NGAO

Real Time Controller

Testing Document

Revision History			
Version	Author	Date	Details
1.0	Marc Reinig and Donald Gavel	May 8, 2009	First draft version.
Ver. 1.2.18		Dec 3, 2009	Updated Draft

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1. Introduction and Overall Requirements

This document details the requirements and strategies for testing the NGAO RTC and specifies the hardware and software to accomplish it. It covers the following:

- Trouble shooting and validation of individual modules during development
- Acceptance testing of individual modules subsequent to development
- Trouble shooting individual modules after commissioning: while they are in the system and on the bench
- Performing system end-to-end testing during integration-and-test, and after commissioning

Notes:

1. Tests for the cameras, deformable or Tip/Tilt mirrors themselves are beyond the scope of this document and are not covered.
2. This document does not cover calibration issues used during the normal operation of the system.

2. Testability Philosophy

Testability comes from obervability and controllability. The RTC system is designed so that critical inputs to the RTC and its sub-systems can be forced to arbitrary values and the results of applying these inputs can be observed at key points down stream.

Files of known good stimuli, their results, and a written procedure for applying capturing them form a test set. The results for these test sets should be constant over time for a working system, can be used to easily validate the system or sub-systems, and are necessary for unit and acceptance tests.

They can also be used to help diagnose the locations of faults during the life of the system.

Further, the ability to use dummy camera data and analyze the resultant centroids and wave fronts allows not only for testing and diagnosis of problems, but for easy analysis of new algorithms.

Similarly, the ability to modify the system and unit clocking and supply voltage parameters allows us to characterize the healthy system's parameter envelopes. Periodic monitoring of these envelopes will allow us to see deviations that might lead to for failure during operations if not diagnosed early.

In some cases, a sequence of test files will need to be applied to test pattern sensitivity and signal interactions.

Key signals or voltage levels in today's dense high-speed circuits need to be easily monitored.

The design goal of the system is to provide these capabilities by designing them in from the start.

3. RTC Test Capabilities

In order to test a unit, we need to be able to place it in a known state, apply known stimuli, and analyze the output. The RTC has this ability built into all sub-systems and into the system as a whole.

Each sub-system can be configured to place all inputs into known configurations either through special buffers or in some cases through external data multiplexors. The sub-systems internal state can be controlled explicitly through its interface with the RTC Control Processor. The sub-system outputs are available for analysis through the RTC telemetry pipe. Additionally, various internal data arrays are also available for finer grained analysis.

A separate test bed is also defined that can provide inputs and control for all sub-systems as well as capture their outputs. This is intended for sub-system acceptance testing and individual sub-system testing when a unit is not in the system.

Each sub-system also has the ability to force all outputs into known configurations. This capability is intended to be used for in system diagnostics and calibrations. This allows us to test the connectivity from one system to the next in the data path while the sub-system is still in the RTC.

4. Testable Units and Test Types

The RTC consists of many hardware components. These units will need to be tested in a variety of ways, at a variety of times: this includes acceptance testing, during integration and test, and after commissioning.

