Assembly instructions for the remote-controlled model submarine

--- SubMarine ---

https://www.modell-u-boote.de

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With GOOGLE-translate or a similar program you can easily have entire documents translated at once. Even the design drawings for the SubMarine can be translated as a whole and of course these assembly instructions as well.

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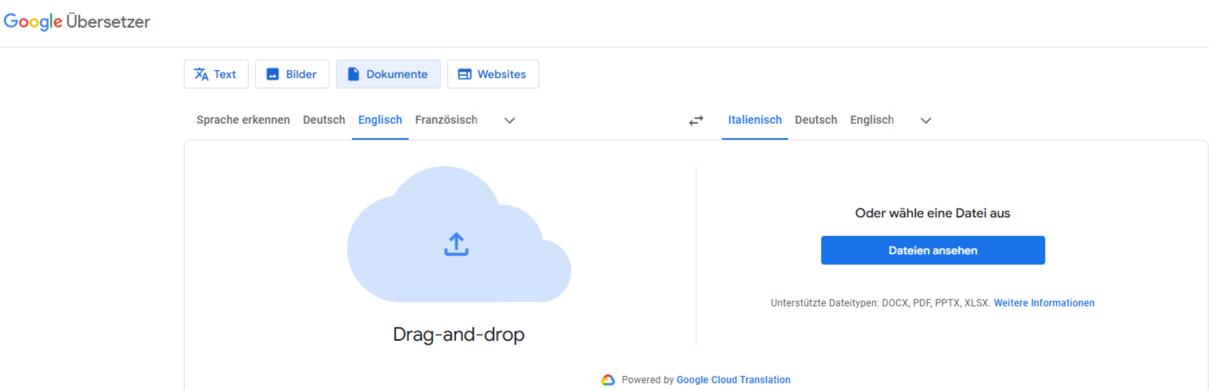

This English version of the assembly instruction is translated by GOOGLE-Translator and was not checked in every detail! The original text is in German language! For reference please take the German version. Also in the case you need a translation, better take the German version for reference and not this English one.

Some general tips and advice followed by building instructions. Please read at least to the beginning of the description of the building sequence on page 4 before you start building. This can save you a lot of time.

The STL and STEP files primarily serve to provide a better understanding of the parts, making them easier to manufacture. They can only be used directly for milling or 3D printing if no custom dimensions need to be applied in the construction drawings. If no CAD program is available to view them, a free online CAD viewer can be used (e.g., https://stpviewer.com - download at your own risk!; the same website also offers an STL viewer).

- When printing the drawings, ensure they are printed to scale; otherwise, you will end up with parts that are too small or too large. Some printers allow you to adjust the scaling very precisely via their software. Alternatively, PDF programs or browsers (e.g., Edge) often offer the option to print at "actual size" or apply a scaling function.

The quality of the 10 mm plywood used plays a crucial role in the boat's eventual strength. The prototype was built from poplar plywood. This wood is relatively soft and not very rigid. Therefore, I recommend using high-quality birch plywood (e.g., from model aircraft construction) or beech plywood.

The bonding of the wooden panels of the pressure vessel also influences its eventual strength and should therefore only be done with a long-curing two-component epoxy resin adhesive (e.g., UHU Plus Endfest 300). A long curing time is important to allow sufficient time for alignment and because these adhesives produce the strongest bonds. A small bead of adhesive in the inner corner of the joint is desirable where possible. Wood glue is only an alternative if the panels were machine-cut—meaning they have perfectly right-angled and straight cuts—and are pressed together for bonding.

Later tests in a hyperbaric chamber showed that the prototype, despite the use of poplar plywood, wood glue, and angled cuts (fret saw), could withstand an overpressure of 300 mbar, corresponding to a diving depth of 3 m. Higher pressures were not tested. Private pools rarely exceed 1.5 m in depth, public swimming pools about 2 m – only the diving area can be deeper. The city park lakes I'm familiar with are hardly deeper than 1–2 m, and here one usually stays near the shore and at depths where the boat is still visible. A diving depth of 3 m is therefore sufficient for most situations. Just a little more and radio communication can become problematic (the SubMarine has a shortened antenna!). Incidentally, the hyperbaric tests showed that the diving servo used in the prototype is only powerful enough to extend the diving pistons down to a depth of 1.3 m. Anyone wanting to dive deeper will need a more powerful servo; otherwise, resurfacing, at least statically, will be impossible.

- Always thoroughly remove dust from the wooden panels before gluing or any surface sanding. Brush them with a clean brush and, if necessary, blow them off with compressed air from a can. Always apply the adhesive to both sides and spread it evenly and in a sufficient layer thickness on the surfaces to be bonded.

