ROBOT ATTITUDE INDICATOR • DARPA • ROVs OF THE SEA
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SERVO
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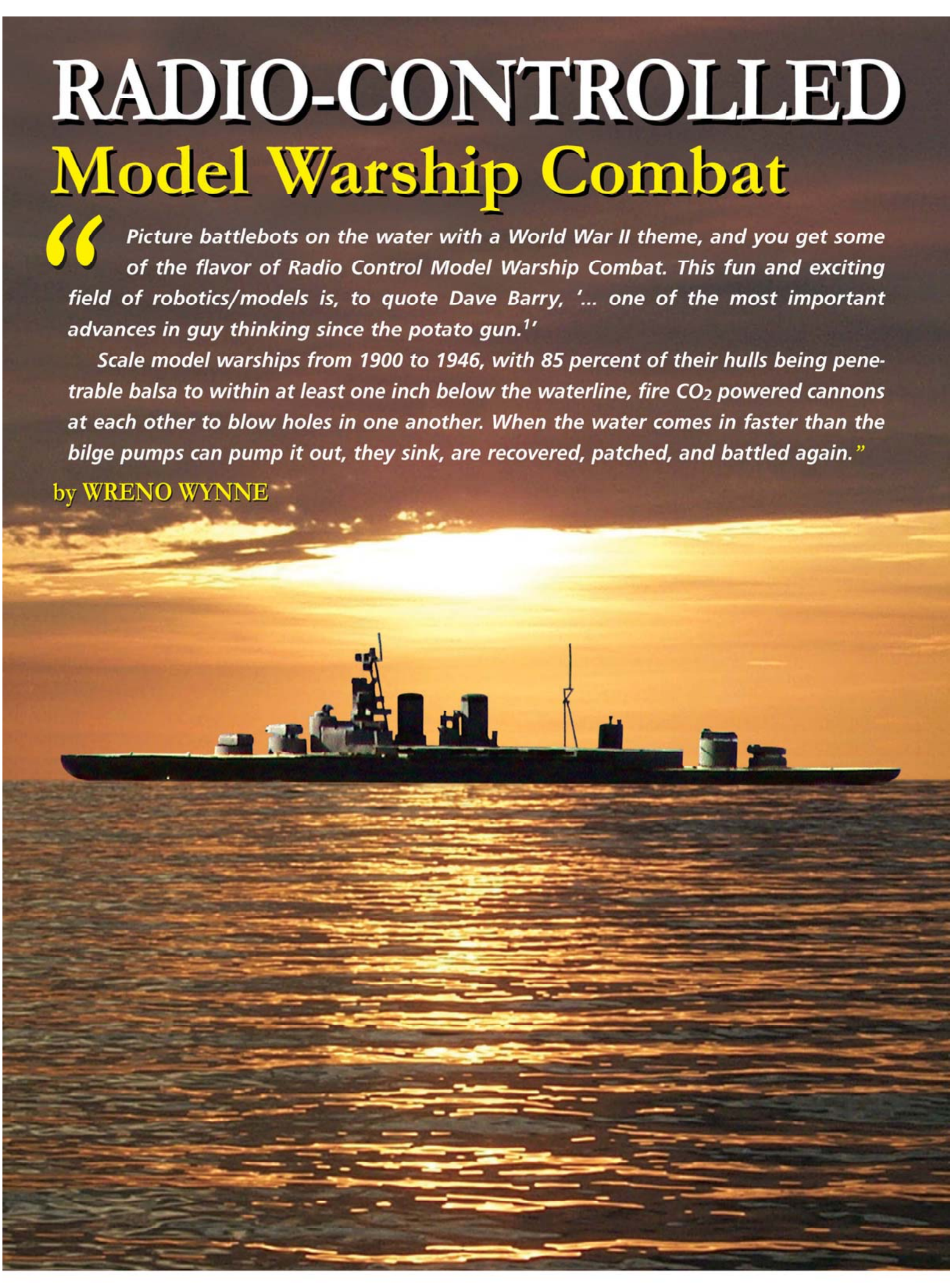
For the Next Generation of Robotics Experimenters
Winter Walkerland
Model Warship Combat
"Battlebots" in the Water
A-Star is Born
Navigating With A* Search Algorithm

RADIO-CONTROLLED
Model Warship Combat

"Picture battlebots on the water with a World War II theme, and you get some of the flavor of Radio Control Model Warship Combat. This fun and exciting field of robotics/models is, to quote Dave Barry, '... one of the most important advances in guy thinking since the potato gun.[1]'

