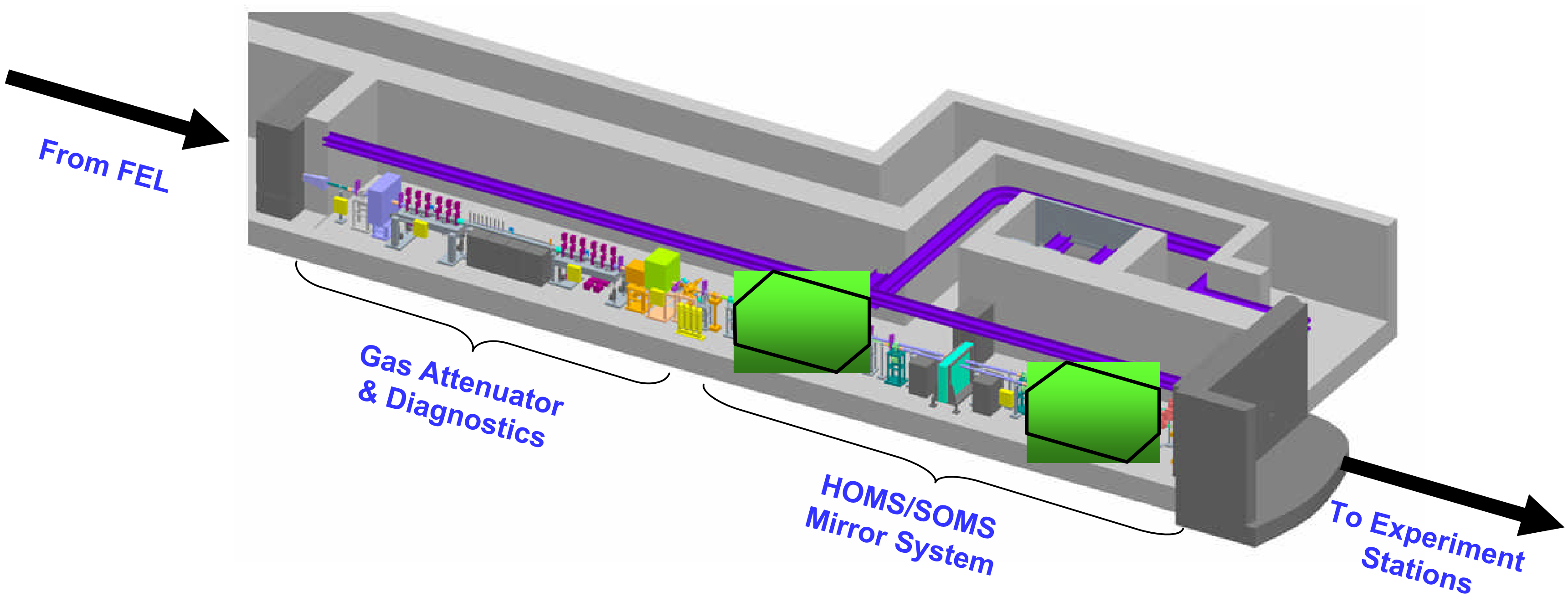
Hard and Soft X-ray Mirror System Design Status



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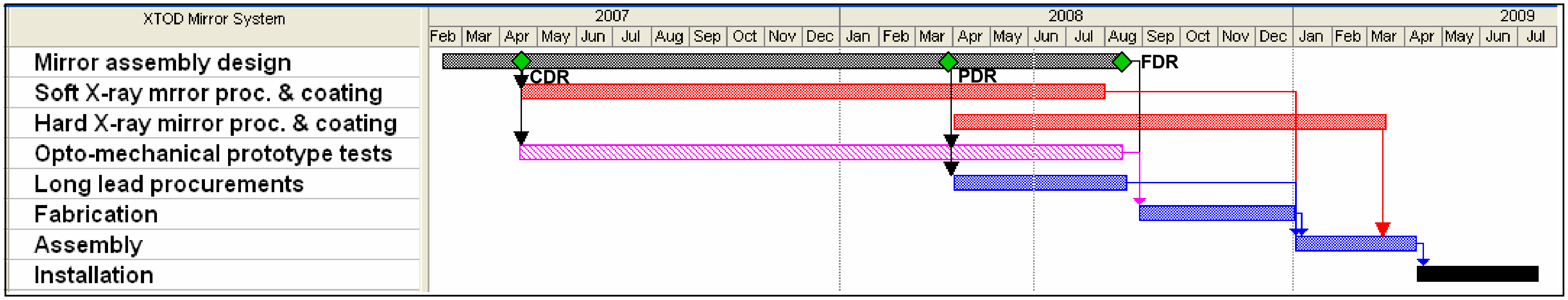
Mirror system testing & final design drawings are nearly complete



- **Prototype tests focused on two high technical risk areas:**

  - Measuring & maintaining HOMS tangential figure
  - Measuring & maintaining HOMS pointing stability

- **Requirements have been demonstrated for both these areas**

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HOMS and SOMS share a common design approach: HOMS requires a few additional features

