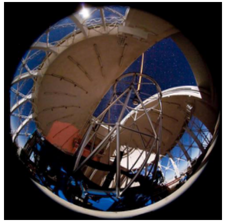
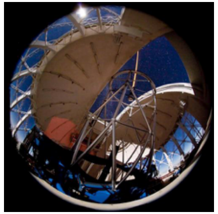


Rejecting Harmonic Vibrations

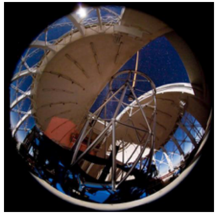
With Real-Time Frequency Tracking at M2

Maunakea Operations Workshop, December 8th, 2016



Overview

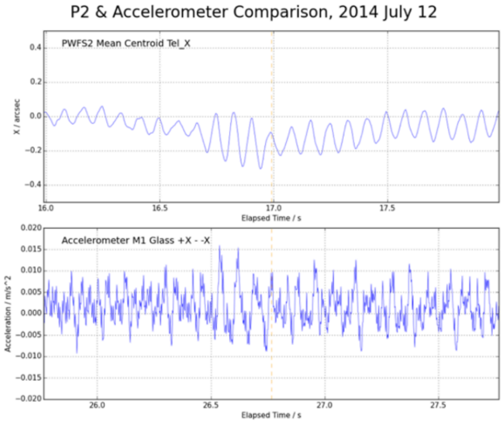
- History and source of Vibration at Gemini North
- Auto-guider and control loop
- Fast tip-tilt secondary mirror
- Closed loop vibration tracking
- Performance and results
- Real-time monitoring



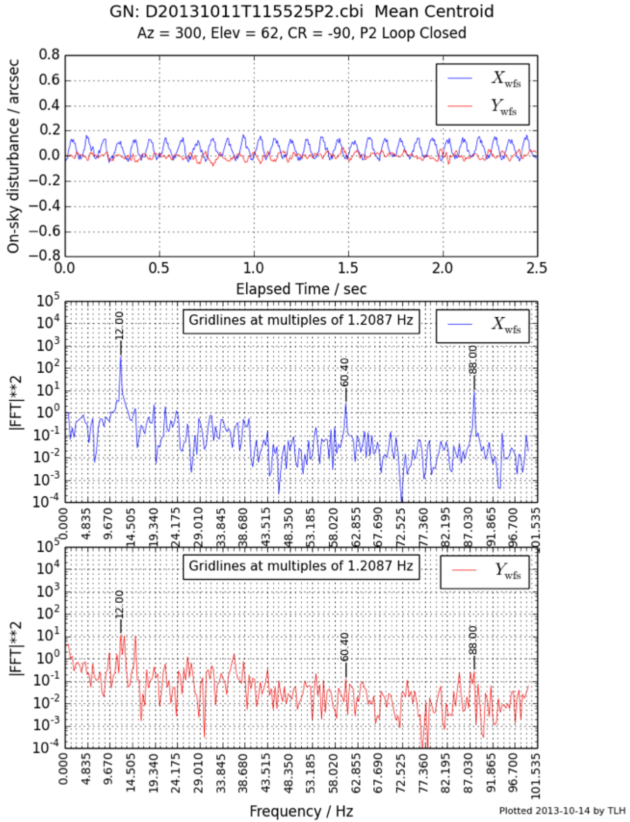
12 Hz Vibration at M1 Can Distort Wavefront ~40%

