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MONSOON

Image Acquisition System (Pixel Server)

Pixel Acquisition Node Software Design Document

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Revision Chart

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0.1.1	20020731	all	First Draft of design document

Identification

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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 Tello International Observatory (CTIO)

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Preface

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

Document Scope

This MONSOON Pixel Acquisition Node Software Design document is the top-level subsystem design document for the MONSOON component that handles the upper level command and data interfaces and communication with the MONSOON DHE. It will incorporate the operational concepts previously defined in the MONSOON Operational Concepts Definition Document (OCDD), and the detailed requirements and constraints from the MONSOON Functional Performance and Requirements Document (FPRD) This Document receives its specification from the MONSOON System Architecture Document.

This document is intended to show the detailed issues of the PAN software and Hardware. It will flow-down the system requirements from the MONSOON System Architecture Document to the PAN system processes and software.

Document Overview

This MONSOON Pixel Acquisition Node Software Design Document is modeled after the IEEE Recommended Practice for Software Design Documents referenced below in section 2. It is intended to communicate system details to the users, developers, and support staff at NOAO.

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 some way affected by this system.

1.0 Definitions, Acronyms, and Abbreviations

1.1 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 Pre-processor 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

1.2 Glossary

Attribute - An entity that 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 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 or attributes) that 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.

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 a 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 techniques such as Fowler sampling, sample up the ramp, etc. (For example, an exposure would be the data array which

results when a single Reset-Readout-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, Co-additions of Images, Orthogonal Transfer Imaging (Guide Region Readout followed by centroid calculation followed by image shift, n times until the 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 an 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 meta-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. 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 fiber-optic interface cable. Previously called the MONSOON Detector Controller.

Pixel Acquisition Node (PAN)- 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 that 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.

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 – is 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 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 may be physically running on a specific computer along with on of the PANs.

1.3 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) NOAO Document - ICD 4.0 Version 0.1.2 - "Generic Pixel Server- Communications, Command/Response and Data Stream Interface Description", Nick C. Buchholz (NOAO), Phil N. Daly (NOAO), Barry M. Starr (NOAO), 20020318
- 9) 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
- 10) NOAO Document - ICD 6.1 Version 0.1.6 - "MONSOON Detector Head Electronics - Command and Data Stream Interface Description", Nick C. Buchholz (NOAO), Barry M. Starr (NOAO), 20020308
- 11)

2.0 MONSOON System Description

2.1 MONSOON System Overview

The MONSOON PAN software is the middle level system in the first-level decomposition of the MONSOON System Architecture. It provides the interface to the MONSOON DHE System and handles the translation from the GPX commands to the DHE interface commands. It provides the pixel data pre-processing and the assembly of the output data sets resulting from an exposure or exposures. Figure 1 below, from the MONSOON System Architecture Document, shows the PAN in the context of the entire MONSOON system.

Monsoon System Context Diagram

(Level 0)

