3D AT DEPTH

MBARI WISSL G2 Detailed Design - DRAFT

July 27, 2023

TOPICS

- Requirements
- Design Architecture Goal
- Point Spacing Calculations
- Data Capture and Processing Tests
- SW CCI and Data Outputs – Summary
- LiDAR Modeling
- Temperature Sensing
- Laser
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- Scanner Design
- Electrical Design
- Preliminary Testing –
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- Budget and Schedule
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PROPRIETARY INFORMATION

NOTICE: This presentation contains 3D at Depth Confidential and Proprietary information.

In order to better describe some of the design decisions and options, this presentation contains details about the internal architecture and design decisions for 3D at Depth's current 3D laser scanning products. Therefore, this information should ONLY be shared with MBARI employees who need to read and evaluate the presentation. 3D at Depth appreciates our customers taking the appropriate safety measures when distributing this information internally.

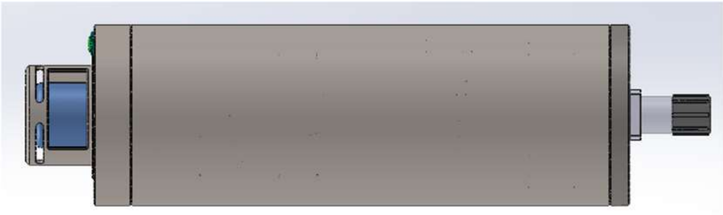
Requirements – WiSSL Gen 2

Reference WiSSL Upgrades Wishlist_R1_1.PDF

Highlighted Requirements	Must	Goal
Depth Rating	4000m	
Size	< 20” diameter, < 3ft long	6.25” diameter, < 20” long, 26.6” tip to tip
Field of View (FoV)	80°	90° (360° possible)
Range	1-meter to 7-meter NADIR, (10-meter LOS max)	1-meter to 7-meter NADIR, (10-meter LOS max)
Range Precision	Same as Gen 1 (<3mm)	
Angular Precision	Same as Gen 1 (<100µrad)	
Electrical Interface	• 18-36VDC • Isolate all peripherals • Less than Gen 1 (~400W)	Less than 200W while scanning (Probably < 100W)
Timing Requirements	Same as Gen 1 (ZDA + PPS)	PTP – baseline ZDA + PPS
Software Interface	SL4 plus updates as defined in Documentation	
Scan Rate	< 1cm spacing at 0.5m/s. Current surveys at 3m altitude and 0.2m/s	< 9mm spacing at 0.5m/s at max altitude < 5mm spacing at 0.5m/s at 3m altitude
Temperature		-2.5° C to 350° C per pulse Precision: +/-1° C

Design Architecture Goal

- Primary Design Goal
    - Single housing capable of full 90° FOV (360° possible) that includes both optical components and electronics.   This bottle connects directly to the ROV/AUV.
- ROV /AUV Connection: 1x 13 pin connector
    - 18 – 36 VDC (4 wire)
    - 10/100 TCP/IP Ethernet connection (2 twisted pair)
    - 1PPS Timing connection (1PPS twisted pair)



- If can implement PTP timing then can switch to 1Gbps TCP/IP Ethernet connection with same connector
    - WiSSL Gen 2 could support PTP directly
    - Will require MBARI to convert from ZDA & PPS to PTP for WiSSL G2
    - Identified two options for generating PTP using Raspberry Pi4
        - Real time hat: https://innoroute.com/realtimehat/
        - Pi4 can also be used directly to measure/generate PTP https://github.com/raspberrypi/linux/issues/4151
    - NOT a major focus at the moment

No change from Phase 1

Point Spacing Calculations

Desired

FOV = 90° (can go up to 360°)

NADIR = 7 meter

Speed = 0.5m/s

Desired Point Spacing = 10mm

Calculations

LOS = 10m

Swath = 14m

Number of points per Swath = 1,400

Number of Forward Track Points per Second = 50

Goal PRF = 350kHz

Given scanner implementation

Forward Track Point Spacing = 10mm

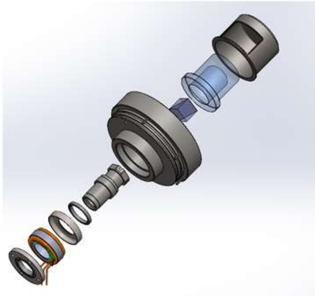
Cross Track Point Spacing = 8mm at 7m altitude

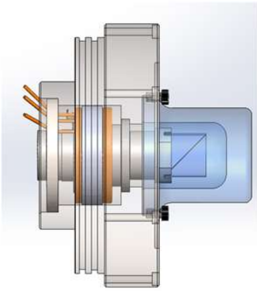
Cross Track Point Spacing = 5.7mm at 5m altitude

Cross Track Point Spacing = 3.4mm at 3m altitude

Speed = 0.3m/s

Forward Track Point Spacing = 6mm





No change from Phase 1

Data Capture and Processing Tests

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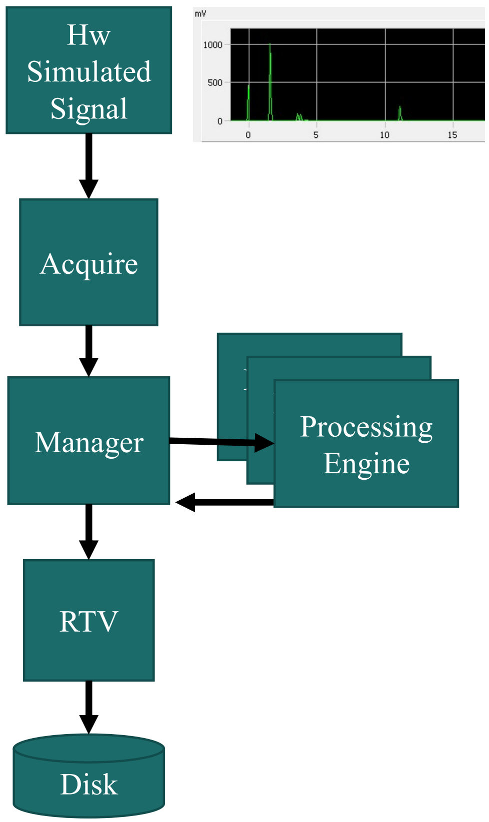
350kHz Data Capture Tests

- Simulated Data through system, direct data path (not going through A2D conversion process)
- Set PRF to 350,140 Hz (350 KHz goal)
- 1000x1000 point file
- Capture data at full speed, no skips, 2.857 seconds/file
- Processing takes 7.8 seconds (5 returns, continuous)
- 100 / 180 degrees = 55%
- 3 / 5 returns = 60%
- 7.8 / 2.85 processing to acquire time * 0.55 (data clipping) * 0.6 (number returns) = 0.91 ratio



Simulation verifies real time data processing

No change from Phase 1

350kHz Data Capture Tests

- This does show that we are not keeping up with data generation in real time, since we are still keeping 5 returns and all data, RawQ is completely full.
- Actual Data rate will be less, estimate at 17.4 MB/s for RIAAT (140 MBit/sec), much less if we process into MBARI custom format which will be targeted for a slower connection (less than 100 Mbit/sec)
- 65 MB/s * 0.55 (clipping data) *0.6 (number returns) = 21.45 MB/s

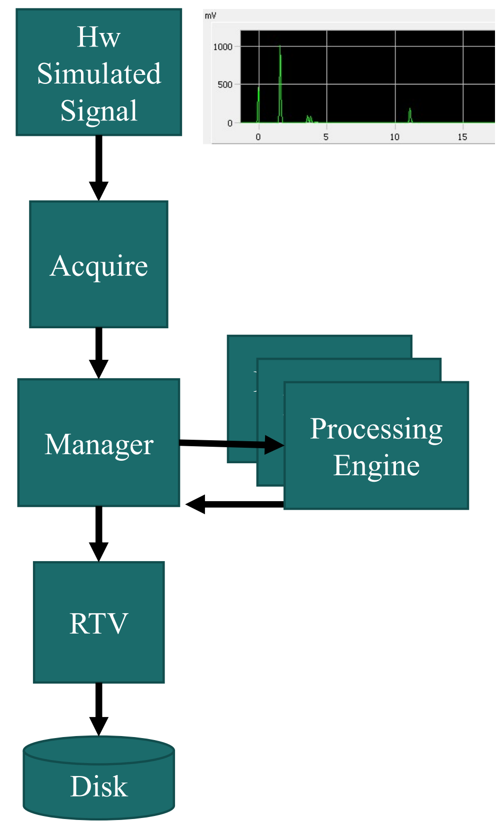
```
Mar 31 23:04:39 sl4n-001.local InstaCloud: RawQ: 0%, ProcE: 86%, In:  12.33 MBytes/s, Out:  62.92 MBytes/s
Mar 31 23:04:40 sl4n-001.local InstaCloud: RawQ: 0%, ProcE: 86%, In:  12.39 MBytes/s, Out:  63.97 MBytes/s
Mar 31 23:04:41 sl4n-001.local InstaCloud: RawQ: 0%, ProcE: 83%, In:  12.41 MBytes/s, Out:  64.05 MBytes/s
Mar 31 23:04:42 sl4n-001.local InstaCloud: RawQ: 0%, ProcE: 83%, In:  11.38 MBytes/s, Out:  59.70 MBytes/s
```

```
Mar 31 22:17:45 sl4n-001.local EC: TPH: Progressing to cart /tmp/scans/sl4_17
Mar 31 22:17:45 sl4n-001.local EC: TPH: Progressing to cart /tmp/scans/sl4_18
Mar 31 22:17:45 sl4n-001.local EC: TPH: Progressing to cart /tmp/scans/sl4_19
Mar 31 22:17:45 sl4n-001.local EC:    Laser Shots per Second: 349565
Mar 31 22:17:46 sl4n-001.local EC: TPH: Progressing to cart /tmp/scans/sl4_20
Mar 31 22:17:46 sl4n-001.local EC: TPH: Progressing to cart /tmp/scans/sl4_21
Mar 31 22:17:46 sl4n-001.local EC: TPH: Progressing to cart /tmp/scans/sl4_22
Mar 31 22:17:46 sl4n-001.local EC: TPH: Progressing to cart /tmp/scans/sl4_23
Mar 31 22:17:46 sl4n-001.local EC:    Laser Shots per Second: 349647
```


No change from Phase 1

194kHz Data Capture Tests

- Hardware loopback test (going through A2D conversion process, real noise)
- Set PRF to 194,553 Hz (Same data rate)
- 1450x1450 point file
- Capture data at full speed, no skips, 10.8 seconds/file
- Processing takes 21 seconds (5 returns, continuous)
- 3 / 5 returns = 60% (estimate) 12.6 sec
- 2 / 5 returns = 40% (estimate) 8.4 sec
- Near the challenging edge of data processing time.
- May need further processing optimizations and/or add more Processing Engines to buy margin



Risk: 3 Return Yellow / 2 Return Green

No change from Phase 1

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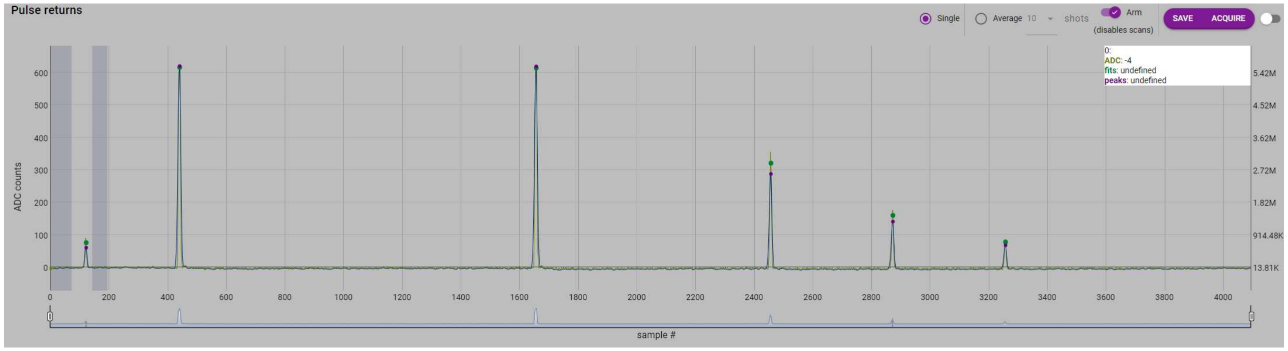
194kHz Data Capture Tests

- This does show that we are not keeping up with data generation in real time, since we are still keeping 5 returns and all data, RawQ is completely full.

May 04 17:45:40 sl4n-001.local InstaCloud[6760]: Laser Shots per Second: 193902
May 04 17:45:41 sl4n-001.local InstaCloud[6760]: RawQ: 39%, ProcE: 100%, In: 4.01 MBytes/s, Out: 20.94 MBytes/s
May 04 17:45:42 sl4n-001.local InstaCloud[6760]: RawQ: 0%, ProcE: 100%, In: 18.92 MBytes/s, Out: 63.17 MBytes/s
May 04 17:45:43 sl4n-001.local InstaCloud[6760]: RawQ: 0%, ProcE: 100%, In: 10.36 MBytes/s, Out: 63.79 MBytes/s
May 04 17:45:44 sl4n-001.local InstaCloud[6760]: RawQ: 0%, ProcE: 100%, In: 8.82 MBytes/s, Out: 59.89 MBytes/s
May 04 17:45:45 sl4n-001.local InstaCloud[6760]: RawQ: 0%, ProcE: 100%, In: 8.55 MBytes/s, Out: 59.37 MBytes/s
May 04 17:45:46 sl4n-001.local InstaCloud[6760]: RawQ: 0%, ProcE: 81%, In: 8.31 MBytes/s, Out: 64.06 MBytes/s
May 04 17:45:47 sl4n-001.local InstaCloud[6760]: RawQ: 0%, ProcE: 81%, In: 8.83 MBytes/s, Out: 63.46 MBytes/s



No change from Phase 1

SW CCI and Data Outputs - Summary

SW Summary

High Level

- Created definition of SW requirements for autonomous operation, output data packets, and low bandwidth support
  - SL Sensor CCI_Manual_C4.pdf
  - RTV CCI Communication Manual_C4.pdf
  - SL Sensor ICD_C9.pdf
  - 3DatDepth_CCI_packets_Revc7.pdf
- Heavily leverages current 3D at Depth SL4 software to minimize development time
- Enables MBARI to take advantage of continual upgrades to SL4 electronics

