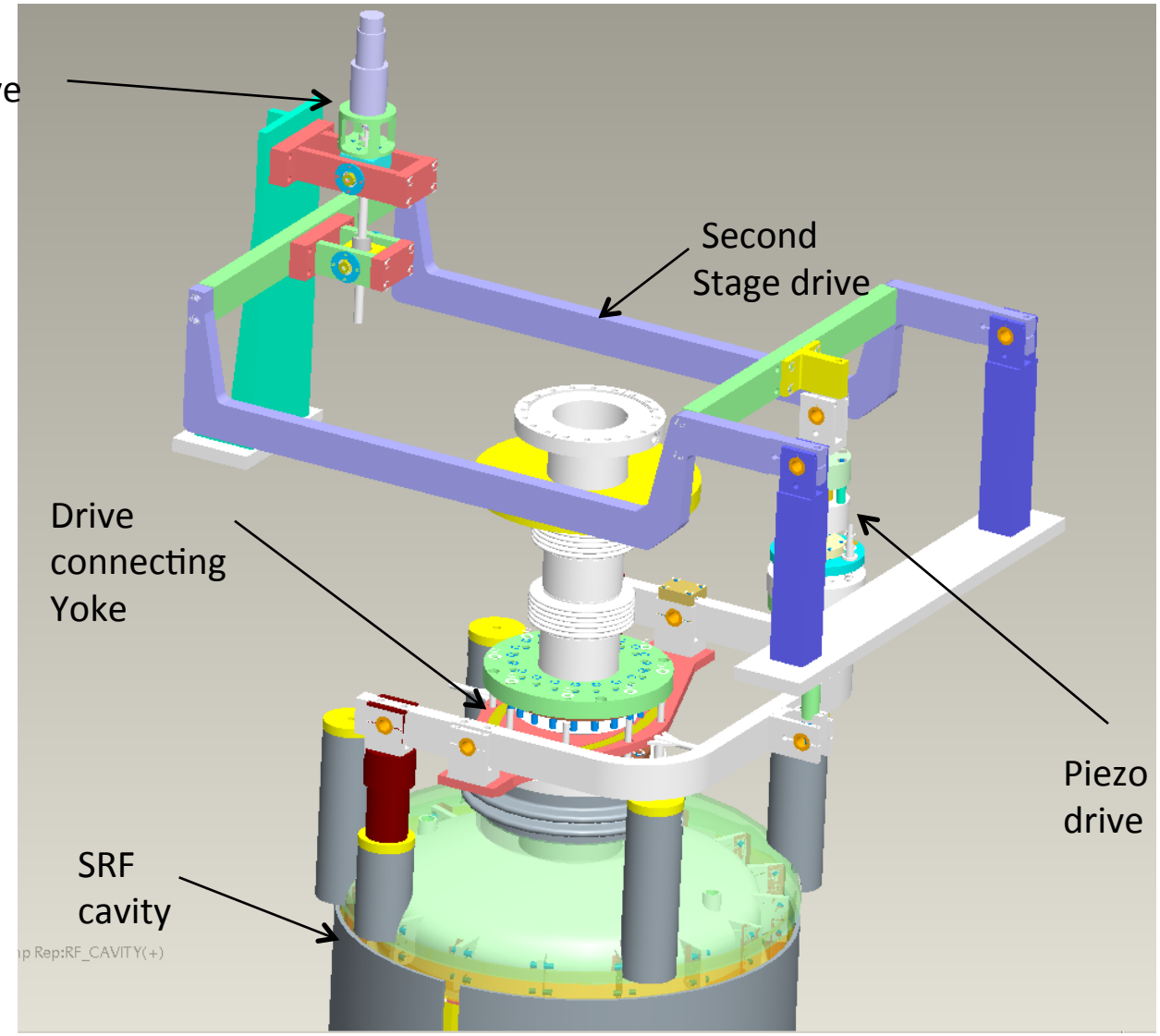
Schematic view of cavity and tuning plate



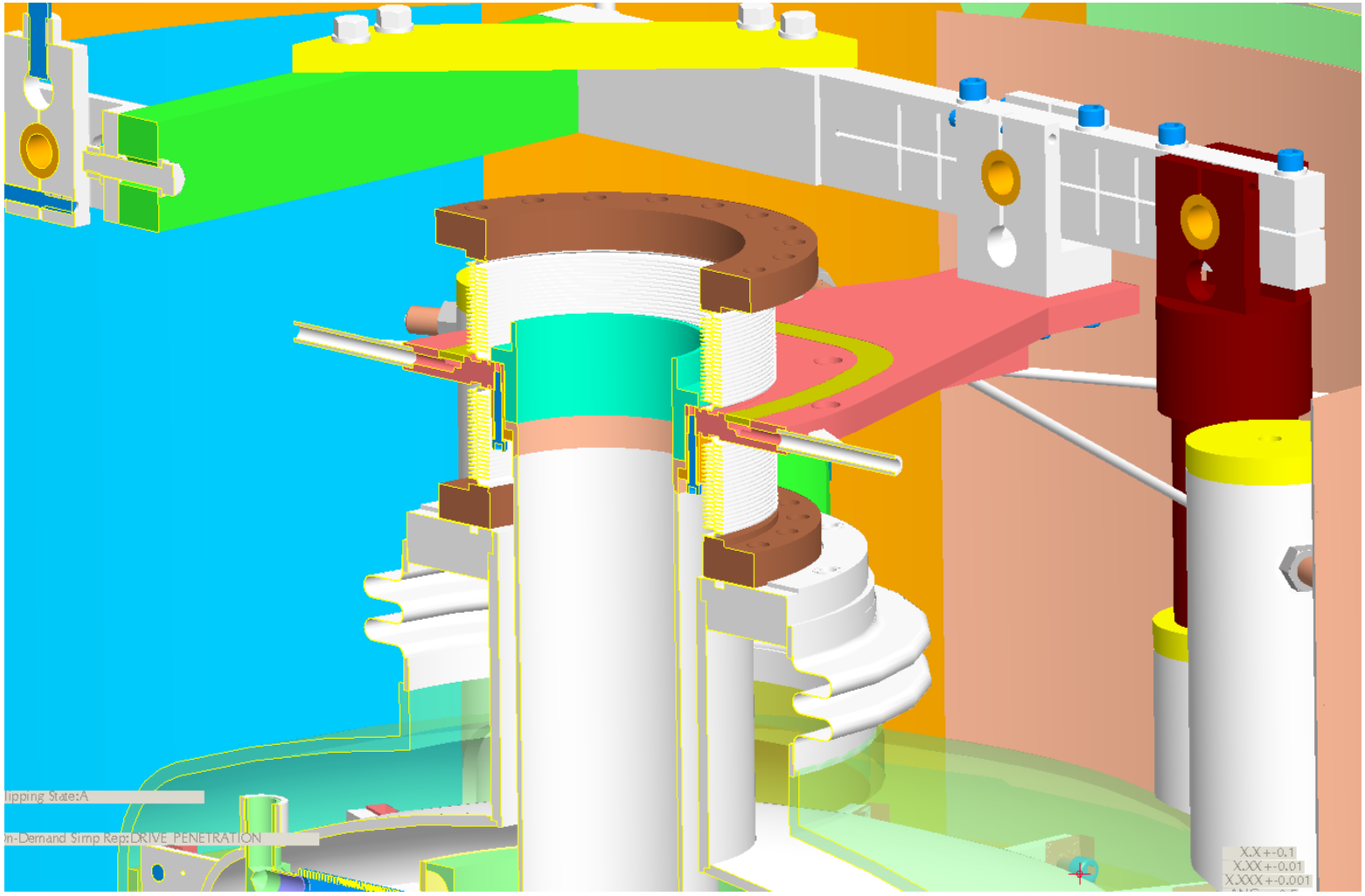
Schematic of Tuner Driving Mechanism



Mechanical Tuner Assembly (Vacuum chamber is not shown)



