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Sean Dooley Nautilus Underwater Systems

Chairman— Martin Redmayne

Good afternoon everyone. Post lunch session—we'll try and bring in an interesting subject, a subject which is very specific to people who are involved in the world underwater. Sean Dooley I've known for a few years and John Aune I've known for a few but not as many. Both are involved in the world of the submarine from a manufacturers' point of view and the flag state of view and are going to talk to you about the burgeoning development of these private subs, which I think are quite incredible but also quite scary in some cases, not necessarily what Sean is doing but there are submarines out there that I would be loath to go anywhere in my bath with.

Sean, do you want to take the stage so we can get on track. We're slightly behind schedule. Sean Dooley, thank you.

Sean Dooley Nautilus Underwater Systems

Good afternoon. We do have some small issues so hopefully they won't be too distracting. There's been a lot of buzz about submarines in the last year or so but also a lot of misinformation and false reports. If all the stories were true there would be 100 submarines under construction or already on yachts. The reality is that there are only a handful but the specialised sector continues to evolve.

So what are we talking about when we say a yacht submarine. Let's start with what it's not. A sub is not a water toy or something that is simply added to the yacht on short notice. There is a high degree of planning and training required but sometimes we run across owners that have a very different idea of what their yacht submarine is going to look like. The reality is, incorporating a submarine on a yacht is similar to incorporating helicopter operations. A submarine, like a helicopter, is a highly specialised machine that excels in a unique environment. It requires specialised crew and follows strict operational and maintenance guidelines. Just as the deckhand does not fly the helicopter, likewise with the yacht submarine. So what are we talking about when we say a yacht submarine? Well today's yachts are larger and more self sufficient. They have more room to accommodate specialised crew and submarines offer owners a new type of adventure, and obviously this is still yachting, with each owner wanting to make their yacht special. Let's start with a basic definition of a yacht submarine. It has to be one-atmosphere, which means the same environmental conditions as us sitting here. The passengers are dry, and not subjected to any dive pressures. They can stay down for hours and immediately come to the surface and exit the sub. It should be autonomous—meaning the sub is free swimming and therefore self sufficient in propulsion, power and safety. It is also private, built specifically for one person to their specifications. The application could be for treasure hunting, wreck exploration, diving, sightseeing or all the above. Today we'll look at three aspects concerning subs on yachts. The design, the safety and the

yacht operations. A basic way to design is the crucial blueprint and the most important stage as it defines all parameters and components in the submarine. It provides the engineering information which ensures the sub will be compliant, operate efficiently and will ultimately be fully compatible with the yacht. Most discussions begin with the owner asking for a certain number of passengers. A required amount of interior air space is therefore specified and that needs to be counterbalanced with weight, therefore a simple formula that we use is $\text{passengers} = \text{space} = \text{weight}$. Using the basic design we also then know the final dry and wet weight of the submarine. And knowing this weight allows us to properly calculate the lifting points on the sub, both for single and double positions and finally defines the amount of total power necessary to meet the maximum required speed as well as provide life support. And as you can see when a basic way to design is calculated and executed properly the results can be seen—this is off a single point and it's pretty perfectly balanced.

Compliance is obviously a very important issue in yachting today. Submarines need to be compliant both in their own design as well as meeting the compliance requirements of the yacht. For a sub to be used on a yacht without issue we recommend the following:-

Class approval: When a submarine is class approved it means the design was reviewed and approved by an experienced, knowledgeable third party authority. Class approval also ensures that construction of the sub was monitored at key stages by that same outside authority; Cayman Island compliance: many of the yachts currently working with submarines today are registered with them. And lastly—United States Coastguard compliance, if the sub is to operate in US waters.

The most important issue we consider when designing and building a submarine is safety. Our worst possible scenario is to have anyone hurt or killed. Generally speaking we ensure the sub has adequate power, speed and manoeuvrability, fire fighting capability, integrated emergency systems, navigation, communication and tracking. Subs are powered by electric batteries and therefore should have plenty of power to meet all sub operations, maximum mission times as well as the 96 hours of prescribed life support. The speed of a sub should have a minimum of 3 knots to make headway against currents or return to port under its own power without surfacing and the manoeuvrability of a sub is essential to negotiate obstacles and avoid potential underwater entanglements.

