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HST Two-Gyro Handbook Update for Cycle 14 Phase II Proposals

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Purpose of Document

This document provides an update to the *HST Two-Gyro Handbook* released with the Hubble Space Telescope *Cycle 14 Call for Proposals*. The information contained herein is based upon an initial assessment of on-orbit test results for the Two-Gyro F2G Mode conducted in February 2005.

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Revision History

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Acknowledgments

The information in this handbook update is a brief summary of the experience gained by many individuals working on the HST two-gyro mode development at STScI and elsewhere. Material contained herein has been presented in various forms at the HST Two-Gyro Science Project Briefing at Goddard Space Flight Center (March 2005) and at the HST Two-Gyro operational Readiness Review (April 2005). We thank Brian Clapp and the HST Pointing and Control Systems group at Lockheed Martin Technical Operations Company for their early analysis of the telescope pointing and jitter data. The following people at STScI contributed to the success of the two-gyro on-orbit test and the early results summarized here:

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CHAPTER 1:

HST Two-Gyro Handbook Update

In this chapter. . .

1.1 Introduction

The *HST Two-Gyro Handbook* is the primary reference for issues related to Hubble Space Telescope observations conducted with an attitude control system relying upon just two gyroscopes. This update to the *HST Two-Gyro Handbook* summarizes recent progress in understanding the telescope pointing and instrument performance while HST is operating in two-gyro mode. In this mode, two gyros are used in combination with the Fine Guidance Sensors to provide fine-pointing information while science observations are being conducted.

On-orbit tests of the HST two-gyro fine guiding mode and its impact on science instrument performance were carried out on 20-23 February 2005. Gyro #1 was removed from the pointing control loop, and Gyros #2 and #4 were used with the FGS to control the HST attitude during all science observations. The control law used during the test was the same as the one that will be used when HST enters two-gyro mode (either deliberately or as a result of gyro failure). More than 450 science exposures were obtained with the Advanced Camera for Surveys (ACS), the Near Infrared and Multi-Object Spectrograph (NICMOS), and the Fine Guidance Sensors during the three day test.

The ACS, NICMOS, and FGS instrument teams are analyzing the data from these tests. Early analyses of those data indicate that the HST instrument performance is excellent. A series of detailed Instrument Science Reports will document the results from these tests, which are summarized briefly below.

HST fine-pointing and instrument performance in two-gyro mode is nearly indistinguishable from the performance observed in three-gyro mode.

1.2 Pointing and Jitter

The HST Pointing and Control Systems group monitored the pointing jitter throughout the two-gyro on-orbit test. For each science exposure, they calculated the jitter at 25 milli-second intervals as estimated by the attitude control law used to maintain the HST pointing. A summary of the 10-second and 60-second jitter root-mean-square running averages and peak excursions is given in Table 1.1. The table lists the two-gyro mean, median, and maximum jitter values for the 10 and 60 second quantities in the sample of 454 exposures. Almost all of the exposures have a mean jitter less than 10 milli-arcseconds. In a few cases, transient pointing disturbances caused small enhancements in the jitter. These types of disturbances are also commonly seen in three-gyro mode (see Chapter 5 of the *HST Two-Gyro Handbook* for more details).

Table 1.1: Jitter Summary

	Jitter (milli-arcseconds, RMS)			
	10-sec Avg	**Peak 10-sec**	**Avg 60-sec**	**Peak 60-sec**
Two-Gyro Mean	5.6	6.5	6.0	6.2
Two-Gyro Median	5.5	6.2	5.7	6.0
Two-Gyro Maximum	9.5	22.2	10.7	18.0
Percentage of Two-Gyro Exposures with Jitter < 10 mas	100%	97.8%	99.1%	98.7%
Three-Gyro Mean	4.1	5.2	4.2	4.3

Notes: Two-gyro values are based on a sample of 454 exposures taken during the two-gyro on-orbit test (20-23 February 2005). Three-gyro values are based on a sample of 24 exposures taken several days prior to the two-gyro on-orbit test.

The mean two-gyro 60-second-averaged jitter in Table 1.1 is slightly higher than the mean 10-second-averaged jitter because the sample includes several series of short dithered exposures; the 60-second running averages span short periods of slightly increased jitter between exposures as the pointing was changed from one dither position to the next. The jitter values measured during the two-gyro on-orbit test are only slightly larger than those observed in three-gyro mode. The two-gyro values are similar to those predicted by high fidelity simulations conducted in late 2004 and are significantly better than the conservative “worst case” jitter ellipse of 30 x 10 milli-arcseconds adopted for Cycle 14 Phase I preparations.

