HST Two-Gyro Mode

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Two-Gyro Science Mode Website
http://www.stsci.edu/hst/hst_overview/TwoGyroMode
(includes links to ISRs)
STScI Two-Gyro Mode Team Effort

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ACS analysis team  NICMOS analysis team  Schedulers
Two-Gyro Mode

• HST uses gas bearing rate-sensing gyros to provide information about changes in observatory pointing.
  - Gyros do not change the pointing. Reaction wheels provide the torques needed to change the pointing.

• The HST attitude control system was originally designed to operate with 3 gyros.
  - 4 of 6 gyros presently installed in HST are functional

• To conserve gyro lifetime and extend the life of the HST mission, HST was preemptively placed in two-gyro mode on 8/28/05.
  - Gyro #4 was turned off 09/01/05
  - Gyro #6 was already off
  - Gyros #1 and #2 are currently on
  - The FGS provide the missing (orthogonal) axis of control during science observations.
Two-Gyro Operations - Key Points

- Science data appear nominal and reveal no significant anomalies.
- HST instrument performance in two-gyro mode is essentially indistinguishable from performance in three-gyro mode.
  - Observations requiring the finest pointing control (coronagraphy and high-resolution imaging) are feasible.
  - Moving targets have been observed (Mars, Uranus).
- Fine-pointing jitter is typically $\leq 5$ milli-arcseconds (RMS over 60 sec interval).
- Scheduling is more restrictive in two-gyro mode because entry into fine pointing mode for science observations is more complicated.
  - Only about 50% of sky available at any given time
- Not allowed
  - Gyro-only tracking
  - Guide star handoffs
  - Single guide star acquisitions
Jitter in Two-Gyro Mode

- Pointing jitter derived from inputs into the two-gyro attitude control law is comparable to the jitter in three-gyro mode.
- This amount of jitter is hard to detect in the science data.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Gyro Set</th>
<th>Over All Exposures</th>
<th>RMS Jitter (milli-arcseconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>10-sec Avg.</td>
</tr>
<tr>
<td>Two-Gyro (Feb. 2005)</td>
<td>2-4</td>
<td>Mean / Max (454 exp.)</td>
<td>5.6 / 9.5</td>
</tr>
<tr>
<td>Two-Gyro (Aug. 2005)</td>
<td>1-2</td>
<td>Mean / Max (262 exp.)</td>
<td>3.3 / 5.3</td>
</tr>
<tr>
<td>Three-Gyro</td>
<td>1-2-4</td>
<td>Mean (24 exp.)</td>
<td>4.1</td>
</tr>
</tbody>
</table>

Data provided by B. Clapp (LMCO)
Two-Gyro Scheduling

- Scheduling efficiency in two-gyro mode is slightly lower than in three-gyro mode (~72 vs. ~80 prime orbits/week).
- For unconstrained observations, any point in the sky is available at some time during the year.
- For constrained observations, placing limits on roll angle or time of observation restricts availability.
- Consult the two-gyro website for detailed scheduling graphs and tables.
Two-Gyro Science Mode Orbital Verification (TGSMOV)

- On-orbit tests during the transition to two-gyro mode verified ACS and NICMOS instrument performance.
  - ACS: #10458-10461
  - NICMOS: #10462,10464
- Tests for
  - PSF width
  - Pointing stability
  - Coronagraphy
  - Moving target tracking

A 10-second ACS/HRC/F555W observation of the globular cluster NGC 2298 taken in two-gyro mode.
ACS PSF Analysis

- Multiple exposures of three rich star clusters with HRC F555W
  - Sequences of 10, 100, 500 sec exposures
  - Slight dependence of PSF width of exposure duration
- FWHM measurements for stars with S/N > 10.
  - Hundreds of stars per image
- Bright and faint guide stars to check results
  - $V = 13$ and $V = 14$
  - No dependence of PSF width on GS magnitude seen
ACS Instrument Performance in Two-Gyro Mode is Excellent

