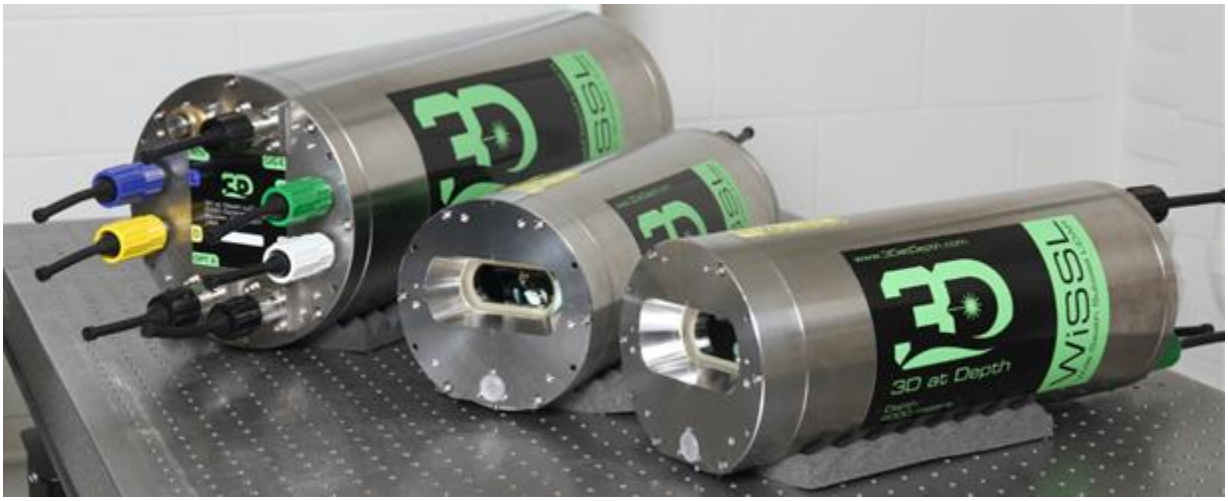

Wide Swath Subsea LiDAR (WiSSL)

User Manual

Rev 1.0

3D at Depth LLC
2450 Central Ave Suite J
Boulder, CO 80301

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1 Purpose

This document contains technical information to help the user with the integration, operation, and maintenance of the Wide Swath Subsea LiDAR (WiSSL) system.

2 Laser Safety

The SL family of laser sensors can emit Class 3B visible laser radiation. Extreme care must be exercised during operation. The International Electrotechnical Commission (IEC) describes Class 3B as follows:

"Class 3B lasers are potentially hazardous if a direct beam or specular reflection is viewed by the unprotected eye (intrabeam viewing). The following preautions should be taken to avoid diret beam viewing and to control spectular reflections.

a) The laser should only be operated in a controlled area
b) Care should be exercised to prevent unintentional specular reflections
c) Conditions for safe viewing of a diffuse reflection for Class 3B visible lasers are: minimum viewing distance of 13cm between the target and the cornea (eye) and a maximum viewing time of 10 s.
d) Eye protection is required if there is any possibility of viewing either the direct or specularly reflected beam, or of viewing a diffuse reflection not complying with the conditions of item(c).
e) The entrances to areas should be posted with a standard laser warning sign."

The SL series emits 40,000 laser pulses per second. For all devices in the SL family, a single laser pulse emitted directly into the eye can cause serious eye damage and possible blindness.

For this reason the 3D at Depth laser system should NEVER be used for topside scanning as it is specifically design for underwater laser scanning. In addition, the system will overheat if operated outside of water.

2.1 Laser Safety Recommendations

WARNING

When operating the laser system, it is recommended that you observe the following safety precautions:

1. While on land or on deck always have the window cover in place when the laser is connected to line power.
2. Limit access to the laser to those familiar with the equipment. Keep the laser out of the hands of inexperienced or untrained personnel.

3. The laser sensor should only be operated by a person trained on the safe operation of the product.
4. While on land or on deck and the laser is on, ensure the entire scan area is completely blocked. Tape barriers or personnel should be used to keep untrained persons out of the scan area.
5. NEVER LOOK DIRECTLY INTO THE MAIN LASER BEAM, NEVER SIGHT DOWN A BEAM INTO ITS SOURCE.
6. Do not allow reflective objects to be placed in the laser beam. Laser light scattered from a reflective surface can be as damaging as the original beam. Even objects such as rings, watchbands, and metal pens or pencils can be hazardous.
7. All personnel should stand behind the laser prior to starting a scan and during all scans. NO personnel should be in the scan area during a scan.
8. The SL systema have an internal attenuator that attenuates the emitted beam to below maximum permissible exposure (MPE) limits (Gains 1-4). When operating the system on land or on deck, the system should **ONLY** be operated with Gains 1-4. When operating in this mode, all of the Safety Recommendations should still be followed to prevent direct viewing of the beam.
9. Once underwater, the system can be operated in Class 3B mode. For diver deployed operations, it is particularly important to follow the Safety Recommendations. The diver must always be behind the laser unit prior to laser light emission. A clear communications channel and operational protocal are required between the the diver and the topside control to ensure the diver is in a safe position and not watching the scan prior to every laser activation.
10. CAUTION – Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.
11. NEVER LEAVE THE LASER ON, OPEN, AND UNATTENDED
12. The operator can reference ANSI Z136.1 for further guidance on the safe use of lasers.

2.2 Additional Laser Safety Information Sources

Sources for additional information and assistance on laser safety are:

Director (HFX-400)
Division of Compliance
Bureau of Radiological Health
5600 Fishers Lane
Rockville, MD 20857
(Regulations and Requirements)

American National Standards Institute, Inc.
1430 Broadway
New York, NY 10018
(Safety Guides)

Laser Institute of America
400 Executive Park Drive
Cincinnati, OH 45241
(Safety Guides)

