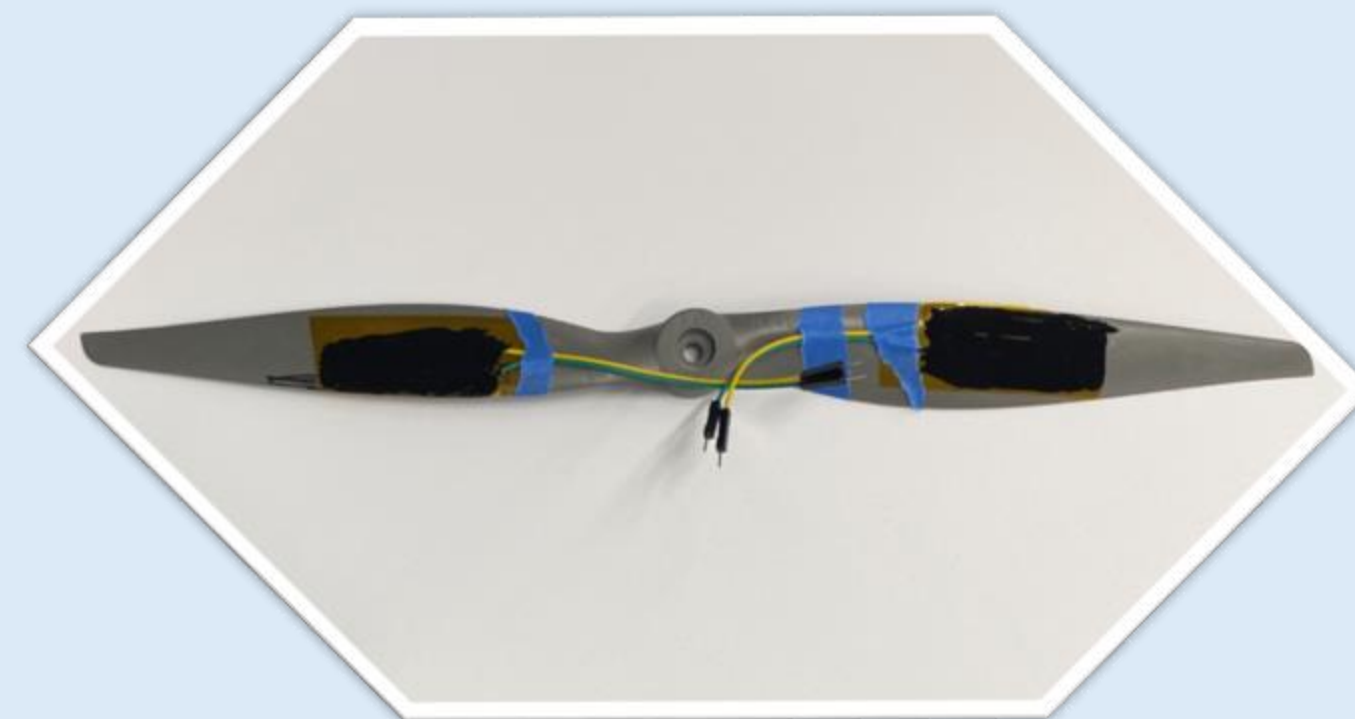


Introduction

Icing is a common occurrence which hinders the aircraft's flight.

- Extra weight
- Lowered thrust
- Loss of flight control



Objectives:

- Low-weight and minimal thickness
- Composite-friendly heater
- Scalable
- Fits inside the propeller



Fig 1 'M' pattern

Method

The thin-film heater is made of 20-micrometer-thick Kapton film and CNT paste, with silver epoxy as a conductive binding between the CNT paste and wires. (Fig. 1, 2)

- 3D reverse pattern
- CNT applied on top of tape
- True pattern left behind

To test the heating capability, a thermal camera and thermocouple recorded and cross-referenced the temperatures produced. (Fig. 3)

- Temperature evaluations made by Braydon Nicklus
- Heating power scaled with input DC voltage

Once these tests confirmed the effectiveness of the CNT-based thin-film heater, preparations were made to fix the propeller to a motor.