The primary reason for a submarine is to go underwater and see things. Submarine optics are quite often overlooked and unfortunately this subject is identified too late at generally a high cost. Spherical optics are common but they do produce a very distinct distortion which can create safety and comfort issues. Distortion also affects distances and knowing how far away a shipwreck actually is can be the difference between getting close and getting entangled. The only method of eliminating all distortion is using flat optics. Both air and oxygen are used not only for breathing but also ballast and lock out operations and all these gases are pressurised. To deal with the possibility of fire the sub's suppression system needs to account for the fact that the occupants cannot immediately exit the submarine and therefore whatever system is used needs to be non toxic and breathable. For this reason most fire fighting systems are pressurised water. Submarines are designed to handle many of the difficult situations encountered underwater but the most difficult to plan against is the threat of entanglement. This can occur if the sub becomes stuck on the seabed, lodged under something or if a line entangles its props or hull. Several counter measures to handle this would be a jettisonable prop should the line be caught there, if that were not applicable the use of manipulators and/or line cutters would need to

be employed. Depending on the size of the sub there might be room for a remote operated vehicle and if none of those systems were effective a deployable buoy would be activated to lift the cable from the sub to the surface. The buoy does have a strobe and EPERM and preferably that cable would be rated to a degree to physically retrieve the sub using the yacht's windlass.

OK, let's move on to operations. Staffing for a sub programme on a yacht is very challenging as the type of personality and preferred skill set is not common. Our personal experiences in the last year looking for submarine crew has taught us a lot and now we look for a few key skills though they are not mandatory. Diving experience is nice but not crucial, as long as the person understands the theoretical. Medical is essential in the case of emergency, while the sub is diving or for treating diving issues if there is an associated accident. Navigation and/or piloting are preferred skills since they are used in both the operation of the sub and the surface tender. Bonus skills are site scan sonar, ROV operator, gas blender, cruise director, underwater photographer. Our latest strategy is we start them young and we keep them on staff for a long time. Tracking: knowing the location of the sub at all times is of paramount importance. The yacht should always know where the sub is and vice versa. Once at depth, submarines don't produce bubbles and they generally don't drag a dive flag behind them. Therefore the sub is constantly tracked using sonar. Many of these systems are three way, allowing both the tender and the yacht to simultaneously track one another. Equally important is communication between the yacht and the sub. Most systems allow for three way conversations between the yacht, sub and tender. This way both the yacht and the sub remain updated on the status of both surface traffic and the conditions underwater. The sub should have its own means of navigation, both on the surface and underwater. This ability to navigate and return under its own power to either the yacht or port is essential. And obviously the knowledge that the sub has this capability gives great comfort to passengers on board because they know that they are self sufficient.

Search and recovery is a written plan which details the rescue or assistance of the submarine should it become distressed or unable to surface of its own accord. Generally we often hear—how deep can your sub go? The reality is, even in the best visibility conditions sunlight penetrates to only 100 or 120 metres and then it becomes increasingly dark. We feel subs on yachts should be rated to a depth where divers can physically descend to the sub and visually inspect or assist. The US Navy diving manual tells us that the maximum depth for a mixed gas diver is 160 metres. Therefore the alternative for a sub that goes deeper is a completely redundant submarine or a sufficiently rated ROV. And the problem with systems like that is that they are mechanical versus the human interaction. Subs are heavy; we currently are building two that are just around 11,000 kilos. Both yachts are using double point lifting systems and that weight will be displaced between the two cranes. Much of the launch and retrieval solutions depend on the specific yacht and basically they can be side launched, they can be drive-in through the rear or they can be placed on the deck. Generally it depends on the clearance of the sub. This is one that's currently being launched out of the tender bays of a 74 metre. And auxiliary equipment to support the submarine would be the breathing gas production equipment for both air and oxygen, would be breathing gas storage to store that gas, a recompression chamber if the submarine is lockout capable and the battery chargers and ventilation for the submarine. And the conclusion—short and sweet—subs are safe as we design, build and use them. Thank you.