Modifications from Standard SL4 software

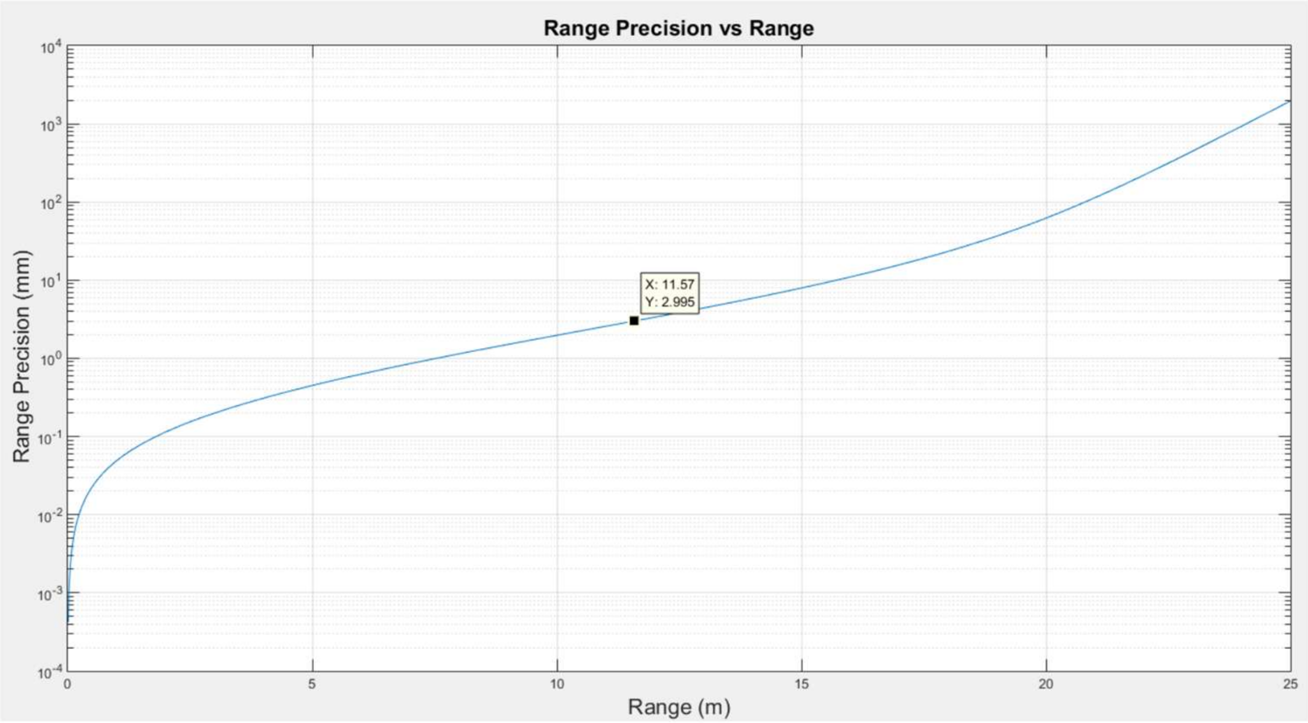
- Will provide option to return 2 or 3 points per line of sight, with 3 points per line of sight larger in size and bandwidth
- Support and limits ethernet to 100Mb/s, do not monopolize all ethernet capacity
- Ability to flag data as opposed to delete data. Classifications good or removed – too close, too far, noise
- Thermal data measurement. Signal and quality measure of signal
- Dynamic laser gain
- Optimized data size, 40% reduction of size or more, compared to SL4 RIAAT data.

No change from Phase 1

LiDAR Modeling

Lidar Modeling – WiSSL Gen 1

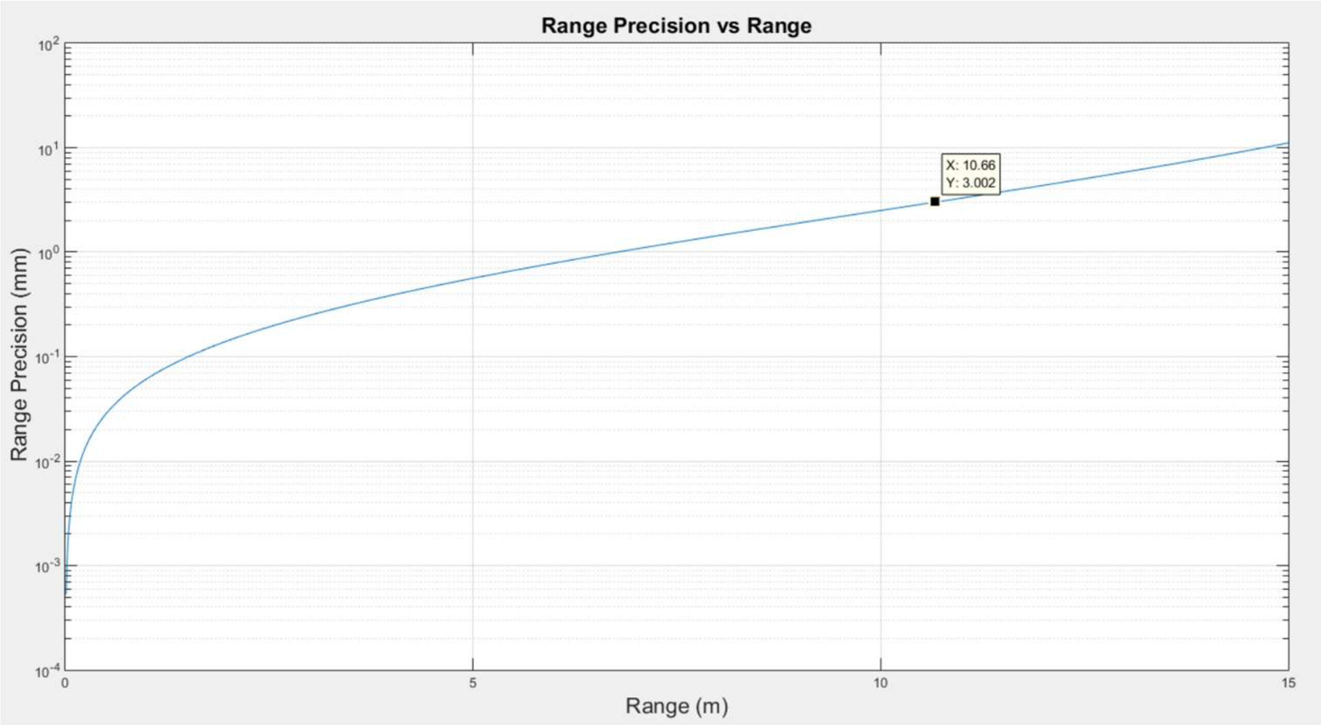
- Goal = 7m NADIR, 11m LOS range
- Water model: Jerlov Type III
- Target model: Lambertian, 10% reflectivity, normal incidence
- Background light: a 'typical' Kongsberg ROV light illumination and color temp
- Detector Gain setting: High



No change from Phase 1

Lidar Modeling – WiSSL Gen 1

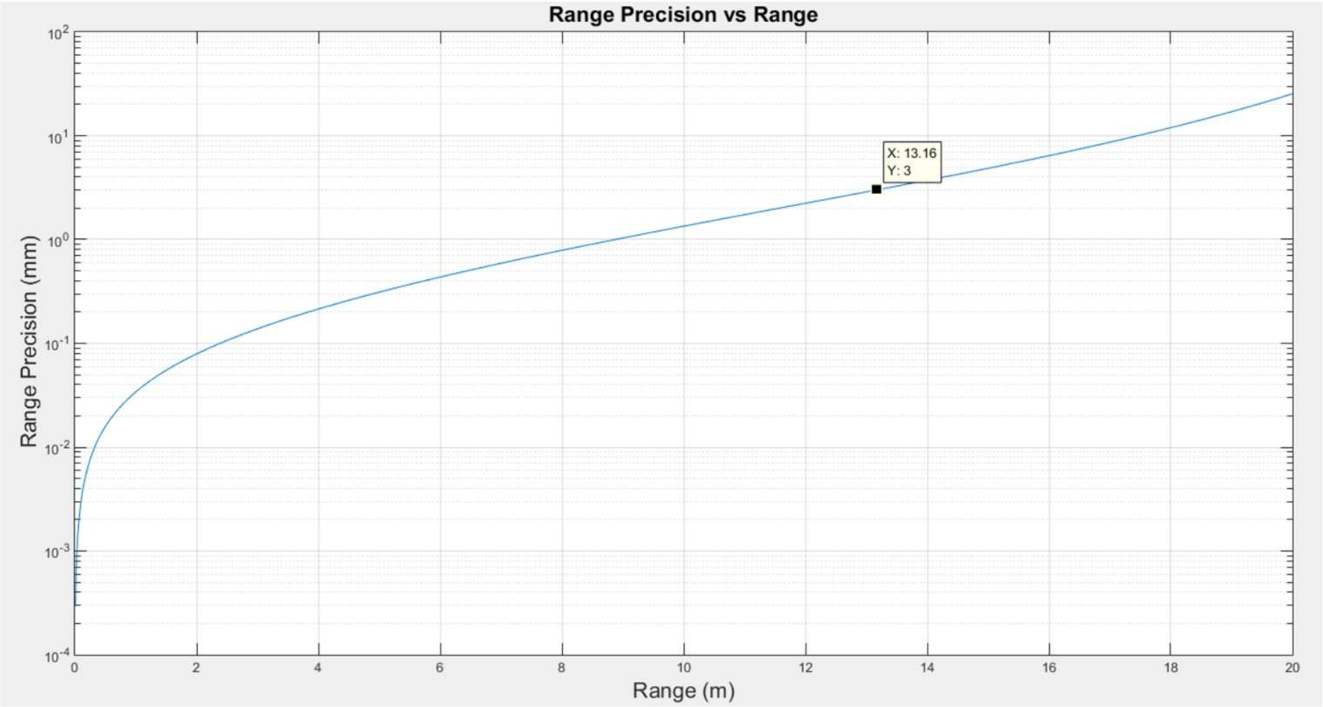
- 50° incidence angle with Lambertian target decreases range below 11m LOS goal
- Water model: Jerlov Type III
- Target model: Lambertian, 10% reflectivity, 50° incidence – below 11m goal
- Background light: a 'typical' Kongsberg ROV light illumination and color temp
- Detector Gain setting: High



No change from Phase 1

Lidar Modeling – WiSSL Gen 2

- 13m LOS range
  ~ 3x increase in clear aperture area
  ~ 30% increase in pulse energy
- Water model: Jerlov Type III
- Target model: Lambertian, 10% reflectivity, 50° incidence
- Background light: a 'typical' Kongsberg ROV light illumination and color temp
- Detector Gain setting: High



No change from Phase 1

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Temperature Sensing

Lidar modeling – Temperature Trade Space

- Use WiSSL Gen 2 design from above, estimate ~3m LOS range (~2m NADIR)

Range NADIR / Max LOS (50°)	Aperture Area	Laser Energy
2m / 3.1m	1	1
5m / 7.8m	~59x	1
7m / 10.9m	~650x	1

Range NADIR / Max LOS (50°)	Aperture Area	Laser Energy
2m / 3.1m	1	1
5m / 7.8m	1	~60x, ~6kHz laser
7m / 10.9m	1	~600x, 583Hz

Range NADIR / Max LOS (50°)	Aperture Area	Laser Energy
2m / 3.1m	1	1
5m / 7.8m	~6.5x	10x, 35kHz

No change from Phase 1

Lidar modeling – Temperature Trade Space

- Spatial Averaging should allow us to use the same LiDAR design and reach the full 4.67m LOS range.
- Expect ~ +/- 2° C accuracy

Range NADIR / Max LOS (50°)	Aperture Area	Laser Energy
2m / 3.1m	1	1
3m / 4.67m	~5x	1
3m / 4.67m	1	~5x, 70kHz
3m / 4.67m	~2.25x* back to custom scanner	~2x, 175kHz
3m / 3.5m (30°) = 60° FOV	~1	~1
3m / 4.67m w/ 100 spatial ave	1	1

No change from Phase 1

Temperature – spatial averaging

- Pulse width ~ 8.5cm in water
- At 3m altitude
  - Cross track point spacing = 3.67mm
  - Forward track point spacing = 5mm

Scenario 1

- Create ~8.5cm square on seafloor to spatial average for temperature
- Equates to 23 cross track pts x 17 forward track points = 389 pts to average
- Takes 340ms to acquire this data

Scenario 2

- Can use more cross track points than forward track points to decrease data collection time
- MBARI agrees that a lateral resolution of 10cm is acceptable
- Spatial averaging will require the temperature cell / feature size to be ~ uniform over the spatial and temporal sample size

Comments from June 2022 Review

- Spectral band filters are ~ 10nm wide. Laser spec is 532nm +/- 0.5nm. Therefore, can handle shifts in transmitter spectrum.
- Modeled number of single shot return Raman scattered photons at 4.7m LOS range = 43 (which is why we need to average)
- New detector is a photon counting detector

No change from Phase 1

Thermal Cell Processing

Gain Increased by averaging

To Increase the gain, several shots are averaged together

10 rows by 10 columns is 100 shots

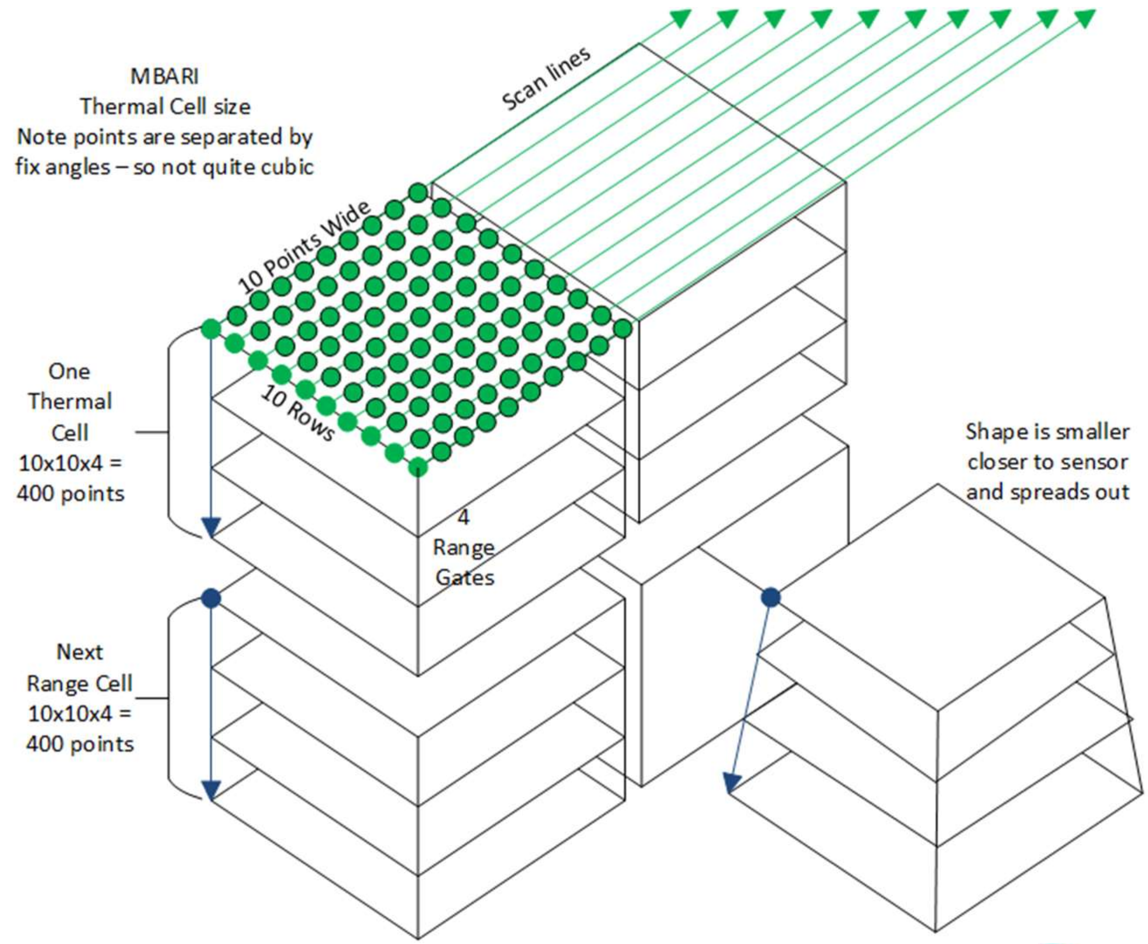
Multiple range gates are also added together, expecting 4 range gates right now.

