R/V *New Sound 39/初音ミク*

Prototype Data Collection Vessel

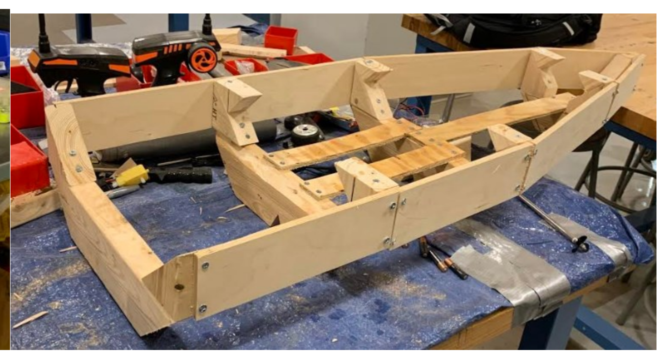
Built by Alexei Sondergeld

Specifications:

- 1/32 scale
- 10 ft. (3.05 m) long – 320 ft. (97.5 m) full scale
- 3 Turnigy SK3 5045 – 450 motors, ~1510 W each with 6s Li Po, probably 755 W with 3S. Total max. power – 4530 W (6.07 hp.) on 6S
- Alien Power brand 120 A X-Car ESC (middle motor), Turnigy 100 A helicopter ESC (outer motors)
- 16 in. beam – 42.6 ft. beam full scale
- ~160 lb. unloaded, 5,242,880 lb. full scale (2621 tons).
- Two watertight bulkheads with watertight doors
- Moon pool for deploying submersible sensor arrays
- Raspberry Pi and Arduino for data collection

This is the largest ship that I have ever built. At 10 feet long, it is longer than Aiko (6.5 feet), and a 7′ 9″ ship I built around 2007. It is also the first prototype of an autonomous data collection vessel that I am developing. As I am a model ship enthusiast, I decided to build this prototype both as a functional data collection vessel and a 1/32 scale model. The size of the vessel allows it to be a stable platform for data collection, and additional stabilizers (such as bilge keels) can be added if necessary for depth measurements or any other roll-sensitive measurements.

I began building the frame at the beginning of the Fall 2019 semester. The frame (above) is made of scrap 2x4 lumber screwed together, then coated with epoxy. Note the notches on the bottoms of the frame pieces. This is to allow water to flow under the ribs to a bilge pump if the bilge is flooded. Also, the ship was built in thirds, with the bow and stern being built first, then connected by the mid-ship cargo/data collection compartment. The two ends, with some plywood attached, are shown below. The three propeller shafts were inserted through holes drilled in the stern rib, then epoxied into place.

