Euclid QLA & HMS

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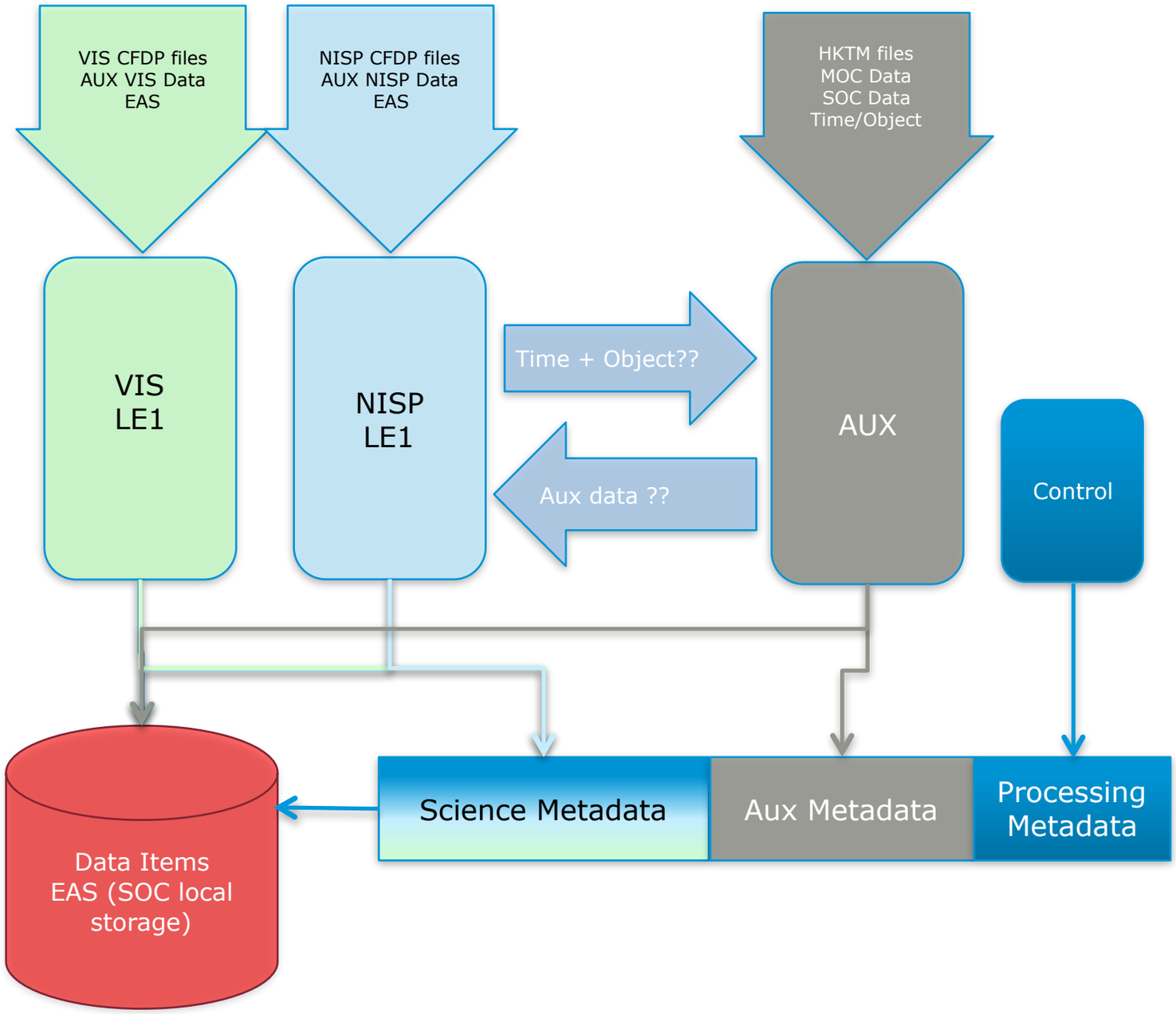
Quick-Look Analysis System

- Euclid SOC is in charge of designing, developing and running a QLA system capable of:
  - running autonomously over ALL data;
  - verifying that the intended planned activities are executed;
  - analysing the data to identify instrument problems (misconfigurations, sudden reconfigurations, impacts, others) that could be mitigated with fast SOC/MOC/IOT intervention;
    - data include VIS, NISP-P, NISP-S “science” data, i.e. including calibration exposures
  - analysing and extracting H/K parameters from instruments and S/C;
  - analysing AOCS data for pointing performance assessment;
  - providing quality flags and alerts, augmenting but not part of the level 1 product (i.e. not defined by level 2 requirements).
- QLA will use level 1 data and run some processing on it - “level 1.5” data produced on the fly (eventually stored only in a local buffer archive). The level of processing is TBD depending on performance.

Euclid Level 1

- Level 1 is the processing function that gathers and conforms to the data model the data from On Board and from ground, ready for processing by the SGS.
- It is a “special” processing function, since its inputs are not Common Data Model compliant.
- It is also “special”, since it is the only processing function where timeliness is required (i.e. 48 hours from reception of last component)
- A level 1 “product” is thus a collection of data containers and associated metadata. It is not necessarily a self standing item (i.e. a zipped file) but a reference in the EAS to metadata and data files.
- The development under EC, however ESAC runs it and contributing to some components: house-keeping telemetry (HKTM), framework, interfaces.
- All the incoming and generated data is ingested in the SOC local EAS Storage, and published in EAS. A distribution policy will ensure that level 1 data is available to all the subsequent Processing Functions.

Level 1 Functional Description



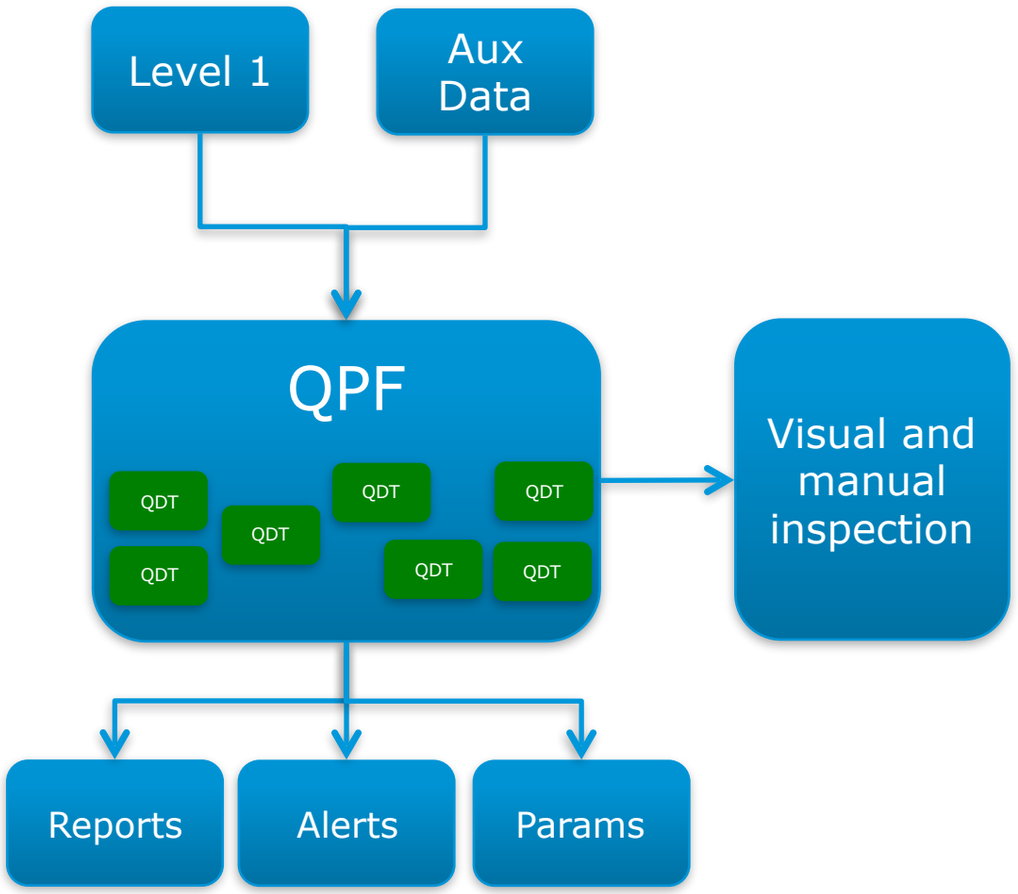
- The system takes as inputs the raw CFDP files containing instrument scientific data, and also HKTM, ancillary & other external items.
- The instrument processors gather all data belonging to an exposure, decompressing it and formatting in the level 1 Common Data Model structure (FITS).
- Another module deals with HKTM and other sources metadata extraction, and with the generation of the HKTM data files.
- Given different time spans (daily for HKTM, per exposure/ dither on the Science), coordination is required.
- The products are registered in the EAS, involving metadata registration and DSS storage of data files.