Martin

Sean thank you very much indeed. John?

John Kaare Aune Cayman Islands Shipping Registry

My name is John Aune; I work as senior surveyor (yachts) for the America's region for Cayman Islands Shipping Registry and the last couple of years I've also got involved with submersibles. The reason for that is the yacht owners want to have a new toy on board their big yachts. And because of that, basically, we consider—well, the submersible, because of the environment they're operating in, we consider the risk factor is so big that we also want to certify the ones that are operated purely for private use.

First of all the definition of a submersible, like Sean was saying, is a one-atmospheric submersible craft, and if they are launched, recovered, operated or supported from a Cayman Islands registered yacht they have to be certified. If they're going to be certified they also have to be classed by one of the class societies. Cayman Islands also offer to do certification against the IMO guidelines for passenger submersible craft that were published a couple of years back. Our regulations were developed back in the late 80s, beginning of the 90s. The reason why we got those regulations in place was because of passenger submersibles that started to operate in Cayman, basically taking cruise ship passengers on dives on the Cayman Wall down to a maximum of 1000 feet on the smaller ones and also you have the big passenger ones that take 40 passengers. But we didn't limit the application of the regulations to passenger submersibles only, we also included it for private use. They were originally based on the UK MCA regulations but we did not include that part of the UK MCA regulations where they actually exempt submersible craft for private use. And the Cayman regulations are applicable to both commercial and private submersible crafts.

Why do you want to be certified? The first reason is basically safety. It's the safety aspects—you have both class society look at the hull and construction part of it and then you have the flag state looking at the operational part of it and also safety equipment and navigational equipment. I also believe that it's going to help the submersible and the yacht if it should get dive permits from the different port or coastal states. If you turn up in a different country than where your yacht is registered you need to ask for a permit basically from that country to be able to start doing dive operations, and it would be a lot easier for that port state to be able to grant the permit if you can actually show a document to them that you meet some international requirements.

I'm also going to go through some of the Cayman Islands requirements but I'm basically going to highlight the ones that differ from the regular class requirements because that's your base level, the class requirements. Then you have the additional requirements that we impose.

We've got two sets of regulations, the construction and equipment regulations for submersibles and then we've got the operational regulations. They cover things such as hull and power, which is normally delegated to class but basically it's best if I said it needs to be built to class; it covers items such as control and stability of the submersible. We specify also that you need to have an alarm and an interlock system to prevent descent of the submersible when the hatch is open. We also specify requirements regarding the release of manipulators etc that can be entangled. The biggest difference from the class rules is probably our requirements for life support systems. Most class rules only specify 72 hours emergency life support. However the Cayman regulations specify 96 hours emergency life support so that's in addition to the life support system for your normal dive operation if the

submersible craft is being operated in water where the chartered depth is more than 50metres. For other areas you only need to have 72 hours emergency support. We also specify items such as emergency supplies of food and water, they need to have medical stores on board, thermal protection and fire extinguishing systems. Regarding communications, like Sean was mentioning, they often go for a system where they can speak both to the yacht and to the dive operations vessel. For us it's a requirement that they can communicate with the dive operation manager and that they have two systems, basically so they can operate on both main and emergency system. And also that the range of the system is twice the max operating depth. So if you have a submersible that's going to be rated for 2000 feet your communications system has to have a range of 4000 feet.

Another item there is navigation and position indication. You need to have a compass, depth sounder, two independent depth gauges in case one fails, then you've always got another one and can check and see if you have an error basically between the two. You've got a highly visible colour so that other vessels can see the submersible when it has submerged, heel and trim indicators for the pilot and a sonic location device so that they can ping you basically from the surface. This is all to assist the pilot so that he can safely navigate and operate the submersible. Also we've got requirements regarding the launch and recovery system. Basically the crane fitted on board the parent craft has to be fit for purpose. And we also look at, if a submersible has a lock out arrangement there's additional requirements for that because of the complexity of having such a system on board.

