KAON # 661

Next Generation Adaptive Optics System

Laser Launch Facility Switchyard

Preliminary Design

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VersionV1.3

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REVISION HISTORY

Revision	Date	Author (s)	Reason for revision / remarks
1.0	Oct 19, 2009	-	Initial release
1.1	Oct 20, 2009	EW	Add KAON number (661)
1.2	Nov 04, 2009	JC	Updated risk summary
1.3	May 07, 2010	TS	Revisions for PDR

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1 INTRODUCTION

As part of the Next Generation Adaptive Optics System (NGAO), a Laser Launch Facility (LLF) System is needed to propagate the laser beam. One component of the LLF System is the Switchyard (SYD). The SYD is located within the Laser Enclosure attached to the elevation ring. It receives the beams from the laser systems, formats them and sends them on to the Beam Transport Optics (BTO). The SYD ensures the laser beams are properly formatted and aligned to the BTO and BGS. The SYD contains the active elements to compensate for pointing errors due to the changing gravity vector as the telescope moves in elevation. This document provides the preliminary design of the SYD.

2 REFERENCES

2.1 Referenced Documents

Documents referenced are listed in Table 1. Copies of these documents may be obtained from the source listed in the table.

Ref. #	Document #	Revision or Effective Date	Source	Title
1	KAON 510	1.0	WMKO	NGAO Preliminary Technical Risk Evaluation
2	KAON 511	0.3	WMKO	NGAO System Design Manual
3	KAON 749	1.0	WMKO	NGAO Laser Enclosure Design

Table 1: Reference Document

2.2 Acronyms and Abbreviations

Table 2 defines the acronyms and abbreviations used in this document.

Acronym/Abbreviation	Definition
BGS	Beam Generation System
BTO	Beam Transport Optics
CW	Continuous Wave
DDR	Detailed Design Review
KAON	Keck Adaptive Optics Note
LE	Laser Enclosure
LGSF	Laser Guide Star Facility
LLF	Laser Launch Facility
NGAO	Next Generation Adaptive Optics System
PSD	Position Sensing Diodes
SYD	Laser Switchyard
WMKO	W.M.K. Observatory

Table 2: Acronyms and Abbreviations

3 OVERVIEW

The LLF layout is shown in Figure 1 which was presented in the NGAO System Design Review (KAON 511). The SYD will encompass the opto-mechanical assembly that receives the laser beams and the structure supporting the three laser heads. The assumption is that lasers can be configured so only the laser heads will be supported in the Laser Enclosure. The main function of the Switchyard is to properly format the outputs from the three lasers into a pattern of appropriate size with the correct beam waist size and location for transport by the Beam Transport Optics. It will also provide polarization controls, safety shutters, and a switchable element to dump most of the beam power to produce a low power alignment beam.

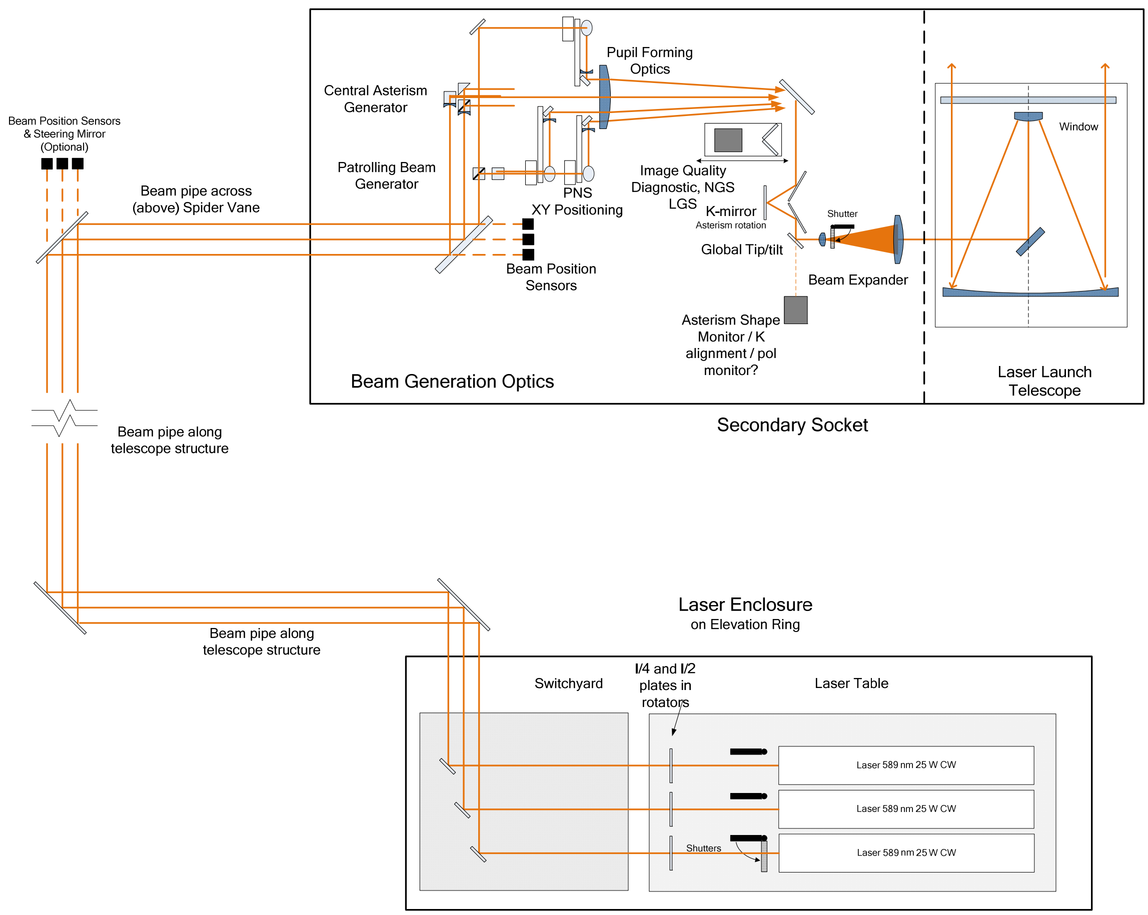

Figure 1: Laser Launch Facility Layout

The location of where the Switchyard fits into the overall NGAO System is shown in Figure 2. The Switchyard will have a mechanical interface to the telescope elevation ring and to the BTO for attachment of the tube structure.

