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MONSOON

Image Acquisition System (Pixel Server)

Functional and Performance Requirements Document (FPRD)

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Revision Chart

Version	Date Approved	Sections Affected	Remarks

Identification

It is NOAO Document # XXXXXXXXXXX.

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.

This document is intended to define the detailed system requirements for a new image acquisition system named MONSOON to be developed for the next generation imaging system requirements at NOAO. It will incorporate the operational concepts previously defined in the MONSOON Operational Concepts Definition Document (OCDD), state all known design constraints, as well as combine the design configuration into a set of detailed requirements.

This document is intended to communicate the requirements of the users, to the technical developers who will design and build the MONSOON system. It is used to form a bridge between the users or stakeholders and the system developers and as such must be understandable by both parties. It will define the system's expected functional capabilities, as well as its performance requirements and the environments it must operate in.

To serve this function the requirements defined in this FPRD should have the following properties:

- 1) Unique Set. Each requirement should be stated only once
- 2) Normalized. Requirements should not overlap
- 3) Linked Set. Explicit relationships should be defined among individual requirements to show how the requirements are related to form a complete set.
- 4) Complete. An FPRD should include all requirements identified by the OCDD, as well as those needed for definition of the system.
- 5) Consistent. The FPRD should be consistent and noncontradictory in the level of detail, style of requirement statements, and in presentation of the material.
- 6) Bounded. The boundaries scope and context of the set of requirements should be identified.
- 7) Modifiable. The FPRD should be modifiable. Clarity and nonoverlapping requirements contribute to this.
- 8) Configurable. Versions should be maintained across time and across instances of the FPRD
- 9) Granular. This should be the level of abstraction for the system being defined..

Document Scope

This Functional Performance Requirements Document (FPRD) is intended to provide a "black-box" description of what the system should do, in terms of the system requirements, performance, functionality, as well as interactions and or interfaces with its external environment.

This document is the second-level development document for the MONSOON Image Acquisition System, consistent with the top-level MONSOON Operational Concepts Definition Document (OCDD). All other MONSOON Documents are required

to be in compliance with this document. Physical implementation details are not included, except where they represent a defined system constraint which must be addressed.

Document Overview

This FPRD is modeled after the IEEE Guide for Developing System Requirements Specifications Document referenced below in section 2. It is intended to communicate detailed system requirements to the users, developers, and support staff at NOAO.

The FPRD is largely based on the initial NDAS Project Concept Definition Document that 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 follow-on document to the FPRD is the MONSOON System Architecture Document where implementation detail will be added and will serve as the top-level system design document.

The intended audience for this FPRD 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 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
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.

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 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, 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.
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- 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
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- 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 Head Electronics - Command and Data Stream Interface Description", Nick C. Buchholz(NOAO), Barry M. Starr(NOAO), 20020308
- 11) NOAO Document ###.###.&&& - ICD 6.1 Version 0.1.2 - "MONSOON DHE - Command and Data Stream Interface Implementation Description", Nick C. Buchholz(NOAO), Barry M. Starr(NOAO), 20020308

12) MONSOON System Description

2.0 General System Description

2.1 System Overview

A fundamental MONSOON System design paradigm is that all astronomical 2-dimensional imaging system operations can be modeled in a similar way regardless of technology or spectral range. This model assumes that the telescope and instrument interface is handled at the next level up in the observatory control hierarchy, and that MONSOON deals with the image acquisition portion only. In the control and data flow of such a system every effort must be used to minimize complexity, partition functions into rational breakdowns and employ proper levels of abstraction in the system design. Data stores should be tailored such that complexity is reduced and information is concentrated in known accessible locations not spread all over the system in multiple configuration files. Data concurrency, system maintenance, and upgrade should be design parameters from the beginning.

Here is 2-d imaging system operation breakdown into 4-step process:

- 1) Define Image Parameters
- 2) Request Image(s)
- 3) Acquire Image
- 4) Process Image Data

Each step can then be further expanded

- 1) Define Image Parameters
 - Submit User Defined Image Parameters (Raster Size, Binning, Integration Time, etc.)
 - Translate to Acquisition System Parameters (if Req'd)
 - Download to Acquisition System Hardware.
- 2) Request Image(s)
 - Send Exposure Initiation Command to Low-Level Hardware(s)
 - Acquire FITS Header Information from External Observatory Systems (if Req'd)
- 3) Acquire Image(s)
 - Apply Appropriate Clocks and Biases to Clear and Readout device
 - Time Exposure
 - Apply Appropriate Gain and Signal Processing to Analog Signal(if Req'd)
 - Digitize Data (if Req'd)
 - Transfer to Data Processing Component
- 4) Process Image Data
 - Process Data (Coadds, Descramble, Shift and Add, etc., if Req'd)
 - Attach FITS Header (if Req'd)
 - Save to Local Disk (if Req'd)
 - Send to Display and Archiving Systems

This is exactly what the MONSOON System must accomplish in a detector-limited performance fashion while minimizing system overheads and down-time in order to maximize observing efficiency.

