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Revision History		
Revision	**Name**	**Comments**
1.0	D. Copley	Initial Version
2.0	D. Copley	Updated wording of many requirements for clarification and changed the following (as per change process) NRT_CR8
2.1	D. Copley	Minor edits prior to upload to Cosmo-sys system
3	D. Copley	General edits incorporating project progress and recent considerations. Adding detail and rationale to many requirements

List of Abbreviations

A&G/AG	Acquisition & Guidance
AcO	Active Optics
CAD	Computer Aided Design
CCI	International Scientific Committee
CIR	Cassegrain Instrument Rotator
DC	Direct Cassegrain
DCP	Direct Cassegrain Port
EE	Encircled Energy
EE80	80% EE
EFL	Engineering First Light
EU	European Union
FEA	Finite Element Analysis
FMEA	Failure Mode Effects Analysis
FoV	Field of View
FP	Folded Port
FWHM	Full Width Half Maximum
GTC	Gran Telescopio de Canarias
H&S	Health & Safety
ID	Identifier
IQ	Image Quality
LT	Liverpool Telescope
M1	Primary Mirror
M2	Secondary Mirror
MOU	Memoranda of Understanding
NF	Narrow Field
NRT	New Robotic Telescope
NS	Non-sidereal
OCD	Operational Concept Document
ORM	Observatorio Roque de los Muchachos
OSS	Optical Support System
PDR	Preliminary Design Review
PLC	Programmable Logic Controller
RMS	Root Mean Squared
SC	Science Case
SE (SE's)	Systems Engineering (Systems Engineers)
SH	Shack Hartmann
SLR	System Level Requirement(s)
SR	Science Requirements
SSA	Segment Support Assembly
SUCOSIP	Site Properties Sub-Committee
S/W	Software
TLS	Telescope Level Systems
ToO	Target of Opportunity
WF	Wide Field
WFS	Wave Front Sensor
WP	Work Package

Contents

1 Reference Documents

RD	Title	Code
RD01	Science Case Document	NRT-LJMU-SCI-RS-1
RD02	Operations Concept Document	NRT-LJM-ENG-RS-2
RD03	Science Requirements Document	NRT-LJM-SCI-RS-2
RD04	System Level Requirements	NRT-LJM-ENG-RS-3
RD05	Phase A Study	NRT-LJM-SCI-RS-2
RD06	List of Abbreviations	NRT-LJM-MNG-LI-4
RD07	Optical Design Document	NRT-LJM-OPT-RP-3
RD08	Optical prescription layout drawing	NRT-LJM-OPT-DR-3
RD09	Environmental conditions document	NRT-LJM-ENG-TN-4
RD10	Optical Error budget	NRT-IAC-ENG-DD-1
RD11	Telescope clear sweep drawing	NRT-LJM-ENC-DR-1
RD12	Low level control architecture document	NRT-LJM-SWC-DC-2
RD13	CAD standards and conventions document	NRT-LJM-ENG-DC-1
RD14	Electrical standards and conventions document	NRT-LJM-ENG-DC-2
RD15	Software architecture document	NRT-LJM-SWC-DC-3
RD16	Software Practices	NRT-LJM-SWC-DD-2
RD17	Infrastructure and Tooling choices	NRT-LJM-SWC-RP-3
RD18	Generic Instrument Requirements Document	NRT-LJM-IN1-RS-2

2 Document Overview

This document is one of the top-level "Foundation Documents" that define the New Robotic Telescope project. The scope of each document is as follows:

- The Science Case Document (NRT-LJMU-SCI-RS-1) provides a summary description of the scientific questions the telescope science team have identified in time domain astrophysics that the telescope aims to address.
- The Operations Concept Document (NRT-LJM-ENG-RS-2) expresses the stakeholders' intentions for the telescope. It provides a high-level summary of the project organization, site constraints and scientific and technical operational plans.
- The Science Requirements Document (NRT-LJM-SCI-RS-2) provides a set of high-level science requirements of the telescope and observatory that are informed by the Science Case and the Operations Concept.
- The System Level Requirements Document (NRT-LJM-ENG-RS-3) (This document). Contains top-level engineering requirements for the telescope and observatory necessary to deliver the Science Requirements and Operations Concept.

3 Introduction

This document is the System Level Requirements Document (SLRD). It is a systems engineering requirements document and is the project's response to the Science Requirements Document (SRD), detailed in the initial phase A review and updated and maintained as part of NRT-LJM-ENG-RS-1, Operations Concept Document (OCD, NRT-LJM-ENG-RS-2), and the Science Case (SC), as part of the phase A review and PPRP submission. The concepts and requirements in these documents flow down to requirements for the observatory (system).
As necessary, requirements from this document flow down requirements to each of the subsystems.
The requirements in this document are numbered in the form of SlrReq:XYZ, where XYZ is the unique alias for each of the requirements. The numbering scheme allows for unambiguous reference to individual requirements.

4 Purpose

This document shall be used as guidance for the system and subsystem level engineering functional and performance requirements of the NRT Observatory.
The requirements documented herein are intended to fully describe the system level engineering requirements to satisfy the criteria of the OCD, SC and SRD. The SLR document will change in response to changes in the OCD and/or SR but should not require modification due to changes in the subsystem requirements documents.

5 Scope

This document contains high-level requirements specific to the NRT. It is site-specific to the ORM.

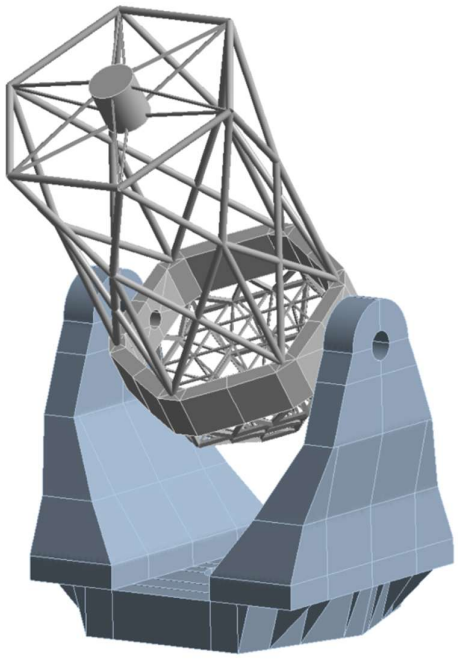
The following areas are defined:
• General Constraints.
• Environmental Constraints.
• Environmental, Health and Safety Requirements.
• System Attributes.
• High Level Software Requirements.
• Telescope and Instrumentation Requirements.
• Facility and Enclosure Requirements.
• Observation Operational Support Requirements.

• Requirements to meet Standards.
• Utility Requirements.
• Reliability and Maintenance Requirements.

6 System Description

The planned NRT is a 4-metre class altitude-azimuth telescope following the Liverpool Telescope's heritage of a fully robotic autonomous observing model. In operation it will be used to conduct a broad range of astronomical scientific research at visible and near infrared wavelengths at its site on La Palma de Canarias at the ORM.

The telescope concept is shown below.



NRT is designed around a ~4m diameter primary mirror made up of 18 hexagonal segments. The collecting area of the segmented design is roughly equivalent to a 4m diameter mirror.

NRT consists of an alt-az mount to support the assemblies and science instruments while providing the ability to acquire and track targets over the majority of the visible sky.

The mount consists of two rotating structures. The Optical Support Structure (OSS) moves in elevation and houses all the telescope optics and instruments located at the Cassegrain focal station and folded Cassegrain ports. The azimuth structure rotates and supports the OSS.

The NRT will not use Nasmyth mounted instruments, and no Nasmyth fold mirror design will be progressed. The platforms at the outer side of the altitude bearings (mount interface to OSS) will be used as part of the mirror segment replacement procedure for access and mounting the required lifting equipment.

Actuators in the primary and secondary mirrors control mirror position and alignment and counteract slowly varying gravity and thermal deflections of the structure and maintain the alignment of the telescope optics in real time. Segment position is fed back via sensors mounted to each segment. A

wavefront sensor in the focal plane provides error signals to allow primary mirror segment alignment before and observing period begins (no simultaneous observing with wavefront sensing planned).

7 NRT Co-ordinate systems

There are two principal sets of Cartesian coordinates fixed to the physical structure of the telescope: one (x,y,z) to the OSS where the elevation axis crosses the azimuth axis and the other (u,v,w) to the Azimuth Platform. These are described in the NRT Coordinate Systems and Vertical Datum (NRT-LJM-ENG-TN-2).

The Reference for the optical surface is the Vertex of the M1 where:

- The X axis is parallel to the elevation bearing axis.
- The Y axis is at right angles to the X axis and points to the sky when the telescope is horizon pointing.
- The Z axis runs along the optical axis towards the M2.

8 Functional and Performance Requirements

8.1 Telescope

NRT is a next-generation 4m-class telescope intended for astronomical scientific research at UV, visible, near infrared wavelengths.The telescope will be located on the island of La Palma de Canarias at the ORM.
A suite of instruments will allow a flexible program of observations that address the science goals set out in the Science Requirements (presented as part of the phase A study) detailed in NRT-LJM-SCI-RS-2.

8.2 Observing Modes

The default NRT observing mode will be a robotic, autonomous software control mode to enable the science goals of the observatory to be met and ensuring efficient science programme. Software controlled observing shall include ToO behaviour to follow up transient sources.

Local control observing will allow a more traditional manual observing mode where science operations are controlled interactively from site or remotely.

The modes differ in the manner and degree to which systems operate without user interaction or in the presence of interlocks but all control systems shall be capable of self-healing from error states (where possible).

