Scuba Doo II
Technical Report
International Submarine Race
#11
May 2, 2011

Team Members:

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Introduction

In January 2011, the Seacoast team was formed with the goal to design, build, test, and race a human powered submarine in the International Submarine Race held in June 2011 at the David Taylor Model Basin. It quickly became apparent that this was an unreachable goal. The team did want to start participating in this activity so the decision was made to take an existing submarine, make and implement some design changes and proceed with a design and construction for the 2013 race. Additionally, there were several repairs and improvements that were required on the submarine. The two areas that were looked at with regard to design changes were a propeller design and a bottom ranging system. The team decided that the propeller design would be a mandatory change while the bottom ranging system would be something that would be experimental in nature. The propeller design is not finalized at this point but will be included in our final submarine Technical Report.

As part of the process for the team to learn about the design and operation of Scuba Doo II, the team reviewed the previous design report and performed a series of reverse engineering activities designed to understand just how the submarine functioned. This included taking accurate measurements of most components, documenting all information in a project engineering notebook, and disassembly of most major components such as the power unit, shaft, propeller, control surfaces, and control cables.

The Team

The team consists of 8 students of which 6 have PADI Open Water certification. The team includes 3 Pre-Engineering students and 1 Biotechnology student.

Design Changes to Scuba Doo II

The propeller design was based on experimental data gathered from a student science fair project (see Appendix A)

See Figure 3, 4, 5, and 6

Hull Construction

The SCUBA-DOO is 12 feet long and has a maximum diameter of 26 inches. There are 6 control surfaces on the hull that are used mainly for stability purposes. The hull was first developed in a program called RUNSUB. The offsets were adjusted in an EXCEL spreadsheet and programmed for 2” intervals. The inner and outer hull are formed using 10 oz glass mat and epoxy resin.

The hull was designed to have a 0.85” thick inner and outer skin with a ¾” thick foam core. The glass cloth used was 9.66 oz and the mat used was 1.5 oz . the composite was made up of 4 piles of glass cloth (for strength reasons) and one outer ply for fairing purposes. Two part laminating epoxy was used.

See Figure 1, 2 and 11

Control Surfaces

The control surfaces of the Seacoast Scuba Doo are quite similar to that of the wings on an airplane. When the Scuba Doo moves through the water, the water current pushes downward on the control surfaces. This downward force on the control surfaces tilts the Scuba Doo down. As the Scuba Doo submerges further down, it becomes positively buoyant, causing it to then rise. This process allows for quick, efficient movement through the water.

The control surfaces are controlled by a cable system. The forward planes are controlled by a hand lever which also contains the emergency buoy release mechanism. The rudder mechanism is also controlled by a cable mechanism controlled by the pilot via a similar lever mechanism.

See figure 7, 8, 9 and 10

Hatch and Safety

The sub is painted with a shade of bright yellow to increase the visibility of the sub under water. Its egress is a large buoyant hinged hatch with a hatch release that can be accessed by the pilot and the rescue and is marked with a 4" patch of orange labeled "rescue." Hatch release is going to be tested in shallow water before the race to ensure it is operating correctly. The pilot will be strapped in with a strap or shoulder harness and the feet will be attached to pedals. The pilot will be able to navigate by looking out of an acrylic dome that allows one to see almost 180 degrees. A strobe light will be placed on top of the upper rudder to allow 360 degrees of visibility. There is an emergency pop up buoy is made of Styrofoam and will carry a tether cord to the surface. This emergency buoy is released by a fail-safe mechanism that requires the pilot to maintain control of at all time or the buoy will be released.

Propulsion

Through reverse engineering, the propulsion system was found to be a cut down bike frame that was welded to an attachment plate, and then bolted to the keel. The other end was bolted to an aluminum cross beam that is fiber glassed to the wall. The bike crank has a clip-on option for shoes. On the opposite side, the bike frame had a set of sprockets for different gear ratios which can only be change by hand. The sprockets are attached to a bevel gear box that turns a threaded ¾ in. diameter shaft using a LOVEJOY coupling.

The coupling has a rubber spider that was designed to reduce strain on the gear box when torque is suddenly applied. The shaft is supported by two bulkheads and flange bearings. Our team has decided to replace the old shoe clips with frog clips instead. Also instead of keeping all five sprockets, our team is going to keep one and get rid of the rest. The whole system was greased, cleaned, and is currently being replaced of any old rusty parts.

Buoyancy Control

To determine the ballasting requirements of the submarine, the team did a reverse engineering technique that measured the circumference of the submarine every 6 inches. The circumference was converted to radial dimensions and placed into Excel to validate the reasonability of the measurements. The data from Excel was used to build a CAD model of the hull using Autodesk Inventor. It was determined that the hull displaced 44677 in^3 with a shell displacement of 6683 in^3. See Figure 1 and 2 and attachment for detailed calculations. The resultant displacement was determined to be 241 pounds requiring the addition of steel ballast. <insert foam density calculation>

Life Support and Safety

Safety is a primary concern when dealing with scratch-built submarines like the ones present at the ISR. There must be a quick, reliable, and effective means of escape for the pilot if something were to go wrong. There is a dead-man switch that must be held in place at all times by the pilot. If it is released, a bright red safety buoy will emerge out of the rear of the hull of the submarine. It will be an alarm to the safety divers that there is an emergency, and they will assist the pilot from the submarine immediately.

The second means of reliable and quick escape is the hatch. There is a small lever on the side of the cockpit, and when moved forward it will cause the main hatch to pop open. This will allow the pilot to exit the submarine quickly and safely.

The life support system seen in the Scuba-Doo is basically a slightly-modified SCUBA rig. It consists of a single air tank housed in two brackets underneath where the pilot is located. The air tank feeds to a regulator which allows the pilot to breathe.

The submarine is equipped with a SCUBA tank and regulator that will provide the primary air supply for the pilot. The tank will contain a pressure gage that will be mounted in such a way as to be visible from the outside of the submarine. Additionally, the pilot will carry a backup air supply. At no time will the primary air supply be allowed to fall below 500 PSI. During operation, the pilot will be required to maintain positive control of a “dead-man’s switch” that will prevent a tethered emergency buoy from being released. If at any time this switch is released, the emergency buoy will float to the surface initiating emergency rescue operations. The positively buoyant egress hatch to the submarine is held in place by a latching mechanism that can be release either by the pilot from inside or by support divers from the outside of the submarine.

Testing

Seacoast Scuba Doo's primary testing sight is the University of New Hampshire's freshwater testing basin. The University of New Hampshire opened their basin to our team on Martin Luther King Jr. day. There will be more practices at The University of New Hampshire's basin. Those wanting to pilot the submarine on race day will have their opportunity to practice. Team Seacoast Scuba Doo's challenge is to find waters to practice in frequently.

Training

For training for the 2011 International Submarine Race, the team members are currently working on SCUBA certification. Upon completion of certification the team is planning on conducting two “sea trials” at the University of New Hampshire Ocean Engineering facility. The goal of this activity is to familiarize team members with the process of handling and ballasting the submarine for neutral buoyancy at a depth of 20 feet.

Project Summary

The Seacoast ISR team has completed overhaul of Scuba Doo II and will be conducting trials and crew training at the University of New Hampshire Ocean Engineering facility in May and June of 2011. The team has completed reverse engineering of the submarine hull. Remaining work to be accomplished prior to the race is to complete a new propeller design and manufacture as well as investigate the feasibility of developing a bottom ranging system to aid the pilot in keeping the submarine a constant depth above the race course bottom. The team is also researching a better method for attachment of the pilot’s feet to the propulsion system pedals.