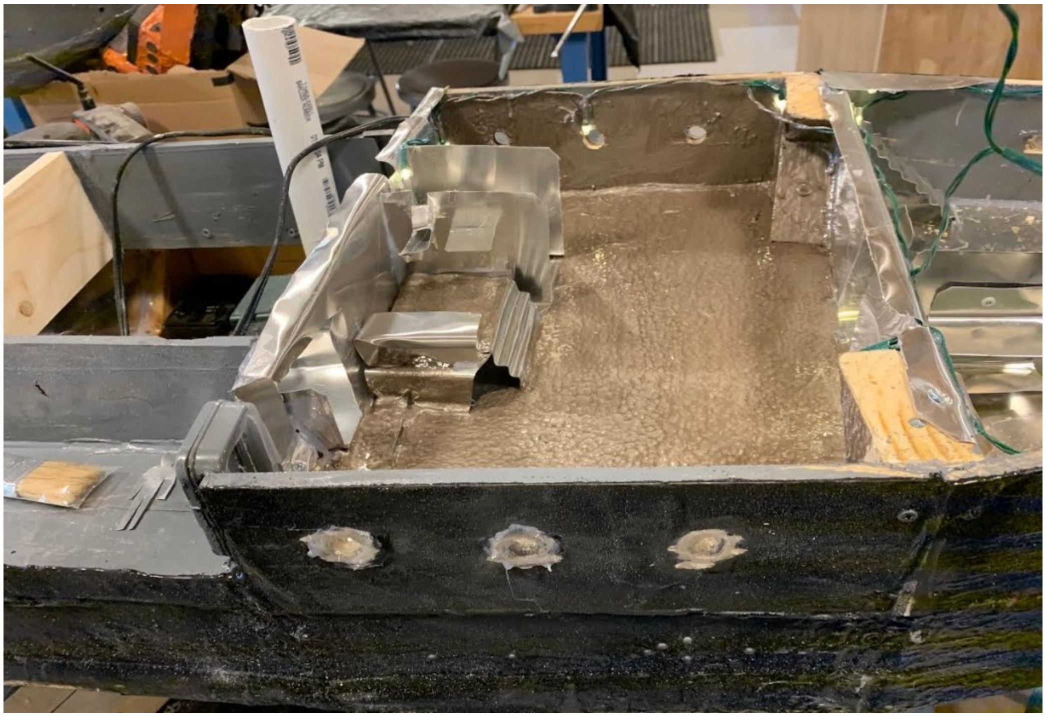


Once the two ends of the ship were constructed, I attached enough of the plywood hull to solidify the structure (above). Since Aiko had problems with water entering and warping the wood through cracked seams, I applied epoxy between each step of construction so that, even if water entered the seams, the epoxy would protect the wood. At this stage, I added the middle section of the ship and an extra rib to support the hull. Similar to the construction of Aiko, I glued the seams between plywood pieces, then applied another layer of epoxy to the hull.

To further inhibit potential cracks in the hull, I decided to use a low-budget composite of weed control tarps (roll of fabric in upper photo) and epoxy. This was applied to the bottom of the hull, which will be continuously immersed when the ship is under way.

Once the epoxy cured, I flipped the ship right-side up and began building the raised stern and forecastle. This was mostly sealed with wood preservative and oil based lacquer, since it will not be continuously submerged.

My next step was one that was somewhat of a miscue. I coated the entire ship in Flex-Seal brand paint-on rubber. I assumed that it was paintable, since the spray-on product is advertised as such. However, once it cured, I discovered that it was not paintable; nothing, even duct tape and epoxy, would stick to it other than dust and dirt. It acted as a magnet for dust and dirt and became somewhat nasty-looking after a few days. It also wasn't removable. While deliberating on what to do with the rubbery mess, I continued to build the inside of the ship. I added sides to the mid-ship cargo area, and cut a hole to install the moon pool, which is the square shaft in the photo below. Instruments can be dropped into this hole to be deployed beneath the hull.