SIrReq:ROM: Robotic Observer Mode
Shall provide a fully autonomous science operations mode using an intelligent scheduler within a Robotic Control System (RCS) layer (acting as the traditional manual operator) as defined in the NRT software architecture document NRT-LJM-SWC-DC-3. This mode shall allow observation of targets triggered by prioritised external alerts as Target of Opportunity (ToO) inputs.
Rationale: This requirement is a flow down from the OCD, section 5.1.5 and is based on LT heritage as a robotic, autonomous facility.

SIrReq:HOM: Human Observer Mode
The NRT shall provide a manual observing mode for performing science operations interactively by a person on site or remote over internet. All mechanisms shall be interlocked from human access.
Shall provide an investigator-directed remote observing mode with user either on site or remote

Rationale: This requirement is a flow down from the OCD, section 5.1.6.

SlrReq:SOB: Simultaneous Observing Mode
Shall provide a means of coordinating observations with other telescopes (LT and external observatories) within 10sec.
Rationale: This requirement is a flow down from the OCD, section 1.4.

9 Architecture

This section includes the requirements for the architecture of the NRT.

SlrReq:TSC: Telescope Configuration
NRT shall have an altitude over azimuth structure with the primary mirror offset from (below) the elevation axis.
Rationale: This is a design choice adopted and approved by the NRT Board. See Document Number: NRT40-01-80-0002-0-1.

SlrReq:COD: Cassegrain Optical Design
The NRT optical system shall be based on a modified Ritchey Chretien Cassegrain prescription with segmented primary and monolithic secondary mirrors as specified in the Optical Design document NRT-LJM-OPT-RP-3.
Rationale: This is a design requirement adopted and approved by the NRT Board. See Document Number: NRT40-01-80-0002-0-1.

SlrReq:OP: Optical Prescriptions
The NRT optical system shall be designed with multiple configurations according to the prescriptions specified in the optical prescription summary document NRT-LJM-OPT-RP-3.
Note: There are two optical configurations specified in this document:
• Direct Cassegrain Port (DCP) of 30arcmin diameter
• Folded Cassegrain Ports (FCP) of 14arcmin diameter
Rationale: This requirement is a flow down from the OCD, section 7.9. This provides a flexible, concurrently mounted instrument suite for a variety of science programs outlined in the Science Case.

9.1 Telescope

SlrReq:TM1: Primary Mirror (M1) Configuration
The NRT shall be designed around a segmented M1 primary mirror consisting of 18 hexagonal, 960mm segments arranged in a circular, 2-ring configuration. Note: The layout is shown in NRT-LJM-OPT-RP-3.
Rationale: This is a design requirement adopted and approved by the NRT Board NRT40-01-80-0002-0-1.

SlrReq:TM2: Steerable Secondary Mirror
The NRT shall provide a secondary mirror composed of a single monolithic blank with tip-tilt and piston capability to aid pointing, focus adjustment and de-centre compensation due to gravity induced tube deflection.
Rationale: This requirement is a flowdown from the OCD, section 3.4. This mirror assembly will be used for initial commissioning of NRT. The diameter and clear aperture are detailed in the optical prescription summary document NRT-LJM-OPT-RP-3.

SlReq:TIS: Incomplete Telescope Segmentation
To the extent practical, NRT systems shall be operable with only an inner row of M1 mirror segments during the commissioning or laboratory test period. First light will be performed with less than the full complement of M1 mirror segments with the inner row as a minimum.
Note: The performance of some systems will be degraded when operating in this mode. This mode is intended to aid in the integration and commissioning phase.
Alignment of the Telescope will be challenging without the full M1 mirror complement.
Rationale: This requirement is a flow down from the OCD, section 5.5. This is to allow Telescope commissioning to start prior to the delivery of all segments.

SlrReq:SFM: Science Fold Mirror
NRT shall provide a deployable monolithic flat mirror to direct the beam to instruments located at the folded Cassegrain ports (FCP).
Note: Fold mirror must be deployable so that it can be removed from the beam for 'straight through' instrument operation. The diameters and clear apertures of the fold mirror are detailed in the optical prescription summary document NRT-LJM-OPT-RP-3. The position and size of the fold mirror are constrained by allowing the optical path to the autoguider while it is in a deployed position. See SlrReq:AGWS and OCD section 3.4.
Rationale: This requirement is a flow down from the OCD, section 4.1 and section 3.4 to provide instrument folded ports and flow down from SR, sciReq:instuments:no.

SlrReq-FSIP: Focal Station Instrument Ports
NRT shall provide seven (7) stations for mounting Science Instruments on the telescope.
Note: The required focal stations are: a) the Direct Cassegrain Port (DCP) with a single port and b) six Folded Cassegrain Ports (FCPs). Note: 'science-support' instrument may occupy the folded ports to support operational functionality (for example, WFS) - See SlrReq:AOWFS.
Rationale: This requirement is a flow down from the SR, sciReq:instruments:no. This is a design requirement adopted and approved by the NRT Board. See Document Number: NRT40-01-80-0002-0-1.

SlrReq-IM: Instrument Mounting
NRT shall provide required services and mounting points at all instrument ports to allow commissioning of new instrument without re-work of service routing or modification to the OSS or focal station structure. Requirements are detailed in the generic instrument requirements document – NRT-LJM-IN1-RS-2.
Rationale: This requirement is a flow down from the OCD, section 7.9. This allows for rapid installation of instruments and ability to move instruments between ports where required.

SlrReq:CFSIR: Cassegrain Focal Station Instrument Rotator (CIR)
NRT shall provide a CIR to compensate for field rotation due to the alt-azimuth tracking motion of the telescope at sidereal and non-sidereal rates and deliver a non-rotating field of view to DCP and FCP Science Instruments mounted on the rotator.
Rationale: The CIR provides field de-rotation for Science Instruments mounted at the DCP and FCPs. Providing field rotation at the telescope rather than on each instrument port delivers the low cost, simple instrument suite described in OCD section 4.1.

SLReq:WFC : Wide Field Correction
The NRT shall provide field dependent aberration correction over the full FoV at the DCP over the full wavelength range specified in SlrReq:DCPWC.
Note: The wavelength range is also specified in requirement SciReq:wavelength.
Rationale: This is required to meet image quality requirements for fields of view (SR sciReq:fov) up to 30' diameter. This requirement flowed down from SR sciReq:iq.

SlrReq:AGWS: Acquisition, Guide, and Wavefront Subsystem
NRT shall include 'science-support' instruments within the OSS Focal Station A&G box. These will include the Autoguider (AG) and Wavefront Sensor (WFS) to support guiding functionality and primary mirror alignment respectively. The autoguider shall be positioned to allow guiding while any instrument is in use (regardless of fold mirror position).
Rationale: The Autoguider supports the acquisition and guide function for the telescope and is a derived requirement to meet the imaging and pointing performance specifications. The WFS supports primary mirror alignment to meet image quality requirements therefore, is also derived from SR sciReq:iq.

SlrReq:MC: Mirror Cover
NRT shall provide a mirror cover for the primary mirror that can protect the mirror from small debris and be efficiently deployed for daily use and fails safe (closed) in a loss of power event.
Rationale: This requirement is a flow down from the OCD, section 3.2 and section 7.2. Mirror covers will help protect from damage and preserve the quality of the mirror coatings, minimize scattered light and will extend the period between cleanings and re-coatings. With a fully open enclosure this also reduces risk to the mirror in an enclosure 'fail to close' scenario.

SlrReq:TB: Telescope Balance
NRT OSS shall be neutrally balanced around the elevation axis to ensure little to no movement of the tube if power is lost (within a couple of degrees) and to reduce Altitude torque requirements/control performance.
Rationale: This is required to protect the telescope in a 'loss of power' event but also to reduce control complexity and motor cost.

SlrReq:TBA: Telescope Balance Adjustment
The telescope shall provide a means to make minor adjustments to the balance of the Optical Support Structure (OSS) and Focal Station when instrument changes impact the OSS CoG position to maintain the neutrally balanced state.
Note: The method for re-balancing during instrument changes will be designed to minimize lost observing time and simple to adjust for operations personnel.
Rationale: This is required to accommodate varying instrument masses, moments and maintain pointing and tracking performance.

9.2 Calibration Systems

A facility calibration system will be provided, per the requirements below, that is available to all instruments. Instruments with additional calibration requirements will provide the capability as part of the instrument system.

SlrReq:Mcal: Mirror Calibration
NRT shall provide, at the telescope, a system for calibrating all mirror positions and wavefront sensors required by the observing modes.
Rationale: This requirement is a flow down from the OCD, section 7.10.

9.3 Optical

The NRT optical system consists of a segmented primary mirror (M1) and a monolithic secondary mirror (M2) that deliver light to a variety of instrument ports with various fields of view and at a wavelength range to enable a wide range of science capabilities. The steerable Secondary Mirror (M2) is a single monolithic mirror. A flat fold mirror is used in FC configurations to send the beam to instrument stations located around optical Axis. Wide-field operation up to 30 arcmin diameter field of view is available at the DCP. The optical prescription for NRT is specified in the optical prescription summary document NRT-LJM-OPT-RP-3.

Many of the following requirements are derived from OCD the Image Quality Error Budget document NRT-IAC-ENG-DD-1. The sources of image blur allocated in the budgets include optical design, optical fabrication, thermal and gravitational distortion of optical elements, alignment, tracking errors, vibrations in the telescope structure, and mirror seeing. The total delivered image quality to science instruments is the RSS of telescope sources of blur and the natural seeing. The conditions under which the image budgets were derived are:

- Zenith angle: 90 degrees.
- Wind speed: 4ms.
- Temperature range: 0-20^{o}C.
- Primary mirror configuration.
    - Segmented and co-aligned (unphased).

