**RFP No. NB3880C**

**Gemini North Adaptive Optics Instrument (GNAOI)**
**Preliminary Design**
**Statement of Work GNAOI-04**

ASSOCIATION OF UNIVERSITIES FOR RESEARCH IN ASTRONOMY, INC. (AURA)
Operating the
Gemini Observatory
Hilo, Hawaii and La Serena, Chile

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Exhibit A: Statement of Work
to
AURA Contract No. **xxxxxxx**

## Contents

## 1    Definitions

In this document, the following capitalized (shown here also in boldface) terms shall have the following meanings:

**Preliminary Design Completion Date:**  This term refers to the date by which all the Work is completed, all deliverables have been accepted, and the contract is considered complete.

**Preliminary Design Documentation Set:**  This term refers to the set of documents due upon the completion of the Preliminary Design stage, details of which are contained in Appendix A.

**GNAOI Associated Hardware.** This term refers to the project deliverable hardware items that are not part of the instrument, per se, but which are necessary for the successful operation and maintenance of the instrument.  These items include any necessary non-commonly available hardware and tools used for alignment, assembly, handling, testing, maintenance, service, and calibration. It also includes the shipping containers for the instrument.  GNAOI Associated Hardware also includes a set of agreed GNAOI Instrument spares.

**GNAOI Associated Software:** This term refers to the project deliverable software items that are not part of the GNAOI Instrument but are necessary for the successful operation and maintenance of the instrument.  These items include any software required for alignment, calibration, maintenance, service, simulation, testing, and data reduction.  Data reduction software products include data simulation tools, quick look tool, nighttime data quality assessment science, science quality data reduction software, unit tests and regression tests, and data reduction software documentation.

Data reduction software should be aimed at maximize the scientific productivity of the GNAOI Instrument.  The data processing functions shall be a collection of building-block tasks associated with the GNAOI Instrument and be integrated into the Gemini data handling and data processing software systems.

**GNAOI Instrument:**  This term refers to the scientific astronomical instrument that is the subject of this contract: the Gemini North Adaptive Optics Imager.  The term includes all operational software (such as the instrument control system and detector control system) running on the instrument hardware.

**GNAOI Key Technical Performance Metrics:**  This term refers to a number of identified metrics that Contractor shall track against during the lifetime of the project.  The values tracked for each metric shall include the requirement, the current best estimate (obtained by design, analysis, or measurement), and the current margin.

**GNAOI Requirements:**  This term refers to the set of contractual requirements stated in Section 4.

## 2    Project Priorities

From the following guidance received from Gemini Governance and the Gemini Science and Technology Advisory Committee,

> *We prioritize meeting the schedule and budget constraints over extra capabilities beyond our baseline and plan to make decisions that, in order of priority:*
>
> - *Meet the core science requirements*
> - *Reduce cost and schedule risk*
> - *Employ currently available technology,*

Gemini has defined a set of Project Priorities that are intended to guide the decision-making process when adverse issues related to capabilities, schedule, and cost are encountered while performing the GNAOI project.   Gemini and Contractor shall make decisions in accordance with these priorities throughout the lifetime of the project.

- Capability.  The instrument must meet the defined technical performance requirements.  This is the first priority.

- Schedule.  The project must be completed by the due date. This is the second priority, and should only be adjusted for adverse issues related to meeting the first priority.

- Cost.  The project must be completed within budget.  This is the third priority, and should only be adjusted for adverse issues related to meeting the first two priorities.

- The addition of extra capabilities or achieving higher performance beyond the defined performance requirements will only be considered if such an addition does not affect schedule or cost.

## 3    Schedule

The duration for the Preliminary Design is indicated in the table below.  This milestone table lists the key contractual milestone events and their completion dates based on the contract start date, $t_0$,

| Contract Event | Date |
|---|---|
| Start Date | $t_0$ |
| Kickoff Meeting | < $t_0$+2 weeks |
| PD Documentation Set Delivery | $t_0$+5 months |
| Complete End-of-Stage Review | ~$t_0$+5 months and 3 weeks |

## 4    Requirements

(a) The GNAOI Instrument will be used with both the in-progress Gemini North Multi-Conjugate Adaptive Optics system (GNAO) and a planned Ground Layer Adaptive Optics system (GLAO).

1.  GNAOI shall use a single 15 micron pixel  HAWAII-4RG detector as its primary science detector.

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

3.  Beyond re-imaging the field onto the detector, GNAOI shall also incorporate two interchangeable cold stops appropriate to the f/32 and f/16 beams to block background thermal flux.

4.  For alignment purposes, GNAOI shall provide a means to image the pupil onto the detector.

5.  GNAOI shall operate between the 0.9 um cut-on of the GNAO beam splitter and 2.4 um.

6.  GNAOI shall optimally Nyquist sample the corrected f/32 beam at 1.65 um within a field that circumscribes the detector.  (We expect the scale to be ~20 miliarcsec/pixel.)