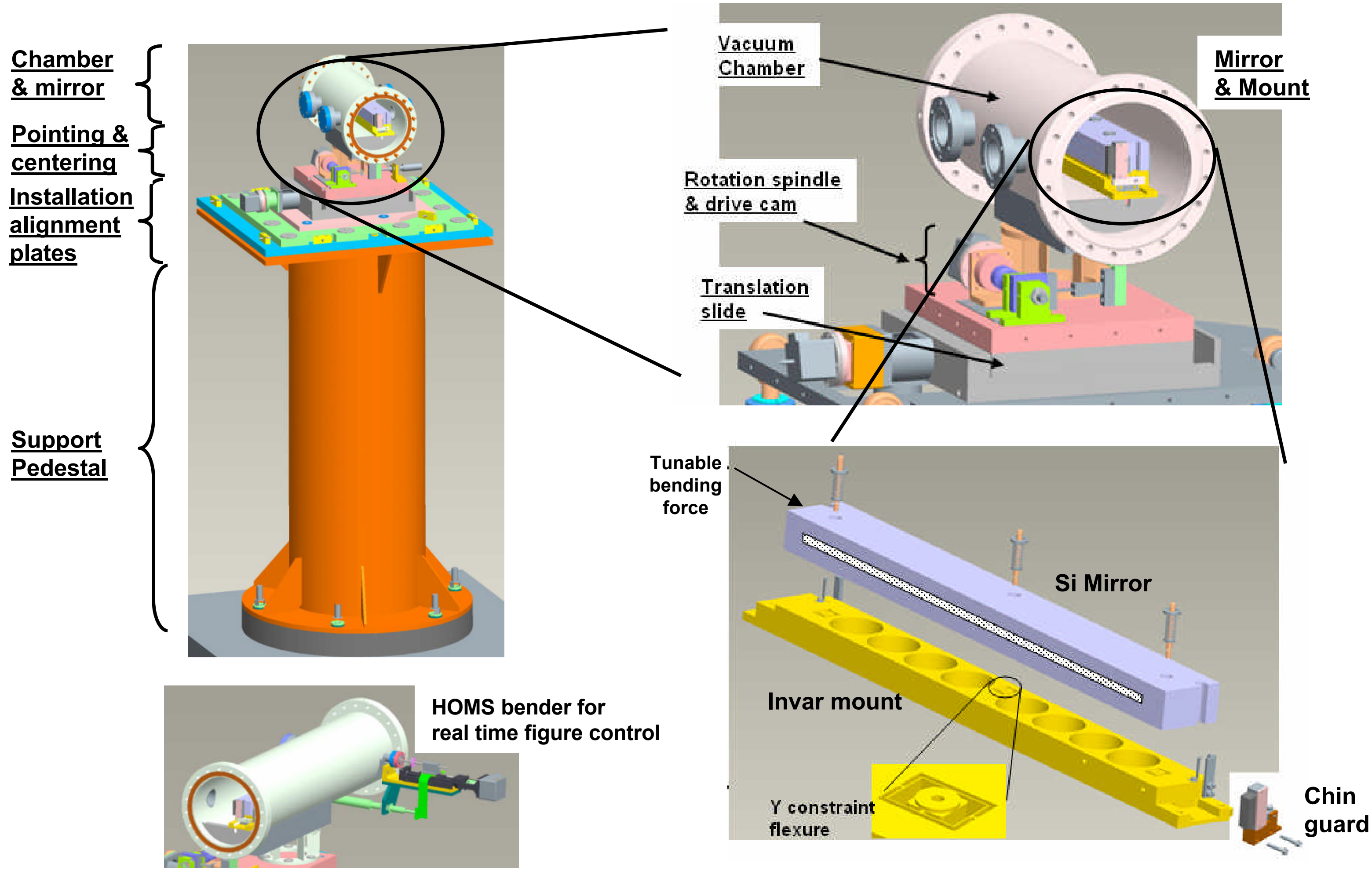

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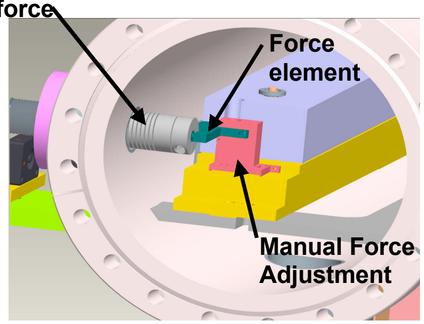
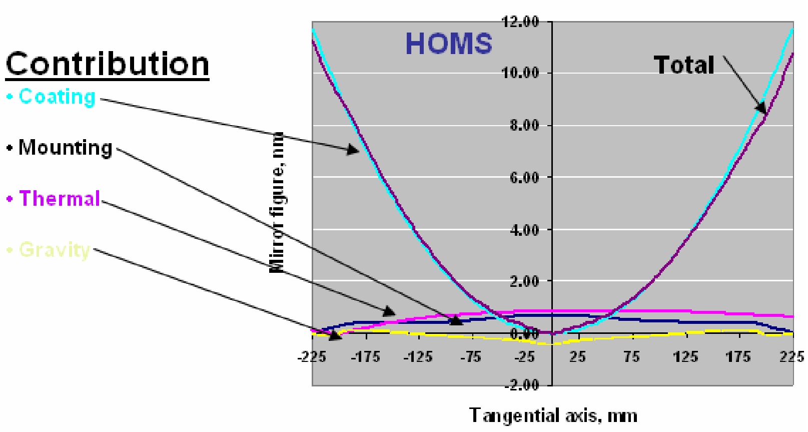
Figure errors predicted by analysis have been verified in prototype tests

