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MONSOON

Image Acquisition System

(Pixel Server)

Detector Head Electronics Architecture Document

(HW&SW)

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Document Acceptance and Concurrence

This document represents the current understanding of the functional and performance requirements of the MONSOON Image Acquisition System to be developed at NOAO and deployed on systems at Kitt Peak National Observatory (KPNO) and at the Cerro Tellolo International Observatory (CTIO)

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Preface

This is an initial draft, submitted for discussion and comment.

Document Scope

This MONSOON Detector Head Electronics Architecture document is the top-level subsystem design document for the low-level detector interface electronics or controller that interface closely to the focal plane. It will incorporate the operational concepts previously defined in the MONSOON Operational Concepts Defintion Document (OCDD), and the detailed requiremenst and constraints from the MONSOON Functional Performance and Requiremenst Document (FPRD), and receives it's specification from the MONSOON System Architecture Document.

This document is intended to show the detailed issues of the DHE, both hardware and software. It will flow-down the system requirements from the MONSOON System Architecture Document to the DHE Backplane and the individual boards that are currently defined by the existing projects in the initial MONSOON Project Scope. All board level technical documents will be in compliance with this document.

Document Overview

This MONSOON Detector Head Electronics Architecture Document is modeled after the IEEE Recommended Practice for Architectural Description of Software-Intensive Systems referenced below in section 2. It is intended to communicate system details to the users, developers, and support staff at NOAO.

This document has taken input from the NDAS Project Concept Definition Document and the MONSOON System Description Document. The NDAS Project Concept Definition Document was circulated for internal and external review in February of 2001. The NDAS Project Concept transitioned to the MONSOON Project during August of 2001. The MONSOON System Description Document. was distributed for external, internal, and IPAC review in October of 2001. The intended audience for this document is the Scientific and Technical Staff at NOAO and elsewhere in the astronomical community who are stakeholders in the MONSOON system. A stakeholder being any individual who either uses, supports, or is in someway affected by this system.

1.0 Introduction

1.1 System Scope

The MONSOON System addresses the needs defined by an Image or Pixel Server. It encompasses the control, sequencing of low-level components, and acquisition of pixel data that form an exposure. MONSOON will address IR and OUV detector needs, both present and future. To accomplish this the System requires a modular and scalable hardware and software architecture. Different subassemblies for device interface or processing will be added and developed as needed. To support this flexibility, It is fundamental that MONSOON has defined interface boundaries and a rational architecture.

MONSOON does not address issues of instrument sequencing such as moving filter wheels or measuring dewar vacuum, nor does it address observational sequencing such as mosaicing or dithering of images that requires telescope movement. These activities are outside the scope of a pixel server and are best handled by higher level processes or layers within the observatory system.

1.2 System Purpose

The MONSOON Image Acquisition System will be a scalable, multi-channel, high-speed image acquisition system. MONSOON must meet or exceed all of the needs of the currently defined, or anticipated in the next ten years, next generation NOAO systems requiring image acquisition capabilities regardless of wavelength or underlying detector technology.

It is fortunate that, the basic needs for these systems are constant regardless of detector technology.

- The need for an interface to the user with the ability for image acquisition parameter definition and image request.
- The need to interface to the technical staff for system configuration and system diagnostics.
- The need for interface to the telescope, instrument, and observatory to acquire status for FITS header information.
- The need to acquire "detector limited" images in an efficient manner which maximizes "open shutter" or integration time.
- The need to interface to the image handling system to pass the packaged FITS image off to the observatory system and observer.

Systems of the scale and performance defined by these next generation systems raise new challenges in terms of communication bandwidth, data storage and data processing requirements which are not adequately met by currently existing astronomical controllers. In order to meet this demand, new techniques for both the detector head electronics and image acquisition architecture, need to be defined. These same concepts will need to be extended to even larger systems such as those proposed for LSST.

Extremely large scale imaging systems also raise less obvious concerns in areas of controller design such as physical size and form factor issues, power dissipation and cooling near the telescope, system assembly/test/ integration time, reliability, and total cost of ownership.

MONSOON then is more than a controller, but rather an image acquisition system. MONSOON has been specifically designed to meet and exceed the requirements of ORION (2k x 2k) INSB R&D effort, NEWFIRM (4k x4k), GSAOI (4k x 4k), OUV Detector R&D, LBNL Mosaic, QUOTA (8k x 8k) , ODI (32k x 32k), and LSST (37k x 37k)

General System Goals;

- Scalable, low-cost, high-performance system.
- Supporting both IR and OUV devices.
- Develop device independent data acquisition architecture.
- Standard interface, bits to FITS!
- Decouple the data flow from the device interface as much as possible.
- Device independence for most of the system
- Small Modular Packaging
- Low Power Dissipation
- Support Laboratory Detector R&D, Instrument Development, and Operational Science Observing

1.3 Acronyms

ADC	Analog to Digital Converter
DAC	Digital to Analog Converter
DHE	Detector Head Electronics
DHS	Data Handling System
FITS	Flexible Image Transport System
FPA	Focal Plane Array
GPX	Generic Pixel Server
MONSOON	Not an acronym
ICD	Interface Control Document
ICS	Instrument Control System
IDPS	Image Data Preprocessor System
ID	Identifier
IR	Infrared
LAN	Local Area Network
N/A	Not Applicable
OCS	Observatory Control System
ROI	Region of Interest
TBD	To Be Decided

1.4 Glossary

Attribute - An entity which describes some aspect of the configuration of a system, subsystem, or component, such as the level of a voltage or the state of a shutter. Certain attributes will be used by as command parameters. The OCS communicates with a science instrument by sending it sets of “attributes” and “values”.

Command - An instruction commanding a system to start some action. The action may result in a voltage changing or some internal parameters being set to particular values. A command may have command parameters (aka. "arguments") which contain the details of the instruction to be obeyed.

Pixel Acquisition Node (PAN)- A component of the MONSOON Image Acquisition System or Pixel Server. The PAN is the computer and associated software which the interface to the Detector Head Electronics (DHE) and provide the image pre-processing of the data stream from the DHE. The PAN was formerly referred to as the Data Acquisition Node in previous MONSOON Documentation.

Pixel Acquisition Node – A component of the MONSOON Image Acquisition System or Pixel Server. The Pixel Acquisition Node runs on a general purpose computer to handle the translation from the GPX interface and the interface to the DHE. This is the node which handles the pixel data pre-processing and the creation of images in the required format. The PAN connects to the DHE through a fiber-optic interface cable.

Data array -The data, while it is stored in data processing memory, which resulted from one or more readouts of an IR array or CCD detector.

Data Set - A self-contained collection of data generated as a result of an Pixel Server obeying a gpxStartExp command. Each gpxStartExp command results in one and only one data set.

Exposure - The name used to describe the process and the data resulting from the activity of resetting/clearing a detector, exposing it to photons and then reading out the data. This may include multiple sample readout techniues such as Fowler sampling, sample up the ramp, etc. (For example, an exposure would be the data array which results when a single Reset-Read-out-Integrate-Readout cycle is performed on an IR detector or a single CCD Clear-Integrate-Readout cycle.)

Single Exposure Sequence – Exposure sequence where all exposure parameters are fixed and the detector is readout (1 to N) times and combined to form a single image. Examples would be a simple reset read cycle of a classic CCD or IR detector, Fowler Sampling, Coadditions of Images, Orthogonal Transfer Imaging (Guide Region Readout followed by centroid calculation followed by image shift, n times til final image formed). .

Multiple Exposure Sequence – Exposure sequences with potentially varied exposure configurations and the data stored as multiple images. Examples would test routines such as the Photon Transfer Curve, multiple time-stamped exposures, multiple exposures synched to an external source such as a AO system or Chopper system.

Frame - A frame is the result of one or more readouts of an array averaged pixel by pixel. Each frame represents the signal values obtained from reading the entire ROI being read out of the detector. Multiple frames may be processed into a single exposure.

Image - The array of detector pixel and description data representing a science or diagnostic image or spectrum. An image is capable of being displayed or processed as a discrete entity. The values in the array may be stored in memory or on disk and are related to the data taken by the detector by some processing algorithm, (for example an image may consist of all the coadded and averaged exposures in one beam of a chop mode gpxStartExp command).

Observation - The process of exposing the detector to photons in one or more exposures. The result of an observation is a picture??? Observation Data Set???? Image????.

Readout - When used as a noun to describe instrument data, this refers to a single read of every pixel in the detector region of interest. A one or more readouts can be averaged pixel by pixel to create a frame.