7.  The f/16-pixel scale will be double the f/32-pixel scale, a single set of camera optics shall be used for both.

8.  GNAOI shall generate a root mean squared (RMS) wave front error of < 65 nm.

9. GNAOI shall provide a means for measuring non-common-path wave-front errors at the GNAOI imager detector.

10. GNAOI shall contain a complement of broad-band and narrow-band filters, TBD, to support a broad range of science applications.

11. GNAOI shall have an optical throughput exceeding 50% for all wavelengths within the range 0.9 - 2.4 microns, excluding the detector.

12. GNAOI shall include optics for viewing its internal cold stop, that can be inserted without disturbing the nominal imager optics.

13. GNAOI shall be able to position and readout an on-detector guide window anywhere on the HAWAII-4RG for use as an on-instrument wavefront sensor.

(b) The GNAOI instrument shall comply with the Gemini interface control documentation requirements listed in the table below.

| Document Number | Title | Rev |
|---|---|---|
| INST-REQ-0001 | Science and Facility Instruments Common Requirements Specification | C |
| ICD 1.5.3/1.8 | Instrument Support Structure to Adaptive Optics ICD | B |
| ICD 1.5.3/1.9 | Instrument Support Structure to Science Instruments ICD | E |
| ICD 1.9/2.7 | Science Instruments to Facility Handling Equipment ICD | E |
| ICD 1.9/3.6 | Science and Facility Instruments to ISS System Services ICD | H |
| ICD 1.9/5.0 | Science and Facility Instruments to Transport, Observatory and Operational Environments ICD | D |
| ICD G0014 | Optomechanical Coordinate Systems | B |
| ICD 1.1.13/1.9 | Interlock System to Science Instruments ICD | A |
| GIAPIBuilderReq-01302009 | GIAPI Software Requirements for Instrument Builders | 04 |

| GIAPIUse-08292006 | GIAPI Design and Use | 08 |
|---|---|---|
| GIAPIC++ICD50-02042008 | GIAPI C++ Language Glue API | 11 |
| ICD 20 | Synchro Bus - Node/Page Specifications | D |
| ITS-STG-001 | Gemini Observatory IT & CyberSecurity Requirements for Facility Instruments | 1.2 |
| GNAOI-SRS-101 | Data Reduction Software Non Functional Requirements | 1.1 |
| GNAOI-SRS-102 | Data Reduction Software Top Level Software Requirements Specification | 0.1 |

(c) The requirements provided in paragraph (a), together with the requirements provided in the latest revision of the Requirements Document approved by the AURA Technical Representative, shall constitute the functional and performance requirements that this Instrument must meet (the GNAOI Requirements).

(d) Contractor is welcome to supply additional requirements.

**5 Project Deliverables, Communication, and Meetings**

**5.1 Deliverables**

The following are the required deliverables for this Work.
- Kickoff Meeting: Presentation report (see section 5.3.1)
- Monthly Progress Meeting: Verbal report (see section 5.3.2)
- Monthly Progress Reports: Written report (see section 5.2.1)
- Preliminary Design Documentation Set [see section 6(c)]
- Contract and Statement of Work Amendment Exceptions

See Section 1 and Appendix A for a definition of the documents.

**5.2 Communication**

**5.2.1 Monthly Progress Reports**

Contractor shall submit a monthly written progress report due the 15th of the month to the Technical Representative describing all of the technical, schedule, and financial progress of the Work as of the end of the previous calendar month, and to include all information regarding any subcontractor work. Each report shall include:

(a) Information regarding the technical status of the Work overall, and in each engineering discipline;

(b) An updated schedule to consist of the most current project plan to completion. Contractor shall compare the current schedule to the last approved baseline schedule. Contractor shall maintain the schedule in Microsoft Project, or equivalent, and present it with a Gantt chart and with a column showing percent complete for each listed task. Contractor shall report the current expected project completion date, including its associated margin and uncertainty;

(c) A table of the major milestones, and cross-institute deliverables, with the original, previous, and current dates by which they will be attained. Contractor shall explain any significant changes from the previous date and include all the explanations from previous lists;

(d) Problem areas related to the Work, including potential for delays, risk mitigation plans, and the status of identified risks;

(e) GNAOI Key Performance Metrics including the requirement, current best estimate, and the current margin. Contractor shall retain and present the entire log of previous monthly values for comparison;

(f) High-level action items for Gemini and Contractor (both open and closed), and associated status. Contractor shall be responsible for recording and tracking the high-level action items.

These reports shall be reviewed at the monthly meeting between the AURA Technical Representative, the Contractor Technical Representative, and any key personnel needed to discuss the current status of the project. Contractor may propose different phasing of these reports so long as the period covered remains equivalent to one calendar month and Gemini receives the report within 15 days of the end of the reporting period.

