NGAO Functional Requirements

Key	Name	Sect	Cat	Priority	WBS	Description	Rationale	Traceability	Status	Version	Verification	Originator	Last Modified
FR-507	Purpose	Overall	Functional	Essential	1.2.7	The laser guide star wavefront sensor subsystem, hereafter referred to as the LGS WFS, shall measure the wavefront using several sodium laser guide stars as reference sources.	Need LGS to achieve high Stehl over large percentage of the sky	Architecture requirements summary spreadsheet (row 10) sky coverage. KAON 499 "NGAO System Architecture Definition"	Draft	1.0	Demonstration	Chris Neyman	Mar 5, 2009 1:39 PM
FR-508	LGS configuration	Overall	Functional	Essential	1.2.7	The laser guider star wavefront sensors shall operate in a configuration with one wavefront sensor channel per laser guide star.	standard configuration for multiple LGS systems, note: "layer oriented" wavefront sensing is at yet unproven, see ESO MAD test in 2008. http://www.eso.org/projects/aot/mad/	KAON 499 "NGAO System Architecture Definition"	Draft	1.0	Inspection	Chris Neyman	Mar 5, 2009 1:47 PM
FR-509	Multiple laser guider star operation	Overall	Functional	Essential	1.2.7	The LGSWFS shall support up to 9 laser guide stars. The current NGAO architecture assumes six lasers arranged in a regular pattern or constellation on the sky. Of these lasers, one is located at the center of the field of view and the other five are arranged in a regular pentagon around the central star. The remaining 3 guide stars can be positioned at random around the field of view for AO correction of natural guide stars used in sensing the tip tilt and other low spatial order aberrations.	Large number of LGS need to minimize the tomography error for wide field instruments. Roving LGS needed for low tip tilt errors high sky coverage.	Architecture requirements summary spreadsheet (row 10) sky coverage and (row 11) high order wavefront error. KAON 499 "NGAO System Architecture Definition"	Draft	1.0	Demonstration	Chris Neyman	Mar 5, 2009 1:48 PM
FR-510	LGS Wavefront sensor performance	Overall	Performance	Essential	1.2.7	The performance level of the LGS WFS is TBD	The level of performance for this wavefront sensor is necessary to meet the NGAO overall wavefront error budget	Wavefront error budget spreadsheet v1.26	Draft	1.0	Test	Chris Neyman	Mar 5, 2009 1:48 PM
FR-511	Location	Overall	Functional	Essential	1.2.7	The LGSWFS shall be located at a dedicated output port of the first stage optical relay. The 589 nm light will be separated from the other output ports of the cascaded relay by a dedicated dichroic beamsplitter that reflects 589 nm light	Design decision to use large dichroic beam splitter to separate LGS light from the other outputs of the first stage of the cascaded relay (detailed specification of the dichroic are include in AO relay section of the requirements). The laser guide star wavefront sensor was placed after the first deformable mirror in order that it need less dynamic range for measuring the laser guide star aberrations.	KAON 499 "NGAO System Architecture Definition" (Figure 5, Pg. 19)	Draft	1.0	Inspection	Chris Neyman	Mar 5, 2009 1:40 PM
FR-512	Cooling	Overall	Performance	Essential	1.2.7	The optical components of the LGSWFS shall be capable of operation at -15° C or must be located outside of the optical window that isolates the cooled area of the AO enclosure. If needed, parts of the LGSWFS, such as electronics that do not require a direct interface to the optical path, might be located in nearby housing and kept at a warmer temperature	Sensitivity in K band requires cooling AO system to -15° C to achieve emissivity, Reference: KAON 501: NGAO Background and Transmission Budgets	Science K band sensitivity SRD sections 2.4, 14.1,6.7, see also KAON 501 (NGAO Background and Transmission Budgets) for temperature derivation	Draft	1.0	Test	Chris Neyman	Mar 5, 2009 1:39 PM