QLA Considerations

- QLA will run automatically over all received data sets:
  - This means being able to “understand” and qualify quickly all possible instrument modes and data types.
  - A report shall be ready within 48 hours from data reception from MOC (including level 1 generation). Not all possible checks fit.
  - QLA is memory-less: runs over single products, without knowledge of other past exposures.
  - It generates metadata quality information gathered in the form of reports, and alerts on the “lesser” quality products.
  - For these lesser quality products, QLA will offer ad hoc visual inspection (through external tools) and processes to be conducted by an operator or scientist.
  - Extracted parameters and results will be uploaded into the ARES database which will fed the health monitoring system (HMS)

QLA Use Cases

- Automatic cases:
  - Data ingestion
  - VIS Checks
  - NISP Checks
  - System Checks (i.e. pointing, certain verification on HKTM, etc.)
  - Alert generation (based on the checks outcome)
- Manual processing of given inputs (all or subset of previous)
- Visualisation of data products
- Extraction and archive of QLA product information as parametric metadata
- Generation of QLA reports
- Interfacing with EAS



The system will run automatically on all data received, based on triggering rules implemented at the QPF. However, it allows for manual operations (Instrument Scientists at SOC) to verify Alarms or to more closely examine given data sets

QLA Architecture

- QLA Processing Framework (QPF) provides the processing framework to execute system functionalities, implements the main HMI, the data access and persistence mechanisms, the logging and the management of the tasking, and the gathering and collection of reports.
- QLA Diagnostic Tools (QDT): they implement different algorithms and functions to perform over the data. They encompass data extraction (HKTM and parametric data), data processing and reporting:
  - Common (including HKTM extraction and processing)
  - VIS functions
  - NISP functions
  - AOCS functions
- On top, it will rely and integrate external tools for more advanced data analysis (e.g. Sextractor, Scamp) and visualisation (e.g. DS9).

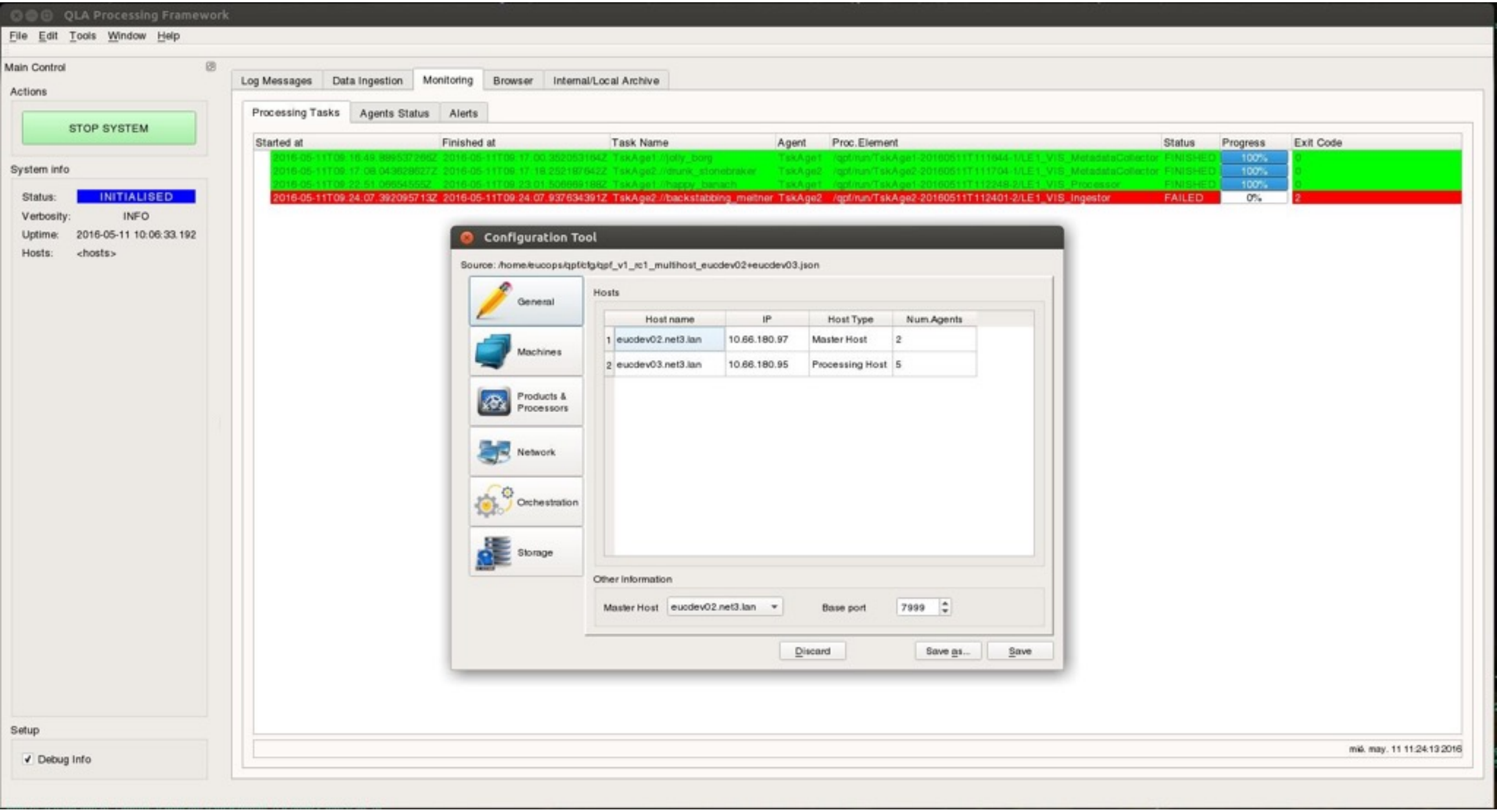
Health Monitoring System

- Euclid SOC is also in charge of designing, developing and running a HMS capable of:
  - gathering all observable parametric information linked to instrument and mission performance;
  - archiving it in a mission-long database: ARES;
  - providing access methods and tools to investigate and identify trends and evolutions;
  - providing this access also to IOTs;
  - running automated analysis;
  - providing systems for automatic alerting.
- Data in the ARES database will come from e.g. H/K information, but also from “higher level” processed products such as parameters obtained during the QLA analysis

