Webinar Transcript:

An autonomous approach to ocean mapping: A Saildrone, USM, and NOAA collaboration

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Good afternoon everyone, I just want to welcome you to this webinar and just a few housekeeping things. Just want to let you know that we will have some time for questions at the end of today's webinar. You'll see that there’s a question function and you can go ahead and type right into there and questions will be answered at the end of the webinar. And I'll turn it over to Brian.

:32 Great, thank you Jill. And welcome everyone to our presentation on the project to do an autonomous ocean mapping using a Saildrone. Funded through NOAA grant to the University of Southern Mississippi with our partners at Saildrone and also shout out to norbit who provided the sonar for the system. Going ahead to the next slide, so real quickly I just wanted to introduce the players today and who will be talking. My name is Brian Connor, and I'm the director of the hydrographic science research center at the University of Southern Mississippi. You're going to hear next from Sebastian de Halleux from Saildrone, he's the Chief Operating Officer there. Then he's going to hand it over to RDML Shep Smith, the director of the office at Coast Survey NOAA and then Matt Paulson whose dosimetry will get into the details of the project and where we are so far. After that we'll go into a Q&A session, so again we'd ask all the questions you can type those in. I'll be monitoring those if I can answer them on the fly during this I will. Otherwise, read those out at the end and I offered up to the panel members here to answer those questions for you. Then we have a quick close out and we're approaching World Hydrography Day, we're going to take credit for this being a World Hydrography Day seminar as well, so happy World Hydrography Day to everyone. That will be on Sunday if you didn’t know. I'm looking forward to this seminar to share with you the exciting things we've been doing with Saildrone over the last 18 months or so. Are we going to see this new technology being put to a different use than it has been used previously. With that, I am going to turn it over to Sebastian and have him kicked off with an overview of Saildrone itself.

2:35 Thank you Brian and a good afternoon everyone. So my name is Sebastian de Halleux, as Brian was saying. I am the Chief Operating Officer here at Saildrone and I'm going to go over the next 15 minutes over a brief overview of what really is the platform that we talkin about here.

Just a quick word about Saildrone as a company, we are a fully integrated company. So we manufacture, operate and provide data services for a collections of partners, in public and the public agencies across the U.S. government as well as academic research institutions. We are based in Alameda, California where manufacturing are planned is based on the formal S station data to those that are familiar. So why does Saildrone exist? We have a very simple mission, the mission is to collect ocean data at scale, to enable new inside. Which means starting with using autonomy for large-scale data collection. But also running large-big data ingestion systems, quality control and a processing layer and then ultimately the delivery mechanism of this data to our partners.

3:52 Of course, a desentive of that solution is an ocean robot. It's a long endurance autonomous vehicle, when I say it's a long endurance, these vehicles are capable of missions over 12 months in duration. And the reason for that is that they have no engines, as a matter of fact they rely on wind power for propulsion and solar power for providing power to the onboard electronics. They are bigger than they appear, about 23 ft long 15 ft tall 6 ft deep and they're connected on show 24/7 by a satellite link for live data exfiltration. So just a bit of backstory for those interested, the wing design looks very simple but it was the result of 10 years of research and development in high performance in urodynamics. Believe it or not, in the desert so far from the ocean in pursuit of speed records in the lanyard. And this was the vehicle that broke that record in 2009 on the dry lake. This works just like a plane, just like a four wheel on the wing of a plane creates lift, when the pilot activates the elevator on the tail of the plane. If you tilt it 90° we have the same arrangement of a wing and a tail component by activating the trim tab on the tail. Can you change the angle of attack of the wings of the wind and generate lift essentially forever. That means we created USV platform that can cross oceans using under 10 watts of power and so we quote on quote solve the propulsion problem. So this has resulted in vacon, **which is tiara nine** [5:20] fully operational. It has no crew, no fuel, no maintenance, no emission, and no noise which is very handy if you try to do high precision acoustics. Couple of things to note is that the vehicles are time in chuuk manship sensitive to reduce the demand on existing days at Sea. So the vehicles that do not require ship support, they are instead launched from any dock using very simple equipment. They sail under their own button onto the operating area and they average are on transit about 3 knots that are capable of reaching any ocean location under 30 days from the nearest shore. As I mention, they are capable of mission duration of up to 12 months.The limiting factor being really sensor calibration and bio falling depending on the region or the availability of light or presence of ice in high latitudes. They are routinely enduring extreme ocean conditions , we send them to the ocean where they encounter waves that are 60 foot and above and designed to be rolled by waves and come right back up and continue. These are completely robust vehicles. The autonomy is called supervisor autonomy, so there's a 24/7 Mission Control started by trained operators, the vehicles are sent way point and corridors by these operators. So their mission managers navigate autonomously from wave point to wave point staying inside the corridors. Taking wave, wind and currents into account that this way, can receive very precise maneuvering and they are capable of serving grades and capable of boeing [7:04] comparison as you can see in the bottom-right and pretty much any mode of operation that you can that you can think of. Another important thing to note is that they are extremely safe. Being slow vehicles, they are equipped with safety features like a navigation light at night, automated identification system (AIS) for awareness traffic around them, they also broadcast as well in high traffic areas, they have onboard cameras with machine learning that can detect traffic. High visibility wings, of course that's 15 meters tall. But ultimately they are low speed vehicles that compare to most traffic that might be operating in the same area. The sensor payload was developed under a public-private partnership with NOAA. Starting with met [8:04] ocean data really as air-sea [8:12] reflux interaction machine and from that interaction came with addition of the acoustic payload initially for fisheries and now for belting beat symmetry [8:19]. Each vehicle is equipped with suite standard sensors and so is the case for this U.S emission are looking at core ocean variables and cold climate variables including atmospheric measurements including wind, temperature, humidity, pressure, solar radiation, ctd, dexus [8:39] of oxygen, chlorophyll A, skin ssd using a infrared parameter, wave, height, impaired, cameras with machine learning to detect targets and then an acoustic payload which was traditionally ADCP or an EK80 Echo-Sounder for water column and which we are now focusing on integrating multibeam echosystem, which Brian mentioned is an orbit tunit. In practice this platform has been operating around the world for the past five years as the collection of regional fleets. From the U.S Arctic to North Atlantic, Gulf of Mexico, Southern Ocean, Eastern Tropical Pacifc, Western Tropical Pacific and many other places. This is really a global range platform. For those of you that are interested, many of those data sets are public. You can access them in various places, most of those are indexed at data.saildrone.com. I just wanted to show you one image of what one of those missions looks like because the goal of the USM NOAA saildrone project is to develop an arctic radio solution. Saildrone has been operating for five years in the arctic, as a matter of fact as we speak it is in its six year of operation across the Bering Sea Chukchi Sea. We sent fleets of vehicles, right now we have a fleet of seven vehicles in the Arctic on the way and these go from the Dutch harbor

