8 LASER FACILITY FUNCTIONAL REQUIREMENTS

Note to reader: This is a draft version and is written to capture major points. In particular capture requirements that are specific to NGAO and perhaps different from K1 and K2 LGS systems. Some parts of documentation from K1 and K2 LGS projects could be adapted for this exercise will be done in detail at a later stage.

8.1 Context diagram

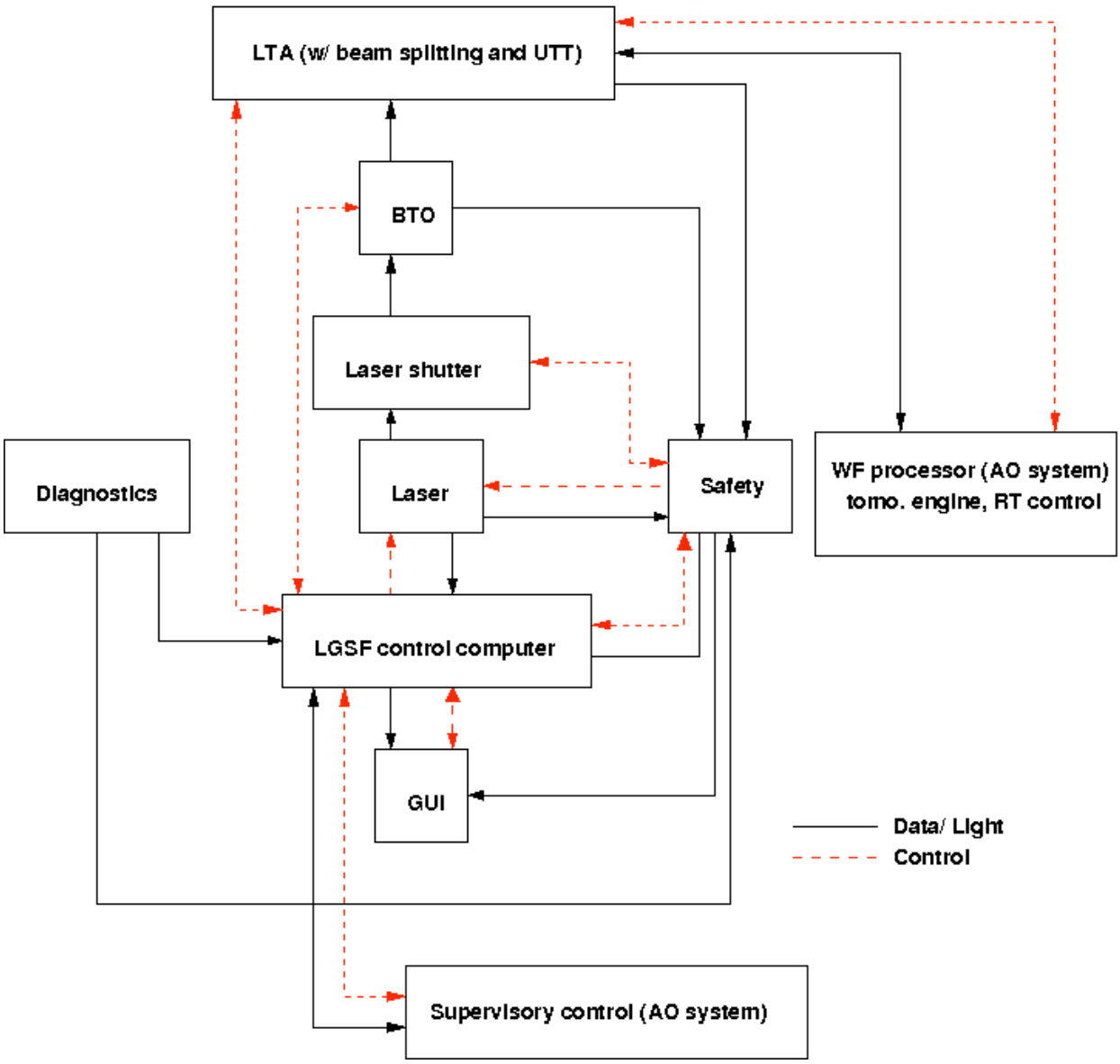

Figure 1: Contextual representation of the LGS Facility showing control and data lines to different sub-systems within LGSF and those that facilitate its interface to the AO system.