Scuba Doo 2 Model Data

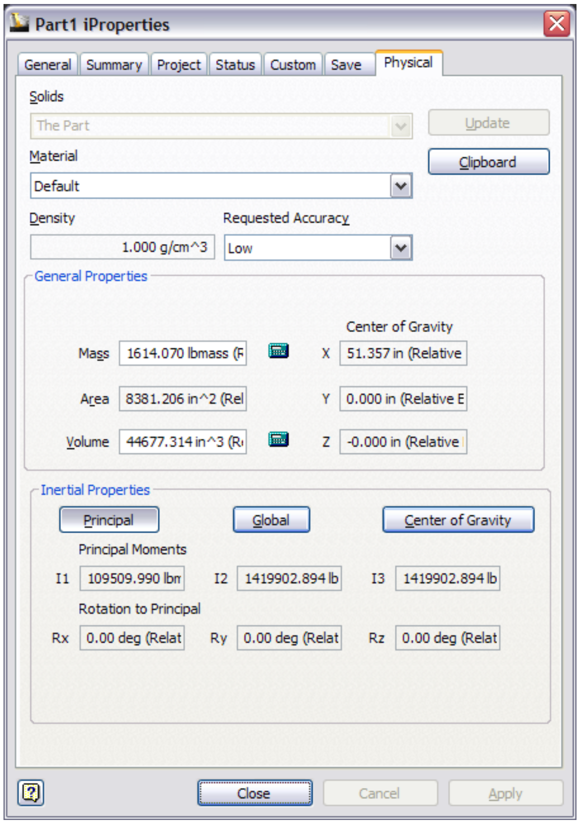


Figure 1 Scuba Doo 2 Solid Model

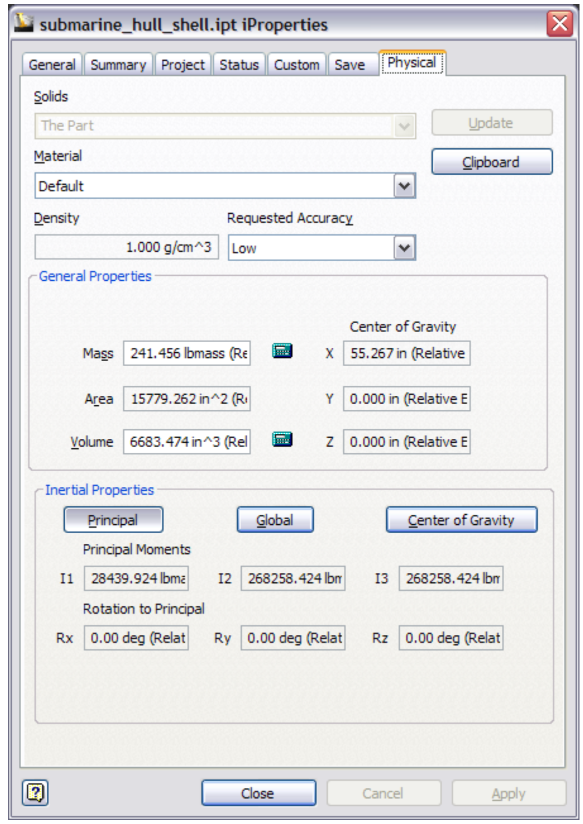


Figure 2 Scuba Doo 2 Shell Model

Volume Calculation:

$$Volume\_Entrained = Total\_Volume - Volume\_Shell$$

$$Volume\_Entrained = 44677 \text{ in}^3 - 6683 \text{ in}^3$$

$$Volume\_Entrained = 37994 \text{ in}^3$$

Displacement Calculation:

$$Displacement = Volume\_Displaced \times Density$$

$$Displacement = 6683 \text{ in}^3 \times 62.37 \, {}^{lb}\!/_{ft^3} \times {}^{1 \text{ ft}^3}\!/_{1728 \text{ in}^3}$$

$$Displacement = 241.2 \text{ lbs}$$

$$Note: Density\ is\ at\ 60\ degree\ \ fresh\ water$$

Entrained Water Calculation:

$$Entrained\_Mass = Entrained\_Volume \times Density$$

$$Entrained\_Mass = 37994 \text{ in}^3 \times 62.37 \, {}^{lb}\!/\!_{ft^3} \times {}^{1 \text{ ft}^3}\!/\!_{1728 \text{ in}^3}$$

$$Entrained\_Mass = 1371.3 \text{ lbs.}$$

$$Note: Density\ based\ on\ 60\ degree\ fresh\ water$$

Appendix A

Langdon Tarbell

Mrs. Shevenell

Honors Chemistry

4/4/11

Variable Pitch of a Propeller's Blades

1. **Question:** Will the pitch of the propeller effect the speed of the boat.
2. **Hypothesis:** if the propeller has a higher the pitch then the faster the boat will be able to travel but with a slower acceleration.
3. **Experiment:**
    1. A small hole was drilled in the back of a small plastic boat and a drive shaft was inserted through the hole. An electric motor was attached to the interior end of the shaft. The outer end of the drive shaft was attached to a propeller that was equipped with variable pitch.
    2. A test basin was constructed about six time longer than the boat and about one inch of clearance on either side of the boat.

3. The variable pitch propeller was constructed from a dowel about one half inch long with holes drilled at two even intervals around the middle of the dowel for which the two identical blades of the propeller were inserted.
4. The blades were made out of a thin plank of wood with dowels glued to the edge of the blade. The dowels were the size of the hole that was made in the propeller hub.
5. The boat assembled was placed in the filled test basin was the motor was started

1. With a 9v battery (the battery was replaced by a new one each trial to escape the variable of battery drain).
2. The boat was then released from and a time was taken of how long the boat took to travel the length of the basin.
3. Step 6 was repeated three time for each of the pitches of the propeller blades.

2. **Results:**

Pitch of propeller	18 degrees	36 degrees	54 degrees	72 degrees
Trial 1 (sec)	54	20	13	20
Trial 2 (sec)	45	19	12	19
Trail 3(sec)	50	18	12	23

Trial	Time
Trial 1 (sec)(ave) 18 degrees	49.67
Trial 1 (sec)(ave) 36 degrees	19
Trial 1 (sec)(ave) 54 degrees	12.33
Trial 1 (sec)(ave) 72 degrees	20.67

Conclusion:

In this experiment, the power cure of a propeller was determined to have max power at around 54 degrees pitch. The experiment was a success because I was able to find the effects of a variable pitch. The places of error are in the moving parts for example the batteries could have had different charges even though they where all supposed to be 9v batteries. The boat also did not have corrective steering so the boat rubbed against the side of the basin while traveling down the tank creating drag potentially effecting the results. The propeller shaft also was disconnected half way through the experiment once because the engine over heated so extra glue was added to the link to prevent that from happening again.