- Slip ring for power transmission of a rotating propeller
- Motor connection

Software and Equipment Used:

- Autodesk Fusion
- Cricut Explore 4
- Bambu H2D 3D Printer
- LabView 2025
- FLIR Thermal Camera

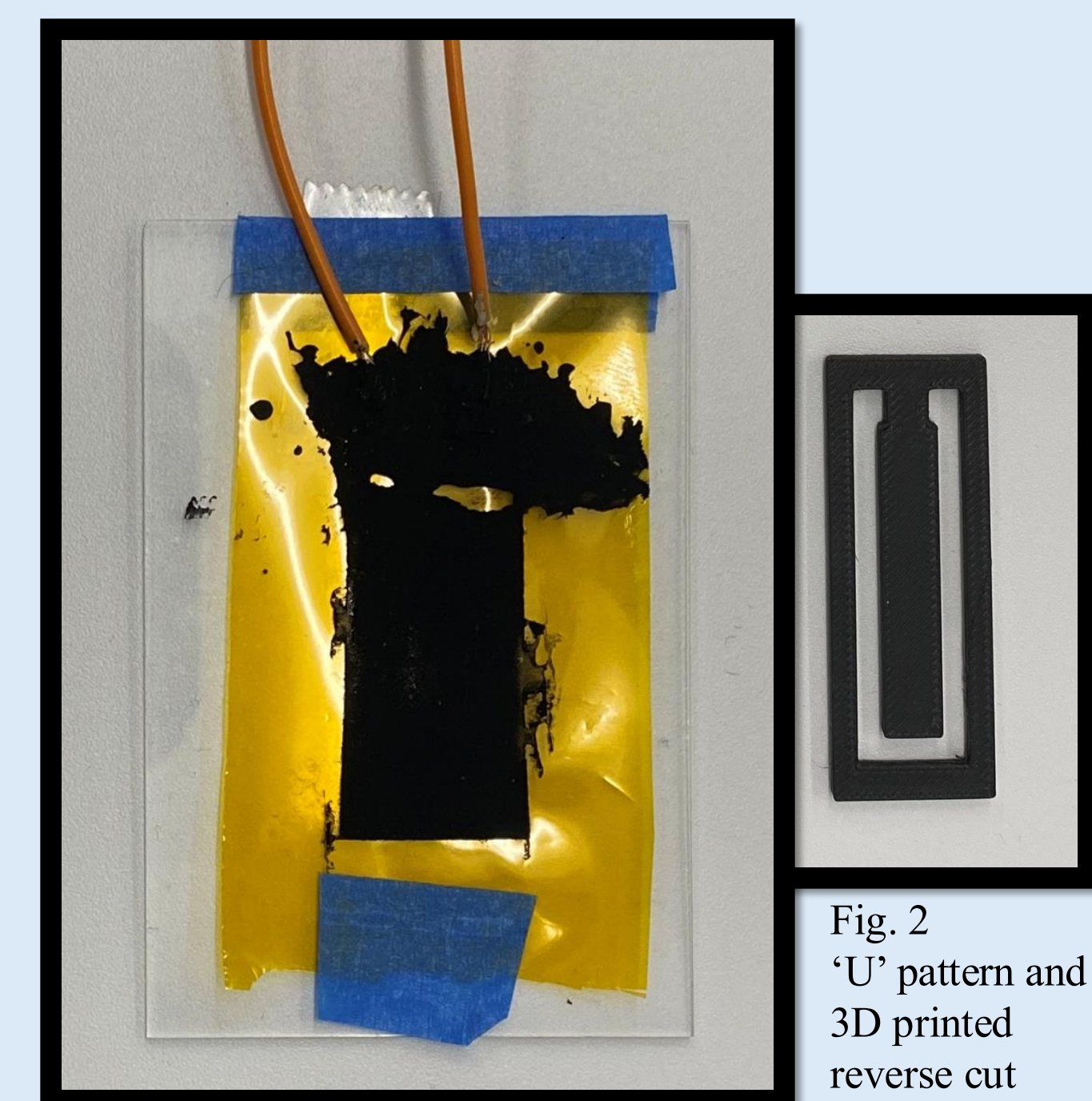


Fig. 2 'U' pattern and 3D printed reverse cut

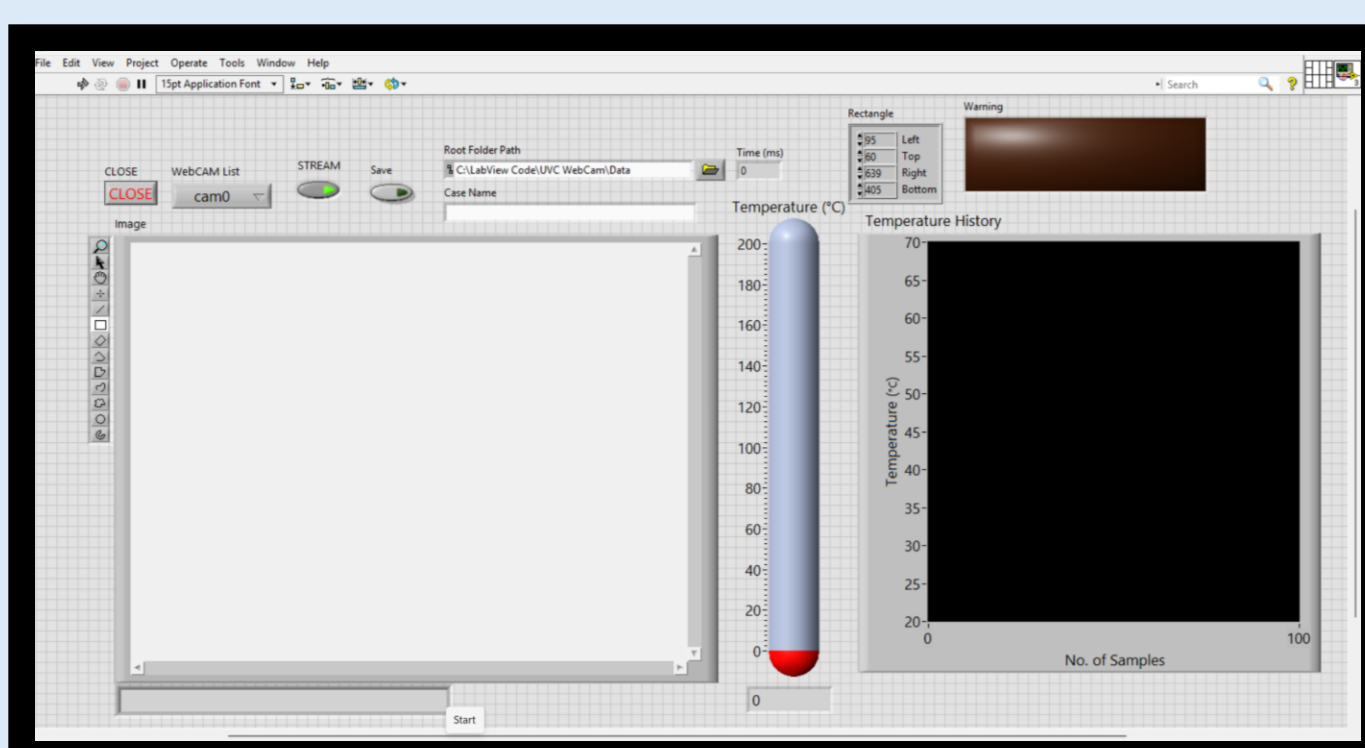


Fig 3 LabView thermal camera and thermal couple measurements

Sample Results



Fig 4 'M' pattern under infrared camera.

The first test used the 'M' pattern. This pattern was made to confirm that CNT paste sticks to Kapton film. Copper tape was used to connect wires to the ends of the pattern. (Fig. 4)

- First pattern
- Resistance testing
- Voltage testing

Second round of tests with the 'U' pattern. The connection from CNT paste to wire was silver epoxy. (Fig. 5)

- Better size
- Higher results
- Even heating
- Resistance 'sweet spot'



Fig. 5 'U' pattern under infrared camera.

