Guide Probe Tests

October 6, 2011

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Revision Summary

1. Date: 6 October 2011
   Revision: 1
   ECR: NA

Table of Contents

1 Introduction

This document describes tests that will be used to check the functionality of the guide probes. Note that the tests do not cover functionality required for non-sidereal observations.

2 TRD Requirements

2.2.2 A new Wide Field Corrector (WFC) will provide a minimum of 22′ diameter field of view with a telecentric focal surface optimized for feeding fibers at f/3.65. This corresponds to an Effective Focal Length (EFL) of 36.500 meters, and to a plate scale of 0.00564″ per micron (i.e. 177.305 micron/arcsec).

2.10.4 The guiding and wave front sensing systems for the telescope shall be sufficiently sensitive to utilize stars available in the outer 1′ radius annulus of the WFC field of view.

2.10.6 Guide camera and WFS probe absolute positioning accuracy shall be 1″.

2.10.7 Guide camera and WFS probe offset positioning accuracy shall be 0.05″ over moves that are up to 1′ long.

2.10.9 When the Guide camera and WFS probes are operating in the outer annular region of the WFC's field of view between 10′ and 11′ field angles, the probes shall not block light (headed towards science and metrology instrument optical inputs that are located above the focal surface) in the inner 20′ diameter core of the WFC's field of view.

3.0 The baseline data acquisition sequence in TRD Section 3.12 states that the guide probes have 30 seconds to move between any two positions within their travel range.

6.15 System shall be designed so that failure of a non-mission-critical system does not prevent science observations.

6.16 System shall be designed so that failure of part of a redundant system does not prevent science observations at a limited capacity. For example, although HETDEX observations require two functioning guide cameras, it may be possible to perform other non-HETDEX related science observations with a single guide camera.

6.17 System shall be designed so that a single guide camera can be used for tracking when performing non-HETDEX related science observations.

6.18 As a goal, system shall be designed so that observations can be made with metrology equipment (e.g. WFSs and DMI) turned off.

3 Hardware Description

Major Axis

- End of travel hard stops – 2 per carriage; goal is to never hit these
- End of travel hard stops depend upon the end of travel arm return spring – if spring fails carriages can collide (TBD)
- End of travel limit switches – 2 per carriage (Hall effect sensors)
- End of travel SW limits
- Collision limit switches – 1 per carriage (Hall effect sensor), carriages can only detect another carriage approaching it from one side, it can't detect the carriage that is on the other side.
- Carriages can collide
- Absolute encoder (spur gear) – used at startup to determine rough probe positions and safe direction for index mark search for incremental tape encoders
- Incremental encoder with index marks (linear tape) – primary position reference; result of each move is compared against this position
- Maxon motor incremental encoder – used to close motion loop; periodically compared to the incremental tape encoder (see above) to check for slippage
- 182° range from hard stop to hard stop TBD
- 180° range from soft limit to soft limit TBD
- Axis must move over entire travel range in ≤ 30 sec
- TBD sec timeout period
- Hall effect sensor failure (including disconnecting sensor) will cause axis to stop

Minor Axis

- End of travel hard stops – 2 per minor axis
- End of travel limit switches – 2 per minor axis (Hall effect sensors)
- End of travel SW limits
- Absolute encoder
- Maxon motor incremental encoder – used to close motion loop; periodically compared to the absolute encoder (see above) to check for slippage
- Minor axis arm has a spring that is used to remove backlash
- 29° range from hard stop to hard stop TBD
- 27° range from soft limit to soft limit TBD
- Axis must move over entire travel range in ≤ 30 sec
- TBD sec timeout period
- Hall effect sensor failure (including disconnecting sensor) will cause axis to stop

