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Standard Operating Procedure (SOP) for Proactive Direct Attack Safety Indicator for Wildland Fire Bulldozers with Enclosed Cabs Install and Configuration

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A. Nomenclature

DO – Data Out
CS – Chip Select
CLK – Clock
GND - Ground
PCTG - Polycyclohexylenedimethylene Terephthalate Glycol
USB – Universal Serial Bus
SD - Secure Digital
TB - Terabyte

B. Purpose and Applicability

The purpose of this Standard Operating Procedure (SOP) is to provide instruction on the preparation and installation of the Standard Operating Procedure (SOP) for the Proactive Direct Attack Safety Indicator for Wildland Fire Bulldozers with Enclosed Cabs system.

This system is designed to assist with situational awareness for bulldozer operators operating within enclosed cabs (envirocabs) where increasing heat is less likely to be felt, leading to dangerous situations where a bulldozer could sustain damage and/or shut down, leaving the operator within the fire, possibly leading to operator injury, equipment damage, and in extreme cases, death. For example, an issue that has occurred is where the debris or internal components within the belly pan will catch fire, damaging internal components and in some cases melting a crucial fuse within the dozer, causing the bulldozer to shut off. Exterior components can also sustain damage, for example, in September we were shown where a wiper blade had melted on a bulldozer that was used in fire operations. If even experienced operators can run into problems, imagine the challenges that new firefighters face. This system can assist those new operators by providing them with additional situational awareness. A red blinking light is a simple system, but it can bring awareness to a dangerous situation while the operator still has time to react.



Figure 1: Melted Wiper Blade

According to a study from May 2022 by the USDA and the Forest service, “Since 1971, there have been more than 60 bulldozer burnovers in the United States, and 34 of these incidents occurred between 2005 and 2019.” (Wu, Petrilli, Grob, & Zemek, 2022)

With this system, when temperatures exceed a threshold, LEDs begin to blink, notifying operators which direction the heat is coming from. The first prototype used two thermocouples, a single LED, an Arduino, and batteries for power. Version 2 built upon the initial prototype, incorporating an additional thermocouple for the belly pan, plus

additional LEDs allowing the operator to quickly identify which thermocouple is hot, and an inverter, allowing the device to be powered by the dozer. Part of the system are GoPros installed to collect valuable fire imagery.



Figure 2 & 3: System installed on bulldozer



Figure 4: LEDs (Mounting will vary based on visibility)

This system uses off-the-shelf components and open-source software to reduce supply chain issues and keep costs low. This system does not log temperatures or other data as that is outside of the scope of this system.

C. Summary of Method

1. Summary of Improvements:

- Added an additional Thermocouple for
- to assign an LED each Thermocouple, allowing operators to see which direction underneath the bulldozer based on feedback on previous prototype from operators
- Added two additional LEDs and rewrote some of the code the heat is coming from
- Added a proto screw shield to each Arduino to better secure wiring as well as improving repairability
- Added an off-the-shelf inverter to power the Arduino once the dozer is turned on to remove the need to replace batteries, improving operational efficiency
- Newly designed 3D printed case printed in PCTG for reduced warping and improved heat resistance and durability

2. System Components

- 1 x PowerVerter PV375USB Power Inverter
- 1 x Wall charger with 3 USB-C ports (20w each) and a USB-A port
- 1 x 9 VDC 1000mA regulated switching power adapter - UL listed
- 1 x Arduino Uno Surface Mount (Revision 3)
- 1 x Proto-Screwshield (Wingshield) R3 Kit for Arduino
- 3 x Thermocouple Amplifier MAX31855 breakout board (MAX6675 upgrade)
- 3 x Klein Tools K-Type High Temperature Thermocouple
- 3 x 0.1uF ceramic capacitors
- 3 x 220-ohm resistor
- 3 x Super Bright Red 5mm LED
- 3 x USB-C Cables
- 3 x Simple USB C Socket Breakout
- 12 x M2.5 x 10mm Socket head Screws
- 12 x M2.5 x 12mm Socket head Screws
- 1 x M3 Nylon Standoff Kit
- 3 x 20mm x 3 mm Round Silver Neodymium Magnets
- 40ft M27500-22SB5T23 Wire (12ft per thermocouple, 4 ft extra, adjust as needed)
- Heat Shrink Tubing
- GoPro
- 5V Square USB Fan - 5 cm
- Hardware for mounting GoPro (Whatever you have that fits the print will work)
- 3D Printed Cases and Parts
    - 1 x Arduino Case w/lid
    - 3 x Thermocouple Cases w/lids
    - 3 x LED cases with Lids
    - 1 x GoPro Charger Pass Through Door
    - 1 x GoPro Mount

