

Science AMA Series: We are engineers and videographers with the Global Foundation for Ocean Exploration and we design, build, and operate underwater robots that explore the deep ocean and the large lakes of the world. Ask Us Anything!

Ocean_Explorers¹and/ScienceAMAs¹

¹Affiliation not available

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Science AMA Series: We are engineers and videographers with the Global Foundation for Ocean Exploration and we design, build, and operate underwater robots that explore the deep ocean and the large lak

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Hey guys,

most submersible equipment that aims to observe lake and ocean floors is invasive in terms of sound echoe, water reverb and most primarily, intense degrees of light.

As a result, deep sea life is rarely seen by current technologies, as what we need to observe deep sea life are the things that deep sea life have evolved to avoid.

How are GFOE getting around this hurdle?

Thanks, Jon

[forgotpasswordagain0](#)

Submersibles and ROVs have a lot of lights and other equipment that is very foreign to the dark deep-water environment. In some cases, this has been shown to attract life, while others move away from the vehicles. On our current expedition, we are mostly surveying for animals that do not move and therefore do not respond to underwater vehicles, such as sponges, corals and other small invertebrates. To survey for highly mobile animals that has the potential to try to avoid the survey equipment researchers have used alternative methods, such as baited cameras that take photos in regular intervals.

We've so far not had any luck calling "Here fishy, fishy!" from the back deck.

Are there any particular "holy grails" you hope to discover during your expeditions?

[L_Sarling](#)

There are several significant discoveries that we hope to make on our current expedition. A large portion of the seafloor in the area has never been charted. Just last night we just came across a large underwater mountain, also known as a seamount, that had never been mapped before. We are also trying to collect geological samples from several of the places we are diving on in order to determine

their geological age. Most of the seamounts in the area have never been sampled and therefore we do not know how old they are. Finally, we are hoping to find large-scale communities of animals. The deep-sea is known to contain such oases of life in many places, and we are trying to find them, so that we can make sure that these important communities are managed and protected.

We are also constantly on the lookout for a nice shrubbery.

Thank you for doing this, I figure this question would be on everyone's minds, but what is the most terrifying/scary/unexpected sight anyone's seen below the depths?

[l0rdc0unt](#)

Well we definitely, definitely have not seen anything remotely close to [this](#)... Definitely not. For the team, the scariest thing we've seen is a submarine cable draped over Seirios and our cable. As far as animals go, we've seen some [predation events](#) that are scarier for the subject being eaten than for us. Also, [this guy](#) kind of haunts our dreams (people with arachnophobia do not click).

Will the ability to detect and excavate fossils ever become a possibility? Do you feel that some areas that were above water millions of years ago hold traces of extinct life we have never seen?

[jjdlg](#)

Fossils have in fact been recovered from several underwater environments. In those cases, the fossils were not covered by large portions of sediment and therefore easily accessible. On this particular expedition, we are surveying depths ranging between 1000-4000 m. At these depths, the entire substrate is usually covered by a thick layer of a manganese-crust, which is a precipitate that forms from seawater and acts to cement the bottom together. Thus, any fossils found at these depths would likely be covered by a thick crust layer, which would make it very difficult to spot underlying fossils as well as recover them.

...and we haven't found any dinosaur bones yet.

Have any animals taken an interest or attacked the ROV's? What's the protocol if or when this happens?

[formlessfish](#)

Oh yeah. Last year in Puerto Rico, one particularly [brazen squid](#) decided to attack our lights. He attached himself to the vehicle frame too and just hung out there for a while. It was a pretty amazing encounter. Also, in 2013, a rarely videoed [Greenland Shark](#) did a swim by of the ROV. He didn't seem too intimidated. Probably because he was about 12 ft long. Also, this [fearless turtle](#) decided to headbutt our main HD camera. We're still scared of that turtle and look out for him every time we're on the surface.

Hi! Thanks for doing an AMA!

Unfortunately this is an area of science that I know very little detail about, however in a previous role I worked with (to an extent) an Autonomous Systems Group who were developing what's called "Swarm AI", using swarms of (in relative terms) small and cheap robots to explore and map unknown areas autonomously with minimal, if any, human input or control. Their end goal was to potentially develop a

swarm of these robots with ESA to map in detail the surfaces of planets and moons in the solar system.

I was just wondering do you use any form of autonomous systems or AI on your robotic systems during deep sea exploration, or do you predominantly use remote-controlled robotics?

[OldBoltonian](#)

For what we do, you can't beat remote control. Our primary focus is very detailed imagery of individual animals and currently AUV just can't do that. Communication is an issue undersea so talking with hundreds of robots over long distances will be a challenge. The attenuation of a typical communication form, say radio, increases with conductivity and seawater is one heck of a conductor. That being said the ocean observatories use a lot of autonomous vehicles including swarm vehicles and AUV that have undersea hangers that they use to recharge and transfer data.

Google has mapping vectors, i.e. satellites and cars, for Google Street View. Is there an initiative to map the sea floor like we have mapped the land? Or what other ambitious goal is looming that will help "open" our oceans to more widespread investigation/resource exploration? For flight, it was jet engines or breaking the sound barrier. What limitation is needed to be overcome that would have the greatest impact on improved underwater exploration?

[Spaceman4u](#)

First we'll provide a context of historical developments in tools for ocean exploration. There were two problems to solve: How to navigate in the ocean and how to explore the ocean? Seafloor has been mapped since times of ancient Egyptians when sounding poles were used to find the areas safe for navigation, [click here](#). The navigation issues were still big technological problems ~ two centuries ago e.g. how to keep time at sea, [here](#). A long lasting "X-Prize" to solve longitude problem was finally awarded to John Harrison in 1737, [here](#). Sonar technology needed to explore oceans quickly (as compared to physical sounding methods) came after world war II and was commercialized in 1980s. So from a historical perspective - last few decades have been revolutionizing for ocean exploration. As for technology limitations that can hamper further ocean exploration - we are at the cusp of doing ocean exploration in more details, more efficiently and with a more meaningful engagement of public that has supported ocean exploration for centuries. Further developments are already on the horizon e.g. setting up permanent observatory stations on the seafloor, [here](#), and mapping localized seafloors at the Google street view resolution, [here](#).