### 5.3 Meetings and Reviews

### 5.3.1 Kickoff Meeting
(a) Contractor shall host a kickoff meeting with AURA personnel and key Contractor personnel within 2 weeks of the beginning of the Preliminary Design Stage.

(b) The kickoff meeting shall focus on the scope of work, plan, and deliverables.

(c) Contractor shall provide Gemini all documentation presented at the kickoff meeting by Contractor, and Gemini will provide Contractor all documentation presented by Gemini.

(d) AURA is responsible for all expenses associated with AURA personnel travelling to and attending the kickoff meeting.

### 5.3.2 Monthly Meetings
During the course of the Work, Contractor shall hold monthly meetings with the Contractor and AURA Technical Representatives, and other AURA and Contractor personnel, as needed, intended not to exceed one hour in duration, to discuss the progress of the Work. These meetings may be held by telephone or videoconference.

### 5.3.3 End-of-Stage Review
(a) At the end of the Preliminary Design stage, Gemini shall hold a formal end-of-stage review for the purpose of down-selecting a single team to complete the second part of the project, the Post-Preliminary-Design work.

(b) The review evaluation criteria shall be based on the Preliminary Design Statement of Work and the Preliminary Design Stage Documentation Set.

(c) Contractor and AURA shall schedule at most two days for the review, to be held at Gemini North Base Facility, Hilo, US.  Gemini intends to provide evaluation criteria prior to the start of the Preliminary Design work.

(d) The Gemini Associate Director for Development shall select an external review committee chair and shall select the review committee members with the advice of the review committee chair, if so requested.  NSF personnel may elect to attend the review.  The AURA Technical Representative will be responsible for making the logistical arrangements for the review.

(e) The end-of-stage review shall not relieve Contractor of any responsibility for the successful completion of the Work outlined in this document.

(f) Contractor shall deliver the end-of-stage documentation to AURA for distribution to the review committee at the end of the 5 month design period. Gemini intends to schedule all the end-of-stage reviews two to three weeks after delivery of this documentation.

(g) Gemini shall be responsible for all end-of-stage review travel expenses and arrangements for two contractor personnel, Gemini staff, and the review committee.

(h) Within 10 working days after the conclusion of the last of all the reviews, the review committee shall produce and deliver an evaluation report to the Gemini Associate Director for Development.

(i) Using the committee evaluation report, schedule, and cost estimates, the Gemini Associate Director for Development shall down-select one of the teams to complete the remainder of the project. If no teams are deemed viable to successfully complete the project, no down-selection will be made. In either case, all teams will be notified of their status at the conclusion of this part of the evaluation.

## 5.4    Project Communication

(a) Primary Contacts and Communications: The primary contacts for this Work are the AURA Technical Representative  and the Contractor Technical Representative. Although regular informal communications between AURA and Contractor personnel, are encouraged to explore possible ideas and gather information, other than issues addressed in Section (c) below, all communications that might be construed as direction or permission to modify any aspect of the GNAOI Requirements or design, including interfaces, must be made by means of written communications between the AURA Technical Representative and the Contractor Technical Representative. Both parties will explain this requirement to all staff involved in this work, and shall ensure that all design/requirement modifications go through the primary contacts.

(b) AURA Technical Representative's role: Contractor acknowledges that the AURA Technical Representative is the only person with authority to provide technical direction with regard to the Work, and that no other person, committee, or board has any authority to direct or influence any aspect of the Work. In the event that Contractor receives direction or a suggestion from any other source that Contractor feels has merit, it shall communicate the direction/suggestions to the AURA Technical Representative with its recommendations, and the AURA Technical Representative shall make a decision in consultation with the Contractor Technical Representative.

(c) Sections 5.4 a and b notwithstanding, the Statement of Work may be modified only by change order and/or contract amendment, as described in  the contract. The AURA Technical Representative does not have authority to modify anything in this Statement of Work. This Statement of Work may be modified only by means of a written document signed by the AURA Contracts Officer and accepted by Contractor. Verbal agreements or direction from anyone other than the AURA Contracts Officer to modify or add work or requirements are void; if anyone at AURA gives Contractor any direction that shall result in a change to the Contract Price, Completion Date, GNAOI Requirements, or Statement of Work, or that may give rise to schedule delays, Contractor shall not implement the direction but shall instead promptly contact the AURA Contracts Officer and request guidance on how to proceed.

(d) When the contract requires that something be documented "in writing," there is no requirement that the writing be in hard copy format unless a hard copy is specified explicitly; email and electronic documents satisfy this requirement.