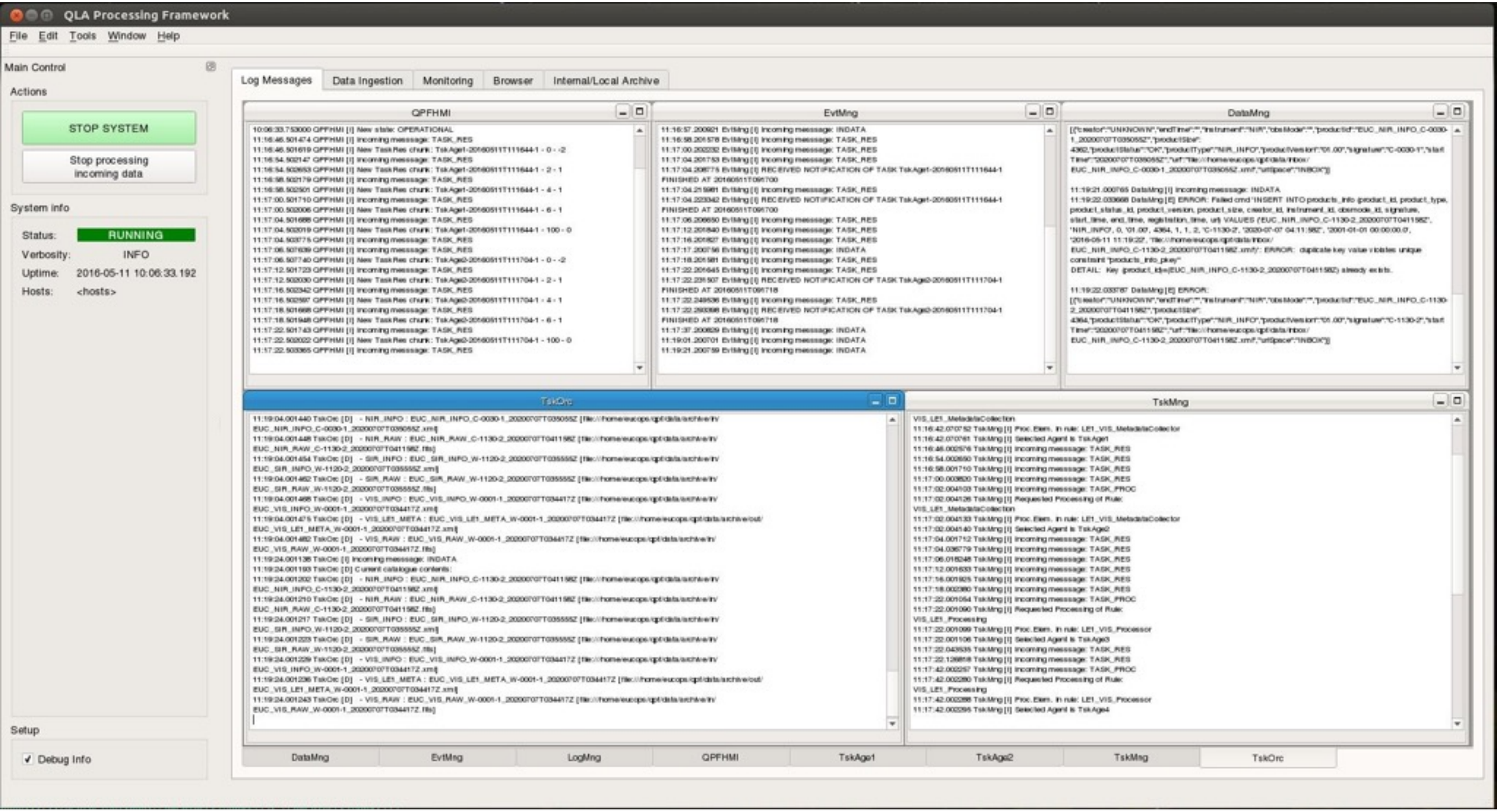
QLA Current Status

- It is a software developed in Python (QDT) and QTk/C++ (QPF)
- The QLA was released as part of the SOC V1 software release in April 2016
- The QPF component very advanced, implementing:
  - HMI (System Start, Stop, Log, Monitor, Partial Configuration)
  - Task registration, configuration and connection
  - Execution of processing
  - Access to EAS/DSS
  - Internal DB for local persistence of products
- The QDT was released for VIS, allowing a subset of checks to be implemented over raw data sets as produced by the VIS SIM data as well as lab data (some reformatting needed). Available as stand alone functions called from command line
- VIS processing emanated from a VIS-QLA Data Description and Diagnostics document, describing the “pipeline”. A NISP similar document under evaluation, provided by IPAC
- Tested successfully on V1 release
- AOCS diagnostic tools developed in MatLab

