Chico State Team
Collegiate Wind Competition
Engineering Contest 2017

CHICO STATE
ENGINEERING

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Executive Summary

The Chico State team identifies with several priorities that are instilled at the college and university. One priority that resonated with this Chico State team is "…promote active learning, curiosity, ... and other expressions of a full and healthy student environment." While raw technical knowledge and skill are an integral part of an engineering project, maintaining a healthy environment through effective teamwork, positive camaraderie and responsible communication promotes success. All five members of the team understand that success is something to share and failure is not an option.

Sustainability is another core value upheld by Chico State. The university states in their strategic plan, "...we will create environmentally literate citizens, who embrace sustainability as a way of living." Holding true to this, an effort was made to re-use materials whenever possible and carefully consider the processes in which designs are manufactured.

Another value which the team agreed on early was to "keep it simple." With this being said, the team was not deterred from taking on challenges and calculated risks which could ultimately contribute to overall project success.

While failure is often perceived in a negative light, the Chico State Team adopted a different opinion: the motto "fail early and fail often" was echoed with the understanding that failures are learning opportunities that can be converted into future successes.

The Chico State Team set a key goal: to achieve first place at competition. To accomplish this, multiple components needed to be integrated into a comprehensive design including a responsive yaw system, advanced pitch control, electrical and mechanical safety measures, and dynamic control systems. Additionally, these systems would be tested and verified with meaningful test data.

New to competition this year is the requirement of autonomously responding to multi-directional wind. A component of the turbine design that satisfies this requirement is the passive yaw system. Composed of a wind vane and lazy-susan bearing, the design ensures proper yaw force to passively realign the turbine in multi-directional winds, while remaining unobtrusive to the wind flow when aligned. This was important for maximizing aerodynamic efficiency.

The airflow blockage by the wind vane and nacelle was a major factor in deciding the aerodynamic design. This led to minimizing the diameter of the nacelle and the thickness of the wind vane to ensure maximum airflow through the blades. The blades were designed for aerodynamic efficiency by selecting airfoils with a high coefficient of lift to drag ratio for the low Reynolds numbers produced by a small turbine. Additionally, pitch control was implemented to optimize efficiency at various angles of attack and wind speeds.

The turbine was designed for manual or controlled safety shutdown in the event of an open circuit or load disconnection. The manual shutdown is triggered by a normally closed switch provided at competition. Controlled shutdown occurs when the current sensed to the load drops to or near zero amps. When the shutdown sequence commences, a microcontroller opens a magnetic switch which is normally closed. This process results in the generator's power and ground wires connecting, grounding the motor and slowing the blades.

A dynamic pitch control system was implemented. Pitch control was pursued to support the system's ability to control stalling as well as optimize power production and efficiency. As wind speeds vary, the pitch of the blades is altered by a servo motor-lead screw assembly. This allows the turbine to reach a stalling point at multiple wind speeds. By translating the servo motor's rotation to linear motion, the system is able to push or pull on a sliding yoke assembly that alters each blade's pitch as a microcontroller searches for maximum power production based on feedback current and resistance. Simulations were conducted to optimize the efficiency of the blade design at a fixed pitch [Figure 1].

Figure 1: Flow over airfoil NACA 2418

Testing is an integral part of the design process. An iterative testing method was utilized to find the best blade design for competition. The closed-loop wind tunnel at California State University, Chico was used to verify theoretical blade performance to experimental. The results shown in Figure 2 represents the coefficient of power versus the tip speed ratio (TSR) of the final blade design. Figure 3 represents the expected power output of the blades at several TSR values.

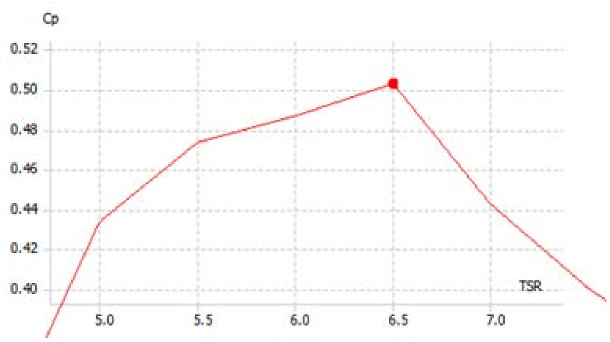


Figure 2: Expected blade coefficient of performance with respect to TSR

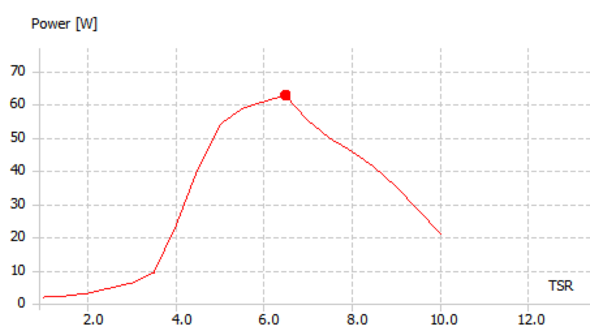


Figure 3: Expected power with respect to TSR

Based on great teamwork, excellent engineering and careful analysis of data and theory, the Chico State prototype wind turbine is predicted to achieve 30 W of power at 8 m/s, respond to multidirectional wind, and dynamically adapt blade pitch to maximize efficiency and performance throughout the rigorous competition wind tunnel testing.

1. **Final Design Description**

1.1 Overview

The purpose of this competition is to build a small-scale wind turbine that offers solutions to problems often encountered in the industry. These include maximizing power across varying wind speeds, accommodating for multidirectional winds, safely shutting down in the event of electrical disconnect, maintaining constant power after a set cut out wind speed and preserving durability. The final design is a horizontal axis wind turbine. The design utilizes three blades. Due to the complex nature of components such as the nacelle and blades, they were 3D printed out of ABS and PLA plastic.

1.2 Maximizing Power

A critical problem the design addresses is maximizing power production across varying wind speeds. This is accomplished with a pitch control system utilizing an Arduino Uno to drive a servo motor-lead screw assembly, actively pitching each blade. The pitch control system operates with the assistance of a bought component called a sliding yoke. Originally designed for RC helicopters, the part is intended to alter the pitch of the blades by moving a collar linearly. As the collar moves, linkage arms that are connected to the blades pivot, effectively altering the pitch.

The lead screw is connected to the collar of the sliding yoke via a connecting arm. The lead screw has a hex nut and brass mounting nut threaded on it to serve as a fixed surface. A brass wire is wrapped around the collar of the sliding yoke and is adhered to the hex nut. Rotation of the lead screw by the servo motor adjusts the position of the sliding yoke. Identical to its intended application, linear travel of the collar translates to pitching of the blades. As the blades are pitched, the angle of attack along the length of the blade is altered to account for the changing direction of the apparent wind.

Figure 4: OXY heli rotor head, sliding yoke assembly

1.3 Accommodation of Multidirectional Wind

Another problem the design addresses is the accommodation of multidirectional wind. To simulate this, the turbine base plate will be mounted to the tunnel base flange and will be forced to yaw up to 720 degrees in a given direction at a rate of up to 180 degrees per second. The design solution includes a passive yaw system composed of a wind vane and a lazy susan bearing. The entire nacelle rests on the lazy susan bearing, allowing for free rotation. The wind vane's purpose is to react to the force of the wind and align the turbine parallel to the wind flow.

1.4 Maintaining Constant Power

To satisfy the rated power and rated rpm categories, the power output as well as rpm must be controlled when wind speeds exceed 11 [m/s]. Without the assistance of pitch control, increasing wind speeds would correlate to higher rpm of the blades and thus an increase in power output. With pitch control active, the blades are forced to stall as wind speeds reach the upper rated limits and the power is held constant. This is the same pitch control process that is described above, but with a slightly different application. Instead of utilizing pitch control to optimize power performance, the goal is to maintain constant power and rpm through increasing wind speeds

1.5 Durability

Durability over a long period of time is a desirable feature in the design of a wind turbine. One important component of the overall durability of a turbine is the structural integrity. Maintaining structural integrity at wind speeds of up to 18 m/s is achieved in the design through proper tower sizing. A SolidWorks Flow Simulation was performed in order to analyze the force on the assembly in the worst case scenario. When the assembly is in an orientation perpendicular to and 18 m/s wind speed, it experiences a maximum force of 37 N. A 1040 steel wall thickness of ⅛ " provides the tower with a factor of safety of 20

1.6 Emergency Shutdown

Turbines must be capable of shutting down quickly and efficiently in the case of an emergency. The turbine has been designed so in the instance of an emergency-stop button press or disconnection of the load, the turbine grounds out to come to a significantly lower rpm. The required rpm for competition is below 10% of the maximum recorded value. The design utilizes a 5v SPDT relay which switches the circuit so that the motors ground and power wires are connected. Controlling the voltage on the line that is powering a magnet in the relay which provides the ability to switch the turbine on and off. The competition provides a normally closed switch that will be wired in series with the SPDT relay. When pressed, this will open the line and stop the turbine. Wiring a SPST relay in series with the SPDT relay magnet allows for the Arduino to be used to cut power to the SPDT magnet This will produce the same grounding effect as described above.

1.7 Aerodynamic Analysis

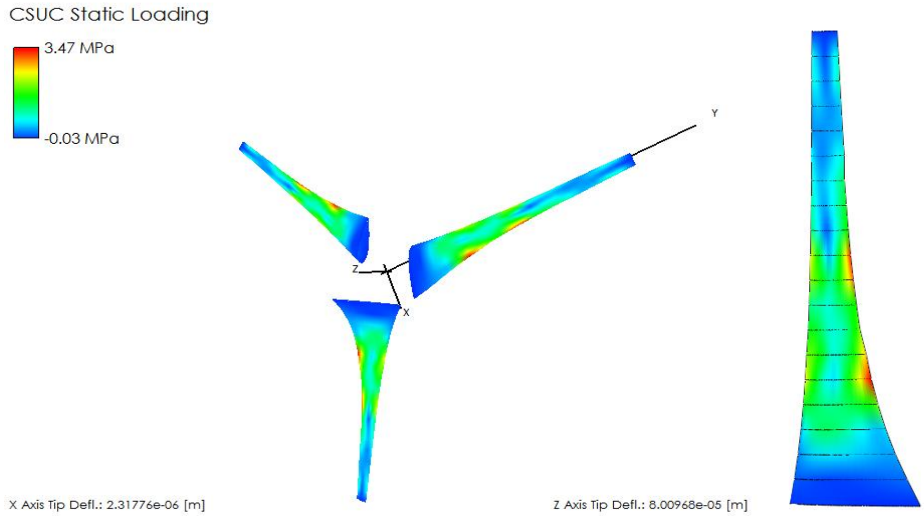


Figure 5: Stress on blades at a wind speed of 18 m/s

Using the loading analysis software QFem, at a wind speed of 18 m/s the blades should experience a maximum stress from the wind of 3.47 MPa as seen in Figure 5. When comparing this stress to the given tensile strength of ABS plastic, given by MakerBot for a mid-grade 3D printer, the blades were found to have a large safety factor of approximately 9.71. The given tensile strength for the material is over 34 MPa.