Ocean exploration has always tried to answer the big questions of the time. Be it to find the closest route to bring spices to your dinner table (and discover Americas in the process) or to find ingredients for next generation drugs, or to study ocean acidification and climate effects on ocean circulation. Thanks for asking this great question!

What is the latest on how ship to roV communication is handled? Ive read bits about how the tether is a single hair wide fiber strand which can break if you look at it funny, is that true?

How do you manage 6+ miles (im guessing?) of cabling in and out of the water, does it need added buoyancy every so often?

Is wireless an option yet?

Do you have any opinions to share about efforts like Camerons sub? Are manned operations limited to the level of being pointless or does the publicity have a noticable impact on all funding?

I liked Camerons documentary but thought it did little except feed his ego. It was like trying to get a feel for the US by driving your car across a parking lot in Pennsylvania.

Thanks for the AMA and your work, will be following this on your stream for sure!

[TweakedNipple](#)

Oh man, there are a lot of good questions in this post! Some vehicles are powered by batteries and use a single fiber to control the vehicle and send video back up to the ship. These are typically referred to as Hybrid ROVs. Nereus out of Woods Hole Oceanographic Institute was like this. The reason this is done is because of the huge design challenge involved in designing a vehicle that can dive to full ocean depth (~11,000m or 7 miles). Our vehicles use a steel jacket 0.68 inch diameter cable that has three copper conductors and three fiber optic cables running through the middle of it. We can dive to 6,000m (3.7 miles) with this setup. If we were to lower *just the cable* to 11,000m, with nothing attached, the weight of the cable itself would break it.

To handle the cable we have a traction winch that has 8,000m (5 miles) of wire on the drum. The traction portion of it allows us to spool the cable onto the drum at a constant tension. If we just had the drum, which many systems do, the tension on the wire would be much higher on the lower wraps than the upper wraps which can reduce the life of the cable. Designing to full ocean depths involves making a lot of design compromises that make the vehicle more delicate and can limit its operation. Being able to dive to 6,000m (3.7 miles) gets us ~95% of the ocean without needing to make too many compromises in the design. This is also true for designing and operating manned submersibles. For the cost of building one manned vehicles you could make 3-4 unmanned vehicles. With ROVs there is no time limit on how long we can stay on the bottom, vehicles have operated for days straight without coming back to the surface, unlike manned ones. People get pretty upset when you keep them in a cold 6ft diameter Titanium sphere for too long. ROVs transmit their data to the ship immediately and allow for much better views than the ones seen from a manned sub. *However*, there is absolutely something about physically being there at the bottom of the ocean that you lose using robotics. It's the difference between sending a person to Mars for posterity vs. sending a robot.

Ooh! I've had a question on my mind for a long time, and finally an opportunity to ask an expert. I'm starting archaeology at university next year, and later on I hope to move into marine archaeology specifically, because it's the most interesting branch of the study in my view. I'm all in favour of the whole scuba-archaeology part of the job, but I'm much more interested in what's out of our reach, what's hidden where divers can't go. So my question: how feasible is it for deep discovery vehicles like yours to participate in archaeological research, i.e. is there any sort of image mapping or chemical sensing you can do to detect traces of archaeological sites previously undiscovered, and are you planning to or do you already do research in that area? (if not then I'd also like to know the chances of being hired to help organise an archaeologically focused branch of your team!)

[TheCasualMarxist](#)

Searching for archaeology targets in deep ocean is like looking for a needle in a hay stack. To add to the problem, you do not know where the hay stack is ! Currently D2 only has limited acoustic scanning capability and that is by design. Where D2 excels is the extremely high definition videos and images. For searching large areas for marine archaeology, you have to rely on low resolution acoustic tools like side scan sonars and multibeam sonars. These sonars provide an initial detection of probable target. Once we have found a probable 'hay stack', we send down D2 to look for the 'needle' in that 'hay stack'. Thanks for your interest in marine archaeology and good luck with your studies.

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[redditWinnower](#)

This is awesome. Thank you so much redditWinnower! We're honored to be a part of your initiative.

Geologist here:

Any plans to muck around in the [giant troughs incised as deep as crystalline bedrock near Antarctic ice stream grounding lines?](#)

Sorry the image has no adequate depth scale. I had to make due with Google image search. These exceed 1000m depth in other troughs.

[Kongsfjorden](#)

We wish that we could! The ship we operate from right now, NOAA Ship Okeanos Explorer, does not have a reinforced hull capable of sailing through the icy conditions present in arctic and antarctic waters. Also, the satellite antenna that supports our telepresence capability (a cornerstone of our program) would not work at such high latitudes. So (for now) we are limited to roughly between 50-degrees N to 50-degrees S.

How bad is the pollution?

[Cimmerian Barbarian](#)

Unfortunately, we do see cola cans and plastic bags and other trash on the ocean floor. [A new study](#) shows that by 2050 there will be more plastic in the ocean than fish. Let's keep that from happening.

Hello, I am a programmer and my dream has always been to help design and build robotic equipment to explore the depths of our world and outerspace.

Can any of your software engineers or other developers comment on their career path? I'm curious what sort of experience they have had to dive in to this stuff.

Thanks!

[MadeThisForDiablo](#)

I don't think any of us had any experience in this field before we got into it. That being said, any work with robotics, i.e. the hardware and software interface, is valuable. Also, GUI design is a big part of it. Our group works with Qt mostly. Web development is useful. We have written several programs to help the onboard scientists and giving them access via a browser makes things easier. We also handle the data management side of things. Each expedition creates around 14-18TB of data. This all needs to be named correctly, organized, verified and archived. A portion gets sent to shore over the satellite and the rest stored on big RAID arrays until we get to shore and then transferred via sneaker net to the long term storage. As you can imagine, for our own sanity, we spend a lot of time automating this process. We have spent a lot of time automating this.

Hi Guys n Gals, thanks for doing this AMA.

I've always found deep sea exploration fascinating, but...if you guy's were asked by NASA/ESA (if you have not been asked already) to design, build and operate a ROV to explore Europa, how would you

go about it?