[10:06] all the way up to the ice edge. You can see here on the left, details of the vehicles leaving Dutch harbor performing fisheries in the Bering Sea and transiting through the Bering strait and gridding pretty much every square mile of the Chukchi Sea. The platform capability for long range navigation in the arctic is well established. The question mark and the focus of this project is, how can we use this platform to perform [??? 10:33] level symmetry in these remote areas? These are very inhospitable areas which are challengingingg for humans to be operating in. Last year with NOAA, we spent 700 days in the arctic circle cumulatively with the fleet, very close to the ice age. These pictures are just beautiful, but they remind you of the danger of navigating in those remote and harsh environments. So any solutions that get divided by this program needs to be able to sustain, you know the types of conditions that are prevalent in the arctic. So very quickly, as part of the symmetry solution spectrum, Saildrone is looking at this in discreet as discrete problems; engineering problems. We have at the moment four sets of solutions: the first one is basic recon using a single beam echosounder to find contour lines in water depth less than a hundred meters. That is combined with the focus of this presentation, which is shallow [??? 11:37] show, complying, multibeam, full water depth of less than 160 meters. We also have developed a more powerful single beam solution that are more suited for looking at features like seamount in the open ocean. As well as full ocean multibeam solution that uses a larger platform called a Saildrone capable up to 7,000 meters. The story you are about to hear in more technical details started with fisheries. What you see here is some of the fisheries research grids that we did with the Alaskan fisheries science center in the Bering Sea. We started cooperating with the office of Coast Survey that looked at the data from those echosounders and used that to update data to spots region of the Bering Sea. Then the question came, that if we could carry a fisheries echosounder how about more specific solutions to meet [??? 12:43] standards and evolve that broad map? That way that works is that this is an autonomous data acquisition system, that Saildrone sail anywhere in the world to an up area without ship support. They turn on the echosounder, acquire the data, send real time data over satellite to mission control and then come back to show at the end of the mission and deliver the post mission, raw data fit for processing using a standard processing pipeline. Although we do get some results during the mission, given the nature and the breadth of the data; a lot of this data is post-processed after the mission. The last thing I will say before I hand it over for the technical part of this presentation is that each problem set and each step requires a specific tool. We together on the seabed 730 [13:37] end with the grant from National Ocean Partnership Program in collaboration with the University of New Hampshire and in barey [13:44] launching a 72 ft version of the Saildrone called Saildrone

Surveyor. This will be a very similar vehicle, as you can see from the look and feel of the vehicle. Wind powered but a much bigger, can carry a much heavier payload which does include a Kongsberg EM 304, 1 by 2 degree, a sonar, EM 2040, full water column EKAT [14:10], 280 ADCP, and as well as an eDNA sampler. That's a platform that's bigger, it's faster, but it has the same long range of economy [14:18] capable of 1.5 million square kilometers per year of mapping in the deep ocean. This is a long story, we are going to be focused on the shallow multibeam and I will hand it over now to RDML Shep Smith for the introduction of the project context from another perspective.

(14:40) Thank you sebastian, I think you covered a lot of what I was going to cover. I think we are very excited about this project and what it seems like on the way and very exciting results. I did want to comment a little bit on the larger map context and how this plays into it. I had the opportunity to be involved with the organization and promotion both the international seabed 2030 program [15:15] that is a joint effort around the world in order to promote ocean mapping and to get the world's ocean mapped by 2030. And a similar effort just announced by the U.S government, office and science technology policy a few days ago called the "National Ocean Mapping Exploration Characterization Strategy". So that each of those have very ambitious mapping goals; in fact M2, so ambitious that we can't do them with the currently deployed technology and it is really only through technology like what we're seeing here with Saildrone. Other similar technologies plus improvements with communications, signal processing and artificial intelligence and other things that we think we will be able to reach the goals that we've set out in both two strategies. This is not just exciting, but this really allows us to have a step-change in the type of ambition that we have for ocean mapping. You know as Sebastian says, that the big change here that we've been working on here with USM and Saildrone is getting a mapping echosounder on there. There are really two parts of switching over from doing fisheries acoustics to surveying for seabottom. The first is it's better to have a multibeam system or Survey System. We can get by with the single beam system, but it's certainly much more effective work and we can really need all of our mapping goals much better with a real mapping system. That is the first challenge and I think we're going to hear quite a bit about that today and the challenges of that. The second clearly has to do with hydrographic work, so if it is driving around looking for fish, yeah, we see the seabed but it wasn't those lines that were not driven specifically for ocean mapping. Can we design and execute a coherent survey where we get full ocean bottom coverage in a survey area. I do want to know that in the picture that Sebastian showed with four different sonar, we did with different depths ranges the depth capability of the norbit shown here; because the level of effort goes up so much in shallow water. That if you look at all the water that needs surveying in the United States and how much level of effort it is not by area, but how many line miles you need to get it done. 90% of the waters in the United States would be excessive 90% of the work could be done by this system. Only 10% of the work in deeper water is out of range, so I think that this is important and to note that shallow water work is where the work is necessary. The last thing I want to say in addition to hydrography and the integration of the multibeam and being able to steer lines, is that one of the biggest challenges is that we need to know the acoustic properties of the water column in order to be able to make a multibeam system work. That was another really big engineering and operation challenge that the USM Saildrone team took on, so I am really looking forward to seeing the results of this and I'm even more excited for you all to see some of what I have already seen. I am really excited about the opportunity for this work going on forward. I will turn it over to the rest of the technical presentation.