To protect the wood from water, it needs to be varnished. Beforehand, however, sharp edges should be rounded off, panel joints smoothed, and the entire exterior surface sanded until a uniform finish is achieved. Any filling or sanding should be postponed. After thorough dusting, I would recommend marine varnish to protect the boat from water damage. For the subsequent coats, it's best to follow the manufacturer's instructions and use systems that specify a step-by-step process (e.g., primer with high dilution, intermediate coat with medium dilution, and topcoat undiluted). This creates a kind of impregnation of the wood surface. Careful intermediate sanding with 320-grit sandpaper is crucial to remove protruding wood fibers and create a well-adhering base for the subsequent coats.

After the intermediate coat of paint, you can use wood filler to repair imperfections. For larger repairs, a white wood filler can be used. For finer repairs, there are white nitrocellulose or alkyd resin fillers available, which are applied with a painter's spatula or Japanese spatula. Always test the compatibility of all products with each other to avoid unpleasant surprises. Usually, several sanding and filling applications are necessary until the result is satisfactory – however, this also depends heavily on personal preference.

After the filling is complete, the surface should be sanded again with 240-grit sandpaper (manufacturer's instructions naturally take precedence) and the final coat applied. Ideally, this should also be applied a second or even third time after an intermediate sanding. A soft (!) brush or, better yet, a small 50 mm foam roller is suitable for painting (you should have both on hand). Since boat varnish is generally transparent, a colored varnish must be applied as a final step. This can also be sprayed on from a can.

The interior of the boat should also be varnished with the same care to prevent water damage to the wood in case of water ingress.

At each stage of construction, you can consider whether you want to carry out some of the surface treatment at that point, as it might be more difficult later due to confined spaces or interfering attachments (which would make filling, sanding, or working with a foam roller more difficult). The interior of the boat, in particular, is naturally not so easy to paint once it's completely sealed and access is only possible through the end panel. The same applies to the stern section. Painting will still be possible, but anyone who wants to sand between coats will find it quite challenging.
Anyone who, based on these considerations, wishes to surface-treat individual panels or panel assemblies before further assembly should ensure that the areas of the panels to be glued later are left uncovered. This allows the adhesive to bond optimally directly to the wood. From today's perspective, I would only glue the front and both rear side panels to the pressure hull once it has been completely painted. I would only apply the final coat of paint after their assembly. Why? So that if water penetrates the front or rear side panels, it cannot spread into the pressure hull.

As an alternative to wood, polycarbonate (PC), as used for the hatch cover, or rigid PVC could certainly be used for the boat. Acrifix 192 would be a suitable adhesive for PC, for example (read the application instructions!). The advantage: plastic sheets are inherently waterproof and eliminate the tedious painting process with all its intermediate steps. On the SubMarine, after only a few uses, the paintwork on the central section of the pressure hull plates had cracked in many places. This was certainly due in part to my careless workmanship, but also to the choice of unsuitable paints. Therefore, in hindsight, I would use marine varnish next time.

If sheet materials other than those suggested here are to be used, their bondability and flexural strength must be taken into account. The poplar plywood used in the prototype has an average flexural strength of approximately 20 N/mm², and at best 40 N/mm². As already mentioned, this allowed the pressure hull of the SubMarine to withstand 300 mbar overpressure (corresponding to a water depth of 3 m) in a pressure chamber. This is a very good value. As a precaution, I would consider a flexural strength of 40 N/mm² as the minimum strength for a sheet material.

- To make sawing out the 10 mm and 5 mm boards easier, please see the drawing "01_Saegeschnitte_sparen".

- Construction drawings often specify ABS or PS plastic sheets as the material. ABS is preferable because it is the stronger and more robust material. However, PS can be used if ABS is unavailable.

- Great care must be taken to ensure a tight seal when gluing in all screws and bushings. On the prototype, leaks occurred at two screws and two glued seams that had cracked (white glue was used).

The Bible verses interspersed throughout the drawings speak for themselves. They are taken from various Bible translations, depending on which I found most understandable. If they resonate with you, simply pray about them and that you will find a good church community.

<u>A rough assembly sequence, listing only the most important steps and parts to be assembled </u>:

1) Fabricate a **diving servo mount**. **(Tauchservohalterung**)

2) **Base plate (drawings 1 + 2) (Bodenplatte)** Prepare the parts. Use the diving servo mount for marking only; do not glue it on yet. The 6 mm screws and spacer plates can be mounted later if you wish to perform a complete or partial surface treatment beforehand (e.g., impregnation, filling, sanding, painting).

