



CANDOR: Achieving rotational tolerances on a polychromatic neutron reflectometer

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Problem Statement and Status

- 4.5-meter-long, 3000 kg CANDOR detector arm rotating from -10° to 140° in relation to the beam line - not meeting scientific angular tolerances of $\pm 0.01^\circ$
- Josh Graybill (NCNR) presented status of this problem at DENIM 2019
- Where are we today?



Detector Arm Rotation Tolerances

Science requires more stringent tolerances

• Before

Rotation of Detector Arm	Tolerance
negative 10° to 10°	±.01°
>10° to 140°	±.02°

• After

Rotation of Detector Arm	Tolerance
negative 10° to <0°	±.005°
at 0° and at .4°	±.001°
>0° to 10° (excluding .4°)	±.002°
>10° to 20°	±.005°
>20° to 140°	±.01°

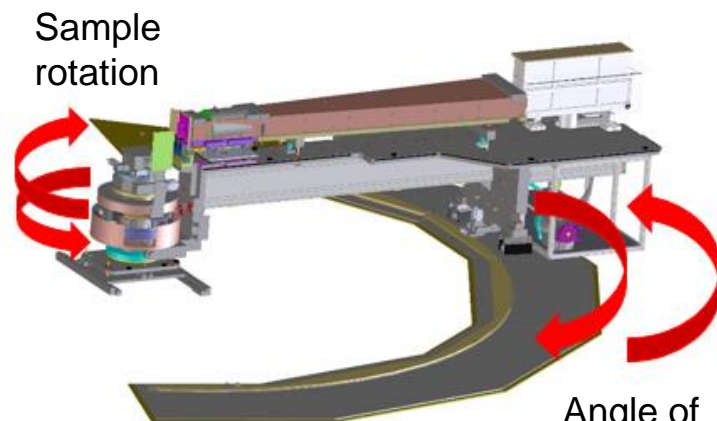
Absolute Encoder Resolution - .0014°

Incremental Encoder Resolution - .0002°

Motor Drive Micro-stepping Resolution - .0001°



CANDOR Detector Arm



R = 3.2 Meter
($\pm 0.001^\circ = 0.1\text{mm}$)

Laser Tracker on
Sample Stage

Absolute
Encoder

Detector arm

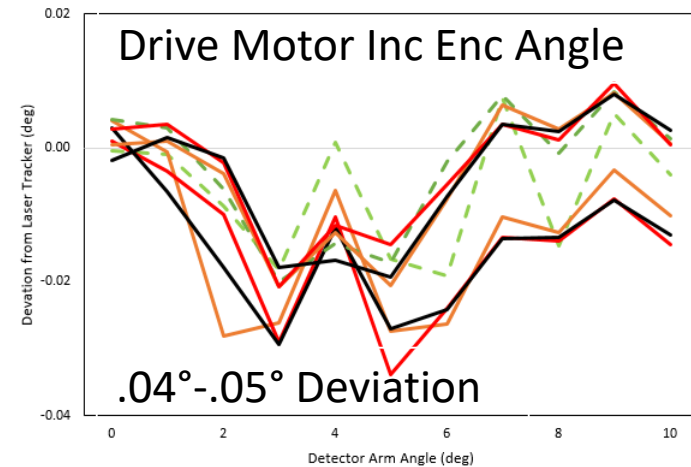
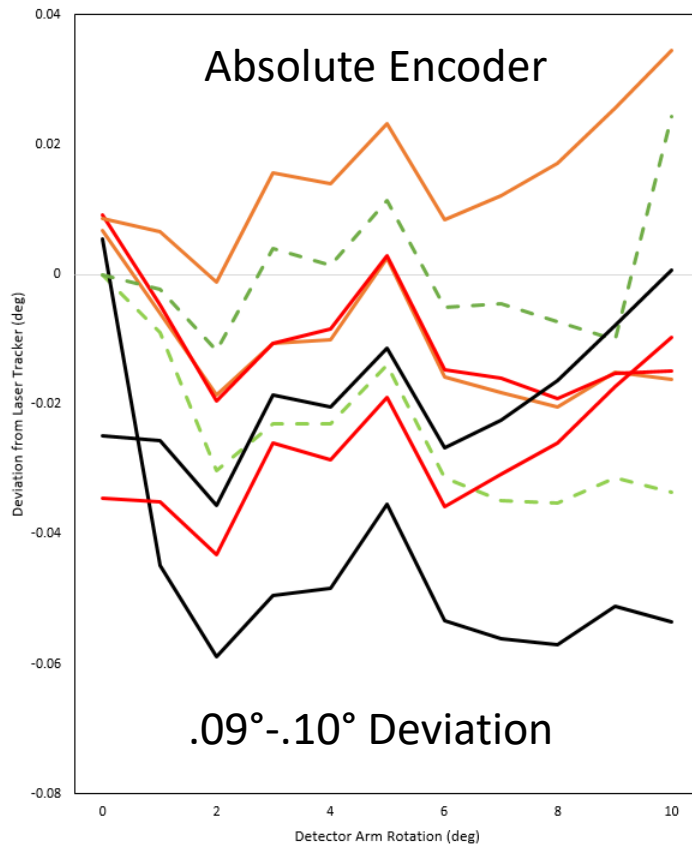
Drive Motor with
Incremental encoder