2.3 Safety and Identification Labels

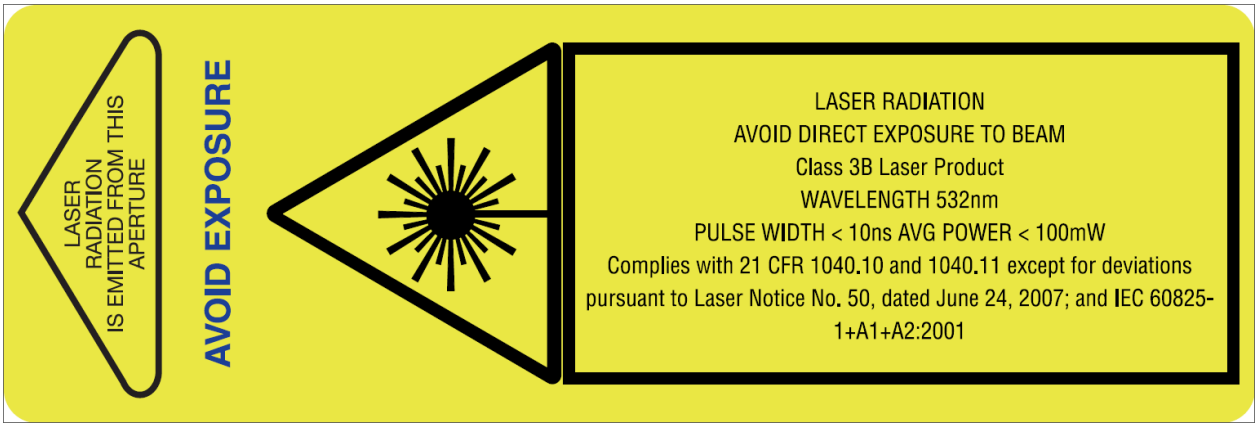

Figure 1 Warning, Certification, and Aperture Warning Label

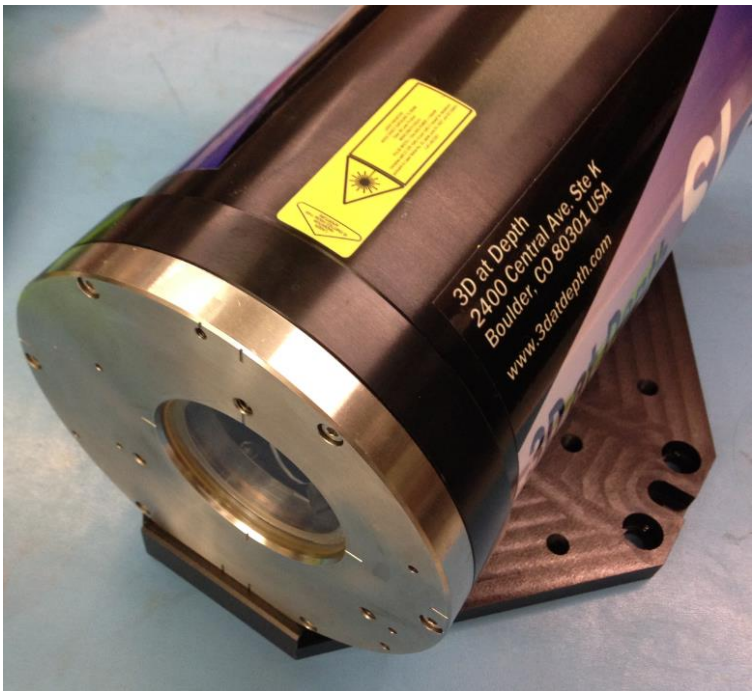

Figure 2 Label Location and Laser Aperture.

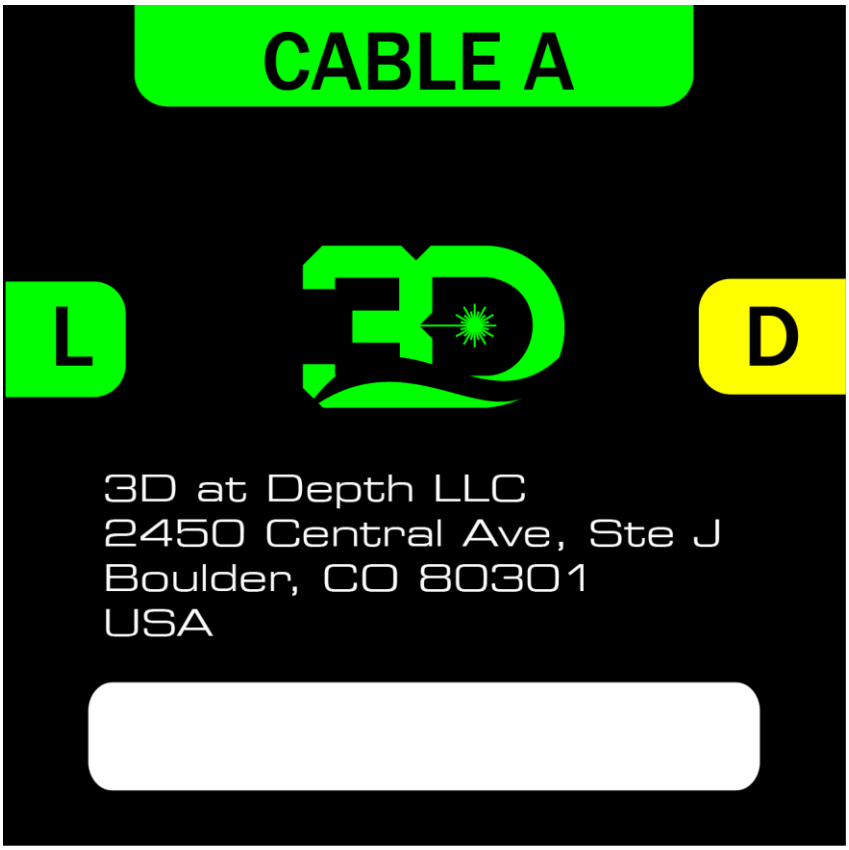

Figure 3 Identification Label.

2.4 General Information on Laser Output

Wavelength:	532 nm
Maximum Average Radiant Power:	< 0.1 W
Beam Divergence:	~373 µrad
Beam Diameter at Laser Aperture:	~2 mm
Pulse Duration:	< 1ns
Pulse Repetition Rate:	40kHz

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3 Connectors and Cables

3.1 Cabling Diagram

Figure 4 below shows the WiSSL cabling diagram.