3) **Rudder servo mount (Seitenruderservo-Halterung)** Including manufacturing the servo.

4) **Stern bulkhead (Heckspant)** Prepare the parts and glue them to the **base plate (drawings 1 and 2) Bodenplatte (Zeichnungen 1+2)**. The attachments can also be mounted after the surface has been treated.

5) Prepare both **side plates (2 drawings) (Seitenplatten)**. The openings for the immersion cells should also be provided at this stage.
Next come the screw holes. For this, you first drill the mounting holes in the handles of the immersion cell housings (see **" Immersion Cells " („Tauchzellen“)** – dimension Sa) and then use these as templates for drilling the holes in the side plates and the **immersion cell sealing plates (Tauchzellen-Dichtungsplatten)**. Theoretically, you could also stack everything on top of each other and drill it all at once.

Then the side panels can be attached to the base panel. and glued to the stern bulkhead. The diving cells and screws can also be mounted later, after the surfaces have been treated as desired.

6) Fabricate **the elevator servo mount (Tiefenruderservo-Halterung)** including the servo.

7) Fabrication of the **bow frame (Bugspant)** including the holes for the **elevator servo mount (Tiefenruderservo-Halterung)** and the rod guide. It is then glued to the base plate and side plates. **Insert nut (Einschlagmutter)** and **sealing washer (Dichtscheibe).** The **plastic tube (Kunststoffröhrchen)** for the rod guide can also be glued in place only after the boat's surface treatment. The T-nut is then simply pressed into the existing indentations, using a clamp if necessary, but not hammered in, as this could, in the worst case, loosen the glue holding the plywood panels together.

8) Fabricate **the front plate (Frontplatte)** and glue it to the boat hull. The deck mounting screw and the eyelet for the safety line can be added later, after the surface treatment is complete. The **diving plane bearings (Tiefenruderlager)** will be installed later, along with the **diving plane (Tiefenruder)** itself.

9) Surface treatment of the boat, either completely or at least in the interior and in the area of the diving system, both inside and out. The stern area is still missing here because the closure plate has to be glued in later, and the two stern side panels would be in the way.

The area of the base plate where the orientation lines for gluing the diving servo mount were drawn, and slightly beyond, should not yet be surface-treated to ensure optimal adhesion.

Overall, care should be taken to ensure that areas subjected to relatively high loads and where gluing will later take place are not yet surface-treated. This applies in particular to the areas where the cover plate will be glued, but also to the holes for the screws.
The area of the diving cell sealing plates, however, can be completely finished, as can the rear bulkhead, both inside and out (except for the top edge). For the area where the T-nut is located, the surface treatment will be postponed, or the T-nut will be glued in place before the surface treatment.

10) Now, in principle, the complete **diving system (Tauchsystem),** including **the diving servo mount (Tauchservohalterung)** and servo, can be installed. See also all other **diving… (Tauch…) drawings**.
The diving servo mount must be watertight after being glued to the base plate. A test should be carried out (after subsequent surface treatment) by filling the mount with water.

As indicated in the drawing "**Diving system assembly** " **(„Tauchsystem-Montage")**, the screws are guided from bottom to top through the holes of the diving levers, so that the stop nuts are on top, which is more practical for later disassembly/assembly.

Before attaching the **servo horn (Servohorn)**, the servo drive must be in its neutral position. This can be achieved using the remote control system by manually setting the corresponding encoder (potentiometer) to the neutral position. A simpler method is to connect a servo tester and set it to neutral.

Over time, the **pistons in the piston housings (Tauchkolben in den Tauchzellengehäusen)** can become increasingly stiff. Especially after extended periods of inactivity, the breakaway force required to free the pistons—which can feel as if they are stuck—can become very high, eventually preventing the syringe servo from moving freely. Since syringe pistons are generally not made of NBR, you must under no circumstances use a grease containing mineral oil. I therefore recommend a silicone grease, such as Lobenswerk's Multi Silicone Grease LW 0101. I applied it generously, particularly in the area between the sealing lips of the elastomer piston. Of course, you can also follow the manufacturer's instructions initially and apply a thin layer.

It is advisable to check before each use of the boat and before closing it up whether the diving pistons can be moved by the diving servo. Otherwise, you can assist them at the servo horn arm by hand or remove the filter covers and – with the boat switched off – push both pistons inwards a short distance simultaneously with your thumbs. After that, the servo should be able to move them again on its own. It is possible that other syringes than the SOL-M type I use are more suitable in this respect.

