NASA SETH – Lowell Discovery Telescope Interface Control Document (ICD) LDT-0596-001-2

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Version	Date	Changes	Approved by
1	5/8/2020	First Release	K. Kuehn
2	8/10/20	SOC Model Update	K. Kuehn

I. Executive Summary

This Interface Control Document (ICD) governs the interactions among NASA SETH subsystems provided by Lowell Observatory and those provided by JPL. Specifically, these include the a) Lowell Discovery Telescope control interface, b) the telescope hardware interface, c) the fiber run from the telescope to the mezzanine floor, d) the mezzanine enclosure for the Photon Counting System, and e) the mechanism for the (off-site) SETH team to acquire the data from the Photon Counting System.

II. Interface Definitions

A. Telescope Control System – To enable successful data transfer, the LDT will receive spacecraft information from the SETH team (i.e., a current ephemeris) and translate it into pointing information for the TCS. Requirements for confirmation of both target acquisition and accurate tracking of the spacecraft during data transfer (as well as a method to update the telescope position if acquisition or tracking fail) will be developed in future iterations of this document.
B. Telescope Hardware Interface – On the LDT side, this includes modifications to the Instrument Cube to accept the Sidewinder fiber relay, as well as the Sidewinder hardware itself. The optomechanical positioning (including tolerances) for the JPL fiber must be specified. Additionally, the fiber routing from the Sidewinder relay output to the mezzanine enclosure must be specified, and any modifications required to the LDT facility must be identified.
C. Mezzanine Enclosure – This includes the physical space requirements and the utilities (electricity, climate control, etc.) needed by the Photon Counting System.
D. Data Transfer – This includes any computers and network interface hardware or software for transport of data from the machines at the LDT to those at remote sites (e.g., JPL).

III. Interface to the TCS

The NASA SETH team is responsible for communicating spacecraft coordinates (in the format specified in the “DCT Science Instrument Software Interface”) to the TCS directly, or to LDT Operator(s), in a timely fashion. Position refinement via RA/Dec offsets can be executed in the lead-up to spacecraft communication. SETH’s position knowledge will come after DSN ranging twice a week. Data will be sent to GSFC FDF (Flight Dynamics Group in MD), who prepares the ephemerides file. They will calculate time-of-observation position, and also extrapolate ~ 4 days until the next ranging determination. The “fresher” the ephemeris product is, the lower the error. Lowell will receive these ephemeris files as soon as they are computed (likely 1-2 days in advance).

Communication between the LDT control systems and instrument software is executed via a message broker, Apache ActiveMQ. The use of a messaging broker allows instruments (and all telescope systems) to maintain and monitor a single connection to the broker, rather than juggle connections to all of the individual subsystems needed for operations. Messages sent to and received from the broker are used to collect observational metadata, or invoke commands that perform on-sky operations such as telescope pointing offsets or focus offsets. There are no additional hard links required from the instrument to the telescope to issue commands or control telescope systems; all commands are communicated via the LDT instrument network to the ActiveMQ broker, which then distributes those messages to the relevant systems.

IV. Lowell Discovery Telescope Hardware Interface

A. Sidewinder Optical Relay Port to the SETH Optical Coupler

1. General description

The instrument cube sidewinder port described here would be located on the Ritchey-Chretien (RC) instrument cube Port-A side specified in the LDT Instrument Cube Interface Specification (LDT-0595-04). The sidewinder port includes a mechanism to deploy a periscope mirror assembly, which intercepts a sub-field of the 0.5° RC field-of-view (FOV) in the same plane as the GWAVES (LDT Guider and Wavefront Sensor) probes. The picked-off beam will be relayed out of the cube to the SETH optical coupler (SOC). The conceptual design of the SETH sidewinder port is documented in LDT-0595-005. This section specifies details of the opto-mechanical interface between the sidewinder port and the SETH SOC.

2. Periscope optical relay

When deployed, the sidewinder pickoff mirror will be located behind element 2 of the RC optical corrector, in the center of the FOV, and oriented at 45° to the telescope Z-axis. The mirror is ∅44.5mm minor axis, yielding an unvignetted circular FOV of ∅0.44mrad. The beam focus is approximately 135mm from the pickoff mirror, and is nominally collimated with a 100mm lens, which also images the exit pupil approximately 16mm inside the cube wall. Alternatively, the periscope could be configured with optics to deliver a beam with a specified f-ratio.

