Next Generation Adaptive Optics System

Laser Launch Facility Requirements Compliance

Oct 13, 2009

1 INTRODUCTION

The requirements for the Laser Launch Facility (LLF) are flowed down from the requirements for the Laser Guide Star Facility and Beam Transport Optical System. There two sets of requirements are extracted from the Contour Requirements Database and presented in Table 1 and Table 2. The requirements that applied to the LLF are highlighted. Non-highlighted requirements are not applicable (N/A) to the LLF. Items in yellow represent diagnostics that will need further investigation to determine how they can be properly inserted into the beams within the allowable volumes.

2 TABLE 1: BEAM TRANSPORT OPTICAL SYSTEM REQUIREMENTS

Short Name	ID	Description	Compliance
Beam Transport System - definition (linked)	FR-1969	The Beam Transport System shall be composed of the optical mechanical system that optically transmits or relays the output beams of the Laser Units along the telescope structure and projects them onto the sky. The Beam Transport System includes opto-mechanical systems located inside the Laser Enclosure, along the telescope tube structure, and across to the telescope secondary mirror support structure. This system also includes opto-mechanical systems inside the secondary structure including the Laser Launch Telescope itself. This system also consists of mechanical and electrical components needed for beam steering and centering. It is also responsible for the generation of the required number and orientation of individual Laser Guider Stars. Monitoring functions such as beam quality, laser power, and polarization not included as part of the supplied Laser Units are also included in this system.	By Design
Standards - new instruments and facilities (linked)	FR-1970	The Beam Transport Facility shall comply with the full set of Keck instrument baseline requirements (TBC). This includes baseline conditions for the operational, non-operational, and shipping environments. It includes the standard for both the vibration environment at the observatory and the allowable amount of vibration a system is permitted to produce. It includes interfaces to the Observatory glycol cooling system. It includes general standards for Optical, Mechanical, Electrical, and Software best practices. It includes implementation requirements that mandate certain technical solutions particularly well adapted to use at the Observatory. It also includes baseline documentation standards.	By Design
Central projection of Laser Guide Stars (linked)	FR-1971	The Beam Transport System shall project each Laser Guide Star beam from an area located behind the Keck Telescope secondary mirror.	By Design
Reuse Keck I or Keck II Laser Launch Telescope (linked)	FR-1972	The Beam Transport System shall use a launch telescope identical in design to the Keck I Laser Launch Telescope manufactured by Galileo Avionica.	The current design is for an identical launch telescope built by Galileo Avionica. The telescope may be altered depending on the proposals by vendors. The LGSF opto-mechanical design may be modified to support the new launch telescope. The expectation is that the final telescope will be similar to the Keck I unit since the requirements are nearly identical.

Short Name	ID	Description	Compliance
Elevation range (linked)	FR-1973	The Beam Transport System shall meet all requirements over its operational elevation range of 20 degrees to 90.5 degrees. The LGS facility shall be able to function in a stand-by mode (TBD) over the elevation range (-5 degrees to 90.5 degrees).	By Design
Interface to LGS Control System - software	FR-1974	The Beam Transport System shall interface with the LGS Control System software via TBD software interfaces.	This is TBD since we do not know the LGS Control System enough to interface with it.
Interface to LGS Control System - electrical	FR-1975	The Beam Transport System shall interface with the LGS Control System hardware via a TBD format.	This is TBD since we do not know the LGS Control System enough to interface with it. However, the LLF team has examined the type of devices required in the LLF and verified they are within the bounds of the Device Architecture that is being considered for NGAO.
Reimage Laser Unit pupil to Laser Launch Telescope	FR-1976	The Beam Transport System shall reimage the exit pupil of the Laser Units onto the entrance pupil of the Laser Launch Telescope.	By Design.
Input beam format	FR-1977	The Beam Transport System shall accept three input beams of diameter 3 mm from each Laser Unit. The Laser Unit will deliver a collimated beam with an output beam waist diameter at 1/e2 equal to 3.0 mm plus/minus 0.1 mm. Output beam waist location: 0.0 m plus/minus 0.5 m with respect to the output aperture of each Laser Unit.	By Design.
Output beam format	FR-1978	The Laser Launch Telescope shall have an output Gaussian intensity profile with a 1/e2 diameter of 0.3 m (TBC).	N/A
Laser Launch Telescope - functional quality	FR-1979	The Laser Launch Telescope shall have as-built optical quality of 60 nm rms (TBC). The requirement is applicable at all operating elevations between 20 and 90 degrees and at all operating temperatures.	N/A
LGS Focus control	FR-1980	The Beam Transport System shall provide an mechanism so that the LGS beams can be focus at the sodium layer for ranges between 80 km and 270 km.	By Design.
Transmission (linked)	FR-1982	The LGS facility optical transmission shall be equal or greater than 75% at a wavelength of 589 nm. The requirement is for all optics from the output of each Laser Unit to the sky. It includes all transmission losses in the Beam Transport System and the Laser Launch Telescope. It also includes losses from the Laser Launch Telescope secondary obscuration.	The performance requirements have been modified per discussion with Rich Dekany. The new requirements are TBD and has been considered in the design.