[Born2Rune](#)

-The remotely operated vehicles (ROV's) that we use are tethered to our ship by a 6-mile long steel cable and our pilots have instantaneous feedback from our cameras as they "fly" around the bottom of the ocean. If we designed a vehicle that could be controlled wirelessly from a distance (say, from Earth), there would be delay issues because the control signals would be limited by the speed of light. The short answer is that an Autonomous Underwater Vehicle (AUV) would be much more feasible and practical; a robot that is smart enough to drive itself, without the need for a pilot. Either that, or we'll just send in Matt Damon.

Thank you for doing this AMA! What is your advice for engineering students looking to get into the field of robotics?

[Miqi95](#)

Most colleges with an engineering school have a robotics club. That's always a good place to start. Any hands on experience with clubs like this or anything in the engineering realm (working on cars, microprocessor electronics, automated cat watering systems, etc) is directly relatable to what we do. Also, check [this](#) out. Our engineers have all had a different path to wind up here. However, the general flow is as follows: Engineering degree -> persistence -> experience -> coffee -> persistence -> cool job exploring oceans.

Could you describe the technology and techniques used to get high resolution maps from the ocean floor? What is the best resolution that technology can obtain? What is the best resolution your systems can obtain? (assuming the two are different)

[tkfx2000](#)

The most effective technology to map ocean floor at high resolution is use of SoNaR (Sound Navigation and Ranging). Sonar works on similar principles as Radar but instead of using electromagnetic (EM) waves use sound waves. Use of sound waves is necessary because EM waves attenuate rather quickly in water as compared to sound waves. That is why you can not see much further in water but can hear distant sounds. The resolution of mapping is defined by the frequency of the acoustic waves which is a function of distance between the sonar and the ocean floor. For deeper waters (> 2000 m), Okeanos Explorer is fitted with a Sonar whose frequency is 30 kHz and can map the ocean floor at ~ 20 m resolution. For shallow waters (< 50 m), Sonars with as high frequency as 450 kHz are used and the resolution can be as high as 25 cm.

You said you explore large lakes as well as oceans. Are the bottoms of these lakes as crazy as the bottom of the ocean?

[Luturtle](#)

Yes! In fact, we are currently designing a robot that will be capable of exploring Yellowstone Lake. The bottom of that lake is known to have towering rock formations, sweeping plains, and colorful hydrothermal vents. It is a complex ecosystem riddled with geothermal features as impressive as the geysers that have made Yellowstone so iconic. You can learn more [here](#).

Which robots could win in a battle? Robots we send to space and different planets or the robots you guys work with?

[TheSensation19](#)

Our underwater vehicles will definitely win the inevitable robot war. They're designed for deep infiltration and to work well under pressure.

A while back some college kids posted on a Reddit sub asking for suggestions on how to make sure their optoisolator had no air bubbles, since at 300 bar a tiny air bubble wanting to escape could blow up their chip and generally end in disaster.

I suggested they pump down their electronics container to a vacuum, since 300 bar squeezing on 0.01 bar can only increase the pressure so much in their electronics container. Of course they'd need a stronger container, but they wouldn't have to worry about making a board that could survive repeated trips to 300 bar.

Or maybe they could have used a liquid dielectric in the electronics container to help resist the pressure, since liquids are mostly incompressible.

My question is: how do you design your electronics to survive the high pressures and the fatigue of many trips to the bottom? How do you deal with trapped air bubbles and prevent your electronics and other equipment from exploding?

Thanks!

[3jt](#)

Most electronics must be enclosed in an air-filled pressure housing that is of sufficient strength to resist the immense hydrostatic pressure of the deep ocean. Electronics such as computers, fiber-optic multiplexer boards, relays (switches), most low voltage DC-DC converters, fuses, etc, must remain in a cool and dry environment. We design the electronics chassis much like a 3D jigsaw puzzle so that the components will fit efficiently into a cylindrical, or sometimes spherical, pressure housing. The Housing is usually constructed of metallic cylinders with flat or hemispherical endcaps, and is sealed at the ends with precisely machined O-ring glands. The material of the housing can be Titanium, Stainless Steel, Aluminum, Beryllium Copper, or Glass. For low pressure ratings, some plastics can be used. Optical viewports in pressure housings are constructed from glass (typically BK-7 borosilicate glass), synthetic sapphire, or acrylic. The material options have their pros and cons: strength, stiffness, density, corrosion resistance, cost, commercial availability, machineability, in some cases weldability. The design of the pressure housing is carefully executed using equations of stress-strain, and verified with Finite Element Analysis. Once machined, the pressure housings are proof-tested in a specialized pressure test chamber. Air bubbles enclosed in pressure housings (see above) are intentional. Any air-filled spaces for wiring-connections or pressure-tolerant electronics must be filled with a non-compressible, and non-conducting medium. We most often use Mineral Oil (e.g. transformer oil or food-grade mineral oil) to fill any air-filled cavities on the vehicles. We use oil-filled Junction Boxes on underwater vehicles as a means of making wiring connections and enclosing certain electronics that are specially designed to be tolerant of immense hydrostatic pressure. Oil is not electrically conductive (no short circuits!) and has a bulk modulus of elasticity similar to that of seawater. The oil inside of hollow junction boxes and cabling/hoses will not shrink or expand appreciably relative to the surrounding seawater. In this manner, we are able to enclose wiring and certain electronics in less-specialized, less-costly, and much lighter enclosures compared with the heavy and costly pressure housings. "Exploding" is a misnomer when dealing with the hydrostatic pressure of the deep sea. A better term would be "implosion," as a failure would be an inwards and catastrophic collapse of the air-filled volume. The shock-wave generated by such an implosion can be of such magnitude that a chain-

reaction of failures of nearby pressure housings could result. That would be a bad day! We are very careful to design, validate, and test the designs for any pressure housings before we put them into service, and we are very careful to fill any air-bubbles in hoses, cables, or junction-boxes with oil.

What computer/boards and software do you use for your submersibles? Are you leveraging Arduino's or Raspberry Pi's in your submersibles?

[lranger2](#)

We just recently redesigned our control boxes and used arduino megas for the analog-to-digital interface. On the ROVs we use PC-104 form factor computers because of how small they are (space is a premium in expensive titanium pressure housings). The PC-104 boards are pretty slow so we do the heavy lifting on the topside computers. The subsea computers are only used to convert commands from the surface to motor commands and to interface between the subsea sensor and the topside software.