8.2 Architectural Assumptions and Overall Requirements

Introduction and scope: this subsection describes the requirements for the NGAO laser guide star facility sub-system. NGAO is envisioned as a multi-guide star. The laser guide star facility includes the laser, the LTA, the beam transport from laser to LTA, safety and diagnostic systems. The document also defines the interface requirements that will need to be met.

Glossary:

TBD - To be looked up
TBWO - To be worked out
TBLU - To be looked up
Shall - necessity
Should - goal
Will - Statement of fact.
Long term -
Short term -
Low power -
MTBF - Mean time before failure

8.2.1 Architectural Assumptions

Some assumptions are (and have to be) explicitly stated as requirements

1. The design shall have 9 LGS beacons. *[Requirement arises from architectural design choices made, science requirements on the FoV and EBS]*
2. There is a central beacon with 5 beacons arranged on equidistant from each other on a circle of radius varying from 11"-101". *[Requirement arises from architectural design choices made, science requirements on the FoV and EBS]*
3. There are 3 roving beacons to perform MOAO on tip-tilt stars that can be independently pointed anywhere in the 202" FoV. *[Requirement arises from architectural design choices made, science requirements on the FoV and EBS]*
4. The asterism shall be fixed with respect to the sky. *[AO system simplicity]*
5. Median Na layer altitude = 90 Km *[legacy literature]*
6. Maximum vertical Na layer speed = 30 m/s *[from EBS for focus change effects]*
7. Each beacon has its own tip tilt (or a dedicated TT in front of the HOWFS for each beacon?). *[Arch. choice still to be made]*
8. Baseline design has no higher order uplink correction. *[Baseline design accepted during design down selection, may change depending on uplink AO TS?]*
9. The LLT shall be mounted behind the secondary, on-axis w.r.t. the Keck telescope optics axis. *[Architectural choice to reduce spot elongation effects]*
10. All performance specifications are stated at "median conditions" *[]*
11. The LGS WFS module with 9 LGS WFS's shall be mounted on a turn-table. *[Even if the asterism is fixed w.r.t. the sky there are observations with the pupil being fixed which will need this mode]*
12. The sodium density at the Mesospheric sodium column density is 4*10^9 (atoms/cm^2) *[from Error Budget Spreadsheet (EBS)]*

13. The LGS facility sub-system and all its components shall conform to Industry Consensus Standards as described in Table below. *[Defining industry standards]*

Source (Organization or Standardizing Body)	**Number**	**Title**
ANSI	Y14.5M-1994 (R1999)	Dimensioning and Tolerancing
ANSI	Y14.1-1995 (R2002)	Decimal Inch Drawing Sheet Size And Format
ANSI	Y14.34-2003	Parts Lists, Data Lists, And Index Lists: Associated Lists
ANSI	Y14.3M-1994	Multi And Sectional View Drawings
ANSI / ASME	Y14.18M-1986	Optical Parts (Engineering Drawings and Related Documentation Practices)
ASME	HPS-2003	High Pressure Systems
ASME	Y14.100-2000	Engineering Drawing Practices
ASME	Y32.10-1967 (R1994)	Graphic Symbols for Fluid Power Diagrams
ASTM	E595-93 (2003)e1	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
ATA	Spec 300-2001.1	Specification for Packaging of Airline Supplies
CENELEC	EN 50082-1:1997[1]	Electromagnetic compatibility – Generic immunity standard – Part 1: Residential, commercial and light industry
Council of the European Communities	EMC 89/336/EEC[1]	Council Directive 89/336/EEC of 3 May 1989 on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive)
County of Hawaii	1995 edition	Hawaii County Code 1983 (1995 edition)
Department of Defense	MIL- STD-171E	Finishing of Metal and Wood Surfaces
Department of Defense	MIL-HDBK-217F-2[1]	Reliability Prediction of Electronic Equipment

1. This reference for information only.

Table 1: Referenced Standards, continued

Source (Organization or Standardizing Body)	**Number**	**Title**
Department of Defense	MIL-STD-810F	Test Method Standard for Environmental Engineering Considerations and Laboratory Tests
EIA	EIA-310-D	Cabinets, Racks, Panels, and Associated Equipment
EIA	EIA-649[1]	National Consensus Standard For