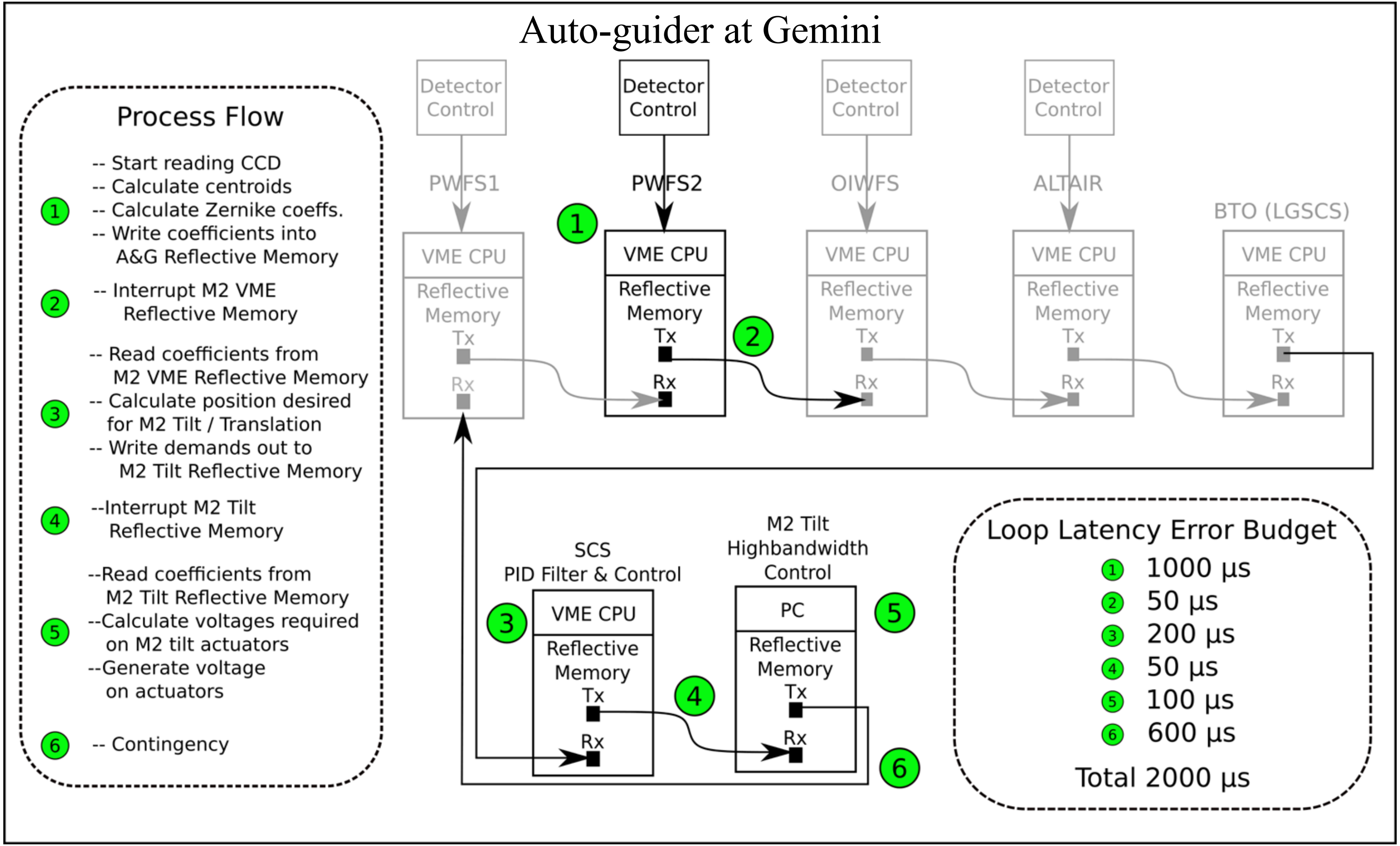
Cryocooler-induced Telescope Optical Vibrations

- Gemini North images have been known to exhibit strong elongations.
- WFS data analysis reveal 12 Hz sinusoidal oscillation: ~100 mas, parallel to elevation (X) axis