That was basically the technical regulations that we have. But we also have a set of regulations for the operation of the submersible. That's actually something that we pay quite a lot of attention to both in the initial approval process but also during the annual surveys when we go on board to verify that the submersible is actually operated in accordance with both the requirements and also the stated procedures on board. Those regulations place the responsibility for the operation of the submersible on the owner and the master of the parent craft. They can of course delegate it and if they do so they also need to have a chain of command basically specifying who is in charge of the different aspects of the operation of the submersible. They need to have an operations manual that includes procedures for everything from communications to their contingency plan and emergency procedures. That's something that they submit to us—basically we go through it, we review it and give our comments back to them and tell them if it's acceptable or not. That's also something that on most of these yachts that have a submersible on board, they're fairly big so over 500 they have an ISM system implemented on board and this operations manual needs to be tied into the safety management system.

We also look at training—we've got requirements for the training of the pilots and the operations controller, the persons that are assisting basically from the surface. Normally the manufacturer of the submersible has been providing this training but it's also up to the owner basically to get consultants from elsewhere to do the training of his pilots as well. Again, it's something—they send us a syllabus of the training programme which we review and say whether it's acceptable or not. Log keeping—they need to keep logs on board both for the dives that the submersible is carrying out but also the pilots. The pilots need to keep their own logs. They need to document how many dives they've been doing, what's happened during the dives, etc. Planned maintenance maintenance is extremely important on these submersibles—if the systems fail then it can have catastrophic results. So maintenance is important. Also to have qualified people to carry out the maintenance on board. Contingency plans they need to have on board; they need to have

procedures for that, procedures for reporting to port or coastal authorities to obtain the permits to actually dive in different places. They need to have their emergency procedures in place if something happens, back up systems like an ROV or other means of being able to recover the submersible. Casualty and injury reporting as well if something happens the owner or the master have to actually inform the shipping registry and also other parties, port states etc about any casualties.

That's basically the Cayman requirements. Also a few years back the IMO actually published a set of guidelines for passenger submersible crafts. And those were developed to provide international standards. And the intention of it is to facilitate international movement and acceptance and safe operation. It's easy for another flag or another port state if you can show them a document showing compliance with the IMO guidelines then they can easily obtain those guidelines and know exactly what you've been certified against. The main difference from Cayman regulations is really a design and construction document that's required under the IMO guidelines. It lists all the standards that have been used in the design and construction of the main components of the submersible—view ports, piping, electrical systems and the life support. And fairly soon actually the Cayman regulations will be updated as well to include those requirements so that's going to be more or less the same but in a year's time.

Certification? Hopefully we're being contacted at the time of the contract; people inform us about it so we can take part and inform both the designer and owner and the manufacturing facility about the requirements. We then attend during construction or towards the end of construction to verify that they've got the equipment—safety equipment, navigational equipment, we leave all the hull design, all the structural strength etc to class. Normally what we then do, just before launch we attend and verify that everything is in order, we issue them a short term certificate, an interim certificate, in order for the submersible to be brought on board the parent craft, the yacht. So they can start training the pilots and other crew members, and then we attend on board after a couple of months, before they start taking passengers we attend on board to do the final survey, to look at the launch recovery systems, to attend on the maximum depth dive to see that all the equipment is working and also to verify that it's being operated in accordance with the manuals and that they keep the correct logs etc. We then would normally issue a two year certificate to the submersible and then with an intermediate survey so you can basically say that there's annual surveys for the submersible. And the annual survey would always include a dive to the maximum operational depth. Other than that the points I'd like to make is that there is a need to have specialist crew on board. This isn't your regular toy, this isn't a wave runner, like Sean was saying as well—you need to have people with the correct background that know how to do maintenance on these submersibles. People should also take into consideration the design implications on the parent vessel, on the yacht, because depending on if the submersible is being launched with personnel inside it or not, it can have quite a few implications on the launch and recovery system. So the cranes sometimes have to be updated and there's other safety factors involved with a submersible than what you would have on a regular tender. Also you have the oxygen plant and the storage of oxygen bottles. Because of the explosion danger attention needs to be paid as to where you're going to store that type of equipment.