There was no loss of fine lock resulting from large pointing disturbances during any of the science observations obtained in two-gyro mode. Loss of lock did occur for 5 of the 36 acquisitions, but these failures have been traced to either bad guide stars or to a minor problem with roll adjustments during the acquisitions at the beginning of the second orbit of several visits. This latter problem is correctable with a minor change to the flight software. The acquisition success rate in two-gyro mode is expected to be >98% once the software patch is in place.

1.3 Scheduling and Target Visibility Issues

Fixed Targets

The Observation Planning portion of the *HST Two-Gyro Handbook* (Chapter 6) describes the scheduling of observations in two-gyro mode. The information contained therein has not changed. Observers filling out their Cycle 14 Phase II proposals should consult the Handbook as well as the Astronomers Proposal Tools (APT) Phase II software documentation to assess the schedulability and visibility periods of fixed targets.

Moving Targets

Development of a two-gyro capability for observations of moving targets is ongoing and expected to be available in Cycle 14. The attitude control software required to track moving targets will be tested when HST enters two-gyro mode. Several types of slews bounding those used to track moving targets were performed in the recent two-gyro test. The jitter and pointing control during those slews was similar to the performance expected in three-gyro mode, thus providing preliminary evidence that moving target observations should be feasible. Proposers wanting to observe moving targets should assume that two-gyro observations will work exactly as three-gyro observations, with the caveats that gyro-only tracking and guide star handoffs for moving target observations will not be available in two-gyro mode. Moving targets are subject to the same general scheduling and visibility constraints as fixed targets (see Chapter 6 of the *HST Two-Gyro Handbook*). See the *Cycle 14 Call for Proposals* (Section 4.1.3) for additional restrictions on moving target observations.

Scheduling Efficiency

The HST Scheduling Group has constructed a long range two-gyro scheduling plan using the Cycle 13 observation pool as a test case to check the scheduling efficiency expected in two-gyro mode. All of the proposals in that cycle were designed for three-gyro mode, so it was necessary to change some of the constraints to make the test proposal pool consistent with implementation under two-gyro mode. The results of the study are an approximation to the scheduling efficiency expected for a fully qualified two-gyro proposal pool. We expect to be able to schedule ~71-73 two-gyro prime orbits per week compared to ~80 prime orbits per week in three-gyro mode. Thus, the scheduling efficiency of HST should remain high. If HST enters two-gyro mode deliberately near the start of Cycle 14, there will be an initial deficit of available orbits in two-gyro mode compared to three-gyro mode. However, over the expected lifetime of the gyros, a net increase of ~2000 orbits could be achieved if HST enters two-gyro mode deliberately in the summer of 2005.

