ROVVR Camera Critical Review

June 6th, 2019 - MBARI Project 901911

Project Objectives

To develop an ROV mounted deep sea panoptic stereo camera system, rated to a depth of 4km, with the ability to live stream video to a virtual reality headset, and record in 4k.

System Goals & Functional Requirements 2019

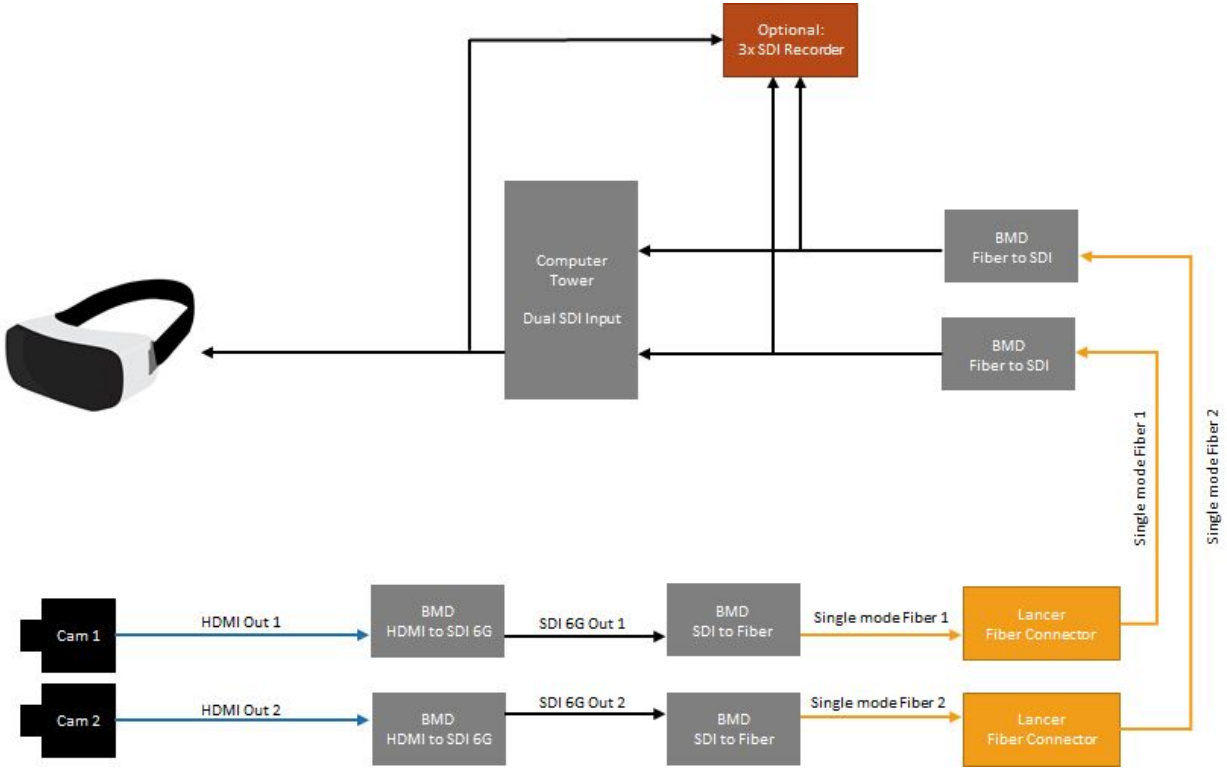
- Install a single stereo housing (4,000 meter rated) utilizing 2x ZCam E2's, capable of capturing high quality 180 3D video on ROV Doc Ricketts.
- The ability to record high quality formats for cinematic storytelling, plus real-time streaming to a virtual reality headset (of MBARI's choosing) on the surface for use by both ROV pilots and science staff.
- Ensure global synchronized controls to each camera on the surface.
- Present a CPU with installed software to MBARI out of the box ready for both cinematic capture and real-time streaming.
- Develop Year 2 goals which can boost science efforts through point cloud capture, sizing/measurement, and volumetric capture + processing.

Key Derived Requirements (Year 1)

1) High quality 180 3D imagery which exceeds spec requirements for natural history sequences with BBC, National Geographic, etc.
2) Real-time streaming to VR headset.
3) Ability to record cameras utilizing uncompressed formats such as ProRes (ZRAW to release in a few months)
4) Ability to capture sparse point clouds for sizing/measurement (to be developed in Year 2).
5) Must integrate to existing electro-optical connections on ROV.

System Concept

System Block Diagram (Topside↔ROV↔Camera)



Z CAM E2G

Product Specifications v1.1 (draft)

(Pre-commercial Unit)

Product Highlights

- **4K @30fps, 10-bit color**
- **12 stops dynamic range**
- **Gigabit Ethernet for data, control & live streaming***
- **1" CMOS sensor with Global Shutter**
- **iOS app for control setting & live preview**
- **Multi-cam synchronization****

* require Z CAM software running on PC

** require Z CAM E2 Sync Cable (not included)

Technical Specifications

Camera

Sensor Type	1" CMOS Sensor
Sensor Size	14.13 x 7.45 mm
Effective Pixels	8.85M
Dynamic Range	12 Stops (Z-Log2)
Lens Mount	Micro Four Thirds
Microphone	Built-in Stereo Microphone