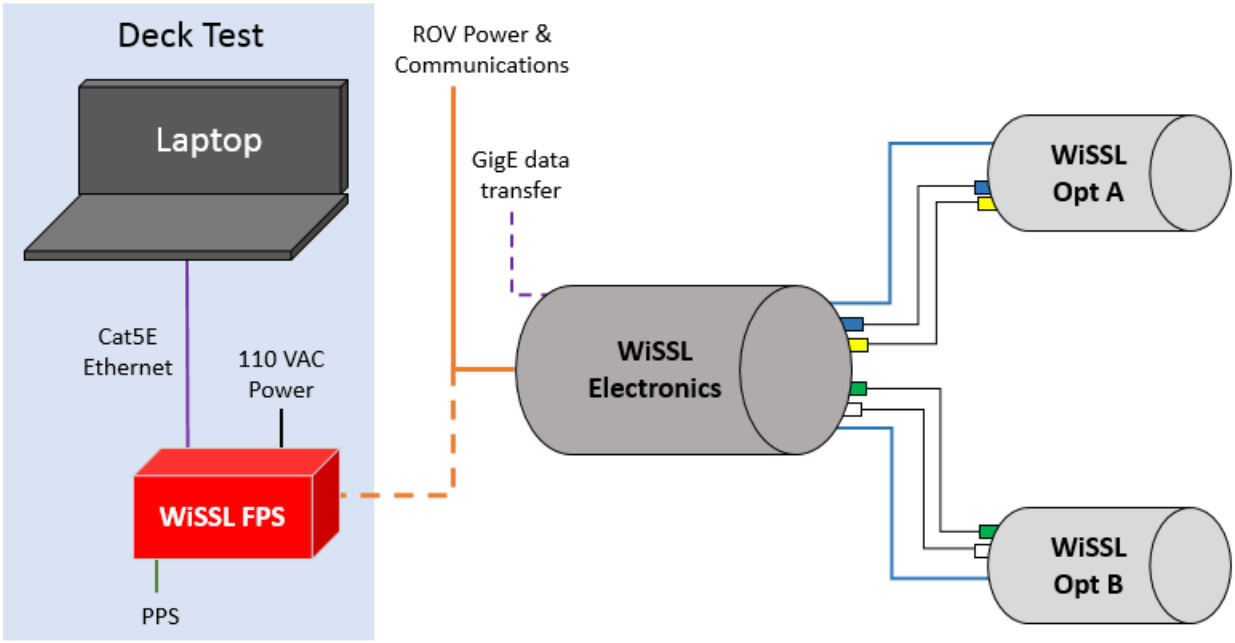

Figure 4 WiSSL Cabling Diagram

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3.2 Optical Bottle Connectors

Figure 5 below show the connectors for each WiSSL Optical head. It is advised to ensure all bottle fasteners and connectors are tightened properly before each dive/campaign. Refer to Section 3.9 for Optical Bottle connector part numbers and costs.

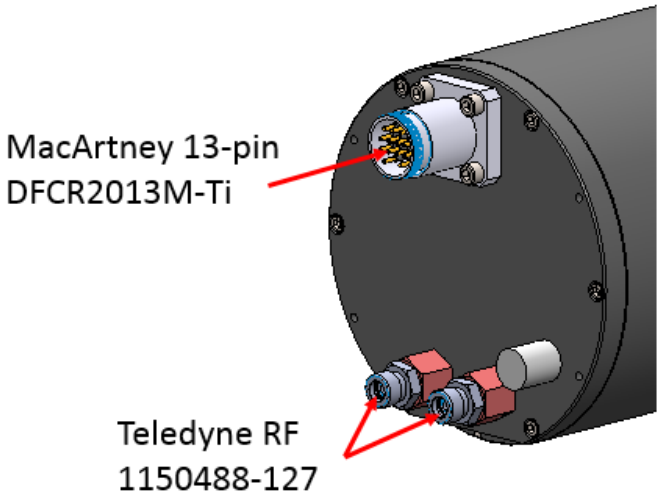

Figure 5 Optical Bottle connectors

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3.3 Electronics Bottle Connectors

Figure 6 below shows the connectors for WiSSL Electronics head. It is advised to ensure all bottle fasteners and connectors are tightened properly before each dive/campaign. Refer to Section 3.10 for Electronics Bottle connector part numbers and costs.