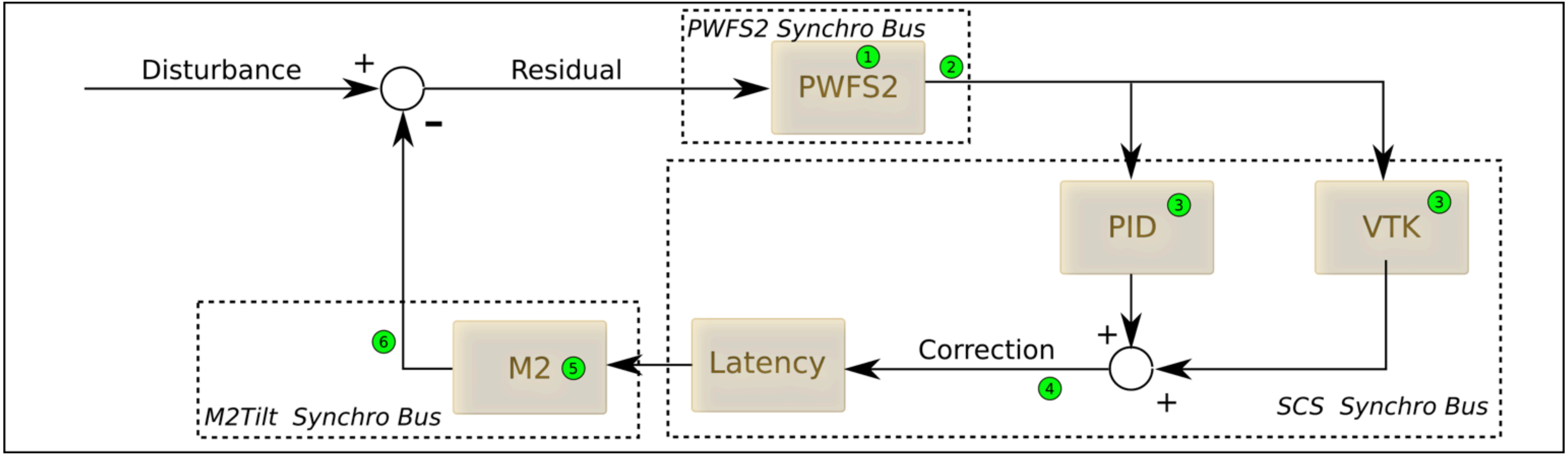


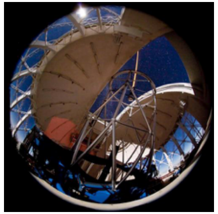
Amplitude correlates with GNIRS coldhead stroke parallel to X axis. 12 Hz amplitude absent parallel to Y.




Auto-guider at Gemini
Process Flow
1 -- Start reading CCD
-- Calculate centroids
-- Calculate Zernike coeffs.
-- Write coefficients into A&G Reflective Memory
2 -- Interrupt M2 VME Reflective Memory
3 -- Read coefficients from M2 VME Reflective Memory
-- Calculate position desired for M2 Tilt / Translation
-- Write demands out to M2 Tilt Reflective Memory
4 --Interrupt M2 Tilt Reflective Memory
5 --Read coefficients from M2 Tilt Reflective Memory
--Calculate voltages required on M2 tilt actuators
--Generate voltage on actuators
6 -- Contingency
Detector Control
PWFS1
PWFS2
OIWFS
ALTAIR
BTO (LGSCS)
VME CPU
Reflective Memory
Tx
Rx
SCS
PID Filter & Control
M2 Tilt
Highbandwidth
Control
PC
Loop Latency Error Budget
1 1000 µs
2 50 µs
3 200 µs
4 50 µs
5 100 µs
6 600 µs
Total 2000 µs

Closed Loop Model





VTK Model

1. Define complex phase oscillator: $R_k = e(-j\theta_k)$
   where $\theta_k = 2\pi \frac{F_0}{F_s}$
   F_0 is initial vibration tracking freqency 12 Hz
   F_s the sample rate of the autoguider = 200 Hz
   R_k is advanced through θ at each cycle k

2. The input vibration signal S_k is projected on the oscillator and accumulated in the complex amplitude with a gain G_a.