Link to outside Driving Mechanism, Detail view



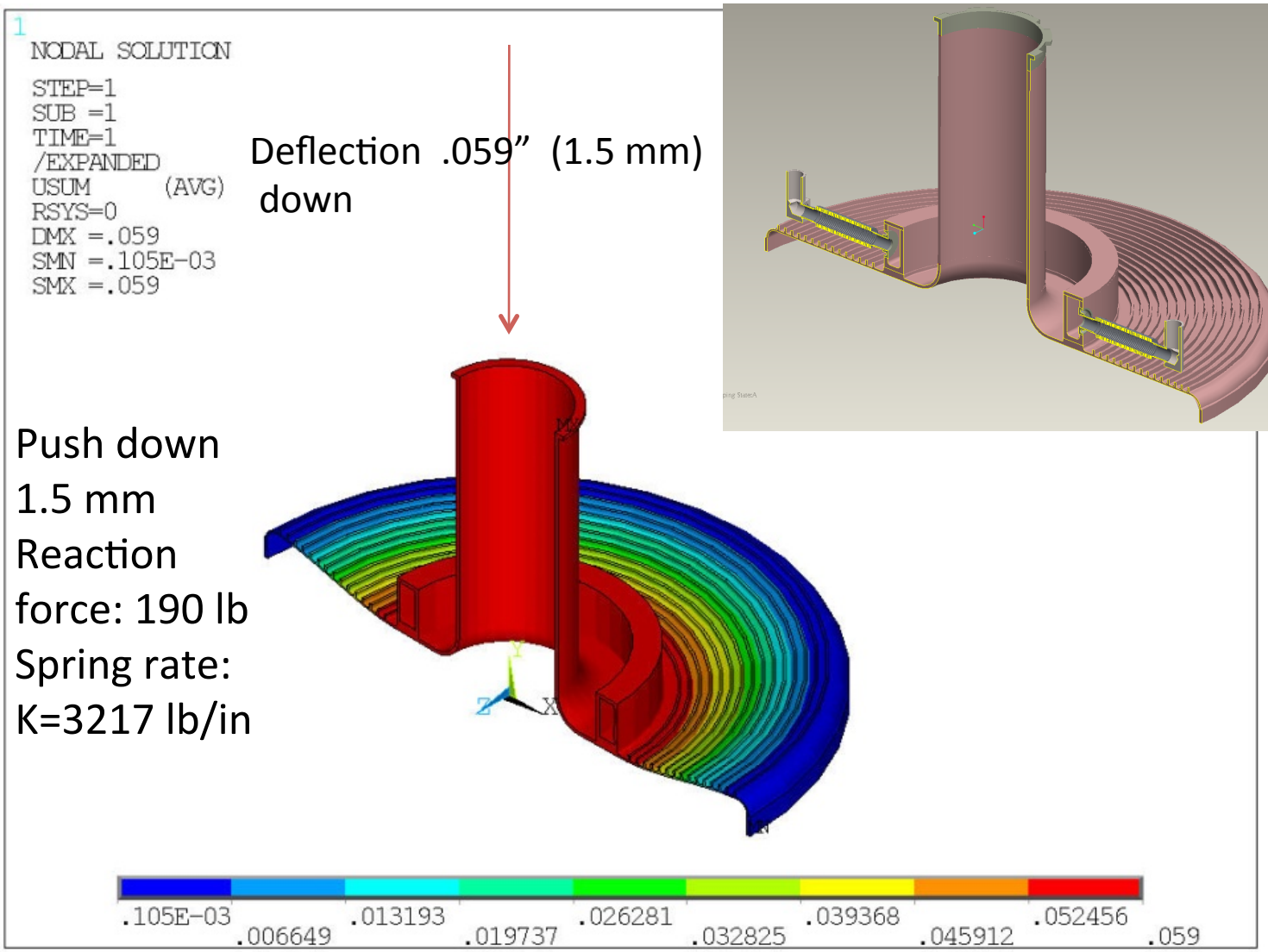
Tuning Sensitivity And Tuning Range

Fundamental Frequency of RF cavity: 56.25 MHz.
RF cavity Tuning Sensitivity: 17kHz/mm
Material Properties: (Limited by low elastic strength)
Pure Niobium
Yield strength: 7,000 psi
Tuning Range

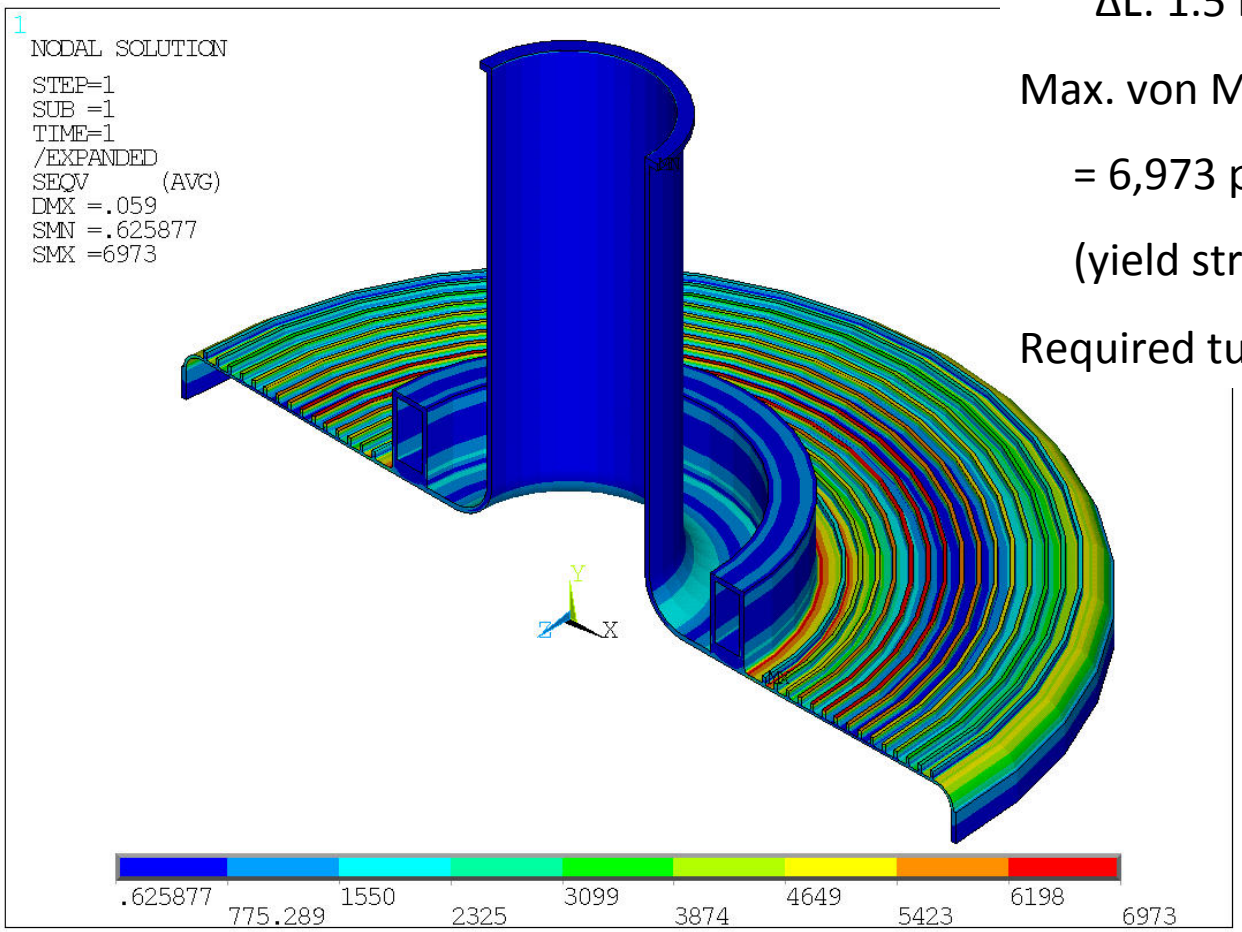
1. Elastic tuning : +/- 1.5 mm (+/-25.5 KHz)
   Tuning force: 190 lb
   Based on yield strength of 7,000 psi at room temperature.
   (Yield strength of niobium at cryogenic temperature is more than 2 times higher.)

2. Plastic tuning: Pushed down 6.0 mm, Residual deflection: 3.1 mm (52.7 KHz).
   Tuning force: 376 lb.
   Note: This plastic tuning is an option, only when large frequency correction is needed.

Spring rate (Elastic) of Tuning plate



Normal Elastic Tuning, Von Mises Stress Plot



psi

Deflection :

ΔL: 1.5 mm down

Max. von Mises stress

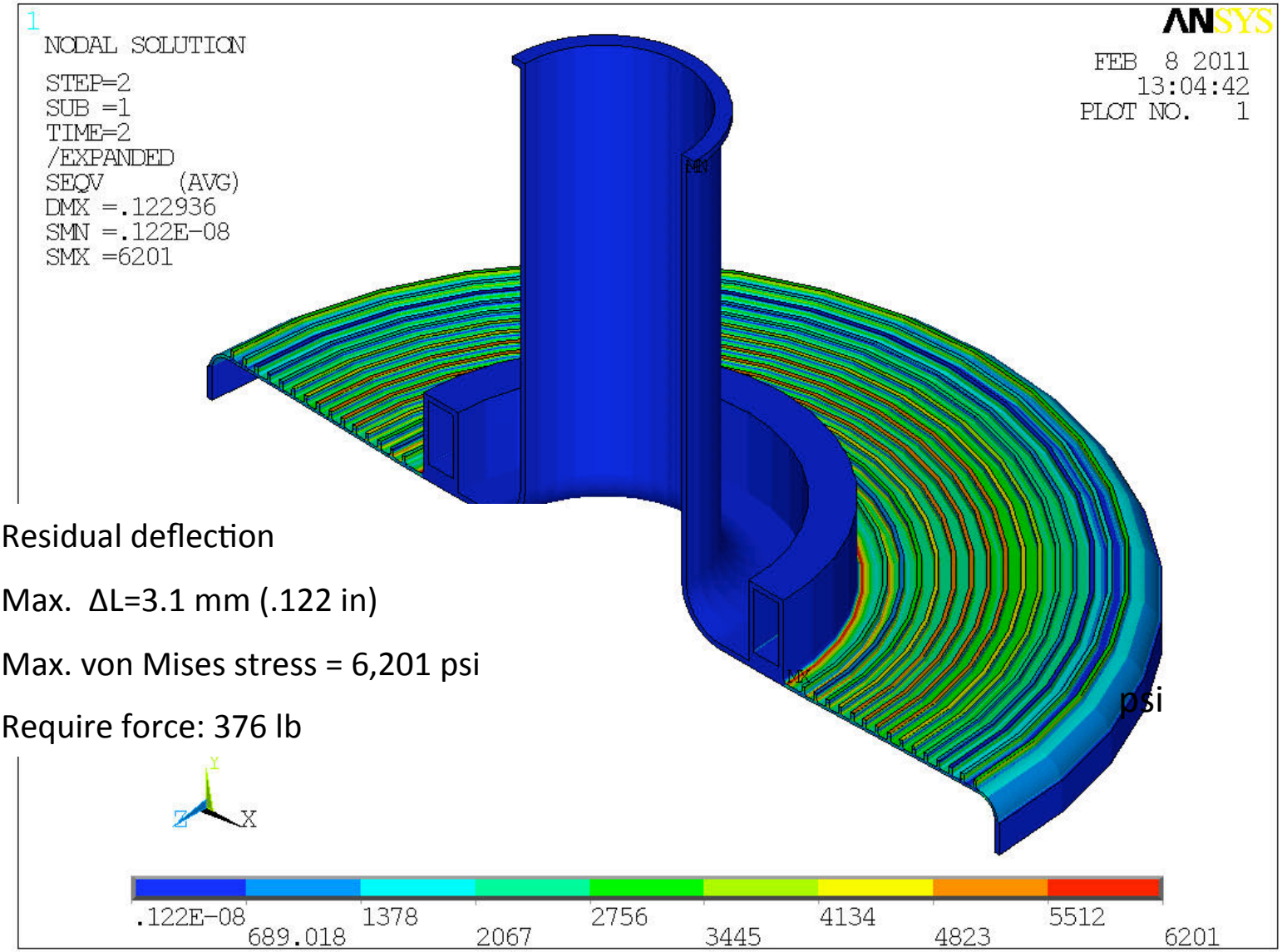
= 6,973 psi

(yield strength: 7000 psi)