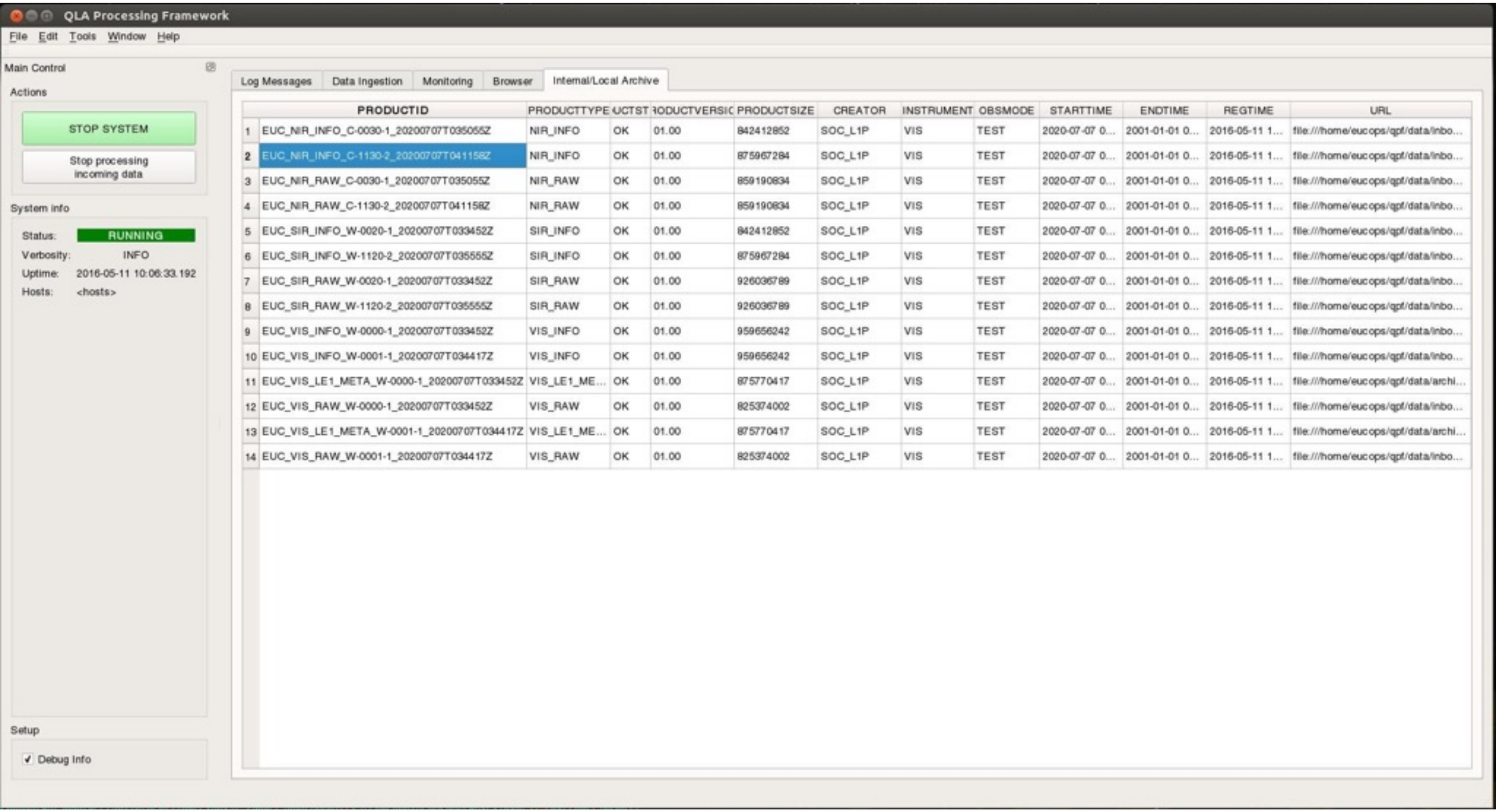
QLA QPF System



QLA QPF System Logging



QLA QPF Local Archive System



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2	EUC_NIR_INFO_C-1130-2_20200707T041158Z	NIR_INFO	OK	01.00	875967284	SOC_L1P	VIS	TEST	2020-07-07 0...	2001-01-01 0...	2016-05-11 1...	file:///home/eucops/qpf/data/inbo...
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4	EUC_NIR_RAW_C-1130-2_20200707T041158Z	NIR_RAW	OK	01.00	859190834	SOC_L1P	VIS	TEST	2020-07-07 0...	2001-01-01 0...	2016-05-11 1...	file:///home/eucops/qpf/data/inbo...
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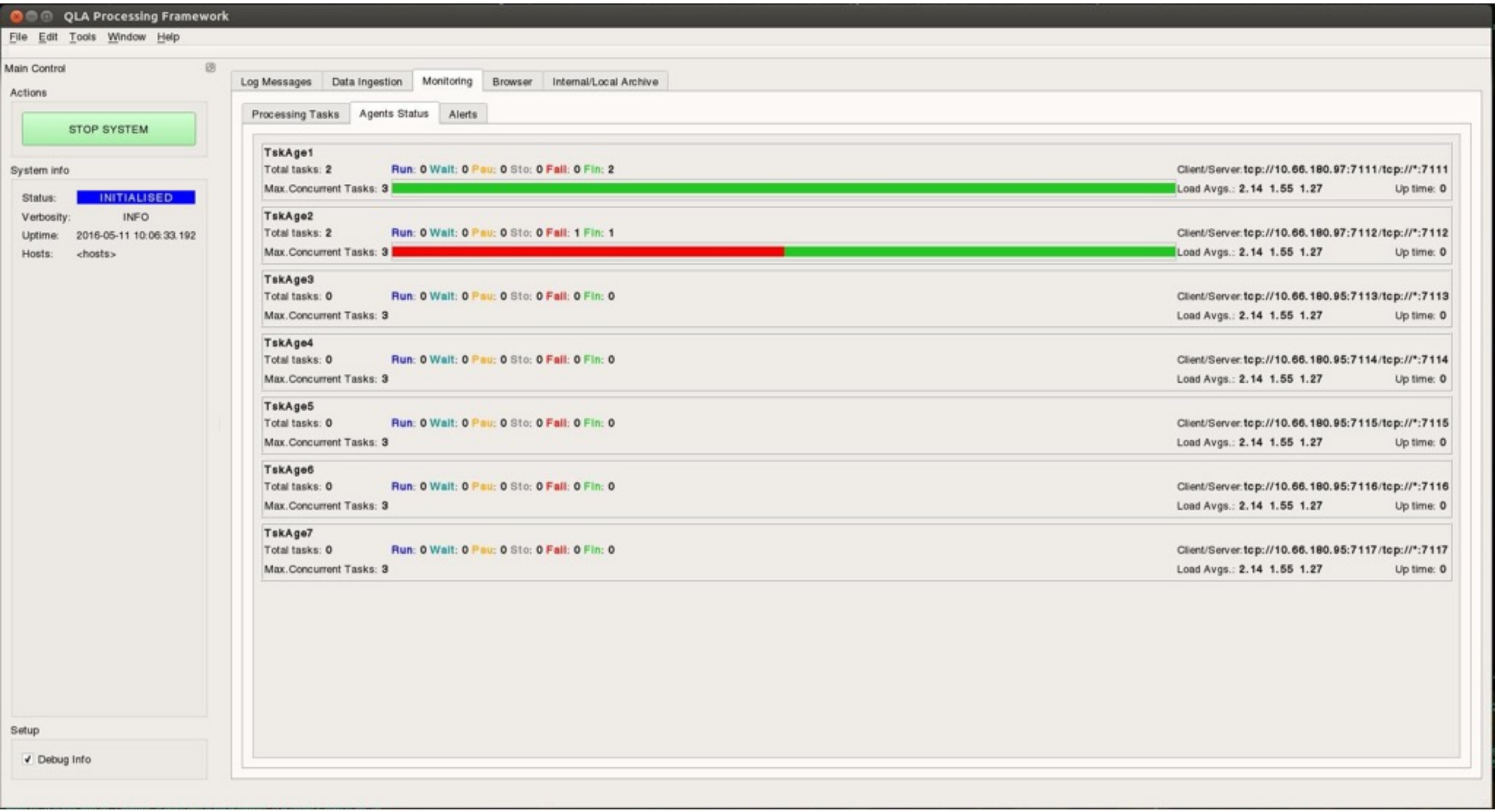
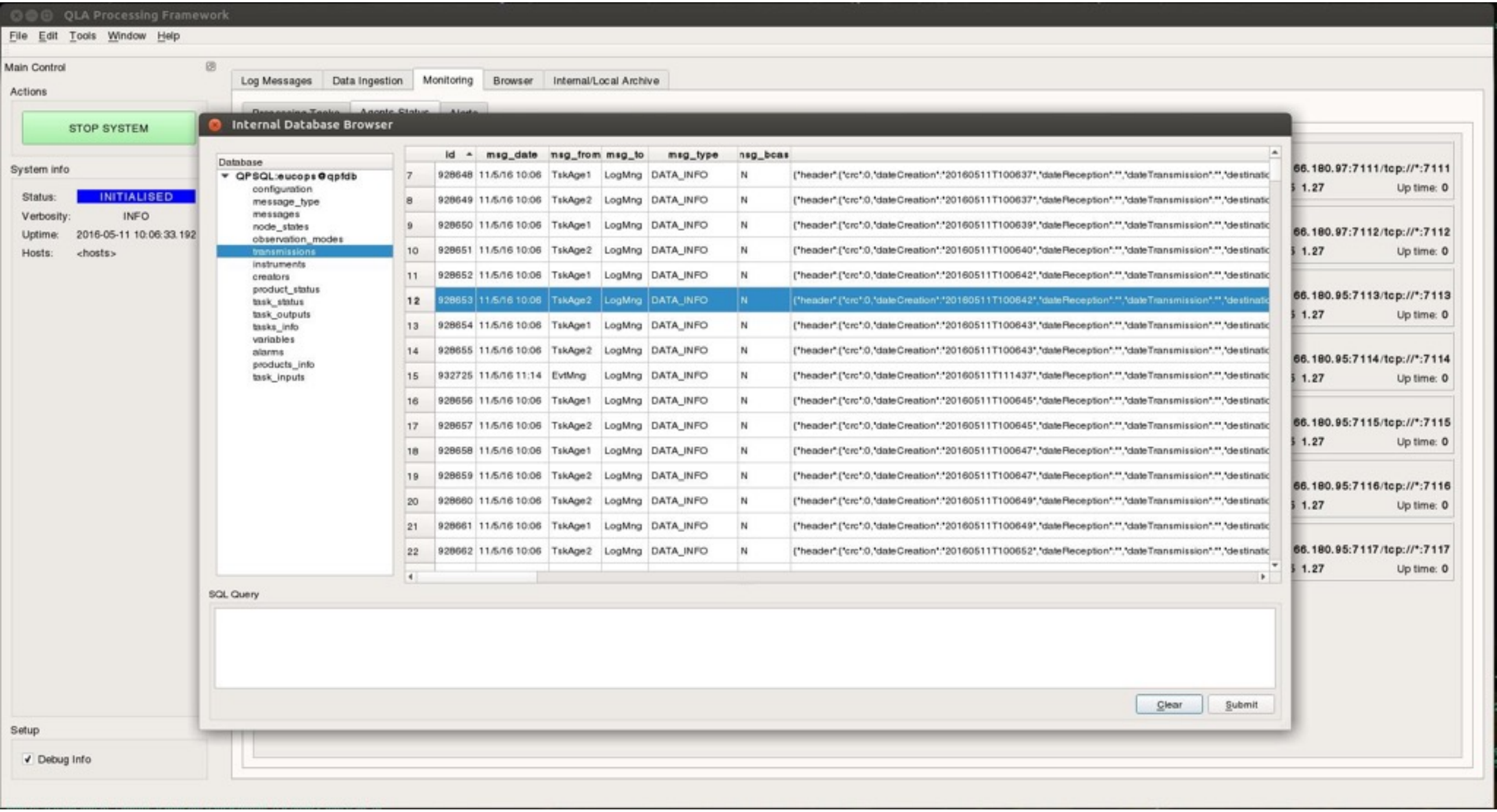
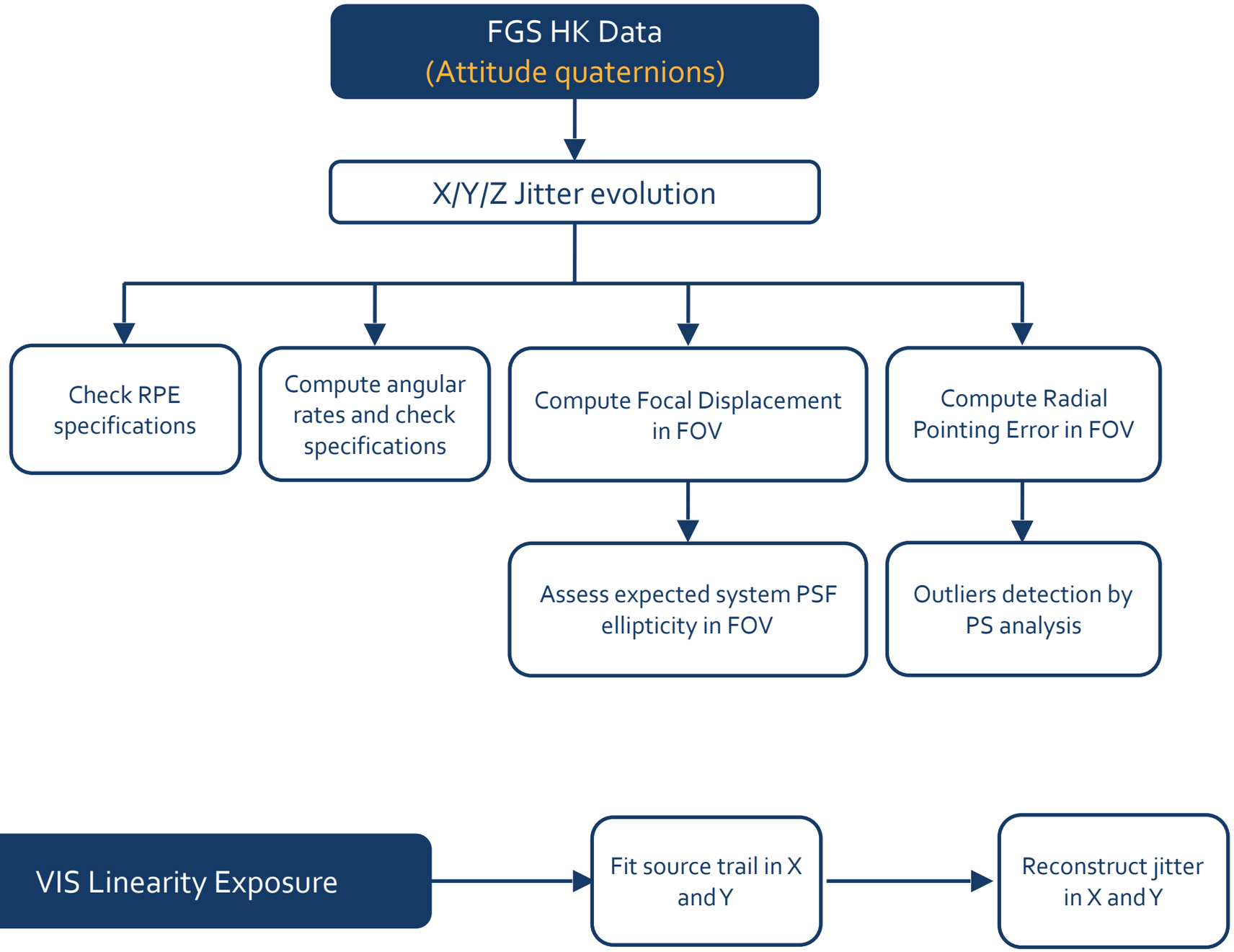
QLA QPF System: Agents And Tasks