		Configuration Management
FCC	Title 47 CFR Part 15[1]	Radio Frequency Devices
IEEE	802.3U revision 95	Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method & Physical Layer Specifications: Mac Parameters, Physical Layer, Medium Attachment Units and Repeater for 100 Mb/S Operation (Version 5.0)
IEEE	1012-2004	Standard for Software Verification and Validation
International Code Council (ICC)	IBC-2006	2006 International Building Code®
ISO/IEC	ISO / IEC 12207:1995	Information Technology - Software life cycle processes
National Electric Manufacturers Association	250-1997	Enclosures for Electrical Equipment (1000 Volts Maximum)
National Fire Protection Association (NFPA)	NFPA 55, 2005 edition	Standard for the Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders and Tanks
NFPA	NFPA 70, 2005 edition	National Electric Code
NFPA	NFPA 99C, 2005 edition	Standard on Gas and Vacuum Systems
Naval Surface Warfare Center	NSWC 98/LE1[1]	Handbook of Reliability Prediction Procedures for Mechanical Equipment
OSHA	Title 29 CFR Part 1910	Occupational Safety And Health Standards
Telcordia	GR-63-CORE	NEBS™ Requirements

Source (Organization or Standardizing Body)	**Number**	**Title**
TIA/EIA	TIA/EIA-568-B	Commercial Building Telecommunications Cabling Standards
Underwriters Laboratories Inc.	Standard for Safety 508	Industrial Control Equipment

1. This reference for information only.

14. Lifetime of the LGS facility sub-system and its components is a nominal 10 year operation including handling, maintenance and repair unless otherwise stated with a specific MTBF. *[Same as the lifetime of the entire AO system]*

8.2.2 Top level requirements:

8.2.2.1 The laser shall produce photon return > 0.12 photons/cm^2/ms/W at the telescope entrance from exciting the Mesospheric sodium layer. *[from EBS]*

8.2.2.2 The LGS asterism shall point up till 60° off zenith *[Sci. requirement?]*

8.2.2.3 LGS spot shall be 1.13 " at median conditions avg. over all subapertures at the WFS *[EBS]*

8.2.2.4 The throughput of the BTO shall be >75% *[TBD, the lasers are expensive so wastage at the BTO must be kept to a minimum]*

8.3 Laser System

8.3.1 Subsystem Requirements

8.3.2 Optical Parametric Requirements

8.3.2.1 Total laser power out of the NGAO laser module shall be xx W [TBWO based on 9 LGSs, their brightness and BTO throughput, photon return assumption and the laser type]

8.3.2.2 The fluctuation in power over 12 hrs of operation shall be less than 10% [TBWO] at the output.

8.3.2.2.1 The "long term" (12 hr. time period) shall be < 10% [TBD].

8.3.2.2.2 The power fluctuation in "short term" shall be < 5%[TBD].

8.3.2.3 The NGAO laser must have a M^2<1.2 at the exit of the laser. *[for fiber coupling and spot size at the mesosphere]*

8.3.2.4 Beam diameter of the laser beam at the output shall be xx mm. *[to design BTO]*

8.3.2.5 Beam profile - X and Y FWHM measurements. *[laser diagnostics]*

8.3.2.6 Laser system must provide quasi-real-time diagnostic of power, beam position, spectral measurement and M^2. *[laser diagnostics]*

8.3.2.7 The laser module shall operate in "low power" mode for alignment and testing without any change in characteristics other than power. *[needed for initial alignment and testing]*

8.3.2.8 Spectral requirements *[depends on laser and governs the Na-return]*

8.3.2.8.1 Nominal wavelength shall be 589.xxxx nm *[TBLU]*

8.3.2.8.2 Spectral BW shall be X.X +/- 0.0X GHz *[TBWO/ TBD]*

8.3.2.8.3 The frequency stability about the central wavelength shall be 50 MHz [TBD]

8.3.2.8.4 Out of band power shall be less than X%

8.3.2.9 Tunability requirements

8.3.2.9.1 Central frequency change step size shall be 1/20th of the spectral BW.

8.3.2.9.2 Central frequency step range shall be 500 MHz.

8.3.2.9.3 Time for frequency shifts shall be xx sec.

8.3.2.10 Pointing stability of the laser beam at output

8.3.2.10.1 Transverse stability

Positional stability
Long term +/- 0.x mm/hr. over a 12 hr. period [TBD]
Short term +/- x um/min [TBD]

8.3.2.10.2 Angular stability

Long term +/- x mrad/hr. over a 12 hr. period [TBD]
Short term +/- x urad/min [TBD]

8.3.2.11 Polarization

8.3.2.11.1 The laser beam leaving the LTA must be right (or left circular) polarization.

8.3.2.11.2 The ratio polarization contrast should be better than 100:1

8.3.2.11.3 The BTO should have the ability to arbitrarily control the polarization of each laser beam propagated out of the LTA.