Required tuning force: F=190 lb

Plastic Tuning

Residual Deformation after 6mm deflection, Von Mises Stress



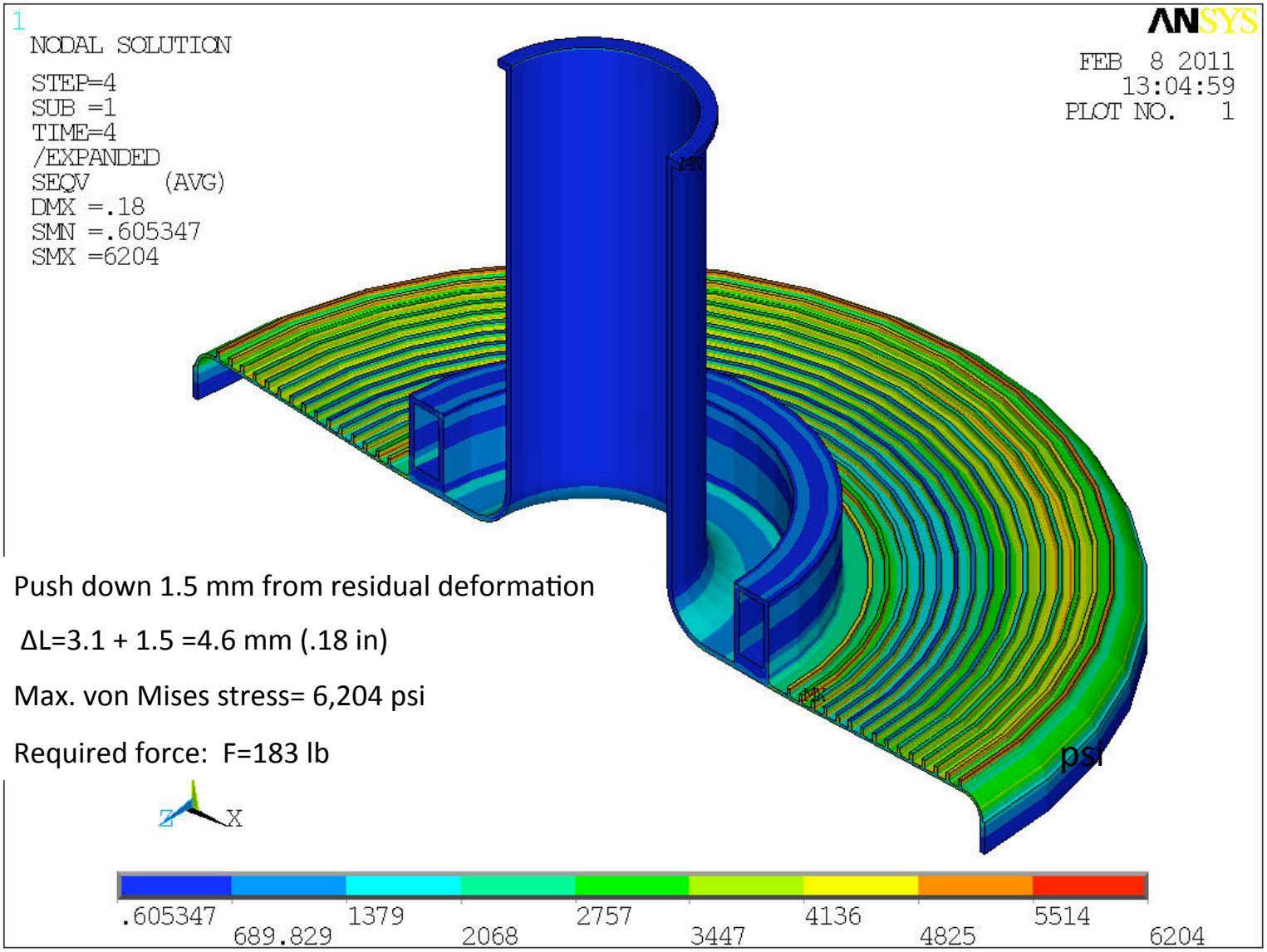
Residual deflection

Max. ΔL=3.1 mm (.122 in)

Max. von Mises stress = 6,201 psi

Require force: 376 lb

Elastic tuning after Plastic Tuning
Von Mises Stress Plot



Push down 1.5 mm from residual deformation

ΔL=3.1 + 1.5 =4.6 mm (.18 in)

Max. von Mises stress= 6,204 psi

Required force: F=183 lb

Mechanical Tuner Drive Parameters:

Type: Two stages of simple lever arm mechanism First stage is in the inside of cryostat (cold). Second stage is in the outside of cryostat (warm).

Mechanical leverage: First stage leverage: 3.77

Second Stage leverage: 6.60

Total: 24.88

Tuning Deflection/force in the tuner linkage:

First stage: 1.5 mm/190 lb

Second Stage: 37.3 mm/ 7.64 lb

Tuning Range:

1. Coarse tuner range: +/- 25.5 KHz, installed in the second stage
2. Fast tuner range: 60 Hz, installed in the first stage