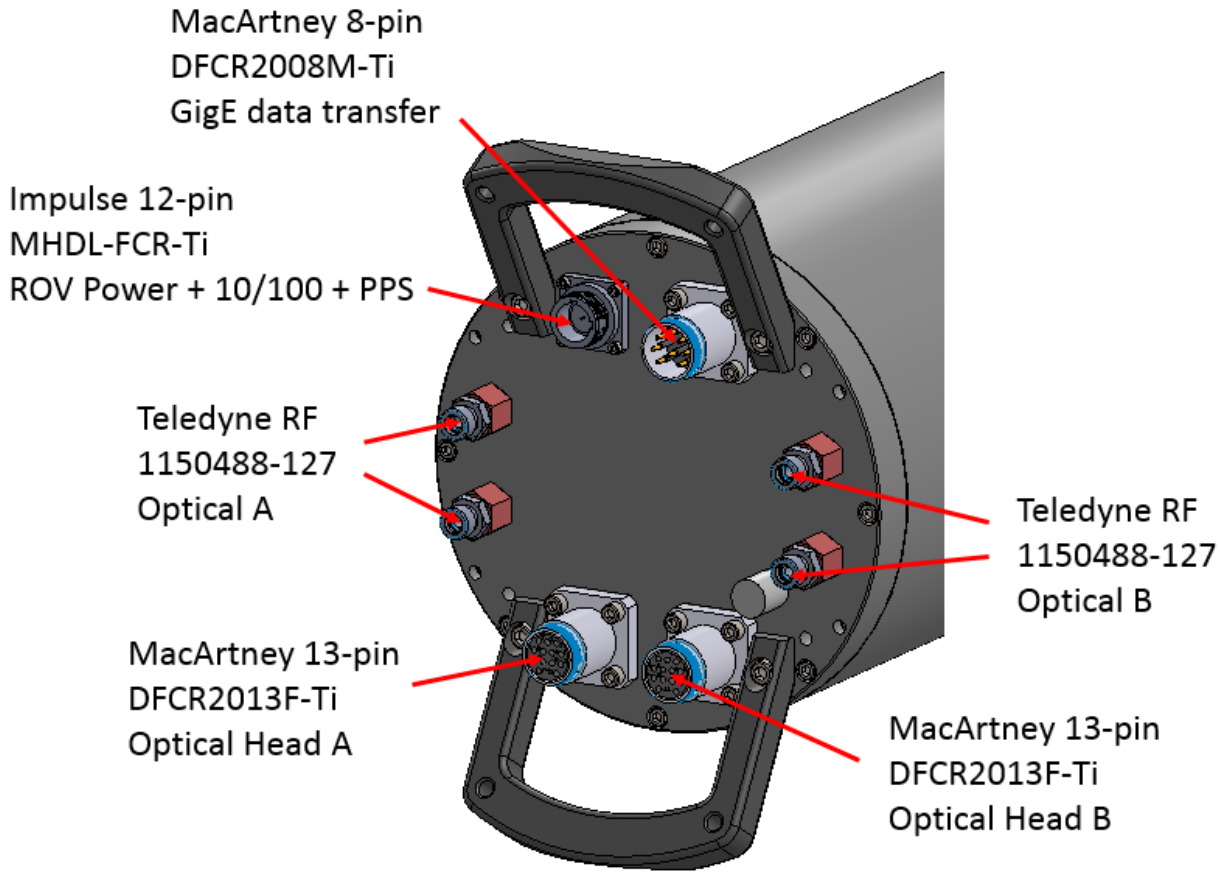


Figure 6 Electronics Bottle Connectors

3.4 ROV Power and Communication Interface

The WiSSL system's primary connection to the ROV is through a Teledyne Impulse 12-pin MHDL connector (SubConn D-P-P4TP24#/4C18# cable). This cable provides power, PPS and 10/100 Ethernet communications to the Electronics. Table 1 shows the pin-out for this connector and cable (TP = twisted pair).

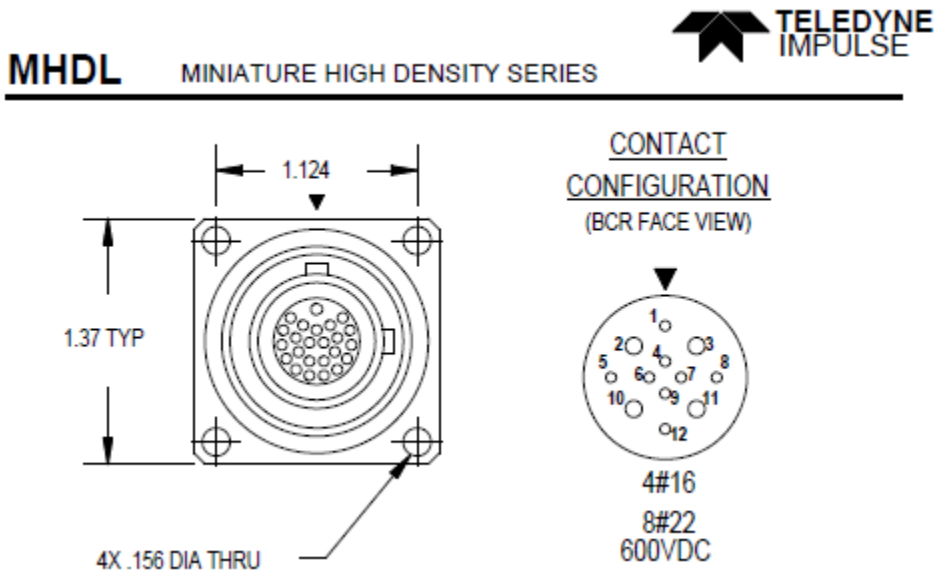


Figure 7 Teledyne 12-pin MHDL Connector

Table 1 Teledyne 12-pin connector and cable pin-out

MHDL-CCP-M-4#16/8#22-SS	D-P-P4TP24#/4C18#	MHDL-CCP-F-4#16/8#22-SS	Signal
1: 22 AWG	TP1a: 24 AWG	1: 22 AWG	PPS Signal
2: 16 AWG	Gnd: 18 AWG	2: 16 AWG	Power Gnd
3: 16 AWG	Gnd: 18 AWG	3: 16 AWG	Power Gnd
4: 22 AWG	TP1b: 24 AWG	4: 22 AWG	PPS Signal Gnd
5: 22 AWG	TP2a: 24 AWG	5: 22 AWG	Ethernet TX-
6: 22 AWG	TP2b: 24 AWG	6: 22 AWG	Ethernet TX+
7: 22 AWG	TP3a: 24 AWG	7: 22 AWG	Ethernet RX-
8: 22 AWG	TP3b: 24 AWG	8: 22 AWG	Ethernet RX+
9: 22 AWG	TP4a: 24 AWG	9: 22 AWG	Spare
10: 16 AWG	+48V: 18 AWG	10: 16 AWG	+48V
11: 16 AWG	+48V: 18 AWG	11: 16 AWG	+48V
12: 22 AWG	Shield	12: 22 AWG	Connected to Housing in sensor
	TP4b: 24 AWG		N/C

3.5 Gigabit Ethernet Interface

In addition to the 10/100 Ethernet communications through the Teledyne 12-pin connector, an 8-pin MacArtney connector is also mounted on the Electronics that provides a gigabit Ethernet connection for data transfer. The mating cable is SubConn D-P4TP24#. Figure 8 shows the pin-out of this connect per the MacArtney/SubConn datasheet.

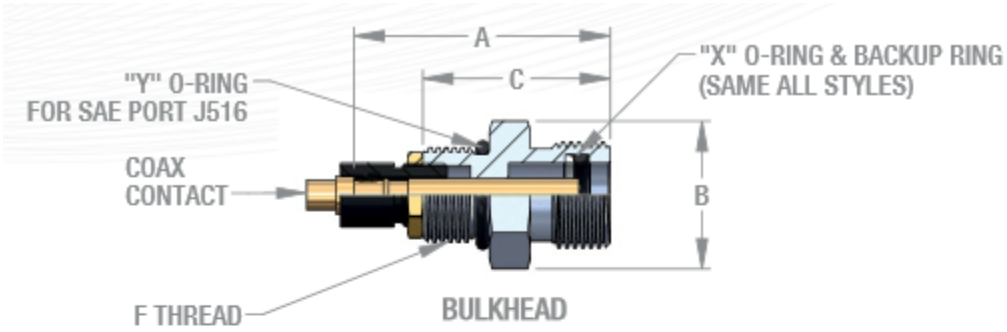
Although sensor communication and control can occur through this interface (in addition to just data transfer), the Teledyne 12-pin must be connected to provide power and PPS to the sensor system.

Figure 8 MacArtney 8-pin Connector Pin-Out

3.6 RF Connectors

Teledyne RF connectors have been chosen for the WiSSL system. The RF connector mate to threaded adapters designed to adapt the connector holes in the bottle end caps (previously sized for MacArtney RF bulkhead connectors) to the Teledyne RF hole. It should be noted that the adapter and RF connector have different torque values. Consult 3D at Depth prior to torquing the Teledyne RF connectors or the adapters.