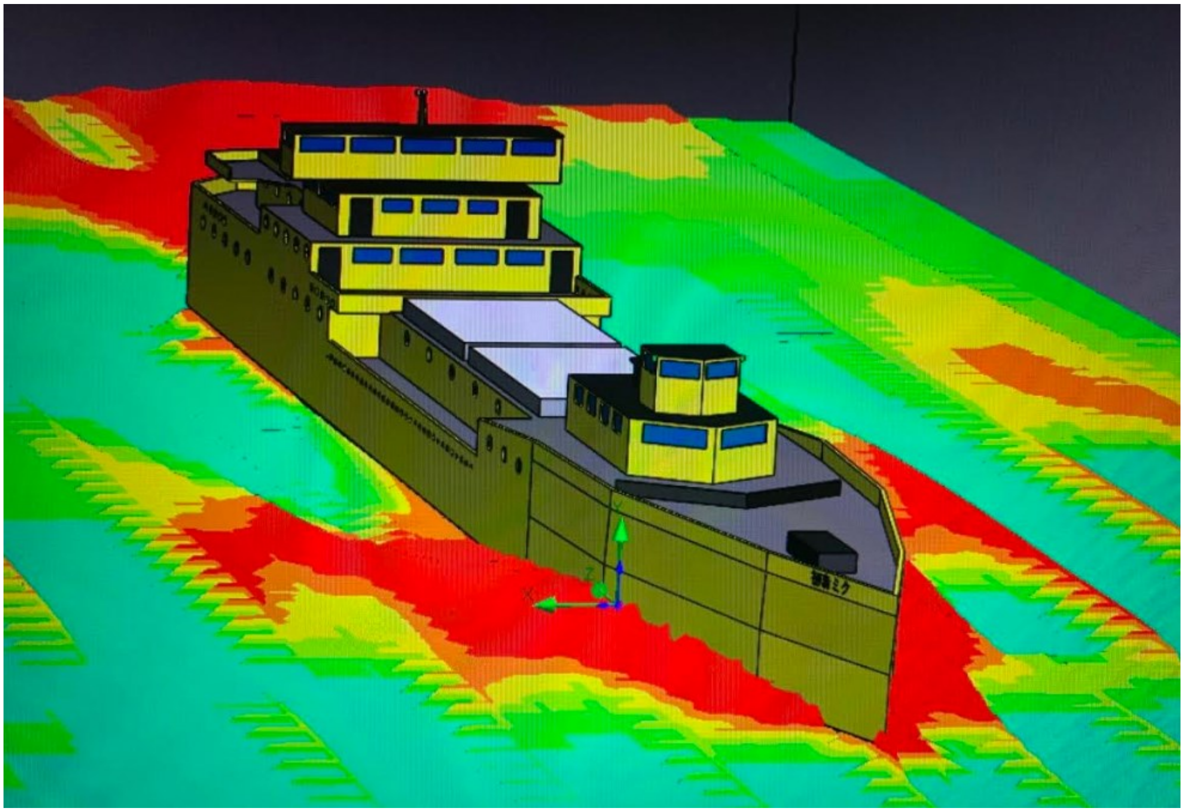


These photos are of the forecastle, which houses the galley and crew quarters. Above is the galley. The sink and counters are at the left side of the photo in the brown-painted room. (The bow is to the right and stern is to the left in the photo.) Behind the galley is a functional head (toilet), and the white PVC pipe is the vent for the sewage system. The brown-painted room would be used as an extension of the galley, with food storage lockers and other equipment (such as stoves, ovens, etc.) being brought in during outfitting. A medium-sized refrigerator, which uses Peltier plates, is located on the deck below the galley. The built-in crew quarters can accommodate six crew members, but the large forecastle space could be outfitted to accommodate more. This space could also be used as a cafeteria due to its proximity to the galley.

The interior of the stern is mostly empty decks that would be used as extra crew accommodations, extra cargo space, or (in the case of a research vessel) lab spaces. As this model vessel is too large to fit inside of a car for transportation, the entire vessel is reinforced in order to allow it to be tied to a roof or into the bed of a pickup truck.

I finally decided that the only way to get rid of the rubber coating was to grind it off with an angle grinder. I also decided to keep the coating on the underside of the hull, since grinding the rubber off would also remove the composite layer. After five exhausting hours of grinding, the hull was down to bare wood and ready to paint with high-visibility yellow paint (above).

I began building the forward superstructure (below) and continued to install lights. I also settled on a name for the vessel, which is discussed below.



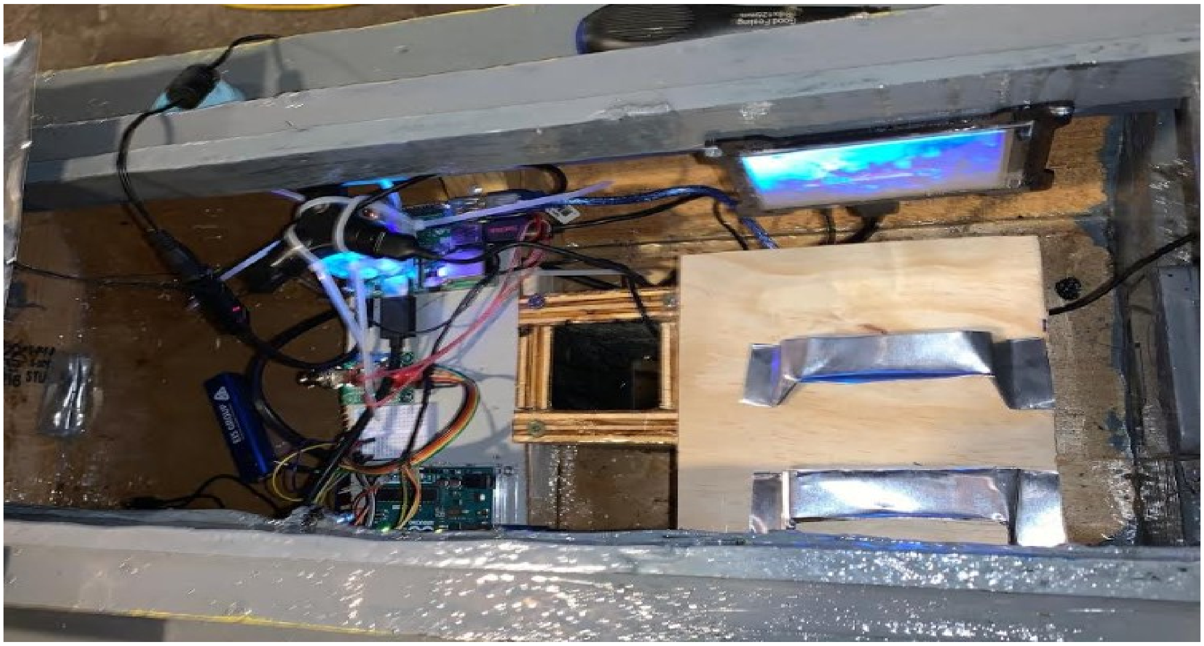
After the coronavirus pandemic closed the lab, I completed a Solidworks model of the vessel and ran free-surface CFD simulations on the hull. From these, I deduced that the waterline will need to be higher at the stern (in other words, proportionally more ballast/heavier at the stern), as the propellers will tend to ingest air at higher hull speeds. The simulations, while not very precise due to the limitations of the computer I was using, also gave a sense of the locations of the waves produced by the vessel as well as a ballpark estimate of the hull's drag at certain speeds.

