GNAOI Data Reduction Software

Top-Level Software Requirements Specification

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Gemini Science User Support

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1. Introduction

1.1 Purpose

PRELIMINARY DOCUMENT – Will need to be revised once the instrument has been better defined.

The purpose of this document is to serve as a guide to designers, developers, and testers who are responsible for the engineering of the GNAOI Data Reduction Software project. It should give the engineers and stakeholders the necessary information to do a preliminary design of the software and cost the project.

1.2 Scope

This document contains the top-level requirements for the functionality and attributes of the GNAOI Data Reduction Software. It consists of a set of top-level requirements covering all

aspects of the software from functionality to performance, development environment to tests and documentation.

Additional information such as use cases, functional requirements and nonfunctional requirements, interfaces descriptions, and data models, which, taken together, form a complete description of the software will be provided in a companion documents. Requirements to that level of details are not included in this document.

1.3 System Overview

Gemini North Adaptive Optics Imager (GNAOI) is a planned imager that will be used with both the planned Gemini North Multi-Conjugate Adaptive Optics system (GNAO), and a planned Ground Layer Adaptive Optics system (GLAO). GNAOI will use a single HAWAII-4RG detector.

GNAO will provide an f/32 beam to the instrument. GLAO will provide and f/16 beam. A single set of camera optics in GNAOI will give a field of view of 85 arcseconds square with GNAO (which will correct a 2-arcminute diameter circular field) and 170 arcseconds square with GLAO (or indeed in natural seeing).

The imager will be provided with a suite of broad and narrow band filters that will support a broad range of science applications. The core wavelength regime is 0.9 - 2.5um, though a strong consideration is to expand this to 0.6 - 5um.

Gemini already has data reduction primitives and recipes for near-infrared imaging. Those will be available to GNAOI. The GNAOI team is requested to reuse as many existing tools as possible to avoid duplication and to avoid unnecessarily increasing the size of the code base, and as the result the maintenance burden. Improvements to existing routines will be welcomed.

The GNAOI Data Reduction Software will:

- Generate automatically or semi-automatically scientific quality calibrated products;
- Generate automatically “quicklook” / ”fast reduction” products for target-of-opportunity follow-up assessment;
- Generate automatically data quality assessment products.

The scope of the project does not include scientific analysis tools.

The GNAOI data reduction software will use Gemini’s DRAGONS pipeline infrastructure. It will use Astrodata and be built to work with DRAGONS’ Recipe System.

1.4 References

- GNAOI Documents
  - ConOps: To be written
- SUSD Documents
  - GNAOI-SRS-101_DRSoftwareNonFunctionalRequirements.docx
  - DPSG-STD-102_CodingStandards.docx
  - DPSG-STD-104_VarianceDQPixelsUnits.docx
  - DRAGONS documentation: https://dragons.readthedocs.io/
- URLs
  - Internet Engineering Task Force RFC 2119, https://www.ietf.org/rfc/rfc2119.txt
  - Test Coverage Philosophy: http://www.artima.com/forums/flat.jsp?forum=106&thread=204677
  - DRAGONS repository: https://github.com/GeminiDRSoftware/DRAGONS

2. Definitions

2.1 Language

Adapted from *Internet Engineering Task Force RFC 2119*.

- MUST: This word, or the term “REQUIRED”, mean that the definition is an absolute requirement of the specification.
- MUST NOT: This phrase means that the definition is an absolute prohibition of the specification.
- SHOULD: This word, or the adjective “RECOMMENDED”, mean that the re may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course.
- SHOULD NOT: This phrase, or the phrase “NOT RECOMMENDED” mean that there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
- MAY: This word means that an item is truly optional.

2.2 Acronyms

- BG: Background (Gemini’s sky illumination constraint)
- CC: Cloud Cover (Gemini’s cloud cover constraint)
- DQ: Data Quality
- ICD: Interface Control Document
- IQ: Image Quality (Gemini’s seeing constraint)
- PDR: Preliminary Design Review
- QA: Quality Assessment
- RTF: Gemini’s Regression Test Framework
- SUSD: Science Users Support Department
- VAR: Variance

3. Use Cases

3.1 Instruments Modes

The instrument modes are to described in the ConOps document. Table 1 needs to be populated once the operating modes have been finalized.

Table 1: Main GNAOI instrument operating modes

Mode	Configuration
Non-Thermal NIR GNAO	f/32, 85 arcsec FOV
Thermal NIR GNAO	f/32, 85 arcsec FOV
Non-Thermal NIR GLAO	f/16, 170 arcsec FOV
Thermal NIR GLAO	f/16, 170 arcsec FOV
High time resolution mode	

3.2 Use Cases

No use cases have been specifically written in support of the top-level requirements. However, the reader should refer to the ConOps document for the discussion of science cases and the data requirements attached to those. The data reduction software must not hinder the achievement of those requirements.