(19:32) With that, we are going to turn it over to Matt Paulson. Whose been our primary partner putting this system together, planning missions, and doing the testing on making everything work together. So Matt, take it away

Thanks Brian, before we begin. I would like to thank a few folks here. I would like to thank RDML Shep Smith and the NOAA Office of Coast Survey for sponsoring this project, first off. I would like to thank Brian, you and the rest of your team at the University of Southern Mississippi for partnering with us and all that work that you have done to get us where we are today. So please tell everyone thank you over there. Also, the gulf port marine research facility - I would like to send a shout out to them for hosting us during our gulf portion of this project. We did have a hurricane scare there and they helped out a lot with getting the vehicle moved and out of harm's way, so I wanted to thank them for that. I am not sure if there are any representatives for norbit online right now, but I wanted to thank them as well. They have continued to be a valuable partner in this project, helping us with hardware and software integration and anything that comes up they have been spot on with getting us those updates and I want to thank them for that. With that, we can go ahead and start the presentation. So as you've heard kind of the project goal here was to just demonstrate high quality over the horizon multibeam survey capability using Saildrones are already arctic ready USV, sounds easier than it is. We have four basic steps: install the multimetco sounder on the saildrone. Again sounds easy in theory but when you're working with the vehicle that is completely a solar and battery powered, high-powered system like the multibeam can be a challenge. Once we have that installed, we need to demonstrate that we can gather high-quality data autonomously and then also demonstrate that over the horizon with minimal human intervention. Then the final goal for that was kind of a clear pathway to getting this vehicle ready to go up to the arctic and collect that data. For the installation here, we chose Norbit iWBMSh STX, we chose that because its low powered fully integrated system, very compact. But it is also capable of high-quality with symmetry, the unit we chose is 400 kilohertz, has a 160 meter depth range and has an integrated applanix pos mv of the ocean master. Kind of the industry standard as far as I am used to go, it's very high accuracy and you can see here .01 degree pitch roll accuracy zero to degrees accuracy and positional accuracy less than 10 cm. You'll see later on with some of the data, we are able to even better than that using some post-processing. We had the antenna separation at 2 meters, so it's kind of max separation we could get and it worked very well with the GPS. As RDML Smith mentions, we had to also do profiling in order to get the multibeam to work. We had to get some velocity profiles to do the ray tracing of the sound, so with our power budget in mind we decided that we were going to build that winch on a second vehicle to do the sound velocity profiling. We have the Saildrone winch vehicle with 100 meter depth capability, the great thing about this is it only takes one single command to automate the entire SVP cast. That's starting it's turning on the censor, getting the location via GPS, the pulling the censor down to a given depth, retrieving the censor and updating our server is all automated - one command. For that, we chose the valeport swift SVP, the reason why we chose that is that it has its own GPS geolocation. So it automatically imprints the location of the SVP cast in the files, it has a 500 meter depth rating, currently we are only using 100 meters of that. But it gives us room to grow, as we seek to fit. It is very high accuracy .02 meters per second accuracy, and then a big one is the bluetooth communications. The bluetooth communication allows us to transfer the data from the sensor without having to use a data or power cable to connect to the unit. This allows us to have a smaller winch, thinner cable and give us more depth capability there. It also have a battery life of up to 30 days and that's when we put the bluetooth in low power and sleep mode. (24:44) So with this, as I said we have resulting two kinds of USB solution of this symmetry data. So the multibeam, we call the surveyors can acquire the multibeam data and they can operate 24/7 collecting multibeam data while the second vehicle, the profiler is going around to drop SVP profiles. Again, that uploads the data - the SVP profiles to our servers within about 5 minutes of the cast completion; we can see that right away. The image there on the left, is an image of our one of our test cast of the SVP profile that we got back. The image on the right is a combined multibeam data post-process with sound velocity off the coast of California, but we will get a bigger picture of that later on. For the project summary, we have them in two parts here. The first part is that we were testing the basics of the multibeam: Can we operate it over the horizon? Can we collect high quality data? For that, we went to Gulfport and launched out of Gulfport from the marine research facility there. We did two deployments about 10 to 14 days each time. Each one of those deployments, we returned back with about 20% battery. So based on the current loadout, we get about 2 weeks of 24/7 survey time out of one charge of the vehicle. The types of data that we collected are: multibeam, backscatter, water column, and sound velocity. The sound velocity wasn't collected during the gulf port mission, we planned on having a bowei [26:33] there.That was going to do sound velocity collection for us, that wasn't actually had arrived at the location yet. By the time we were doing the survey, some of this data was processed without sound velocity; but you can still see the quality in there. Some of project metric, between the survey that we did around 925 linear nautical miles, multibeam collection over 28 day period and over 1 and a half terabytes of data were collected. During the gulf of mexico portion of the survey, we actually detected three wrecks. Two of them were charted in the area and the third one that you can see in the image on the left, was actually an uncharted wreck. You can just see that this data in the image is not sound velocity corrected. It is just raw data, just clean for noise in the water column which due to our vehicle having no engine, being very low noise, the data was very clean to begin with. Not a lot of acoustic noise anyways. So you can still see that the data looks without the sound velocity, it only gets better from there as we will show you later on. The first thing we did in gulf port was perform a patch test, so we can check for the pitch role offsets. Just for the sensor installation, we did this across the gulfport channel. We did several passes, I believe four lines across the channel and a few other lines here as you can see on the image on the left there shows the process data and this was done with a sound velocity profiler that was hand dropped of the tow vehicle. This was fully processed using tides and sound velocity with