QLA QPF System: Database Interface

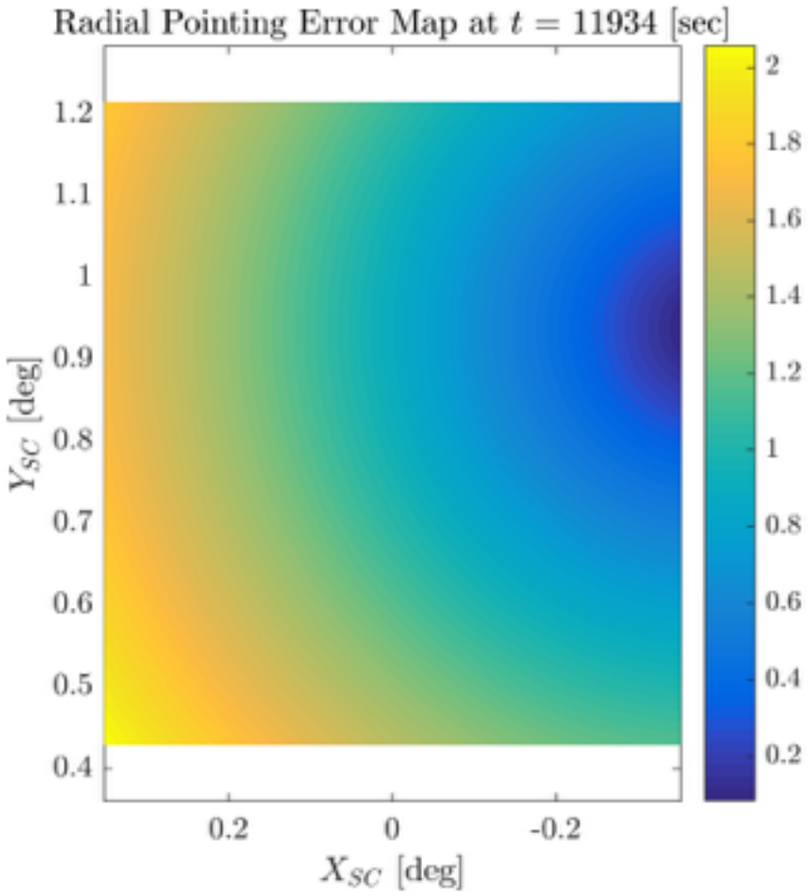


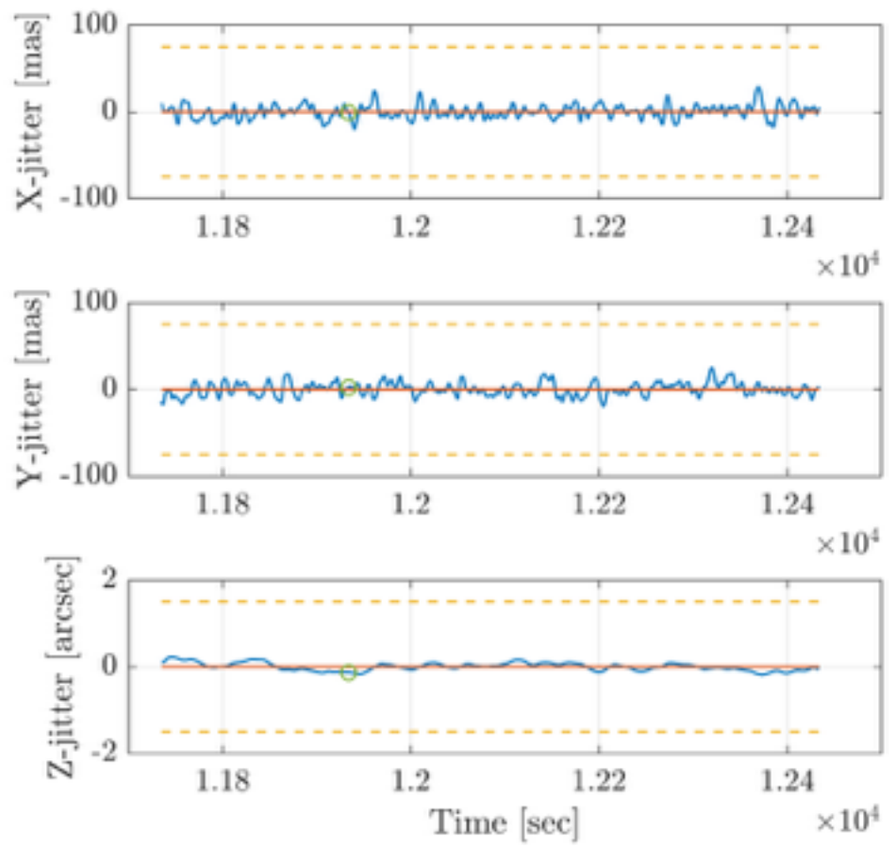
List Of AOCS Checks



Radial Pointing Error

- Translate jitter angles into displacement on the VIS and NISP focal plane
- Radial error evolution in the field of view (FOV)

