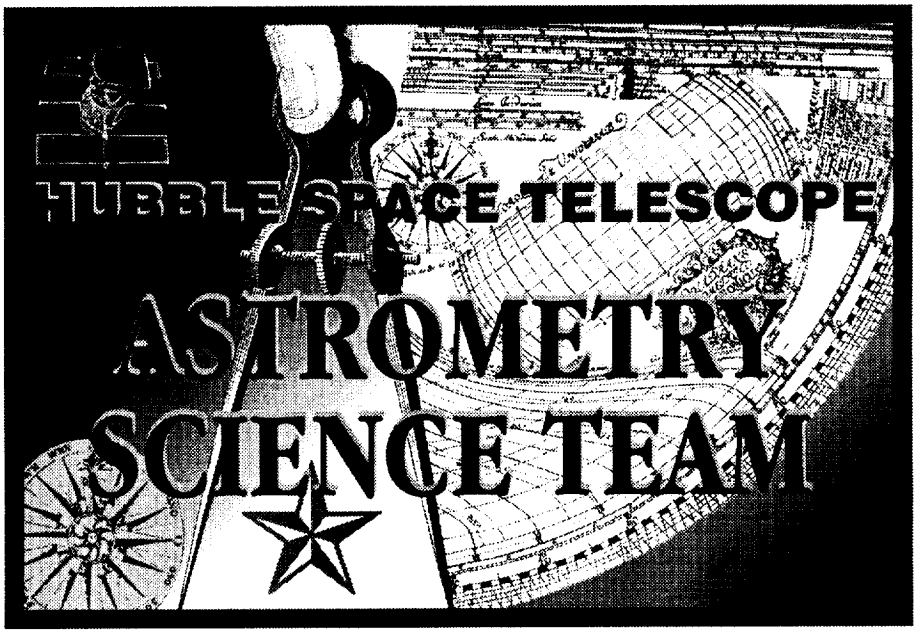

SEMIANNUAL REPORT

1996 JULY 1 – 1996 DECEMBER 31

Eleventh Semi-annual Progress Report
NASA Grant NAG5-1603
Hubble Space Telescope GTO Program
Astrometry Science Team

1996 July 1 - 1996 December 31

Prepared for
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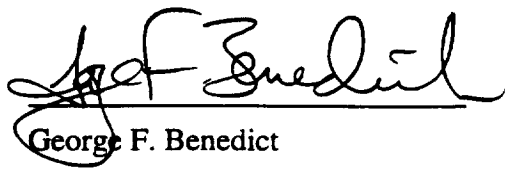

George F. Benedict
Deputy Principal Investigator

Meetings and Travel

Only one Astrometry Science Team meeting was held this reporting period, at Lowell Observatory on 21 October 1996.

Story routinely provided STAT representation and input to Guide Star Working Group meetings, Systems Management Board meetings, FGS Servicing Mission meetings, MOSES weekly Performance Reviews, MOSES PCS performance enhancement reviews, OTA Optical TIMS, general Servicing Mission planning sessions, and daily operations meetings, all at GSFC.

Nelan attended many meetings at GSFC which addressed the replacement FGS.

Personnel

Whipple left the University of Texas on December 31, 1996 to work for Allied-Signal on the HST MOSES team at Goddard Spaceflight Center. While he will personally be missed, his new duties fortunately allow him to continue to have an active interest in FGS issues. We look forward to continued and mutually beneficial collaboration.

Calibration and Astrometry Pipeline

McArthur continued to maintain the FGS 3 OFAD (Optical Field Angle Distortion), using the ongoing LTSTAB (Long-Term STABility) test series. She also updated the high-level (at U Texas) pipeline with more features and wrote several Macintosh-based plotting routines to illustrate our results. She continued to re-reduce older data with the new calibrations.

Nelan routinely retrieves all STAT, selected GO, and Calibration astrometry data from the STScI archives and performs the front -end pipeline data reduction processing, generating compact summary files ready for input to the Austin and Lowell pipelines. McArthur then performs the back-end calibration of all POS mode astrometry data for all STAT, selected GO, and Calibration data sets, while Wasserman and Franz at Lowell carry out similar reductions and quality control checks on TRANS mode data.