2.1 Prescription

The optical layout of the concept periscope optics is shown in Figure 1, and the prescription is listed in Table 1. The collimating lens is a fused silica plano-convex singlet with an aspheric convex surface, delivering an approximate ∅40.6mm beam to the auxiliary port with an accessible pupil within the periscope for a warm Lyot stop. The collimating lens is optimized for a wavelength of 1.55μm and field angles of 0μrad, 122μrad and 218μrad, and has a convex aspheric departure of 34μm. If the same lens is utilized to make a 1:1 f/6.1 relay, the model delivered image quality is 0.16″, 0.18″, and 0.24″ FWHM for these field angles, respectively; these spot diagrams are shown in Figure 2. The largest residual aberrations at 218μrad field angle are spherical aberration (0.06 waves) and coma (0.034 waves, both at 1.55μm).

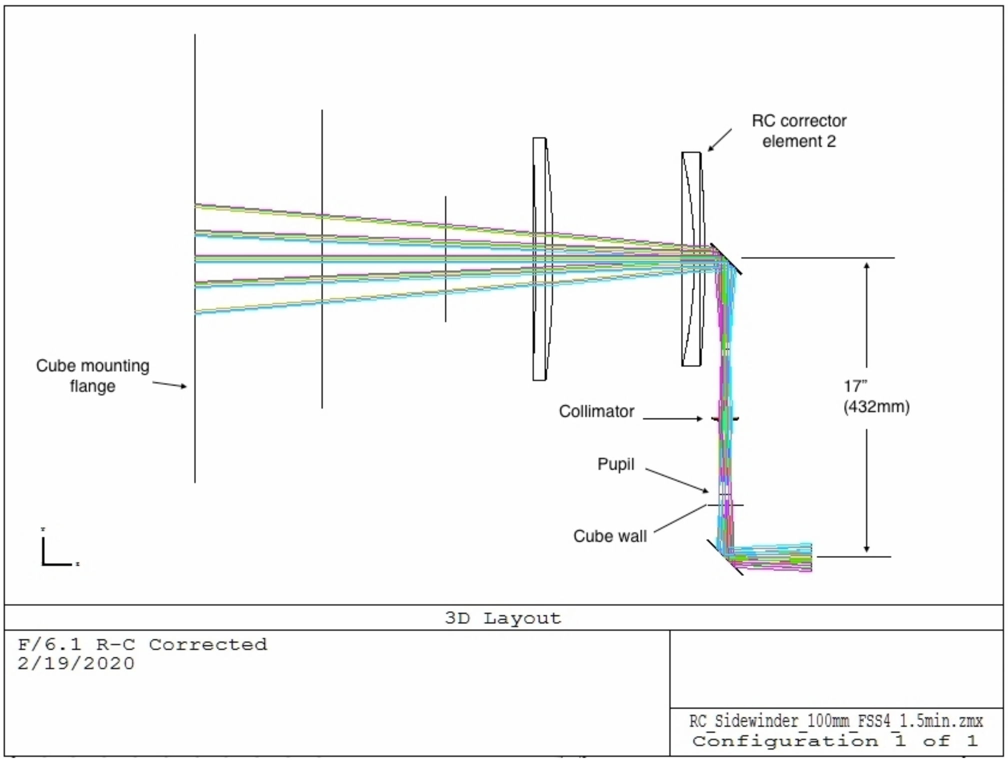

Figure 1. Sidewinder periscope and instrument cube optical layout.