3. Software:

- Program: Arduino IDE

- File: AI_LED_multithermocouple_V3_Modified.ino

D. Cautions

1. Arduino protoshield connections

- Ensure that all connections are properly grounded. Failure to properly ground connections can lead to errors or damage to components.

2. Electrical Components

- All mounted internally to the envirocab except the thermocouples to keep them dry and away from extreme temperatures, when possible, this will not always be possible in the field.

3. Operational Considerations

- Due to the system and its components being installed on a bulldozer, properly secure all components to reduce likelihood of damage

4. Dozer

- While this system is designed to increase operational awareness, this system does not replace rules, policies, procedures, manufacture specifications, or operator experience and knowledge.

E. Interferences

1. Wireless Interference

- Since this system does not transmit data, interferences are of limited concern. Due to the use of threshold temperature and the location and method of securing of the thermocouples, no precise measurements are being collected.

2. Initialization

- After installation, temperature thresholds will likely have to be adjusted, this is due to the fact that factors such operating temperatures and environmental differences can lead to higher or lower ambient temperatures

F. Personnel Qualifications

This SOP is written for individuals installing, maintaining, or using the system. Installation requires some knowledge of electronics and programming of the system may require a short introduction to the software.

G. Equipment and supplies

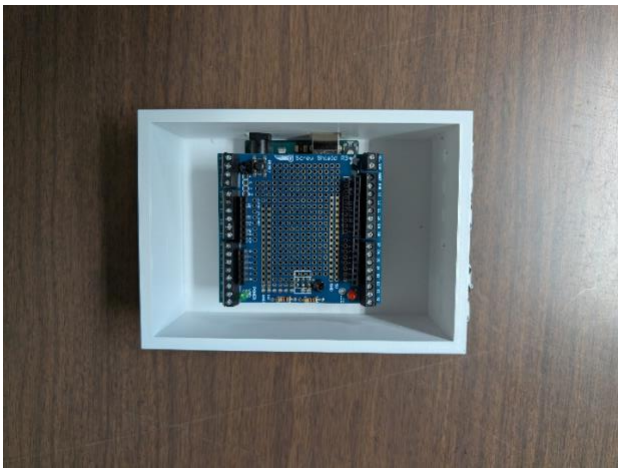
1. Inverter

- The inverter will be plugged into the 12v Socket inside of the bulldozer that is tied to the starter


Figure 5: Inverter

2. Arduino with Protoshield and Case

- Arduino and Protoshield should be secured to the 3D Printed Case with Nylon Screws to reduce the chance of a short


Figure 6 – Arduino Uno R3 secured to 3D Printed Case

3. Cables

- USB-C cables will be used to connect LEDs to Arduino Board
- 5 Conduit wire will be used to connect thermocouple amplifier wire to Arduino board

4. LEDs

- LEDs will be connected via USB-C, ensure cases are glued shut



Figure 7 - LEDs in cases with USB-C cables plugged in

5. GoPro With Fan

- The GoPro should have the battery removed, a large SD card (Check manufacture information for compatible SD card and size limit), a pass through door for charging (can be 3D printed, official versions are available as well), and a 3D printed fan mount with a 5v fan


Figure 8 – GoPro with Fan and 3D Printed mount

H. Procedural Steps

Inverter, Arduino, Thermocouples, and LEDs Setup:

1. Start by deciding the location of the inverter based on the location of the 12 Volt outlet.
2. Once the inverter location has been decided on, place thermocouple amplifiers and determine how you plan to route the wires.
3. Place LEDs and determine wire routing
4. Once everything is place, run wires through the holes of the Arduino case and begin securing cables using screw terminals based on information below
5. Thermocouple Amplifier Cable Wire Colors (may vary based on cable used)
    - Red = Power
    - White = Ground
    - Orange = DO
    - Green = CS
    - Blue = CK