These connectors also have user-serviceable o-rings that must be checked prior to dive. Failure to install these o-rings may compromise the integrity of the pressure vessel housings and could result in catastrophic failure. Figure 9 shows details of the Teledyne RF Bulkhead Connector. The user-serviceable o-ring is size of -012. Figure 10 shows details of the Teledyne RF Pressure Cap. The user-serviceable o-ring is size -013. This same o-ring size is also used on the RF cables.



	Bulkhead
Receptacle Part No.	1100001-101
A	1.5
B (across hex nut flats)	0.75
C	1.1
D	n/a
E	5/8-18UNF
F	9/16-18UNF
O-ring "X"	MS28775-012
Back-up Ring	1102109-501
O-ring "Y"	M83461/2-906
Coax Contact	1131016-101
Cable Accommodated	RG-58, CN-4

(Dimensions in inches)

Figure 9 Teledyne RF Bulkhead Connector

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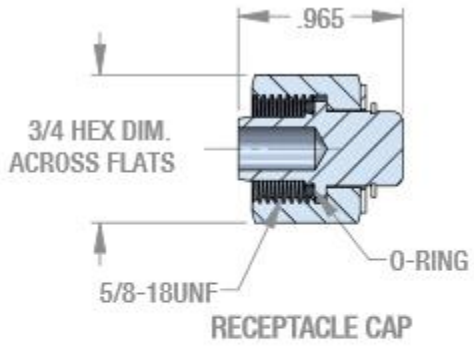

	Receptacles
Pressure Proof Cap Part No.	1104001-101
Material	316 Stainless Steel
O-ring	MS28775-013 (Buna-N)

(Dimensions in inches)

Figure 10 Teledyne RF Pressure Cap

3.7 RF Cables

Each Optical head is connected to the Electronics via (2) RF cables. (6) sets of RF cables are included with the system. In a cable set, one cable is connected to the "L" port and one is connected to the "D" port on both the Electronics bottle and the Optical bottle. The cables are color coded to assist in identification. Figure 11, Figure 12 and Figure 13 show the product labels applied to each bottle end cap. These labels designate which color of cable has been calibrated for that particular bottle.

Figure 11 Optical head A label

Figure 12 Optical head B label

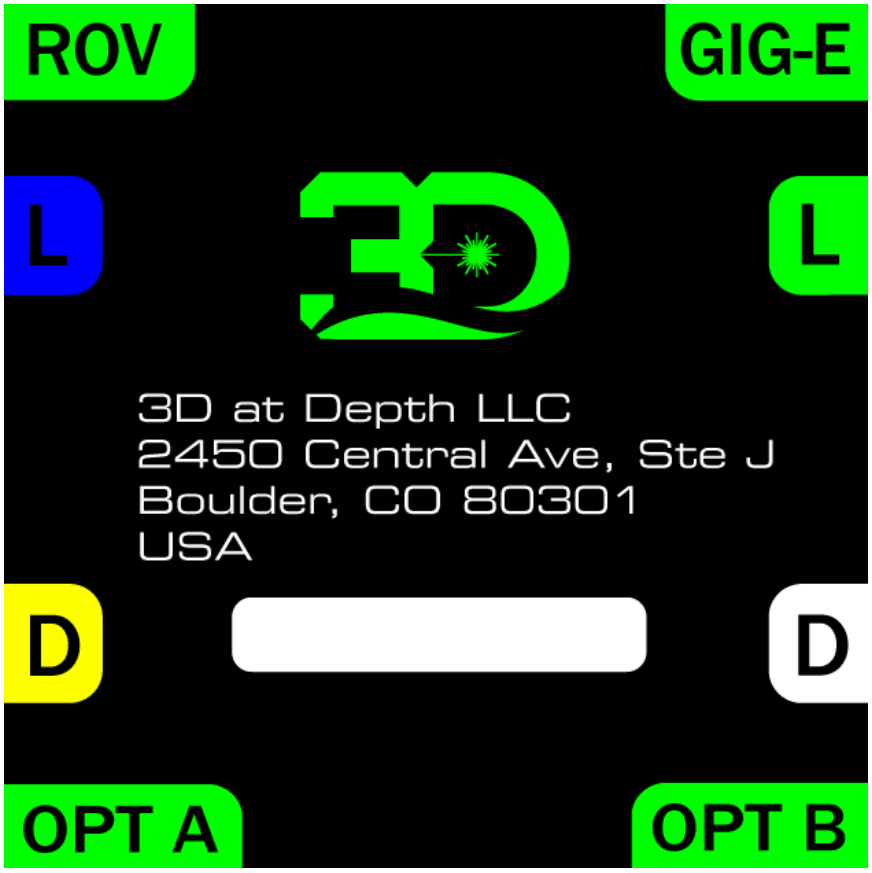

Figure 13 Electronics head label

Each WiSSL Optical head will have (1) “primary” cable set that has been either calibrated for each Optical head. These primary cables have been identified with a single color, as shown in Figure 14. Additionally, (4) “secondary” sets are cables have been cross-calibrated and can be used on either Optical head if a primary cable(s) is damaged. These secondary cables have been identified with two colors, as shown in Figure 15. All cable sets are serialized with a RF-M-xx number, also shown in these Figures.

Figure 14 Primary cable set, single color identification

Figure 15 Secondary cable set, two color identification

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Each cable set has associated calibration coefficients that must be used when that cable set is in use. The coefficients are unique to each cable set and to each head. For example, if the operator is using cable set RF-M-04 on Head B, then the 'RF-M-004 Optical B' coefficients must be entered into the config file. The calibration coefficients are all saved on each head under D:\3D\CFG\WSparams_ec.cfg. To select the correct coefficients, comment out all of the coefficients that should not be used with "//" placed before each line. Make sure that the coefficients to be used are not commented-out. Figure 16 below shows and example of how to use the coefficients for RF-M-01 on Optical Head A. Note that the coefficients for cable RF-M-01 are not commented out, but the coefficients for RF-M-03 are commented out. Refer to the config file for all coefficients for all calibrated cable sets.

```
//RF-M-001 Optical A
T1_WATER_G4000          =  1.4674
FF_WATER_G4000          =  0.98373
T1_WATER_G3000          =  1.4446
FF_WATER_G3000          =  0.98327
T1_WATER_G2000          =  1.4637
FF_WATER_G2000          =  0.98330
T1_WATER_G1000          =  1.5298
FF_WATER_G1000          =  0.98349
T1_WATER_G400           =  1.4790
FF_WATER_G400           =  0.98370
T1_WATER_G300           =  1.4859
FF_WATER_G300           =  0.98396

//RF-M-003 Optical A
//T1_WATER_G4000          =  1.7837
//FF_WATER_G4000          =  0.98308
//T1_WATER_G3000          =  1.7992
//FF_WATER_G3000          =  0.98327
//T1_WATER_G2000          =  1.8183
//FF_WATER_G2000          =  0.98330
//T1_WATER_G1000          =  1.9301
//FF_WATER_G1000          =  0.98367
//T1_WATER_G400           =  1.8550
//FF_WATER_G400           =  0.98397
//T1_WATER_G300           =  1.8351
//FF_WATER_G300           =  0.98371
```

Figure 16 Example RF cable coefficients

Once the operator has the config file setup with the right constants, save the config file, then reboot the sensor to re-load the new configuration.