Short Name	**ID**	**Description**	**Compliance**
Damage threshold	FR-1983	All optical components and coatings used in the Beam Transport System optics shall withstand 100 W CW laser power if they transmit or reflect one laser beam. All optical components and coating used in the Beam Transport System optics shall withstand 300 W CW laser power if they transmit or reflect 7 or more laser beams. The energy density will vary as the beam size increases or decreses in the Beam Transport Optical system. In general laser beam energy density will vary depending on the instanteanous size and f/number of indivudual laser beams, however typical maximum energy density for optical coating would be to withstand greater than or equal to 4.5 kW (TBC) per centimeter squared CW laser power for wavelengths between 580-600 nm (TBC).	This will have to be examined further; however, initial examination of commercially available coatings will meet this requirement.
Automated alignment	FR-1984	The Beam Transport System shall include automated optical alignment mechanism for the laser optical path from the Laser Units output to the input of the Laser Launch Telescope.	The devices to support this function are being implemented. Further consideration must be made with the Control Systems to ensure this requirement is met.
Beam splitting	FR-1985	The Beam Transport System shall include automated beam splitters and steering mirror to produce the power fraction required and number of LGS on the sky from the outputs of the Laser Units.	By Design.
Asterism generation	FR-1986	The Beam Transport System shall include optics to orient and position the laser beams for input to the Laser Launch Telescope so that the required asterism is generated on the sky.	By Design.
Deployable LGS control	FR-1987	The Beam Transport System shall include optics to orient and position the laser beams for input to the Laser Launch Telescope so that 3 LGS are created which can be positioned at locations coincident with natural guide stars used for tip tilt correction by other NGAO systems.	By Design.
Offload mirrors - function	FR-1988	The Beam Transport System shall include a single mirror for repointing the on axis LGS asterism. Each deployable LGS (Point and Shoot asterism) beam shall have its own independent mirror for repointing. These mirrors shall be driven by pointing error offload from the up-link tip tilt steering mirrors inside the LGS wavefront sensors of the AO system.	By Design.
Offload mirrors - update rate	FR-1989	The Beam Transport System mirrors used to repoint the LGS beams shall be driven by offload error from the up-link tip tilt mirrors at a rate of 10 Hz (TBC).	The devices to support this function are being implemented. Further consideration must be made with the Control Systems to ensure this requirement is met.
Offload mirrors	FR-	The Beam Transport System mirrors used for off loading up-link tip tilt	By Design.