11) When the boat's interior is complete (diving system is installed, surface treatment has progressed as far as desired, but the electronics are not yet integrated except for the diving servo), then the **closure plate (Verschlussplatte)** can be built and finally glued into the boat hull.

The outer surface of the closure plate, especially in the area where the sealing cord will be glued, should be filled and sanded for surface preparation, as thin superglue, which is known to have poor gap-filling properties, will be used here later. Before gluing, the **sealing cord (Dichtschnur) (see**

drawings Sealing Cord 1 + 2) , the **rod retainer (Gestängeniederhalter)** (see "Closing Plate"), and the screws must be attached. For the gluing technique, see also "Base Plate 2". The **deck bracket (Deckhalterung)** can also be glued on at this stage; alternatively, you can wait until the deck is finished so that any necessary adjustments can be made more easily.

The drawing **“Closure plate assembly” („Verschlussplatte-Montage“)** is used to show how to mount the closure plate.

12) Fabricate both **tail side plates (Heckseitenplatten)**. Only glue the **spacer (Abstandshalter)** (see “Tail Side Plates 1” („Heckseitenplatten 1“) and “Rudder Linkage 1 + 2” („Seitenruder-Gestänge 1 + 2“)) in place once the **rudder linkage 1 + 2 (Seitenruder-Gestänge 1 + 2)** is mounted. The tail side plates should only be glued to the pressure hull once the **tail bulkhead (Heckspant)** has been completed with the desired surface treatment and all attachments (“**pressure gauge**” („**Druckanzeige**“) etc.; see “**Tail Bulkhead**” („**Heckspant**“)), except for the rudder servo mount, which is not needed here.

The plastic tube for the pushrod guide may or may not yet have been glued into the **tail bulkhead (Heckspant)**; see **"Rudder Pushrod 1"** **(„Seitenruder-Gestänge 1“)**. It might be better to wait a little longer to allow for adjustments if necessary. It is important to use a suitable plastic primer/adhesion promoter with materials such as PE, PP, PA, and PTFE to ensure a tight seal (e.g., TOOLCRAFT Primer for Superglue).

13) Fabricate **engine housings 1, 2, and 3 (Motorgehäuse 1, 2 und 3)** and **the engine mount (Motorhalterung)**. Once the **stern side plates (Heckseitenplatten)** are glued to the pressure hull, the engine mounts can also be glued in place. The **engine wiring (Motorleitungen)** should only be routed into the pressure hull at the very end, when the boat is almost finished. This way, the engine can remain completely outside the boat if needed.

14) Fabricate **the rudder bearings (Seitenruderlager)** and **the rudder (Seitenruder)**. The completed rudder is also needed to mount the lower rudder bearing. The rudder is held in place solely by the clamping action of the two rudder bearings. However, a long M2 screw or a threaded rod can also be inserted completely through the tube and the bearings. In this case, the bearings must, of course, be drilled through.

15) Once the boat's exterior has been completely painted, all the attachments that were not yet installed because they would have been in the way during the surface treatment can be fitted. These include, among other things, the **rudder (1 + 2) (Seitenruder- (1 + 2)).** and the **dive control linkage (Tiefenrudergestänge)** just like the **motor (Motor)**. Optionally, the **immersion cell protective screens (Tauchzellen-Schutzsiebe)** can also be manufactured and assembled.

The electronics, including the **servo mounts (Servohalterungen)** for the rudder and elevator and the two servos themselves, should not be installed yet. This should only be done after the leak test.

16) Assembly of the complete upper and **lower deck sections (Deckoberteil** and **Deckunterteil)** (see all **deck (Deck…) drawings**) with **conning tower (Turm)** and **conning tower end plate (Turmabschlussplatte)**. Masking work can be saved during painting if the upper deck section with the side rails, the lower deck section, and the turret with the turret end plate are painted separately and then glued together.
The conning tower opening in the upper deck section must accommodate the conning tower with a minimal oversize (the thickness of the paint). This must be checked before painting.
Attaching the window to the conning tower is easier as long as the conning tower base is still flat and has not been shaped into a tower.

Due to the small volume of the diving system (approx. 45 ml), only a small amount of adhesive – preferably thin superglue – should be used for all bonding operations on the upper deck and the conning tower. Only the trailing edge of the conning tower, particularly in the upper area where the antenna rests when extended vertically, should be reinforced with an additional adhesive, such as a polymer adhesive. Otherwise, the adhesive seam could tear there (as happened with the prototype).