The calibration coefficients are saved in the config files on each sensor head and they are also saved in the delivered file "RF_Cable_Coefficients.xlsx"

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3.8 13-pin MacArtney Cable

In addition to the RF cables, each Optical head is also connected to the Electronics via (1) 13-pin MacArtney cable. The 13-pin cables (SubConn D-P-P4TP24#/4C18#) are interchangeable between the two Optical heads. These cables have been custom-molded with a right-angle connector on one end, as shown in Figure 17. The right-angle plug mates to the Optical head and the straight plug mates to the Electronics. Table 2 and Figure 18 describe the connector and cable pin-outs.

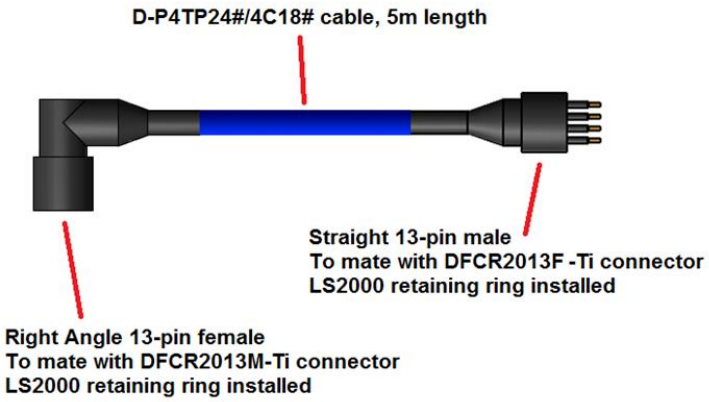


Figure 17 MacArtney 13-pin Cable Details

Table 2 MacArtney 13-pin Pin-Out

DIL13M	MacArtney:D-P-P4TP24#/4C18#	DIL13F	Signal
1	Gnd: 18 AWG	1	Power Gnd
2	Shield	2	Connect to Housing
3	Gnd: 18 AWG	3	Power Gnd
4	TP1a: 24 AWG	4	X Ctrl Pos
5	TP1b: 24 AWG	5	X Ctrl Neg
6	TP2a: 24 AWG	6	X Position Pos
7	TP2b: 24 AWG	7	X Position Neg
8	TP3a: 24 AWG	8	RS232 Tx from computer
9	TP3b: 24 AWG	9	RS232 Gnd
10	TP4a: 24 AWG	10	RS232 Rx to computer
11	TP4b: 24 AWG	11	RS232 Gnd
12	+24V: 18 AWG	12	+24V
13	+24V: 18 AWG	13	+24V

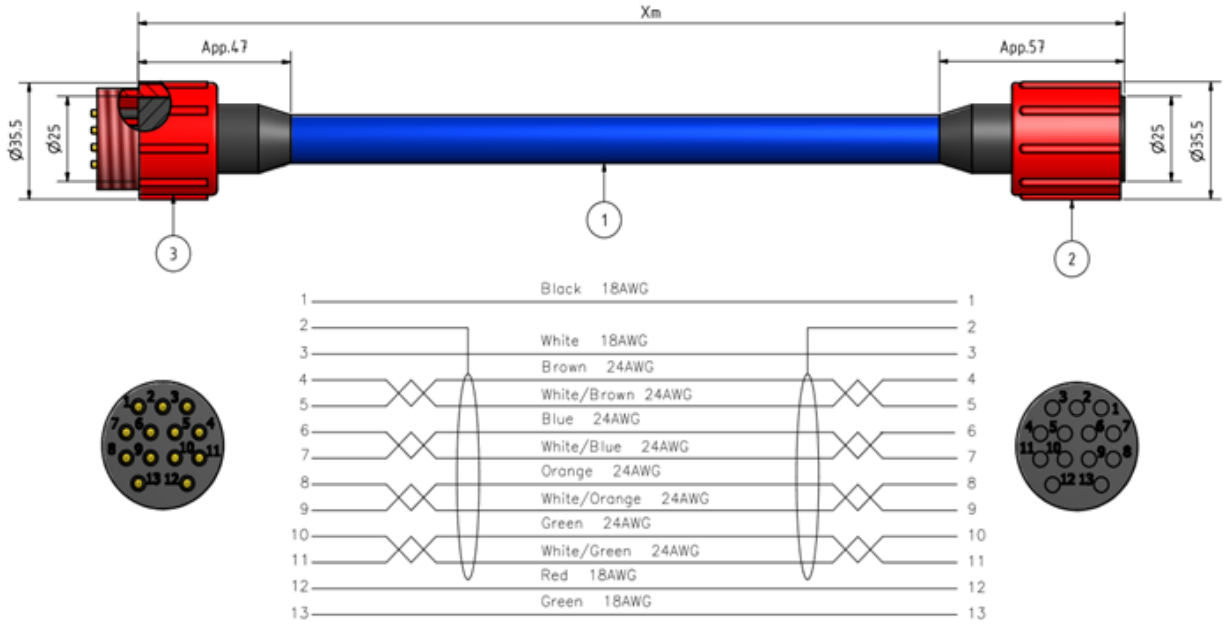


Figure 18 MacArtney 13-pin Wiring Diagram

3.9 Optical Bottle Connector Part Number and Costs

Table 3 shows part numbers and costs for Optical bottle connectors, dummy plugs and locking sleeves. Prices are at the time of purchase and may change if replacements are needed. Prices for the Teledyne RF products are not listed as MBARI was the purchaser.

