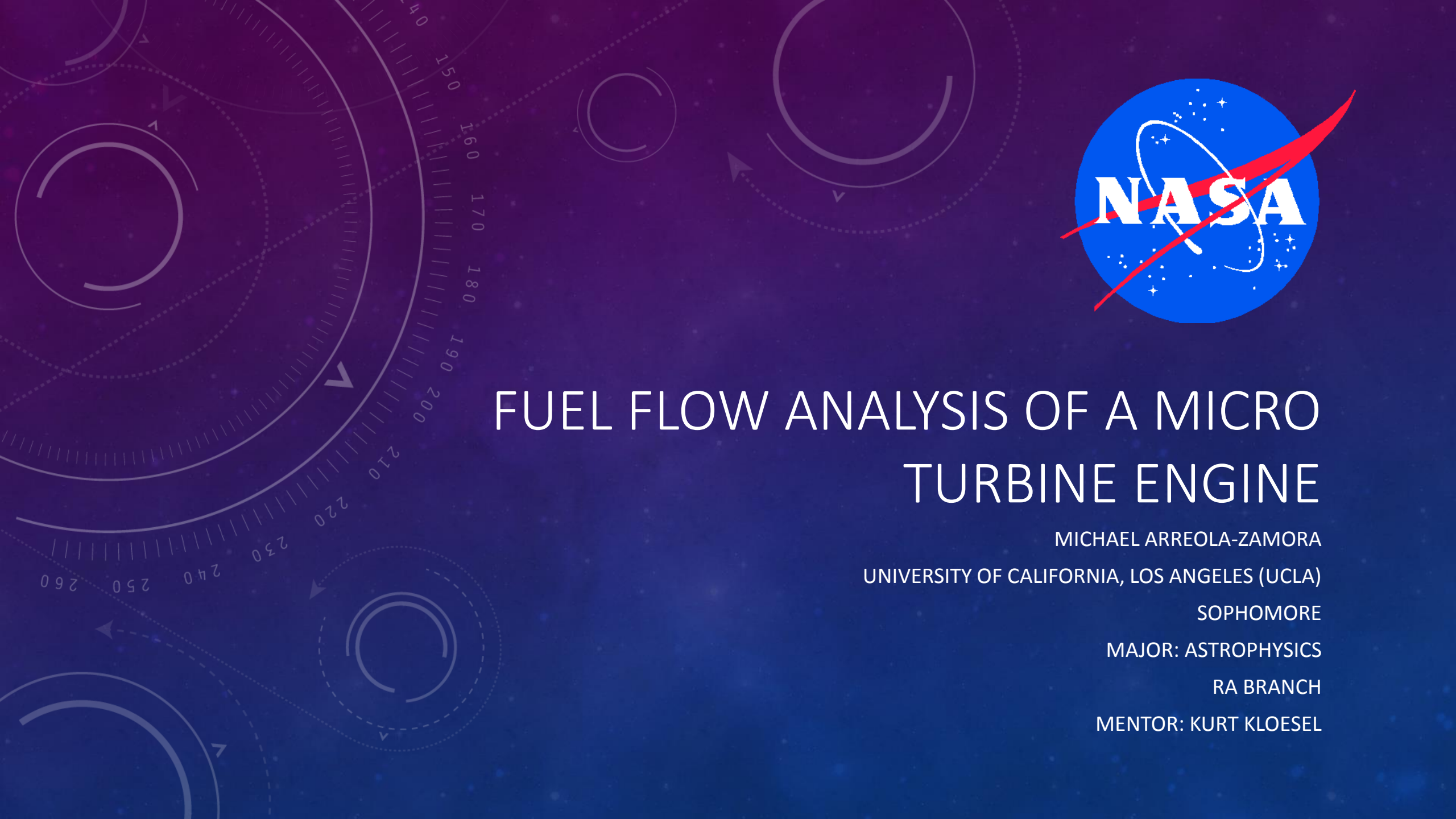

FUEL FLOW ANALYSIS OF A MICRO TURBINE ENGINE

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OBJECTIVES

- Understand the processes a micro-turbine engine goes through
- Use micro-turbine engines to predict how bigger turbines would function
- Program an Arduino Uno to act as an engine control unit