When searching, do you scan first? Have you ever just wanted to map an entire floor with visuals? Have you done so to a body of water? Why is it not a priority to scan everything underwater? There has got to be so much cool stuff - skeletons, ships, gold, things long since forgotten. Is it possible a very aged ship would look like rock or bulge in floor, yet really be something of worth?

[NimSudo](#)

I am assuming you mean acoustic scanning by 'scan'. While searching for underwater objects scanning in the most cost effective way. The sound waves travel much farther in water than light, so to get a visual image of the seafloor, the resources required are approximately several times more than acoustic scanning. Acoustic scanning, however, only provides low resolution. As you mentioned, a ship wreck might just look like a lump on the seafloor. We identify those acoustic targets and then get a confirmation based on visual images. Acoustic surveys are regularly conducted for smaller areas to study the details e.g. areas around Titanic were surveyed visually to construct mosaics: [click here!](#)

What do you have to do to make an ROV waterproof?

[ForsakenFury](#)

Things that can handle the pressure get put in oil filled tubing and oil filled plastic housings. The oil is nonconductive and allows the pressure to equalize. Things that can't handle the pressure, like computers and fuses, get placed in specially designed custom housings. These are typically made out of Titanium for weight and size reasons. Some housings are made out of aluminium (AL60-61-T6) in order to assist in heat transfer. The interesting thing though is that the actual seal in these bottles comes down to small, \$1-2 rubber o-rings.

I know that water does not compress. Is there a way to use water, inside the watercraft, to deal with the immense pressure exerted on the craft?

[emende21](#)

We do! But we use oil instead. Water has this nasty tendency to conduct electricity so we use mineral oil which, at the voltages we are dealing with, doesn't. Anything that can handle the high pressure like wires and simple electronics gets put in oil. For example, all of the electrical connections to the different

sensors on the vehicle are made with oil filled hoses. We have a transformer on the vehicle that is also sitting in oil. There are also several plastic junction boxes on the vehicle that are oil filled. The pressure equalizes which allows us to create housings out of plastic instead of titanium so we do it as much as possible.

One thing to point out though is that water does in fact compress, but because in most situations it compresses very little, the assumption that water is incompressible is sufficient usually okay. One simple way to prove that it does compress is that sound travels through it. If it were incompressible it would be impossible for sound to travel through it. When dealing with the pressures that we deal with the assumption of incompressibility cannot be used. In fact, if we filled something with oil/water and then sent it to depth the fluid would compress enough for salt water intrude and/or it would implode. To compensate for the compression and temperature induced volume change we have a series of pressurized belloframs that fill in for the lost volume. They also pressurize the systems to 10 psi above ambient so that if we spring a leak, oil will leak out rather than water leaking in (mineral oil is safe for the environment, fyi)

Hi! Thanks for doing this AMA. I'm part of an underwater robotics team in the MATE competition. I love ROVs and I think they're so fun to build and fly.

How difficult is it to control the robots in a real world situation as opposed to a controlled environment like a pool?

Also, how did you get into the job you are in now and what can help get someone there?

[ju bl](#)

Great! Good luck to your robotics team! The real world presents a lot of challenges that a controlled environment doesn't. Probably the biggest challenge is being on a moving platform. Our ship is constantly moving in heave and roll and pitch which makes it difficult to operate and launch and recover the vehicles. For instance, today we had to cancel the dive because of rough seas and high winds. It also takes a little longer to get the vehicles down to and up from 6,000 m (4 hours each way). Finally, we can't see the vehicles as they're ascending or descending like you can in a pool so we rely on acoustics (sonar and USBL) to navigate). This can provide challenges when obstacles like submarine cables or overhanging walls come up.

[See here](#) for a little more info on how to get into this field! We'll see you out here one day.

What camera equipment do you use, and how do you deal with color loss at those depths?

[Triweb](#)

The ROV is equipped with multiple cameras, some for video transmission and some for navigation. The broadcast units are Ikegami cameras with Fujinon lens in Insite underwater housings. They constantly record topside. The color loss at depth is not a problem with the 16 forward facing daylight balanced LED lights producing 6000 lumen each. Color balance change is constantly monitored by the camera operator in the control room on the ship.

Assuming you are limited by funding as most researchers are, if funding wasn't an issue, what would be different about your submersibles? What materials or designs are you not able to afford right now but dream about having, if any?

[eabigyear](#)

For starters we would put a latte machine on the vehicle for on deck operations. A nice americano would be great during pre-dive checks. Also, Titanium. Almost everything would be made out of Titanium - no more worries about corrosion if it's all Ti. We would also put a multibeam and LIDAR on the the vehicle. We would perhaps design a small AUV with a LIDAR and still camera on it that we could deploy from the ROV if we came across something we wanted to map. I'm sure all of our engineers have their own dream projects that they will add.

What is one of the general population's greatest misconceptions regarding the great blue sea?

[scubapollo](#)

That it is void of life. For a long period people believed that the deep ocean did not contain any life. Some scientists even referred to the deep ocean as the azoic zone, which literally means void of life. It was not until early deep-water explorations in the 1800s that scientists started collecting samples using dredges and trawls. These expeditions showed that the deep ocean actually contains a rich and diverse fauna.

Also, we have no credible evidence for the existence of mermaids.

First off, thanks for doing an AMA. Secondly, what is the most unexpected thing you've found so far, during your research?

[Echo5Kilo](#)

[See here](#). It's also worth mentioning the "[tar lillies](#)" that we found in the Gulf of Mexico. Those were completely unexpected.

Not really a scientific question, but how'd you get your jobs/what were your backgrounds in under/postgrad?

[MizarsAsterism](#)

We all have various engineering degrees. We have ocean and aerospace engineers, electrical engineers, mechanical engineers, software engineers and video engineers. The schools vary from Virginia Tech to MIT to Davidson to UMASS and more. However, we all got here through a combination of experience, interest, persistence, and the desire to understanding a world that no one has seen or been to before.

What is more important? The study of our waters or space?

[TheSensation19](#)

That's a tough one. The easy answer for us is our own waters here on Earth (sorry our friends at NASA!). Without healthy oceans, humans don't exist on Earth. The oceans produce half of the oxygen in our atmosphere and absorb MOST of the carbon from it. We think it's our obligation to know as much as we can about our oceans because of how vital they are to our planet. Space is pretty cool too though. Check out our cousin [Curiosity](#) doing some amazing things on Mars.