2.2 System Context

2.2.1 Detector Research and Development Operations

The MONSOON system will be used extensively in the NOAO Detector Research and Development laboratory activities for both IR and OUV devices. As such MONSOON must be able to be efficiently integrated with lab test dewars and provide the capabilities to adjust device interface parameters which will promote the characterization and development of detector technologies.

2.2.2 Instrument Development

The MONSOON system will be used extensively in the NOAO next generation instrumentation development efforts such as NEWFIRM, GSAOI, QUOTA, ODI, and LSST. As such it must provide capabilities and facilities to aid instrument development such as extensive system diagnostic and self-test features. Additionally it must be reliable, compact, low-power, and modular to ensure that it integrates well with the instrument development life cycle.

2.2.3 Science Operations

The MONSOON system will be used extensively in multiple ground-based astronomical observatory environments from within NOAO (KPNO and CTIO) to other outside institutions. As such it must provide a well-defined interface, robust operation and solid error detection, logging, and diagnostics to support multiple years of service. In addition it must provide detector limited performance and maximized open-shutter time by minimizing system overhead and reliability losses. It must be compact to fit small enclosure requirements, low-power to minimize heat near the optical beam, and generally ease impact on observatory infrastructure in order to support it's incorporation it systems.

2.2 System Modes

The MONSOON System Modes follow directly from those defined in the MONSOON OCDD.

There are 5 basic modes of operation for the MONSOON system:

1. Science Observing
2. System Calibration
3. System Diagnostic
4. Detector Research and Development
5. Detector Characterization
6. Instrument Development

2.2.1 Science Observing Modes

Below is a list of observing modes that must be supported by the MONSOON system. The details of sequencing the telescope, instrument or exposure parameters needed to achieve these modes is outside the scope of the MONSOON system and will be handled by the Science Client system.

- Microstepping
- Dithering
- Chopping
- Nodding
- Mosaicing
- External Time Stamping
- Sequence Control
- Drift Scanning
- Nod and Shuffle
- Speckle Mode
- Orthogonal Transfer Imaging

2.2.2 System Calibration Modes

The MONSOON System must provide the capabilities to support the calibration modes below. The details of sequencing the telescope, instrument or exposure parameters needed to achieve these modes is outside the scope of the MONSOON system and will be handled by the Science or Engineering Client system.

- Focus Sequences
- Darks
- Flat Fields
-

2.2.3 System Diagnostic Modes

The MONSOON System must provide extensive remote diagnostic capability. This will include but not be limited to

- Power Supply Voltage and Current Readback,
- Clock and Bias Voltage Readback,
- Digital Communication Pathway Diagnostics,
- Generation of Predetermined Pattern Data - Generate known test pattern data instead of image data to test communication links and data reduction algorithms.
- Multiple External Clients - MONSOON will provide for multiple clients to link to the system in order to monitor current system activity. This capability will allow multiple observers or technical staff to monitor current science operations.

2.2.4 Detector Research and Development Modes

The MONSOON System must provide an effective solution for automatic device characterization such as that needed for effective test and optimization of a large number of detectors represented by the next generation systems described previously. Included in this capability will be the automated control and read back of detector clock and bias voltages as well as timing patterns necessary to optimize device operation. The operational mode to be supported in this context would be to provide the capability to support scripting of a large number of images taken with a predetermined parameter variation over an

extended period of time. The MONSOON system should provide the capability to automatically perform the following tests and procedures:

- Photon Transfer Curve
- QE Tests
- CTE Tests
- Dark Current Measurements
- Automated Adjustment of All Clock and Bias Voltages
- Automated Adjustment of All Timing Patterns

2.2.5 Detector Characterization Mode

The MONSOON System when used in this mode must provide the capabilities required for detector characterization and optimization. This will require the support of a variety of image sequencing modes such as the photon transfer curve and detector clock and bias variation for device optimization. In this mode it will need to be able to control laboratory light sources and instruments such as filter wheels, blackbodies, mono-chronometers, etc. These mode functions are outside of those needed for the following described modes of Instrument Development and Science Operations, and as such may be addressed outside of the Pixel Server System boundary through an external Engineering Client Module.