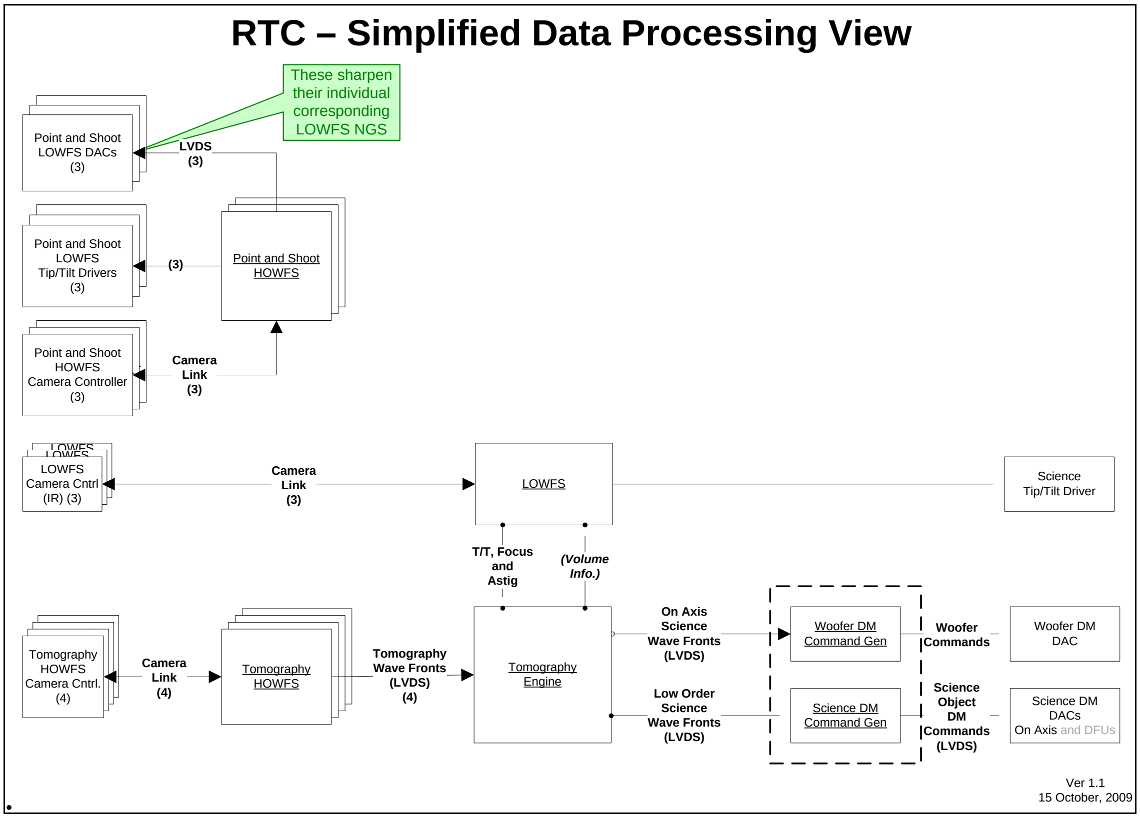

Figure 1 Simplified View of the RTC

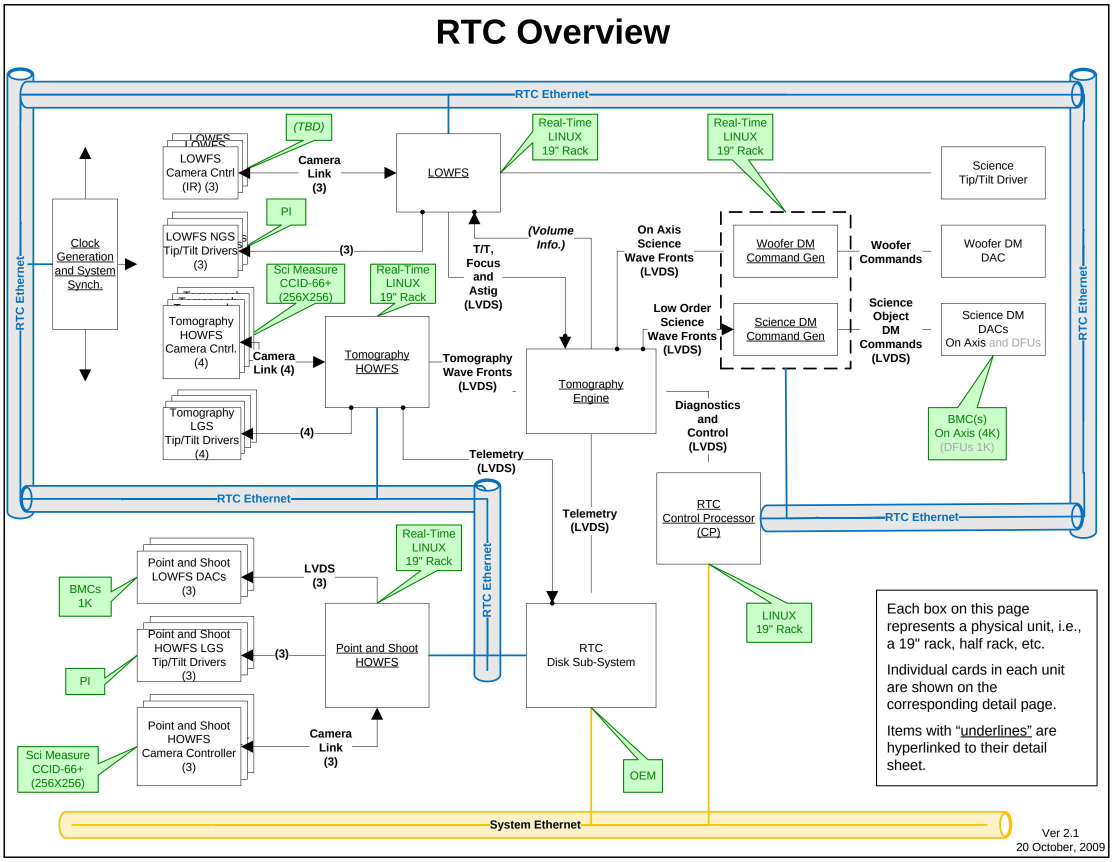

Figure 2 RTC Detailed View

4.1 Testable Units

1. The Entire RTC Data Path
2. Control Processor (CP)
3. LOWFS
4. Point-and-Shoot HOWFS
5. Tomographic HOWFS
6. Tomography Engine
7. DM and Mirror Command Generators
8. Woofer Command Generator
9. Science DM Command Generator
10. Disk Sub-System
11. Clock Generations and Distribution
12. Power Distribution and Cooling

13. RTC Test Bench

4.2 Test Types

These tests fall into three categories: acceptance, unit, and operational. Each category may have separate hardware and software tests associated with it.

4.2.1 Acceptance Tests

These tests are performed when accepting a new sub-system or when a sub-system has been significantly changed or upgraded enough to be similar to a new, untested unit.

They are generally performed once or a limited number of times during the life of a sub-system.

4.2.2 Unit Tests

Unit tests are performed on sub-systems that have been removed from the RTC. This will normally be done with the assistance of the RTC Test Bench.

4.2.3 Operational Tests

Tests of the RTC during operation will be supplied to assess basic Go/No-go functionality of the RTC or to identify a major unit that is not performing correctly. The RTC Test Bench and Unit Tests will provide more detailed analysis of specific problems with a major unit.

The initial operational test will run on initialization of the RTC system. It requires no optical configuration in order to be performed.

It will simulate camera inputs by using stored internal dummy camera images in the HOWFSs and LOWFS. The WFSs, Tomography Engine, and DM command generators will process these images normally as if they came from real camera inputs. The output data of the DM command generators will be compared to previously stored outputs using the same dummy inputs. A successful comparison results in a Go and an unsuccessful one results in a No-go.

To identify the major unit that is causing the failure. Individual Unit functional tests can be run. All major units (WFS, tomography engine, DM command generators) have the capability to have dummy inputs loaded and are able to report their outputs using Telemetry and Diagnostic outputs to assist in identifying the problem. These outputs can be compared to known good outputs that correspond to the stored dummy inputs.

Once a failed major unit has been identified, further diagnostics will be performed on the RTC Test Bench.

4.2.4 Diagnostic Tests

Diagnostic tests are performed to determine the nature and location of a fault in the system. They may be performed with the sub-system in the RTC or removed and attached to the RTC Test Bench. They are intended to perform fine-grained failure location to facilitate speed of repair.

These tests may also be used to detect insipient failures before they cause failure during normal operations.