The Astrometry calibration pipeline continues to be maintained and upgraded as the need becomes apparent. In the reporting period it became clear that the HST roll angle needs to be computed from telemetry data since the predicted roll angle lacks the accuracy needed to fully support astrometry science obtained with the HST/FGS. This effort was well underway and near completion at the end of this reporting period. Other pipeline enhancements have included upgrades to the detection of "false locks" in POSITION mode, robust computation of the background photometry, and better calculation of the photometry of the astrometry targets.

For the reporting period there have been 1599 individual astrometry observations processed by the STAT pipeline, all without problems (at the computer program level). When and if problems do occur, repairs to the software are made.

Software support tools have been upgraded as it becomes apparent that FGS data needs to be analyzed in new ways. For example, the important diagnostic tool "FGS_PLOTTER" has been upgraded to remove the background photometry from the astrometry target. This

is significant when performing a quick look assessment of the quality of a TRANSFER scan on faint targets.

Late in the reporting period the transfer of the front end of the STAT pipeline from U. Texas to STScI was completed. It was tested and found to perform satisfactorily. Work was begun on transferring the back end pipeline (and the expertise required to run it) from U Texas to STScI.

McArthur continued to maintain our Sparc Station and Macintosh support computer systems (backups, disk installations, software upgrades).

Astrometry Anomaly Analysis

Nelan (co-located at STScI) and Story (co-located at GSFC) routinely assessed anomalistic behavior from all GO, GTO, and calibration astrometry pipeline data for all STAT members.

Trending of FGS performance continues. This includes measurement of the drift of the astrometric targets in POSITION mode, changes to the coarse track to finelock bias, and photometry of frequently observed stars in FGS 3.

Anomaly assessment now includes routine initial plate overlays for all GTO and selected GO POS-mode observation set reference frames (carried out by McArthur).

Story (co-located at GSFC) finished a drift study. He concluded that there was an inconsistent correlation between the derived measurement of the RGA with the FGS measurement of mechanically induced transient response in LOS pointing of the vehicle. The premise that the vehicle command frame would be commensurate and scaleable with inertial witness motion was found to be false in two specific cases;
a. V3 disturbance events associated with thermal changes inducing rear drum flexing
b. V2/V3 standoff error associated with terminator crossings
Until these phenomenon are better understood, this technique for drift removal will not be feasible. The effort to resolve issues (a) and (b) above will be continued at a later date when the appropriate resources are made available.

Wasserman and Franz at Lowell carry out quality control checks on all STAT, selected GO, and Calibration TRANS mode data.

GO Support

We (U Texas and Lowell) routinely processed FGS data Cycle 6 GO projects, including proposals 6468, 6566, 6764, 6768, 6479, 6881 and all CALIBRATION proposals.

Replacement FGS

The STAT pipeline and software analysis tools have been used in support of the ground testing of FGS 1R, both at HDOS and in the VEST.

During this reporting period the STAT also assisted the FGS group at STScI in assessing the singularity of the calibration star candidates to be used for the peak-up of the s-curves in FGS 1R (the Fold Flat 3 calibration star).

Story moved full-time into Flight Servicing (Code 442) support of the FGS 1 replacement for SM-2. He continued support on the FGS systems integration/test team for launch

preparation of flight spare FGS1-R, and supported test/analysis development for the returned FGS 2 unit. He is presently evaluating the test plan and generating the appropriate commanding to support bearing degradation testing on the returned unit. Finally, he evaluated the astrometric science capability of FGS 1R through ground testing. To date, the data from the instrument indicates a high potential for future scientific use.

GTO Program

Low-mass Companion Searches

The team continues its investigations to discover low-mass companions orbiting Proxima Centauri, Barnard's Star, and L726-8AB. The latter M dwarf binary system provides the following cautionary tale.

