Deep Water Imaging in 4K

By William N. Lange
Advanced Imaging and Visualization Laboratory
Woods Hole Oceanographic Institution
Woods Hole Oceanographic Institution is the largest private non-profit oceanographic research institution in the world and home for nearly 2 decades to the Advanced Imaging and Visualization Lab (AIVL). AIVL has been at the forefront of high quality optical imaging in the deep ocean since its inception. An early adopter of High Definition for underwater use, AIVL has become widely known for some of the first stunning images of hydrothermal vents and most notably from the shipwreck RMS Titanic.
Deep Water Imaging in 4K

As good as HD has been for science, the need for more resolution has never diminished. Just like Hollywood needs to be able to blow their images up to massive movie screens, scientists have the need to present high resolution images for print in scientific journals. In fact scientific journals are the life blood for scientists trying to gather new understandings and observations of the world we live in. Although the words are important — imagery is what makes the covers, imagery is what inspires young children, and imagery as data is what often brings in the next round of understanding, questions and eventually funding. And as we all know there is one big problem when you start pulling stills from video and trying to print them — they just don’t look very good when compared to a good still photo. Out of this frustration for scientists’ needs AIVL once again partnered with Sony to begin their “Beyond HD” program for scientific imaging.

From the beginning AIVL has recognized that images coming back from a journey of scientific discovery and exploration are not only costly to acquire, but are frequently the most critical data set for scientists engaged. With this in mind AIVL has partnered with Sony over the years to develop numerous imaging systems constantly striving for better signal to noise, crisper blacks, greater sensitivity and more accurate color fidelity. The stunning results have been seen in nearly every significant documentary on the deep ocean, but most importantly to AIVL and the scientific community they serve, AIVL was able to give eyes to scientists in the inky darkness miles below. For the first time the images they saw with cameras were becoming better than the ones they could see through the view ports of the submarine with their own eyes and science has not been the same since. 15 years later AIVL still has numerous HD camera systems in the field, and although the novelty of HD has gone away it has become the workhorse of the community for high quality imaging.
Sony’s first foray into 4K (although technically 8K) imaging that AIVL worked with was the F65. This is a beautiful camera, with incredible dynamic range and color, but for those of us at AIVL trying to take it underwater there is one major problem — for underwater applications it is huge!

Typically the scenario for us developing a new camera for science use is to test it on land and make sure we like what we see on the charts. Next it goes into one of our generic housings where we pair up sensor, optics (traditionally Fujinon) and dome viewports, add one of the many control telemetries developed at AIVL and then send it out for test dives.

Only then do we decide if we take it all the way through the pipeline where we completely disassemble and rebuild the cameras for deep sea.

Getting the F65 into the water was no easy task. To begin with we liked what we saw on land and decided it was worth testing in the water. Unfortunately to get it in the water without completely disassembling and modifying the camera required a housing that was 16” in diameter and about 28” long made out of delrin which created one very large air space. Even with all the weight of the camera, lens, and an Anton Bauer VCLX battery packs in the housing, we still needed nearly 140lbs of lead to sink the test housing. Since we didn’t have a large test budget we brought the camera out on a 3D measurement and mosaic job on shipwrecks out in the Great Lakes. We spent one day in the pool working on “trim” for the camera — unfortunately for a camera that size on a testing budget, trim consisted of bricks of lead strapped around the housing! The lead belts were definitely not ideal, but OK for the pool and the short test dive in 22’ of fresh water off Milwaukee the following day. For our tests we lucked out with some clean clear water and nice ambient light. With fiber run to the housing we had full lens and camera control and proceeded to shoot a series of in-water shots where we pushed ISO, exposure, mechanical and electronic shutter along with onboard RAW recording. We are always interested to see how things hold up under ideal water conditions (like this spot) and less than ideal where there is low light, heavy attenuation and thick particulate.

“WE SPENT ONE DAY IN THE POOL WORKING ON “TRIM” FOR THE CAMERA — UNFORTUNATELY FOR A CAMERA THAT SIZE ON A TESTING BUDGET, TRIM CONSISTED OF BRICKS OF LEAD STRAPPED AROUND THE HOUSING!”
One of the great things about working with an imaging lab that specializes in building systems for hostile environments is that we usually get to take these systems to the “hostile” environment.

In general we liked what we saw, but after the tests it was decided that the F65 would take considerably more effort and funding to shrink it for underwater use on the deep submergence vehicles we planned on using. We did, however, improve the overall system and use it for shallow water science work. The first major job for the new and improved F65 system was during a coral health study among small remote islands in the Pacific nation of Micronesia. During this cruise, scientists drilled coral over 8’ in diameter which actually can give them a sample of what the ocean climate was like over the past 400 years, thus giving an incredibly accurate baseline for industrial age ocean temperatures and acidification — not to mention overall coral health. The F65 was deployed in an effort to document some of these last pristine coral reefs and was incredibly successful in capturing the reefs and scientists like never before. A little skeptical at first due the size, the chief scientists were huge fans by the end as they saw the product that materialized and are already planning further trips for Cuba and China. The F65 still to this day continues its underwater role in shallow water and future panoramic imaging projects. Fortunately for us, Sony had just released one of our favorite cameras to date, the F55.