Recording

Resolution	4096 x 2160 / 3840 x 2160 3536 x 2092 / 1920 x 1080
Frame Rate	29.97 / 25 / 24 / 23.98 fps
Max Variable Frame Rate	120 fps for 1920 x 1080 (H.265 & H.264)
Max Bit Rate	200 Mbps for all resolutions (H.265 & H.264)
Color Bit-depth	10-bit (H.265) / 8-bit (H.264)
Video Encoder	H.265 main 10 profile / H.264 high profile
Audio Format	24-bit 48 kHz
Audio Encoder	AAC / PCM (for MOV only)
File Format	MOV / MP4
Record Mode	Video / Time Lapse Video

Settings

ISO	Auto, Manual (1250 ~ 40000)
Shutter	Shutter Speed: Auto, Manual (up to 1/8000") or Shutter Angle: Auto, Manual (1° ~ 360°)
White Balance	Auto, Preset, Manual (2300K ~ 7500K)
Focus Mode	MF / AF / CAF
Image	Brightness / Contrast / Saturation / Sharpness
Image Profile	Rec.709 / Z-Log2 / FLAT / HLG
Audio	Audio In / Out Level
Time Code	Current Time / Manual Input

Storage

Media	CFast 2.0
File System	exFAT

Connectivity

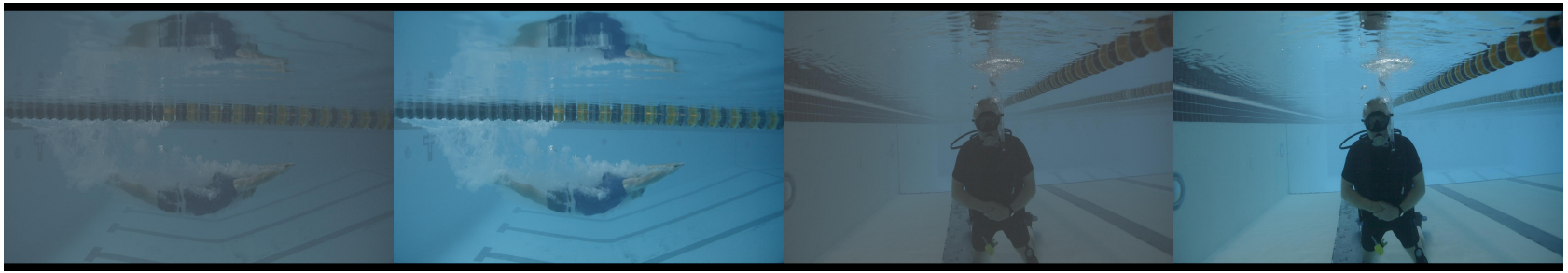
HDMI	HDMI 2.0 Type A (video output up to C4K @ 30fps)
USB	USB 3.0 Type C for camera control & data transfer only
I/O	10-pin LEMO port for synchronization (require additional Sync Cable, not included)
COM	DB-9 connector, supports RS-232
Remote Control	2.5 mm jack socket (Sony LANC compatible)
Audio-in	3.5 mm stereo jack socket for active microphone only, or 5-pin LEMO port for dual channel XLR microphone (require additional XLR audio connector)
Audio-out	3.5 mm stereo jack socket
Wi-Fi	802.11n, 2.4G with external antenna port
Ethernet	Gigabit Ethernet port for control, setting & live streaming

Power

Battery	Sony NP-F series compatible (Battery not included)
External Power Supply	DC 12V 5A (4-pin LEMO socket), with LEMO connector and AC/DC power adapter, hot swap supported.