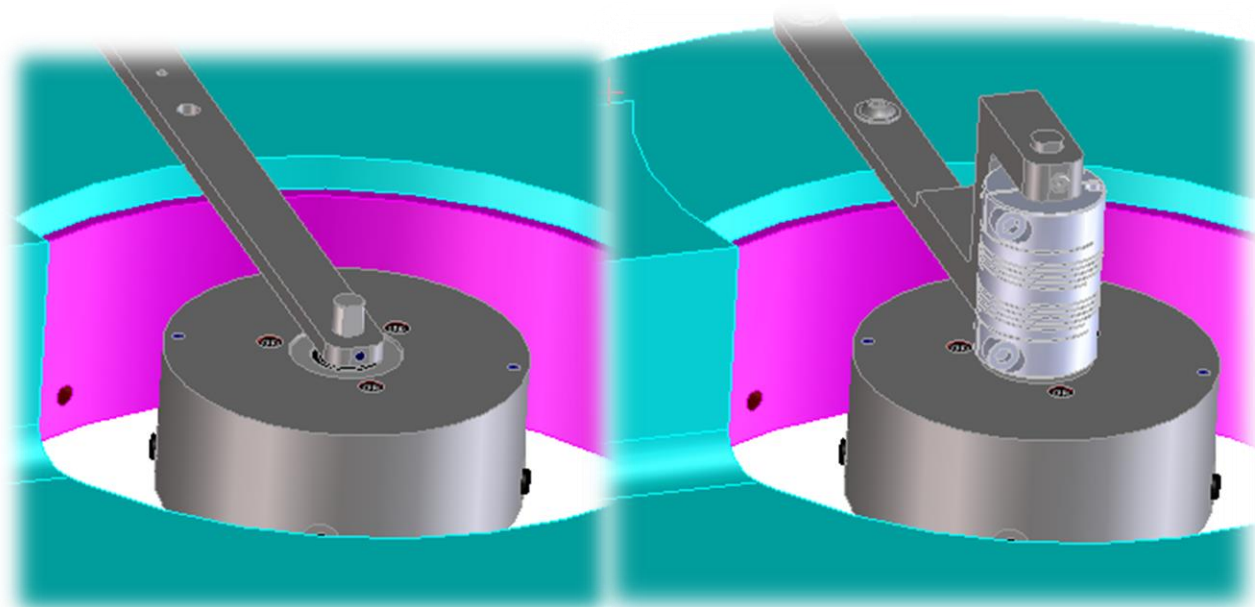
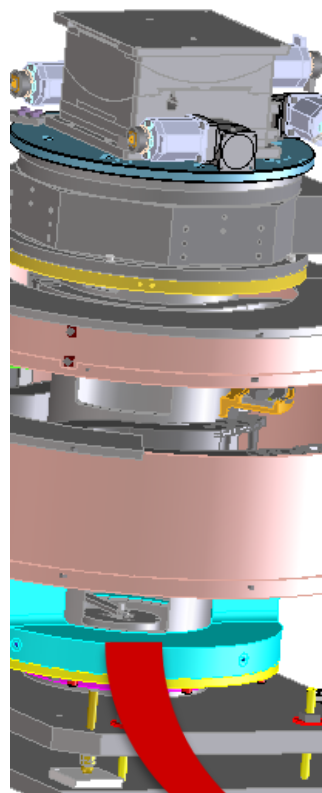
Status as of DENIM 2019



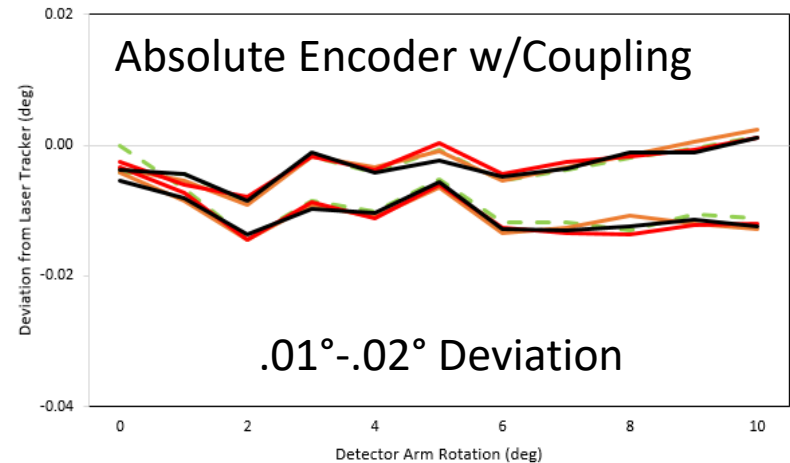
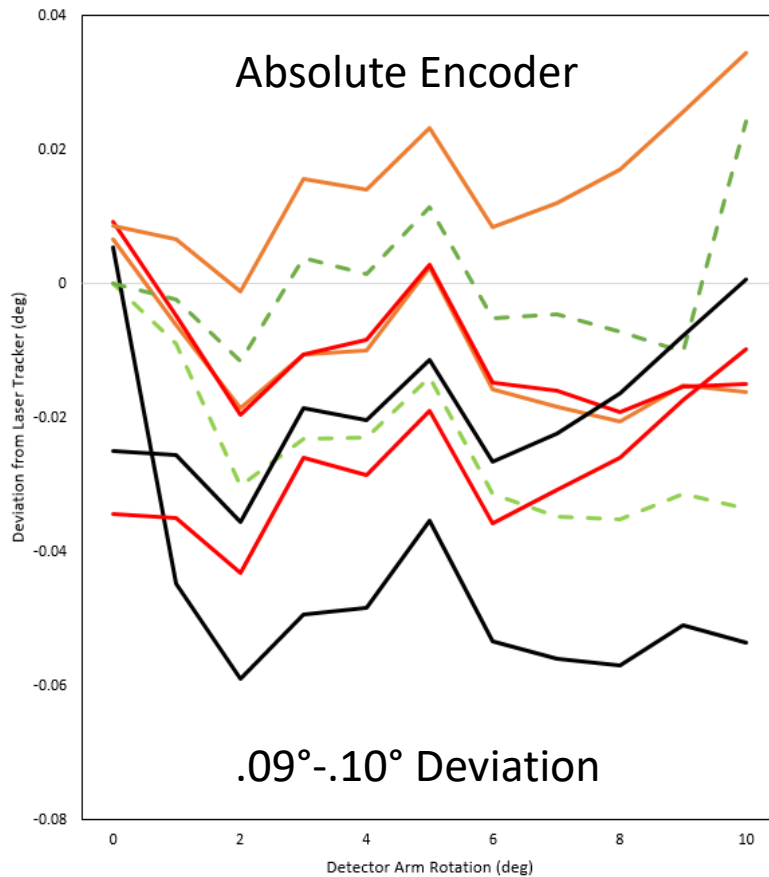
- Problem with positioning detector arm
 - Neither the incremental or absolute encoders matched the laser tracker angle
- What is wrong with the Absolute Encoder?