Have about 140 bins across a scan line

Range of 4 gates in water is approximately 112 mm (28 mm each)

Gain is 10x10x4 = 400.

For greater distances, more points may need to be averaged together.



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Temperature Sensing

1. Theory and lab demonstrations published in 2015 Optics Express: C.P. Artlett and H. M. Pask, *Optical Remote Sensing of Water Temperature using Raman Spectroscopy*
2. Image clearly shows the intensity variation due to temperature at one wavelength and no variation at a different wavelength
3. Selected detector covers all 3 wavelengths, so we use the exact same receiver design for all 3 channels
4. LiDAR modeling performed to calculate SNR and number of return signal photons in the presence of Jerlov Type III water, Raman backscatter cross section, detector responsivity and gain, and losses due to the custom optics. Calculate successful detection at the 4.67m range with 100 spatial averages. We are designing for ~400 spatial and temporal averages.

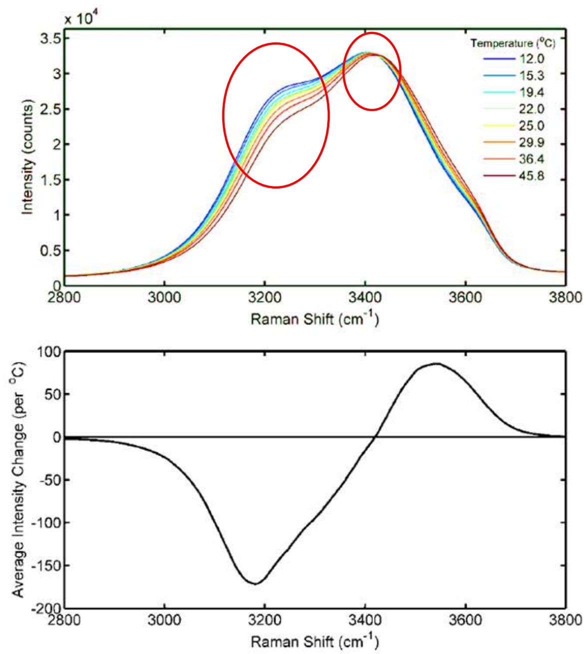
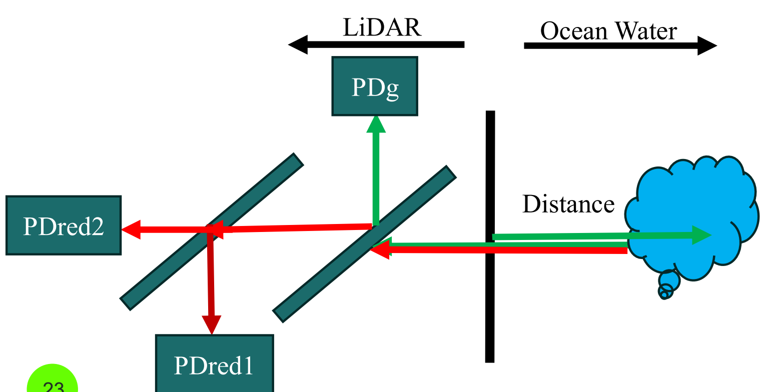


Fig. 2. (a) Unpolarized Raman spectra of RO filtered water with varying temperature. (b) Variation in unpolarized Raman signal intensity in response to temperature change.



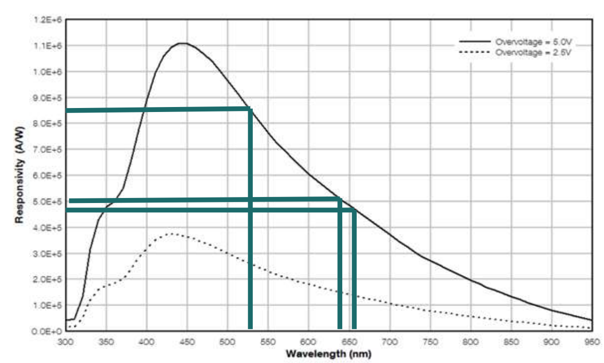


Figure 4. Responsivity versus Wavelength

Laser

Laser

Found a Finland based company, which was founded in 2021 by a team of engineers with long-term experience in fiber optics, high speed electronics, optics and industrial laser systems as spin-off from Aalto University.

They provide customized laser source designs. "The ultracompact dimensions and maximum possible energy efficiency of our laser are supplied as a response to worldwide need for green industrial technologies to minimize carbon footprint and production costs."

Infrared fiber laser

Second Harmonic Generator (SHG) to convert from IR to 532nm

Specifications

Wavelength: 532 +/- 0.5nm

Max Repetition Rate: 350kHz

Min Repetition Rate: 200kHz

Leadtime: 16 weeks

Cost:

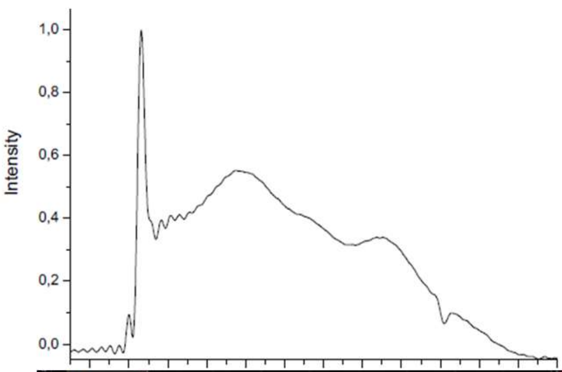
~ $40k each w/tax and shipping (Qty 2)
~$30k each (Qty 5)

50% paid ARO

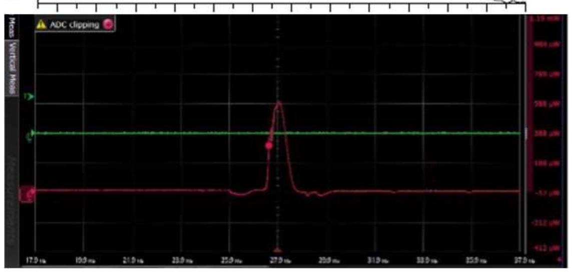
Warranty: 12 month standard, vendor open to longer

Laser - Prototype

Vendor built a prototype IR laser and performed initial testing at their own cost

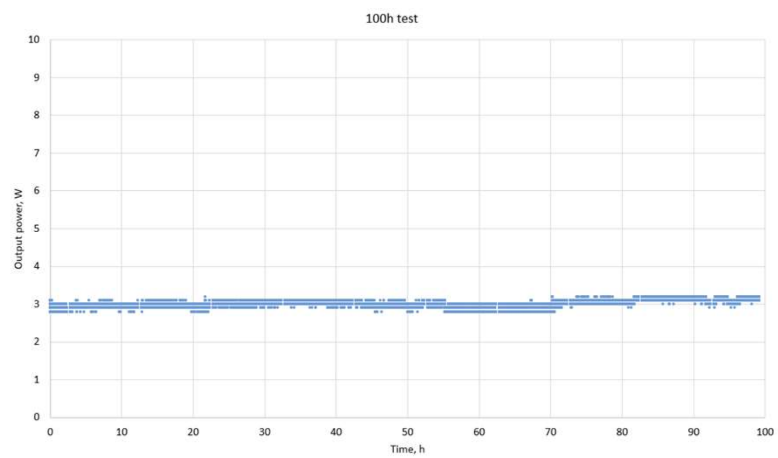


1st attempt temporal pulse width



2nd attempt temporal pulse width
Required new electronic driver for pump diodes.

Stability data when running the prototype at full IR pump power at the repetition rate of 300 kHz for 100 hours.



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Laser - Reliability

Vendor current reliability test program for similar products

1. 10 hours burn in tests for 100% units
2. 100 hours periodic test using randomly selected unit

Note: We will request 100hr burn in

3. 1000 hours test when a new product is introduced. Also perform periodical 1000 h tests for the standard products.

Note: 1000hr ~ 42 days. I have requested they continue these tests to 10,000 hrs. Vendor expects no issues with 10,000hr lifetime.

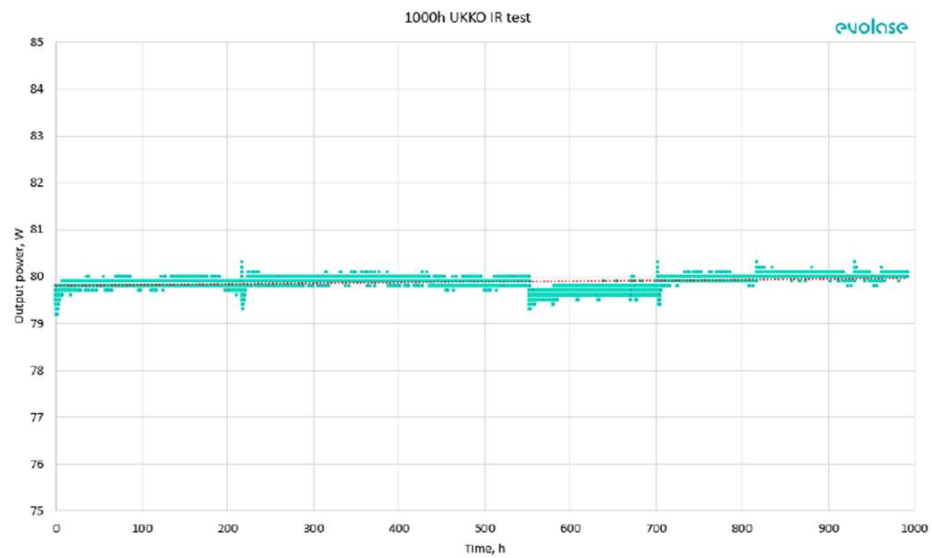
4. Sinusoidal vibration 20-30 Hz, acceleration 2g

Note: We still need to specify our shock/vibration tests for them. May impact price.

5. Operation temperature range -10C ...+ 35C, however expect 40C to be OK

Note: We will spec a temp cycle test for them. May impact price.

UKKO ps fiber laser 1000 h stability data



Power variation less than 2%

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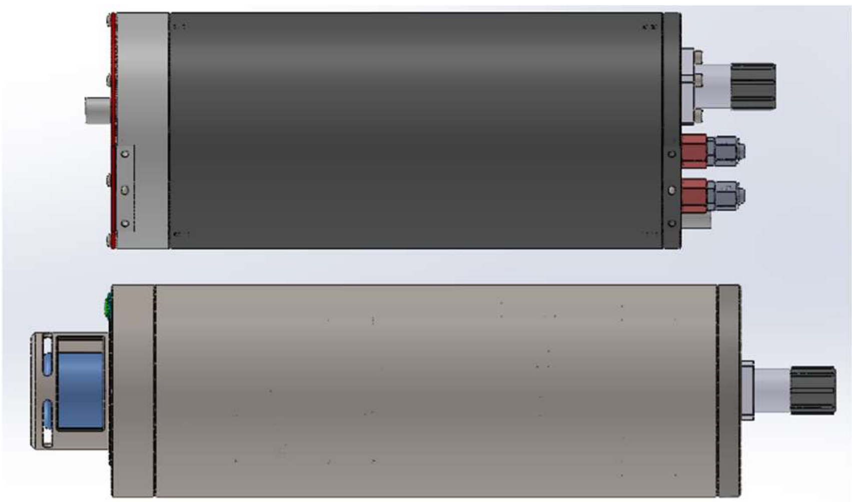
Mechanical Housing and Connector Summary

Comparison to WiSSL Gen 1 Optical Sensor

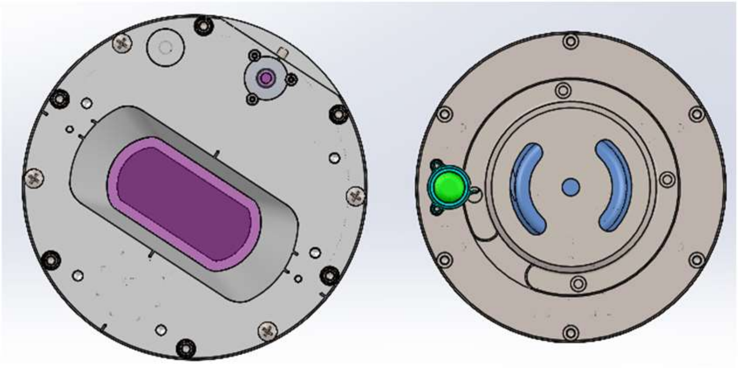
Old Optical Bottle (x2)

- OD: 6.94”
- Endcaps + Tube Length: 16.625”
- Tip-to-tip Length: 20.29”
- Weight of tube + endcaps: 42.41 pounds



New All In One

- OD: 6.25”
- Endcaps + Tube Length: 22.37”
- Tip-to-tip Length: 26.60”
- Weight of tube + endcaps: 58.985 pounds
- Tube material: TI-6AL-4V Grade 5
- Output Endcap material: 17-4 PH HH1150
- Connector Endcap material: TI-6AL-4V Grade 5

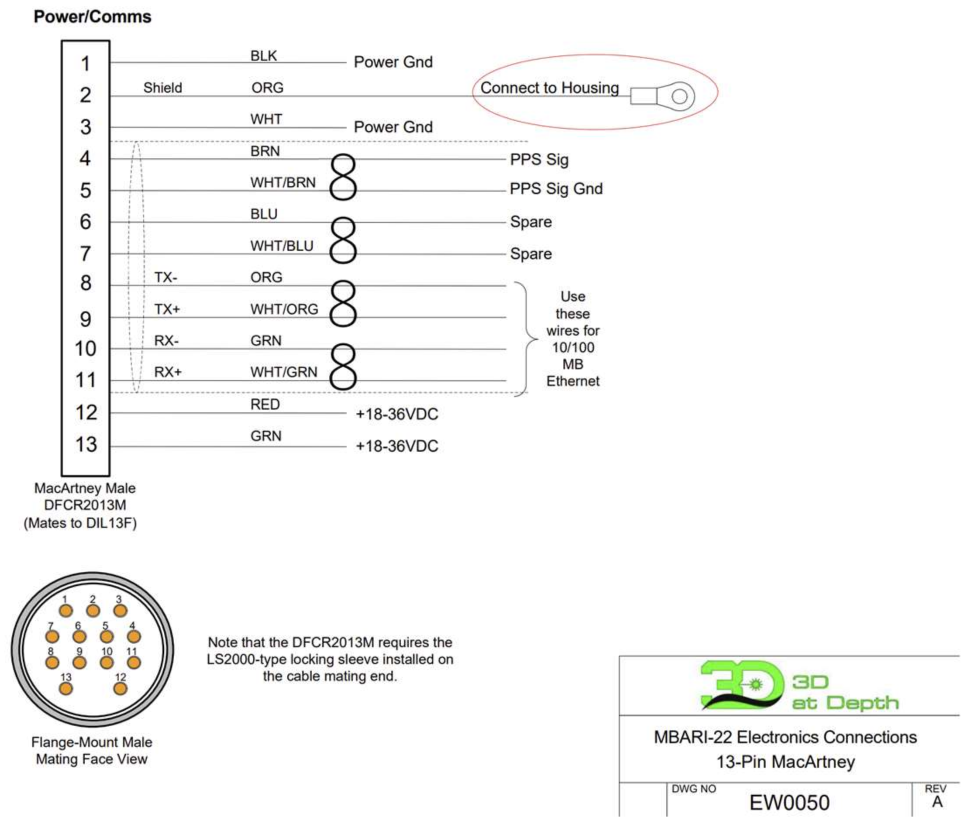


Single Connector

Reduction from 12 connectors across 3 bottles!!