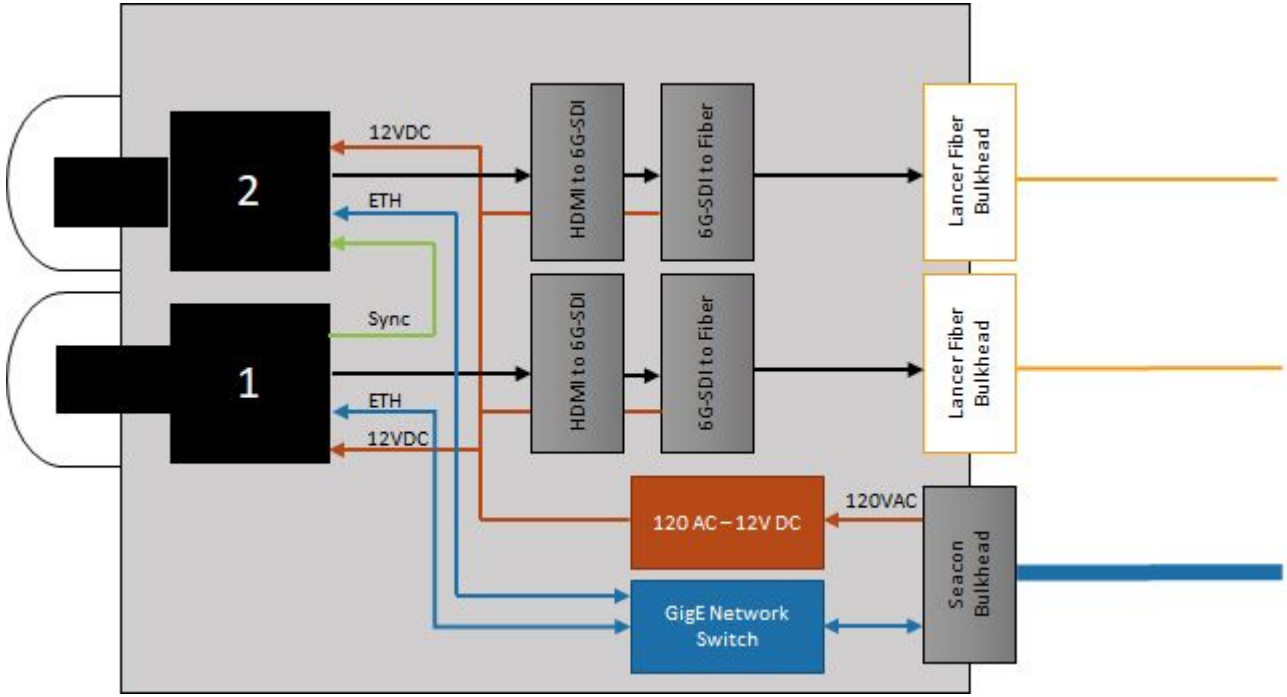
5/30 Pool Test Assessment

- Sample footage for review
- No internal heat issues with cameras; Very good stereo 3D results in headset
- 4k H.265 data stream is 16mb/second vs ProRes at about 70mb/second
- Total resolution of 2180 x 2180 per eye with 175 degree FOV at 30fps
- Live streaming image quality was grainy with a lot of room for improvement; can be fixed with post-processing (Neat Video)



Electrical Design

Camera Internal Electrical Block Diagram



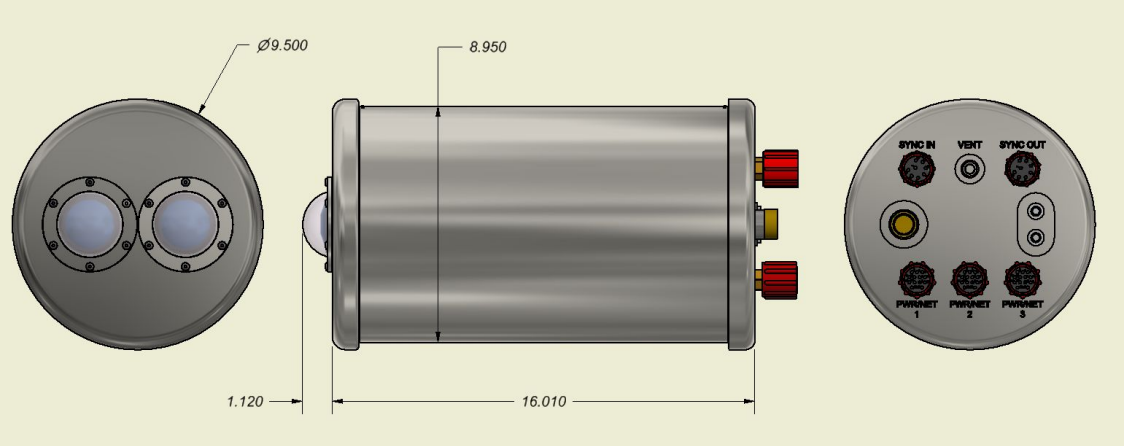
Camera Electrical Power Budget

Component	Voltage (VDC)	Amperage	Watts (V*A)	Qty	Total Watts
ZCam E2	12	2	24	2	48
BMD Mini Fiber Converter	12	.17	2	2	4
BMD HDMI to SDI Converter	12	.37	4.44	2	8.88
Netgear GS105NA	12	.225	2.7	1	2.7
				System Total	63.58

Mechanical Design

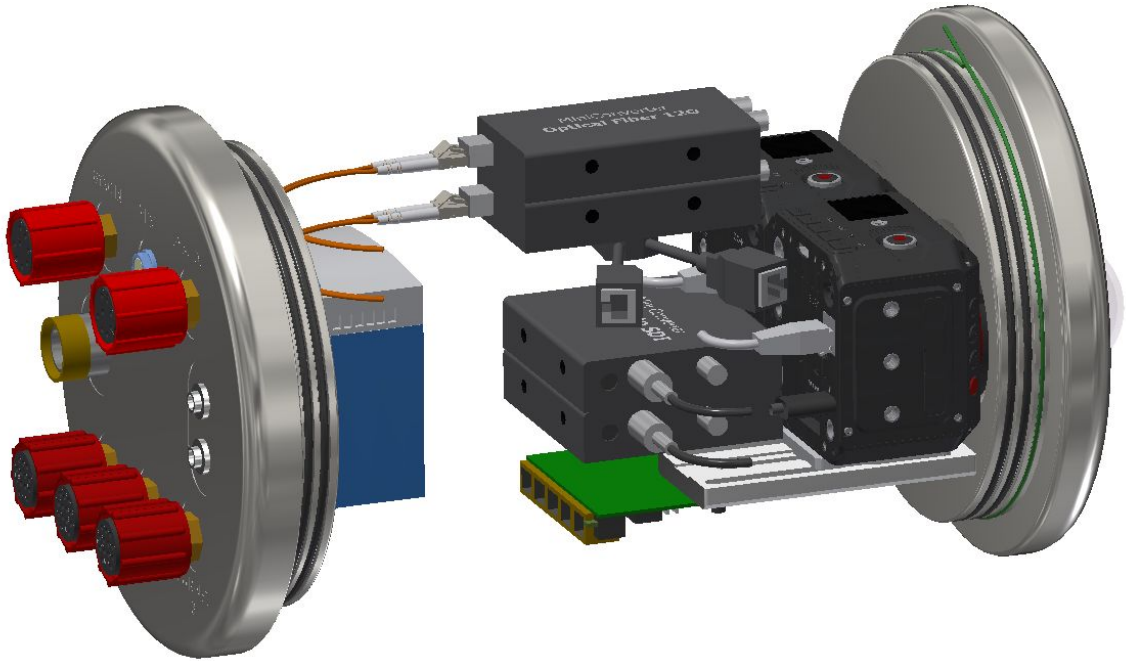
Housing External Design (6/5/2019)