Carriage Patrol Zones

- Inner radius 84.96 mm
- Outer radius 116.82 mm

4 Guide Probe Tests

4.1 Axis Initialization & Normal Shutdown

Item	Instructions & Questions	Result
1	Turn on guide probes.	
2	Did the system wait for permission from the user to make any moves?	
3	Execute initialization command.	
4	Does the system perform the following within a reasonable amount of time: ▪ Wake up ▪ Read the absolute encoders to see where the axes are ▪ Determine if any of the axes are past their SW limits ▪ Read all end of travel limits switches to ensure that the axes have not exceeded their normal operating limits ▪ Read all collision sensors to ensure there are no collisions ▪ Determine which directions are safe to travel for each axis ▪ Move each major axis by a small amount to find their respective incremental encoder marks ▪ Report that the initialization process is complete	
5	Review code to verify logic of initialization procedure. Is it OK?	
6	Move all axes to a set of user-specified positions.	
7	Execute the park command.	
8	Do the axes move to their park positions within the appropriate amount of time?	
9	Turn off guide probes.	
10	Did any motion occur after the guide probes were turned off?	
11	Repeat steps 2 through 9 several times.	

4.2 Travel Limits and Hard Stops

Item	Instructions & Questions	Result
1	Command axis to go to a position near the hard stop.	
2	Did SW limit stop axis at the appropriate position within the appropriate amount of time?	
3	Command axis to move past SW limit in the unsafe direction.	
4	Did the system refuse?	
5	Command axis to back away from SW limit by a few millimeters.	
6	Did axis move the appropriate amount in the appropriate direction in the appropriate amount of time?	
7	Disable SW limit.	
8	Command axis to go to a position near the hard stop.	
9	Did end of travel limit switch stop axis at the appropriate position	

	within the appropriate amount of time?	
10	Command axis to move past end of travel limit in the unsafe direction.	
11	Did the system refuse?	
12	Command axis to back away from end of travel limit by a few millimeters.	
13	Did axis move the appropriate amount in the appropriate direction within the appropriate amount of time?	
14	Disable end of travel limit switches.	
15	Command axis to go to a position beyond the hard stop.	
16	Was any hardware damaged when hard stop was encountered?	
17	Does code detect a following error when hard stop was encountered?	
18	Does code detect a motor current increase when hard stop was encountered?	
19	How long did it take for the motor current to turn off after encountering the hard stop?	
20	Command axis to back away from hard stop by a few millimeters.	
21	Did axis move the appropriate amount in the appropriate direction within the appropriate amount of time?	
22	Did motor current need to be increased to move off of the hard stop?	

4.3 Recovery from Power Failure

Item	Instructions & Questions	Result
1	Turn on guide probes.	
2	Execute initialization command.	
3	Wait for all axes to initialize.	
4	Command all axes to move to some specified set of coordinates.	
5	Turn off power while axes are moving.	
6	Turn power back on.	
7	Did the system wait for permission from user to make any moves?	
8	Give permission to make moves.	
9	Did the system recognize that it needed to be initialized and did that initialization succeed?	

4.4 Hall Effect Sensor Failure

Item	Instructions & Questions	Result
1	Turn on guide probes.	
2	Execute initialization command.	
3	Wait for all axes to initialize.	

4	Command one axis to move to some specified set of coordinates.	
5	Disconnect one of the axis's hall effect sensors while the axis is moving.	
6	Did the affected axis stop?	
7	Reconnect the hall effect sensor.	
8	Did the affected axis stay stationary?	
9	Repeat steps 1 through 5 with the axis' other hall effect sensors.	
10	Did the affected axis stop?	
11	Reconnect the hall effect sensor.	
12	Did the affected axis stay stationary?	
13	Repeat steps 1 through 5 with all axes moving simultaneously, and with all of the affected axis' hall effect sensors.	
14	Did the affected axis always stop while all of the other axes kept moving?	
15	Reconnect the hall effect sensor while all of the other axes are still moving.	
16	Did the affected axis always stay stationary while all of the other axes continued to complete their moves?	

Note that disconnection of a hall effect sensor when all axes are moving may result in a collision between carriages.

4.5 Encoder Failure

Item	Instructions & Questions	Result
1	Turn on guide probes.	
2	Execute initialization command.	
3	Command one major axis to move to some specified position.	
4	Disconnect the axis' incremental encoder while the axis is moving.	
5	How many times did the axis try to reach final position?	
6	Did the affected axis finally stop?	
7	Reconnect the incremental encoder.	
8	Did the affected axis remain stationary?	
9	Did the system notice that the axis ought to be re-initialized?	
10	Disconnect the major axis' absolute encoder.	
11	Attempt to execute initialization command.	
12	What happens?	
13	Repeat steps 1 through 4 with all axes moving simultaneously, and with the absolute encoder on the minor axis as well.	
14	Did the affected axis always stop while all of the other axes kept moving?	
15	Reconnect the encoder while all of the other axes are still moving.	
16	Did the affected axis always stay stationary while all of the other axes continued to complete their moves?	