no actual installation. Picture role correction, you can see in the image on the left there as a cross section cloud image of all the points across the channel. Not sure if you can see it's kind of a small image to show on the screen here, but each color in the image is a different line. So different lines run at a different speed, different direction. You can see how well you can catch the edges of that channel and how well all the data line up without any correction. Again, this norbit system performed extremely well and we are extremely happy with it. Some more data that was given to us by USM, this is some lines we collected over a three day period in about 21 meters of water. This data again is not sound velocity corrected, but it is corrected for tides. You can see we have lines going in all different directions, not sure if you can see the image as it is kind of small. We also had one line running through the data when the vehicle is tacking back and forth, zig-zag pattern through all this data and again it's against a cross-sectional point-cloud of all these different lines. You can see how flat the bottom looks without even without sound velocity correction. The data is very clean, very accurate and you will see again once I show the sound velocity corrected surface. It’s beautiful. Again, after we had the Gulf of Mexico survey completed - we shipped the vehicle back to California. For some preps with the winch drone and the surveyor drone to survey and console with each other. This data here as I believe one meter resolution gridding there on the right, the surface. This is the data that has been sound velocity corrected and tide corrected, all the noises were clean off this data. The image on the left there, these are the lines that the vehicle actually ran to do this survey. You can see the steady wind, those lines are almost perfectly straight. It was an extremely good test for this vehicle, we almost got 100% coverage there. But that’s one of the challenges, but I will discuss that later. You can see the data, once it’s corrected for sound velocity and tides - it looks perfect. Here are some images that we took during the processing. The image on the left is a QC report from Charis [31:25] takes into account the standard deviation of the actual surface. Based on the standard deviation portion of the IHO specification, 100% of the data met IHO order one A 96+ percent of it was within special order. Now there are other specifications that go in there for the total survey to meet those, but according to the QC report and standard deviation - that portion is good. The right side here, is the estimated position accuracy after we did post processing of our GPS data using the pose [32:03] pack MMS, with a PPRTAK [?] post processing. So you can see the positional of uncertainty, the north and east things or around the centimeter on average. Just maybe a little over a centimeter of uncertainty, vertical we average about two to two in half centimeters of uncertainty - so that's very good. These challenges and lessons learned, the biggest one is the power budget. As Sebastian had mentioned earlier, a typical sensor payload is less than 10 watts. The multibeam system itself is 65 watts; so we had that big challenge right off the jump trying to figure out how we were going to power the system and enable it to a long duration survey. We had some challenges there, we were able to add some more batteries, do some things to get it to a point where we were about two weeks of survey time out of it. But then again, in order to do long range 30-90 day missions, we need to consume less than we produce obviously. And to do that we need to decrease the power drawn from the multibeam system which we are working on a few things there. Then increase the USB generator power, which we have a few solutions that are in the pipeline for that as well. The other thing that I had mentioned is the coverage optimization, so you can see on the survey previously that we had a few gaps in that surface. It becomes very challenging when you're working over to radium trying to get data through very high latency times, very low throughput. We are working on the ability to see coverage surface similar to what you would see when you're on a ship doing the actual survey, so you can know what your coverage looks like. Going along with that is the challenge when you're going upwind or downwind, driving straight lines or sailing straight lines - I should say it becomes difficult as well as when the wind falls below the threshold and you kind of just drifting. Those are just some of the challenges that we had as far as coverage. Sound velocity profiling, currently with our one command that I said we gave it a user enable user set depth that drops so that everything it does is great. We are looking to integrate a solution where it can auto detect with a depth is and drop the profiler to adapt that's safe based on that depth without having to user input. We are also working on increasing the battery life of the sensor itself, to get up to the high end of that window. That 90 days, we're currently at 30 - we would like to get to 90. The next step goes hand-in-hand with those challenges right, so improved command and control of the sonar system. Currently as the system stood when we did this survey, we could only send basic commands: turn the system on and off, start record, stop record, the rest of the system was kind of an automatic mode. We are working with Norbit on improving that commander control, getting some data back from the sensor itself. Kind of health data heartbeat type data and the ability to send some more high-level commands to the unit. We are also leveraging Norbit has a new tool called their data collection tool that comes free with their software. It enables you to have a coverage surface and on the vehicle will be a web tile server that gives the coverage that we can remote into and we can pull up to see in real time what our multibeam coverage actually is. Again, I spoke with increasing USV generated power and decreasing the load, those go hand-in-hand to just increasing the capability and range of the vehicle. We are also working on some software enhancements and hardware enhancements to the way we sail. To improve how we drive straight lines or sail straight lines in most weather conditions. Of course we are working with the manufacturers to increase the battery life of the sound velocity profiler. Thank you. (36:49)

Thanks Matt, really appreciate that look at the project. We have had a few questions online, so we'll go ahead into the Q&A now. So again if you got any questions, please put it in the question box. I have answered a few questions as we've been talking here. But I would like to go ahead and some of these will be questions for Saildrone. Someone might be able to answer or Chuck [37:00] may be able to answer. One of the questions is wondering, if NOAA had looked at considering marine operation on the pacifc as a Saildrone homeport in their caught up launch recovery somewhere he had considered at the western end of that period. I thought that Sebasian, maybe you could explain your concept of delivery and how you do the logistics for these vehicles.