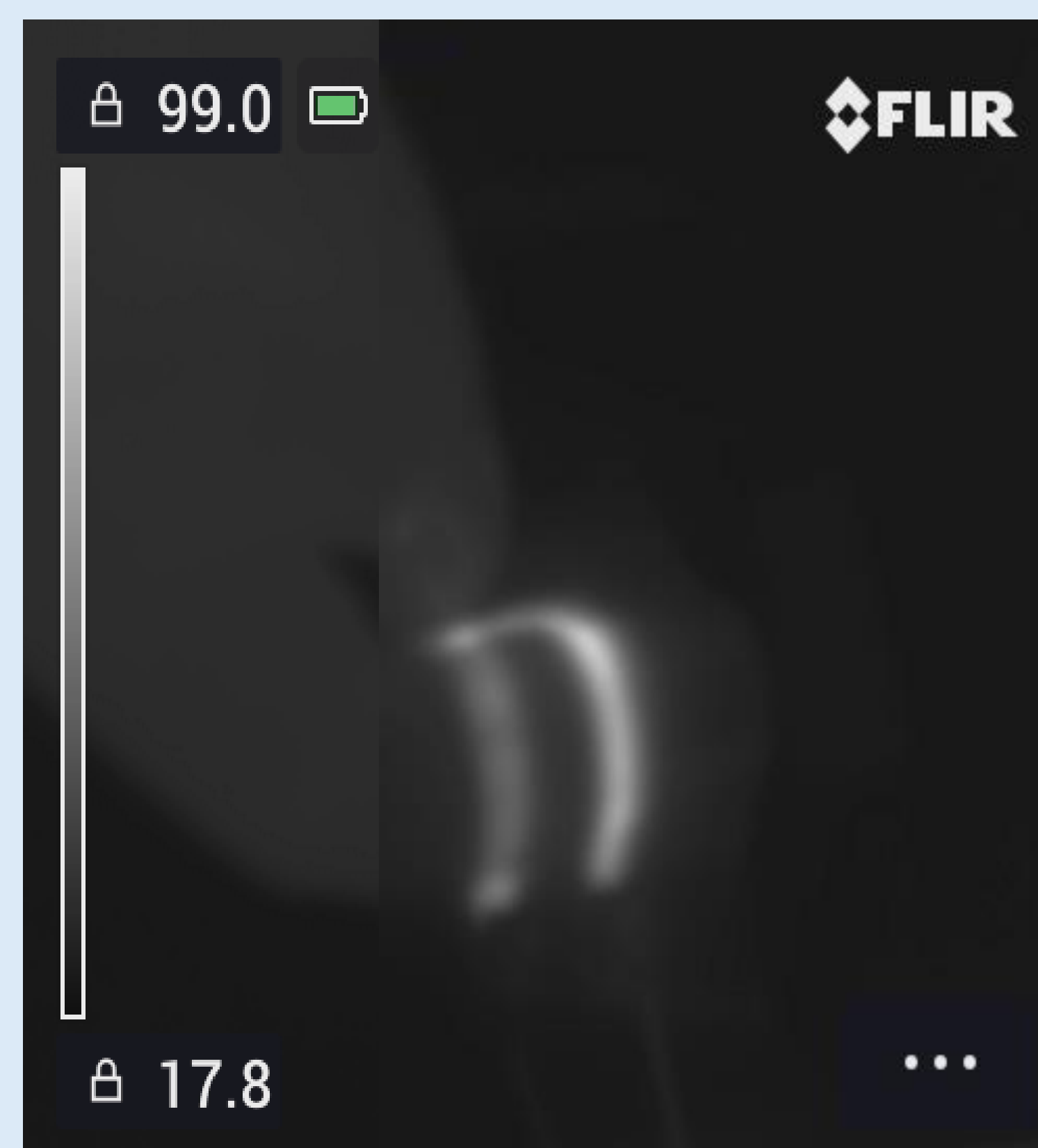


Fig 6 'U' pattern being bent under infrared camera.

Once the 'U' pattern passed the first test, it was subjected to bending to test the efficiency of the heating when on a drone propeller. (Fig. 6)

- Even heating under bending/large local strain
- Flaking CNT
- Epoxy and paint

Discussion

The first iterations of the CNT thin-film heaters were made entirely by hand. This created some issues due to human error.