- MacArtney Connector: DFCR2013M
- 13 pins
- Body: Chloroprene rubber
- Flange: Titanium

- 2x Power
- 2x Power Ground
- 4x 100Mb Ethernet (2x twisted pairs)
- 1x PPS Signal
- 1x PPS Gnd
- 1x Cable Shield
- 2x Spare



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Housing Analysis

Mechanical analysis at 4,600m - summary

Analysis pressure

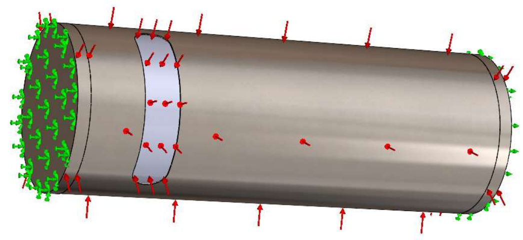
- 4,600m at 6,723 psi (15% margin)

Tube

- ID: 5.600”
- OD: 6.25”
- Wall thickness: 0.325”
- Material: TI-6AL-4V Grade 5
- Tube length = 16.5”
- Factor of safety of buckling: 1.24
- Factor of safety of yield: 1.96
- Minimal diameter improvements result in significantly less resistance to buckling

Tube deflections are at least as good as SL3 sensor and MBARI WiSSL Gen 1

Will re-perform for updated tube length



No change from Phase 1

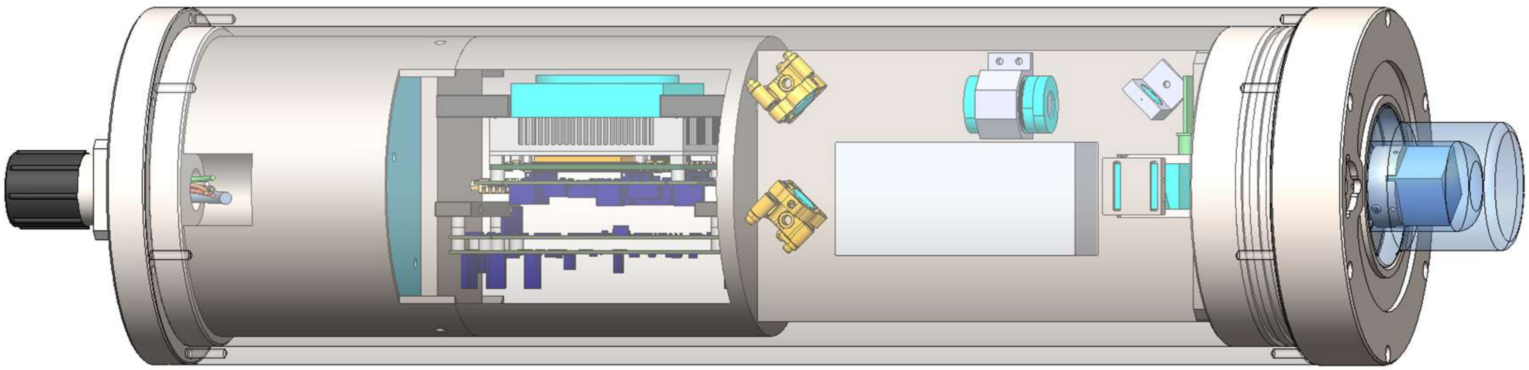
Investigated multiple configurations

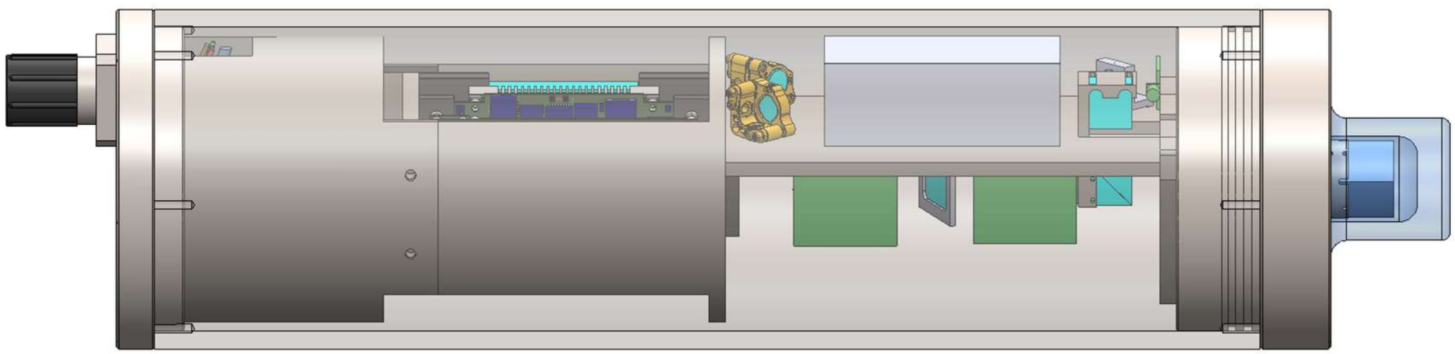
Variable	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	SL3
ID (in)	5.625	5.69	5.625	5.625	5.674	5.625	6.21
OD (in)	6.25	6.25	6.181	6.25	6.25	6.198	6.94
Wall (in)	0.3125	0.280	0.278	0.3125	0.288	0.2865	0.365
Design PSI	6723	6723	6723	6723	6723	6723	6723
Length (in)	15.5"	15.5"	15.5"	16.5"	16.5"	16.5"	14.5"
Material	TI-6AL-4V	TI-6AL-4V	TI-6AL-4V	TI-6AL-4V	TI-6AL-4V	TI-6AL-4V	TI-6AL-4V
Yield (psi)	128,000	128,000	128,000	128,000	128,000	128,000	128,001
Max real stress (psi)	65,440	72,910	72,580	65,400	70,490	71,340	63,000
Max real displacement (mm)	0.293	0.330	0.326	0.287	0.318	0.316	0.305
Buckling failure (psi)	8,901	6,766	6,737	8,344	6,746	6,740	8,429
Yield FOS over design	**1.96**	**1.76**	**1.76**	**1.96**	**1.82**	**1.79**	**2.03**
Buckling FOS over design	**1.324**	**1.006**	**1.002**	**1.241**	**1.003**	**1.003**	**1.254**