Scale model warships from 1900 to 1946, with 85 percent of their hulls being penetrable balsa to within at least one inch below the waterline, fire CO_2 powered cannons at each other to blow holes in one another. When the water comes in faster than the bilge pumps can pump it out, they sink, are recovered, patched, and battled again."

by WRENO WYNNE



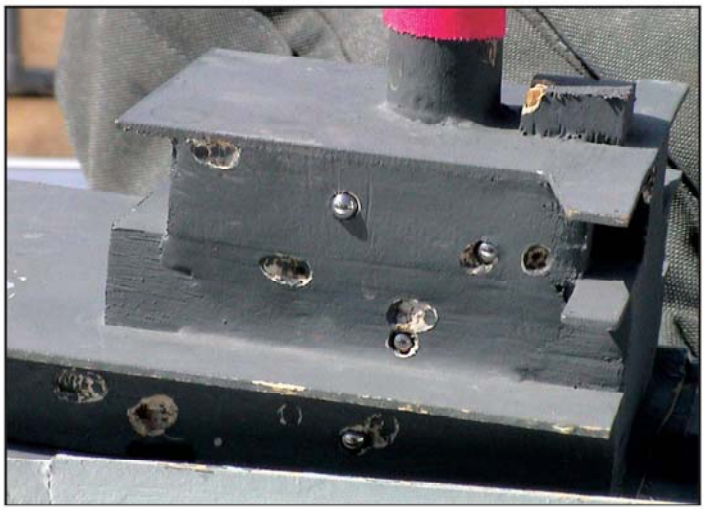


Figure 1. A club Liberty ship taking some damage to the superstructure (ouch).

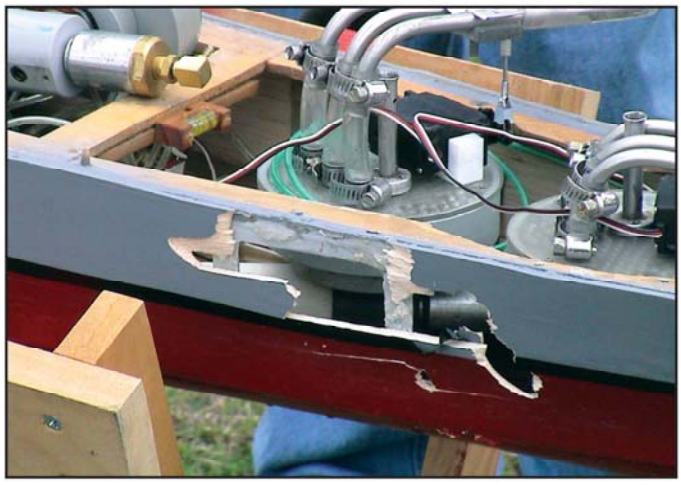


Figure 2. Mike Weber's Scharnhorst shows off damage from an accumulator rupture. He should have remembered his blast shielding.

Technical challenges can be extensive, and many solutions can be adapted to other hobbies (just as we have adapted from others – let me here give a special thanks to the antweight robotics guys). While Model Warship Combat involves the same radio control, servo, and mechanical issues as other hobbies, it adds the complexities of pneumatic (the guns) and hydrodynamic (buoyancy, stability, etc.) issues as well; and, of course, the waterproofing and armoring.

Like battlebots, this is real combat, with real damage, not a simulation. The difference is that most damage is limited to the easily and cheaply repaired/replaced skin. Damage to the mainly cosmetic superstructure (Figure 1), while it occurs and is entertaining, doesn't even score points. Assuming proper waterproofing techniques and blast shields (Figure 2), damage to internal components is relatively rare (Figure 3), and usually not major.

The origins of this hobby are attributed by some sources to a couple of guys in Amarillo, TX, with model battleships and BB-guns in the 1970s, and by others to different originators in the 1960s. Frankly, most of us who built model battleships at some time or another in our youth have fantasized about making them go and making them shoot, so multiple concurrent origins are certainly plausible.

Regardless of its origins, Radio Control Model Warship Combat has evolved into several distinct flavors, based on scale and armament. The most popular scale is 1/144 (12 feet to the inch). With this scale, the largest battleships are just over six feet long and about one foot wide – a size that can be readily handled and transported by an individual. Small ships, like destroyers, are more difficult to build and arm effectively, while PT Boats (about 6" long in this scale) and submarines are basically just novelties. There are clubs who battle in larger scales, like 1/96 and 1/72, but, considering a 1/72 scale battleship could be well over 12 feet long and weigh in at hundreds of pounds, they are largely limited to the small ships, like destroyers and smaller cruisers. Battling submarines

Figure 3. Some battle damage on Jerry Ethridg's Lutzow. Damage to servo cases like this is rare.