6. USB C
    - Depending on the USB-C cable used the power and ground will vary so use a multimeter to figure out the power and ground of your cable
    - Note: USB-C does not have a color code standard and most cables are proprietary and lack a wiring diagram
7. Pin Outs
    - Thermocouple Amplifier 1 (Left)
        - Power = 3V
        - GND = GND
        - DO = Arduino Pin 2
        - CS = Arduino Pin 3
        - CLK = Arduino Pin 4
    - Thermocouple Amplifier 2 (Bottom)
        - Power = 3V
        - GND = GND
        - DO = Arduino Pin 5
        - CS = Arduino Pin 6
        - CLK = Arduino Pin 7
    - Thermocouple Amplifier 3 (Right)
        - Power = 3V
        - GND = GND
        - DO = Arduino Pin 8
        - CS = Arduino Pin 9
        - CLK = Arduino Pin 10
    - Left LED
        - Power = Pin 13
        - GND = GND
    - Middle LED
        - Power = Pin 12
        - GND = GND
    - Right LED
        - Pin 11
        - GND = GND
8. Wiring Notes
    - Thermocouple amplifier grounds should be Soldered together
    - LED grounds should be soldered together
    - A jumper wire may be required if the combined power or grounds don’t fit in the screw terminals
    - Tinning wires will make securing wires in screw terminals easier, but is not necessary
9. Once wiring is complete, plug Arduino into laptop with Arduino IDE
10. Pull up most recent the most recent version of the Arduino sketch
11. Select the board from the dropdown menu in the top left corner by the upload button