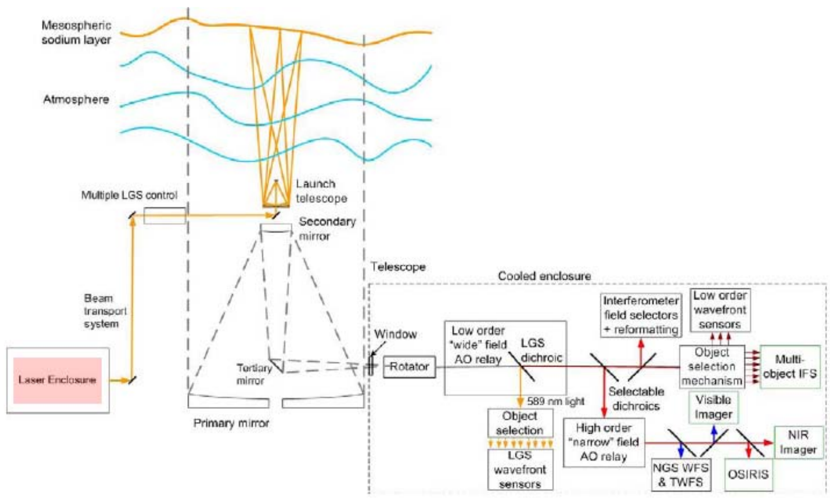

Figure 2: Laser Launch Facility Switchyard (shaded in red) within the NGAO System

4 REQUIREMENTS

The requirements for the Switchyard are presented in the LLF Requirements Document. The Switchyard is part of the Laser Launch Facility and will apply the requirements as outlined by the LLF and the LGSF.

The main requirements or flow down of requirements for the Switchyard are as follows:

- The SYD will format the three laser beams from the laser systems and properly align them for entry into the Beam Transport Optics system.
- The SYD will provide a means to control the power of the laser beams for alignment purposes.
- The SYD will support the control of polarization for the laser beams with the goal of circular polarization at the output of the launch telescope.
- The SYD will provide laser beam diagnostics.

5 DESIGN

The design of the SYD is based on the current preliminary detail design for the lasers. The final design for the laser will be completed during the NGAO detailed design phase. The layout of the laser heads has a significant impact on the SYD design.

5.1 Methodology

The current switchyard design is based on using the same infrastructure that is currently available on the Keck II telescope. The re-use of existing infrastructure will minimize cost for supporting the SYD. It will also minimize risks associated with new infrastructure on the telescope. The SYD and the new lasers will replace the current laser table on the Keck II telescope.

The current Keck II laser enclosure on the telescope is expected to be reused per KAON 749. This enclosure attaches to the elevation ring where it houses the Keck II laser table. The elevation ring has been stiffened as part of the Keck II design to ensure minimal flexure of the existing laser table. Figure 3 shows the enclosure and its location with respect to the elevation ring with the telescope pointed at zenith. The enclosure provides an environment for personnel to service and maintain the lasers and the SYD.

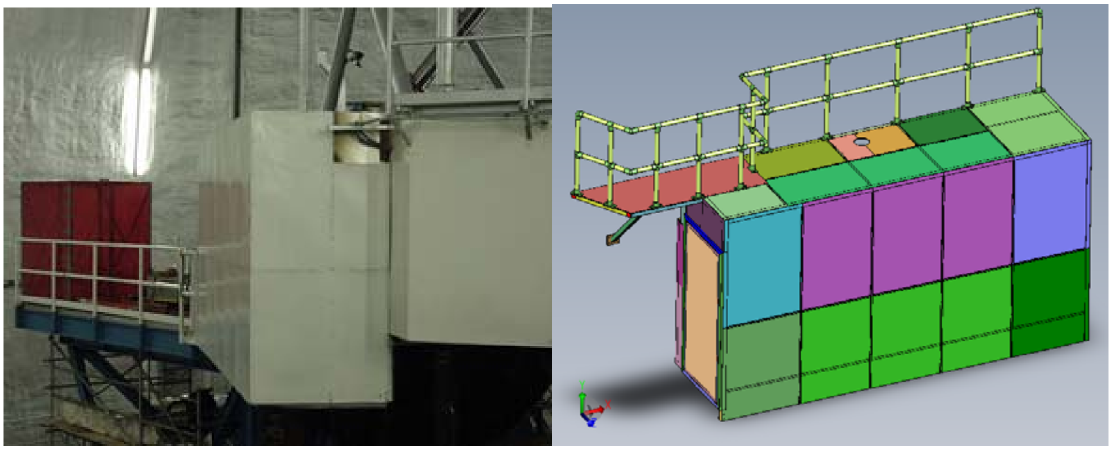

Figure 3: Laser Service Enclosure

Figure 4: Laser Service Enclosure and Optical Bench for the Keck II Laser System

5.2 Layout of Laser System

Figure 5 shows a layout of three 25W CW lasers within the SYD in the enclosure. The assumption is that there will be a need for 3 identical lasers to meet the 75W CW NGAO requirement. To minimize flexure, all three lasers heads and the SYD opto-mechanical components will be mounted on the same platform for stability. A distinction is being made that only the laser heads themselves will be required to be located on this platform. The electronics and possibly pump lasers will be located at the Left Nasmyth Platform.