Mechanical Leverage Mechanism of Tuner drive

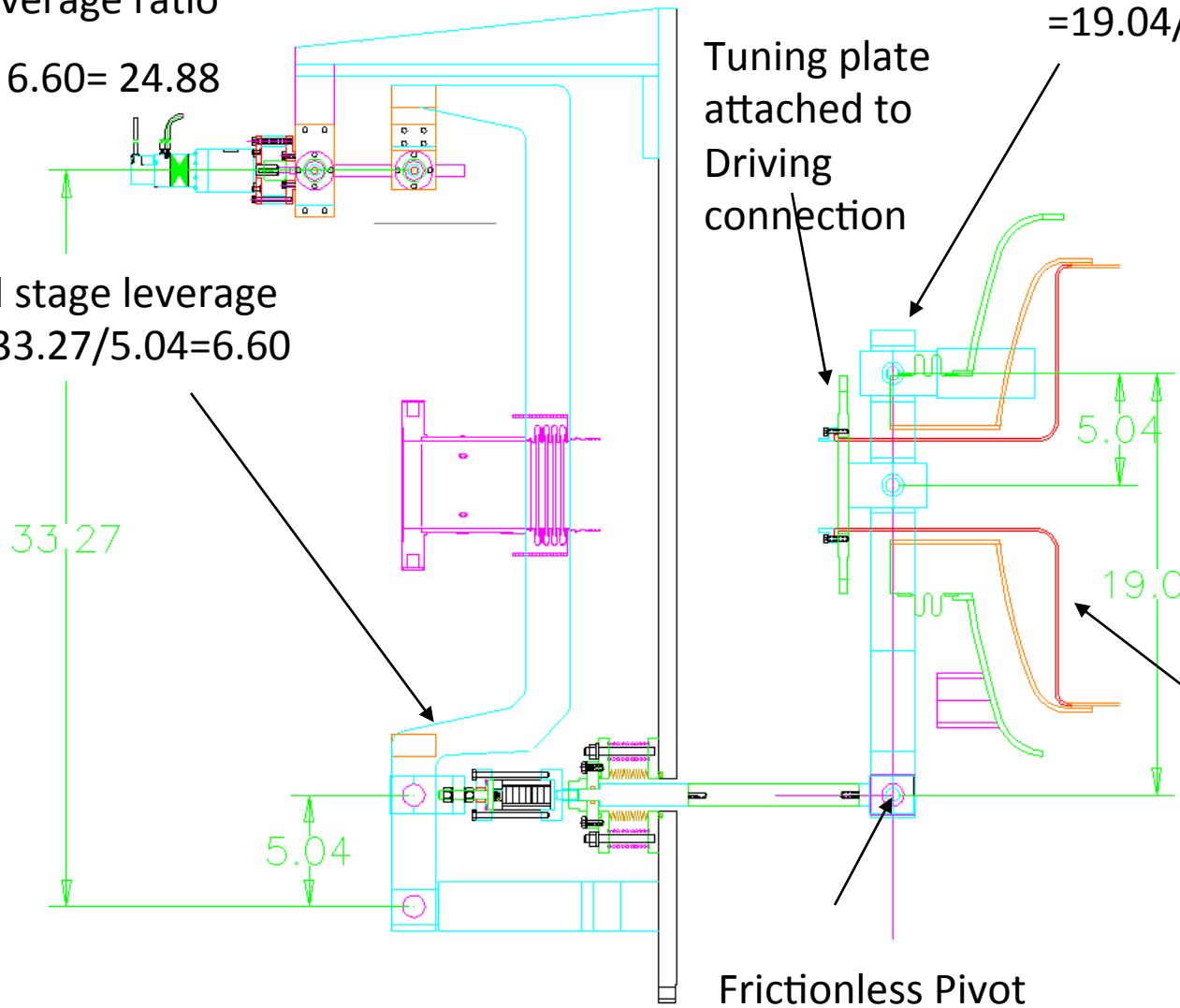
Total leverage ratio

=3.77 x 6.60= 24.88

First stage leverage ratio
=19.04/5.04=3.77

Tuning plate attached to Driving connection

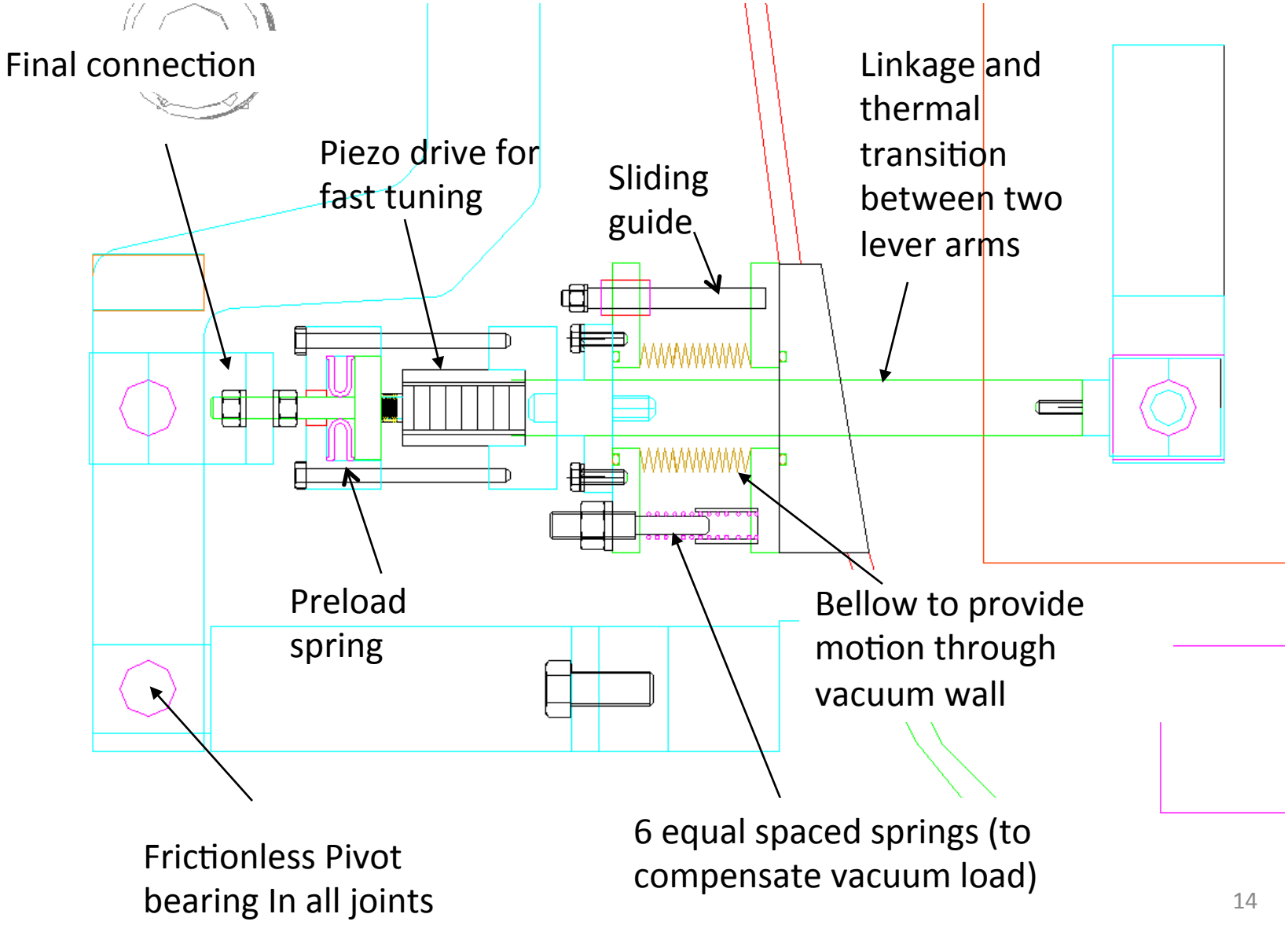
Second stage leverage ratio =33.27/5.04=6.60



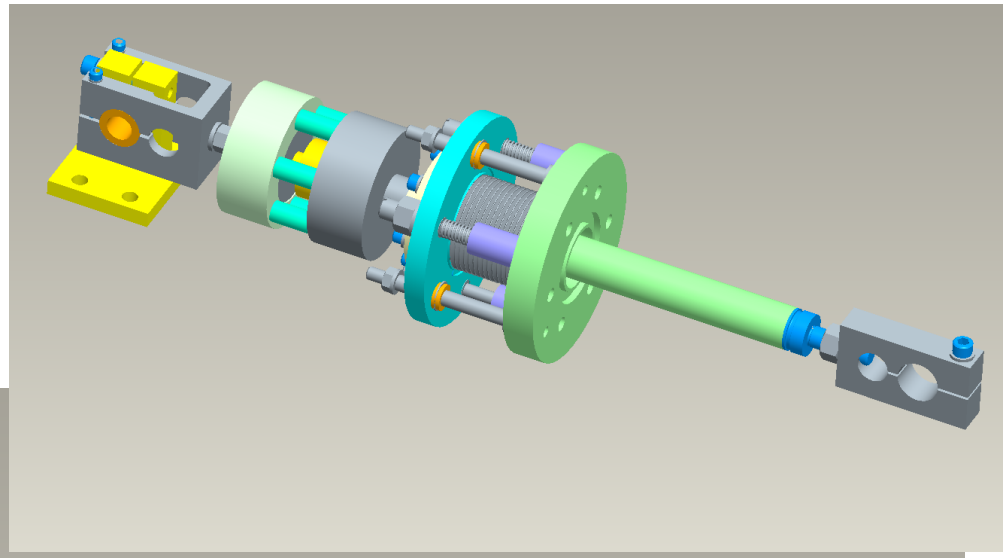
Tuning plate

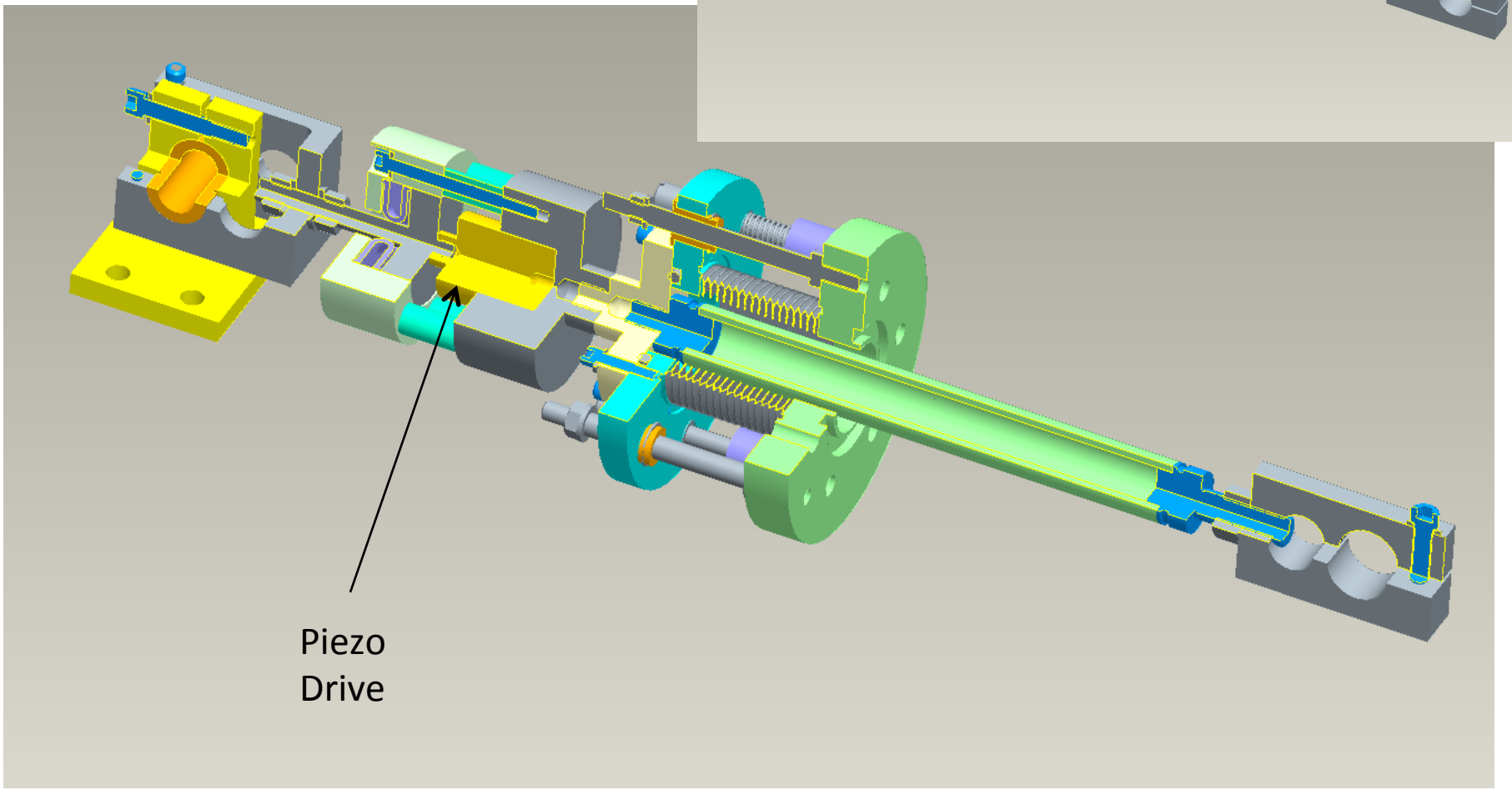
Frictionless Pivot bearing In all joints