Hello guys!

How close are we to mining the bottom of the oceans and what kind of resources can we expect to find there: rare earth metals, common metals, rare metals?

[EHStormcrow](#)

In the deep waters of the central Pacific Ocean there are numerous places that have very high aggregations of manganese nodules, which are being prospected by the deep-sea mining industry due to their high content of manganese, nickel, cobalt, and many rare Earth minerals. People have known about these deep-water deposits for a long time, but until recently it was just not economically viable and technologically feasible to extract them. As terrestrial sources of these minerals are becoming increasingly depleted, and there are more affordable technologies to sample the deep sea, the mining industry is increasingly looking at these deep-water deposits. Some areas to extract Mn-nodules have already been identified, and prototypes of machines to extract the resources are already being build. Thus it is not a question of if it will happen, but rather when, and the answer is likely within our lifetime.

One thing that we are trying to accomplish with this particular expedition is to understand where the most vulnerable biological communities are found in the deep sea, so that we can steer the mining industry away from them. Life is not uniformly distributed throughout the deep sea, and there are some places where the extraction would cause much more harm than in others. Since the extraction has not yet begun, there is a rare opportunity to guide the industry through dedicated research efforts like ours, and develop sustainable practices before it is too late.

Thanks for this AMA!

At what depth does it become more practical to send a robot vs a diver? What are the advantages of robots over divers, except being able to operate at a much greater depth?

[zoot](#)

First of all, "Robot vs Diver" would make a great action b-movie. Great question! Traditional diving is much more practical at shallower depths, usually less than 500 feet (~150 meters). The record for the deepest scuba dive was set in 2014, when Ahmed Gabr got down to 1,089 feet (332 meters) in the Red Sea. But most of the ocean floor is much deeper than that, at an average of 12,200 feet (3,720 meters). The Deep Discoverer and Seirios ROV's can dive to 19,700 feet (6,000 meters)! They can also potentially stay at the bottom for days at a time, where as a human diver would have to come back up to the surface every once in while...except Aquaman.

Thanks for doing this AmA, I've always been a fan of exploring our ocean/lake depths. Few questions

1: what was your biggest "that's awesome" moment that you guys have found so far?

2: have you found any new creatures that have surprised you?

3: I've gotta ask. Some kids wanted to be an astronaut, I wanted to explore the depths of loch Ness as a kid(would still love to!) Do you guys have any plans of ever going there with your rov's? And if so how do I sign up?

[Jack Bartowski](#)

A "that's awesome" moment is the perfect way to describe a lot of what we see. We think some of the highlights have to be the two, [200 year old shipwrecks](#) we found in the Gulf of Mexico, this [WWII submarine](#) outside of Honolulu, and again, that amazing [shark fly by](#). No current plans to go to Loch Ness but we do have the Great Lakes of the World Initiative ongoing. Maybe Loch Ness will be a stop!

Hello intrepid explorers! Back in the 60's, 70's my dad worked on the Glomar Challenger, which was a ship that went around drilling core samples from the ocean bottom for scientists to study.

We've obviously come a long way since then in technology, so my question to you is, what do you think we'll be doing in another 40 or so years? Will we have explored most of the ocean by then? Are technological advancements needed before we can reliably explore the deepest depths of the ocean? And do you see humans in the future going underwater to do things, like mining, or farming or any other kind of futuristic stuff.

TL;DR what does the future hold for people exploring the ocean.

[WellPlayed100](#)

Well, first of all, your Dad sounds like a pretty cool guy. We have come a long way from technology that your Dad worked with but we still have a long way to go. Technological advancements DEFINITELY need to be made in order to reliably explore the oceans. Advancements in mapping techniques would be a good start – AUVs that can dive deeper and stay out longer, higher resolution ship mounted multibeam sonar, more extensive sidescan sonar surveys, etc. We can't really dive places where we don't have at least some bathymetry data. For the close up, quality images and video we will need a higher depth rated vehicle to explore to full ocean depth. As stated in other answers, this will require a large amount of design work. The exciting thing is that this is what we're actively working on! We are on the front lines of this exploration and hopefully for the next 40 years, we continue to take steps towards full ocean exploration. How can we know more about the moon and other planets than the bottom of the ocean on our own? We need to fix that and hopefully that's accomplished in the next 40 years.

How far can your robots see? I know it's dark but can you shine enough light to see stuff in the distance?

[Algernoq](#)

You can see our response to a similar question [here!](#)

Hi, thanks for doing this AMA. I'm working in marine renewable energy and at the moment, underwater cable laying is limited by ROVs capabilities to cope with currents. How do you guys deal with that ? And how do you communicate with the robot ? Is it link or wireless ? Thanks again !

[Jean-talu101](#)

Current can definitely be a big deal for ROVs. Unfortunately, just because of how they are ROV are not super streamlined and as a result have pretty large drag coefficients and do not operate well in high current areas. The only solution I see are more powerful thrusters and very accurate autopilot. A ground based vehicle might work better in high current areas, but it would mean a lot of sacrifices in mobility and on impact to the area of operation.

We communicate over fiber optics to the vehicles. It would be awesome if wireless signals worked, but unfortunately, wireless signals attenuate after a few inches in water. Autonomous systems send updates to the ship via acoustic comms (AComms) but rate of transmission is super slow. They can only really send position and some limited data about a few times a minute (depending on depth). Some systems use lasers, but again, light attenuates exponentially, so the range is very limited.

How dangerous are seabed vents? And do they keep you from exploring certain areas?

[druidofdark](#)

Vents are typically only dangerous if you get right in the super-heated water flow. We have filmed vents before, and they are always very beautiful. The most impressive one we ever found was a [huge chimney](#) gushing hot water. The entire structure was swarming with little white shrimp. Sometimes we do avoid exploring in areas that have underwater cables, which could entangle the vehicles but if there is no apparent danger, we're there!

Are the Great Lakes very well explored? I understand lake superior is the deepest but with little population surrounding it are there still more species to discover?

Thanks and cool job!