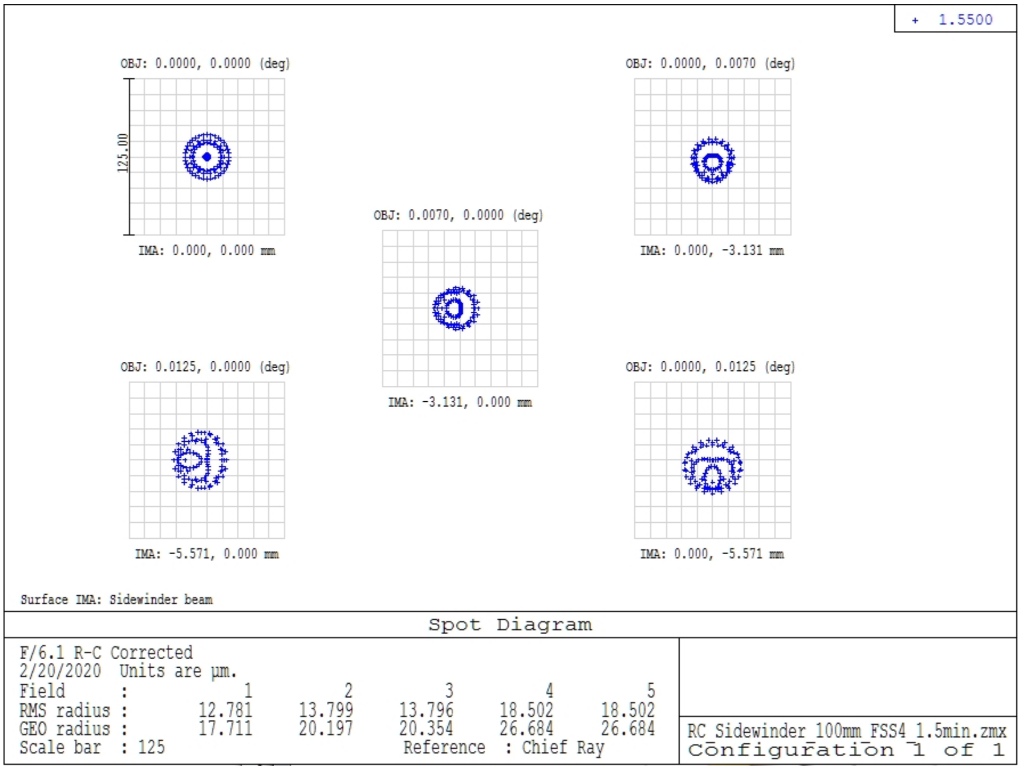

Figure 2. Spot diagrams for a 1:1 f/6.1 periscope relay. The field angles are [0, 0.007°, 0.0125°]=[0, 122µrad, 218µrad]=[0, 25.2″, 45″]. Box size is 125µm, or 1″.

Table 1. RC Cube Sidewinder Optical Prescription

File : C:\Users\tbida\Zemax\dct\rc\RC_D11\RC_Sidewinder_100mm_FSS4_1.5min.zmx
Title: F/6.1 R-C Corrected
Date: 2/19/2020
Dimensions are mm.

SURFACE DATA SUMMARY:

Surf	Type	Radius	Thickness	Glass	Diameter	Conic	Comment
OBJ	STANDARD	Infinity	Infinity		0	0	
1	STANDARD	Infinity	0		1400	0	
2	STANDARD	Infinity	5700		0	0	
STO	STANDARD	Infinity	137.7		0	0	Aperture stop
4	COORDBRK	-	0		-	-	
5	STANDARD	-15994.7	-5617.078	MIRROR	4250	-1.0827	Primary
6	COORDBRK	-	0		-	-	
7	STANDARD	-6925.79	5617.078	MIRROR	1310	-4.5029	Secondary
8	COORDBRK	-	0		-	-	
9	STANDARD	Infinity	1100		600	0	Primary hole
10	STANDARD	Infinity	183.058		159.615	0	Mounting flange
11	STANDARD	Infinity	103.24		129.3041	0	Upper bulkhead
12	COORDBRK	-	76.2		-	-	
13	STANDARD	Infinity	130		180	0	Fold Mirror
14	STANDARD	-3658.611	25	F_SILICA	350	0	Element 1
15	STANDARD	-1509.664	204.81		350	0	
16	STANDARD	-699.84	15	F_SILICA	310	0	Element 2
17	STANDARD	-2007.457	30.24		310	0	
18	COORDBRK	-	0		-	-	
19	STANDARD	Infinity	0	MIRROR	49.73059	0	Sidewinder fold
20	COORDBRK	-	0		-	-	
21	COORDBRK	-	-130		-	-	
22	STANDARD	Infinity	-0.28		11.28282	0	Focus
23	STANDARD	Infinity	-99		11.24957	0	
24	STANDARD	Infinity	-5.7	F_SILICA	38.1	0	Collimator
25	EVENASPH	45.6	0		38.1	-0.7518484	
27	COORDBRK	-	-105		-	-	
28	STANDARD	Infinity	0		17.00007	0	Pupil

29	COORDBRK	-	-15.62		-	-	
30	STANDARD	Infinity	0		50	0	Cube outside wall
31	COORDBRK	-	-76.2		-	-	
32	COORDBRK	-	0		-	-	
33	STANDARD	Infinity	0	MIRROR	40.14648	0	Relay fold
34	COORDBRK	-	125		-	-	
IMA	STANDARD	Infinity			40.44843	0	Sidewinder beam