- Ti-Grade 5
  - 8.0” ID, 0.5” Wall Thickness
  - Doors 1.95” thick
- Bk7 Glass Domes
- Air Weight: 70.6 lbs
- Displacement: 1039in^3
- Buoyancy (seawater): -32 lbs



Housing Internal Layout

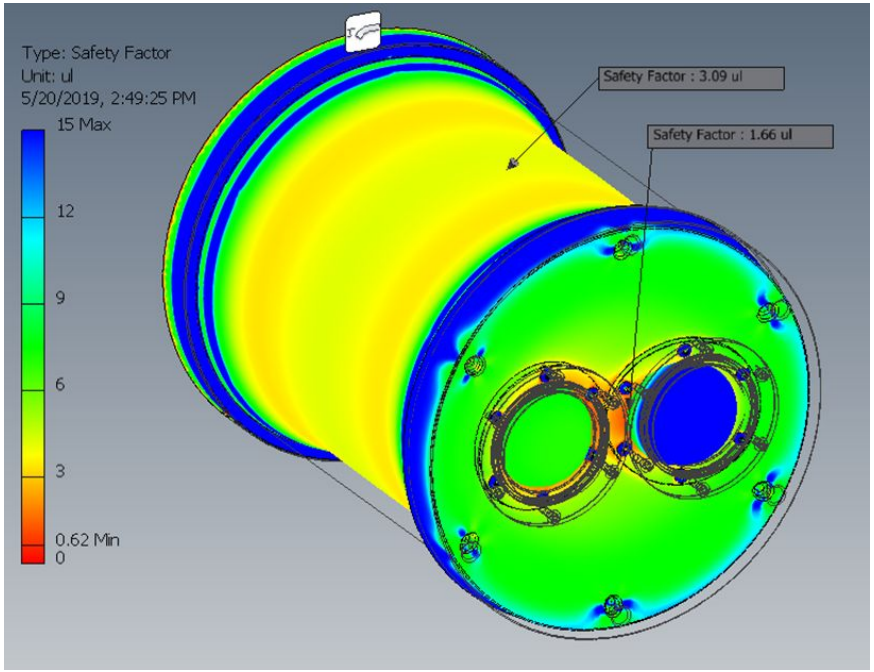
- Requires final review
- Internal tray components need to be modeled



Mechanical Analysis

- FEA performed in Autodesk Inventor 2020 environment
- Basic tube and door shapes validated using DSPL Under Pressure software.
- Low safety factor value (0.62) caused by part grounding in analysis and should be ignored.

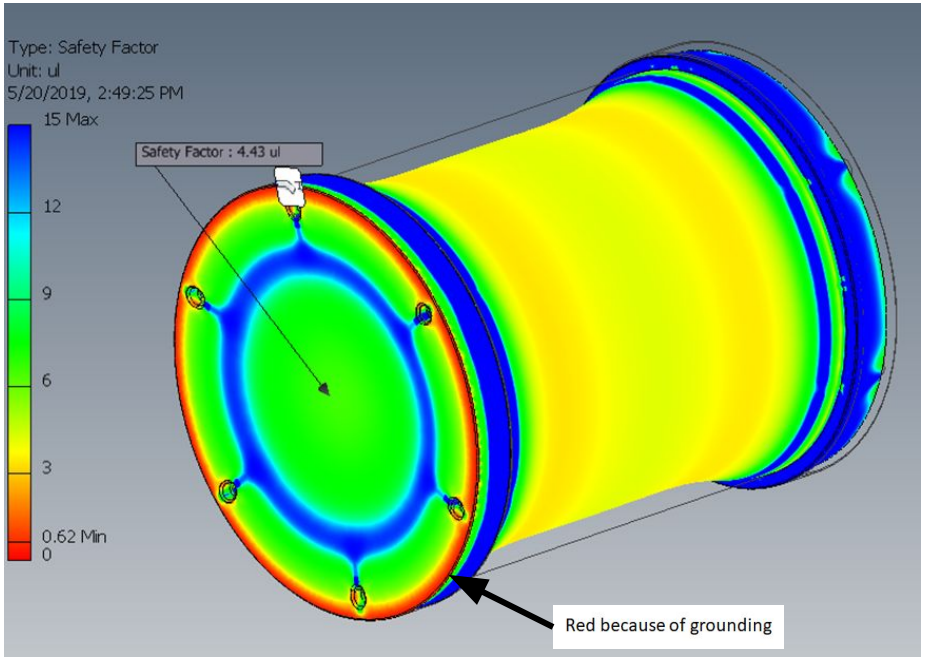
4000m (5846 psi), Rear Door perimeter fillet fixed, .02 mesh