Missing Coupling on Absolute Enc.

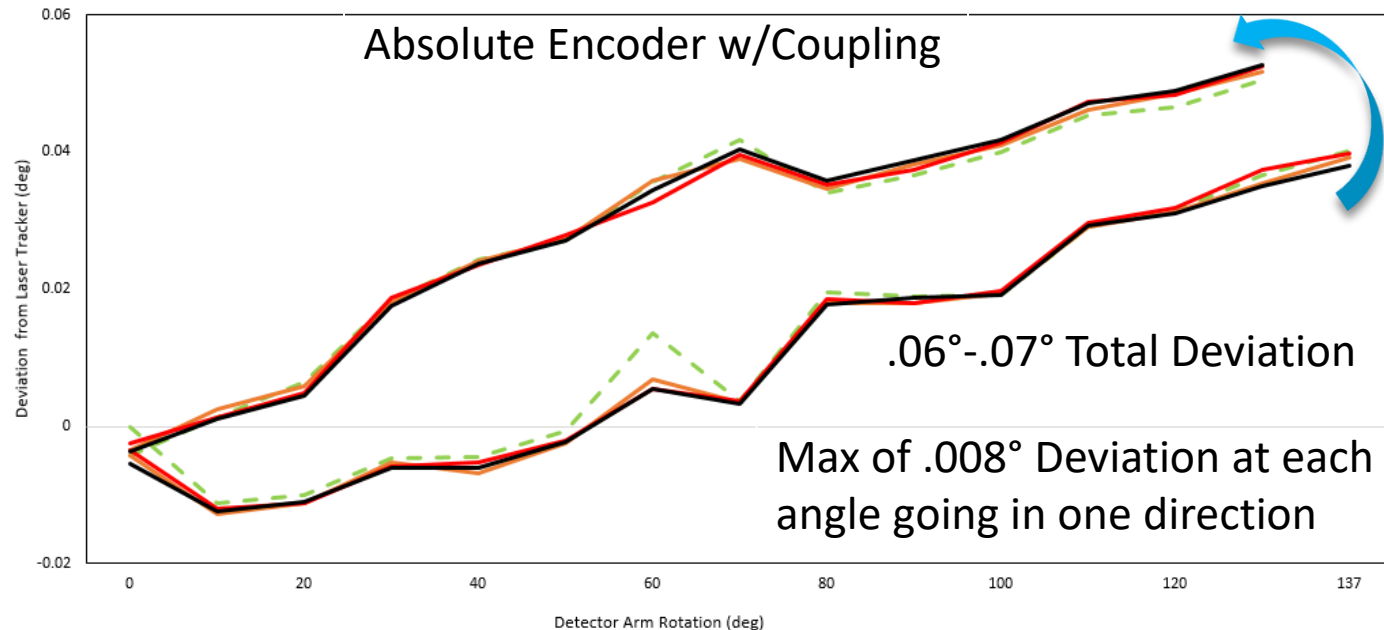


Effects of Adding Coupling



Effects of Adding Coupling

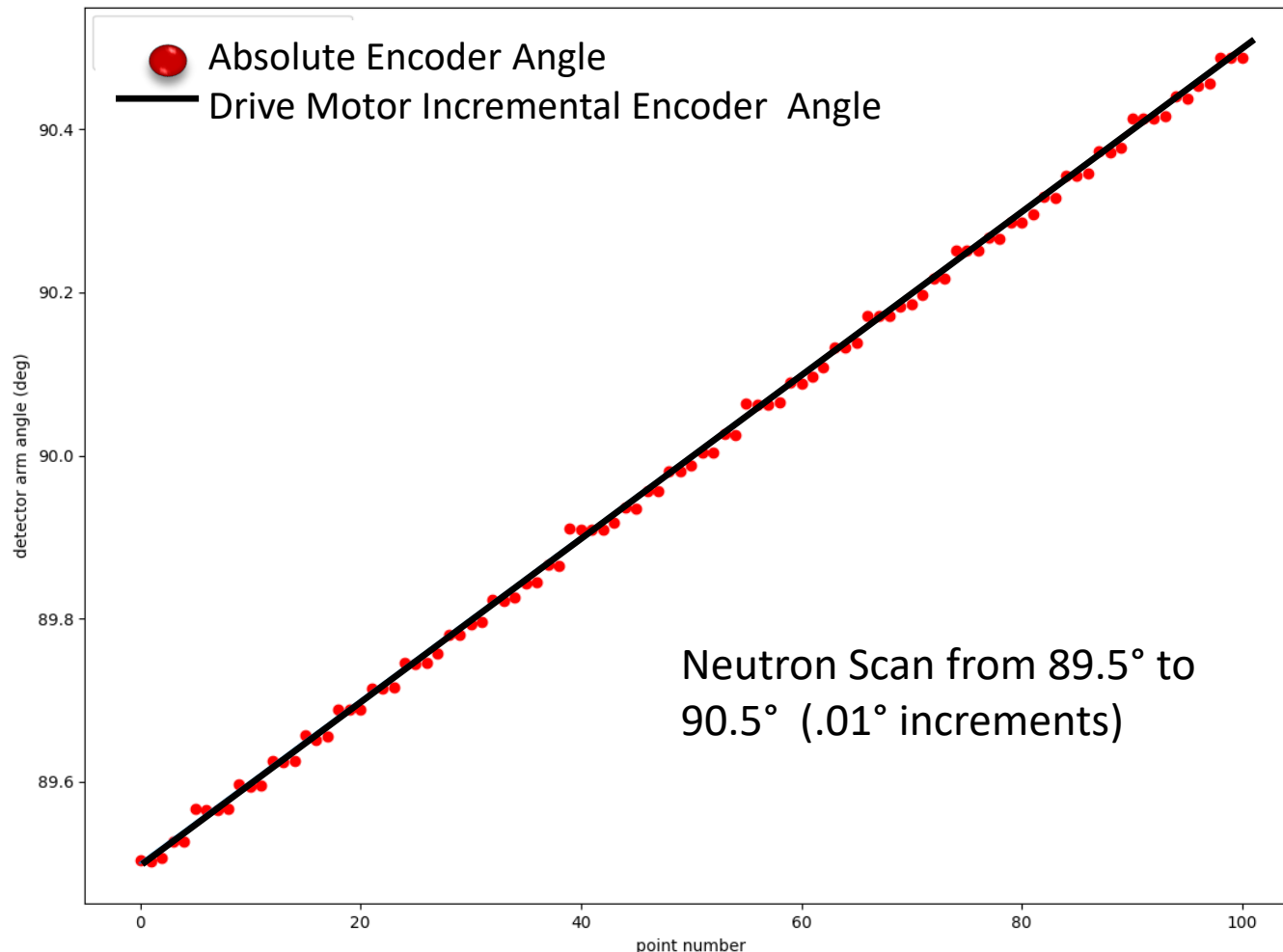
Rotation of Detector Arm – 0-140-0°



- Lookup Table?
- Direction Reversal - Are the outboard wheels aligned to the center of rotation?