ROI - A Region of Interest is a sub array of the available detector area. There are two types of sub-arrays, which can be defined. The Sequence ROI is an ROI on the active surface of the array used to increase the frequency of the Array readout. The Data Reduction ROI is an arbitrary rectangle of any size, which fits on the Array. Data Reduction ROI's are defined to reduce the volume of data sent to the disk or DHS even when the entire Array is being read out.

Value - The value associated with an "attribute".

Detector Head Electronics (DHE)- A component of the MONSOON Image Acquisition System or Pixel Server. The lowest level MONSOON subsystem, normally closely connected to the detector and the dewar in which the detector resides for signal integrity issues. The DHE connects to the PAN through a fiberoptic interface cable. Previously called the MONSOON Detector Controller.

Pixel Server - A system that produces images when requested to do so by some client system. The MONSOON Image Acquisition System is a Pixel Server.

Generic Pixel Server Interface- A pixel server command and data interface that conforms to the GPX Interface description. The goal is to allow multiple pixel server implementations conform to the same interface definition.

Supervisory Node. A component of the MONSOON Image Acquisition System or Pixel Server. The Supervisory Node is the software layer that coordinates multiple Pixel Acquisition Node – Detector Head Electronics node pairs into a single integrated system. In the event where only a single PAN-DHE node pair is needed the Supervisory layer is not needed. The Supervisory Layer and the PAN all adhere to the GPX interface defined above, and in the case of a single PAN-DHE node pair can be simply removed from the system if desired. If used in the system the Supervisory Node may run on a separate computer networked to the PANs or be physically running on a specific computer along with on of the PANs.

1.5 References

1) SPE-C-G0037, "Software Design Description", Gemini 8m Telescopes Project.
2) "ICD/16 — The Parameter Definition Format", Steve Wampler, Gemini 8m Telescopes Project.
3) WHT-PDF-1, "FITS headers for WHT FITS tapes", Steve Unger, Guy Rixon & Frank Gribbin, RGO.
4) NOST 100-1.0, "Definition of the Flexible Image Transport System (FITS)", NASA Office of Standards and Technology.
5) GEN-SPE-ESO-00000-794, "ESO Data Interface Control Document", Miguel Albrecht, ESO.
6) IEEE Std 610.12-1990 - "IEEE standard glossary of software engineering terminology", Standards Coordinating Committee of the IEEE Computer Society, USA, 19901210
7) ANSI/IEEE Std 754-1985 - "IEEE Standard for binary floating-point arithmetic" - Standards Committee of the IEEE Computer Society, USA 19850812
8) xxxx "XDR - Extended data representation Standard" ????
9) NOAO Document ###.$$$$.&&& - ICD 4.0 Version 0.1.2 - "Generic Pixel Server-Communications, Command/Response and Data Stream Interface Description", Nick C. Buchholz(NOAO), Barry M. Starr(NOAO), 20020308
10) NOAO Document ###.$$$$.&&& - ICD 6.0 Version 0.1.2 - "Generic Detector Controller - Command and Data Stream Interface Description", Nick C. Buchholz(NOAO), Barry M. Starr(NOAO), 20020308
11) MONSOON System Description

2.0 MONSOON System Description

2.1 MONSOON System Overview

The MONSOON DHE is the lowest level assembly in the first-level decomposition of the MONSOON System Architecture. It provides the low-level detector interface of the MONSOON System and is often referred to as a controller. **Figure 1** below shows the DHE in the context of the entire MONSOON system.

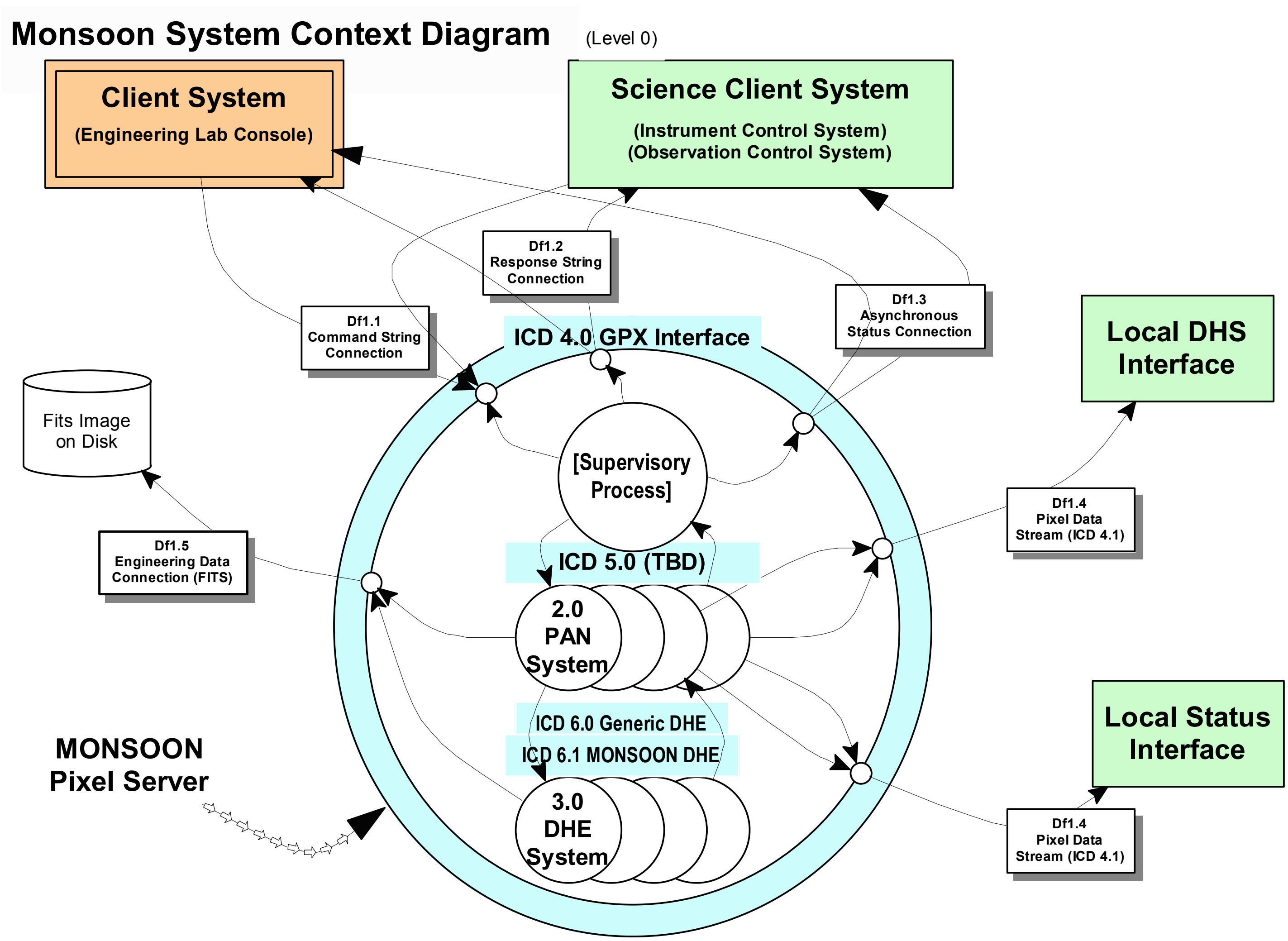

Figure 1 MONSOON System Context Data Flow Model. This shows the major "layers" of the MONSOON System. The Supervisor Layer, the Pixel Acquisition Node (PAN) Layer, and the Detector Head Electronics (DHE) Layer, as well as external entities, that are sources and sinks of data in and out of MONSOON

MONSOON is based on a scalable network of powerful yet low-cost of LINUX-based PC's, each supporting a commercial 1Gb/sec (or 2.4Gb/s) fiber optic link. This architecture, shown below in Figure 2, yields an attractive digital communications and processing platform for large imaging systems.