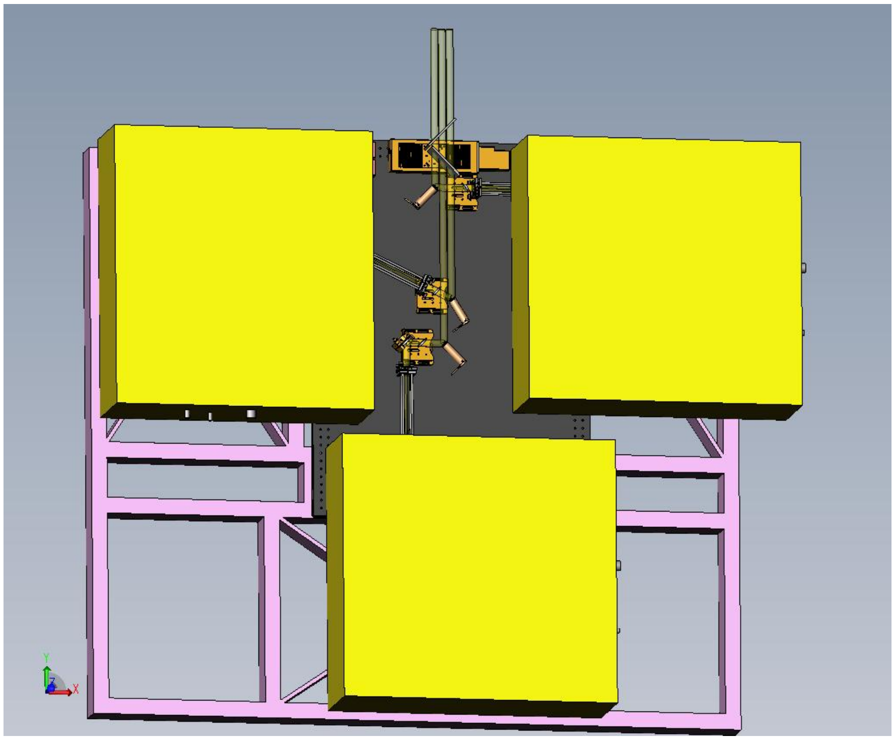

Figure 5: Possible Laser Heads Layout in Existing Laser Enclosure

The new laser heads, along with the SYD components, auxiliary hardware, and the enclosure will be required to weigh no more than 1700 Kg. This mass was removed from the telescope as part of the overall balance for the Keck II subsystems on the elevation ring. The existing laser table is shown in Figure 6 as it is mounted onto the elevation ring. Having the three lasers and the SYD components mounted to the same structure will simplify installation and minimizes independent motions between the lasers and the SYD components.

Figure 6: Laser Mounting onto Elevation Ring

5.3 Opto-Mechanical Design

5.3.1 Opto-Mechanical Layout

The layout of the SYD is shown in **Error! Reference source not found.** Figure 7 and Figure 8**Error! Reference source not found.**. There are four main sub-assemblies, the polarization control, low power mode optics, reimaging optics, and the tip/tilt pattern forming mirrors. Currently it is assumed that there will be three 25W CW lasers entering the switchyard from three sides.

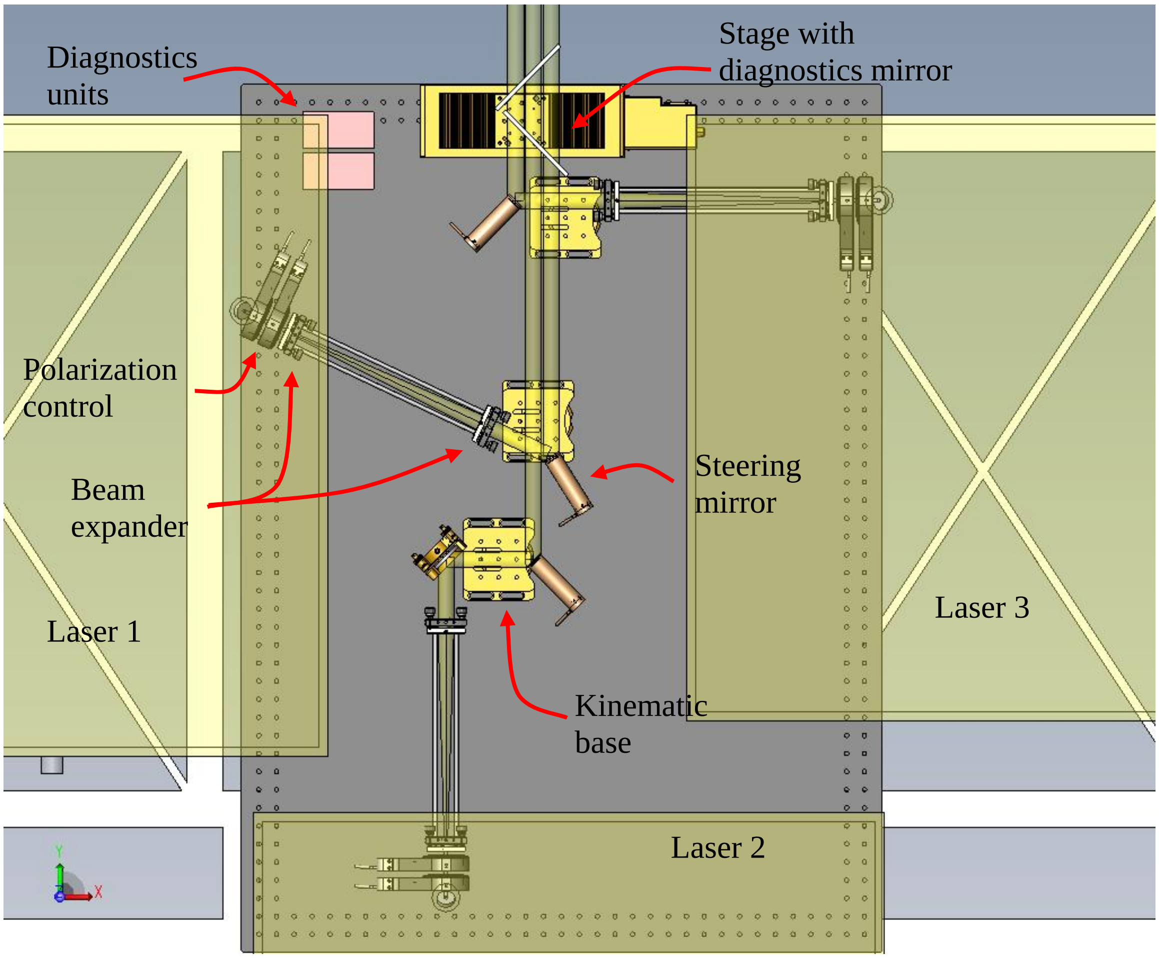

Figure 7: Switchyard Opto-Mechanical Layout. The laser units are transparent in this drawing to show the components underneath them.