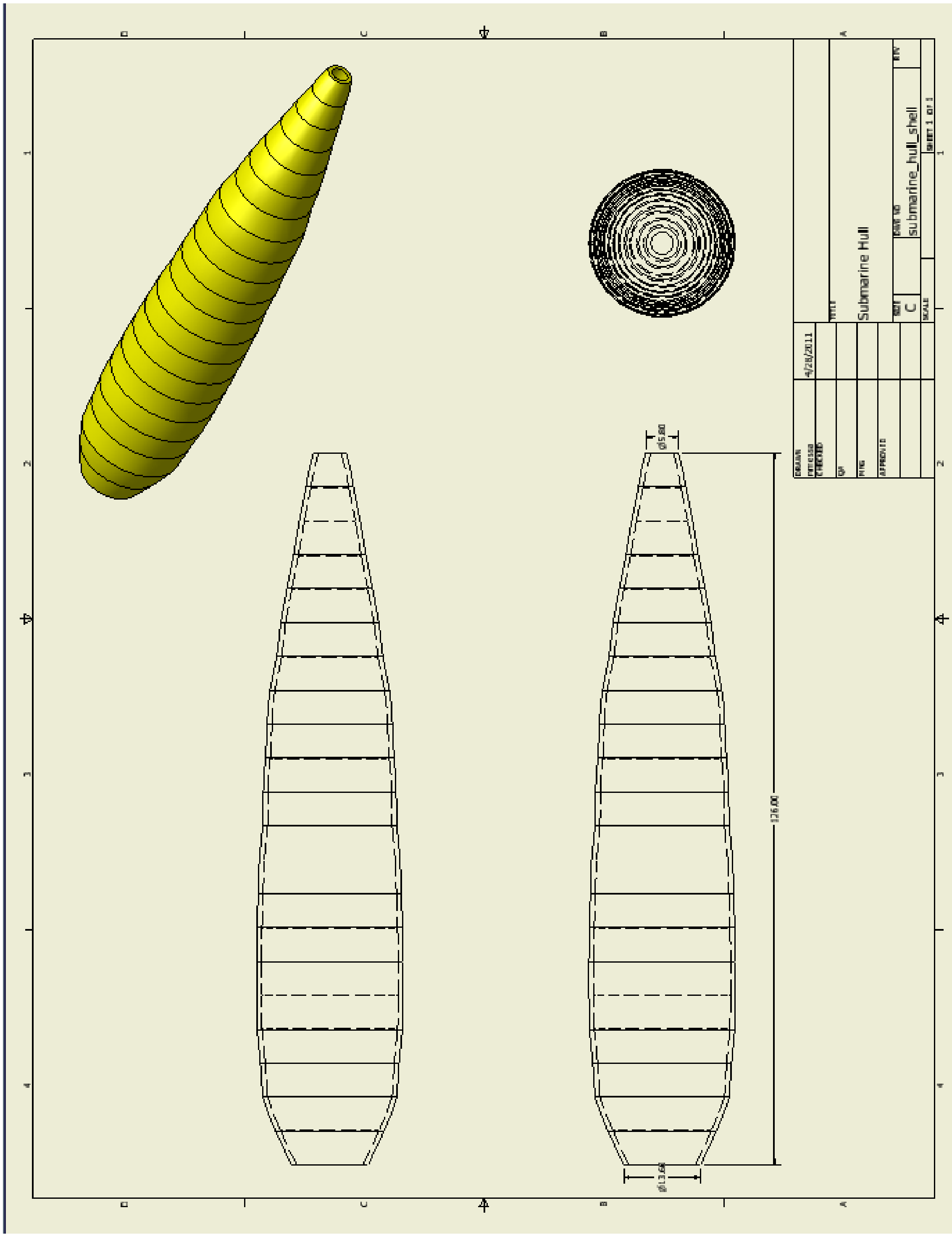


Figure 1 Submarine Hull

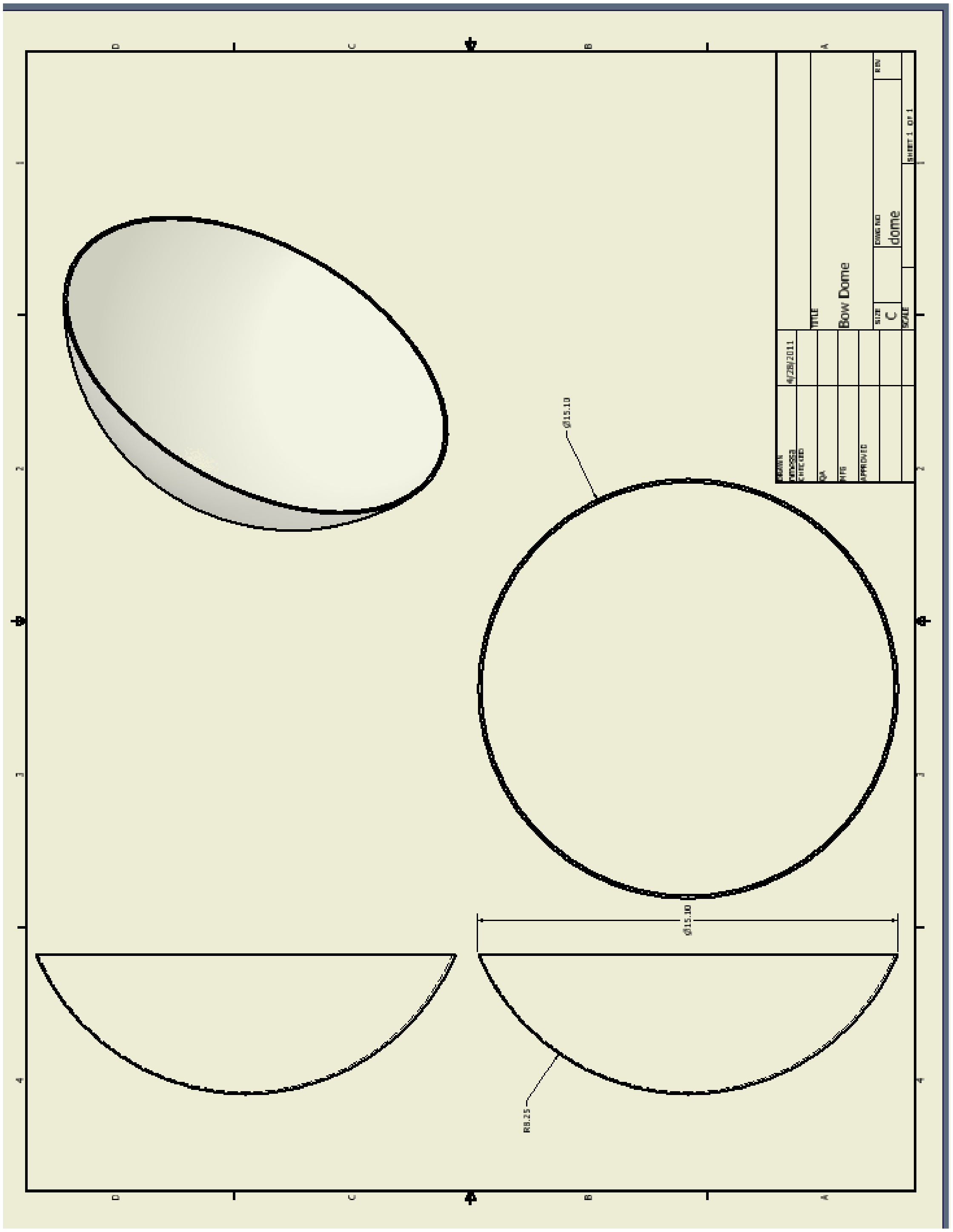


Figure 2 Clear Bow Dome

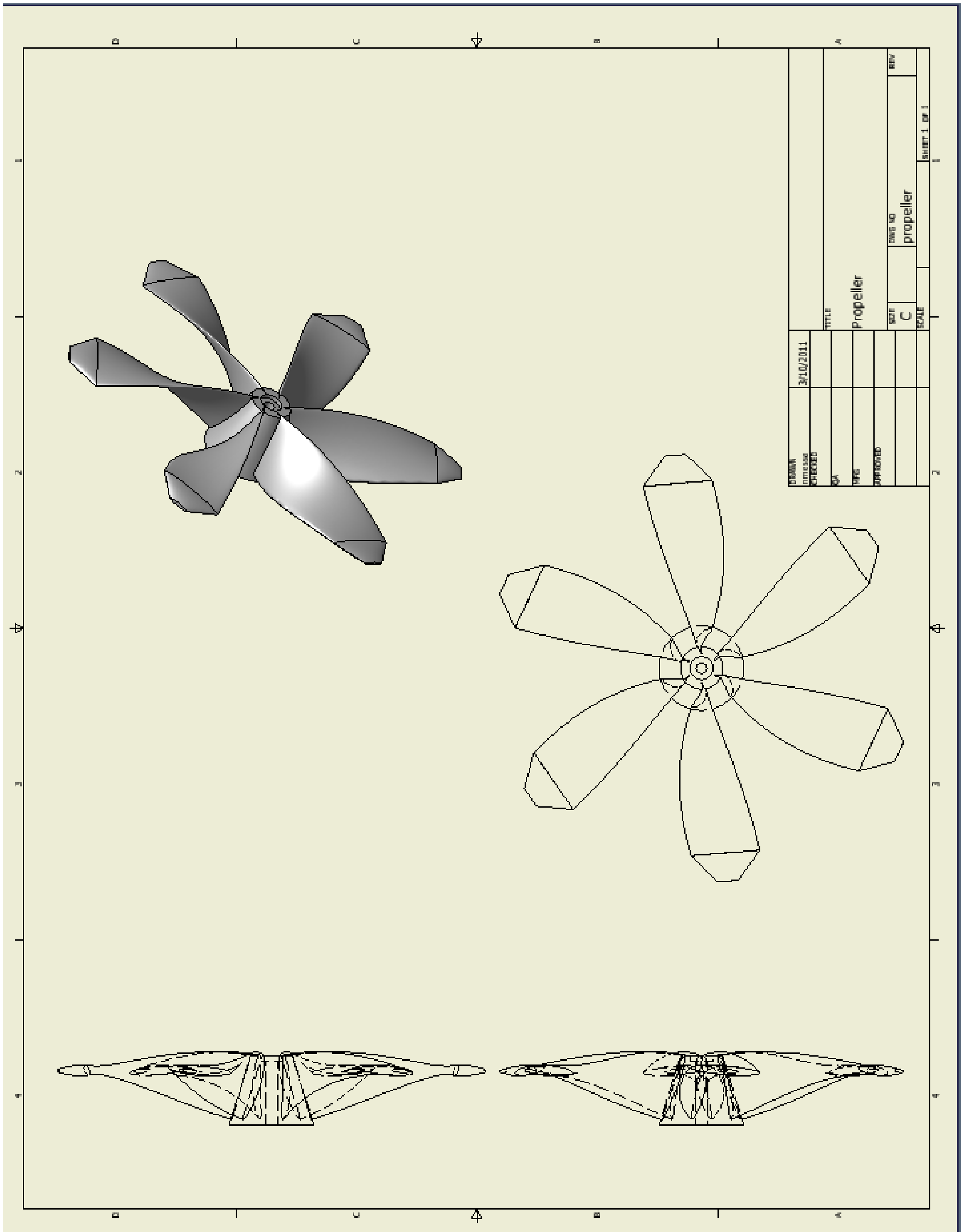


Figure 3 Propeller Assembled

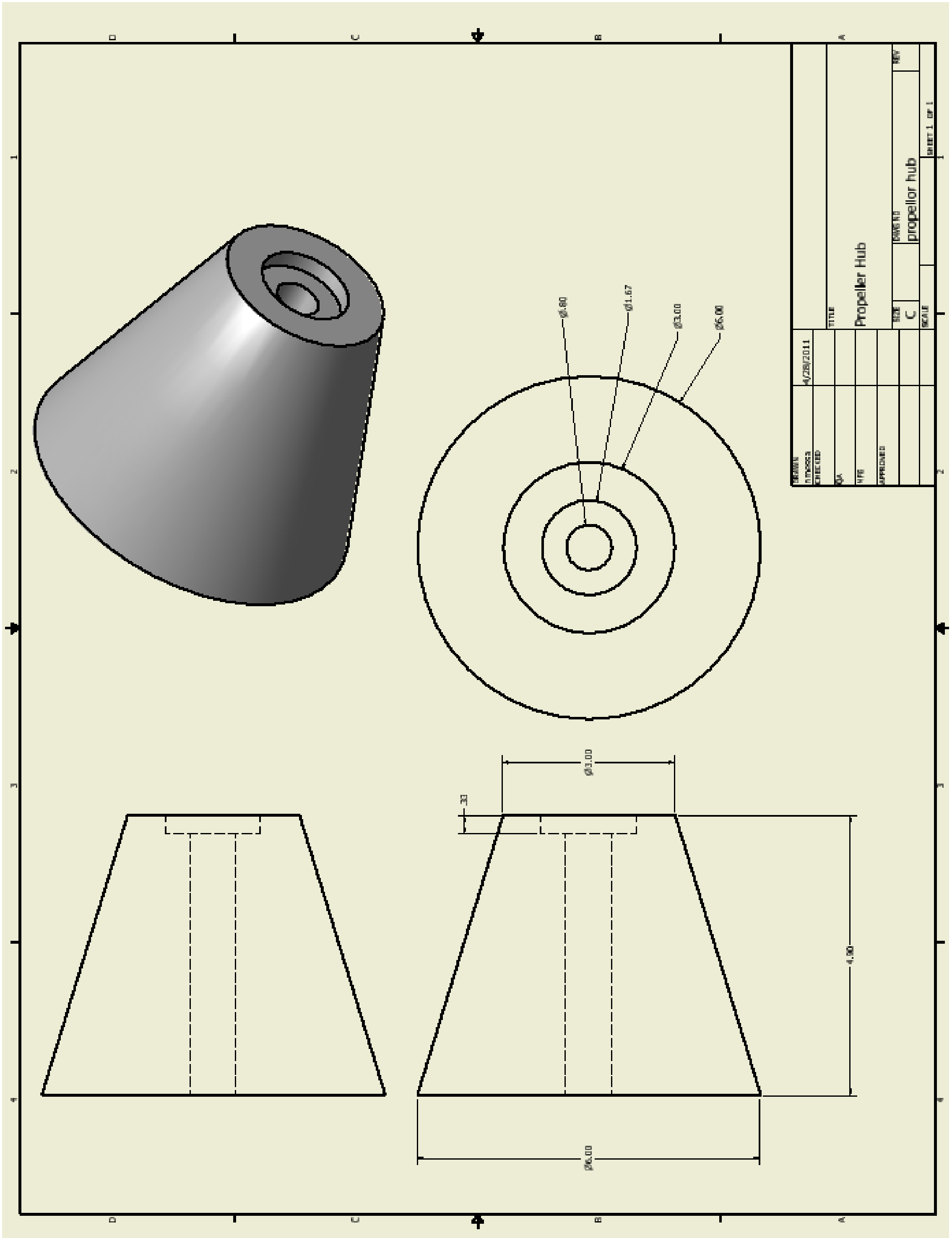