More learned from science team

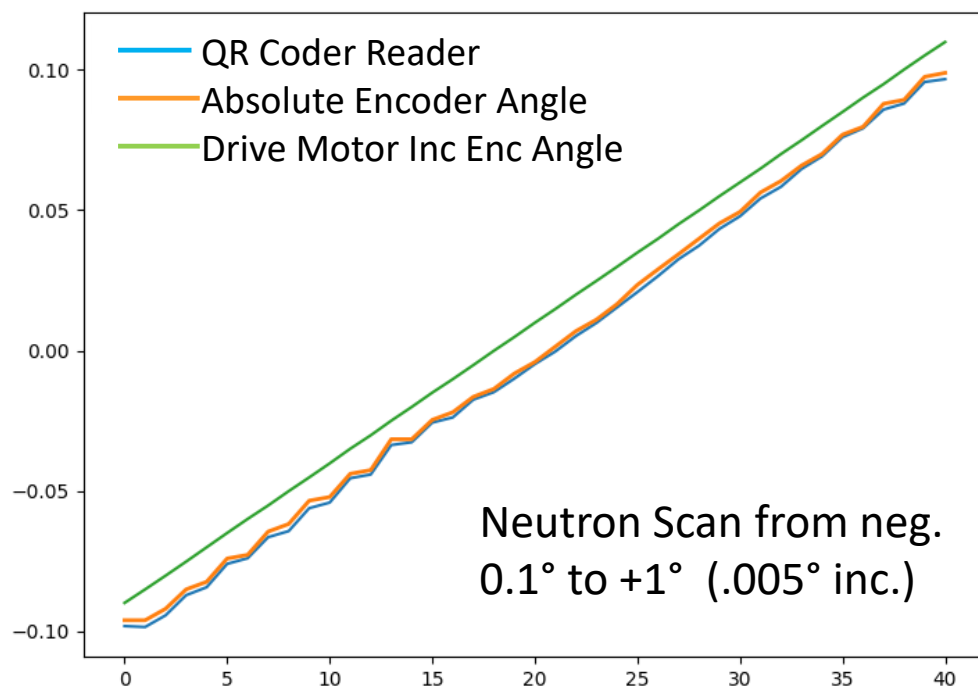
Encoder positions recorded during neutron scan show mismatch



Novel QR Code Reader Application

QR Code Reader

- Matches Absolute Encoder



Neutron Scan from neg.
 0.1° to $+1^\circ$ ($.005^\circ$ inc.)

Courtesy of Brian Maranville (NCNR)



Observations and Possible Causes

● Observations

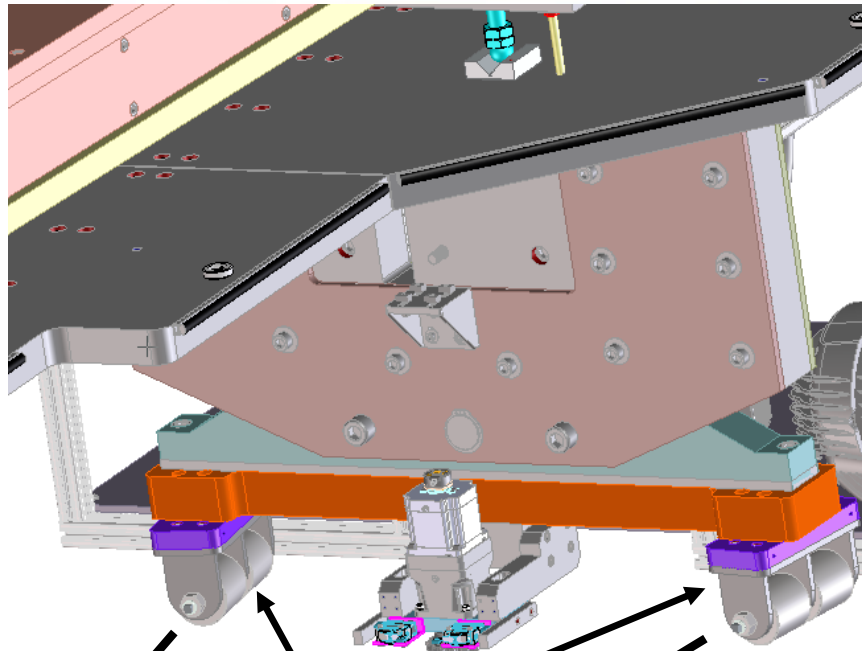
- Detector arm positioning erratic
 - Not rotating smoothly with the drive motor
- Direction of rotation affects detector arm angle

● Possible Causes

- Wheels not aligned on the axis of rotation
 - 2° of back driving in one direction does not fix this
 - Several small neutron scans at 0 degrees enable wheels to relax into a repeatable position after large arm rotations (data available upon request)
- Faulty sprocket engagement with roller chain