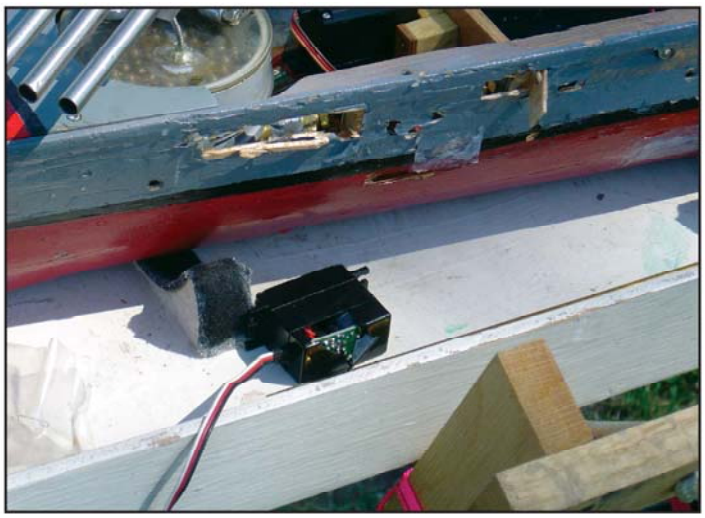
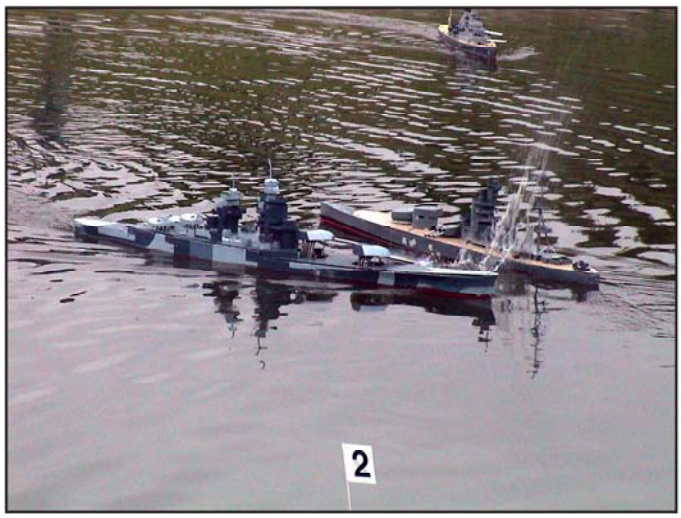


Figure 4. Mike Duffy's Richelieu lays a shot on John Mianowski's HMS Nelson.



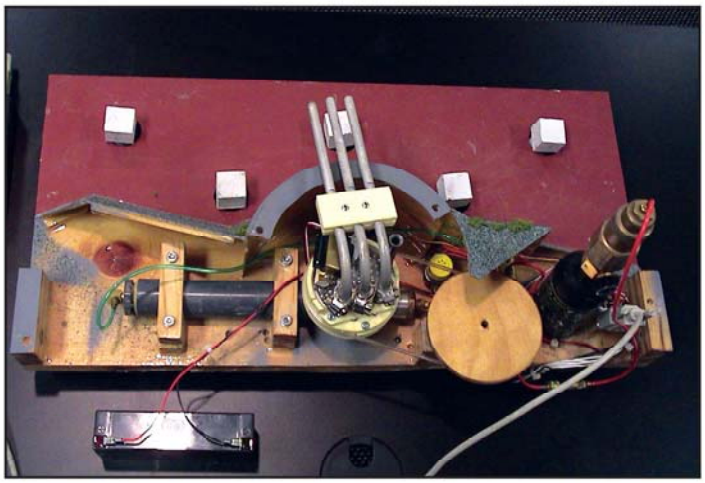


Figure 5. The guts of a shore battery. A microcontroller allows control without a radio and handles the damage. (As each white block is shot off by a ship, the firing interval is increased.)

Figure 6. The "French Dip." Mike Duffy's Richelieu is sandwiched by John Mianowski's HMS Hood and Jeff Burn's USS Dallas.

is possible in 1/72 scale as well, but still difficult (remember, if the enemy can't see your sub, neither can you!).

The two major distinctions — based on armament — are Big Gun and Small Gun (also known as Fast Gun).