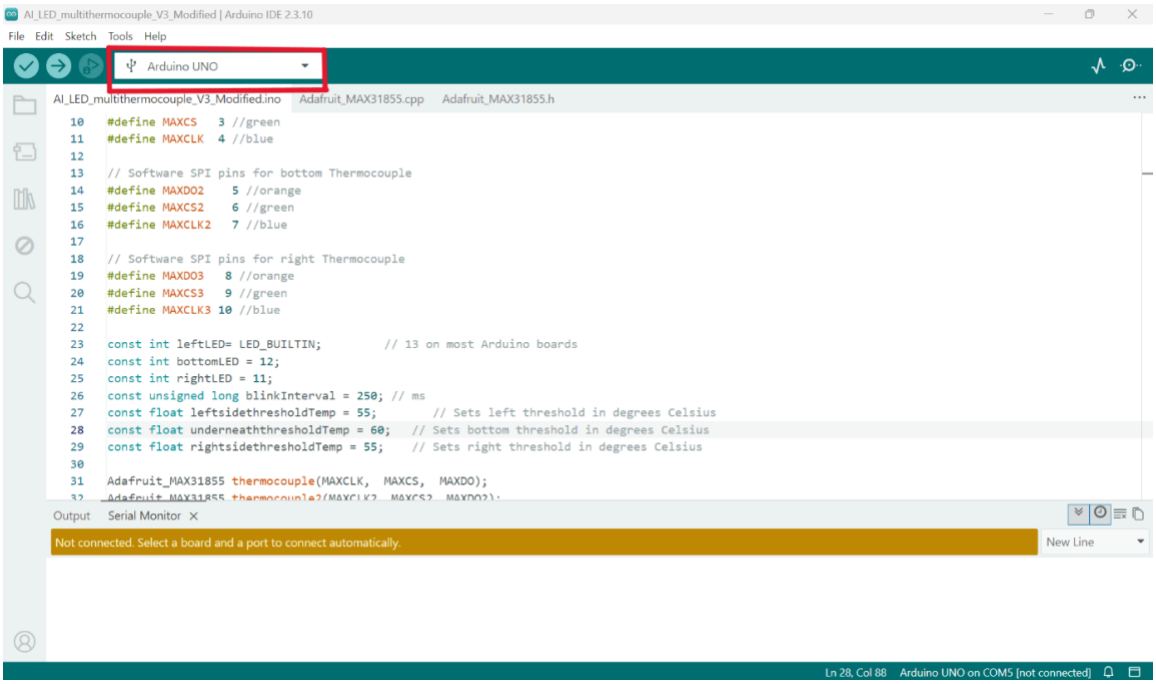


Figure 9 – Arduino Select

12. With the correct board selected, select the verify button (the checkmark)

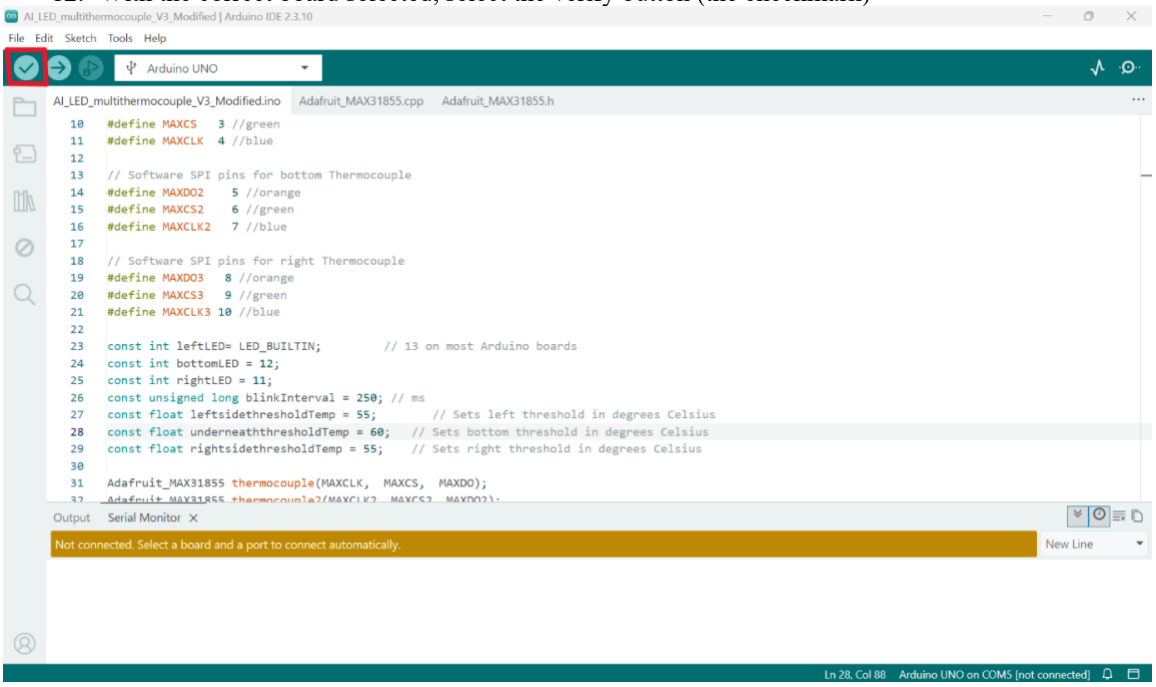


Figure 10 – Verify Sketch

13. After the program compiles successfully, click upload