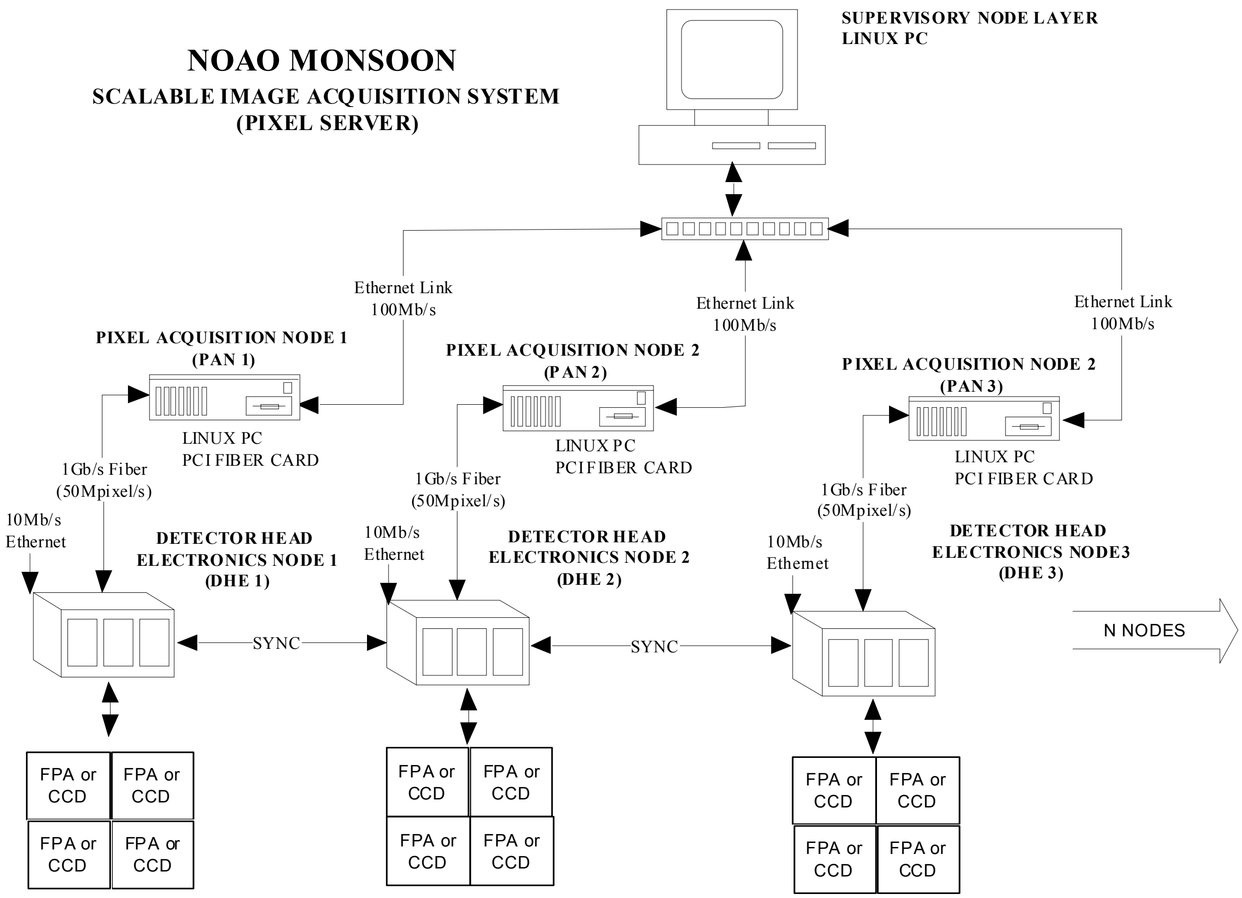

Figure 2 MONSOON Scalable Image Acquisition System Architecture Illustrates a possible N node implementation. Nodes are added to the system as needed and or as costs permit.

In the case of a 1-node system, which will be the case for the ORION, NEWFIRM or QUOTA systems, the "Supervisory Node" is not needed. The supervisory node and the supervisory layer of the software acts to combine data from each Pixel Acquisition Node and provide a single entry point to the MONSOON system for the observatory or instrument control systems. Whether or not multiple Pixel Acquisition Nodes are needed in a given application is unnecessary information to higher levels of a system and can therefore be hidden. In this design nodes can be added as needed up to an arbitrarily large limit.

2.2 MONSOON System Performance Specification

Detector technology should be the limitting system performance parameter for this system. A formal analysis and requirements flowdown to the interface electronics has been performed based on the most optimistic and demanding performance parameters projected. These general requirements are as follows:

- •All Data Pipelines to Support 32-bit Transfer for Future Expansion
- •Current Dynamic Range: > 60,000:1

- –16-Bit 1MHz ADC Resolution, supporting S/N > 90dB
- •NonLinearity: < 0.01% over Entire Range
- •ReadNoise: < 10% Contribution to Total System Readnoise
- –Actual Input Noise and System Gain & Bandwidth Set By Detector Used
- •Channel to Channel Crosstalk: < 0.005%
- •Pixel to Pixel Crosstalk: < 0.01%
- •Data Rates: Upto 120Mpixel/sec per Controller Chassis
- •Data Processing Rates at Controller
- •# of Channels/Controller: Upto 256 Channels per Controller Chassis
- •Calibrated, Measured, Recorded Performance.
-

Detailed Requirements Flowdown to the Board Level will be detailed for the individual modules as referenced in section 1.3 of this document.

3.0 Detector Head Electronics Hardware Description

The MONSOON System Architecture partitions the system into 2 fundamental subsystems, the image data acquisition system (digital domain, non-sensor specific) and the detector interface.

Barry - Add verbiage -ncb

3.1 DHE Sequencing

The MONSOON DHE will address sequencing issues limited to exposure timing, shutter control, as well as clocking and readout of the array. This includes lowest level sequencing of detector clocking, and integration timing, as well as taking multiple exposures with various exposure parameters compatible with detector characterization (photon transfer curve e.g.). Because of the need for such tight coupling of the shutter to readout, the shutter sequencing and timing measurement will also be controlled within MONSOON. While the MONSOON DHE may be easily extended to provide the means to connect to auxiliary functions that may be characterized as "instrument functions" such as filter wheel control or temperature sense/control outside of the focal plane, these are currently outside of the system scope.

3.2 External DHE Communications Links

Using the Figure 2 above as a reference, 3 significant communication links to the DHE should be pointed out for extended explanation, the fiberoptic link, the synchronization link, and the Ethernet links.

3.2.1 The SL100/SL240 Fiberoptic Link

The first link under discussion is the 1 to 2.4 Gb/S fiberoptic link. These are commercially available standard products from Systran Corp known as SL100/SL240 FiberExtreme with a significant user base in a wide range of data acquisition systems. They employ a low-latency link protocol based on Fiberchannel fc0/fc1 standards. The links provide point-to-point, as well as broadcast, and loop topologies, which can be redirected for varying data processing pipeline requirements. The 1 Gb/s links support

100Mbyte/sec transfer rates (50 Mpixels/sec), and they can be upgraded if necessary to a 2.4Gb/s link if desired. These links provide high-speed full-duplex bidirectional communication both from the Detector Head Electronics Node to the Pixel Acquisition Node.

The DHE will have a Systran FiberXtreme CMC daughter card embedded within it to provide the fiberoptic link capability.

3.2.2 The DHE Synchronization Link

The second significant communication link is between Detector Head Electronics Nodes for synchronization purposes. It is fundamental for low-noise performance that all clocks for all imaging devices (CCDs or IRFPAs) be synchronous to avoid crosstalk and clock coupling issues. To address this a low voltage differential signaling (LVDS) clock distribution network with skew control will tie all system components together into a single synchronized whole.

3.2.3 The Ethernet Links

The third communication network is ground-isolated 10-base-T Ethernet. Each Detector Head Electronics will have a small embedded-microcontroller with Ethernet and TCP/IP network support. This link is for system configuration and diagnostic/error recovery only. It is not part of the system "pixel" path, it is only provided for system support. This embedded PC can be removed form the DHE if desired with the corresponding loss of it's capability.

At the controller level is based on a high-speed standard backplane. This allows cards to be added to the system as desired. We can easily adapt to FPA requirements as needed.

3.3 Detector Head Electronics Hardware

The Detector Head Electronics nodes shown below in **Figure 3** will be comprised of 3 types of boards:

1) Master Control Board
2) Clock and Bias Board
3) Acquisition Board

The Master Control Board will be common among all MONSOON systems, this constitutes the "digital domain" boundary of the system which will be common independent of detector technology. The analog portions of the system are best served with a variety of boards that can be used as needed.

The Clock and Bias Boards will be tailored to the individual requirements of the detector with at least 2 boards currently envisioned (1 for CCDs, 1 for IR).

The Acquisition Boards will likely have at least 2 versions due to the need for pixel level CDS on the CCDs and not on the IR. The Acquisition Boards will have at least 16-channels per board to allow high channel count densities in a small form factor.

