

**REQUEST FOR PROPOSALS (RFP) – CONTRACT  
ND1013C**

**FOR**

**GEMINI NORTH ADAPTIVE OPTICS (GNAO)**

**“LASER LAUNCH TELESCOPE (LLT)”**

**SPECIFICATIONS**

**V 2.0**



# Table of Contents




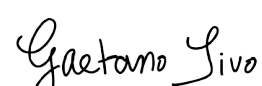
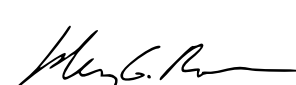
1	Applicable Documents .....	6
2	Reference Documents .....	6
3	Executive Summary .....	6
4	Scope .....	6
5	Description .....	6
6	Terms and Definitions .....	7
7	Product Description .....	7
7.1	Product Context.....	7
7.2	Product Interfaces .....	9
7.2.1	LGSF System Controller .....	9
7.2.2	Beam Expander and Control Node (BEaCoN) .....	9
7.2.3	Environment.....	9
7.2.4	Telescope Mechanical .....	9
7.2.5	Telescope Facilities .....	9
7.3	Reference System Architecture.....	9
7.4	Reference Functional Design .....	11
8	Requirements .....	11
8.1	Requirements Documentation Structure .....	11
8.2	Requirements.....	13
8.2.1	LLT Physical Requirements .....	13
8.2.1.1	LLT Mass.....	13
8.2.1.2	LLT Length.....	13
8.2.1.3	LLT Width.....	13
8.2.1.4	LLT Depth.....	13
8.2.1.5	LLT input beam orientation .....	13
8.2.1.6	LLT mechanical flexure .....	13
8.2.1.7	LLT First Mechanical Resonance .....	13
8.2.1.8	LLT power dissipation .....	13
8.2.2	LLT Orientation Requirements.....	14
8.2.2.1	LLT Operational Elevation Angle.....	14
8.2.2.2	LLT Maintenance Elevation Angle .....	14
8.2.2.3	LLT Storage Elevation Angle .....	14
8.2.3	LLT Optical Requirements.....	14
8.2.3.1	LLT Beam Input Size .....	14
8.2.3.2	LLT Beam Output Size .....	14
8.2.3.3	LLT Beam Input Polarization .....	14
8.2.3.4	LLT Beam Output Polarization.....	14
8.2.3.5	LLT Throughput.....	14
8.2.3.6	LLT Wave Front Error (WFE).....	15
8.2.3.7	LLT Thermally Induced Defocus.....	15
8.2.3.8	LLT Coating robustness .....	15
8.2.4	LLT Beam Position Performance Requirements.....	15
8.2.4.1	Projected Beam Patrol Field .....	15
8.2.4.2	Projected Beam Positioning Accuracy .....	15



8.2.4.3	Projected Beam Positioning Speed.....	15
8.2.4.4	Projected Beam Positioning Settling Time.....	15
8.2.4.5	Projected Beam Position Control .....	15
8.2.4.6	Remote Positioning Controller Interface .....	15
8.2.4.7	Remote Positioning Control.....	15
8.2.5	LLT Environmental Requirements.....	16
8.2.5.1	LLT Operating Temperature.....	16
8.2.5.2	LLT Operating Temperature Rate of Change .....	16
8.2.5.3	LLT Operating Wind Speed .....	16
8.3	Non-Functional Requirements.....	16
8.3.1	Hardware Requirements .....	16
8.3.1.1	Use of Commercial Components.....	16
8.3.2	Documentation Requirements .....	16
8.3.2.1	Documentation Standards .....	16
8.4	RAMS Requirements .....	16
8.4.1	Reliability.....	16
8.4.1.1	Mean Time Between Failures .....	16
8.4.2	Availability.....	16
8.4.2.1	Start Time .....	16
8.4.3	Maintainability.....	17
8.4.3.1	Mean Time to Repair .....	17
8.4.3.2	LLT Polarization control .....	17
8.4.3.3	LLT Cleaning procedures .....	17
8.4.4	Safety.....	17
8.4.4.1	Loose parts .....	17
9	Acronyms and Abbreviations .....	18

## Document Acceptance and Release Notice

The Specifications Document is a managed document. To identify changes, each page contains a release number and a page number. This document is authorized for release once all signatures have been obtained.