The beam exits the laser units from the bottom side. From there it is turned parallel to the table and into the polarization controller. This consists of a half-wave and a quarter-wave plate in independent rotation mounts to allow generation of an arbitrary elliptical polarization from the linearly polarized laser head output. The requirement is to produce a circularly polarized output beam from the launch telescope, however if the beam at the switchyard is circularly polarized the output will not be since the optics between the laser heads and the launch telescope output will change the polarization state of the beam as it transits the system into some arbitrary elliptical polarization. To produce a circularly polarized output from the launch telescope, the input beam to the system must have the conjugate elliptical polarization to counteract the added polarization effects. As this would be difficult to determine empirically and may change over time, the input polarization state will be empirically chosen to maximize the return from the sodium layer.

The next sub-assembly is a beam expander which reimages the laser output to form a waist size and location as specified by the BGS design. To minimize the field required and the wavefront error for the beam expander each laser will have its own set of reimaging optics.

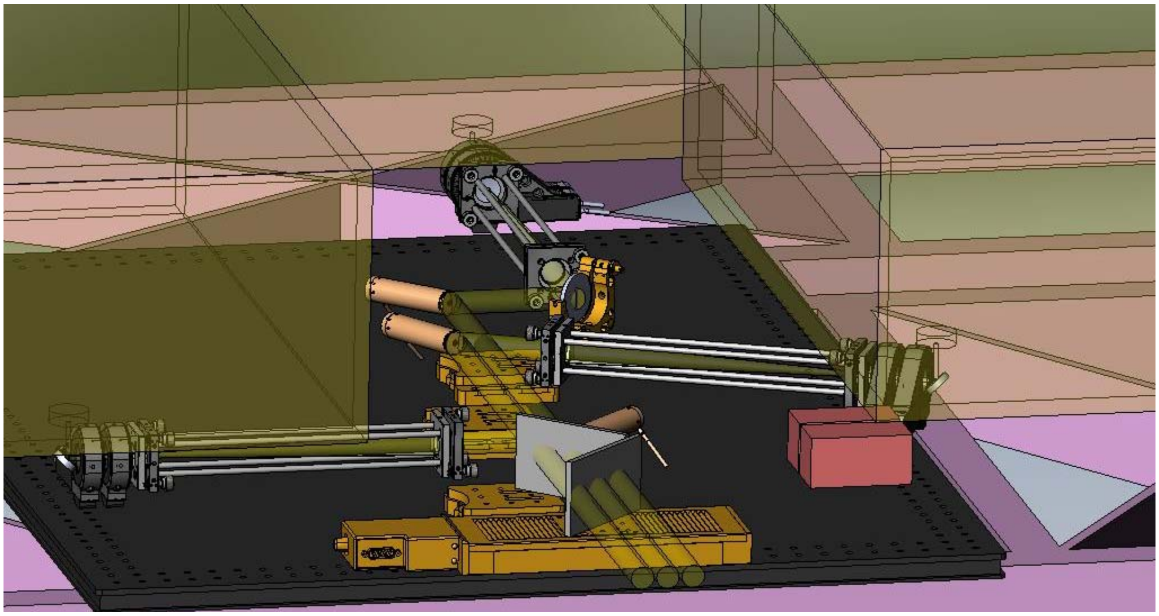

Figure 8: Switchyard layout.

After the beam expander a base plate for a kinematic removable mount will be attached to the table. This allows placing beamsplitters or mirrors in the beam prior to the steering mirror. In case one of the three lasers is inoperable, a mirror can be placed in its mount to receive the light from a beamsplitter placed in one of the functioning units. The arrangement on the bench allows any laser to be split and supply either of the other two units. These mounting points can also be used to couple an alignment laser into the system. Figure 9 shows an example of using part of the output from laser 2 to compensate for the loss of laser 3. Obviously this will reduce the laser beacon brightness, but it will allow operation at a lower performance level in case one of the lasers malfunctions. This operation is expected to take a few hours and require an optical technician, so would only be done during the day. Although it would be possible to automate this task, given the expected reliability of these laser units it does not seem cost-effective.

Following the beam expander will be the high precision steering mirror. This will be controlled by sensors located on the BGS assembly to stabilize the beam location at that point. This stabilization will correct for both telescope flexure and jitter and drift in the laser output. The BTO design document has a detailed analysis of the steering requirements.

The final sub-assembly has multiple purposes. It is built around a high reflectivity mirror on a translation stage that can be inserted into the output beam pattern. The reflected light is sent to a wavefront sensor/M^2 monitor, a polarimeter, and a beam dump. By selecting the stage position, any of the three output beams can be sent to any of the three instruments. When it is fully inserted, the small amount of leakage sends a low power beam suitable for alignment to the rest of the LGSF. An uncoated plane parallel plate with identical thickness is placed at a complementary angle in the leakage beam to compensate for the beam shift due to the thickness of the mirror. The mirror will be a high quality dielectric mirror with leakage of approximately 0.2%, resulting in an approximately 50 mW leakage beam. There will be some residual astigmatism and other aberrations in the alignment beams, but the alignment mode will not be used to measure wavefront error, only centration and angle alignment and to confirm beam pointing during setup. This stage will be remotely controlled and the mirror assembly will be large enough to cover all three beams simultaneously. The beam dump will be made from an appropriately sized calorimeter for measuring the power of the laser beams as an additional diagnostic. The beam dump will also include glycol cooling to remove the heat.