## 6    Work Description

(a) This section of the Statement of Work describes the Work to be conducted by Contractor.  This is the Work needed to complete the Preliminary Design Stage for the GNAOI Instrument.  If down-selected after this Work, Contractor will proceed with additional design, build and commissioning stages.

(b) The work shall begin at the contract start date and conclude with the completion of the End-of-Stage Review.

(c) Contractor shall create the Preliminary Design Documentation Set as described in Appendix A.   These documents are:
- Project Management Plan
- Systems Engineering Management Plan
- Science Cases
- Concept of Operations Document
- Requirements Document
- Preliminary Design Document
- Instrument Interface Control Documents
- Contract and Statement of Work Amendment Exceptions

Together, these documents shall form the Contractor's proposal for the Post-Preliminary-Design work.

(d) Contractor shall prepare a Preliminary Design for the GNAOI Instrument,the GNAOI Associated Hardware,  and the GNAOI Associated Software. Contractor shall complete the following tasks for the design to be considered a preliminary design:
1) Determine all aspects of the design.
2) Reduce all major design risks to an acceptable level.
3) Verify compliance with all telescope interface requirements.
4) Determine procurement methods for all mechanisms (purchased commercially, subcontracted, produced in-house, etc.).
5) Provide a preliminary bill of materials for all component procurements.
6) Establish and document all system budgets (performance, error, mass, power, etc.) and tolerances.
7) Perform preliminary performance analysis of the opto-mechanical design including, but not necessarily limited to:
    - Sensitivity analysis;
    - Ghosting;
    - Scattered Light;
8) Calculate instrument throughput vs. wavelength at 100nm intervals across the entire observable wavelength range; and
9) Performance degradation consistent with the flexure, vibration, and tolerance analyses of the instrument design.
10) Perform instrument vibration analysis, including both vibrations generated by the instrument and those received from the telescope/environment, paying  particular attention to vibration effects on instrument stability and the vibrations transmitted to the Instrument Support Structure from the instrument.
11) The current values of the GNAOI Technical Performance Metrics.
12) Detail the software design as follows:

a) An overview of the software architecture for the chosen solution. All the major software components shall be described. The associated hardware and physical layout of the software components shall be included.

b) Information shall be included on items to be controlled, sequencing issues, and FITS data formats the instrument will write. The initial dictionary of status items and configuration items shall be produced.

c) The software design shall be described to the level of detail required to explain how the system will operate under typical required situations using a uniform methodology.

d) A demonstration of how instrument status, sequence commands, and events flow in the system shall be included.

e) A set of user scenarios (or use cases) demonstrating how the software will enable the science objectives of the instrument.

f) Plans for or progress on the Engineering User Interface that shall be used for acceptance testing. This shall include an overall description of the design and required software tools.

g) Detector controller software/firmware preliminary design.

h) A preliminary set of internal system interface documents. All interfaces between internal hardware or software subsystems shall be defined and documented, including any software systems from third-party vendors.

i) A description of required development platforms and tools shall be included, highlighting what needs to be acquired. Development plans that show collaborative development and testing as outlined in the "Guidelines for Designing Gemini Instrument Software" document shall be described.

j) A summary of data processing choices shall be documented. An initial list and design description of data processing pipeline recipes tied to the major instrument observing modes shall be included. Essential calibrations data and procedures associated with those recipes shall be identified. Relevant software components and algorithms shall be identified and show how pipeline integration will occur. Execution times and processing requirements for data processing shall be estimated, and data processing-related risks shall be identified.

k) Identify software milestones and releases and schedule points for Gemini collaborative testing at each milestone.

l) A description of the computing hardware, networking, and any extra hardware needed to interface the computing system to the instrument shall be provided. This information shall be final or near final at this stage.

## 7    Appendix A: GNAOI  Preliminary Design Documentation Set

This appendix contains a description and scope for each deliverable document listed here.

NAOI-01   Project Management Plan
NAOI-02   System Engineering Management Plan
NAOI-04   Science Cases
NAOI-05   Concept of Operations Document (ConOps)
NAOI-06   Requirements Document
NAOI-10   Preliminary Design Document
NAOI-11   Instrument Interface Control Documents
               Contract and Statement of Work Amendment Exceptions


Each document should contain a title page containing at least: the document title, document number, author, author's institute, contract number, version number, release date, and page number.

Each page of each document should contain at least the document title, document number, version number, release date, page number, and total number of pages.

Each deliverable document contained within Appendix A should be delivered in source file (e.g. *.docx,.xlsx,* etc.) and in *.pdf* formats.

Documents may  be accompanied and supported by electronic materials of an alternative file format. For example: wiring diagrams, 3d models, OpticStudio (formerly known as ZEMAX) files, Microsoft Project files, etc.

Each document should be written with brevity and only include relevant content.