$$A_k = A_{k-1} + G_a R_k S_k$$

3. Vibration compensated by commanding M2

$$C_k = -2 * real(conj(A_k) * R_k * A_{PID})$$

4. Frequency Tracking

$$\delta\varphi_k = \varphi_k - \varphi_{k-1}$$ find phase change

$$\delta F_k = \frac{\delta\varphi_k}{2\pi} F_s$$ scale to frequency

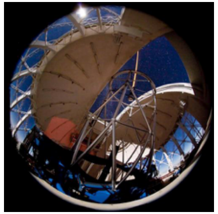
$$F_{k+1} = F_k - G_F \delta F_k$$ filter frequency tracking calculated for next cycle k+1

$$\theta_{k+1} = \frac{2\pi F_{k+1}}{Fs}$$ phase angle for next cycle tracks the frequency of vibration.

Initialize Rk =

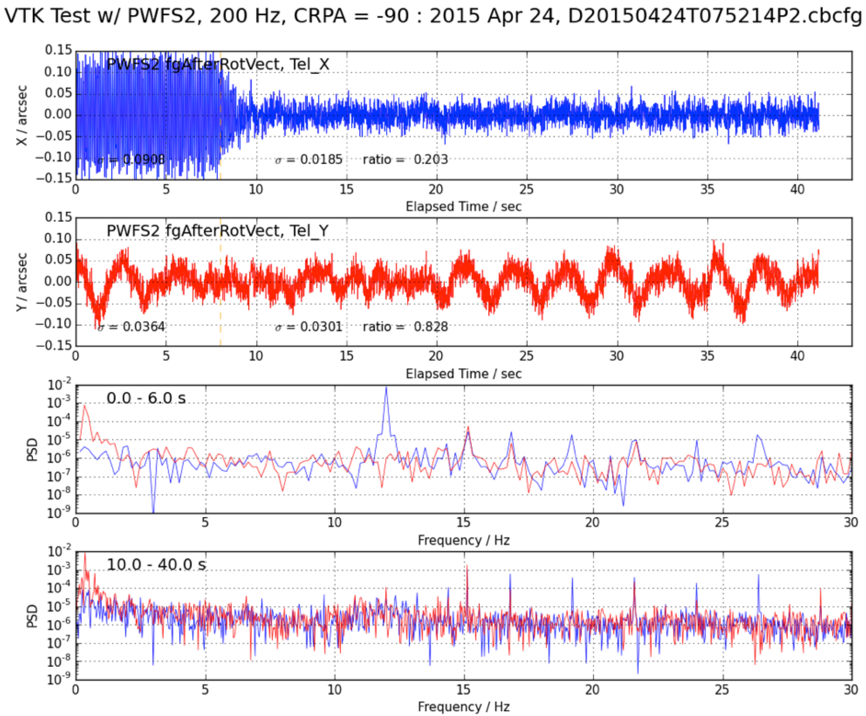
$$\begin{bmatrix} \cos\theta_K & -\sin\theta_K \\ \sin\theta_K & \cos\theta_K \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

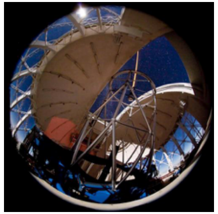
- If the amplitude of Sk (the 12 Hz vibration signal) goes to zero, the commanded VTK amplitude also goes to zero!
- With the sample rate Fs = 200 Hz we can track the frequency of the vibration by monitoring the phase change from the current and previous cycle.



Results

- VTK is capable of rejecting the 12Hz vibration of M1 induced by harmonics in the GNIRS cold heads.
- Control methods may help reject the most prominent harmonics, but this does not remove the vibrations.
- During commissioning a real-time spectrum analyzer was developed to monitor the health of the VTK. See QRcodes for YouTube demo.
- Graph shows convergence as operators assert VTK.





GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

Thank you!

Embedded With RTEMS
www.rtems.com