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## Change Record

Version	Date	Description	Owner Name
1.0	3/17/20	Approved for release	E. Marin
2.0	4/1/20	Updated spec 8.2.3.4 to read "The LLT shall project a circularly polarized beam with a <b>polarization extinction ratio of <math>\geq 97\%</math></b> ", and updated spec 8.2.3.7 to remove " <b>RMS</b> " from the requirement.	E. Marin

# 1 Applicable Documents

Applicable documents are binding to the contract.

**Table 1 Applicable Documents.**

	Document #	Title
[AD-01]	GNAO-LLT-RFP-001	GNAO LLT RFP Statement of Work
[AD-02]	ICD1.9 to 5.0	Transport, Observatory and Operational Environments
[AD-03]	TBD	GNAO LLT System Internal Command and Status Interface
[AD-04]	TBD	Interface between the BEaCoN and the LLT

# 2 Reference Documents

Reference documents are not binding to the contract.

**Table 2 Reference Documents**

	Document #	Title
[RD-01]	GNAO-SYS-REQ-001	GNAO System Requirements
[RD-02]	GNAO Reference Drawing	GNAO LGSF initial modular layout
[RD-03]	N/A	Gemini Hilo Base Facility Guidelines
[RD-04]	N/A	Gemini Maunakea Facility Guidelines

# 3 Executive Summary

The purpose of this document is to formalize the scope, rationale, specifications, and deliverables of one Laser Launch Telescope, part of the Laser Guide star Facility of the Gemini North Adaptive Optics system, hereafter referred to as LLT or “The Product”. This specification is an integral part of the associated work package document which defines how The Product will be developed. It is expected that this specification will evolve during the concept design phase as work on background studies and option selection progresses.

# 4 Scope

The scope of this document is restricted to the specification of a LLT (Laser Launch Telescope) to be developed for the Gemini North Adaptive Optics system (GNAO). Five LLTs are required for GNAO.

# 5 Description

This Sub-system Specification provides a complete specification for the Gemini North LLT. The information herein should be sufficient for the design, construction, and delivery of the LLTs ready to be installed on the Gemini North telescope and integrated into the LGSF (Laser Guide Star Facility).

## 6 Terms and Definitions

The following terms have a specific meaning in the context of this specification:

**“Goal”**: Something to try and achieve if at all possible. Not a mandatory requirement

**“Reference Design”**: A conceptual design that contains the essential elements of the system which can be enhanced or modified by the designers, intended as a means of conveying information to the designers of a system.

**“Shall”**: Mandatory requirement

**“Should”**: see Goal,

**“The Product”**: Refers to all of the deliverables specified in the Statement of Work [AD-01] and the effort required to produce them.

**“Will”**: a fact or declaration of purpose.

## 7 Product Description

The GNAO LGSF Laser Launch Telescopes are integrated components of the LGSF. The LLT takes an input 589nm laser beam and projects that beam on to the mesospheric sodium layer. The LLT is required to expand the beam per this specification and provide circular polarization.

The LLT must also support dynamic steering of the beam. Slow steering is required to create and position the desired laser guide star asterism.

This section describes the LLT and provides guidance for their construction. The formal requirements the LLT must satisfy are defined in the next section.

### 7.1 Product Context

The LLTs are an integral part of the LGSF GNAO System as shown in Figure 1. They integrate closely with the other GNAO systems, the telescope, and the science instrument(s) to reduce optical aberrations introduced by the atmosphere.





## **7.2 Product Interfaces**

### **7.2.1 LGSF System Controller**

The Product will interface to the LGSF System Controller to receive commands, and provide status. The communications protocol for command and status has yet to be finalized.

### **7.2.2 Beam Expander and Control Node (BEaCoN)**

The Product will optically interface to the BEaCoN. The BEaCoN will send a 589nm laser beam to the LLT.

### **7.2.3 Environment**

The Product will interface to the environment by projecting the beam into the sky and operating in exposed conditions near the summit of Maunakea Hawaii.

### **7.2.4 Telescope Mechanical**

The Product will interface to the structure of the Gemini North telescope.

### **7.2.5 Telescope Facilities**

The Product will interface to the facility power, plumbing (if required) and network connections of the Gemini North telescope.

## **7.3 Reference System Architecture**

A conceptual LGSF system architecture is shown in Figure 2 to illustrate the relationship between the LLT and the rest of the LGSF system. This reference architecture is intended as a means of conveying information to the developers of the Product, not a prescriptive solution that developers must implement.