Short Name	ID	Description	Compliance
- range and precision	1990	correction shall have a range of 30 arc seconds (TBC) and a positioning tolerance of 0.3 arc seconds (TBC).	
Image natural stars with Laser Launch telescope	FR-1991	The Beam Transport System shall be able to make pointing and optical alignment checks of the Laser Launch Telescope using natural stars. This will require an sensor such as a CCD (TBC) and other optics to be mounted near the Laser Lauch Telescope looking upward at natural stars.	By Design.
Quarter wave plate	FR-1992	The Beam Transport System shall have several quarter wave plates needed to convert the linearly polarized output of the Laser Units to circularly polarized output.	By Design.
Quarter wave plate control	FR-1993	The quarter wave plates shall be automated to compensate for depolarizing effects of the other optics in the Beam Transport System.	By Design.
Laser safety - general requirement	FR-1994	The Beam Transport System shall be delivered in compliance of ANSI Standards for Laser Safety. Areas on non-compliance must be agreed upon by NGAO System Team. Additional highlighted safety requirements are meant to bring additional attention to the design, but are in compliance with the standards.	By Design.
Laser safety - Interior finish	FR-1995	The Beam Transport System shall be fabricated with properly finished surfaces that come in contact with the laser and viewed by personnel. The surfaces shall comply with nominal hazard zones for the laser.	Further considerations will need to be in place to meet this requirement.
Laser safety - E-Stop	FR-1996	The Beam Transport System shall provide an emergency stop button to the laser safety system to terminate the laser beams from entering the Launch Facility.	By Design.
Laser safety - Status Indicator	FR-1997	The Beam Transport System shall provide status indicators on the outside of the enclosure. These indicators are for personnel to determine the laser status prior to entry. The indicators shall be momentary if any light source is used so as to not contaminate the dome environment.	By Design.
Laser safety: laser radiation exposure	FR-1998	The Beam Transport System shall insure personnel must not be exposed to the maximum exposure levels (MPE) as defined by the ANSI standards (Z136.1) and beam hazard analysis. Interlocks shall be installed to meet these requirements.	By Design.
Laser safety: hazard labeling and warning signs	FR-1999	The Beam Transport System shall include hazard labels for a Class-4 lasers in accordance with ANSI Standards.	This will be implementation during integration.
Pointing reference	FR-2000	The Beam Transport System shall have a mean to initialize its motion control devices to known fiducial.	By Design.
Shutter	FR-	The Beam Transport System shall accept a command from the Laser Safety	The devices to support this function are being

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	2001	System to close a final shutter if necessary. The location of the final shutter will depend on the Beam Transport System design.	implemented. Further consideration must be made with the Control Systems to ensure this requirement is met.
Environmental monitoring	FR-2002	The Beam Transport System shall provide inputs to the environmental control and monitoring system for temperature and humidity. The subsystem of the LGS facility that performs environmental control is LGS Control System (TBC).	Further considerations will need to be in place to meet this requirement.
Yield strength	FR-2003	The Beam Transport System shall be designed and constructed to a minimum safety factor of TBD on yield strength for all structural elements.	By Design.
Positive pressure	FR-2004	The Beam Transport System shall be positive pressure with dried filtered air to minimize particulates inside of the Launch Facility. The flow rate will be TBD. The output flow shall be distributed for laminar flow and not a point source.	By Design.
Installation and removal process	FR-2005	The Beam Transport System component systems shall each be able to be removed and installed within 4 hours or 1/2 day of daycrew operations. The installation shall have a repeatable factor of TBD.	This requirement will be supported for mechanisms that will require servicing. This will not hold true for permanent structures such as beam tubes.
Installation and removal repeatability	FR-2006	The components of the Beam Transport System shall be installed with kinematic fixture for easy of removal and reinstallation. The repeatability factor is TBD.	By Design for BGS.
Installation and removal handling	FR-2007	Mechanical supports shall be implemented to simplify the installation and removal of the parts of the Beam Transport System that are located inside the telescope secondary and along the telescope tube structure. If possible, the interface to the Laser Launch Telescope shall be installed as a single unit. The components of the Beam Transport System shall provide supports such as lifting bolts to assist in installation and removal.	By Design for BGS.
Electrical power capacity	FR-2008	The Beam Transport System shall be provided with 1500 Watts of 120 VAC power.	By Design.
Allowable volume	FR-2019	The Beam Transport System volume shall conform to volume limits of the current f/15 secondary and its mounting structure. Those parts of the Beam Transport System mounted behind the f/15 secondary mirror must allow for the removal, storage and installation of the f/15 secondary module. Furthermore, these parts shall 1) not extend beyond the module in the x,y-directions and 2) must not extend more than 1 m beyond the top of the telescope structure.	Further design will be needed in the interface between the BTO and the BGS to ensure it does not impact the removal, storage and installation of the f/15 secondary module.
Maintenance accessibility	FR-2020	The diagnostics of the Beam Transport System shall not interfere with maintenance of existing equipment in the f/15 Secondary module. When possible 50 cm (20 inches) of access shall be provided around equipment that requires	By Design.