Example:

Performing operational tests on the tomography engine, while varying combinations of power supply voltages and clock parameters will produce data that indicated the combination of parameters for which the system will run and fail. When these parameters are plotted against each other and pass-fail regions are identified, they are called “shmoo” diagrams. These diagrams outline the operating range of the system. The min/max specified operating parameters should always fall within the boundaries of these diagrams.

These tests should be done on acceptance to provide a base line. As the system ages, it will become more and more sensitive to the above parameters and the shmoo diagram will shrink towards the min/max operating parameters. When some portion of the diagram has actually creeps into the min/max operating range, it is probable that the system will fail at some point while the parameters are within spec. This does not happen overnight and by periodically performing the shmoo test and comparing the results to the baselines, incipient failures can be found before they occur during operation.

5. Test Details

The following are detailed descriptions of the tests for each of the major units in the RTC. They include descriptions of the tests for both hardware and software and any special hardware or software needed that is not part of the unit itself. This includes any optical or special hardware required.

5.1 End-to-End RTC Tests

These tests are intended to verify the overall functionality of the RTC. They can be used during the integration and test phase and during normal operations as confidence tests prior to normal operation.

5.1.1 Overall RTC Operation (RTC_O_1)

Using the telescope simulator as a source of turbulence for the fiber source, insure that the RTC corrects the spot appropriately. This should be determined by evaluating both the science image and the reported residual wave front error.

This test should be performed at various frame rates and fiber intensities and for various algorithm selections.

5.1.2 RTC Telemetry Operation (RTC_O_2)

Using previously stored camera images for all WFS the telemetry system should be set to store the maximum number of data records, while the offload processor has been set to send the maximum amount of offload data.

Both RTC output streams should be examined to insure that the data is consistent with the output data previously recorded for the given input pseudo camera inputs.

5.2 Control Processor (CP)

The RTC control processor, which controls all major state transitions of the RTC, is normally controlled by the supervisory processor. Its interface to the telescope system is through an Ethernet socket connection, but it can also be controlled through a simple terminal and a telnet interface.

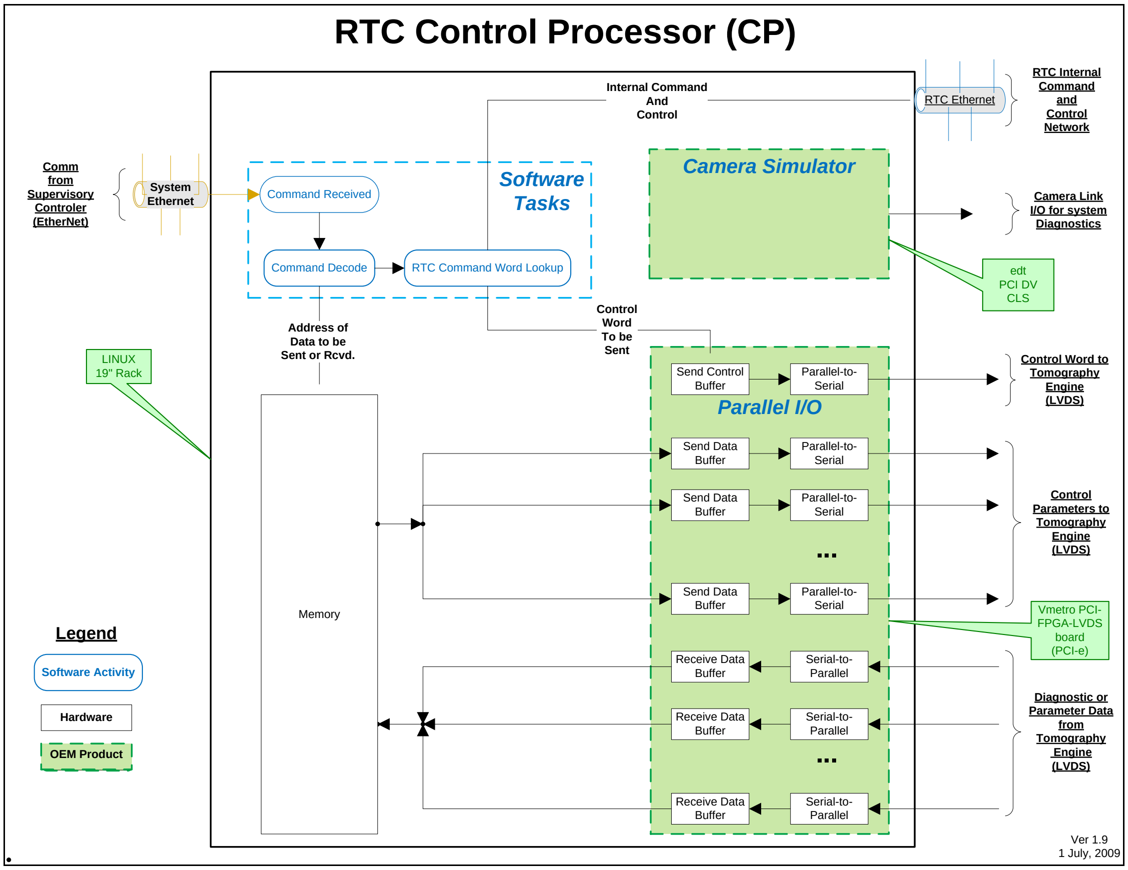

Figure 3 Control Processor

This unit is built around a standalone Linux PC with a real-time kernel, in a desktop or rack form factor. Testing of the computer itself will be done using the standard diagnostics common to all such computers.

5.2.1 Operational Tests

5.2.1.1 CP Overall Functionality (CP_O_01)

The overall functionality of the CP can be verified by sequencing through a subset of commands that change system parameters and verifying that the parameters on the sub-systems have actually changed. This can be done by examining a combination of the telemetry streams and performing read backs of the parameters from the sub-systems.