Equation 1: $y = 269.87x + 6.175$

Using a linear fit from calculations [Equation 1], the apparent wind speed on the blade varied with the length of the blade. X represents the distance along the blade from the center of the rotor, while y represents the apparent wind speed. This equation had a root mean squared value of 0.9964 to the values calculated. With this wind speed equation, the maximum pressure along the blade was found to be about 300 Pa and the maximum wind speed experienced by the blade was about 42 m/s using SolidWorks Flow Simulation.

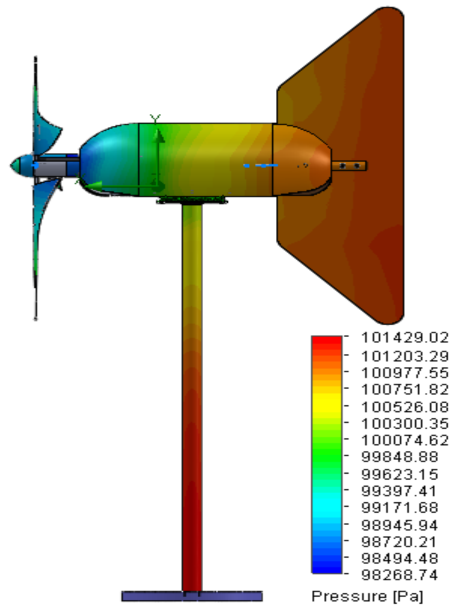


Figure 6: Pressure on the turbine with a crossflow of air at 18 m/s and a 90-degree angle

Pressure on the wind vane were analyzed using a worst case scenario of an 18 m/s wind flowing perpendicular to the length of the assembly. The maximum pressure on the tip of the wind vane was found to be about 101.4 kPa as can be seen in Figure 6. The low pressure difference in the simulation from atmospheric (101.3 kpa) gives confidence that the wind vane will survive. From preliminary testing, it is apparent that this worst case will never occur without serious malfunction.

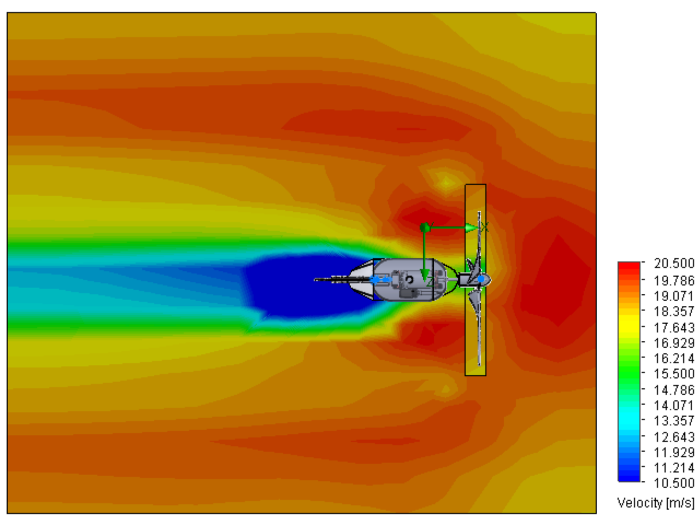


Figure 7: Velocity of air travelling over wind turbine

The changes in velocity of the air traveling through the turbine can be seen in Figure 7. This analysis was run using SolidWorks Flow Simulation with an input wind speed of 18 m/s and a blade rotation speed of 3000 RPM. The blade rotation was simulated using a rotating region in the form of a disk around the blades. The analysis demonstrated the streamlining the design, allowing for decisions about the nacelle size.

1.8 Blade Design

When researching rotor features such as desired Tip Speed Ratios (TSR) and ideal number of blades (Manwell, page 94), *Wind Energy Explained* offered a table which compared a range of TSR values and how closely they could theoretically meet the BETZ limit, the theoretical maximum power coefficient (C_p) for wind turbines is .592. For TSR values above 5, the drop in C_p was less than .022. Below 5, C_p dropped much more rapidly. Following this, *Wind Energy Explained* stated that turbines which generate electrical power should maintain a TSR greater than 5 and it was recommended that for TSR values higher than 4, designs should have 1-3 blades. *Wind Energy Explained* also advised against using less than 3 blades due to dynamic structural problems that could arise. From this, a 3 bladed design with a TSR greater than 5 was selected.

The airfoils of the blade were chosen out of a family of airfoils which perform well at low Reynolds numbers. The airfoil used for the first third of the blade (the root airfoil, NACA 2420) was chosen because it provided a relatively high coefficient of lift while still being thicker to provide stability. Next, the middle of the blade (the primary airfoil, NACA 2418) uses the airfoil which has the highest coefficient of lift out of the airfoils utilized. The airfoil on the last third of the blade (the tip airfoil, Naca 2414) was chosen because it has the highest coefficient of lift to drag ratio. This is meant to decrease the stress on the blade.

When making calculations, the designed turbine speed of 3000 RPM and wind speed of 11 m/s were used. This led to a design tip speed ratio (TSR) of 6.43. These values were gathered from the most efficient projected speed of the generator and maximum projected competition point distribution.

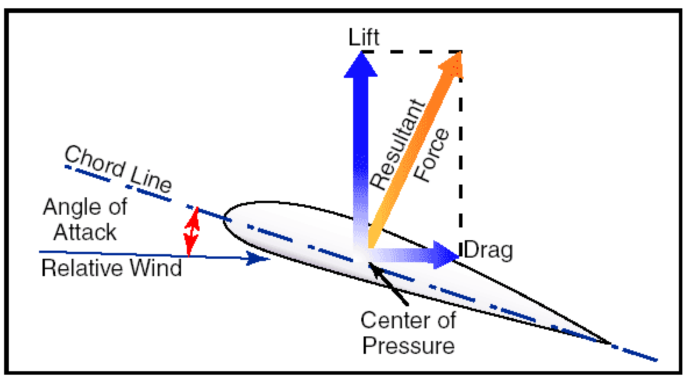


Figure 8: Forces acting on airfoil

Equation 2: Relative wind speed = sqrt((wr)2+(wind speed)2)

The relative wind speed, which can be seen in Figure 5, the wind that the airfoil sees while spinning, was calculated using Equation 2. This equation takes into account the rotational speed of the blades, the radial position along the blade, and the wind speed. Because this equation uses the radial position along the length of the blade, the relative wind will be a different value at different points on the blade.

Equation 3: Reynolds # = (relative wind speed*chord length)/(kinematic viscosity of air)

Based on simulations done with QBlade on the three airfoils used, it was found that a higher Reynolds number is more efficient for the small scale of this turbine. For this reason, using Equation 3, the chord length was iteratively calculated to maintain a Reynolds number of approximately 80,000. The kinematic viscosity of 1.46 x 10-5 m^2s was used.

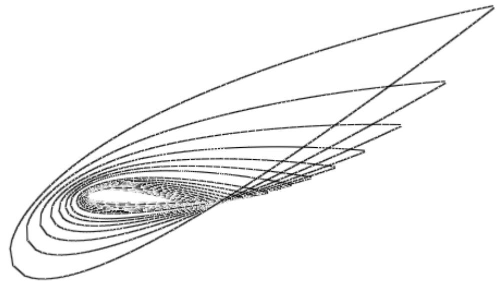


Figure 9: Airfoil twist

The twist is shown from the end on view of the airfoils in Figure 6. This twist is to allow each airfoil to perform at its optimal angle of attack. The angle of attack represents the angle at which the airfoil sees the relative wind as seen in Figure (9). Through simulations done using QBlade, it was found that the optimal angle of attack for all three airfoils was approximately 12 degrees from the relative wind.

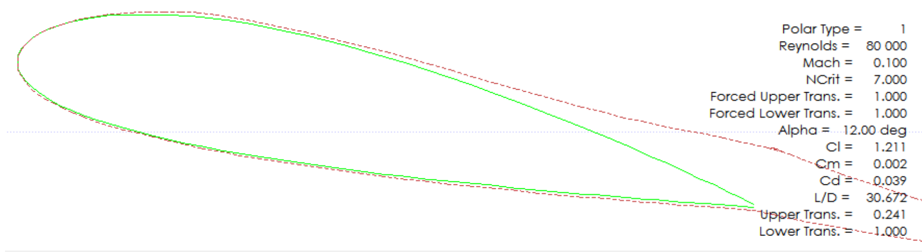


Figure 10: Flow over airfoil NACA 2418

Using XFoil, the flow over each airfoil was viewed at various relative wind speeds and angles of attack. Utilizing the design wind speed and the most efficient angle of attack, the flow over each airfoil used is shown in Figure 7. These simulations show the lift and drag coefficients, the ratios between the lift and drag coefficients, as well as the upper and lower transition points. The transition points represent where along the blade the airflow separates from the airfoil which makes the flow go from laminar to turbulent. A higher Reynolds number on this turbine's scale results in a transition point further along the blade, decreasing drag.

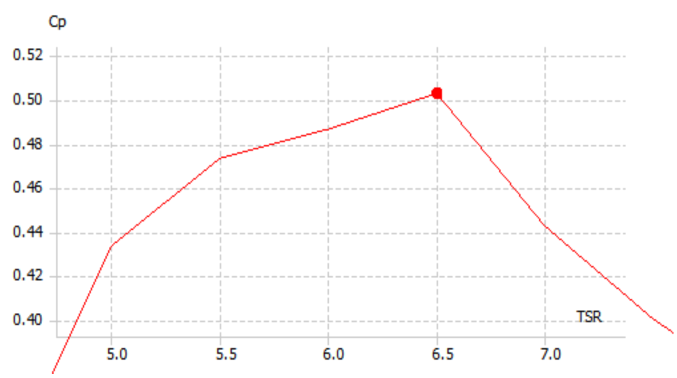


Figure 11: Expected blade coefficient of performance with respect to TSR

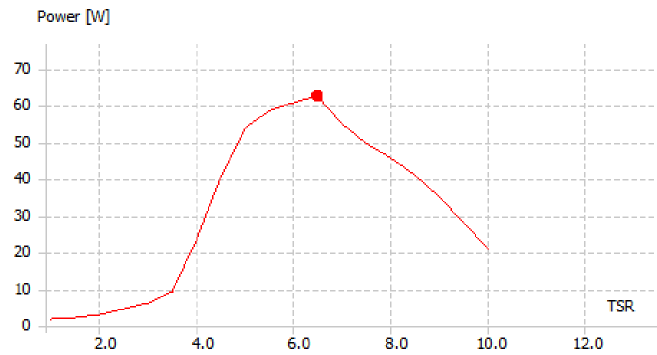


Figure 12: Expected power with respect to TSR

Figures 8 and 9 show the performance of the blades as predicted by QBlade. The blades were designed for peak performance at the design TSR of about 6.42 with the maximum power of 62 W and a coefficient of performance of 0.503. Due to unideal surface conditions, these values are expected to decrease.