Short Name	ID	Description	Compliance
		maintenance.	
Mechanical Interface	FR-2021	The Beam Transport System shall interface with the telescope, secondary socket, and f/15 structure (TBD).	By Design.
Wavefront error	FR-1981	The Beam Transport Facility optics excluding the Laser Launch telescope shall have an RMS wavefront error of 60 nm rms (TBC).	The performance requirements have been modified per discussion with Rich Dekany. The new requirements are TBD and has been considered in the design.
Power	FR-2009	The diagnostics of the Beam Transport System shall measure the power of the laser beam to 100 mW resolution (TBC) and an accuracy of plus/minus 100 mW peak-to-peak.	TBD. More effort will be required to verify the diagnostics and their ability to fit into the BGS system.
Wavefront	FR-2010	The diagnostics of the Beam Transport System shall measure the wavefront of the laser beam to 0.05 wave at 633 nm (32 nm rms TBC). This may be done offline.	TBD. More effort will be required to verify the diagnostics and their ability to fit into the BGS system.
Encircled energy	FR-2011	The diagnostics of the Beam Transport System shall provide the encircled energy radius of the laser beam; resolution 100 microns (TBC).	TBD. More effort will be required to verify the diagnostics and their ability to fit into the BGS system.
Centroid	FR-2012	The diagnostics of the Beam Transport System shall provide centroiding of the beam; resolution 10 microns (TBC).	TBD. More effort will be required to verify the diagnostics and their ability to fit into the BGS system.
Polarization	FR-2013	The diagnostics of the Beam Transport System shall measure the polarization of the laser beam; Stokes parameter accuracy better than 0.1% (TBC). The location for the polarization measurement can be at anyplace in the beam train. The polarization will be verfied at the start of night and as needed by inserting a sampling element into the laser beams.	TBD. More effort will be required to verify the diagnostics and their ability to fit into the BGS system.
M-squared	FR-2014	The diagnostics of the Beam Transport System shall provide the M-squared of the laser beam to an accuracy of 0.05 (TBC).	TBD. More effort will be required to verify the diagnostics and their ability to fit into the BGS system.
Profile	FR-2015	Beam profile shall be provided by the diagnostics of the Beam Transport System; resolution 1 micron (TBC). This measurement may be made offline and not realtime.	TBD. More effort will be required to verify the diagnostics and their ability to fit into the BGS system.
Remote capture	FR-2016	The diagnostics of the Beam Transport System shall be able to be operated remotely and make the measurements in real time (TBC) ; unless otherwise	TBD. More effort will be required to verify the diagnostics and their ability to fit into the BGS system.

Short Name	ID	Description	Compliance
		specified.	
Minimize lost Laser Unit power	FR-2017	The diagnostics of the Beam Transport System shall not remove more than 0.3% (TBC) of the Laser Unit power entering its optical sampling elements, for example beam splitters or mirrors.	TBD. More effort will be required to verify the diagnostics and their ability to fit into the BGS system.

3 Table 2: Laser Guide Star Facility Requirements

Short Name	ID	Description	Compliance
LGS production capability	FR-1932	The Laser Guide Star Facility shall be responsible for the production of laser guide stars used by the NGAO Adaptive Optics system for sensing optical distortions caused by atmospheric turbulence. This includes all systems needed for production, setup, calibration, pointing, focusing, and control used to produce laser guide stars in the atmospheric sodium layer.	By Design. The LLF supports this requirement.
LGS Facility subsystems	FR-1933	The Laser Guide Star Facility shall be composed of the following systems: Laser System, Laser Enclosure, Beam Transport System, LGS Control System, LGS Safety Systems, and Laser Traffic Control System. (note Laser Guide Star abbreviated LGS)	By Design. The LLF supports the Beam Transport System.
Laser System - definition	FR-1934	The Laser System shall be composed of two or three (TBD) individual Laser Units. In addition, the system consists of other associated mechanisms, electronics, control software, and other closely associated hardware provided by the laser supplier/vendor.	By Design. The LLF supports this requirement.
Laser Enclosure - definition	FR-1935	The Laser Enclosure shall be composed of a fully enclosed room mounted on the Keck Telescope structure (tube or elevation ring TBD) that houses the Laser System. This system is composed of the enclosing room along with associated mechanisms and electronics.	By Design. The LLF interfaces with the lasers within the Laser Enclosure.
Beam Transport System - definition	FR-1936	The Beam Transport System shall be composed of the optical mechanical system that optically transmits or relays the output beams of the Laser Units along the telescope structure and projects them onto the sky. The Beam Transport System includes opto-mechanical systems located inside the Laser Enclosure, along the telescope tube structure, and across to the telescope secondary mirror support structure. This system also includes opto-mechanical systems inside the secondary structure including the Laser Launch Telescope itself. This system also consists of mechanical and electrical components needed for beam steering and centering. It is also responsible for the generation of the required number and orientation of individual Laser Guider Stars. Monitoring functions such as beam quality, laser power, and polarization not included as part of the supplied Laser Units are also included in this system.	By Design. The LLF supports this requirement.