[bunknow](#)

Not yet! One of our projects is the Large Lakes of the World initiative exploring - like [Yellowstone Lake](#). We'd love the opportunity to explore the Great Lakes and hope to get there someday. Lake Superior gets to ~ 11,000 ft (400 m). That's just begging to be explored!

How far can your robots see? I know it's dark but can you shine enough light to see stuff in the distance? Hello! What is/was the most interesting thing you have found in using the robots?

[princes456](#)

With our cameras and lights we can see around 30ft in clear water. Sometimes we can barely see the robotic hand in front of the camera. We can see out to about 150ft with the sonars on the vehicles. We don't do this, but some groups have used the sonars for station keeping. If we had a LIDAR we would have inch resolution out to about 100ft. Sonar is super important for AUVs to help them avoid running into things. As you can tell, sound is much more effective, at least in terms of range, when you are trying to pierce the darkness.

We spent a lot of time in our design process trying to get the lights and camera positions correct. One of the challenges working in the deep ocean is that the water isn't empty. It's filled with marine snow and other particulates. All of these things floating in the water reflect the light back at the camera. If we put the lights right next to the cameras we would see lot of backscatter from all of these particles and the image would get blown out. To mitigate this we put the lights up top, the camera down low and angle the lights so that we have a nice even light pool in front of the vehicles. We also have lights on carbon fiber rods attached to hydraulic pan and tilts so that we can adjust the lighting on the fly. This is super useful because the light pool is different if we are looking up slope, looking at a cliff or trying to look under an overhang.

I'm trying to mix my mechanical engineering degree and my love for photography and video in the future(2 years out of school so far). Are there other organizations or professions similar to what you do? It sounds fascinating!

[Crespo79](#)

We have a mechanical engineer on our team who uses his ME degree and passion for amazing imagery to assist the video engineers with what they do. So far, the product has been outstanding. [See here to get involved!](#)

Thank you for exploring the depths of our beautiful weird world! My question: What new species (plant or lifeform) have you guys been able to identify with the use of these explorers?

[Arioka](#)

Since 2009, we've discovered hundreds of new species. For instance, just the other day Chief Pilot Karl discovered [this little guy](#) here in the mid-Pacific.

How do you handle finding a seemingly unidentifiable species of coral, sponge, other invertebrate, or even fish, and how frequently (or infrequently) do situations like this occur?

[daysruntogether](#)

When you explore places that have never been explored before you will find new things. On this expedition, we are surveying an area that has only marginally been surveyed in the past, and therefore we routinely come across species that have never been found before. In those cases, we thoroughly document the animal through video and photos, and in select cases collect a sample that can be studied in more detail in the laboratory. During last year's expedition aboard the Okeanos Explorer we imaged hundreds of animals that were either not known to exist in this region or not known at all (new species). Additionally, we collected over 30 specimens, all of which ended up being either new species or new records for this region. We anticipate making similar discoveries on this expedition.

I really don't know any good question to ask, but tell me fun fact about anything you do :)

[JanzoMan](#)

No worries! We'll tell you a couple of facts. The foam pack on D2 is approximately 3600 lbs in air (half the weight of the whole vehicle) but in water, it's -3000 lbs or, more accurately, positively buoyant by 3000 lbs. #density. Another fun fact is when you're out to sea for 3-4 weeks at a time multiple times a year, mustache competitions get pretty old.

Any close calls (and if so, example) of losing equipment or personnel?

[Mephistopheles13](#)

We are very careful and systematic in checking the vehicles for potential issues before, during, and after every dive. Our engineers follow a vetted checklist routine and don't leave things to memory, even if they've been doing this for years. We are just as careful during deployment and recovery operations and try to have as many eyes on the deck as possible. So far we've seen over 150 launches and (thankfully) 150 recoveries of the Deep Discoverer ROV! We did have a close call with an undersea cable near Puerto Rico. We were working in a canyon and didn't realize that there was an old cable hanging across it several hundred feet above us. At the end of the dive we attempted to spool in and recover the vehicles, and we saw a lot of tension as the cable was jammed up against the camera platform. It took some careful ship and vehicle moves and some very tense minutes, but we were able to escape. Fortunately, after replacing a few bent brackets and carefully inspecting the vehicles we were able to get them back in the water.

Have you ever done anything at Lake Baikal? This lake fascinates me as it is the world's deepest lake

and one of the clearest lakes!!

[KrakenGoon](#)

We're on the same page there. We haven't done anything in Lake Baikal yet but it is one of our main targets for the Great Lakes of the World Initiative. It holds 20% of the world's unfrozen, surface fresh water! We cannot wait to get up there and explore it.

How much extra effort is needed to bring tech, like a new sensor, under water? What are the challenges when designing a deep-sea robot?

Also, where's the focus on research related to those robots? Like resisting water-pressure, propulsion, etc.

[RacingCucumber](#)

The short answer is: 1. It's hard to package gadgets for the deep sea, and 2. It's hard to communicate with the gear when its underwater. Here's a bit more detail:

1. Packaging sensors, cameras, gadgets underwater is difficult because anything placed in the deep ocean must be able to resist immense hydrostatic pressure. The pressure at 6,000 meters (D2 and Seirios' depth rating) is 8,900 pounds per square inch. Ouch. Gear that would ordinarily live near atmospheric pressure and in dry air must be packaged in a pressure resistant housing. No leaks or implosions allowed. Electronics don't like getting wet (try dropping your cell phone in water) and most electronics components cannot tolerate high pressures. Those two facts, put together, cause much consternation when we wish to package electronics, sensors, cameras, etc in the deep ocean. Please refer to another question that goes into more detail about underwater pressure housings.
2. If you package a bit of Tech, how are you going to communicate with it? Much of the electromagnetic spectrum is absorbed by water! Forget about the space-age convenience of radio-waves (e.g. Wifi). Any sort of "tech" that must communicate with the vehicle platform (an ROV in our case), or directly with the surface ship, is relegated to using: a. copper wires, b. fiber optic cable (lots of data bandwidth!), c. acoustics (sound travels great through water), d. visible light over short distances, or e. you don't communicate with the "tech" at all (e.g. internal data storage).

Let's assume that you have a clever mechanical engineer that successfully packages your "tech" in an underwater pressure housing, your left with challenge #2. Here are examples of the five means of communicating with a piece of "tech" underwater.