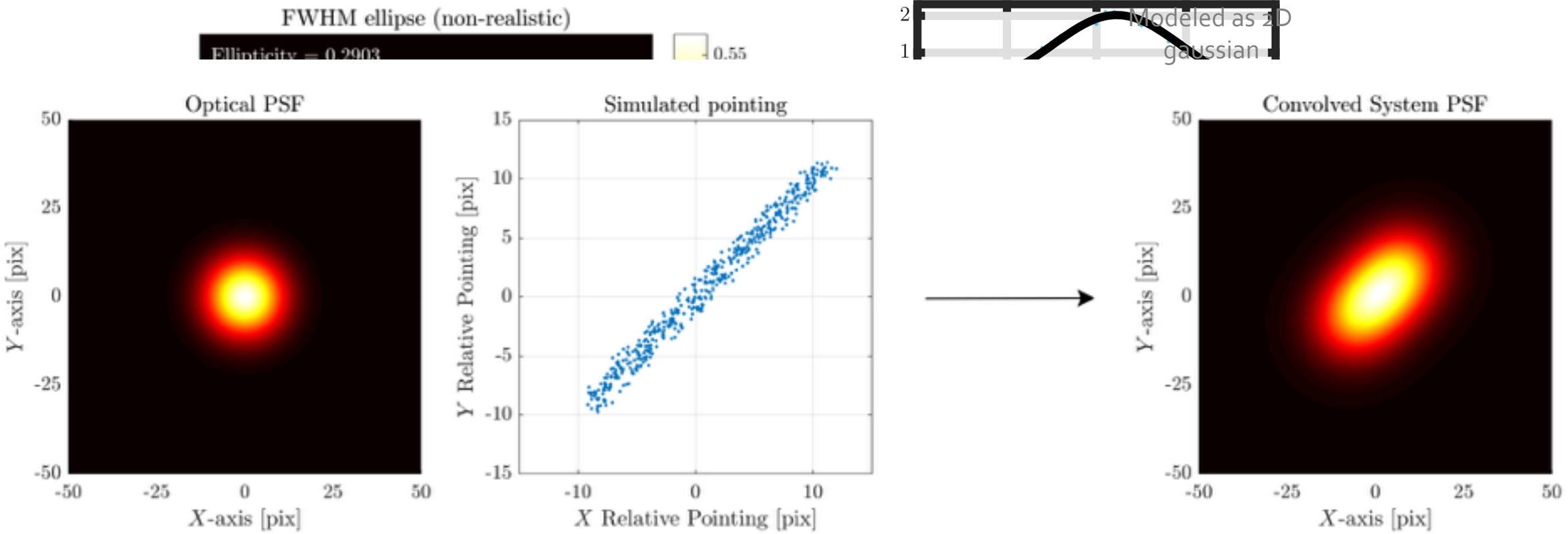




Ellipticity

- Compute ellipticity induced by jitter on a Gaussian beam
- Methods:
  - Quadrupole moments
  - Ellipse fitting at FWHM
  - 2D gaussian fit

$$\mathrm{PSF}_{\mathrm{sys}} = \underbrace{\mathrm{PSF}_{\mathrm{opt}}}_{\text{Modeled as 2D gaussian}} \otimes \mathrm{Jitter}$$

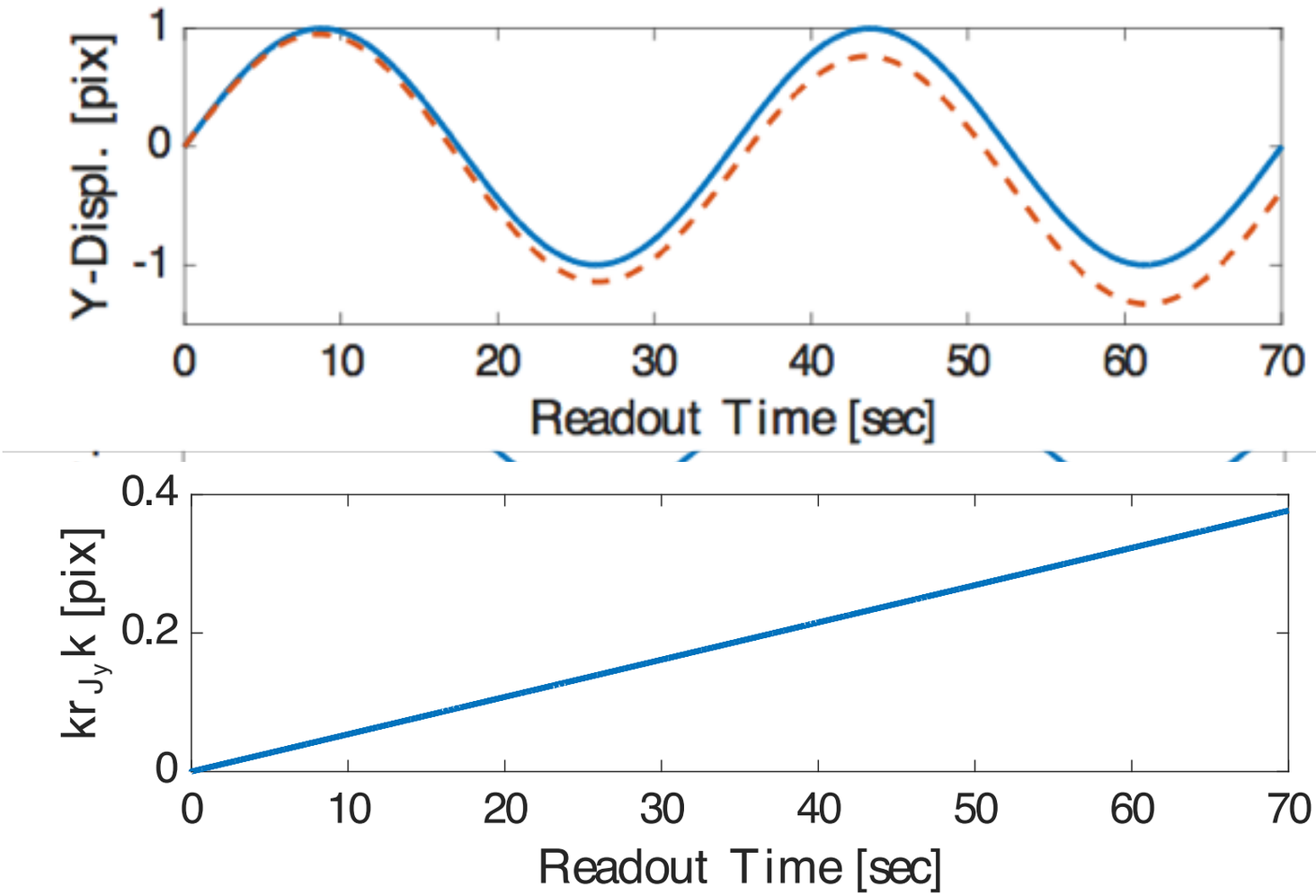


Pointing Reconstruction

- Target: reconstruct focal displacement (and eventually the spacecraft's attitude if possible) by using the CCD readout during the linearity observations. Pros:
  - Independent source of information
  - Higher frequency than FGS HK data
- Simulation concept: simulate the readout of a CCD quadrant region with some specified width around the original position of the selected source.
  - Evaluate optical PSF according to a known focal displacement (X/Y) and readout velocity (Y).
  - Noise and background characterised from images generated with the VIS simulator.
  - Limitations: no CTI, cosmic rays not included in the simulations, Gaussian PSF.
- Reconstruction basis: Perform one-dimensional fits of the PSF along Y-cutouts to infer the focal displacement evolution.
- X/Y problems are decoupled:
  - X-direction: evolution of PSF's mean relative location.
  - Y-direction: evolution of PSF's area.

Y-direction Reconstruction

- Y-jitter can be *viewed* as slowing/accelerating the movement of charges during the read-out
- The curve along the read-out direction will be equivalent to the derivative of the jitter plus a constant: the number of electrons generated during a read-out in case of no jitter



Simulated Focal Displacement (J_y)