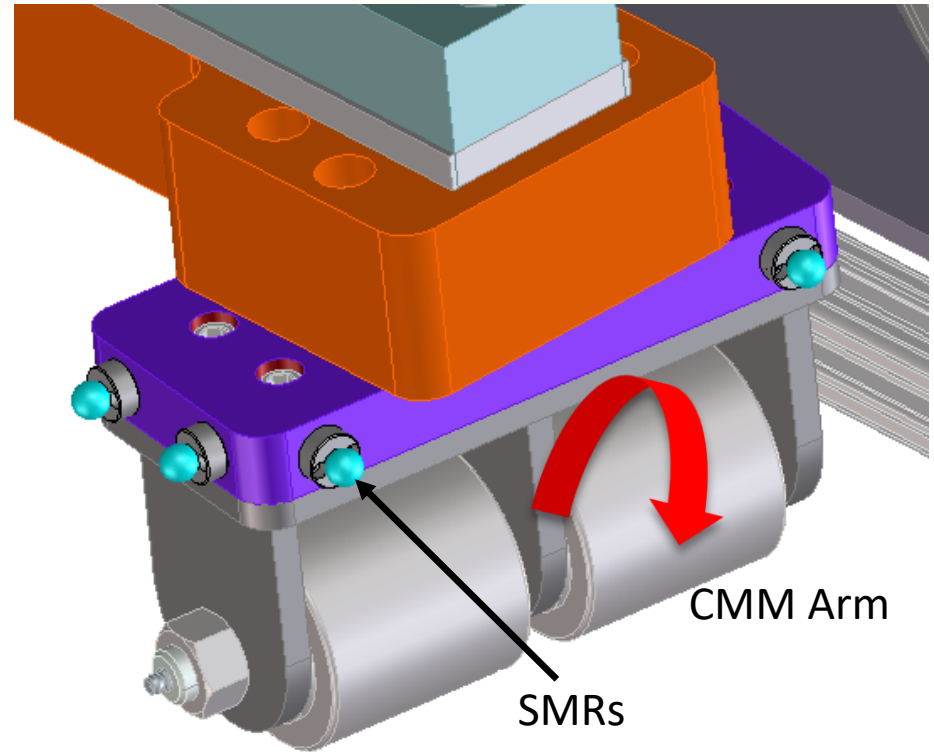


Wheel alignment



Casters

Aligned on Axis
of Rotation?



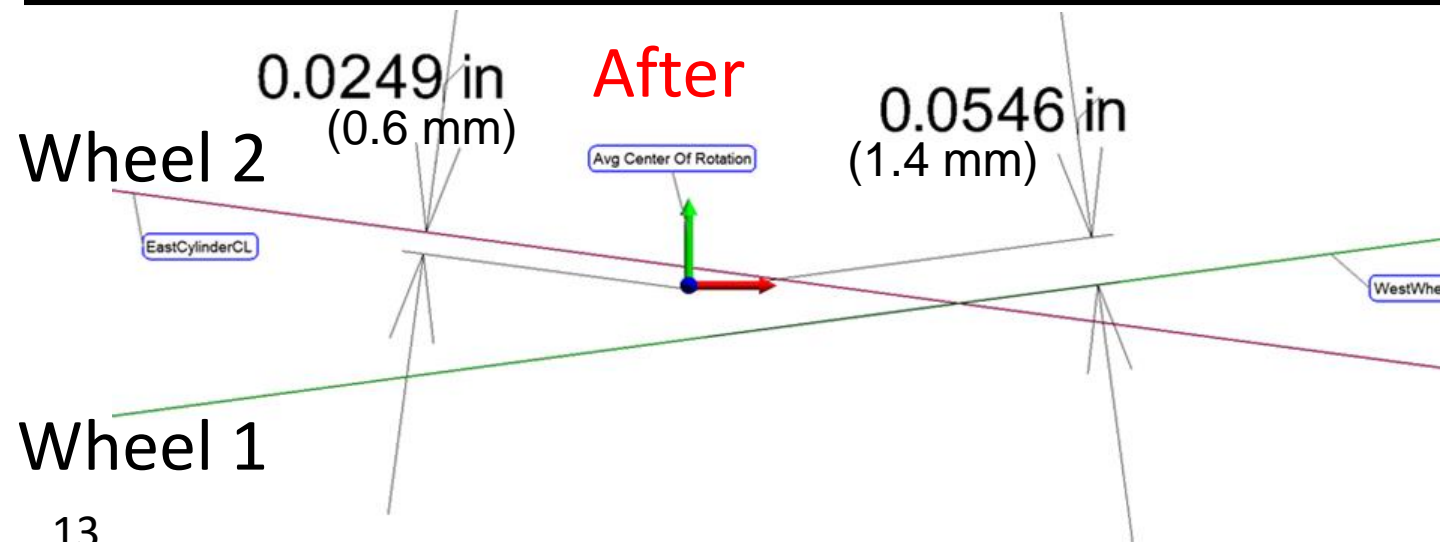
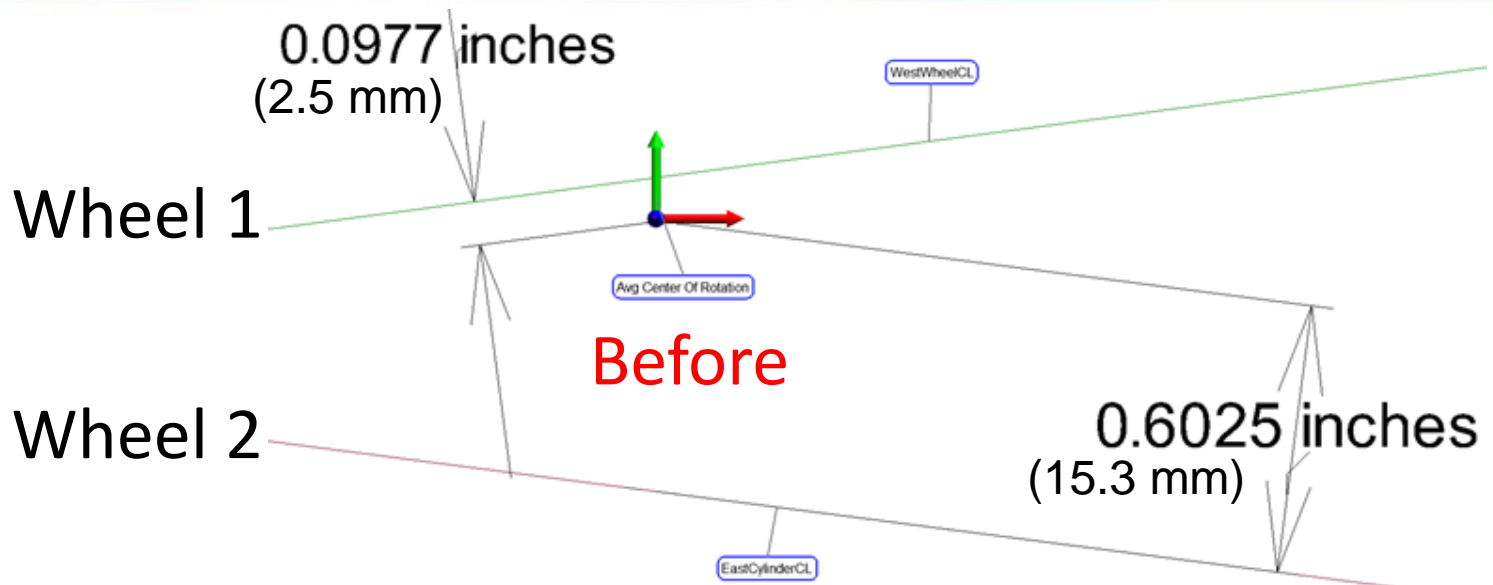
CMM Arm