- a. Over short distances, we can communicate with a sensor over copper wires. For a piece of gear that can be readily mounted on an ROV, this is a good option. Serial comms (RS-232/485/422) or ethernet are good examples. Ethernet is good for 100m if you're really careful with the cable type and end-fittings (which, incidentally, isn't so easy when you're trying to connect twisted-shielded wire through a thick metallic pressure housing). Longer lengths aren't going to work, so that leads to the next option:
- b. Over long distances, and for LOTS of data bandwidth, we convert the data to Fiber. That's how we communicate between the surface-ship and our ROV's. You can fit many colors of light onto a single fiber optic cable using clever technology known as a Course Wave Division Multiplexer. Each color of light can cram LOTS of data into a series of digital light pulses that travel at the speed of light. Magic. This is great unless you can't be bothered being "connected" at all.
- c. That brings us to acoustics. Once again, you can't transmit radio waves through water, so acoustics win the cake underwater, but data bandwidth is limited. No GPS. No radio-waves. No Wifi. Its amazing that we can communicate with a Mars Rover through outer-space via radio-waves, but we are

challenged to communicate through our own ocean. Acoustics are used for a wide array of instruments underwater: for mapping (mapping sonar), eco-location (navigational sonar), or direct data transmission (acoustic modem). Research continually progresses in the field of ocean acoustics, sonar technology, and signal processing.

d. Visible light is great for taking photos and video underwater (as long as you bring your own power-hungry lights). Sounds simple, right? Not really. Say you want to package a fancy new 4k High-Definition video camera underwater. First, refer to #1, get a clever Mech Engineering to package that big hunky camera in an underwater housing that can resist the immense pressure of the ocean. But then you need to worry about the optics. To avoid image distortion, you would need to account for the difference in refractive index between air inside the housing, the glass (or acrylic or synthetic sapphire) viewport, and seawater. Good underwater video cameras have multiple corrective lenses to correct for optical distortion.

e. Some sensors carry their own electrical power and have onboard data-acquisition. An example is the network of ocean-bottom seismometers that "listen" to the earth's grumbings and vibrations for up to two years. They are self-powered (lots of batteries!) and have their own low-power data acquisition and storage system.

"What are the challenges when designing a deep-sea robot?" 1. Hydrostatic Pressure in the deep ocean 2. Corrosive and conductive nature of seawater 3. Electrical power transmission through a LONG cable, or else self-powered via batteries 4. Communication/ Data-transmission over long distances ...to name a few.

"Also, where's the focus on research related to those robots? Like resisting water-pressure, propulsion, etc." The focus of much research, outside of the ever-present task of designing the vehicles to carry all of the gear, is to further develop sensor and mapping technologies for underwater use.

Hi, I'm a Failure Analysis Scientist for the electronics and materials sectors. (@themcsgroupuk)

Do you encounter a lot of issues with the materials you use in the construction of your robots that environment? Problems with corrosion etc? How do you go about evaluating failures and issues you have?

[Tia_Avende_Alantin](#)

Material selection for various components on the underwater vehicles is an important consideration. All materials have pros and cons, and must be carefully considered in light of the design restrictions for each part. Strength, Density, Stiffness, Cost, Availability, Corrosion resistance, chemical resistance, UV resistance, thermal conductivity, etc.

Here are some examples:

D2's frame is made from Aluminum 6061-T6. This alloy of Aluminum is low-density, strong, and readily available at low-cost in a wide variety of shapes and forms (sheet, plate, bar, extrusion profiles, etc). It is readily machined and welded, and can be plated (Anodized) for corrosion prevention. However, despite the ability to protect the material with Hardcoat Anodized coatings, aluminum in its various alloys is prone to corrosion. It is low on the galvanic scale when compared with more noble metals such as stainless steel, brass/bronze, titanium, etc. The only metals lower on the galvanic scale that will sacrificially corrode in favor of aluminum are zinc and magnesium alloys...hence we often attach sacrificial zinc (or sometimes magnesium) anodes to "protect" the more noble aluminum alloys. For lightweight structures and certain brackets, you simply can't beat the strength-to-weight properties of marine aluminum alloys.

D2's and Seirios' primary electronics pressure housings are made from Titanium Grade 5 (6%Al, 4%

Va). The main pressure housings of our vehicles are of critical importance, as they enclose the "brains." Degradation of the material due to corrosion that could result in failure or a leak would be catastrophic. Titanium is nearly impervious to corrosion at temperatures that the ROV's will encounter, fantastically strong, relatively light (65-75% denser than aluminum alloys), and reasonably available on the commercial market. The downside to Ti alloys is the very high cost at around \$20 per pound for raw material.

We often use stainless steel or copper alloys where corrosion resistance is important and where weight is not critical, as these alloys are about 3x the density of aluminum. They are reasonably strong (depending on the alloys used), and very stiff. Certain copper alloys have superb corrosion resistance and quite strong (e.g. Beryllium Copper) but are costly and heavy. Stainless steel, despite its name, has some corrosion issues in a low-oxygen environment (e.g. seafloor mud or in small crevices).

Plastics also play a large role in the fabrication of various components on the ROVs. Corrosion is not a large issue, they are very low density, some plastics are low-cost, many are readily machineable, and some are heat-weldable. Many brackets are machined from Delrin (Acetal Homopolymer), ABS, PEEK, Acrylic, Polycarbonate, PVC ,etc. Bumpers and skids are often machined from rubbery-like Polyethylene.

Corrosion is covered above, but we should add a special note to mention that placing dissimilar metals in close proximity is a bad idea. Putting materials of varying degrees of galvanic nobility in contact with each other, and placing them in a conductive medium (seawater), is a recipe for localized corrosion. We avoid this wherever possible. A common example is using stainless screws to fasten aluminum components. We try to isolate the materials with plastic washers/sleeves where possible, and apply a liberal coating of marine grease to the surfaces of the mating parts.

We aim to avoid failures by carefully engineering, validating, and testing our designs before putting them in the field. Careful material selection and stress calculations are made for the various components. In many situations, empirical data and/or relevant experience by our senior members is a useful guide for defining the design requirements for a particular component. Ultimately, putting the components in the field and subjecting them to the corrosive and punishing effect of the deep ocean is the ultimate test. Any corrosive degradation of components is carefully monitored and corrected.