Mechanical Analysis

- FEA performed in Autodesk Inventor 2020 environment
- Basic tube and door shapes validated using DSPL Under Pressure software.
- Low safety factor value (0.62) caused by part grounding in analysis and should be ignored.
- Materials:
  - Ti 6AL4V
  - BK7 Glass Domes

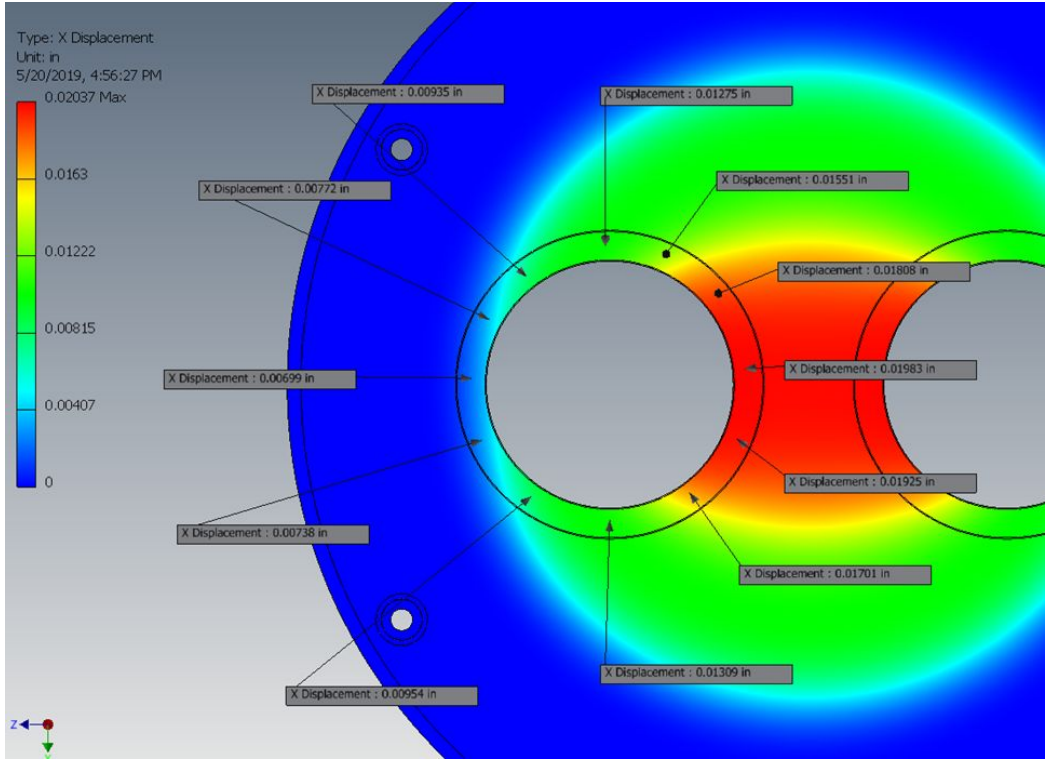
4000m (5846 psi), Rear Door perimeter fillet fixed, .02 mesh



Mechanical Analysis

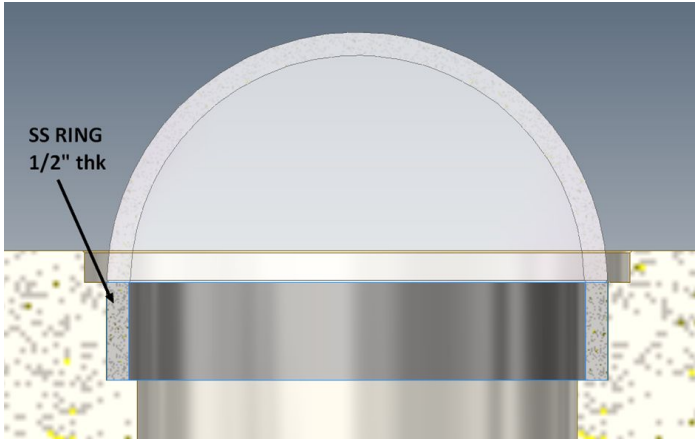
- Displacement ranges from .007” to 0.020” in a non-linear fashion.
- BK7 glass dome will seat directly onto measured surface