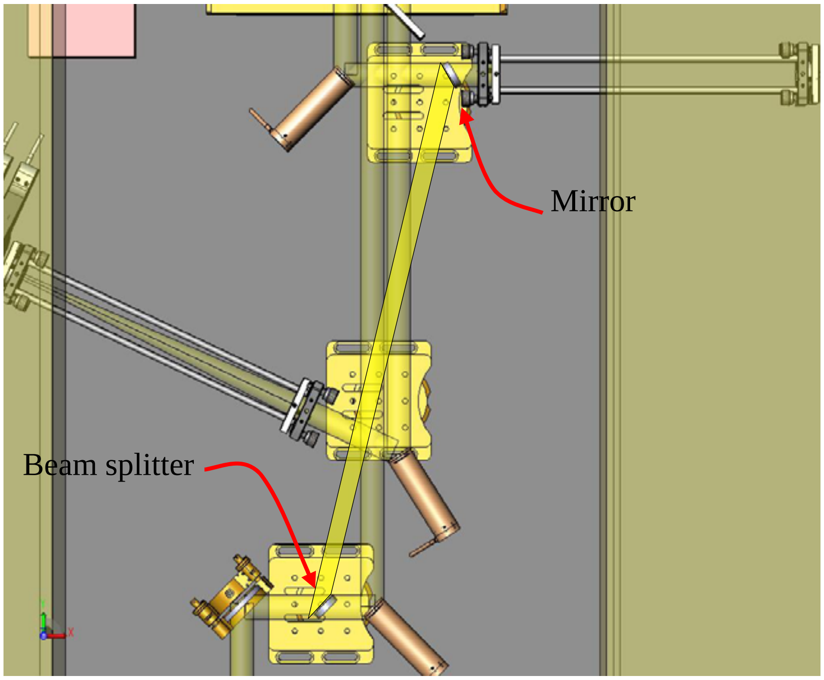

Figure 9: Splitting Laser 2 to compensate for loss of Laser 3.

5.3.2 Support Structure

The three laser heads and the optical bench with the switchyard optics will be mounted to a welded support frame. Using a single large breadboard was considered, but not chosen due to weight and cost issues.

5.3.3 Optical Design

The design input to the BGS is a 1.14 mm diameter waist located 22.69m from the laser enclosure. This results in a required output beam size at the laser enclosure of 14.7 mm $1/e^2$ diameter. A nominally afocal beam expander telescope with a magnification of 4.9 is required to create this beam from the 3mm diameter output from the laser heads.

The output beam arrangement will consist of all three lasers in a line, separated by approximately 25 mm. This will result in a 25 mm x 75 mm pattern.

5.3.4 Tolerances

The beam expander is the only portion of this design that has optical power, so it is where the tightest tolerances are expected. It is, however, an optically slow system so the tolerances are quite reasonable. A decenter tolerance of 100µm and a tilt tolerance of 0.025 degrees will keep the resulting wavefront error from the beam expander under 7nm rms. However, the focus tolerance is more critical. To keep the waist size and position constant to within 5%, the spacing between the beam expander elements can only vary by 25µm. This may require an invar or other low thermal expansion material metering structure.

The magnitude of the tilt and decenter tolerances for other elements are less critical due to the feedback from the position sensors at the BGS, however the flexure terms should be repeatable with little hysteresis. If the beam position sensors at the BGS are 10 mm square, the maximum angular error permissible from the switchyard is approximately 45 arcseconds before the beam wanders off of the detector and is lost. Since the switchyard steering mirrors will use an open-loop lookup table based on elevation and possibly telescope tube temperature for the initial BGS pointing solution, this 45 arcsecond limit is actually the permissible error in the pointing model. As long as the element deflections are repeatable and do not exhibit hysteresis then the pointing model will compensate for them.

5.4 Motion Control

The SYD will require motion control to support the polarization adjustment, tip/tilt for beam steering into the BTO/BGS, and insertion of the beam splitter for low power mode. Of the three, only the tip/tilt beam steering will require a high level of precision. This stage will require a mirror with a piezoelectric actuator to achieve the resolution needed for beam steering. The position sensing devices used in the BGS will have a limited range, so to ensure that the lasers are always within the capture range of the PSDs in the BGS the steering mirrors will use an open-loop lookup table to calculate their position whenever the PSD signal is invalid. Additionally, if the telescope elevation has changed significantly since the last time the laser was propagated, the low power mode will be used to confirm that all three lasers are properly pointed prior to high power transmission. After some period of testing if the flexure model is proven accurate enough this step may be eliminated.

	Device	DOF per stage	No Each	TL DOF	Type	Axes	Range	Accuracy / Repeatability	Tracking Device	Tracking Rate	Slew Rate	Notes
1	Tip/tilt Laser1	2	1	2	Tip/tilt	x,y	3.5 mrad	0.05urad	Yes	Slow; Elevation	17urad/s	PI tip/tilt mirror S330 Tracking to correct telescope flexure
2	Tip/tilt Laser2	2	1	2	Tip/tilt	x,y	3.5 mrad	0.05urad	Yes	Slow; Elevation	17urad/s	PI tip/tilt mirror S330 Tracking to correct telescope flexure
3	Tip/tilt Laser3	2	1	2	Tip/tilt	x,y	3.5 mrad	0.05urad	Yes	Slow; Elevation	17urad/s	PI tip/tilt mirror S330 Tracking to correct telescope flexure
4	Half-wave plate Laser1	1	1	1	Rotational	θ	360 deg	µrad	No	Slow; Rotator Motion	10 deg/s min, 30 deg/s preferable	
5	Half-wave plate Laser2	1	1	1	Rotational	θ	360 deg	µrad	No	Slow; Rotator Motion	10 deg/s min, 30 deg/s preferable	
6	Half-wave plate Laser3	1	1	1	Rotational	θ	360 deg	µrad	No	Slow; Rotator Motion	10 deg/s min, 30 deg/s preferable	
7	Quarter-wave plate Laser1	1	1	1	Rotational	θ	360 deg	µrad	No	Slow; Rotator Motion	10 deg/s min, 30 deg/s preferable	
8	Quarter-wave plate Laser1	1	1	1	Rotational	θ	360 deg	urad	No	Slow; Rotator Motion	10 deg/s min, 30 deg/s preferable	
9	Quarter-wave plate Laser1	1	1	1	Rotational	θ	360 deg	µrad	No	Slow; Rotator Motion	10 deg/s min, 30 deg/s preferable	
10	Alignment Mode / Diagnostics Beam-Splitter	1	1	1	Linear	x	100mm	100µm	No		min: 10mm/sec Goal: 50mm/sec	

Table 3: Switchyard Motion Devices

5.5 Diagnostics

The beam dump mirror stage at the exit of the switchyard can send all three beams to the diagnostic devices. These diagnostics are described in Table 4. An alignment laser along with a manually located insertion mirror optic will be used to align the LLF (Figure 10). This laser will be used for rough alignment as well as alignment verification when the 589nm lasers are not available. The 589nm lasers are be required to have their own shutters and a second shutter is in the BGS so no extra shutters are required in the switchyard.