Table 3 WiSSL Optical Bottle Connector Part Numbers

Description	Part Number	Manufacturer	Price ea	Qty	Price ext
MacArtney 13-pin connector, male, dual o-ring, flange-mount, titanium	DFCR2013M-Ti	MacArtney	$ 691.36	2	$ 1,382.72
MacArtney 13-pin dummy plug, female	DDC13F	MacArtney	$ 15.60	2	$ 31.20
MacArtney Locking sleeve, female (BLACK) w/ snap ring	LS2000 (BLACK)	MacArtney	$ 9.28	2	$ 18.56
Teledyne RF Bulkhead Connector	1150488-127	Teledyne	-	2	-
Teledyne RF Pressure Cap	1104001-101	Teledyne	-	2	-

3.10 Electronics Bottle Connector Part Numbers and Costs

Table 4 shows part numbers and costs for the Electronics connectors, dummy plugs and locking sleeves. Prices are at the time of purchase and may change if replacements are needed. Prices for the Teledyne RF products are not listed as MBARI was the purchaser.

Table 4 WiSSL Electronics Connector Part Numbers

Description	Part Number	Manufacturer	Price ea	Qty	Price ext
MacArtney 13-pin connector, female, dual o-ring, flange-mount, titanium	DFCR2013F-Ti	MacArtney	$ 650.24	2	$ 1,300.48
MacArtney 8-pin connector, male, dual o-ring, flange-mount, titanium	DFCR2008M-Ti	MacArtney	$ 674.85	1	$ 674.85
MacArtney 13-pin dummy plug, male	DDC13M	MacArtney	$ 32.00	2	$ 64.00
MacArtney 8-pin dummy plug, female	DDC8F	MacArtney	$ 8.60	1	$ 8.60
MacArtney Locking sleeve, female (BLACK) w/ snap ring	LS2000 (BLACK)	MacArtney	$ 9.28	3	$ 27.84
Teledyne Impulse 12-pin MHDL, FCR, male, titanium, 4#16/8#22	MHDL-12-FCR TI (4#16/8#22)	Teledyne	$ 3,347.25	1	$ 3,347.25
Teledyne Impulse MHDL, dummy plug, stainless steel	MHDL-SCP	Teledyne	$ 93.00	1	$ 93.00
Teledyne RF Bulkhead connector	1150488-127	Teledyne	-	4	-
Teledyne RF Pressure Cap	1104001-101	Teledyne	-	4	-

3.11 Cable Part Numbers and Costs

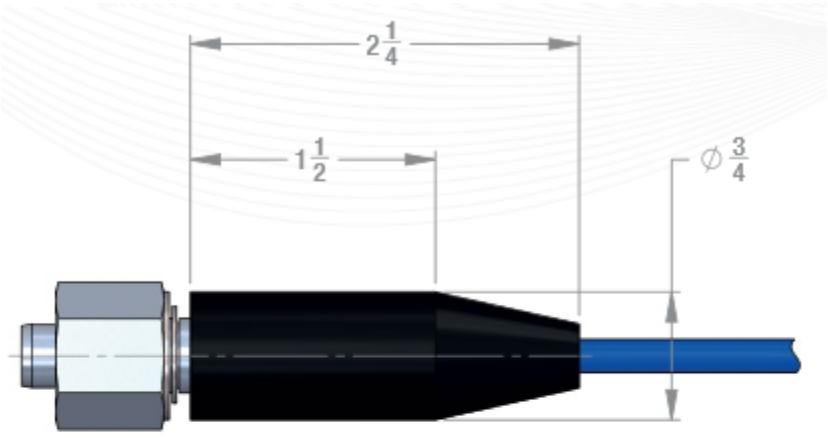
Table 5 shows part numbers and costs for cables. Prices are at the time of purchase and may change if replacements are needed. Prices for the Teledyne RF products are not listed as MBARI was the purchaser.

Table 5 WiSSL Cable Part Numbers

Description	Part Number	Manufacturer	Price ea	Qty	Price ext
MacArtney 13-pin cable, 5m, female RA/male, LS2000 retaining rings, standard ethernet-series wiring	DILRA13F//LS2000F//5M D-P-P4TP24#/4C18#//LS2000F//DIL13M	MacArtney	$ 720.00	2	$ 1,440.00
MacArtney 8-pin whip, 5m, female, LS2000 locking sleeve	DIL8F//LS2000F//5M D-P4TP24#	MacArtney	$ 341.85	1	$ 341.85
MacArtney custom cable, 15m, D-P-P4TP24#/4C18# cable - Quote US135636, Stainless Teledyne Impulse CCP connectors on both ends	MHDL-CCP-F-4#16/8#22-Stainless//15M D-P-P4TP24#/4C18#//MHDL-CCP-M-4#16/8#22-Stainless	MacArtney	$ 2,134.87	1	$ 2,134.87
Teledyne Impulse 12-pin MHDL, BCR, female, stainless steel, 4#16/8#22	MHDL-12-BCRSS (4#16/8#22)	Teledyne	$ 281.25	1	$ 281.25
Teledyne RF cable, 5m	1150455-103	Teledyne	-	12	-

3.12 Cable Datasheets

Figure 19, Figure 20 and Figure 21 below show manufacturer specifications for the Teledyne and MacArtney cables.



	CN-4
Cable Assembly Part No.	1150452-XXX
Plug Part No.	1101001-101
Plug Qty.	1
Cable Type	CN-4
Cable Length	AVAILABLE IN 5 FEET INCREMENTS
Cable Diameter	0.26
Over-molding	Neoprene

(Dimensions in inches unless otherwise noted)

Figure 19 Teledyne RF Cable Datasheet

Subconn Power/Ethernet Cable Type: D-P-P4TP24#/4C18#

Document no.	2013018SC
Revision	C
Date	11.06.2014
Prepared by	AGT
Approved by	KL

Construction Characteristics

Power conductor	0,80 mm² (18 AWG) stranded tin-plated copper conductors insulated with tefzel (4 ea.)
Twisted pairs	0,20 mm² (24 AWG) Two silver-plated copper conductors insulated with teflon and twisted together (4 ea.) Each pair has a different twist-rate for crosstalk performance and each pair has a TPE belt-to round jacket for performance at pressure. Colour code for twisted pairs: 1. TP = White/Blue + Blue 2. TP = White/Orange + Orange 3. TP = White/Green + Green 4. TP = White/Brown + Brown
Shield	Aluminium/polyester tape and tinned copper braiding (85% coverage) with an overall polyester tape.
Filler	The cable is filled with cable filling compound
Outer jacket	Polyurethane jacket. Colour blue