FR-513	Laser guide star range												

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	related focus correction mechanism	Overall	Functional	Essential	1.2.7	The LGS WFS shall have a means to focus its sensors on the sodium layer. This mechanism must compensate for slow range changes in the sodium layer distance.	These changes arise both from structural changes in the sodium density profile and zenith dependent changes as the telescope elevation changes.	Wavefront error budget spreadsheet v1.26, cell Residual Na Layer Focus Change	Draft	1.0	Test	Chris Neyman	Mar 5, 2009 1:49 PM
FR-514	Laser guide star range related focus correction control	Overall	Functional	Essential	1.2.7	The LGS WFS focus correction will be provided by the focus manager task of the AO Control function.	These changes arise both from structural changes in the sodium density profile and zenith dependent changes as the telescope elevation changes.	Engineering decision (C. Neyman), and KAON 499 "NGAO System Architecture Definition"	Draft	1.0	Demonstration	Chris Neyman	Mar 5, 2009 1:49 PM
FR-515	LGS range related higher order aberration mitigation	Overall	Functional	Essential	1.2.7	The LGSWFS shall provide a means of calibration or correction of range dependent aberrations created by the LGS traveling through the telescope and first stage optical relay at the incorrect optical conjugate (i.e. defocused).	If not accounted for results in large LGS wavefront sensing error	Engineering decision (C. Neyman), and KAON 499 "NGAO System Architecture Definition"	Draft	1.0	Demonstration	Chris Neyman	Mar 5, 2009 1:50 PM
FR-516	LGS on rotator stage	Overall	Functional	Essential	1.2.7	The laser guide star wavefront sensor will be mounted on a rotating stage in order to track the motion of the LGS spots on the sky. This needs rewriting to be consistent with the current thinking on the LGS WFS design. As of the SDR, all LGS camera heads will rotate to compensate for rotations induced by the pickoff arms.	In modes of observation where LGS are not stabilized by input K-mirror, LGS wavefront sensors must track this motion.	KAON 499 "NGAO System Architecture Definition"	Draft	1.0	Inspection	Chris Neyman	Mar 5, 2009 1:50 PM
FR-517	Type of wavefront sensor and geometry	Overall	Functional	Essential	1.2.7	The LGSWFS shall be composed of nine wavefront sensors of a Shack-Hartmann configuration, utilizing square lenslets in a rectangular array.	At this time no studies support an advantage for curvature or pyramid wavefront sensors over shack Hartmann when measuring extended laser guide stars. This may change is higher order uplink ago correction and or pulse tracking is adopted.	Engineering decision (C. Neyman)	Draft	1.0	Inspection	Chris Neyman	Mar 5, 2009 1:42 PM
FR-518	Pupil sampling	Overall	Functional	Essential	1.2.7	The pupil sampling for the LGS wavefront shall have one mode that has 64 subapertures across the Keck (10.949 m) pupil. The pupil sampling for the LGS wavefront shall have one mode that has 128 subapertures across the Keck (10.949 m) pupil. Options for other pupil sampling values are goals, exact values are TBD, but might include 48, 32, and 20 subapertures across the Keck telescope pupil.	The 64 apertures driven by the balancing of the wavefront error budget between fitting, measurement and servo bandwidth errors.	KAON 499 "NGAO System Architecture Definition"	Draft	1.0	Demonstration	Chris Neyman	Mar 5, 2009 1:41 PM