2.2 System optical efficiency

The system optical efficiency for the sidewinder port is determined by the reflectivities of the LDT primary and secondary mirrors, the transmission of the 2-element RC corrector, the reflectivities of the periscope mirrors, and the transmission of the collimating lens. SETH's laser will operate at 1.55μm, and an estimate of the system throughput at that wavelength is shown in Table 2, with the following assumptions and data:

a. Metallic coatings reflectivities are estimated from literature and commercial datasheets.
b. The RC corrector lenses AR coatings were applied by Infinite Optics in 2013, and optimized over 0.3μm-1.1μm, with average reflectivity of 0.82%. Reflectivity in the NIR has been measured directly in Nov 2019 by the vendor with witness samples from the 2013 Lowell coating runs. At 1.5μm, R=12.8%, which should provide a lower limit for transmission of 87% per surface. The vendor has agreed to provide transmission measurements from the witness samples as well.

Table 2. Sidewinder Periscope System Optical Efficiency (Estimated)

Element	Coating	Transmission efficiency (1.5μm)	Notes
LDT M1	Bare Al	0.90	Estimate for bare Al
LDT M2	Bare Al	0.90	Estimate for bare Al
RC Corrector, 2 elements, 4 surfaces	Optical optimized AR	0.58	Infinite Optics, measured single surface R=12.8%
Periscope M1	Protected Ag	0.98	Edmund Optics 89-459, protected silver
Collimating lens	NIR optimized AR	0.98	Estimate
Periscope M2	Protected Ag	0.98	Edmund Optics 89-459, protected silver
Total transmission		0.44	

3. Opto-mechanical layout and interface

3.1. Periscope assembly

The periscope assembly deploys into the optical axis of the instrument cube, and retracts to avoid collisions with the two movable GWAVES probes. The tube moves 229mm between the stow and deployed positions, avoiding interference with internal cube hardware, and facility instrumentation installed on or adjacent to Port-A (for example, the DeVeny Spectrograph and RIMAS). The periscope assembly must be designed and constructed for ease of installation and removal from the cube, with facility instrumentation installed concurrently. The concept periscope assembly is shown in two views in Figure 3.

3.2. Periscope installation

Installation of a periscope assembly requires modification of the Port-A side plate of the cube; other cube parts may also require modifications. Only the Port-A plate is designed to be removed from the cube assembly. Accessing this cube plate for modification first requires removal of all science instruments from the 5 cube ports, then removal of the cube assembly from the telescope, and then partial disassembly of the cube to remove the plates and parts requiring modification. Figure 4 shows a rendering of a partial Port-A plate modification to facilitate the periscope installation.