Absolutely, the concept of the operation for the Saildrones is really a global fleet distributed around a region a local operation hub. In theory, you can say all the Saildrones came from California to wherever they need to go. In practice, as you would imagine there's no point in sailing thousands of miles to get to an area. So we do have about 15 operation hubs, I mentioned Dutch Harbor which is the U.S arctic operation hub. We have a similar one for the European hub in Bergian, Norway. We have operate in the Pacific, we have a place in Hawaii, we are working from Guam, we are working even on John servicing on the atomic palmyra. With the nature conservation which operates on tropical pacific preservation. We have sudden ocean hubs in New Zealand, in Australia, and a whole lot of varieties of hubs on the east coast and on the cobble berry islands [38:39] with Geomar, Germany. Trieste, Italy for the med. It's a collection, and the way that this works is the vehicles get manufactured in California. The senses are calibrated, the seatrail takes place in California offshores water, then the vehicles are disassembled and then packed three vehicles in a 40 ft container. Which then gets shipped to a deployment hub, there a Saildrone logistic team flies out to receive the box. Resembles the vehicles, perform dock tests, make sure all the systems are green light and the vehicle stays on its own bottom to the operating area. There is no ship involved anywhere to support the vehicle and the day after 12 months or however long the mission duration is. They sail themself back to an operating hub and for demobilization and retrieval of the raw data. Meanwhile during the mission, they send data at one minute interval; these low resolution files that we have been referencing. So anyone who's got a mission, we can leverage using existing facilities and in many cases as Matt was mentioning. We try to leverage our partners' facilities like we did in Gulfport, for example the demands are really minimal. All we need is a dock that is able to receive a 40 ft container, a small crane capable of putting on 1,500 lbs from the water, and that's about it. Very easy to deploy even in a very remote environment. I hope that answers your question. (40:14)

Great, I think that covers it well Sebastian. Another question from Denny Haines in Canada, he was just curious about how many collisions or other damage have you seen of your vehicles over the five years of operations.

Yes, absolutely. Over the five years of operation, I am glad to report that we did not have any security incidents - collisions. First of all we operate in very remote areas, where there relatively is to be light traffic. Even in the high traffic areas like the North Sea or the Bering Sea, where there is very intense fishing fleets or the coast of California with other types of traffic. We are very slow vehicle and highly visible. Broadcasting IS, light at night and so it's typical problem of a bicycle on the freeway. The bicycle doesn't swerve to avoid the car, it's more of the opposite. And through lot of outreach, a lot of discussion with pilots and captains. With a lot of safe come ups, which mean we had perfect traffic in safety. We however had comes up on lost vehicles, the ocean is an unforgiving place and we've had series of damages as we tried to push the envelope higher and higher. The enemy here is not so much wind, it's really sea stake. When the wind blows, 65 knots and above you get into fully developed sea stake with massive breaking waves. The vehicle is designed to roll, but if large breaking waves break onto the wing. This can damage the wing, and we had some instances of this especially in the Southern Ocean or North East Pacific in the winter. In those cases, the vehicle has enough redundancy to come back to the port even with a damaged wing. We always get the vehicles back, but we did suffer some damage. We had to work with NOAA to test a hurricane wind, with the goal to actually being able to sample in an environment with wind in excess of 100 knots. That's the current pursuit, so stay tuned if you're interested in those extreme environments. On that note, the testing redeemed here is to test on the field and not in simulation. So you might have read that we recently completed the first Ivor circumnavigation non-stop of Antarctica. That was 198 days with 3 Saildrones over at Antarctica, as you all know that these are one of the toughest conditions on the planet. That's how we are really testing these platforms and I am glad to report that the sense of the vehicle made it. We learned a lot there from an engineering perspective, how to find tune a solution. The vehicle we lost in a super typhoon in Youtoo [43:10] operating near the tropical waters of Japan. Typhoon was forecast to go North, but went West instead and unfortunately the vehicle sank due to collision with an submerged object during the typhoon. We lost another one in the Southern Ocean, as we tried to do waves around the Southern Ocean. It got in a case in a rapidly advancing ice in the Southern Atlantic portion, that vehicle was also lost. When we lose vehicles like this, it’s because we try to push the boundaries of what are possible. Then we try to improvise engineering lessons and come up with lessons for safe operations future. (44:03)

Okay great, Thanks Sebastian. Another question came from Neil from NOAA. He asked about how many watts are needed to power our 12 plus sensors. I would be able to answer that one, I would say that depends on the sensors. You heard Matt said that the Norbit when it came in, requires about 65 watts of power. And so you would think the standard of 10 watt generation of power to run the typical metox [44:28] centrix on board of the Saildrone. Again if you are adding sensors with requirements of higher power you have to take a look at additional battery packs or potentially adjust your time of lengths that you are willing to have it out there.