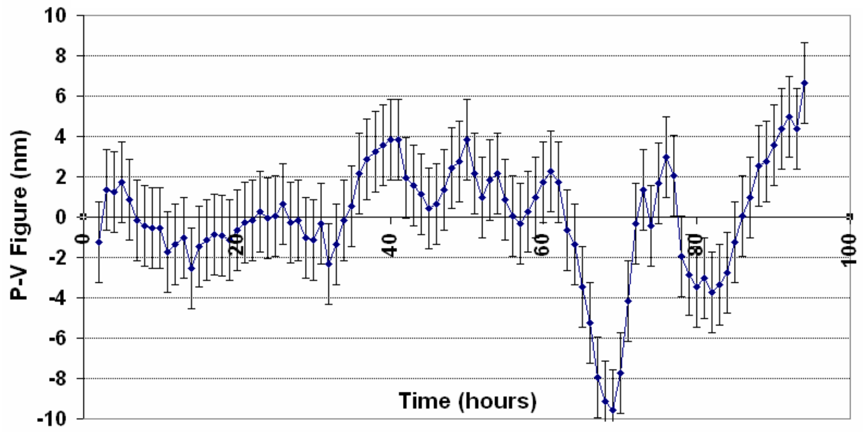
- **Figure budget limits "power" imparted upon reflection**

Mirror Flatness Requirement			Figure error budget, nm				
Axis	"Best Fit" Radius, km	Peak to Valley, nm	Mounting	Thermal	Coating	Gravity	Fabrication
HOMS/SOMS Sagittal	>~3	<5	<<1	<<1	<<1	<<1	<1
SOMS Tangential	>188	<20	<1	<1.5	<4	<-1	<10
HOMS Tangential	>2600	<9	<1.5	<1.5	<12	<-1	<20



- **Finite element analysis guided design optimization**





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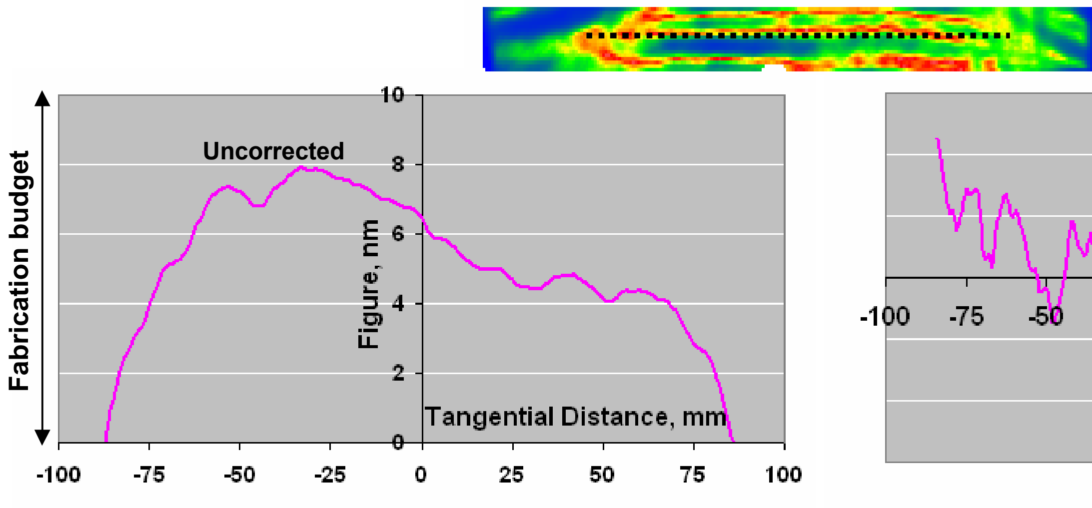
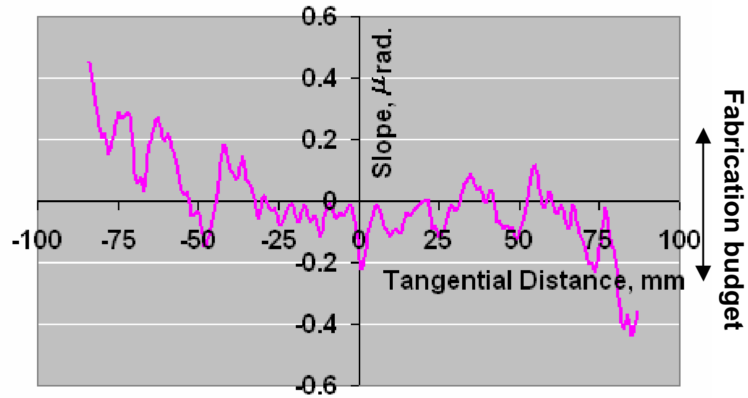
SOMS mirror #1 tangential (horizontal) figure has been measured (transmission flat correction not yet applied)