Short Name	ID	Description	Compliance
LGS Control System - definition	FR-1937	The Laser Guide Star Control System shall be responsible for controlling the Beam Transport System for purposes of laser beam steering/pointing and laser beam diagnostics. The LGS Control System shall control the overall state of the Laser System by an appropriate interface to the Laser Unit control software. The LGS system shall have interfaces with the Laser Traffic Control System and the LGS Safety System. The Laser Guide Star Control System shall coordinate/interface to the overall NGAO Multi-system Command Sequencer, the AO Control System and the NGAO Data Server.	The LLF is designed to support this requirement through the control system.
LGS Safety System - definition	FR-1938	The LGS Safety Systems shall include three sub-systems: Laser Safety System, Aircraft Safety System, and the Satellite Safety System. The Laser Safety System shall be responsible for ensuring safe interaction between observatory personnel and the Laser Units. The Laser Safety System shall provide environmental monitors and controls for both the Laser Enclosure and Beam Transport system, ensuring that the Laser Units are not damaged (i.e. "safe"). The Aircraft Safety System shall be responsible for ensuring that aircraft are not illuminated by lasers propagated from the Keck Telescope dome. The Satellite Safety system shall be responsible for ensuring that satellites are not illuminated by lasers propagated from the Keck Telescope dome, in coordination with United States Space Command.	N/A
LGS Traffic Control System - definition	FR-1939	The LGS Traffic Control System is defined as the computer system that monitors the status and coordinates the activities of all telescopes on Mauna Kea which participate in Mauna Kea Laser Traffic control, to prevent accidental illumination of any participating telescopes. This includes all telescopes which are either propagating lasers or may be impacted by laser light from other telescopes. The LGS Facility shall have an interface to this Mauna Kea wide service.	N/A
Operational lifetime	FR-1940	The LGS Facility system and its components shall be designed to have a 10 year operational lifetime.	The selection of components will be chosen to support this requirement. This requirement will be given further review during the PDR.
Downtime	FR-1941	The LGS Facility shall have less than 5% (TBC) downtime lost to faults of all systems inclusive.	This operational requirement will be given further review during the PDR.
LGS asterism configuration	FR-1942	The laser guide stars shall be arranged in the following pattern or asterism on the sky. The on-axis pattern is composed of a fixed LGS asterism consisting of one on-axis LGS and three LGSs symmetrically located on a radius of 10 arc seconds	By Design.