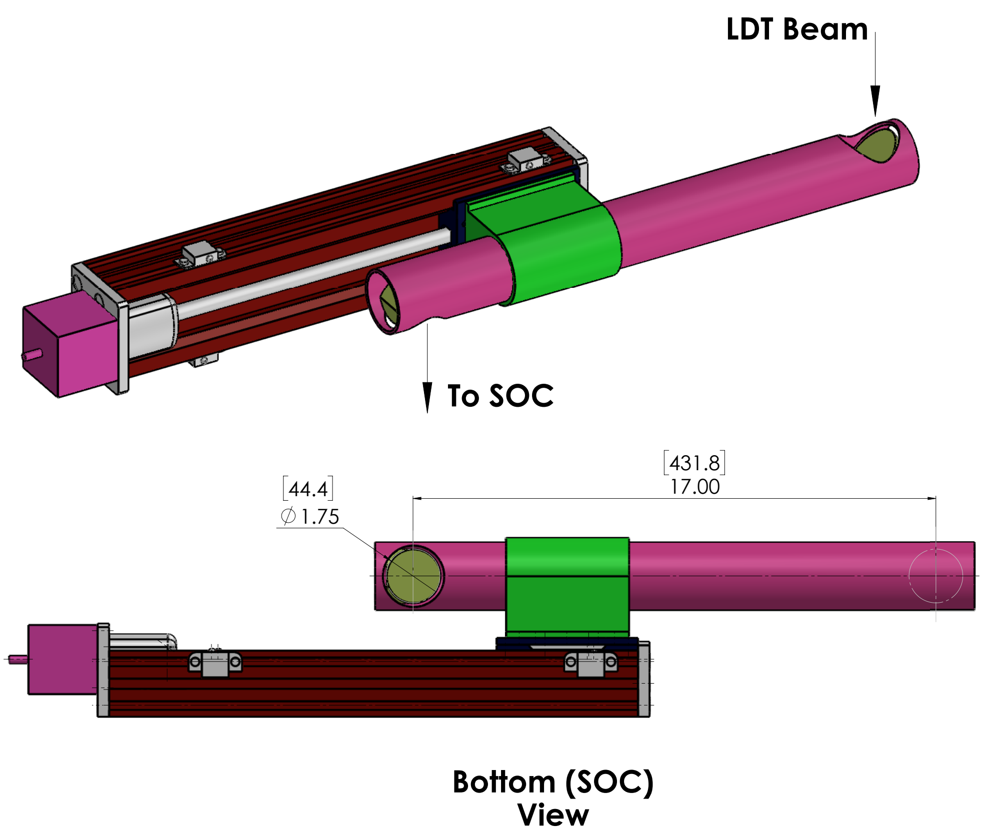

Figure 3. Sidewinder periscope concept assembly. Dimensions are [mm] and inches.

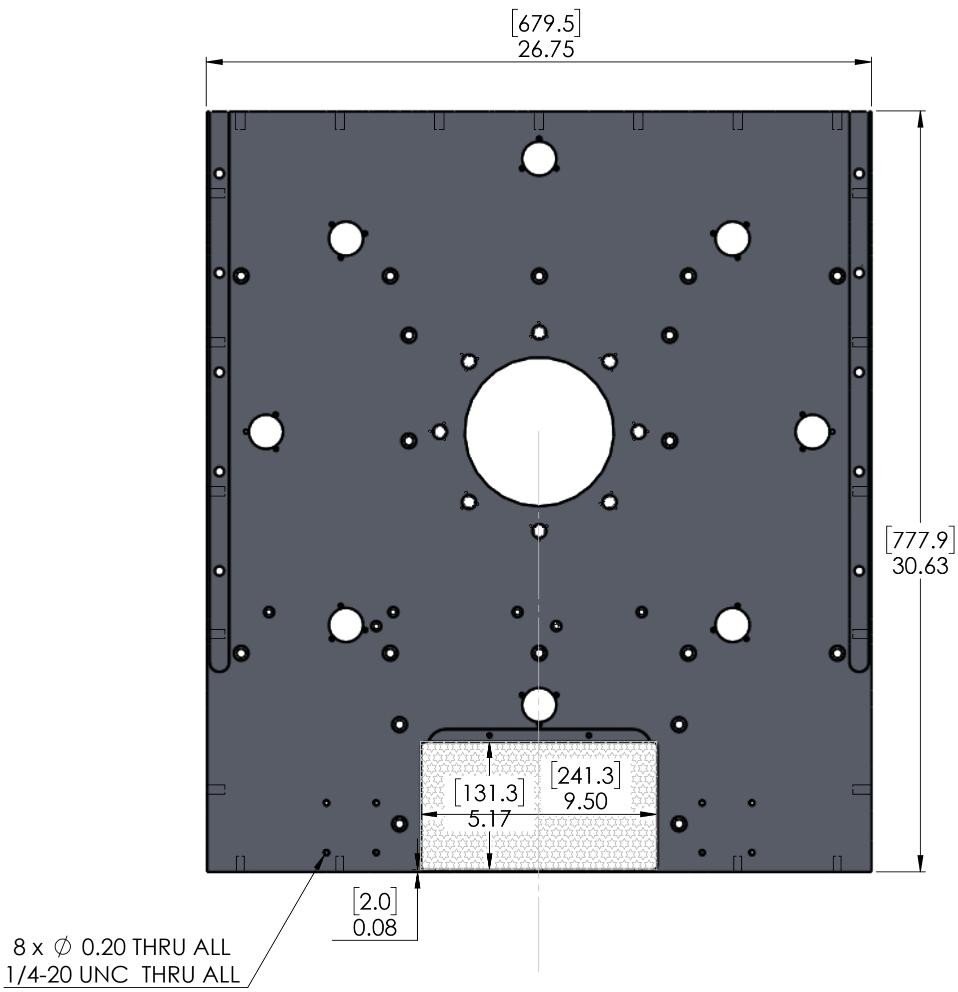

Figure 4. Cube A-side plate modifications, including removal of the hatched area and the addition of tapped holes. Dimensions are [mm] and inches; hole callout dimensions are inches.