SOMS #1 mirror figure and slope





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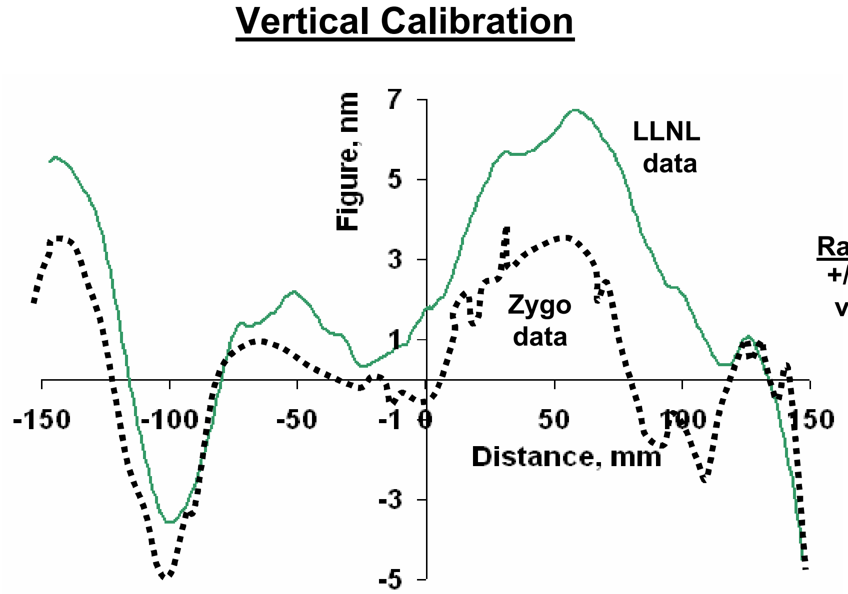
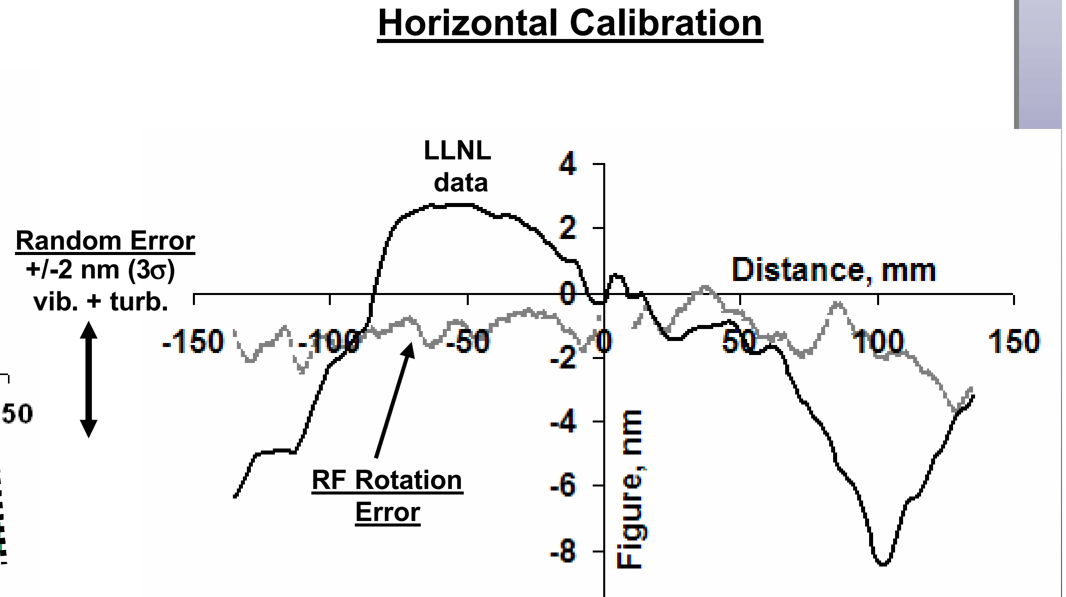
We recently calibrated our interferometer transmission flat

- Zygo does not calibrate the horizontal axis of "large" transmission flats (TF)
  - requires rotating a TF about the horizontal, which could break glass/epoxy bond
  - by design, 12" TF mounting cell design precludes this rotation

- Our horizontal calibration was done using two TF's & the un-silvered side of an RF
  - a reflection flat (RF) mounting cell allows all three rotations (no glass/epoxy bond)





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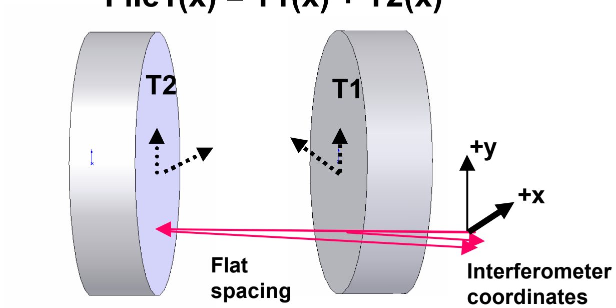
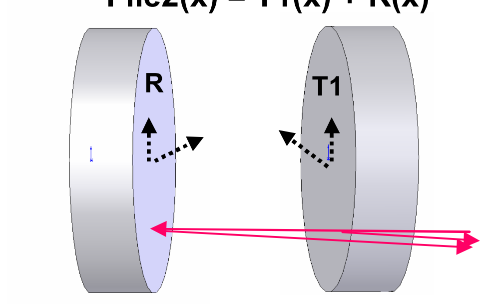
Algorithm for calibrating the horizontal axis of large flats

Interferometer coordinates — Flat coordinates

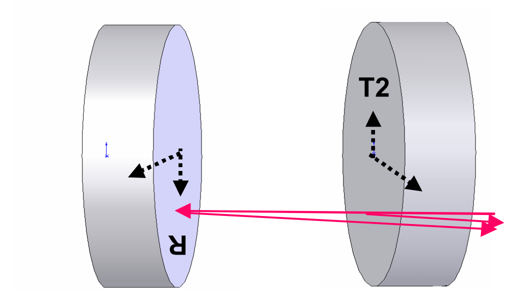
File1(x) = T1(x) + T2(x)



File2(x) = T1(x) + R(x)



File3(x) = T2(-x) + R (-x)