1.9 Yaw System

The turbine's yaw system is composed of two main components: a lazy-susan bearing and a passive wind vane. Together, they create a passive yaw system in which the turbine maintains alignment with the wind, receiving no aid from the control system. The wind vane is designed with a large cross-sectional area on its sides to maximize the force it can capture from the wind. This enables the turbine to stabilize when faced with multi-directional wind at low cut in wind speeds. This concept was tested in the California State University, Chico closed loop wind tunnel. Testing with cardboard to represent the wind vane, the turbine easily maintained alignment with the wind when subjected to multiple turns at various yaw rates.

1.10 Circuit Analysis

Critical deliverables for the circuit design include emergency shutdown and control systems. The turbine is required to perform an emergency shutdown in which the rotor comes to a stop or drops below 10% of the maximum average rpm achieved in the power performance category. It must then return to operational conditions. This is achieved by grounding the motor and allowing the generator to produce large counter torque on the blades, effectively acting as an electrical shutoff. Size 18 american wire gauge was chosen for its current carrying capacity of 10A. The peak current production of the generator is 6.1A allowing for a safety factor of 1.63. As shown in the figure below, the circuit utilizes a single pole double throw (SPDT) relay. SPDT relays have both a normally closed output and a normally open output. When the competition provided normally closed switch is pressed, the line to the magnetic coil is opened and the circuit will ground the motor. When the load is disconnected, a normally open single pole single throw (SPST) relay will be de-magnetized, switching the SPDT relay to ground. To accomplish this, current flowing into the load will be measured. The load side of the turbine consists of power resistors sized for maximum power production, found on the generators datasheet.

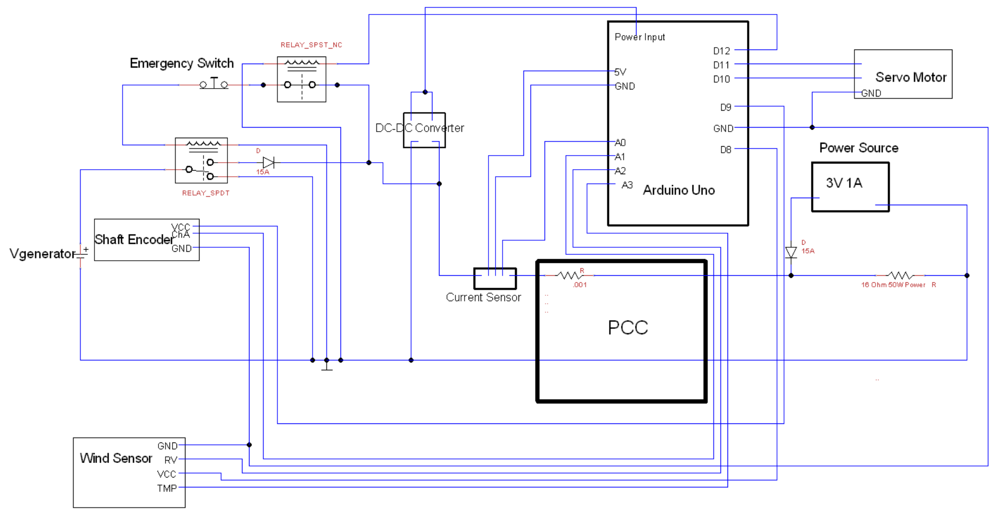


Figure 13: Circuit diagram

Through Q-Blade, an operating rpm for the blades was found which correlates to the wind speeds the turbine will be subject to at competition. The designed value is 2800-3000 rpm and the generator selection is based on this, with a rated rpm of 3100. The Crouzet 89800908, a 24v DC brushed motor, operates at speeds of this value with a torque value of 75 mNm. To control these circuit components, an Arduino Uno has been placed in series with a dc to dc converter to ensure the correct voltage is supplied. A shaft encoder is mounted on to the motor to read in the rpm of the turbine. When the turbine reaches the upper limit of the provided wind speed, the Arduino commands the servo motor to change the blades pitch and stall the turbine. This ensures a constant power output at the higher wind speeds. The Arduino uses the current sensor, previously mentioned, to measure the current as the pitch of the blades change. This way, the turbine is altering the pitch while searching for the maximum power output at the current wind speed.

1.11 Control State Diagram

The designed circuit has a control system with an Arduino commanding and reading the components in the Figure 10. The main feature consists of a continuous rotation servo motor which alters the pitch of the blades via a sliding yoke assembly. This allows for rated speed and rated power control based on inputs from our ACS712 current sensor and HEDM 5500 shaft encoder. To achieve maximum power with this control system, an array is used to store current values and compare each one to the last while having the servo rotate until the software sees a significant drop in current. A tactile lever switch is mounted at the shaft of the servo which functions as a homing switch, making sure the blades can fully pitch on each software startup. This is beneficial for the safety task where power to the Arduino will be lost and a starting blade position is necessary.

1.12 Laboratory Testing

All testing was done at the CSU wind tunnel. While this provided convenient access for testing, it also provided challenges such as having a cross sectional area that was too small to accurately test full scale blades. Due to this limitation CSU design team was limited to either testing smaller scaled blades or testing full sized blades in a chamber that did not allow for ideal airflow. The tunnel also lacked the ability to test blades at wind speeds lower than 7.5 m/s which limited the amount available data.

All design iterations were tested at the wind speeds: 8,9,10,11,13,17 at varying resistance values. During testing: RPM, Load voltage, current, air pressure in the tunnel, air temperature, and atmospheric pressure were consistently measured. A LabVIEW program was created to take in these measurements and calculate the wind velocity, motor torque, shaft power, electric power, TSR and Coefficient of power for analysis.

A control blade (NACA Blade 8) was made and scaled to 12 inches in diameter. This model was tested with a very streamlined nacelle body provided by Chico State. A second blade known as 7.7B was also tested with the Chico States Team's competition nacelle. Both blades were tested with a fixed pitch ideal for the higher competition wind speeds. The resulting wind speeds vs shaft power, electric power and torque can be seen below in figures 14 and 15. Neither the power or torque values met the team's expectations and further design is in the way to increase both blades power outputs. Tests indicate a need for future iterations in both blade and nacelle design.

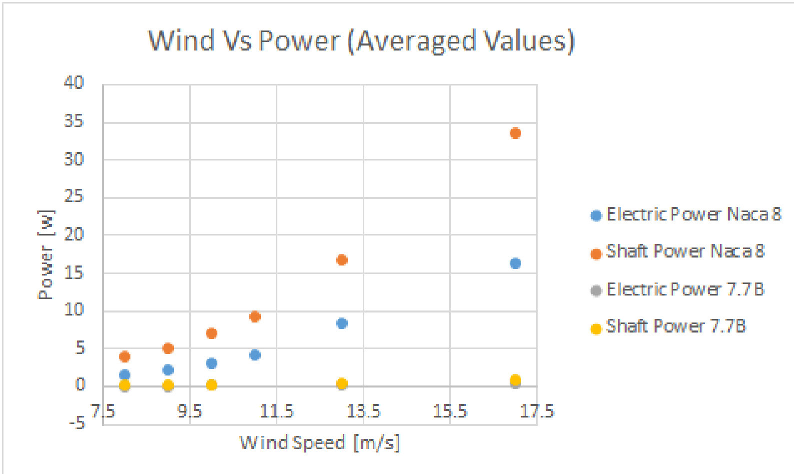


Figure 14: Wind speed vs power

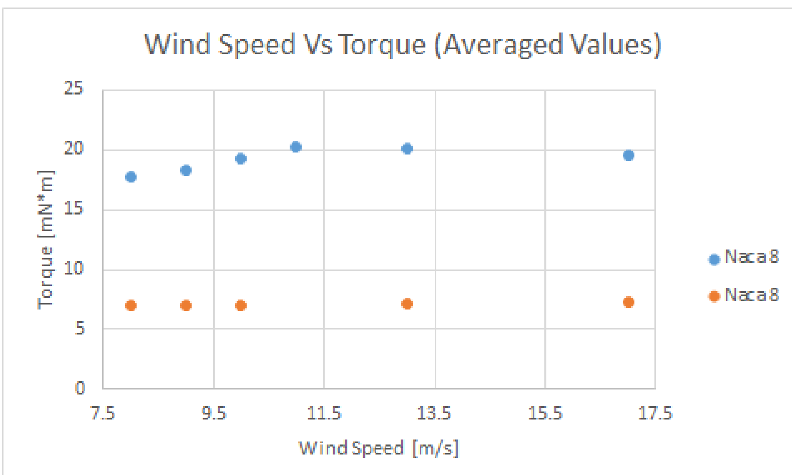


Figure 15: Wind speed vs torque

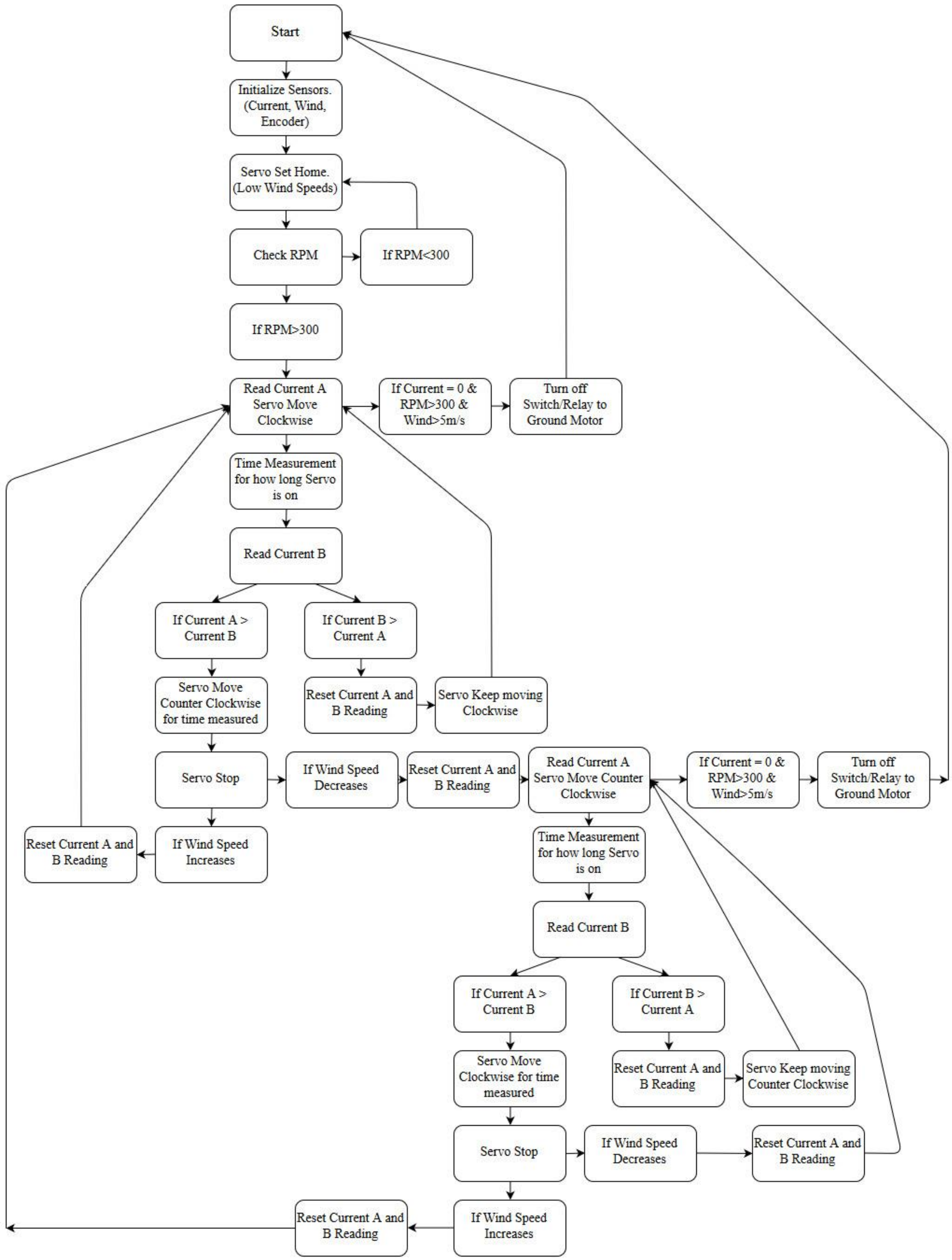


Figure 16: State Diagram

2. References

Manwell, J. F., J. G. McGowan, and Anthony L. Rogers. *Wind energy explained: theory, design and application*. Chichester, U.K.: John Wiley & Sons, Ltd., 2011. Print.