Ref #	Item Name	Component Description	Accuracy/Requirement
1	Beam dump	Beam dump / calorimeter for laser when in alignment mode	0.1 Watts
2	M^2 / Wavefront sensor	Shack-Hartmann wavefront sensor with M^2 calculation software	
3	Polarimeter	Used to measure polarization state of lasers	
4	Alignment laser/optic	One to three lasers for alignment the LLF without the use of the 589nm lasers	125mW

Table 4: Switchyard Diagnostics

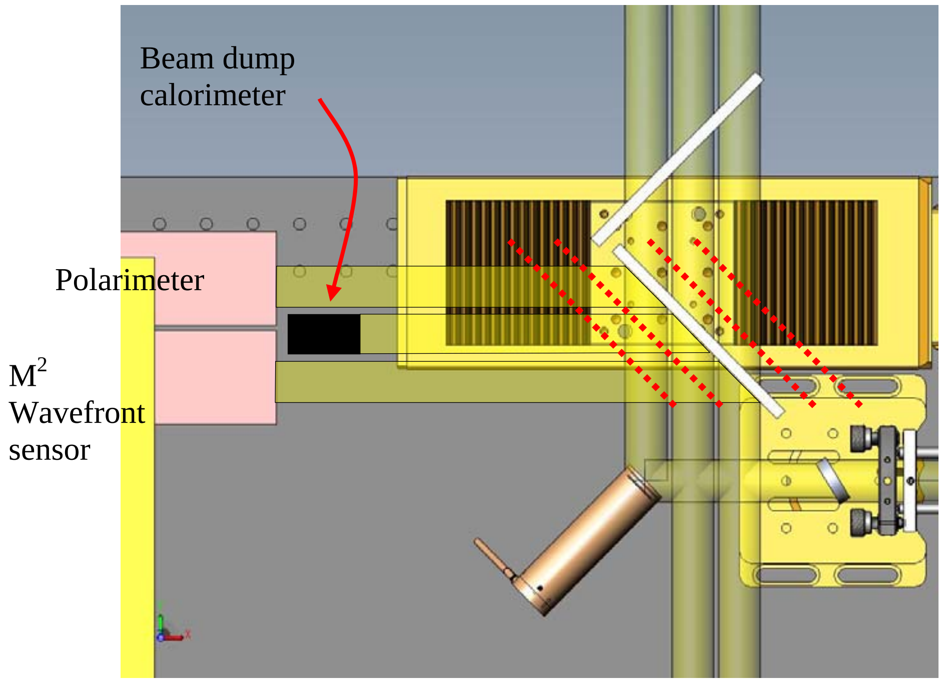

Figure 10: Mirror on stage selects any of the three beams for the diagnostics. (Red dotted lines show the different mirror positions required to send any of the three beams into any of the diagnostics)

5.6 Safety

The SYD will be considered a Class IV laser facility since the power at this location is above 500mW. The ANSI Standard Z136.1 will be used to ensure proper precautions are followed. Since the SYD is only one segment of the LLF, the entire LLF should be examined as a whole for safety concerns and mitigation. The discussion in this document will address the mitigations that are part of the Switchyard.

5.6.1 Laser Containment

The SYD will include covers to control laser radiation. Since the lasers will already has protection covers, only covers will be provided over the central area between the lasers. This will allow personnel to enter the LE without exposure to radiation. The cover will have a switch to interlock the LE entry door. The cover will also act as containment for heat generated within the SYD.

5.6.2 Laser Status Indicators

Laser status indicators shall be provided at entry point to the SYD. The indicators will be represented in the following tables.

	Status Level	Status Description
1	Green	No hazardous radiation in the Switchyard
2	Red	Hazardous radiation in the Switchyard

Table 5: Laser Status Indicator Definition

5.6.3 Laser Shutter Disable

Either for service or in case of emergency, a switch shall be located at the SYD to lock the laser shutters in a closed position. The switch will be an input to the safety system and will remove the hardware shutter permissive to the laser systems. This will prevent any laser beams from entering the SYD optics during servicing.

5.7 Interfaces

5.7.1 External Interfaces

5.7.1.1 Mechanical Interface to the elevation ring / laser enclosure

A mounting frame (Figure 11) similar to the unit to support the Keck II table will be built to support the SYD and the laser heads. The frame attaches to six contact pads (green) that were tied to supports within the elevation ring. The structure members of the frame will be aligned to provide attachment points for the laser heads. The laser heads and the SYD can be installed or removed from the telescope using this mounting frame.

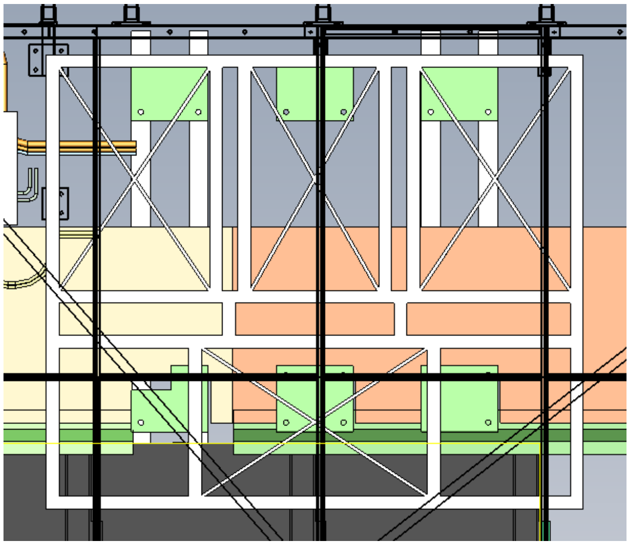

Figure 11: Switchyard support structure

5.7.1.2 Infrastructure Interfaces

The SYD will have an interface to the pneumatic and instrument glycol interfaces at the elevation ring. Both of these interfaces are currently available on the elevation ring and are being used by the Keck II laser table. No new infrastructure is needed to support the SYD. This does not include infrastructure necessary to operate the laser systems. The infrastructure required to operate the laser will be part of the Laser Enclosure design.