8.3.2.12 Pulse format and Modelocking requirements

Laser dependent :(*[Will need to document at a later stage, if two lasers are chosen as parallel paths then we write this as 2 sections]*

8.3.2.13 The laser(s) should have the ability to optically pump the sodium layer. *[needed for increased Na return]*

8.3.3 Mechanical Requirements

8.3.3.1 Mass and size constraints: The mass and size constraints shall conform to document xxx. This document will be based on the table below:

Parameter	Envelope	Units	Notes
Mass of laser bench	TBD	Kgs	
Size of the laser bench	aaXbbXcc	mm	
Mass of electronics rack	TBD	Kgs	
Size of electronics rack	aaXbbXcc	Mm	

8.3.3.2 Operating environment: The laser shall perform as per the requirements stated in this document under standard operating conditions:

Parameter	*Min.*	*Typ.*	*Max.*	*Units*	*Notes*
Altitude					
GS	0	-	2700	m	
Keck I	0	-	4300	m	
Temperature					
GS	-10	9	20	¼C	
Keck	-10	0	20	¼C	
Rate of change	-0.8	-	0.8	¼C/h	
Humidity	0	-	90	%	
Gravity orientation	-	-1	-	g	
Vibration	-	-	$1x10^{-5}$	g^2/Hz	

8.3.3.3 Non-operating environment: The laser shall survive the following non-operating conditions given by:

Parameter	*Min.*	*Typ.*	*Max.*	*Units*	*Notes*
Altitude					
GS	0	-	2700	m	

Keck I	0	-	4300	m	
Temperature					
GS	-10	9	20	¼C	
Keck	-10	0	20	¼C	
Rate of change	-0.8	-	0.8		¼C/h
Humidity	0	-	90	%	
Gravity orientation	-	-1	-	g	
Vibration	-	-	8.0×10^{-4}	g^2/Hz	
Shock	-	-	15	g	
Acceleration					
Due to handling	-	-	-	g	
Due to seismic activity	-	-	2	g	

8.3.3.4 Transportation/ Shipping requirements: The laser, LTA and other sub-system shall survive the conditions stated by:

Parameter	***Min.***	***Typ.***	***Max.***	***Units***	***Notes***
Altitude	0	-	4,572	m	
Temperature	-33	-	71	¼C	
Temperature shock	-54	-	70	¼C	
Humidity	0	-	100	%	
Gravity orientation	-	-	-	NA	
Wind	-	-	67	m/s	
Vibration	-	-	0.015	g^2/Hz	
Shock	-	-	15	g	
Acceleration					
Due to transport	-	-	4	g	
Due to seismic activity	-	-	2	g	

8.3.3.5 Cooling/ Heat dissipation requirements

8.3.3.5.1 The laser system must dissipate less than xx Watts into the ambient air. Rest of the heat will be dissipated via. Glycol cooling lines provided.

8.3.3.5.2 Cooling requirements: The laser module shall dissipate less than xxx KW of total heat into the facility glycol.

8.3.3.5.3 Cooling system monitoring:

8.3.3.5.4 Enclosure temperature (A/C requirement)

8.3.3.5.5 Servo control requirement

8.4 Asterism requirements (some of these are new as compared to K1 and K2 LGSs)

8.4.1 There shall be nine LGS's *[Architectural assumption based on the EBS]*

8.4.2 All observing scenarios shall have a central LGS *[Architectural assumption]*

8.4.3 Around the central LGS there shall be five LGS's that are on a circle

8.4.4 The five LGS's shall be arranged on the circle such that they are 72 degrees apart.

8.4.5 The diameter of aforementioned circle shall have the ability to move between 20" - 202". *[Architectural assumption]*

8.4.6 There shall be 3 LGS beacons that can point anywhere in the 202" to sharpen TT stars. *[Architectural assumption]*

8.4.7 Each LGS beacon shall have a separate uplink tip-tilt correction. *[needed to do tomography]*

8.4.8 Each LGS beacon shall have separate uplink high order correction option built into the design, though not implemented. *[can we operate with the WFE over the 202" range without extra compensation?]*

8.4.9 A single Laser Launch Telescope shall be used to propagate all nine laser beams.

8.4.10 The LLT and any other beam splitting mechanism must fit within the volume suggested by xxx document

8.4.11 The loss from laser output to the exit of the LTA shall be >40%.

8.4.12 The LLT shall be mounted behind the secondary and the LGS's launched from the optical axis.

8.4.13 The LGSs shall conform to geometry (and tolerances) specified in xxx document.

Clean room requirements

The clean room shall conform to class 100 with appropriate filters installed.