- Small variations in size
- Uneven thickness
- Similar resistance

Research is currently being conducted to connect the CNT patterned propeller to a motor. (Fig. 7)

- Slip ring
- Cable management
- Test rig

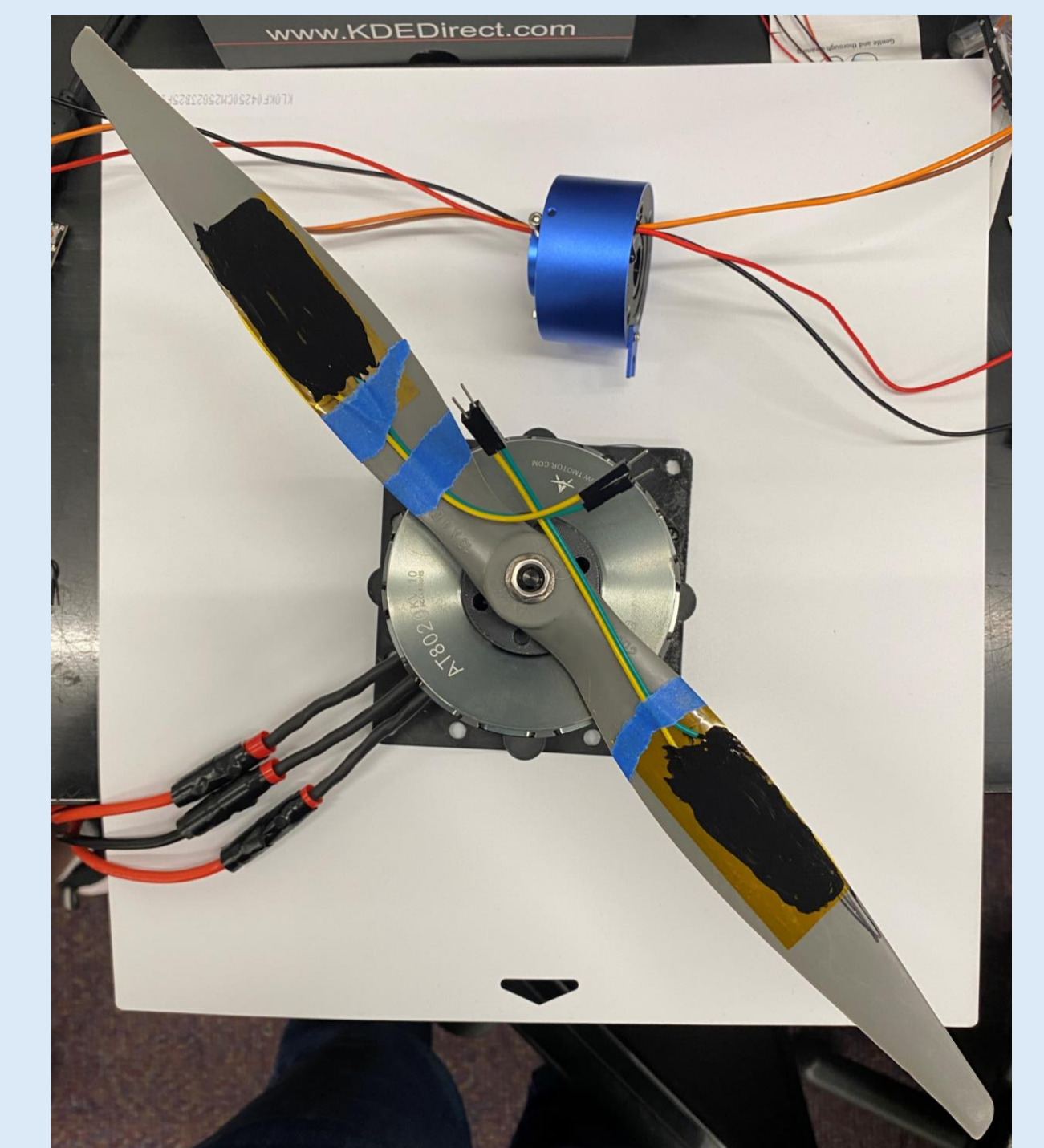


Fig 7 CNT-based heated propeller on a motor, slip ring included.

The **next major steps** are to test the heating element against the weather as the propeller spins and create larger CNT patterns.

- Weather simulation
- Larger patterns (Fig. 8)
- Epoxy resin coating

The issue of pattern similarity was fixed after the use of the Cricut Explore 4, ensuring the exactness of each reverse tape pattern.