3. Appendix

A. Software Documentation

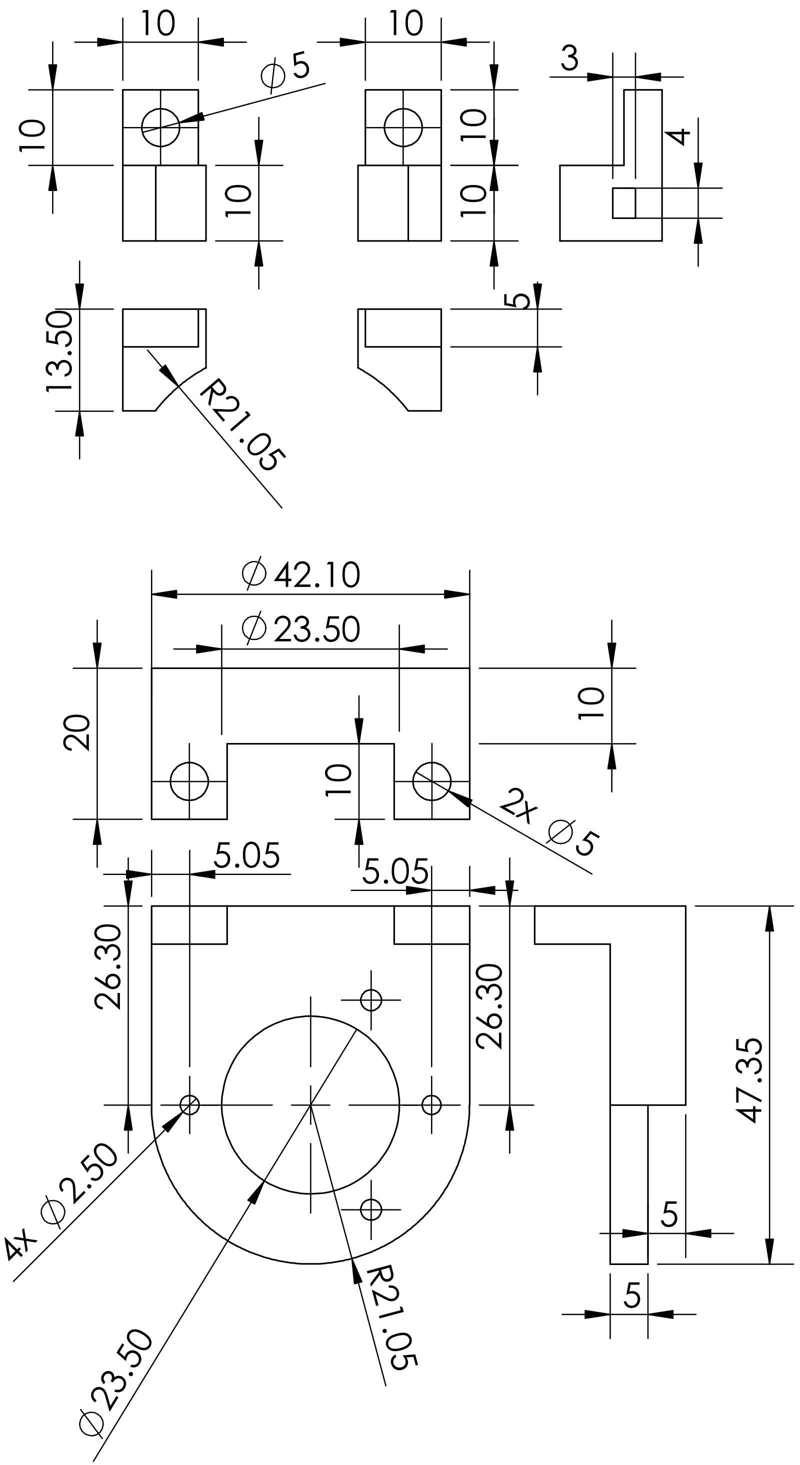
```
void setup() {                                    //code to run once on setup
  Serial.begin(115200);
  attachInterrupt(0, rpm_motor, FALLING);   //interrupt 0 is pin 2 on arduino uno for encoder
  myservo.attach(9);                    // attaches the servo on pin 9 to the servo object
  pinMode(RelayPin, OUTPUT);              // sets the digital pins as either outputs or inputs and high or low
  pinMode(Ground, OUTPUT);
  pinMode(ServoPower, OUTPUT);
  pinMode(CurrentPower, OUTPUT);
  pinMode(tactswitch, INPUT);
  pinMode(SwitchTact, INPUT);
  pinMode(HomingButton, INPUT);
  digitalWrite(RelayPin, HIGH);
  digitalWrite(ServoPower, HIGH);
  digitalWrite(CurrentPower, HIGH);
  digitalWrite(Ground, LOW);
  int homing = digitalRead(HomingButton);      //read input from homing sensor on startup
  while(homing == LOW){
    myservo.write(75);
  }
  myservo.write =(90);                  // spin the servo until the homing switch is pressed closed then stop
  }
void loop() {
  if (millis() - lastmillis >= 1000) {            //Update every one second, equal to reading frecuency (Hz).
    detachInterrupt(0);                          //Disable interrupt when calculating
    readings[index] = rpmcount * .060;            //Convert frecuency to RPM 1000 count per revelution
    total = 0;
    for (int x = 0; x <= 9; x++) {
      total = total + readings[x];               //updates array
      /*Serial.print("total: ");
        Serial.println(readings[x]);*/
    }
    RPM_average = total / (10);   //index +1?               //averages array values
    rpm = RPM_average;
    rpmcount = 0;                               // Restart the RPM counter
    index++;                                    // Go to next spot in array
    if (index >= numreadings) {
      index = 0;
    }
    TMP_Therm_ADunits = analogRead(analogPinForTMP);            //wind sensor read in raw values
    RV_Wind_ADunits = analogRead(analogPinForRV);
    RV_Wind_Volts = (RV_Wind_ADunits *  0.0048828125);
```

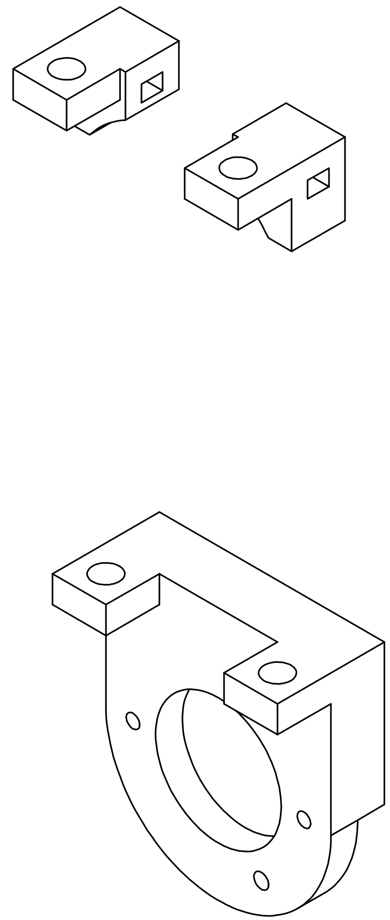
```
   TempCtimes100 = (0.005 * ((float)TMP_Therm_ADunits * (float)TMP_Therm_ADunits)) - (16.862 *
(float)TMP_Therm_ADunits) + 9075.4;

   zeroWind_ADunits = -0.0006 * ((float)TMP_Therm_ADunits * (float)TMP_Therm_ADunits) + 1.0727 *
(float)TMP_Therm_ADunits + 47.172; //  13.0C  553  482.39

   zeroWind_volts = (zeroWind_ADunits * 0.0048828125) - zeroWindAdjustment;
   WindSpeed_MPH =  pow(((RV_Wind_Volts - zeroWind_volts) / .2300) , 2.7265);
   WindSpeed_ms = WindSpeed_MPH * .44704;                          // Wind speed in mph conversion
to m/s
     if (Current_average > PrevCurrent){         // rotate servo based on current readings
       myservo.write(110);
       delay(300);
       myservo.write(90);
   }
   else if(Current_average < PrevCurrent)  {
       myservo.write(70);
       delay(300);
       myservo.write(90);}
  }
    if (WindSpeed_ms >= 5.0 && Current_average == 0) {          // load disconnect
     digitalWrite(RelayPin, LOW);
   }
     float Current_average = 0;
   for (int i = 0; i < 100; i++) {
     Current_average = Current_average + (.0264 * analogRead(A4) - 13.51); //for the 5A mode,
     delay(1)}
   float PrevCurrent = Current_average;
   if (millis() > 2000) {                  // wait for Sensors to stabalize and print values to monitor
   lastmillis = millis();                  // Uptade lastmillis keep timer updated accurately
   attachInterrupt(0, rpm_motor, FALLING);     //enable interrupt after calcs
void rpm_motor() {         //  will be executed every time the interrupt 0 (pin2) gets low to read the
encoder pulses.
  rpmcount++;
```

B. Mechanical Drawings





DIMENSIONING AND TOLERANCING PER ASME Y14.5 1994

DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED

TOLERANCES ARE AS FOLLOWS UNLESS OTHERWISE SPECIFIED

x = ±1
x.x = ±0.3
x.xx = ±0.05
Angles = ±2°

MATERIAL: PLA

FINISH: N/A

Mechanical Engineering, Mechatronic Engineering, & Manufacturing Technology

California State University, Chico

Template version 060411

	NAME	DATE
DRAWN	M.Reynaud	170405
CHECKED		
ENG APPR		
MFG APPR		
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TITLE