Motion Feedthrough and Piezo Drive



Piezo Drive and motion feedthrough

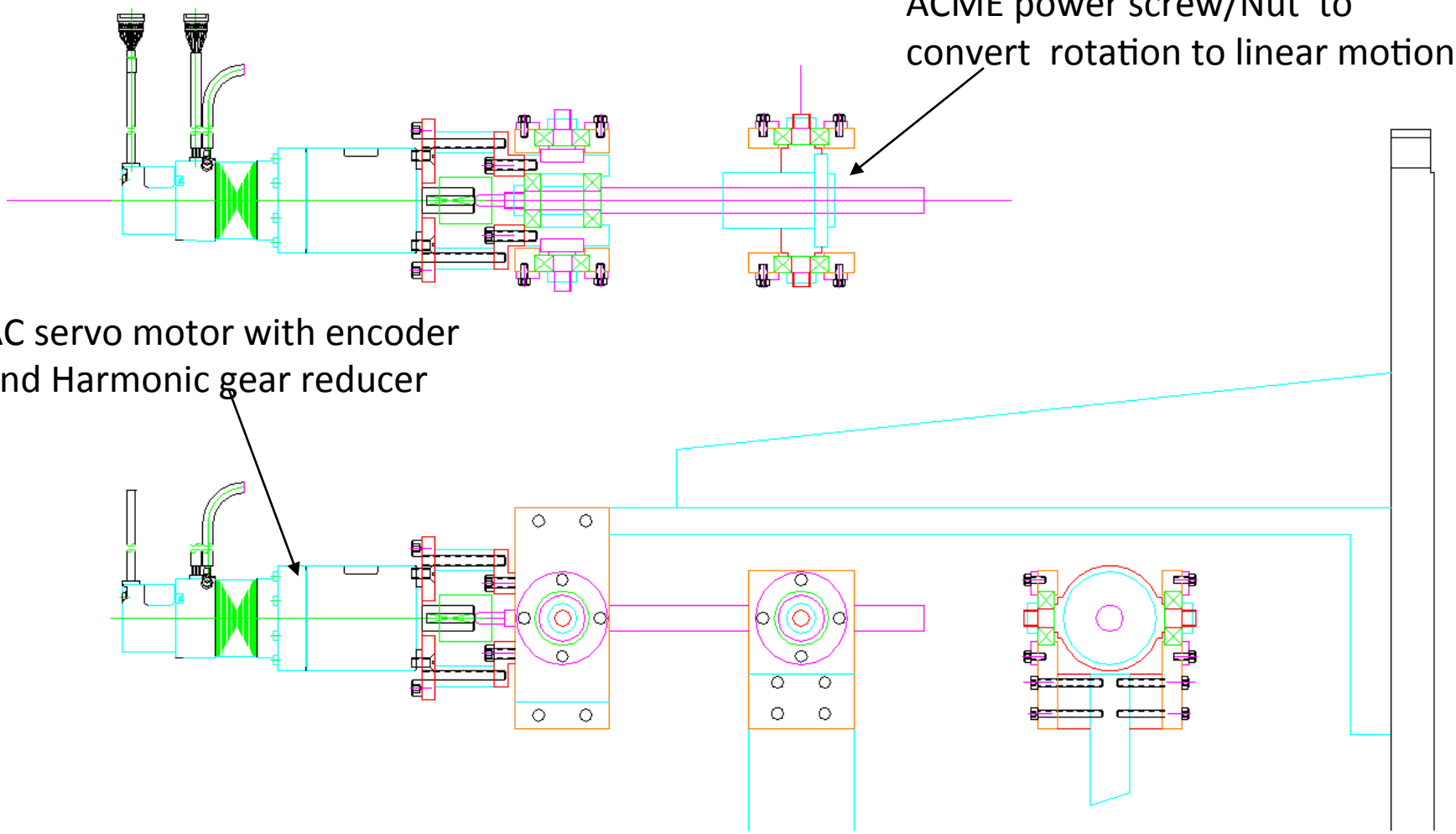




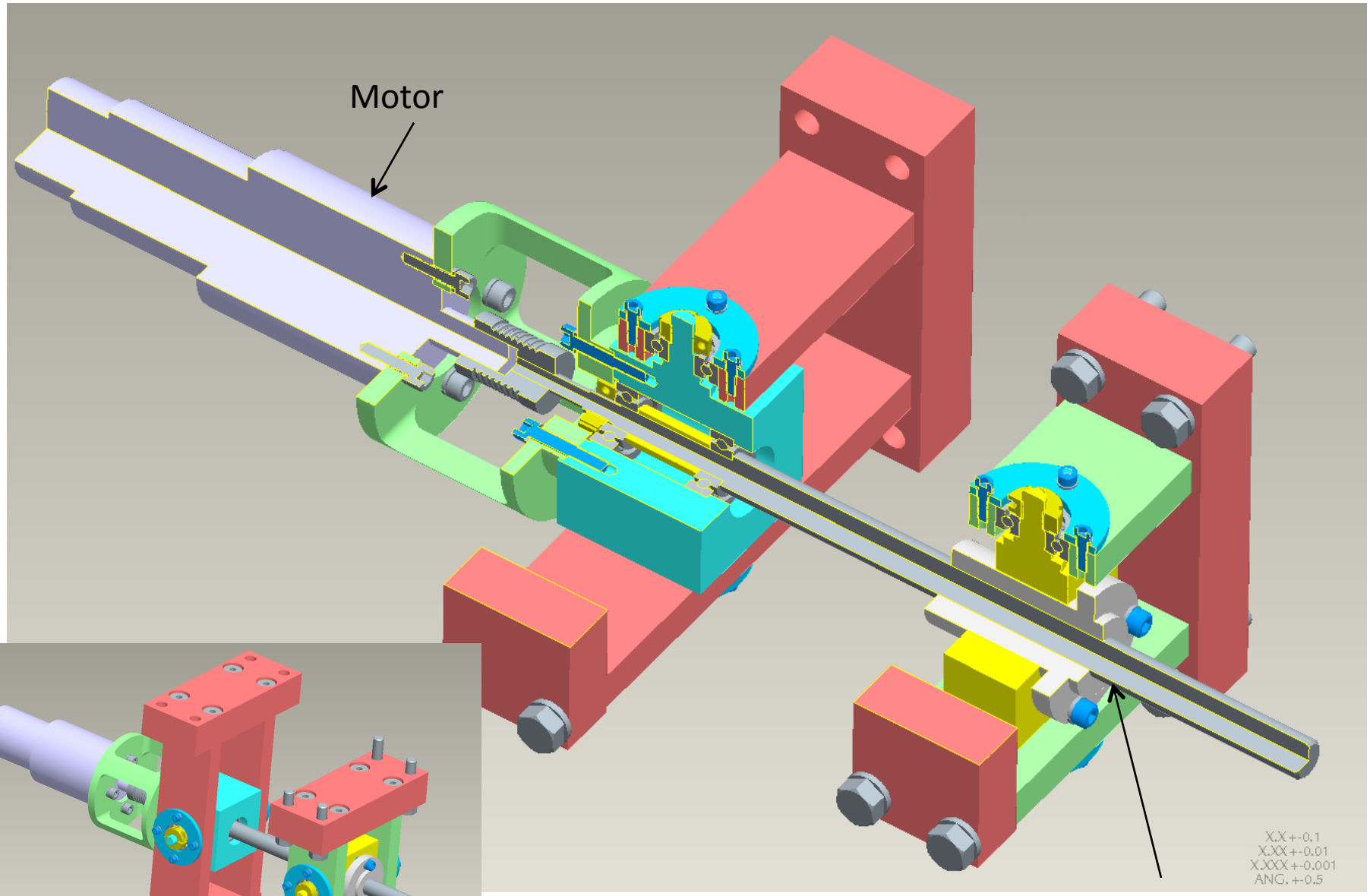
Schematic of Motor Drive and Power Screw

Self Locking –non backlash
ACME power screw/Nut to
convert rotation to linear motion

AC servo motor with encoder
and Harmonic gear reducer



Motor Drive and Power Screw



Components used in Tuner Drive System

Coarse Tuner

Motor : Integral AC Servo Motor with reducer and Encoder.

Model RSF-14B-50-F-100-24B HD harmonic LLC

Gear Reducer : Harmonic gear reducer,

Reduction ratio: 50:1

Encoder: 1000 step/ rev resolution on motor shaft

Power Screw: Non-Backlash ACME screw and nut

1/2”-10, .1”/rev pitch

Fast Tuner

Type : High Voltage Piezo Drive

Model: PSt 1000/25/17

maximum Stroke: 17 um @ 1000 Volt

Pivot bearing in every joint:

Frictionless

Stick-Free

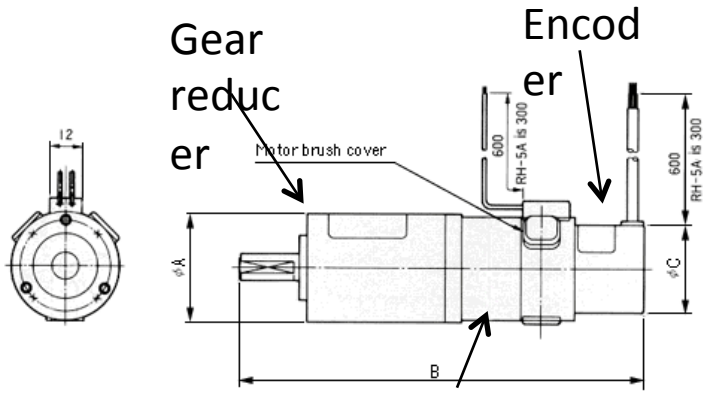
No lubrication required (good for cryo and vacuum application)

Maintenance free.