SMRs

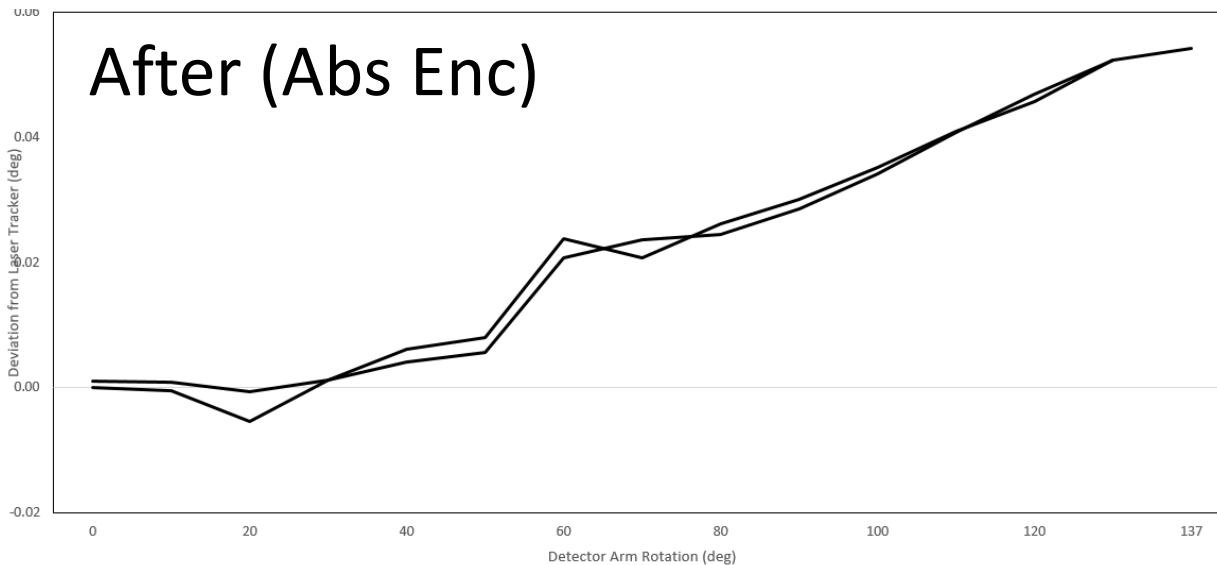
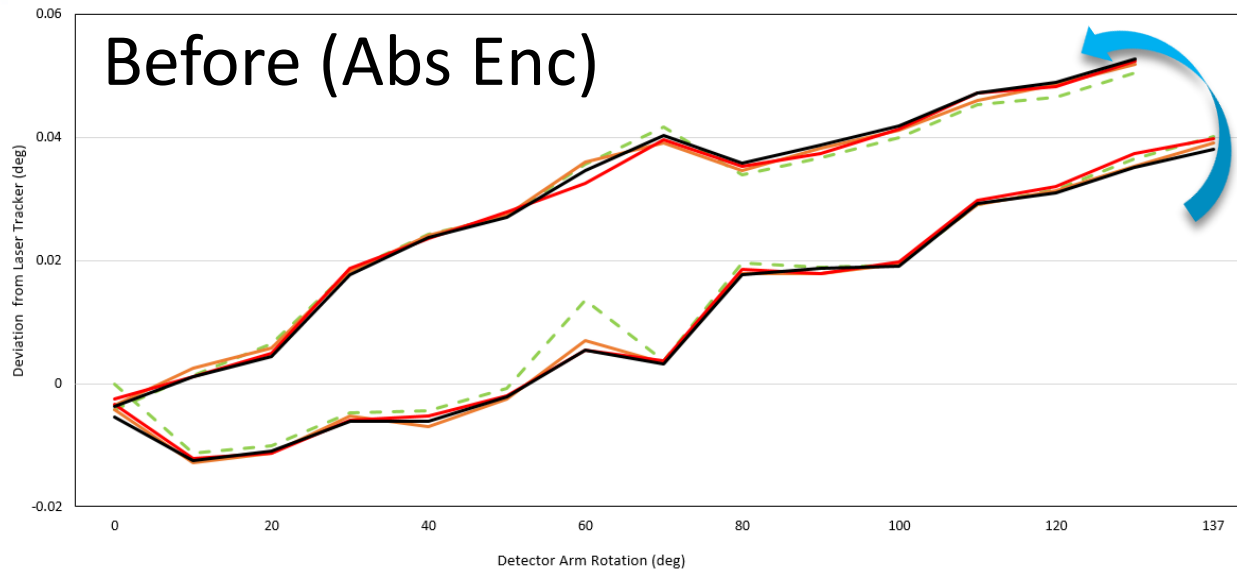
Characterize wheels &
check alignment



