Large Synoptic Survey Telescope (LSST)
LSE-66: Guider Interface Between the Camera and Telescope

Paul Lotz

Latest Version: 3.2
Latest Revision Date: March 6, 2017
# Table of Contents

1 Change Record .................................................................................................................. 6

2 LSE-66 Overview ............................................................................................................. 7
  2.1 Related Documents ........................................................................................................ 8
  2.2 Contents ......................................................................................................................... 8

3 Requirements .................................................................................................................... 8
  3.1 Data Exchange ............................................................................................................... 8
    3.1.1 Data Provided by Camera ......................................................................................... 8
      3.1.1.1 Data Content ..................................................................................................... 8
        3.1.1.1.1 Region of Interest Data ................................................................................ 8
          3.1.1.1.1.1 Image Metadata ...................................................................................... 8
          3.1.1.1.1.1.1 Image Location .................................................................................... 9
          3.1.1.1.1.1.1.1 Sensor to Focal Plane Registration ...................................................... 9
        3.1.1.1.1.1.2 Guider Data Sample Size .................................................................... 9
        3.1.1.1.1.3 Time Tag ................................................................................................. 9
        3.1.1.1.1.3.1 guiderTime ............................................................................................ 9
        3.1.1.1.1.4 Spatial Identifier ...................................................................................... 9
        3.1.1.1.1.5 Pixel Binning Level ................................................................................... 10
        3.1.1.1.1.5.1 Issue: Consider making unbinned = 1 comment a referenced element. ... 10
        3.1.1.1.1.6 Issue: Add requirement to include ROI dimensions ................................... 10
      3.1.1.1.2 Guider Data Sample Size .............................................................................. 10
      3.1.1.1.2.1 Guider data format .................................................................................... 10
    3.1.1.2 Data Transport Mechanism .................................................................................... 10
      3.1.1.2.1 Transfer Interface .......................................................................................... 10
      3.1.1.2.2 Performance Constraints ............................................................................. 11
        3.1.1.2.2.1 Data Delivery Latency ............................................................................ 11
        3.1.1.2.2.1.1 dataDeliveryLatency ........................................................................... 11
        3.1.1.2.2.2 Frame Rate ............................................................................................ 11
        3.1.1.2.2.2.1 FrameRate .......................................................................................... 11
        3.1.1.2.2.3 Data Availability ...................................................................................... 12
      3.1.1.2.3 Deployment ...................................................................................................... 12
        3.1.1.2.3.1 Camera Provided Software ...................................................................... 12
        3.1.1.2.3.1.1 T&S Provided Host Computer ................................................................. 12
        3.1.1.2.3.1.1.1 Execution Environment .................................................................... 12
        3.1.1.2.3.1.1.2 Dual-homed ....................................................................................... 12
        3.1.1.2.3.1.1.3 Ethernet Port Speed .......................................................................... 12
        3.1.1.2.3.1.1.4 IPv4 Support ...................................................................................... 13
        3.1.1.2.3.1.1.5 Network Configurability .................................................................... 13
      3.1.1.2.4 Data Provided by Telescope ............................................................................. 13
      3.1.1.2.4.1 Region of Interest Definition ..................................................................... 13
        3.1.1.2.4.1.1 Exposure ............................................................................................. 14
        3.1.1.2.4.1.2 Guide Sensor ....................................................................................... 14
        3.1.1.2.4.1.3 Guide Sensor Set .................................................................................. 14
        3.1.1.2.4.1.4 ROI Definition ...................................................................................... 14
        3.1.1.2.4.1.4.1 ROI Dimensions .............................................................................. 14
        3.1.1.2.4.1.6 ROI Location ....................................................................................... 15
        3.1.1.2.4.1.7 Object ................................................................................................. 15
        3.1.1.2.4.1.8 Region of Interest Dimensions Request ................................................. 15
3.1.2.1.8.1 Region of Interest Dimensions .......................................................... 15
3.1.2.1.8.1.1 ROIDimensions ........................................................................ 16
3.1.2.1.2 Region of Interest Location Request ......................................................... 16
3.1.2.1.2.1 Avoidance of Detector Middle ................................................................ 17
3.1.2.1.3 Integration Time .................................................................................... 17
3.1.2.1.3.1 Detector Integration Time ....................................................................... 17
3.1.2.1.3.1.1 Integration Time .............................................................................. 17
3.1.2.1.3.1.1.1 Issue: Use base units? ................................................................... 17
3.1.2.1.3.1.2 Issue: Make Detector Integration Time a constraint ............................. 17
3.1.2.2 Data Transport Mechanism ....................................................................... 17
3.1.2.2.1 Control Commands ............................................................................... 17
3.1.2.2.2 Performance Constraints ........................................................................ 18
3.1.2.2.2.1 Region of Interest Lead Time ................................................................. 18
3.1.2.2.2.1.1 Issue: Derive requirement for TCS ...................................................... 18
3.1.2.2.2.1.2 Issue: Reference definition of start of exposure ................................. 18
3.1.2.2.2.1.3 Issue: Update definition mechanism ............................................... 18
3.1.2.2.2.1.4 ROILeadTime .................................................................................. 18
3.2 Sensing Requirements ...................................................................................... 18
3.2.1 Detector Requirements ............................................................................... 19
3.2.1.1 Windows Per Sensor ................................................................................. 19
3.2.1.1.1 Number of Windows .............................................................................. 19
3.2.1.2 Available Area .......................................................................................... 19
3.2.1.2.1 Sensor Area ............................................................................................ 19
3.2.1.3 Detector Pixel Size .................................................................................... 19
3.2.1.3.1 pixelSize ................................................................................................. 20
3.2.1.4 Detector Read Noise .................................................................................. 20
3.2.1.4.1 Issue: Change text to less than or equal to .............................................. 20
3.2.1.4.2 Issue: Change to "acquired at the nominal integration time" ................. 20
3.2.1.4.3 readNoise ............................................................................................... 20
3.2.1.5 Detector Position ....................................................................................... 21
3.2.1.5.1 Sensor z-axis Tolerance .......................................................................... 21
3.2.1.5.1.1 guiderZTolerance ............................................................................... 21
3.2.1.5.2 Sensor z-axis Stability ........................................................................... 21
3.2.1.5.2.1 guiderZStability ................................................................................. 21
3.2.1.5.3 Sensor x/y Stability ................................................................................ 21
3.2.1.5.3.1 guiderXYStability ............................................................................. 22
3.2.1.5.4 Issue: Add a drawing ............................................................................ 22
3.2.1.5.5 Issue: Parameterize exposure time? ....................................................... 22
3.2.2 Guide Sensor Integration Timing ................................................................. 22
3.2.2.1 Integration Time Start ............................................................................... 22
3.2.2.1.1 intDelay ................................................................................................. 22
3.2.2.2 Integration Time Synchronization .............................................................. 23
3.2.2.2.1 guideSync .............................................................................................. 23
3.3 Camera Control ............................................................................................... 23
3.3.1 Diagnostic Mode .......................................................................................... 23
3.3.1.1 Binning .................................................................................................... 25
3.3.1.2 Frame Rate ............................................................................................... 25
3.3.2 Issue: Clarify that only ROI location changes per sensor ............................. 25
3.3.3 Issue: Delete requirement? .......................................................................... 25
3.3.4 Issue: Identify method to change mode ....................................................... 25
3.4 Definitions ....................................................................................................... 25
3.4.1 Pixel Identification ....................................................................................... 26