3.3. SETH optical coupler installation concept

A location on the instrument cube is identified for installation of the SETH Optical Coupler (SOC) that should not interfere with existing or planned instrumentation. Reserved volumes on the cube for the periscope and sidewinder-fed instrumentation have been drafted and will be detailed in LDT-0595-005. The SOC opto-mechanical model was designed by JPL according to the optical interface specified in Section 2. The SOC enclosure has dimensions 346mm x 652mm x 235mm, and will be mounted to the bottom of the cube with a large angle bracket(s) attached to existing tapped assembly holes. The model SOC is shown mounted in the sidewinder beamline in Figures 5 and 6, located below the cube and adjacent to the LMI filter wheel. Mounting hole locations on the cube are shown in Figure 7. Requirements for the SOC assembly and supporting hardware include the capability to be installed and removed from the cube with facility instrumentation installed, while preserving service access to cube instrument systems and the SOC.

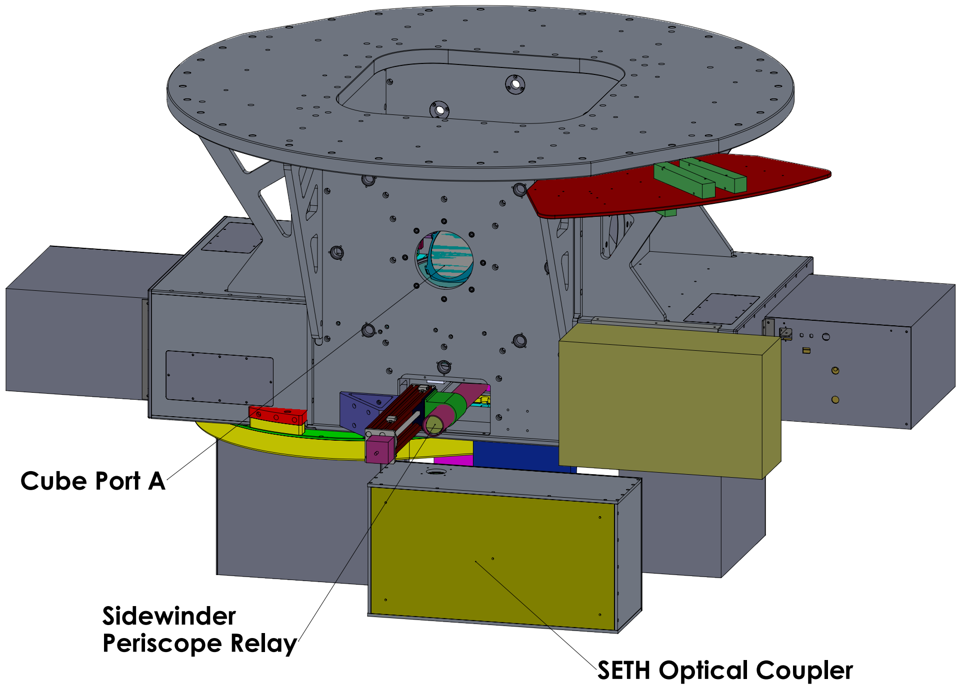

Figure 5. Sidewinder periscope relay and SETH optical coupler installation on the cube Port-A side.