8.4.14 Laser enclosure requirements *[baser on K1 laser enclosure requirements]*

8.4.14.1 Operational requirements: The operating environment for the enclosure is given by :

Parameter	***Min.***	***Typ.***	***Max.***	***Units***	***Notes***
Laser bench enclosure dimensions	-	-	1830 x 2750 x 1067	mm	2
Laser electronics enclosure dimensions	-	-	2320 x 1270 x 970	mm	2

Parameter	***Min.***	***Typ.***	***Max.***	***Units***	***Notes***
Height of LSE	2440	-	-	mm	2

8.4.14.2 Power failure requirements

8.4.14.3 Size constraints

8.4.14.4 Mass constraints

8.4.14.5 Electrical power requirement

8.4.14.6 Heat removal

8.4.14.7 Heat dissipation into the observatory dome

8.4.14.8 Ventilation air

8.4.14.9 Doors, Access and Covers

8.4.14.10 Glycol cooling

8.4.14.11 Floor and point load

8.4.14.12 Mechanical requirements

8.4.14.13 Laser maintenance

8.4.14.13.1 Electronics rack specs

8.4.14.13.2 Space for a control computer

8.4.14.14 Air Flow

8.4.14.15 Control system: The temperature, RH shall be monitored and controlled

8.4.14.16 Clean room:

Monitor Point	Format	Local/Remote	Description
Laser Room Particulates	Visual/Display	Local	Goal
Bench Area Temperature	Visual/Display	Local and Remote	
Bench Area Relative Humidity	Visual/Display	Local and Remote	
Gowning Area Temperature	Visual/Display	Local and Remote	
Gowning Room Relative Humidity	Visual/Display	Local and Remote	

8.4.14.17 Laser status indicator

8.4.14.18 Installation requirements

8.4.14.19 Removable ceiling

8.4.14.20 Pneumatics

8.4.14.21 Vibration

8.4.14.22 Condensation

8.4.14.23 Laser servicing

8.4.15 Electronic/Electrical Requirements

Communications: The LSE shall be equipped with Ethernet and phone lines.

Power dissipation

The power dissipation of the entire laser system is based on :

Parameter	*Requirement Number*	*Min.*	*Typ.*	*Max.*	*Units*	*Notes*
Power dissipation						
GS						
To ambient	REQ-LS-0690	-	-	500	Watts	
To coolant supply	REQ-LS-0691	-	-	15,000	Watts	1
Keck I						
To ambient	REQ-LS-0692	-	-	500	Watts	
To coolant supply	REQ-LS-0693	-	-	10,000	Watts	1

Power supply requirements:

Parameter	*Requirement Number*	*Min.*	*Typ.*	*Max.*	*Units*	*Notes*
Power input						
GS						
Voltage	REQ-LS-0785	187	208	229	Vac	1
Current	REQ-LS-0786	-	-	60	Amperes	2
Frequency	REQ-LS-0787	47	50	53	Hz	
Power factor	REQ-LS-0784	0.6	-	-	-	
Keck I						
Voltage	REQ-LS-0796	187	208	229	Vac	1
Current	REQ-LS-0797	-	-	40	Amperes	
Frequency	REQ-LS-0798	57	60	63	Hz	
Power factor	REQ-LS-0799	0.6	-	-	-	

Lighting

Status signals:

Electrical outlets

Power failure

All systems shall be able to cope with a sudden power failure.

Over-current Protection

Shutdown requirements

Emergency shutdown

All systems shall be able to cope with a emergency shutdown.