4 Details ................................................................................................................. 26
4.1 Component Interactions .................................................................................. 26
4.1.1 Interface Data
4.1.1.1 Init Guider
4.1.1.1.1 Exposure
4.1.1.1.2 ROI Definition
4.1.1.1.3 ROI Dimensions
4.1.1.1.4 Init Guider
4.1.1.2 ROI Usage
4.1.1.2.1 Guide Sensor
4.1.1.2.2 Guide Sensor Collection
4.1.1.3 Guider Data
4.1.1.3.1 Guider Data
4.1.1.3.2 Guider Sensor Data
4.1.1.3.3 Image Identifier
4.1.1.3.4 Image Metadata
4.1.1.3.5 Pixel Binning Level
4.1.1.3.6 ROI Location
4.1.1.3.7 Sensor ID
4.1.1.3.8 Sensor to Focal Plane Registration
4.1.1.3.9 Time Tag
4.1.1.3.10 Versioning Information
4.1.1.3.11 Image Data

4.2 Deployment
4.2.1 Camera System
4.2.1.1 Camera Interface Computer
4.2.1.1.1 Camera Interface Environment
4.2.1.2 DAQ Computer
4.2.1.2.1 DAQ Server Environment
4.2.1.2.1.1 DAQ Service
4.2.2 Telescope Control System
4.2.2.1 Telescope Guider Computer
4.2.2.1.1 DAQ Client Environment
4.2.2.1.1.1 DAQ Client
4.2.2.1.2 Guider Application Environment
4.2.2.1.2.1 Telescope Guider
4.2.2.1.2.2 Telescope Guider Client
4.2.3 Other System
4.2.3.1 Other Component Computer
4.2.3.1.1 Other Component Environment
4.2.3.1.1.1 Other Component

4.3 Interfaces Interpretation
4.3.1 IDAQClient
4.3.2 IDAQSrvce
4.3.3 ITelescopeGuiderClient
4.3.4 Image
4.3.5 Metadata
4.3.6 DAQ Client Interaction
4.3.6.1 MergeNode
4.3.6.2 ActivityFinal
4.3.6.3 ActivityInitial
4.3.6.4 Receive Guide Sensor Data
4.3.6.5 Subscribe to Guide Sensor Data
4.3.6.6 Unsubscribe from Guide Sensor Data
4.3.6.7 Wait for more data?
4.3.6.8 Subscribe to Guide Sensor Data
4.3.6.8.1 Object
4.3.6.8.2 Client1
4.3.6.8.3 Client2
4.3.6.8.4 DAQClient1
4.3.6.8.5 DAQClient2
4.3.6.8.6 MessageEnd
4.3.6.9 Receive Guide Sensor Data
4.3.6.9.1 Object
4.3.6.9.2 Client1
4.3.6.9.3 Client2
4.3.6.9.4 DAQClient1
4.3.6.9.5 DAQClient2
4.3.6.9.6 MessageEnd
4.3.6.9.7 MessageEnd
4.3.6.9.8 MessageEnd
4.3.6.9.9 MessageEnd
4.3.6.9.10 MessageEnd
4.3.6.10 Unsubscribe from Guide Sensor Data
4.3.6.10.1 Object
4.3.6.10.2 Client1
4.3.6.10.3 Client2
4.3.6.10.4 DAQClient1
4.3.6.10.5 DAQClient2
4.3.7 GuideSensorDataSignal
4.3.7.1 GuideSensor1Data
4.3.7.2 GuideSensor2Data
4.3.7.3 GuideSensor3Data
4.3.7.4 GuideSensor4Data
4.3.7.5 GuideSensor5Data
4.3.7.6 GuideSensor6Data
4.3.7.7 GuideSensor7Data
4.3.7.8 GuideSensor8Data
4.3.7.9 GuideSensorDataSignal
# 1 Change Record

The revision history of this document is as follows.

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Description</th>
<th>Owner name</th>
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<tr>
<td>1</td>
<td>10/19/2010</td>
<td>Initial version</td>
<td>V. Riot, J. Sebag, M. Warner</td>
</tr>
<tr>
<td>1.1</td>
<td>6/16/2011</td>
<td>Elevation to LSE handle</td>
<td>C. Claver</td>
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<tr>
<td>1.2</td>
<td>7/4/2011</td>
<td>General edits</td>
<td>J. Sebag</td>
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<td>1.3</td>
<td>8/11/2011</td>
<td>General edits</td>
<td>J. Sebag</td>
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<tr>
<td>1.4</td>
<td>4/25/2012</td>
<td>Expanded detail</td>
<td>J. Sebag</td>
</tr>
<tr>
<td>2</td>
<td>10/28/2014</td>
<td>Incorporates geometric and tolerancing definition agreed to by all parties. Approved via LCR-255</td>
<td>B. Selvy</td>
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<tr>
<td>3</td>
<td>1/28/2016</td>
<td>Incorporates LCR-360, which updated the ROI size and associated interface requirements</td>
<td>B. Selvy</td>
</tr>
<tr>
<td>3.1</td>
<td>11/10/2016</td>
<td>Restructured requirements to make relationships clear. Added connectors and diagrams to detail the relationships. Modified text for clarity. Added a number of issues. Added requirement (previously proposed) for Spatial Identifier in metadata. Made modifications to text for clarity in: Guider Data Sample Size (added “per pixel”) Frame Rate (changed “size” to “dimensions”). (Made equivalent changes elsewhere.) Expanded TS Provided Host Computer requirement into multiple requirements. Added diagram and model elements describing Deployment and message content. Did some restructuring and added text to structural elements of document to make the generated document more readable. Added text to packages and elements where appropriate.</td>
<td>P. Lotz</td>
</tr>
<tr>
<td>3.2</td>
<td></td>
<td>Made changes to follow up on agreements during discussions with Camera and Systems Engineering teams 29 Nov 2016 and 02 Dec 2016. Updated Overview text. Cleaned up Data Content hierarchy. Image Data requirement (0001): Added &quot;to the Telescope&quot; to the text. Sensor to Focal Plan Registration requirement (0031): Reworded to include the phrase, &quot;The Camera shall provide&quot; for clarity. Added statement indicating this is</td>
<td>P. Lotz</td>
</tr>
</tbody>
</table>