Once I retrieved the ship at the end of the spring, I brought it to my garage at home for completion.

An initial on-water assessment verified that the ballast that I included was sufficient. As my simulation predicted, the propellers tended to suck in air at higher speeds, but I made no ballast changes since the stern superstructure (and its attendant weight) was not present yet.

Unlike Aiko (and all of the other ships that I have built so far), I decided to build the aft superstructure with thin plywood, rather than metal. This was just painted inside, as it is high enough above the water that it is unlikely to become submerged (if it does, the ship will have bigger problems than a soggy superstructure!). The exterior was also painted, then coated with epoxy for weatherproofing. I built a trailer/cart for the ship with scrap lumber and wheels from my grandmother’s old walker.

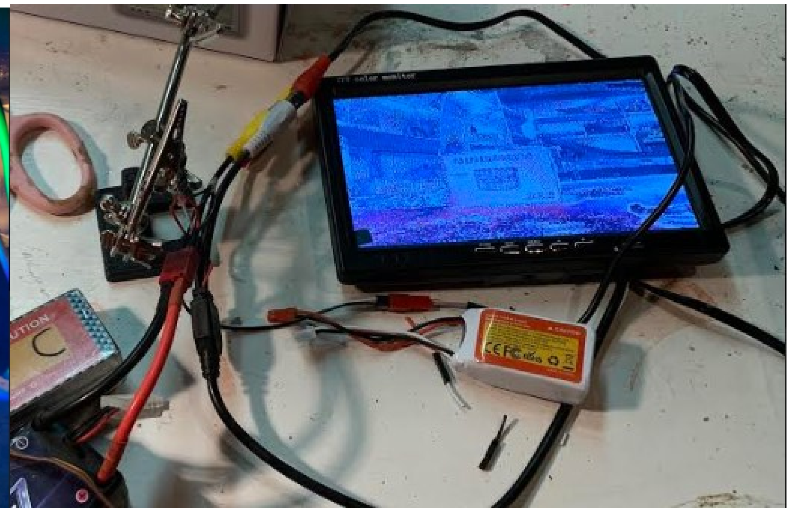
After painting the superstructure, I coated the rest of the ship in epoxy, then applied more Flex-Seal rubber to the hull. This coating of rubber extends to an inch above the waterline to protect the seam. The name of this ship is a deliberate mis-translation of the name of a Japanese character (Hatsune Miku). The 39 in its name is both a translation of part of the Japanese name and also a reference to the fact that this is the 39th functional vessel that I have built since I started building model boats in 2006. I painted this character on the bow with acrylic paint, then coated the illustration with marine epoxy for waterproofing.