No change from Phase 1

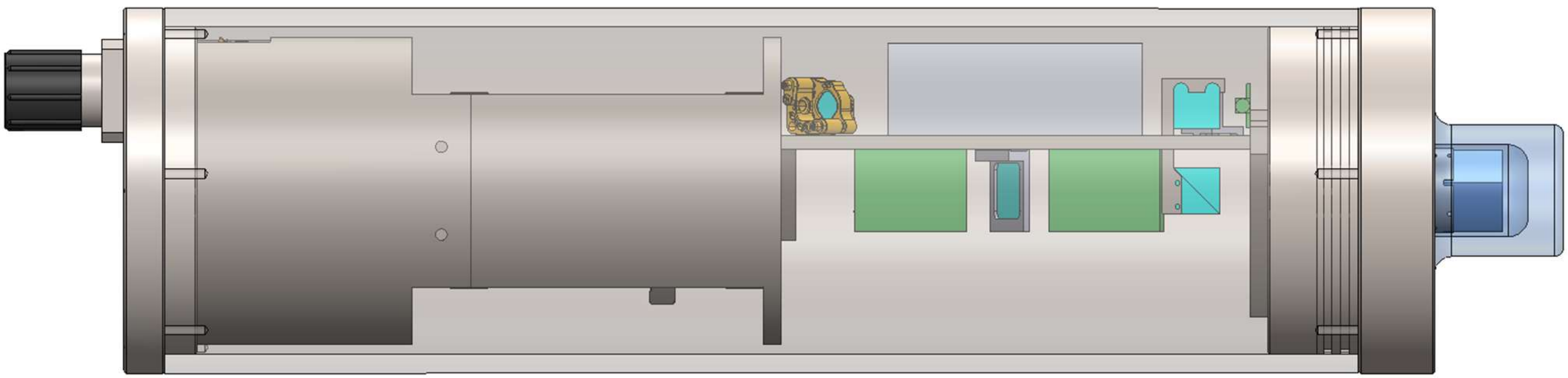
Internal Mechanical Design

WiSSL Gen 2

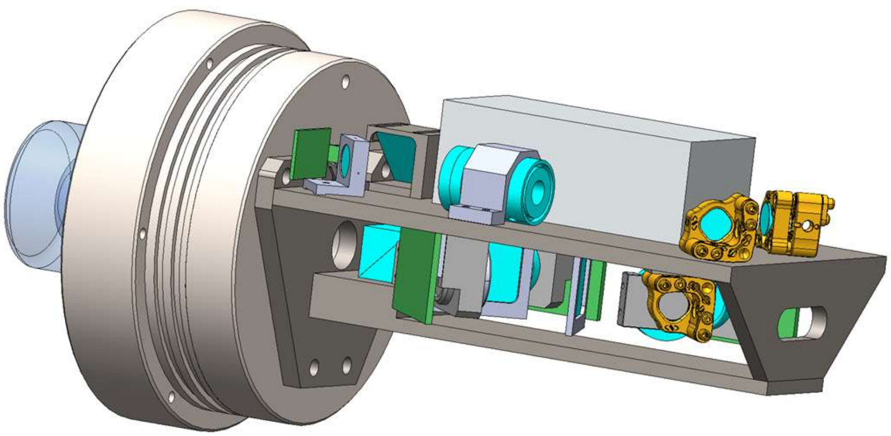


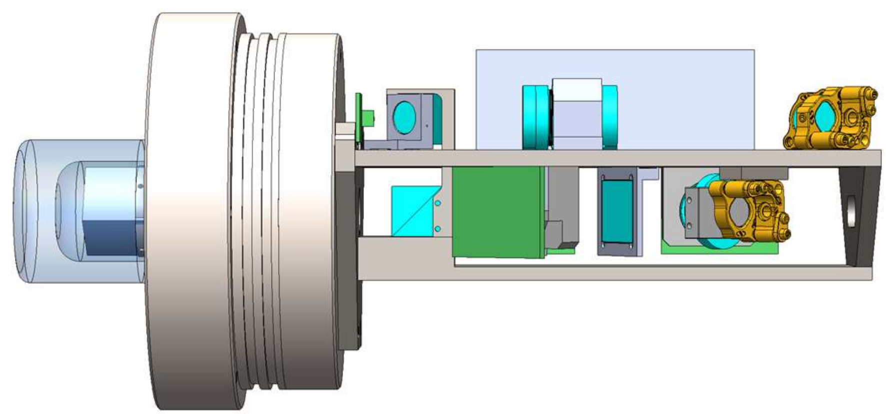


WiSSL Gen 2

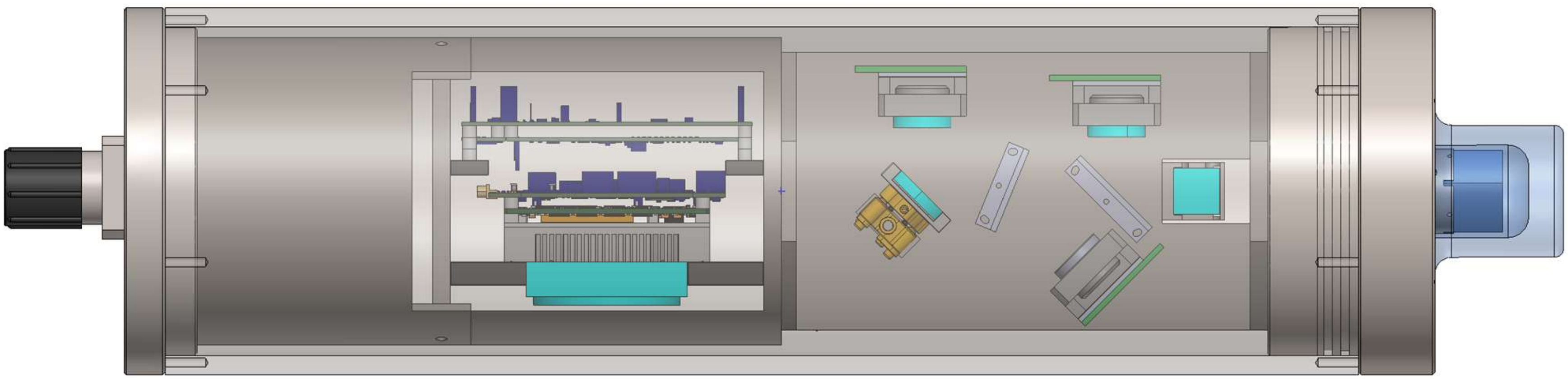


WiSSL Gen 2 - Optical Side

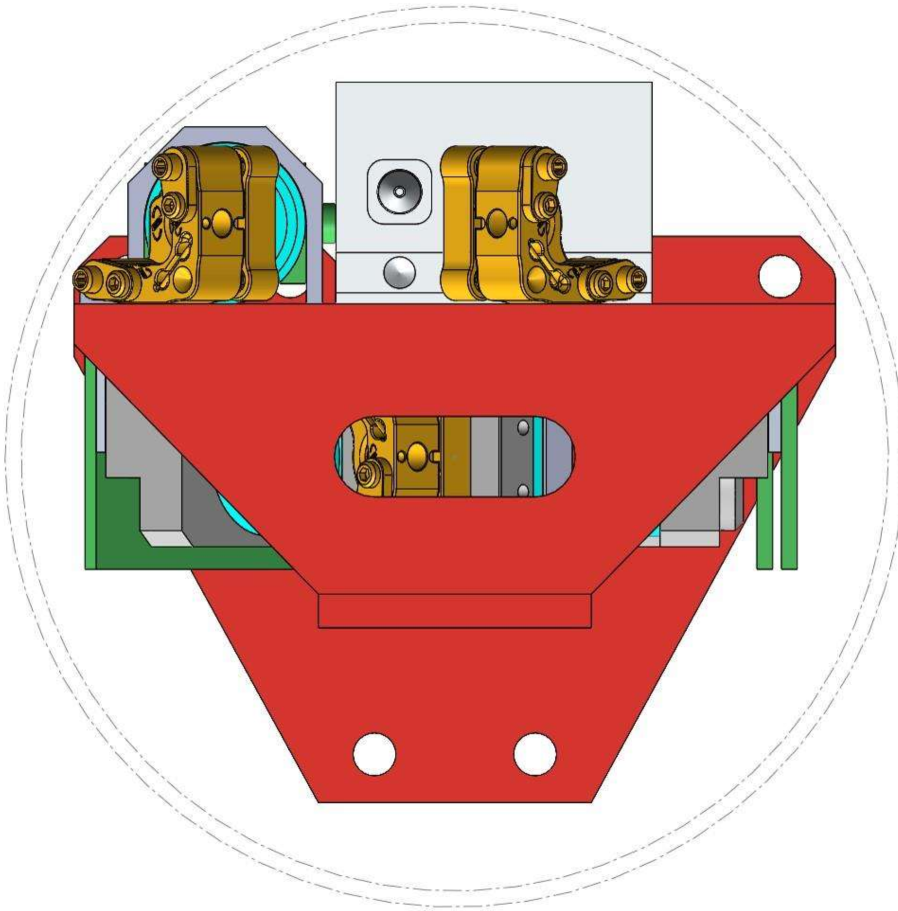




WiSSL Gen 2 - Electronics and Temp Sensing Layout



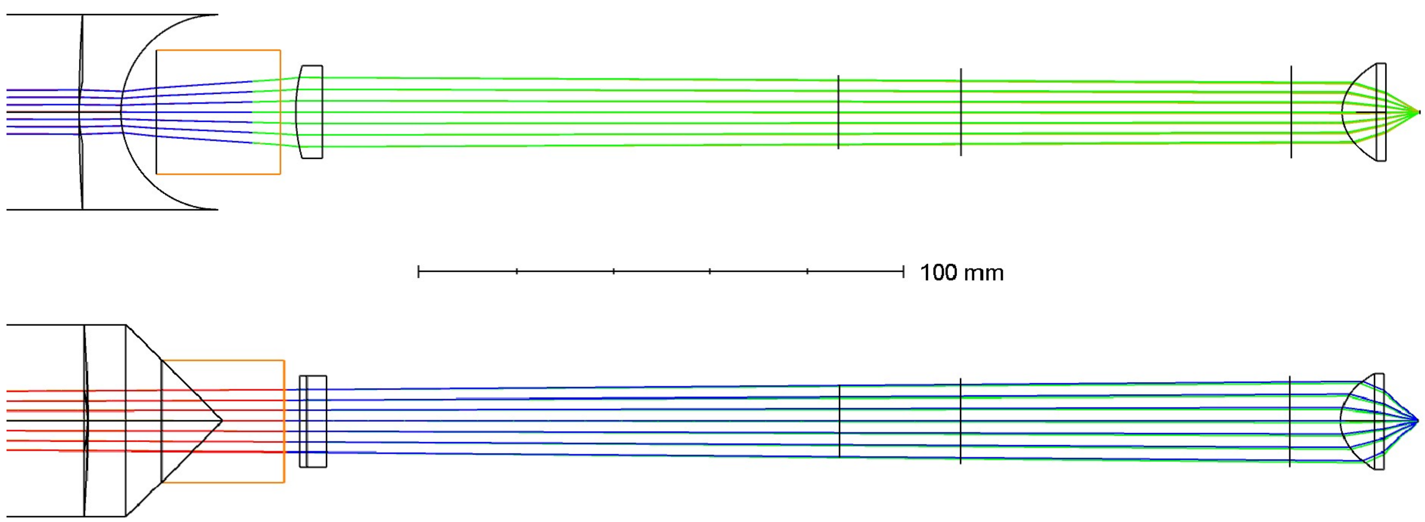
WiSSL Gen 2 – End View Component Fit



Optical Design

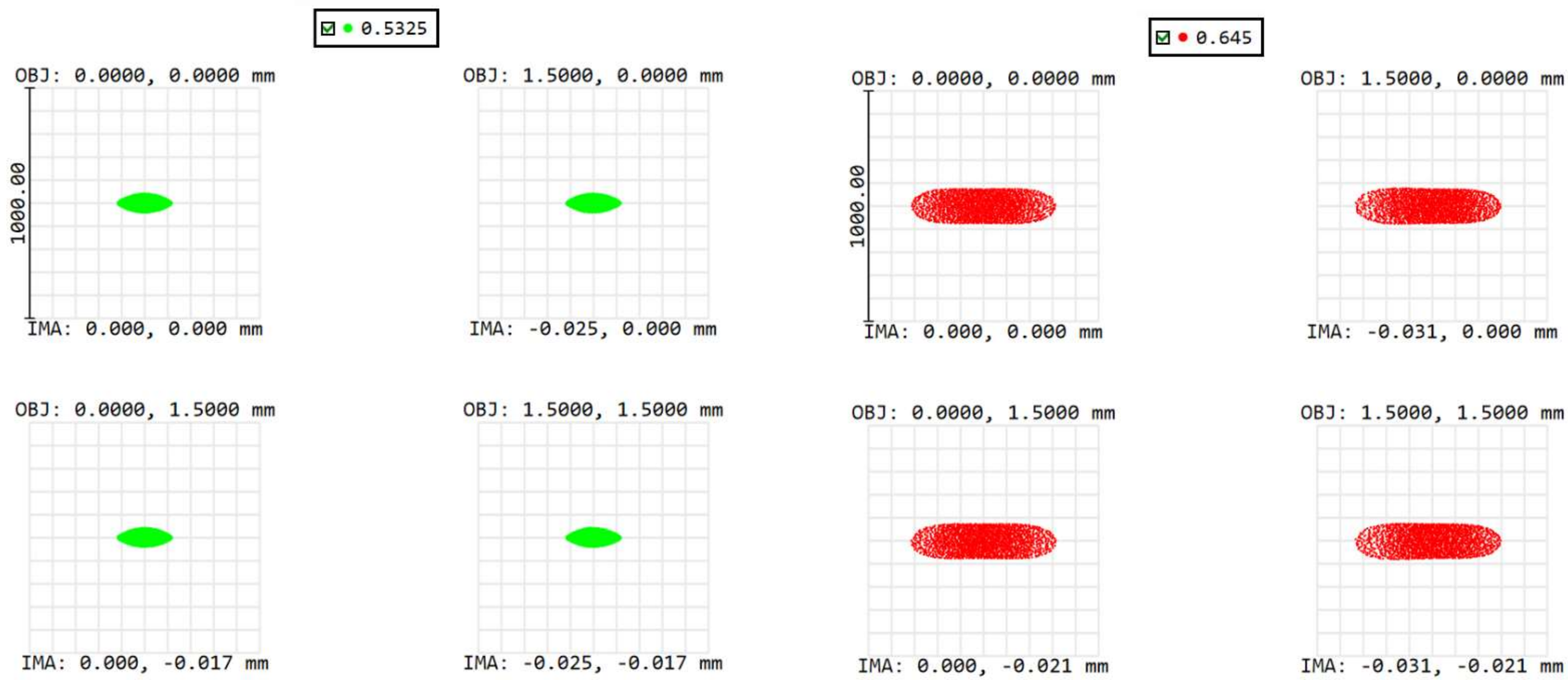
Optical Design

- Custom spinning prism designed and quoted. Preferred vendor is $1,350ea for Qty (5) or $788ea for Qty (10)   10 week lead
- Custom corrector lens designed and quoted. Preferred vendor is $684ea for Qty (5) or $610ea for Qty (10)
- Custom transmit / receive optic designed and quoted. Preferred vendor is $684ea for Qty (5)
- Optics for temperature system designed
  - Found COTS optics for entire temp sensing optical train except for one
  - Custom optical filter to split the two red temperature bands identified and quoted.



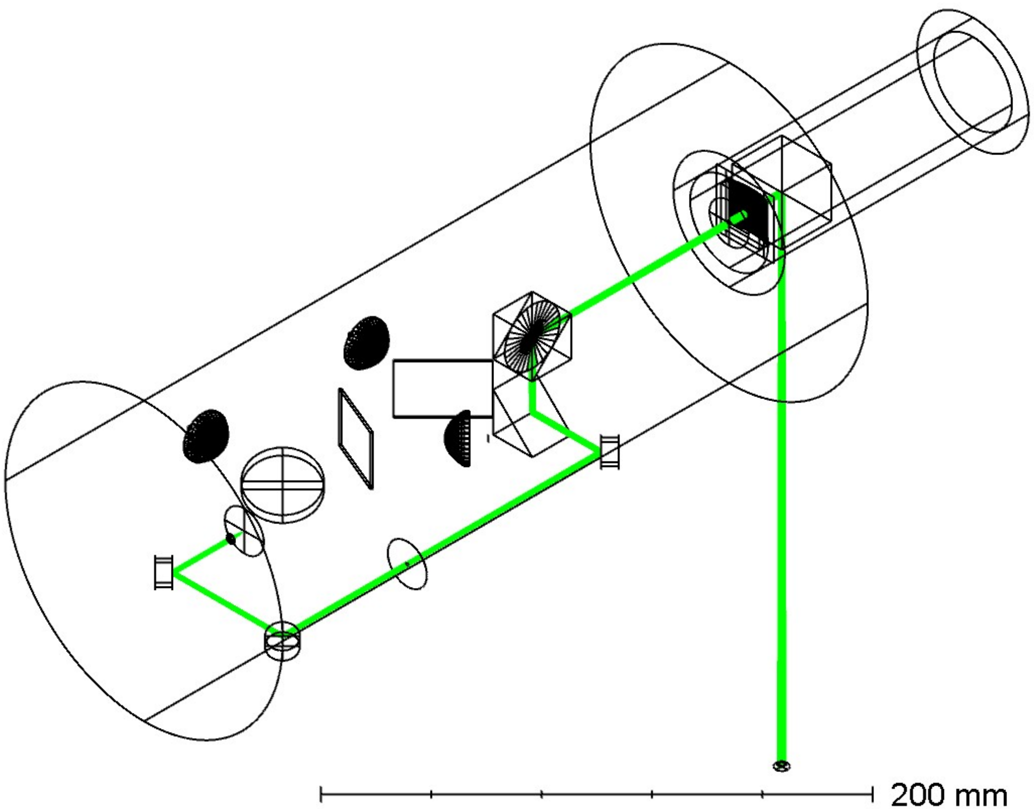
3D AT DEPTH

Receiver Optical Design

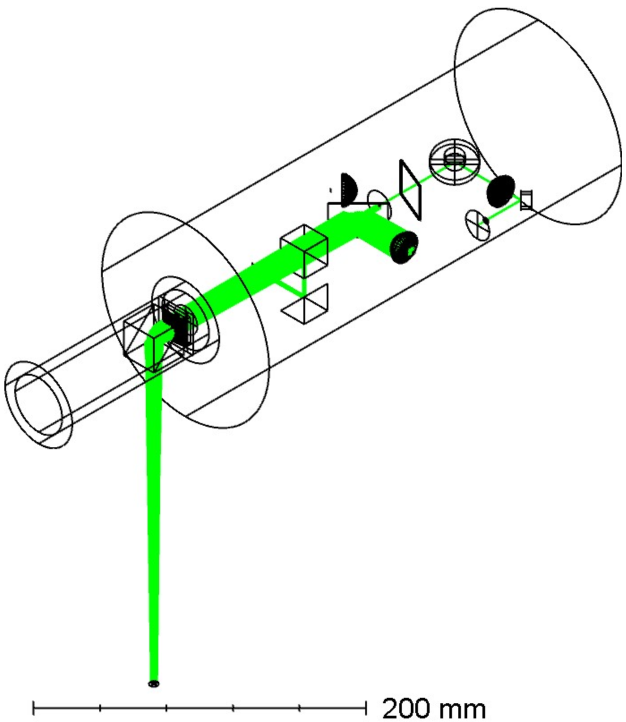


Margin for 100% return signal collection on detector for both wavelengths over multiple fields

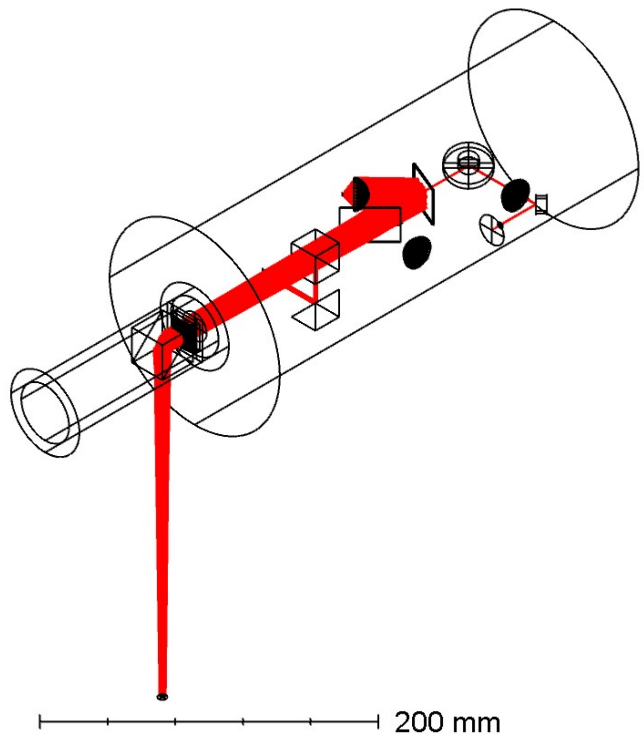
Transmit Optical Design – Green out



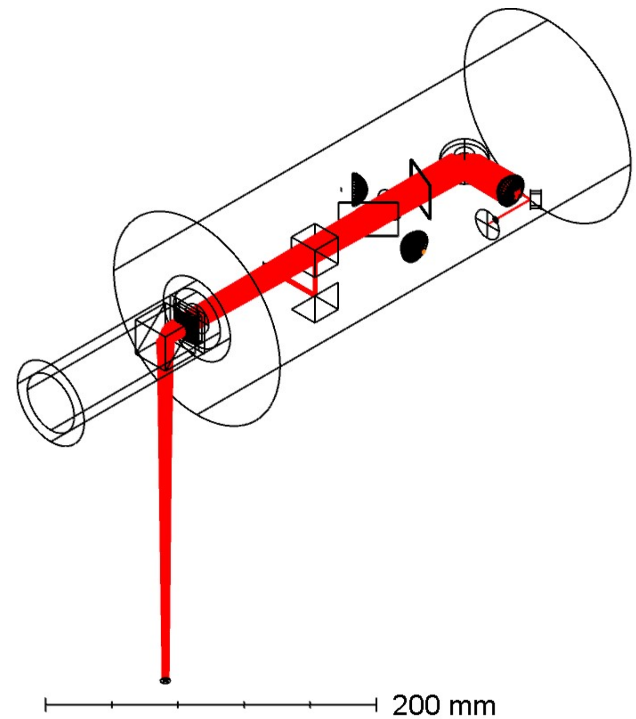
Receiver Optical Design



Green Light Return



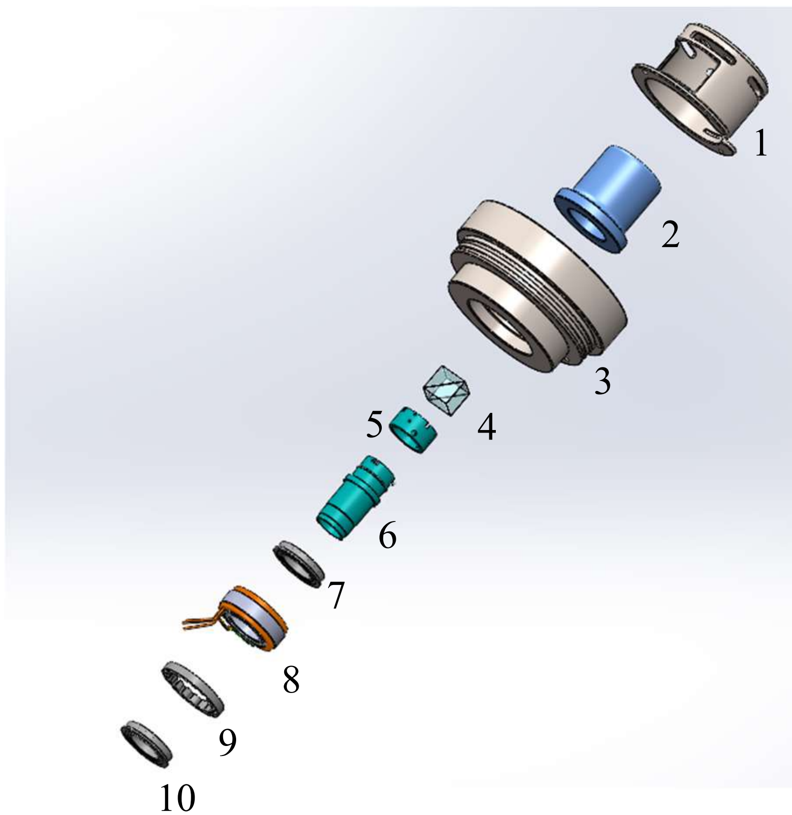
Red 1 Return

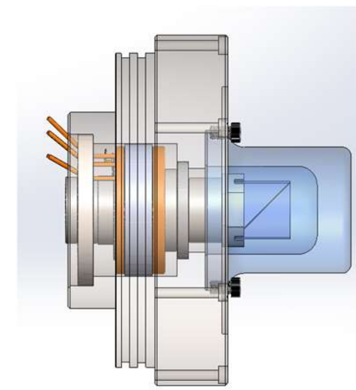


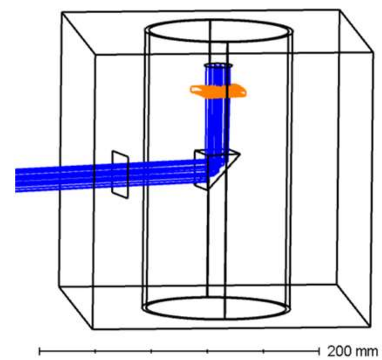
Red 2 Return

Exploded View – Scanner Assembly

1. Shroud
2. Window
3. Output Endcap
4. Prism
5. Shaft part 1
6. Shaft part 2
7. Ball bearing
8. Motor
9. Deflection reduction
10. Ball bearing