2.2.6 Instrument Development Mode

The MONSOON System when used in this mode must provide the capabilities required for effective instrument development. This will require the support of a variety of image sequencing modes within the instrumental development life cycle. Of particular interest are system diagnostics to evaluate system induced noise and reliability issues.

2.3 System States

The MONSOON System in each of the above imaging modes will move through a sequence of states from initialization through error detection and recovery, the state diagram shown below in **Figure 1** illustrates these state transitions. It should be well understood that this model is a simplification of the actual system operation where these individual states may be partitioned further into additional states for implementation reasons. Additionally it should be noted that a given state may spawn a separate software process to handle a necessary function such as Accept Connections or Process Captured Data. This level of detail is not included in this document and will be shown in lower level system documentation where it is more appropriate for system understanding.

MONSOON Top-Level System State Diagram

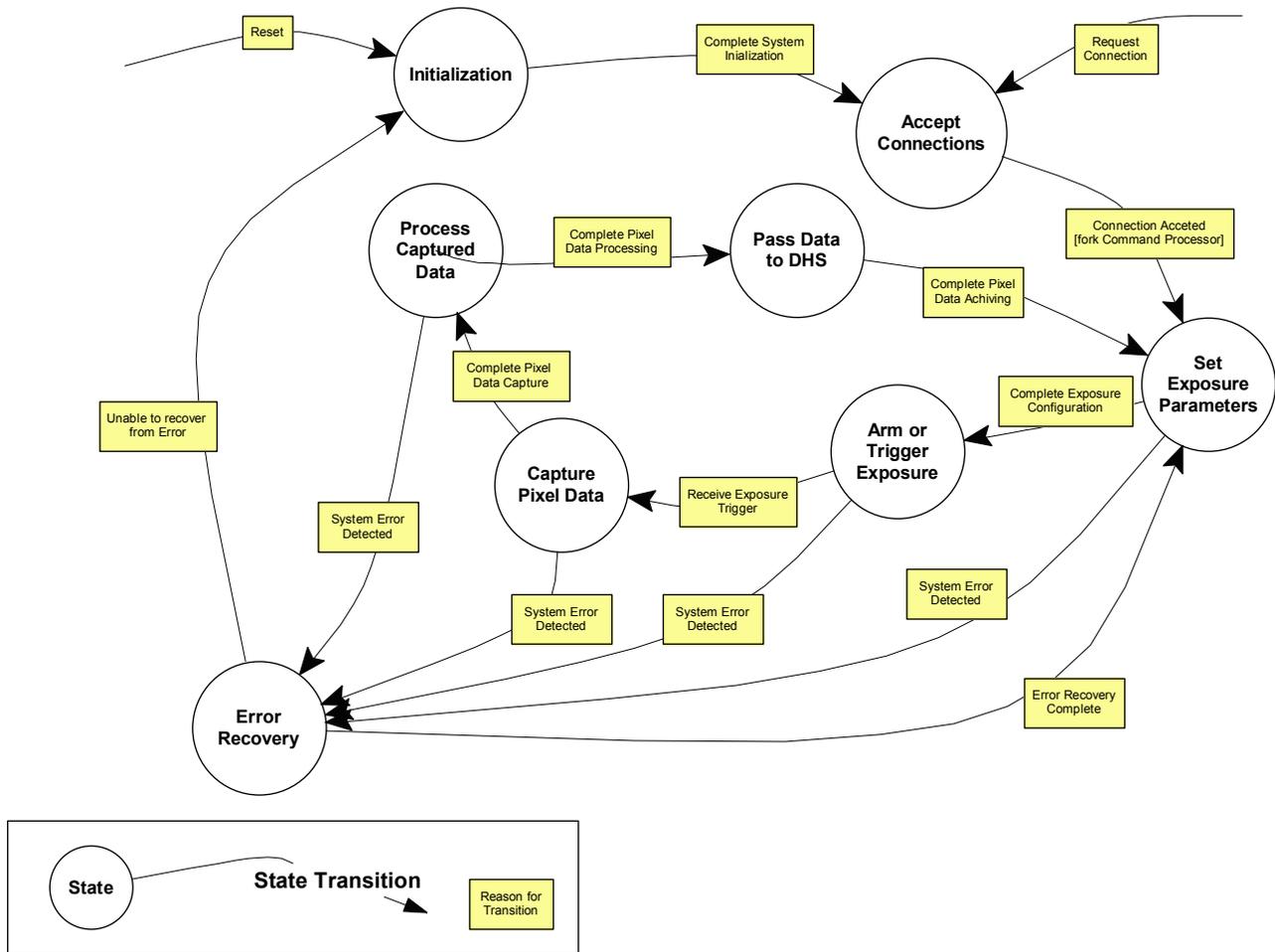


Figure 1. MONSOON System State Diagram. This diagram shows the basic state transition behavior of the MONSOON system design.