What I'll also take the opportunity to show you is a couple of the projects that we've been working on over the last couple of years. One here that I unfortunately can't show you a picture of but it's an 8 passenger two pilot submersible that's been launched recently; it's rated for over 1,000 feet, between 1,000 and 1,500 feet. We

also have had in Cayman for several years a 40 passenger two pilot submersible rated for 110 feet, operates on the Cayman Wall year round, taking cruise ship passengers. This is a submersible that was launched about 6 months ago; it's built in Vancouver by a company there; it's a 2 person submersible, it's actually individual pressure hulls, it's got a rated depth of 2,000 feet; one pilot one passenger but you can actually split it, you can split it on two separate frames and operate it as two individual submersibles, both of them having all the operations equipment and they can be used as two separate submersibles. We've also got a submersible here being built by US Submarines in Florida—it's called a Triton 1000, it's got a rated depth of 1000 feet, one pilot one passenger, the pressure hull is a full acrylic sphere so you've got a very good view. And it's under construction at the moment; I just got that picture on your left—that's only from last week, I think. They're ready to launch it later this month and hopefully have it operational just after or before Christmas. That's actually going on a yacht that was delivered a couple of months back, the latest delivery from Trinity Yachts and it will probably be the first yacht/submarine package that will be available for charter. They're getting full certification so they're going to charter out both the yacht and the submersible. We've also been working a bit with a company called SEAmagine—they've been selling submersibles for quite a few years for tourist industry but also research. They have several different ones, their rated depth is from 500 to 3,000 feet, one pilot, one to two passengers; they've got a couple operating in Cayman where you actually have the pilot in scuba gear operating it from outside, it's limited to 80 feet I believe. And the same thing here where the pressure hull is a full acrylic sphere. These are some old ones of the Paris submarines PC12 series—they used to have two that operated in Cayman, been laid up for the last year but there's talk about recommissioning them again. This is actually a picture of the Cayman Wall taken from one of those on a manual survey from one of those Paris submarines so there is stuff to look at at 1,000 feet as well. There are quite a lot of different things to look at. Thank you.

Martin

John, thank you. OK we have 10 minutes for a few questions. These are what I call shorter snapshot sessions and really it's a couple of people describing the market as it is with technology. And then you guys ask the questions of Sean or John. Any questions from the floor? I've got one little question—Sean, are there people available to drive these things?

Sean

Yes.

John Munford John Munford Design

My question is—you mentioned that you actually train staff to run the submersibles and they take up space, so first of all you've got the real estate of its docking station plus you have what—two crew members that look after the boat? So

Martin

Can you put the microphone closer to your mouth, please John. As if you're singing karaoke. Remember that?

John

Not recently!

Sean

Is your question how many crew are needed to run the submersible on the yacht?

John

How many crew and how much accommodation space because obviously if you're running various toys on the boat, you're running things like helicopters and so on, you need pilot spaces, so apart from your own present yacht crew how much space does the whole thing take up?

Sean

In my experience on the projects that we're doing now they have dedicated cabins for 4 dedicated crew. They intend to have a fairly active diving programme so that's a normal allotment in I guess the total complement of the crew. We're doing a 74 metre and they have 3 full time diving department personnel. So the 3 run everything in the dive department including the submarine and I guess they have cabin space for themselves, but they're part of the full crew. But for us the important thing is that they're dedicated diving crew, they're not a sous chef that dives.

Martin

Is it possible for those guys to fly in and fly out as you need them?

Sean

Totally.

Martin

Do you provide those guys?

Sean

The reality is that the people we're dealing with right now want to dive, they're experienced, they know what they want to do, they don't want rotational crew because they want to dive 7 days a week when they're on board. But there are people that certainly have experience, both with submarines and diving; we've been doing it for years. But yes, the boats have to accommodate them just like the helicopter pilot. But I think they're going to be on board more often than the pilot—well the ones we're dealing with for sure. The one we're dealing with also has a helicopter so does that answer your question?