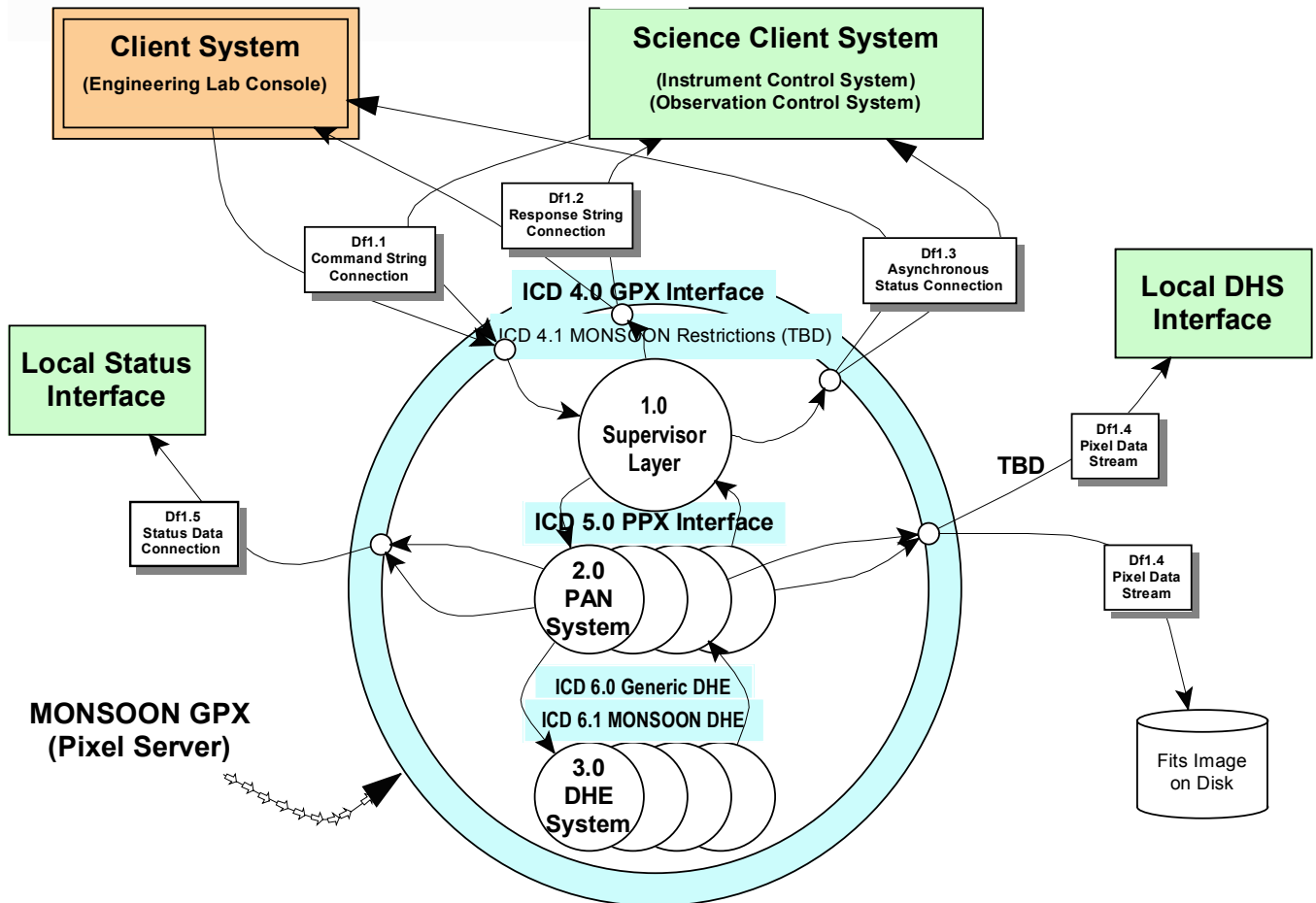


Figure 1 MONSOON System Context Data Flow Model. Shows the major “layers” of the MONSOON System. The Supervisor Layer, the Pixel Acquisition Node (PAN) Layer, and the Detector Head Electronics (DHE) Layer, as well as external entities, that are sources and sinks of data in and out of MONSOON.

The MONSOON system is based on a scalable network of powerful, low-cost 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 digital communications and processing platform that can be used for large imaging systems.