MICRO TURBINE ENGINE

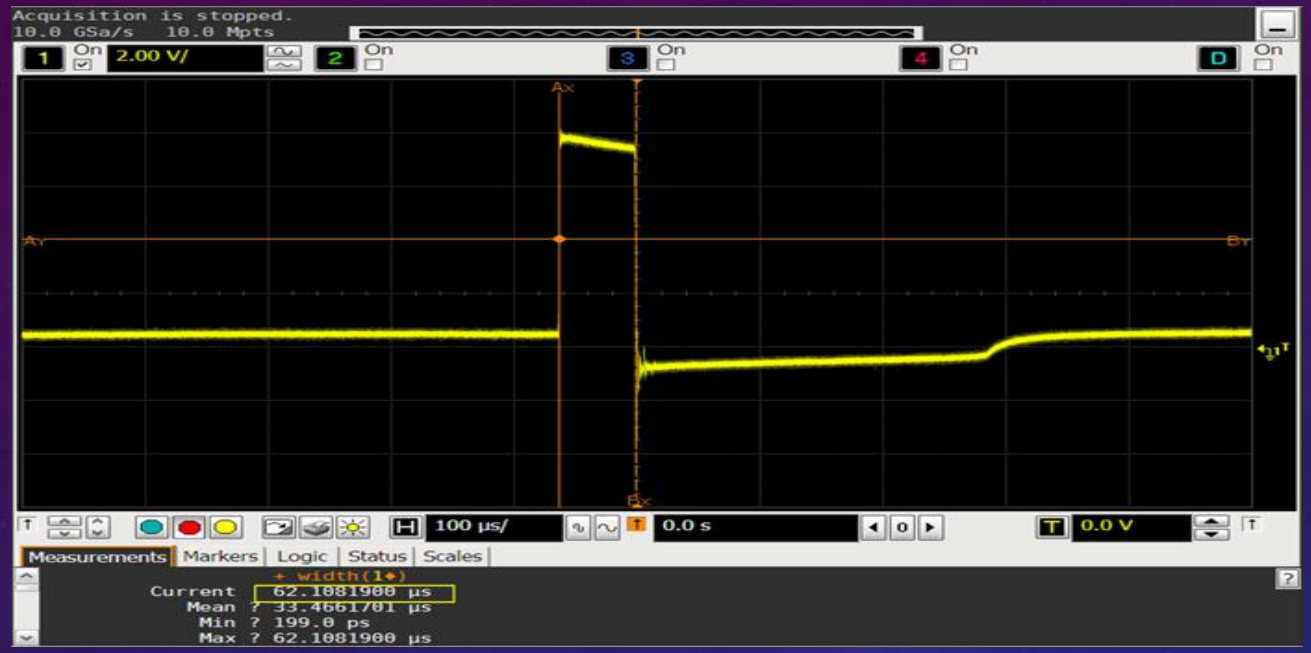
- Produces 15 pounds of thrust using propane and kerosene
- Relies on the fuel pump and engine control unit to begin running

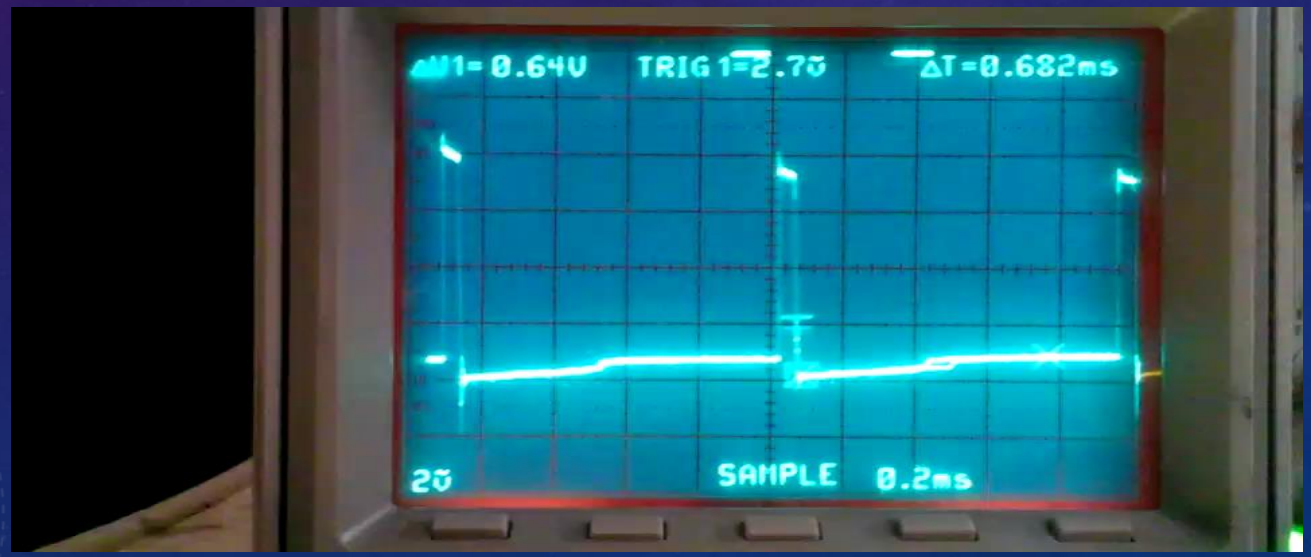
- Used to theorized operations of a larger turbine
- Able to achieve up to 120,000 RPMs

ESSENTIAL COMPONENTS OF THE TURBINE

- The engine control unit (ECU) is necessary for the operation of the turbine and receives inputs: RPM, temperature, and user throttle
- The engine control unit communicates with the fuel pump
- ECU informs the fuel pump and user if any errors occur (Ex. temperature too high)
- Monitors the amount of fuel being poured into the turbine