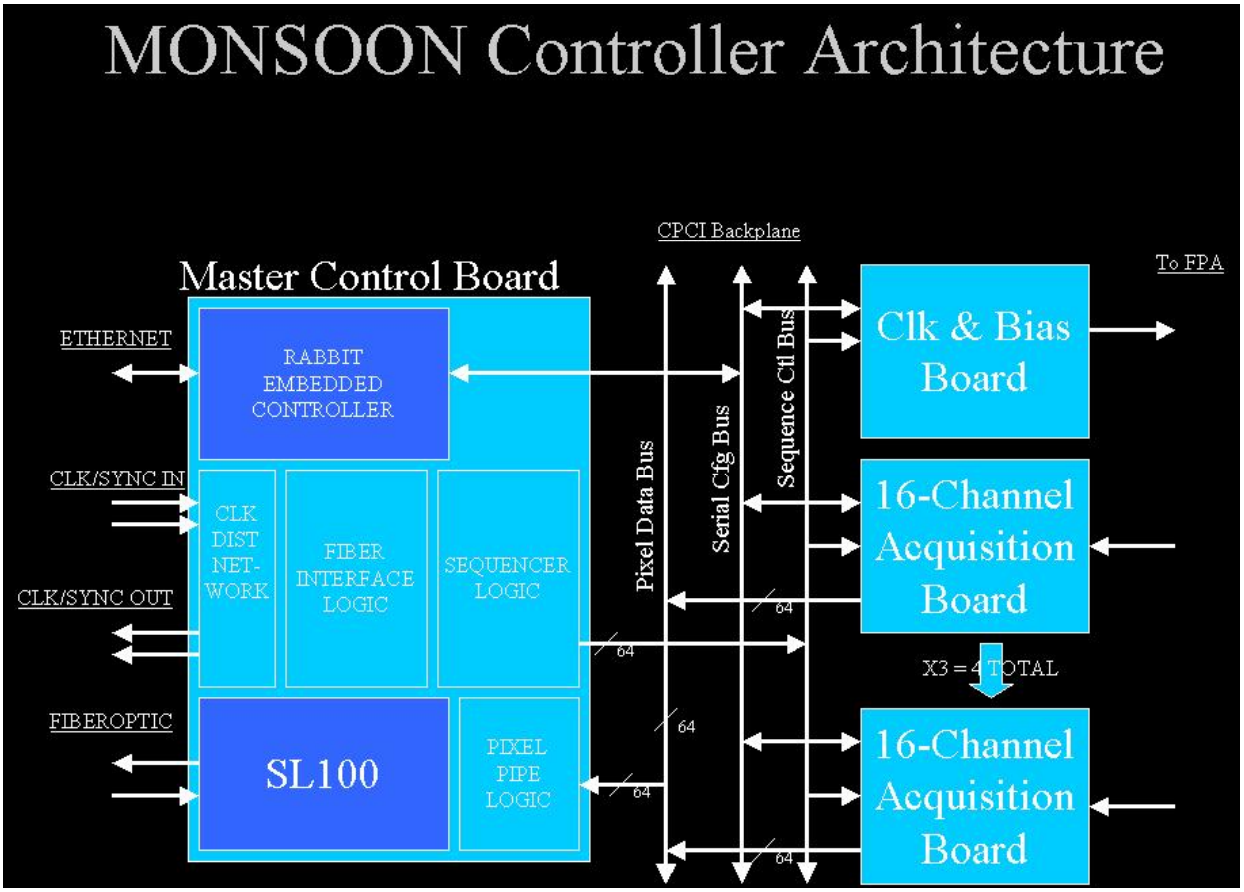

Figure 3 MONSOON Controller Architecture. Illustrates the 3main components of the system and the internal and external interconnection mechanisms.

The system is designed to be extremely modular and very simple to assemble, configure, test, and support. It will be in a 6U Eurocard Format to provide a nice compromise between small package size and appropriate system channel count density. It will employ 2 backplanes for signal distribution, a standard Compact PCI backplane for digital signal and digital DC power distribution, with a custom analog backplane for interface to the focal plane. The CPCI backplane will follow CPCI signal integrity standards but not the CPCI signal timing protocol in order to maximize system performance for our application. We have no need for the bus master arbitration or interrupt capabilities of CPCI, we simply want a high-speed controller impedance, high-signal count backplane we can buy at an affordable cost, instead of building ourselves. The 3 digital busses shown above (Pixel Data, Serial Cfg, & Sequence Ctl) are mapped onto existing CPCI signals. These busses will be detailed further in (???? refer to section 1.3). The analog backplane will incorporate all necessary over voltage and static protection circuitry for both the focal plane, and will be an integral part of the dewar assembly and focal plane interconnect through the use of rigi-flex technology.

The end result of this will be a minimum of system cabling, assembly, and test time. A model illustrating this concept for NEWFIRM is shown below in Figure 6.

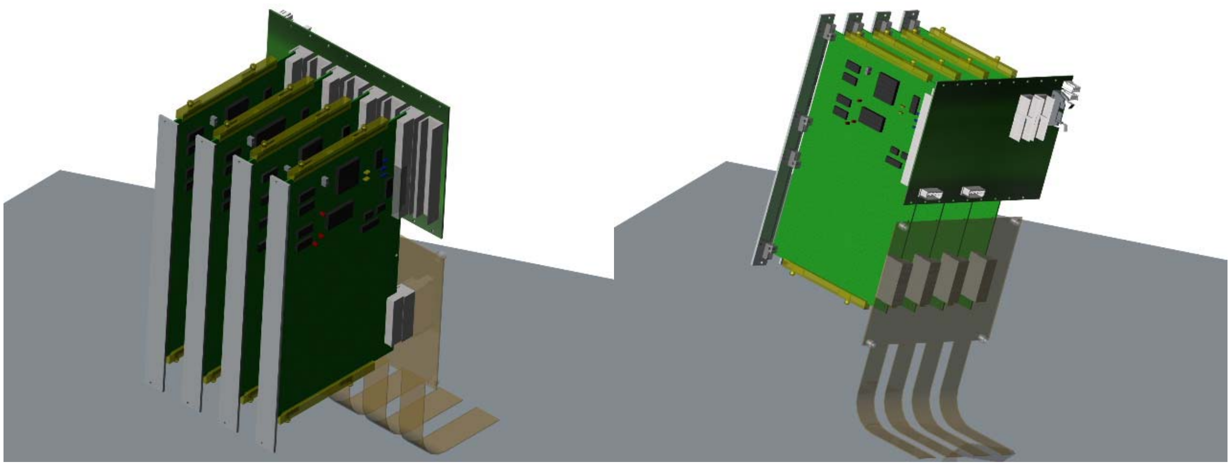

Figure 4 MONSOON Controller Solid Model. Illustrates the physical design of controller and flex circuit interconnect to focal plane. Shows 6U implementation which is now planned for board space reasons.

It should be pointed out however that the board or system design does not prevent the use of more "traditional" cabling to attach analog connections from the dewar to controller chassis. The connectors chosen for the analog circuitry interface both to board mounted and coaxial cable mating connectors. Therefore, the analog backplane shown above can be replaced by cables if desired, or for test, debug and development reasons. The design also does not preclude the use of preamps or other signal conditioning between the controller and the focal plane whether internal or external to the dewar. These are system choices to be made on an instrument-by-instrument basis.

Technologies enabling these impressive densities and performance advantages have been developed recently using monolithic CMOS designs for mixed-signal components. Illustrated below in Figure 7, is the striking size comparison breakthroughs of monolithic CMOS to hybrid bipolar technologies of just 5 years ago. There are corresponding reductions in power and cost as well. Refer to Figure 9 further in the document to see the 12-channel Single Board Controller CCD Prototype under test currently at NOAO.

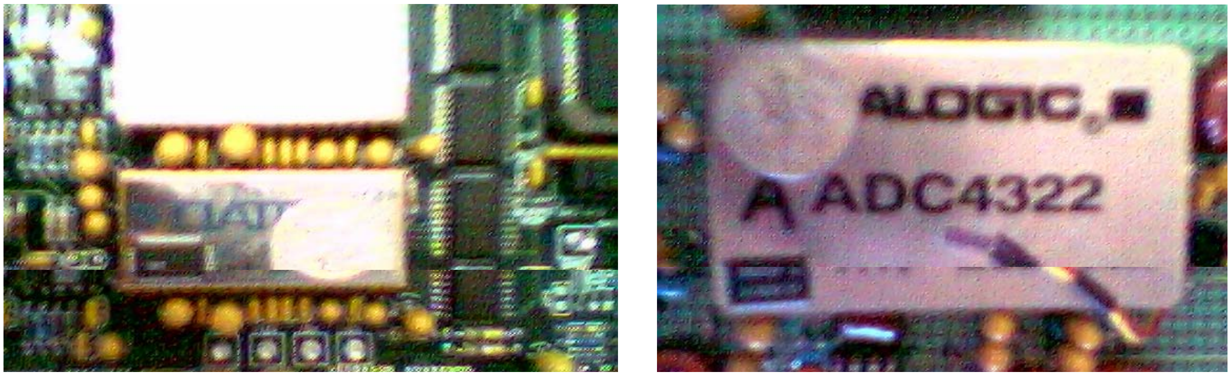

Figure 5 CMOS ADCs. *Illustrates the size reeduction in new ADCs. On the left SDSU ADC's, with new 16-bit 5 Mhz CMOS device and a dime. On the right the ADC's used in Wildfire and Redstar 2&3 systems, same CMOS ADC and a dime. There are corresponding reductions in power and cost.*

4.0 DHE Software Architecture

Figure 1 on page 9 shows where the PAN software exists in the overall MONSOON system. The interface to the PAN nodes will be ICD 5.0, this interface should be a proper subset of ICD 4.0 the GPX interface. The Supervisory Process exists in the system to handle all the details imposed on the system by multiple PAN-DHE node pairs. **Figure 6** below details the context for the PAN software.