Absolutely, just to add so there is no confusion with the audience. The 10 watts, that’s what we achieved for the code navigation. Since they are on the board computers, the medium link, kern configuration of what we call generation five which you saw on the images with the solar panels. They generate on average, 50 to 60 watts steady in sunny conditions. The answer is we do have some head room for the Met Ocean Street that you have seen displayed. We can carry an ADCAP or EKAT [45:23] and carry it for months, the multibeam was really pushing it. It was over the envelope but not by much, but by some. But the real challenge comes when you move this vehicle to upper area in the arctic, where the amount of available light is heavily reduced due to the incident angle and how cloudy it can be. So in those situations, we look at more power generation through other devices. One of which is a hydro generator that we’ve been fine-tuning over the years, which means that when it’s very windy you can transform the forward momentum of the vehicle into electrical power very efficiently. When there is no wind, you usually have sunny conditions and the solar panels do a great job and by variables of all of this. Yes, there’s a battery, but the battery is just a buffer for operation during very cloudy conditions and night time. The battery pack cannot provide power for 12 months of operation, so you need to budget the power in the worst way possible conditions which you need to operate from pole to pole. (46:43)

Alright, thanks for that. There are a couple questions here, regarding the positioning system and I think Matt got to that. Talking about the integrating positive ENV, with the multibeam, and also getting the data off the vessels. So right now, there’s no data coming off . As Matt talked about it's one of our things to work on, how do we portray the data that is being collected. In such a way that we are comfortable we’re meeting our standards for data coverage, in the health status in the sonar itself and those types of things; that is a challenge certainly. Another question was, is there data redundancy on board? So Matt, I would ask you maybe you can talk about both the data redundancy and what you deal with on board from a hard drive space and things.

Right so, as far as redundancy currently there is no data redundancy. At least on this first system, we intend to fix that in our next iteration of the system. This was a proof of concept, can we get it to work? Again, that is one of our challenges dealing with the data itself. We have plenty of hard drive space on board, but that's not an issue. But it was difficult when we downloaded all of the data over the ethernet connection that we have, it took several hours to download the data, to get it uploaded and make sure you get it to post processing. Again, those are some things that are being worked on; some more high speed data throughput connection. Some more ways to get that data off the QC analysis done while we are in the field, to make sure we are meeting all the requirements for density of sounding coverage, and the lights. Norbit has been a great partner with that and their data collection tool is hopefully going to help us with the way forward with that. (48:42)

I think for the audience here, it is important to realize the long arc of autonomous technology. The long arc, as long as you all know we are moving to 5G. We are moving to 5G from space, we're looking at massive new constellation coming on board and I want to reference this with one example. Currently the infiltration of the pipe that Matt references is iridium, it is equivalent to a 1980s modem. There's no way you can get multibeam data through that pipe, maybe a low rev surface. We are now working with iridium, a new protocol called "iridium next" and tweaking in developing your own files streaming rigitherm. We have been able in experimental test to multiple the band width by 225x. You can see from the engineering perspective there is a lot of enthusiasm about what is about to be possible with those next generation satellites that are being launched. They are really part of the system right, it is a unique time in our history that we are able to get such a huge advantage band width. It is a constant game between how much do you process on the vehicle and how much do you send back to shore. But the underline parameters in the enabling technologies are evolving very fast. (49:56)

We have another good question on the vertical reference system, essentially a reference survey that we will be working with. Mostly in remote areas such as the arctic, in regards to the arctic. We have a question regarding, what do you have to worry about when you're working near the ice edge. Since you have been working up there, maybe Sebastian you can give us some of your thoughts on the challenges of working right next to the ice.

Yes, it is a massive challenge. The ice edge is [50:37] that is exposed to the atmosphere for the first time, in I guess millions of years. The ice edge is very hard to track, the satellite products that are available are out of date because they can be days old. The ice ridge that flows can extend to a hundred, thousands of miles and very hard to predict in a very dynamic environment. The first year of operation with NOAA was a very crude method. If we sailed north, we would look at all the ice desk products. We would estimate where all the ice was and we would look for the signals. The signals typically can include a drop in salinity and water temperature. We are looking for those kinds of signals and try to devise alerts, but those signals are not always reliable. Recently what we have embarked on is a vision bass machine learning system, which can take the sensor from the onboard cameras and detect the ice visually. Then process frames using machine learning to recognize where the ice edge is and take corrective action. That's in development - in the past though, we just made the vehicle robust enough to be able to hit the ice without damage. Looking carefully at the conditions, so many of the pictures that you have seen that have been displayed during the presentation are vehicles which scraped the ice edge. Took some amazing photos and then kind of sailed backwards. That's one of the great things about the Saildrones, they can sail both forwards and backwards. So we can get outside of sticky situations there and really touch the ice and go. We spend about 45 days doing this back and forth, touching the ice edge and sampling five miles away and then coming back. But it has been very crude, it's evolving towards machine learning. The challenge in machine learning as you all know it's lack in training data, so there is no way you can decide to develop this algorithm without having hundreds and thousands of images of the ice edge across multiple lighting conditions and angles. And each Saildrone has four cameras that take pictures every few minutes, so we have been busy collecting this training datas. We are expecting big strides in ice recognition, it is a much bigger problem in the Southern Ocean. Because over there we actually hit an iceberg during the second navigation, way further north than what we expected or that anyone expected. It turned out the iceberg was five miles long, it was highly visible to space. So goes to show, you can never be too careful. The vehicle survived the collision and continued the second navigation. But these are very different problems because detecting an iceberg doesn't give you any alerts, it's just there. A lot of challenges to resolve, but ice is definitely challenging. (53:33)

Thanks Sebastian. Interesting question on, do you have any mitigation strategies for your vehicles with respect to marine mammals, feeding, mating and social communication when you have these sonars on board?
Very good question, it's very interesting. This is the beginning of this, the sonar that we use are very low power sonar. Like the EDAK [54:06] from Simrad is less of an issue. As we progress towards a higher power biometrics solution, it definitely becomes relevant. But this is where our work with machine learning camera recognition comes into play. This system which now moves the camera to the wing tip, enables us to detect anything on the surface. Whether they are marine mammals nearby and birds even in the sky, we can not only detect this but also quantify. This is equivalent for a look out essentially, we have available at all times including the human operators in mission control. We are developing those come ups, the goal is to define a safe operation as safe as possible. Following the guidelines that NOAA is using for their own ship base operation. (55:00)

Great, a question for RDML Shep Smith. Let's give Sebastian a break, to drink some water. The question comes from Ross from NGA, if NOAA created a creative a strategic employment use plan or an operational use plan for concept? Specifically for the use of the Saildrones.

