areaDetector: A module for EPICS area detector support

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areaDetector Talk Outline

- Motivation & goals for areaDetector module
- Overview of architecture
- Drivers for detectors & cameras
- Plugins for real-time processing
- Viewers and other clients
- Emphasis on what is new and plans for future
- Today: Morning lecture, afternoon demonstration
- Tomorrow: Hands-on practice with simulation or real detectors
- Next week: Writing software for a new detector or a new plugin

areaDetector - Motivation

- 2-D detectors are essential components of synchrotron beamlines
  - Sample viewing cameras, x-ray diffraction and scattering detectors, x-ray imaging, optical spectroscopy, etc.
- EPICS is a very commonly used control system on beamlines, (APS, DLS, SLS, SLAC, NSLS-II, Shanghai, etc.)
- Need to control the detectors from EPICS (useful even on non-EPICS beamlines, since other control systems like SPEC etc. can talk to EPICS)
- Clear advantages to an architecture that can be used on any detector, re-using many software components
- Providing EPICS control allows any higher-level client to control the detector and access the data (CSS, SPEC, medm, Python scripts, IDL programs, etc)
  - The client needs only to know how to talk to EPICS, not the details of the detector

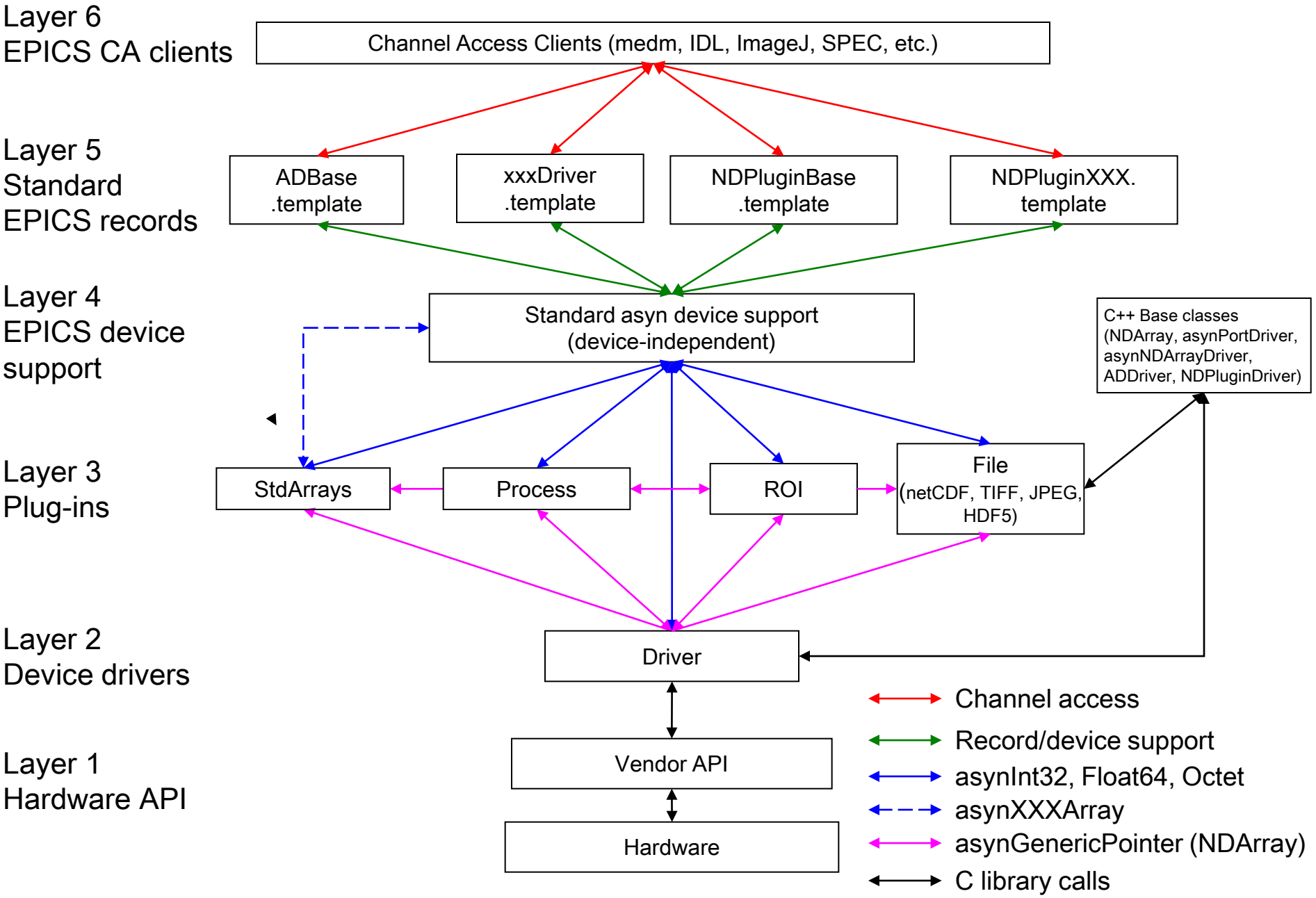
areaDetector - Goals

- Drivers for many detectors popular at synchrotron beamlines
  - Handle detectors ranging from >500 frames/second to <1 frame/second
- Basic parameters for all detectors
  - E.g. exposure time, start acquisition, etc.
  - Allows generic clients to be used for many applications
- Easy to implement new detector
  - Single device-driver C++ file to write. EPICS independent.
- Easy to implement detector-specific features
  - Driver understands additional parameters beyond those in the basic set
- EPICS-independent at lower layers.
- Middle-level plug-ins to add capability like regions-of-interest calculation, file saving, etc.
  - Device independent, work with all drivers
  - Below the EPICS database and Channel Access layers for highest performance

areaDetector – Data structures

- NDArray
  - N-Dimensional array.
    - Everything is done in N-dimensions (up to 10), rather than 2. This is needed even for 2-D detectors to support color.
  - This is what plug-ins callbacks receive from device drivers.
- NDAttribute
  - Each NDArray has a list of associated attributes (metadata) that travel with the array through the processing pileline. Attributes can come from driver parameters, any EPICS PV, or any user-written function.
    - e.g. can store motor positions, temperature, ring current, etc. with each frame.
- NDArrayPool
  - Allocates NDArray objects from a freelist
  - Plugins access in readonly mode, increment reference count
  - Eliminates need to copy data when sending it to plugins.

EPICS areaDetector Architecture



areaDetector – Data structures

Look at NDArray.h

Look at NDAttribute.h

Look at an XML attribute file

areaDetector R2-0 Release

- areaDetector was getting too big.
  - New releases being held up waiting for testing on one detector types, etc.
- Hard to collaborate with other sites using APS Subversion repository
  - git and github provide much better tools for multi-site collaborations

R2-0 Organization

areaDetector
Top-level module
RELEASE files, documentation, Makefile

ADCore
Core module
Base classes, plugins, simDetector, documentation

ADBinaries
Binary libraries for Windows (HDF5, GraphicsMagick)

ADProsilica
Prosilica driver

ADPilatus
Pilatus driver

…

- Each box above is a separate git repository
- Can be released independently
- Hosted at http://github.com/areaDetector project
- Each repository is a submodule under areaDetector/areaDetector

Source Code Organization on github

- https://github.com/areaDetector is top-level project
- Contains configure/ directory where paths and versions of supporting software are defined
- Contain .gitmodules to define submodules that will be cloned with git clone –recursive
- Contains documentation directory that builds and installs documentation
- Contains a top-level Makefile to build all or selected submodules

Types of Detector Drivers

- Vendor C/C++ library
- Vendor socket protocol
- Vendor application program with automation mechanism

Detector drivers (23 total)

- ADDriver (in ADCore)
  - Base C++ class from which detector drivers derive. Handles details of EPICS interfaces, and other common functions.
- Simulation driver (in ADCore)
  - Produces calculated images up to very high rates. Implements nearly all basic parameters, including color. Useful as a model for real detector drivers, and to test plugins and clients.
- Prosilica driver (ADProsilica)
  - Gigabit Ethernet cameras, mono and color
  - High resolution, high speed, e.g. 1360x1024 at 30 frames/second = 40MB/second.
  - Controlled via calls to vendor PvAPI C library
- Firewire (IEEE-1396 DCAM) (ADFireWireWin, firewireDCAM)
  - Vendor-independent Firewire camera drivers for Linux and Windows
  - Controlled via open-source libraries on Windows and Linux

Detector drivers

- Roper driver (ADRoper)
  - Princeton Instruments and Photometrics cameras controlled via Microsoft COM control of WinView applications
- PVCAM driver (ADPvCam)
  - Princeton Instruments and Photometrics cameras
  - Controlled via PVCAM C library
- Pilatus driver (ADPilatus)
  - Pilatus pixel-array detectors.
  - Controlled via sockets to vendor camserver application
- marCCD driver (ADmarCCD)
  - Rayonix (MAR-USA) CCD x-ray detectors
  - Controlled by socket communication to marCCD remote control
- ADSC driver (ADADSC)
  - ADSC CCD detectors
  - Controlled by C calls to vendor library

Detector drivers (continued)

- mar345 driver (ADmar345)
  - marResearch mar345 online image plate
  - Controlled by socket communication to mar345dtb socket server
- Perkin-Elmer driver (ADPerkinElemer)
  - Perkin-Elmer amorphous silicon flat-panel detectors
  - Controlled by C calls to vendor library
- Bruker driver (ADBruker)
  - Bruker CCD detectors
  - Controlled via their Bruker Instrument Server (BIS) socket server
- LightField driver (ADLightField)
  - Princeton Instruments detectors, including all recent models
  - Controlled via their LightField application using the Microsoft Common Language Runtime to automate it

Detector drivers (continued)

- PICAM driver (ADPiCam)
  - Princeton Instruments cameras, including recent models
  - Controlled via PICAM C library
  - Currently under development by John Hammonds
- PSL driver (ADPSL)
  - Photonic Sciences Limited detectors
  - Controlled via socket connection to their Python PSLViewer server
- URL driver (ADURL)
  - Driver to display images from any URL. Works with Web cameras, Axis video servers, static images, etc.
  - Controlled by calls to GraphicsMagick library

Detector drivers (continued)

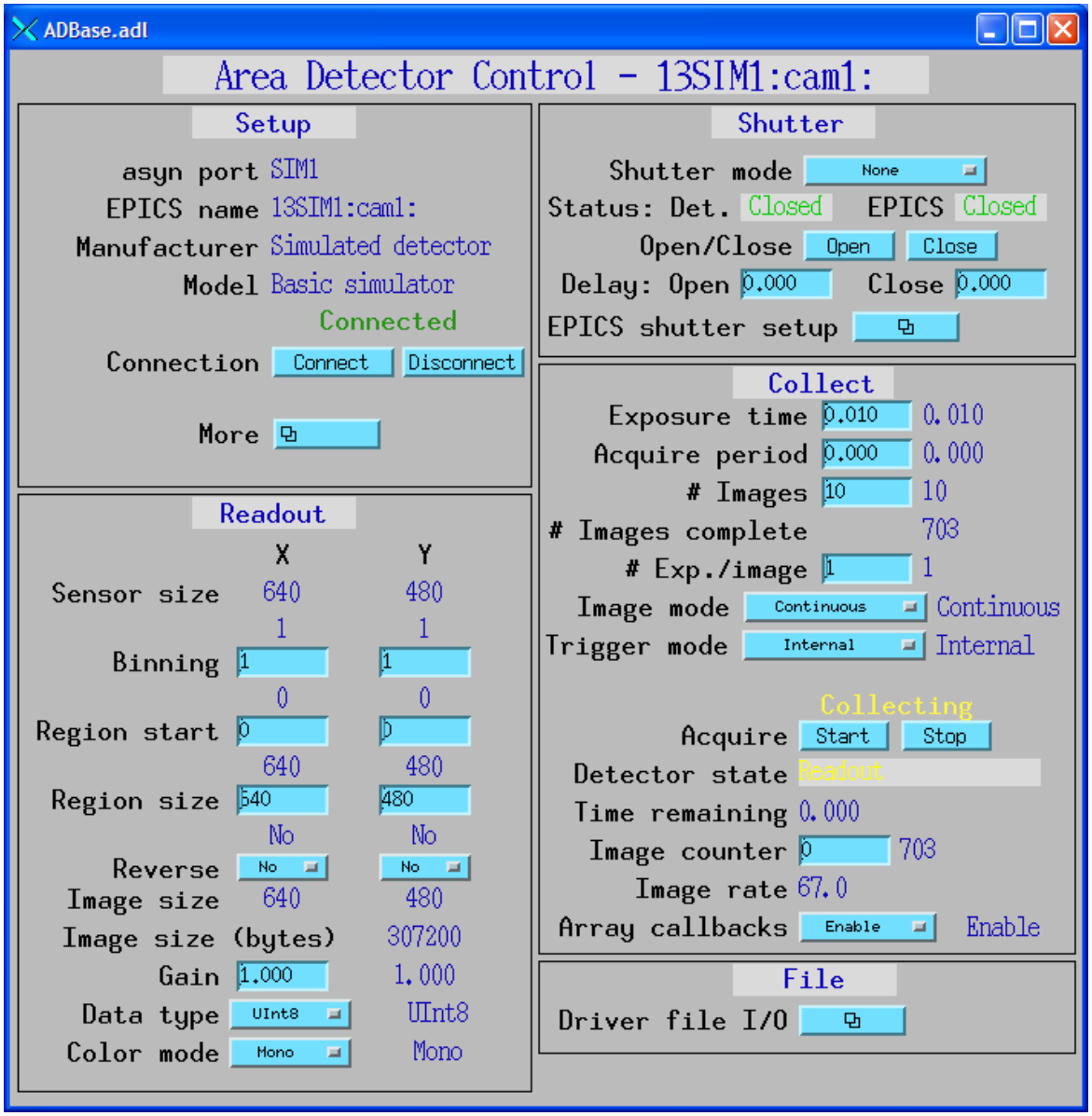
- Andor driver (ADAndor)
  - Driver for Andor CCD cameras
  - Controlled by calls to V2 of their C SDK
- Andor3 driver (ADAndor3)
  - Driver for Andor sCMOS cameras
  - Controlled by calls to V3 of their SDK
- Point Grey driver (ADPointGrey)
  - Driver for GigE, USB-3.0, USB-2.0, and Firewire cameras from Point Grey Research
  - Controlled by calls to their C SDK
- Pixirad driver (ADPixirad)
  - Driver for CdTe pixel-array detectors from Pixirad
  - Controlled by TCP and UDP communication with their detector

Detector drivers (continued)

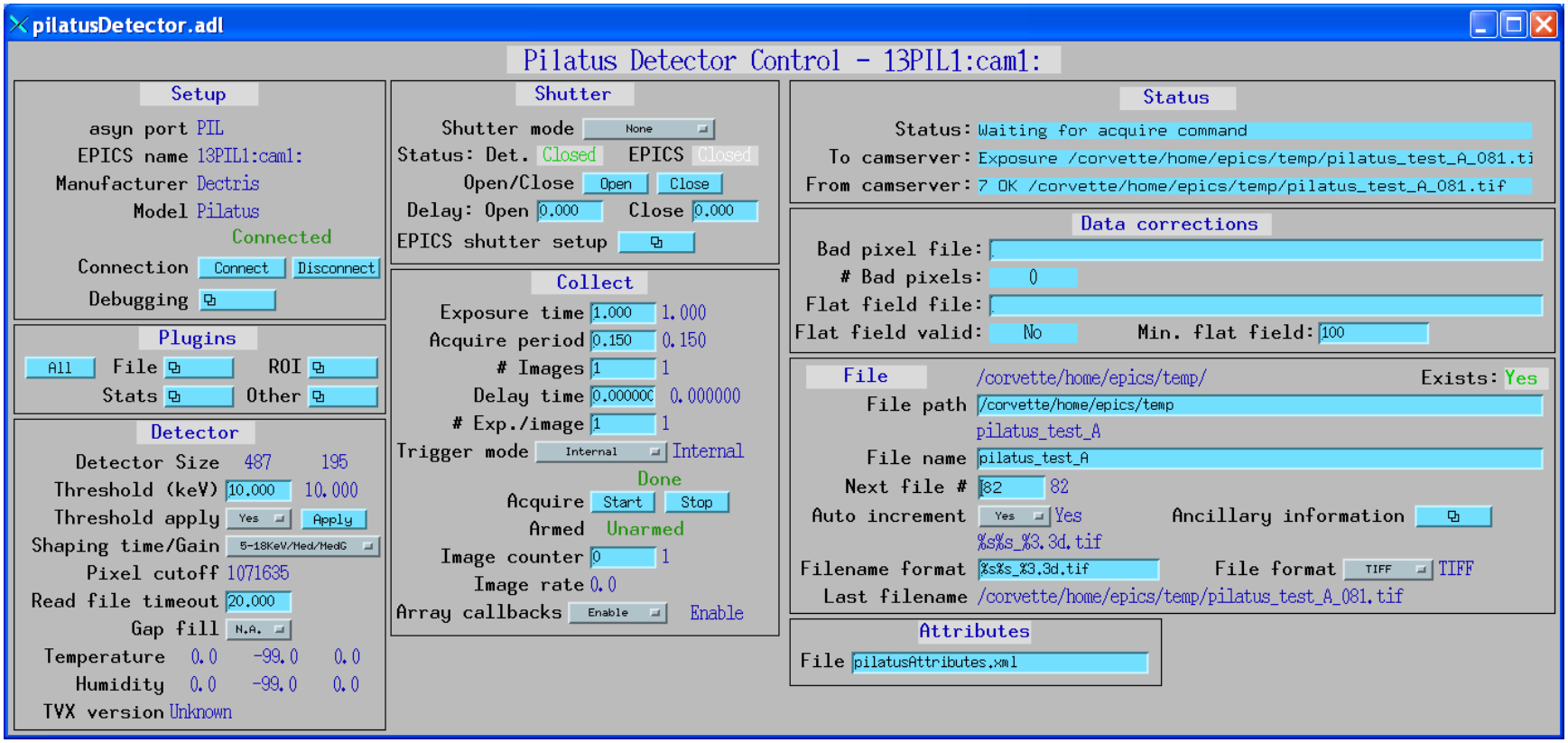
- Generic GigE driver (aravisGigE)
  - Should work with any GigEVision compliant camera. From Tom Cobb at Diamond.
  - Controlled using the Aravis reverse-engineered GigEVision library
- QImaging driver (ADQImaging)
  - QImaging cameras.
  - Controlled using Qimaging SDK
  - Written by Arthur Glowacki
- ADPvAccess
  - Driver that receives NDArrays over EPICS V4
  - Allows plugins to run in an EPICS IOC on a different machine than the detector
  - Written by David Hickin from Diamond.