FR-519	Deployable about the field of view	Overall	Functional	Essential	1.2.7	The LGSWFS shall be able to make measurements on any LGS that is in the field of view passed by the first stage of the Cascaded Relay.	Large number of LGS need to minimize the tomography error for wide field instruments. Roving LGS needed for low tip tilt errors high sky coverage.	KAON 499 "NGAO System Architecture Definition"	Draft	1.0	Demonstration	Chris Neyman	Mar 5, 2009 1:40 PM
FR-520	Elevation distance	Overall	Performance	Essential	1.2.7	The LGSWFS shall meet its performance goals at elevations of 30 degrees and higher. Requirement for differential atmospheric refraction compensation (DAR) is TBD.	The NGAO system must meet performance when operating at low elevations.	ScRD, galactic center science case	Draft	1.0	Test	Chris Neyman	Mar 5, 2009 1:51 PM

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FR-521	LGS uplink tip tilt compensation	Overall	Functional	Essential	1.2.7	The LGSWFS shall provide a measurement of the LGS full aperture tilt for driving the LGS tip tilt control loop. This is often referred to as uplink tip tilt compensation.	Need to stabilize the LGS images on their respective wavefront sensors. The current design calls for compensation of the atmospheric tip tilt on the LGS beams to occur on the uplink just before the LGS light leaves the launch telescope. This compensation could also occur on the down link with tip tilt mirrors inside each LGSWFS channel This compensation could also occur on the down link with tip tilt mirrors inside each LGSWFS channel.	Engineering decision (C. Neyman)	Draft	1.0	Demonstration	Chris Neyman	Mar 5, 2009 1:51 PM
FR-522	Natural guide star mode	Overall	Functional	Important	1.2.7	As a goal, the channels of the LGSWFS shall be able to sense light from natural guide stars for testing purposes. There is no requirement on minimum NGS brightness. There is no requirement on measurements from multiple natural guide stars simultaneously.	Advantageous to test performance of LGS wavefront sensor on natural stars.	Engineering decision (C. Neyman)	Draft	1.0	Demonstration	Chris Neyman	Mar 5, 2009 1:51 PM
FR-523	Wavelength of operation	Optical	Functional	Essential	1.2.7	The LGS WFS optics shall be optimized for the sodium D2a line. This includes chromatic aberrations, chromatic focal shift, etc.	The LGS wavefront sensor must be optimized to work with sodium laser guider stars.	KAON 499 "NGAO System Architecture Definition", Architecture requirements summary spreadsheet (row 10) sky coverage and (row 11) high order wavefront error. wavefront error budget spreadsheet	Draft	1.0	Analysis	Chris Neyman	Mar 5, 2009 1:44 PM
FR-524	Transmission	Optical	Functional	Essential	1.2.7	The transmission of the LGS WFS shall be optimized for the sodium D2a line. See overall transmission requirements.	Need to make efficient use of expensive LGS photons.	KAON 499 "NGAO System Architecture Definition", wavefront error budget spreadsheet measurement v1.26	Draft	1.0	Analysis	Chris Neyman	Mar 5, 2009 1:43 PM
FR-525	Focus	Optical	Performance	Essential	1.2.7	The LGSWFS optics shall reimage the DM onto the LGSWFS lenslets to an accuracy of TBD mm in focus.			Draft	1.0	Test	Peter Wizinowich	Mar 5, 2009 1:52 PM
FR-526	Registration	Optical	Performance	Essential	1.2.7	The LGSWFS optics shall register the DM actuators onto the LGSWFS lenslets to an accuracy of TBD % of a subaperture.			Draft	1.0	Test	Peter Wizinowich	Mar 5, 2009 1:52 PM
FR-527	Lenslet size	Optical	Performance	Essential	1.2.7	The LGSWFS shall have lenslet arrays corresponding to 0.171 m and 0.0855 m on the telescope primary mirror. These correspond to 64 and 128 subapertures, respectively, across the primary.			Draft	1.0	Inspection	Peter Wizinowich	Mar 5, 2009 1:53 PM