**A.1    Project Management Plan (NAOI-01)**

A.1.1    **Purpose**

The purpose of the Project Management Plan is to provide a top-level summary of the Contractor's proposed Post-Preliminary-Design work and communicate Contractor's project management approach, methodology, practices, processes, and tools they shall apply through the lifetime of the project.  This plan shall also communicate the specifics related to the creation, monitoring, and control of management elements including budget, schedule, risk, work elements, resources, and communication.

A.1.2    **Description**

The plan shall start with a summary of the proposed GNAOI Instrument along with a proposed fixed price cost and schedule to complete the Post-Preliminary-Design work.  The plan shall expand on relevant material contained within the proposal to describe how the management team shall manage the project from start to end.

The plan shall include a description of the project management team's approach and methodology, including any incorporated institutional practices and standards.  It should also describe any project management support and training available to the management team by the host institute, such as a project management office and any active mentoring arrangements.  It shall include details of any other support needed to successfully manage the project such as accounting, contracts, and finance.  It shall include details of the project approach to ensure all deliverables, including documentation, are developed meeting requirements and delivered on time.

The plan shall include a section that describes project management processes and tools covering organizational project resource allocation processes, budget creation and monitoring tools, schedule tracking and monitoring tools, the process for assigning risk mitigation budget, and schedule contingencies.  The section should include what information is provided by each institute to the project and how it is processed by the project and reported to Gemini.

The plan shall include an organizational structure and a description of how the management team fits into its institutional organizational chart.  It shall include project organizational chart(s) displaying the project relationship between institutions and individuals including external stakeholders.  It shall describe the roles, responsibilities, and relevant experience of the project's key personnel, including the levels of effort for each. It shall list backup options available for key team personnel.

The plan shall include a communication plan for the project including details of internal and external meeting and reporting.  It shall explain how communication and reporting shall be managed and monitored.  It shall describe how Gemini staff will be able to access Contractor documentation during the project.

The plan shall describe the proposed Post-Preliminary-Design Work Breakdown Structure in enough detail to facilitate reliable costing and tracking throughout the lifetime of the project.  Each Work Breakdown Structure element shall include the duration, cost, and workforce required.  The section should describe how any portions of the work will be subcontracted.  The WBS, itself, shall be attached as an appendix.

The plan shall include a project budget, demonstrating how it is derived from the work packages listed in the Work Breakdown Structure. It shall provide enough detail from the WBS along with the

corresponding labor hours and charge rates for each task, such that an independent cost analysis may be performed at any point in time. It shall include three-point cost estimates to obtain overall cost margins. This budget section shall describe how costs will be managed, tracked, and controlled during the lifetime of the project. It shall describe how the Contractor intends to use the risk mitigation budget, along with schedule and scope contingency to actively control budget. An appendix shall contain the details of the budget (the "Cost Breakdown").

The Cost Breakdown shall contain a list of the expected procurements, describing all major and/or significant components and materials that will need to be purchased. This list shall include the description of the component/material, the estimated quantity, the estimated price with a margin of error, a description of the source of pricing information, the estimated date the procurement will need to be initiated, the estimated vendor's lead time, and the date the item is needed.
The budget discussion shall include an expected distribution of expended funds within the Gemini Participant host countries.

The plan shall describe how the schedule was created. It shall include stage delivery dates with a margin of error and provide an explanation on the schedule structure, schedule reserve and critical path. It shall include a description of the development and delivery schedule for the instrument (through all stages). It shall demonstrate how the schedule adequately accommodates known risks and likely variations in the plan. It shall clearly identify decision points, especially those related to up-scope and descope options. This section shall describe how the schedule shall be managed, tracked, and controlled during the lifetime of the project. A project Gantt chart shall be attached as an appendix and shall clearly identify all stages of the project, each major work package, dependencies, milestones, long lead items, schedule reserve and shall clearly display the critical path.

The plan shall describe how risks are identified, categorized, assigned, assessed (for probability and impact), and managed. It shall describe the overall risk management and mitigation approach. It shall describe the major risks identified at the start of the project and include a narrative description of the research, analysis, or demonstrations that would need to be done to establish the viability of any key or high-risk components. A risk register shall be attached as an appendix. It shall include key risks to schedule, cost, performance, personnel, or any other aspect that would prevent the project from being successful.

The budget and schedule must include an appropriate allocation for risk reduction (cost and schedule reserve) of no less than 15% of the total cost and schedule.

The Plan shall include a description of Contractor's plan to produce, track, and manage the required set of Post-Preliminary-Design documentation.

The Plan shall also include a description of Contractor's health and safety rules and regulations and how they will be applied to the proposed work.

The Plan shall describe why Contractor's organization is interested in designing and building the GNAOI Instrument and what value the organization brings to Gemini in performing this work. Provide any available statements of support from Contractor and subcontractor (if relevant) organization and/or sponsors. Describe the relative priority of this project compared to others in your organization(s).