Error recovery

Wire and cable rating

9 SERVICE AND MAINTENANCE REQUIREMENTS

The LSE shall be designed to minimize the effort required to maintain the LSE. An acceptable level of effort is defined as not to exceed 4 hours of maintenance / month by 2 personnel.
The servicing will include but not limited to the following:

1. Calibration service of the Oxygen Sensor (Quarterly: 1 Hr)
2. Oxygen Sensor Replacement (Anually: 1 Hr)
3. LSE Room Prefilter replacement (Quarterly: 1 Hr)
4. HEPA Filter replacement (Annually: 2 Hr)
5. Clean Room Consumables (Monthly: 1 Hr)
6. Clean Room Cleanliness (Monthly: 1 Hr)

9.1.1 Safety Requirements

9.2 Safety

9.2.1 Mechanical

9.2.1.1 The LSE shall provide restraint railings to meet OSHA requirements.

9.2.1.2 The LSE shall be designed and constructed to a minimum safety factor of 4 on yield strength for all structural elements.

9.2.1.3 A ladder for accessing the roof of the LSE shall be provided with the appropriate caging to protect personnel during ascent and descent on the ladder.

9.2.1.4 The roof of the LSE must be able to support 2 personnel during servicing of LSE equipment.

9.2.2 Laser Class IV Environment

9.2.2.1 The LSE shall conform to ANSI standard Z136.1-2000 “American National Standard for the Safe Use of Lasers”.

9.2.2.2 The LSE shall be light tight to contain a class IV laser environment.

9.2.2.3 The inside of the LSE shall be black with a dull surface to minimize reflections.

9.2.2.4 A sliding opaque curtain is to be provided if the HIRES electronics are contained within the LSE. This will allow HIRES or other servicing without being affected by laser light from the laser bench area.

9.2.3 Electrical

9.2.3.1 The LSE shall have emergency lighting for egress in case of power failure.

9.2.3.2 The LSE shall provide emergency stop buttons that will interface with the LM-CTI laser to terminate laser light. There shall be sufficient number of buttons that can be accessed throughout the LSE without exposing personnel to laser radiation. A button is expected to be located on the exterior near the entry of the laser room.

9.2.4 Environmental

9.2.4.1 The LSE shall have smoke detectors with an audible alert located on the exterior of the LSE for annunciation. These smoke detectors shall be tied into the control system for disabling the laser.

9.2.4.2 The LSE shall provide appropriate fire extinguisher in the laser room and on the exterior near the entry of the LSE.

9.2.4.3 The laser room shall have a standalone oxygen monitor unit to alert personnel of a low oxygen environment. The notifier shall be on both the inside and outside of the LSE when the oxygen level is lower than 19.5%.

9.2.4.4 A video surveillance camera shall be installed in the LSE. The camera shall be accessible via the network.

Laser shutters

Will follow ANSI regulations on laser safety

9.2.5 Software Requirements

Laser software system consists of vendor supplied laser control system software that has been tested.

9.2.5.1 Basic functional requirements

9.2.5.1.1 GUI/ Display requirement:

GUI shall display

9.2.5.1.1.1 Laser power(s) shall be displayed from photodiodes w/ appropriate gains on the GUI at xx Hz

9.2.5.1.1.2 Spectral profile shall be displayed on the GUI at xx Hz

9.2.5.1.1.3 Absolute wavelength from a wavemeter shall be displayed on the GUI at xx Hz

9.2.5.1.1.4 Polarization at the laser and at the LTA shall be displayed on the GUI at xx Hz

9.2.5.1.1.5 Sodium cell absorption shall be displayed on the GUI at xx Hz

9.2.5.1.1.6 M^2 of the laser beam(s) shall be displayed on the GUI at xx Hz

9.2.5.1.1.7 Near and far field spot patterns shall be displayed at xx Hz

9.2.5.1.1.8 All controls and/or dither loop performance of the laser shall be displayed on the GUI at xx Hz

9.2.5.2 Error recovery

9.2.5.3 Telemetry requirements

The telemetry system shall record:

9.2.5.3.1 The laser power(s) at xx Hz

9.2.5.3.2 Spectral profile at yy Hz

9.2.5.3.3 Absolute wavelength at xx Hz

9.2.5.3.4 Polarization (at the laser and at the LLT) each at xx Hz

9.2.5.3.5 Sodium cell absorption at xx Hz

9.2.5.3.6 M^2 of the laser beam(s) at xx Hz

9.2.5.3.7 Near and far field spot patterns at xx Hz.

9.2.5.3.8 Control/ dither loops inside the laser at xx Hz

9.2.5.4 Interface to AO system software

9.2.5.4.1 Shall be able to get tune/detune commands from the AO system

9.2.5.4.2 Shall be able to shutter and propagate the laser beam(s).

9.2.5.4.3 Shall have the ability to focus the laser spot.

9.2.5.4.4 Shall have the ability to query and display parameters that are recorded as part of telemetry

9.2.5.4.5 Shall be able to remotely power up and power down the lasers

9.2.5.4.6 The software shall facility shall be able to tune/detune of the sodium D2 line remotely.

9.2.5.4.7 Shall be able to perform basic tweaking up of laser performance [TBD]

9.2.6 Interface Requirements

Interface requirements w/ the AO system [tbd]