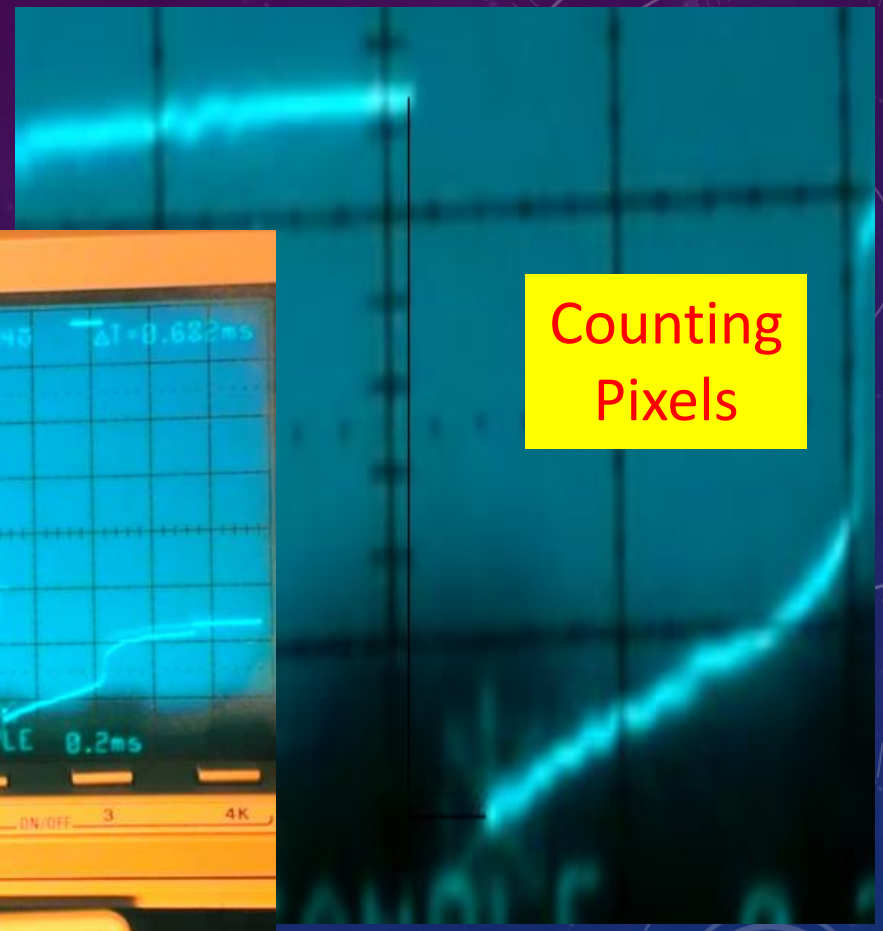
PULSE WIDTH





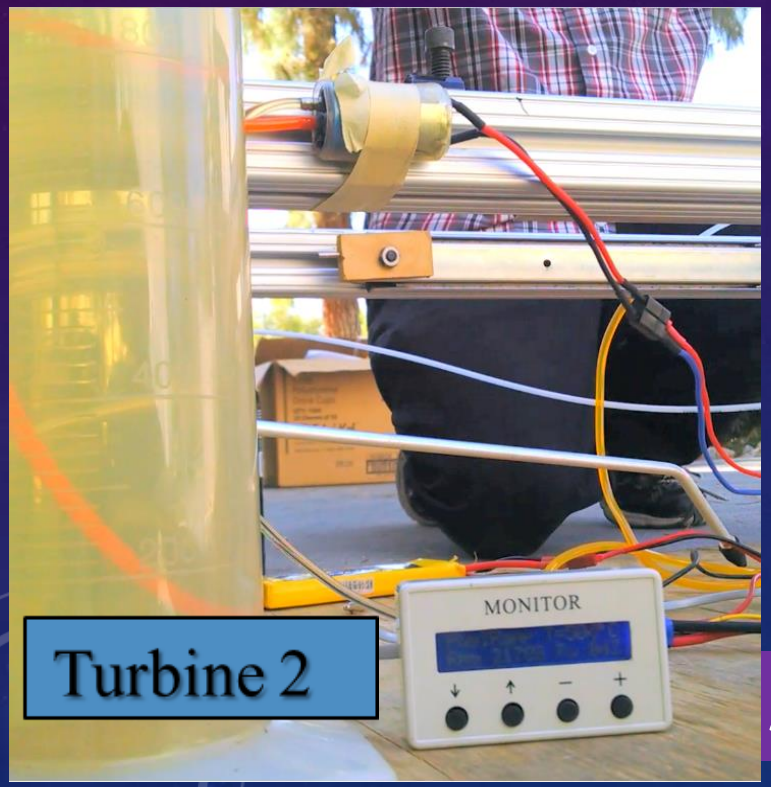
- What is pulse width?
  - ➢ Time (micro seconds) that the object runs at full power
- The highlighted number is the pulse width and will be approximately the same as the pulse width on the display monitor
- This also shows that the turbine will give a desired range of performance up to 8 volts
- The fuel pump has a pulse width measuring the amount of fuel being pumped into the turbine
- Knowing the pulse width is essential to understanding the turbine