The Plan shall describe the current structure of Contractor's organization and the organization's current approach to project work including the organization assigns resources to projects. Include a description of Contractor's ability to adjust the level of resources used in the project and give specific examples based on past projects. Describe the organization's and team's past work and results relevant to the GNAOI Instrument work. Describe at least two of Contractor's past projects that required technical and management skills similar to what will be required for this work. Include names, addresses and telephone numbers of the customers/sponsors for these projects. Provide CVs for all key team members and important relevant publication references. Describe the backup options for key team personnel. Include similar information on any planned subcontractors.

The plan shall include a description of Contractor facilities relevant to the Post-Preliminary-Design work. The Plan shall also describe how Contractor shall manage facility resource loading and what backups exist for needed facilities.

A.1.3 **Composition (Shall include, but not be limited to, the following sections)**

- Instrument and Proposal Summary
- Project Management Approach, Methodology, and Support
- Project Management Processes and Tools
- Project Structure, Roles, and Responsibilities
- Project Communication, Reporting, and Monitoring
- Project Work Breakdown Structure
- Project Budget, Cost Management and Control
- Project Schedule, Schedule Management and Control
- Project Risk Management, Register, and Mitigation Plans
- Documentation Control and Management
- Safety Management
- Institutional Motivation and Support
- Heritage and Facilities

**A.2    System Engineering Management Plan (NAOI-02)**

A.2.1    **Purpose**

The purpose of the System Engineering Management Plan is to communicate the Contractor's system engineering approach, methodology, practices, processes and tools it shall apply to the project during the Post-Preliminary-Design work. This plan will describe the model, approach, processes, activities, and tools that will be used by the GNAOI Systems Engineering Team to support the design and construction of the GNAOI project. The technical objectives of the systems engineering effort are to ensure that as a system GNAOI meets all the requirements derived from the instrument's science cases and requirements, and the concept of operations (ConOps). The resulting top-level requirements are to be systematically decomposed to generate the instrument requirements specification, and to define the most effective cost/schedule design solution that allows its implementation and integration for a smooth acceptance test to transition to science operations.

Gemini is currently creating the Gemini Observatory Systems Engineering Management Plan for Facility Class Instruments, which, when completed, may be used as a template. The Gemini Observatory System Engineering Model is based on Function Based Systems Engineering. The model is a tailored version of the approach described in the National Aeronautics and Space Administration Systems Engineering Handbook.

A.2.2    **Description**

The plan shall expand on the material contained within the proposal to describe how the management team shall employ systems engineering to manage the technical aspects of the project from start to end.

The plan shall include a description of the management team's general approach and methodology to technical management and system engineering, including any incorporated institutional practices and standards. It shall also include any system engineering support, training, and mentoring available to the team.

The plan shall include a section describing how systems engineering roles and responsibilities are organized within the team. It should also include the system engineering communications methods used within the project.

The plan shall include sections that describe the project's systems engineering approach for requirements management, interface management, budget management, information and configuration management, quality management, and verification management. Each section shall describe the process(es) employed, any tools used, the process owners, location and structure of information, and how change control is supported. These sections should also include what technical information each institute is to provide to the project and how it is processed and reported to Gemini.

The plan shall include a requirement management section describing how requirements (science and technical) were structured and created, how they will be flowed down, and how they will be managed, cross referencing the Requirements Document as appropriate.

The plan shall include an interface management section on interface definition. It shall describe how project interfaces were created, the current architecture, and how the interfaces shall be maintained and verified.

The plan shall include a performance management section describing the performance, error and tolerance budgets including how they were constructed, how contingency was determined, and how they will be maintained throughout the projects. The Performance/Error Budgets shall be attached as an appendix.

The plan shall contain an information and configuration management section detailing the configuration management process used for this project including how documents will be numbered, stored, and accessed by partners.

The plan shall include a quality management section describing the activities and techniques used to realize quality. These include optimization of science and operational performance through the use of various analysis and trade studies during design, measurement or inspection of completed parts, issue tracking and resolution, and internal and external reviews.

The plan shall include a verification management section describing the verification methods that will be used, including details such as planned modeling and simulation, and test events.

The plan shall include sections that describe the project's systems engineering activities that occur during each stage of the project.

A.2.3    **Composition (Shall include, but not be limited to, the following sections)**

- Introduction
- System Engineering Approach and Methodology
- System Engineering Processes
- Requirements management
- Interfaces management
- Budgets management
- Information and configuration management
- Quality management
- Verification management
- Project Stages and Systems Engineering Activities

### A.3 Science Cases (NAOI-04)

#### A.3.1 Purpose
The purpose of the Science Cases document is to communicate the science cases for the instrument.

#### A.3.2 Description
The document describes the science cases for the instrument and motivates the scientifically required operations modes and scenarios that are developed in the ConOps. It provides a narrative explaining how the instrument design satisfies the science requirements that result from the presented science cases. The science requirements themselves are derived from these science cases, but are included in the Requirements Document. Gemini will provide an initial set of GNAO science cases, and welcomes additional cases and requirements from Contractor.