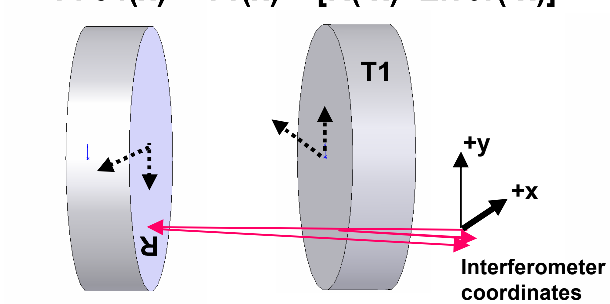


- **Convert File3(x)→File3(-x) and solve for T1(x), T2(x), R(x):**

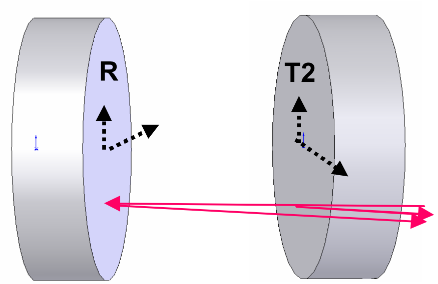
T1(x) = ½[F1(x)+F2(x)-F3(-x)] **T2(x) = ½[F1(x)-F2(x)+F3(-x)]** **R(x) = ½[-F1(x)+F2(x)+F3(-x)]**

- **The systematic error from RF weight reversal can be evaluated**

File4(x) = T1(x) + [R(-x)+Error(-x)]



File 5(x) = T2(-x) + [R(x)+Error(x)]



Check
Error(x) = F4(-x)-T1(-x)-R(x)
and double check
Error(x) = F5(x)-T2(-x)-R(x)

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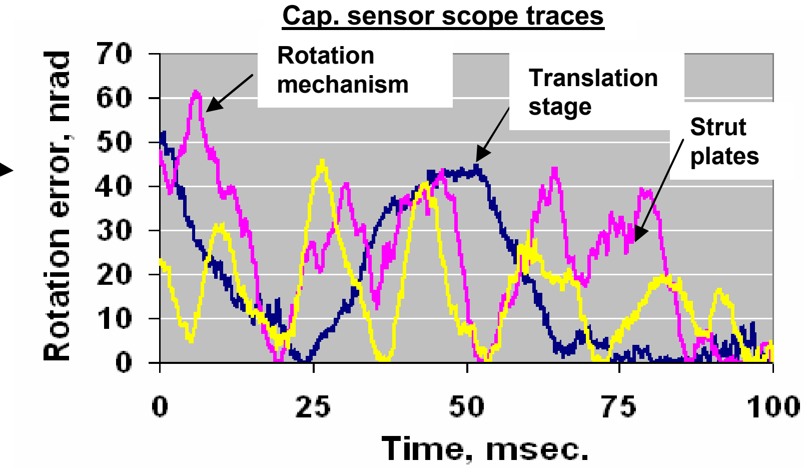
Effect of ground motion amplification on pointing stability has been addressed

- **Pointing jitter was noticed on our first HOMS prototype**

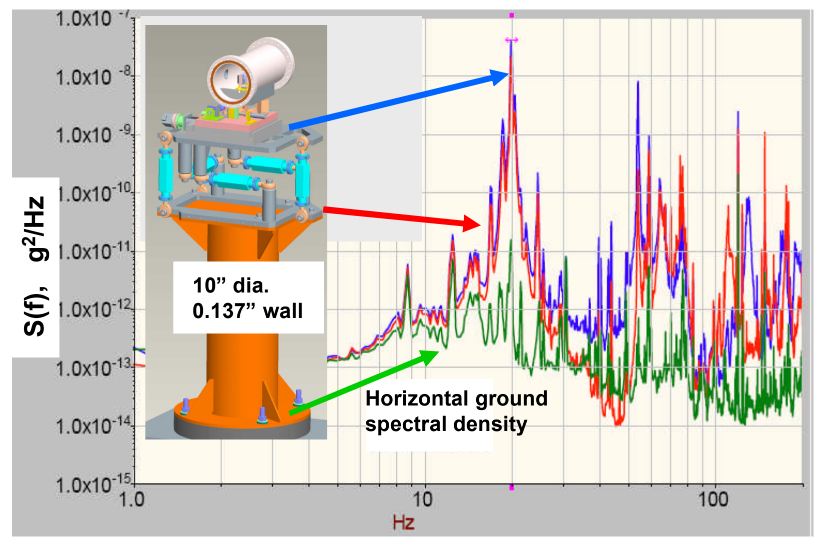


- **Motion amplification was measured with accelerometers**
  - **rms amplification relates to mean square acceleration S(f) by:**

$$\langle x_{top}\rangle_{rms} / \langle x_{ground}\rangle_{rms} = \sqrt{S_{top}(f)/S_{ground}(f)}$$

≈ 150 at 20 Hz

- **The final design corrects this problem**



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The final design fundamental frequency is over 80 Hz

- **Modes calculated by a finite element model**

PDR design

Mode	Hz	%Mass participation		
		X	Y	Z
1	27	66	0	0
2	32	0	0	74
3	80	3	3	0
4	97	1	53	0
5	100	12	2	0

FDR design

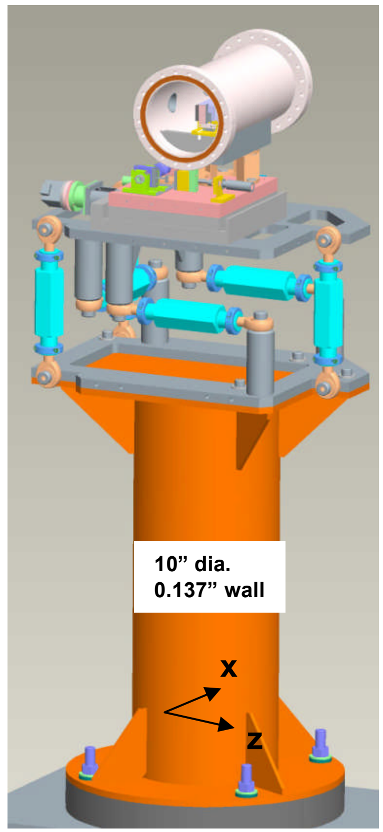
Mode	Hz	% Mass Participation		
		X	Y	Z
1	83	2	0	63
2	83	64	0	2
3	190	1	37	0
4	249	0	0	6
5	313	5	8	0