The contents of this document are subject to configuration control and may not be changed, altered, or their provisions waived without prior approval of the LSST Change Control Board.
expected to be part of the camera calibration data. Merged Region of Interest Parameters (0002) with Region of Interest Defintion (0039).
Linked attributes to "Pixels" value type in LSST definitions.
Replace Control Commands requirement (0040) with a package.
Region of Interest Lead Time requirement (0021): Replaced TCS with Telescope.
Detector Pixel Size (0005): Rephrased to clarify that the Camera is providing this.
Detector Read Noise (0015): Rephrased to clarify that this applies to for the nominal integration time.
Changed Detector Position requirement (0016) to a package.
Followed up on more changes from late 2106 agreements:
Deleted Issue: "Delete windows per sensor requirement".
Ethernet Port Speed requirement: Rephrased to say "shall support" 10 Gigabit Ethernet.
Configured requirements diagrams not to print in documentation.

### 2 LSE-66 Overview

**Purpose**
This ICD is to be used for developing final designs of hardware, software, and interface protocols on both sides of the interface. Further updates to this document are expected prior to finalizing component designs, with any/all changes subject to the LSST change control and approval processes.

**Introduction and Scope**
The guider interface defines the requirements on the interface between the LSST Camera and Telescope subsystems related to measuring the system tracking error for the purpose of maintaining the image quality requirements.

The overall architecture of the guide sensors is described in the OSS. They are located in the corner raft (2 guide sensors per corner raft).

This interface defines the requirements for:
1. Guider data exchange between the Camera and the Telescope & Site subsystems;
2. Guider data format

Definitions

Best Fit Science Detector Plane - The best fit detector plane is determined by fitting a single plane to the camera science CCD surfaces as installed using a least squares fit.

2.1 Related Documents

This section lists related documents.

2.2 Contents

The primary topics appear below.

3 Requirements

This section covers requirements on the interface.

3.1 Data Exchange

The Camera and Telescope exchange data regarding parameters required to capture ROI data and for providing the captured data.

3.1.1 Data Provided by Camera

This section describes the data the camera must send and how it must provide it.

3.1.1.1 Data Content

The camera provides image data and associated metadata. The telescope will compute the centroids from the image data to be used for telescope guiding.

3.1.1.1.1 Image Data

ID: CA-TS-GDR-ICD-0001
Specification: The Camera shall provide to the Telescope the image data from the guide sensors.

3.1.1.1.2 Region of Interest Data

ID: CA-TS-GDR-ICD-0022
Specification: The camera shall read out the unique region of interest for each guide sensor and provide that data to the TCS.

3.1.1.1.3 Image Metadata

ID: CA-TS-GDR-ICD-0027
Specification: The camera shall include data associated with the image (metadata).

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3.1.1.1.1.1.1 Image Location
ID: CA-TS-GDR-ICD-0030
Specification: The camera shall provide the pixel coordinates (start row and start column) of the region of interest with the guide data for each guide sensor.

3.1.1.1.1.1.1.1 Sensor to Focal Plane Registration
ID: CA-TS-GDR-ICD-0031
Specification: The Camera shall provide the transformations of guide sensor pixel position (row, column) to (X,Y) science focal plane coordinates for each guide sensor. This is expected to be provided as part of the camera calibration data.

3.1.1.1.1.1.1.2 Image Identifier
ID: CA-TS-GDR-ICD-0028
Specification: The camera shall provide a unique identifier for each image with the image data from each guide sensor.

3.1.1.1.1.1.1.3 Time Tag
ID: CA-TS-GDR-ICD-0029
Specification: The camera shall provide time information sufficient to allow reconstruction of the image integration start and stop times to within guiderTime.

3.1.1.1.1.1.1.3.1 guiderTime

<table>
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<th>ATTRIBUTES</th>
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<tbody>
<tr>
<td>guiderTime : msec  Private = 1</td>
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<tr>
<td>Guider time tag resolution</td>
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[ Is static False. Containment is Not Specified. ]

3.1.1.1.1.1.1.4 Spatial Identifier
ID: CA-TS-GDR-ICD-0047
ID: CA-TS-GDR-ICD-0046
ID: CA-TS-GDR-ICD-0046
ID: CA-TS-GDR-ICD-0046
ID: CA-TS-GDR-ICD-0046
ID: CA-TS-GDR-ICD-0046
Specifiction: The Camera shall provide a spatial identifier of the sensor corresponding to the data.

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**Discussion:** This identifier will follow TBD agreed on observatory wide naming conventions.

### 3.1.1.1.1.1.5 Pixel Binning Level

**ID:** CA-TS-GDR-ICD-0041  
**Specification:** The camera shall provide the pixel binning level in the image metadata. Unbinned operation shall be indicated as binning level = 1.

### 3.1.1.1.1.5.1 Issue: Consider making unbinned = 1 comment a referenced element.

**ID:**

### 3.1.1.1.1.6 Issue: Add requirement to include ROI dimensions

**ID:**

The ROI dimensions, in addition to the location, are critical. I don't know if these can be derived unambiguously from the image data or not. The ROI may not be square! Still, I expect these can be determined from the image data. If not, they need to be in the metadata.

### 3.1.1.1.1.2 Guider Data Sample Size

**ID:** CA-TS-GDR-ICD-0026  
**Specification:** The camera shall provide to the telescope the guider data in an ordered pixel image format with a number of bits per pixel of \texttt{GuidePixBits}.

#### 3.1.1.1.1.2.1 Guider data format

<table>
<thead>
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<tbody>
<tr>
<td>\texttt{GuidePixBits} : int  Private = 18</td>
</tr>
</tbody>
</table>

Guide data number of bits  

[ Is static False. Containment is Not Specified. ]

### 3.1.1.2 Data Transport Mechanism

### 3.1.1.2.1 Transfer Interface

**ID:**

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ID:
Specification: The Camera shall implement a publish/subscribe interface with the characteristics in DAQ Client Interaction.

3.1.1.2.2 Performance Constraints
The following requirements apply to the Camera provided data interface.

3.1.1.2.2.1 Data Delivery Latency
ID: CA-TS-GDR-ICD-0009
Specification: The latency from the end of the ROI readout to the delivery of the image data to the telescope shall be less than dataDeliveryLatency for a nominal ROI dimensions of ROINomWidth and ROINomHeight.

Discussion: The latency can increase for ROIs larger than ROINomWidth and ROINomHeight.