Short Name	ID	Description	Compliance
		(TBC). In addition, the LGS asterism shall have three movable or point-and-shoot (PNS) LGSs to be used to AO correct or "sharpen" three natural guide stars located outside of the fixed asterism. The three LGSs will be positioned at the locations of these randomly located NGSs. As such, the movable LGSs will be located in an annulus that has an outer radius of 60 arc seconds and an inner radius of 15 (TBC) arc seconds.	
LGS asterism power levels	FR-1943	The LGSs shall be allocated different power levels depending on function. A total of 50W (TBC) of laser power will be distributed uniformly between the four fixed LGSs. A total of 25W (TBC) of laser power will be distributed uniformly between the three movable or point-and -shoot LGSs.	By Design.
LGS asterism orientation	FR-1944	The Laser Guide Star facility shall provide a mechanism either optical or mechanical (TBD) for keeping the individual laser guide stars fixed with respect to field stars. The Laser Guide Star asterism shall maintain a fixed orientation with respect to background field stars when the Adaptive Optics system is operated in its "fixed field" mode. When the AO system is operated in its "fixed pupil" mode the LGS asterism shall remain fixed with respect to the telescope pupil and rotate with respect to the background stars. In this mode, the movable or Point-and-Shoot asterism will NOT maintain orientation with the three NGS used for tip-tilt compensation.	By Design.
LGS photon return	FR-1945	The LGS Facility shall produce a return flux of 740 ph/cm2/sec (TBC) for each of the 4 LGS in the on axis fixed asterism (science asterism) and 495 photons/cm2/sec (TBC) for each of the 3 LGS in the movable asterism. These flux values are measured at the Keck Telescope primary mirror (i.e. the pupil) when the laser projection system is pointed at zenith. This requirement assumes a sodium column density of 3e9 atoms/cm2, mean distance to the sodium layer of 90 km, a one-way atmospheric transmission of 89.6%, and laser beam powers of 9.4 W and 6.25 W respectively. Return flux variations will result from changes in the sodium column density and the direction of the earth's magnetic field.	By Design. This should be TBD expanded.
Transmission	FR-1946	The LGS facility optical transmission shall be greater than or equal to 75% at a wavelength of 589 nm. The requirement is for all optics from the output of each Laser Unit to the sky. It includes all transmission losses in the Beam Transport System and the Laser Launch Telescope. It also includes losses from the Laser Launch Telescope secondary obscuration.	The performance requirements have been modified per discussion with Rich Dekany. The new requirements are TBD and has been considered in the design.

Short Name	ID	Description	Compliance
Polarization	FR-1947	The laser beams leaving the Laser Launch Telescope shall be circularly polarized to greater than or equal to 98% (TBC). The handedness, right or left, is arbitrary (TBC) but the beams should be fully polarized to the value given in one or the other of these states.	This requirement is not fully considered in the design; but will be included in the PDR.
Laser Guide Star projected size	FR-1948	The LGS spots at the sodium layer shall be less than or equal to 0.9 arc seconds (TBC) without considering the effects of atmospheric turbulence.	By Design.
Uplink tip tilt offload	FR-1949	The LGS Facility shall be able to adjust pointing of the lasers in order to offload the correction of up-link tip tilt from the up-tip-tilt mirrors.	The devices to support this function are being implemented. Further consideration must be made with the Control Systems to ensure this requirement is met.
LGS position - stability	FR-1950	The LGS Facility shall maintain the asterism orientation and shape to 1 arc second (TBC) rms. The asterism orientation must be maintained as the telescope tracks astronomical targets for periods up to one hour (TBC).	The devices to support this function are being implemented. Further consideration must be made with the Control Systems to ensure this requirement is met.
LGS position - tip tilt residual	FR-1951	The projected (up-link) tip tilt residual for each LGS shall be less than or equal to 0.5 arc seconds rms (one sigma) on-axis (TBC). This includes the residual from atmospheric turbulence, wind shake, and vibrations. The correction of this residual motion shall be performed on the return trip (down-link) by the AO System Real Time Controller and fast steering mirrors location inside the laser guide star wavefront sensor optics.	N/A. TBD?
LGS position - blind pointing	FR-1952	The blind pointing of the LGS asterism shall be less than 10 arc seconds rms (TBC) with a goal of 1 arc second rms (TBC).	By Design.
Flexure compensation	FR-1953	The LGS Facility shall be capable of correcting for the effects of flexure between the telescope top end structure and the elevation ring structure by up to 20 mm (TBC) in translation (perpendicular to the primary mirror optical axis) and 2 milliradians (TBC) in tilt (relative to the primary mirror optical axis) over elevation angles between 0 and 90 degrees.	By Design.
Central projection of	FR-1954	The Laser Guide Star Facility shall project each Laser Guide Star beam from an area located behind the Keck Telescope secondary mirror.	By Design.