In Small Gun, armament is limited to .177 (the common BB) caliber, and armament, pumping capacity, etc., is determined by class, based on a negotiated ship list, which gives each ship an assigned number of "units." Generally, gun rotation is not allowed, gun depression is fixed, and the number of guns is usually three or less. Guns are usually based on adaptations of common 1/4" plumbing fittings. However, rate of fire is unlimited (hence the "Fast Gun" designation). Due to the small caliber, the penetrable balsa skin is thin, only 1/32". It appears that all Small/Fast Gun clubs battle in 1/144 scale.

In Big Gun, if the ship had a cannon 3" or over, you can arm it. If it can be rotated and depressed, you can rotate and depress it on the model. And, the bigger the cannon on the prototype ship, the bigger the cannon on the Big Guns model (most clubs allow four calibers — .177", 3/16", 7/32", and 1/4"). Also — as in real life — the larger the caliber, the longer the reload (firing) interval (two, four, six, and eight seconds, respectively). Guns are usually custom-made affairs, and the variety is astounding. Torpedoes are generally simulated with 1/4" guns at a 30-second firing interval. Mines are also utilized. Mines are simulated by small floats, with strings attaching them together and an anchor at one end. Mines serve to entangle the propellers of ships which pass over them, thereby disabling the ship. Thickness of the balsa skin is relative to the armor of the prototype ship, ranging from 1/16" to 1/8" and armor belts, in the form of a thin stringer under the balsa, are sometimes allowed.

Keep in mind that a 1/4" steel ball-bearing, traveling almost 200 feet per second, can do some serious damage to things other than the balsa ship skins, therefore safety rules and procedures are paramount. For example, safety glasses are required in the battle area at all times, guns are not allowed to fire above the horizontal, total penetration energy is restricted, and no pyrotechnics are allowed in most clubs. Of course, this means no plunging shellfire (a staple in actual modern naval warfare) or exploding rounds (another staple).

Since the guns can fire only horizontally or lower, and are relatively low to the water, the effective battle range is limited by ballistic trajectory to approximately 15 feet or so. However, the balls can skip on the surface of the water, increasing your range dramatically. If they ricochet off the deck of the target, they will reach shore, spectators, parking lots, etc., when least expected. Remember, safety glasses are a must. Due to the effective range, the factor that you are aiming the guns remotely, and the fact that you really, really want to hit the enemy ship in that one inch below the waterline without being so low as to bounce off the impenetrable area (and keeping in mind the dramatic effect of water on both trajectory and energy), most shots are taken from less than two feet (Figure 4).

"While Model Warship Combat involves the same radio control, servo, and mechanical issues as other hobbies, it adds the complexities of pneumatic (the guns) and hydrodynamic (buoyancy, stability, etc.) issues as well."

As you can tell from the complexity of that last sentence describing what goes into making a shot, there are many variable and changing factors, all being weighed concurrently, that you must juggle to get that really good shot. Do not forget that you must do this calculation while both you and

your target are maneuvering. And, you might also want to consider the non-physics aspects such as the behavior of your target (When is he going to shoot at you?), the nature of your target, and the overall battle situation (Is another ship coming up on your off-side, for instance?).

While there is certainly room for the "Pirate," "Lone Wolf," and "Berserker," good teamwork is definitely rewarded. Teamwork is essential in protecting unarmed convoy vessels (Yes, these are definitely part of the game, as are armed merchantmen, commerce raiders, "Q" ships, shore batteries [Figure 5], and so on.), but teamwork is terribly valuable in taking on the enemy warships, as well (Figure 6). Keep in mind that the Lone Wolf, regardless of how big and bad his ship is, is also an unprotected target who is on his own and can be dealt with using far inferior ships, given proper teamwork.

Now that we have a basic idea of the Radio Control Model Warship Universe, let's focus on one flavor, and see where it takes us. The club I belong to — the North Texas Battle Group (**www.ntxbg.org**), which is based in the Dallas, TX area, is a 1/144 scale Big Gun club, so it is their rules, techniques, procedures, and so on that provide the framework for the remainder of this article.

Keep in mind that the ships are models of real ships. As such, they reflect many of the strengths and weaknesses of

GET VEXED!

One of our members in the North Texas Battle Group sent out a query on the RadioShack Vex Robotics radio control system that intrigued me. On looking at the system, I noted that it included some unique-looking servos and "motors" that looked identical to the servos. Could it be that, although designed to work with a microcontroller-based system, these might both be pretty much hobby servos with some different and unique features? The answer is yes and no. Unfortunately, at this writing, there is a dearth of information readily available on this product in the way of technical or operational specifications.