3.1.1.2.2.1.1 dataDeliveryLatency

Attributes:

- dataDeliveryLatency : msec Private = 1
  - Delay between end of ROI readout to delivery
  - [Is static False. Containment is Not Specified.]

3.1.1.2.2.2 Frame Rate
ID: CA-TS-GDR-ICD-0013
Specification: The camera shall deliver the ROI data at a rate no slower than guideRate for the nominal integration time, Int-Time, and nominal ROI dimensions (ROINomWidth x ROINomHeight) during normal operations.

Discussion: For longer integration time or larger ROI dimensions, the frame rate requirement does not need to be met.

3.1.1.2.2.2.1 FrameRate

Attributes:

- guideRate : Hz Private = 9
  - Minimum ROI delivery rate
  - [Is static False. Containment is Not Specified.]
3.1.1.2.2.3 Data Availability

**ID:** CA-TS-GDR-ICD-0037  
**Specification:** The guide data shall be delivered until total closure of the shutter.

3.1.1.2.3 Deployment

The following deployment requirements apply.

3.1.1.2.3.1 Camera Provided Software

**ID:**  
**ID:** CA-TS-GDR-ICD-0050  
**Specification:** The camera shall install software libraries that provide access to the DAQ system on T&S provided computers.  
- These libraries will be in C++, and will include sharable images and necessary include (header) files.

3.1.1.2.3.1.1 T&S Provided Host Computer

**ID:**  
**ID:** CA-TS-GDR-ICD-0051  
**Specification:** The T&S shall provide at least one host computer with the following characteristics.

3.1.1.2.3.1.1.1 Execution Environment

**ID:**  
**ID:**  
**Specification:** The host computer shall support code execution under an observatory sanctioned O/S.

3.1.1.2.3.1.1.2 Dual-homed

**ID:**  
**ID:**  
**Specification:** A host computer shall be at least dual-homed. One interface is connected to the DAQ network with other interfaces used for non-DAQ related traffic.

3.1.1.2.3.1.1.3 Ethernet Port Speed

**ID:**
ID: Specification: The host computer's interface connected to the DAQ network shall support 10-Gigabit Ethernet (10-GE).

3.1.1.2.3.1.4 IPv4 Support
ID: ID: Specification: The host computer O/S shall provide an IPV4 based TCP/IP stack with standard POSIX interfaces.

3.1.1.2.3.1.5 Network Configurability
ID: ID: Specification: The host computer shall be configured so that the camera can install the DAQ network configuration.

3.1.2 Data Provided by Telescope
The Telescope provides guiding parameters.

3.1.2.1 Data Content
The Telescope requests the region of interest parameters and the integration time.

3.1.2.1.1 Region of Interest Definition

Figure: Region of Interest Definition
An ROI Definition applies to an Exposure.
The ROI Dimensions are the same for all Guide Sensors. There is an ROI Location for each Guide Sensor.

**ID**: CA-TS-GDR-ICD-0039

**Specification**: For each exposure, the Telescope shall provide the requested Regions of Interest (ROI) definition per sensor to the Camera in terms of the pixel location (row, column) for the first pixel of the window, followed by the dimensions of the ROI (pixels), to define the location and dimensions of the image data to be transferred to the Telescope.

**Discussion**:

### 3.1.2.1.1 Exposure

*ID:*

### 3.1.2.1.2 Guide Sensor

*ID:*

### 3.1.2.1.3 Guide Sensor Set

*ID:*

### 3.1.2.1.4 ROI Definition

*ID:*

### 3.1.2.1.5 ROI Dimensions

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### 3.1.2.1.6 ROI Location

**ID:**

**ATTRIBUTES**

- **ROI Height** : Pixels  Private  
  [ Is static False. Containment is Not Specified. ]

- **ROI Width** : Pixels  Private  
  [ Is static False. Containment is Not Specified. ]

### 3.1.2.1.7 Object

### 3.1.2.1.8 Region of Interest Dimensions Request

**ID:**

The telescope shall specify the Region of Interest Dimensions (shared by all sensors) in terms of the dimensions in pixels for each exposure.

#### 3.1.2.1.8.1 Region of Interest Dimensions

**ID:** CA-TS-GDR-ICD-0006  
**Specification:** The camera shall accommodate ROI dimensions from **ROI\text{MinWidth}** by **ROI\text{MinHeight}** to **ROI\text{MaxWidth}** by **ROI\text{MaxHeight}** physical pixels (no binning) using the data interface defined in this ICD, or full CCD (using the LSE-68 data interface). The nominal ROI dimensions shall be **ROI\text{NomWidth}** by **ROI\text{NomHeight}** physical pixels.

**Discussion:** The Region of Interest does not need to be square. The range of ROI dimensions is a mitigation measure for potentially impaired telescope pointing due to larger than expected hysteresis in the Telescope Mount Assembly (TMA). Larger than nominal ROI will result in reduced guider sampling rate, which in turn will lead to slightly increased image jitter. However, the corresponding estimated sensitivity loss is negligible. For more details...
of the estimate, please see Document-17851. Any ROI larger than the maximum will be read out as the full CCD.

3.1.2.1.8.1.1 ROIDimensions

ID:

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<td></td>
</tr>
<tr>
<td>ROINomHeight : Pixels</td>
<td>50</td>
<td>False</td>
<td>Not Specified</td>
</tr>
<tr>
<td>Nominal ROI Height</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROIMaxWidth : Pixels</td>
<td>400</td>
<td>False</td>
<td>Not Specified</td>
</tr>
<tr>
<td>Maximum ROI Width</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROIMaxHeight : Pixels</td>
<td>400</td>
<td>False</td>
<td>Not Specified</td>
</tr>
<tr>
<td>Maximum ROI Height</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.1.2.1.2 Region of Interest Location Request

ID: 
ID: 
Specification: The telescope shall specify the location of the ROI for each sensor in terms of the pixel coordinates (row, column) of the first pixel.

Discussion:
3.1.2.1.2.1 Avoidance of Detector Middle

ID: CA-TS-GDR-ICD-0033
Specification: The telescope shall not position the ROI across the middle of the detector.

Discussion: The middle of the detector is the line separating the first and second eight amplifiers.

3.1.2.1.3 Integration Time

ID: CA-TS-GDR-ICD-0038
Specification: The telescope shall specify the integration time (duration of the exposure) in milliseconds.

3.1.2.1.3.1 Detector Integration Time

ID: CA-TS-GDR-ICD-0034
Specification: The integration time shall be Int-Time for ROIs of nominal dimensions.

3.1.2.1.3.1.1 Integration Time

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Int-Time : msec Private = 50](nominal integration time)</td>
</tr>
<tr>
<td>Nominal Integration Time</td>
</tr>
</tbody>
</table>

[ Is static False. Containment is Not Specified. ]

3.1.2.1.3.1.1 Issue: Use base units?

ID:
Example: s, not ms.