Incidentally, the large cutouts in the upper deck and the conning tower are primarily designed to minimize water accumulation. When surfaced, any puddles that form become a weight that the diving system must overcome. Without the central opening, approximately 3.5 grams of water would collect on the conning tower roof alone.

The openings also have the advantage of allowing a partial view into the boat's interior. For example, the prototype has a LiPo battery monitor installed, whose flashing alarm is clearly visible through the hatch cover.

17) Manufacturing of the **hatch cover (Lukendeckel)** including all attachments.

18) Production of the **ballast plate (Ballastplatte)**. The hammerheads and additional ballast will be mounted later.

19) Completely manufacture **the diving plane (Tiefenruder)**, insert the **diving plane bearings (Tiefenruderlager)** into the control surface axes and attach the whole assembly to the front plate – see also "**Diving Plane Assembly**" („**Tiefenruder-Montage**").

20) August 23, 2026 – New SubMarine version with **buoy (Boje)** and modified **lower deck (Deckunterteil)**: At this point, I would fabricate the complete buoy assembly **("Buoy 1 to Buoy 6" („Boje 1 bis Boje 6"))** and install it in the front plate and bow bulkhead. It is particularly important for the subsequent leak tests that the servo is mounted and the cable is already sealed watertight in the bow bulkhead.

21) Once the pressure hull is completed, initially only **leak tests (Dichtigkeitstests)** are carried out, by completely submerging the boat in the bathtub. With the exception of the diving servo, which would be quite difficult to remove later, the electronic components are not yet installed to protect them from water ingress. The water temperature should be equal to or slightly higher than the ambient temperature to prevent the boat's interior from cooling down and creating a vacuum that could draw water in.

The **sealing cord (Dichtschnur)** for the hatch cover is coated with glycerin (>95% for the prototype) (or a glycerin-dish soap mixture, see " Sealing Cord 1 ") using a soft brush, unless a silicone foam cord is used. This is because the pores of the sealing cord material are not completely closed, and it can therefore be somewhat permeable to water. Silicone cord is said to be 100% pore-proof, but we have no personal experience with this.

Initially, attempts were made to use only petroleum jelly, which was readily absorbed into the rubber cord. Since petroleum jelly is a petroleum derivative and could potentially damage an EPDM sealing cord, its use was discontinued fairly quickly. Since then, only a glycerin-dish soap mixture has been applied before each dive. This mixture is now only applied to the top of the sealing cord; it is no longer necessary on the sides. It's possible that the petroleum jelly alone has already provided a long-term seal. The EPDM sealing cord has not been affected by this treatment (petroleum jelly and glycerin-dish soap mixture) so far. It is possible, therefore, that the glycerin-dish soap mixture alone will not be sufficient, and that petroleum jelly will need to be applied several times around the entire cord.

Inside, the boat floor is lined with paper tissues, which can sometimes indicate where water has entered. The hatch cover is used to observe whether water is seeping in anywhere. The water detects even the smallest leaks. The task is simple: locate and seal them. An even better view is possible if the hatch cover is not installed and the boat is only submerged enough so that at least the pressure hull penetrations are underwater.

Water can penetrate behind the diving cell sealing plates, as well as behind the diving cell O-rings. The control linkages for the rudder and diving planes can also leak, as can the plastic tubes and the two sealing washers at their respective bonded connections to the bow and stern bulkheads. The pistons of the diving system can, of course, also leak. The pressure gauge, stern cable entry, ventilation, antenna, and the cable entry for the lifebuoy servo are further items to check. The glued seams of the pressure hull can leak, as can all screws that pass through the pressure hull.

If overpressure is created in the boat during leak tests, leaks may be detected even more easily. Furthermore, those without a sufficiently large tank can also perform dry tests by spraying or applying a leak detection spray (e.g., Würth Leak Detector) without corrosion protection, or alternatively a soap bubble solution, to all potential leak points and observing for bubble formation.

To create a defined overpressure in the boat, the pistons are extended manually (to the point where they stop). Then the vent is opened and the hatch cover closed. A syringe filled with 45 ml of air is connected to the vent. This air is then pumped into the pressure hull. The pressure increase can be seen and felt on the pressure gauge. It is practically the same as if the pistons had been retracted. Now all areas that might be leaking can be sprayed with leak detection spray.

If the boat is leaking, this will also be indicated on the pressure gauge. The pressure may drop so quickly that air has to be pumped in repeatedly to locate the leak. However, no additional air should be injected, as this could increase the pressure unacceptably. Instead, the syringe must be removed each time, allowing the pressure in the boat to drop to normal, and then reattached before pumping in the 45 ml of air. Larger volumes of air could, for example, cause the glued seams to tear.