One of the great things about working with an imaging lab that specializes in building systems for hostile environments is that we usually get to take these systems to the “hostile” environment.
We have had imaging systems on observatories over 14,000 feet in the mountains all the way down 20,000 feet below the surface of our planet’s great oceans; they have been attached to animals cruising through the water and been fixed to planes traveling at high speeds through the clouds. The common denominator with all these systems (yes they are often Sony products) is that they have been designed from the lens interface all through the post process work flow and tested rigorously both in the lab and in the field long before they ever saw the first real science or production shoot. It is one of the reasons AIVL has been so successful over the decades.

We received our first F55 early in 2013, well before NAB, and almost as soon as the camera was delivered it was installed in one of our test housings to take an ad hoc trip to the Florida Keys for field testing. We had a day or so to “test” in the lab before getting it in the water and although we noticed a few inconsistencies, we were on our way. The test was generally a bust due to poor weather conditions but it did give us the opportunity to find some necessary software improvements and break a few things which we reported to Sony along with some of the footage. When Bill Lange (Director of AIVL) humorously related our issues and software suggestions, the first thing they said is “Why is it always you Bill??” To their credit within days software improvements were already being developed and as our long standing friendship with Sony can testify, I think they appreciate the honest feed back and the fact that we often use their cameras in ways the design engineers don’t imagine. With the new software in hand we had a very nice shoot with the test housing and our partners at National Park Service in the Dry Tortugas. NPS has been an instrumental part of our testing over the last 5-6 years as they have been interested in finding better ways to use the technology to interpret sites and bring these sites to the public.

AS SOON AS THE CAMERA WAS DELIVERED IT WAS INSTALLED IN ONE OF OUR TEST HOUSINGS TO TAKE AN AD HOC TRIP TO THE FLORIDA KEYS FOR FIELD TESTING.”
With the Tortugas shoot finished, the footage corrected and many of our workflows worked out, we felt the camera was ready for deep submergence and use on deep ocean submarines and remotely operated vehicles (ROV). All we had to do was raise the money to build a series of these cameras for science. Simple we thought. This is exactly what science is looking for...

Unfortunately for our camera development and science, budgets were at its lowest funding levels in decades and funding was not available. Even with all the testing, repackaging for the deep sea is not a cheap endeavor. The housing and dome port alone need to withstand the intense pressure of thousands upon thousands of feet of water. In many ways that is the easy part since AIVL has spearheaded housing development for years and has several designs that would already match the sensor and optics of the F55, but there is still a cost of $40-60K for the housing.

Then there is the engineering involved in taking a camera that is very happily nestled in its Sony provided squarish outer shell, tearing it out and shrinking it to fit in a cylindrical titanium tube. It quickly becomes over a $100K effort and with money tight, we waited. And waited. And waited...

Not to be deterred by a lack of scientific funding and with support of a WHOI Board Member we decided that we could still move ahead with certain components and continued to build the deep prototype. We laid out the many things that would have to change and made a few calls to Sony USA and Japan for some “spare parts.” Not many questions were asked (although a few eyebrows were raised) and within a few months we had enough new designs, custom parts, a viable plan and just needed the last little bit of time and funding to make it work. Luckily for us, NGS-TV had a ship in the Pacific with a few little submarines in need of imaging support for a project they were producing. This cruise provided the incentive and urgency to complete the system and AIVL went into high gear.

“The housing and dome port alone need to withstand the intense pressure of thousands upon thousands of feet of water subjected to it.”
For 2 weeks a small team of people worked around the clock building all the interfaces to the new camera, machining the new brackets to hold the guts of our F55 and all the other pieces to make it work on the sub. Then to top it all off, we were told that NGS-TV really wanted to have 2 4K cameras systems — one for each sub. Like an audible called right before the final play of a huge football game, Lange pulled the latest trick out his hat and Sony’s F700 magically appeared in front of the team. Unbeknownst to the team, Bill had been “secretly” building the camera for deep water use and with a little help from the team, within 2 weeks they were able to get not only one, but 2 new Sony 4K cameras capable of operating at 6,000 meters ready to send to me out in the middle of the Pacific.

Anyone who has worked in engineering development knows what prototypes are like — and typically it is not something that gets sent out to eagerly waiting clients on a ship 10,000 miles away. The cameras were hand carried by one of the team and they survived intact despite TSA’s best attempts. The 4K camera telemetry system on the sub was prepped before the cameras arrived and the install went like clock work so within a day we had 2 new Sony 4K’s ready to go. For the next 10 days the cameras performed flawlessly and despite minor issues with sub power and fiber we were able to record countless hours of footage on wrecks and sea life in this little studied area of the world. As with any prototype, there are things that need to change — the control interface was clunky, lens control off a laptop was challenging in a crowded sub, and the camera chassis itself needs a Rev 2 to allow for more versatility in lensing.

The important part is that they worked — and worked well. Like the faint whispering heard in Field of Dreams that said “If you build it, he will come,” AVL has worked with its partner Sony to build one of the best new systems in deep water imaging in decades, and the science community is beginning to show up.

There will undoubtedly be a plethora of startling new images — both motion and still — that scientists will bring home to study, educate and, most importantly, inspire in our children the need to understand and preserve our oceans and planet in the years to come. And for now, there is only one small thing that stands in their way — international shipping and the 6 weeks it is taking to get the cameras back from the field...