9.3.1 Configurations

9.3.1.1 Direct Cassegrain (DCP)

The Direct Cassegrain Port (DCP) optical configuration consists of the segmented primary (M1) and monolithic secondary (M2) mirror, as described in the optical prescription summary document NRT-LJM-OPT-RP-3. The DCP configuration delivers a nominal optical beam to Science Instruments mounted at the DCP.

SIrReq:DCPWC: DCP Wavelength Coverage
NRT shall provide wavelength coverage of 0.33 to 2.0um at the DCP.
Rationale: This requirement is a flow down from the OCD, section 1.1 and SR sciReq:wavelength.

SIrReq:DCPFoV: DCP Science Field of View
NRT shall provide 14arcmin diameter (target), 10arcmin (base) at the DCP.
Rationale: This requirement is a flow down from the OCD, section 7.9 and SR sciReq:fov.

SIrReq:DCPIQ: DCP Optical Image Quality
NRT shall ensure < 0.3 arcsec deterioration of site seeing at 80% EE at the FCP [goal: <0.2] which shall cover 99% (3 sigma) of cases (across field). This allows 0.9arcsec from all error sources (RSS). Expected errors are distributed between sources and detailed in the Image Quality Error Budget NRT-IAC-ENG-DD-1.
Note: Total allowable error can be calculated from $RSSerror80EE = \sqrt{(1.6^2 - 1.3^2)}$ where 1.3'' is the median seeing 80EE at the ORM (650nm) and 1.6 represents the addition of 0.3 to the seeing i.e. 1.3+0.3arcsec.
Rationale: This requirement is a flow down from the OCD, section 3.1 and SR sciReq:iq.

9.3.1.2 Folded Cassegrain Port (FCP)

The Folded Cassegrain optical configuration consists of the segmented primary (M1) and secondary (M2) mirror and flat fold mirror as described in the optical prescription summary document NRT-LJM-OPT-RP-3. The fold mirror is deployed by a mechanism that inserts it in the DC beam and redirects the beam to one of six available FCPs.
The FCP configuration delivers a nominal optical beam with science Instruments mounted at the FCP. The position and curvature of the FCP focal surface is not required to be coincident with the DCP focus. Instruments will, in general, be designed for one or the other configuration or will be able to compensate for the difference.

SIrReq:FPWC: FCP Wavelength Coverage
NRT shall provide wavelength coverage of 0.33 to 2.0um at the FCP.
Rationale: This requirement is a flow down from the OCD, section 1.1 and SR sciReq:wavelength.

SlrReq:FPFoV: FCP Science Field of View
NRT shall provide 14arcmin (target) and 10arcmin diameter (base) at the FCP.
Rationale: This requirement is a flow down from the OCD, section 7.9 and SR sciReq:fov.

SlrReq:FPIQ: FCP Optical Image Quality
NRT shall ensure < 0.3 arcsec deterioration of site seeing at 80% EE at the FCP [goal: <0.2] which shall cover 99% (3 sigma) of cases. This allows 0.9arcsec from all error sources (RSS). Expected errors are distributed between sources and detailed in the Image Quality Error Budget NRT-IAC-ENG-DD-1.
Note: Total allowable error can be calculated from $RSSerror80EE = \sqrt{(1.6^2 - 1.3^2)}$ where 1.3" is the median seeing 80EE at the ORM (650nm) and 1.6 represents the addition of 0.3 to the seeing i.e. 1.3+0.3arcsec. The FCP budget shall include terms for the fold mirror error and contribution from differential flexure when guiding.
Rationale: This requirement is a flow down from the OCD, section 3.1 and SR sciReq:iq.

9.3.2 Throughput and Stray Light

High reflectivity, low emissivity mirror coatings that cover the operating spectral range are important for meeting the science objectives of NRT. Achieving and maintaining coating performance in service is a key project objective. The primary segments and secondary mirror will be coated with aluminium providing spectral coverage from the atmospheric cut-off out to 2.5microns. A coating chamber at the ORM will be used to coat the primary segments and secondary mirror.

The fold mirror may be coated at the same facility but could be sent off the island due to its size (if a spare is available so as not to increase telescope time off sky).

The requirements below show the expected throughput of the NRT optical system for the baseline coatings. Values for freshly coated surfaces and expected degraded performance over time are based on operational experience on other telescopes.
The total emissivity of the NRT optics is assumed to be 1.0 minus the throughput (transmission) values. The emissivity will vary considerably depending on the condition (fresh vs. aged) of the Coatings.

SlrReq:M1M2thro: M1/M2 System Throughput
The NRT M1 and M2 mirror system shall meet or exceed the average throughput value of 85%.

Note: In operation, coatings for each mirror segment will be applied at different times; therefore, the overall throughput will be less than the specification for fresh coatings.
These requirements will be met by a schedule of periodic cleaning and re-coating of the telescope mirrors. The specification does not include losses in the instruments. The specifications are generally achievable in practice with high quality aluminium coatings.
Rationale: This requirement is a flow down from the OCD, section 3.2. This requirement is derived from actual coating performance data for aluminium coatings on optics.

SlrReq:Fthrou: Fold Mirror Throughput
The NRT fold mirror shall meet or exceed the throughput target of 85%.
Rationale: This requirement is a flow down from the OCD, section 3.2.

SlrReq:AGthrou: AG Pickoff Mirror Throughput
The NRT Autoguider pick off mirror shall meet or exceed the throughput target of 85%.
Rationale: This requirement is a flow down from the OCD, section 3.2.

SlrReq:Baff: Optical Baffling System
Optics shall include baffles that prevent off axis rays impacting the focal plane.
Rationale: This is required to minimize sky background.

9.3.3 Thermal

SlrReq:AHS: Active Heat Sources
The NRT shall provide cooling or remove warm air from sources of heat where required and exhaust waste heat from concentrated sources that could measurably degrade image quality.
Note: Exception - Equipment with very low duty cycles such as cranes and lift platforms and equipment only operated when not observing is exempt.
Rationale: This requirement is a flow down from the OCD, section 3.1. Heated air migrating in front of the telescope will degrade imaging performance.

SlrReq:THS: Total Heat Sources
The total heat released from active sources within the telescope chamber shall not exceed the allowable error contributor defined in the Image Quality Error Budget - NRT-IAC-ENG-DD-1
Note: Active sources include electrical equipment, drive mechanisms, instrumentation, pumps and coolers. This is a particular consideration for placement of motor drives close to the optical path.
Rationale: This requirement is a flow down from the OCD, section 3.1. Non-ambient thermal conditions inside the telescope enclosure may degrade imaging performance, especially if they are concentrated heat sources.

SlrReq:TEIQ: Telescope Thermal Effects on Image Quality
Telescope thermal effects shall contribute no greater than the allocated error contribution for the individual elements as defined in the Image Quality Error Budget- NRT-IAC-ENG-DD-1
Note: Thermal effects include primary mirror figure, mirror seeing, and mount expansion effects after correction. This source of image enlargement is combined in RSS with other contributors in the Image Quality budgets.
Rationale: This requirement was derived from the Error Budget analysis - NRT-IAC-ENG-DD-1.

9.3.4 Structural

SlrReq:WDEIQ: Wind Disturbance Effects on Image Quality
NRT shall be designed such that wind disturbance of the telescope structure (windshake) contributes no greater than the allocated error in arcsec 80% EE diameter, to the Image Quality budget - NRT-IAC-ENG-DD-1.
Note: Wind disturbance errors include M1 figure, optical alignment and pointing, and focus. This source of image enlargement is combined in RSS with other contributors in the Image Quality budgets.
Rationale: This requirement was derived from the Image Quality Error Budget analysis.

SlrReq:SVEIQ: Structure Vibration Effects on Image Quality
The NRT shall be designed such that vibrations transmitted through the telescope structure contribute no greater the allocated error in arcsec 80% EE diameter, to the Image Quality budget - NRT-IAC-ENG-DD-1.
Note: This includes vibrations transmitted from the enclosure through the pier due to wind and rotation, and vibrations due to mechanical equipment on and off the telescope.
This source of image enlargement is combined in RSS with other contributors in the Image Quality budgets.
Rationale: This requirement was derived from the Image Quality Error Budget analysis.

9.3.5 Motions

The azimuth and elevation mounts comprise the main axes of NRT and move to allow the telescope to point at all positions within the observing range for science operation and up to the zenith for maintenance. The focal station rotator will move to compensate for field rotation caused by the azimuth elevation mount movement.

SlrReq:TST: Telescope Slew Times
The NRT shall not exceed the slew time of 20 seconds when re-pointing the telescope between any two positions within the permitted azimuth and elevation and instrument rotator angles.
Rationale: This is a flowdown from OCD, section 3.4 and SR sciReq:slewtime. This slew time is derived from conceptual designs of the telescope mount to determine maximum achievable jerk, acceleration and speed conditions. This target forms part of the time to target science requirement and precedes the settling case in the largest travel range (azimuth 180 degree rotation). This target does not include events where the azimuth axis needs to unwrap the cable twister.

SlrReq:ST: NRT Sidereal Tracking
The NRT shall support tracking at the sidereal rate over the full range of azimuth and elevation angles.
Rationale: This requirement is a flow down from the OCD, section 3.4. This is required to accurately track objects at sidereal rates.