Amplitude "scaling" for mode f_n

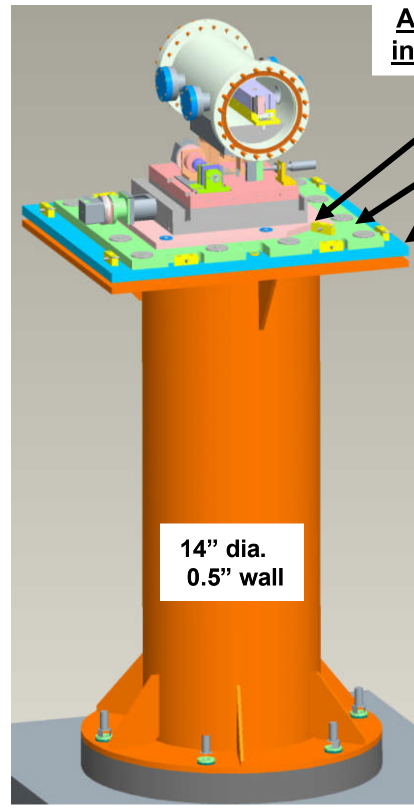
$$\langle x \rangle_{rms} = \frac{\left[\pi f_n S(f_n) / \zeta \right]^{1/2}}{2k}$$

damping (ζ)
stiffness (k)

PDR design



FDR design



Adjustable plates for installation alignment

Z rotation
X,Z
Tip/tilt & Y

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Temperature induced pointing error has been measured and controlled

(1) **Beam pointing drift < 10% of diameter required during experiments:**

- **dθ = 90 nrad for HOMS**
- **dθ = 900 nrad for SOMS**

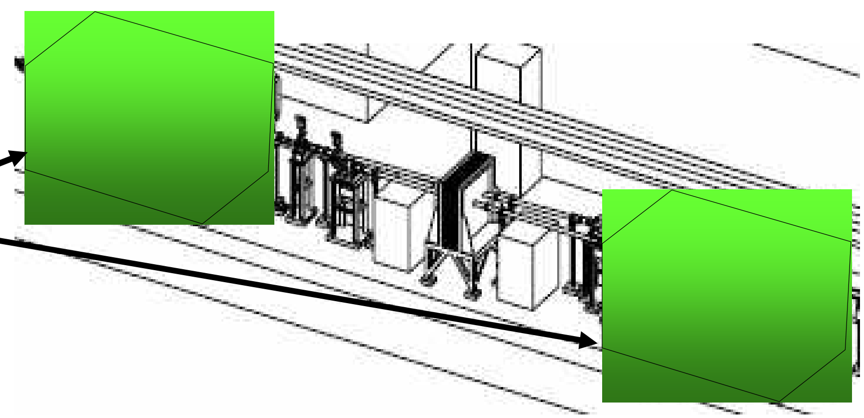
(2) **Temperature dependence of mirror pointing has been measured: (next page)**

- **dθ/dT ≅ 300 nrad/0.1 °C**

∴ Temperature stability < 0.03 C required for HOMS

(3) **The challenge: to demonstrate closed loop stability < 0.03 C/week**

- **0.01 C demonstrated in an insulated enclosure around our prototype**



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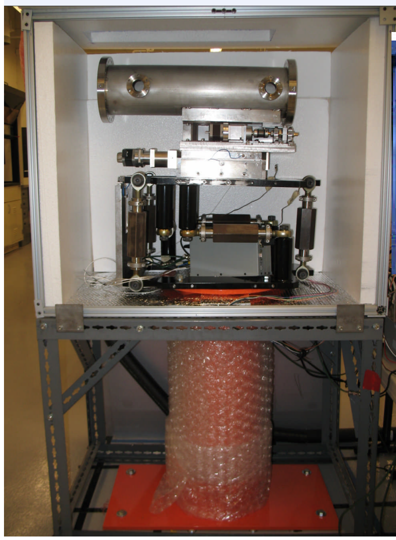
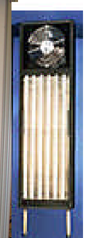
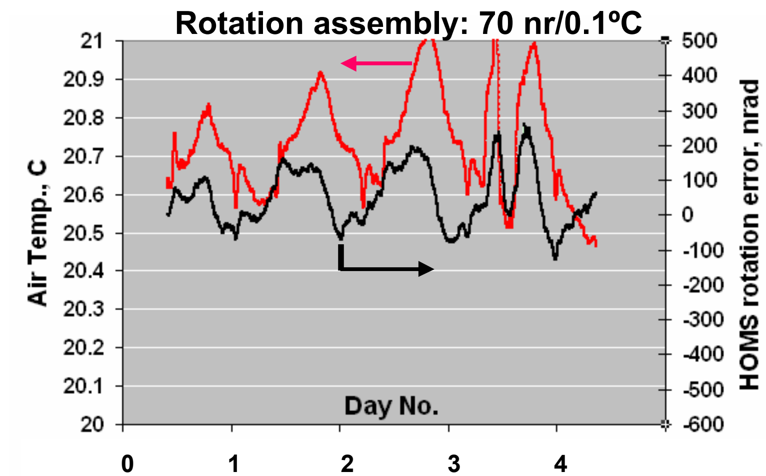
Pointing error Δθ/ΔT was measured with our prototype