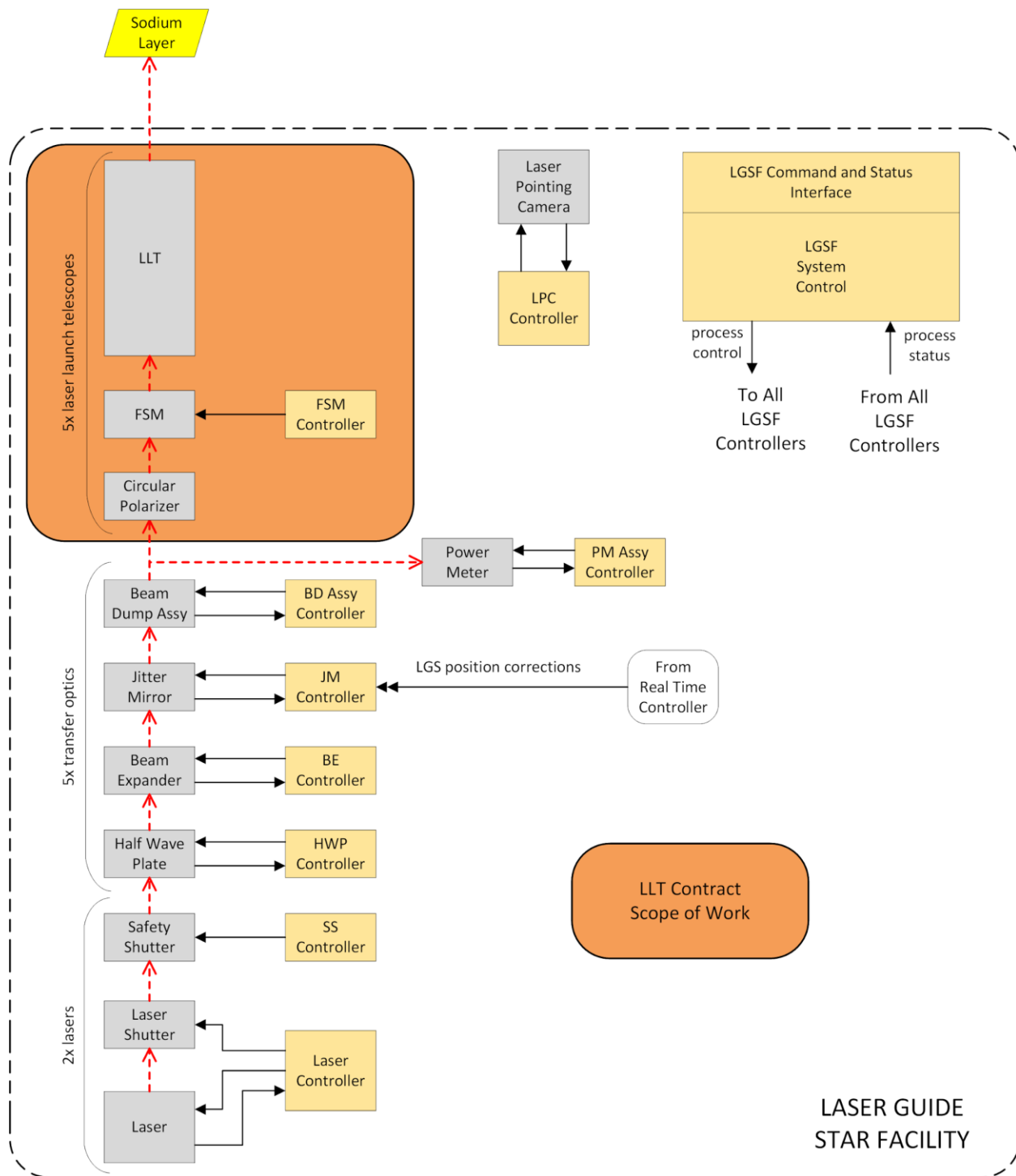
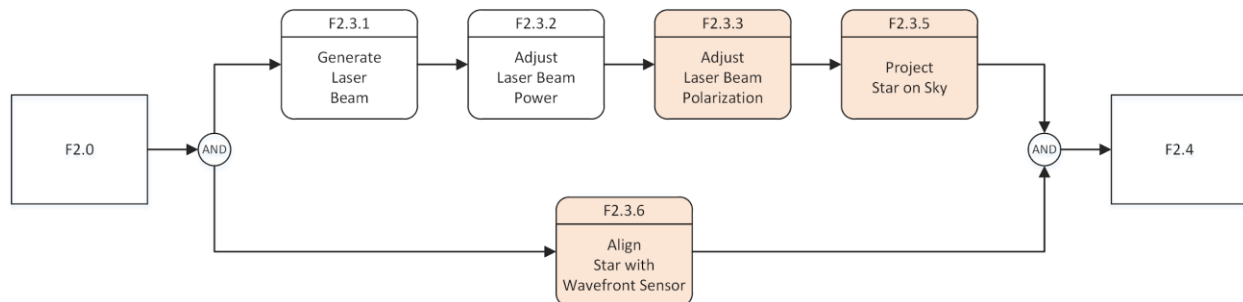


Figure 2. LGSF LLT Reference Architecture.