Base units are a bit easier to handle unambiguously in interfaces.

3.1.2.1.3.1.2 Issue: Make Detector Integration Time a constraint

ID:
This text should be "will", not "shall", and should be a constraint on the Integration Time requirement.

3.1.2.2 Data Transport Mechanism

3.1.2.2.1 Control Commands

The contents of this document are subject to configuration control and may not be changed, altered, or their provisions waived without prior approval of the LSST Change Control Board.
The commands to set the guider control parameters are defined in LSE-71, OCS-Camera Software Communications Interface.

### 3.1.2.2 Performance Constraints

These constraints apply to the Telescope to Camera messages.

#### 3.1.2.2.1 Region of Interest Lead Time

**ID:** CA-TS-GDR-ICD-0021  
**Specification:** The Telescope shall provide the Region of Interest (ROI) for each of the 8 guide sensors at least $\text{ROILeadTime}$ before the start of the exposure using the LSST agreed communication mechanism.

#### 3.1.2.2.1.1 Issue: Derive requirement for TCS

**ID:**  
The TCS should have a derived requirement to obtain the details of the next exposure from the OCS, I guess. Or how will the system manage this?

#### 3.1.2.2.1.2 Issue: Reference definition of start of exposure

**ID:**

#### 3.1.2.2.1.3 Issue: Update definition mechanism

**ID:**  
The text "using the OCS provided configuration definition mechanism".

Probably this just refers to SAL.

SAL definitely is a means of communication, not a configuration definition mechanism.

SAL is (architecturally) an infrastructure element, not part of the OCS.

#### 3.1.2.2.1.4 ROILeadTime

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{ROILeadTime : msec}$ Private = 200</td>
</tr>
</tbody>
</table>

Lead time of ROI configuration availability before the start of the exposure  
[ Is static False. Containment is Not Specified. ]

### 3.2 Sensing Requirements

The contents of this document are subject to configuration control and may not be changed, altered, or their provisions waived without prior approval of the LSST Change Control Board.
This section describes sensing requirements on the Guider related to Camera - Telescope interface.

### 3.2.1 Detector Requirements

The following requirements apply to the detectors used for guiding.

#### 3.2.1.1 Windows Per Sensor

**ID: CA-TS-GDR-ICD-0004**

**Specification:** The camera shall provide the capability to read out \( n_{\text{Windows}} \) windows in each of the 8 guide sensors.

#### 3.2.1.1.1 Number of Windows

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n_{\text{Windows}} : \text{int} ) Private = 1</td>
</tr>
</tbody>
</table>

Number of windows per guide sensor

[ Is static False. Containment is Not Specified. ]

#### 3.2.1.2 Available Area

**ID: CA-TS-GDR-ICD-0003**

**Specification:** The camera shall provide a minimum active area of \( \text{sensorArea} \) in each of the 8 guide sensors.

#### 3.2.1.2.1 Sensor Area

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{sensorArea} : \text{mm}^2 ) Private = 1612.9</td>
</tr>
</tbody>
</table>

Minimum area per guide sensor

[ Is static False. Containment is Not Specified. ]

#### 3.2.1.3 Detector Pixel Size

**ID: CA-TS-GDR-ICD-0005**

**Specification:** The Camera shall provide a nominal guide detector pixel size (length of each side of square pixel) of \( \text{pixelSize} \).

**Discussion:** The plate scale is 0.2 arcsec per pixel of 10 microns.
3.2.1.3.1 pixelSize

ATTRIBUTES

| pixelSize : microns Private = 10 |
| Nominal guider pixel size |

3.2.1.4 Detector Read Noise

ID: CA-TS-GDR-ICD-0015

Specification: The camera read noise shall be less than readNoiseMax for data from the ROI acquired at the nominal integration time. This specification includes dark current.

Discussion: The goal is to have a read noise of less than readNoiseGoal. For shorter integration times, the read noise will be larger.

3.2.1.4.1 Issue: Change text to less than or equal to

ID: Is the intent < or <= ?

3.2.1.4.2 Issue: Change to "acquired at the nominal integration time"

ID: The phrase "data from the ROI acquired within the integration time requirement" is unclear. In particular, for shorter integration times, I think we would expect the noise will be greater. I think the intent is to specify performance at the nominal integration time.

3.2.1.4.3 readNoise

ATTRIBUTES

| readNoiseMax : electrons Private = 9 |
| Maximum Read Noise |

| readNoiseGoal : electrons Private = 7 |
| Goal Read Noise |
3.2.1.5 Detector Position
The following requirements on detector position apply to the Camera.

3.2.1.5.1 Sensor z-axis Tolerance
ID: CA-TS-GDR-ICD-0017
Specification: Each guide sensor shall have \%ActiveArea\ of its active area contained in a vertical band that is +/- guiderZTolerance to a plane defined by the science sensors for all operational conditions.

Discussion: This includes camera orientation and thermal effects.

3.2.1.5.1.1 guiderZTolerance

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>%ActiveArea : Percent Private = 95</td>
</tr>
<tr>
<td>Percent of the active area contained in the guiderZTolerance band.</td>
</tr>
</tbody>
</table>

| guiderZTolerance : micron Private = 30 |
| Guider z axis tolerance relative to science sensors | [ Is static False. Containment is Not Specified. ] |

3.2.1.5.2 Sensor z-axis Stability
ID: CA-TS-GDR-ICD-0018
Specification: The maximum z-axis variation of any position on the guide sensor relative to the best fit science detector plane shall be less than guiderZStability within a 15 second exposure.

3.2.1.5.2.1 guiderZStability

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>guiderZStability : Microns Private = 2.5</td>
</tr>
<tr>
<td>Guider z axis stability relative to best fit science detector plane.</td>
</tr>
</tbody>
</table>

3.2.1.5.3 Sensor x/y Stability

The contents of this document are subject to configuration control and may not be changed, altered, or their provisions waived without prior approval of the LSST Change Control Board.
**ID:** CA-TS-GDR-ICD-0019  
**Specification:** Each guide sensor's X,Y position relative to the neighboring science sensors shall be stable to within `guiderXYStability` during each 15 second exposure.

### 3.2.1.5.3.1 guiderXYStability

**ATTRIBUTES**

<table>
<thead>
<tr>
<th>guiderXYStability : micron Private = 0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guide Sensor XY stability</td>
</tr>
</tbody>
</table>

[ Is static False. Containment is Not Specified. ]

### 3.2.1.5.4 Issue: Add a drawing

**ID:**
This requirement is difficult to understand without an image of some kind.

Also, I think what is described is a horizontal band, not a vertical one. Maybe we can think of a better way to say this.