Figure 4 Propeller Hub

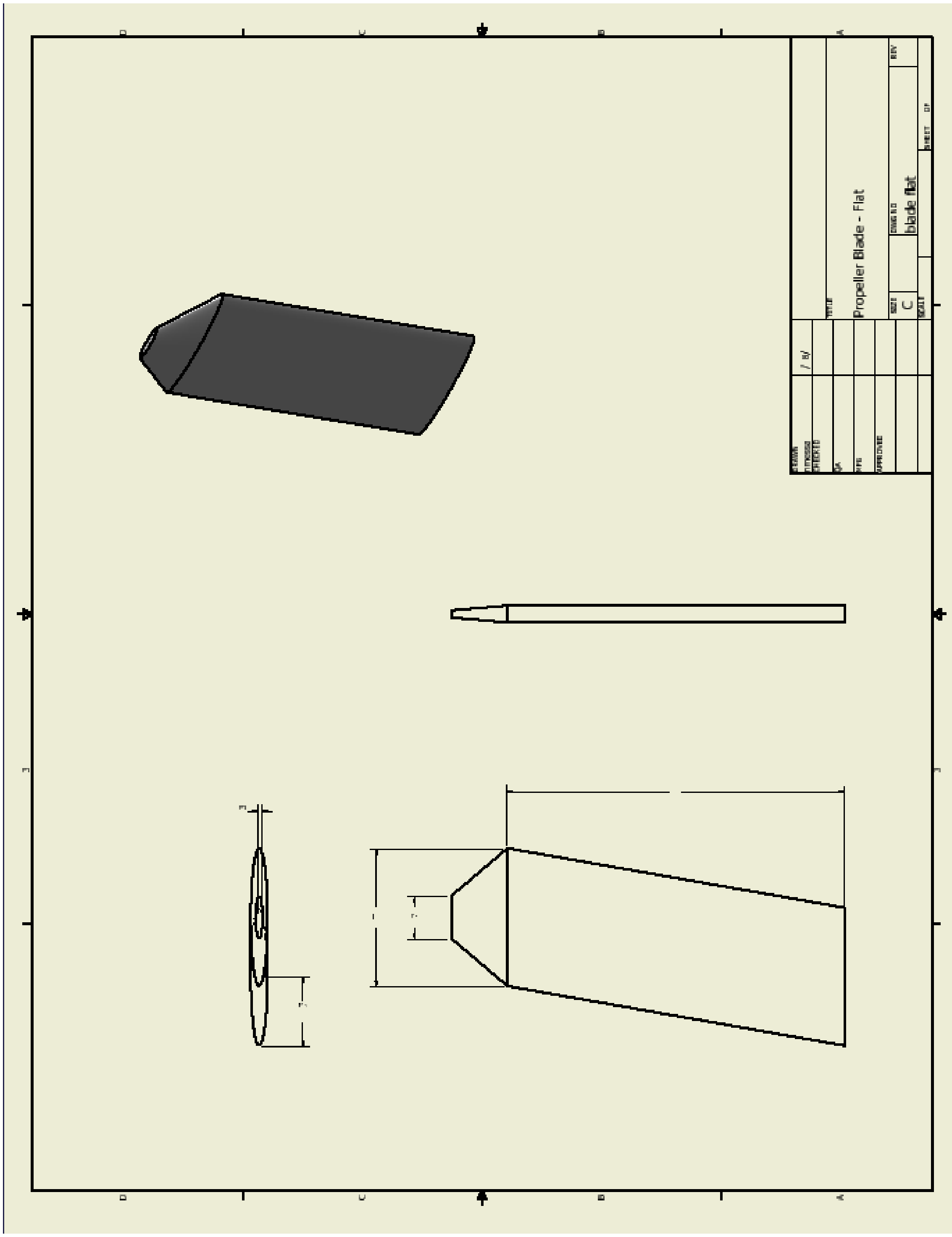


Figure 5 Propeller Blade Straight

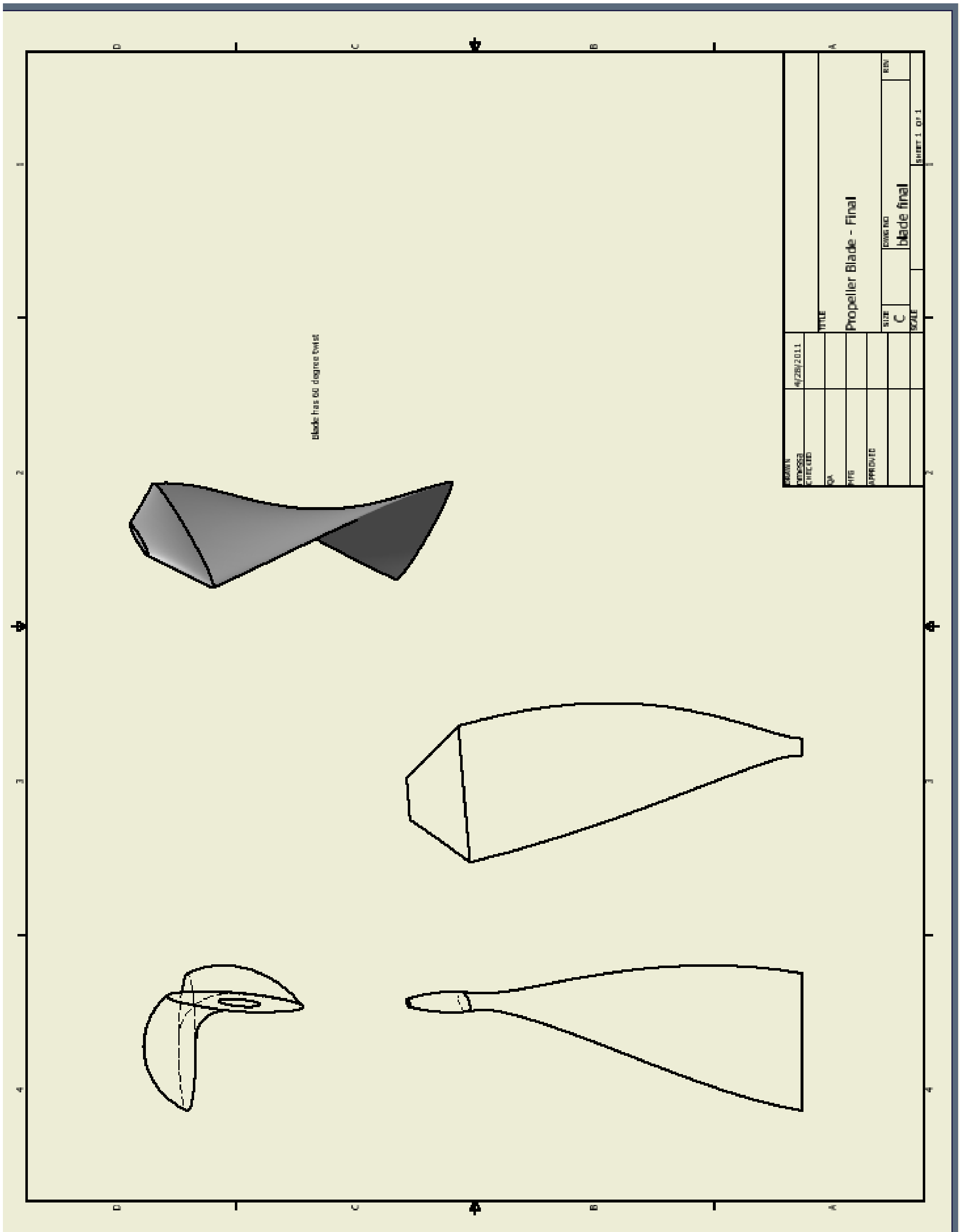


Figure 6 Propeller Blade with 60 degree twist

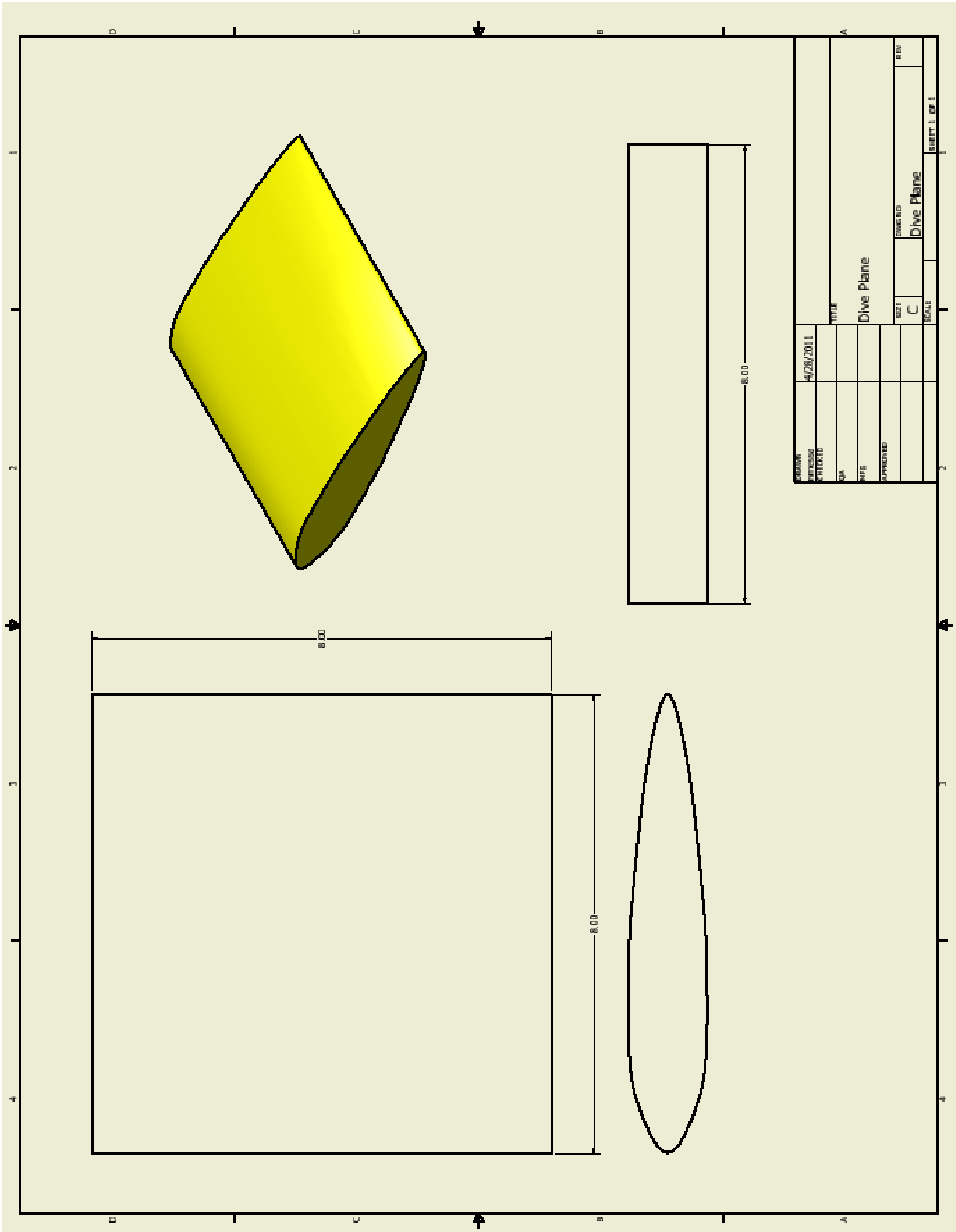