Motor Mounts

SIZE	DWG NO	REV
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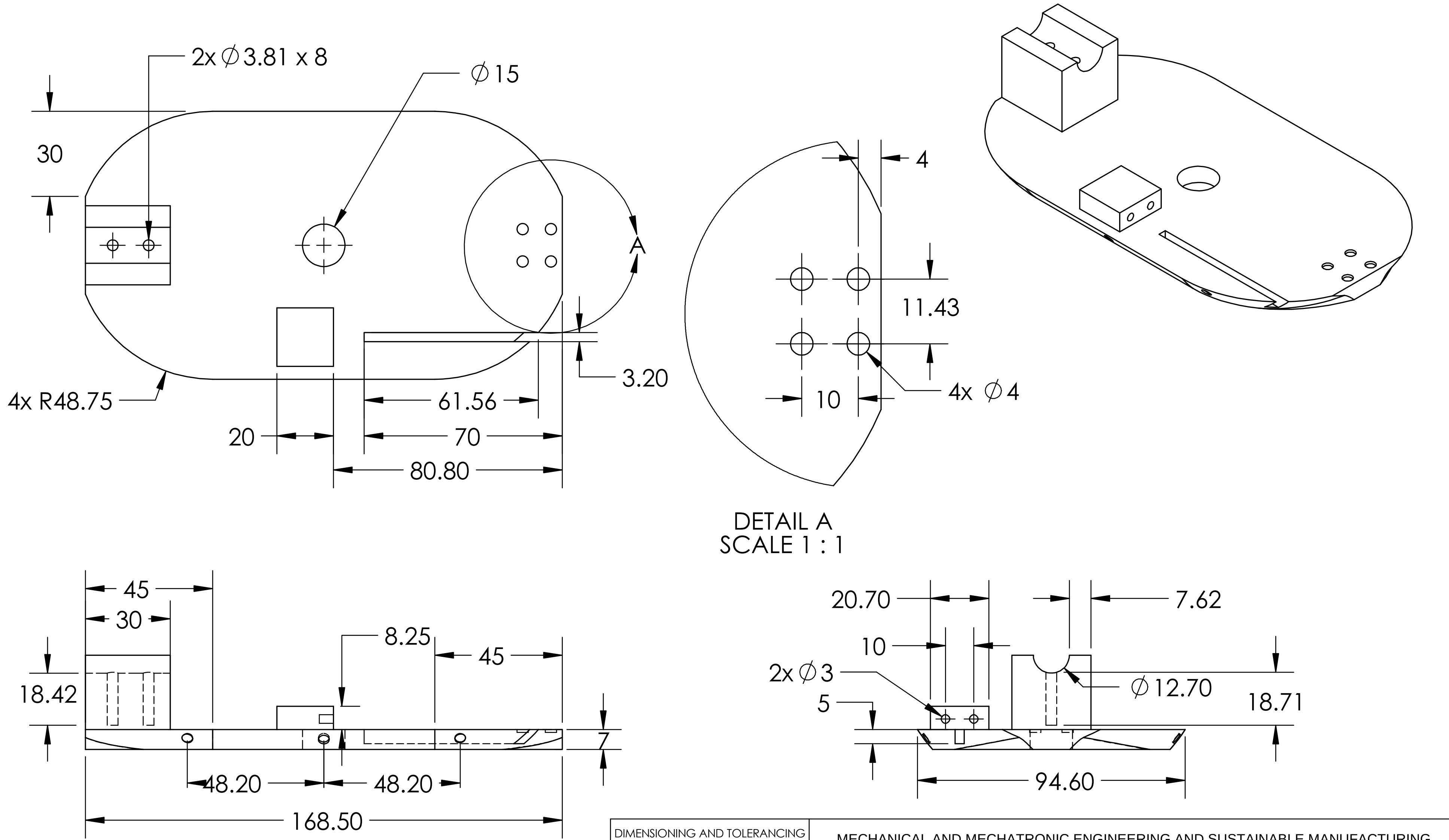
SCALE 2:1 | SHEET 1 OF 1