SlrReq:NST: NRT Non-Sidereal Tracking
The NRT shall support tracking over the full range of azimuth and elevation angles at /better than 0.2arcsec over one hour moving at 15arcsec/sec.
Rationale: This requirement is a flow down from the OCD, section 3.4 and SR SciReq:nonsidereal. This is required to accurately track objects at non-sidereal rates.

SlrReq:TFR: Track at fixed derotator (Rotator Axis PA)
The NRT shall include a mode of operation in which the Cassegrain rotator shall be able to be fixed stationary while pointing axes track targets.
Rationale: This use case is based on experience from Liverpool Telescope operations.

SlrReq:TCSR: Track at constant sky orientation (Rotator Sky PA)
The NRT shall include a mode of operation in which the Cassegrain rotator shall be able to coordinate with pointing axes to keep image orientation fixed on the focal plane.
Rationale: This use case is based on experience from Liverpool Telescope operations.

SlrReq:RF: Rotator FLOAT
The NRT Cassegrain rotator shall be able to start or stop tracking sky rotation from whatever location it may be in.
Rationale: This use case is based on experience from Liverpool Telescope operations.

9.3.5.1 Ranges

SlrReq:AzRange: Azimuth Observing Range
The NRT mount shall provide an observing range of azimuth motion of +/-270 degrees.
Note: This is the permitted range for science observing. Pointing and tracking specifications are valid in this range.
Rationale: This is the derived range of motion needed to achieve the sky coverage defined in the SR sciReq:skyaccess and OCD section 1.1.

SlrReq:ElvRange: Elevation Observing Range
The NRT mount shall provide an observing range of elevation motion of 20.0 - 88.0 degrees [Goal: 20.0 - 89.0 degrees].
Note: This is measured from elevation = 0° (horizon pointing) to elevation = 90° (zenith). This is the permitted range for science observing. Pointing and tracking specifications are valid in this range.
Rationale: This is the derived range of motion needed to achieve the sky coverage defined in the SR SR sciReq:skyaccess and OCD section 1.1.

SlrReq:EAZ: Elevation Access to Zenith
The NRT shall provide stationary access to 90.0 degrees elevation.
Note: This is the elevation stow position of the telescope.
Rationale: This is needed for calibrations, M1 segment changes, instrument changes, and other service operations. This is a flow down from OCD section 7.1, 3.2.

SlrReq:CIRRange: CIR Observing Range
The NRT shall have a minimum Cassegrain Instrument Rotator (CIR) range of motion of +/-270 degrees for observing.
Note: This is the permitted range for science observing. Pointing and tracking specifications are valid in this range. This observing range does not include margin to reduce the frequency of "unwrap" conditions when slewing to new targets.
Rationale: This is the derived range of motion needed to achieve uninterrupted observing as defined in the OCD section 1.1 and SR sciReq:access.

9.3.5.2 Blind Pointing

SlrReq:IBP: Initial Blind Pointing
Shall provide a target acquisition camera to allow acquisition of position reference stars for initializing and calibrating the telescope pointing system from a cold start.
Rationale: This requirement is a flow down from the OCD, section 3.4 and SR sciReq:pointingblind.

SlrReq:BPA: Blind Pointing Accuracy
The NRT shall blind point to targets on the sky with a pointing error less than 5.0 arcsec rms over the full range of telescope azimuth and elevation angles.
Rationale: This requirement is a flow down from the OCD, section 3.4 and SR sciReq:pointingblind.

SlrReq:Padj: Pointing Adjustment
The NRT shall use an M2 Hexapod to make minor corrections to pointing error with adjustment range required by the adjustments and offsets required by the relevant science requirements.
Rationale: This requirement is a flow down from the OCD, section 3.4 and SR sciReq:pointingfield.

9.3.5.3 Pointing

SlrReq:CPM: Creating pointing model
The NRT shall provide an interactive mechanism for construction of astrometric pointing models. (I.e., map axis coordinates to sky pointing residuals for later offline fitting).
Rationale: This requirement is a flow down from the OCD, section 3.4 to allow creation of and adjustments to the pointing model to achieve pointing and image quality requirements.

SlrReq:PMC: Pointing model changes
Shall permit changes to pointing model while system is operational to apply intra-night changes.
Rationale: This requirement is a flow down from the OCD, section 3.4 to allow creation of and adjustments to the pointing model to achieve pointing and image quality requirements.

SlrReq:PADC: Pointing Accuracy at instrument ports
Repeatability and stability of all deployment and positioning mechanisms in the optical path shall be such that the ten-minute time-averaged relative pointing shifts between instrument and autoguider focal planes not exceed the allocated error budget value.
Rationale: This requirement is a flow down from the OCD section 3.4 and SR sciReq:guided.

9.3.5.4 Tracking

SlrReq:DCTS: DCP Tracking Stability
Tracking errors shall contribute no greater than the allocated error in arcsec 80% encircled energy diameter in the DCP Image Quality Budget - NRT-IAC-ENG-DD-1
Rationale: This requirement was derived from the Error Budget analysis - NRT-IAC-ENG-DD-1.

SlrReq:FPTS: FCP Tracking Stability
Tracking errors shall contribute no greater than the allocated error in arcsec 80% encircled energy diameter to the seeing-limited FCP Image Quality Budget - NRT-IAC-ENG-DD-1
Rationale: This requirement was derived from the Error Budget analysis - NRT-IAC-ENG-DD-1.

9.3.6 Instrument Ports

SlrReq:FSinstMass: Total Instrument Mass of Cassegrain Focal Station
The NRT shall allow up to 560kg total instrument mass distributed across all available instrument ports at the Cassegrain Focal Station.
Note: This does not include the Autoguider.
Rationale: This is a flow down from the SR sciReq:massspace. A maximum instrument mass is required to ensure total instrument mass across all available ports is within the structural/performance limits of the A&G box and the OSS remains balanced.

SlrReq:IPDC: Number of DCP Instruments
The NRT shall allow 1 instrument to be mounted at the DCP.
Rationale: This requirement is a flow down from the OCD, section 7.9 and SR sciReq:massspace.

SlrReq:PMassInst: Total Mass and envelope of DCP Instruments
The NRT DCP will support a science instrument up to 120kg with a maximum envelope of 1.4x1.4x1.8m (target), 1.4x01.4x1.0m (base).
Rationale: This requirement is a flow down from the OCD, section 7.9 and SR sciReq:massspace.

SlrReq:DCPE: Exchanging DCP Instruments
The NRT shall provide mechanism(s) for inserting/removing installed DCP instruments between DCP and FCPs.
Rationale: This requirement is a flow down from the OCD, section 7.8 and 7.12.

SlrReq:DCPET: Time to Exchange DCP Instruments
The NRT shall allow the ability to exchange installed DC instruments in a typical single day shift to reduce time off sky during instrument commissioning.
Rationale: This requirement is a flow down from the OCD, section 7.5 and 7.6.

SlrReq:FSIP: Number of FCP Instrument Ports
The NRT shall provide 6 FCP mounting positions.
Rationale: This requirement is a flow down from the OCD, section 7.9 and SR scireq:instrument:no.

SlrReq:DCPM: Total Mass and envelope of FCP Instrumentation
The NRT FCP will each support a science instrument up to 120kg with a maximum envelope of 0.72x0.72x1.5m (target), 0.72x0.72x0.9m (base).
Rationale: This requirement is a flow down from the OCD, section 7.9 and SR sciReq:massspace.

SlrReq:FPET: Time to Switch FCP Instruments
The NRT Fold mirror shall be able to switch the optical path between FCPs in less than 10s (GOAL: 5s).
Rationale: This requirement is a flow down from the SR sciReq:instrumentchange.

SlrReq:ICT: Fold Mirror Deployment Time
The NRT Fold mirror will be deployed in less than 10s (GOAL: 5s).
Rationale: This requirement is a flow down from the SR sciReq:instrumentchange.

9.3.7 Acquisition, Guiding and Active Optics

SlrReq:AcO: Telescope Active Correction (AcO)
The NRT shall ensure segment to segment error shall meet the target set out in the Image Quality Error Budget – NRT-IAC-ENG-DD-1 defined in 80EE to meet the image quality requirement.
Rationale: This requirement was derived from the Error Budget analysis - NRT-IAC-ENG-DD-1.

SlrReq:AcOC: AcO Calibration
shall provide a means of unsupervised aligning the segments using a WFS and camera with feedback to segment actuators for position control.
Note: This mode will likely be supervised (remotely) for some time after first light.
Rationale: This requirement is a flow down from the OCD, section 5.3 and derived from the robotic, segmented nature of the telescope base design.

SlrReq:AcOD: AcO Disable Mode
The NRT shall allow segment correction to be switched off during observing.
Rationale: This requirement will ensure flexibility and robustness in delivering different observing modes for specific use cases as well as for testing and operational modes.

SlrReq:AcOST: AcO Calibration Time
Shall be possible to complete AcO M1 segment calibration within 30 minutes to reduce delay or impact to other pre-observing operations.
Rationale: This requirement is derived from OCD, section 7.5 and 7.5 to limit the amount of lost possible observing time.

SlrReq:FOS: Focusing of optical system
The NRT shall allow a means of automatic focusing of the full optical system at all instrument ports. This shall include automatic correction during operations for temperature and altitude variations (“Focus Tracking”).
Rationale: This requirement is a flow down from the OCD, section 3.4.