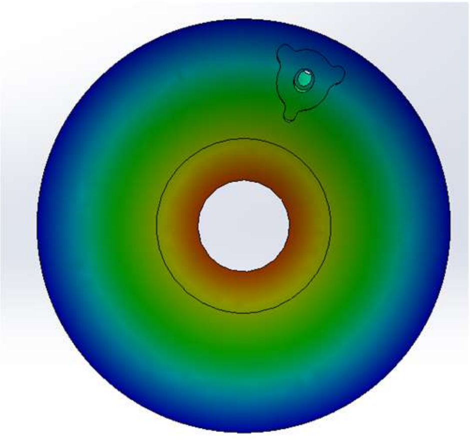




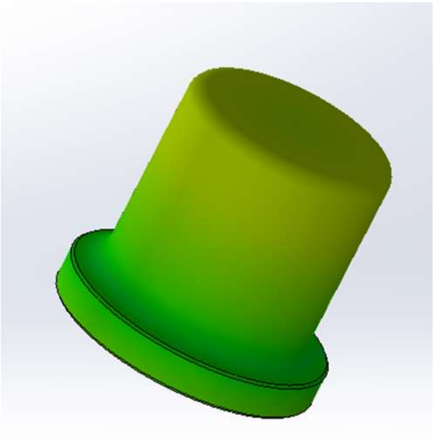
3D AT DEPTH

FEA summary – 6,723 psi (4,600m)

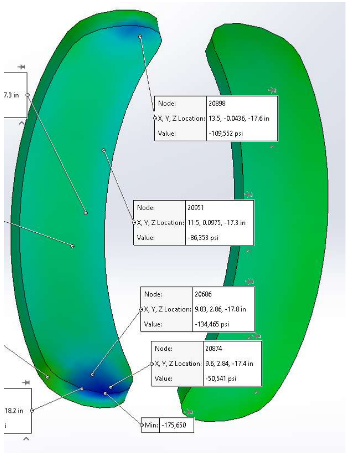
- Acceptable deflections and stresses
- Less endcap deflection than current product
- Comparable window stress to current product



Uniform Deflection



Uniform Stress



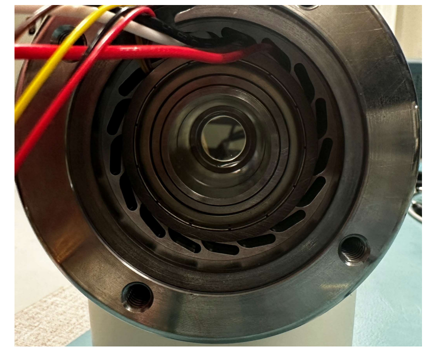
Eliminates concerns from previous design

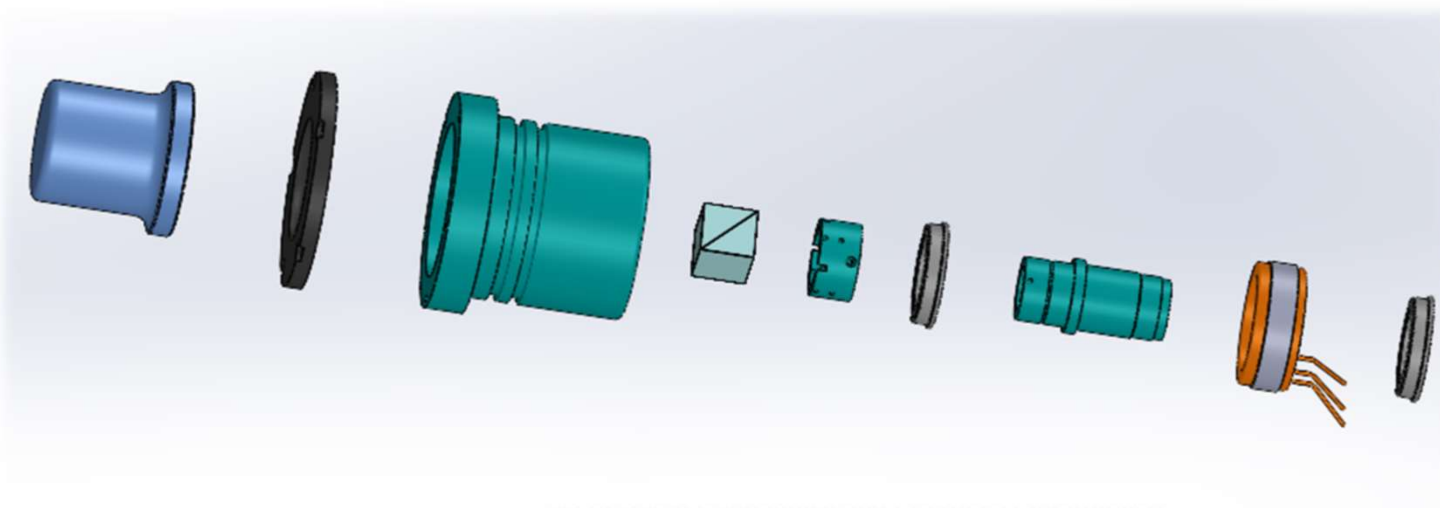
No change from Phase 1

Scanner Assembly Built with non-MBARI funding









Electrical Design

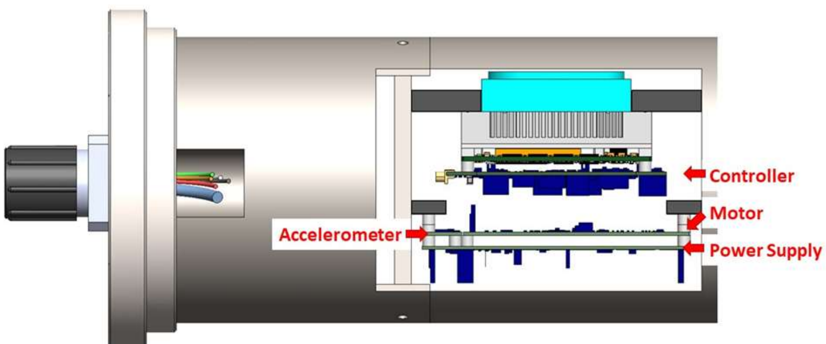
Electronic PCBs & Components Status

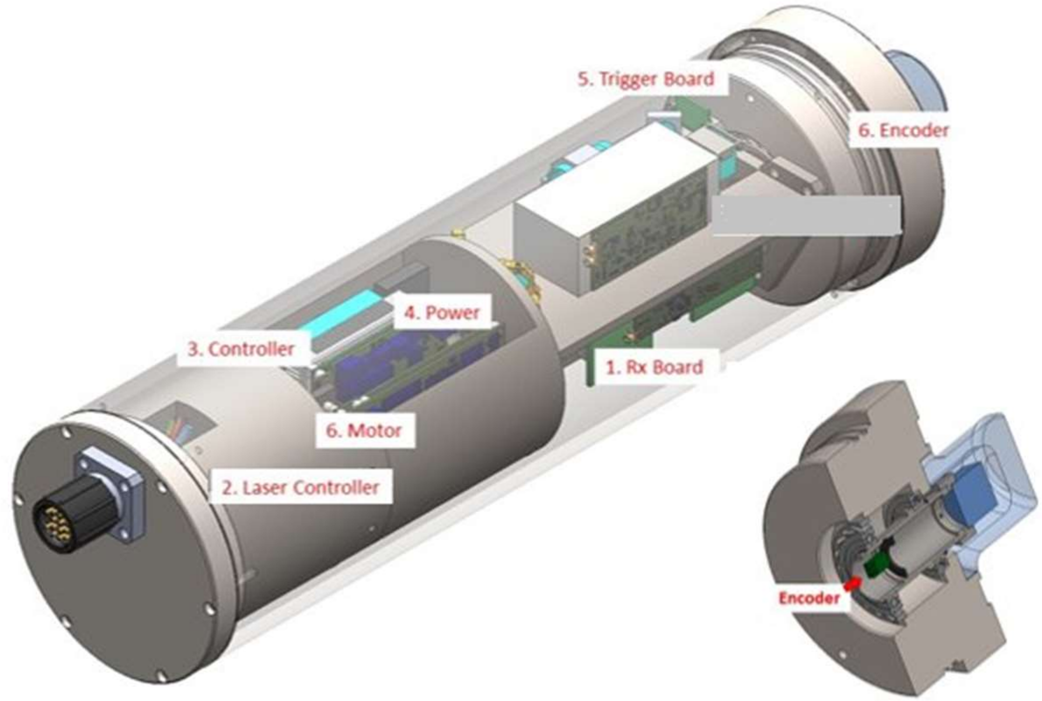
1. Rx Board/Photodetector *
   - 1st Turn functional; 2nd turn with updated outline and mounting holes
2. Laser Controller/Laser
   - Selected Quoted, 16-week Lead time
3. Controller/Digitizer/Computer *
   - Bench set available for testing – functional; Updated form factor ready to turn
4. Power/MCC Board Plus DC/DC Module* - build August 23
5. Trigger Board – In Design 50% complete; making use of Rx board – little risk; to test with existing trigger board
6. Encoder - Selected; quoted; purchased for test*
7. Motor - Purchased for different product; purchased and tested*

*(built or built and tested with non-MBARI funding = free risk reduction)

Electronic PCBs & Components (location of PCBs)

- Rx Board/Photodetector
- Laser Controller/Laser
- Controller/Digitizer/Computer
- Power/MCC Board Plus DCDC Module
- Trigger Board
- Encoder
- Motor

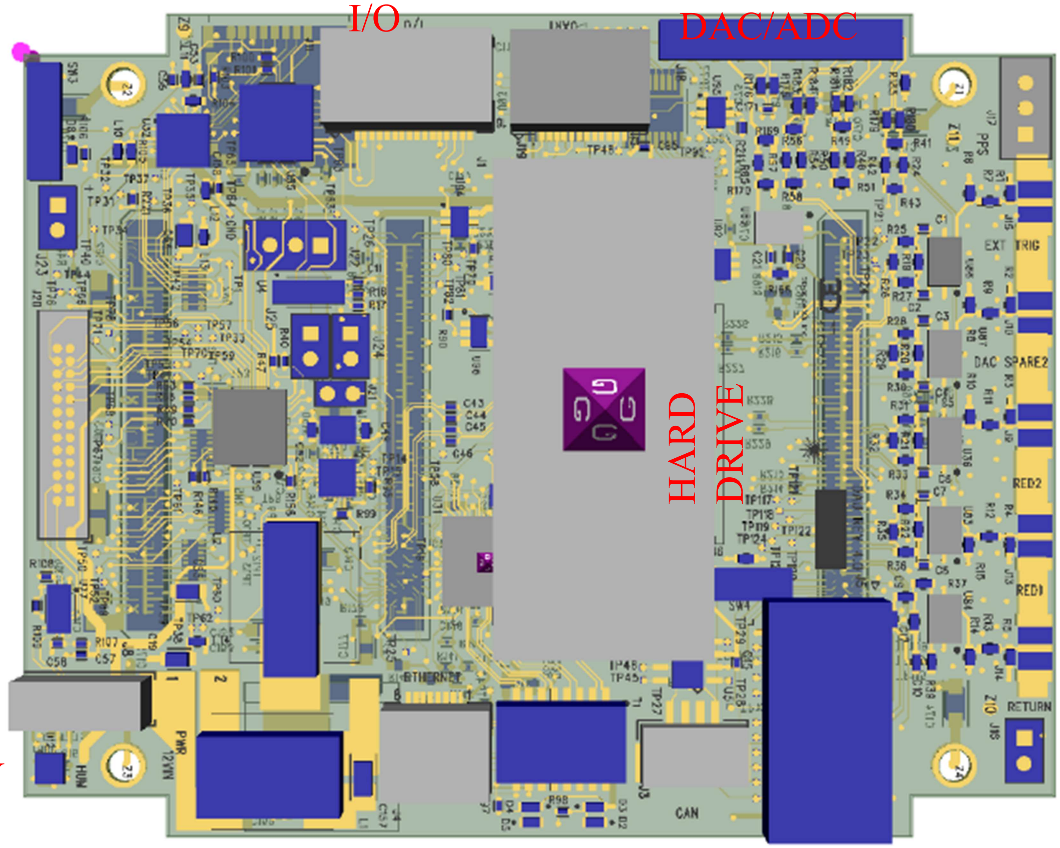




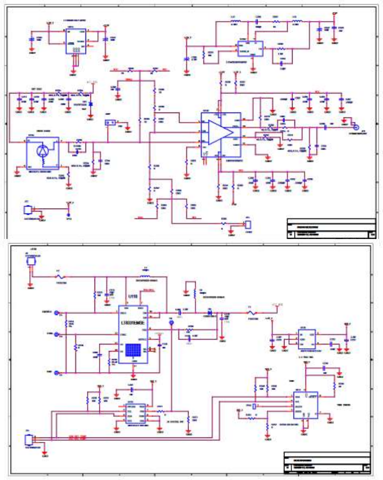
3D AT DEPTH

Controller / Digitizer

*(built and tested with non-MBARI funding) - less spinner testing



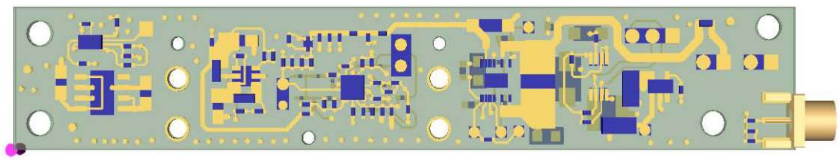
Receiver Board



Built Board Ver 2.