Are you guys hiring? Specifically electrical engineers with experience in this field.

[cdmove](#)

Yes, we are always accepting resumes for people who are interested in ocean exploration. Check out our [website!](#)

What's the weirdest thing you guys ever found??

[hulkhawk](#)

Probably not the weirdest but [this guys](#) pretty strange.

What is the biggest challenge with designing robot arm joints that operate under such high pressure, and how do you overcome the problem?

[Hylaar](#)

High pressure and the corrosive environment are the biggest concerns we face. To mitigate corrosion

we use bolt-on zincs throughout the vehicles as a sacrificial material (commonly used on boats as well). To make a manipulator move we use hydraulic pistons in most joints. The hydraulic system runs at ~2000psi, making the manipulator strong enough to hold up 200lbs fully extended. We use a system of fluid filled bladders called compensators that allow for the pressure differential inside and outside the system to remain constant. This is done when the seawater squeezes the bladder and raises the hydraulic reservoir pressure by exactly the amount changed on the outside. The deeper we go, the harder the bladder is squeezed. The 2k-pressure differential inside the system is done with a hydraulic motor and pump on board the ROV. Specifically for the joints, they require constant maintenance, attention, and movement.

Have you found that gaining information in one area, biology or geology, is easier to focus on in your development if the bots? If so why? Or do you more build to a user/contracts requirements?

[hockeyhead019](#)

This is generalizing a fair amount but we typically design the core components of the vehicle to reach a desired depth. The specific biology and geology missions are typically accomplished by adding specific sensors or collection devices that are devoted to a specific mission. For example, last year we added a couple of beautiful rock boxes for geological samples. We also added two thermally insulated bio collection boxes that we place bio samples in. In the past, we've also designed, built, and operated temperature probes, [methane collection devices](#) (a favorite of ours), and Niskin bottles for at depth water collection.

Thanks for this AMA! This seems like such a cool career you guys have made for yourselves - do you have any structural engineers on your team? some of the deep sea pressures must be of an incredible magnitude and I'm curious as to how that is factored into the design of some of your robots.

[evanbananas](#)

Most of our ME's have very strong structural backgrounds and you are absolutely right! The deep sea pressures can be as high as 300 times the atmospheric pressure you feel on the earth. This high pressure governs every design we make and we must be very thorough (using proper materials, proper compensation techniques, and proper sealing structures) so that our ROV can complete its daily task. [See here](#) for a little more on structures and our pressure housings.

As someone who has been working on developing a control system (both hardware and programming) for what I would consider a shallow ROV (hopefully one day AUV), what sensors have you have the most difficulty with? I don't know what sensory systems you use on Deep Discoverer, but I would like to if the information isn't proprietary.

[J_J_K](#)

We have a bunch of sensors that we use for navigation. The primary navigation sensors are the Doppler Velocity Logger (DVL) which gives us altitude and speed over ground, the depth transducer, the Ultra-Short Baseline acoustic tracking system (USBL) which gives us position relative to the ship, the ships GPS which we use along with the USBL to calculate absolute position, and finally the PHINS 6000 Inertial Navigation System (INS) which gives us compass heading as well as heave, yaw and other accelerations.

We don't really have any problems with any of these systems specifically. The PHINS accelerations are usually pretty bad by the time we make it to the bottom because we do the calibration on the

surface. We could stop and wait 20 minutes to calibrate once we get to the bottom, but we currently don't use the acceleration in the nav solution. If we started doing 3D mapping we would probably start calibrating at depth. The largest source of error in the calculations is in the USBL. The speed of sound is not constant with depth so there is some error introduced into the system as a result. This error gets worse with depth. Still, we get pretty damn close in absolute terms. Typically we have a precision of around 20m at shallow depths, around 50m during the really deep dives.

I have a degree in television production and am currently pursuing a biology degree. My passion and dream is to be in a marine research field...videography on top of that would be a plus.

My question is how did you end up in your field? Was it your initial choice of career or did you find it later on? Do you have any advice to someone seeking a career in this field?

[velocityoflove](#)

Hopefully [this](#) helps!

Is there a limit to what types of lights, and how powerful of lights you can use at those depths? Also, have you accidentally found anything other people are looking for like ships or planes?

[Hempsterball](#)

The biggest consideration for the lights is power efficiency or "bang for your buck". LEDs are the way to go for us. Their bright and cost effective and small. Each of our LED lights is 6,000 lumens and we have 24 on our D2 vehicle and 18 on Seirios. To answer your second question, we certainly see things that WE don't expect to see all the time. Like this "tar lilly" and the 200 year old Monterrey shipwrecks. We're not sure if other people were looking for these items but we sure found them!

What scope do civil engineers have in the job you are doing?

[himalayan19](#)

Where we're going, we don't need roads... No, no we love CEs. We don't have any civil engineers on our team at the moment but like all engineers, civil engineers possess the ability to solve problems and are trained to analyze. Specifically, CEs are structural experts, well-versed in materials and loading patterns – like that of a ship. They also think in 3D and can see contours and grading – like our bathymetry data. They've also taken "foundations" and are familiar with soils and geological formations –like the ocean floor. So, yeah. All interested CE see [here](#).

How deep are the robots going down and how does it compare to known deepest parts of the ocean?

[Dnnout](#)

Our deep sea robots that we work with on the Okeanos are rated to 6,000 meters – that's 3.73 miles. If we use an average cat length (without tail) of 18 inches, that's 1094 cats. The deepest parts of the Ocean (Challenger Deep in the Mariana Trench) are around 11,000 m. We fall a little short of that number but with D2 and Seirios we can explore at least 90% of the world's Ocean. That's an A on a test! Edit: Karl thinks the average is more like 17.5 inches. Accuracy is our forte.

Have you been to Crater Lake, Oregon, and if so how deep did you get?

[tgienger](#)

Crater Lake is definitely on the list for the Great Lakes of the World Initiative. That place is amazing. We can't wait to get a vehicle there.

How many species have you as a group discovered as a result of your extensive research? Thanks, Bryce

[brycass10](#)

[See here!](#)

Do infrared cameras work underwater?

[bethabara9](#)

Infrared cameras do work underwater... but IR dissipates quickly underwater more quickly than visual light.