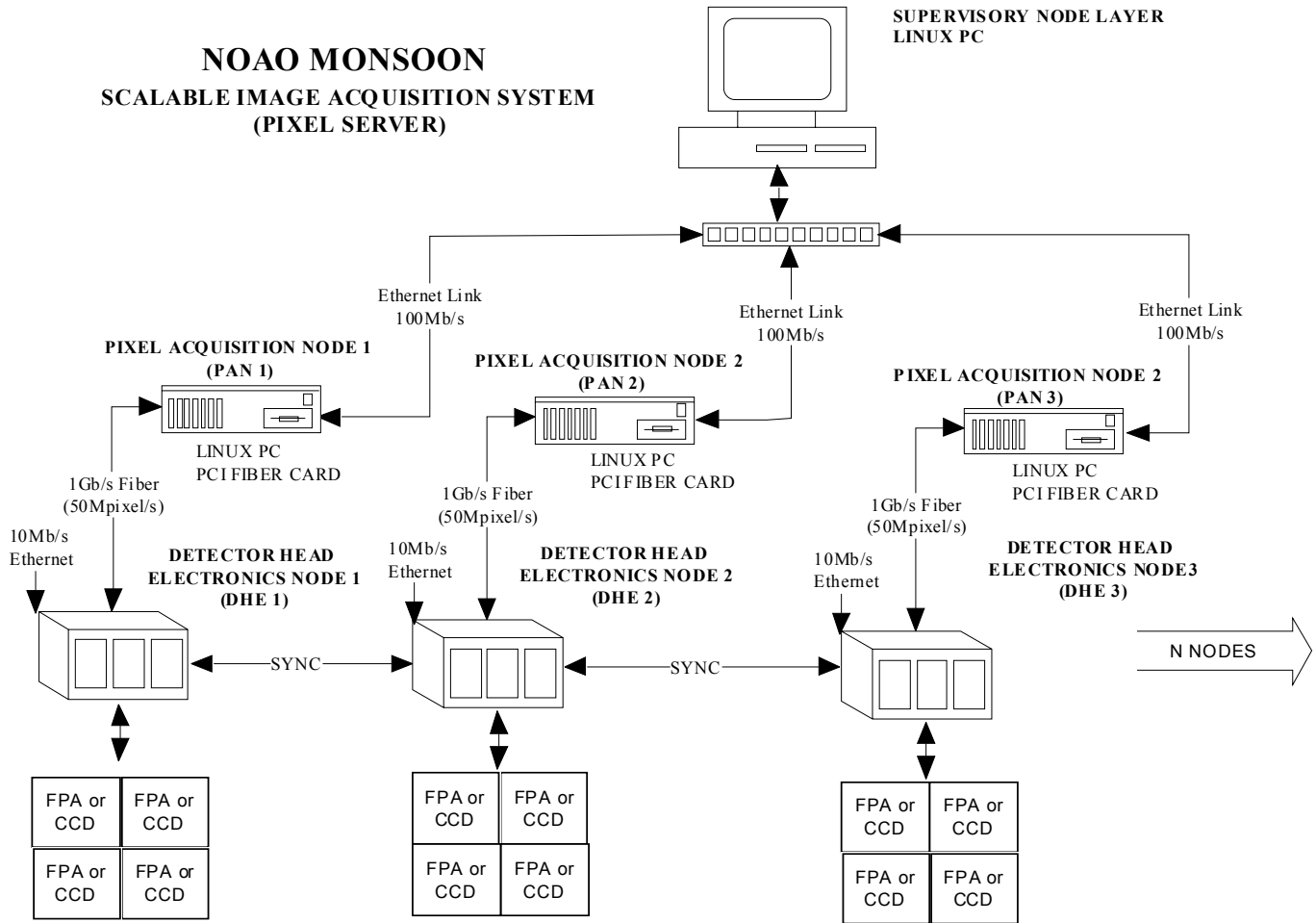


Figure 2 MONSOON Scalable Image Acquisition System Architecture, Illustrates a possible N node implementation. Nodes are added to the system as needed and or as costs permit.

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 limiting 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.

2.3 MONSOON PAN Hardware Description

The MONSOON Image Acquisition System Architecture Diagram in Figure 2 above outlines the most general form of a MONSOON system. A simplification of the general case, consisting of a single PAN-DHE node pair, will be used to in the description process. Since the PAN-DHE node pairs in a system use identical software and the Supervisory layer is the only part of the system which needs to know the actual configuration for most purposes the description of a single node system is sufficient to outline the basic design of the PAN software

2.3.1 PAN Computer Description

The PAN hardware consists of a single general purpose computer equipped with Ethernet connections to external systems, a fiber optic link to the DHE Node, an internal hard disk and internal memory equivalent 1 Giga-Byte. The current design calls for the use of LINUX PCI bus based systems with Giga-Hz class CPU's.

2.3.2 PAN Communications Links

Using the Figure 2 above as a reference, two significant communication links between the PAN and other parts of the system exist. These are: The fiber optic link to the DHE and the Ethernet Links to the outside world.

2.3.2.1 The SL100/SL240 Fiber optic Link

The fiber optic link to the DHE is a 1.0 to 2.4 Gb/S fiber optic 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 bi-directional communication between the PAN and Detector Head Electronics.