5.7.2 Internal Interfaces within the LGSF

5.7.2.1 Mechanical Interface to the BTO

The interface between the SYD and the BTO shall be dust- and light-tight with a clear aperture greater than 25 mm x 75 mm. The interface shall be compliant to ensure that as the BTO flexes with temperature or telescope motion, stresses are not transferred to the SYD optical bench.

5.7.2.2 Optical Interface to the Lasers

The lasers shall provide a linearly polarized beam with a $1/e^2$ size of 3mm diameter to the SYD.

5.7.2.3 Electronic Interfaces

The SYD shall have an electrical interface with the Motion Control System for motion devices as well as diagnostics. Diagnostics will interface with the Safety System for safety related impacts and/or the Laser Control System. Table 6 describes the physical interfaces of the SYD with the Motion Control System or the Safety System.

Ref #	Device Types	Cabling	Connection	Quantity	From	Description	Format
1	Servo Motion	25 wire	Mil-Circular	4	Motion Control System	DC Servo System; drive, encoder, limits	Low DC Voltage Analog

Ref #	Device Types	Cabling	Connection	Quantity	From	Description	Format
2	Piezo Motion	6 wire	Mil-Circular, LEMO	3	Motion Control System	High voltage piezo control; feedback	High DC Voltage Analog
3	Digital I/O	2 wire	Mil-Circular, DB	2	Safety System	Cover Switches	Low Voltage Digital
4	Calorimeter	2 wire	Mil-Circular, DB	1	Safety System; Laser Control System	Beam Dump	Low Voltage Analog

Table 6: Electronic Interfaces

6 SYSTEM PERFORMANCE

6.1 Optical

6.1.1 Transmission

A mirror reflectivity of 99.8% and a lens AR coating transmission of 99.8% are assumed based on a quote from Advanced Thin Films. They have applied similar coatings for both the K1 and the Gemini laser projects. An additional transmission factor of 99.5% is incorporated to account for dust or other surface imperfections.

With these guidelines, the overall throughput of the SYD is 97.6% with clean optics which drops to 92.9% with the 0.5% scattering loss. A full listing of the transmission values is in the system summary document.

6.1.2 Wavefront Error

Due to the tight specifications for this project, all optical figure quality is specified using rms wavefront error. A typical value of 7 nm rms is applied to all surfaces in the switchyard, which yields a wavefront error of 24.8 nm rms. The detailed breakdown of this can be found in the system performance document.

Mechanical

6.1.3 Mass

Table 7 shows the total mass of the SYD and associated electronics. As a comparison, 1,700 Kg was removed from the front face of the Keck II telescope to compensate for the addition of the laser table, associated electronics, and the laser enclosure on the telescope. Table 7 shows the weight of the SYD, lasers, and assorted hardware. The value does not include the laser enclosure which will increase the mass to the 1,700Kg allowance. There should be additional savings in weight as the existing launch tube and L4 optic will be removed from the telescope and replaced with smaller and lighter structures for the Beam Transport Optics.

	Item	Mass (Kg)
1	Optical Breadboard	25
2	SYD Opto-Mechanics	40
3	Laser Mounting Hardware	125

4	Lasers	200
5	Cover	10
6	Diagnostics	10
7	Laser Room and Infrastructure	349
8	Cable and Glycol Lines	45
	Total	**804**

Table 7: Switchyard mass including lasers and electronics

6.1.4 Pneumatics

Dried and filtered air will be used in the Switchyard at a rate of 1 CFM to keep dust and particulates out of the enclosure.

6.1.5 Heat Dissipation and Glycol requirements

The three laser beams will require a beam dump at the SYD during low power operations. The total power dissipated will be 75W or greater; thus requiring a liquid cooled unit. In addition, the lasers located within the SYD will dissipate 50W each into the surrounding area. The total heat dissipated into the area will require an additional heat exchanger to remove the ambient heat. Glycol is already available at the laser enclosure in Keck II; no significant additional work will be needed to support the SYD.

	Item	**Power (W)**
1	Beam dump for lasers	75
2	Motor Control (13 DoF)	13
3	Diagnostics	15
4	Lasers	150
	Total	**253**

Table 8: SYD Heat Dissipation

6.1.6 Electrical

Commercial and clean power is already available at the existing laser enclosure location. The required power not associated with the laser themselves is expected to be significantly less than the existing 120VAC 20 amp circuits. All SYD related requirements will be fed by other systems within the Switchyard such as the lasers, motion control, and the safety system. From an AC point of view, only the diagnostic cameras will require power.

7 Operations

7.1 Mode

7.1.1 Operational Mode

During normal operations, the Switchyard shall operate at full laser power with three laser beams operating at 25 watts each.

7.1.2 Alignment Mode

During alignment mode, the Switchyard will reduce the power of each laser beam to approximately 50 milliwatts. The rest of the LGSF will be aligned at this lower power. Once the system is aligned, the Switchyard will return laser power to its operational level.

This alignment mode will be used to verify that the lasers are properly aimed at the position sensors in the BGS prior to high power propagation after any significant telescope move in elevation. The remaining power will go into a calorimeter beam dump for diagnostic measurement.

7.2 Procedures

7.2.1 Alignment Procedure

The beam expander units will be aligned as a unit prior to installation in the switchyard. In general, the placement of the remaining elements is not critical as long as they do not vignette the beams. All elements will be placed in their approximate locations using either measurements or a full size SolidWorks print of the layout. When all elements are roughly in place, the system can then be fine tuned starting with the turn mirror immediately after the laser exit and working down the beam train. The beam should be centered on all elements. Note that if the lasers do not have a lower power mode it may be too dangerous to do the alignment in this manner. In this case, the fold at the laser exit will be left out and a low power laser will be substituted to align the system. After it is aligned, the fold can be carefully replaced and its alignment checked by placing the test laser at the switchyard output and directing it back into the laser head.

After the internal alignment is complete, the beam dump mirror will be inserted to provide a low power beam to align to the BTO/BGS. The inclusion of an alignment laser will minimize the need of the main 589nm lasers and also allow testing and integration of the alignment tools if the main 589nm lasers are not available. This was found to be quite useful during Keck 2 laser pointing integration. This procedure shall be provided during DDR.