Reconstructed Focal Displacement $(\hat{J}_y)$

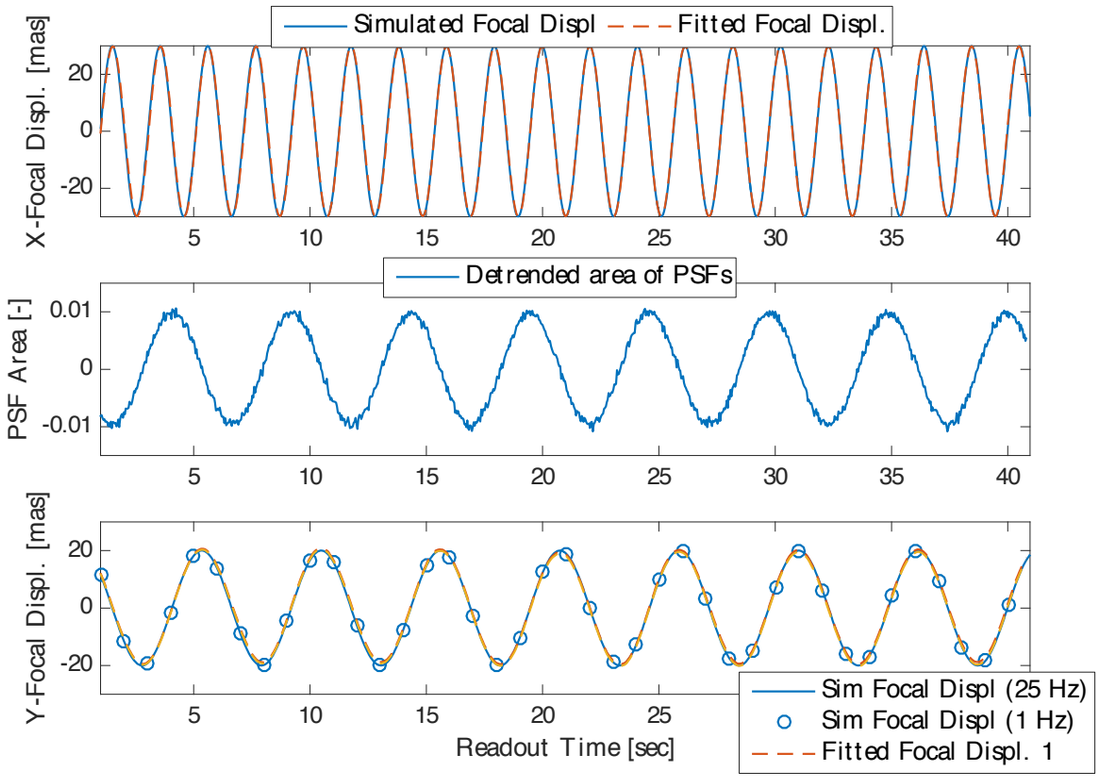
$$\bar{I}(p) = \frac{\mathrm{d}J_y(p)}{\mathrm{d}p} + \bar{c}$$

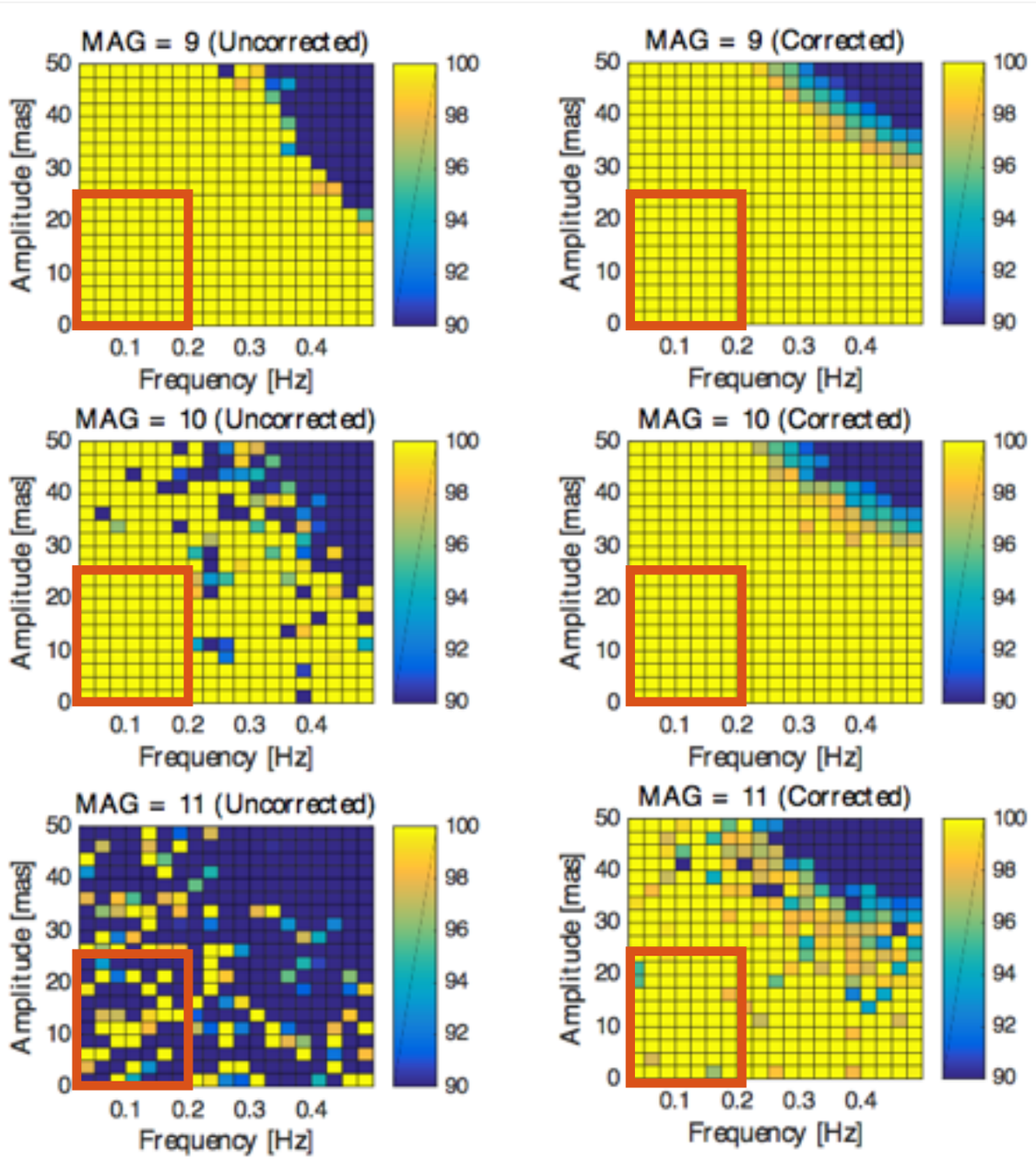
$$\left(c = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} PSF(x,y)\ \mathrm{d}x\ \mathrm{d}y \right)$$

$$\hat{J}_y(p) = \int_{p_0}^{p_n} \left(\bar{I}(p) - \bar{c} \right) \mathrm{d}p$$

Reconstruction Envelope

- Further correction available:
  - Linear fit 1 Hz residuals from FGS HK data
  - Combine the reconstruction of different sources in the FOV
- Simulations show stars of magnitude 11 or below are needed for proper reconstruction





List Of VIS QDT Checks

Common Checks
identify the VIS observing mode
compare commanded to executed/downloaded data.
subract the bias, for each of the 144 quadrants
convert to FLOAT each of the 144 quadrants
run a series of checks on exposures taken in all modes
identify all overflow pixels in each of the 144 quadrants
identify all underflow pixels in each of the 144 quadrants
determine the readout noise in each of the 144 quadrants
determine the electronic offset value in each of the 144 quadrants
Nominal Exposure Checks
determine saturation level in each of the 144 quadrants
identify saturanted pixels in each of the 144 quadrants
determine, for each of the 36 CCDs, the sky background statistics: mean, median, stddev, …
identify cosmics in each of the 36 CCDs
create a catalogue of objects for each of the 36 CCDs
identify potential objects, for each of the 36 CCDs
create list of fitlered objects, for each of the 36 CCDs
determine objects centroid, for each of the 36 CCDs
determine objects flux, for each of the 36 CCDs
determine, for each of the 36 CCDs, mean PSF image quality
determine WCS, for each of the 36 CCDs
determine pointing parameters, for each of the 36 CCDs
Bias Exposure Checks
flag new hot columns, for each of the 144 quadrants
determine the electronic offset value in each of the 144 quadrants

Flat Field Exposure Checks
set different thresholds depending on the LED used
identify saturanted pixels in each of the 144 quadrants
check how many pixels has less than TBD and compare to a given threshold, in each of the 144 quadrants
determine the flat field fluence
determine small area PRNU, in each of the 144 quadrants
determine serial CTI from trailing, in each of the 144 quadrants
check the gain & offset consistency across quadrant boundaries, in each of the 36 CCDs
determine the particulate contamination
Dark Exposure Checks
identify pixels affected by cosmics for each of the 144 quadrants
determine the average dark signal for each of the 144 quadrants
derive some statistics/information regarding the spatial distribution of cosmics: are they clustered or spread on the FPA?
derive some statistics/information regarding the energy deposited by cosmics
Charge Injection Exposure Checks
identify saturanted pixels in each of the 144 quadrants
determine the charge injection pattern for each of the 144 quadrants
determine the charge injection level for each of the 144 quadrants
determine parallel CTI from first pixel response for each of the 144 quadrants
determine parallel CTI from trailing for each of the 144 quadrants
determine serial CTI from trailing for each of the 144 quadrants
Trap Pumping Exposure Checks
identify saturanted pixels in each of the 144 quadrants
determine dipole contrast