I decided to purchase one of the RadioShack Vex Robotics Motor Kit modules and check it out for myself. Hooking it to a standard RC receiver was the first challenge. It (the servo too) has male pins instead of the normal female plug on most servos, and no, it is not the old Futaba G standard. I could have changed the plug, or built an adapter, but for the "smoke" test, opted to just touch the appropriate pins together with their corresponding receiver pins, holding them by hand. It passed the smoke test (i.e., no smoke), and indeed, functioned like a hacked servo (actually like a servo box that has had the servo electronics replaced by an Electronic Speed Controller, or ESC).

On testing with an Astro Flight, Inc., Servo Tester — range 1.0 ms to 2.0 ms — powered by the BEC of a Proboat ESC, I found the following: Max RPM was about 60. Deadband was from about 1.4 ms to 1.6 ms. At full stall, I believe it pulls about 1.3 to 1.8 amps. Speed increase was nice and gradual from the deadband out to full speed.

I believe this motor is supposed to be something like 8.4-volt tolerant, while my BEC puts out about five volts. I have not yet tested at higher voltages.

It is my understanding that the top RPM at higher voltages is also higher, with some third party tests indicating about 100 RPM at about 8.4 volts.

On corresponding with Ricky Torrance of Innovation First, Inc. (sponsors of the VexLabs website at **www.vexlabs.com**) after my initial tests, I was given the following specs on the motor: free speed RPM at 7.5 volts is about 100 RPM; nominal operating in the system voltage is 5.5 to 9.0 volts; maximum range (outside the Vex microcontroller system) is 4.4 to 15 volts, but motor life is reportedly reduced outside the nominal range; deadband nominal range is 1.47 ms -1.55 ms, but with temperature and voltage, could vary up to 1.36 ms 0 1.68 ms. Motor stall torque is approximately 6.5 inch/lbs. All of these specifications are in line with my observed tests.

With the relatively high voltage tolerance (and assuming the servo has similar tolerances), a decided advantage appears over the common servo, many of which are only 6.0-volt tolerant. With the proper radio (such as the Sombra Labs, Inc., Shadow 3, which is 3.5-volt to 9.0-volt tolerant), you can match radio, motor, servo, etc., in a 7.2-volt or 8.4-volt system with no BEC or other voltage twiddling. Everything can be powered off one main bus, making for simpler construction and wiring.

Electrically, this motor kit is very different from a hacked servo. There is no potentiometer to adjust, nor a resistor array. It is a nice, clean, circuit board with three ICs. The board is effectively an ESC, instead of servo (positioning) electronics. Basically, it is a servo with a brain transplant.

Mechanically, this motor kit is also very different from a hacked servo. It has a female 1/8" square socket for drive instead of the usual splined hub. It also includes a clutched drive. If you want a regular splined hub, there is probably a servo gear that can be adapted (I have heard reports that some Cirrus brand final gears may fit and work, but have not confirmed this).

To field-strip this module (and probably void the warranty), begin by removing the clutch and shaft stub (just pulls out). Then remove the four screws on the top of the case. Remove the case top. The gears will remove easily — keep in mind for reassembly that some of the gears nest and have to be replaced together. After all the gears are removed, you will note two tiny screws on either side of the motor — remove them. Now turn the case over, and remove the four screws on the bottom of the case. Remove the case bottom. The motor and controller module will now slide out easily.

You will note a circuit board soldered directly to the motor, which runs the full length of the case. This is the ESC.

To reassemble, put the motor and circuit board in the case first, then use the two tiny screws to secure it. After that is done, the case bottom can be reattached, then the gears and case top.

There are lots of interesting potential uses for this little gem and for its associated parts. In the North Texas Battle Group, it will probably find life in gun rotation, and perhaps, even ship propulsion systems.

RadioShack VEX Motor Kit

Figure 7. John Mianoski's HMS Nelson's nine 1/4" main guns can really pack a punch.

Figure 8. Mike Weber's Scharnhorst inspects his handywork — sunken Lake Shore — for survivors.

the ships they are modeled after. For instance, the HMS Nelson (Figure 7), is heavily armed with three triple 1/4" caliber turrets in the bow that can fire as one, resulting in nine holes magically appearing in the enemy target's hull. However, Nelson is relatively slow, turns poorly, and, with all her superstructure in the stern, handles wind poorly. Further, with all her heavy armament in the bow, enemies coming at her from the stern quarter are difficult to handle. She may not be able to chase anyone down, but she can protect a battle group or convoy with deadly results. With teammates to protect her vulnerable stern, and to drive faster ships to her, she becomes a dangerous "anvil" to be pounded against.