FR-529	Plate scale	Optical	Performance	Essential	1.2.7	The LGSWFS shall provide a plate scale of TBD arc sec/pixel.			Draft	1.0	Test	Peter Wizinowich	Mar 5, 2009 1:53 PM
FR-530	Pixels per subaperture	Optical	Functional	Essential	1.2.7	The LGSWFS shall provide TBD pixels per subaperture.			Draft	1.0	Demonstration	Peter Wizinowich	Mar 5, 2009 1:54 PM
FR-531	Field stops	Optical	Functional	Essential	1.2.7	The LGSWFS shall provide spatial filtering with field stops.			Draft	1.0	Inspection	Peter Wizinowich	Mar 5, 2009 1:55 PM
FR-533	Static calibration errors	Optical	Performance	Essential	1.2.7	The acceptable level of static wavefront calibration errors in			Draft	1.0	Test	Chris Neyman	Mar 5, 2009 1:43 PM

Key	Name	Sect	Cat	Priority	WBS	Description	Rationale	Traceability	Status	Version	Verification	Originator	Last Modified
						the LGSWFS is TBD							
FR-534	Pupil distortion	Optical	Performance	Essential	1.2.7	The maximum pupil distortion at the LGS WFS lenslet array shall be TBD.			Draft	1.0	Test	Chris Neyman	Mar 5, 2009 1:42 PM
FR-535	WFS dynamic range	Optical	Performance	Essential	1.2.7	The dynamic range of the LGSWFS is TBD.			Draft	1.0	Analysis	Chris Neyman	Mar 5, 2009 1:44 PM
FR-536	Athermalization	Optical	Performance	Essential	1.2.7	The LGS WFS shall be able to satisfy its optical requirements at both cooled (-15° C) and ambient temperatures (0° C).			Draft	1.0	Test	Chris Neyman	Mar 5, 2009 1:42 PM
FR-537	CCD window	Optical	Functional	Essential	1.2.7	The LGSWFS flatness, wedge and AR coating requirements are TBD.			Draft	1.0	Test	Peter Wizinowich	Mar 5, 2009 1:56 PM
FR-538	Packaging	Mechanical	Functional	Essential	1.2.7	The optics, mechanisms, and electronics of the LGS WFS will be compatible with the AO enclosure and main optical relays			Draft	1.0	Inspection	Chris Neyman	Mar 5, 2009 1:47 PM
FR-539	Mechanisms	Mechanical	Functional	Essential	1.2.7	The LGSWFS shall have mechanisms for the exchange of optics for the purpose of configuring the pupil sampling and dynamic range (plate scale). These mechanisms will be controlled by AO Control (the non-RTC AO controls system).			Draft	1.0	Inspection	Chris Neyman	Mar 5, 2009 1:45 PM
FR-540	Mechanism motions	Mechanical	Performance	Essential	1.2.7	Motion control requirements for the LGS WFS: Number and type of mechanisms is TBD. Speed of mechanism motions is TBD. Accuracy of the mechanism motions is TBD. Focus tracking accuracy is TBD.			Draft	1.0	Test	Chris Neyman	Mar 5, 2009 1:45 PM
FR-541	No mechanism vignetting of optical beam	Mechanical	Performance	Essential	1.2.7	Mechanical systems inside and around the AO enclosure will not obscure the optical beam from a 202 arc second transferred field of view from the first relay and a 40 arc second transferred field of view from the second relay.	Design decision based on current AO practice.	"Cascaded Relay Requirement Flowdown and Open Issues", R. Dekany NGAO Team Meeting #9 and KAON 499 "NGAO System Architecture Definition	Draft	1.0	Test	Chris Neyman	Mar 5, 2009 1:46 PM
FR-542	Mechanism controller	Overall	Functional	Essential	1.2.7	The opto-mechanics of the LGWFS system shall be controlled remotely by the AO Controls system.	Design decision based on current AO practice.	"Cascaded Relay Requirement Flowdown and Open Issues", R. Dekany NGAO Team Meeting #9 and KAON 499 "NGAO System Architecture Definition	Draft	1.0	Demonstration	Chris Neyman	Mar 5, 2009 1:57 PM
FR-543	CCD requirements	Overall	Performance	Essential	1.2.7	The LGSWFS CCD requirements (pixel size, dark current, read noise, and quantum efficiency) are TBD at this time.			Draft	1.0	Test	Chris Neyman	Mar 5, 2009 1:46 PM