Turbine 3



Counting Pixels

Turbine 1

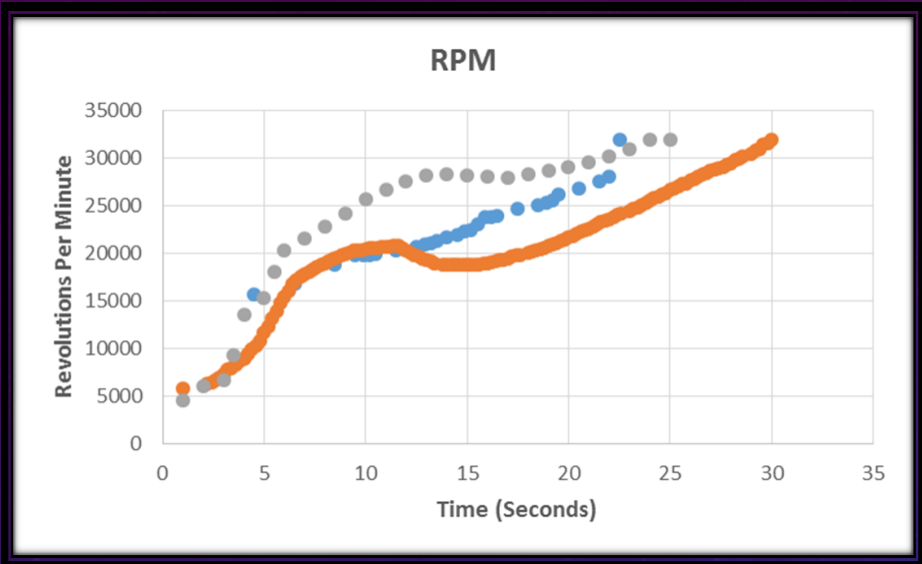


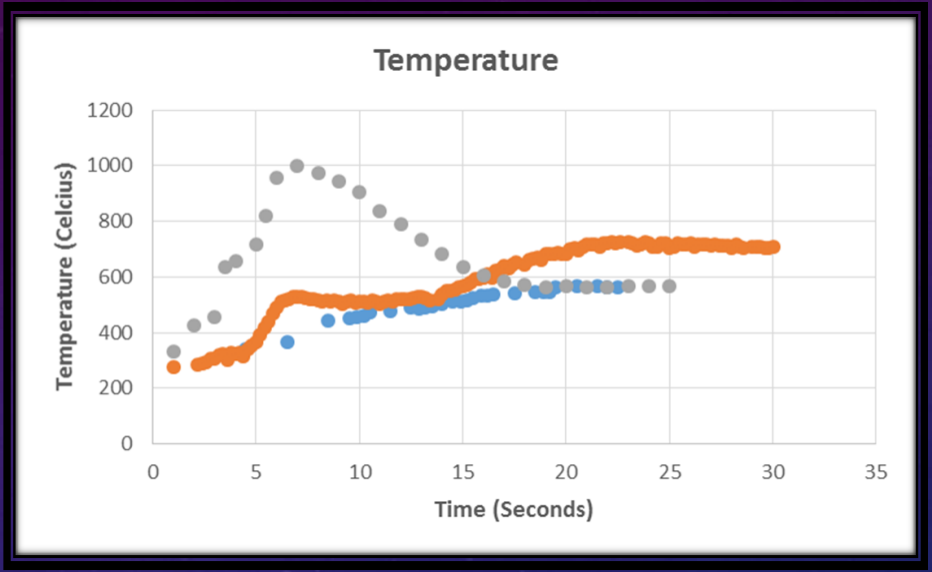
Turbine 2

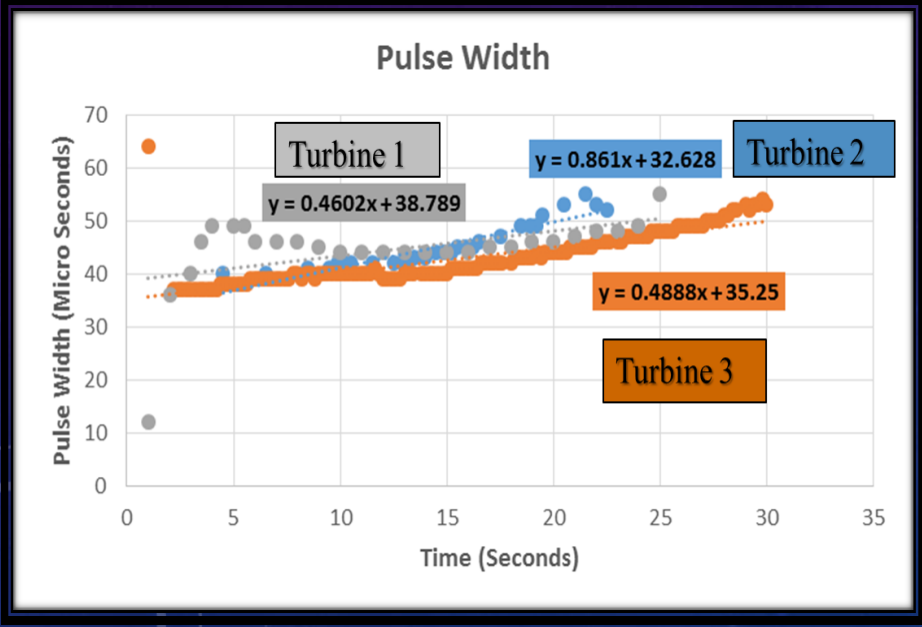
- Used frame-by-frame technology to gather data from each video
- Used Microsoft paint to enlarge images