2.3.1 Initialization State

The MONSOON System will boot-up when turned on and initialize itself to begin the data taking process. The system components will perform individual initializations that will leave the detector in a default safe state ready to be configured to take data. The system components will then connect to each other and perform whatever initial self-tests are appropriate. When this process is complete the software will be in a state that will allow clients to connect to it and begin configuration and data taking.

2.3.2 Accept Connections State

The system will allow multiple clients to connect, view activity and issue commands. The system will verify the authorizations of each connection request and will, if necessary initialize the connection. The first initialized connection will be the default *Primary Connection*. The *Primary Connection* will handle

Asynchronous Messages from the MONSOON Pixel Server system to the Client systems. When a connection is made the system will start the command processor. The *connection acceptor* process will revert to waiting for additional connections.

2.3.3 Set Exposure Parameters State

The command processor will wait for commands from the available connections, accepting each command and processing it in order. All command and response behavior of the MONSOON system will be in compliance with ICD 4.0 the Generic Pixel Server ICD [9]. A single string response will be returned to the connection initiating the command for each command received. Commands will be passed to the command routines to be verified for correctness and executed as required. All commands will be assumed to be in a format that is compliant with ICD 4.0[9]. Command completion will be indicated by an asynchronous message or by the command response message.

2.3.4 Arm or Trigger Exposure State

The low-level system components will either be triggered to begin an exposure or will be armed thereby allowing an external trigger to for exposure control.

2.3.5 Pixel Data Capture State

The pixel data will be captured and transferred for low-level data processing.

2.3.6 Process Captured Data State

The pixel data will be processed to support the required data processing modes such as Fowler sampling, image coadditions, image descrambling or some combination of such processing.

2.3.7 Error Recovery State

Extensive error detection, logging, and correction will be provided.

2.4 Major System Capabilities

This section outlines the major capabilities of a MONSOON system as they have been so far identified

2.4.1 Client Connections

2.4.1.1 Multiple connections accepted

2.4.1.2 On-Telescope connection priority

2.4.1.3 Single Response connection (Async Messages)

2.4.1.4 Connection, Command and Parameter Security

2.4.2 System Functions

2.4.2.1 Detector Configuration Database Access and Management

2.4.2.2 Exposure Configuration Database Access and Management

2.4.3 Mosaic handling

2.4.3.1 Device Selection (1 to N, for mosaics)

2.4.3.2 Mosaics handled as a single Focal plane

2.4.4 Exposure Configuration and Control

2.4.4.1 Integration Time Selection

2.4.4.2 Exposure types

- Photon Capture/Object – shutter is open during integration time
- Bias – Shutter closed, zero integration time exposure
- Dark – Shutter closed, long integration time
- Reference - Single IRFPA Read
- Separate - Non subtracted, Non-CDS, double read of IRFPA

2.4.4.3 Device output Selection

2.4.4.4 Pixel Readout Modes

- Standard - One Pixel, Single Read
- Digital Filtering - One Pixel, Multiple Reads
- Binning - Multiple Pixels, Single Reads
- False Data at several levels in the hardware
-

2.4.4.5 Detector Sampling modes

- IR, CCD Single Readout
- IR Double Correlated Sampling
- IR Fowler Sampling
- IR Sample-Up-The-Ramp - (fixed time intervals through readout)
- Pixel by Pixel (2^N Samples Only) ?????