9.2.7 Reliability Requirements

Time for full operational condition from start up

Start-up requirements

9.2.8 Spares Requirements

9.2.9 Service and Maintenance Requirements

9.2.10 Documentation Requirements

Shall have all standard operating procedures documented

9.3 Diagnostics

9.3.1 Subsystem Requirements

9.3.2 Optical requirements

The diagnostics for the LGS facility shall record

9.3.2.1 Laser power(s) at xx Hz

9.3.2.2 Spectral profile at yy Hz

9.3.2.3 Absolute wavelength at xx Hz

9.3.2.4 Polarization (at the laser and at the LLT) each at xx Hz

9.3.2.5 Sodium cell absorption at xx Hz

9.3.2.6 M^2 of the laser beam(s) at xx Hz

9.3.2.7 Near and far field laser spot patterns at xx Hz.

9.3.2.8 Control/ dither loops inside the laser at xx Hz

9.3.3 Mechanical Requirements

9.3.4 Electronic/Electrical Requirements

9.3.5 Safety Requirements

9.3.6 Software Requirements

9.3.7 Interface Requirements

9.3.8 Reliability Requirements

9.3.9 Spares Requirements

9.3.10 Service and Maintenance Requirements

9.3.11 Documentation Requirements

9.4 Beam Transport System

Shall convey > xx% of the laser power from the laser enclosure to the LTA.

9.4.1 Subsystem Requirements

9.4.2 Optical requirements

9.4.3 Electronic/Electrical Requirements

9.4.4 Safety Requirements

9.4.5 Software Requirements

The telemetry system shall record BTO parameters at xx Hz
The diagnostics for the LGS facility shall record BTO parameters at xx Hz

9.4.6 Interface Requirements

9.4.7 Reliability Requirements

9.4.8 Spares Requirements

9.4.9 Service and Maintenance Requirements

9.4.10 Documentation Requirements

9.5 Launch Telescope

9.5.1 Subsystem Requirements

uplink TT requirements

9.5.2 Optical requirements

9.5.2.1 Alignment accuracy/tolerance (internal and to the optical axis of the K1 telescope) shall be

9.5.2.2 The optical coatings used in the LTA optics shall withstand xx J of power in xx mSec.

9.5.2.3 Beam input beam diameter shall be

9.5.2.4 The output beam diameter shall be

9.5.2.5 The BTO/ LTA shall be testable without the use of a 589-nm Na laser

9.5.2.6 The total WFE (RMS) of the LTA shall be <42 nm within the operating range of the LTA (20° to 90.5°)

9.5.2.7 The LTA shall work between -5° to 90.5°.

9.5.2.8 The alignment tolerance shall be document

9.5.2.9 The throughput of the telescope shall be >95%

9.5.2.10 The LLT shall work over 400-700 nm so that star-light can be used to align it properly (should we specify some chromatic spec. here?)

9.5.2.11 Shall work both in laser projecting mode and star viewing mode.

9.5.2.12 Shall have an active focus mechanism

9.5.2.13 Focusing accuracy shall be

9.5.2.14 The focusing mechanism shall have a resolution of xx um (design dependent).

9.5.2.15 The LTA shall take a input beam specified by and produce a output beam that is 50 cm [TBD] in dia.

9.5.2.16 The LTA shall have an unvignetted FoV of 202" with <42 nm of WFE

9.5.2.17 Each LGS beacon shall have a pointing accuracy of 0.x arcsec

9.5.2.18 The LTA shall be operational over a 250” FoV with xx nm of WFE.

9.5.2.19 The LTA shall be able to withstand xxx Watts of 589.xxx nm power with spectral and the pulse format defined in xxx document

9.5.2.20 Each beacon shall have the ability to be pointed on sky to better than 0.x arcsec.

9.5.2.21 The secondary structure (if any) and spiders (if any) should have an area of $1/100^{th}$ of he beam(s) they obscure.