7.2.2 Cleaning Procedure

The Switchyard shall be designed for a 10 year life time. The Switchyard shall be designed as a sealed unit to minimize particulates contamination. However, considerations shall be made in the design to clean the optics in the Switchyard and possibly recoat as necessary. Witness samples may be used in the switchyard for reflectivity measurements to determine the periodicity for the cleaning.

7.3 Operational Resources and Preventative Maintenance

Additional information shall be provided during DDR on required operational resources. Outside of troubleshooting of the Switchyard, Operations team will be required to support maintenance procedures in 7.2. Cleaning will require both personnel and the telescope as resources due to accessibility to components. The cleaning of the optics (dozen) is expected to take no more than 2 hours in-situ.

8 Development and Testing

This section will be presented at the DDR.

9 Requirements Compliance Verification

The compliance matrix will be presented as a whole for the entire LGSF Compliance Matrix document.

10 RISK AND RISK REDUCTION PLAN

Table 9 shows individual risks within BGS in accordance with KAON 510.

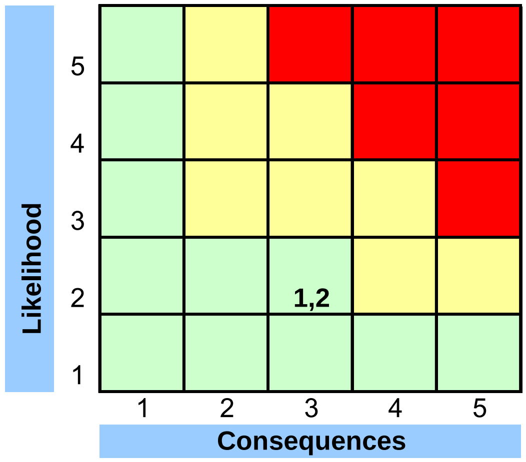

Table 9: Risk Matrix

#	Consequence	Likelihood	Description	Status	Mitigation
1	3	2	Laser System does not fit onto the Switchyard bench	This particular risk will not be fully understood until the final design of the laser is complete. Once the lasers are designed with their physical layout, this risk can mitigated	Although the final design is not complete, the currently layout does allow for some growth.
2	3	2	Polarization changes requiring additional waveplate	The requirement for the laser is a 200:1 linear polarized laser beam. The polarization will be impacted by the angles of the BTO, Switchyard, and BGS.	If the polarization becomes elliptical, an additional waveplate may be necessary to achieve a circular polarized beam at the output of the launch telescope

Table 10: Risk Analysis

10.1 Laser Configuration

The current design of the Switchyard is heavily dependent on the laser configuration. The current SYD design is based on the laser manufacturer able to produce a laser with a three 25W laser heads that can be mounted onto an optical bench similar in size to the existing Keck II laser table. This assumption is based on knowledge currently available in the current laser designs in support of the NGAO lasers. If the laser head size grows slightly, there is still sufficiency space in the enclosure to support them with additional mechanical modifications. If they grow significantly, the fallback position is to place only two of the three lasers at the current location occupied by the Keck II laser table. The third laser will required to be placed elsewhere on the telescope. It is unlikely the laser heads will grow significantly. The design of the laser system will be solidified prior to the DDR.

10.2 Polarization Variations

The current plan is to compensate for polarization changes in the system by adjusting the input to be the conjugate polarization, resulting in a circularly polarized output. This depends on all beams experiencing the same polarization effects over the system. Current data from coating vendors indicates that this should be possible, but more analysis needs to be done to verify that this is the case. If this proves to not be possible then each of the seven individual beacons will need their own set of waveplates. This will have to be done in the BGS and will add to the motion control cost and complexity.

11 DELIVERABLES

Figure 12 shows the deliverables for the Switchyard.

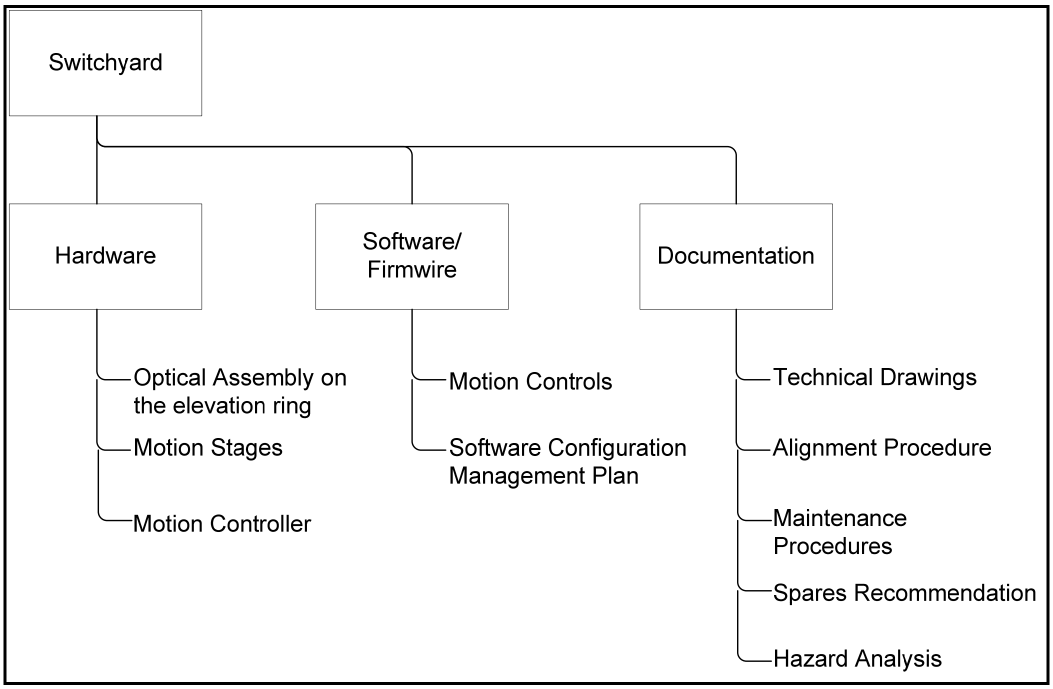

Figure 12: Switchyard Deliverables

12 MANAGEMENT

Management issues will be presented in other areas of the Preliminary Design Review.