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

2.3.2.2 The Ethernet Links(s)

The Ethernet network is ground-isolated 10-base-T Ethernet. This can be upgraded to 100-Base-T if necessary or additional 100-Base-T links can be added for data transmission.

3.0 PAN System Software Design

Figure 1 on page 7 shows where the PAN software exists in the overall MONSOON system. The interface to the PAN nodes will be ICD 5.0; this interface will be a 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.

Monsoon Pixel Acquisition Node Data Flow Diagram (Level 0)

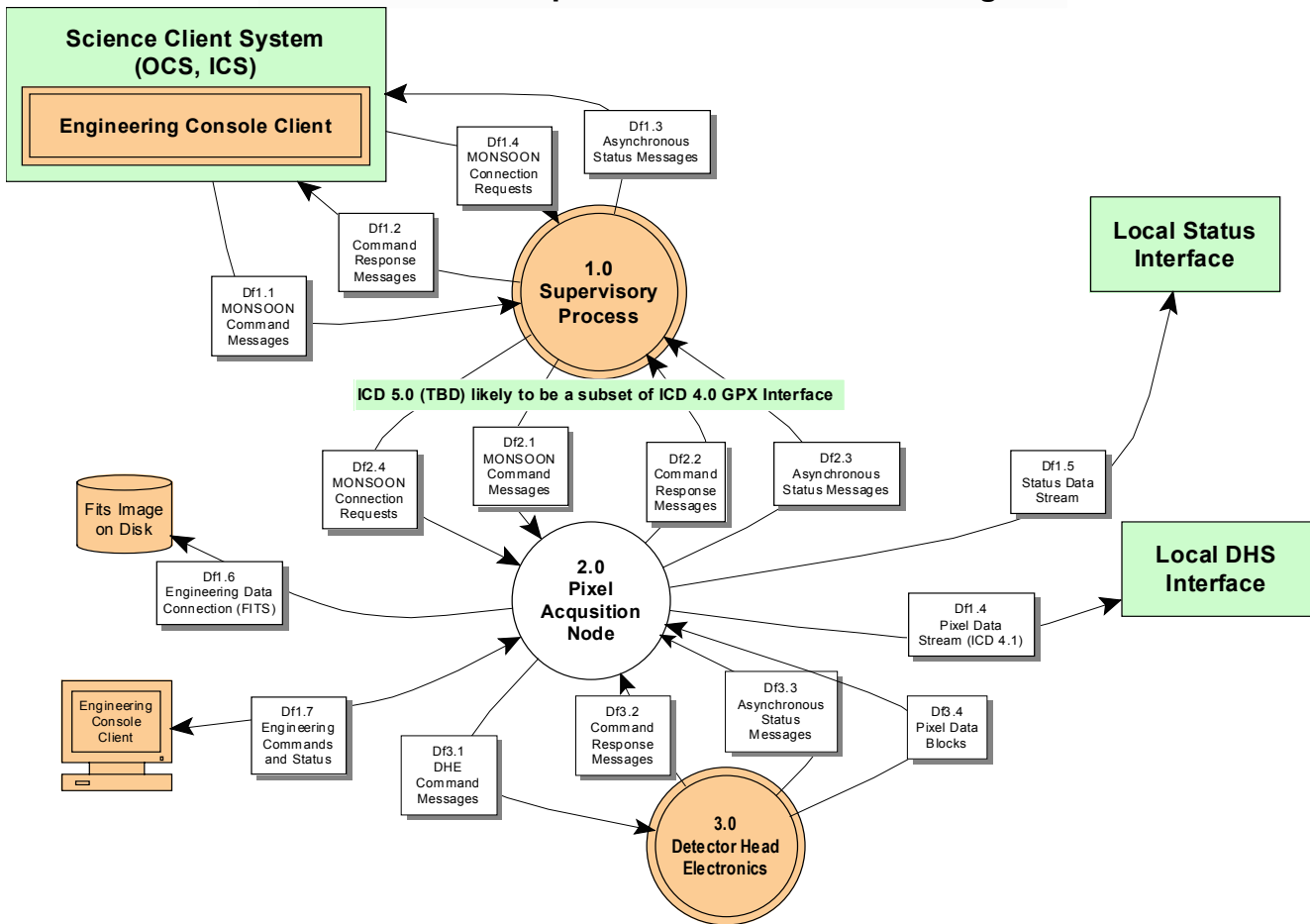


Figure 3 below details the context for the PAN software. Note that in this context the PAN software is limited to those routines and