9.3.8 Acquisition, Guiding and Wavefront Subsystem

SlrReq:AGN: Number of Acquisition and Guide Sensors (AG)
The NRT shall allow the use of >4 Autoguiders.
Note: The Autoguider shall be available for use with any instrument port. I.e. it shall not be blocked by deployment of the fold mirror or other equipment/fore optics.
Rationale: This requirement is a flow down from the OCD section 3.4. There shall be provision for additional autoguiders within the TLS to allow for guiding from other instruments or WFS for example.

SlrReq:AOWFS: Number of Active Optics Wavefront Sensors (AcWFS)
The NRT shall use 1 Wave Front Sensor (WFS) system.
Note: This will be used with the fold mirror so the baseline design will not allow use during standard observing modes with science instruments. The correction calibration will take place before observing begins.
Rationale: This requirement is a flow down from the OCD section 1.1.

SlrReq:SkyCov: AG Sky Coverage
Guide star probability over sky range > 99%.
Rationale: This requirement is a flow down from the OCD, section 3.4 and SR sciReq:guided.

SlrReq:CLGR: Guide rates
Closed loop guiding possible at both sidereal and non-sidereal rate up to the specified NS rate (SlrReq:NST).
Rationale: This requirement is a flowdown from the OCD, section 3.4 and SR sciReq:guided.

SlrReq:AcONFA: Active Optics Narrow-Field Alignment
Alignment and focus errors of the optical components in the telescope shall contribute no greater than the allocated residual error in arcsec 80% encircled energy diameter in the Image Quality Error Budget - NRT-IAC-ENG-DD-1.
Rationale: This requirement was derived from the Error Budget analysis - NRT-IAC-ENG-DD-1.

SlrReq:AcOWFA: Active Optics Wide-Field Alignment
Alignment and focus errors of the optical components in the telescope shall contribute no greater than he allocated residual error in arcsec 80% encircled energy diameter in the Image Quality Error Budget - NRT-IAC-ENG-DD-1.
Rationale: This requirement was derived from the Error Budget analysis - NRT-IAC-ENG-DD-1.

SlrReq:OD: Offset Distance
shall provide offsetting for offset distances at least 2.0 arcminutes.
Rationale: This requirement is a flow down from the OCD, section 3.4 and SR sciReq:pointingfield.

SlrReq:OA: Offset Accuracy
0.050 arcsecond (over 10 arcsec offset).
Rationale: This requirement is a flow down from the OCD, section 3.4 and SR sciReq:pointingfield.

SlrReq:CO: Coordinated Offsets
Control System shall coordinate the operation of offsetting and Science Instrument data collection.
Rationale: This requirement is a flow down from the OCD, section 3.4 and SR sciReq:pointingfield.

SlrReq:OE: Offset Efficiency
shall offset in times less than indicated in i) <5 arcsec in 3sec ii)5-30arcsec in 5sec.
Rationale: This requirement is a flow down from the OCD, section 3.4 and SR sciReq:pointingfield.

SlrReq:LGLI: Lock guide loop while integrating
shall be possible to enable/disable guide loop while a science integration is exposing without introducing discontinuity into the telescope tracking of greater than the already specified SlrReq:DCTS, SlrReq:FPTS limits.
Rationale: This requirement is a flow down from the OCD, section 3.4.

SlrReq:DG: Defocused guiding
shall allow guiding with science instrument defocused.
Rationale: This requirement is a flow down from the OCD, section 3.4.

10 Operating Modes

SlrReq:SoftCon: Software Control
Full software control of all telescope systems with hardware interlocks to prevent access to enclosure observing floor or any spaces containing moving equipment.
Rationale: This requirement is a flow down from the OCD, section 5.2 and 5.2.4.

SlrReq:LocCon: Local Control
Shall provide a site-wide state during which all remote, software initiated and/or robotic movement shall be prevented. All systems on the telescope (axes, mechanisms, instruments) will be able to be controlled from within the dome only, via an industrial control pendant, direct PLC control or equivalent and require the holding of a dead man's switch.
Rationale: This requirement is a flow down from the OCD, section 5.2 and 5.2.4.

SlrReq:EngCon: Engineering Mode
Shall provide an engineering mode where telescope is fully operational and full access is permitted to the enclosure when specific conditions are met (including no lone working) and required approvals have been sought through a permit to work procedure.
Rationale: This requirement is a flow down from the OCD, section 5.2 and 5.2.4.

SlrReq:LTC: Laser Traffic Control
Shall provide software tools to integrate with site-wide laser traffic control.
Rationale: This requirement is an externally derived requirement from the operating procedures laid out by CCI as part of the operating agreement for facilities on the ORM. It is also covered by flow down from the OCD, section 2.2.1.

11 Operational Readiness and Recovery

SlrReq:AutoStartStop: Automated Start-up/Shutdown Procedures
shall implement automated start-up and shutdown procedures which can monitored under operator control or initiated/stopped remotely depending on selected operating mode.
Rationale: This requirement is a flow down from the OCD, sections 5.2.1, 5.3.

SlrReq:TCST: Telescope Cold Start Time
Less than 30 minutes.
Rationale: This requirement is derived from OCD, section 7.5 and 7.5 to limit the amount of lost possible maintenance time (during daytime operations).

SlrReq:RM: Readiness monitoring
Shall continuously monitor all critical telescope subsystem to identify failures or impaired operation.
Rationale: This requirement is derived from OCD, sections 6.1.5, 7.14, 7.5, 7.5, 8.1.1, 8.1.2 to limit the amount of lost possible observing time and reduce system failures.

SlrReq:AFR: Automated fault recovery
Shall be able to identify failed subsystem and automatically perform reboot and reinitialise all critical subsystems without human intervention.
Rationale: This requirement is a flow down from the OCD, section 7.1.4.

SlrReq:AS: Automated Safe
Shall automatically activate a Safe State for equipment protection in event of unanticipated and otherwise unhandled exceptions.
Rationale: This requirement is a flow down from the OCD, section 7.1.4.

SlrReq:WP: Weather protection
Shall respond to weather monitoring (SlrReq:EnvMon) to protect equipment.
Rationale: This requirement is a flow down from the OCD, section 2.1.8.

SIrReq:InstReady: Instruments Readiness
Instruments designated as available for use on a given night shall be maintained in a state of readiness to minimize overhead during instrument changes.
Rationale: This requirement is a flow down from the OCD, section 7.8.

SIrReq:LossNetwork: Loss of Network
The telescope control system shall continue to operate at full observing functionality in a loss of network situation.
Rationale: This requirement is a flow down from the OCD, section 7.14.

12 Instruments

SIrReq:InstComp: Instrument Compatibility
Instruments, Facility or visitor, shall be compatible with the NRT Optical Design given in NRT-LJM-OPT-RP-3.
Rationale: This requirement is a flow down from the OCD, sections 4.1.1, 4.1.2, 7.8.

SIrReq:InstCharCali: Instrument Characterization Calibration
Each instrument shall provide software and hardware tools to automate basic instrumental characterization calibrations (bias, dark, flat, etc).
Rationale: This requirement is a flow down from the OCD, section 7.10.

SIrReq:ISC: Instrument Science Calibration
Must be calibratable to provide quantified, science ready data products.
Rationale: This requirement is a flow down from the OCD, section 7.10.

SIrReq:AI: Autonomous instruments
Instruments must be capable of performing their science function autonomously without operator interaction.
Rationale: This requirement is a flow down from the OCD, sections 4.1.1, 4.1.2, 7.8.

SIrReq:OSI: Off-sky use of instruments
Shall allow instrument control independent of telescope for daytime self-calibration tasks.
Rationale: This requirement is a flow down from the OCD.

SIrReq:ConstInstPower: 24hour power to instruments
Shall permit instruments to be powered independently of telescope.
Rationale: This requirement is based on operational experience of LT to maintain temperatures and functionality while maintenance work is carried out on other telescope systems.

SIrReq:FS: Facility Instruments
Shall provide and support Facility Instruments.
Rationale: This requirement is a flow down from the OCD, section 4.1.1.

SIrReq:LPIInst: Visitor PI Instruments
Shall provide facility access and documentation for bringing visitor instruments to NRT.
Rationale: This requirement is a flow down from the OCD, section 4.1.2 and sciReq:visitor.

Facilities

This section specifies requirements for the buildings and infrastructure that support the operation of the NRT observatory. The telescope Enclosure requirements and requirements for common services are in separate sections.

12.1 Observatory Site

The Facility Building, Observatory Enclosure, Storage areas, parking access are located at the Summit Site as well as other support infrastructure such as the Environmental Monitoring Facility (weather station). The Observatory Enclosure Building, Facility Building, any required storage areas will be located in close proximity to each other for easy and safe access between buildings. They will be positioned within the agreed site constraints detailed in NRT-LJM-ENC-RP-2. Other outside installations at the summit site may include chillers, fans, etc.

SlrReq:OSE: Observatory Site Extents
All observatory facilities shall be positioned within the agreed site extents detailed in NRT-LJM-ENC-RP-2 and documented in the SUCOSIP/CCI submission.
Rationale: This requirement is a flow down from the OCD, section 2.1.1.

SlrReq:FB: Facility Building
NRT shall provide a building (Facility Building) at the summit site for technical support of the Observatory and telescope.
Rationale: This requirement is a flow down from the OCD, section 7 and supports the operations and additional equipment and facilities required at the site.

SlrReq:OS: Office Space
The NRT Facility Building shall provide office space for the operations staff and visitors.
Rationale: This requirement is a flow down from the OCD, section 7 and supports the operations and additional equipment and facilities required at the site.