On the other hand, the Scharnhorst (Figure 8), sporting 7/32" guns, does not have quite the broadside capability of the Nelson, but she is highly maneuverable and fast, being able to "run and gun," taking the battle to others on her terms. The diminutive Espana only has two double turrets, thus sporting only four of the 1/4" caliber guns, and is the slowest ship in the fleet. However, she is incredibly maneuverable, and very small, making herself an exceptionally difficult target. Of course – as in real life – the Missouri and the Bismarck are deadly ships, if built reliably and in the hands of a good captain, with a strong mix of maneuverability, firepower, and reserve displacement (the ability to take in water without sinking). But there are dozens of other ships out there that have their place in the right hands, and every captain has his favorite that fits his fighting style.

One thing I have found is that each model ship, even those based on the same prototype ship, is unique, reflecting the experiences and desires of the builder. As an example, let's look at the issue of waterproofing the electronics.

Some builders elect to design and build a waterproof box for the electronics (Figure 9). Many of these boxes are made from epoxy covered wood, some from plastic, some from converted watertight boxes used by swimmers and scuba divers. Even in these, there is variety. Some just contain the radio, others also contain some, or all, of the servos. In either case, the pass-throughs for electrical, CO_2, or mechanical linkages can be a challenge to keep reliably waterproofed. Some builders go so far as to make sure the CO_2 firing valves vent into the box to keep it pressurized, with a one-way (check) valve to provide a vent.

Other builders just embrace the dunking, electing to just flood the electronics with alcohol and let them dry out before battling again (they drill holes in the servo cases to facilitate this).

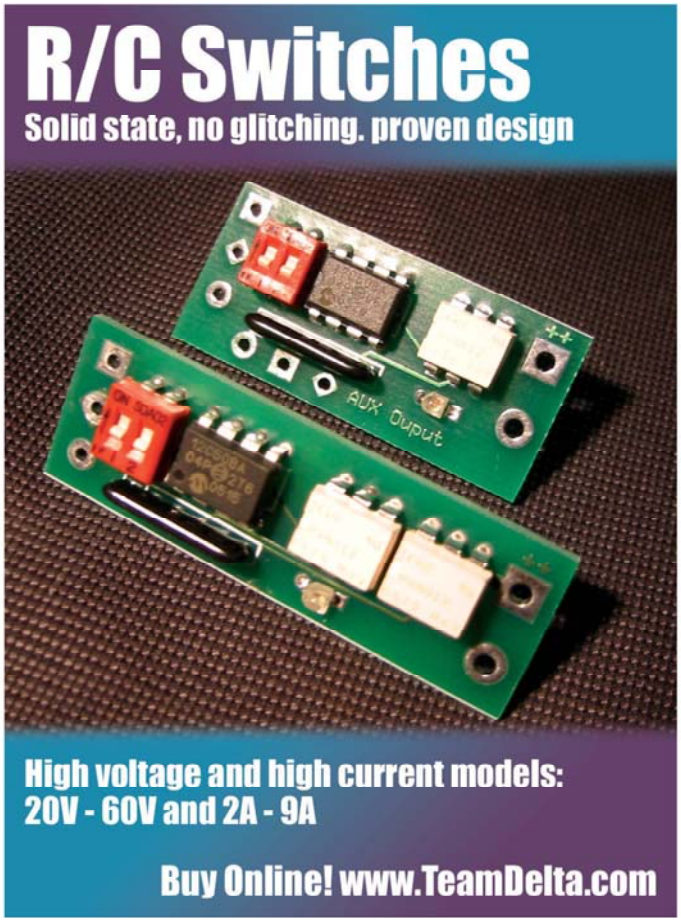


Figure 9. The stern of Don Payne's USS Missouri, showing his water-tight box and belt drive rotation system.

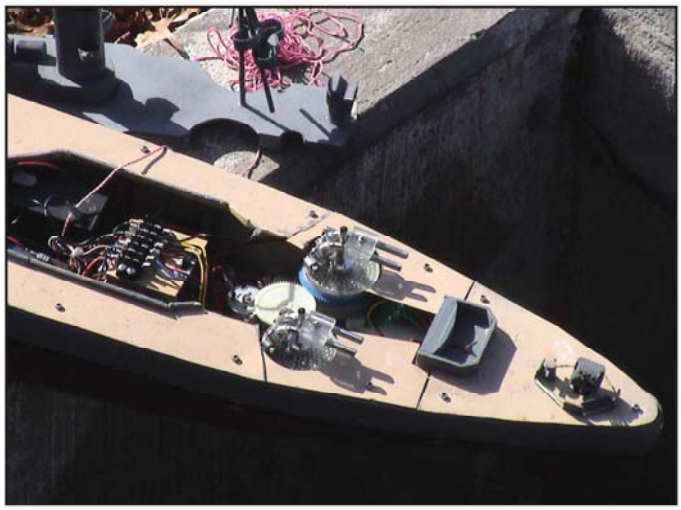


Figure 10. John Mianowski's HMS Nelson shows its gear-drive stern guns.