2.4.4.6 Internal Exposure Mode support

- Single Exposure Image (CCD, IR)
- Multiple Individual Images (CCD, IR)

2.4.4.7 External Exposure Mode Support

- Microstepping
- Dithering
- Chopping
- Nodding
- Mosaicing
- Focus Sequences

- External Time Stamping/Sequence Control
- Drift Scanning
- Nod and Shuffle
- Speckle Mode

2.4.4.8 Readout Speed Select

- Fast/Slow Readout Select

2.4.4.9 Region of Interest Definition

- Multiple Region of Interest Support

2.4.4.10 Charge Shifting - Orthogonal transfer imaging

2.4.4.11 Exposure Control

- Start -
- Pause - Close Shutter, Hold Image on CCD, Pause Integration Timer
- Resume - Open Shutter, Continue Integration and Readout
- Stop - Terminate and Save Data
- Abort - Terminate and Purge Data
- Arm Exposure - Wait for External Trigger

2.4.5 Interaction with External Systems

- Master Mode (Provide Trigger Signal to External Systems)
- Slave (Accept Trigger from External Systems)

2.4.6 Shutter Mechanism Control

The MONSOON system will provide the capability to control a shutter. The system will determine from the configuration parameters if the shutter is to be opened at the start of an integration and closed at the end of the integration. The system will also be able to control the shutter independently of the integration and detector state.

2.4.7 Housekeeping/Status tracking

The MONSOON system will periodically collect housekeeping data for use as engineering telemetry and as an addition to the pixel data to be included in with the Science data. This data will be collected at regular intervals, except that no such data will be gathered during the time the pixel data is being digitized. The system will also provide a means for all data to be tagged by TIME stamp and with an exposure ID unique to each image produced. The saving of engineering telemetry with the science data will be controllable by the client system.

2.4.8 Detector Monitoring, Maintenance and Protection

The MONSOON SSW will on boot-up insure the detector is in a safe state. It will insure that safe operations are maintained while it is running. It will verify that configuration and control commands are safe before executing them. It will perform such temperature monitor as is provided and insure that the array is operated safely given its current temperature.

The MONSOON system will be provided with power controls for the Detector bias voltages which allow safe operation of the detector bias voltages to be verified.

2.4.9 Self-Tests

The MONSOON SSW will be able to test the Fiber interconnection to insure the PAN-DHE Fiber is functioning properly. It will be able to test the bias voltage circuits to insure proper operation. and will be able to test the ADC chains to insure proper operation.

- Data Path Integrity Tests (Digital Test Patterns)
- Bias and Clock Voltage Readback Telemetry
- Transfer Curve Tests
- Bias Tests

2.4.10 Error Detection, Logging, and Correction

In the face of errors the MONSOON system will attempt to continue or resume the data taking process without human intervention where it is deemed appropriate. Appropriateness will be defined by the nature of the errors and their impact on the system and particularly the detector safety, and how well the errors are understood and anticipated. One example of an appropriate error to handle automatically, maybe a power glitch at the DHE. This may be anticipated due to the well-known issues of power instability found in a number of observatories. An example of an inappropriate automatic error correction would be if a detector interface voltage was found to be out of range. This error should raise a concern for detector safety and require intervention by qualified support staff before operation is resumed.

Under all conditions, connections between the PAN and DHE will be re-established if lost. Data that has been processed will be preserved to a permanent media for later retrieval.

When possible the system will be able to detect the following types of errors.

- Socket Transmission Errors
- FIBER Transmission errors
- Lost Client Control connections
- Lost Client Response connections
- Lost Client Async Message Connection
- DHE hardware errors (broken DAC's, ADC's)
- Power Glitches <100ms
- Power Outages >100ms

In addition the MONSOON SSW will attempt to recover from the following errors without human intervention:

- Socket Transmission Errors
- FIBER Transmission errors
- Lost Client Response connections
- Lost Client Async Message Connection
- Power Glitches <100ms

2.4.11 Post Image Acquisition Data Processing

This defines the processing required for image data prior to FITS packaging and transfer to the Image Handling System (IHS). These requirements should be based on observing efficiency, the direct impact on the observer's ability to do on-sky image acquisition. If processing can be done further down stream in the "pipeline" without negatively impacting the observers immediate efficiency it should. Certain of these functions are very specific to the focal plane in question, and do not often translate well into universal "do all" elements. It's my opinion that those processing modes should be implemented as software "plug-ins" as stated previously to ease in system configuration control and software maintenance issues. This is an attempt to keep the NDAS as simple and manageable as possible. This will be broken into two categories IR and Visible

2.4.11.1 Descrambling

2.4.11.2 Centroiding (for ODI Fast Guiding on "OTCCDS" for example)

2.4.11.3 Data Scaling

2.4.11.4 Data Processing Modes:

- Correlated Double Sampling (CDS, Image Subtraction)
- Multiple Sample Readout Reductions (listed in section)
- Coadds
- IR Reference Pixel Subtraction
- Other modes must easily added as required for special purpose applications