John

Can I ask the second part, which is launching the boat, you showed it coming from the shell door. And can you launch it say for instance from under the boat, or can you make like a moon pool or have a sort of—

Sean

We love James Bond. I love moon pools but we haven't been able to convince anybody yet. A moon pool is actually, for a lot of reasons, from a diving perspective, preferable because the most obvious is that it's an environmentally controlled area so if you've ever been standing around in your dive gear waiting for something, sweating to death, and then when you jump in the water it's—you know you almost pass out when it's cold water etc. But moon pools are environmentally controlled and they can actually eliminate a lot of wave action depending on where they're placed on the boat. So from a diving perspective whether it's scuba diving or submarine diving I would have to say that that's the best scenario. But it's fallen on deaf ears.

Martin

Is it a cost issue, construction of a moon pool?

Sean

I don't think so. I've seen a lot of boats, mostly research—I think it takes up a little bit more space than they're willing to give. Because an actual—I mean I'm not a naval architect but from the ones I've seen—a true moon pool will go through the decks up so there's no air entrapment, because if it's a room then it's a pressure vessel and it gets complicated. But I think moon pools are great. Boats are getting bigger and I bet we're going to see one in the next year or two, at least the design. But most of them now, the ones that we're dealing with, are just tender launched, which come out of the side, with a two point lift. The ones we build are maximum heights 2.5 metres so it fits generally in those spaces.

Martin

Any comment John?

John

We actually see different systems. You get normal ones where it's launched from deck with a deck crane, I've seen moon pool systems but not on a yacht, but on offshore dive vessels, normally then with an ROV not with a manned submersible. But we've also got yachts where they actually flood the compartment where the submersible is stored and the submersible floats out basically in the whole opening as well. So you can do everything as long as you design it correctly.

Sean

I'm going to jump in real quick here—that's all accurate but the other thing that also you guys have—you can either launch it manned or unmanned so preferably in my situation it's unmanned because you're not in a machine that's getting launched over the railing of a vessel with whatever might happen, so if the submarine is able to be launched unmanned and then loaded while it's in the water, generally I think most people would prefer that. But some submersibles aren't able to get rated for that so they have to be launched manned. Newco is one of those.

John

And it brings up the cost of the crane as well of the launching appliance a lot. It's a lot more complicated, cranes, higher safety factors, and other issues as well. So

preferably if you can launch it unmanned and then you have passengers and crew enter the submersible in the water.

Martin

Any more hands out there? At the back, thank you.

Lucia Bedano Fincantieri Yachts

What about the technical requirements of the compartment where the submarine will be stored? I mean, explosion proof, and anything else?

John

Basically what you need to look at there is if you're going to keep the oxygen bottles on board the submarine or if you can take the bottles off and store them somewhere else. But if you do have the oxygen bottles on the submersible then the compartment needs to be rated. Normally what we look at is that you use the same requirements as for a compartment where you have petrol driven equipment, so you've got all your electrical appliances there rated to the relevant IP standard, you've got sufficient dedicated ventilation systems in place that don't pass through other compartments, and you've got additional fire fighting, you've got a drencher system, stuff like that, in case something actually happens. And oxygen sensors etc.

Lucia

Is this due to the oxygen bottles or due to the hydrogen of the batteries?

John

It's both, actually. You need to look at the battery storage as well, that's correct. But it's also the oxygen, with the explosion danger. But it depends on the battery system as well—if those are in completely sealed units and they're only opened on deck in an open environment then that's not a huge problem. If it's being worked on in a closed compartment that's also something that needs to be paid attention to.

Martin

Any final question, anyone?

Tork

I saw in the basic requirements navigation is more or less dealt with by a compass but are there more sophisticated systems that you actually normally fit on a superyacht submarine for underwater navigation?

Sean

Yes.

Tork

Tell me more.

Sean

Basically it's a lot of decommissioned ex military stuff, declassified. But essentially they use a lot of computers to extrapolate via dead reckoning; they'll take a position and generally it's within 2-3% which is pretty good.

Tork

Is that like an inertial navigation system?

Martin

Watch this space!

John

One thing that I was commenting on there as well is really only the additional requirements that we have, there are other requirements as well and you've got your sonar systems and all of that on most of them. It's more than what I was specifying there. If anyone's interested I've got the regulations with me and I can go through all of them if you want me to, but that's rather boring. But we do specify what type of navigational equipment you need, both for on surface and underwater.

Martin

So I think we'll wrap this session and move onto the glass. Thank you very much guys.