SlrReq:IAL: Instrument Assembly Lab
Facility Building shall provide a lab for assembling instruments, detectors and optical subsystems.
Rationale: This requirement is a flow down from the OCD, section 4 and supports the commissioning, assembly and maintenance of instrumentation on site.

SlrReq:ComRoom: Communications Room
Facility Building shall provide suitable infrastructure and space for telecommunications and IT equipment.
Rationale: This requirement is a flow down from the OCD, section 7 and supports the operations and additional equipment and facilities required at the site.

SlrReq:WE: Work Environment
The Facility Building shall provide a clean and well-lit working environment conforming to local H&S and welfare regulations.
Rationale: This requirement is a flow down from the OCD, section 7, 8 to provide a safe and pleasant working environment for staff when working on site.

SlrReq:EDP: Electrical Distribution Panels
Facility and Enclosure buildings shall house electrical distribution panels and breakers for the facilities.
Rationale: This requirement is a flow down from the OCD, section 7 and supports the site infrastructure required for operations, additional equipment and facilities required at the site.

SlrReq:UPS: UPS Power
The facility building or enclosure building shall house UPS power units and distribution panels for electrical equipment and enclosure fail safe operation.
Rationale: This requirement is a flow down from the OCD, section 7.14 and supports the remote, robotic nature of the facility to reduce down time and chance of critical failures.

SlrReq:EMF: Environmental Monitoring Facility
Shall provide the facility to house and support instruments for monitoring the environmental conditions as specified in the OCD.
Rationale: This requirement is a flow down from the OCD, section 2.1.8.

SlrReq:TP: Thermal Pollution
Facilities on the observatory site shall minimize the amount of waste heat given off by the buildings, infrastructure and equipment.
Rationale: This requirement is driven by image quality requirements SR sciReq:iq and derived from the Error Budget analysis - NRT-IAC-ENG-DD-1. In addition, this requirement guides reduction of any impact on neighbouring ORM facilities (CCI policies).

SlrReq:WHE: Waste Heat Exhaust
Shall exhaust waste heat from equipment on the summit where it will not migrate into the NRT field of view.
Rationale: This requirement is driven by image quality requirements SR sciReq:iq and derived from the Error Budget analysis - NRT-IAC-ENG-DD-1.

SlrReq:TEGC: Thermal Effects of Ground Cover
Exposed surfaces around the enclosure such as roads and parking areas shall minimize the amount of waste heat released at night
Rationale: This requirement is driven by image quality requirements SR sciReq:iq and derived from the Error Budget analysis - NRT-IAC-ENG-DD-1.

12.2 Infrastructure

SlrReq:VA: Vehicle Access
Shall provide access to site from the existing ORM access road with parking and turn-around areas designed for oversize loads as required during observatory construction and operations.
Rationale: This requirement is a flow down from the OCD, section 7. It supports efficient operations including segment recoating replacement procedures.

SlrReq:WS: Water Systems
Shall provide potable water at the summit and support facilities and wastewater treatment or removal to ORM site wide service network.
Rationale: This requirement is a flow down from the OCD, section 7 and provides essential services routed from the ORM network. As well as staff facilities this requirement allows cooling services to be provided to equipment as well as equipment maintenance, mirror washing etc.

SlrReq:CP: Commercial Power
Shall provide commercial power from existing ORM electrical service network at the observatory site with sufficient capacity to operate the facility.
Rationale: This requirement is a flow down from the OCD, section 7 and provides essential services routed from the ORM network.

SlrReq:EPI: Electrical Power Infrastructure
Shall provide an electrical power Infrastructure/distribution at the observatory site per the requirements relevant island and national standards and codes.
Rationale: This requirement is a flow down from the OCD, section 7 and provides essential services routed from the ORM network and distributed safely and effectively throughout the facility.

13 Enclosure

The Enclosure Building will be comprised of the Enclosure moving frame, Enclosure fixed base and the Telescope Pier & well.
The Enclosure is a large hemispherical clamshell structure that houses the telescope and protects it from adverse environmental conditions. The Enclosure opens to allow viewing of sky at night and remains open until end of observing, a weather alert is triggered or a remote user requests it.
The telescope and Enclosure are free to move independently of each other. All of the structures and entities below the moving frame (except Telescope Pier and well) will be part of the Enclosure Base. Both the fixed base and moving frame will protect the telescope. The top of the Pier will interface to the Telescope Azimuth Track.

13.1 General Requirements

SlrReq:EncOps: Enclosure Operations
Enclosure shall open to provide NRT with an un-vignetted view of the sky over the full range of azimuth and elevation specified by the sky coverage.
Rationale: This requirement is a flow down from the OCD, section 1.1 and SR sciReq:skyaccess.

SlrReq:EEC: Enclosure Closure Conditions
Enclosure shall be closed and parked when environmental conditions exceed the operating conditions specified in NRT-LJM-ENG-TN-4.
Rationale: This requirement is a flow down from the OCD, section 2.1.8.

SlrReq:SP: Seal Protection
Enclosure Building, when closed, shall seal against external environmental conditions that could damage or degrade performance of the telescope systems.
Rationale: This requirement is a flow down from the OCD, section 7.5 to protect systems in the enclosure building from weather.

SlrReq:TVP: Telescope Vertical Position
Mirror height from site ground shall be at least +4.5m driven by DCP instrument size envelope and reducing local seeing impact on image quality error budget.
Rationale: This requirement is derived from the Error Budget analysis - NRT-IAC-ENG-DD-1 and a detailed aero-optic analysis to estimate impact from local seeing.

SlrReq:PI: Telescope Pier Isolation
Pier shall be mechanically isolated from the Enclosure Building.
Rationale: This requirement is OCD derived from the need to provide a stable base for the telescope to achieve pointing, tracking and image quality requirements.

SlrReq:MLS: Moon Light Shielding
Enclosure shall be designed and oriented to limit direct illumination of the telescope optical surfaces by moonlight or reflections from neighbouring observatories (where possible using enclosure mid-travel positions).
Rationale: This is required to minimize impact of moonlight on science exposures.

SIrReq:DLI: Daytime Light Infiltration
Enclosure shall minimize light infiltration to allow daytime calibrations, where required.
Rationale: This requirement is a flow down from the OCD 7.1.

SIrReq:EC: Enclosure Opening
Enclosure shall, when open, provide an un-vignetted field of view for the telescope as defined in SR SciReq:skyaccess.
Rationale: This requirement is a flow down from the OCD 1.1, 7.2.

SIrReq:ETtO: Time to Open the enclosure
Enclosure shall open fully from any operational position in a time not to exceed 2.0 minutes [Goal: 1:30 min].
Rationale: This requirement is a flow down from the OCD, section 7.2 to ensure observing efficiency when opening after a weather event or system recovery during night-time operations.

SIrReq:ETtC: Time to Close the enclosure
Enclosure shall close fully from any operational position in a time not to exceed 2.0 minutes [Goal: 1:30 min].
Rationale: This requirement is a flow down from the OCD 7.2.

SIrReq:ETtA: Time to Reposition Enclosure from mid Position
Enclosure shall not limit the telescopes ability to achieve the time to target requirement if it is in a mid-position during a new slew operation (where it is being used as a moon or wind screen).
Rationale: This requirement is a flow down from the OCD sciReq:slewtime.

SIrReq:EncClear: Enclosure/Telescope Free movement
Enclosure shall be free to open and close independently without interference with the NRT over the full mechanical ranges of motion for the telescope and Enclosure as defined by NRT-LJM-ENC-DR-1.
Rationale: This requirement is a flow down from the OCD 7.2.

SIrReq:DS: Dome Seeing
Enclosure shall be designed such that the temperature difference between the air inside the enclosure telescope chamber and the outside ambient air shall not be greater than the allocated value in the Image Quality Error Budget.
Rationale: This requirement is driven by image quality requirement SR sciReq:iq and derived from the Error Budget analysis - NRT-IAC-ENG-DD-1 regarding local thermal effects on image quality.

SIrReq:PV: Passive Ventilation
Enclosure shall provide ventilation openings to promote wind-driven air exchange within the telescope chamber.
Rationale: This requirement is OCD derived from a building and operations safety need to allow venting of gasses where required.

SIrReq:GLS: Ground Layer Suppression
Enclosure Building external structure shall be designed to minimize incursion of the turbulent ground layer into the telescope chamber.
Rationale: This requirement is driven by image quality requirement SR sciReq:iq and derived from the Error Budget analysis - NRT-IAC-ENG-DD-1 regarding local thermal effects on image quality.

SIrReq:RTE: Rapid thermal equalisation
Enclosure structure shall be designed for rapid thermal equilibration with the ambient air once opened.
Rationale: This requirement is driven by image quality requirements SR sciReq:iq and derived from the Error Budget analysis - NRT-IAC-ENG-DD-1 regarding local thermal effects on image quality.

14 Observatory Operations

14.1 Engineering Software Tools and modes

SlrReq:OOMS: Observing and Operation Mode Support
Software tools and user interfaces shall support the operational and observing modes of the telescope depending on the roles and access requirements.
Rationale: This requirement is a flow down from the OCD, Section 5.2.

SlrReq:PQA: Product Quality Assessment
Shall provide software tools to assess the validity of observation data products.
Rationale: This requirement is a flow down from the OCD, section 6.1.8, 8.1.4.

SlrReq:EDS: Engineering Data System
Shall provide an engineering data system to monitor the health of all subsystems critical to the functioning and performance of the observatory.
Rationale: This requirement is a flow down from the OCD, section 6.1.5.