ADBase.adl – Generic control screen

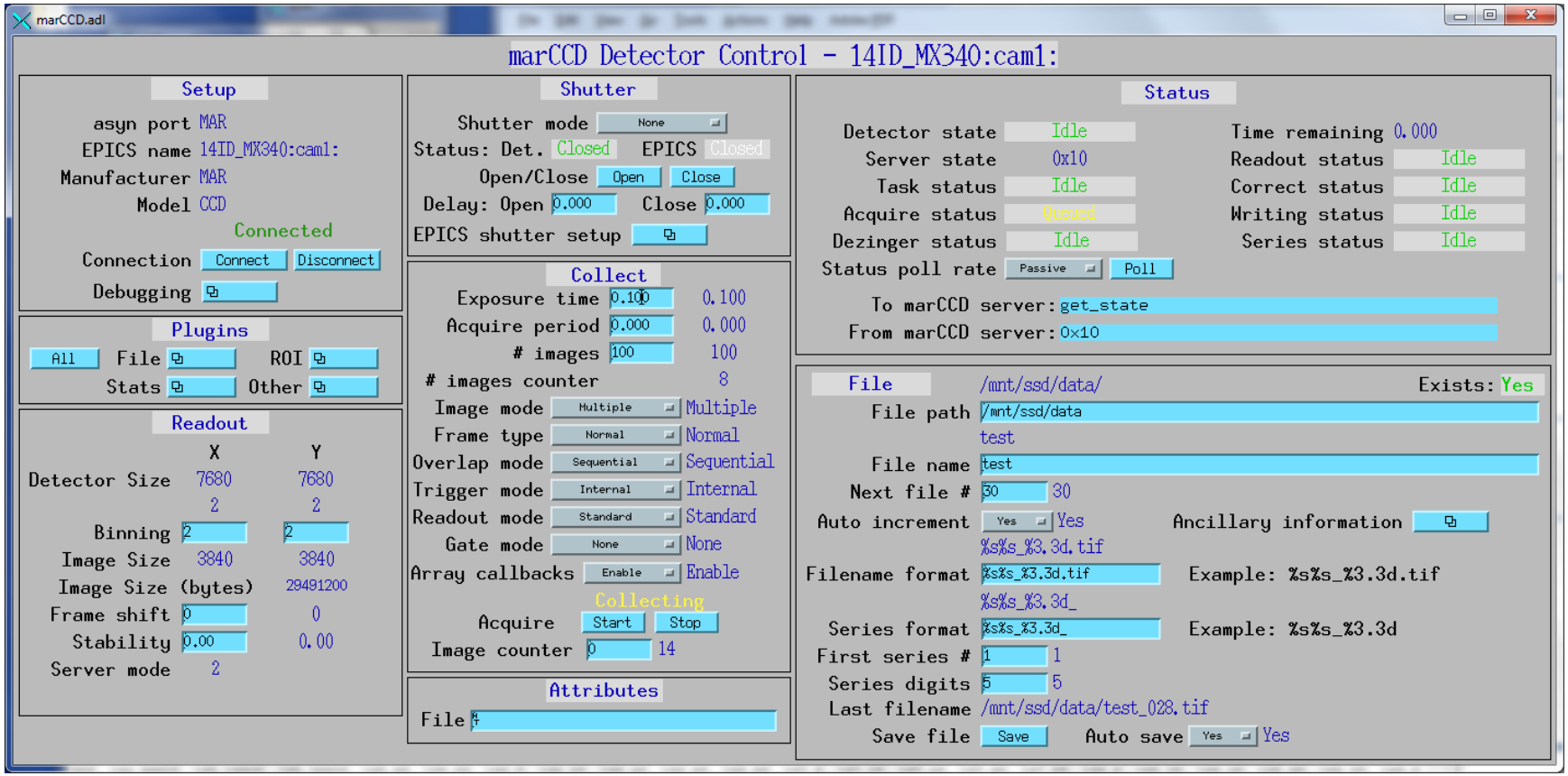
- Works with any detector
- Normally write custom control for each detector type to hide unimplemented features and expose driver-specific features



