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NIRSPEC

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NIRSPEC Cryo-mechanics Design Note 3.00
Prototype Wheel Tests

Goals

The motion requirements of NIRSPEC are extremely challenging (see NCDN0200). It is unclear how to best meet these demands, but it is certain that we must improve on our past motion control systems, both in design and implementation. A new wheel mechanism has been designed which should improve wheel stability, thermal paths and motor/worm/wheel alignment. Anti-backlash, detent and postion referencing concepts have also been identified.

It was made clear at PDR that these ideas must be proven if we are to pass CDR. Specifically, we must quantify five separate characteristics:

Repeatability. The tolerable error associated with moving a mechanism and demanding that it return to the same position is very low. One tenth of a pixel at the array is the defined goal, which corresponds to as little as 0.8 arcsec of wheel rotation for some mechanisms. We must determine the repeatability we can achieve with several different anti-backlash schemes and with detents.

Resolution. The prototype wheel is the largest we have made. It is a 300-tooth wheel, giving a moving resolution of 10.8 arcsec for a 400 half-step motor. Given the potential difficulties associated with a larger wheel, its reliability must be ascertained.

Position referencing. High resolution is not effective if the position of the mechanism cannot be determined to the same level. Due to large switch activation ranges and worm/wheel backlash, it is challenging to reference positions to an accuracy of a resolution element (i.e. one motor half-step), and our ability to do this must be demonstrated.

Thermal cooling time. The cooldown time of Gemini is governed by the cooldown times of its mechanisms. While the instrument itself reaches equilibrium in about 24 hours, it takes an additional 24 hours for the mechanisms to operate reliably. By improving the thermal path to the wheels and motors, we hope to shorten this cooldown time. Tests should allow us to determine whether the problem is at the worm/wheel or the rotor/stator, and to estimate the cooldown time required for the new mechanism design.

Mechanism endurance. We need to know if the image rotator motor can withstand regular, short motor moves without overheating and being damaged. In addition, cryogenic motors will need to be refurbished occasionally. The bearings have a finite lifetime, and the whole motor may need to be replaced. We have no idea how often this maintenance will be required. Gemini's short wave filter wheel is the most heavily exercised motor in that instrument, and it has been operational for over 1 year (8 runs) with no failures. It would be nice if we could be more specific; if not for CDR then upon delivery of the instrument.

Description of Mechanism

The prototype mechanism consists of a 300-tooth worm gear that will be similar to the Gemini wheel mechanisms but with the following changes. There will be only enough outer casing to support the wheel axle and mount the motor/worm assembly and not fully enclose the wheel. This should aid in visual diagnostics. The motor and worm are aligned as a single unit, independent of the worm/wheel alignment (like the NavyCam mechanism). The wheel support pedestal is 2" in diameter instead of 3/4" to help eliminate the tendency for the wheel to ride up on the worm and also to provide a better thermal path to the wheel. The motor also has a better thermal path to reduce heating problems.

Repeatability/accuracy will be measured by mounting a reflective surface to the wheel. A HeNe laser will be fired into a chamber viewing port and reflected out the same port to a marking surface. Any wheel rotation will cause a displacement of the laser spot on the marking surface. The reflective surface will be either a flat mirror or a curved surface such as a shiny ball bearing. We would like to measure the repeatability of the mechanism to an accuracy of 1/30 of a motor half-step, which is the inherent repeatability of the motor. This corresponds to 0.36 arcsec of wheel rotation on this mechanism. For a flat mirror to displace the laser spot 1 mm in 0.36 arcsec of wheel rotation, the beam would have to be thrown

$$D = (1mm)/(2*1.75*10^{-6}rad)$$

or 286 meters. But after about 20 meters, the spot size has increased to 30 mm diameter, making 1 mm difficult to distinguish. A 20 meter throw would make 1 mm correspond to about 5 arcsec of wheel travel. For a 3/4" diameter ball bearing, the beam throw is

$$D = (1mm)*(9.5mm)/(2*115mm*1.75*10^{-6}rad)$$

or 24 meters, where 9.5mm is the bearing radius and 115mm is the distance from the bearing to the wheel axle. However, the curved surface greatly disperses the laser beam, increasing the size of the laser spot to an extent that the spot position is almost undiscernable even after 1 m of throw. A pinhole placed in front of the laser could reduce this effect, but probably not enough.

It seems clear that we will be unable to accurately measure a fraction of an arcsecond of wheel rotation, but we should be able to discern 5 arcsec, or 0.5 motor half-steps. This would correspond to about 0.6 pixels on the NIRSPEC array for the grating mechanisms and less than 0.1 pixel for all other mechanisms.

Description of Tests

Phase I: Thermal/Stability

* mechanism mounted in the chamber
* six temperature diodes placed at various points in the chamber:
    LN can, mounting plate, wheel casing, wheel, motor casing, motor shaft
* cool down the chamber, marking all temps at regular intervals until equilibrium is reached
* repeat as necessary, making improvements to chamber and mechanism
* remove diodes from moving parts, rotate wheel while monitoring wheel wobble, worm stability, temperatures
* start with a slow top motor speed (~1000 Hz) and increase until at nominal (~6000 Hz)

Phase II: Anti-Backlash

* 1st spring-loaded worm system: simple loading of worm shaft opposite motor
* 2nd spring-loaded worm system: double worm/miter gear, one worm loaded against wheel
* 3rd system: unbalanced wheel, using gravity to load wheel against worm
* define a "home" position such that laser bounces off wheel mirror through viewing port
* set up apparatus such that laser travels >20 m for 0.5 half-step measuring resolution
* take wheel to defined "home" position, mark position of laser
* single direction: move wheel 0.25x4, 0.5x2, 1, 2, etc, revolutions and mark position of laser
* both directions: move wheel forward and then backward to original spot, marking laser

* change home position by 1 half-step, repeat above tests. Do this for 8 consecutive half-steps.
* delay should be programmed into moves between ramp-down and power-off, marking laser positions for both
* cycle motor power without moving to check for creep (for 8 consecutive half-step positions)
* switch initializations: use CY545 "home" command and/or Gemini init procedure
  rotate wheel until switch activates
  center wheel on switch
  manually reset the motor drive

initialize mechanism, then move to "home" position (if not there) and mark laser spot

Phase III: Detents

* remove spring-loaded worms, install spring-loaded rockers and unloaded worm
* move wheel out of and back into the detent, from both directions, marking laser spot every time wheel is locked into position
* this tests the ability of the detent to force the wheel into position, the ability of the motor to drive the wheel out of the position, and the positional repeatability of the detent

Phase IV: Destructive

* with temp sensor on wheel casing and motor, simulate the motor activity of the image rotator
* set up an automated cycling program that moves the motor every few minutes indefinitely, to estimate motor lifetime
* after 2 weeks, repeat positional tests to compare to performance when new