functions dealing with data capture, pre-processing and handling and with the communications with and control of the DHE hardware. These functions can be separated both from the design standpoint and as a matter of policy from the higher-level functions involved in observing. The PAN is considered to have little or no understanding of science observations, it simply executes or passes on commands and processes and archives incoming data without needing to understand the purpose of the commands.

Monsoon Pixel Acquisition Node Data Flow Diagram (Level 0)

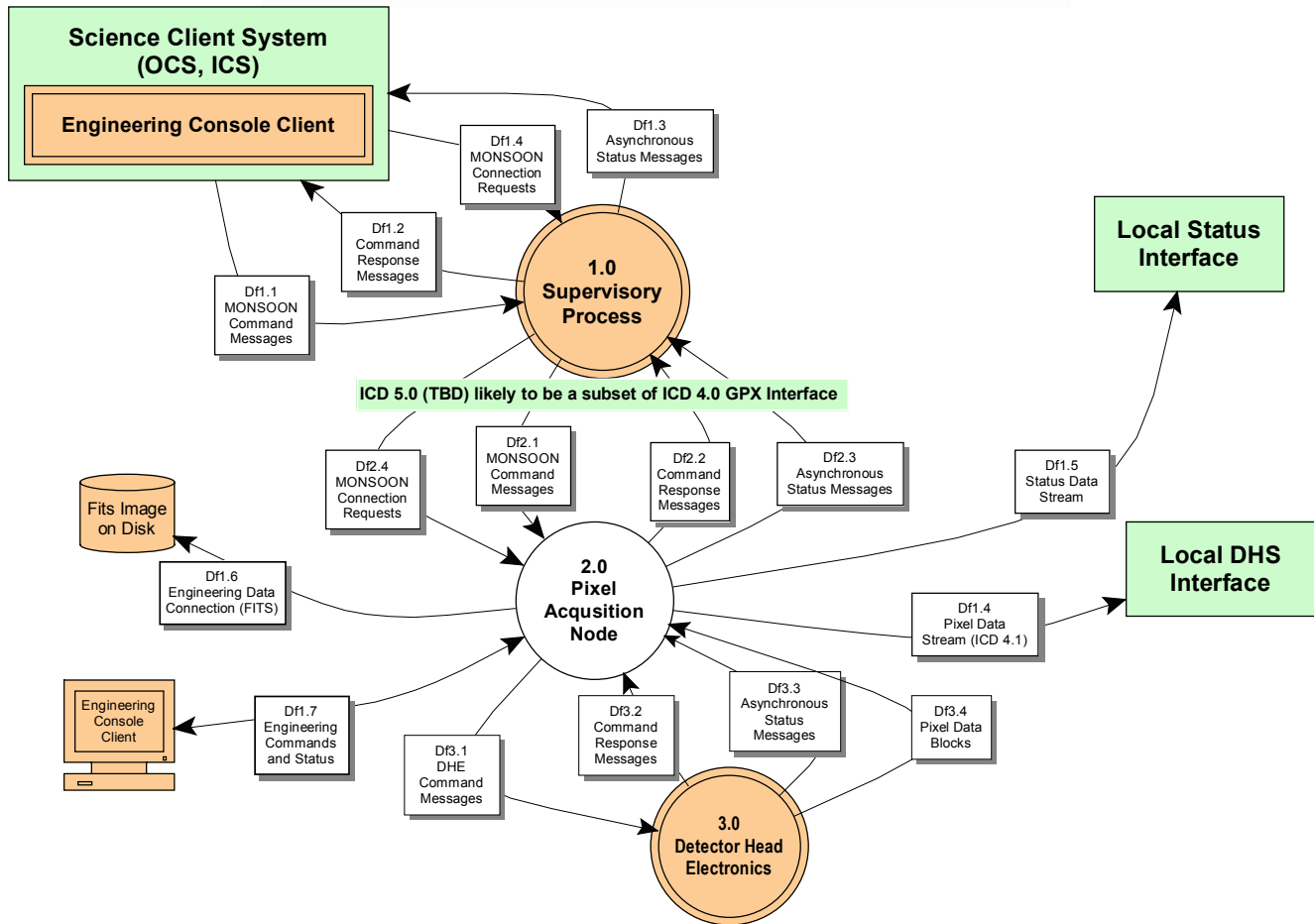


Figure 3 MONSOON PAN Context diagram – This diagram shows the data flows between the PAN and the external sources and sinks of data and commands.