4000m (5846 psi), Dome Seat Displacement

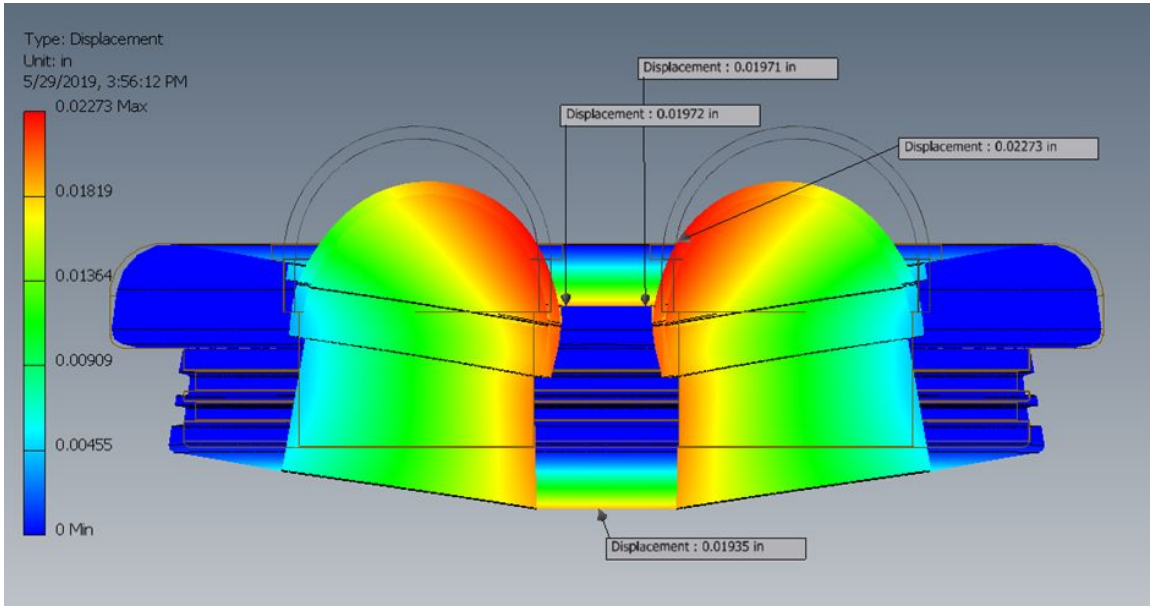


Mechanical Analysis

- We have explored adding a steel seat under the dome
-

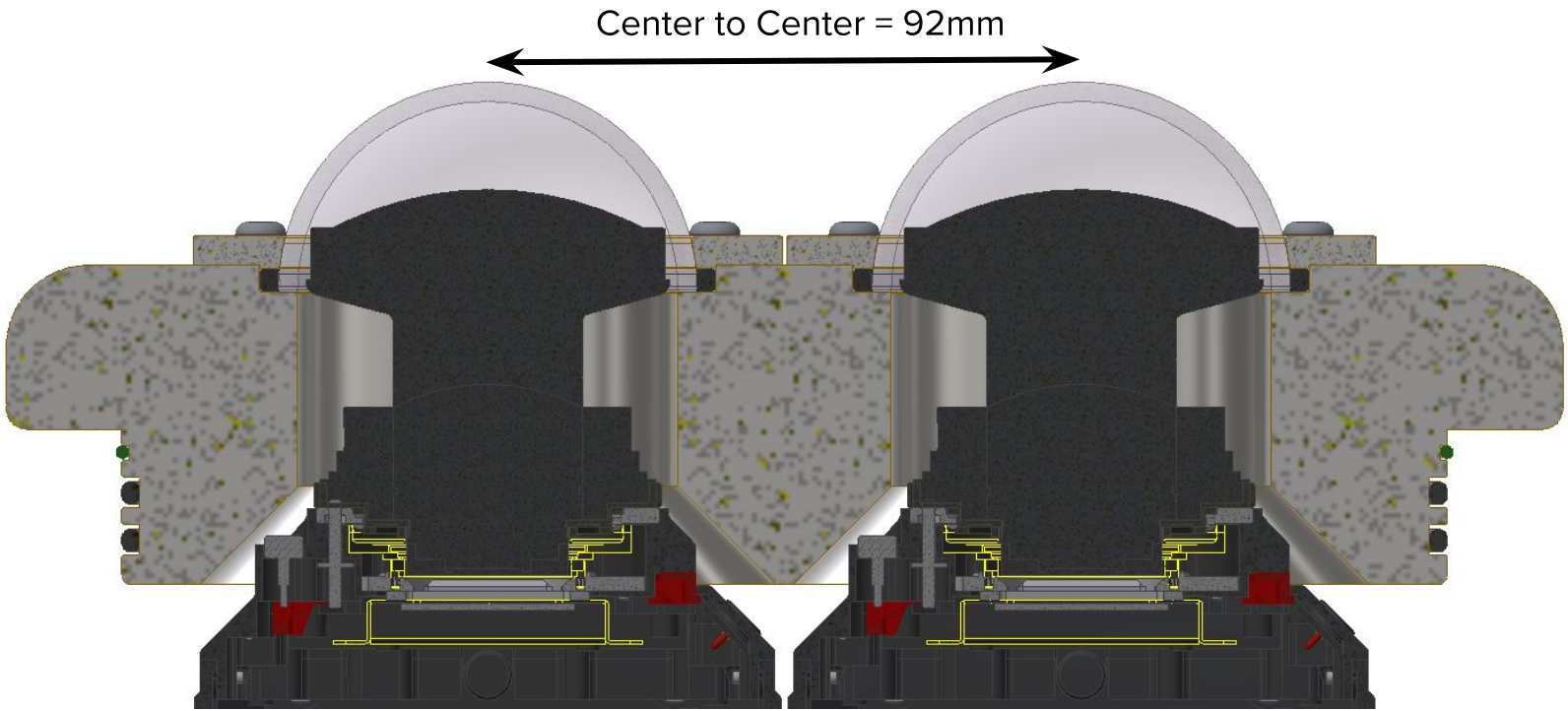


Displacement results are exaggerated to improve visibility

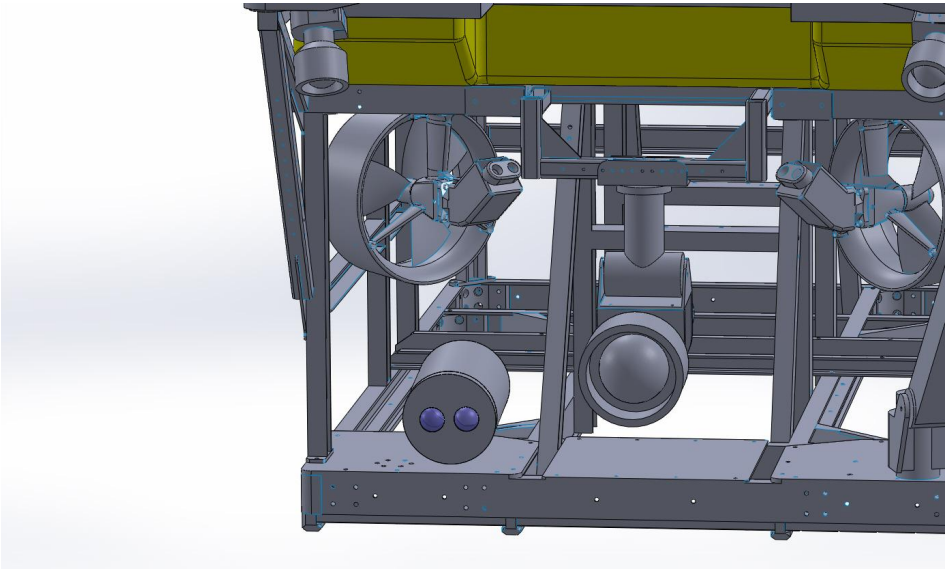


Lenses: Fujinon FE185C057HA-1 - 1.8mm

Optics Model



Doc Ricketts Mounting Options



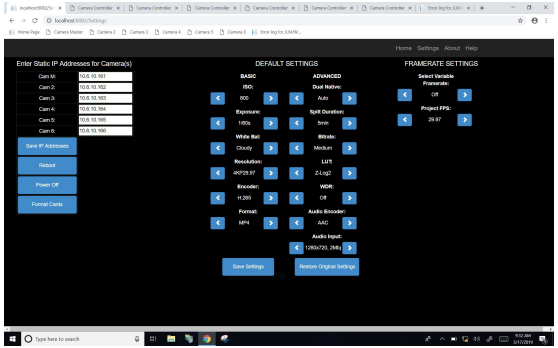
Software Design

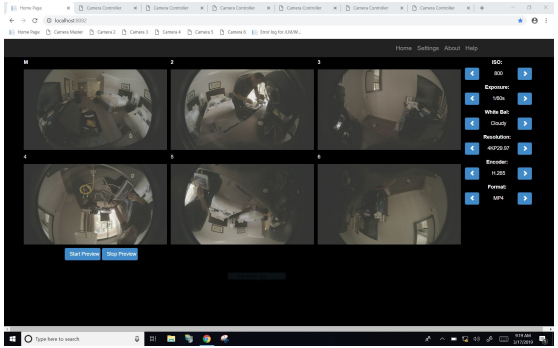
VR Live Stream

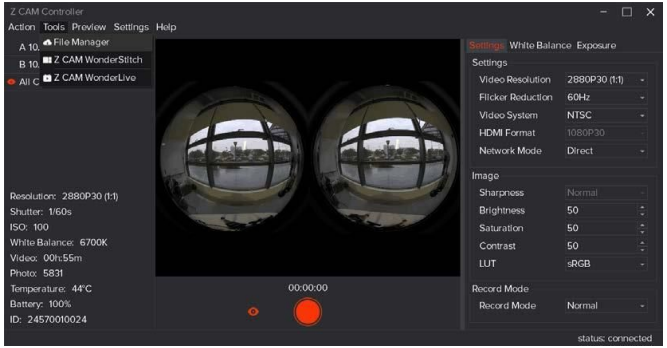
- #1 recommendation is StereoStitch based on its simplicity and costs
- We are developing a single workflow which can do uncompressed recording + real-time streaming to a VR headset
- Below 100ms of latency; capable of up to 8k per eye
- Potentially a minimal frame disparity between cameras using HDMI while doing real-time streaming; still needs to be tested
- $3k perpetual license (vs Voysys which is $1k+/month)
- StereoStitch Tutorial (180 3D is a slightly different process than 360 3D)

Global Controls & Recording

- Custom VRTUL // Sexton software
- Able to globally change all camera settings, but not start/stop recording functionality
- ZCam native web app is only able to control one camera at a time; used for start/stop recording of all cameras (based on Master/Slave configuration)