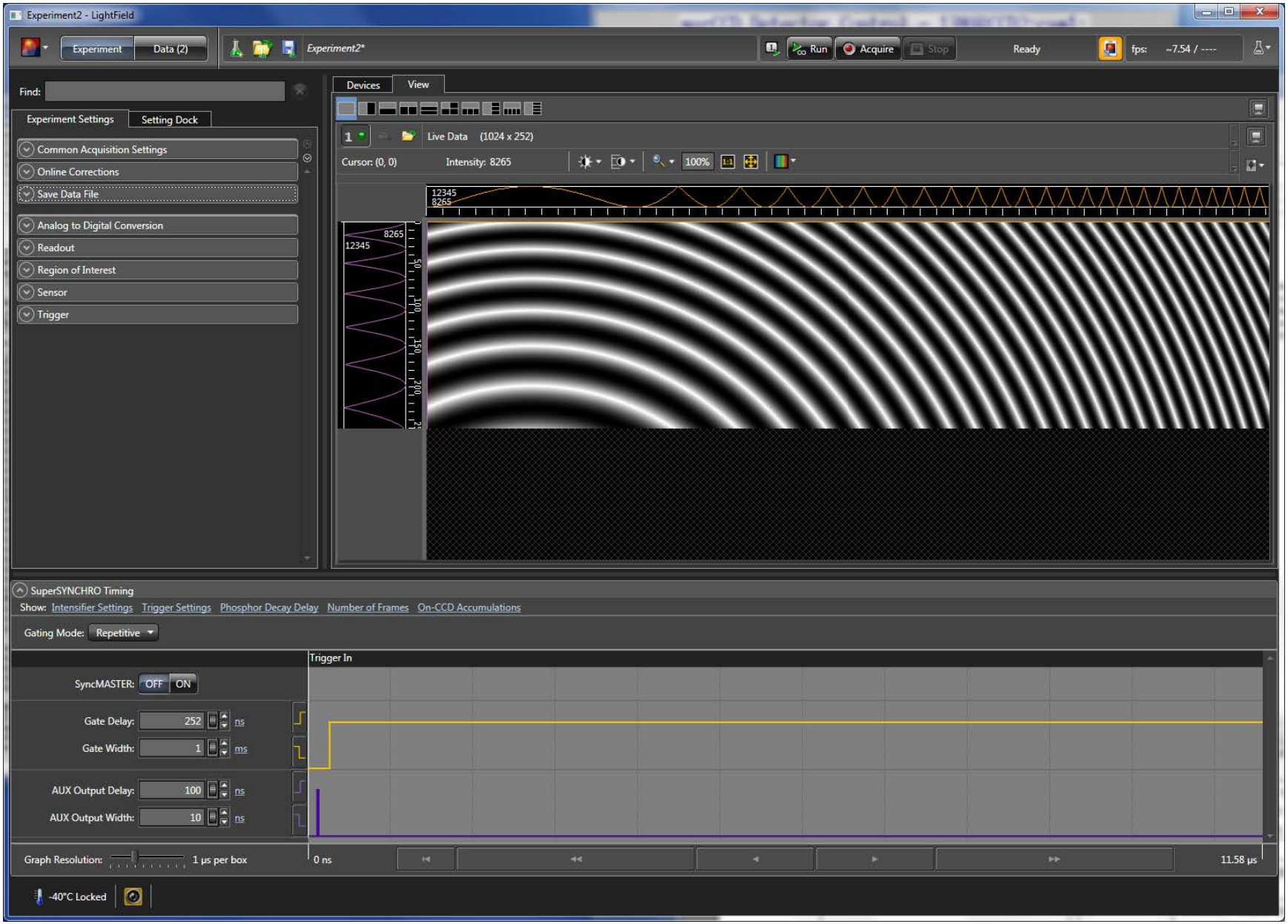
Pilatus specific control screen



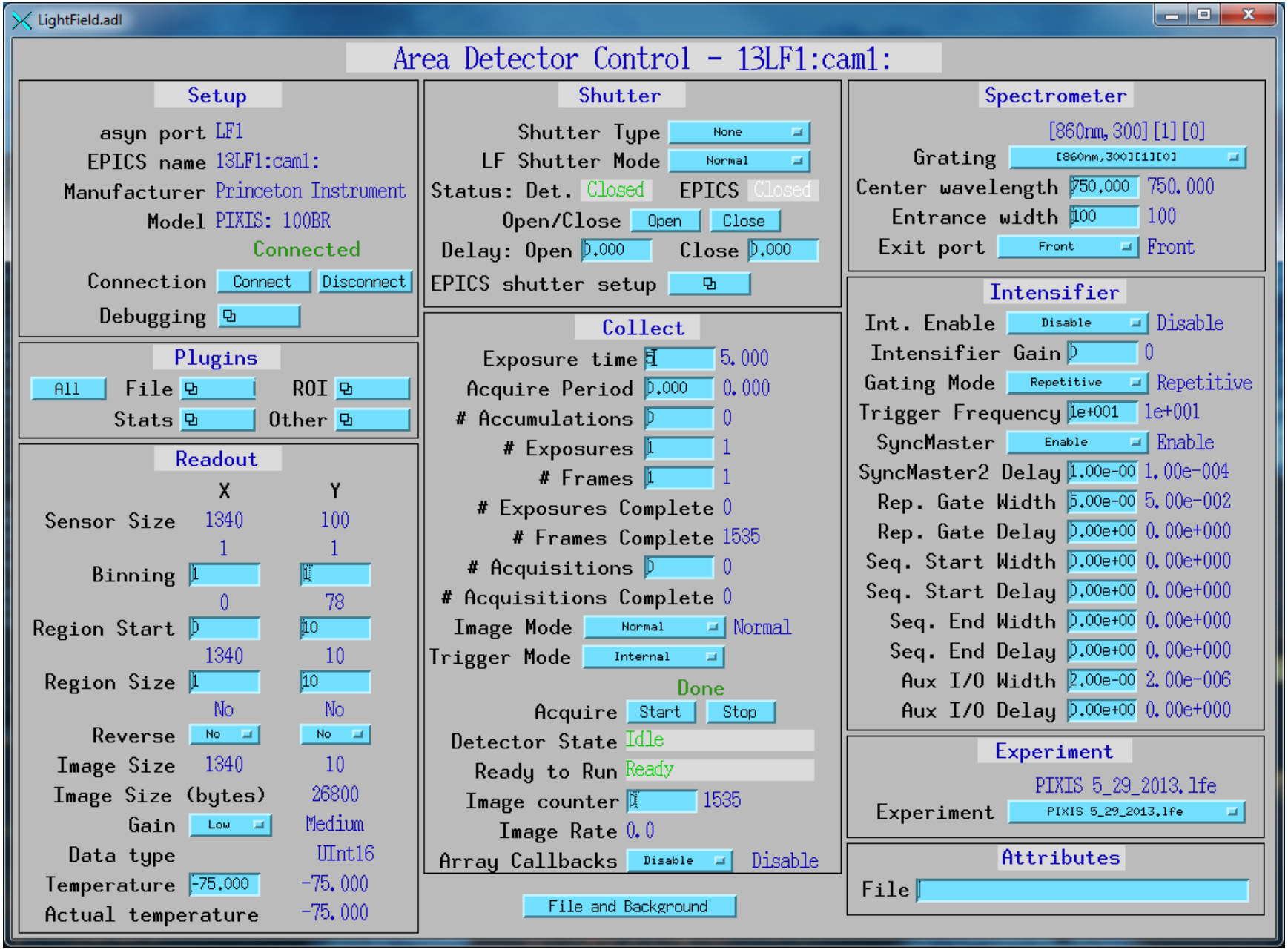
MAR-345 specific control screen



LightField driver

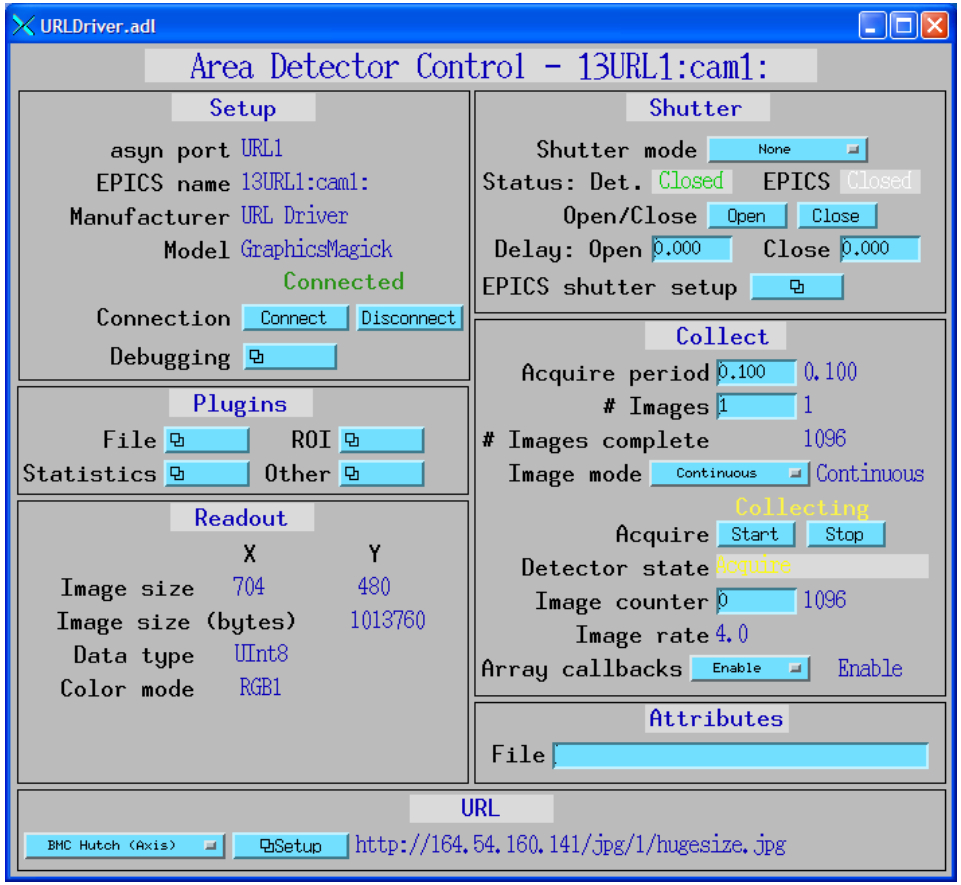


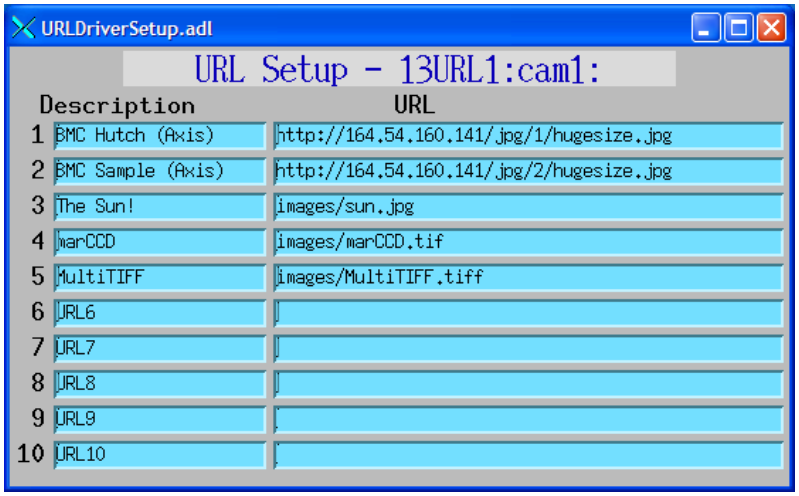
LightField driver



URL Driver

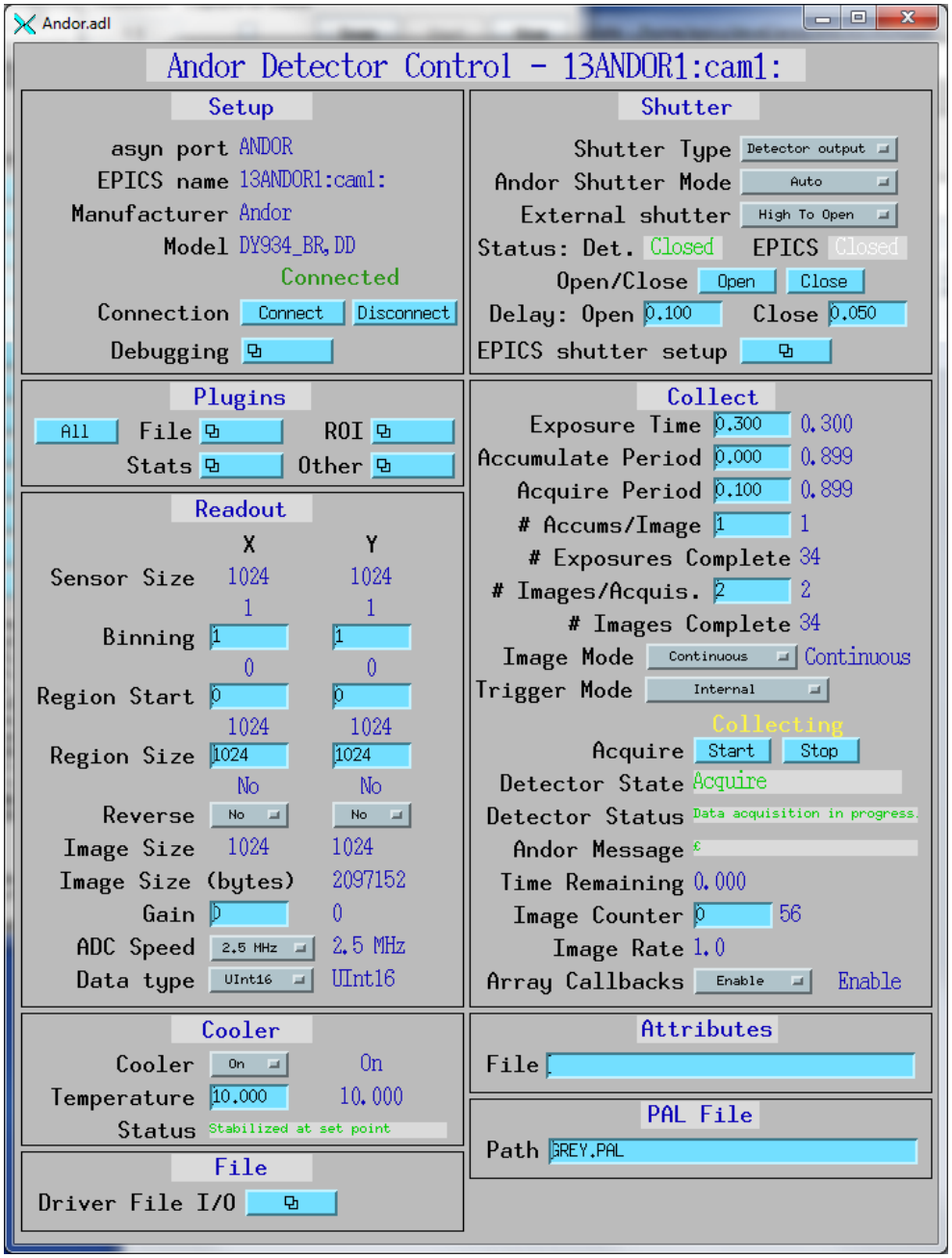
- Driver that can read images from any URL.
- Can be used with Web cameras and Axis video servers.
- Uses GraphicsMagick to read the images, and can thus handle a large number of image formats (JPEG, TIFF, PNG, etc.).



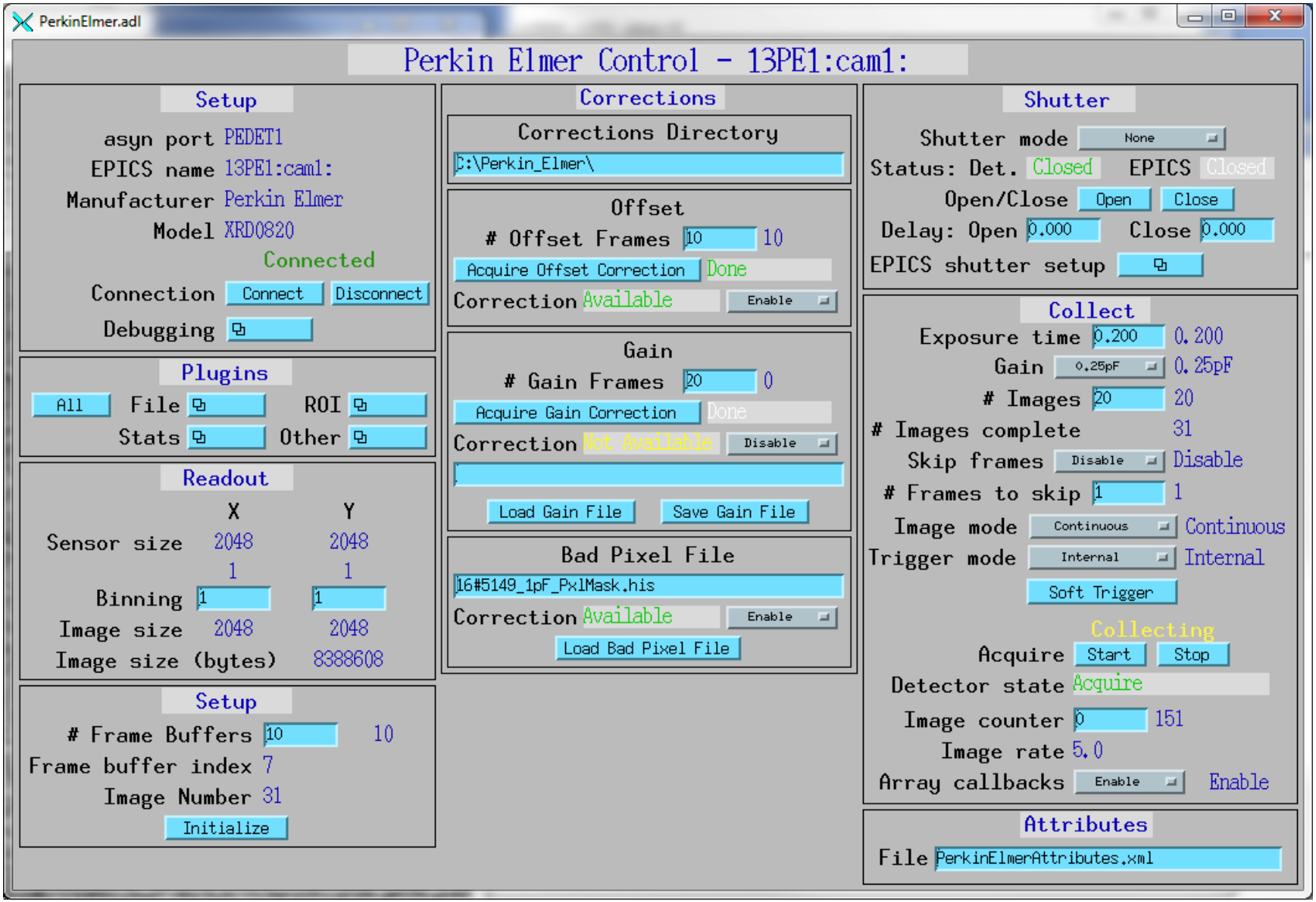


Andor Driver

- Supports USB and PCI CCD cameras from Andor.
- Runs on 32-bit and 64-bit Linux and 32-bit and 64-bit Windows.
- Original version by Matt Pearson from Diamond Light Source.



Perkin Elmer Flat Panel Driver



R2-0: Point Grey driver

- New driver for all cameras from Point Grey using their FlyCap2 SDK.
- Firewire, GigE and USB 3.0
- High performance, low cost

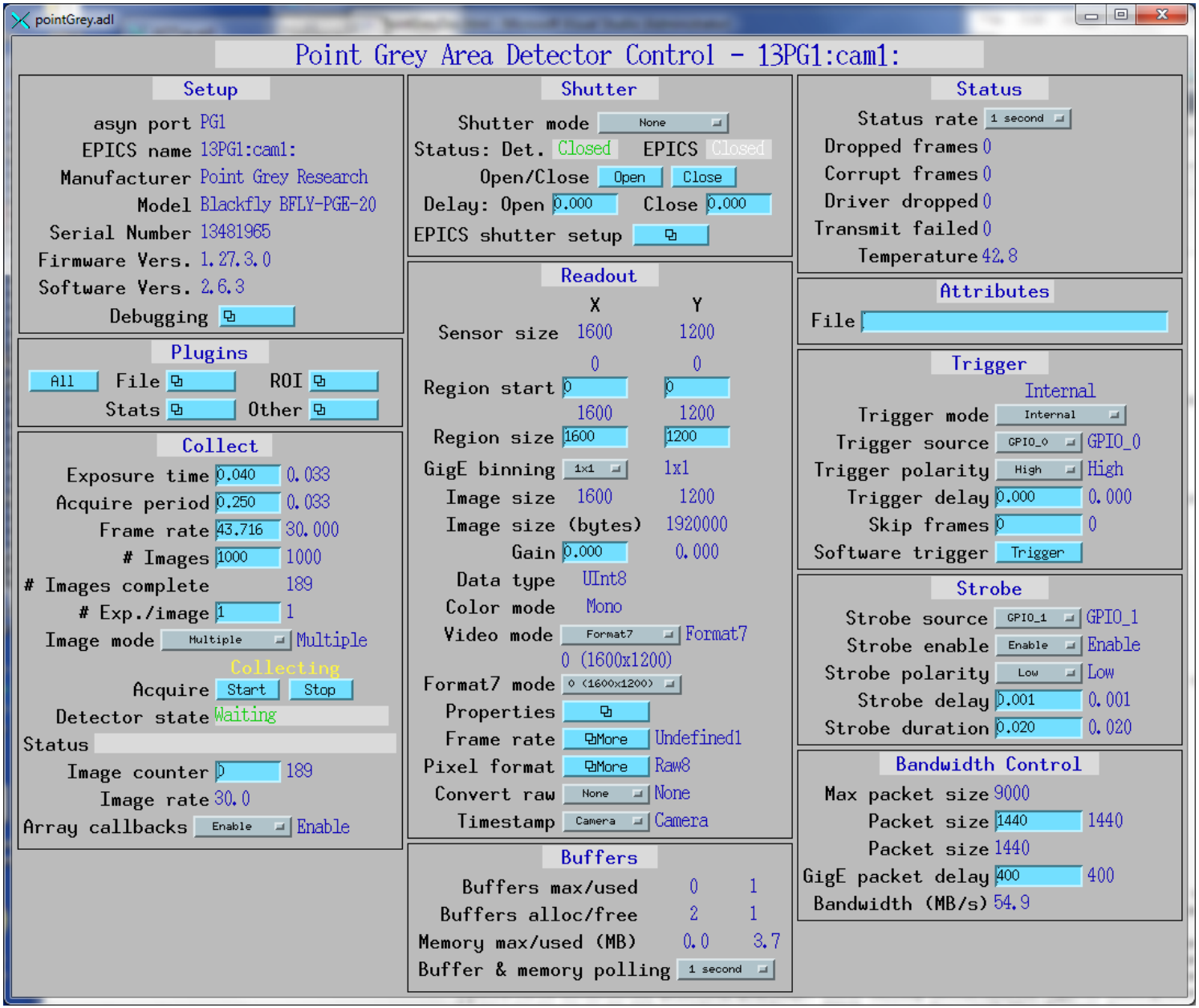
Point Grey GigE Camera BlackFly PGE-20E4C

- e2v EV76C570 CMOS sensor
- Global shutter
- 29 x 29 x 30 mm
- Power Over Ethernet
- 4.5 micron pixels
- 1600 x 1200 pixels, color (mono)
- 47 frames/s
- $595
  - 5X cheaper than comparable Prosilica cameras we bought in the past

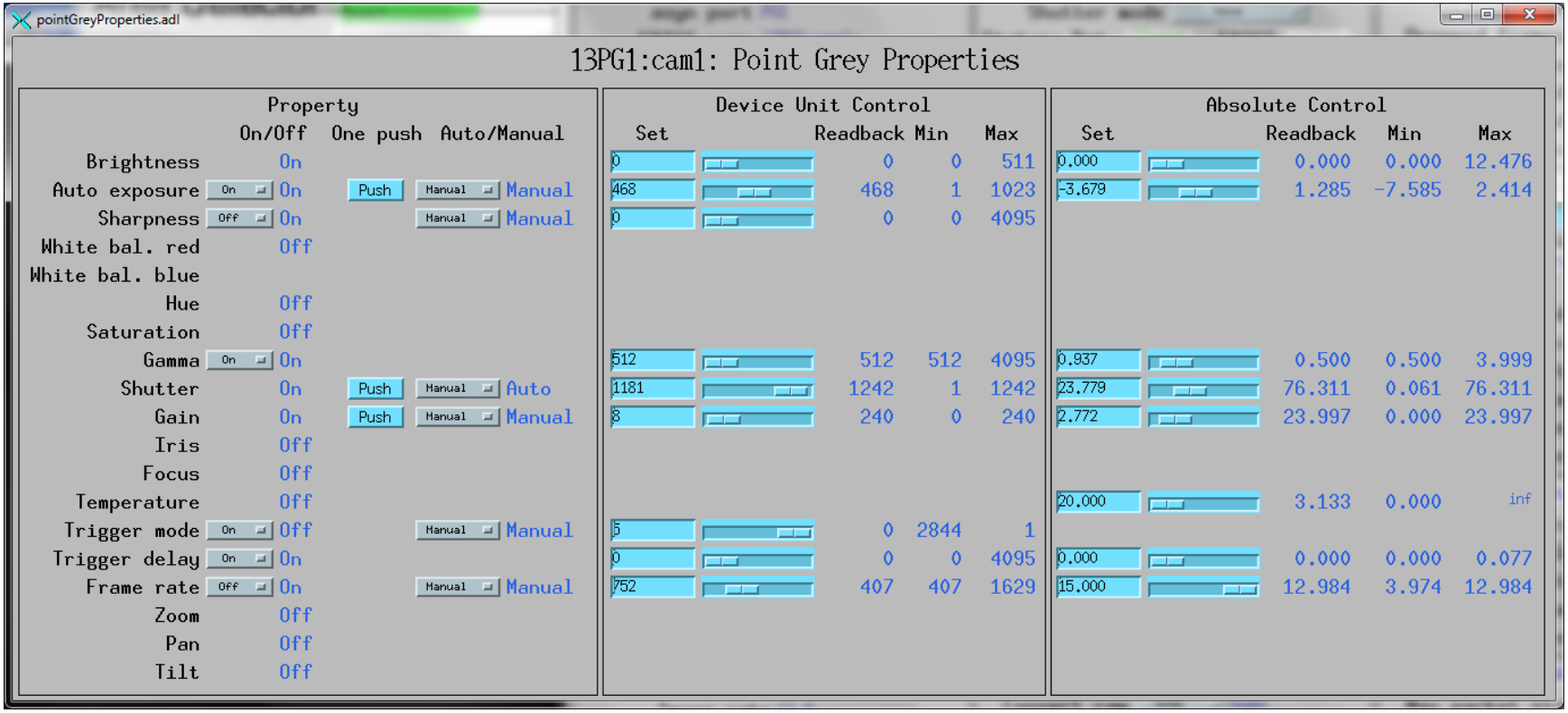
Point Grey USB-3.0 Camera Grasshopper3 GS3-U3-23S6M

- 1920 x 1200 global shutter CMOS
- Sony IMX174 1/1.2
- No smear • Distortion-free
- Dynamic range of 73 dB
- Peak QE of 76%
- Read noise of 7e-
- 12-bit or 8-bit data
- Max frame rate of 162 fps
  - ~356 MB/S, >3X faster than GigE
- USB 3.0 interface
- $1,295

Point Grey Driver



Point Grey Driver (Grasshopper3 camera)



Plugins

- Designed to perform real-time processing of data, running in the EPICS IOC (not over EPICS Channel Access)
- Receive NDArray data over callbacks from drivers or other plugins
- Plug-ins can execute in their own threads (non-blocking) or in callback thread (blocking)
  - If non-blocking then NDArray data is queued
    - Can drop images if queue is full
  - If executing in callback thread, no queuing, but slows device driver
- Allows
  - Enabling/disabling
  - Throttling rate (no more than 0.5 seconds, etc)
  - Changing data source for NDArray callbacks to another driver or plugin
- Some plugins are also sources of NDArray callbacks, as well as consumers.
  - Allows creating a data processing pipeline running at very high speed, each in a different thread, and hence in multiple cores on modern CPUs.