The diagram contains two external entities labeled “Engineering Console Client”. This indicates that while the normal engineering access to the PAN system will be through the standard ICD 4.0/5.0 interface. The engineering console client system will probably include methods that will allow the normal interface to be by-passed in the case that this is necessary.

3.1 Interfaces

Three Interface documents exist that outline the 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 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), Phil N. Daly (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

3.2 Pan Top-level Functions and Requirements

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

1. Boot-up and Initialize the PAN hardware and software. **FPRD 2.2.2.1**
2. Start-up, initialize and connect to the PAN-DHE fiber link driver and DHE software. **FPRD 2.2.2.1**
3. Accept Client system Connection requests and connect to Client systems.
4. Receive, Verify and reformat Client Commands. **FPRD 2.2.2.2**
5. Execute Valid Commands, pass commands to the DHE and other PAN components as required **FPRD 2.2.2.3**
6. Accept, generate and pass on Command responses from system components. **FPRD 2.2.2.3**
7. Accept, generate, respond to or pass-on Asynchronous messages from the DHE or other components **FPRD 2.2.2.3**
8. Capture Pixel Data into processor memory **FPRD 2.2.2.4, FPRD2.2.2.5**
9. Perform such pixel data Pre-Processing tasks as are required by the current exposure mode **FPRD 2.2.2.6**
10. Cause the processed data to be preserved or archived for later use **FPRD 2.2.2.6**
11. Capture, generate and publish status data required for efficient use of the Pixel Server system. **FPRD 2.3.6, FPRD 2.3.7**
12. Maintain and access the configuration database for the current and stored configurations. **FPRD 2.4.2.1, FPRD 2.4.2.2**
13. Maintain and access the configuration database for the current exposures. **FPRD 2.4.2.2**
14. Detect, log and recover from errors as able. **FPRD 2.3.7**
15. Detect, log and announce "unrecoverable" or "Detector Unsafe" errors **FPRD 2.3.7**

3.3 System Decomposition

This section will decompose the PAN software into modules. The modules are chosen to efficiently accomplish the functions and requirements assigned to the PAN software and to allow independent development of the modules. Some modules may be implemented as Processes and some as libraries of routines to be used by the processes. Part of the decision process for this decomposition was the ability for modules to be developed independently.

Figure 4 below is the first level Data flow decomposition of the PAN software. Following the diagram are explanations of the Data Flows, Data stores, Processes and external entities displayed in the diagram.