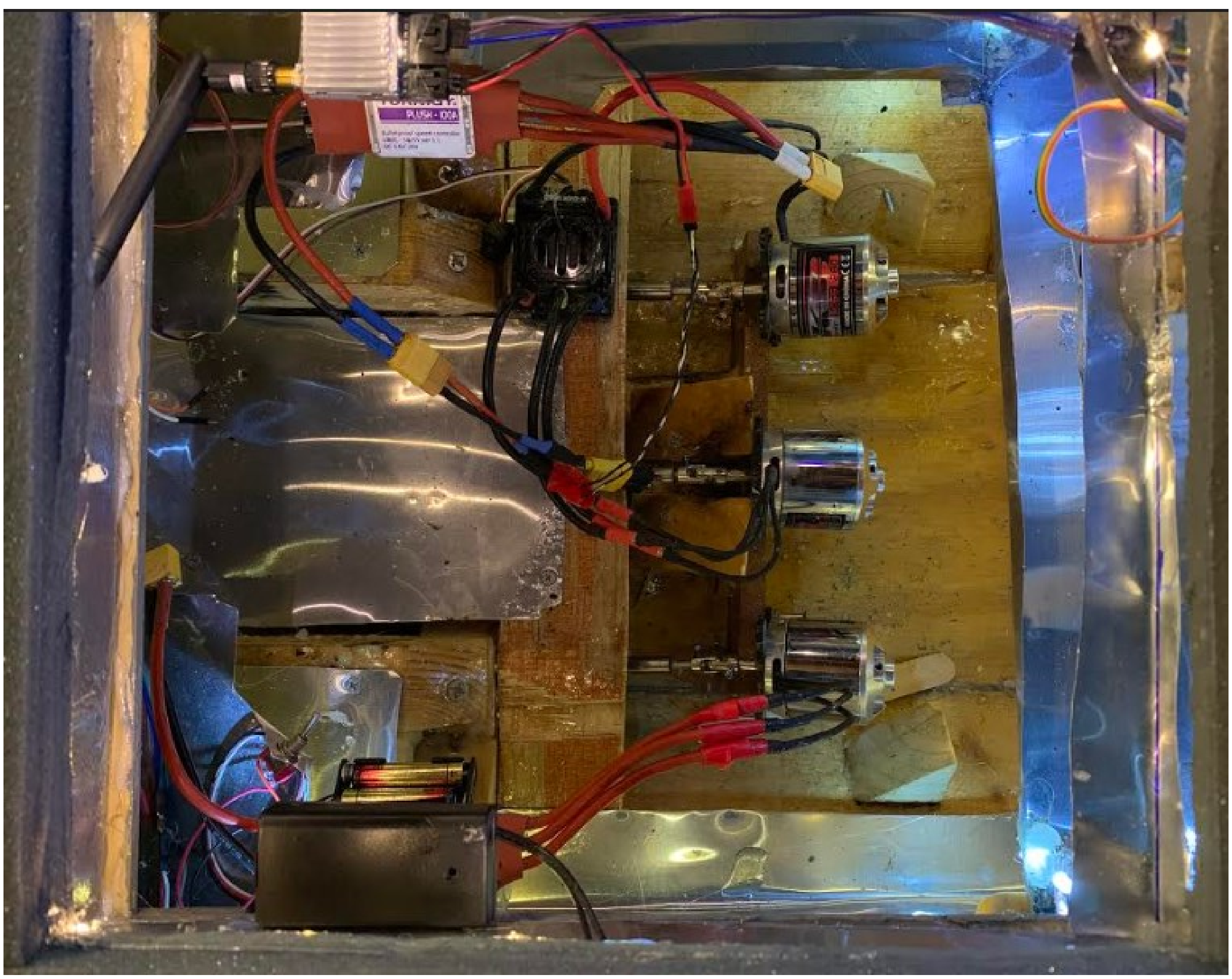
The next step was to program and install the electronics. A GPS was mounted to the roof of the forward pilothouse, and the Arduino and Raspberry Pi were mounted to a board that is secured into the ship just aft of the moon pool. A small screen on board the ship allows me to program the computer without having to remove it from the ship. It also allows me to easily start/stop data collection and monitor results. I use a mini USB mouse and a mini wireless USB keyboard for these functions.

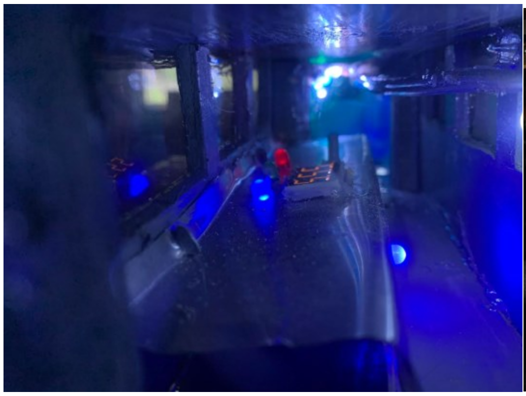
A side benefit of the small screen is that it doubles as a 1/32 scale movie theater! The photo to the right shows the view from the second bench in the completed theater, with the screen showing the desktop of the Raspberry Pi.