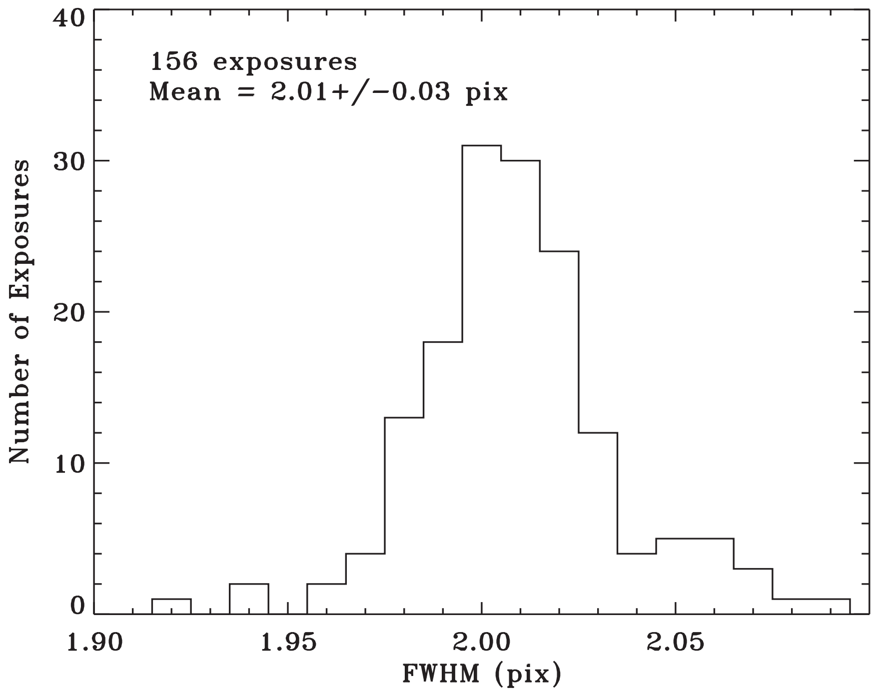
1.4 Science Instrument Performance

Science instrument performance in two-gyro mode appears to be very similar to science instrument performance in three-gyro mode. Observers constructing their Cycle 14 Phase II programs should therefore use the three-gyro point spread function (PSF) properties specified in the individual Instrument Handbooks rather than the overly conservative two-gyro PSF properties adopted in Chapters 7-11 of the *HST Two-Gyro Handbook*. The Exposure Time Calculators for each instrument are being updated to reflect this change. Please note that there are still some two-gyro-specific issues related to NICMOS coronagraphy and FGS astrometry, as outlined in Chapters 9 and 11 of the *HST Two-Gyro Handbook*.

Advanced Camera for Surveys (ACS)

The two-gyro on-orbit tests included measurements of the ACS point spread function shape and stability, coronagraphic acquisition accuracy, and coronagraphic light rejection. The PSF tests included exposures with durations of 10, 100, and 500 seconds. Pointing stability within individual orbits was found to vary by less than a few milli-arcseconds from exposure to exposure. Instrument performance in two-gyro mode is indistinguishable from that in three-gyro mode. For information about the three-gyro performance, see the ACS Instrument Handbook.

Figure 1.1: Two-Gyro ACS/HRC F555W Point Spread Function Widths.



The distribution of point spread function widths for 156 ACS/HRC F555W exposures of globular clusters NGC 6341 and Omega Cen is shown in Figure 1.1. The data for this plot were provided by the ACS Group as part of their early analysis of the two-gyro test observations. The PSF results do not depend strongly on FGS guide star magnitude or exposure duration. The average two-gyro ACS/HRC PSF width of 2.01±0.03 pixels is comparable to the three-gyro mean ACS/HRC PSF width of 1.99±0.02 pixels for a series of 18 F555W exposures of NGC 6341 several days before the two-gyro on-orbit test. The two-gyro PSF width is also well within the more extensive three-gyro historical average distribution of ACS/HRC PSF widths (2.04±0.03 pixels), which includes data taken at different focus positions and at different times over a period of several years. Note that the last HST focus update was performed in December 2004, so the two-gyro PSFs during the on-orbit test (and the preceding three-gyro comparison data for NGC 6341) tend to mimic the narrow end of the historical three-gyro PSF width distribution.

Near Infrared Camera and Multi-Object Spectrograph (NICMOS)

The two-gyro on-orbit tests for NICMOS included point spread function characterization, dither pattern functionality, coronagraphic acquisition accuracy, and coronagraphic light rejection. NICMOS instrument performance for all of these tests in two-gyro mode is indistinguishable from that in three-gyro mode. Observers filling out their Cycle 14 Phase II proposals should consult Chapter 9 of the *HST Two-Gyro Handbook* for restrictions on coronagraphic observations in two-gyro mode; in general, it will be possible to obtain NICMOS coronagraphic observations at only one field orientation within an orbit. For information about NICMOS performance in three-gyro mode, see the NICMOS Instrument Handbook.

Fine Guidance Sensors (FGS)

Several FGS science observations were performed as part of the two-gyro on-orbit test. These observations were used to check the pointing stability as measured by FGS tracking of guide stars. The FGS POS-mode data analyzed to date indicates that RMS pointing errors within an orbit are typically 3.0-3.5 milli-arcseconds for a range of guide star magnitudes. This performance is similar to that observed in three-gyro mode and is in good agreement with the jitter estimates from the gyro data. Observers filling out their Cycle 14 Phase II proposals should consult Chapter 11 of the *HST Two-Gyro Handbook* for restrictions on astrometric observations in two-gyro mode. For information about FGS performance in three-gyro mode, see the FGS Instrument Handbook.