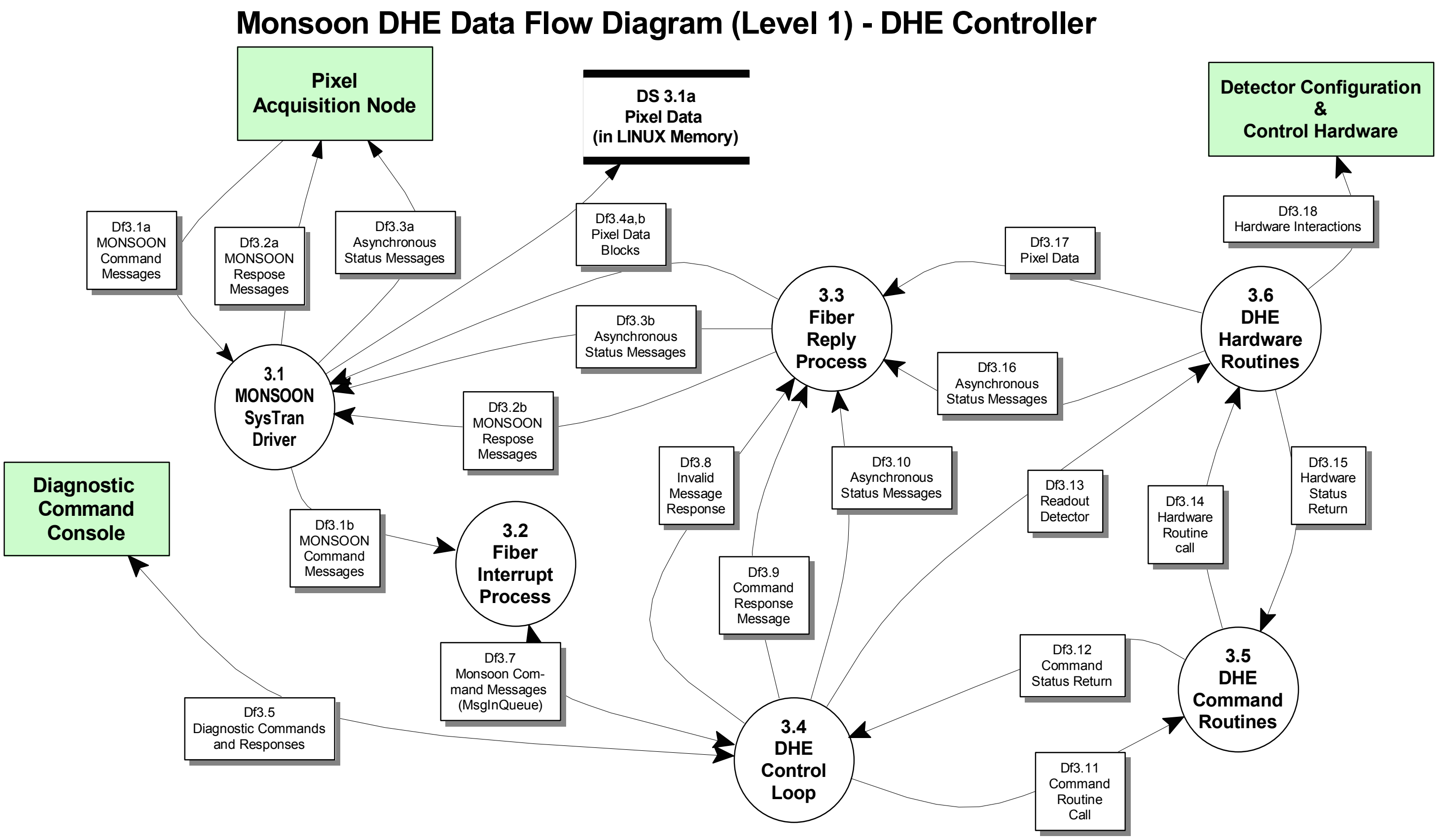

Figure 6 MONSOON PAN Context diagram – *This diagram shows the data flows between the PAN and the external sources and sinks of data and commands.*

4.1 Interfaces

Three Interface documents exist that outline the four command, response and data streams between the PAN and external entities. These include: the GPX interface and Supervisory Node-PAN interfaces in ICD 4.0/5.0, the Generic DHE interface in ICD 6.0 and the MONSOON specific interface between the DHE driver software and the DHE software in the DHE in ICD 6.1.

Interfaces between the various components of the PAN software will be described below in the sections dealing with those components.

- NOAO Document ###.$$$$.&&& - ICD 4.0/5.0 Version 0.1.2 - "Generic Pixel Server- Communications, Command/Response and Data Stream Interface Description", Nick C. Buchholz(NOAO), Barry M. Starr(NOAO), 20020308
- NOAO Document ###.$$$$.&&& - ICD 6.0 Version 0.1.2 - "Generic Head Electronics - Command and Data Stream Interface Description", Nick C. Buchholz(NOAO), Barry M. Starr(NOAO), 20020308
- NOAO Document ###.$$$$.&&& - ICD 6.1 Version 0.1.2 - "MONSOON DHE - Command and Data Stream Interface Description", Nick C. Buchholz(NOAO), Barry M. Starr(NOAO), 20020308

4.2 DHE Top-level Functions and Requirements

The MONSOON DHE system must be able to perform the following functions:

1) Initialize itself on power-up to a "Detector Safe" state. **FPRD 2.3.1**
2)

4.3 System Logical Partition

4.3.1 Detector Head Electronics Layer

Currently it is also envisioned that we will not have the case of multiple Detector Head Electronicss feeding a single Pixel Acquisition Node. Rather the system will be scaled in Pixel Acquisition Node/Detector Head Electronics Node Pairs. The reasoning behind this is due to the cost performance issues of the system. If you need multiple controllers (anticipated because you exceed Fiber Bandwidth requirements) you'll most likely exceed your PC data processing capabilities or the PCI Bus bandwidth. In further support of this notion is due to the extremely low-cost of additional PC's would make it hard to fathom at this point that you'd not just scale in Node Pairs. Within the system the will only be one Supervisor Layer, orchestrating the entire system and providing a single point interface to the system, hiding the details of how many Pixel Acquisition Nodes are present to external systems. With regard to the Detector Acquisition Nodes and Detector Head Electronics Nodes there are two fundamental "operating states", that of Master or Slave. Within a multiple node MONSOON implementation there can be at most 1 Master Node Pair, all other most be configured as Slave node pairs. A Master Node controls the triggering of an exposure and exposure timing. Each Slave Node pair is "armed" and waiting for an exposure trigger that comes from a single Master. Then all nodes run in synch. The entire N node systems can be configured as a Slave Nodes with the logical Master Node being an external system such as a AO system, Chopper Signal, Time Sequencer, etc. The Detector Head Electronicss are hard synched by a distributed clock and serial sync (control) line. This is discussed above in section 2.2.1??? and is further detailed in XXXX reference section 1.3.