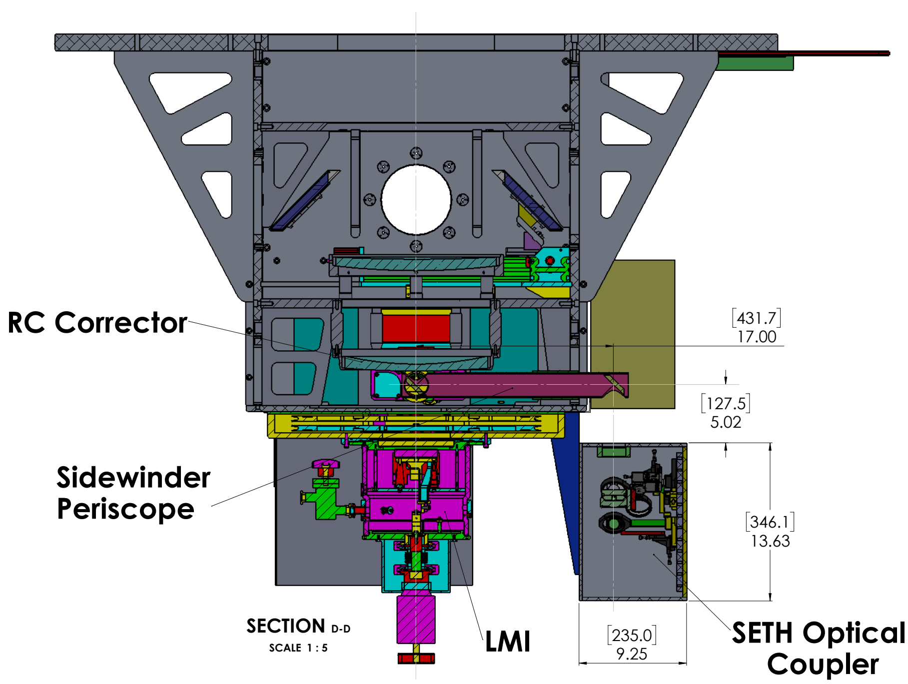

Figure 6. Cross section of the cube sidewinder-SOC installation and facility instrumentation. Dimensions are [mm] and inches.

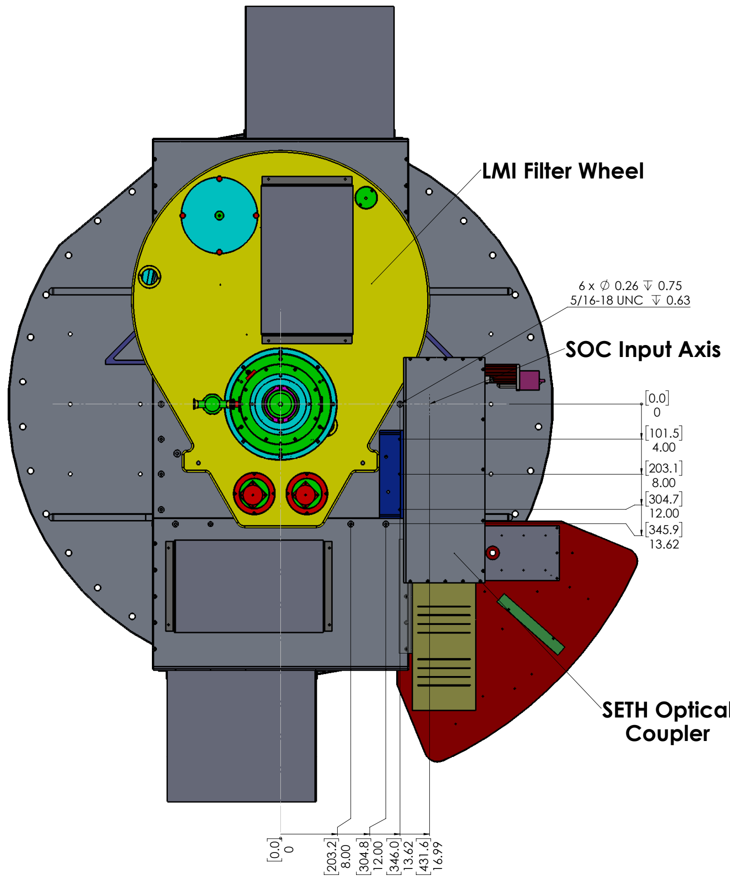

Figure 7. Position of the SETH optical coupler and a model mounting bracket with details of existing tapped mounting holes. Dimensions are [mm] and inches; hole callout dimensions are inches.

B. Fiber Output from Sidewinder and routing to Mezzanine Enclosure

While the final fiber route has yet to be determined, one feasible option is for the SETH fiber to run from the SOC into the LDT pier, and then out of the pier on the ground level using existing cable trays in the ceiling of the electrical room and then up through the floor to the mezzanine close to the south wall.

V. Mezzanine Enclosure

Volume available for SETH support equipment located on the SE section of the Mezzanine is 10ft x 10ft x 8ft. A proposed layout for the Mezzanine Enclosure is shown in Figure 8. Current utilities available are: UPS protected 110V ac, ethernet. Additional utilities will need relocation, including: chilled glycol (approximately 6°C), compressed air (instrument grade and facility grade), and compressed helium. Both a 10 MHz and 1 Pulse-Per-Second (PPS) GPS locked signal are available from the facility GPS receiver and can be routed to the mezzanine enclosure via a BNC terminated coaxial cable. IRIG signals may become available in future upgrades to the facility GPS receiver.