It seems to me that this constrains the combination of position along the z-axis (piston) and x- or y- tilts.

### 3.2.1.5.5 Issue: Parameterize exposure time?

**ID:**

### 3.2.2 Guide Sensor Integration Timing

The following timing requirements apply.

#### 3.2.2.1 Integration Time Start

**ID:** CA-TS-GDR-ICD-0035  
**Specification:** The camera shall start the ROI integration within `intDelay` of the start of the exposure.

**Discussion:** A delay allows for one or two dark ROI images before the ROI is exposed to light.

#### 3.2.2.1.1 intDelay
### 3.2.2.2 Integration Time Synchronization

**ID:** CA-TS-GDR-IDC-0036  
**Specification:** The camera shall coordinate the timing of the ROI integration so that all active guide sensors are synchronized to within $\text{guideSync}$.  

#### 3.2.2.2.1 guideSync

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
</table>
| $\text{guideSync} : \text{msec} \ Private = 1$  
Maximum difference between the start of ROI integration for any two sensors  
[ Is static False. Containment is Not Specified. ] |

### 3.3 Camera Control  

The Camera supports a diagnostic mode.  

#### 3.3.1 Diagnostic Mode
The ROI Definition, Frame Rate, and Binning parameters apply to an Exposure.

The ROI Dimensions, Frame Rate, and Binning are the same for all Guide Sensors. Each ROI Location applies to a single Guide Sensor.

The contents of this document are subject to configuration control and may not be changed, altered, or their provisions waived without prior approval of the LSST Change Control Board.
**ID:** CA-TS-GDR-ICD-0025  
**Specification:** The camera shall implement a diagnostic mode that will provide access to and control of the guide sensor data collection parameters through a camera provided control panel. This mode shall allow at minimum changes of integration time, frame rate, binning, ROI dimensions and ROI locations in accordance with CA-TS-GDR-ICD-0006..

**Discussion:** When in diagnostic mode, the ROI dimensions cannot be larger than $\text{ROIMaxWidth} \times \text{ROIMaxHeight}$ while using the guider data transport interface defined within this ICD. However, there is access provided to the entire guide chip with a 15 second integration through the LSE-68 data transport interface.

### 3.3.1.1 Binning

**ID:**

### 3.3.1.2 Frame Rate

**ID:**

### 3.3.2 Issue: Clarify that only ROI location changes per sensor

**ID:**

The other parameters all apply to the group of sensors?

### 3.3.3 Issue: Delete requirement?

**ID:**

All these parameters are in the initGuiders command?

### 3.3.4 Issue: Identify method to change mode

**ID:**

If this is really a separate mode. It sounds more like the requirement should be to support changing settings.

Note that this interface date provides mechanisms for the TCS to specify the integration time and ROI dimensions and locations, but not the frame rate, nor the binning.

### 3.4 Definitions

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6 March, 2017
3.4.1 Pixel Identification

ID:
The first pixel is the one closest to the amplifier. It will be in the first row of the ROI shifted into the CCD serial register and will be the first pixel of that row that is read out by the CCD.

4 Details

4.1 Component Interactions

The components involved in the interaction and their interfaces are as follows:

The Telescope (or a Telescope Guider component within it), creates parameters for an Init Guider command, and makes this available [via the OCS somehow?] to the Camera component, which provides the Guider Settings to the DAQ Server.

The DAQ Server acquires the Guider Sensor Data, which it streams to the DAQ Client. The DAQ Client provides Guider Data to one or more Telescope Guider Clients that are part of the Telescope Guider assembly.

4.1.1 Interface Data

This section details the data on the interfaces.

4.1.1.1 Init Guider

The contents of this document are subject to configuration control and may not be changed, altered, or their provisions waived without prior approval of the LSST Change Control Board.
In Init Guider command applies to an Exposure.

**Figure**: Init Guider

### 4.1.1.1 Exposure

### 4.1.1.2 ROI Definition

### 4.1.1.3 ROI Dimensions

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ROI Height</strong>: Pixels  Private  [ Is static False. Containment is Not Specified. ]</td>
</tr>
<tr>
<td><strong>ROI Width</strong>: Pixels  Private  [ Is static False. Containment is Not Specified. ]</td>
</tr>
</tbody>
</table>

The contents of this document are subject to configuration control and may not be changed, altered, or their provisions waived without prior approval of the LSST Change Control Board.

6 March, 2017
4.1.1.4  Init Guider

4.1.1.2  ROI Usage
The ROI Dimensions are the same for all Guide Sensors, but the ROI Location may vary per Guide Sensor.

![ROI to Guider Mapping Figure](image)

4.1.1.2.1  Guide Sensor

4.1.1.2.2  Guide Sensor Collection

4.1.1.3  Guider Data
Guider Data includes Guide Sensor Data from one or more of the Guide Sensors.

The data for each Guide Sensor includes Image Data and associated Image Metadata.
4.1.1.3.1 Guider Data

4.1.1.3.2 Guider Sensor Data

4.1.1.3.3 Image Identifier

4.1.1.3.4 Image Metadata

4.1.1.3.5 Pixel Binning Level

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>level : unsigned long Private = 1</td>
</tr>
<tr>
<td>Unbinned =1</td>
</tr>
</tbody>
</table>

The contents of this document are subject to configuration control and may not be changed, altered, or their provisions waived without prior approval of the LSST Change Control Board.

6 March, 2017
4.1.1.3.6 ROI Location

 ATTRIBUTES

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Pixel Row : Pixels</td>
<td>Private</td>
</tr>
<tr>
<td>First Pixel Column : Pixels</td>
<td>Private</td>
</tr>
</tbody>
</table>

4.1.1.3.7 Sensor ID

4.1.1.3.8 Sensor to Focal Plane Registration

4.1.1.3.9 Time Tag

4.1.1.3.10 Versioning Information

 ATTRIBUTES

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firmware Version : short</td>
<td>Private</td>
</tr>
<tr>
<td>Software Version : string</td>
<td>Private</td>
</tr>
</tbody>
</table>

4.1.1.3.11 Image Data

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4.2 Deployment

The deployment of the components within the Camera System and Telescope Control System are as follows.

![Diagram of deployment](image)

Figure: Deployment

### 4.2.1 Camera System

#### 4.2.1.1 Camera Interface Computer

Computer where Camera component deploys.

#### 4.2.1.1.1 Camera Interface Environment

Environment where Camera component deploys.

The contents of this document are subject to configuration control and may not be changed, altered, or their provisions waived without prior approval of the LSST Change Control Board.

6 March, 2017
4.2.1.1.1 Camera
This component receives the guider initialization parameters for each exposure and sets up the guiders accordingly.