Figure 7 Diving Plane

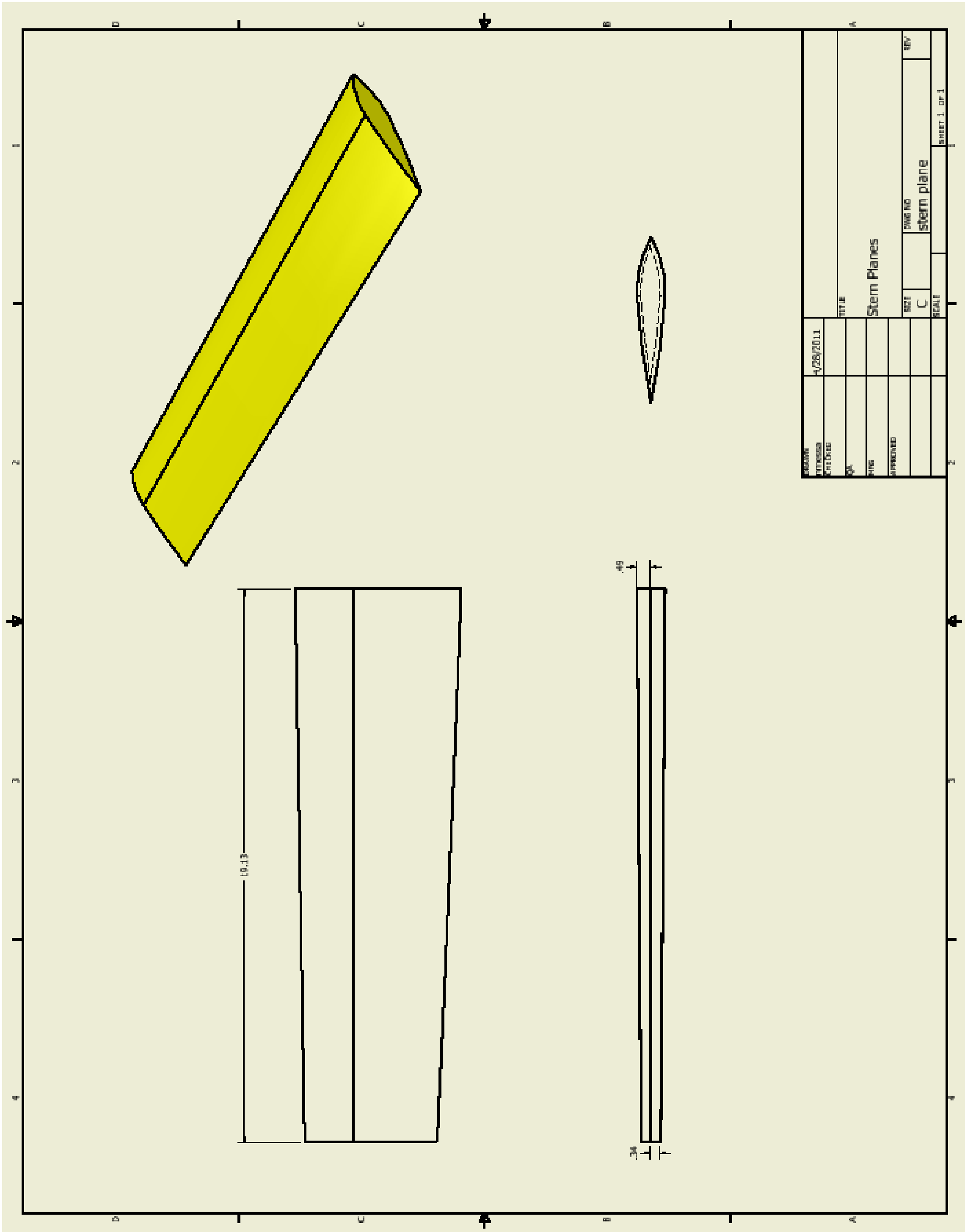


Figure 8 Fixed Stern Plane

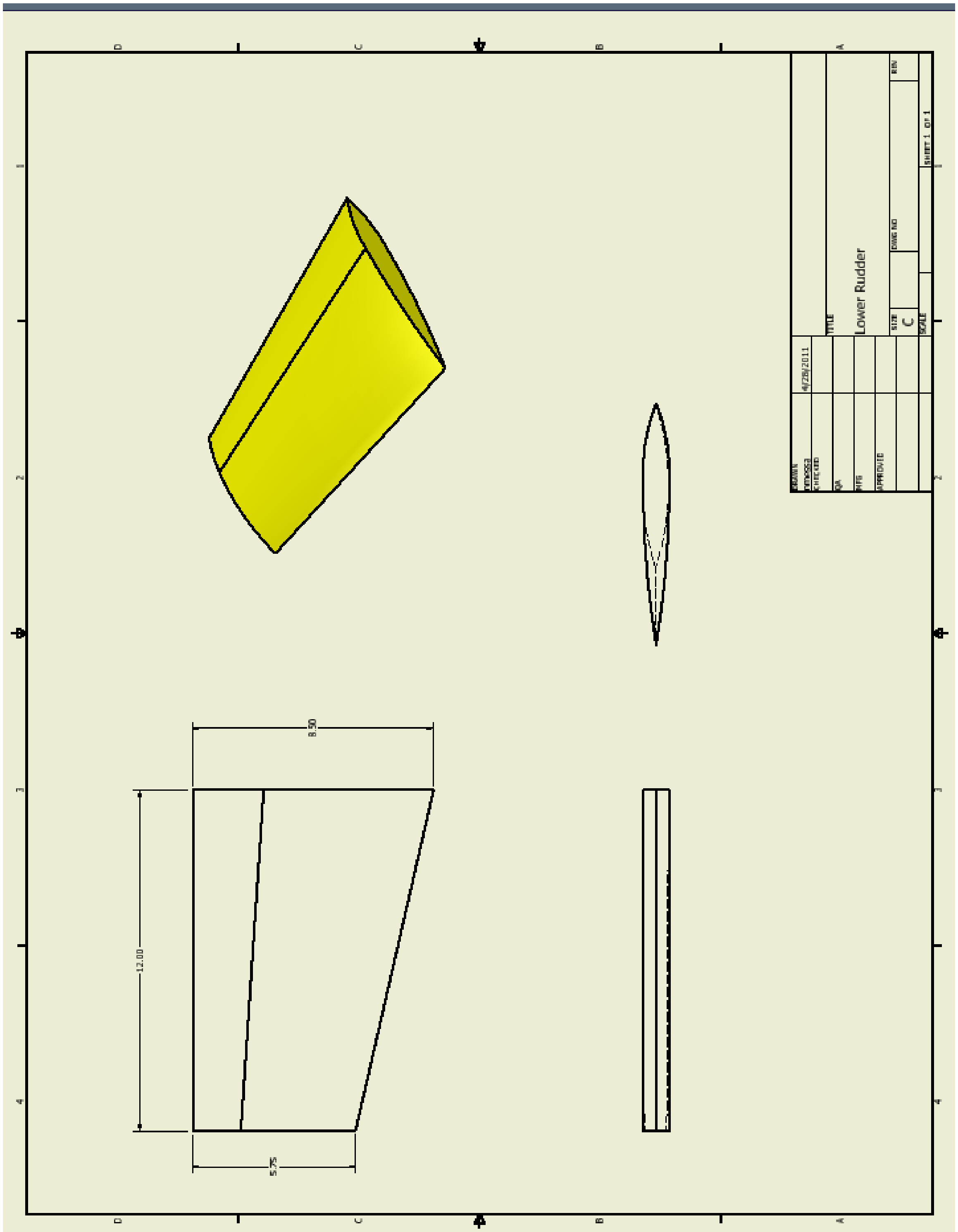


Figure 9 Lower Rudder

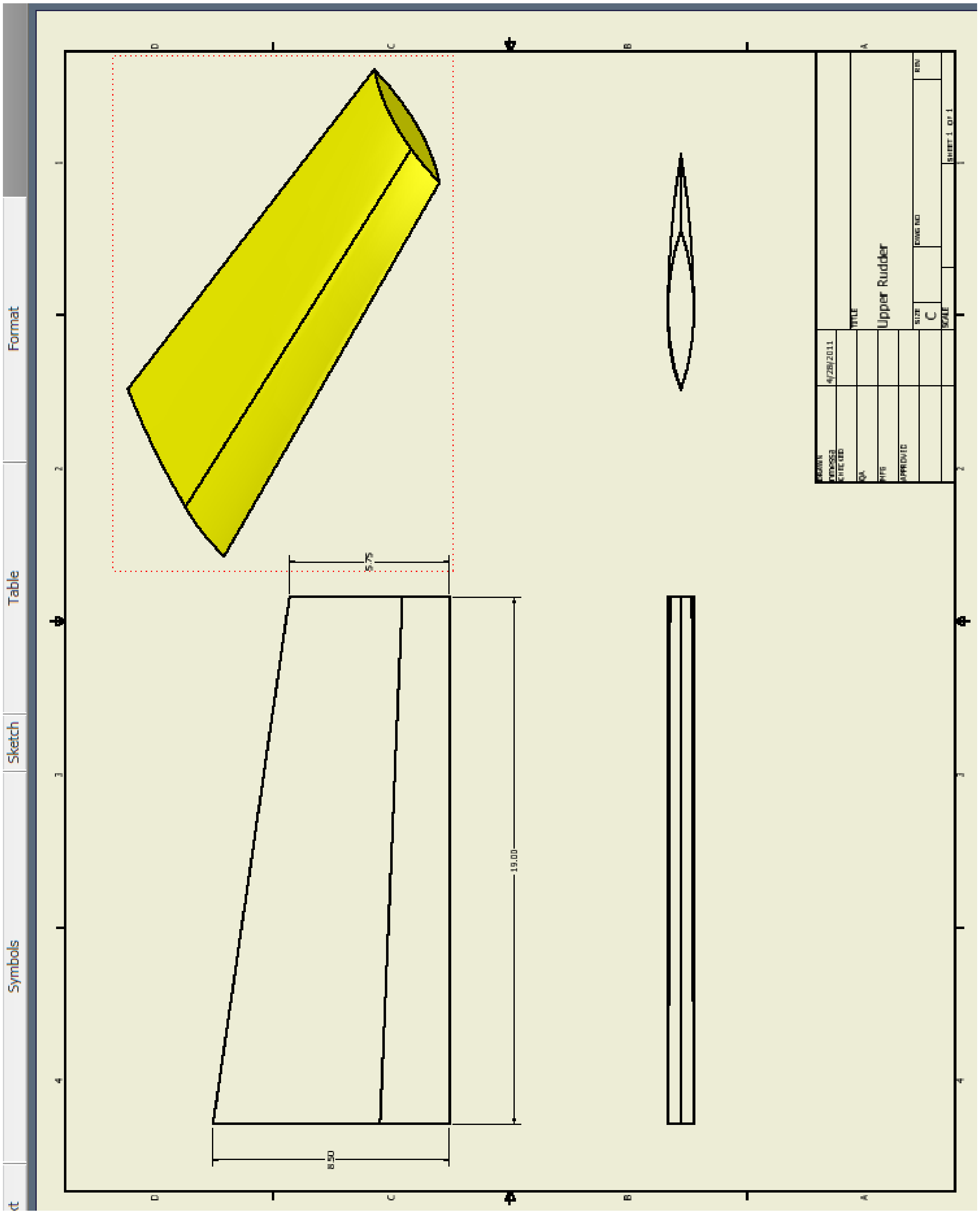


Figure 10 Upper Rudder