During the previous report period it became increasingly obvious that FGS TRANS-mode observations of L726-8 indicated a striking peculiarity. By April 1996 Shelus (our lead in this investigation) had a sufficient number of data sets to produce an HST-only relative orbit for components A and B. Residuals to this orbit could be seen to be periodic even in small scale orbit plots. During May and June Shelus, Franz, McArthur, Girard (Yale), and Jefferys independently obtained elements for a possible perturbation orbit. The perturbation was consistent with a 13 M_{Jup} companion in a nearly circular, highly inclined (to the plane of components A and B) orbit. The period was very nearly 0.5 year. Alarm bell number one. The existence of a third body in a binary system naturally raises questions concerning the stability of the companion orbit, especially in the mind of our resident dynamicist, Whipple. A stability analysis carried out by Whipple suggested that the possible companion was in an unstable orbit. Alarm bell number two. We were either seeing a system at a special time in its evolution, or the perturbation was not astronomical in origin.

At this point (June 1996) we all explored various possible FGS-intrinsic causes for the observed signature, but were stymied by the roll history of HST. Nominal roll follows the Sun and introduces a one-half year periodicity in the roll. Our perturbations could equally well be predicted by spacecraft roll or by the perturbation orbit. After considerable STAT discussion, we decided to utilize two GTO orbits to test the hypothesis that TRANS observations could be affected by spacecraft roll. On August 21, 1996 a test devised by Whipple and implemented by Nelan produced two sets of TRANS observations of L726-8AB at two different roll angles.

If the perturbation was intrinsic to L726-8AB, the separation between A and B should remain constant as HST rolls. If the perturbation was caused by the HST/FGS 3, we would see a predictable difference in separation. By 1330 CDT on 22 August six STAT members had independently verified that the signal seen in the FGS 3 data was instrumental, not astronomical, in origin. Over the next several months Whipple used these test results along with all of the other observations of L726-8 to develop an empirical correction to TRANS mode data which removes this effect. He then successfully applied this correction to a set of TRANS mode observations of GL 748, another M dwarf binary system. Application of the correction brought the residuals to the relative orbit down to 1 mas.

The magnitude of the correction depends both on the roll angle of HST and the separation of the components being examined in TRANS mode. The correction will become a permanent step in the TRANS mode pipeline. The physical explanation (from HDOS) appear to be a rotation of the X Koester's prism midline relative to the Y prism midline. Hence, the effect only occurs in TRANS, not in POS mode astrometry.

We are not done with L726-8AB. We have a number of observations yet to obtain. The residuals to the A-B relative orbit, once corrected for TRANS systematics, are a rich set of data with which to finish our probing for low-mass companions.

Benedict continued to assess and preen the Proxima Centauri and Barnard's Star reference frames. Best results (with the metric being smallest position residuals) are obtained with a six plate constant model (differing X and Y scales), allowing for reference star parallax and proper motion. Residual distributions are well-described by a gaussian with $\sigma \sim 1.5$ mas (millisecond of arc). Additionally, Benedict obtained near-final values for the proper motion and parallax of the two science targets. Using GaussFit, comparison of two techniques (either including the target star with the reference frame or solving for parallax and proper motion of the target stars separately) demonstrated their complete equivalence.

The final residuals for both Proxima Centauri and Barnard's Star still contain a low-amplitude (~ 1 mas), but significant, periodic component with P = 0.5 y. Once this last systematic error is removed (unmodeled OFAD? Lateral Color?), periodograms indicate no companions with masses greater than $0.5M_{Jup}$ for $P>125^d$.

Parallaxes of Astrophysically Interesting Objects

With three epochs (6 orbits) Benedict obtained a preliminary parallax for the old nova, RW Tri. The reference frame is found to be relatively simple to model. A solution employing four plate constants yields a reference frame catalog with average uncertainties σ_ξ=1.2 mas, σ_η=1.5 mas. Assigning parallaxes to the reference stars using WIYN spectral classifications (see Yale Subcontractor Report below) we obtain $\pi = 1.2 \pm 1.3$ mas. We await the two remaining epochs in the parallax series with keen anticipation.

HST- Hipparcos Extragalactic Link

Hemenway, with Dr. Liz Bozyan, is preparing a paper detailing the final results of this investigation.