Analyzing Fuel Pump Pulse Width In Multiple Turbine Runs

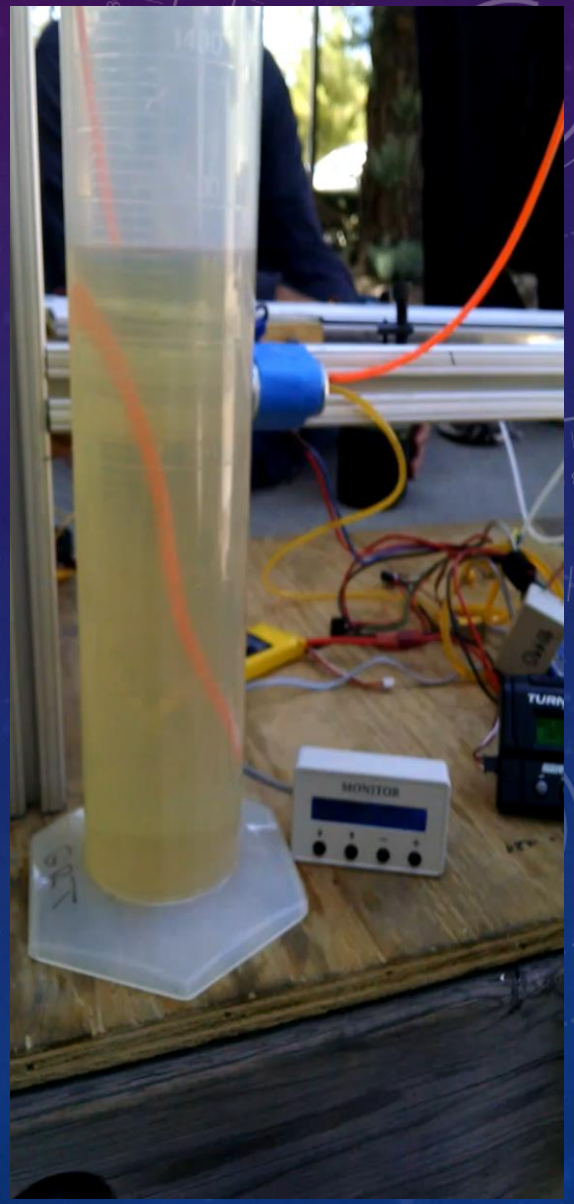
ANALYZED DATA







- Data was captured in three different runs with two different turbines (Same turbine in 2 & 3)
- Temperature becomes constant before the end of the fuel ramp
- In turbine 1, the temperature rose to 999°C which lowered the pulse width in order to stabilize
- Run times varied by a few seconds