Wheel alignment



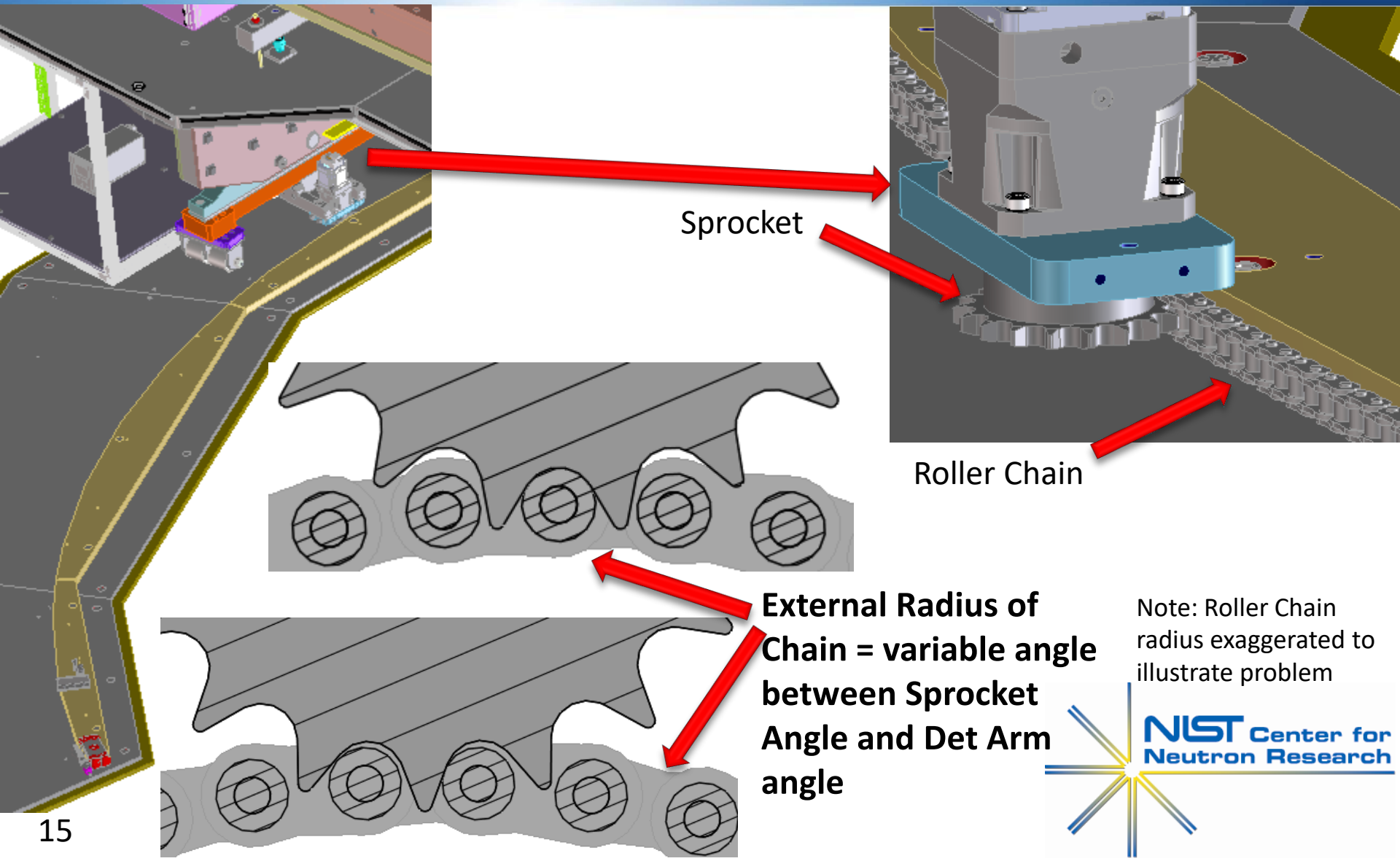
Before & after wheel alignment



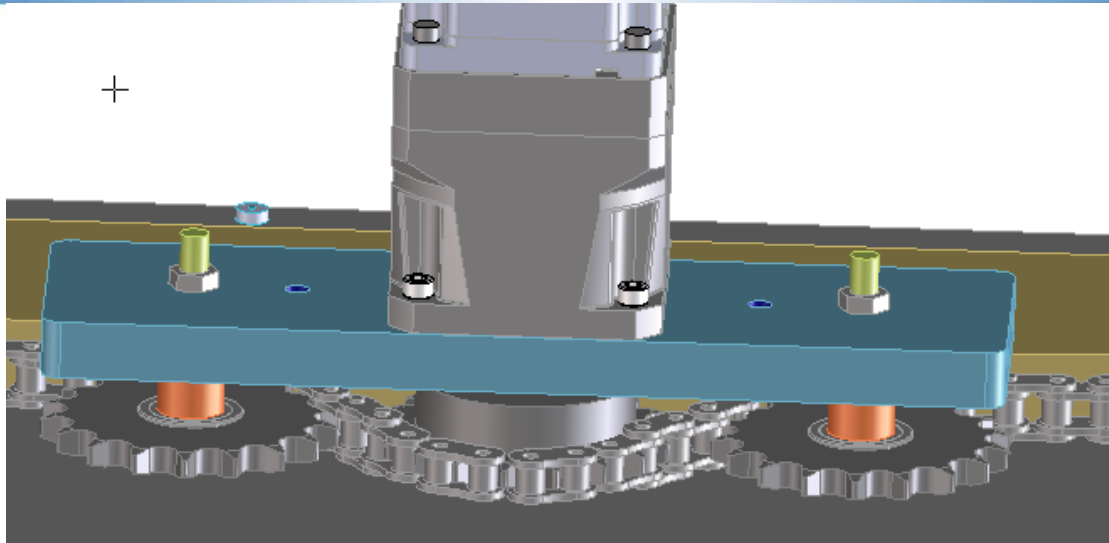
Note: Detector Arm Positioned by Drive Motor (not absolute encoder)