If the boat is watertight, assembly can continue.

22) Assembly of the **Elevator and rudder servo mounts (Tiefen- und Seitenruderservo-Halterungen)** including servos and connection to the **elevator and rudder (1 + 2) linkages (Tiefen- und Seitenruder (1 + 2)-Gestänge)**, which are also fully assembled.

23) Installation of the electronics (see **" Electronics Installation Proposal " („Elektronik-Einbauvorschlag")**). Mount a 40 MHz receiver (alternatively 27 MHz, but not recommended due to insufficient interference immunity; 868 MHz is also possible – however, the author has no experience with this) and speed controller using Velcro. Test-mount the battery using Velcro (store the battery outside the boat in a fireproof location afterwards). The antenna length is shortened to approximately 55 cm. 20 cm of this remains on the receiver, and 35 cm is attached to the hatch cover via a separate contact. The original antenna length of the prototype was approximately 90 cm. However, even with the reduced antenna length, a good radio connection is still ensured.

24) Complete **remaining assembly (Restmontage)** except for the ballast plate

25) **Electrical setup (Elektrische Einstellung)** and adjustment of all electronic components. It is important that no servos are blocked or that control surfaces are not engaged/blocked (use servo travel adjustment on the transmitter). The diving servo must not engage at the piston stop (see diagram " Diving Cell Assembly 1 "). Furthermore, this function should be assigned to a rotary

encoder – also to prevent excessively rapid reciprocating of the pistons, as this could overload the diving servo mount. The servo horn should not rotate more than 2 x 45° – see " Diving System Assembly ".
Slightly deviating center positions of the servos can also be corrected via the transmitter (center point adjustment via general trim or e.g. "subtrim" function).
If the propeller is running in the wrong direction, the transmitter channel can be reversed or the motor cables can be swapped. Never reverse/swap the power supply cables on the speed controller!

26) For the subsequent **hover adjustment (Schwebeeinstellung),** the boat must be fully equipped, including the battery and ballast plate. The bolts that extend into the ballast plate should be centered in the elongated holes.

The following procedure should be followed not only here, but also on subsequent dives, to prepare the boat for diving:

1. After switching on the transmitter, connect the battery in the boat – as well as the voltage monitor, if present. You can now check all functions again.
2. Now, glycerin or a glycerin-dish soap mixture can be applied to the top of the sealing cord.
3. Connect the antenna.
4. Open the ventilation to prevent overpressure in the boat when tightening the lid in the next step, as the lid acts like the piston of an air pump when tightened.
5. Close the boat with the hatch cover (tighten the screws crosswise).
6. Extend the pistons to their maximum extent.
7. Close the ventilation. The boat will therefore be started at normal ambient pressure.
8. Assemble the deck.

Point 6 is important because later, when the pistons are retracted for diving, a slight overpressure is created in the boat, which is desirable to this degree (in contrast to the pressure increase caused by tightening the lid).

If the ventilation were closed (7.) while the pistons are retracted, a negative pressure would be created in the boat when it surfaces (pistons extend), which would put additional stress on the pressure hull. Furthermore, water could also be drawn into the interior.

Once the deck is installed, the boat is ready for use and can be launched. If our test basin is not deep enough to completely submerge the antenna, it can be bent back 90° before the deck is fitted.

The pistons are now almost fully retracted for the following adjustments – to about 3-5 millimeters, which corresponds to a total volume of approximately 6-10 ml. This is the position of the diving pistons for hovering the boat. This volume can later be used to statically sink the boat and ground it . The filled volume of the diving cells, approximately 35-39 ml, is used for surfacing and floating the boat.

First, the air bubbles in the boat must be removed. These are located in the outer areas of the diving cells, between the bottom and ballast plates, under the deck, etc. To do this, the boat is tilted sideways and lengthwise several times at an angle of approximately 30° to 45° and moved back and forth to allow the air to escape. This procedure is also necessary before all subsequent dives. This method will not remove all air bubbles, but that is not necessary.

The goal now is for the fully equipped boat, with the diving pistons almost completely retracted as described above and any additional weights, to hover horizontally in the water, completely submerged – neither rising nor sinking. This is never 100% achievable, but we are trying our best.

First, attach the two hammerheads to the ballast plate as shown in the "Ballast Plate" drawing. However, this doesn't have to be their final position. Therefore, for now, they should only be secured with two 20 x 20 mm dots of double-sided foam tape each (perhaps more to ensure they don't fall off!). Later, they can be glued along their entire length using this tape or MMA adhesive. If using MMA adhesive, any excess that squeezes out can be trimmed with a metal spatula once it's pliable. This prevents it from interfering with the placement of balancing weights on the sides.