2.4.11.5 FITS Packaging

2.4.12 Auxiliary Control Issues

Auxiliary control functions that are not directly part of the detector interface but are closely linked include the following:

2.4.12.1 Focal Plane Temperature Control and Sense

2.4.12.2 Remote System Reset

2.4.12.3 Power Supply ON/OFF Control

2.4.12.4 Power Supply Voltage/Current Readback

2.4.13 Detector Interface Parameters

The interface requirements to detectors can be divided into two broad categories: Stimulus and Acquisition. Though individual detectors have unique detailed requirements in these areas, particularly in clock and bias levels, all current devices still require these same functional elements. These two categories can be further partitioned as follows. Specification for actual devices will have to be handled on a device by device and potentially system by system basis. The MONSOON System must be designed to allow impacts of changes in device interface requirements has a minimum impact of the system in entirety.

2.4.13.1 Clock Driver Requirements

- Number
- Voltage Levels
- Voltage Adjustability (if Req'd)
- Timing Adjustability
- Clocking Patterns (Sequencing)
- Clock Cross Over
- Drive Capability
- Noise
- Stability
- Repeatability

2.4.13.2 Biases

- Number
- Voltage Levels
- Voltage Adjustability
- Timing Adjustability
- Clocking Patterns (Sequencing, if Req'd)
- Drive
- Noise
- Stability
- Repeatability

2.4.13.3 Signal Processing

- CDS (CCDs only)
- Offset
- Gain Select
- Bandwidth Select
- Digitization

2.4.14 Detector limited performance

A formal analysis and requirements flow-down to the interface electronics has been performed based on the most optimistic and demanding performance parameters projected. These 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: < 0.1% 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: Unlimited with Fiber Broadcast Capability
- # of Channels/Controller: Upto 256 Channels per Controller Chassis
- # of Controllers/System: >100
- Calibrated, Measured, Recorded Performance.

2.5 Major System Conditions

2.6 Major System Constraints

- PCI Bus Linux based PC
- PC brand irrelevant.
- Implemented with Standard Well-Known Languages
- Open Source development
- Distributed Multi-Site Development
- Source code version control system (Remote CVS)
- Documentation Standards Observed
-

2.7 User Characteristics

2.8 Assumptions and Dependencies

2.9 Operational Scenarios

3.0 System Conditions, and Constraints

3.1 Physical

3.1.1 Construction

3.1.2 Durability

3.1.3 Adaptability

Computers, Operating Systems, Networks, Components....

3.1.4 Environmental Conditions

3.1.4.1 Temperature Environment

- a) Operating Temperature Range - The MONOSOON system shall be designed to operate over a temperature range of -15° to 25° C without damage. All performance requirements must be met within this range.
- b) Survival Temperature Range - The MONSOON system shall be designed to operate over a temperature range of -25° to 50° C without damage. All performance requirements must be met within this range.

3.1.4.2 Humidity Environment

- a) Operating Humidity Range - The MONSOON system shall be designed to operate over a range of 0 to 100% relative humidity.
- b) Operating Humidity Range - The MONSOON system shall be designed to be stored and or transported over a range of 0 to 100% relative humidity, with condensing moisture.

3.1.4.3 Mechanical Environment

- a) The MONSOON system will be designed to operate in the general telescope mechanical environment. These systems will be able to withstand shipment by land, sea or air with G-force shock limits of 2 G's.
- b) The MONSOON system shall be designed to withstand telescope slew rates of 2° per second in azimuth and elevation. It must also be able to withstand rotations of telescope rotators to maintain alignment with the parallactic plane at these slew rates.

3.2 System Performance Characteristics

3.2.1 Example Cases

These are very preliminary estimates. May have errors.

3.2.1.1 Orion 2k x 2k InSb (1-5um)

Requirements

- Readout Channels: 64 Channels
- ReadNoise: 20e-
- Gain (uV/e-): 2
- Pixel Rate/Output 1.5 uS per output
- Full Well (1% Linearity) 150,000e-
- Dynamic Range: 16-bit
- Image Size 2048x2048 = 4M pixels
- Readout Time 100mS
- Data Rate 4million pix/100mS = 40million pix/S <50M pix/sec rate