#### A.3.3 Composition (Shall include, but not be limited to, the following sections)
- Science Cases
- Science Requirements
- Competition
- Science Cases Linked to Instrument Parameters
- Motivations for Operating Modes

The following matrix summarizes the driving science parameters, distilled from the GNAO science cases. The Conceptual Design level GNAO science case document will be made available, as will subsequent revisions, to all proposing teams.

| Science case | Spectral range | Field of view | Astrometric accuracy | Photometric accuracy |
|---|---|---|---|---|
| **Extragalactic and Cosmology** | | | | |
| High z galaxy dynamics | 0.9-2.4 um | 3" | <100mas | ~10% |
| Galaxy metallicity maps | 0.9-2.4 um | 3" | <100mas | ~10% |
| Nuclear star clusters & disks | 0.9-2.5 um | 20"x20" | | |
| Central parsecs around AGN | 0.9-2.5 um | <~ 10"x10" | | ~10% |
| Cosmological Constraints from Strongly Lensed, Multiple-source Systems | 1.2 -2.5 um | 30" | 1 mas | ~10% |

| | | | | |
|---|---|---|---|---|
| Follow-up and Monitoring Gravitationally Lensed Transients | 0.7-2.5 um | 2' | 10 mas | 2% |
| **Galactic and nearby extragalactic** | | | | |
| Galactic young massive star clusters | 1-2 um | >2' | <0.3mas | few % |
| Globular clusters | 1.5-2.4 um | 4" | <10mas | <20% |
| Galactic Nucleus | 1-2.9(-5) um | >2' | <0.2 mas | few % |
| Galactic young massive star clusters (Arches, Quintuplet, central pc) in Galactic center | 1-2.9 um | ~0.5' | | yes |
| **Brown dwarfs, solar system** | | | | |
| The lowest-mass products of star formation (astrometric orbits & resolved spectra) | 1-2.5 um | ~1" \| ~10' | n/a \| ~1 mas | n/a |
| Giant Planet Atmospheres and their Disks | 1-5 um | 1' | <1mas | few % |

### A.4    Concept of Operations Document [ConOps] (NAOI-05)

#### A.4.1    Purpose
The purpose of the Concept of Operations Document (ConOps) is to communicate the instrument's operating modes and key operating scenarios.

#### A.4.2    Description
The ConOps presents the concept of operations. It describes each of the instrument's operating modes and key operating scenarios. It contains specific example science observations created from the science cases, which then lead to a detailed description of the required operating and instrument modes necessary to complete them. Some instrument and operational requirements in the Requirements Document are then based on the needs derived here. The operating scenarios shall be described in sufficient detail for a technically and scientifically skilled, but non-expert, audience to understand. Operating scenarios shall be presented to be comprehensible to a person familiar with telescope operations in general, but not Gemini, specifically. Besides being used to derive some of the operations related requirements in the Requirement Document, this section of the ConOps shall later form the basis for the instrument User's Manual.

#### A.4.3    Composition (Shall include, but not be limited to, the following sections)
- Instrument Overview
- Instrument Operating Modes
- Daytime Calibrations
- Nighttime Observations
- Data Processing, Reduction, and Pipeline

### A.5 Requirements (NAOI-06)

#### A.5.1 Purpose
The purpose of the Requirements Document is to communicate the requirements associated with the GNAOI Instrument.

#### A.5.2 Description
The Requirements Document shall contain all the requirements pertaining to the deliverables, mostly for the instrument and supporting hardware and software. It shall contain all science, instrument, system, subsystem, and component requirements. Each requirement shall follow the structure communicated in the Systems Engineering Management Plan and should be either derived from the primary sources (for example: science cases, Gemini requirements, interface control documents) or flow down from other requirements that are in turn derived from the above three primary sources.

Appendix A of the Gemini Instrument Common Requirements document describes a set of recommended data fields and the following fields are required for each requirement:
- A unique identifying number to make it easy to reference
- A running, consecutive version number and corresponding date.
- The source(s) used to derive it including a brief description of how the requirement was derived from its source along with any assumptions made in the derivation.

Each requirement must be captured such that it is objectively verifiable at some stage in the project. Each requirement must identify the intended method(s) and project stage(s) of verification.

#### A.5.3 Composition (Shall include, but not be limited to, the following sections)
See Appendix A of the Gemini Instrument Common Requirements document.

### A.6    Preliminary Design Document (NAOI-10)

#### A.6.1    Purpose
The purpose of the Design Document is to communicate the current design of the GNAOI Instrument, the GNAOI Associated Hardware, and the GNAOI Associated Software.