FR-544	Mechanism control software	Software	Functional	Essential	1.2.7	The mechanism control software for the LGS WFS will be part of the AO Controls system.	Design decision based on current AO practice.	"Cascaded Relay Requirement Flowdown and Open Issues", R. Dekany NGAO Team Meeting #9 and KAON 499 "NGAO System Architecture Definition	Draft	1.0	Demonstration	Chris Neyman	Mar 6, 2009 10:08 AM

Key	Name	Sect	Cat	Priority	WBS	Description	Rationale	Traceability	Status	Version	Verification	Originator	Last Modified
FR-545	LGSWFS Control	Software	Functional	Essential	1.2.7	The focal plane arrays that are part of the LGS WFS shall be remotely controlled by the AO Controls system and send pixel data streams to the AO system RTC.	Design decision based on current AO practice.	"Cascaded Relay Requirement Flowdown and Open Issues", R. Dekany NGAO Team Meeting #9 and KAON 499 "NGAO System Architecture Definition	Draft	1.0	Demonstration	Chris Neyman	Mar 6, 2009 10:09 AM
FR-546	Interface to AO Controls	Interface	Interface	Essential	1.2.7	The LGSWFS shall have an interface to the AO Controls system. All motion control and configuration of the LGSWFS subsystem (including plate scale selection, camera setup, frame rate, input optical pickoff, etc.) shall be done by AO Controls. Subsystem health and status information shall be reported to the AO Controls system.	Design decision based on current AO practice.	"Cascaded Relay Requirement Flowdown and Open Issues", R. Dekany NGAO Team Meeting #9 and KAON 499 "NGAO System Architecture Definition	Draft	1.0	Demonstration	Chris Neyman	Mar 6, 2009 10:11 AM
FR-547	Interface to AO acquisition system	Interface	Interface	Essential	1.2.7	The LGSWFS shall have an interface to the AO acquisition system, the subsystem of the AO Controls system that is responsible for coordinating this task between AO subsystems, and the telescope.	Design decision based on current AO practice.	"Cascaded Relay Requirement Flowdown and Open Issues", R. Dekany NGAO Team Meeting #9 and KAON 499 "NGAO System Architecture Definition	Draft	1.0	Inspection	Chris Neyman	Mar 6, 2009 10:10 AM
FR-548	Interface to AO real-time control system	Interface	Interface	Essential	1.2.7	The LGSWFS shall have an interface to the AO real-time control system. The pixel data from the LGSWFS focal planes will be routed to the RTC for the purpose of reconstruction the wavefront.	Design decision based on current AO practice.	"Cascaded Relay Requirement Flowdown and Open Issues", R. Dekany NGAO Team Meeting #9 and KAON 499 "NGAO System Architecture Definition	Draft	1.0	Demonstration	Chris Neyman	Mar 6, 2009 10:11 AM
FR-1366	turntable	Overall	Functional	Essential	1.2.7	The LGS WFS module with 9 LGS WFS's shall be mounted on a turn-table. This needs rewriting to be consistent with the current thinking on the LGS WFS design. As of the SDR, all LGS camera heads will rotate to compensate for rotations induced by the pickoff arms.	Even if the asterism is fixed w.r.t. the sky there are observations with the pupil being fixed which will need this mode	KAON 499 "NGAO System Architecture Definition"	Draft	1.0	Inspection	Viswa Velur	Mar 6, 2009 10:13 AM
FR-1526	Acquistion accuracy	Overall	Performance	Essential	1.2.7	Acquisition accuracy of the LGS WFS shall be better than 100 mili arc seconds	Requirement needs to be flown down to the (probe arm) the WFS channel, the uplink TT mirror and the requirement on asterism deformation	Anna Moore's OSM KAON, *in press*	Draft	1.0	Test	Viswa Velur and Anna Moore	Mar 6, 2009 10:12 AM
FR-1527	Dither accuracy	Overall	Performance	Essential	1.2.7	The LGS asterism must be counter dithered when the laser follows the source to 100 mili arc seconds accuracy (TBD).	Dithers where the lasers asterism needs to be fixed on sky WRT the source; it needs this requirement	rainbow chart	Draft	1.0	Demonstration	Viswa Velur & Anna Moore	Mar 6, 2009 10:13 AM