Plugins (continued)

- NDPlugInStdArrays
  - Receives arrays (images) from device drivers, converts to standard arrays, e.g. waveform records.
  - This plugin is what EPICS channel access viewers normally talk to.
- NDPluginROI
  - Performs region-of-interest calculations
  - Select a subregion. Optionally bin, reverse in either direction, convert data type.
  - Divide the array by a scale factor, which is useful for avoiding overflow when binning.
- NDPluginColorConvert
  - Convert from one color model to another (Mono, RGB1 (pixel), RGB2 (row) or RGB3 (planar) interleave)
  - Bayer conversion removed from this plugin, now part of Prosilica and Point Grey drivers.
- NDPluginTransform
  - Performs geometric operations (rotate, mirror in X or Y, etc.)

Plugins (continued)

- NDPluginStats
  - Calculates basic statistics on an array (min, max, sigma)
  - Optionally computes centroid centroid position, width and tilt.
  - Optionally Computes X and Y profiles, including average profiles, profiles at the centroid position, and profiles at a user-defined cursor position.
  - Optionally computes the image histogram and entropy
- NDPluginProcess
  - Does arithmetic processing on arrays
  - Background subtraction.
  - Flat field normalization.
  - Offset and scale.
  - Low and high clipping.
  - Recursive filtering in the time domain.
  - Conversion to a different output data type.
- NDPluginOverlay
  - Adds graphic overlays to an image.
  - Can be used to display ROIs, multiple cursors, user-defined boxes, text, etc.

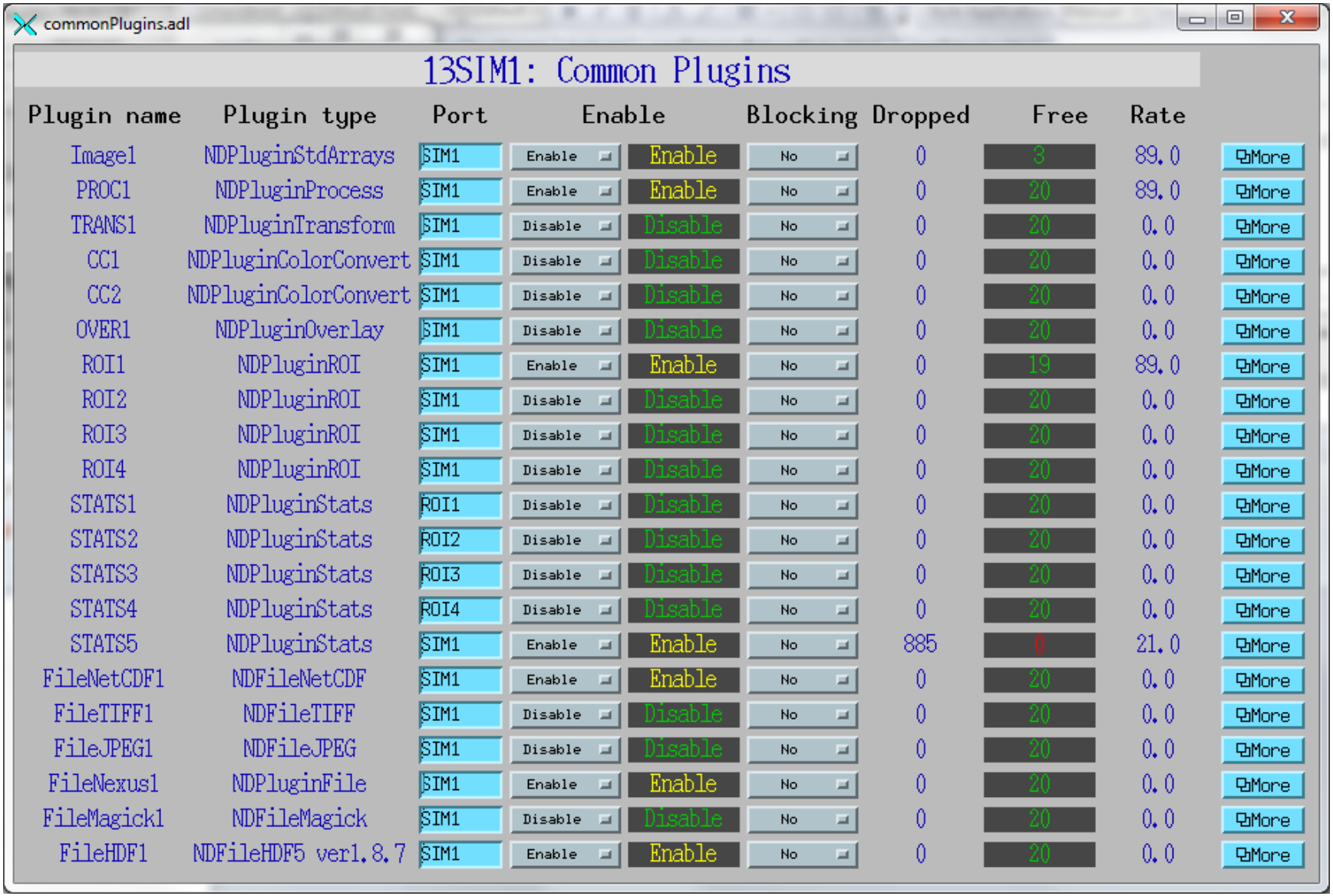
Plugins (recent additions)

- NDPluginCircularBuffer
  - Buffers NDArrays in a circular buffer.
  - Outputs the arrays on receipt of a trigger, either as PV or NDArray attribute.
  - Supports pre-trigger and post-trigger samples
  - Written by Alan Greer at Observatory Sciences
- NDPluginAttribute
  - Extracts an attribute from an NDArray and publishes as a scalar and an array
  - Written by Matt Pearson at ORNL
- ADPluginEdge
  - Does edge detection using the OpenCV Canny function
  - Written by Keith Brister at LS-CAT

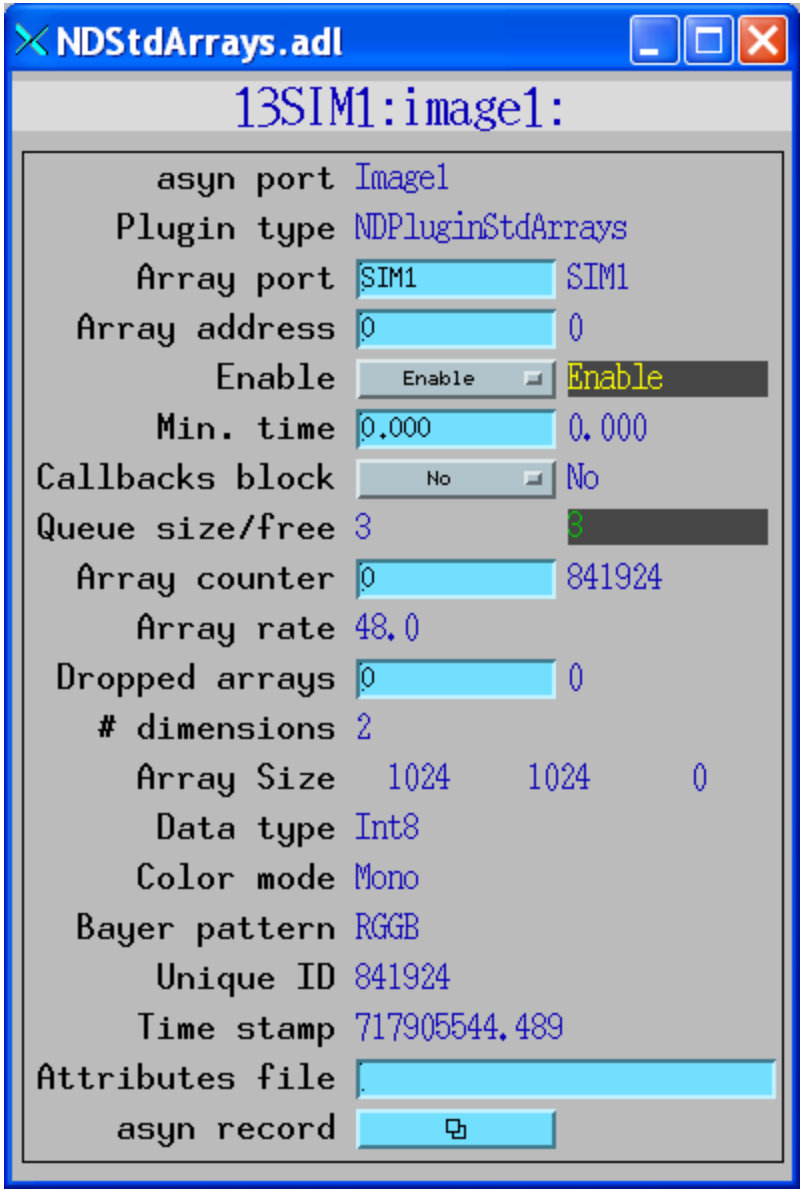
Plugins (recent additions)

- NDPluginROIStat
  - Computes simple statistics on multiple ROIs.
  - More efficient than chaining an NDPluginROI and NDPluginStats when there are many ROIs
  - Written by Matt Pearson at ORNL
- ffmpegServer
  - MJPEG server that allows viewing images in a Web browser. From DLS.
  - Puts compressed images on the network, greatly reducing bandwidth compared to uncompressed channel access arrays.
- ADPvAccess
  - Plugin that sends NDArrays over EPICS V4
  - Allows plugins to run in an EPICS IOC on a different machine than the detector
  - Written by David Hickin from Diamond.

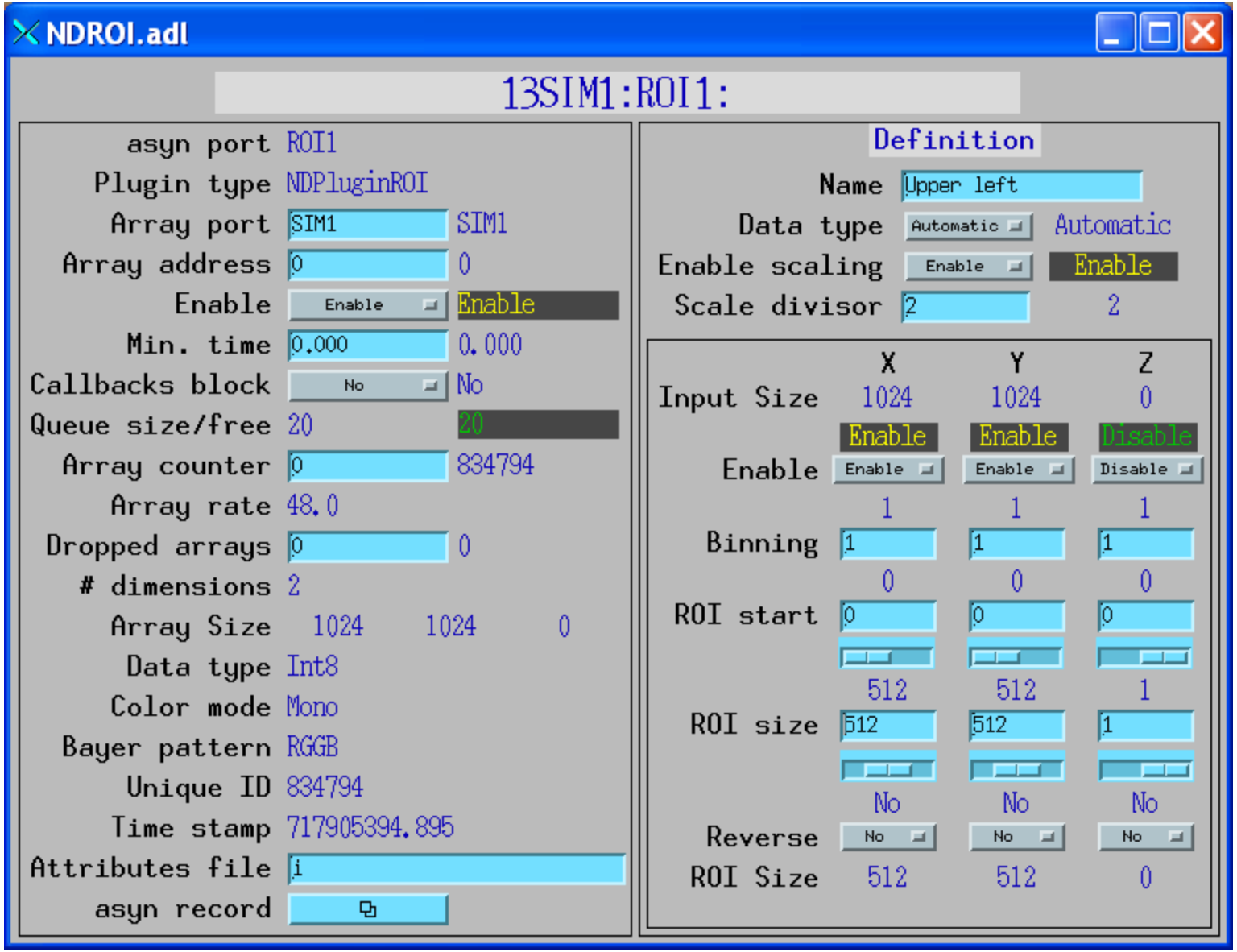
commonPlugins.adl All plugins at a glance