4.2.1.2 DAQ Computer
Computer where DAQ Server deploys.

4.2.1.2.1 DAQ Server Environment
Environment where DAQ Server deploys.

4.2.1.2.1.1 DAQ Service
This component provides guider sensor data streams.

4.2.2 Telescope Control System

4.2.2.1 Telescope Guider Computer
Environment where Telescope Guider Control System deploys and the DAQ Client on which it relies deploy.

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="ethernet-ports-min.png" alt="Image" /> Ethernet Ports (min) : int Private = 2 [ Is static False. Containment is Not Specified. ]</td>
</tr>
<tr>
<td><img src="ethernet-port-speed-gbps-min.png" alt="Image" /> Ethernet Port Speed, Gb/s (min) : unsigned long Private = 10 [ Is static False. Containment is Not Specified. ]</td>
</tr>
<tr>
<td><img src="configurable-network.png" alt="Image" /> Configurable network : boolean Private = true Camera must be able to install DAQ network configuration. [ Is static False. Containment is Not Specified. ]</td>
</tr>
</tbody>
</table>

4.2.2.1.1 DAQ Client Environment
Environment where DAQ Client deploys.

The contents of this document are subject to configuration control and may not be changed, altered, or their provisions waived without prior approval of the LSST Change Control Board.
4.2.2.1.1  DAQ Client
This component receives the Guider Sensor Data streams and assembles these into Guider Data that it provides to clients.

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS : string Private = Observatory sanctioned OS</td>
</tr>
<tr>
<td>Network configuration : string Private = IPv4 based TCP/IP stack with standard POSIX interfaces</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Type : string Private = C++</td>
</tr>
</tbody>
</table>

4.2.2.1.2  Guider Application Environment
Environment where Telescope Guider and Telescope Guider Client deploy.

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS : string Private = Observatory sanctioned OS</td>
</tr>
</tbody>
</table>

4.2.2.1.2.1  Telescope Guider
This component determines the parameters used to initialize the guiders for each exposure. It also processes the guider data to determine the guide error and determines the parameters used to initialize the guiders.

4.2.2.1.2.2  Telescope Guider Client
This component is a client that receives the guider data.

4.2.3 Other System

4.2.3.1  Other Component Computer

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4.2.3.1.1 Other Component Environment

4.2.3.1.1.1 Other Component

4.3 Interfaces Interpretation 3

This section describes the interfaces associated with the components.

![Diagram](image-url)  
**Figure:** Interfaces Interpretation 3

4.3.1 IDAQClient

DAQClient interface

<table>
<thead>
<tr>
<th>OPERATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>✷ wait (guiderID: unsigned short, image: Image, metadataMemPtr: Metadata): void Public</td>
</tr>
</tbody>
</table>

The contents of this document are subject to configuration control and may not be changed, altered, or their provisions waived without prior approval of the LSST Change Control Board.

6 March, 2017
### OPERATIONS

<table>
<thead>
<tr>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>ea_guid = {812D7082-4374-4ba7-8E4D-2CAAAC4A8456}</td>
</tr>
</tbody>
</table>

#### DAQClient () : void Public

<table>
<thead>
<tr>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>ea_guid = {BAC8608C-F8AA-430a-B128-D06185D58672}</td>
</tr>
</tbody>
</table>

#### ~DAQClient () : void Public

<table>
<thead>
<tr>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>ea_guid = {35247310-0F8F-4153-91FA-92867EDA1F2D}</td>
</tr>
</tbody>
</table>

### 4.3.2 IDAQService

DAQServer client

### 4.3.3 ITelescopeGuiderClient

TelescopeGuiderClient interface

#### 4.3.4 Image

Pointer

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>image : Image Data Private</td>
</tr>
<tr>
<td>Is static False. Containment is By Reference.</td>
</tr>
</tbody>
</table>

#### 4.3.5 Metadata

Pointer

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>metaData : Image Metadata Private</td>
</tr>
<tr>
<td>Is static False. Containment is By Reference.</td>
</tr>
</tbody>
</table>

#### 4.3.6 DAQ Client Interaction

The contents of this document are subject to configuration control and may not be changed, altered, or their provisions waived without prior approval of the LSST Change Control Board.
**Figure:** DAQ Client Interaction

### 4.3.6.1 MergeNode

### 4.3.6.2 ActivityFinal

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4.3.6.3 Activity Initial

4.3.6.4 Receive Guide Sensor Data

4.3.6.5 Subscribe to Guide Sensor Data

4.3.6.6 Unsubscribe from Guide Sensor Data

4.3.6.7 Wait for more data?

4.3.6.8 Subscribe to Guide Sensor Data

The Camera publish/subscribe interface has the following characteristics:
- The interface supports one or more subscribers
- The Camera permits each subscriber to subscribe to an arbitrary subset of the 8 streams
- The subscription interface is synchronous; i.e., it blocks waiting on the requested data
- The interface is thread safe and supports multiple subscribers per process, as well as multiple subscribers from multiple processes.
1.0 Guide sensor data may arrive before any DAQ clients have been instantiated. These data are not available to clients instantiated later.

1.1 Client1 creates an instance of a DAQ Client. The DAQ Client is preconfigured to subscribe to one or more of the available (<=8) streams. For the purposes of this example consider that the client is configured to receive streams from guide sensors 1, 2, and 4.

1.2 A second client, Client2, may also obtain the same data by creating an instance of the DAQ client. Again, since the DAQ client is preconfigured to subscribe to certain streams, Client2 will have access to the same data streams as Client1.

The DAQ Client is preconfigured (possibly through the initGuiders command) to subscribe to information from an arbitrary set of the eight guider streams. A DAQClient may subscribe to only a single stream, to all streams, or to any subset in-between.

An end client in an application (Client1 or Client2 in this example) creates an instance of the DAQ client. This instance is valid for the session.

Once published, information cannot be republished. If no clients are subscribed when information is published that information is lost.

The end clients (Client1 and Client2 in this example) are responsible for aligning the streams, if necessary, for each exposure.