The moon pool was extended a few inches above the wooden shaft to avoid water sloshing over the top in rough water. The water column in the pool is prone to oscillating and sloshing due to pressure variations caused by hull hydrodynamics, especially when the vessel begins to roll or heave in rough water. While the lower hatch acts as a damper to prevent this when it is closed, large bundles of sensors will necessitate opening the hatch during data collection. I will likely add a hatch with a small gasket for sensor wires (modified Altoids tins work well).

Finally, a first-person viewing (FPV) system was installed. The camera (top left) is installed with its lens against one of the bridge windows, and it transmits to a video screen on land (top right). The transmitter is mounted in the engine room (below), and is currently tapped into the port ESC's battery wire.






In the photos above, two extra views of the ship are shown. On the left is the interior of the bridge, and on the right is a view of the ship's lights.

For the ship's first test, I took it to West Hill Lake in northwest Connecticut. The ship performed well, other than a broken rudder mount from hitting the tailgate of the pickup truck that it was transported in. The weight of the stern superstructure eliminated the propeller ventilation (sucking in air) problem as expected, and the small amount of water that entered through the broken rudder post was easily contained by the watertight bulkhead.

The ship has completed two data collection trips so far, both at West Hill Lake in Connecticut. Below is a map of the two temperature data sets. The first was taken in mid-afternoon on a sunny day, and the second was taken at sunrise a couple weeks later. In the first, it seems that the shadow of the trees and hills around the lake are lowering the temperature on the west (left in photo) side of the lake, but this may also be due to a greater concentration of springs in that region. It can also be seen that the first run cuts off three coves; this was done because I was having trouble with the motors and rudder and wanted to get back to the dock quickly. The blue dots in the second data set could represent the location of cold water from springs, but more data sampling is needed to test this. It seems that solar heating and springs are the main drivers of temperature gradients on the surface of the lake, but more testing at different times in the day will be able to better determine the influence of each.

Battery life is a perennial problem, especially for autonomous data collection. During the initial trials of the vessel, I follow it with a canoe in case of propulsion or steering problems. I used 5 A*h 3S LiPo batteries for all three motors for the first two tests. The two outer motors proved to be useful in the event of a main motor failure. However, the ship is slow with only the outer motors operating. Also, as the outer motors' prop wash does not intercept the rudder, the ship is very slow to turn on only outer motors. Therefore, the main motor will be the focus of battery improvements, since the 5 A*h batteries on the outer motors seem to be sufficient to bring the vessel to shore in case of a main motor failure.

As the goal is to allow this vessel to operate fully autonomously (in other words, no chase canoe!), range must be extended. I found that the main motor battery needed to be replaced one to two times per trial in the first two trials (each trial lasts about an hour). In the third test, I used a set of two 5 A*h 5S batteries wired in parallel for the main motor. Even so, at the end of the trial, the low voltage cutoff activated on the main motor and I had to use the outer motors to return to the dock.

I am considering three options: either buying even more batteries and wiring them in parallel, buying one huge battery, or converting the middle motor to a gas engine. The first option is most cost effective in the short term, but it is time consuming and irritating to need to balance voltage on lots of batteries before plugging them in on a parallel wiring harness. The second option is expensive (a suitable battery is $500+), but comparable of the sum of the cost of lots of parallel batteries, and also relatively clean (fewer wires running everywhere in the engine/battery compartment). The third option would be much cheaper, as the engine would probably be ~$300 (comparable to the ESC and motor combination). A gallon of gasoline also holds (roughly) the energy contained in 75 of the batteries that I have been using, and is a fraction of the cost. However, a retrofit would be difficult, as the engine compartment is designed for small electric motors rather than a gas engine and related components. Also, designing a suitable muffler would be extremely difficult, as it needs to be quiet enough to run at night near lakeside houses. I will likely adopt the first option, and mitigate the battery annoyance by buying a better charger that can charge multiple batteries at once.