9.5.2.22 The input laser beam shall have xxx characteristics

9.5.2.23 The LTA shall propagate a laser beam that produces a spot of 0.x arcsec at the sodium layer under median operating conditions.

10 THE OPTICAL COATINGS USED IN THE LTA MUST BE ABLE TO SURVIVE THE LASER POWER (AT THE PARTICULAR PULSE FORMAT) SPECIFIED BY REQUIREMENT X.X.X.X.X

11 THE OPTICAL QUALITY OF THE LTA SHALL BE TESTABLE IN-SITU.

12 ALIGNMENT SCHEME [TBD]

12.1.1 Mechanical Requirements

12.1.1.1 Flexure/ FEA: The LTA flexure and strain characteristics shall conform to those prescribed by xxx document.

12.1.1.2 Temperature:

12.1.1.3 Space constraints

12.1.1.4 Mass

12.1.1.5 Volume

12.1.1.5.1 The LTA must fit within a volume of 610x680x635 mm *[5]*

12.1.1.5.2 The LTA must interface to the K1 telescope as described in document KAON xx and CARA drawing # xx.

12.1.1.6 Center of gravity,

12.1.1.7 Eigen modes

12.1.1.8 Dry N_2 seal (Hermetic seal?)

12.1.1.9 The LTA unit shall be keep in a controlled atmosphere filled with dry N_2. The LTA shall be air-tight from the entrance window to the exit window between xx-yy PSI pressure prevailing inside the assembly.

12.1.1.10 Motion control (if any)

12.1.1.11 Cooling

12.1.1.12 Storage and shipping requirements

12.1.2 Electronic/Electrical Requirements

12.1.2.1 The LTA and associated electronics shall consume less than xx KW of electrical power

12.1.2.2 LTA electronics shall use facility glycol to vent heat.

12.1.2.3 The LTA shall not dissipate more than xx W of heat to the ambient air

12.1.3 Safety Requirements

12.1.4 Software Requirements

12.1.4.1 Shall display parameters [tbd] that show the state of the LTA.

12.1.4.2 LTA parameters at xx Hz

12.1.5 Interface Requirements

12.1.6 Reliability Requirements

12.1.6.1 Reliability

12.1.6.2 Maintainability

12.1.6.3 Maintainance frequency

12.1.6.4 Preventive maintanance

12.1.6.5 On-site repair

12.1.6.6 Transportation and Handling

12.1.6.7 Spares

12.1.6.8 Storage

12.1.6.9 Routine cleaning

12.1.6.10 Protective covers

12.1.7 Spares Requirements

12.1.8 Service and Maintenance Requirements

12.1.9 Documentation Requirements

12.1.9.1 The mechanical assembly shall be documented

12.1.9.2 The alignment procedure of the LTA shall be documented

12.1.9.3 A system level document describing the LGS facility and sub-systems shall be prepared.

12.1.9.4 A software document shall be written describing the software architecture and implementation.

12.1.9.5 A laser user manual shall be written

12.1.9.6 A BTO and LTA user manual shall be written

12.2 Laser Air Traffic Safety System

This subsystem is responsible for coordinating all air traffic related safety issues for production of LGS over Mauna Kea for NGAO and any legacy LGS systems. The safety system is inclusive and includes air traffic proper plus personnel, satellites, and telescope collisions.

12.2.1 Subsystem Requirements

12.2.2 Optical requirements

12.2.3 Mechanical Requirements

12.2.4 Electronic/Electrical Requirements

12.2.5 Safety Requirements

12.2.6 Software Requirements

12.2.7 Interface Requirements

12.2.8 Reliability Requirements

12.2.9 Spares Requirements

12.2.10 Service and Maintenance Requirements

12.2.11 Documentation Requirements

References:

1. Requirements for the Gemini South and Keck I Laser Systems (Version 2.91), d'Orgeville et. al.
2. Instrument baseline requirements document (Draft, Version 0.1), Adkins.
3. NGAO system requirements document (Version 1.13), Wizinowich et. al.
4. K1 LGS AO system preliminary laser service enclosure requirements document (Version 2.0), Chin et. al.
5. K1 LGS AO system preliminary launch telescope assembly requirements Chin et. al.
6. Error budget spreadsheet (Version 1.26), Dekany

Compliance matrix

Requirement #	Description	Verification	
		Design	Test/ Inspection