For the removal of any adhesive tape residue, cleaning fluid or lighter fluid can be used, for example. The ballast plate should remain in its neutral position as much as possible throughout the entire adjustment process.

Additional weights (e.g., 5g car wheel weights) are placed on the deck and arranged until the vessel achieves horizontal balance. A slight rise is safer than a slight sink.

To keep the volume of the weights small, the adhesive foam can be removed; however, this was not done on the prototype for practical reasons.

Now the boat is taken out of the water again so that these weights can be attached inside or outside the boat. When attaching them to the ballast plate, just as with the hammerheads, only a small amount of household tape should be used initially, as several adjustments will be necessary until the desired result is achieved.

Another option is to attach the weights to the sides of the hammerheads, i.e. vertically, and not to the ballast plate.

Mounting **inside the** boat is also possible. In this case, the area around the diving servo mount is recommended. This is particularly useful for compensating for adjustments to the boat's heel, should it list to starboard or port. The prototype has 550g of ballast stored there (partly attached to the base plate with Velcro and partly on the side of the diving servo mount). Approximately 290g of this weight would be reduced by using heavier woods like birch or beech instead of poplar plywood. The total ballast in the prototype is approximately 1800g (550g internal ballast + 2 x 500g hammer heads + 250g balancing weights on the ballast plate). In principle, hammer heads weighing up to 2 x 800g could be used, but this would naturally reduce the scope for future expansion – this needs to be considered on a case-by-case basis.

In an upgrade, 2 x 700g weights were installed, and the remainder was mounted as balancing weights on the ballast plate. There is no longer any ballast in the boat. All videos in the SubMarine version with the rescue buoy were filmed with this upgrade. I can't say that the handling characteristics have changed negatively as a result, which was my concern at times, because:

- The lower center of gravity could have had a negative impact (however, the response to the elevator seems to have become somewhat more sluggish),
- as well as the significantly larger number of vehicle weights that now had to be additionally attached to the ballast plate, which certainly also increased the driving resistance.
- Incidentally, the remaining bits of wood were knocked out of the hammerheads because they had gotten wet. I had originally intended to fill the resulting holes to avoid creating unnecessary turbulence and negatively impacting the hydrodynamics, but then I decided against it. However, the arrangement of the vehicle weights has at least partially closed the holes on the inside.

If a different panel material is used, e.g., polycarbonate (note: in this case, the cover plate could be left clear for even better visibility, and portholes could easily be created by masking the desired areas during painting), the required ballast weight will likely change. It can be easily calculated: The boat's total displacement is approximately 3260 g. Subtracting this from the current weight, measured on a scale, gives the remaining ballast required, because displacement and weight must be equal for the boat to float.

It is practical if a certain amount of ballast (e.g., 20 g in the prototype) is not permanently installed but rather placed loosely, for example, in the deck area. Depending on the season or body of water, the buoyancy will vary, which can then be compensated for by removing or adding weight, allowing the boat to be quickly brought back into optimal buoyancy without much effort. Any subsequent adjustments to the horizontal position can be easily made by moving the ballast plate.

If the additional weights are 5g automotive wheel balancing weights, they can be placed, for example, between the hatch cover and the front plate. Each of the two compartments can hold 30g stacked weights (3 layers of 2 x 5g). Weights can also be placed on the locking plate at the other end of the hatch cover. However, a Velcro fastener would be needed for this.

Weights should not be attached anywhere they would protrude into the deck area, specifically the section that should be above water when surfacing (the upper deck with the conning tower). Anything placed in this area requires additional buoyancy chamber volume. Conversely, this would reduce the boat's ability to surface as far.

The hammerheads should always be attached very securely so that they don't fall on your feet.

A crucial aspect of this entire operation is ensuring the boat is horizontally suspended (or slowly rising) in the water with the pistons retracted to within a few millimeters. If in doubt, it's better to have the boat slightly bow-heavy, as it tends to surface under speed. This basic setting can also be decisive for the optimal effectiveness of the diving plane. It hasn't yet been mentioned that the ballast distribution also influences the boat's maneuverability. The deeper it sits, the more stable the boat is in the water, but the more sluggishly it reacts to diving plane movements. Therefore, there are also some ways to influence the boat's handling.