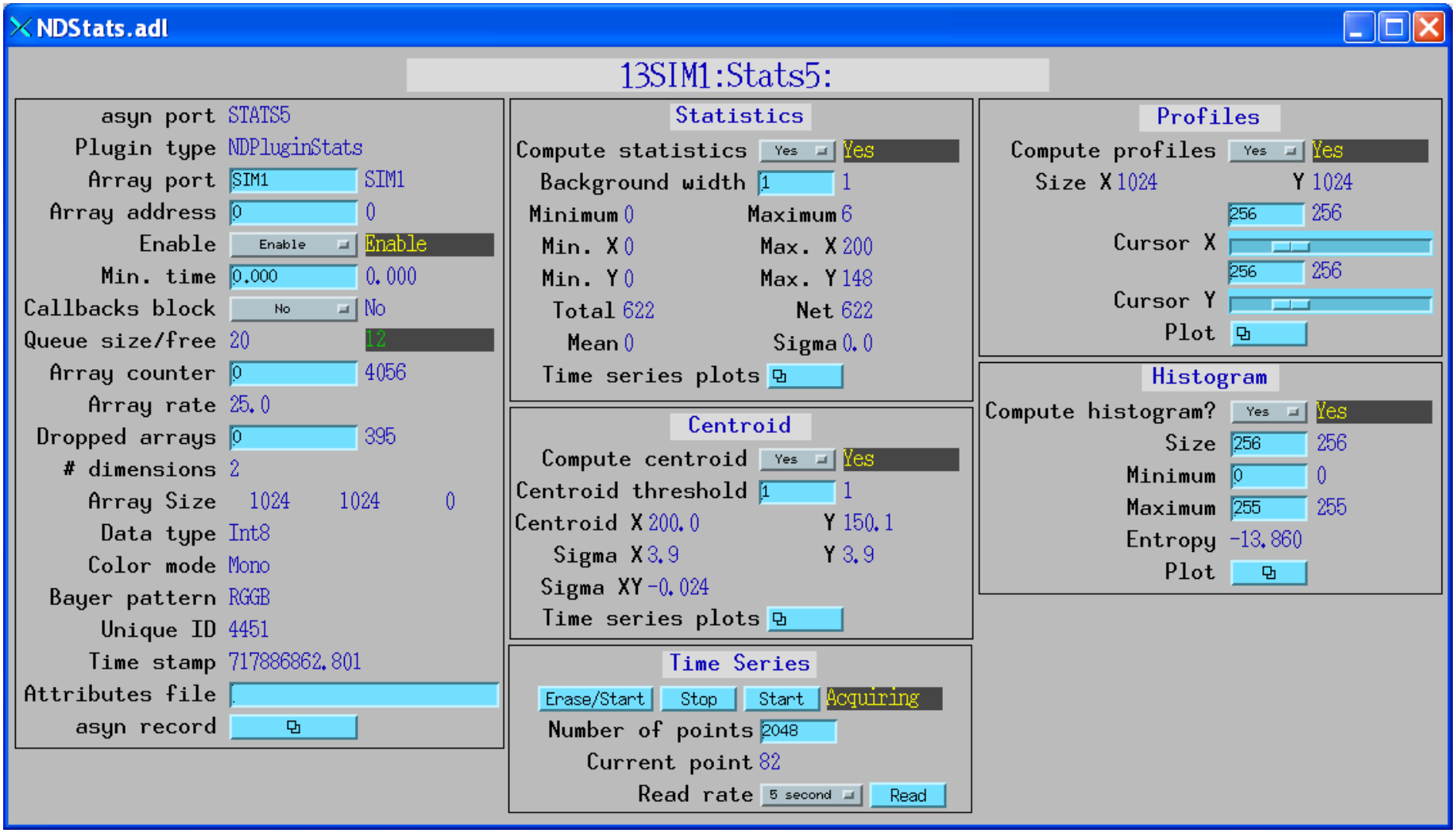
NDStdArrays plugin



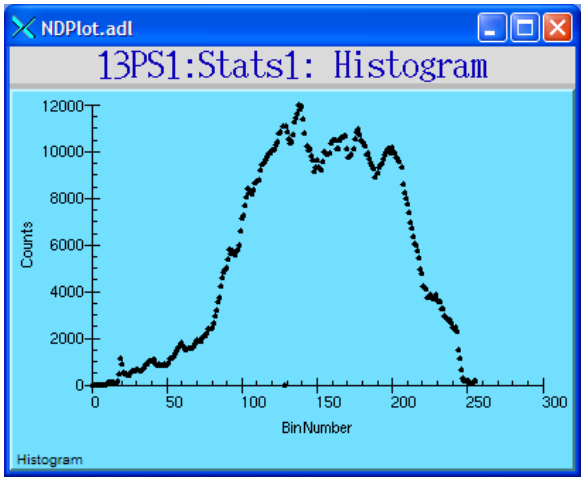
ROI plugin

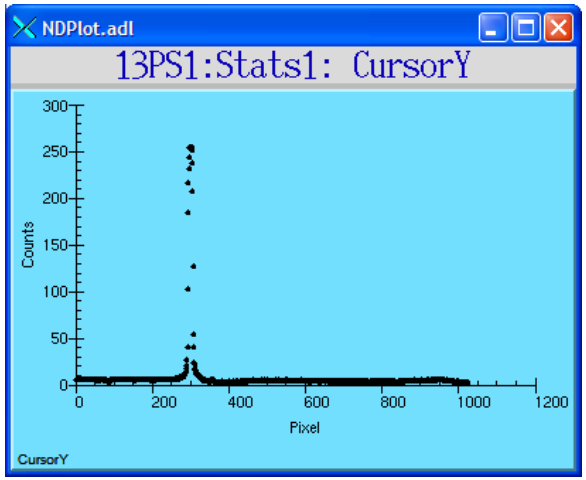

NDROI.adl
13SIM1:ROI1:
asyn port ROI1
Plugin type NDPluginROI
Array port SIM1 SIM1
Array address 0 0
Enable Enable Enable
Min. time 0.000 0.000
Callbacks block No No
Queue size/free 20 20
Array counter 0 834794
Array rate 48.0
Dropped arrays 0 0
dimensions 2
Array Size 1024 1024 0
Data type Int8
Color mode Mono
Bayer pattern RGGB
Unique ID 834794
Time stamp 717905394.895
Attributes file
asyn record
Definition
Name Upper left
Data type Automatic Automatic
Enable scaling Enable Enable
Scale divisor 2 2
X Y Z
Input Size 1024 1024 0
Enable Enable Enable Disable
Binning 1 1 1
ROI start 0 0 0
ROI size 512 512 1
Reverse No No No
ROI Size 512 512 0

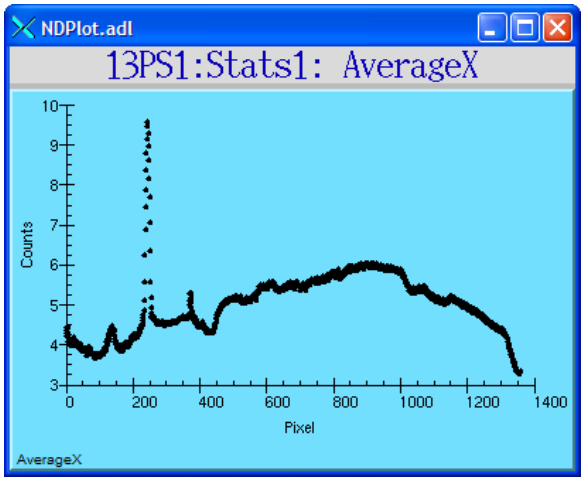
Statistics plugin

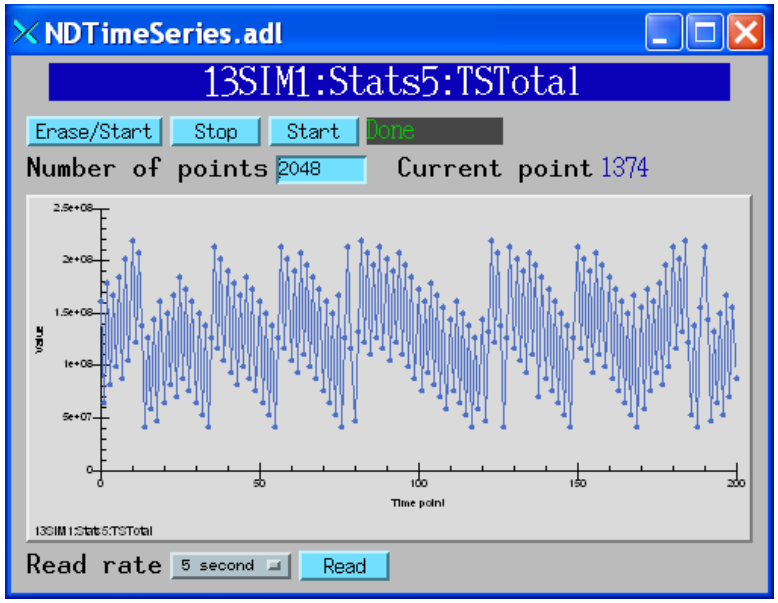


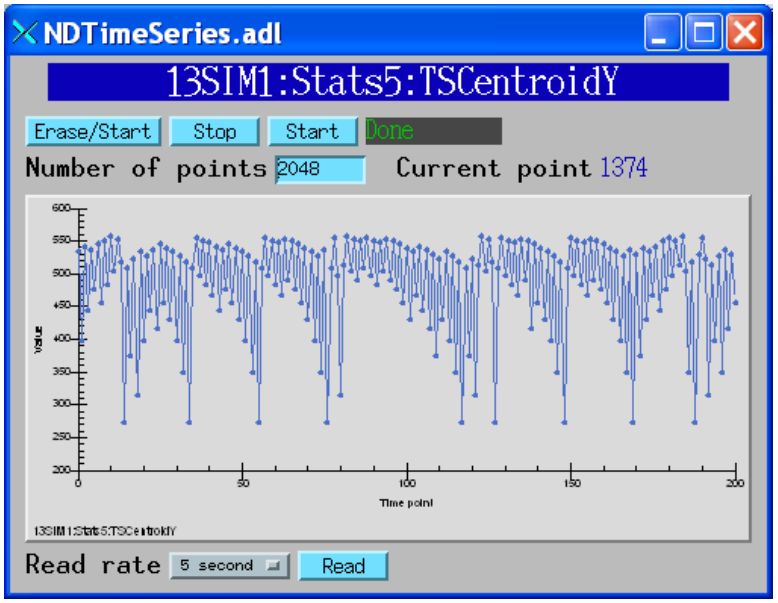
Statistics plugin (continued)