## 7.4 Reference Functional Design

The basic capabilities that the LLT must provide are highlighted in the overall LGSF *Generate Artificial Star* functional design decomposition shown in Figure 3. Each of the relevant functional blocks are summarized below.



**Figure 3 LGSF “Generate Artificial Star” Functional Decomposition.**

### F2.3.3 Adjust Laser Beam Polarization

The LLT must be capable of projecting a circularly polarized beam given a linearly polarized input beam.

### F2.3.5 Project Star on Sky

The LLT must be capable of projecting a star of the correct size and image quality on the sodium layer.

### F2.3.6 Align Star with Wavefront Sensor

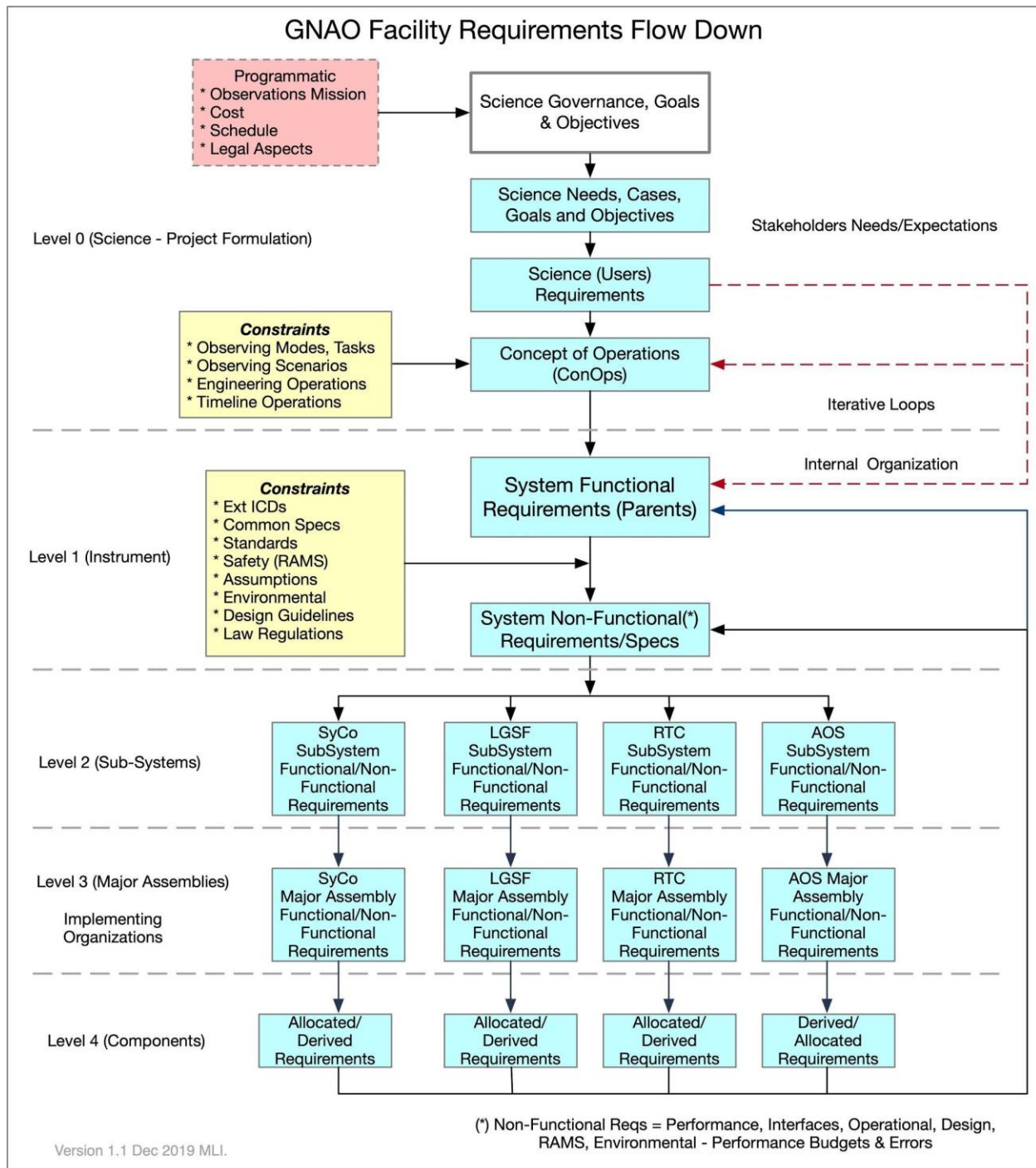
In order to align the projected star with the wavefront sensors located on the AOB the LLT must be capable of remotely adjusting the position of the star on the sky.