3.3 Top-Level Data Reduction Charts

In the Appendix A, example top-level flow chart for the data reduction near-IR imaging is presented.

The chart is not a requirement per se, and is not complete by any means. It does not necessarily represent what the contracted data reduction team will deem optimal. It is an example to guide the top-level discussion. It is included to provide context and background for the actual requirements. It is meant to inform on the overall processing that is envisioned and to be a starting point for discussion and analysis of what it will take to *properly and optimally* process GNAOI data. That chart is expected to evolve and grow into more detailed and accurate flow charts as the project progresses (see SRS-NFR-025 and SRS-NFR-026 in GNAOI-SRS-101_DRSoftwareNonFunctionalRequirements.docx).

4. Top-Level Requirements

Name	**SRS-TL-001 – Recipe System**
Summary	The software is designed and implemented for the DRAGONS *RecipeSystem*
Rationale	DRAGONS and the *RecipeSystem* is Gemini's official pipeline platform.
Requirements	The software must be designed and implemented for the DRAGONS *RecipeSystem*. It must use the Primitive and Recipe model and use AstroData for dataset IO. The software must be written in Python. The software dependencies must be included in the AstroConda distribution (including their dependencies). It must not depend on IRAF.
References	

Name	**SRS-TL-002 – Science Quality**
Summary	The software produces science quality outputs
Rationale	The user community expects the outputs to be accurate and scientifically valid.
Requirements	The software must process the raw data with accuracy, and in a scientifically and mathematically correct manner. The software must apply valid and optimal calibrations and corrections to make the outputs ready for scientific analysis.
References	

Name	**SRS-TL-003 – Near-real-time Quality Assurance**
Summary	The software generates quality assurance products at night in near-real-time
Rationale	The night observers need to assess the quality of the data obtained during the night and make observing queue decision based on that quality assessment.
Requirements	The software extracts quality assurance products from the datasets written to disk. If possible, the software must extract the standard Gemini sky conditions that defines the IQ (seeing), CC (cloud cover), and BG (background) constraints bands. Other than the sky conditions bands, the software must display non-extracted data, and the extracted data to allow for visual evaluation at night. The specific quality assessment (QA) products will depend on the type of data and the type of guidance the night observers will need.
References	

Name	**SRS-TL-004 – Instrument modes**
Summary	All official instrument modes are supported
Rationale	All Gemini GNAOI programs using standard modes are entitled to data reduction support.
Requirements	The software must be able to produce Science Quality outputs, and Quality Assurance outputs, for data from all the official instrument modes.
References	

Name	**SRS-TL-005 – Master Dark**
Summary	The software creates a master dark frame
Rationale	Minimize noise by using several dark images. Standard near-IR array data processing, when dark current is large or non-uniform.
Requirements	The software must mathematically combine dark images of matching characteristics to create a master dark. The absolute noise in the master dark depends on the noise already present in individual darks and on the number of dark frames being combined. The software must not introduce noise and must produce a noise level in accordance with the propagation of read noise and Poisson noise.
References	

Name	**SRS-TL-006 – Dark Correction**
Summary	The software removes the dark signal
Rationale	Standard near-IR array data processing.
Requirements	The software must subtract the master dark from the datasets. The software must correctly associate the dataset with a master dark of matching characteristics. The software must not introduce noise and must produce a noise level in accordance with the propagation of read noise and Poisson noise.
References	

Name	**SRS-TL-007 – Flat Field**
Summary	The software produces a processed flat field.
Rationale	Standard near-IR array data processing. The flat field is created from GCAL lamp flats or on-sky frames (thermal near-IR).
Requirements	The software must produce a processed flat field of GCAL lamp flats or on-sky frames.
References	

Name	**SRS-TL-008 – Flat Field Correction**
Summary	The software applies the flat field correction
Rationale	Standard near-IR array data processing
Requirements	The software must apply the processed flat field to the science and sky data to correct for variation in the pixel-to-pixel response.
References	

Name	**SRS-TL-009 – Sky Frame**
Summary	The software masks sources and stack observations to create a sky frame.
Rationale	Standard processing for imaging data in near-IR regime. The science frames or an offset to sky series can be used.
Requirements	The software must mask sources in the science observations or sky observations then stack them to create a sky frame for sky subtraction.
References	

Name	SRS-TL-010 – Sky Subtraction
Summary	The software subtracts the sky emission from the target observations.
Rationale	Standard processing for near-IR imaging data.
Requirements	The software must remove the sky emission signatures from the science observations. Cases requiring off-set to sky (e.g. extended objects) must be handled appropriately.
References	