The middle choice (and the methodology I happen to use due to space considerations) is to individually waterproof the various electronic bits. There are numerous products you can use to waterproof most electronics, depending on the particular item under consideration. For Electronic Speed Controllers (ESCs) — the one electronic component most sensitive to water damage — the solution is simple — purchase one *already* waterproof, like the Mtroniks or Proboat brands. If you buy a different ESC that is not already waterproof, a quick solution can be a dunk in a waterproofing agent.

Aeroplate or Corrosion-X (WD-40 is *not* recommended for this purpose) has been found to be effective by many (though my Hitec HS-55 servo did *not* like this treatment, most of my servos loved it). This method does need frequent reapplication for effectiveness. Surprisingly, Liquid Electrical Tape or Tool Dip are not particularly good long-term solutions in our application, as the other chemicals and immersion tend to deteriorate them. A better solution, though exceedingly ugly in its appearance on your circuit board, is 3M Skotchkote. Many of our members use this product extensively.

Another aspect showing a great deal of individualism and innovation is getting the guns to rotate (traverse). Drive trains vary from friction drives (say, a rubber tire rotating against the side of the magazine) to belts (also seen in Figure 9), cables, gears (Figure 10), chain and sprocket, and hybrid drive trains including two or more of the drive linkages named above (Figure 11). Some are proportional, using sail servos (remember, you are rotating a perhaps 4-5 inch diameter turret up to 270 degrees), while many are not. Personally, mine is set up with a sail servo, as my son and I like the proportional control. Many have used regular hacked servos to give them "rotate left" and "rotate right" functions (not proportional), but drift and coordination have caused them to lose favor in our club.

Instead, several of our members strip the electronics out of a hacked servo and just use it as a geared motor with handy mounts, replacing the electronics with an ESC (usually a water-

Figure 11. Hybrid sprocket/chain system tied to cables for rotation on Mike Duffy's Richelieu. Note that different sprocket sizes allow the turrets to converge fire.

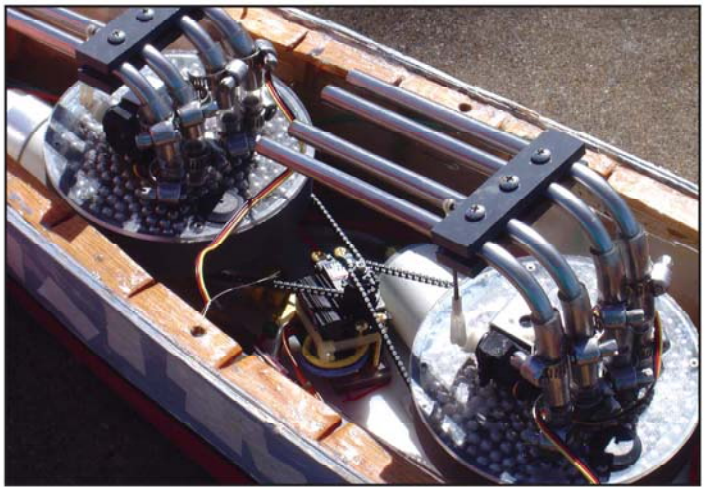
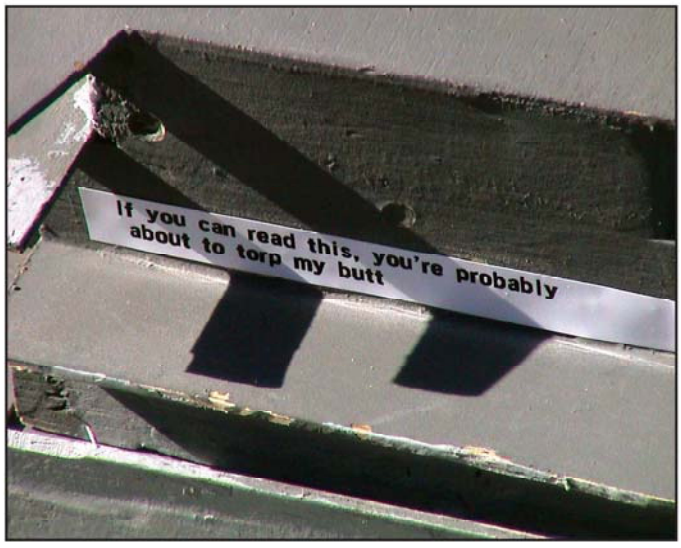


Figure 12. A Liberty Ship captain shows some humor.



proofed antweight motor controller). This method results in both eliminating drift and in giving you adjustable rotation speed, allowing you to "fine tune" your shot (move to the general area quickly, then make fine adjustments slowly).