#### A.6.2    Description
The Design Document shall expand on the design material contained within the proposal to provide the current design of the GNAOI Instrument, GNAOI Associated Hardware, and GNAOI Associated Software.

The Design Document shall begin with an executive summary followed by an introduction before providing a technical overview describing the high-level design.  Throughout the document, relevant material contained in other deliverable documents should be adequately cross-referenced.

The Design Document shall include a technical overview section and include, at least, the following items:
- A description of the instrument's subassemblies.
- A summary of performed trades.
- Results of analyses and any trade studies performed during the stage.
- Performance results of any instrument simulations.
- Flexure analysis taking into account both optical and mechanical effects.
- Opto-mechanical error budgets constraining or resulting from the baseline design. Details should be given for particularly difficult or challenging tolerances.
- A summary of existing component designs (hardware or software) to be used in the instrument as a means of reducing risk and/or development time.
- A summary of the technical high-risk items included in a risk register table.
- Remaining up-scope and de-scope options against the baseline.
- A description providing a comprehensive overview of the entire design of the instrument.
- A description of priorities in balancing science vs. performance trades.
- Science cases cross-referenced to instrument requirements. A summary of the flow down of the science cases cross-referenced to the instrument requirements, as listed in the Requirements Document. The ConOps develops this flow down in more detail, but a general overview and summary of the key science drivers and requirements is desired here.
- A compliance summary matrix comparing the requirements and the current design.

The structure of the remainder of the document should be such that it is easy to follow and links well with information provided in other documents.  Whether arranged by work package or by discipline, the design document shall include the following items:

**Optical design** items:
- A depiction of the general layout of the optical components.
- A description of optical mounting schemes, including the general approach used to mount and align all optical components.
- A description of key risks associated with the optical design, e.g. long-term stability of optical alignment, manufacturability, coating reliability, expected lifetimes, etc.
- A summary of expected throughput.
- A summary of all optical elements contained in the instrument and coatings that will be used.
- A description of the throughput budgets.

- Detailed surface specifications (material, purity, surface curves, dimensions, scratch/dig, coatings, etc.) for each optical element so that replacements may be obtained if necessary.

**Mechanical design** items:
- An overview of the instrument's mechanical design.
- An overview of the instrument's subassemblies schematics in the mechanical layout.
- Designs (3D models / drawings) for all subassemblies.
- A description of the design elements that are common to multiple assemblies.
- Outline of instrument integration procedure to verify that there are no significant integration and testing challenges.
- Analysis showing there are no significant instrument handling or space envelope issues with the design as conceived.

**Electrical design** items:
- An overview of the instrument's electronic systems.
- Estimate of the number of separate control systems the electronics design must support.
- Description of approach to controlling stepper motors and actuators.
- A general layout and wiring scheme for major electronic components.
- A summary of the use of commercial vs. custom boards.
- A description of the detector and controller.

**Software design** items:
- An overview of the software architecture.
- Description of all major software components.
- Description of the instrument's status and commands.
- Description of development platform and tools.
- Description of processing design choices.

**Data reduction software design** items:
- An overview of the data processing choices and system design choices
- The data reduction architecture
- A list and description of data reduction recipes.
- A list of software tools needed to create, build and run the data reduction software
- Designs for each identify data reduction module.

Other items to be included:
- A current design description of the GNAOI Associated Hardware and Software.

A.6.3 **Composition (Shall include, but not be limited to, the following sections)**
- Executive Summary
- Introduction
- Technical Overview
- Design details (structured to provide the best read and flow for the current stage)

**A.7    Instrument Interface Control Documentation Set (NAOI-11x)**

A.7.1    **Purpose**

The purpose of the Instrument Interface Control Documentation Set is to communicate the instrument's internal interfaces.

A.7.2    **Description**

These documents shall define all interfaces between internal hardware or software subsystems including any software systems from third–party vendors.

A.7.3    **Composition (Shall include, but not be limited to, the following sections)**
- Introduction
- Interface Details

### A.8    Contract and Statement of Work Amendment Exceptions

#### A.8.1    Purpose
The purpose of the Contract and Statement of Work Amendment Exceptions document is to provide AURA with a list of exceptions to the draft Amendment for the Post-Preliminary-Design work.

#### A.8.2    Description
The document shall list all Contractor exceptions to the draft Post-Preliminary-Design Contract and Statement of Work Amendment provided by AURA. Contractor shall provide alternate wording for each noted Article.  Only articles highlighted in this document will be subject to negotiation if Contractor is selected for the Post-Preliminary-Design work.

#### A.8.3    Composition (Shall include, but not be limited to, the following sections)
- Contract Exceptions
- Statement of Work Exceptions