Name	SRS-TL-011 – Registration and Stacking
Summary	The software registers and stacks multiple images of the same field.
Rationale	Increase signal-to-noise ratio. Standard processing.
Requirements	The software must detect and use sources found in the individual images to register them relative to each other. The software must stack the registered images, ignoring bad pixels. The stacking options include whether to average or median combine, and options to select a pixel value rejection algorithm (e.g. sigma clipping, min max) and associated input parameters. The variance plane and data quality planes are propagated to the output image.
References	

Name	SRS-TL-012 – Bad Pixel Mask
Summary	The software creates a bad pixel mask and attaches it to the dataset as a data quality plane
Rationale	Bad pixels contain no valuable information and must not be used in calculations.
Requirements	The software uses calibration frames to create a bad pixel masks for the detector. The software must add the appropriate bad pixel mask to the data quality (DQ) plane of the dataset being processed. Normally the DQ plane is created from the bad pixel mask.
References	

Name	SRS-TL-013 – Variance and Data Quality
Summary	The software keeps track of the error budget (variance plane) and the pixels quality (data quality plane)
Rationale	Characterize scientific value of the measurements and eliminate bad pixel values from calculations.
Requirements	The software must calculate or generate the initial variance and data quality planes and correctly propagate those planes throughout the processing, from raw to processed, updating them as scientifically necessary.
References	DPSG-STD-104_VarianceDQPixelsUnits.docx

Name	SRS-TL-014 – Flux Calibration
Summary	The software flux-calibrates the image
Rationale	Depending on the objective of the program the absolute flux of the signal received can be essential.
Requirements	The software must use standard star observations to calculate the photometric zero point leading to an absolute flux calibration.
References	

Name	**SRS-TL-015 – High time resolution**
Summary	The software must recognize and processes high time resolution sequence observations.
Rationale	High time resolution observations are normally interested in the individual observations rather than a stack of all the them. The software must be able to select an appropriate recipe automatically. Also, the data will likely be stored in data cube. The software must be able to handle that. (This requirement particularly needs inputs from a ConOps and a Science Case.)
Requirements	The software must be able to recognize a high-time resolution dataset, select the appropriate recipe to deal with a time sequence, and accept x,y,time cube data.
References	

Name	**SRS-TL-016 – Programmer's Documentation**
Summary	The software's design and implementation are fully documented
Rationale	The software will be delivered to Gemini who will then become responsible for maintenance and further development, hence it must be documented from a programmer's perspective.
Requirements	The software's design and implementation must be fully documented. The documentation must be written for Sphinx such that HTML and PDF formats can be generated automatically. A template with section headings covering the minimum requirement will be provided to the contractor. At the time of writing, here is the desired outline: Introduction: general description, description of the modes, required calibrations and associated observations, important instrument characteristics and issues. Flow: list of typical sequences, top-level flow charts for processing calibrations, top-level flow charts for processing science. AstroData Tags: relevant AstroData tags, association tables Recipes: reduction modes, recipes, technical flow chart for each recipe, issues and limitations. Primitives: for each primitive, purpose, input/outputs, input parameters, AstroData tags, inheritance and primitive set, location, algorithms, issues and limitations. Test Suite: tests available, missing or desirable tests, running the tests
References	

Name	**SRS-TL-017 – User's Documentation**
Summary	The software's usage is fully documented
Rationale	Users of all level of expertise will be using the software. They must have everything they need to successfully run the software and understand what is happening to the data.
Requirements	The software's usage must be fully documented and must be written for an audience of non-SCORPIO expert astronomers. The documentation must be written from Sphinx such that HTML and PDF formats can be generated automatically. A template with section headers covering the minimum requirement will be provided to the contractor. At the time of writing, here is the desired outline: Overview: description of the instrument, description of the data Recipes: typical processing flows (flow charts and recipes), other supported processing flows (flow charts and recipes) Tips and Tricks: for each topic, description, examples, screenshots, solutions. Issues and limitations: any appropriate content. (general) Primitives: for each primitive, purpose, input and outputs (including input parameters), summary of the algorithm, issues and limitations.
References	

Name	**SRS-TL-018 – Tests**
Summary	The software is fully tested and the tests are documented
Rationale	The software needs to be maintained in the long-term, both programmatically and scientifically. Tests ensure stability, robustness, and accuracy and help keep maintenance costs down. pytest is used for unit tests to align the Gemini data reduction software with the community project Astropy.
Requirements	A test suite including unit tests and integration tests must be delivered with the software. The unit tests must use pytest. The unit tests are appropriate to test functions and methods. The integration tests are appropriate to test sequences of primitives with simulated or real data. As for the coverage requirement in general, check the reference below.
References	Test coverage wisdom: http://www.artima.com/forums/flat.jsp?forum=106&thread=204677

5. Detailed Revision History

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As distributed to the Gemini development team. Needs to be revised once the instrument's characteristics are defined.

Top-Level Example Flow Chart

Figure 1: Near-infrared Imaging