Temp Sensor

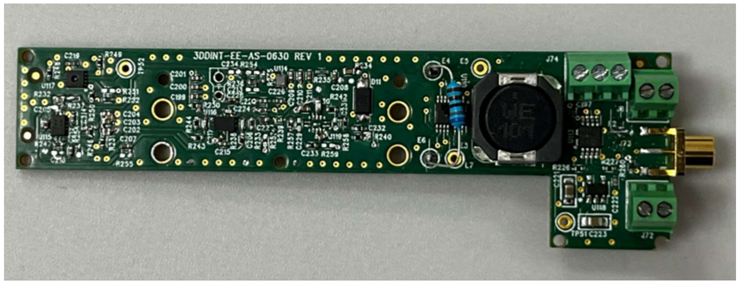
PhotoDetector

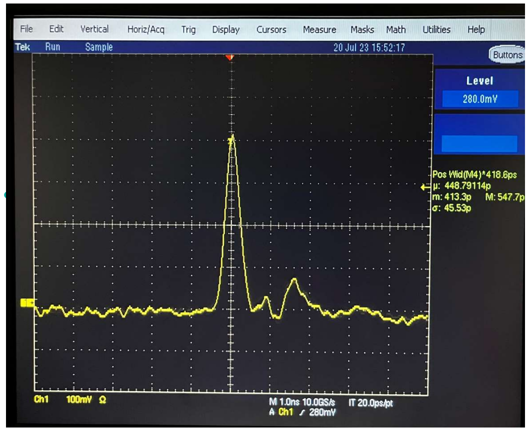


Return Sig Out

(Updated design)

Built Board Ver 1.

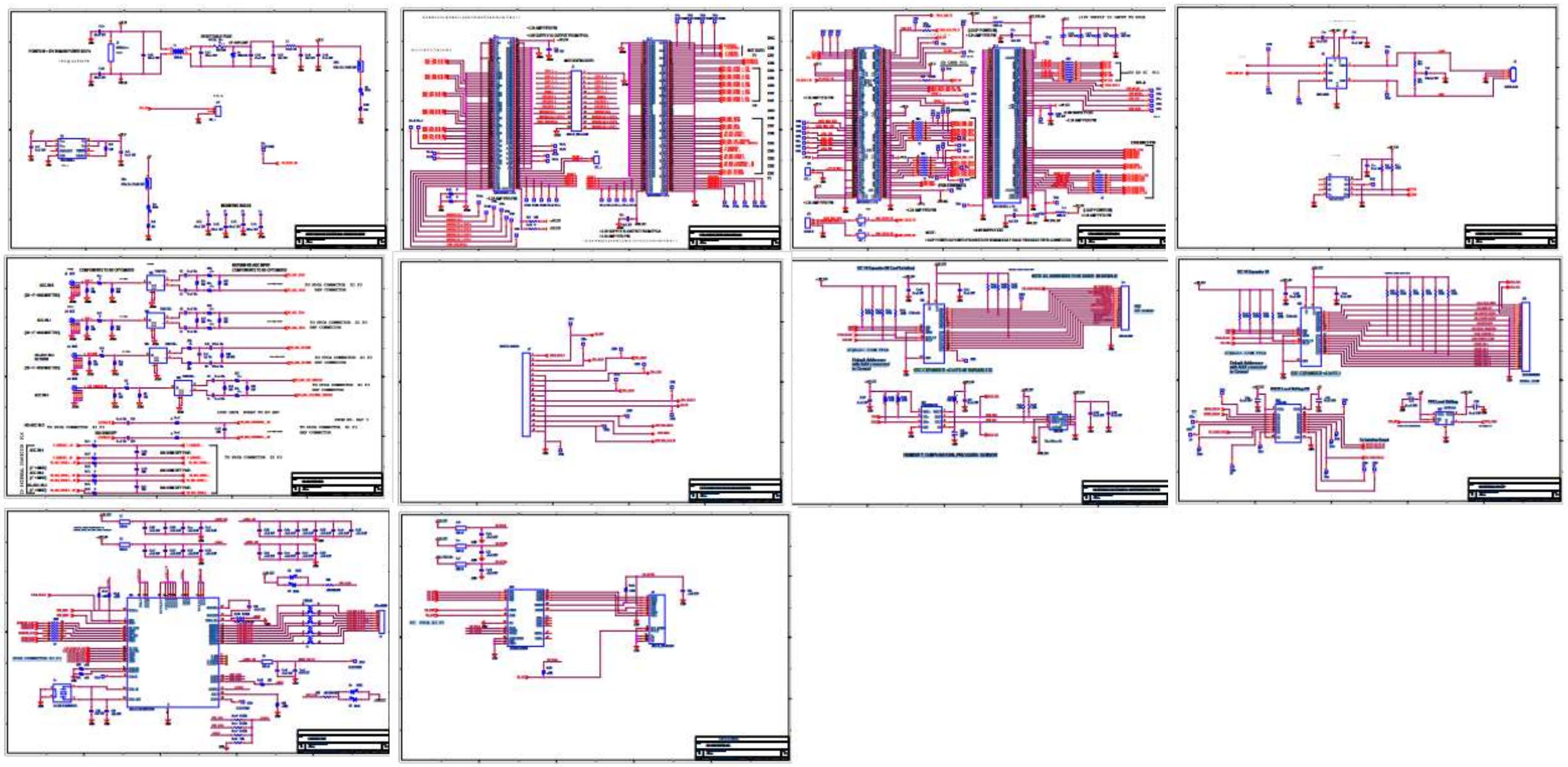




Return - Excellent Pulse Width performance

*(built and tested with non-MBARI funding) = free risk reduction

Controller/Digitizer Schematic

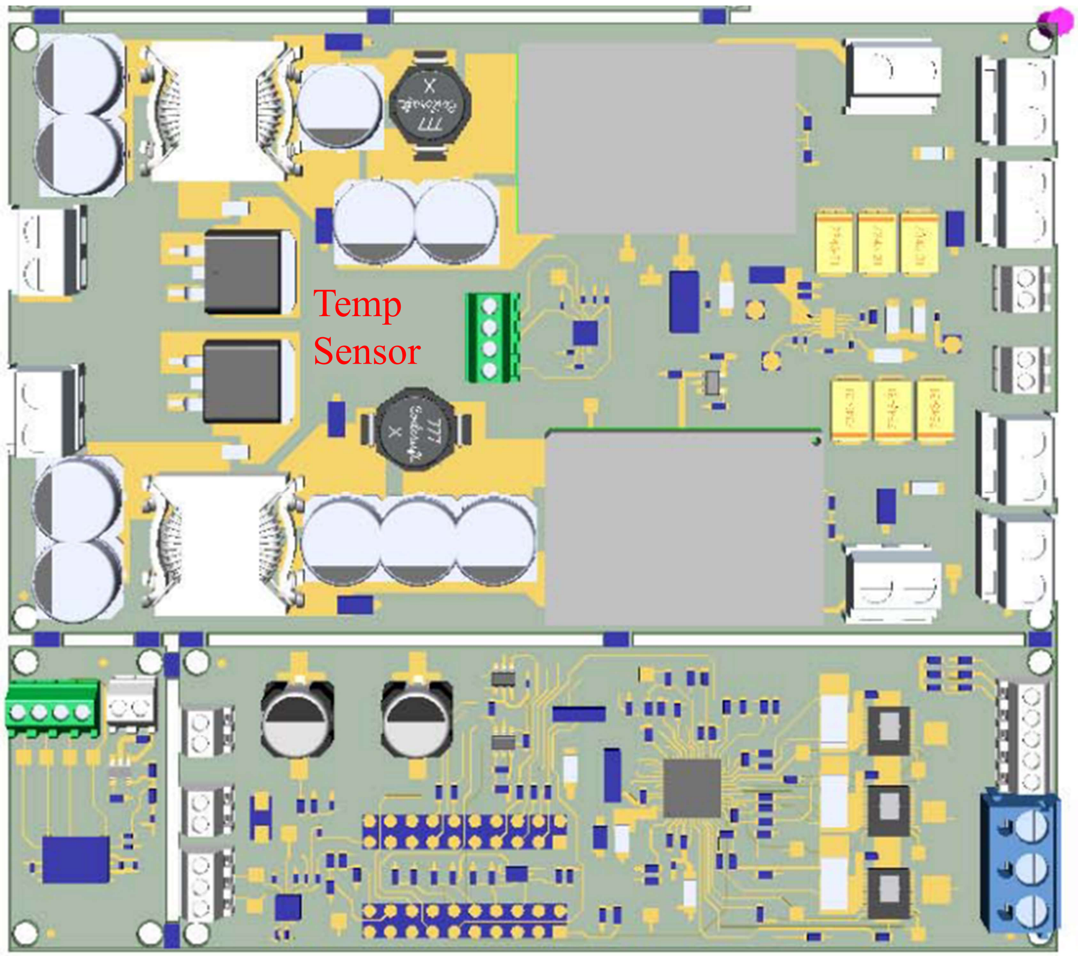


Power Board, Motor Controller, DC/DC Switcher Module

Power In

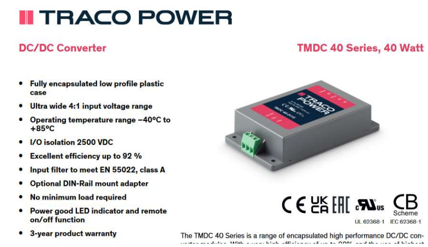
Power In

Temp Sensor



Accelerometer

Tec Power



DC/DC 48v and 24 volt Isolated modules

12v Out

Hall Input

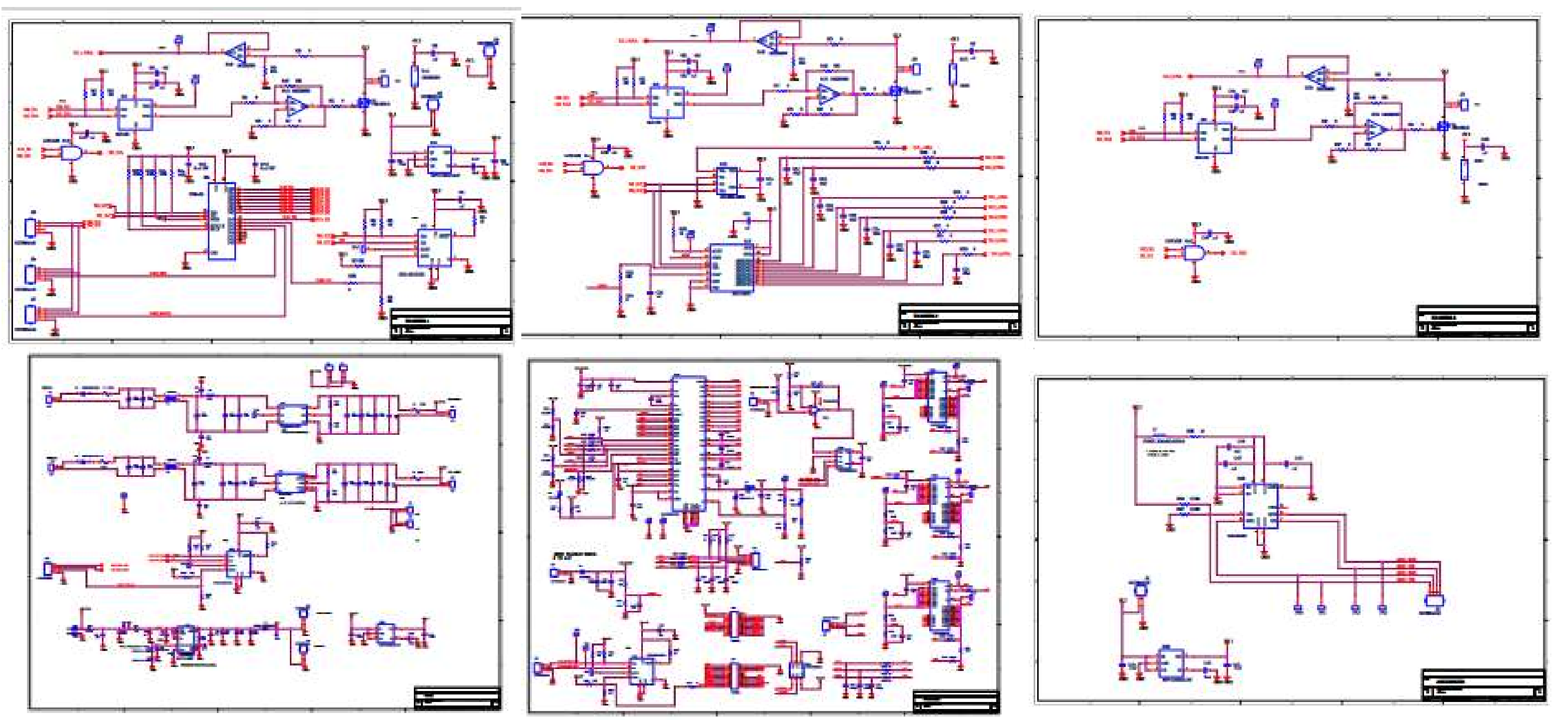
Motor Control

Input Voltage 18 –36 Volts

1. 12V; <200W General Purpose
2. 5V; <150W – Not to be stuffed
3. 5V; Rx Amps
4. 35V; 22W –TBD Motor
5. Temp Sensor added w/ 3V
6. DC/DC Module for Motor 48v and 24 volt
7. Isolated Supplies

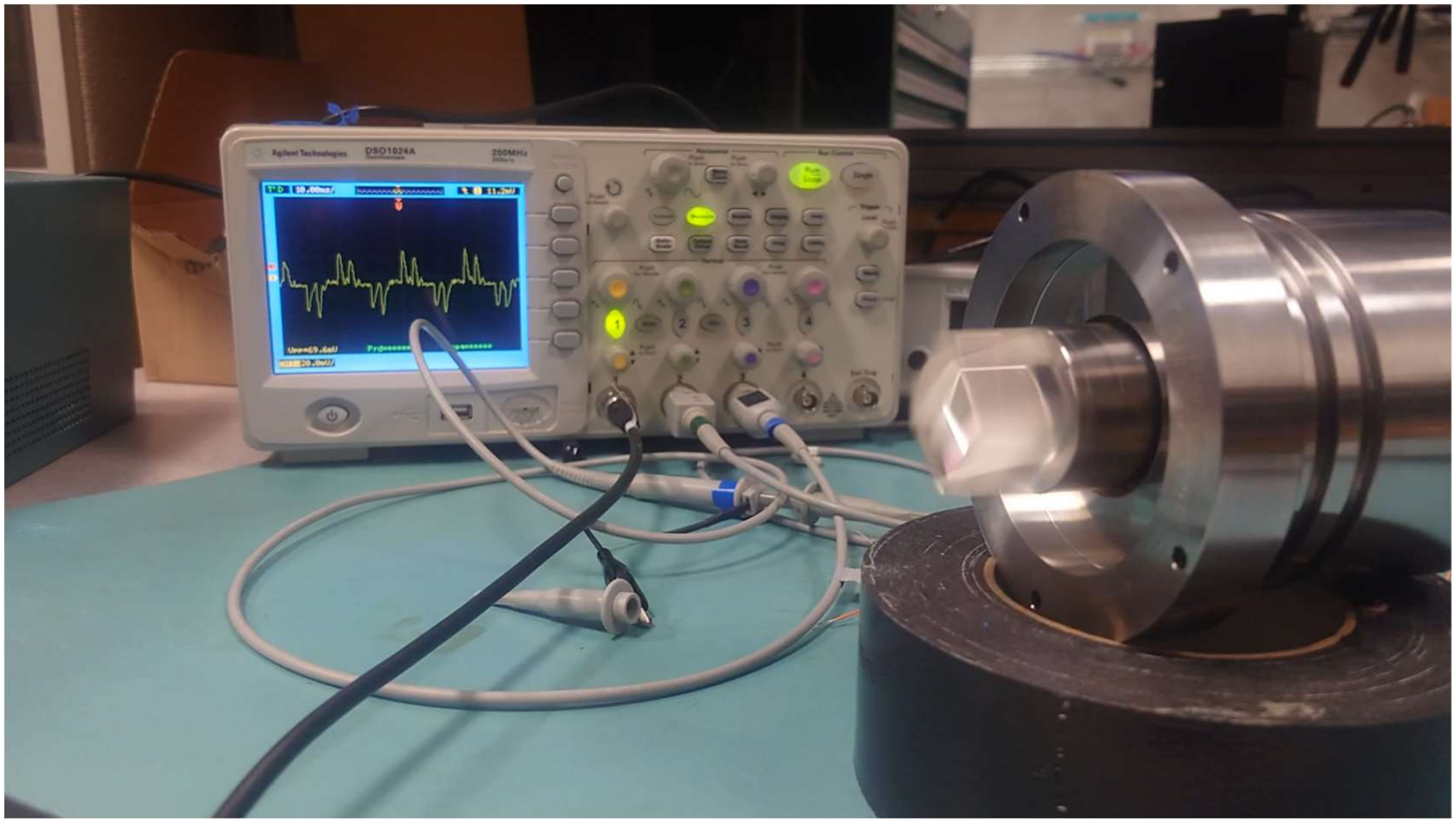
*(Designed with non-MBARI funding)