SlrReq:EngMode: Engineering Mode
Control software shall include an engineering mode that allows low-level control of components and subsystems.
Rationale: This requirement is a flow down from the OCD, section 5.1.8.

SlrReq:DS: Diagnostic Software
Shall provide software tools for displaying real-time and long-term trends in the performance of individual components/subsystems and to correlate that information with time-stamped data from other subsystems.
Rationale: This requirement is a flow down from the OCD, section 6.1.5.

SlrReq:EDA: Engineering Data Archive
Shall provide an archive for storing engineering data for the lifetime of the observatory.
Rationale: This requirement is a flow down from the OCD, section 6.1.5.

SlrReq:PEP: Program Execution Planning
Shall provide software tools for the observatory staff for advanced planning of observing programs within the SODC software layer.
Rationale: This requirement is a flow down from the OCD, section 5.1.4, 5.1.5.

SlrReq:OpsExt: Operating mode external source (formally SlrReq:LTC)
Shall provide software tools to integrate with and receive triggers from site-wide inputs, for example from facilities using guide stars or seeing/weather monitoring.
Rationale: This requirement is an externally derived requirement from the operating procedures laid out by CCI as part of the operating agreement for facilities on the ORM. It is also covered by flow down from the OCD, section 2.2.1.

Science Data Management

SlrReq:SDArchive: Science Data Archive
Shall provide a data archive system for collecting, storing and retrieving all raw data acquired during observations, including metadata (TBD), for the lifetime of the observatory.
Rationale: This requirement is a flow down from the OCD, section 6.1.4.

SlrReq:SDPP: Science Data Proprietary Period
Shall make the data archive available to NRT partner scientists subject to the limits of proprietary periods.
Rationale: This requirement is a flow down from the OCD, section 6.1.6.

SlrReq:SDAccess: Science Data Access
Shall be accessible following the policies and procedures as approved by the NRT board.
Rationale: This requirement is a flow down from the OCD, section 6.1.6.

SlrReq:SDVO: Science Data Virtual Observatory
Shall be compatible with Virtual Astronomical (VAO) standards.
Rationale: This requirement is a flow down from the OCD, section 6.1.1.

SlrReq:SDF: Science Data Formats
Shall adopt the Flexible Image Transport System (FITS) to capture a record of each observation.
Rationale: This requirement is a flow down from the OCD, section 6.1.1.

14.2 User tools and programme execution

SlrReq:IUI: Integrated User Interface
Shall provide an integrated and consistent user interface.
Rationale: This requirement is a flow down from the OCD, sections 5 & 6.

SlrReq:PP: Proposal Preparation
Shall provide software tools to assist astronomers in the proposal process within the SODC software layer.
Rationale: This requirement is a flow down from the OCD, section 5.1.4, 5.1.5 and is intended to build upon the existing LT Phase1 and Phase2 process with modern web-based tools.

SlrReq:OPD: Observing Program Definition
Shall provide software tools to assist astronomers in defining observing programs within the SODC software layer.
Rationale: This requirement is a flow down from the OCD, section 5.1.4, 5.1.5.

SlrReq:OPE: Observing Program Execution
Shall provide software tools for autonomous execution of Observing Programs.
Rationale: This requirement is a flow down from the OCD, section 5.1.5.

14.3 Instrument Support

SIrReq:IS: Instrument Handling
Shall provide the infrastructure necessary for safely lifting, handling, and transporting.
Rationale: This requirement is a flow down from the OCD, section 7.12.

SIrReq:AIS: Automated Instrument Switching
Shall allow the automated switching of science instruments during the night initiated and monitored by the TLS.
Rationale: This requirement is a flow down from the OCD, section 5.3.3 and SR sciReq:instrumentchange.

14.4 Mirror handling and maintenance

SIrReq:CM: Coating Maintenance
Observatory design as well as handling equipment shall allow M1 segment removal and replacement (after re-coating) with limited support staff on site with a target replacement duration during daytime non-observing hours.
Rationale: This requirement is a flow down from the OCD, section 3.1, 3.2 and SLR throughput targets.

SIrReq:MCH: Mirror Re-Coating Handling
Observatory and telescope systems shall be designed to support the mirror handling operations in a safe manner that limits risk of damage to optics or interfacing structures or equipment.
Rationale: This requirement is a flow down from the OCD, section 3.1, 3.2 and SLR throughput targets.

SIrReq:M2H: M2 Handling
M2 Can subsystems and interfacing telescope/observatory systems shall allow the safe handling of the M2 mirror for washing, maintenance or recoating procedures.
Rationale: This requirement is a flow down from the OCD, section 3.1, 3.2 and SLR throughput targets.

SIrReq:M1C: M1 Segment Cleaning
A defined procedure with required support/handling equipment will be provided to allow safe and efficient cleaning process of the M1 segments.
Rationale: This requirement is a flow down from the OCD, section 3.1, 3.2 and SLR throughput targets.

SIrReq:M2C: M2 Cleaning
A defined procedure with required support/handling equipment will be provided to allow safe and efficient cleaning process of the M2 mirror.
Rationale: This requirement is a flow down from the OCD, section 3.1, 3.2 and SLR throughput targets.

SIrReq:FMC: Fold Mirror Cleaning
A defined procedure with required support/handling equipment will be provided to allow safe and efficient cleaning process of the fold mirror.
Rationale: This requirement is a flow down from the OCD, section 3.1, 3.2 and SLR throughput targets.

14.5 Staff Support

The NRT Operations Plan will define the staffing for the observatory (both remote and on-site) during the operations phase and, although there will be various skilled positions required for operations and support, there are key operations staff that will assist with the nightly operations or daytime maintenance and support procedures at the telescope and thus need to be considered in the design requirements.

SIrReq:TO: Telescope Duty Officers
Telescope Duty Officers shall work on-site and/or remotely. They shall be trained in the use of NRT software systems and procedures including but not limited to: observation start-up, shut-down and "making safe" in the event of critical system failure.
Rationale: This requirement is a flow down from the OCD, section 1.3.5.

SIrReq:SOSup: Science Operations Support
Day time science operations shall be overseen by professional astrophysics researchers.
Rationale: This requirement is a flow down from the OCD, section 1.3.5.

14.6 DevOps, software tooling and infrastructure

The NRT Operation philosophy regarding software relies heavily on modern DevOps technologies, and any piece of running software should be considered in a continuous state of development. Therefore, we consider the following requirements.

SIrReq:Code: Changeable code
The software built must be compliable, buildable and generally changeable at any point in the lifetime of the telescope, using modern technologies. Defined in NRT-LJM-SWC-DD-2.
Rationale: This requirement is a flow down from the OCD, section 7.13.

SIrReq:DHA: Data High Availability
The data produced by the facility, both telemetric and scientific, shall be readily available to relevant users in a reasonably secure and usable interface.
Rationale: This requirement is a flow down from the OCD, section 6.

SIrReq:Scale: Scaleability of Software infrastructure
The software tooling shall be deployed in a scalable and robust manner, to allow for situations where usage increases temporarily. Defined in NRT-LJM-SWC-RP-3.

15 General Requirements

SIrReq:Governance: Governance
The facility shall be designed, constructed, and operated following all policies and procedures approved by the NRT board.
Rationale: This requirement is a flow down from the OCD, section 1.3.1.

SIrReq:LawsRegs: Laws and Regulation
Shall be constructed and operated in accordance with all applicable laws and regulations approved by governmental agencies with local jurisdiction.
Rationale: This is an external requirement

SIrReq:CC: Code Compliance
Shall be designed and constructed in accordance with all applicable local building safety codes and to satisfy the requirements of insurers.
Rationale: This is an external requirement.

SIrReq:Safe: Safety
Shall establish and enforce standards and procedures to ensure the safety of the NRT facility, equipment and personnel at all times.
Rationale: This requirement is a flow down from the OCD, section 7.12.

16 Standards

SIrReq:SoftStand: Software Standards and development practices
Shall establish and enforce standards and procedures for software and methods of development and maintenance as defined in NRT-LJM-SWC-DD-2.
Rationale: This requirement is a flow down from the OCD, section 7.

SIrReq:HardStand: Hardware Standards and development practices
Shall establish a set of hardware standards including fixing types (e.g. metric where possible), drawing standards, CAD standards and naming conventions as defined in CAD standards and conventions document NRT-LJM-ENG-DC-1.
Rationale: This requirement is a flow down from the OCD, section 7.

SIrReq:ElecStand: Electrical Standards
Shall establish a set of electrical standards.
Rationale: This requirement is a flow down from the OCD, section 7.

SIrReq:ComsProtocol: Communication Protocols
Shall define a set of software protocols and APIs that allow the communication with the required performance between different components and systems. Defined in NRT-LJM-SWC-DC-2 and NRT-LJM-SWC-DC-3.
Rationale: This requirement is a flow down from the OCD, section 7.

SIrReq:ComsStand: Communication Standards
Shall define a set of physical communication protocols to integrate its different components and systems.
Rationale: This requirement is a flow down from the OCD, section 7.

17 Health & Safety

SIrReq:ISS: Interlock Safety System (ISS)
Shall include an integrated interlock system that interfaces to all subsystems, globally monitors the health of the system, provides indication of any unsafe condition, and automatically controls safety interlocks. Defined in NRT-LJM-SWC-DC-2.
Rationale: This requirement is a flow down from the OCD, section 7.11.

SIrReq:PS: Personnel Safety
Shall implement systems and procedures to provide a safe working environment at the Observatory.
Rationale: This requirement is a flow down from the OCD, section 7.11.