<table>
<thead>
<tr>
<th>Message</th>
<th>Message Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Guide sensor data may arrive before any DAQ clients have been instantiated. These data are not available to clients instantiated later.</td>
</tr>
<tr>
<td>1.1</td>
<td>Client1 creates an instance of a DAQ Client. The DAQ Client is preconfigured to subscribe to one or more of the available (&lt;=8) streams. For the purposes of this example consider that the client is configured to receive streams from guide sensors 1, 2, and 4.</td>
</tr>
<tr>
<td>1.2</td>
<td>A second client, Client2, may also obtain the same data by creating an instance of the DAQ client. Again, since the DAQ client is preconfigured to subscribe to certain streams, Client2 will have access to the same data streams as Client1.</td>
</tr>
</tbody>
</table>

**Object**

**Client1**

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4.3.6.8.3  Client2

4.3.6.8.4  DAQClient1

4.3.6.8.5  DAQClient2

4.3.6.8.6  MessageEnd

4.3.6.9  Receive Guide Sensor Data

The Camera publish/subscribe interface has the following characteristics:
- The interface supports one or more subscribers
- The Camera permits each subscriber to subscribe to an arbitrary subset of the 8 streams
- The subscription interface is synchronous; i.e., it blocks waiting on the requested data
- The interface is thread safe and supports multiple subscribers per process, as well as multiple subscribers from multiple processes.
The server streams data from each guide sensor. A DAQ Client immediately forwards any requested data to each telescope guider client that requested the data. A telescope guider client may act on each data packet immediately or rendezvous data, as needed.

The contents of this document are subject to configuration control and may not be changed, altered, or their provisions waived without prior approval of the LSST Change Control Board.
To receive guider information the caller invokes a wait() method that requires as parameters pointers to buffers to contain both data and metadata. (The order in which pixel data is copied to its buffer is TBD.)

The order in which data arrives may vary.

**Data Freshness:**
The DAQ service stores this data in a first-in, first-out buffer (FIFO). In order to obtain fresh data, an as yet unspecified mechanism will be necessary.  
One option would be for the DAQ to provide a function to clear the buffer.  
Another option (shown in this example) would be for the recipient to read the buffer repeatedly until there is no data, but there are issues with this:
- It requires multiple reads.
- Even if there is only one item in the buffer, it requires an extra read to know there are no more elements, and, unless there is a timeout, this read would block.
- Moreover, data could be arriving rapidly, so just because the buffer is now empty does not determine which previous data was valid.
- Also, this is complex, since the application may not know which data is valid until later.
- Data delivery is not guaranteed in this protocol.
(These issues could be mitigated by providing the number of buffered items. It would also be possible to implement a way to discard data older than a specified age, in order to eliminate stale data. A waitWithTimeout() method may be appropriate.)

<table>
<thead>
<tr>
<th>Message</th>
<th>Message Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Client1 calls wait().</td>
</tr>
<tr>
<td>1.1</td>
<td>Data starts to arrive from the DAQ Service. The order of data arrival may vary.</td>
</tr>
<tr>
<td>1.2</td>
<td>Since the DAQ Client is preconfigured to receive guide sensor 1 data, the DAQ Service pushes it to both DAQ Client instances.</td>
</tr>
<tr>
<td>1.3</td>
<td>DAQClient1 pushes sensor 1 data to Client1, since Client1 is waiting for it.</td>
</tr>
<tr>
<td>2.0</td>
<td>Client1 calls wait() again.</td>
</tr>
<tr>
<td>2.1</td>
<td>Data from guide sensor 2 arrives.</td>
</tr>
<tr>
<td>2.2</td>
<td>Both instances of the DAQ Client receive the sensor 2 data.</td>
</tr>
<tr>
<td>2.3</td>
<td>DAQClient1 pushes sensor 2 data to Client1.</td>
</tr>
<tr>
<td>2.4</td>
<td>Client2 also calls wait().</td>
</tr>
<tr>
<td>2.5</td>
<td>DAQClient2 pushes the buffered sensor 1 data to Client2.</td>
</tr>
<tr>
<td>3.0</td>
<td>Client2 calls wait() again.</td>
</tr>
<tr>
<td>3.1</td>
<td>DAQClient2 pushes sensor 2 data to Client2.</td>
</tr>
<tr>
<td>3.2</td>
<td>Client1 calls wait() again.</td>
</tr>
<tr>
<td>3.3</td>
<td>More data is available at the service. The DAQ Client is not configured to receive this data, so the service does not send it to the DAQ Client.</td>
</tr>
<tr>
<td>3.4</td>
<td>More data is available at the service. The DAQ Client is not configured to receive this data. Again, the order data arrives is not fixed.</td>
</tr>
</tbody>
</table>
3.5 Data from guide sensor 4 arrives.

3.6 Both DAQ Clients receive the sensor 4 data.

3.7 Client1 has called wait() and thus receives the sensor 4 data.

3.8 Client2 calls wait().

3.9 Client2 receives the buffered sensor 4 data.

4.3.6.9.1 Object

4.3.6.9.2 Client1

4.3.6.9.3 Client2

4.3.6.9.4 DAQClient1

4.3.6.9.5 DAQClient2

4.3.6.9.6 MessageEnd

4.3.6.9.7 MessageEnd
4.3.6.9.8 MessageEnd

4.3.6.9.9 MessageEnd

4.3.6.9.10 MessageEnd

4.3.6.10 Unsubscribe from Guide Sensor Data

The Camera publish/subscribe interface has the following characteristics:
- The interface supports one or more subscribers
- The Camera permits each subscriber to subscribe to an arbitrary subset of the 8 streams
- The subscription interface is synchronous; i.e., it blocks waiting on the requested data
- The interface is thread safe and supports multiple subscribers per process, as well as multiple subscribers from multiple processes.

![Diagram showing unsubscribe process]

1.0 Client1 deletes its DAQ client.
1.1 Client2 deletes its DAQ client.

At the end of a session the DAQClient instances are destroyed.

<table>
<thead>
<tr>
<th>Message</th>
<th>Message Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Client1 deletes its DAQ client.</td>
</tr>
<tr>
<td>1.1</td>
<td>Client2 deletes its DAQ client.</td>
</tr>
</tbody>
</table>

4.3.6.10.1 Object

4.3.6.10.2 Client1
4.3.6.10.3 Client2

4.3.6.10.4 DAQClient1

4.3.6.10.5 DAQClient2

### 4.3.7 GuideSensorDataSignal

There are guide sensor data signals associated with each guide sensor. All of these have the same form.

**Figure:** GuideSensorDataSignal

There is a GuideSensorData signal for each Guide Sensor.

#### 4.3.7.1 GuideSensor1Data

#### 4.3.7.2 GuideSensor2Data

#### 4.3.7.3 GuideSensor3Data

#### 4.3.7.4 GuideSensor4Data

The contents of this document are subject to configuration control and may not be changed, altered, or their provisions waived without prior approval of the LSST Change Control Board.

6 March, 2017
4.3.7.5  GuideSensor5Data

4.3.7.6  GuideSensor6Data

4.3.7.7  GuideSensor7Data

4.3.7.8  GuideSensor8Data

4.3.7.9  GuideSensorDataSignal

Abstract signal. The concrete signals are those for the specific guide sensors.

<table>
<thead>
<tr>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>sensorData : Guider Sensor Data  Private</td>
</tr>
</tbody>
</table>

[ Is static False. Containment is Not Specified. ]