Short Name	ID	Description	Compliance
Laser Guide Stars			
Reuse Keck I launch telescope	FR-1955	The Laser Guide Star Facility shall use a launch telescope identical in design to the Keck I Laser Launch Telescope manufactured by Galileo Avionica.	The design is expected a similar if not identical telescope.
Location of Laser Units	FR-1956	The laser units shall be mounted on the elevation ring of the telescope. This location varies in orientation with respect to the gravity vector as the telescope tracks in elevation. Additional equipment required by the laser units, such as support electronics, control computers, or cooling systems may be located in the laser enclosures or on the telescope Nasmyth platform. If mounting of the laser units on the elevation ring is not feasible, an alternate location must be agreed upon with the NGAO design team.	The LLF interfaces expect a laser mounted on the elevation ring.
Cannot vignette Keck Telescope	FR-1957	No part of the Laser Guide Star Facility shall vignette the main telescope beam. In particular, any parts of the Beam Transport System that cross the secondary mirror support struts (spiders) shall not enlarge these obstructions to incoming starlight.	By Design.
Elevation range	FR-1958	The LGS facility shall meet all requirements over its operational elevation range of 20 degrees to 90.5 degrees. The LGS facility shall be able to function in a non-propagating standby mode (TBD) over the full elevation range of the telescope (-5 degrees to 90.5 degrees).	By Design.
Standards - new instruments and facilities	FR-1959	The Laser Guide Star Facility shall comply with the full set of Keck instrument baseline requirements (TBC). This includes baseline conditions for the operational, non-operational and shipping environments. It includes the standard for both the vibration environment at the observatory and the allowable amount of vibration a system is permitted to produce. It includes interfaces to the Observatory glycol cooling system. It includes general standards for Optical, Mechanical, Electrical, and Software best practices. It includes implementation requirements that mandate certain technical solutions particularly well adapted to use at the Observatory. It also includes baseline documentation standards.	By Design. More information to be provided at PDR.
Laser safety standards	FR-1960	The LGS Facility shall conform to ANSI standard Z136.1-2000 American National Standard for the Safe Use of Lasers. The LGS Facility shall conform to ANSI Z136.6 -2005 "Safe Use of Lasers Outdoors", Approved December 22, 2005.	By Design.

Short Name	ID	Description	Compliance
Laser light leaks	FR-1961	The Laser Guide Star Facility shall not emit laser radiation or other light into the Keck Observatory dome during normal operations. One exception is made for laser radiation at 589 nm that leaves the output aperture of the Laser Launch Telescope. Laser radiation and other stray light shall not leak from other parts of the Beam Transport System or the Laser Enclosure into the dome.	By Design.
Interface to Keck Telescope structure	FR-1962	The LGS facility shall have interfaces with the telescope structure at several locations (TBD). These interfaces must not effect the performance of the Keck Telescope when used with NGAO or other instruments. Details will be provided in the subsystem requirements and an interface control document.	The design specifies these TBD locations.
Interface to Keck Observatory facilities	FR-1963	The LGS facility shall have an interface with the Keck Observatory facilities such as electrical power and glycol cooling. Details will be provided in the subsystem requirements and an interface control document.	By Design.
Interface to NGAO software - Multi-system Command Sequencer	FR-1964	The LGS Control system shall have an interface to the NGAO Multi-system Command Sequencer. The overall coordination of the LGS Facility with the NGAO System will be done through this interface. Details will be provided in the subsystem requirements and an interface control document.	N/A
Interface to NGAO software - Data Server	FR-1965	The LGS Control system shall have an interface to the NGAO Data Server for the purpose of transmitting LGS Facility telemetry, diagnostics, command and status information to the data server. Details will be provided in the subsystem requirements and an interface control document.	N/A
Interface to AO system - Real Time Control	FR-1966	The LGS Facility shall have an interface with the AO Control System to communicate offloads between the AO system LGS wavefront sensor and the LGS Facility Beam Transport system and to communicate laser shutter status to the AO Control System. Details will be provided in the subsystem requirements and an interface control document.	N/A
Interface to NGAO software - acquisition	FR-1967	The LGS Facility shall have an interface with the AO Control System for communication between the acquisition and guiding control tasks and the LGS Facility Beam Transport System. Details will be provided in the subsystem requirements and an interface control document.	N/A

Short Name	ID	Description	Compliance
system			
Allowable mass	FR-2018	The LGS Facility mass shall conform to following weight limits. The maximum weight of the LGS Facility on the azimuth rotating part of the telescope shall not exceed 10,000kg. The maximum weight of the LGS Facility on the elevation moving portion of the telescope shall not exceed 1700 kg (elevation ring mounting). The maximum weight of the LGS Facility in the top-end module (secondary) shall not exceed 150kg. All mass values are (TBC).	By Design.