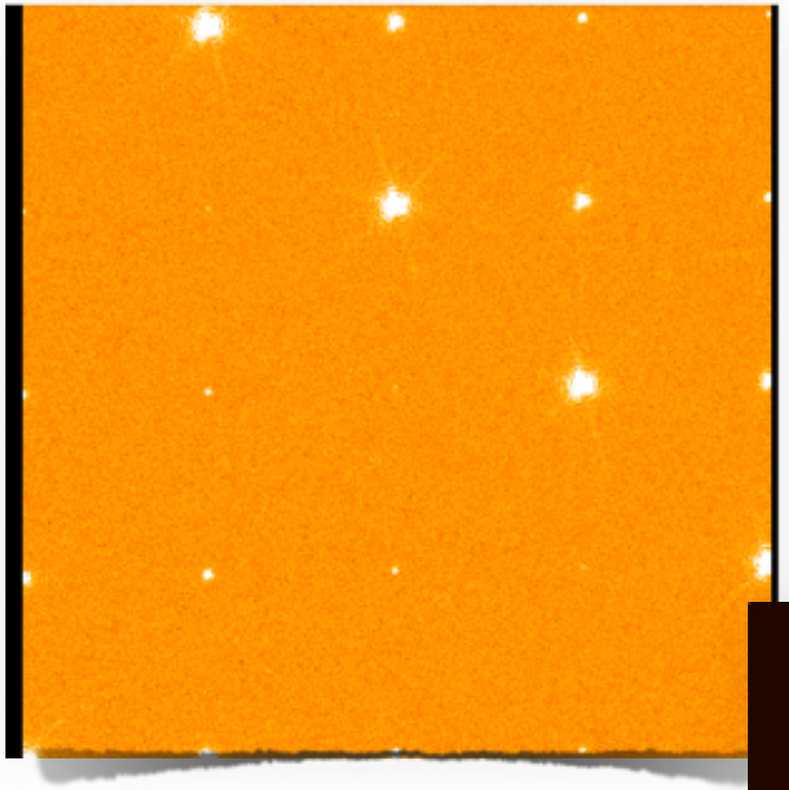
List Of NISP QDT Checks

Common Checks
identify the NISP observing mode
compare commanded to executed/downloaded data
run a series of checks on exposures taken in all modes
identify all overflow pixels in each of the 16 detectors
identify all underflow pixels in each of the 16 detectors
apply bad pixel, dark, and reference correction for each of the 16 detectors
convert to FLOAT each of the 16 detectors
Flat Field Exposure Checks
determine image statistics
Dark Exposure Checks
determine image statistics
Linearity Exposure Checks
determine image statistics
check correct number of ramps are downloaded

Nominal Exposure Checks
apply linearity correction
subtract dark frame
determine, the sky background statistics: mean, median, stddev, …
identify cosmics
determine objects centroid
determine mean PSF image quality
run noise pixel statistics on objects to check for blurring
determine photometry
determine WCS
determine pointing parameters
identify spectra (check the grism PA)
identify lines (TBD)
All Ramp Data Checks
run on-board processing algorithm
measure read-out noise

QLA Diagnostic Report Example

Simulated 4 identical quadrants with different biases



Generate report
Raise warnings
where applicable

Create CCD image from the 4 quadrants

report.out

nes/root/SOC_SW_TESTING/V1_RELEASE/QLA/TEST_DATA/VIS/QLA_Checks/Flat/OUTPUT_DATA/report.out


```
"CCD_NoCTI_NoCR_FLAT_Consistency.fits": {
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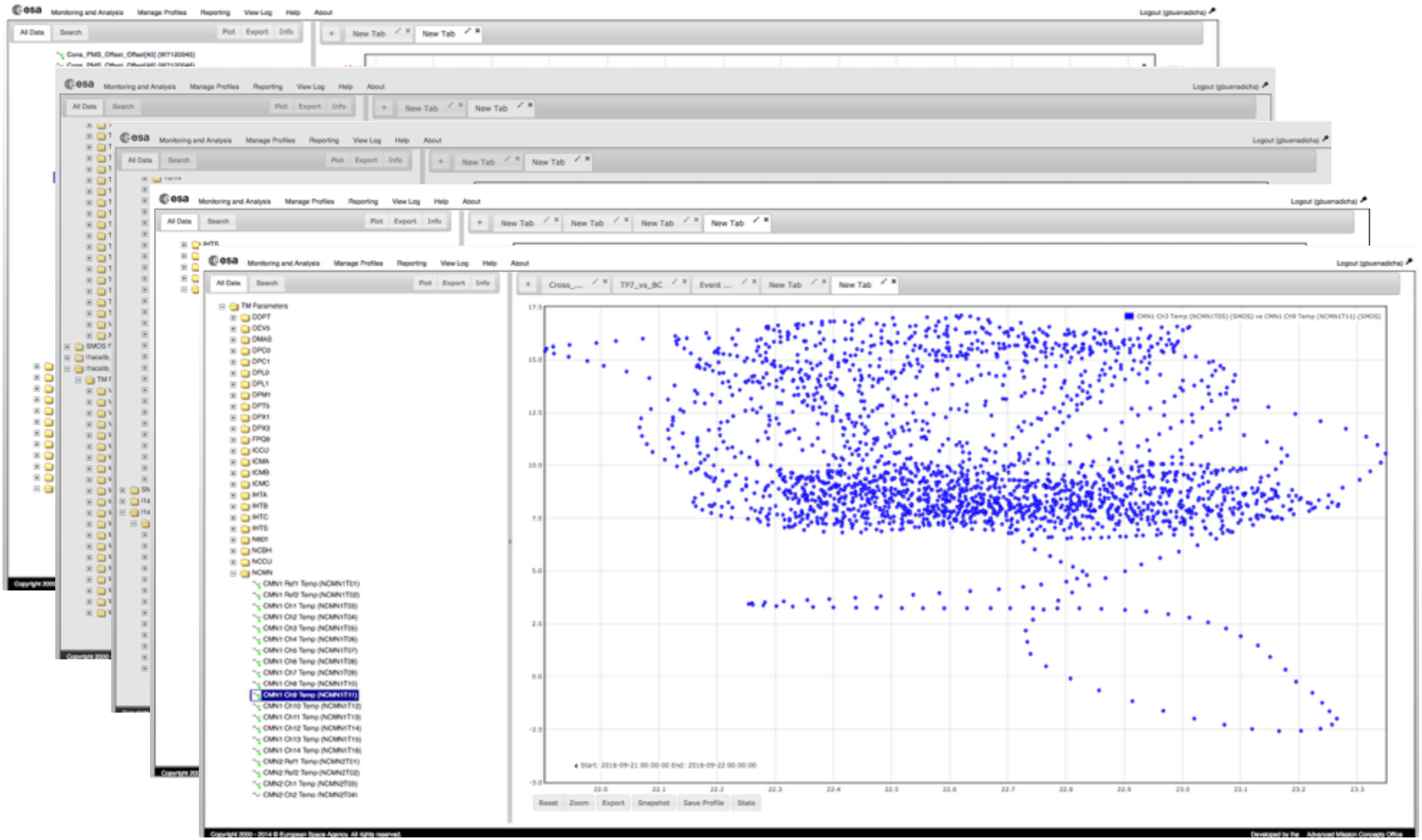
HMS Web Interface (ARES For SMOS)



QLA Development Ahead

- Another main release of the system foreseen for Q4/2016, and then another prior to the DR in 2017
  - Consolidation of the QPF and QDT functions
  - QPF orchestrator as per user request (currently per product type)
  - Full integration between QPF and QDT
- VIS processing functions enlarged with test data coming from ground testing and OU-SIM simulations
- NISP processing functions:
  - Data description and diagnostics document under discussion with IPAC
  - Development of the processing algorithms will be part of an ongoing agreement with IPAC for collaboration in the QLA development
- AOCS processing functions:
  - consolidation and conversion of diagnostic tools into Python
  - full integration with QPF and QDT (for the pointing extraction from VIS linearity data)

QLA Team

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  - John Hoar
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- NASA - IPAC
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  - George Helou
  - Harry Teplitz