DIMENSIONING AND TOLERANCING PER ASME Y14.5 1994

DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED

TOLERANCES ARE AS FOLLOWS UNLESS OTHERWISE SPECIFIED
X = ±1
X.X = ±0.3
X.XX = ±0.05
ANGLES = ±2°

MATERIAL
PLA PLASTIC

FINISH
ROUGH

MECHANICAL AND MECHATRONIC ENGINEERING AND SUSTAINABLE MANUFACTURING

CALIFORNIA STATE UNIVERSITY, CHICO

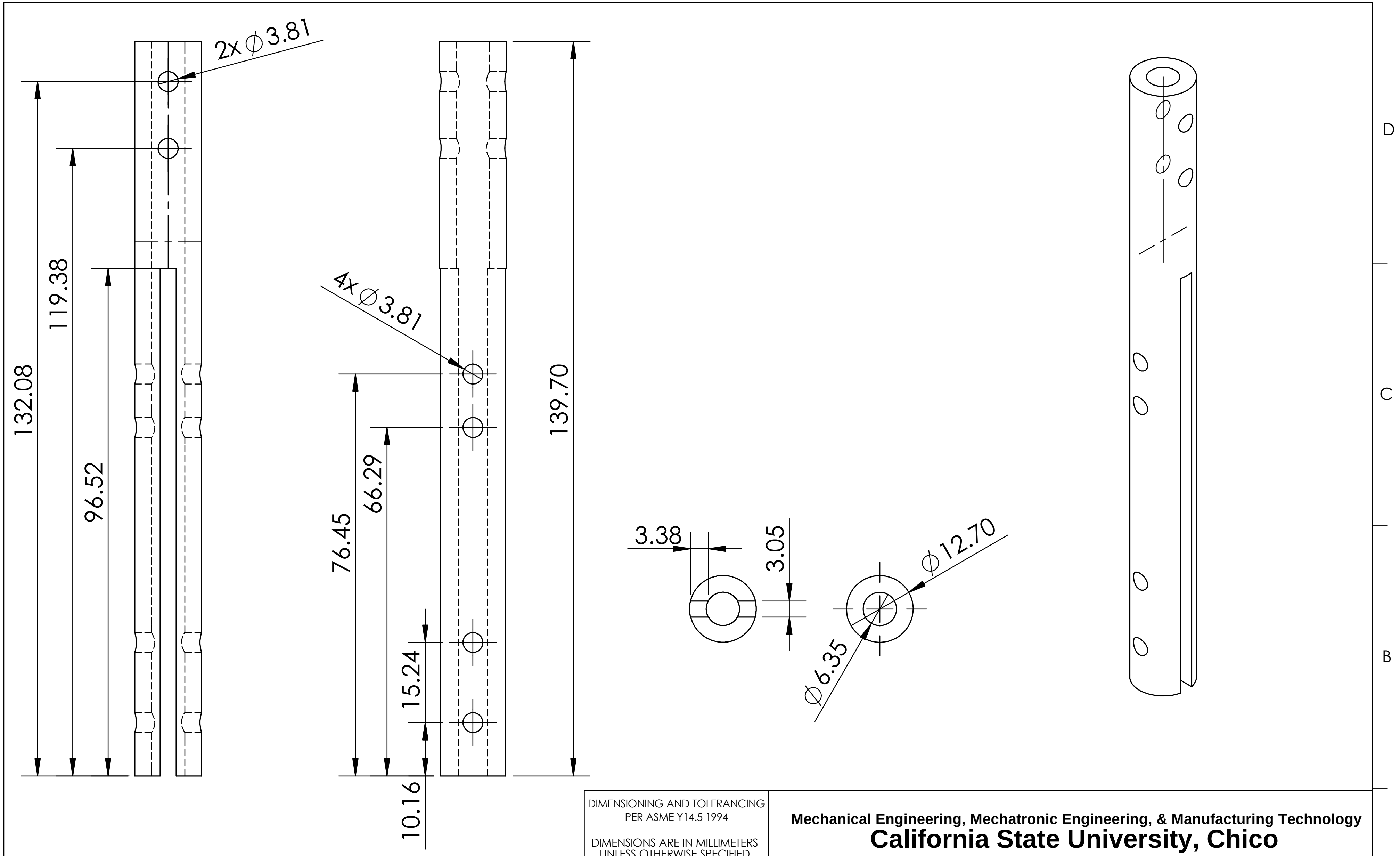
Template version 091813

	NAME	DATE
DRAWN	COLLEGIATE WIND TEAM	04012017
CHECKED		
ENG APPR		
MFG APPR		
Q A		

TITLE
NACELLE PLATE

SIZE	DWG NO	REV
A	440A-1-S17-A1-D2	-

SCALE 1:1 | SHEET 1 OF 1



DIMENSIONING AND TOLERANCING PER ASME Y14.5 1994

DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED

TOLERANCES ARE AS FOLLOWS UNLESS OTHERWISE SPECIFIED
x = ±1
x.x = ±0.3
x.xx = ±0.05
Angles = ±2°

MATERIAL: PLA Plastic

FINISH: N/A

Mechanical Engineering, Mechatronic Engineering, & Manufacturing Technology

California State University, Chico

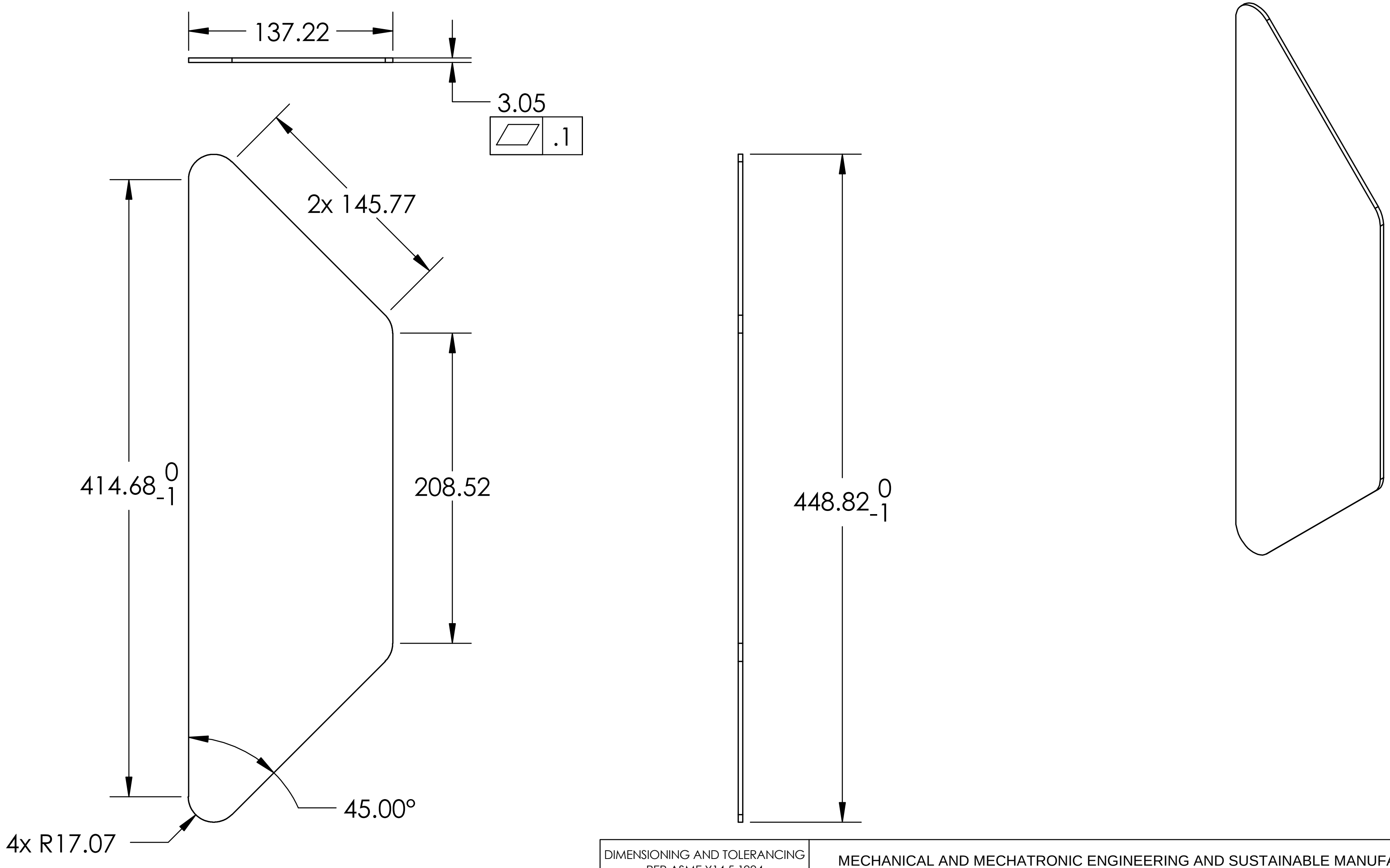
Template version 060411

	NAME	DATE
DRAWN	M.Reynaud	170403
CHECKED		
ENG APPR		
MFG APPR		
Q A		

TITLE

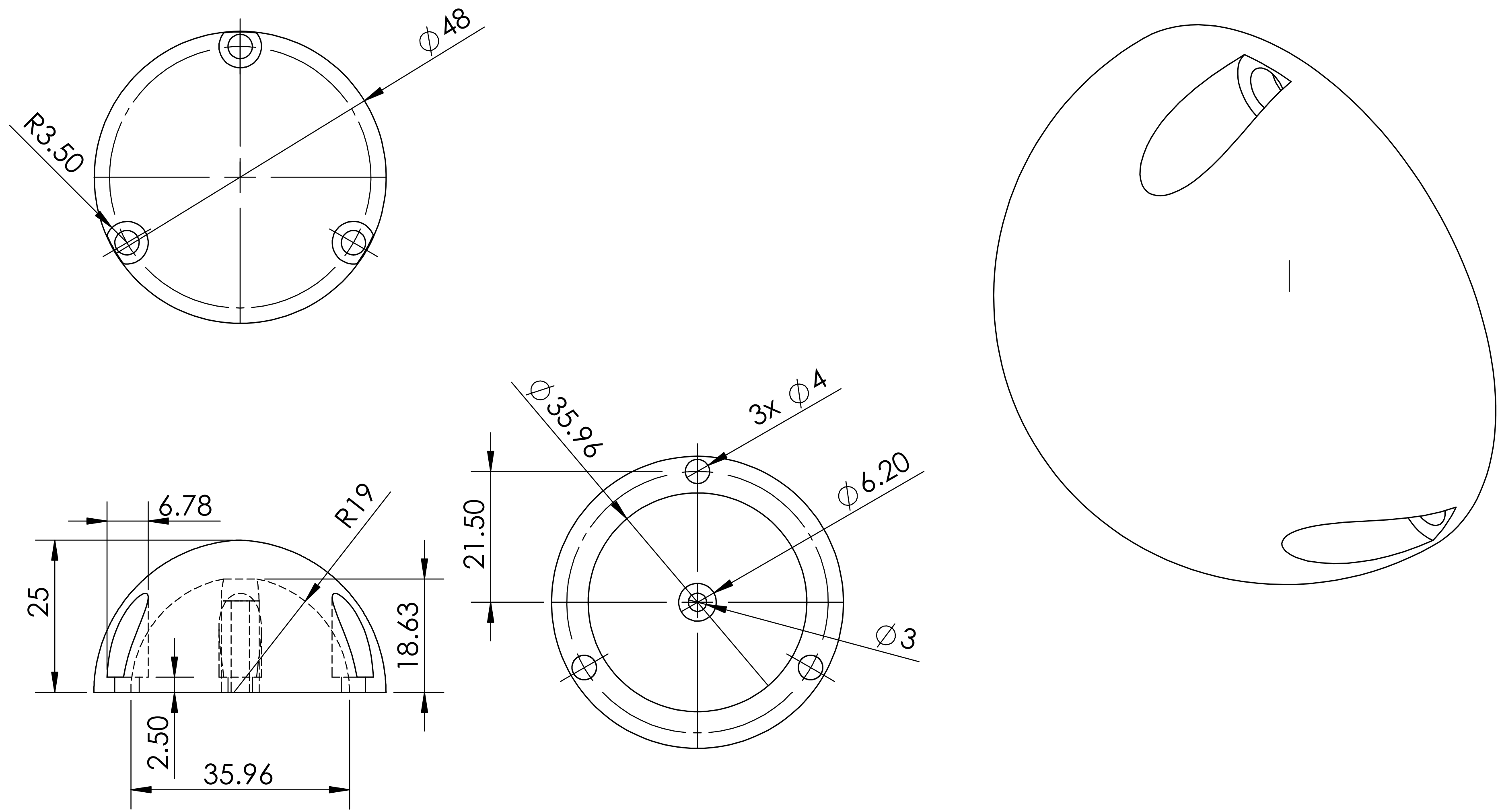
Tail Fin Shaft

SIZE	DWG NO	REV
A	440A-1-S17-A1-D3	-
SCALE 1:2		SHEET 1 OF 1



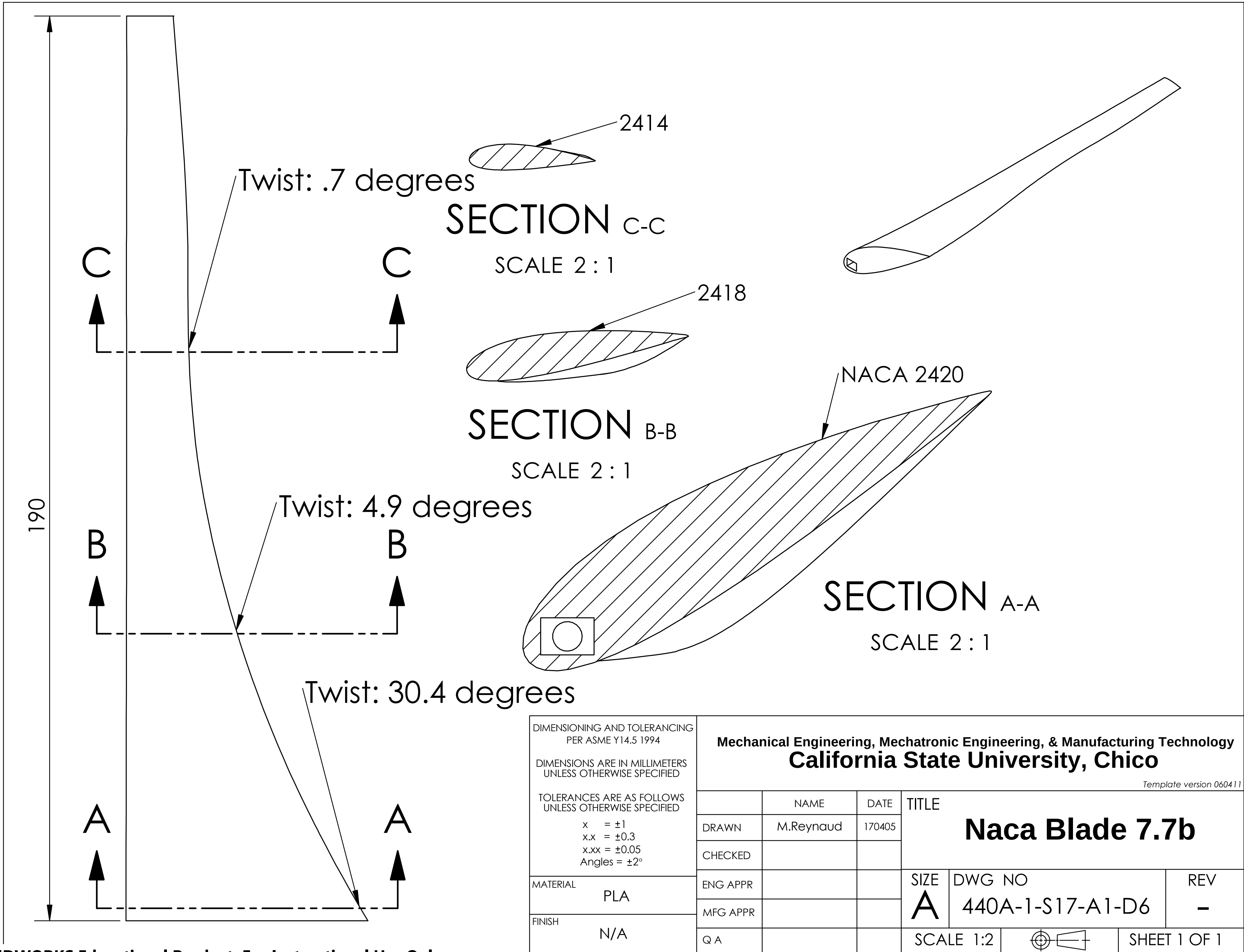
NOTE: ALL ARCS ARE TANGENT WITH THEIR CORRESPONDING COINCIDENT LINES

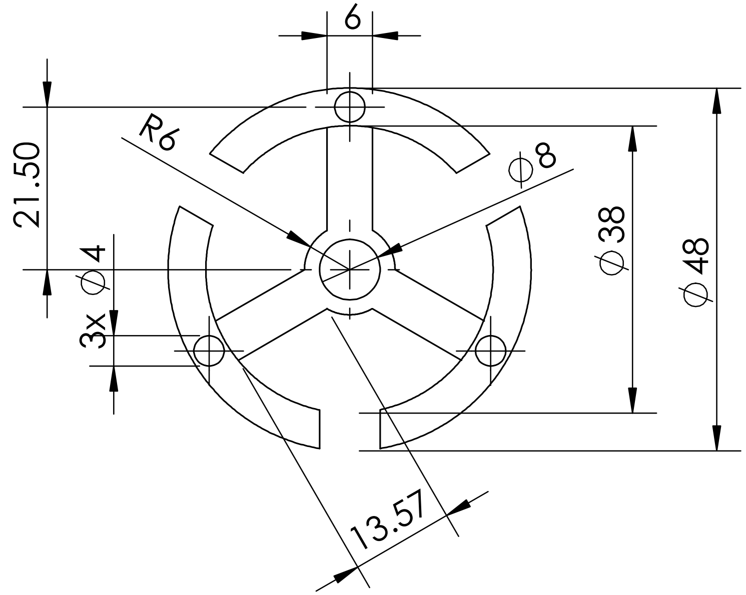
DIMENSIONING AND TOLERANCING PER ASME Y14.5 1994 DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED TOLERANCES ARE AS FOLLOWS UNLESS OTHERWISE SPECIFIED X = ±1 X.X = ±0.3 X.XX = ±0.05 ANGLES = ±2°	MECHANICAL AND MECHATRONIC ENGINEERING AND SUSTAINABLE MANUFACTURING **CALIFORNIA STATE UNIVERSITY, CHICO** *Template version 091813*			
		NAME	DATE	TITLE
	DRAWN	COLLEGIATE WIND TEAM	04012017	**TAIL FIN**
	CHECKED			
MATERIAL N/A	ENG APPR			SIZE A · DWG NO 440A-1-S17-A1-D4 · REV -
	MFG APPR			
FINISH N/A	Q A			SCALE 1:1 · SHEET 1 OF 1