Facility glycol for use with the SETH air handler can potentially be run through the same route as the optical fiber (see Section IV.B).

The mezzanine receiver station will dissipate no more than 4kW of heat into the telescope dome during operations.

The cryocooler compressor shall require 15A of 480V 3-phase power.

Lowell observatory will provide piping for 250psi compressed helium running from the cryocooler compressor to the mezzanine floor.

The mezzanine receiver station will require up to 4kW of 120V single-phase electrical power.

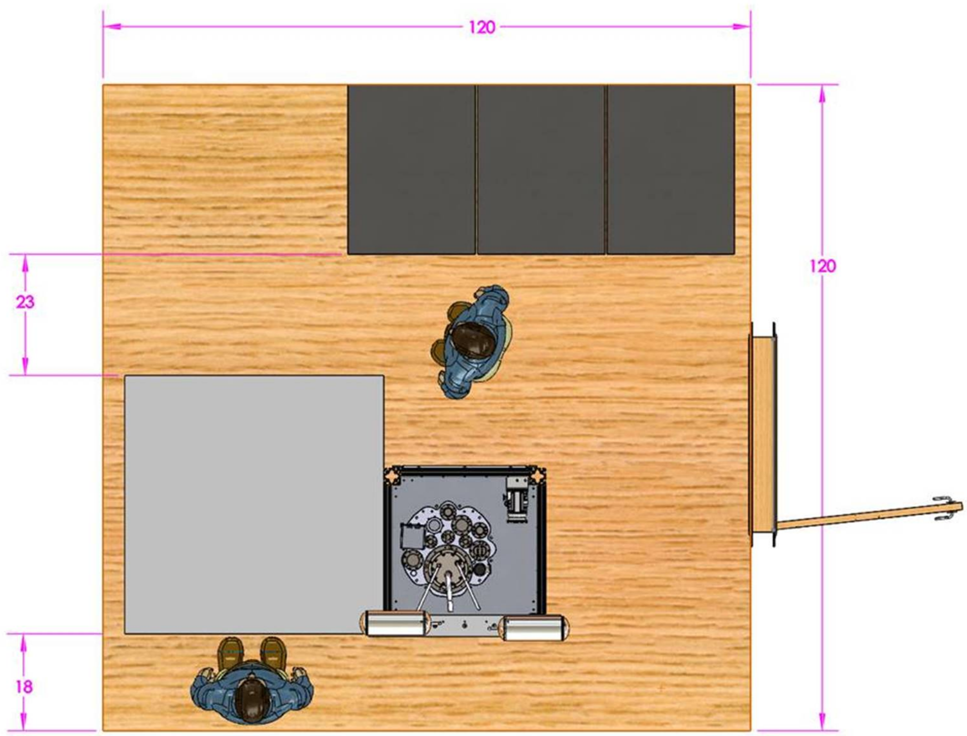

Figure 8. Internal view of the proposed Mezzanine Enclosure. Dimensions are inches.

The temperature, apparent atmospheric pressure, and humidity of the mezzanine have been continually monitored via a simple COTS sensor (Bosch Sensortec BME280) since December 2019. The exterior weather information is measured by a COTS weather station (Columbia Weather Systems Orion). The sensor was not rigorously calibrated so the following statistics are for information only:

Table 3. Mezzanine Atmospheric Conditions (November 2019 thru April 2020)

		Minimum Observed	Maximum Observed
Mezzanine	Temperature (°C)	-8.6	25.2
	Relative Humidity (%)	16	82
	Apparent Pressure (hPA)	749	786
Exterior	Temperature (°C)	-12.8	24.8
	Relative Humidity (%)	6	99
	Apparent Pressure (hPA)	750	777

Note: apparent atmospheric pressures *have not* been corrected to sea level. The site altitude is approximately 2337 meters.

VI. Data Transfer Hardware, Software, and Communication Protocols

The NASA SETH team is responsible for acquiring all data from the Photon Counting system to whatever off-site facility they desire. Lowell Observatory supports VPN access by specified users for this purpose. If other mechanisms for data transfer are required, they need to be specified and agreed to in advance by the Lowell SETH team.

Referenced Documents

Document Number	Document Title	Notes
LDT-0595-004	LDT Instrument Cube Interface Specification	
LDT-0595-005	LDT Instrument Cube, SETH Sidewinder Port Conceptual Design	