5.2.1.2 Camera Simulator (CP_O_02)

The CP camera simulator should be used to supply a WFS with previously stored camera data by selecting the WFS input multiplexor to select the output of the camera simulator rather than that of the camera.

The centroid output of the WFS should be examined and should be identical to the previously stored output for the dummy camera data.

5.2.1.3 RTC Internal Ethernet and LVDS I/O CP_O_03)

Commands will be give to the CP to set parameters in the TE engine and other sub-systems that use the RTC's internal Ethernet and LVDS inputs and outputs.

The correct functioning of these I/O ports is indicated by the sub-system in question correctly using the parameters supplied.

5.2.2 Unit and Acceptance Tests

5.2.2.1 CP Overall Functionality (CP_U_01)

The overall functionality of the CP can be verified by sequencing through all of commands that change system parameters and verifying that the LVDS ports and Ethernet actually send the correct values and report the correct responses.

This can be done using the test bench record the transmissions and simulate the responses that would occur in the operating RTC.

5.2.2.2 Camera Simulator (CP_U_02)

The functionality of the camera simulator can be tested with the RTC Test Bench using the Camera Link inputs of the test bench, also used for testing the actual WFS cameras.

5.3 LOWFS

The LOWFSs are housed in one or more real-time Linux boxes or racks.

The inputs to the LOWFS are through a Camera Link interface, which includes camera control. This input would normally be connected to the LOWFS cameras during operation or to the RTC Test Bench during acceptance or Unit Tests.

For operational (or any) tests, the inputs can be derived from an onboard buffer loaded with generated or previously stored data instead of the Camera Link inputs. The control of the input source and the alternate data is through an Ethernet connection. This mode of testing will test the internals of the WFS, but will not tests the camera link interface, or the camera control capabilities.

For unit and acceptance tests, the inputs can be connected to a camera simulator. This will allow testing of the Camera Link interface, including camera controls.

The internal buffering can also be used for testing for analysis that is more detailed.

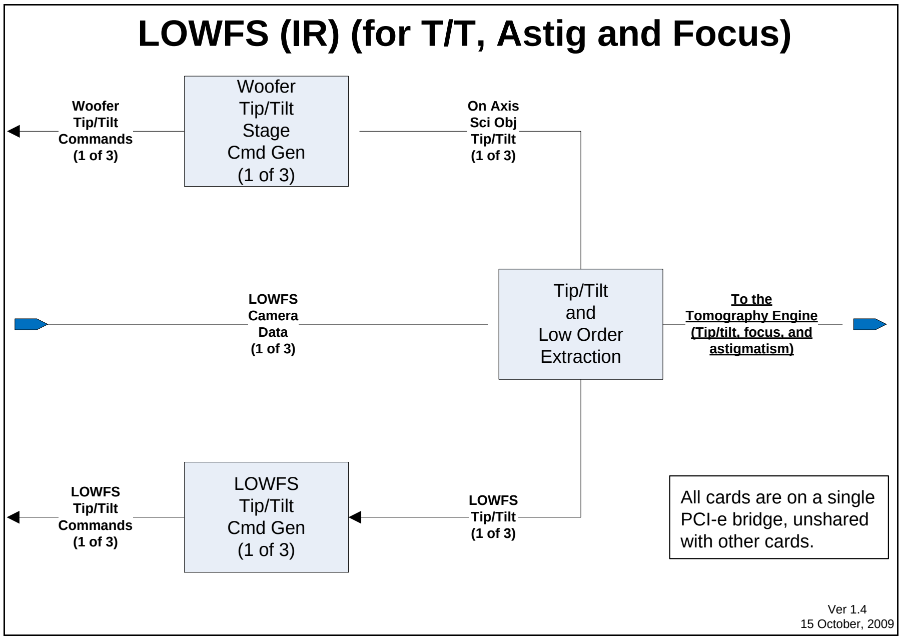

Figure 4 LOWFS

5.3.1 Operational Tests

5.3.1.1 LOWFS Overall Functionality (LO_O_1)

Using a previously stored camera image, verity that the TT is correct for that image, include Focus and Astigmatism if appropriate.

5.3.1.2 LOWFS Overall Functionality (LO_O_2)

Using a previously stored camera image, verity that the TT telemetry steam is correct for that image, include Focus and Astigmatism if appropriate.

5.3.2 Unit and Acceptance Tests

The Test Bench for is used for Unit and Acceptance tests

5.3.2.1 LOWFS Overall Functionality (LO_U_1)

Using a previously stored camera image, verity that the TT is correct for that image, include Focus and Astigmatism if appropriate.

This test is performed using the Camera Simulator and LVDS input facilities on the Test Bench.

5.3.2.2 LOWFS Overall Functionality (LO_O_2)

Using a previously stored camera image, verity that the TT telemetry steam is correct for that image, include Focus and Astigmatism if appropriate.

This test is performed using the Camera Simulator and LVDS input facilities on the Test Bench.

5.4 Point-and-Shoot HOWFSs

The Point-and-Shoot HOWFSs are housed in one or more real-time Linux boxes or racks.

The Point-and-Shoot HOWFSs are identical to the Tomography HOWFSs with the exception that they include the command generator for the DM, which they service.

The Point-and-Shoot HOWFS command generators have the same architecture as the command generator used for the science DM, which is a standalone unit.

The inputs to the Point-and-Shoot HOWFSs are through a Camera Link interface, which includes camera control. This would normally connect to the HOWFS cameras during operation and to the RTC Test Bench during acceptance or Unit Tests.

For operational (or any) tests, the inputs can be derived from an onboard buffer loaded with generated or previously stored data. The control of the input source and the alternate data is through an Ethernet connection. This mode of testing will test the internals of the WFS, but will not tests the camera link interface, or the camera control capabilities.

For unit and acceptance tests, the inputs are connected to a camera simulator. This will allow testing of the Camera Link interface, including camera controls.