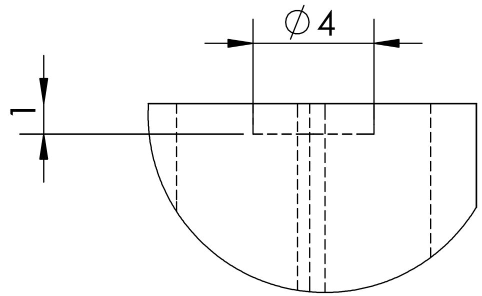


DIMENSIONING AND TOLERANCING PER ASME Y14.5 1994 DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED TOLERANCES ARE AS FOLLOWS UNLESS OTHERWISE SPECIFIED x = ±1 x.x = ±0.3 x.xx = ±0.05 Angles = ±2°	Mechanical Engineering, Mechatronic Engineering, & Manufacturing Technology **California State University, Chico** *Template version 060411*		
	NAME	DATE	TITLE
DRAWN	M.Reynaud	170405	**Nose Cone Part 1**
CHECKED			
MATERIAL PLA	ENG APPR		SIZE A — DWG NO 440A-1-S17-A1-D5 — REV -
FINISH N/A	MFG APPR		
	Q A		SCALE 1:1 — SHEET 1 OF 1

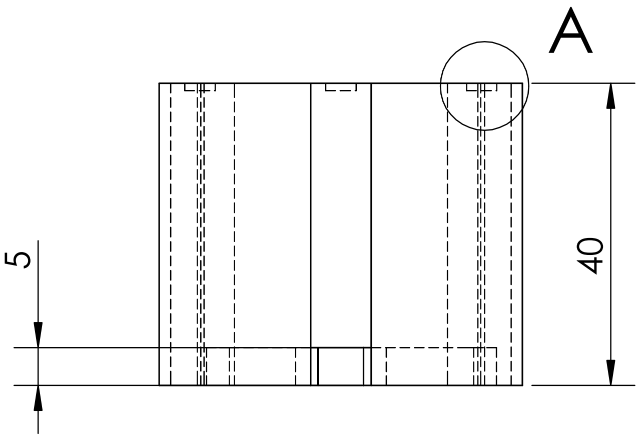
D C B A
3 2 1

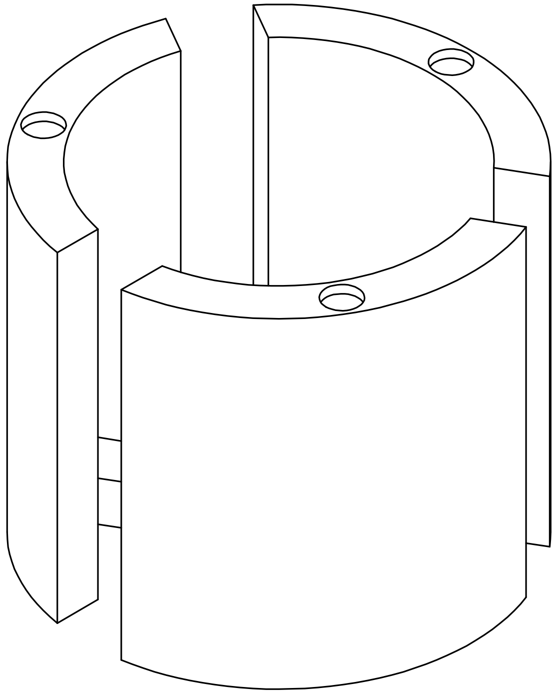

190
C C
B B
A A
Twist: .7 degrees
Twist: 4.9 degrees
Twist: 30.4 degrees
2414
SECTION C-C
SCALE 2 : 1
2418
SECTION B-B
SCALE 2 : 1
NACA 2420
SECTION A-A
SCALE 2 : 1
D
C
B
A
3
2
1
DIMENSIONING AND TOLERANCING PER ASME Y14.5 1994
DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED
TOLERANCES ARE AS FOLLOWS UNLESS OTHERWISE SPECIFIED
x = ±1
x.x = ±0.3
x.xx = ±0.05
Angles = ±2°
MATERIAL
PLA
FINISH
N/A
Mechanical Engineering, Mechatronic Engineering, & Manufacturing Technology
California State University, Chico
Template version 060411
NAME
DATE
DRAWN
M.Reynaud
170405
CHECKED
ENG APPR
MFG APPR
Q A
TITLE
Naca Blade 7.7b
SIZE
A
DWG NO
440A-1-S17-A1-D6
REV
-
SCALE 1:2
SHEET 1 OF 1





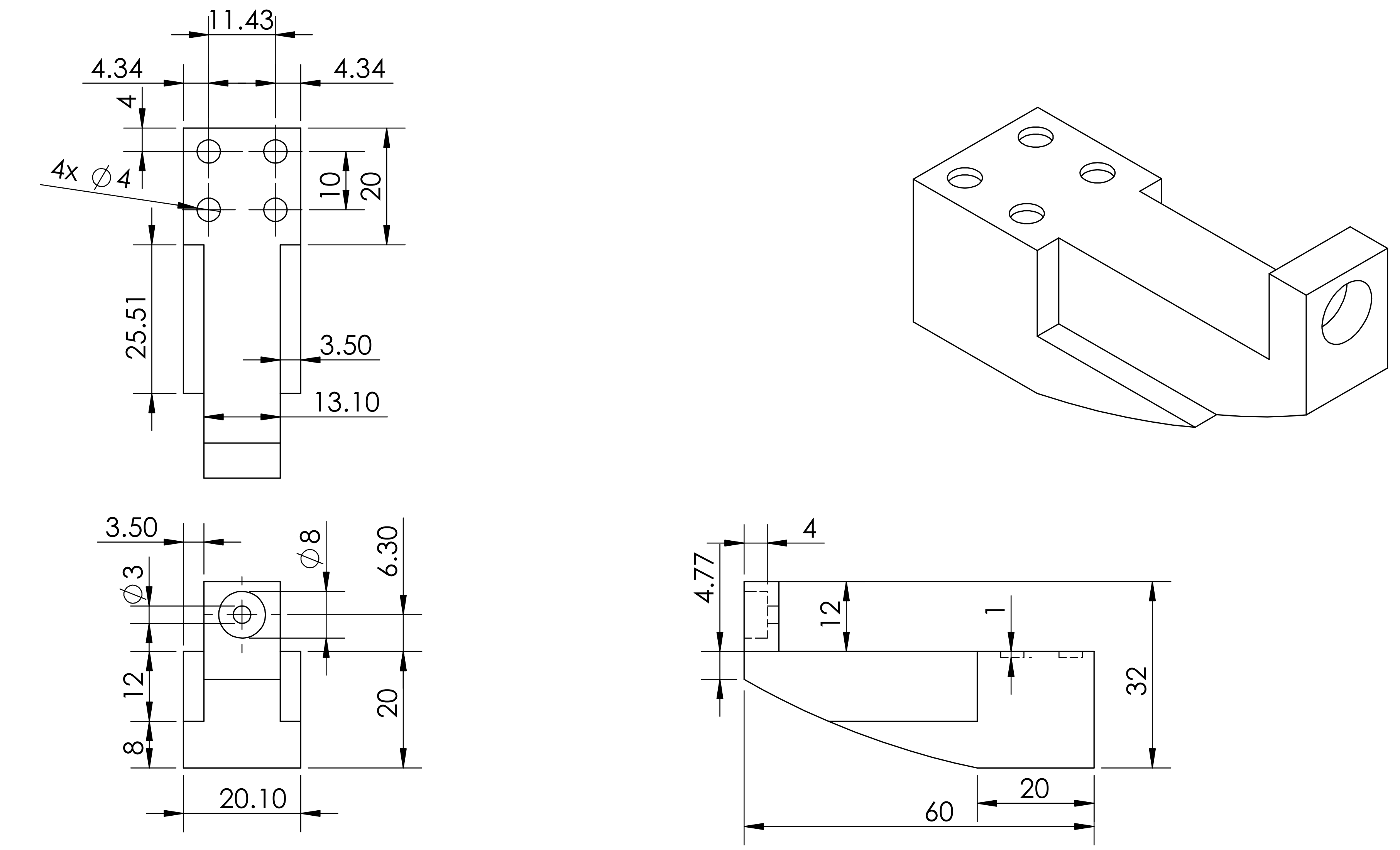
DETAIL A
SCALE 4 : 1





DIMENSIONING AND TOLERANCING PER ASME Y14.5 1994 DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED TOLERANCES ARE AS FOLLOWS UNLESS OTHERWISE SPECIFIED x = ±1 x.x = ±0.3 x.xx = ±0.05 Angles = ±2°	**Mechanical Engineering, Mechatronic Engineering, & Manufacturing Technology** **California State University, Chico** *Template version 060411*			
		NAME	DATE	TITLE
	DRAWN	M.Reynaud	170405	**Nose Cone Part 2**
	CHECKED			
MATERIAL PLA	ENG APPR			SIZE A / DWG NO 440A-1-S17-A1-D7 / REV -
FINISH N/A	MFG APPR			
	Q A			SCALE 1:1 / SHEET 1 OF 1