3.2.1.2 HAWAII-2 (1-2.5um, or 1-5um)

Requirements

- Readout Channels: 32-36 Channels (36 if using Reference Outputs)
- ReadNoise: 10e-
- Gain (uV/e-): 3-6
- Pixel Rate/Output 3 uS per output
- Full Well (1% Linearity) 100,000e-
- Dynamic Range: 16-bit
- Image Size 2048x2048 = 4M pixels
- Readout Time 500mS (based on 3uS/output all outputs used)
2.5S (based on 2.5um background per R.Probst)
- Data Rate 4M pixels/500mS = 10Mpixels/Sec < 50M pixels/sec rate

3.2.1.3 NEWFIRM (HAWAII-2 (1-2.5um))

Requirements

- Readout Channels: 4 x 32 (36) = 128 (144) Channels
- ReadNoise: 10e-
- Gain (uV/e-): 3-6
- Pixel Rate/Output 3 uS per output
- Full Well (1% Linearity) 100,000e-

- Dynamic Range: 16-bit
- Image Size $4 \times 2048 \times 2048 = 16\text{M}$ pixels
- Readout Time 500mS
- Data Rate $16\text{M pixels}/500\text{mS} = 32\text{Mpixels}/\text{Sec} < 50\text{M pixels}/\text{sec rate}$

3.2.1.4 NEWFIRM (ORION (1-2.5um))

Requirements

- Readout Channels: $4 \times 64 = 256$ Channels
- ReadNoise: $20e^-$
- Gain ($\mu\text{V}/e^-$): 2
- Pixel Rate/Output 1.5 μS per output
- Full Well (1% Linearity) $100,000e^-$
- Dynamic Range: 16-bit
- Image Size $4 \times 2048 \times 2048 = 16\text{M}$ pixels
- Readout Time 100mS (based on ORION projected limit)
2.5S (based on 2.5um bckgrnd per R.Probst)
- Data Rate $16\text{M pix}/100\text{mS} = 160\text{M pix}/\text{S} > 50\text{M pix}/\text{s rate}$
> 120M pix/s rate

Note: We can support a 150mS frame time (7Hz) if we use a single 2.4Gb/s fiberlink

3.2.1.5 QUOTA (4 OTAs)

Requirements

- Readout Channels: 64 Channels
- ReadNoise: $5e^-$
- Gain ($\mu\text{V}/e^-$): 5
- Pixel Rate/Output 2 μS per output
- Full Well (1% Linearity) $100,000e^-$
- Dynamic Range: 16-bit
- Science Image Size $(15 \times 15) \times (512 \times 512) = 56\text{M}$ pixels
- Readout Time 49s
- Data Rate Science $56\text{M pixels} / 49\text{s} = 1.2\text{Mpixels}/\text{Sec} < 50\text{M pixels}/\text{sec rate}$
- Guider Image Size ??
- Guider Readout Time 49s
- Data Rate Guiding $16\text{M pixels}/500\text{mS} = 40\text{Mpixels}/\text{Sec} < 50\text{M pixels}/\text{sec rate}$

3.2.1.6 ODI (QUOTA x 16)

Requirements

- Readout Channels: 1024 Channels
- ReadNoise: $5e^-$
- Gain ($\mu\text{V}/e^-$): 5
- Pixel Rate/Output 2 μS per output
- Full Well (1% Linearity) $100,000e^-$
- Dynamic Range: 16-bit
- Science Image Size $32\text{k} \times 32\text{k} = 1\text{G}$ pixels
- Readout Time 49s

- Data Rate Science $1\text{G pixels} / 49\text{s} = 1.2\text{Mpixels/Sec} < 50\text{M pixels/sec rate}$
- Guider Image Size ??
- Guider Readout Time 49s
- Data Rate Guiding $16\text{M pixels}/500\text{mS}=40\text{Mpixels/Sec} <50\text{M pixels/sec rate}$

3.2.1.7 LSST(assuming 1400 1k x 1k CCDs)

Requirements

- Readout Channels: 4 Channels
- ReadNoise: $5e^-$
- Gain ($\mu\text{V}/e^-$): 5
- Pixel Rate/Output 2 μS per output
- Full Well (1% Linearity) $100,000e^-$
- Dynamic Range: 16-bit
- Science Image Size $1\text{Mpixels} \times 1400 = 1400\text{Mpixels}$
- Readout Time 520mS ???
- Data Rate Science $1400\text{M pix} / 520\text{ms} = 2700\text{Mpix/S} > 50\text{M pix/s rate}$

Note : Would require 53 (1Gb/s) fiberlinks $2700/50 = 53$ Or 21 x (2.4 Gb/s) fiberlinks

3.3 System Security

3.3.1 Connection Security

Connections will be authenticated before they are accepted. The form of this authentication will be determined at a later date. The authentication may include originating address restrictions, passwords, the use of secure connections (ssh), and/or encrypted messages.