Ground-based Observations of Radial Velocities

Whipple, Benedict and Franz had four observing runs (22-25 Aug, 7-10 Oct, 14-17 Nov, 5-8 Dec) on the McDonald Observatory 2.1 m Otto Struve telescope with the Cassegrain echelle spectrograph. The high frequency of observing sessions was motivated by the possible planetary-mass companion to L726-8 discussed above. These runs resulted in radial velocity observations of many stars in the Hyades cluster and many other M-dwarfs that are being observed by the astrometry team with the FGS.. The reduction and analyses of these observations are on-going (Hatzes). The radial velocity observations will provide the third component of motion which, when combined with the FGS plane-of-sky observations, will yield complete three dimensional characterizations of the motions of these targets. These RV's will contribute importantly to defining the mass ratios of binary components. They will also allow us to scale the binary orbits independently of or in addition to parallax measures. These orbital RV's will thus play an important role in the determination of accurate component masses of the FGS target binaries.

Hatzes continues his collaboration with an ESO-based group to obtain radial velocities of Proxima Cen and Barnard's Star. Measurements for Proxima Cen, now twenty epochs

over three years, are indistinguishable from gaussian noise with $\sigma = 92$ m s^{-1}. Barnard's Star shows no RV variations greater than 20 m s^{-1}.

Subcontractors

Lowell Observatory

Franz and Wasserman continued work on the reduction, analysis, and interpretation of FGS TRANS-mode data and on binary orbit calculations based upon the FGS results.

Combining the first detection observations at visible wavelength obtained under GTO 5174 with a series of observations made under collaborative GO proposals, we obtained not only the first "visual" orbit of the low-mass nearby M-dwarf binary GL748 = W1062, but indeed the first orbit of any binary based exclusively on HST-FGS astrometry. This work is now being prepared for publication.

VA351 (total V=13.2) was first resolved as a 51-mas pair of near- equal components on 1994 d45 in the course of our search for binaries among faint probable Hyades cluster members under Cycle-4 GTO proposal 4892. With five additional observations obtained through 1996, we have achieved position-angle coverage of more than 180°, sufficient to compute the first dependable "visual" orbit of VA351 (and thus of any Hyades cluster member fainter than V=8) with P=3.85 ± 0.17 y and a=0.067 ± 0.002 arcsec. Although still preliminary and subject to further improvement, these orbital elements are already sufficiently accurate so that the accuracy of the component masses of VA351 is almost entirely dependent on the accuracy of its parallax.

University of Virginia

Since last July 1st Fredrick has been busy measuring photographic plates of VV Cephei taken with the Sproul Refractor at Swarthmore College. He has one-half of the plates, approximately 1000, and has about 2/3rd measured as of the 21st of December 1996.

Fredrick and Sarazin proposed observing VV Cephei with ROSAT. The proposal was accepted and observations begin in January 1997.

Yale University

GTO Globular Cluster Internal Motions

The "STAT and collaborators" proposal for the GO Cycle 7 was prepared, submitted and approved to obtain the second epoch frames for our GTO program on the internal motions in 47 Tuc, NGC 6752 and M15. Next year we plan to submit a proposal for Cycle 8 to take the second epoch frames of NGC 6656 and M13. In addition, the GO Archival Research proposal submitted by D. Dinescu and collaborators was also approved to examine Archival frames of Globular clusters to search for those with extra galactic objects in the background which might be used to determine their absolute proper motions.

GTO Hyades Cluster Member FGS Parallaxes

Parallax solutions were made by Chun lin Lu, J. Lee and van Altena for all seven of the Hyades Cluster Members with excellent results. Two of the seven had been causing problems but the bad reference stars were finally isolated and good solutions obtained. All

of the six reference frames have been observed for spectroscopic parallaxes with the WIYN Hydra spectrograph. All of the spectra have been processed in IRAF and classified by Lu and Lee. UBV CCD photometry were obtained for the six fields by I. Platais and are now being reduced by Lee. Finally, A. Klemola and R. Hanson at Lick Observatory are determining the absolute proper motions of the reference stars so that the resulting FGS relative proper motions can be corrected to absolute and then also used to determine the position of the stars in the cluster.