Monsoon Pixel Acquisition Node Data Flow Diagram (Level 1) <Under Revision>

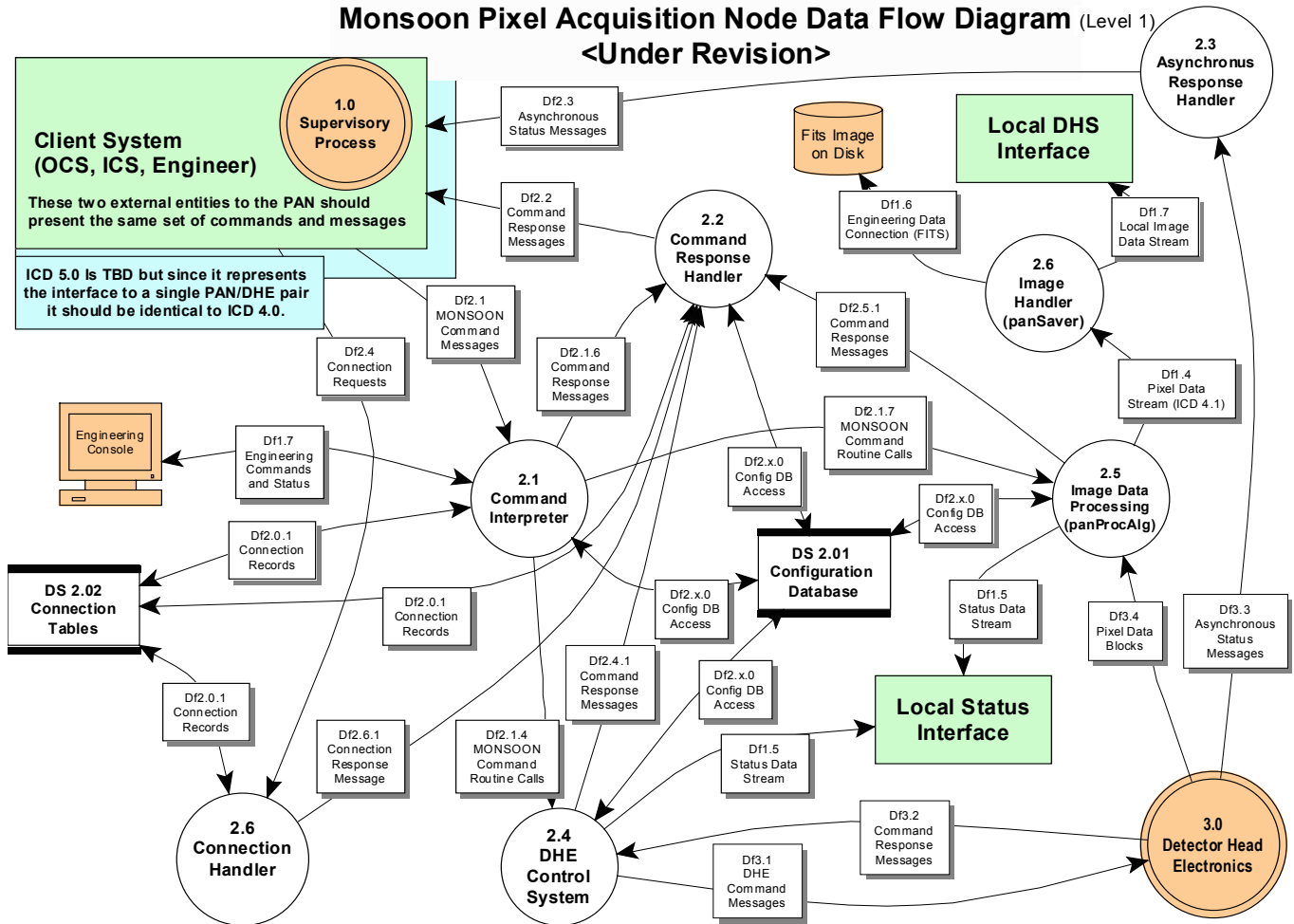


Figure 4 MONSOON PAN Level 1 System Decomposition

I. External Entities

- Client Systems – systems which will connect to and use the PAN software. At a minimum an Engineering client will be built for testing. The interface to the MONSOON Supervisory layer or to the PAN Engineering interface will both follow ICD 4.0.
 - Engineering Console Client – an engineering client for testing and detector development
 - 1.0 Supervisory Layer – The top layer of the MONSOON system which implements ICD 4.0 the GPX interface
- Local DHS Interface – the interface to the local DHS. This entity will act as a translator between the GPX data stream definition and the local DHS. At a minimum this entity should be able to take a FITS image in memory and write it to the local disk.
- Local Status Interface – This entity will translate between the GPX status data stream and the local status publication mechanism. At a minimum this

entity should be able to display status information on an xterm or console window.

- FITS image on Disk – the PAN must be able to write a FITS image of the captured data to the local disk or use the Local DHS Interface to perform that function.
- 3.0 Detector Head Electronics – the low level hardware and software which directly control the configuration and readout of the detector.