3.3.2 Code Security

All source code will be kept at a central repository under the control of a CVS system set up to accept connections from all participating institutions and sites. The use of ssh will be required to connect to the repository.

3.3.3 Telescope Exposure Security

When a system is in use on the telescope the prime connection will be considered the telescope connection. In addition the exposures started from the telescope connection will be completed as requested. Secondary connections to a telescope mounted system will be unable to abort or stop an exposure started by the Primary connection.

3.4 Information Management

3.4.1 Project Software configuration database

3.4.2 Project board configuration and performance Database

3.4.3 Detector and Exposure Configuration Databases

3.5 System Operations

3.5.1 System Human Factors

3.5.2 System Maintainability

3.5.2.1 Hardware Maintainability

3.5.2.2 Software Maintainability

- Software will be designed and coded as a set of interacting modules which meet a defined interface.
- Software will be documented, commented and formatted in accordance with established procedures.
- Software will be constructed so that each module can be understood, modified and recompiled without accessing other modules.
- Software architecture and disk layout will use well understood techniques and procedures.
- Makefiles or scripts will be provided to build each part of the system. Makefiles and scripts will be clear and commented. They will not use obscure or complex features of make. Each makefile will stand on its own to the greatest extent possible.
-

3.5.3 System Reliability

3.5.3.1 Hardware Reliability

3.5.3.2 Software Reliability

- Software systems will be robust in the face of transmission errors, permission problems, network connectivity problems.
- Software systems will be resistant to outside hacker attacks.
- Software systems will not lose data due to insufficient disk space, permission problems, network connectivity problems or other foreseeable, detectable problems.
- Software will be as bug-free as possible.
- Software will undergo testing and verification before release.
- Software releases will be easily "backed-out" in the face of serious bugs.

3.6 System Life Cycle Sustainment

3.6.1 Reviews

MONSOON will under go a formal design review cycle for the Project consistent with NOAO Standard Practice and appropriate for the project scale. This will include project reviews and component reviews.

Project Reviews

Conceptual Design Review
Preliminary Design review
Critical Design Review

Component Reviews

All PCB Designs
All Software Modules

3.6.2 Testing and verification

Each component defined in the MONSOON work breakdown structure will be required to generate a test procedure and a completed test record consistent with the MONSOON Test and Integration Plan

3.6.3 Maintenance

The system will provide both hardware and software maintenance manuals to assist in long-term maintenance by operations staff. The system design will be such that it is module with extensive diagnostic capability built in to aid in maintenance.

4.0 System Interfaces

4.1 Hardware Interfaces

The system design shall be such that signal integrity is maximized in the observatory environment. As such the system will be partitionable such that the analog interface electronics can be in immediate proximity to the focal plane and the data processing circuitry can be located at a large distance.

4.1.1 External Client Interfaces

The hardware interfaces to external clients will be through 100baseT Ethernet Links.

4.1.2 Detector Interfaces

MONSOON shall support flexible circuit interconnects to the focal planes to allow optimum signal integrity by minimizing electrical path length

MONSOON shall also support tradition cabling techniques such as coaxial cable, twisted pair cable and single conductor cabling

4.1.3 Mechanical Interfaces

MONSOON shall be able to be rack mounted in a 19" rack thermal enclosure if so desired

4.2 Software Interfaces

4.2.1 Client System to Pixel Server

The interface between the MONSOON system and its Client systems will comply with **[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

All deviances from this ICD will be clearly delineated in the System Architecture document for the level at which the deviation occurs

4.2.2 Pixel Acquisition Node to Detector Head Electronics

Two interfaces can be described between these two MONSOON systems. One of them is the Generic interface which every DHE should comply with. This interface is described in **[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. This interface describes the Command response and data transfer behavior between the PAN software and the DHE software.

The second interface is described in **[11]** NOAO Document ###.###.&&& - ICD 6.1 Version 0.1.2 - "MONSOON DHE - Command and Data Stream Interface Implementation Description", Nick C. Buchholz(NOAO), Barry M. Starr(NOAO), 20020308. This interface describes the hardware, low level commands and data stream used to implement the requirements of ICD 6.0 in the MONSOON system.

All deviances from these ICD's will be clearly delineated in the System Architecture document for the level at which the deviation occurs.

4.2.3 Engineering Console Interface

The engineering console will be a GPX compliant Client system.