We are building into that, we haven't really mentioned it here. We have four Saildrones under contract to NOAA. On their way to the arctic right now, equipped with single beam systems. Part of our goal there is to build experience with mission planning, project execution, and data delivery etc. Sort of mission planning it remote in a difficult environment with those systems. We are hoping and expecting, these multibeam systems will be available to us for years and years ahead. There are still a few glitches that they are working on, but it is going very well. When that capability comes online, we do have some plans with this technology that would be appropriate to help with. I am not sure what's being really stressed enough, but unlike some autonomous surface vessels - these Saildrones are not for sale. They are essentially a platform for lease and so, we can access Saildrone technology through our survey contractors or directly contract through Saildrone. That's basically directly where we are heading and we are thinking primarily about arctic applications right now because it's a gigantic problem and because the collision avoidance is less of a problem than open waters like that. (57:09)

Great, thank you RDML. Couple other questions out there, we have comments that Dr. David Wells mentioned that the logistics for the 72 ft deep water model is more likely to be complicated. I would say that's a yes. We also had a question on, what will be for EM304 that's on there. Is that a two degree by two degree system that's on board? So I don't know if you have the specifics to that, Sebastian?

It's a one by two degree. Comes by a EM304 system, it's been really designed to be a set up that's equivalent to a research vessel: to reach areas that are too far, too deep or too expensive. So the primary goal there is seabed 2030, a connective objective of mapping remote areas. Of course, you know the search for Malaysian Airlines flight comes to mind, the challenges operationally. The mind assets that where the up era is far upshore that it is very challenging, so this is a device or solution that builds with that because it uses no fuel. It can survey for a very long, very period of time before it comes to shore. It does have something more complex logistics in and different price point obviously. But it uses the exact same principles, you know [*indecipherable* 58:45] profile. On board processes that are being developed, so all those projects feed onto each other. For those who are interested, we can connect offline on the specificity. It has the same kil depth, so it can operate in the same waters in the 2040s - also a very capable system. It is a different approach but really the purpose there is the deep ocean, the symmetry to try to make seabed 2030 like a goal of mapping the whole world in 10 years as a possibility to come up. (59:21)

Excellent. For Matt, you mentioned trying to get a better life out of the Bellport. There was a question, are you working directly with Bellport? Or are you looking at a different sensor on extending that battery life?

So right now we are having discussions with Bellport, I can't really say too much about it. But I had a few discussions with them, we are also looking at our own solution. But that's all I can really say about that.

Thank you. We have a couple of questions on the comm system, are we looking at the new technologies? And I think for all of us in the unmanned vessel business, we're all looking at starlink at the other lower orbit constellations that are coming online as potential compath for us to use. But we are still pretty early on that, that is something we are still investigating down at USM at one of our other projects. But yes, we are considering those and it's still early days. I think with respect to how those will operate and what the requirements would be. Sharon from ESI is asking questions about the sensor, the netox sensors that are onboard on this particular platform and were they all according to the Saildrone NOAA crater. Is that data even out testing, is this going back out via GTS to support the model?

Very good question, I am glad that you asked this. The short answer is yes, under our crater with NOAA. All the vehicles are currently broadcast subsets of the ocean data onto the GTS via NBC broadcasting point of NOAA in Bedford Format and they each have a [*indecipherable* 1:01:14] ID. It's only a subset, the buffer template for the house specialist here, that is currently being used is the drifting bowie. If you see a drifting bowie GTS, that's moving quite fast - that is a Saildrone if you click it on it. But the WMO working group at the opening GTS project led by Kevin and Brian at NOAA had developed a USB buffer format that would be switching to shortly. Working with models around the world to the best leverage, what would be called commodity answer data if you want. Given the prime mission here would be the symmetry, how can you best leverage the data that could be collected using those platforms? If you are interested in some of those data or if you really want to dive into the data, it is available CDF format - both on the NOAA archive and PELM [1:02:06], as well as various specialized archive like socat for carbon, IC for EK80, EMUD in Europe, Podcast or Saildrone.com.

Great. How important are the ocean currents for mission control and could the Saildrone operate a ADCB and multibeam simultaneously? I'll also add we had some questions on how do you actually operate and manage all these Saildrones? How many operators are watching each one?

Again, very good question. I mean ocean currents are critical to the navigation of the Saildrones is the answer. In many cases, they can be very powerful and western boundaries current conditions and others. We track those very closely in two ways: first of all, the Saildrone itself can independently navigate without a human intervention from wave point to wave point taking currents and wind into consideration. An operator creates a corridor in between two wave points, the vehicle aims for the next wave point and if the current or the wind pulls it to the side of the corridor - it will automatically attack the other side. So that way it stays within the safety corridor between the two wave points. It doesn't even need to measure the currents, it just feeds the effect of current and navigation terms. In terms of measuring the effect of the currents, the standard Saildrone configuration is an ADCP, we currently use a teledyne workhorse monitor 300 kilohertz that is mounted on all the vehicles. However, when we are looking at high power applications like the multibeam - we swap the ADCP for this. The keyrail, which is modular is not big enough to accommodate both units and the power is certainly not available for both. It is actually a different way of thinking, it's much cheaper and easier than just to put on the second vehicle with an ADCP in the same era. If you want to also get kerns, then to cram as much sense into one vehicle. The cost is not the vehicle itself, the cost is the infrastructure. This is why we came into conduction like the one that Matt described earlier, that if you need a big winch on the Saildrone. Don't try to put everything into one vehicle, rather use a fleet. The fleet is very powerful because you can have slightly different configurations on certain vehicles. Left alone if you have the two then need to worry about two acoustic synchronization and interference, which would be a whole new problem in itself. Right now, we are tracking on the horizon new phased array type devices. That can combine various functions, acoustic functions, we hope that would be some of the future. But that is leading edge, at the moment we try to rely on trusted single use sensors and if we need two different measurements - we will use two Saildrones. The ratio of operators per Saildrones are a single operator can manage up to 50 vehicles globally. We have watches, 24/7 on mission control and food redundancy. It is a dual system, the user has a mission control panel which is a secure web application. That's why Brian's team would have for example, able to track the location of the vehicle and see the data in real time and mission control has master control where they are the only ones able to send commands to the vehicle. If I use the one to send commands, they send waypoints. The waypoints are actually sent to mission control, who checks them for safety and making sure to not go over rocks on the beach then send them to the vehicles. That's really how we manage safety, but there is a high level of automation. Our goal is to have about a 1,000 units - we have about 100 right now and it scales extremely well with the amount of operators. It's only when you get to extreme precise piloting for very new shore applications that you need to increase that ratio. But for deep ocean application, the system is very atomistic. (1:06:32)