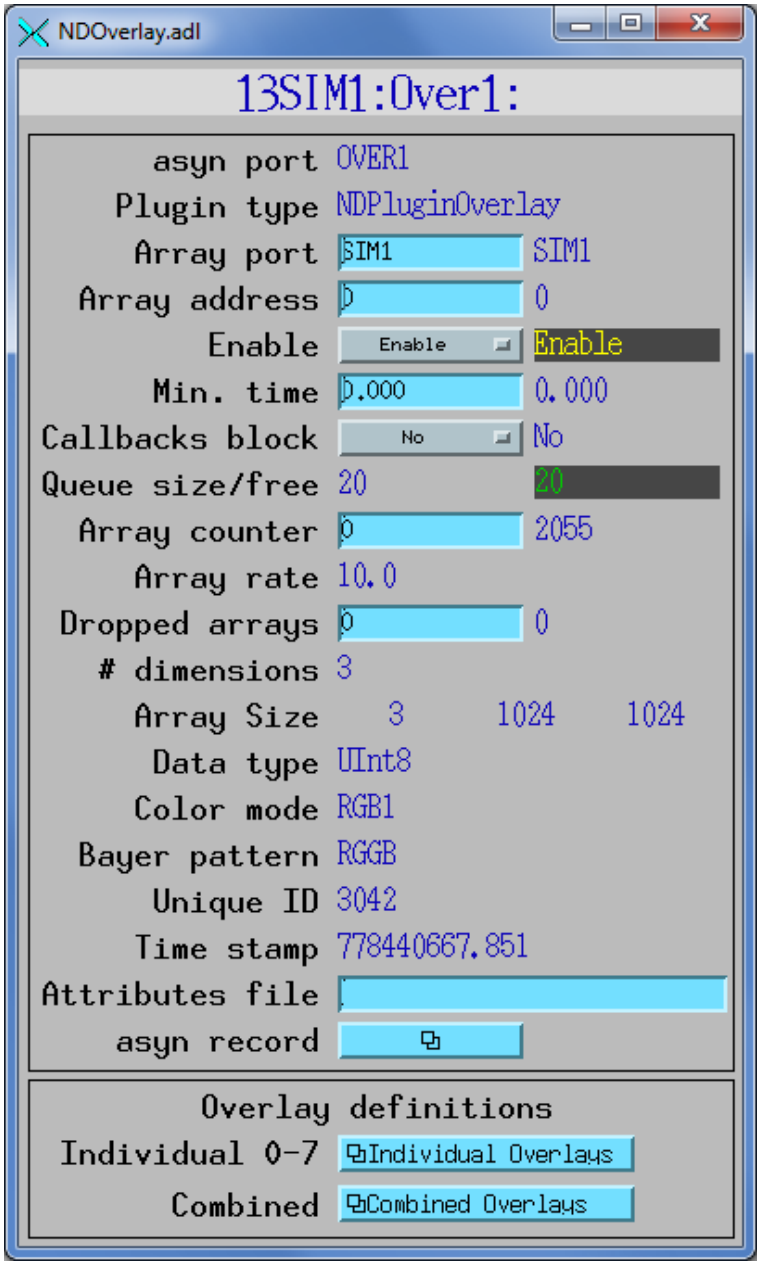




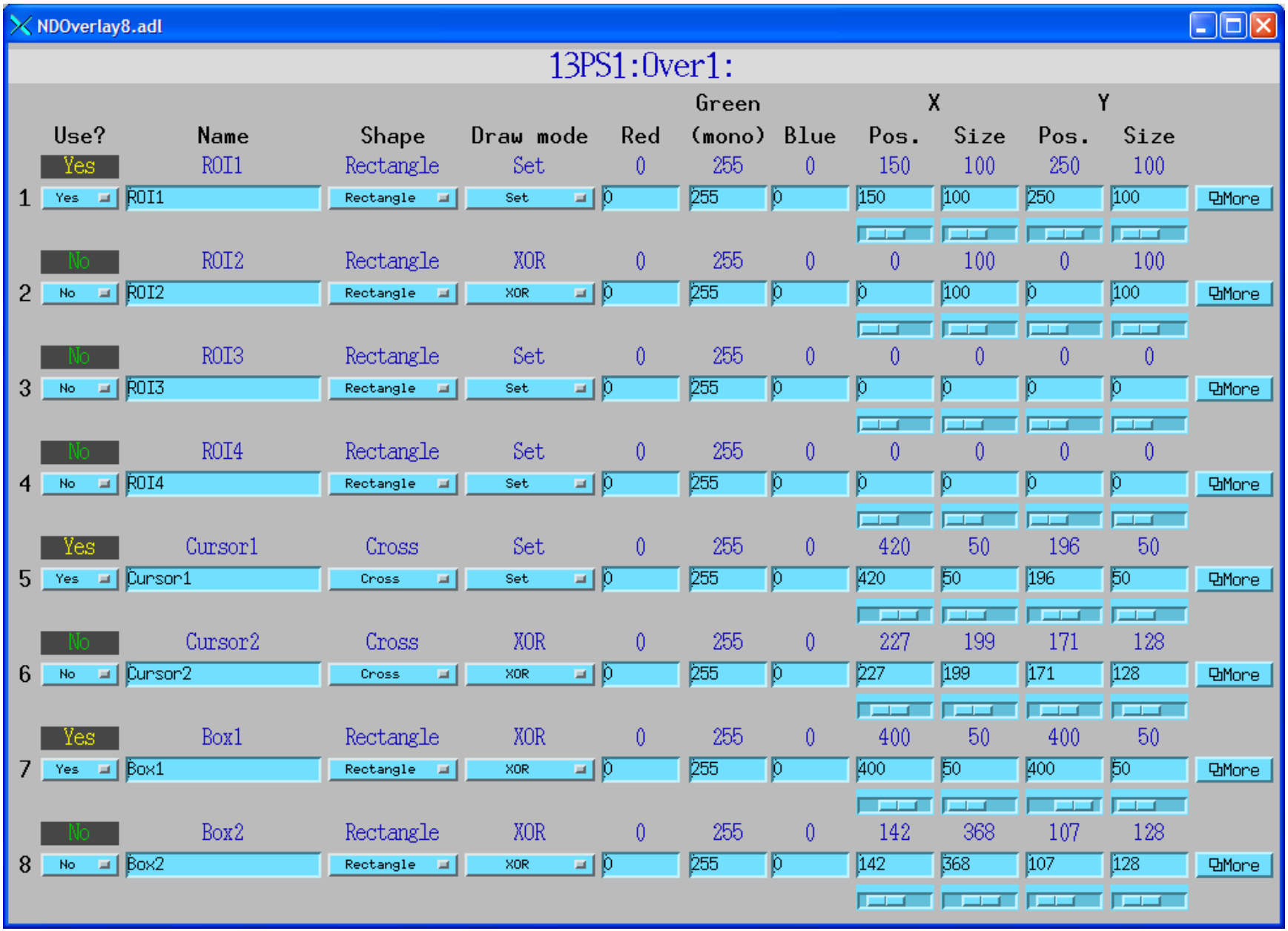




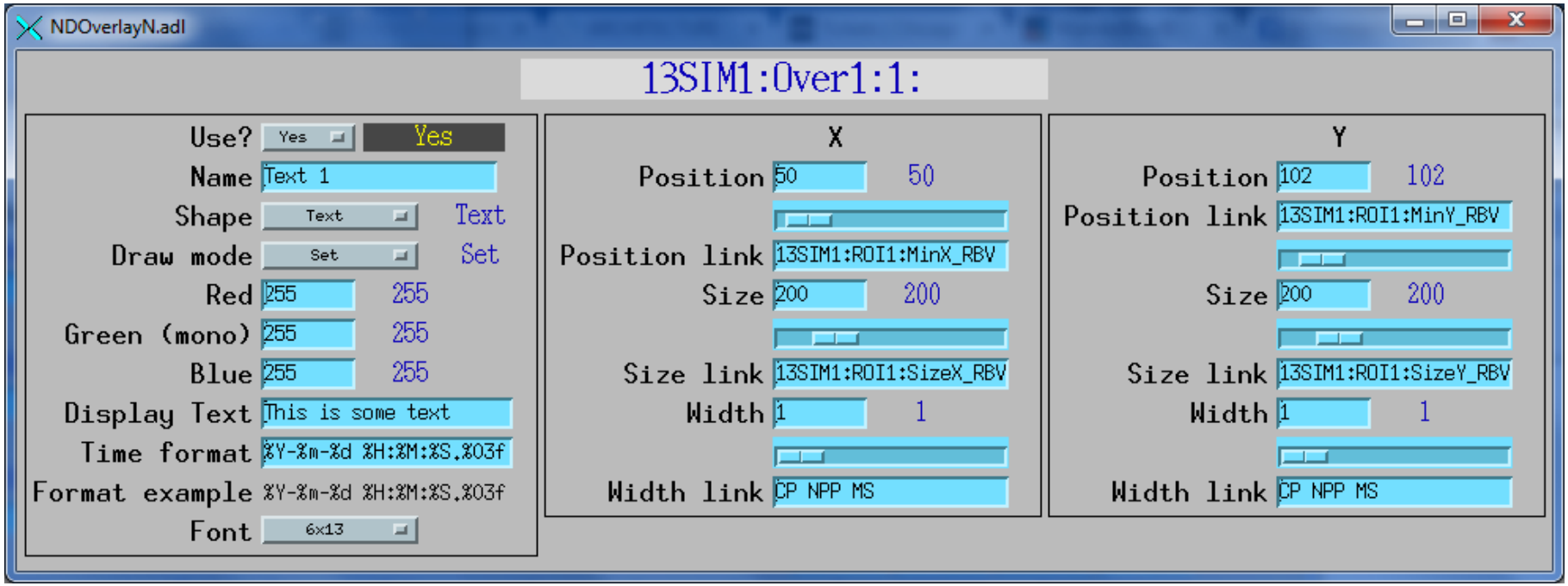
Overlay plugin



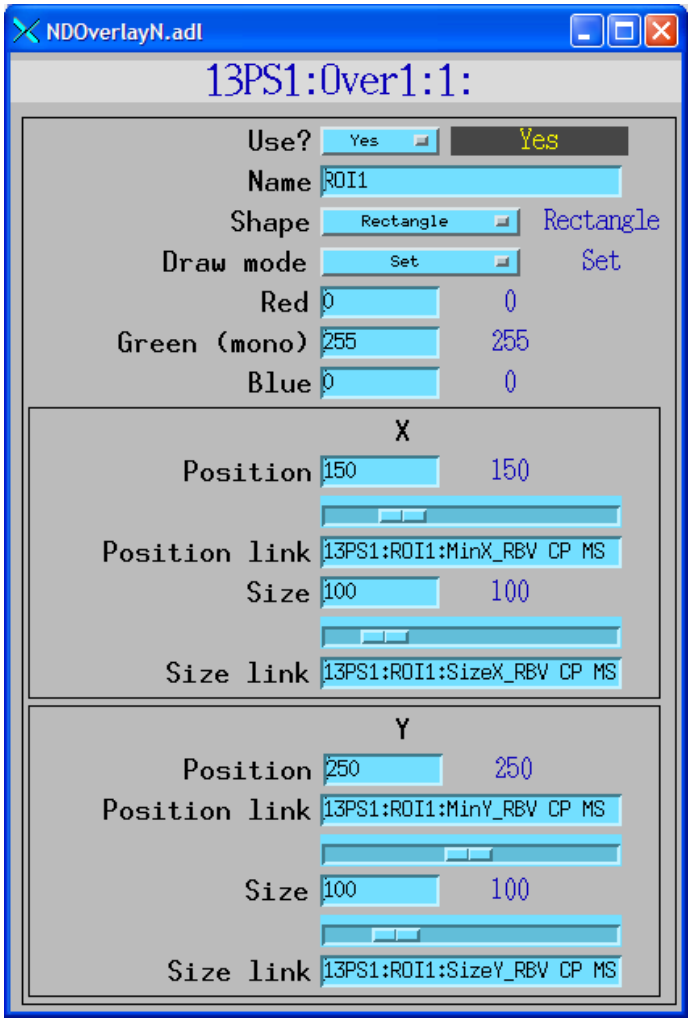
Overlay plugin

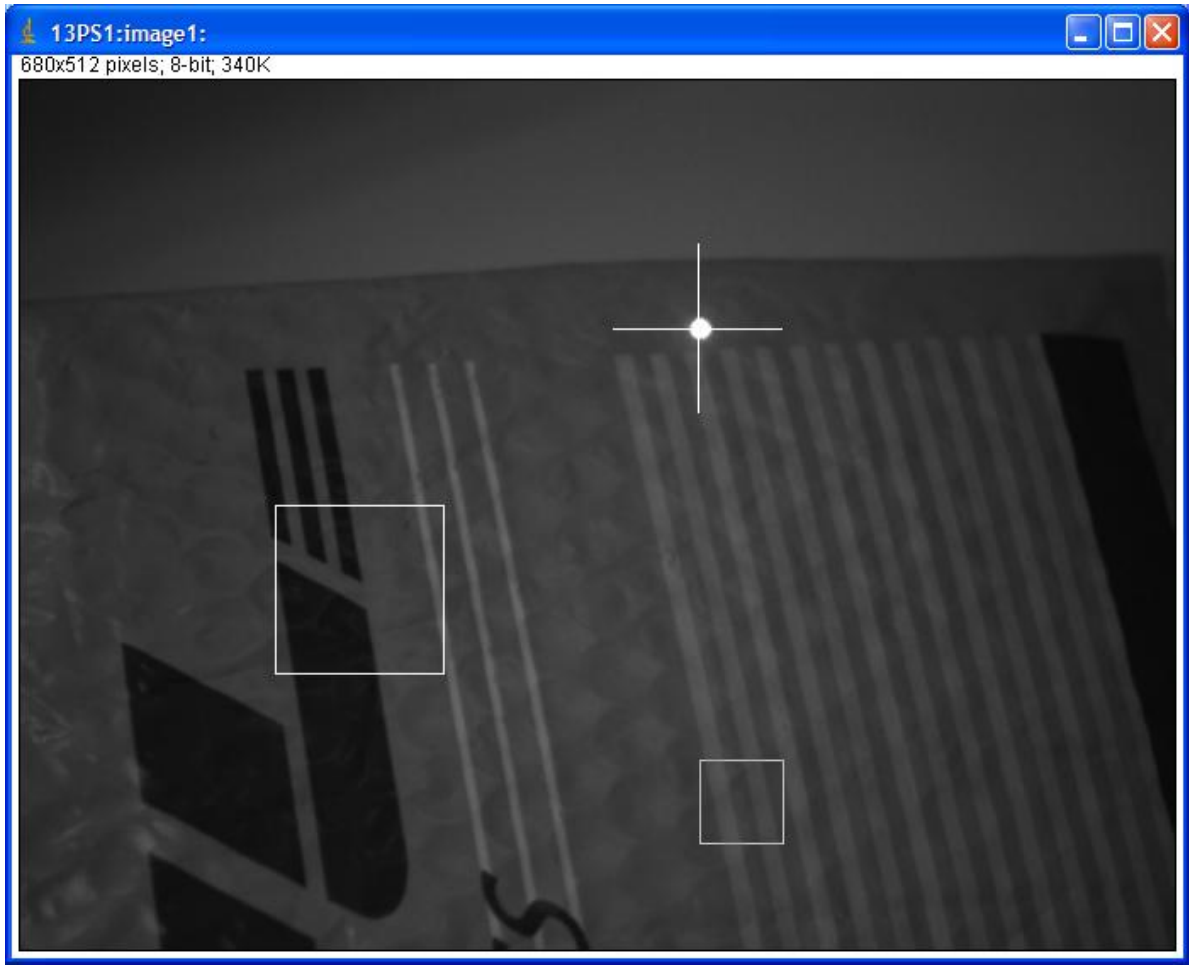


Overlay plugin



Overlay plugin

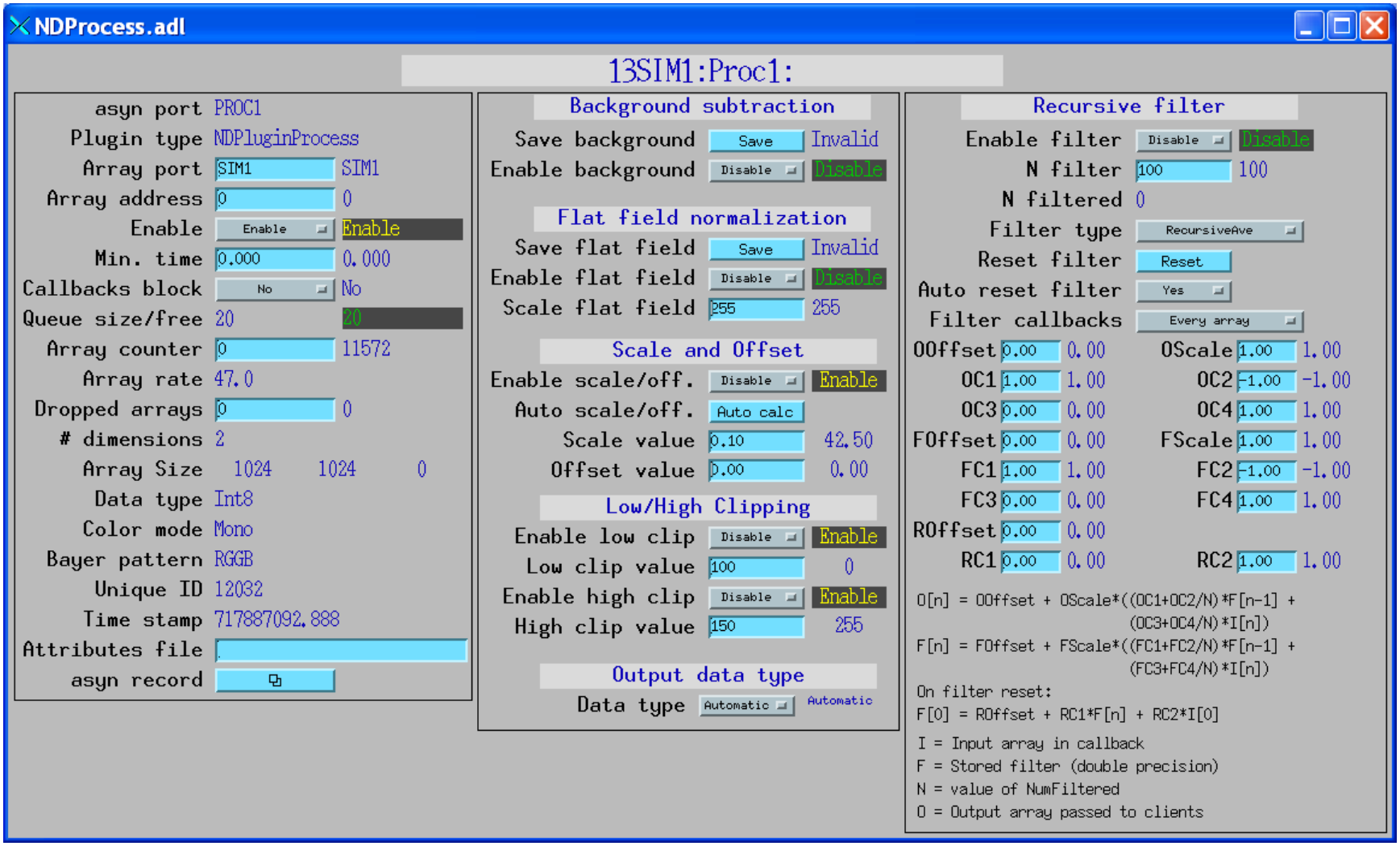




Centroid of laser pointer calculated by statistics plugin

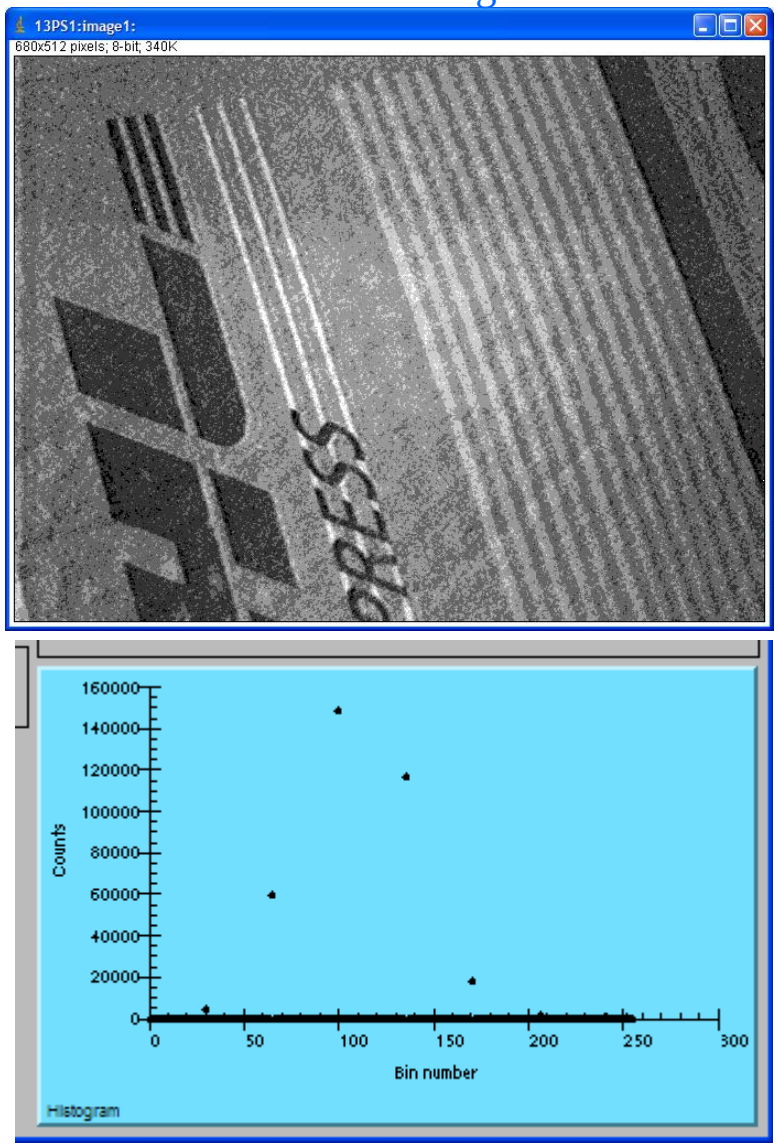
Cursor overlay X, Y position linked to centroid

Processing plugin

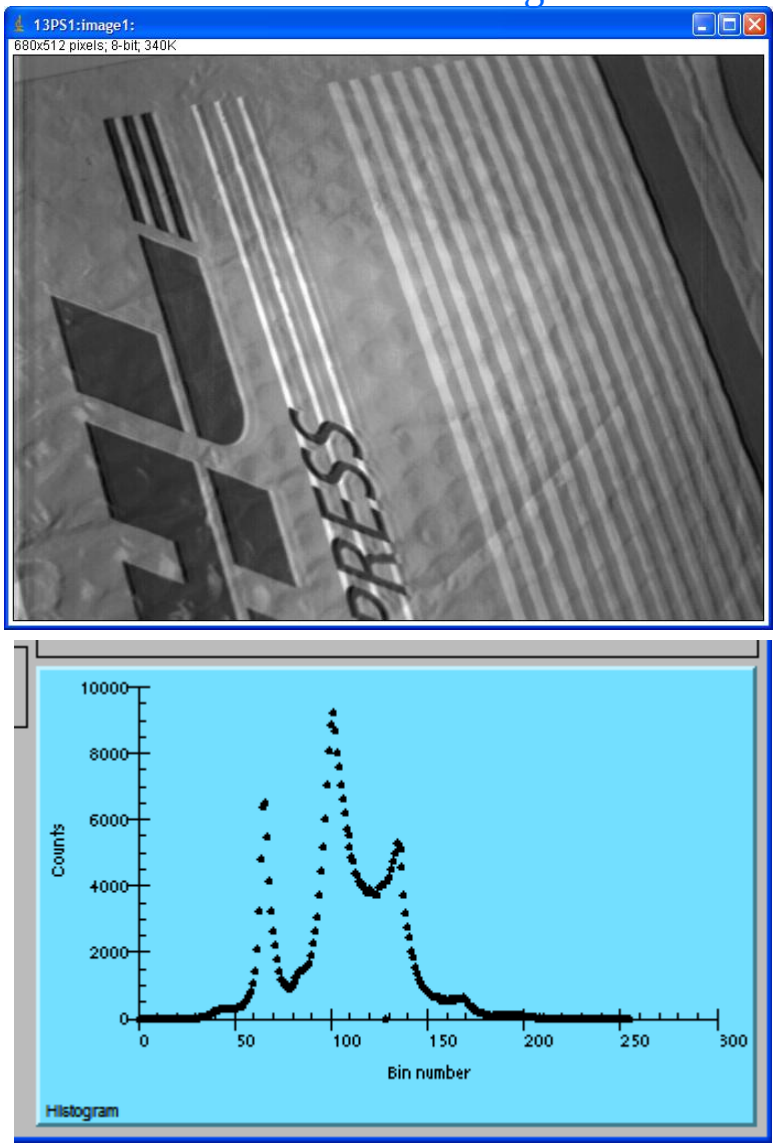


Processing plugin
30 microsec exposure time

No filtering



N=100 recursive average filter



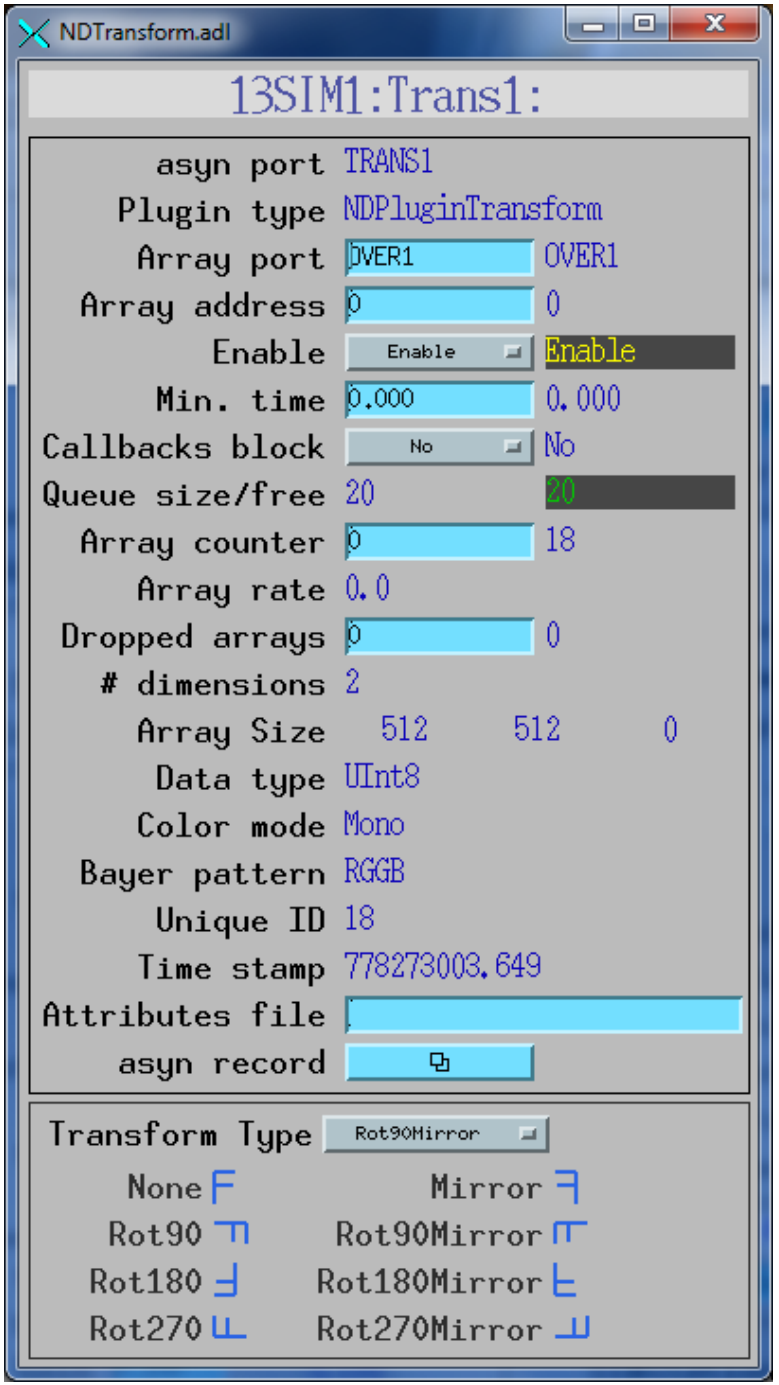
Processing plugin
Pre-defined recursive filters