Manipulation of a Micro Turbine Engine

RPM through a signal generator

Throttle Control

Temperature through a volt power source

Input

Input

Input

Engine Control Unit

Response

Output

Display Monitor

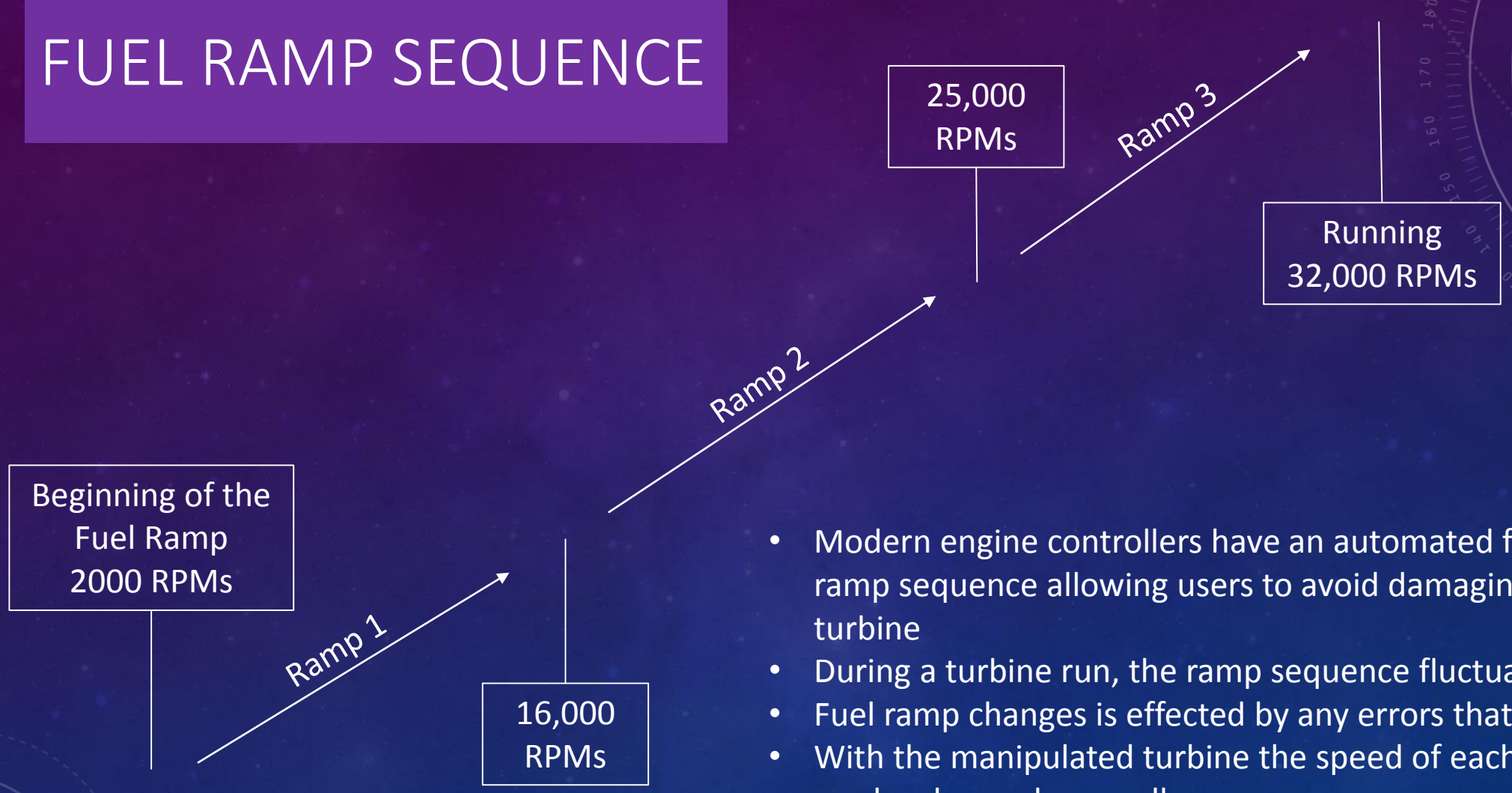
Output

Fuel Pump

Output

Oscilloscope measuring fuel pump pulse width

FUEL RAMP SEQUENCE

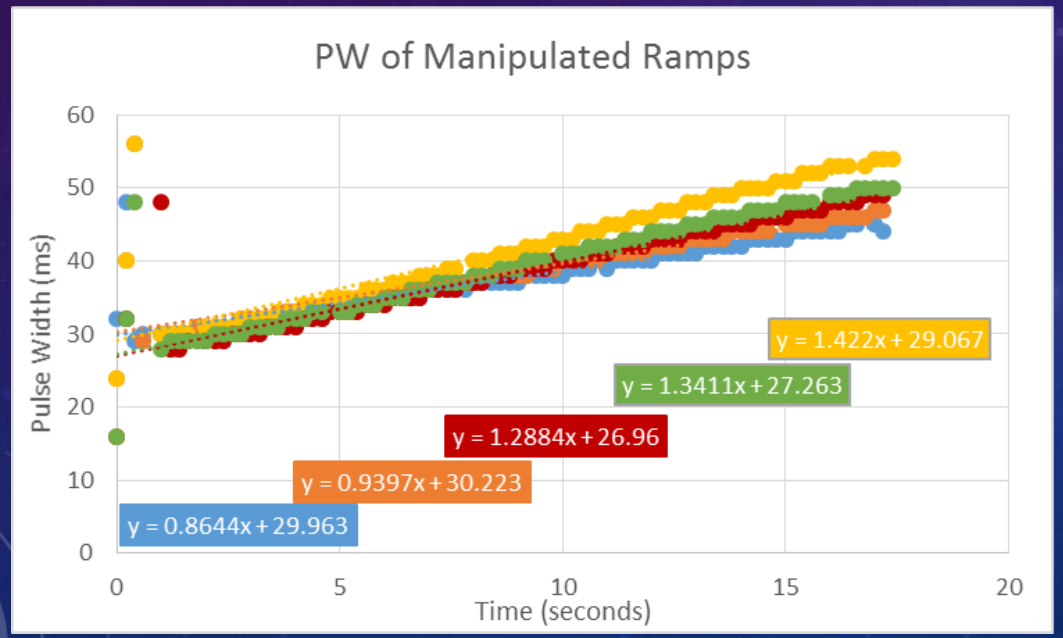


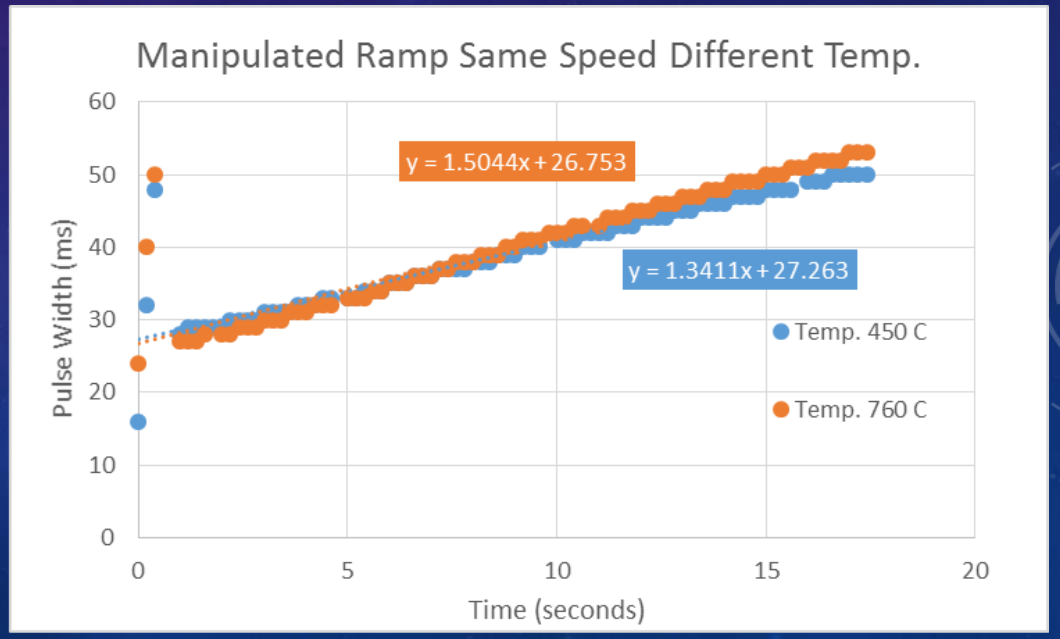
- Modern engine controllers have an automated fuel ramp sequence allowing users to avoid damaging the turbine
- During a turbine run, the ramp sequence fluctuates
- Fuel ramp changes is effected by any errors that occur
- With the manipulated turbine the speed of each ramp can be changed manually