One method I have advocated, but not yet implemented in battle or prototype, is based on standard servo electronics. Start with a servo that has the gear train hacked to allow full rotation. Remove the internal potentiometer (pot), and wire an external multi-turn waterproof pot in its place which is mechanically coupled to the guns. This methodology would work with all drive methods to precisely aim the guns proportionally. Even with the inherent slippage in a friction drive, the servo electronics will send power to the motor to change position until the correct position of the guns is sensed by the pot.

As you can begin to see, Radio Control Model Warship Combat provides a plethora of technical issues to deal with electronically, mechanically, pneumatically, and so on, all while staying within the parameters of size and weight determined by the choice of ship. Actual battling continues the challenge by incorporating maneuvering, gunnery, strategy, situational awareness (Figure 12), teamwork, weather, and, of course, luck. And, it allows you to blow something up (or, if you are an unarmed transport captain, to dare the odds with pluck and skill)!

If your interest is peaked, you may be wondering how to get started. First, find the closest club. Do not give up if there is not one in your immediate neighborhood – many battlers routinely travel well over 100 miles for a battle, and some have been known to go as far as 1,300 miles on occasion [1] (yes, it is that fun). Attend some battles. Talk to the captains. Read construction tips on the websites. Subscribe to the discussion groups. Listen to advice on your first project. Remember, every new captain has that "great idea" to revolutionize the hobby, and some of them even work.

Once you have experience, you will quickly figure out whether the idea was really a useful innovation and can incorporate it or not. Above all, be careful to research the type of battling your local club is involved in and build to that specification. Recommendations for another branch of the hobby not only may not apply to your branch, it may be 180 degrees wrong. For instance, Deutschland class "pocket" battleships (the Lutzow, Graf Spee, and Admiral Scheer) are considered decent "rookie" ships in Small/Fast Gun, but are considered difficult/advanced by most Big Guns clubs. The hull is the same, but differences in the equipment layout, speed rules, and so on, make huge differences in the skill level required. So, again, pick a club, attend battles, and then dive right in. The water's fine. **SV**

[1] *Macho Males Just Using Large Brains*, Dave Barry, Miami Herald et. al., November 23, 1997.

Wreno Wynne found Radio Control Model Warship Combat through his son, Wes. They began Model Warship battling together in 2002. Wreno currently captains the USS Lake Shore, which, at 22 inches, is the smallest cargo ship in the North Texas Battle Group fleet, and holds the current record for successful cargo runs in one sortie — 46.

WEB CONNECTIONS

FAST GUN CLUBS

International Radio Control Warship Combat Club
www.ircwcc.org
Yahoo Group: IRCWCC

Model Warship Combat Club
www.modelwarshipcombat.com

NOTE: *The IRCWCC and MWC are the two larger umbrella organizations for Fast Gun clubs. Check with them to find a club that's near you.*

BIG GUN CLUBS

North Texas Battle Group
www.ntxbg.org

Valparaiso Shipyards (Midwest)
http://rcwarships.msiunix.com

Chesapeake Battle Group (Maryland area)
www.chesapeakebattlegroup.org/

Mid Atlantic Battle Group (Virginia area)
http://mabg.org

Midwest Battle Group
www.midwestbattlegroup.org

South Coast Battle Group (California)
www.southcoastbattlegroup.com

Western Warships (California)
www.westernwarshipcombat.com

Australian Battle Group
www.ausbg.org

Danish Model Task Group
www.dmtg.dk

Swedish Seabattle Club
www.phdatalogi.se/sss

1/96 scale Warship Combat
www.battlestations.org

1/72 scale Queen's Own Scale Model Warship Club
www.nwlink.com/~pfleming
Yahoo Group: BigGunsModelWarship

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Star Brand Ranch Executive Retreat — *Home Port for the North Texas Battle Group and the North American Big Gun Open.*
www.starbrandranch.com

Battlers Connection — *1/144 scale hulls, Fast Gun cannon*
www.battlersconnection.com

BDE RC Combat Supplies — *1/144 scale plans, Big Gun cannon*
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R/C Naval Supply — *Propellers and miscellaneous bits*
www.rcnavalsupply.com

Swampworks — *1/144 scale hulls, Fast Gun cannon*
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