SlrReq:SS: Software Safety
Shall provide low level PLC system software to enhance the safety and integrity of the system as part of the ISS as defined in NRT-LJM-SWC-DC-2.
Rationale: This requirement is a flow down from the OCD, section 7.11.

SlrReq:MS: Mechanical Safety
Shall provide position sensors, interlocks and limits on mechanical systems with motion range limits to guarantee safe operation.
Rationale: This requirement is a flow down from the OCD, section 7.11.

SlrReq:LS: Limit Redundancy
Shall include redundant limits on all systems with moving parts that present an over travel hazard risk.
Rationale: This requirement is a flow down from the OCD, section 7.11.

SlrReq:MIO: Manual Interlock Override
Shall provide protected manual overrides on interlocks.
Rationale: This requirement is a flow down from the OCD, section 7.11.

18 Environmental

SlrReq:EnvStat: Environmental Statistics
Shall compile statistics of the Environmental Data and make it available to users by the Observatory.
Rationale: This requirement is a flow down from the OCD, section 2.1.8.

SlrReq:EnvMon: Monitoring of Weather Conditions
Shall provide sensors and equipment to collect, display in real time, and store weather data during observatory operations.
Rationale: This requirement is a flow down from the OCD, section 2.1.8.

SlrReq:AtmosSee: Monitoring of Atmospheric Seeing
Shall provide methods/equipment for night-time monitoring of the integrated seeing through the atmosphere above the NRT site.
Rationale: This requirement is a flow down from the OCD, section 2.1.8.

SlrReq:Dust&Cloud: Dust and Cloud Monitoring
Shall provide equipment to measure in real time, atmospheric dust in the Enclosure and external cloud density above the observatory.
Rationale: This requirement is a flow down from the OCD, section 2.1.8.

19 Conditions

SlrReq:SOL: Safe Operating Limits
Shall be designed to conduct science observations over the range of safe operating limits specified in NRT-LJM-ENG-TN-4.
Rationale: This requirement is a flow down from the OCD, section 2.1.7.

SlrReq:SurCon: Survival Conditions
Shall be designed to survive with minimal damage the extreme environmental conditions specified in NRT-LJM-ENG-TN-4 with the enclosure and buildings closed and secured.
Rationale: This requirement is a flow down from the OCD, section 2.1.7 and NRT-LJM-ENG-TN-4.

SlrReq:dust: Dust Conditions
Shall be designed to operate in the ORM dust environment described in NRT-LJM-ENG-TN-4.
Rationale: This requirement is a flow down from the OCD, section 2.1.7 and NRT-LJM-ENG-TN-4.

SlrReq:lightning: Lightning Protection
Shall provide an engineered interconnected lightning protection system for equipment and facilities on the summit.
Rationale: This requirement is a flow down from the OCD, section 2.1.7 and NRT-LJM-ENG-TN-4.

SlrReq:OLE: Operational Level Earthquake
Shall be designed to survive earthquakes with minimum consequential damage and be returned to operations within 7 days. This shall hold for earthquakes no more severe than the maximum operational level earthquake (OLE) as defined in NRT-LJM-ENG-TN-4.
Rationale: This requirement is a flow down from the OCD, section 2.1.9.

SlrReq:SLE: Survival Level Earthquake (SLE)
Shall be designed to survive without major structural failure a maximum survival level earthquake (SLE) as defined in NRT-LJM-ENG-TN-4.
Rationale: This requirement is a flow down from the OCD, section 2.1.9.

20 Transportation and storage

SlrReq:StorTrans: Storage and Transporting
Shall comply with the storage and transportation specifications for either controlled or uncontrolled environments as defined in NRT-LJM-ENG-TN-4.
Rationale: This requirement is a derived requirement from expected equipment handling, storage and transport conditions.

21 Services

SlrReq:telecon: Telecommunications
Shall provide telecommunication between the facilities on the summit, the support site, the base facility, and connection to external commercial providers.
Rationale: This requirement is derived from expected operations outlined in OCD and to support a range of science and operations expected at the site.

SlrReq:network: Network
Shall provide network connections to support the specified Observing Modes and data transfer rates of 1Gbps between the summit, base or remote facility.
Rationale: This requirement is derived from expected operations outlined in OCD and to support a range of science and operations expected at the site.

SlrReq:dataStore: Data Storage
Shall provide an on-site data storage facility with sufficient capacity to store up to one months worth of observing data and telemetry logs.
Rationale: This requirement is a flow down from the OCD, section 6.1.4.

SlrReq:coolants: Coolants
Shall provide chilled liquid system(s) to provide coolant for instrumentation and telescope systems.
Rationale: This requirement is derived from expected operations outlined in OCD and to support a range of science and operations expected at the site.

SlrReq:CompAir: Compressed Air
Shall provide a source of clean, dry compressed air to support operation of the telescope and general services.
Rationale: This requirement is derived from expected operations outlined in OCD and to support a range of science and operations expected at the site.

SlrReq:CableTrays: Cable Trays
Shall provide cable trays to allow efficient and safe installation of instruments and equipment.
Rationale: This requirement is derived from expected operations outlined in OCD and to support a range of science and operations expected at the site.

SlrReq:CablingInfra: Cabling, Connectors and Cabinets
Shall provide a cabling infrastructure to support general services.
Rationale: This requirement is derived from expected operations outlined in OCD and to support a range of science and operations expected at the site.

22 Electrical

SlrReq:PFG: Power Filtering and Grounding
Shall provide power filtering and a grounding system accessible both off-mount and on-mount at the instrument ports designed to minimize electrical interference.
Rationale: This requirement is derived from the OCD to ensure reliability, safety and optimum performance of electrical systems – sensitive detectors in particular.

SlrReq:ESD: Electrostatic Discharge
Shall provide ESD safe work areas where sensitive sensors and electronics will be handled.
Rationale: This requirement is derived from the OCD to ensure sensitive equipment can be assembled, maintained and commissioned without causing damage through ESD.

SlrReq:ES: Electrical Systems
Electrical design shall comply with the NRT Compliance to Regulations, Codes and Standards.
Rationale: This requirement is derived from the OCD to ensure reliability, safety and optimum performance of electrical systems.

SlrReq:CableConsCabinets: Cabling, Connectors and Cabinets
Shall comply with the connector, cabling, and cabinet specifications.
Rationale: This requirement is derived from the OCD to ensure reliability, safety and optimum performance of electrical systems.

23 Reliability and maintenance

SlrReq:life: NRT Lifetime
Shall be designed for a 25-year lifetime assuming routine maintenance of the telescope and facilities and periodic upgrades of field replaceable components and subsystems.
Rationale: This requirement is a flow down from the OCD, section 7.1.

SlrReq:Instlife: Instrument lifetime
Facility Instruments shall have a design operational lifetime of not less than 10 years [goal: not less than 15 years].
Rationale: This requirement is a flow down from the OCD, section 7.8.

SlrReq:reliability: Reliability
Shall be designed for reliable operation to minimize downtime and maximize efficiency.
Rationale: This requirement is a flow down from the OCD, section 7.5.

SlrReq:ESA: Equipment Service Access
Shall provide safe access to all areas with serviceable components.
Rationale: This requirement is a flow down from the OCD, section 7.11, 5.2.3.

SlrReq:CS: Critical Spares
Shall provide spares for critical subsystem and instrument components as defined in the NRT Critical Spares Document - TBD.
Rationale: This requirement is derived from the NTR lifetime requirement and reliability requirements detailed in the OCD.

SlrReq:SEP: Service Equipment and Procedures
Shall provide basic equipment, tools and procedures necessary to maintain all critical components and systems over the lifetime of the observatory.
Rationale: This requirement is derived from the NTR lifetime requirement and reliability requirements detailed in the OCD.

SlrReq:PMP: Preventative Maintenance Time
Shall develop a preventative maintenance program for scheduled servicing of operation critical equipment.
Rationale: This requirement is a flow down from the OCD, section 8.1.2.

SlrReq:SMT: Scheduled Maintenance Time
Shall be designed such that no more than 3% of the nights in a year will be required for scheduled maintenance once NRT is in routine operation.
Rationale: This requirement is a flow down from the OCD, section 7.6.

SlrReq:DT: Down Time
Shall be designed to limit the number of science observing hours lost due to failures to less than 3% per year of available time for science observations once routine operations have begun.
Rationale: This requirement is a flow down from the OCD, section 7.5.

24 Documentation

SlrReq:TD: Technical Documentation
Shall provide technical documentation in the form of manuals, drawings, and online tools to support operation, maintenance, and repair of all instrument subsystems.
Rationale: This requirement is a flow down from the OCD, section 5.4.

SlrReq:TDA: Technical Documentation Archives
Shall provide an archive to store and maintain all technical documentation needed for the operation, maintenance and repair of the observatory for its lifetime.
Rationale: This requirement is a flow down from the OCD, section 5.4.

SlrReq:UD: User Documentation
Shall provide users with online guides and manuals for all equipment and facility instrumentation that is used during routine operations.
Rationale: This requirement is a flow down from the OCD, section 5.4.

SlrReq:MD: Mechanical Drawings
Shall provide mechanical drawings that comply with NRT CAD standards for all mechanical components – Defined in NRT-LJM-ENG-DC-1.
Rationale: This requirement is a flow down from the OCD, section 5.4.

SlrReq:EES: Electrical and Electronic Schematics
Shall provide electrical and electronics schematics that comply with NRT CAD standards
Rationale: This requirement is a flow down from the OCD, section 5.4.

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