Note that disconnection of an encoder when all axes are moving may result in a collision between carriages.

4.6 Burn In and Collision Avoidance

Item	Instructions & Questions	Result
1	Command all axes to move to predetermined positions that may or may not be legal in terms of carriage collisions or end of travel limits.	
2	Did code properly detect and react to commanded positions that would result in carriage collisions and/or exceeding travel limits?	
3	Did any collisions occur?	
4	Were any travel limit switches encountered?	
5	Repeat steps 1 through 4 TBD times.	
6	For each test repetition, did code properly detect and react to commanded positions that would result in carriage collisions and/or exceeding travel limits?	
7	For each test repetition, did any collisions occur?	
8	Specifically test cases that require all probes to move at once.	
9	Were those moves also successful?	

4.7 Coordinate Transformations

Item	Instructions & Questions	Result
1	Command the probes to move to various positions.	
2	For each set of commanded positions, did the final axis encoder readings agree with the "hand calculated" coordinates to within the hardware's positioning accuracy?	
3	For all three coordinate systems: (θ, φ), (r, θ), and (X, Y)?	
4	To within a low-precision physical verification (e.g. tape measure) of coordinates?	

4.8 Code/Mathematical Formula Instability

Item	Instructions & Questions	Result
1	Inspect code to see where the math in the code "blows up".	
2	Move probes to each position where math could "blow up".	
3	Code does not "blow up" in θ, φ coordinate system.	
4	Code does not "blow up" in r, θ coordinate system.	
5	Code does not "blow up" in X, Y coordinate system.	

4.9 Move Time

Item	Instructions & Questions	Result
1	Move axis over its entire travel range.	
2	Travel time did not exceed 30 sec.	
3	Modify the system so that the axis timeout can be tested (e.g. put a "wait" statement into the code at an appropriate point, or set the axis speed to a very low value).	
4	Command the axis to move.	
5	Timeout period did not exceed TBD sec.	

4.10 Axis Accuracy & Repeatability, Following & Over Current Errors

Item	Instructions & Questions	Result
1	Look for "rough spots" in the axis' range of motion by examining its motor current and following error as a function of position. Make 10 sets of plots to see if the location of the motor current and following error always occur at the same positions.	
2	Do the reported encoder positions show any evidence of "drive slippage"?	
3	Move the axis at least 5° away from its roughest spot.	
4	Command the axis to move through the roughest spot.	
5	Repeat steps 3 and 4 ten times and note: (1) How long it takes to complete each move (2) The difference (Δ_{FC}) between the final and commanded positions (3) The difference (Δ_{FM}) between the final position and a micrometer measurement	
6	Time required for the axis to complete each move did not exceed TBD sec.	
7	Standard deviation (σ) of Δ_{FC} did not exceed 2.96 μm. $\sigma = \frac{1}{3}\left(\frac{0.05}{0.00564}\right) = 2.96$	
8	Standard deviation (σ) of Δ_{FM} did not exceed 2.96 μm.	
9	Set the following error threshold to a value that will be just exceeded at one of the axis's rough spots.	
10	Command the axis to move through the rough spot.	
11	Did the code detect the following error?	
12	Did the axis stop?	
13	Set the motor current threshold to a value that will be just exceeded at one of the axis's rough spots.	
14	Command the axis to move through the rough spot.	

15	Did the code detect the motor over current error?	
16	Did the axis stop?	

4.11 Axis End of Travel Limit Switch Position Repeatability

Item	Instructions & Questions	Result
1	Disable axis SW limits.	
2	Move the axis at least 5° away from end of travel limit switch 1.	
3	Command the axis to move to end of travel limit switch 1.	
4	Repeat steps 2 and 3 ten times and note: 1) How long it takes to complete each move 2) The difference (Δ_{FC}) between the final and commanded positions	
5	Repeat steps 2, 3, and 4 for end of travel limit switch 2.	
6	Time required for the axis to complete each move did not exceed TBD sec.	
7	Standard deviation (σ) of Δ_{FC} did not exceed TBD µm.	
8	Standard deviation (σ) of Δ_{FM} did not exceed TBD µm.	