Resolution of Coarse Tuner Drive

ACME Screw Lead Resolution:

- Encoder resolution: 1,000 step/rev
- Gear ratio Harmonic reducer: 50 to 1
- Pitch of ACME power screw: .1” /rev
- Lead: 2.0x10-6 in/step or .051 um/step



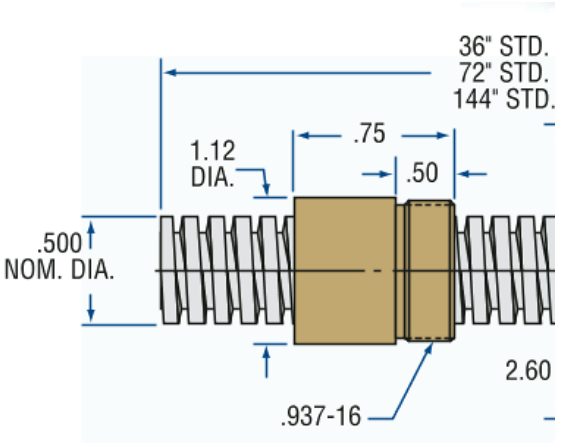
Motor

RF Cavity Tuning resolution:

- Total Mechanical leverage: 24.88
- Tuner plate Deflection per step: 2.00×10^{-3} um
- Tuning sensitivity: 17 Hz/um
- Cavity tuning resolution: .034 Hz/step

Tuning Speed (Max.):

- Motor drive Speed (RPM): Normal: 60, Max. 120
- Steps per second: 120*50*1,000/60=100,000
- Max. Tuning Speed: 3,400 Hz/sec



½ in- ACME-10 Screw and Nut set

Resolution of Fast Tuner Drive

Type：Piezo Drive

Model: PSt 1000/25/17

Driving Voltage: 0 to 1000 Volt.

Maximum free stroke: 17um.

Stiffness: 900 N/um

Maximum force generation: 5,612 lb

Mechanical leverage in first stage: 3.77

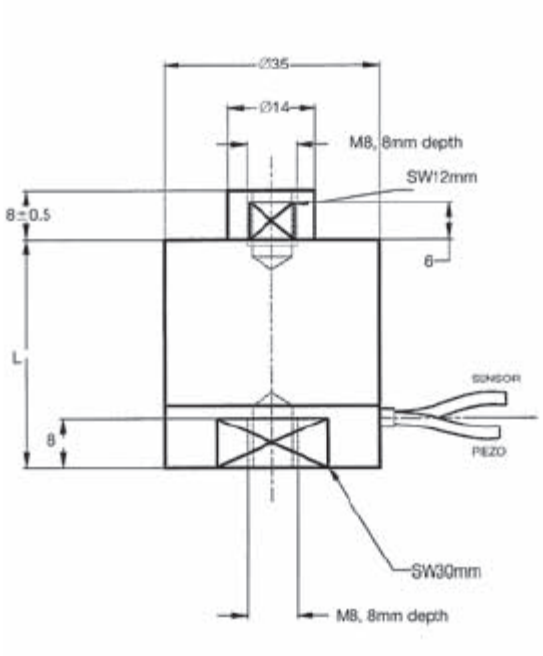
Useful Piezo stroke: 14 um (Reduced by preloac,

Real Tuning stroke: 3.5 um

Tuning sensitivity: 17 Hz/um

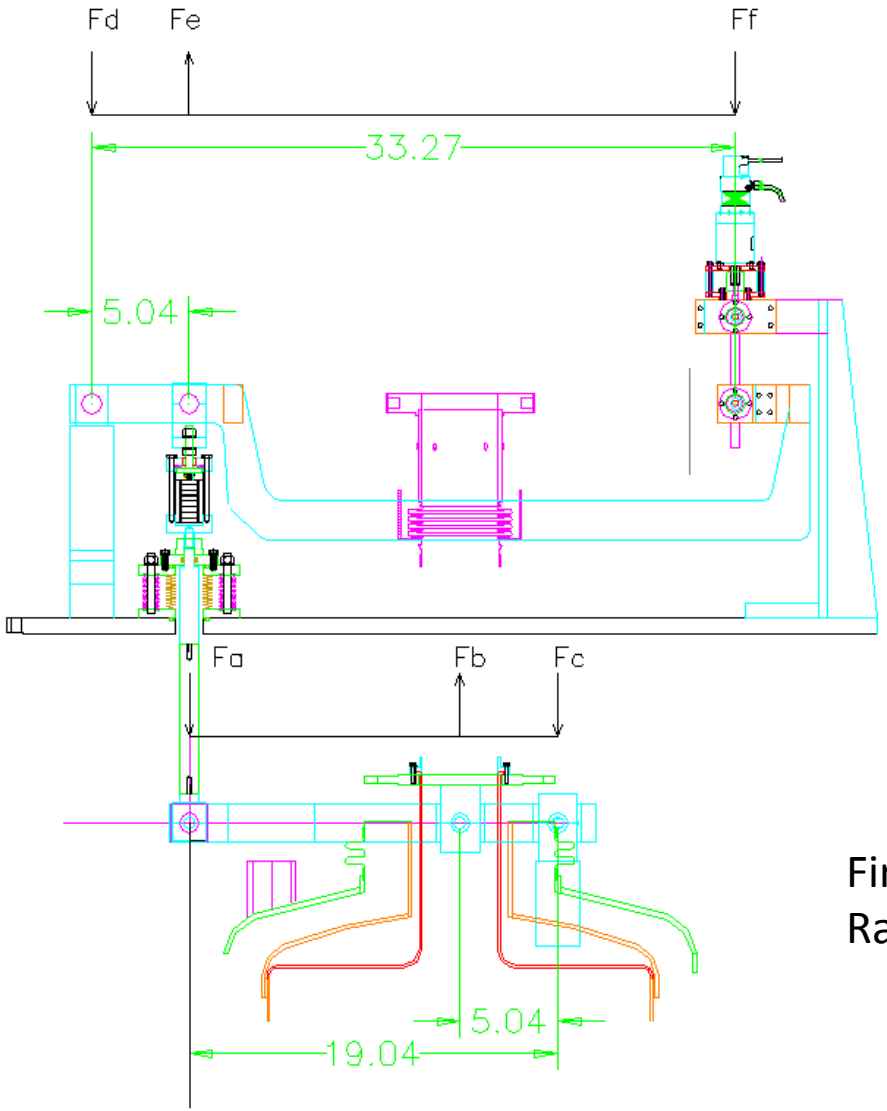
Tuning range: 60 Hz.

Tuning resolution: .06 Hz/Volt (depends on power supply capability)



Verification of Tuner Drive :

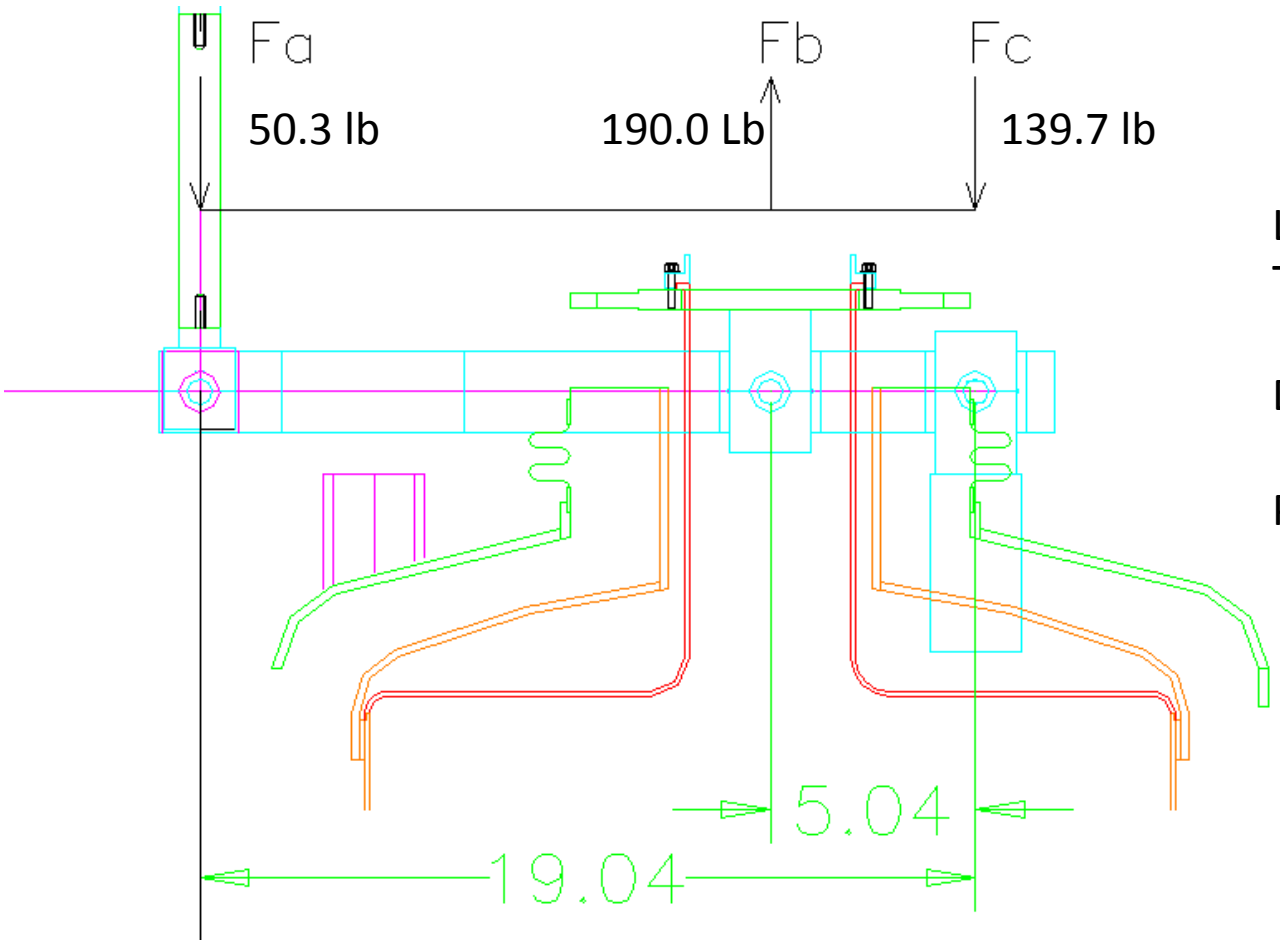
Tuner Schematic, Two Stage Drive,
Total leverage ratio: 24.88