What is the cost comparison of a Saildrone to a ship? What is the business case for doing this? RDML Smith, maybe you can speak further into this. However we are still trying to figure this out. For Saildrone as a business proposition to be profitable and also affordable for the community to be used.

There is certainly a lot of potential for this to be a game changer for the cause. I think the data that you have seen here all today, is basically all the data there is. For multibeam mapping, we are interested in more prolonged deployment in a real operational setting in order to be able to assess the real endgame efficiency will be. This project has been really about being able to do something comparable to a ship by having a multibeam on board. That's a huge step, I think it's very promising but we are just going to have to get the experience over the next couple of years to be able to get a comparison that are apples to apples.

From a Saildrones perspective, the company was started in order to accelerate science by using new technologies - that was the mission of the company. We are really building on the shoulders of the giants, you know the building on cloud infrastructure for extreme hughes. We are building on advance materials, we building on microcomponents that come from the cellphone industry. Battery technology from autonomous cars, GPU from video games. There's a lot of technology that we are bringing to the fort with the goal of decreasing the costs. For us, I can only talk about what has been done vs what is being done. The symmetry is still very new, the new senses are very different and I am not going to talk about pricing there. But otherwise our pricing is public, it's published on New York Times for MET Oceans. Saildrones are $2500 a day for operation anywhere in the world. That price point is extremely cost efficient because of the technology scale, the goal is to enable new things that were not possible before. The goal here is to not compete with ships, to replace ships, but the goal is to augment the observing system which we all know is way too far into the ocean to understand find scale phenomenon. That's the overall goal, the cost production whether it's the small Saildrone or the large Saildrone is really basic math. You take a specific capability, you look at the data and the product that you are trying to get. Then you remove the human crew, all the support system, you remove the engine, remove the fuels, remove the consumables. You are then left with is the sensors and whatever is necessarily to run the sensors. Then you keep all the staff on shore, nice and cozy out of harm's way for those missions. That enables a new mode of operation - so that's really the goal. What we see for you to do, is to think beyond those goals and to see what can be done with fleets that was not possible before. We just finished with NOAA, an anatomic eureka campaign in the Carribean. Where a rays of Saildrone carry ADCP were able to do three dimensional mapping of the boundary layer acoustically because trying to get two ships by ADCP is very expensive. But getting six Saildrones to do that in lines is totally doable. So there are new cases, where we are always amazed by what our users always come up with distributing infrastructure.

Great, thanks for that. Folks are asking, how many Saildrones do you have operating?

We have 100 small USV, which are 23 ft that we have been discussing and one medium USV which is 72 ft. At the moment, due to Covid we have less Saildrones in the water than we originally planned. Mostly because most of the campaign are related to man-assets interaction with planes and ships, which unfortunately aren't able to happen. However, we have been launching mission after mission and right now we have about 25 Saildrones in mission. In the arctic, Pacfic, in the Atlantic, and Mediterranean Sea. Very proud to have been constantly launching missions during this Covid timeline. It's one of the realisations that you can do signs remotely during trine time that we are all experiencing. (1:12:24)

Great. I want to thank everyone. There are other questions out there, but we are not going to be able to get to. But you can reach out to me, with any of those questions and I will try to get those questions answered for you. But I really want to thank everyone for joining us today. I think it's been an enlightening look at this project that we are very proud to be working with NOAA and Saildrone from a USM perspective to accomplish this. It's a precursor of many things to come, I think when it comes to these robotic vessels collecting data for us. In the areas where its very difficult to get a ship to get to or you want to be able to throw many assets as you can because of the environmental finishes especially the arctics where [icefree 1:13:18] amount of time. With that I'm going to offer it up to RMDL Shep Smith for any closing words from you, Sir.

I just wanted to thank everyone for coming, we peaked a little between 200-250 people. Quite a few people stuck through to the end and a lot of great questions. Really great turnout, I am just really excited about this technology and to see what's next. Thank Sebastian, Matt and Brian for all the hard work of making this happen in the course of the last few years. So thank you.

Thank you very much RDML, Sebastian?

Likewise? I would just like to say what Matt Paulson said, thank you for NOAA's leadership and getting those projects started. Collaboration of University of Southern Mississippi, this would not be possible without hundreds of people who collaborated on this project. A lot of credit, where a lot of credit is due. And we share the excitement around the emerging of these RND phases. Crossing towards operational outcomes, where this is really what it’s about.

Thanks. Before we go, thank Jill and Christian from NOAA who setted up this webinar. With that, we will bid you out farewell. Have a great weekend and a great world Hydrography Day on Sunday!