- RecursiveAve
  - Recursive average.
  - Computes running average with 1/N contribution from new frame
- Average
  - True average, averages next N frames
- Sum
  - Sum of the next N frames
- Difference
  - Difference of frame N and N-1
- RecursiveAveDiff
  - Difference of recursive average and frame N
- CopyToFilter
  - Make the last stored frame be the next frame

Transform plugin

R2-1 changes

- Greatly simplified: just 8 operations including null operation
- 13-85 times faster than previous releases depending on data type, color mode



Plugins: NDPluginFile

- Saves NDArrays to disk
- 3 modes:
  - Single array per disk file
  - Capture N arrays in memory, write to disk either multiple files or as a single large file (for file formats that support this.)
  - Stream arrays to a single large disk file
- For file formats that support it, stores not just NDArray data but also NDAttributes

Plugins: NDPluginFile

- File formats currently supported
  - NDFileTIFF
    - Supports any NDArray data type
    - Stores NDAttributes as ASCII user tags (R2-1)
    - One array per file
  - NDFileJPEG
    - With compression control
    - One array per file
  - NDFileNetCDF
    - Popular self-describing binary format, supported by Unidata at UCAR
    - Multiple arrays per file

Plugins: NDPluginFile

- NDFileHDF5
  - Writes HDF5 files with the native HDF5 API, unlike the NeXus plugin which uses the NeXus API. Supports 3 types of compression.
  - R2-1 supports using an XML file to define the layout and placement of NDArrays and NDAttributes in the HDF5 file
- NDFileNeXus
  - Standard file format for neutron and x-ray communities, based on HDF5, which is another popular self-describing binary format; richer than netCDF
  - May be deprecated in a future release since NeXus files can now be produced with the NDFileHDF5 plugin using an appropriate XML layout file
- NDFileMagick
  - Uses GraphicsMagick to write files, and can write in dozens of file formats, including JPEG, TIFF, PNG, PDF, etc.
- NDFileNull
  - Used only to delete original driver files when no other file plugin is running

NDPluginFile Recent Features

- New record, DeleteDriverFile. Allows file writing plugins to delete the "original" file that the driver created for that array if the following are all true:
  - The DeleteDriverFile record is "Yes".
  - The file plugin has successfully written a new file.
  - The array contains an attribute called "DriverFileName" that contains the full file name of the original file. The driver attributes XML file should contain a line like the following:

    <Attribute name="DriverFileName" type="PARAM" source="FULL_FILE_NAME" datatype="string" description="Driver file name"/>
- Support for getting the file name and file number from array attributes rather than from the normal EPICS PVs. Allows the driver to control which plugin saves a particular array. (Ulrik Pedersen)
- 2 new records, WriteStatus and WriteMessage to display status of file writing operations.

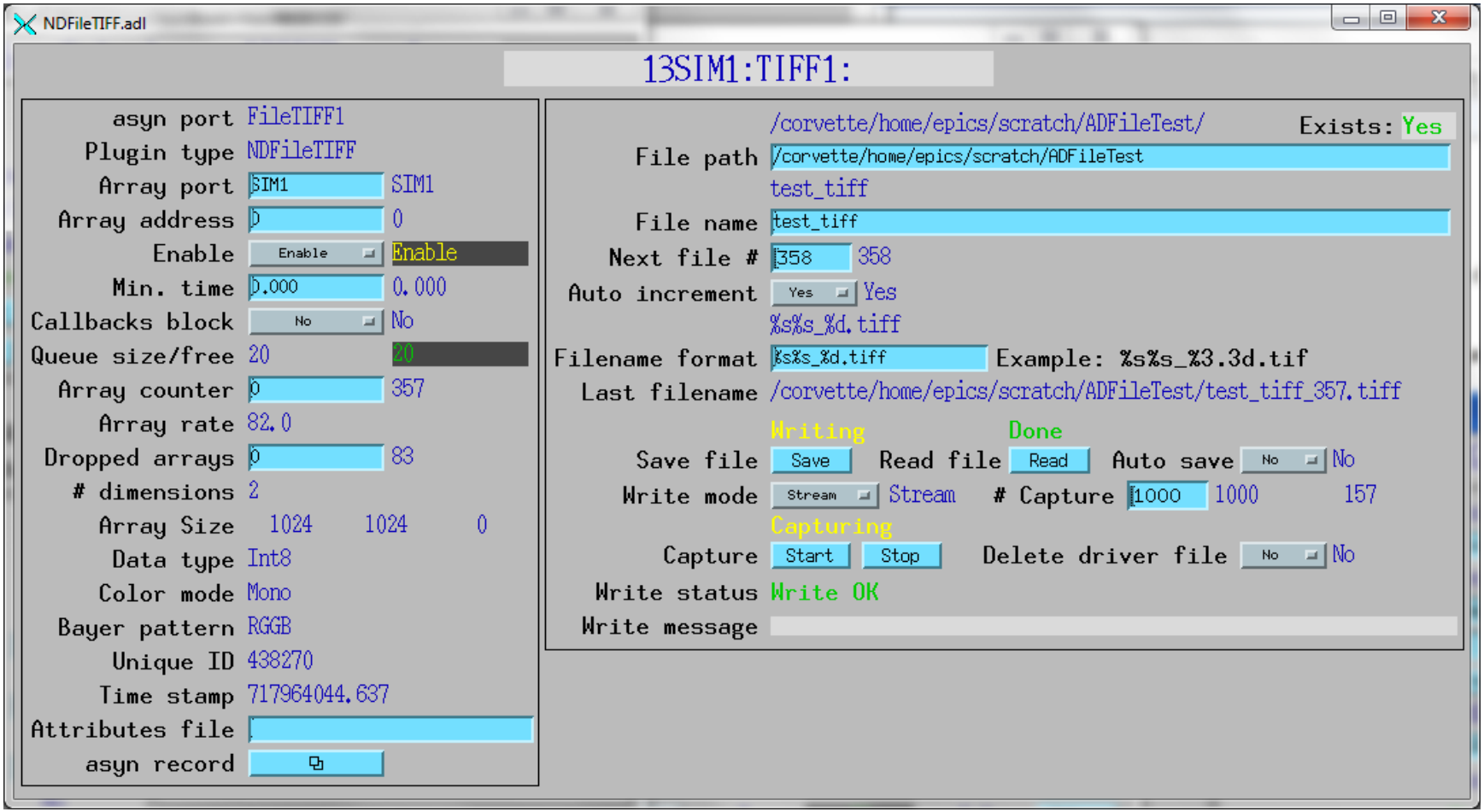
NDPluginFile Recent Features

- “Lazy-open” (R2-1)
  - Normally files in stream mode are opened when Capture PV is set to 1
  - This requires that there have already been an NDArray received by that plugin with the correct dimensions and attributes
  - “Lazy-open” is selected the file is not opened until the first NDArray callback happens after Capture is set to 1.
  - Simpler for users, but poorer performance, can lead to dropped arrays
- File plugins can now create directories (R2-2)
- File plugins can write files with a temporary suffix and then rename the file after writing is complete. (R2-2)
  - Allows rsync, etc. to be used to copy files, with guarantee that they are complete

File saving with driver

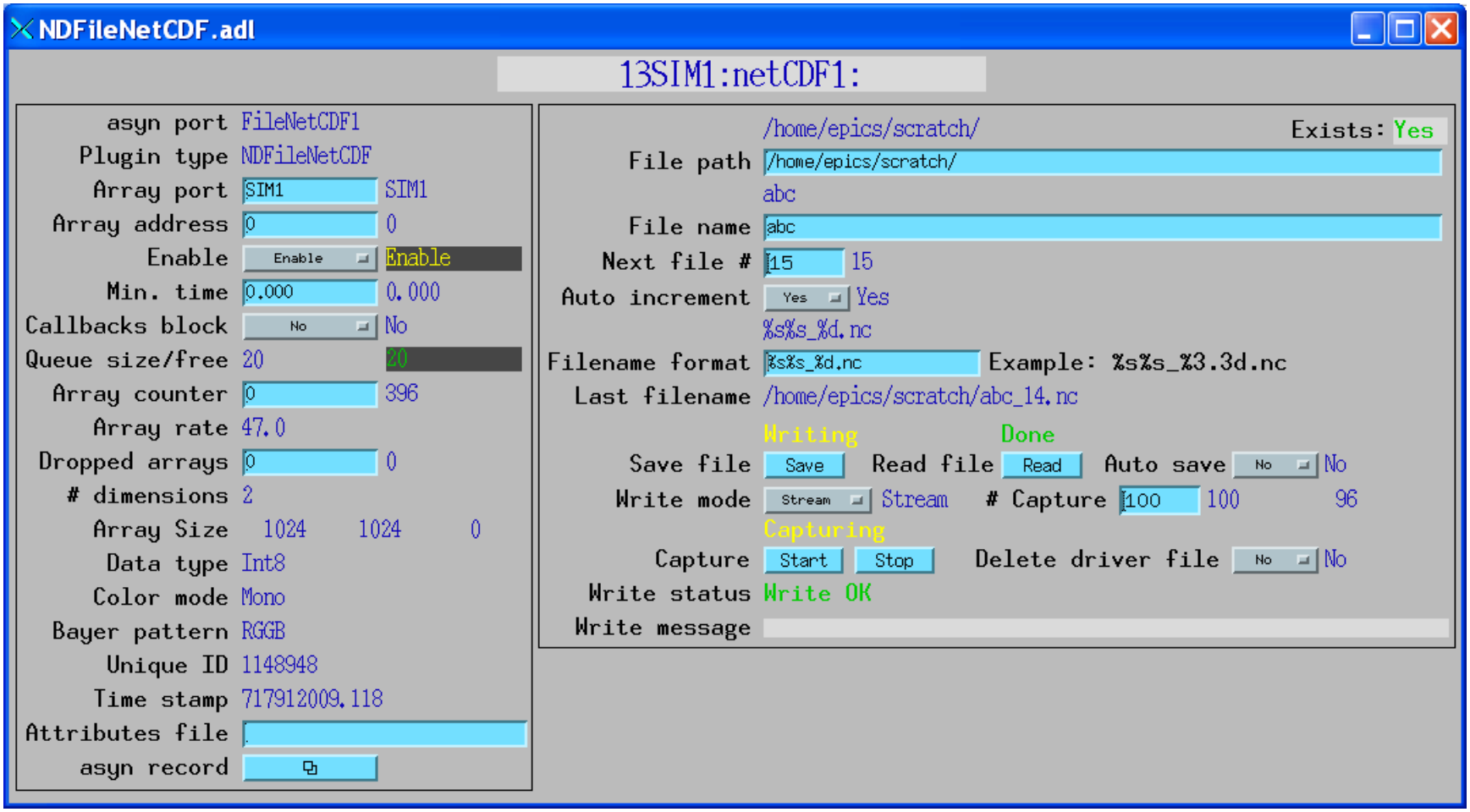
- In addition to file saving plugins, many vendor libraries also support saving files (e.g. marCCD, mar345, Pilatus, etc.) and this is supported at the driver level.
- File saving plugin can be used instead of or in addition to vendor file saving
  - Can add additional metadata vendor does not support
  - Could write JPEGS for Web display every minute, etc.

NDPluginFile display: TIFF



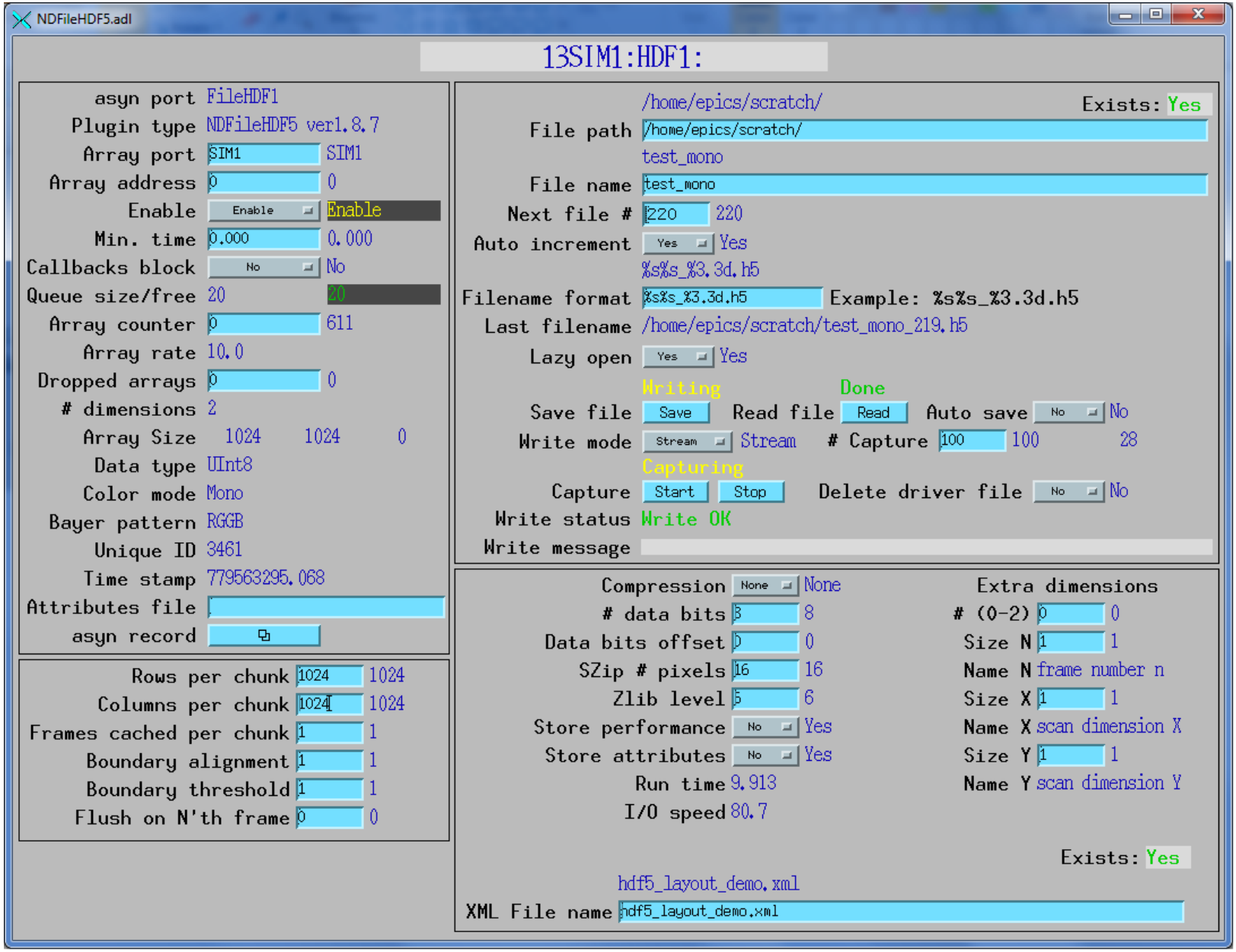
Example: saving 82 frames/second of 1024x1024 video to TIFF files, a few dropped frames.