4.4 DHE Design Decomposition

4.4.1 Start-up and Intialization

4.4.2 MONSOON Systran Driver

4.4.3 Control Loop

4.4.4 Fiber Response Handler

4.4.5 DHE Command Routines

4.4.6 DHE Hardware Routines

4.4.7 Exposure Control

4.4.8 Error Recovery Routines

4.4.9 Ethernet Command loop

4.5 Module Interface APIs

4.5.1 Initialization Routine

4.5.2 Command Routines

4.5.3 Error Recovery Routines

4.5.4 DHE Hardware Routines

4.5.5 Ethernet Command loop

4.6 Process Descriptions

4.6.1 Command Loop

4.6.2 Ethernet Command loop

5.0 DHE Software Detailed Design

5.1 Detailed Interface Support

5.2 Data Flows

Monsoon DHE Data Flow Diagram (Level 0)

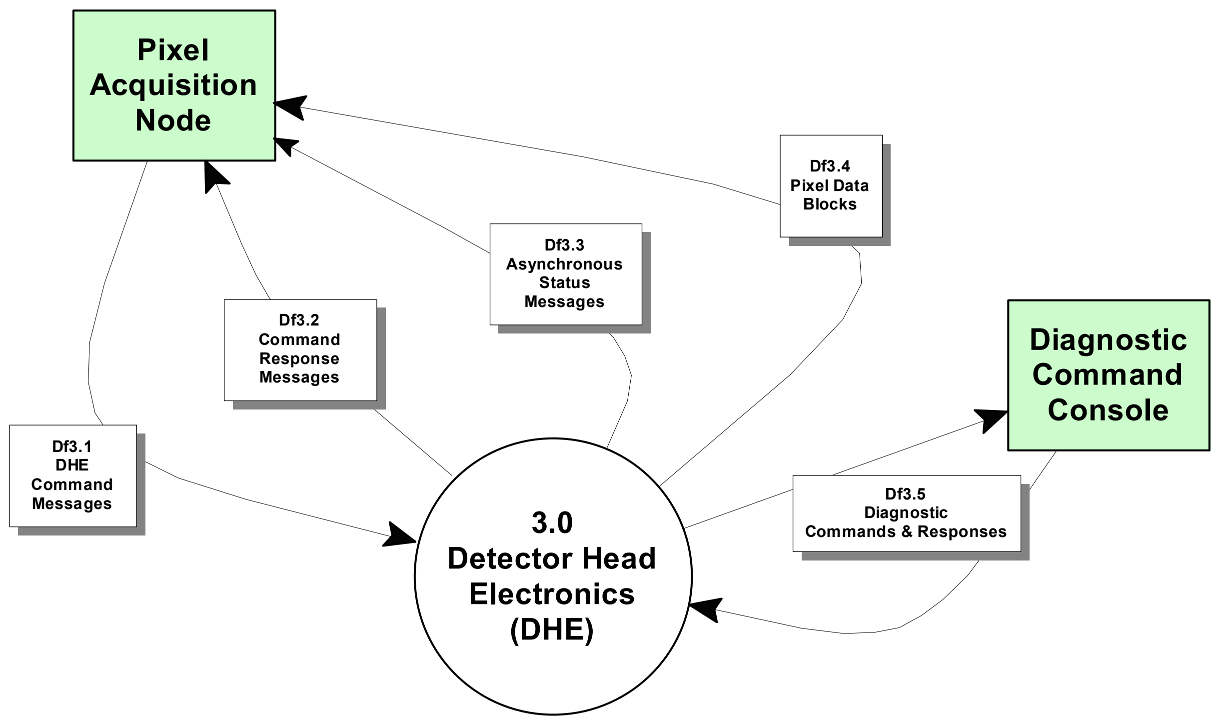