SPEED CHANGE BETWEEN RAMP SEQUENCES

- Kept ramp 2 & 3 at a fixed speed, only changing ramp 1
- Want to know the difference between speeds
- Will reference this data when programing the Arduino

- Used same speed but with different temperatures
- Suggests that the temperature effects the pulse width
- Need more evidence to conclude this statement





ARDUINO UNO PULSE WIDTH

- Use the fading example to produce a square wave
- Generate a pulse width from the Arduino
- Do not directly hook up the Arduino to the motor [It will not work]

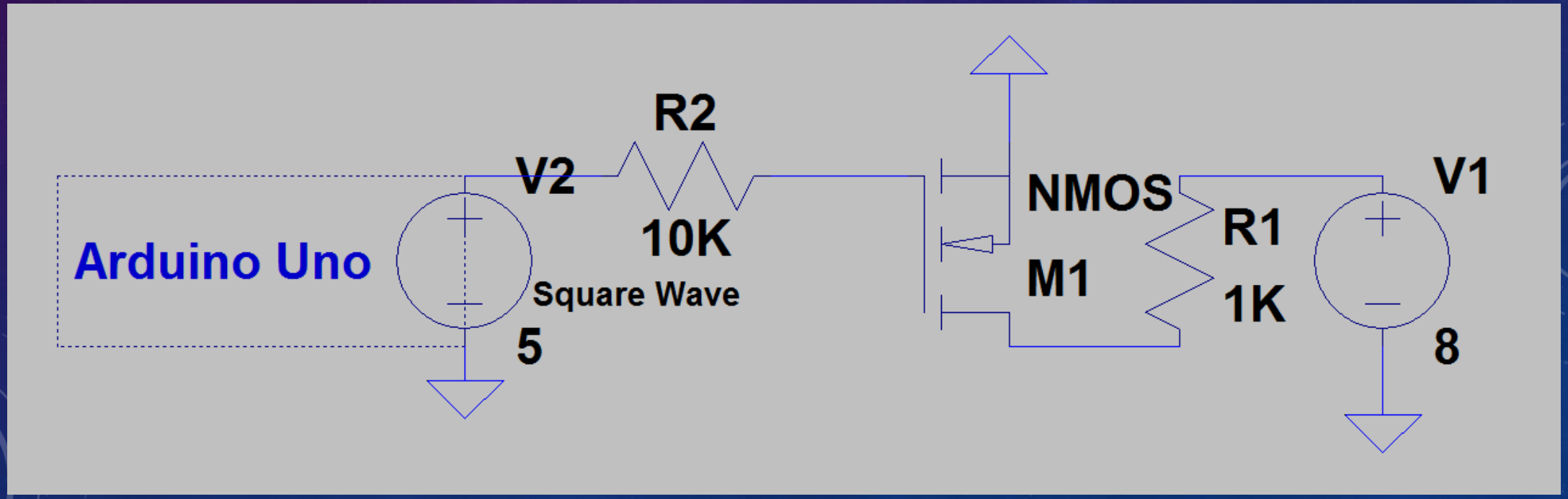
File Edit Sketch Tools Help

Fading

```
int ledPin = 9;    // LED connected to digital pin 9

void setup() {
  // nothing happens in setup
}

void loop() {
  // fade in from min to max in increments of 5 points:
  for (int fadeValue = 0 ; fadeValue <= 255; fadeValue += 5) {
    // sets the value (range from 0 to 255):
    analogWrite(ledPin, fadeValue);
    // wait for 30 milliseconds to see the dimming effect
    delay(30);
  }

  // fade out from max to min in increments of 5 points:
  for (int fadeValue = 255 ; fadeValue >= 0; fadeValue -= 5) {
    // sets the value (range from 0 to 255):
    analogWrite(ledPin, fadeValue);
    // wait for 30 milliseconds to see the dimming effect
    delay(30);
  }
}
```