NDPluginFile display: netCDF



Example: streaming 47 frames/second of 1024x1024 video to netCDF files, no dropped frames.

NDFileHDF5


NDFileHDF5.adl
13SIM1:HDF1:
asyn port FileHDF1
Plugin type NDFileHDF5 ver1.8.7
Array port SIM1 SIM1
Array address 0 0
Enable Enable Enable
Min. time 0.000 0.000
Callbacks block No No
Queue size/free 20 20
Array counter 0 611
Array rate 10.0
Dropped arrays 0 0
dimensions 2
Array Size 1024 1024 0
Data type UInt8
Color mode Mono
Bayer pattern RGGB
Unique ID 3461
Time stamp 779563295.068
Attributes file
asyn record
Rows per chunk 1024 1024
Columns per chunk 1024 1024
Frames cached per chunk 1 1
Boundary alignment 1 1
Boundary threshold 1 1
Flush on N'th frame 0 0
/home/epics/scratch/ Exists: Yes
File path /home/epics/scratch/
test_mono
File name test_mono
Next file # 220 220
Auto increment Yes Yes
%s%s_%3.3d.h5
Filename format %s%s_%3.3d.h5 Example: %s%s_%3.3d.h5
Last filename /home/epics/scratch/test_mono_219.h5
Lazy open Yes Yes
Writing Done
Save file Save Read file Read Auto save No No
Write mode Stream Stream # Capture 100 100 28
Capturing
Capture Start Stop Delete driver file No No
Write status Write OK
Write message
Compression None None
data bits 8 8
Data bits offset 0 0
SZip # pixels 16 16
Zlib level 6 6
Store performance No Yes
Store attributes No Yes
Run time 9.913
I/O speed 80.7
Extra dimensions
(0-2) 0 0
Size N 1 1
Name N frame number n
Size X 1 1
Name X scan dimension X
Size Y 1 1
Name Y scan dimension Y
Exists: Yes
hdf5_layout_demo.xml
XML File name hdf5_layout_demo.xml

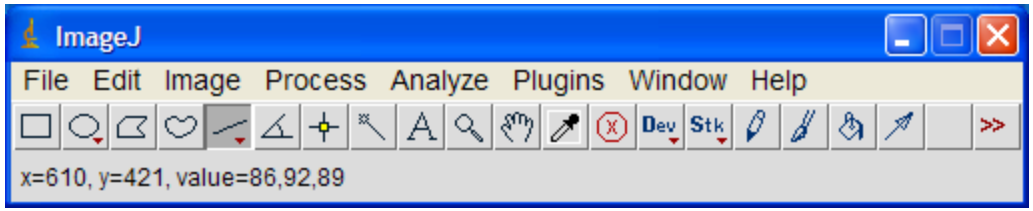
NDFileHDF5
XML file to define file layout

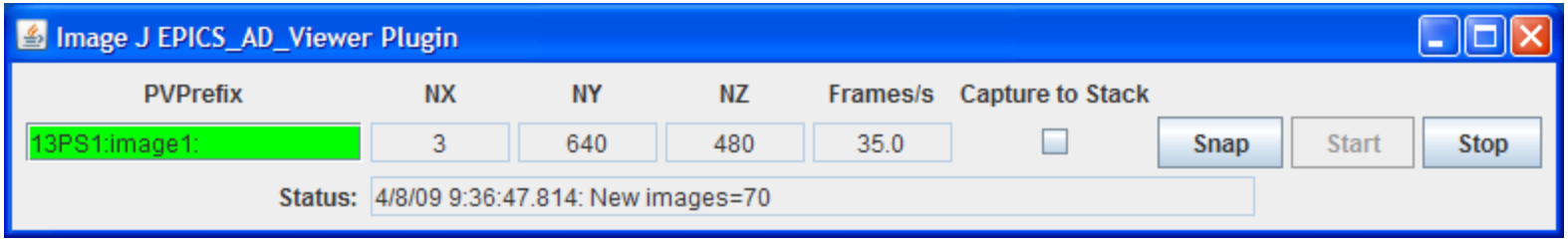
```
<xml>
  <group name="entry">
    <attribute name="NX_class" source="constant" value="NXentry" type="string"></attribute>
    <group name="instrument">
      <attribute name="NX_class" source="constant" value="NXinstrument" type="string"></attribute>
      <group name="detector">
        <attribute name="NX_class" source="constant" value="NXdetector" type="string"></attribute>
        <dataset name="data" source="detector" det_default="true">
          <attribute name="NX_class" source="constant" value="SDS" type="string"></attribute>
          <attribute name="signal" source="constant" value="1" type="int"></attribute>
          <attribute name="target" source="constant" value="/entry/instrument/detector/data"
                     type="string"></attribute>
        </dataset>
        <group name="NDAttributes">
          <attribute name="NX_class" source="constant" value="NXcollection" type="string"></attribute>
          <dataset name="ColorMode" source="ndattribute" ndattribute="ColorMode">
          </dataset>
        </group>          <!-- end group NDAttribute -->
      </group>            <!-- end group detector -->
      <group name="NDAttributes" ndattr_default="true">
        <attribute name="NX_class" source="constant" value="NXcollection" type="string"></attribute>
      </group>            <!-- end group NDAttribute (default) -->
      <group name="performance">
        <dataset name="timestamp" source="ndattribute"></dataset>
      </group>            <!-- end group performance -->
    </group>              <!-- end group instrument -->
    <group name="data">
      <attribute name="NX_class" source="constant" value="NXdata" type="string"></attribute>
      <hardlink name="data" target="/entry/instrument/detector/data"></hardlink>
      <!-- The "target" attribute in /entry/instrument/detector/data is used to
           tell Nexus utilities that this is a hardlink -->
    </group>              <!-- end group data -->
  </group>                <!-- end group entry -->
</xml>
```

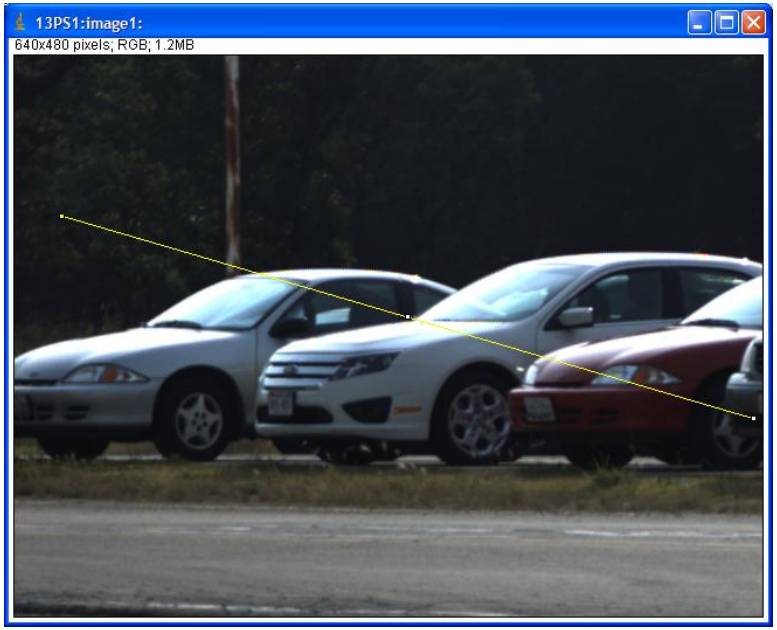
Viewers

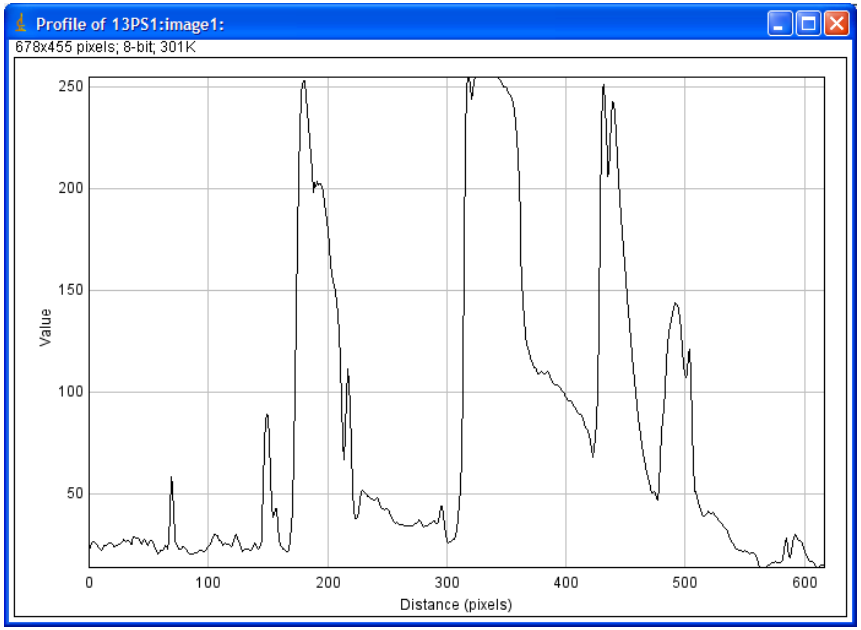
- areaDetector allows generic viewers to be written that receive images as EPICS waveform records over Channel Access
- Current viewers include:
  - ImageJ plugin EPICS_AD_Display. ImageJ is a very popular image analysis program, written in Java, derived from NIH Image.
  - IDL EPICS_AD_Display.
  - ffmpegServer allows image display in any Web browser
  - ffmpegViewer high-performance Qt-based viewer for MJPEG stream

ImageJ Viewer

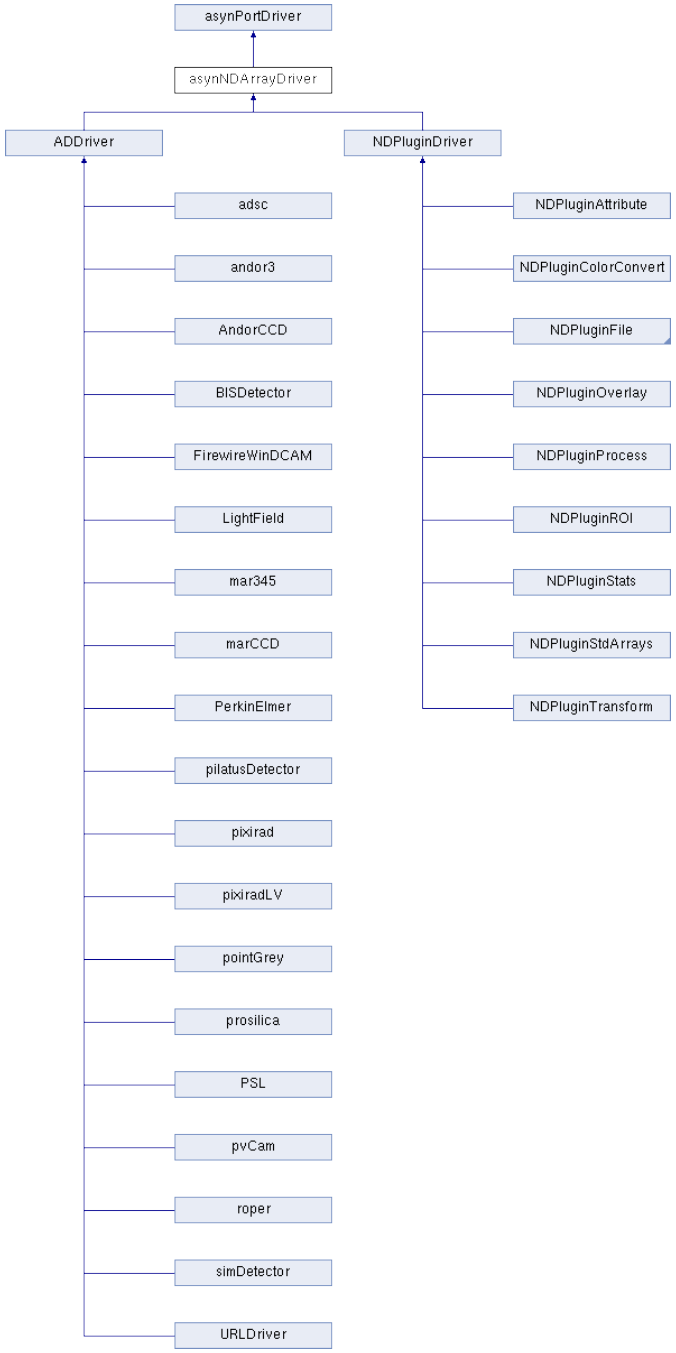








Internals
Class hierarchy



Recent Changes (R2-0)

- Added EPICS timestamp field to NDArray
- EPICS records can get the timestamp when the image was collected by setting TSE=-2.
- Added NDAttributeFunct, allows user-written function to set the value of an attribute

Recent Changes (R2-1)

- NDPluginTransform
  - Greatly simplified and performance improved
- NDPluginFile
  - Added support for “lazy-open”
- NDFileHDF5
  - Support for defining the layout of the HDF5 file via an XML file
- NDFileTIFF
  - NDAttributes are written to user ASCII TIFF tags (up to 490)
- NDPluginOverlay
  - Support for text overlays
  - Support for defining the line width in rectangle and cross overlays

Recent Changes (R2-2, not released)

- NDPluginFile
  - Added support for creating directories
  - Added support for using a temporary suffix and renaming on close
- NDPluginROIStat
  - New plugin to do simple statistics on multiple ROIs
- simDetectorNoIOC
  - Example standalone C++ application that instantiates a simDetector without running an EPICS IOC
  - Shows that areaDetector drivers and plugins only depend on libCom and asyn libraries. Can be used from other control systems.

Future Ideas (R2-3?)

- Make trigger modes in ADBase be Free Run, Fixed Rate, External. Now it is Internal, External.
- AcquirePeriod would only apply in fixed rate, not in Free Run. This is easier for users.

Future Ideas (R3-0?)

- Simplify NDPluginFile base class and way file saving works
  - Remove the Single/Stream/Capture mode.
- Two parameters
  - # NDArrays to save (already present)
  - # NDArrays per file (new)
  - This allows saving only 1 array per HDF5 file, which is not possible now in Stream mode.
- Capture mode can be replaced:
  - Make input queue large enough OR
  - Use new NDPluginCircularBuffer

Future Ideas

- Put more functionality into ADDriver base class
  - Currently it does not do much, all code is in each driver for:
    - Doing callbacks to plugins
    - Processing new exposure time with writeFloat64 function
  - writeFloat64 in ADDriver base class would call setExposure() in derived class
  - Derived class would call ADDriver::doPluginCallbacks(), which would handle setting attributes, getting timestamp, calling plugins, etc.
- This is the way the Model 3 motor driver, which also uses asynPortDriver, is written
- Demultiplexor/multiplexor plugin
  - Allow multiple plugins to work on the same data stream when it saturates a single core

Future Ideas

- Extend areaDetector concepts to other types of detectors:
  - ADCs
  - Electrometers
  - Waveform digitizers
  - Oscilloscopes?
- They all produce 1-D (or 2-D for multi-channel inputs) arrays that could benefit from plugins for file saving, FFTs, ROI extraction, digital filtering, etc.

Future Ideas

- Export NDArrays via EPICS V4
- David Hickin (DLS) has demonstrated:
  - A plugin that exports NDArrays as V4 objects over Channel Access
  - An ADDriver that receives the V4 objects on another machine and has its own set of plugins
- Allows using multiple machines, and multiple processes, not just multiple cores in a single IOC for plugin processing

areaDetector Collaboration

- The move to GitHub has really helped areaDetector become a collaborative effort
- Many more people are contributing via additions and bug fixes.
- Make changes in their fork on github and then issue a “pull request”.
- Collaboration meeting ~monthly on Google Hangout (U. Pedersen, M. Rivers, A. Glowacki, M. Pearson, M. Kraimer, N. Rees, D. Hickin, T. Cobb)
- In-person meetings ~2 times/year.
- Developed a road-map, following it pretty well.

Conclusions

- Architecture works well, easily extended to new detector drivers, new plugins and new clients
- Base classes, asynPortDriver, asynNDArrayDriver, asynPluginDriver actually are generic, nothing “areaDetector” specific about them.
- They can be used to implement any N-dimension detector, e.g. the XIA xMAP (16 detectors x 2048 channels x 512 points in a scan line)
- Can get documentation and pre-built binaries (Linux, Windows, Cygwin) from our Web site:
  - http://cars.uchicago.edu/software/epics/areaDetector
- Can get code from github
  - https://github.com/areaDetector

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- Keith Brister (LS-CAT)
- Bruce Hill (SLAC)
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- Thanks for your attention!!!