Figure 7 Level 0 DHE Dataflow Diagram

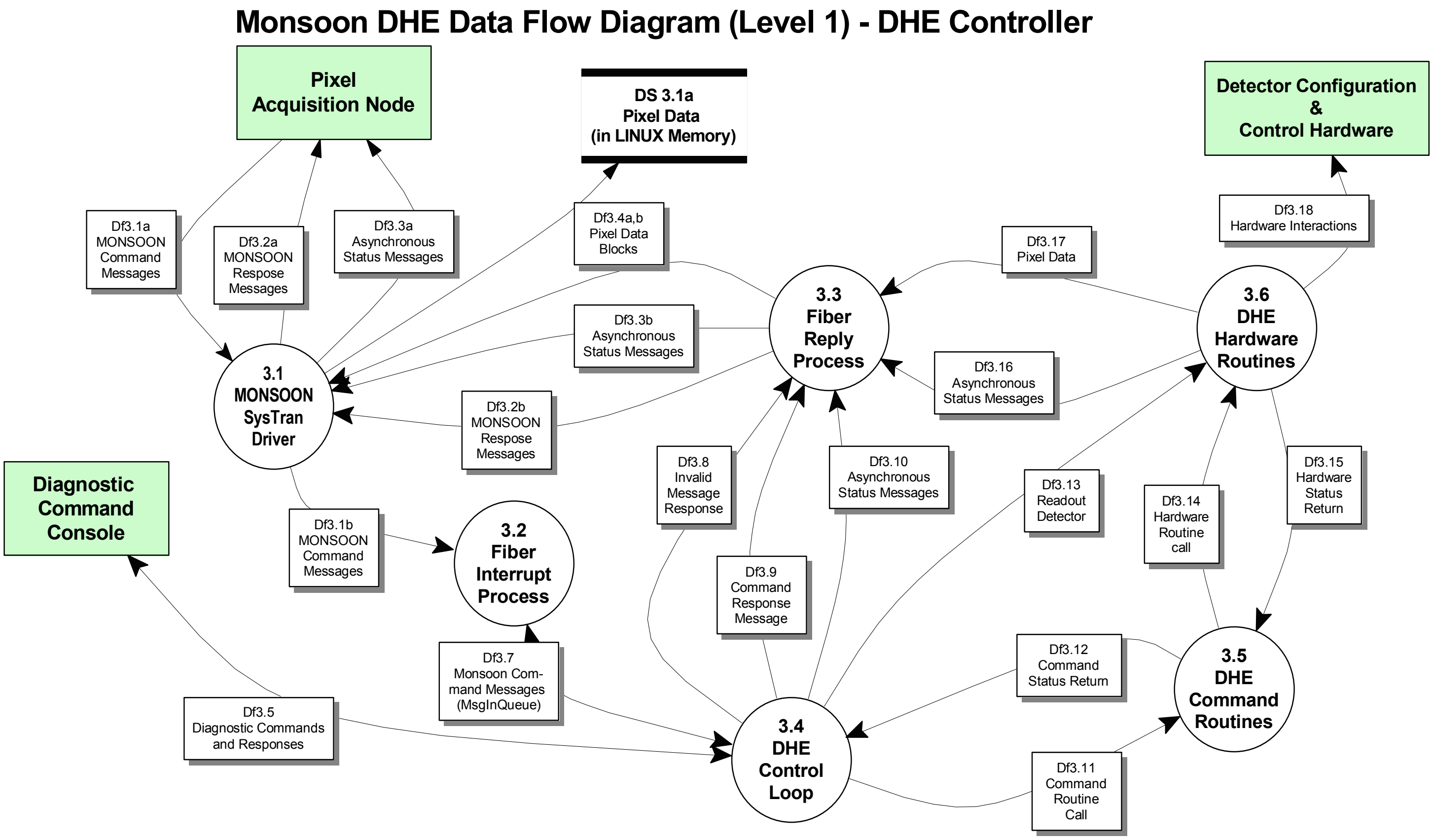

Figure 8 Level 1 DHE Dataflow Diagram

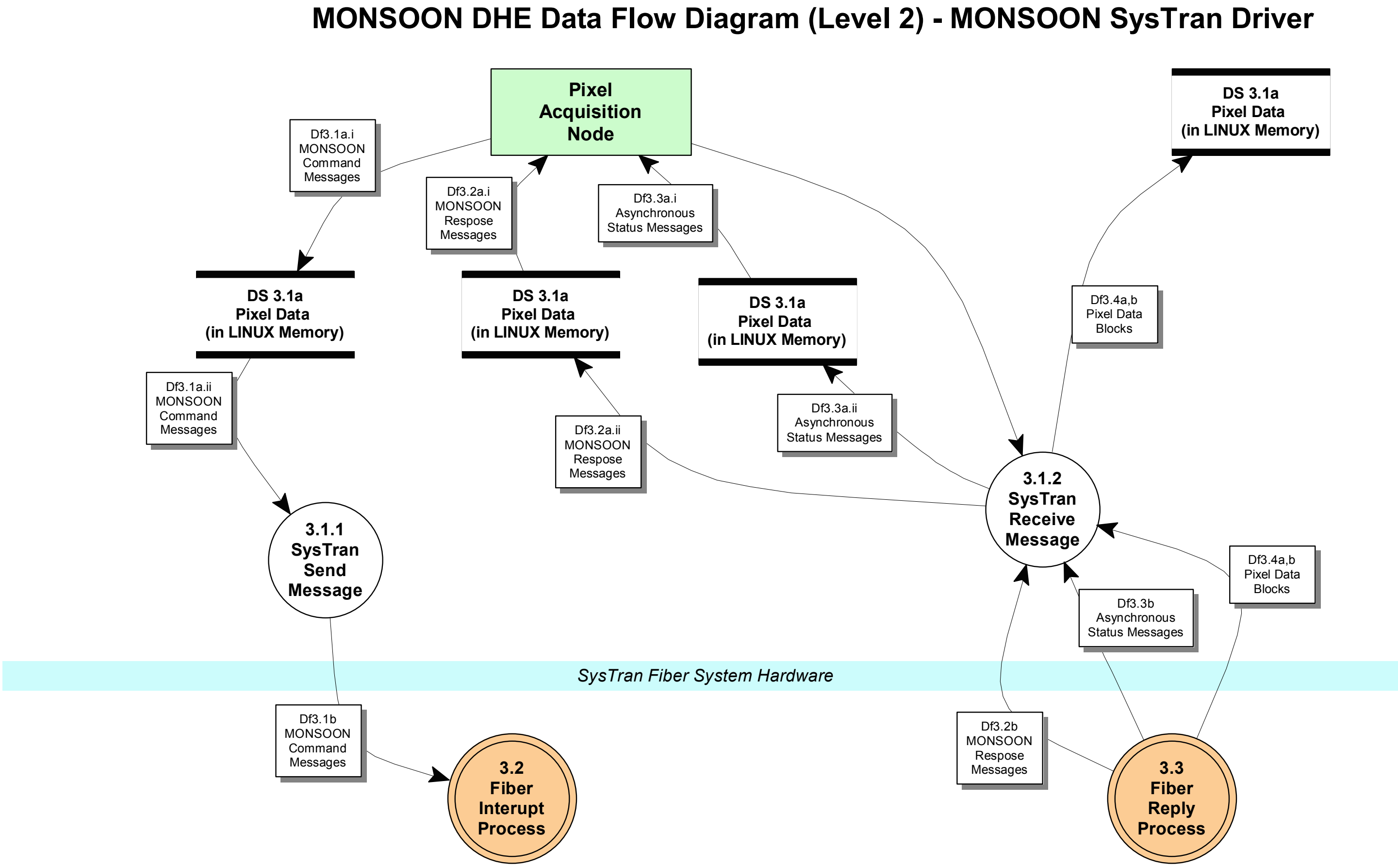

Figure 9 Level 2 DFD – 3.1 MONSOON Systran Driver

MONSOON DHE Data Flow Diagram (Level 2) - Fiber Interrupt and Reply Process

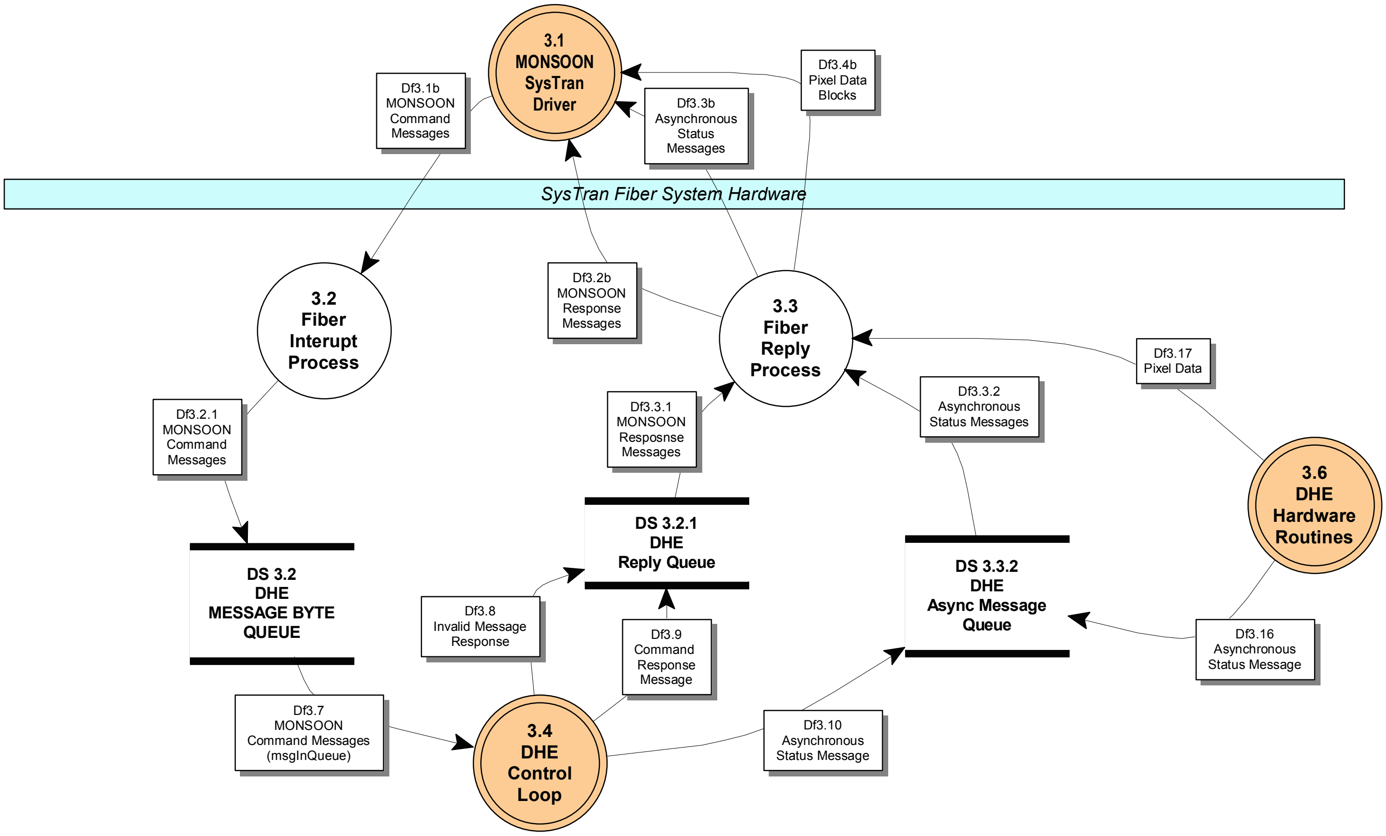

Figure 10 Level 2 DFD 3.2, 3.3 Fiber Interrupt and Reply

MONSOON DHE Data Flow Diagram (Level 2) - DHE Control Loop

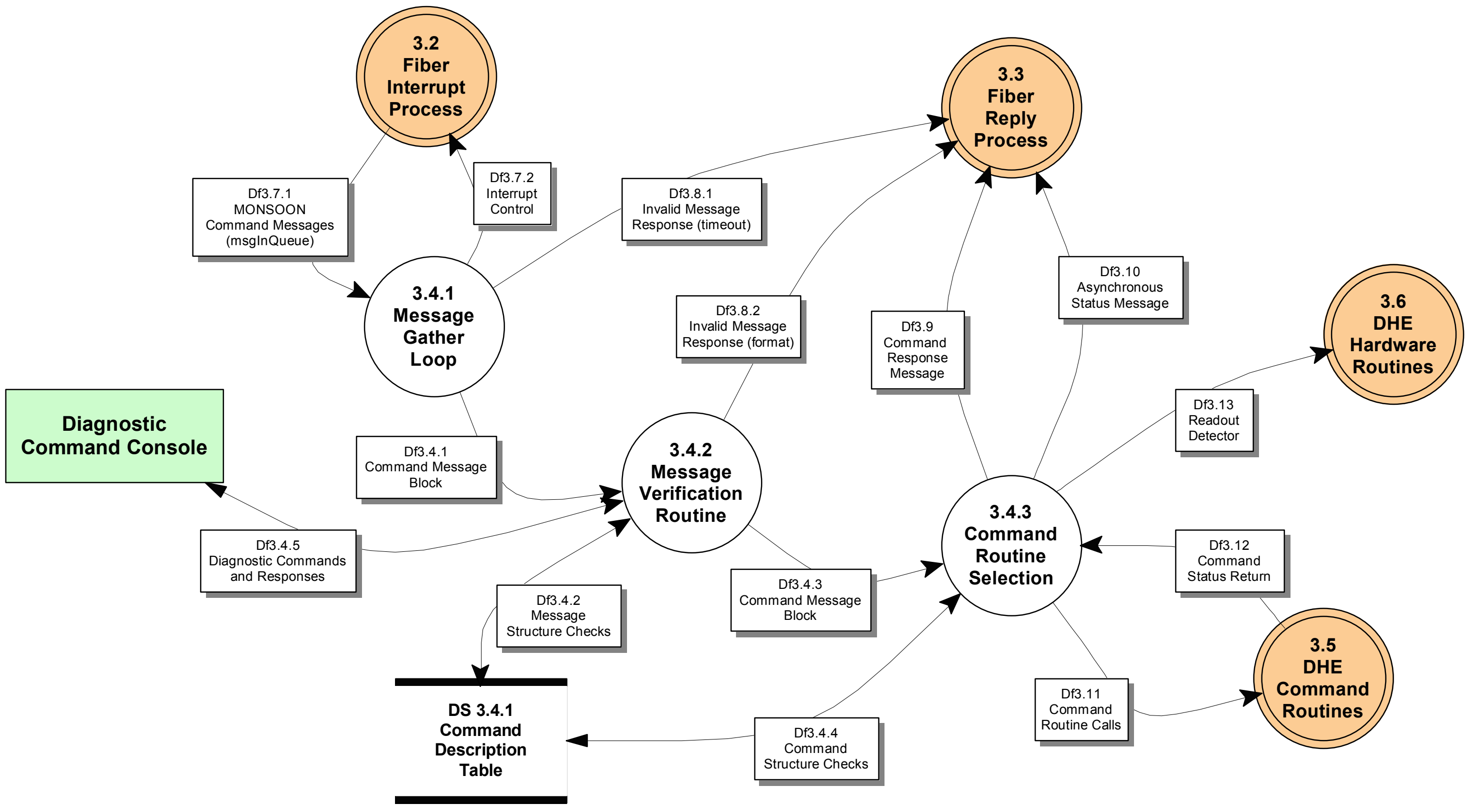

Figure 11 Level 2 DFD - 3.4 DHE Control Loop

MONSOON DHE Data Flow Diagram (Level 2) - 3.5 DHE Command Routines

Command Routine Calls

readValue
writeValue
loadWaveForm
readDetector
resetDetCntrlr
abortReadout
detPwrCntrl