Second Stage
Ratio:6.6

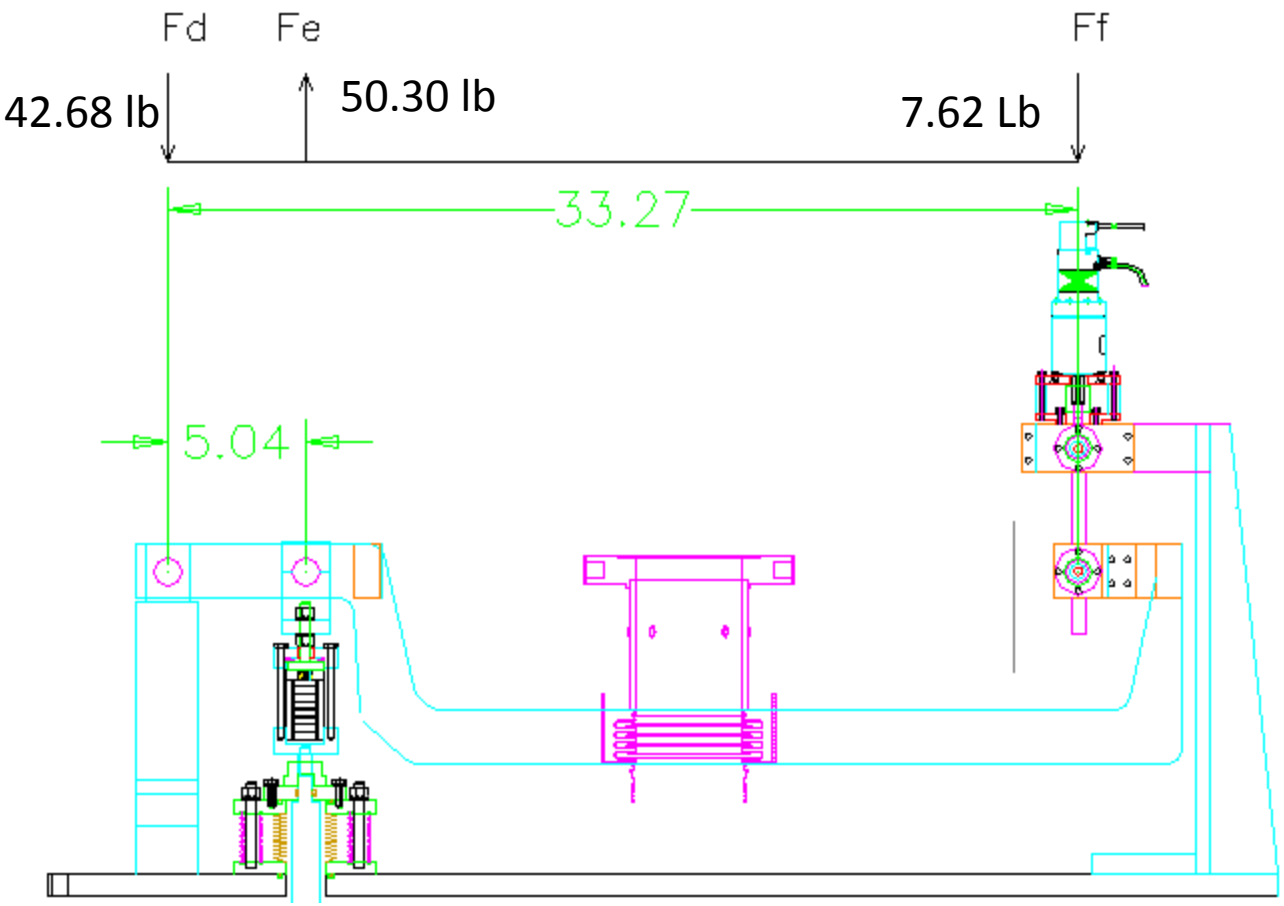
First Stage
Ratio: 3.77

Force Diagram, First Stage



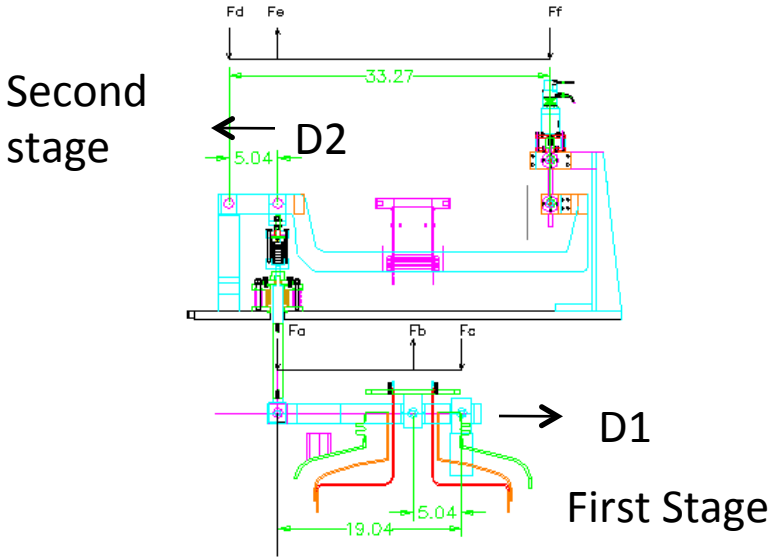
Leverage: 3.77
Tuning Force :
Fb: 190.0 Lb
Driving Force:
Fa: 50.3 lb
Pivot Force:
Fc: 139.7 lb

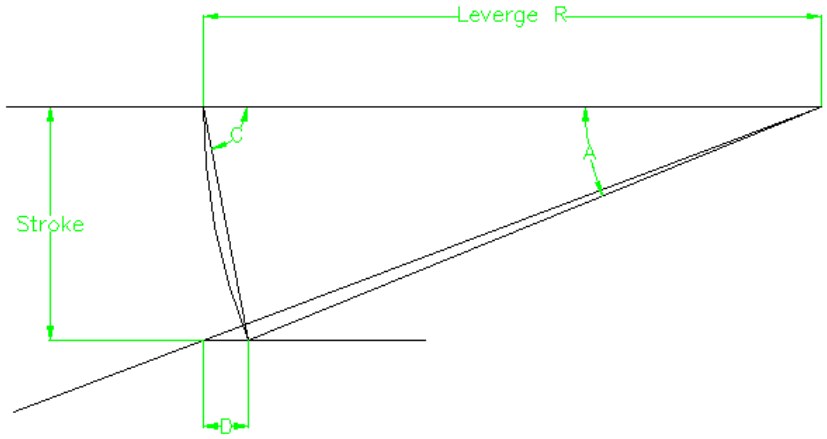
Force Diagram, Second Stage



Leverage: 6.60
Driving Force:
Fe: 50.30 lb
ACME screw Force :
Ff: 7.62 Lb
Pivot Force:
Fd: 42.68 lb

Non-linear sideway Motion of Driving Linkage





For regular tuning:

Stroke: 1.5 mm (.060")

Second Stage

Angle A: 2.580 degree

Side motion: D2= .0051"