So far, we've only discussed the boat's attitude towards floating, and this is indeed crucial. If the ballast tanks are completely emptied, the boat will likely be flush with the water's surface, with the top of the deck leveling down. Further rising is not to be expected due to the low ballast tank volume, even if it should be theoretically possible. Firstly, the design of the deck area plays a role here, in that its volume must be as small as possible. Secondly, the surface tension of the water, which holds the deck in place, unfortunately also has an influence. And thirdly, the puddles of water that collect on the deck when surfacing are also detrimental.

The first deployment

The first test run should take place in the shallow waters of a calm freshwater body. Saltwater is unsuitable due to the insufficient penetration depth of the radio waves. For safety, the boat can be operated while tethered. To achieve this, thread a lengthwise pierced section of sealing line (approximately 8 mm long) onto the first 50 cm of a fishing line (for example, 8 m long) every 4 cm, so that it floats and cannot get caught in the propeller. Braided line inherently has positive buoyancy compared to monofilament line. It can be attached to the rear deck opening.

As previously described, the sequence for starting a diving trip is as follows:

1. Switch on the transmitter and connect the battery. Check all functions. If necessary, perform a range test on land according to the manufacturer's instructions.
2. Apply glycerin or the glycerin-dish soap mixture to the top of the sealing cord.
3. Connect the antenna.
4. Open the ventilation.
5. Close the hatch.
6. Extend the piston to its maximum extent.
7. Close the ventilation.
8. Assemble the deck.
9. Remove air bubbles.

If the boat is warmer than the surrounding air, it will contract and the internal pressure will drop. This happens very quickly, especially in autumn and winter. Therefore, it's a good idea to check the pressure gauge regularly during use, or even without checking it, to open the vent every 10 minutes, extend the pistons, and then close the vent again. This procedure can be avoided, or at least the check interval extended, by waiting until the boat has reached ambient temperature before using it.

In the current version of the SubMarine (August 23, 2026), the lower deck section has been modified. It is now cut out further, providing an even better view into the boat's interior without having to remove the deck. This also makes it easier to spot alarm indicators, such as a lit or flashing LED inside the boat, even while passing by. In the prototype, this indicator shows when the battery voltage is approaching a critical level (see "**voltage monitor bracket**" („**Spannungswächter-Halterung**“)). This eliminates the need to mount the LED indicator on the outside of the boat.

Those still using the old version can adapt it with a small hand-held multi-tool (Dremel) with a mini circular saw blade and sanding sleeve. Only a kind of bridge (see drawing "Deckunterteil_DIN-A4_hinten" – dashed area) needs to be inserted.

Furthermore, the four semicircular cutouts in the lower deck section were enlarged to facilitate removal and installation of the deck when the antenna is used horizontally. This can also be done retroactively if someone has the earlier version; however, I don't recommend it because the holes are in a visible area and considerable experience is required to achieve a satisfactory result. A large metal half-round file (cut 1) is helpful for the final shaping, in addition to the tools already mentioned.

In addition, a rescue buoy has been added, which can be deployed remotely at any time. It also reacts in case of reception problems, should the servo make uncontrolled movements. For those who also want a release in case of water ingress or low voltage, a servo tester can be activated using the additional electronic circuitry. This tester moves the connected buoy servo to a preset position. Deploying the buoy results in a loss of buoyancy of approximately 5 g. Therefore, it's not surprising if the boat sits slightly lower in the water after surfacing. If the buoy is deployed while the boat is in hover mode, it will sink. In this situation, simply bail more water out of the ballast tanks or surface completely. Those who still have the first deck version should add the two small vertical struts at the bow ("Decktop_DIN-A4_front") and modify the deck mounting at the bow.

But now:
Have fun building and many successful dives with the SubMarine!

Stephan Post

- Reconstruction and operation of the boat are undertaken at your own risk and responsibility. The author assumes no liability whatsoever for incorrect information or for the malfunction of the submarine or any parts thereof.

No liability is assumed for consequential damages arising from construction or operation.
Replicating this model is only recommended for experienced model builders who are familiar with the machines, tools, paints, and adhesives used and can assess the associated hazards. The manufacturers' safety data sheets must be observed.
The instructions provided here and in the drawings are intended only as non-binding aids to assist the model builder with construction suggestions. These instructions do not relieve the model builder of the responsibility to assess their suitability and, if necessary, choose more appropriate methods.
The mention of brand names should not be interpreted as meaning that these are the only products that can be used in a given application. Many other equally suitable products may exist. Only those products used in the prototype or with which the author has prior experience are listed here, in the drawings, and in the parts list.
- The drawings used the two fonts Droid Serif by Steve Matteson and Swansea by Roger White
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