## 8 Requirements

### 8.1 Requirements Documentation Structure

The top-level Product requirements are derived from the overall GNAO system requirements [RD-1] and sits at Level 3 as a component of the LGSF sub-system defined in the GNAO Facility Requirements Flow Down, presented in Figure 4.

These requirements are expressed as the capabilities and characteristics of the system to be delivered in the following sections.



**Figure 4 GNAO LGSF Requirements Documentation Structure.**

## 8.2 Requirements

### 8.2.1 LLT Physical Requirements

The following requirements pertain to the physical characteristics of the LLT

#### 8.2.1.1 LLT Mass

**Requirement:** Each LLT shall have a total mass of less than 240 kg. The goal is a mass of under 200 kg.

#### 8.2.1.2 LLT Length

**Requirement:** The LLT length shall be less than 1800 mm. The goal is a length less than 1500 mm. Length is along the telescope Z axis (line of sight).

#### 8.2.1.3 LLT Width

**Requirement:** The LLT shall have a width less than 500 mm. The goal is a width of less than 400 mm. Width is parallel to the side mounting surface of the LLT.

#### 8.2.1.4 LLT Depth

**Requirement:** The LLT shall have a depth less than 500 mm. The goal is a depth less than 400 mm. Depth is orthogonal to the side mounting surface of the LLT.

#### 8.2.1.5 LLT input beam orientation

**Requirement:** The LLT shall accept an input beam in a left and a right orientation from the BEaCoN as shown in [RD-02].

#### 8.2.1.6 LLT mechanical flexure

**Requirement:** The self-weight deflection of the LLT over the full range of motion shall not cause a beam deviation of >5% of the patrol field

#### 8.2.1.7 LLT First Mechanical Resonance

**Requirement:** The LLT Assembly when bolted to an "infinitely rigid base" shall have a first mechanical resonance greater than 72 Hz.

#### 8.2.1.8 LLT power dissipation

**Requirement:** The LLT shall dissipate no more than 50 W to the telescope environment.

## 8.2.2 LLT Orientation Requirements

The following requirements pertain to the LLT physical orientation during operation and storage.

### 8.2.2.1 LLT Operational Elevation Angle

**Requirement:** The LLT shall operate to specifications at all angles from vertical (zenith) to 60 degrees off vertical.

### 8.2.2.2 LLT Maintenance Elevation Angle

**Requirement:** The LLT shall be accessible for service and maintenance while mounted on the telescope without damage at both vertical (zenith) and horizontal (+/- 90 degrees off zenith) orientations.

### 8.2.2.3 LLT Storage Elevation Angle

**Requirement:** The LLT shall not be damaged if stored or transported at an angle.

## 8.2.3 LLT Optical Requirements

The following requirements pertain to the LLT optical characteristics.

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### 8.2.3.1 LLT Beam Input Size

**Requirement:** The LLT shall operate with fixed beam input size. The fixed beam width as defined by  $1/e^2$  shall be within 3 to 20 mm inclusive  
Vendor to recommend preferred beam input size.

### 8.2.3.2 LLT Beam Output Size

**Requirement:** The LLT shall project a beam  $\geq 200\text{mm}$ . Defined as  $1/e^2$ .

### 8.2.3.3 LLT Beam Input Polarization

**Requirement:** The LLT shall operate with a linearly polarized input beam.

### 8.2.3.4 LLT Beam Output Polarization

**Requirement:** The LLT shall project a circularly polarized beam with a polarization extinction ratio of  $\geq 97\%$ .

### 8.2.3.5 LLT Throughput

**Requirement:** The LLT throughput at 589 nm shall be greater than 95% as measured from the entrance port to the exit beam.