II. PAN Processes

- 2.1 Command Interpreter -
- 2.2 Command Response Handler
- 2.3 Asynchronous Message Handler
- 2.4 Detector Control System (dheCS)
- 2.5 Image Data Pre-processor System
- 2.6 Connection Handler

Not shown but also possibly present are an Initialization Handler, Database Handler and Error Recovery process

III. Data Stores

- DS 2.01 – Configuration Database
- DS 2.02 – Connection Datastore

IV. Data Flows

- Df 1.4 Pixel Data Stream (ICD 1.1)
- Df 1.5 Status Data Stream
- Df 1.6 Engineering Data Connection (FITS)
- Df 1.7 Engineering Commands and Status
- Df 2.0.1 Connection Records
- Df 2.1 MONSOON Command Messages
- Df 2.1.4 MONSOON DCS Command Routine Calls
- Df 2.1.6 Command Response Messages
- Df 2.1.7 MONSOON IDPS Command Routine Calls
- Df 2.2 Command Response Messages
- Df 2.3 Asynchronous Status Messages
- Df 2.4 Connection Requests
- Df 2.4.1 Command Response Messages
- Df 2.5.1 Command Response Messages
- Df 2.6.1 Connection Response Message
- Df 2.x.0 Configuration DB Access
- Df 3.1 DHE Command Messages
- Df 3.2 Command Response Messages
- Df 3.3 Asynchronous Status Messages
- Df 3.4 Pixel Data Blocks

3.4 PAN Design Decomposition

3.4.1 Start-up and Initialization

- 3.4.1.1 Buffers, Shared Memory**
- 3.4.1.2 Queues, Semaphores**
- 3.4.1.3 Command Table**
- 3.4.1.4 Attribute Table**
- 3.4.1.5 Socket connection structures**

3.4.2 Connection Handler

- 3.4.2.1 Security**
- 3.4.2.2 Connection restriction**
- 3.4.2.3 Create, Bind, Listen on sockets**
- 3.4.2.4 Connect**

3.4.3 Command Interpreter

- 3.4.3.1 Parse command**
- 3.4.3.2 Call command function**

3.4.4 Command Execution

- 3.4.4.1 Verify parameters**
- 3.4.4.2 Log command**
- 3.4.4.3 Execute command**
- 3.4.4.4 Verify response**
- 3.4.4.5 Verify execution**

3.4.5 Command Response Handler

- 3.4.5.1 Gather response**
- 3.4.5.2 Log response**
- 3.4.5.3 Send to MSL**

3.4.6 Data Capture Routines

3.4.7 Image Data Pre-processor System

3.4.8 Asynchronous Response Handler

3.4.9 Error Recovery Routines

3.4.10 DHE Communications Routines

3.4.11 Database Interface Routines

3.4.12 Image Output Routines

3.4.13 Status Info Gather and Publish

3.5 Module Interface APIs

- 3.5.1 Initialization Routine**
- 3.5.2 Command Response Handler**
- 3.5.3 Detector Control System**
- 3.5.4 Image Data Pre-processor System**
- 3.5.5 Asynchronous Response Handler**
- 3.5.6 Error Recovery Routines**
- 3.5.7 DHE Communications Routines**
- 3.5.8 Database Interface Routines**

3.6 Process Descriptions

- 3.6.1 Initialization / Connection Handler**
- 3.6.2 Command Acceptor & Interpreter**
- 3.6.3 Command Response Handler**
- 3.6.4 Detector Control System**
- 3.6.5 Image Data Pre-processor System**
- 3.6.6 Asynchronous Response Handler**

3.7 Engineering Console Client

3.7.1 Test sequencing

3.7.2 Test Hardware Control

3.7.3 GPX control

'C', Python, Java or LABVIEW implementation of GPX interface ICD 4.0

3.7.4 Error handling

4.0 PAN Software Detailed Design

4.1 Detailed Interface Support

4.2 Process Designs

4.2.1 Initialization / Connection Handler

4.2.1.1 Data Flow Diagrams

4.2.1.2 Process State Diagrams

4.2.1.3 Process Psuedo Code

4.2.1.4 Correctness

4.2.2 Command Acceptor & Interpreter

4.2.3 Command Response Handler

4.2.4 Detector Control System

4.2.5 Image Data Pre-processor System

4.2.6 Asynchronous Response Handler

4.3 Engineering Console Support

Console may have a direct link to DHE code to facilitate low level debugging. Though this is **NOT** necessary.