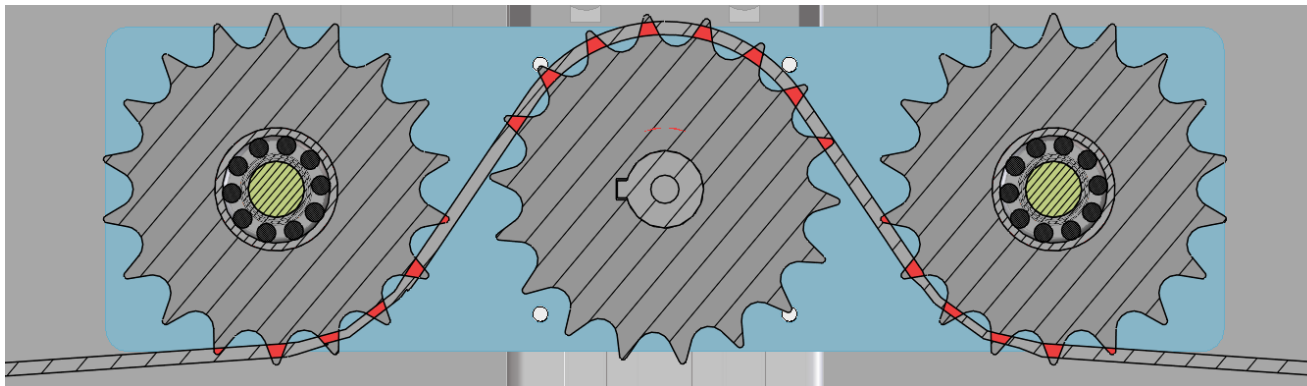
Drive Motor Sprocket & Chain



Add 2 Sprocket Idlers

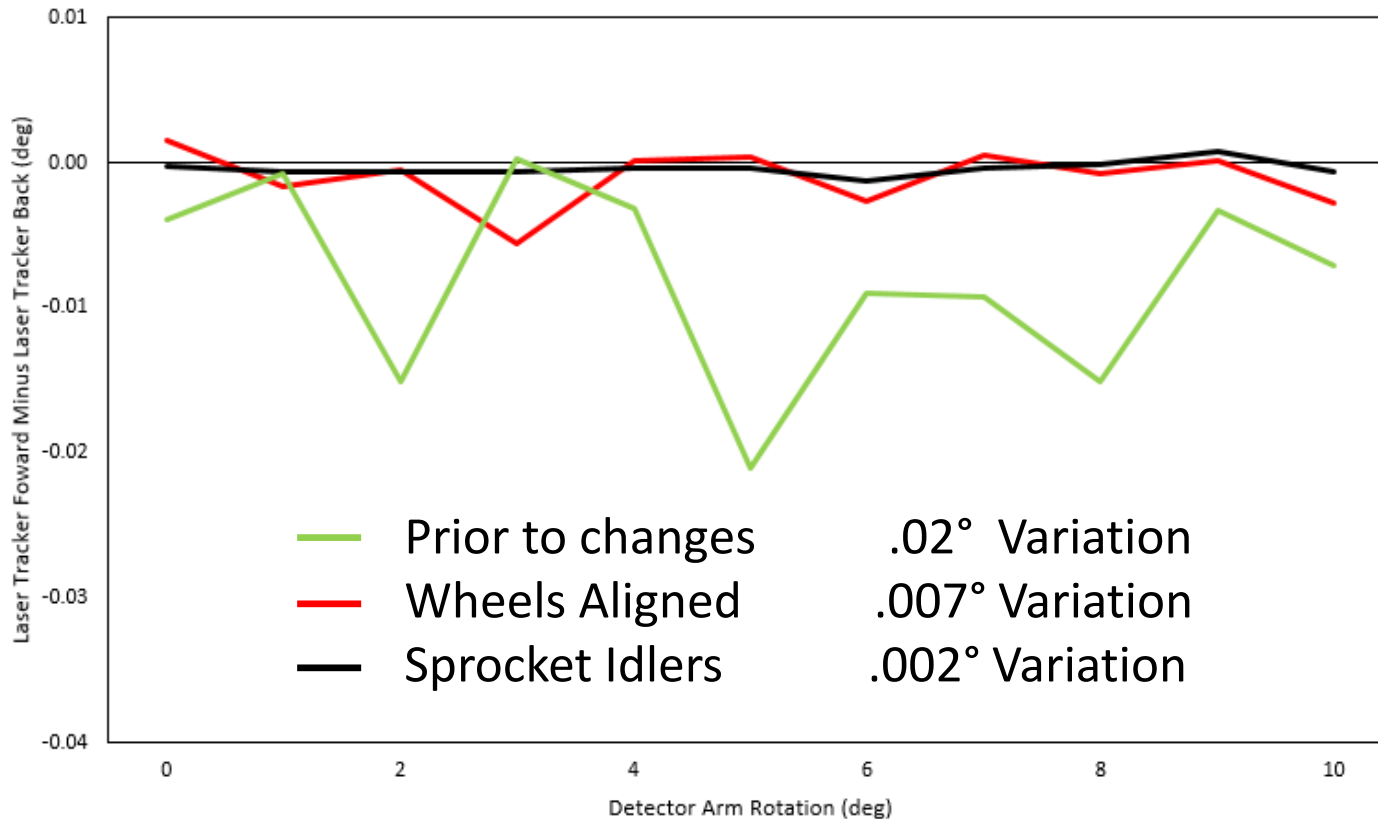


→ Roller Chain
spring tensioner
at end (not
shown)



Detector Arm Repeatability – 10x better

Laser Tracker (0-10°) MINUS Laser Tracker (10-0°)



Note: Detector Arm Positioned by Drive Motor
(not absolute encoder)



Future Plans



- Install and test a finer resolution absolute encoder for tighter scientific tolerances
- Fine tune the scaling factor applied to the drive motor to better match the laser tracker angle
- Use QR codes to provide absolute positioning at 0° and other angles (if necessary)

Thanks to the CANDOR Team

- Chuck Majkrzak
- Brian Maranville
- Alex Grutter
- David Hoogerheide
- Nick Maliszewskyj
- Jeff Ziegler
- Kevin Pritchard
- Peter Tsai
- George Baltic
- Don Pierce
- Dan Adler
- Ed Binkley
- Christoph Brocker
- Doug Johnson
- Doug Ogg
- Danny Ogg





And thanks for
listening! Questions?