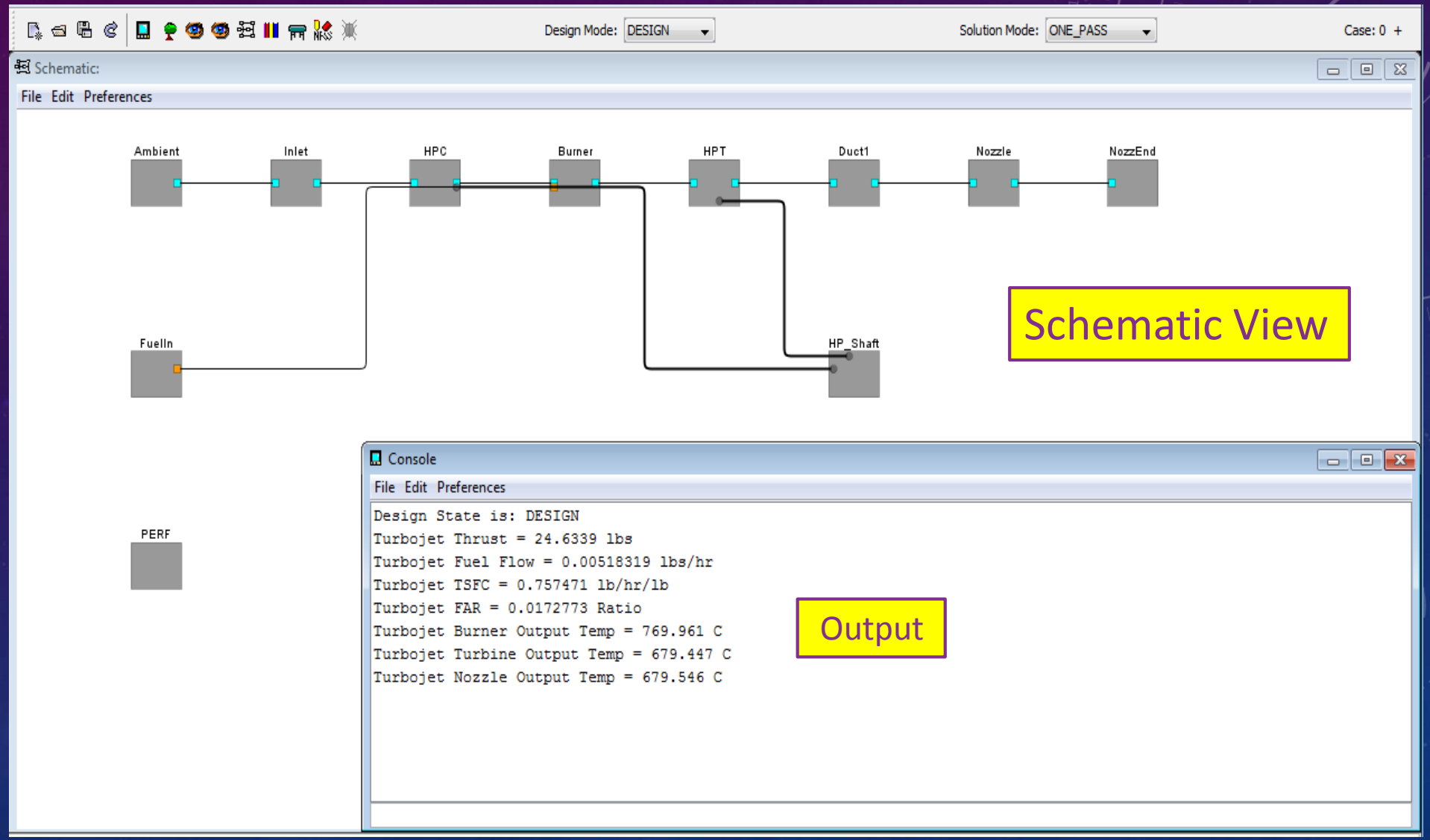
RUN THE MOTOR USING THE ARDUINO

- First step: Understand how the mosfet/transistor works (Use a power supply instead of Arduino)
- Second Step: Use a signal generator instead of Arduino to see how the square wave affects the transistor
- Third Step: Run the motor using the signal generator
- Fourth Step: Plug the Arduino in and see if it works like the signal generator (without motor)
- Final step: Run the motor with the Arduino Uno



NUMERICAL PROPULSION SYSTEM SIMULATION (NPSS)

- NPSS allows the user to model the turbine in depth
- Simulates a turbine to output specific values
- Uses a compressor map to simulate multiple runs at once
- Helps understand which inputs effect which outputs



FUTURE

- With further investigation, this model can be used as a basis for future turbine engines in hybrid-electric airplanes
- The next step is to take this information from the micro turbine engines and apply it to a 65kW turbine
- The Arduino will allow for more research on the micro turbine engine at a cheaper cost
- This information may be transferred to aid other NASA projects (Ex. HEIST - Hybrid Electric Integrated System Test-bed)

WHAT I HAVE DONE AND LEARNED FROM THIS INTERNSHIP

If You Ain't Burnin'...
You Ain't Learnin'

ACKNOWLEDGEMENTS

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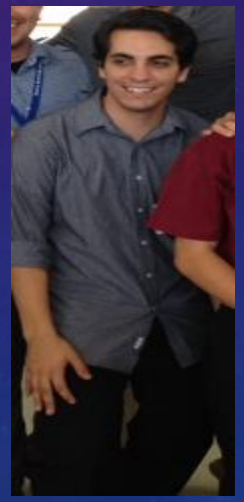

K. A. R. A. T. E. SQUAD

QUESTIONS?