August 2005

114 exposures
3 clusters
- NGC 2298
- NGC 1891
- NGC 6752

October 2005

72 exposures
1 cluster (CVZ)
- NGC 6752

Three-gyro historical data
Avg (FWHM) = 2.04±0.03

PSF analyses by M. Sirianni, C. Pavlovsky, R. Lucas

186 HRC exposures
Min (FWHM) = 1.89
Avg (FWHM) = 2.00
Max (FWHM) = 2.19
NGC 6752 Two-Gyro Observations

August 2005
18 exposures
Non-CVZ time
Sun Angle ~ 115°

October 2005
72 exposures
CVZ time
Sun Angle ~ 80°

Sun Angle for the two other clusters was ~70° and ~89°.

NGC 6752 (October)
Min = 1.89
Avg = 1.97
Max = 2.06

NGC 6752 (August)
Min = 2.04
Avg = 2.09
Max = 2.19
PSF Dependence on $T_{\text{exp}}$

Longer exposures have slightly broader PSFs.

The longer exposures were taken later in each orbit.
PSF Dependence on Time in Orbit

- PSFs get broader with time in individual orbits.
- PSF variation is larger than expected simply from exposure time differences.
- Dependence is likely due to normal changes of focus caused breathing cycle of the telescope during the orbit.

Analysis by Matt Lallo.
ACS - Pointing Stability Test
ACS - Pointing Stability Test

Pointing stability in two-gyro mode is indistinguishable from stability in three-gyro mode.

<table>
<thead>
<tr>
<th></th>
<th>Total Shift (RMS, milli-arcsec)</th>
<th>Roll Angle r.m.s. (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Gyro (Feb ‘05)</td>
<td>2.29</td>
<td>0.00097</td>
</tr>
<tr>
<td>2-Gyro (Aug ‘05)</td>
<td>2.08</td>
<td>0.00070</td>
</tr>
<tr>
<td>3-Gyro</td>
<td>2.19</td>
<td>0.00093</td>
</tr>
</tbody>
</table>
Two-Gyro Moving Target Test

- 32 x 0.3 sec F435W HRC images of Mars over 1 orbit.
  - Median ~ 10000 e-/pixel
  - Up to 30000 e- in icecap
- Rotation of Mars complicates cross correlation of images to find shifts
- Made mask (> 5000 e- =1 < 5000 e- =0) and cross correlated masks with drizzle tools to find shifts.
Mars Position Measurements

- Compared measured shifts of Mars image to expected shifts from the difference between predicted and final HST ephemeris.
- Direction and scale of shifts agree, but small differences of ~16 mas remain.
- Residuals are smaller than the unavoidable errors from in-track HST positional uncertainties.

Analysis by C. Proffitt
ACS Coronagraphy

- Coronagraph spot jumps unpredictably by up to 3 HRC pixels between visits.
  - Variation of spot position is more significant than two-gyro pointing uncertainties.
  - Earth flats taken weekly to measure position offset.
  - Offset chosen for subsequent observations to minimize position error.
- Coronagraphic test compared coronagraph images through four filters.
  - Three-gyro mode, September 2002
  - Two-gyro mode test, February 2005
  - Two-gyro mode, August 2005
- No significant differences found between two-gyro and three-gyro modes.
ACS Coronagraphic Images

HD 130948A
F625W
Three-gyro image
September 2002
Exposure 30 sec

HD 130948A
F625W
Two-gyro image
February 2005
Exposure 300 sec

HD 216149
F625W
Two-gyro image
August 2005
Exposure 300 sec

KRS 18
ACS Coronagraphic Image
Radial Profiles

Solid Line: Three-gyro
Dotted line: February Two-gyro
Dashed line: August Two-gyro

Analysis by C. Cox
NICMOS Coronagraphy

Observations of HD 17925, (G star, V=6.0)

Direct images

Acquisition successful, repeatable

Coronagraphic images

See NICMOS ISR 2005-001 (Schultz et al.) for analysis of similar observations in February 2005.