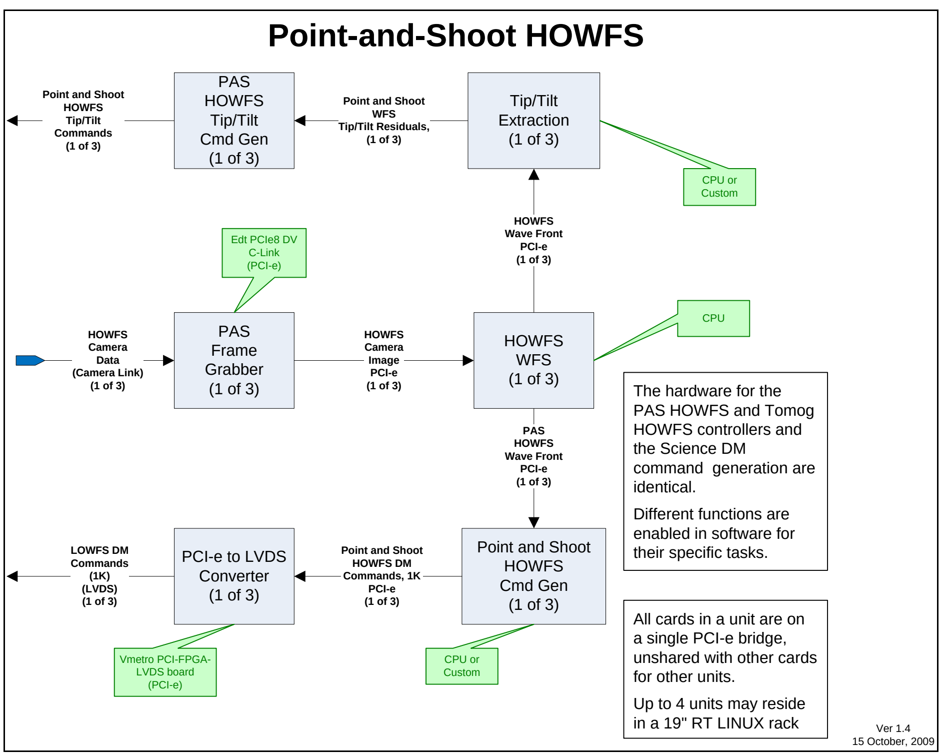

Figure 5 Point-and-Shoot HOWFS

5.4.1 Operational Tests

5.4.1.1 Point-and-Shoot HOWFS Overall Functionality (HOP_O_1)

Using a previously stored camera image, verity that the wave front and T/T information generated are correct for that image.

5.4.1.2 Point-and-Shoot HOWFS Camera Control (HOP_O_2)

Set each camera parameter and verify it by reading the camera parameters. Do this sequentially for all parameters.

5.4.1.3 Point-and-Shoot HOWFS Overall Functionality (HOP_O_3)

Using a previously stored camera image, verity that the telemetry steams are correct for that image. This includes TT and the wave front.

5.4.2 Unit and Acceptance Tests

The Test Bench for is used for Unit and Acceptance tests.

5.4.2.1 Point-and-Shoot HOWFS Overall Functionality (HOP_U_1)

Using a previously stored camera image, verity that the DM Commands and T/T values are correct for that image.

This test is performed using the Camera Simulator and LVDS input facilities on the Test Bench.

5.4.2.2 Point-and-Shoot HOWFS Camera Control (HOP_O_2)

Set each camera parameter and verify it by reading the camera parameters. Do this sequentially for all parameters.

This test is performed using the Camera Simulator and LVDS input facilities on the Test Bench.

5.4.2.3 Point-and-Shoot HOWFS Overall Functionality (HOP_O_3)

Using a previously stored camera image, verity that the DM Commands and T/T telemetry steams are correct for that image.

This test is performed using the Camera Simulator and LVDS input facilities on the Test Bench.

5.5 Tomography HOWFSs

The Tomography HOWFSs are housed in one or more real-time Linux boxes or racks.

The inputs to the Tomography HOWFSs are through a Camera Link interface, which includes camera control. This would normally connect to the HOWFS cameras during operation and to the RTC Test Bench during acceptance or Unit Tests.

For operational (or any) tests, the inputs can be derived from an onboard buffer loaded with generated or previously stored data. The control of the input source and the alternate data is through an Ethernet connection. This mode of testing will test the internals of the WFS, but will not tests the camera link interface, or the camera control capabilities.

For unit and acceptance tests, the inputs are connected to a camera simulator. This will allow testing of the Camera Link interface, including camera controls.