#### **8.2.3.6 LLT Wave Front Error (WFE)**

**Requirement:** The LLT RMS WFE of the projected beam shall be less than 75 nm.

#### **8.2.3.7 LLT Thermally Induced Defocus**

**Requirement:** The LLT thermally induced defocus shall be  $\leq 0.2$  PV waves over the specified operating range.

#### **8.2.3.8 LLT Coating robustness**

**Requirement:** Coatings on all exposed optical elements must be able to withstand ambient conditions of GN ([AD-02]).

### **8.2.4 LLT Beam Position Performance Requirements**

The following requirements pertain to the beam position control characteristics of the LLT.

#### **8.2.4.1 Projected Beam Patrol Field**

**Requirement:** The LLT shall have a patrol field with a 8' (arc-minute) minimum diameter. The goal is a patrol field with a 14' (arc-minute) diameter.

#### **8.2.4.2 Projected Beam Positioning Accuracy**

**Requirement:** The LLT shall have a pointing error  $\leq 0.3''$  inside the field of view.

#### **8.2.4.3 Projected Beam Positioning Speed**

**Requirement:** The LLT shall have a minimum 0.03 mrad / sec angular pointing velocity in any direction in the patrol field.

#### **8.2.4.4 Projected Beam Positioning Settling Time**

**Requirement:** The LLT projected spot shall have a 90% settling time of less than 0.2 s for a 1" step, with a setpoint refresh rate of at least 1 Hz.

#### **8.2.4.5 Projected Beam Position Control**

**Requirement:** The LLT shall allow the projected beam position to be controlled remotely.

#### **8.2.4.6 Remote Positioning Controller Interface**

**Requirement:** The LLT shall provide a beam positioning hardware controller with an ethernet interface as specified in [AD-03].

#### **8.2.4.7 Remote Positioning Control**

**Requirement:** The LLT shall select, as a goal, a beam position controller with an existing EPICS software driver.



## 8.2.5 LLT Environmental Requirements

The following requirements pertain to environmental conditions the LLT will be subject to. These requirements override what is in the [AD-02]

### 8.2.5.1 LLT Operating Temperature

**Requirement:** The LLT shall operate at temperatures from -10 to +10 degrees C.

### 8.2.5.2 LLT Operating Temperature Rate of Change

**Requirement:** The LLT shall be able to operate with temperature changes of 2 degrees C / hour for the first hour of the night and then with temperature changes of 0.5 degrees C / hour for all additional time.

### 8.2.5.3 LLT Operating Wind Speed

**Requirement:** The LLT shall operate at wind speeds from 0 m/s to 20 m/s

## 8.3 Non-Functional Requirements

### 8.3.1 Hardware Requirements

#### 8.3.1.1 Use of Commercial Components

**Requirement:** The LLT System shall use commercially available hardware components to the greatest extent practicable.

### 8.3.2 Documentation Requirements

#### 8.3.2.1 Documentation Standards

**Requirement:** The LLT shall have well documented Operational procedures, Maintenance procedures, Installation procedures, safety procedures, and Test procedure. [Goal, not testable]

## 8.4 RAMS Requirements

### 8.4.1 Reliability

#### 8.4.1.1 Mean Time Between Failures

**Requirement:** The LLT shall have a MTBF of 2 years.

### 8.4.2 Availability

#### 8.4.2.1 Start Time

**Requirement:** The LLT shall take no more than ten (10) minutes to transition from a power off state to a fully operational state.



### **8.4.3 Maintainability**

#### **8.4.3.1 Mean Time to Repair**

**Requirement:** The LLT shall have a MMTR of four (4) hours with trained staff necessary equipment, and spares on site.

#### **8.4.3.2 LLT Polarization control**

**Requirement:** The LLT shall provide a means to adjust the polarization angle without disassembly.

#### **8.4.3.3 LLT Cleaning procedures**

**Requirement:** The LLT shall have a detailed cleaning procedure that can be executed by certified observatory staff in situ, without disassembly.

### **8.4.4 Safety**

#### **8.4.4.1 Loose parts**

**Requirement:** The LLT shall not have any parts that can detach during telescope motion, wind events, and seismic events.

## 9 Acronyms and Abbreviations

***Table 3 Acronyms and Abbreviations***

AOS	Adaptive Optics System
BEaCoN	Beam Expander and Control Node
GN	Gemini North
GNAO	Gemini North Adaptive Optics system
LGS	Laser Guide Star
LGSF	Laser Guide Star Facility
LLT	Laser Launch Telescope
MTBF	Mean Time Between Failures
MMTR	Maximum Mean Time to Repair
RTC	Real Time Controller
TBA	To Be Assigned
TBC	To Be Confirmed
TBD	To Be Determined