D C B A
3 2 1



DIMENSIONING AND TOLERANCING PER ASME Y14.5 1994

DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED

TOLERANCES ARE AS FOLLOWS UNLESS OTHERWISE SPECIFIED

x = ±1
x.x = ±0.3
x.xx = ±0.05
Angles = ±2°

MATERIAL PLA

FINISH N/A

Mechanical Engineering, Mechatronic Engineering, & Manufacturing Technology

California State University, Chico

Template version 060411

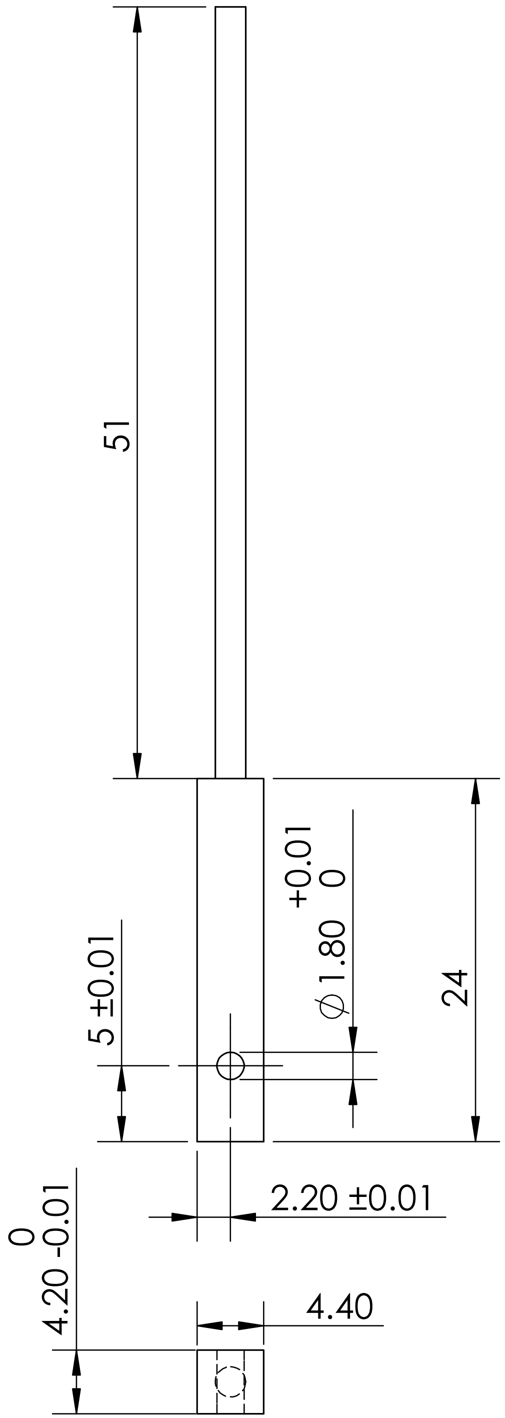
	NAME	DATE
DRAWN	M.Reynaud	170405
CHECKED		
ENG APPR		
MFG APPR		
Q A		

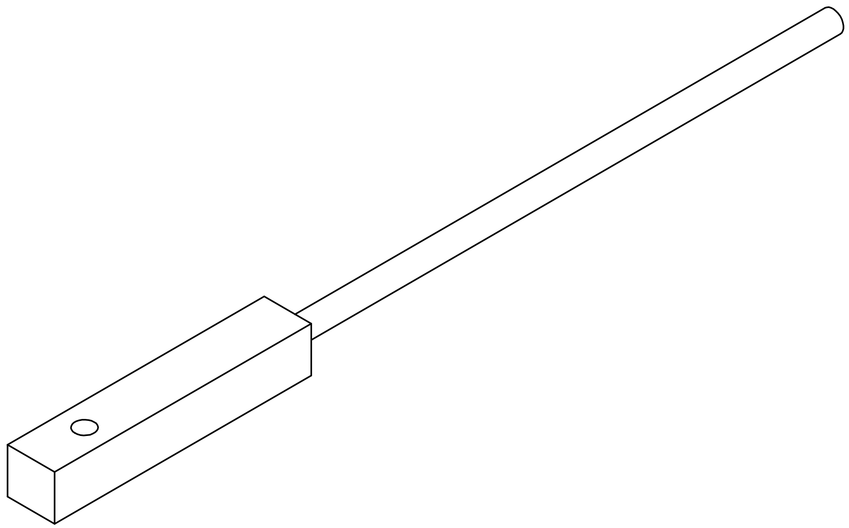
TITLE

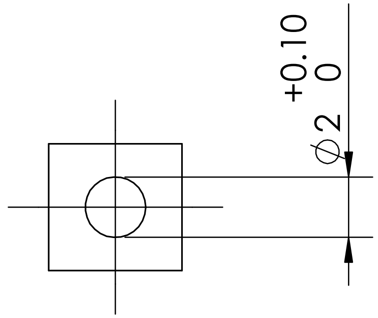
Bearing Holder

SIZE	DWG NO	REV
A	440A-1-S17-A1-D8	-

SCALE 1:1 | SHEET 1 OF 1







DIMENSIONING AND TOLERANCING PER ASME Y14.5 1994

DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED

TOLERANCES ARE AS FOLLOWS UNLESS OTHERWISE SPECIFIED
x = ±1
x.x = ±0.3
x.xx = ±0.05
Angles = ±2°

MATERIAL 1040 Steel

FINISH N/A

Mechanical Engineering, Mechatronic Engineering, & Manufacturing Technology

California State University, Chico

Template version 060411

	NAME	DATE
DRAWN	M.Reynaud	170403
CHECKED		
ENG APPR		
MFG APPR		
Q A		

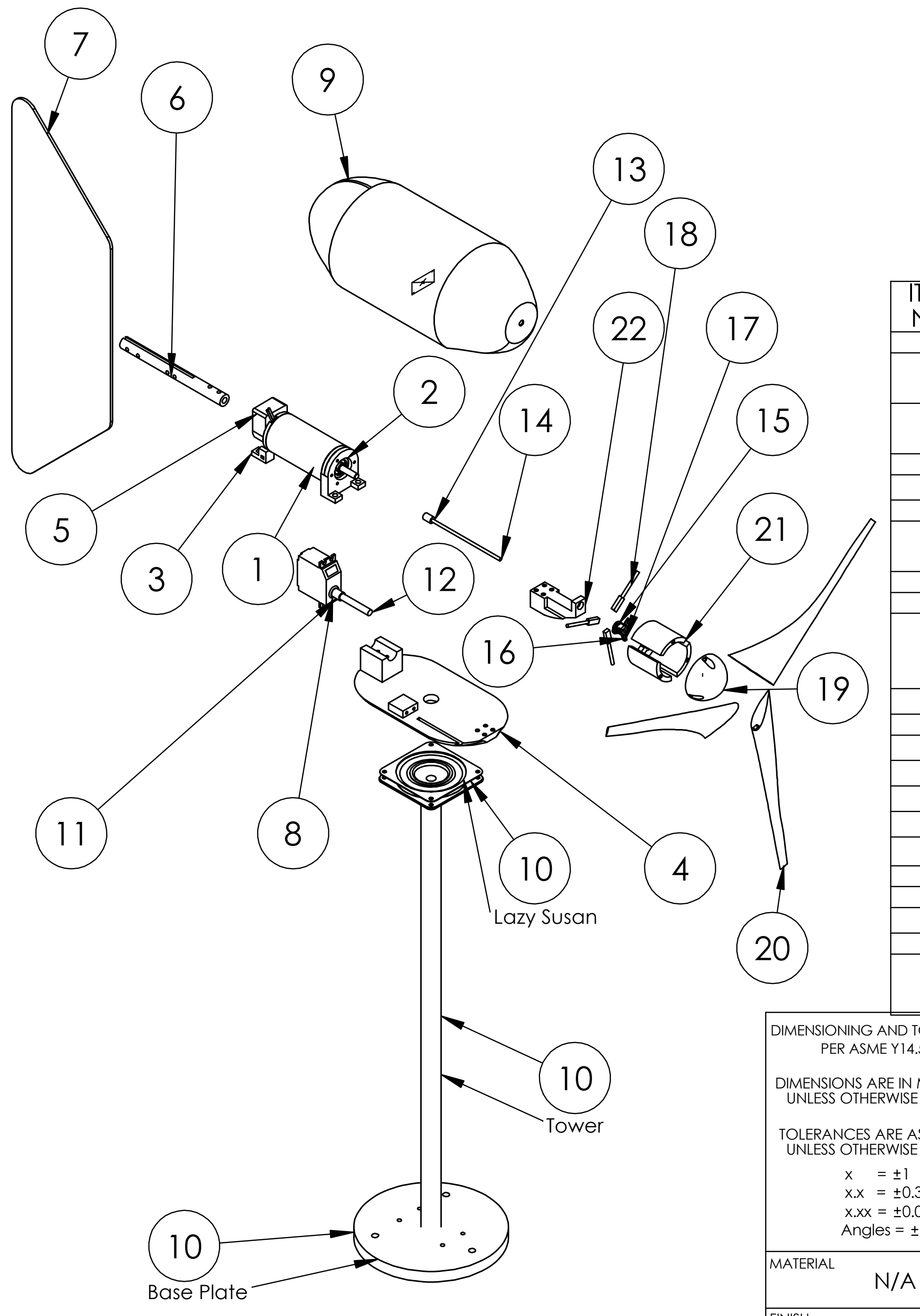
TITLE

Fin Pin

SIZE	DWG NO	REV
A	440A-1-S17-A1-D9	-

SCALE 1:1 SHEET 1 OF 1

D C B A 3 2 1



ITEM NO.	Description	Part Number	Default/QTY.
1	Crouzet Motor	898000	1
2	Motor Support Front^Two Piece Nacelle Assembly	440A-1-S17-A1-D1	2
3	Motor Support Back^Nacelle Assembly	440A-1-S17-A1-D1	1
4	Nacelle Plate	440A-1-S17-A1-D2	1
5	Avago HEDM Shaft Encoder	HEDM Avago 5500#b12	1
6	Tail Shaft	440A-1-S17-A1-D3	1
7	Tail Fin^Two Piece Nacelle Assembly	440A-1-S17-A1-D4	1
8	Servo motor SM-S4303R	SM-S4303R	1
9	Nacelle Shell	Dr. Shasta	1
10	Tower Assembly 3:(Lacy Susan, Tower, and Base Plate)	440A-1-S17-A1-D10	1
11	Servo-Coupler	FSA125	1
12	Lead Screw	Roton	1
13	Shaft Coupler 6mm to 3mm	625212	1
14	Sliding Yoke Shaft	a14061800ux0155	1
15	Sliding Yoke Collar	OXY3-097	1
16	Sliding Yoke Pins	OXY3-097	1
17	Fin Pin Attachment	OXY3-097	3
18	Blade Fin Pin	440A-1-S17-A1-D9	3
19	Nose Cone	440A-1-S17-A1-D5	1
20	NACA_BLADE_7.7b_comp	440A-1-S17-A1-D6	3
21	Nose Cone Part 2	440A-1-S17-A1-D7	1
22	Bearing Holder	440A-1-S17-A1-D8	1

DIMENSIONING AND TOLERANCING PER ASME Y14.5 1994

DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED

TOLERANCES ARE AS FOLLOWS UNLESS OTHERWISE SPECIFIED
x = ±1
x.x = ±0.3
x.xx = ±0.05
Angles = ±2°

MATERIAL N/A

FINISH N/A

Mechanical Engineering, Mechatronic Engineering, & Manufacturing Technology

California State University, Chico

Template version 060411

	NAME	DATE
DRAWN	M.Reynaud	170405
CHECKED		
ENG APPR		
MFG APPR		
Q A		

TITLE

Final Turbine Assembly

SIZE	DWG NO	REV
A	440A-1-S17-A1	-

SCALE 1:20 SHEET 1 OF 1

D C B A 3 2 1