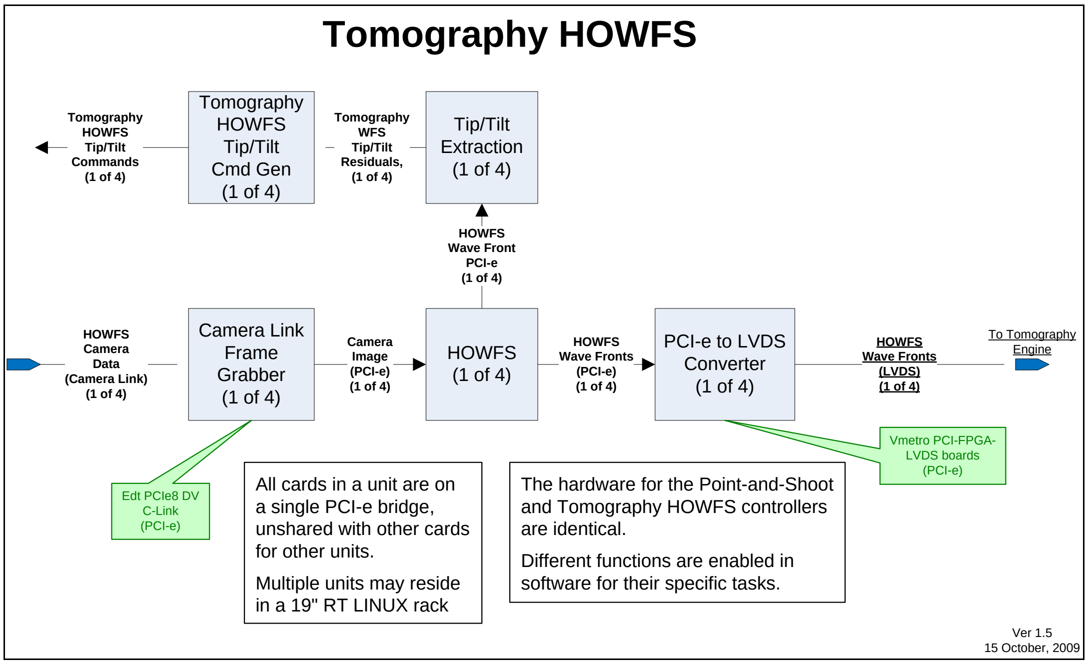

Figure 6 Tomography HOWFS

5.5.1.1 Tomography HOWFS Overall Functionality (HOT_O_1)

Using a previously stored camera image, verity that the wave front and T/T value generated are correct for that image.

5.5.1.2 Tomography HOWFS Camera Control (HOT_O_2)

Set each camera parameter and verify it by reading the camera parameters. Do this sequentially for all parameters.

5.5.1.3 Tomography HOWFS Overall Functionality (HOT_O_3)

Using a previously stored camera image, verity that the telemetry steams are correct for that image. This includes TT and the wave front.

5.5.2 Unit and Acceptance Tests

The Test Bench for is used for Unit and Acceptance tests.

5.5.2.1 Tomography HOWFS Overall Functionality (HOT_U_1)

Using a previously stored camera image, verity that the wave front and T/T value are correct for that image.

This test is performed using the Camera Simulator and LVDS input facilities on the Test Bench.

5.5.2.2 Tomography HOWFS Camera Control (HOT_U_2)

Set each camera parameter and verify it by reading the camera parameters. Do this sequentially for all parameters.

This test is performed using the Camera Simulator and LVDS input facilities on the Test Bench.

5.5.2.3 Tomography HOWFS Overall Functionality (HOT_U_3)

Using a previously stored camera image, verity that the wave front and T/T telemetry steams are correct for that image.

This test is performed using the Camera Simulator and LVDS input facilities on the Test Bench.

5.6 Tomography Engine

This system is a completely custom design including the enclosures. It consists of multiple custom boards and cables (clock, power, and data). Many of these are identical and differ only in their position in the array.

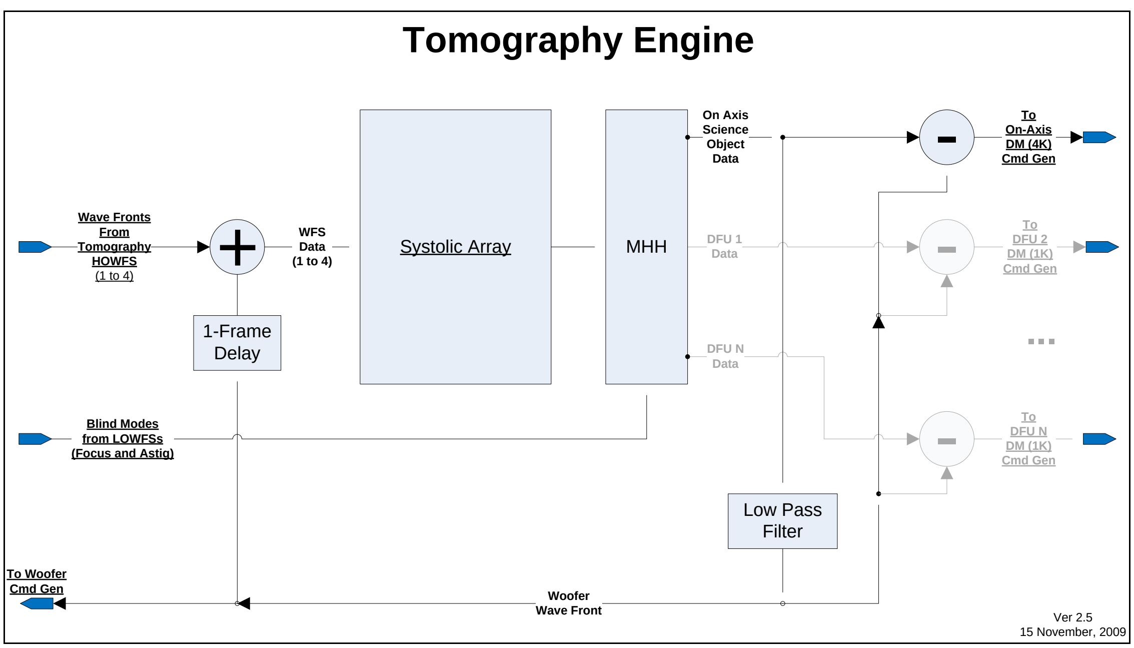

Figure 7 Tomography Engine

Test Bench for Unit and Acceptance tests to provide I/O.

Programmable power supplies, controlled by the RTC Test Bench, will be used to insure the boards can function over their intended operating range.

Programmable clock generators, controlled by the RTC Test Bench, will be used to insure the boards can function over their intended operating range of clock voltages and timing.

5.6.1 Operational Tests

5.6.1.1 Tomography Engine Overall Functionality (TE_O_1)

Using previously stored tomography HOWFS wave fronts, verity that the science wave front generated is correct for those wave fronts.

5.6.1.2 Tomography Engine Telemetry (TE_O_2)

Using previously stored tomography HOWFS wave fronts, verity that the telemetry generated is correct for those wave fronts.