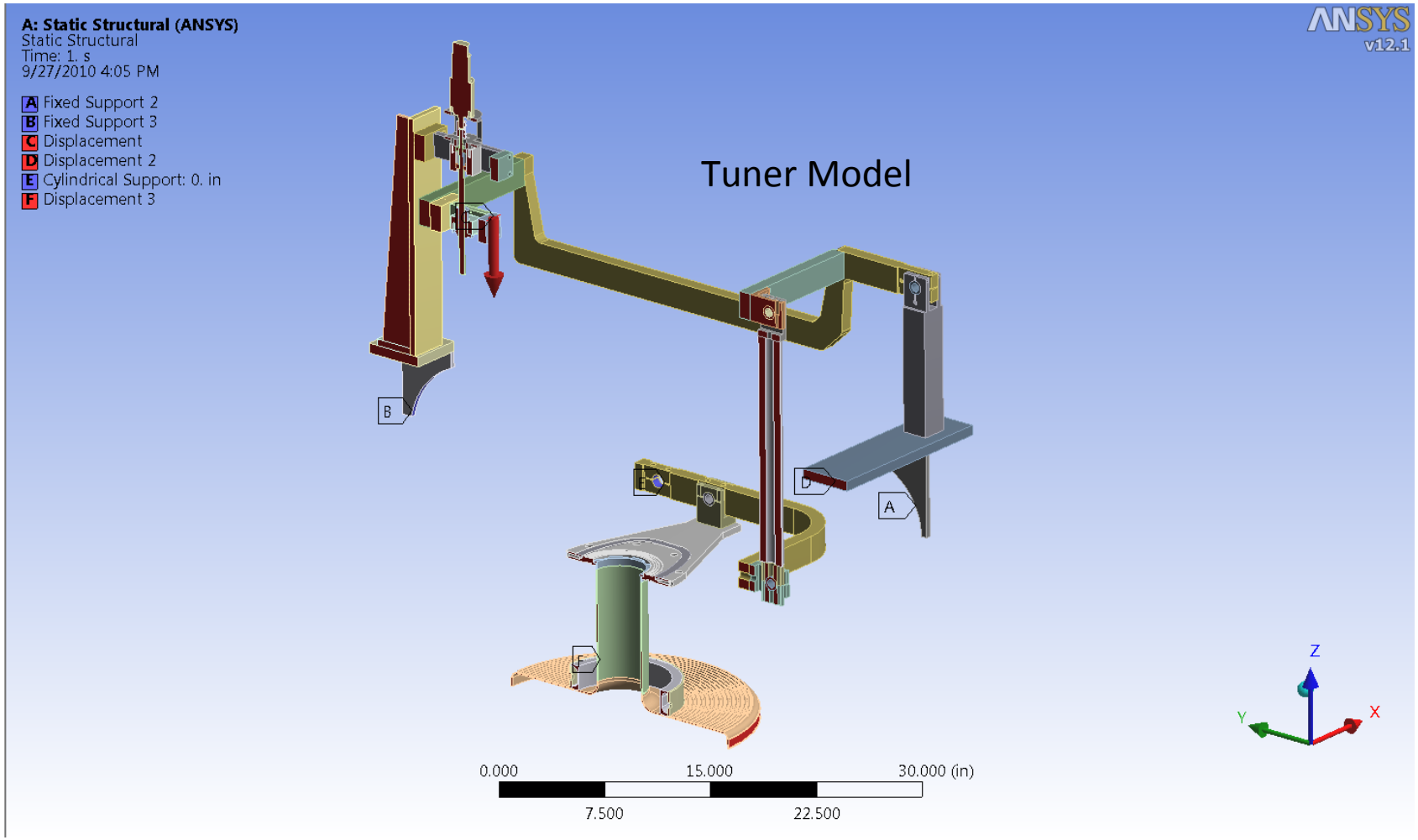
First Stage

Angle A: .682 degree

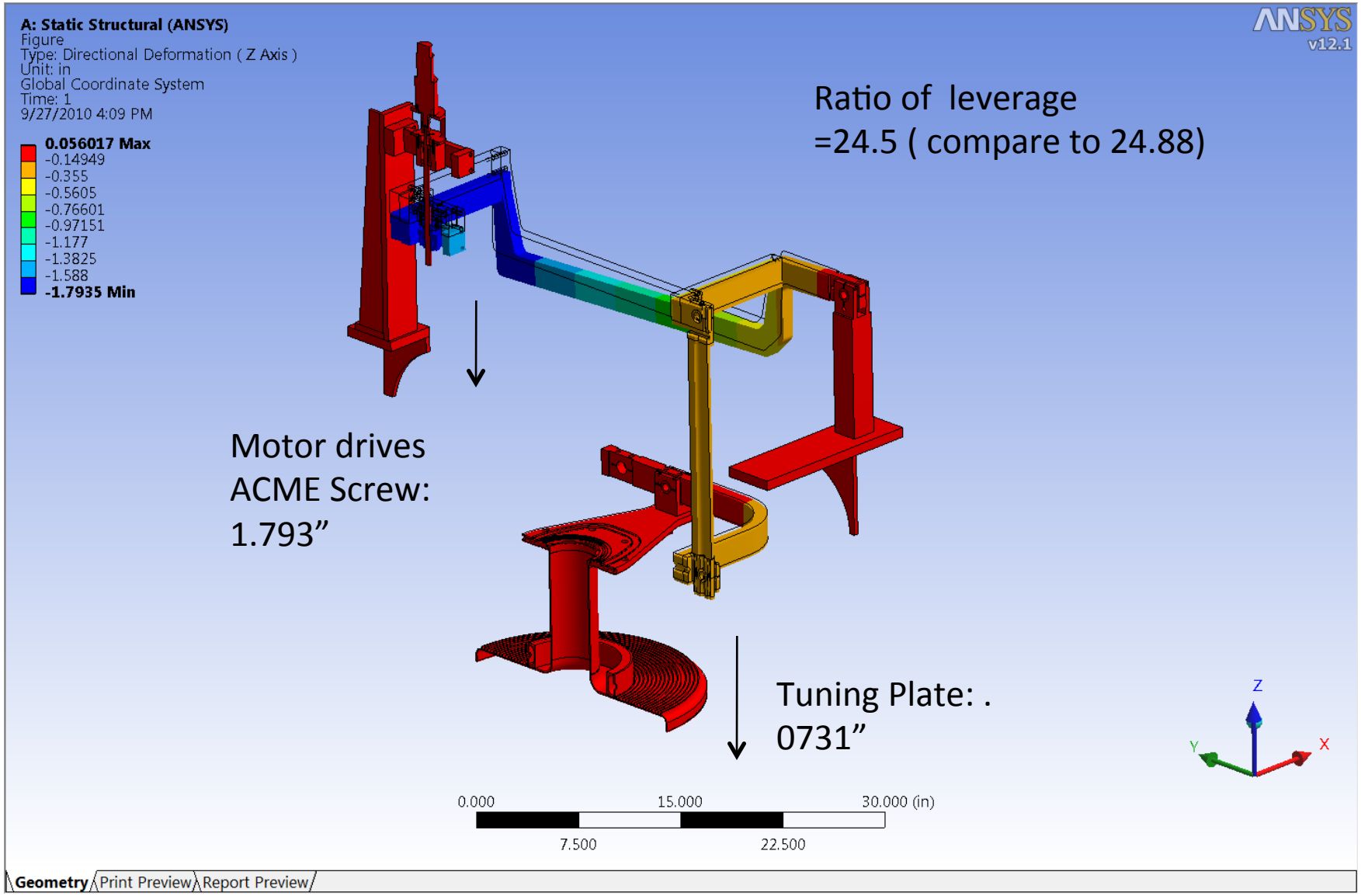
Side motion: D1= .00036"

Computer model simulation:

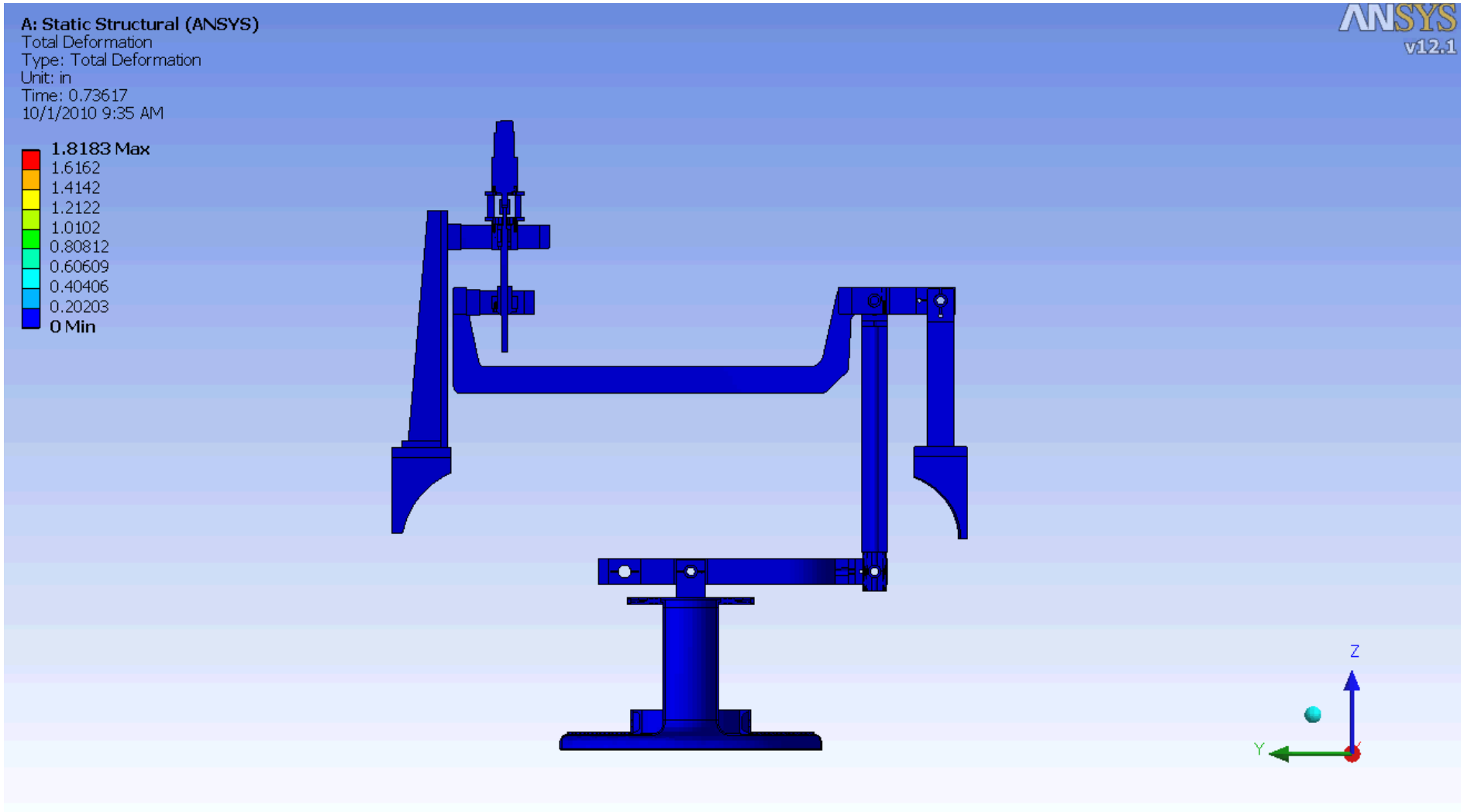
Loading displacement: apply 1.5 inches in the ACME screw



Result Displacement plot: in Z direction



Animation


A: Static Structural (ANSYS)
Total Deformation
Type: Total Deformation
Unit: in
Time: 0.73617
10/1/2010 9:35 AM
1.8183 Max
1.6162
1.4142
1.2122
1.0102
0.80812
0.60609
0.40406
0.20203
0 Min
ANSYS
v12.1
Z
Y

RHIC 56 MHz Cryomodule

External Review 03/08/11

- Tuner
- Design Complete 06/22/11
- Parts Procurement Complete 02/15/11
- Mock-up Assembly Complete 03/15/12
- Tuner in Cryomodule & Tested 05/22/12