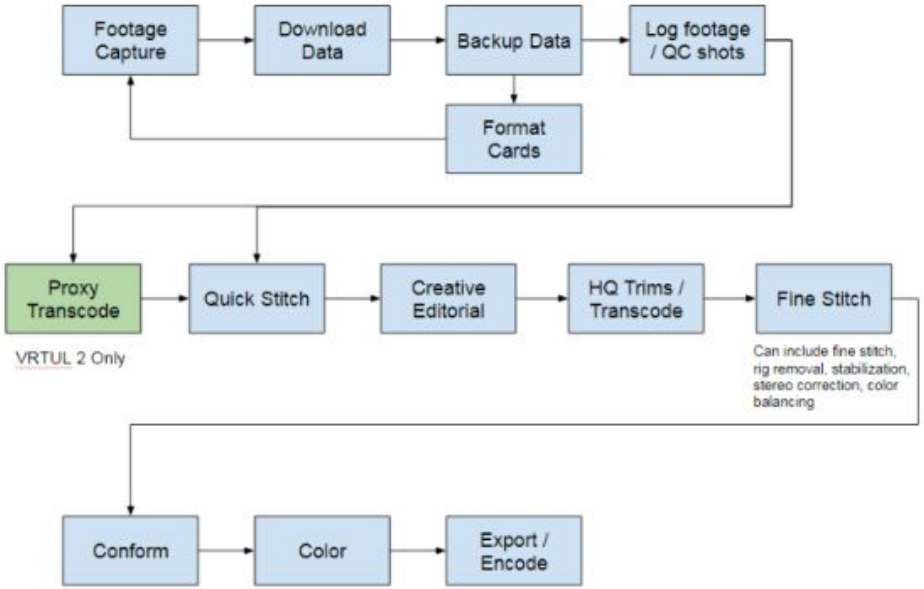




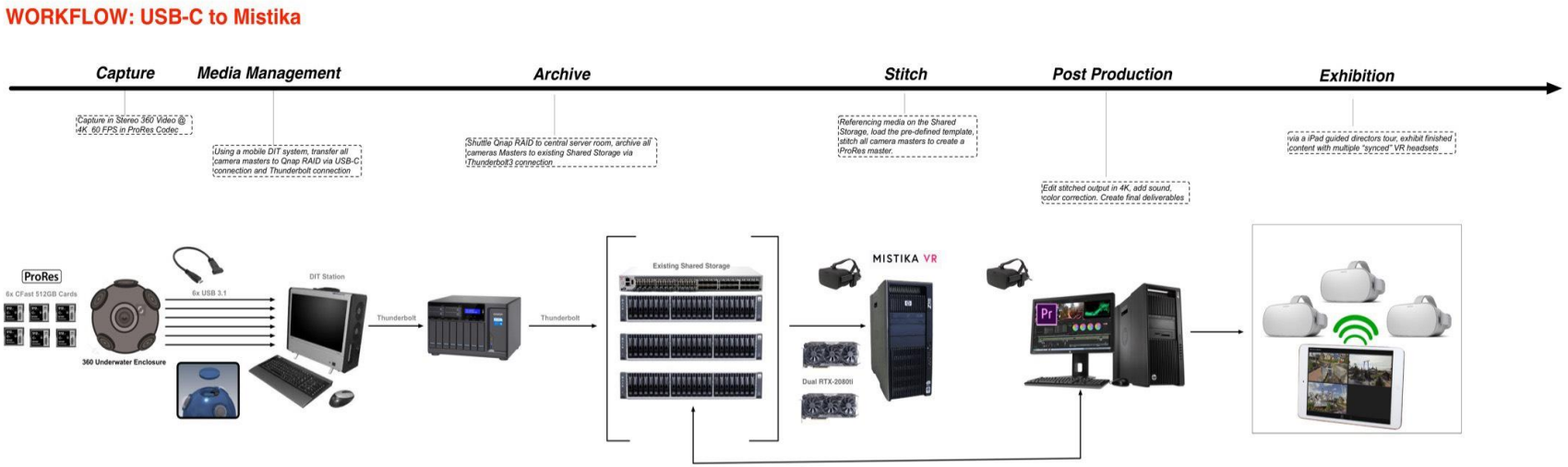
Post-Stitch Workflow Steps

1. Raw Footage Degrain - Neat Video or ZCam Denoiser
2. Quick Stitch - Mistika
3. Editorial Reviews - Premiere
4. Fine Stitch - Mistika
5. Comp / Seam Fix / Paint - Fusion or Nuke + CaraVR
6. Stabilization - Fusion or Mocha or Mistika or Nuke + CaraVR
7. Stereo Correction - Fusion or Nuke + CaraVR
8. Conform - Premiere
9. Color - Resolve or Scratch VR
10. Encoding - Media Encoder or ffmpeg

Reference Post-Workflow Steps (Recommended)



Reference CFast Recording Data Workflow (Based on 6x Camera Design)



Native Z-Cam Software Tools Available

1. LUTS & Color Correction Plug-In (For Premiere & Resolve)
2. Video Concatenator
3. DeNoiser
4. Transcoder
5. “LiveStudio” (livestreaming tool, but only for single cameras): example video

*** Links to software tools here ***

***Link to LiveStudio here ***

Post-Stitch Workflow Cost List

1. Neat Video - $99
2. Mistika - $50/month
3. Premiere - $20/month
4. Fusion - $300
5. Nuke + CaraVR - $10k+/year
6. Mocha - $295/year
7. Davinci Resolve - $300
8. Scratch VR - $1,795
9. Data Storage - Variable

Schedule / Testing

Schedule

- Aggressively targeting integration and deployment in mid-August for Katija Cruise.
- Most components have been tested/vetted,
- Fiber equipement still needs testing.

Testing

- Hull test expected for July:
  - 10 cycles to 6,500 PSI
  - Overnight Hold
  - Facility TBD

Fin