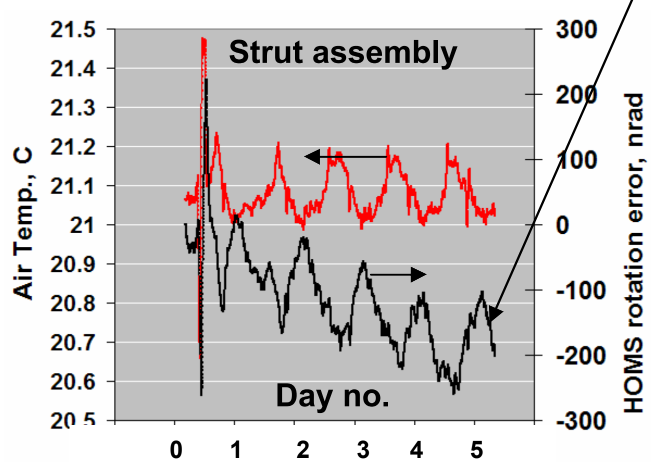


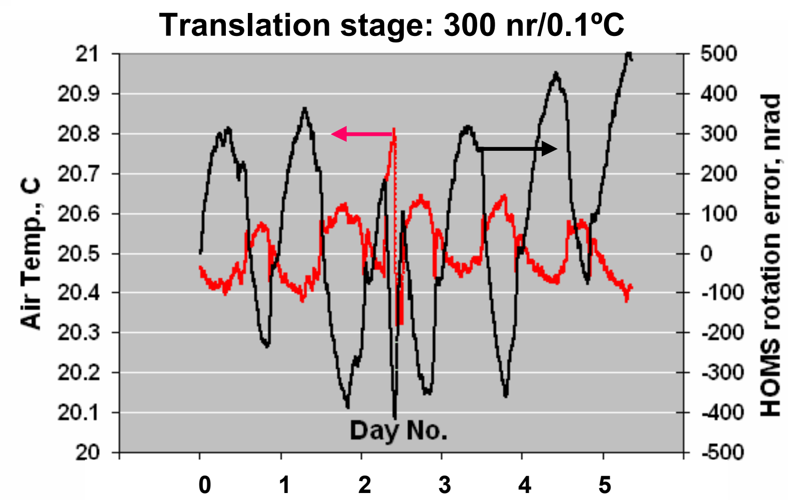


Chiller control
+/- 0.1 C



Uncorrelated drift was the basis for replacing struts with adjustable plates





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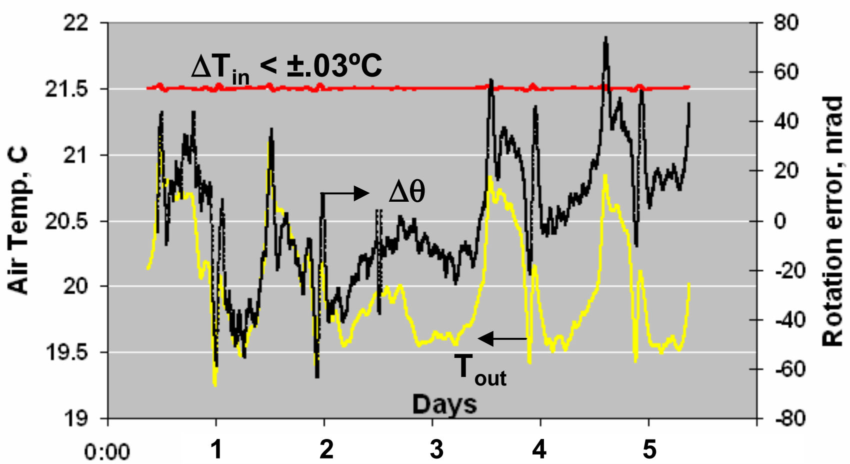
Pointing stability has been demonstrated in a thermal enclosure

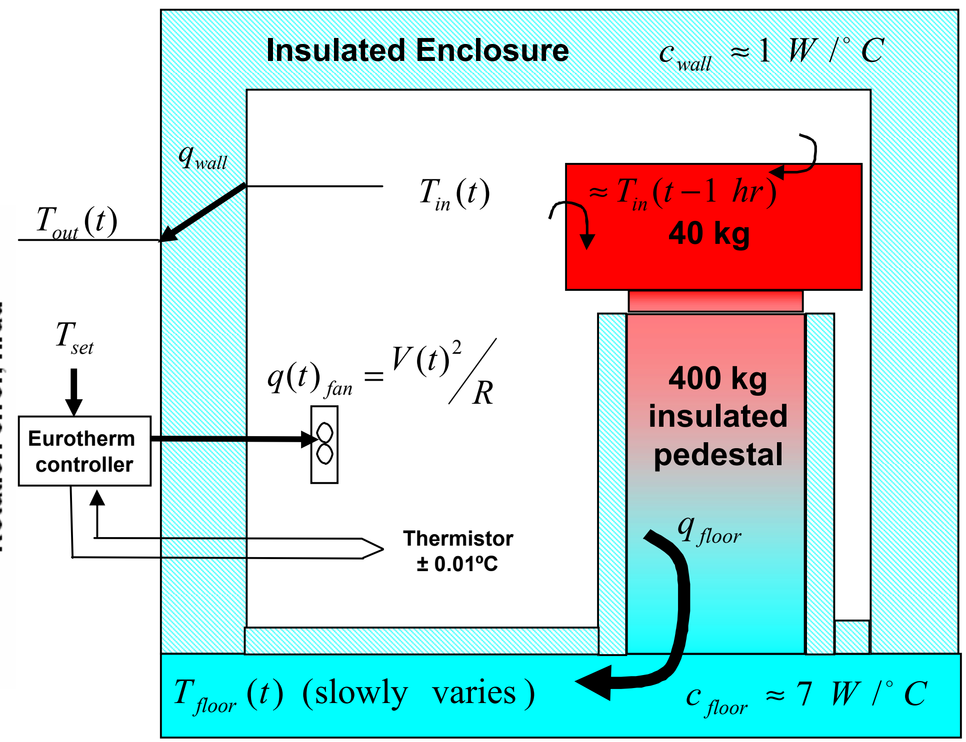
- **Heat balance:** $q_{fan}(t) = q_{wall} + q_{floor} \approx c_{wall}[T_{in}(t) - T_{out}(t)] + c_{floor}[T_{in}(t-1\ hr) - T_{floor}(t)]$