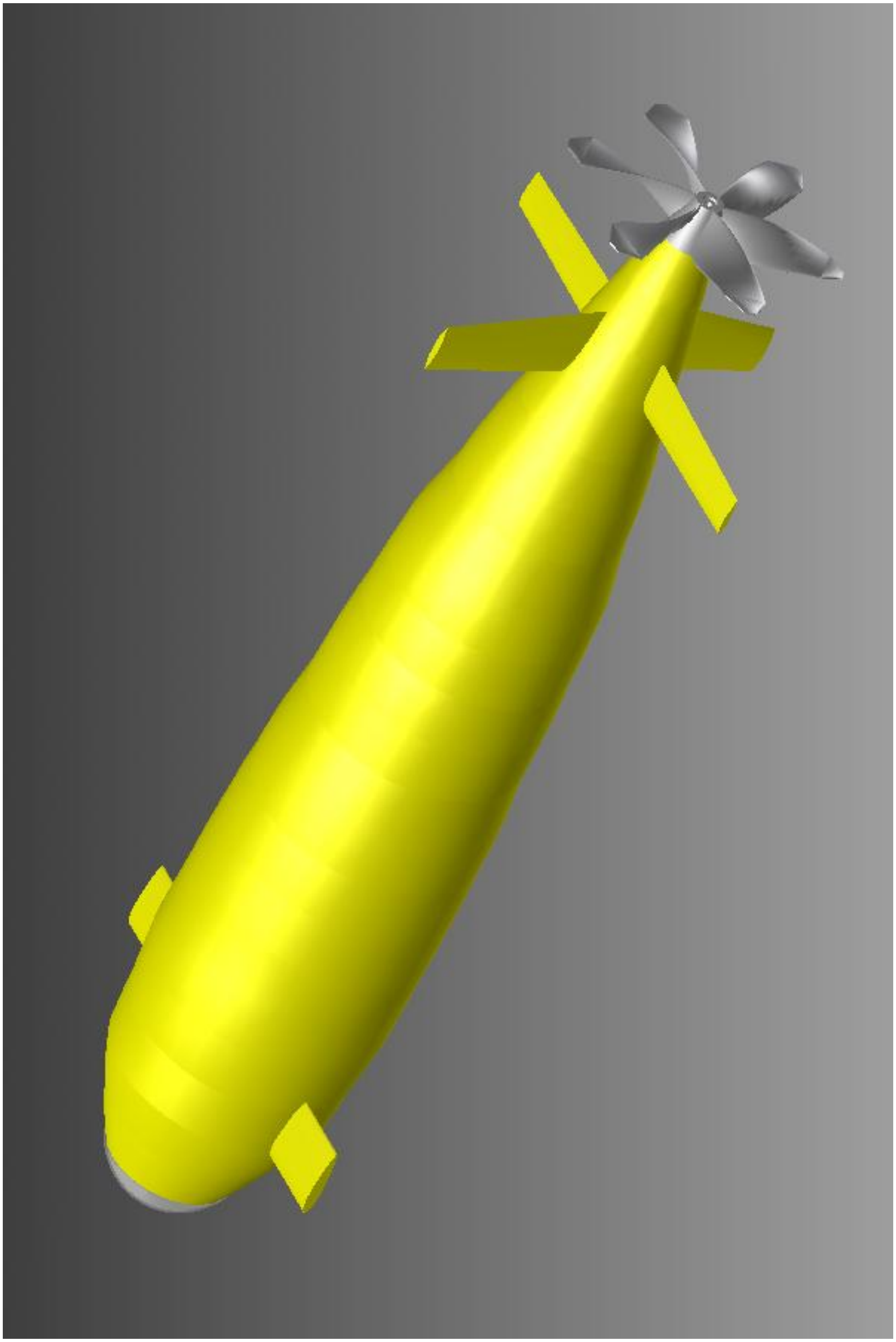
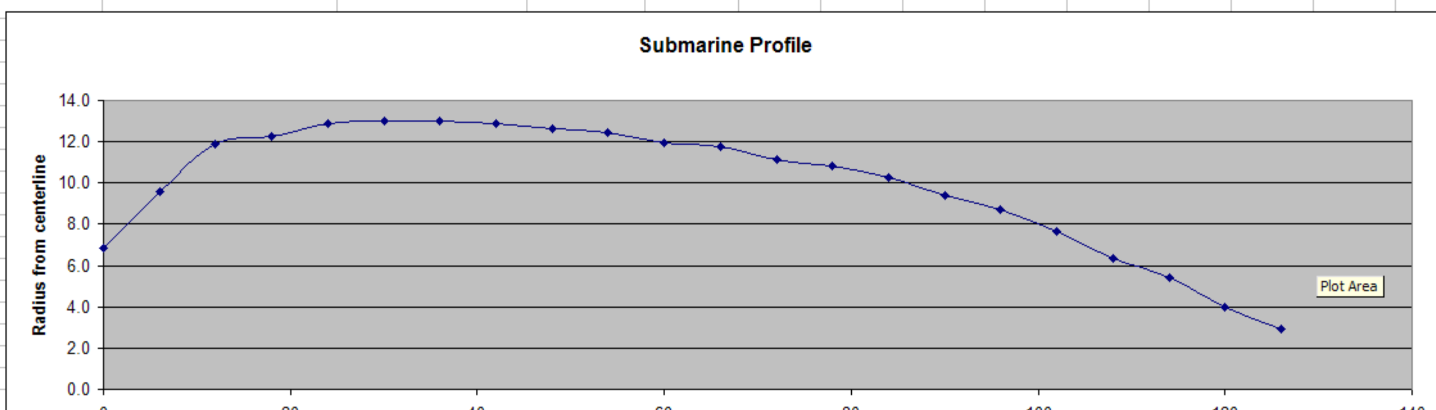


Figure 11 Assembled Submarine

Microsoft Excel - Submarine Profile.xls

Distance	Distance in Inches	Circumference	Diameter	Radius
0' 0"	0	43	13.7	6.8
0' 6"	6	60	19.1	9.6
1' 0"	12	74.5	23.7	11.9
1' 6"	18	77	24.5	12.3
2' 0"	24	81	25.8	12.9
2' 6"	30	81.5	26.0	13.0
3' 0"	36	81.5	26.0	13.0
3' 6"	42	80.75	25.7	12.9
4' 0"	48	79.5	25.3	12.7
4' 6"	54	78.25	24.9	12.5
5' 0"	60	75	23.9	11.9
5' 6"	66	74	23.6	11.8
6' 0"	72	70	22.3	11.1
6' 6"	78	68	21.7	10.8
7' 0"	84	64.5	20.5	10.3
7' 6"	90	59	18.8	9.4
8' 0"	96	54.75	17.4	8.7
8' 6"	102	48	15.3	7.6
9' 0"	108	40	12.7	6.4
9' 6"	114	34	10.8	5.4
10' 0"	120	25	8.0	4.0
10' 6"	126	18.5	5.9	2.9



Sheet1 Sheet2 Sheet3

Ready