5.6.1.3 Tomography Engine Overall Shmoo Plots (TE_O_3)

Using previously stored tomography HOWFS wave fronts, step through all combinations of supply voltages, and clock parameters, verifying that the science wave front generated is correct for those wave fronts. For each test, record a pass or fail and continue until all combinations have been completed. Plot all combinations and store for reference, recording information containing all boards' serial numbers, revisions, ROM revisions, and locations.

5.6.2 Unit and Acceptance Tests

The Test Bench for is used for Unit and Acceptance tests. Special tomography wave fronts need to be generated and used that are appropriate for the size of a single board. The tomography performed by the board will be on this sub section of the total number of sub-apertures in the RTC. Outputs appropriate to these wave fronts will also need to be generated as will special tomography code, modified to the smaller problem size.

5.6.2.1 Tomography Engine Individual Board Overall Functionality (TE_U_1)

Using previously stored tomography HOWFS wave fronts, verity that the science wave front generated is correct for those wave fronts.

This test is performed using the LVDS input and LVDS output facilities on the Test Bench.

5.6.2.2 Tomography Engine Individual Board Telemetry Functionality (TE_U_2)

Using previously stored tomography HOWFS wave fronts, verity that the telemetry data generated is correct for those wave fronts.

This test is performed using the LVDS input and LVDS output facilities on the Test Bench.

5.6.2.3 Tomography Engine Individual Board Shmoo Plots (TE_U_3)

Using previously stored tomography HOWFS wave fronts, step through all combinations of supply voltages, temperature, and clock parameters, verifying that the science wave front generated is correct for those wave fronts. For each test, record a pass or fail and continue until all combinations have been completed. Plot all combinations and store for reference, recording information containing the board's serial number, revision, and ROM revisions.

This test is performed using the LVDS input and LVDS output facilities on the Test Bench and a special cooling fixture to adjust the temperature.

5.7 Science Object High Order DM Command Generator

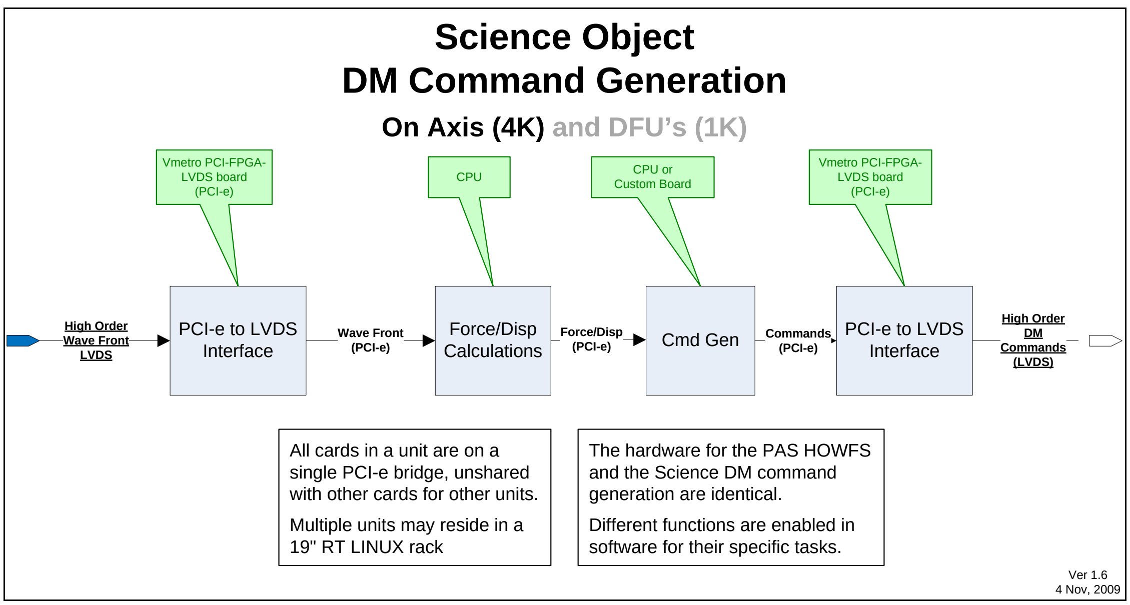

Figure 8 Science Object DM Command Generator

5.7.1 Operational Tests

5.7.1.1 Tweeter Command Generation Operation (T_O_1)

Load the science wave front output of the Tomography Engine with a previously saved Science Wave front. Insure that the tweeter commands generated are appropriate for that wave front.

5.7.1.2 Tweeter Command Generation Telemetry Operations (T_O_2)

Load the science wavefront output of the Tomography Engine with a previously saved Science Wave front. Insure that the telemetry stream is correct for that wave front.

5.7.2 Unit and Acceptance Tests

The Test Bench for is used for Unit and Acceptance tests.

5.7.2.1 Tweeter Command Generation Operation (T_U_1)

Load the wave front input buffer of the tweeter command generator with a previously saved high order wave front. Insure that the tweeter commands generated are appropriate for that wave front.

5.7.2.2 Tweeter Command Generation Telemetry Operations (T_U_2)

Load the wave front input buffer of the Woofer command generator with a previously saved high order wave front. Insure that the telemetry stream is correct for that wave front.

5.8 Low Order (Woofer) DM Command Generator

5.8.1 Operational Tests

5.8.1.1 Woofer Command Generation Operation (W_O_1)

Load the science wavefront output of the Tomography Engine with a previously saved Science Wave front. Insure that the woofer commands generated are appropriate for that wave front.

5.8.1.2 Woofer Command Generation Telemetry Operations (W_O_2)

Load the science wavefront output of the Tomography Engine with a previously saved Science Wave front. Insure that the telemetry stream is correct for that wave front.

5.8.2 Unit and Acceptance Tests

The Test Bench for is used for Unit and Acceptance tests.

5.8.2.1 Woofer Command Generation Operation (W_U_1)

Load the wave front input buffer of the Woofer command generator with a previously saved low order wave front. Insure that the woofer commands generated are appropriate for that wave front.