  $dq_{fan}(t) \approx -c_{wall} dT_{out}(t)$

- **Control parameters:** $T_{set} = 21.5^{\circ} C$

  $q_{max} \approx 15\ Watts$





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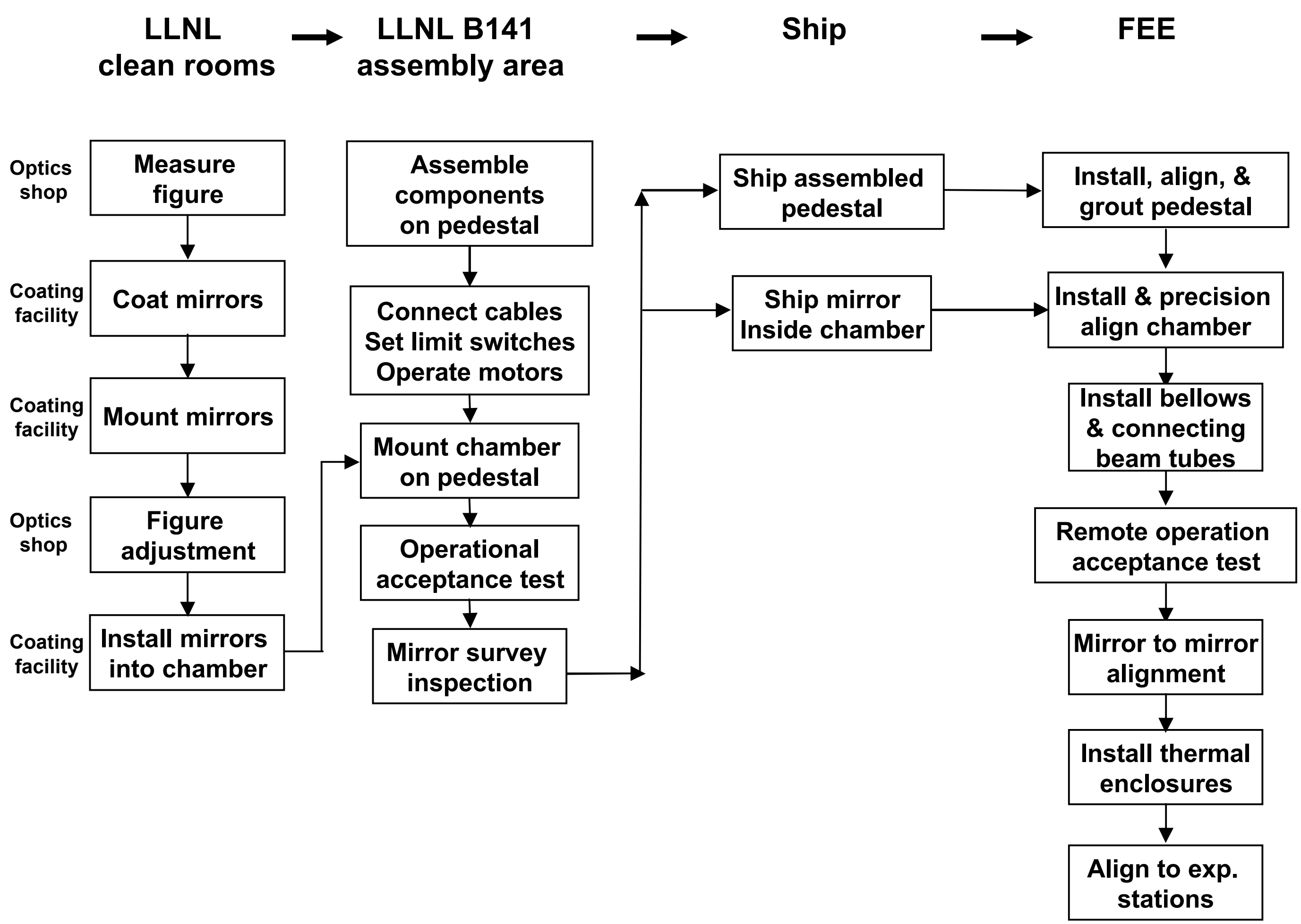
Summary of a mirror system “traveler”



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Tasks remaining this FY:

- **Complete ESD, fabrication drawings, & final review – August**
  - calculate survey installation coordinates

- **Measure & coat SOMS mirrors – in August**

- **Bid and award fabrication drawings – Sept.**
  (1) chamber
  (2) pedestal & slide plate assembly
  (3) mirror mount & chin guard assembly
  (4) cam assembly

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