4.12 Carriage Accuracy and Repeatability

Item	Instructions & Questions	Result
1	Align the guide probes with the focal surface center and radius of curvature as per the procedure described in Gary's *PFIP Subsystem Assembly and Alignment* presentation that was given at the July 2011 PFIP Review.	
2	Command each axis to move to a predefined grid of 100 (TBV) positions. For each move note: 1) How long it takes to complete each move 2) The difference (Δ_{FC}) between the final and commanded positions 3) The difference (Δ_{FL}) between the final position and laser tracker measurement	
3	Repeat step 2 ten times.	
4	Time required for the axis to complete each move did not exceed TBD sec.	
5	Standard deviation (σ) of Δ_{FC} did not exceed 2.96 µm.	
6	Standard deviation (σ) of Δ_{FL} did not exceed 2.96 µm.	

4.13 Carriage Collisions and Disabled Carriages

Item	Instructions & Questions	Result
1	Try to force a collision between two carriages by sending invalid coordinates (i.e. coordinates that will cause collisions between two carriages) to two of the carriages and valid coordinates to the other two carriages.	
2	Repeat steps 1 and 2 as needed to try and force collisions for all combinations of carriages.	
3	For each of the above tests, did the SW detect the invalid coordinates, not move any of the carriages, and report that it received invalid coordinates?	
4	Disable the portion of the SW that detects invalid coordinates.	
5	Force a collision between two carriages by sending invalid coordinates to two of the carriages and valid coordinates to the other two carriages.	
6	Did all of the carriages stop when a collision occurred, and did the SW report the collision?	
7	Execute the collision recovery command.	
8	Did all carriages move to one of their end of travel limits?	
9	Repeat steps 4 and 5.	
10	Did all of the carriages stop when a collision occurred, and did the SW report the collision?	
11	Disable in HW one of the carriages that was involved in the collision, so that it cannot move when commanded to move by the software.	
12	Execute the collision recovery command.	
13	Did all carriages move to one of their end of travel limits, except for the disabled carriage?	
14	Did the SW report that the disabled carriage did not move?	
15	Enable the portion of the SW that detects invalid coordinates.	
16	Undo step 11, and then issue the command that tells the SW to disable the carriage that did not move.	
17	Command the carriages on either side of the disabled carriage to move to invalid coordinates (i.e. coordinates that would result in a collision with the disabled carriage).	
18	For each of the above tests, did the SW detect the invalid coordinates, not move any of the carriages, and report that it received invalid coordinates?	
19	Command the carriages on either side of the disabled carriage to move to valid coordinates that are very close to the invalid coordinates that were chosen in step 17.	
20	Did the carriages function normally?	
21	Disable the portion of the SW that detects invalid coordinates.	

22	Force a collision between three carriages by sending invalid coordinates to three of the carriages and valid coordinates to the other carriage.	
23	Did all of the carriages stop when a collision occurred, and did the SW report the collision?	
24	Execute the collision recovery command.	
25	Did all carriages move to one of their end of travel limits?	
26	Repeat steps 21 and 22.	
27	Did all of the carriages stop when a collision occurred, and did the SW report the collision?	
28	Disable in HW all of the carriages that were involved in the collision.	
29	Execute the collision recovery command.	
30	Did the one working carriage move to one of its end of travel limits (if possible) , and the others remain stationary?	
31	Did the SW report that the disabled carriages did not move?	
32	Enable the portion of the SW that detects invalid coordinates.	
33	Undo step 28, and then issue the command that tells the SW to disable the carriages that did not move.	
34	Command the one moving carriage to move to invalid coordinates (i.e. coordinates that would result in a collision with the disabled carriages).	
35	For each of the above tests, did the SW detect the invalid coordinates, not move any of the carriages, and report that it received invalid coordinates?	
36	Command the one moving carriage (which has not been disabled) to move to valid coordinates that are very close to the invalid coordinates that were chosen in step 17.	
37	Did the carriage function normally?	