Mechanical Characteristics

Diameter	13,97 mm nom. (0550 ± 0,010 inch)
Weight in air	246 kg/km nom. (165 lbs/1,000 feet nom.)
Weight in seawater	90 kg/km nom. (60 lbs/1,000 feet nom.)
Min. bending radius	130 mm (5 inch)
Depth Rating	6000 metres (8700 psi)

Electrical Characteristics

Power operating voltage (18 AWG)	600V, max. 4 amp
Power operating voltage (24 AWG)	250V, max. 1 amp
Conductor resistance (18 AWG)	≤ 21 ohm/km (6,5 ohm/1,000 feet)
Conductor resistance (24 AWG)	≤ 85 ohm/km (26 ohm/1,000-feet)
Capacitance (TP 24 AWG)	42 pF/m to for 55 pF/m (13 pF/feet to for 17 pF/feet)
Impedance (TP 24 AWG)	85 ohm to 115 ohm

Figure 20 MacArtney 13-pin Power/Ethernet Cable Datasheet

Subconn Ethernet Cable — Type D-P4TP24#

Document no.	2013019SC
Revision	B
Date	06.03.2014
Prepared by	AGT
Approved by	KL

Construction Characteristics

Twisted pairs	0,20 mm² (24 AWG) Two silver-plated copper conductors insulated with teflon and twisted together (4 ea.) Each pair has a different twist-rate for crosstalk performance and each pair has a TPE belt-to round jacket for performance at pressure. Colour code for twisted pairs: 1. TP = White/Blue + Blue 2. TP = White/Orange + Orange 3. TP = White/Green + Green 4. TP = White/Brown + Brown
Shield	Aluminium/polyester tape and tinned copper braiding (85% coverage) with an overall polyester tape.
Filler	The cable is filled with cable filling compound
Outer jacket	Polyurethane jacket. Colour blue

Mechanical Characteristics

Diameter	10,4 mm nom. (0410 ± 0,010 inch)
Weight in air	140 kg/km nom. (95 lbs/1,000 feet nom.)
Weight in seawater	53 kg/km nom. (36 lbs/1,000 feet nom.)
Min. bending radius	100 mm (4 inch)
Depth Rating	6000 metres (8700 psi)

Electrical Characteristics

Operating voltage	250V max. 1 amp
Conductor resistance	≤ 85 ohm/km (26 ohm/1,000-FT)
Capacitance	42 pF/m to for 55 pF/m (13 pF/FT to for 17 pF/FT)
Impedance	85 ohm to 125 ohm

Figure 21 MacArtney 8-pin Ethernet Cable Datasheet

4 Power

4.1 Power Requirements

Primary operational input power is 48VDC to 72VDC. The system can handle glitches and transients from 36VDC to 75VDC. The input power is isolated and fused.

Below is the *estimated* power draw from datasheet values.

Table 6 WiSSL Estimated Power Draw

	Nominal	Maximum
Estimated Power	500 Watts	800 Watts
Current at 48VDC	10.4 Amps	16.7 Amps

Measured current draws during FAT were 6.00A at idle (+3.0A in-rush) and 8.00A while both heads are scanning, at 48VDC.

4.2 Field Power Supply (FPS)

The WiSSL system is supplied with a Field Power Supply (FPS) that can be used to deck-test the system if no other power source is available (i.e. from the ROV). Figure 22 shows the connection diagram for the FPS.

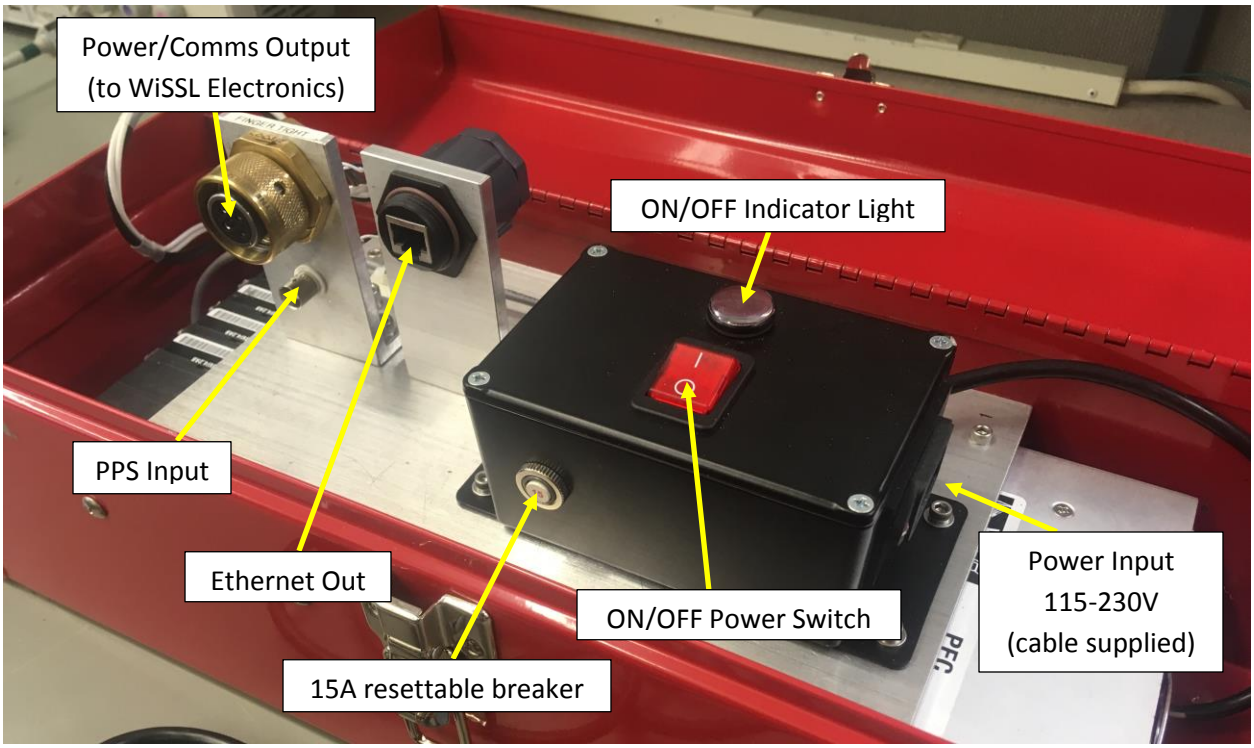


Figure 22 FPS Connection Diagram

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5 Mechanical

Refer to drawing number M000508 *"WIDE SWATH TLA MECH ICD"*