5.8.2.2 Woofer Command Generation Telemetry Operations (W_U_2)

Load the wave front input buffer of the Woofer command generator with a previously saved low order wave front. Insure that the telemetry stream is correct for that wave front.

5.9 Clock Generation and System Synchronization

This is a custom board, which generates all the major timing for the RTC system. This includes synchronizing the cameras and the master clock for the tomography engine. It interfaces to the Control Processor through Ethernet.

Breakout board for LVDS signals.

Frequency Counter

Storage Oscilloscope (>2GHz)

DVM

5.9.1 Operational Tests

Shmoo diagrams and save

Change clock speed and duty cycle

Change supply voltages

Verify interlocks

5.9.2 Unit and Acceptance Tests

Save Waveforms and voltage levels for later reference.

Shmoo diagrams and save

5.10 Disk Sub-System

This is a storage system from an OEM supplier

5.10.1 Operational Tests

5.10.2 Unit and Acceptance Tests

5.11 Power Distribution and Cooling Tests

5.11.1 Required tools

Air flow meter

5.11.2 Operational Tests

5.11.2.1 Test the power control panel on the rack (PWR_O_1)

At each power control unit, turn each unit on and verify it is on, turn each unit off and verify it is off.

5.11.2.2 Test the power control panel on the rack (PWR_O_2)

Test interlocks and verify that they interrupt what they are supposed to and that the CP reports the correct status, send any appropriate errors or warnings to the AO Control and enters the event in the appropriate log.

5.11.2.3 Test the power control from CP (PWR_O_3)

From the CP, turn each unit on and verify it is on, turn each unit off and verify it is off.

5.11.2.4 Test air flow monitoring at the CP (PWR_O_4)

Measure airflow for each unit and verify that the CP monitoring software reports the value correctly.

5.11.2.5 Test air flow monitoring at the CP (PWR_O_5)

Block the airflow and verify the CP monitoring software indicates the flow is zero and that all appropriate errors, warnings, and events are generated.

5.12 Custom Hardware and Software Acceptance Tests

5.12.1 Hardware

The following should be delivered and inspected or verified for each piece of custom hardware.

1. Cad files
2. Films for fab
3. Manufacturing stack-up
4. Design rules
5. Schematic Diagram
6. Version number is present and readable visibly and by software.
7. Facility to automatically give a board a location id independent of manual intervention, i.e., no manually placed jumpers.
8. Functional documentation
9. Ability to set and read the power supply voltage through the CP, if there is an on board regulator

5.12.2 Software

1. Ability to read the version number of each module of any compiled code
2. Functional documentation
3. Listing of code printed from the source
4. All make files and compiler revisions
5. All ROM code
6. All code loaded at any time that is not resident on board
7. Compile all code, starting from a virgin machine, using only the documentation, which among other things must provide all information for all programs and files that need to be loaded.

After all code has been built and installed, the unit should be validated using the appropriate acceptance tests.

If there are any deviations from the documentation or failures during the build, the documentation should be updated, the failures rectified, and the test restarted from a virgin machine.

An archive of the files should be made when the unit in question has passed its acceptance tests.

6. RTC Test Bench

The Test Bench performs stand-alone tests on RTC major or sub units.

Two permanent benches will be maintained: one at Keck and one at Santa Cruz.

Their purpose is to provide rapid and accurate acceptance, functional, development, diagnostic and debug test of all major RTC components.

The Test Bench can plug into the Camera Link output from a Camera or the LVDS outputs from a HOWFS, LOWFS, a tomography engine board, a DM Command Generator or the Clock Generator and System Synchronizer and capture and analyze their outputs.

It can supply simulated input information to WFS, tomography engine cards or DM Command Generators and simultaneously capture their outputs to validate the unit's functionality.

It is meant as a bench tool to be used in the lab rather than as an operational piece of the RTC.

It has all facilities necessary to provide the correct control to the devices through LVDS, Camera Link, or Ethernet.

Three types of tests will be provided:

1. Push button (Go/No Go) confidence tests to validate the basic functionality of the unit.
2. Manually run tests to do detailed analysis of the functionality or performance of the unit.
3. Tests to test the Test Bench itself

To test the Tomography Engine boards, a special jig will be supplied that includes all necessary power supplies and cables, clock generators and speed selection, monitoring and ***cooling***.

Easy to use methods to vary voltages of the supplies and voltages and timing parameters of the clock systems will also be provided.

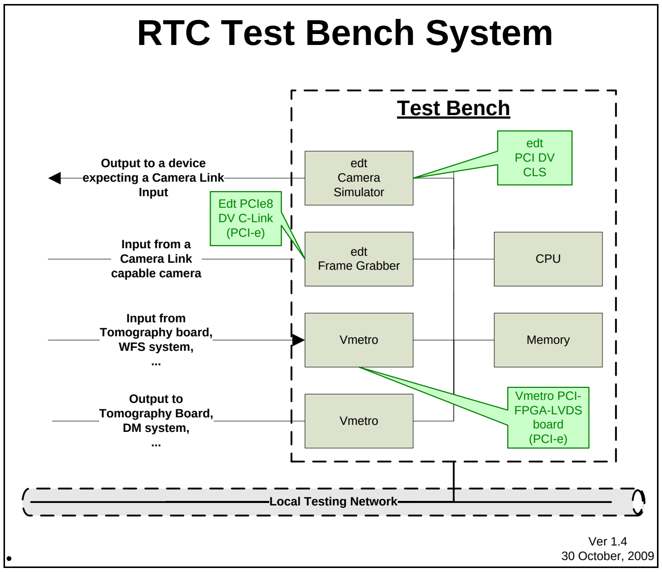

Figure 9 RTC Test Bench

6.1.1 Operational Tests

6.1.2 Unit and Acceptance Tests

Appendices

A. Glossary

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