shutterCntrl
biasPwrCntrl
asyncResponse
readValueArray
writeValueArray
testDatalink
testClockDrivers
testDCBiasSup
testA/DConv
testD/AConv
testDI/OCircuit
asyncStatusMsg
startExp
pauseExp
abortExp
resumeExp
stopExp

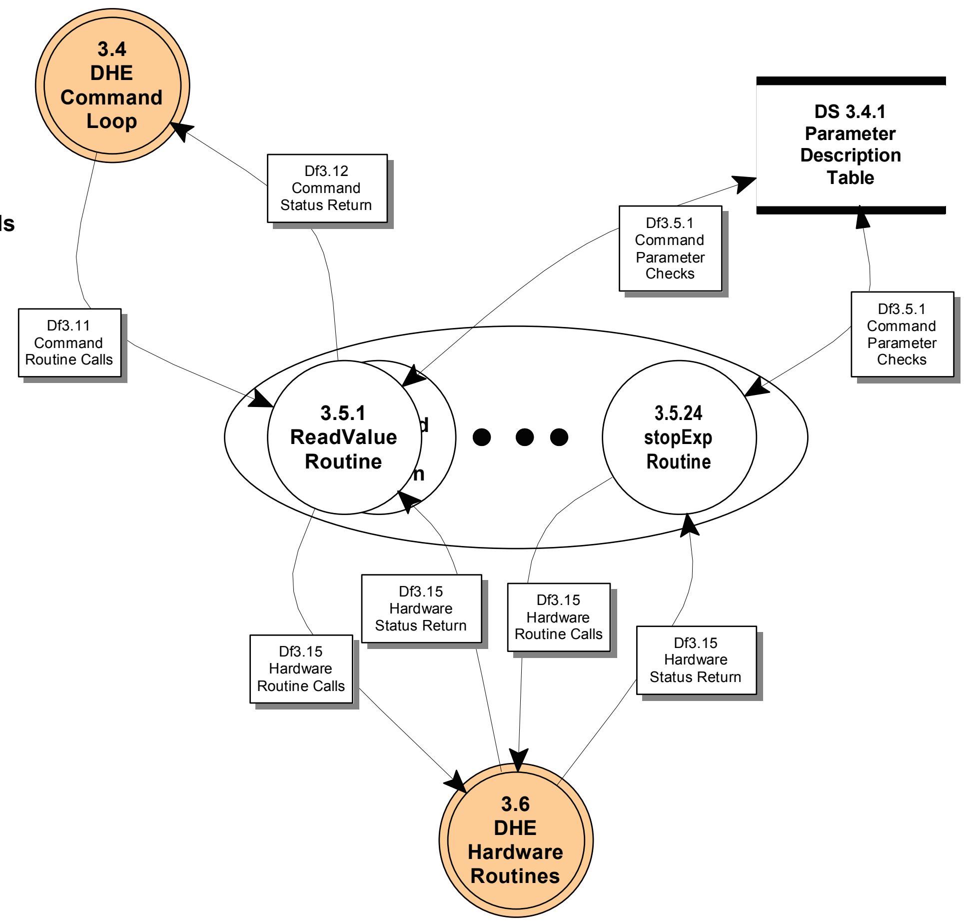

Figure 12 - Level 2 DFD - 3.5 DHE Command Routines

MONSOON DHE Data Flow Diagram (Level 2) - 3.6 DHE HardwareRoutines

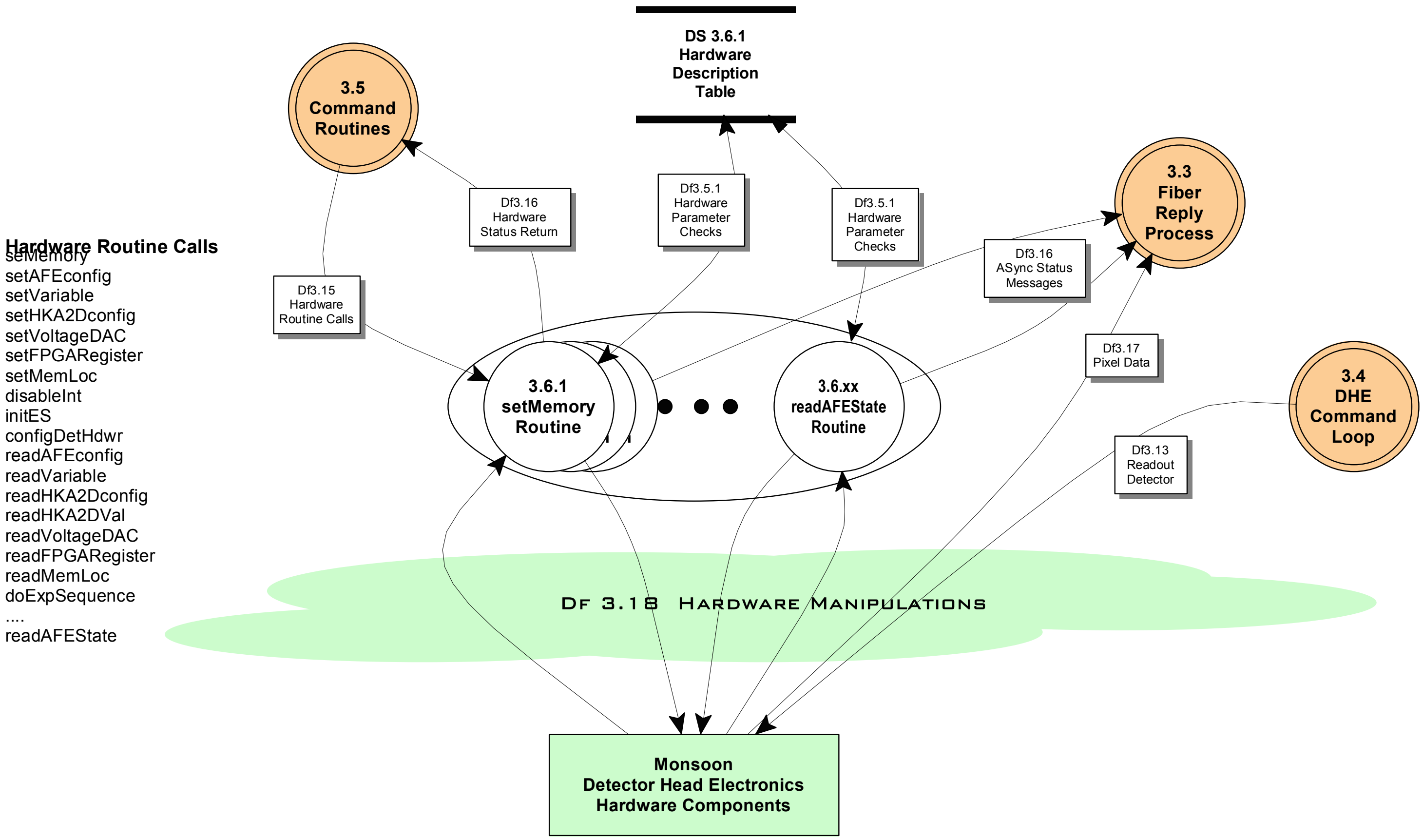

Figure 13 - Level 2 DFD - 3.6 DHE Hardware Routines

5.3 Program Designs

5.3.1 Initialization / Connection Handler

5.3.1.1 Data Flow Diagrams

5.3.1.2 Process State Diagrams

5.3.1.3 Process Psuedo Code

5.3.1.4 Correctness

5.3.2 Control Loop

5.3.3 Ethernet Command Response Handler