- Efficient
- Resistance too high
- Further research being conducted

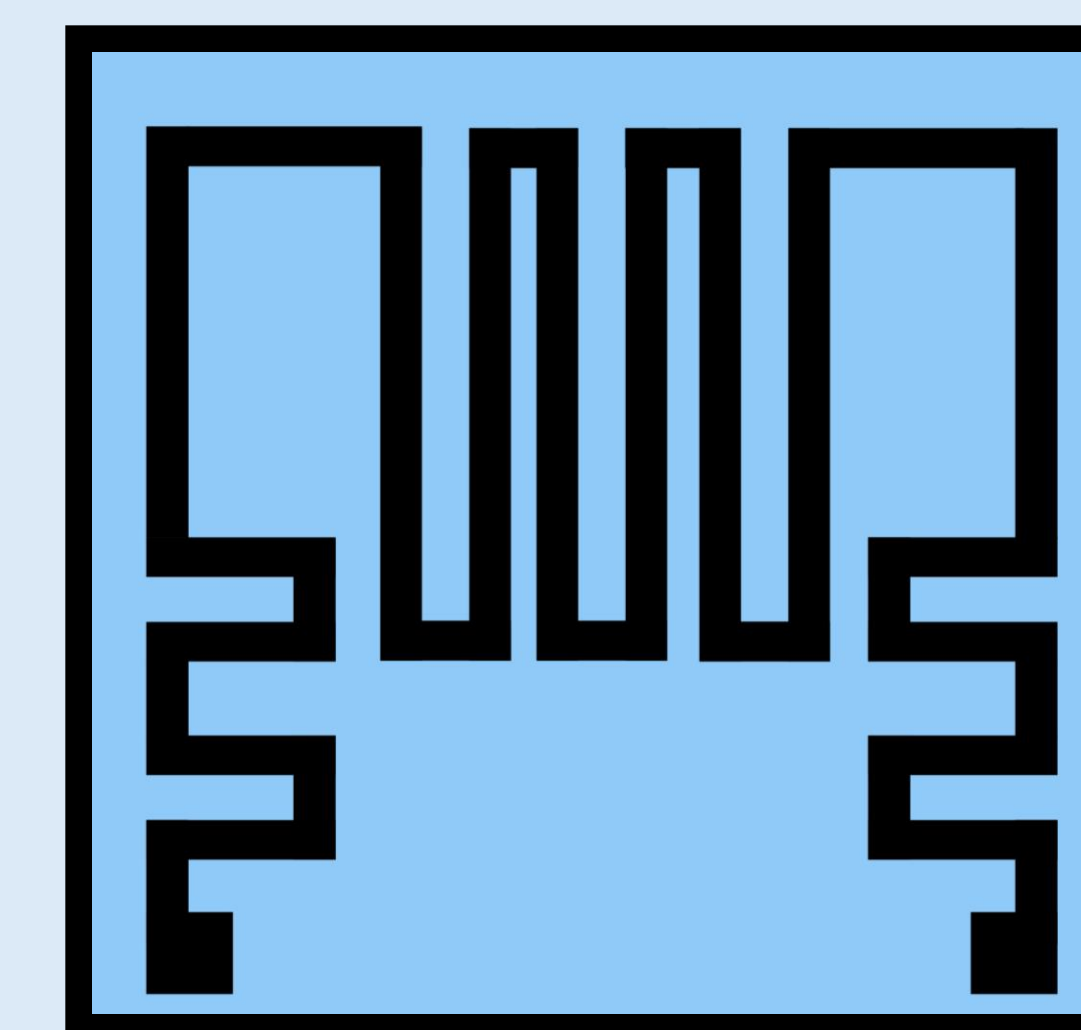


Fig. 8 Large CNT pattern made using Cricut machine

References

- [1] Amjadi, M., & Sitti, M. (2018). Self-Sensing Paper Actuators Based on Graphite-Carbon Nanotube Hybrid Films. *Advanced Science*, 5(7). <https://doi.org/10.1002/advs.201800239>
- [2] National Instruments. (2025). LabVIEW (Version 2025) [Windows]. Austin, TX.