Power Board, MCC Schematics



Preliminary Testing – Risk reduction from build and test with non-MBARI funding

Scanner Assembly

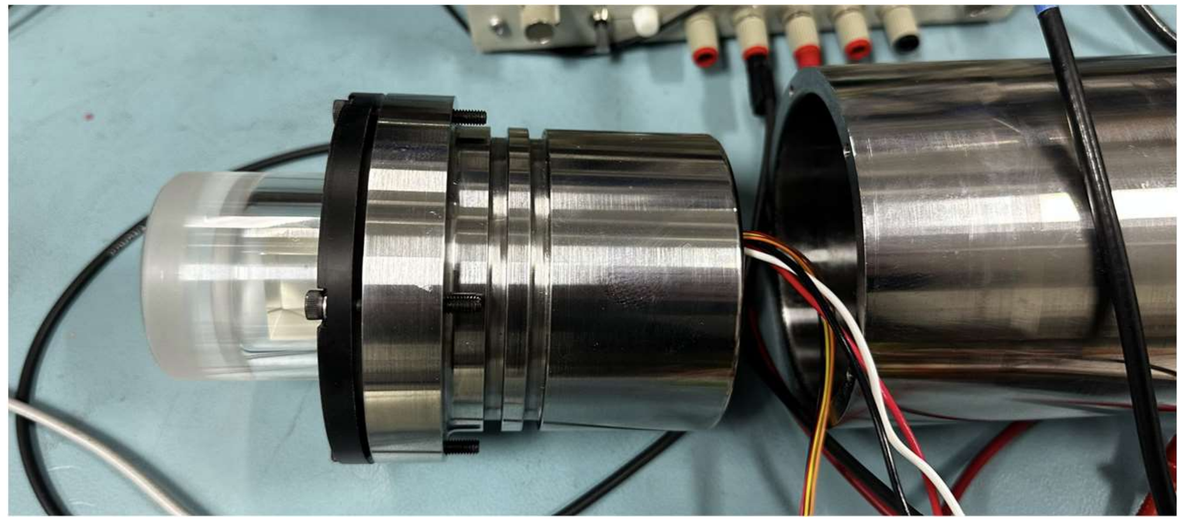


*(built and tested with non-MBARI funding)

With Laser Pointer

*(built and tested with non-MBARI funding)

Scanner Assembly + Pressure Housing



*(built and tested with non-MBARI funding)

Window - Pressure Testing Results

1. Pressure test at 3,000m
   1. Two 10-minute holds and one 1hour hold
2. Pressure test at 4,000m
   1. Two 10-minute holds and one 1hour hold
3. Pressure test at 10,000psi
   1. Two 10-minute holds and one 1hour hold
4. Pressure test with motor running
   1. No increase in motor torque at 10.5 ksi
   2. See table

Pressure (PSI)	Motor Current (mA)	Notes
0	0.42	
1,000	0.41	
2,000	0.42	
3,000	0.42	
4,000	0.42	
5,000	0.41	
6,000	0.41	
7,000	0.42	
8,000	0.42	
9,000	0.41	
10,000	0.41	Initial
10,000	0.40	After 30-minute hold
10,500	0.40	Initial
10,500	0.40	After 30-minute hold
0	0.41	After de-pressure
0	0.41	After removed from vessel

*(built and tested with non-MBARI funding)

Budget and Schedule

Phase 2 – From 28 Oct. 2022 Proposal

- Below are the scope, deliverables, schedule, and budget from the 28 Oct. 2022 proposal [1271] MBA-WiSSL2DesignBuild2022_R2

Scope

Phase 2 – Detailed Design

The goal of the second phase is to perform detailed design of the new system building upon the requirements, trade studies, and preliminary designs of the first phase. Primary goals derived from the preliminary design include:

1) Drastic reduction of the Size, Weight, and Power (SWaP) usage of the system to better enable deployment on an AUV.

2) Faster data collection rates – increased laser Pulse Repetition Frequency (PRF) to enable faster vehicle speeds.

3) Wider scan angles to match MBARI camera systems and eliminate dual-head system.

4) Ability to measure water temperature from the same laser pulse.

Note the proposed design is based upon 3D at Depth's SL4 electronics, which have been developed internally by 3D at Depth over the last two years at no charge to MBARI. The added benefit of using the SL4 electronics architecture is the WiSSL 2.0 will be in-line with standard 3D at Depth products which allows MBARI to take advantage of the continual upgrades to the standard products.

Schedule

Phase 2 – Detailed Design

It is anticipated that Phase 2 will commence the first week of November 2023 and will last approximately 8 months. 3D at Depth does not guarantee this schedule but will use its best efforts to achieve it, subject to unforeseen circumstances and the cooperation of MBARI.

Deliverables

Phase 2 – Detailed Design

The deliverables for Phase 2 are as follows:

1) Monthly design reviews by phone with the MBARI team to provide updates on the design and to gather feedback and direction from the MBARI team.
2) Final power point presentation of the agreed upon design including size, weight, power, and expected performance. Critical design review to be held at MBARI.
3) Solid models of the final housing design for integration into the AUV solid model
4) Price and schedule quote for Phase 3

Budget

3D at Depth Fixed Price Cost Summary – Phase 2		
Item	**Description**	**Project Budget Amount** ($USD)
1	**Phase 2 – Detailed Design**	$158,935
2	**Travel and expenses for four people to Critical Design Review at MBARI (estimated – charged at actual + 15%)**	$6,000
	Phase 2 Total Cost	**$164,935**

Maintained budget

Phase 3 – From 28 Oct. 2022 Proposal

- Below are the deliverables, pricing, and schedule from the 28 Oct. 2022 proposal [1271] MBA-WiSSL2DesignBuild2022_R2

Scope

Phase 3 – Build and FAT at 3D at Depth

The goal of Phase 3 is to build, calibrate, and test the new WiSSL 2.0. This includes all material costs and labor for component purchase, build, software development, alignment, calibration, internal test, and Factory Acceptance Test at 3D at Depth's facility in Longmont, CO.

Deliverables

Phase 3 – Build and FAT at 3D at Depth

The deliverables for Phase 3 are as follows:

1) Signed FAT document
2) Price and schedule quote for Phase 4

Schedule - Original

Phase 3 – Build and FAT at 3D at Depth

It is estimated that Phase 3 will take 7 months to complete. This schedule could be compressed if some long-lead items are ordered during Phase 2. Phase 3 final schedule will be dependent upon the detailed design performed in Phase 2. It is anticipated that MBARI personnel will be on-site for two full days for the FAT. 3D at Depth does not guarantee this schedule but will use its best efforts to achieve it, subject to unforeseen circumstances and the cooperation of MBARI.

Budget - Original

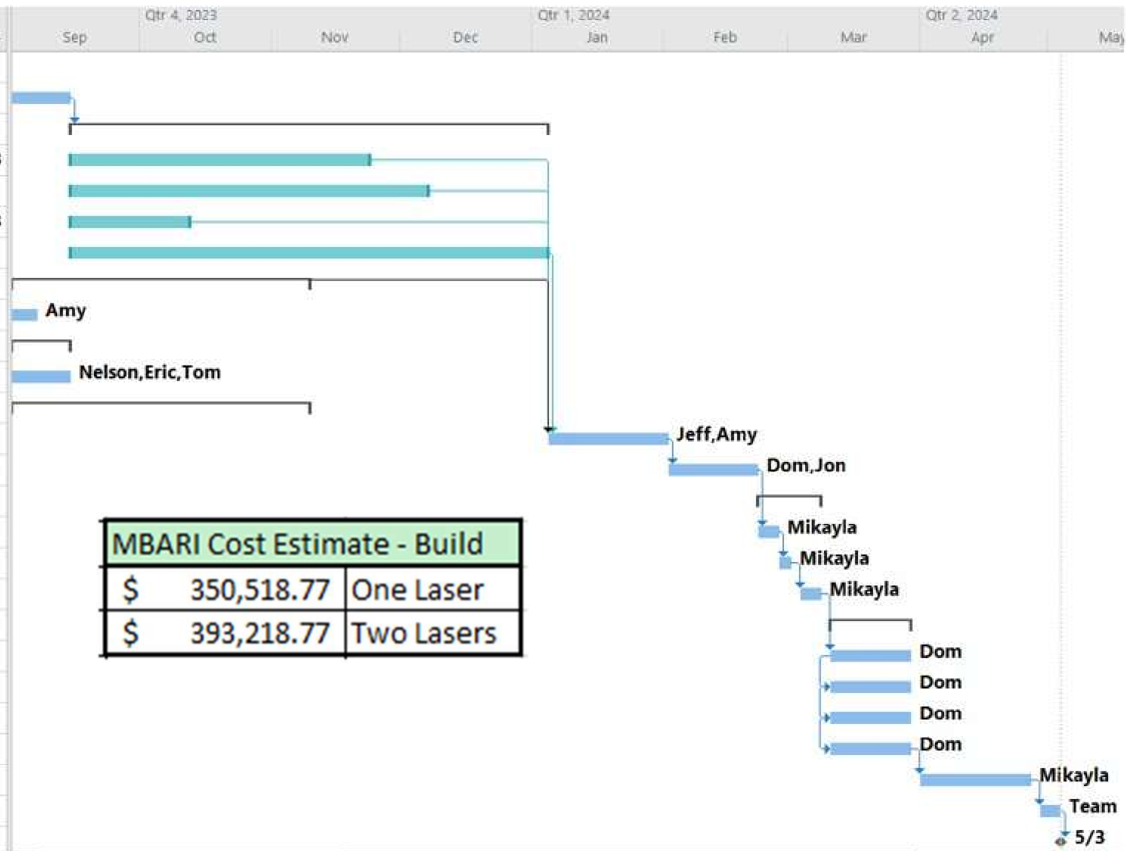
3D at Depth Fixed Price Cost Summary – Phase 3		
Item	**Description**	**Project Budget Amount ($USD)**
1	**Phase 3 – Build and FAT at 3D at Depth**	$291,409
	Phase 3 Total Cost	**$291,409**

Payment Terms

3D at Depth will invoice MBARI $35,000 at the end of each calendar month up to Month 7 ($245,000 total). The remainder will be invoiced upon delivery of the approved Factory Acceptance Test sign-off.

Phase 3 - Build Schedule and Cost Estimate

Task Mode	Task Name	Duration	Start	Finish
	MBARI 1271 Build			
	Authority to Proceed	2 wks	Fri 9/1/23	Thu 9/14/23
	Procurement	**80 days**	**Fri 9/15/23**	**Thu 1/4/24**
	Mechanical Orders	10 wks	Fri 9/15/23	Thu 11/23/23
	Optical Components/Laser	12 wks	Fri 9/15/23	Thu 12/7/23
	Electrical	4 wks	Fri 9/15/23	Thu 10/12/23
	Laser	16 wks	Fri 9/15/23	Thu 1/4/24
	Development Efforts	**50 days**	**Fri 9/1/23**	**Thu 11/9/23**
	Mechanial Interface	4 days	Fri 9/1/23	Wed 9/6/23
	Electrical	**10 days**	**Fri 9/1/23**	**Thu 9/14/23**
	Trigger Board Development	2 wks	Fri 9/1/23	Thu 9/14/23
	Software Development	**50 days**	**Fri 9/1/23**	**Thu 11/9/23**
	Build	4 wks	Fri 1/5/24	Thu 2/1/24
	Temp Sensor Testing	3 wks	Fri 2/2/24	Thu 2/22/24
	Calibration	**11 days**	**Fri 2/23/24**	**Fri 3/8/24**
	Range	3 days	Fri 2/23/24	Tue 2/27/24
	Angle	3 days	Wed 2/28/24	Fri 3/1/24
	Temperature	1 wk	Mon 3/4/24	Fri 3/8/24
	SW Integraton (show)	**15 days**	**Mon 3/11/24**	**Fri 3/29/24**
	Theraml SW	3 wks	Mon 3/11/24	Fri 3/29/24
	Laser Control SW	3 wks	Mon 3/11/24	Fri 3/29/24
	Trigger SW	3 wks	Mon 3/11/24	Fri 3/29/24
	Data Processing SW	3 wks	Mon 3/11/24	Fri 3/29/24
	SIT (Validation)	4 wks	Mon 4/1/24	Fri 4/26/24
	System FAT	1 wk	Mon 4/29/24	Fri 5/3/24
	Sensor Available	0 days	Fri 5/3/24	Fri 5/3/24



MBARI Cost Estimate - Build	
$ 350,518.77	One Laser
$ 393,218.77	Two Lasers

3D AT DEPTH

Phase 4 – From 28 Oct. 2022 Proposal

- Below are the deliverables, pricing, and schedule from the 28 Oct. 2022 proposal [1271] MBA-WiSSL2DesignBuild2022_R2

Scope

Phase 4 – Validation Tests in MBARI Tank and Sea Trials

The goal of Phase 4 is to assist with validation tests in the MBARI tank and sea trials. Major tasks include:

- Design and build of custom shipping container. Potentially can use standard Pelican case with custom foam design and build
- Software and general owner's manual generation and delivery
- Shipping from 3D at Depth to MBARI
- Travel and time for 3D at Depth personnel to support tank tests and open water trials

Schedule

Phase 4 – Validation Tests in MBARI Tank and Sea Trials

Phase 4 will occur in 2024. Schedule should be determined during or after Phase 3.

Deliverables

Phase 4 – Validation Tests in MBARI Tank and Sea Trials

The deliverables for Phase 4 are as follows:

1) WiSSL 2.0 at MBARI (with shipping container)
2) General owner's manual
3) Software manual
4) Assistance with validation tests at MBARI

Budget

Phase 4 – Validation Tests in MBARI Tank and Sea Trials

As Phase 4 will be conducted in 2024, we suggest Phase 4 be priced during or after Phase 3.

MBARI Feedback

MBARI modifications requested Questions:

1. Changed to SubConn 13 pin flange Ti connector
2. PPS baseline – will not work on PTP for now.
3. Added dual access accelerometer to optical bench
4. Mounting / integration points / features need to be defined – in progress
5. Define FAT – draft provided

New Questions

3D AT DEPTH

Questions ?

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1900 S. Sunset St.,
Suite 1-D
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USASales@3DatDepth.com

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