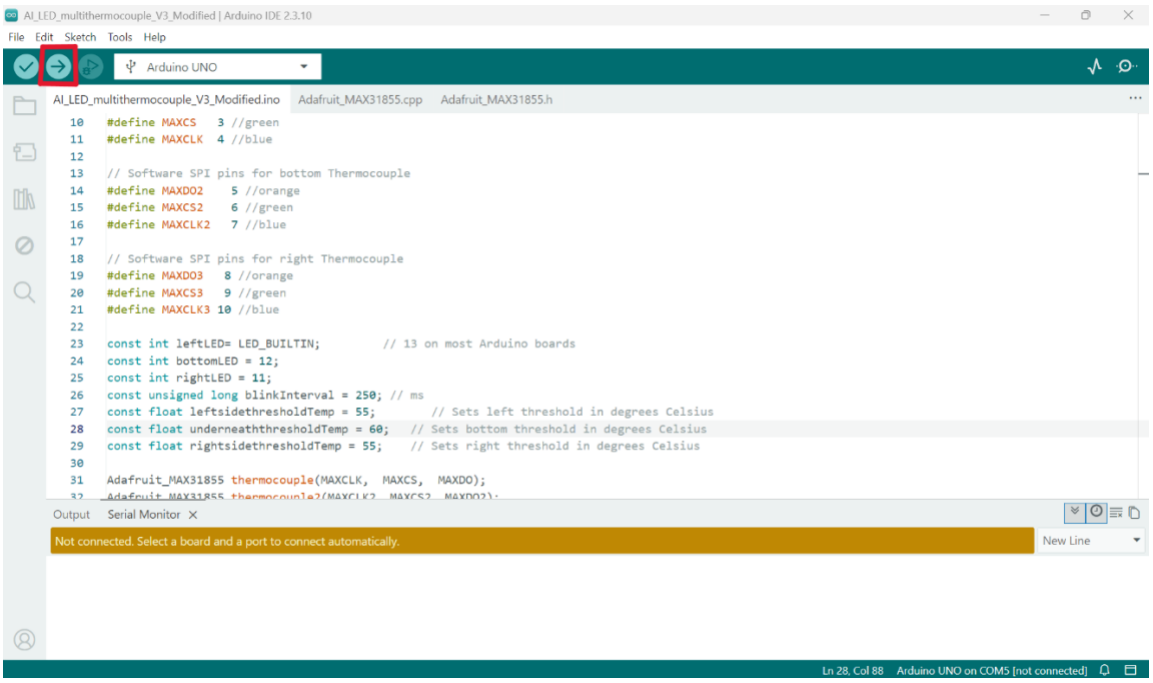


Figure 11 – Upload Sketch

14. Once you see upload complete, select serial monitor

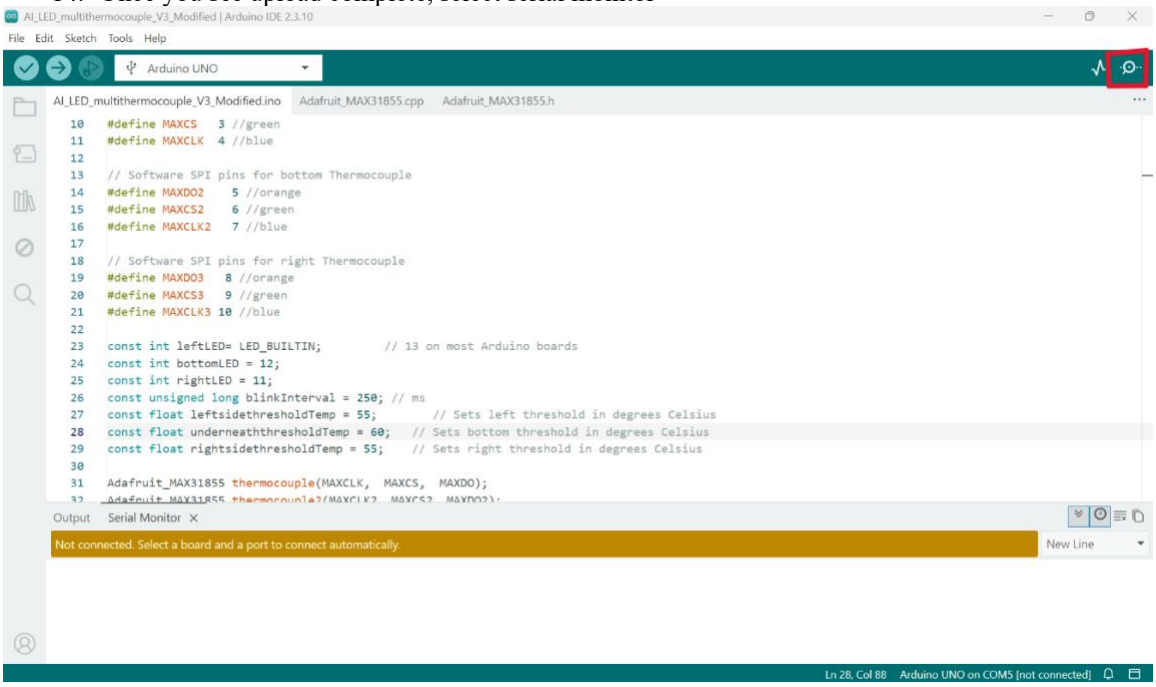


Figure 12 – Serial Monitor

15. Change Baude rate to 9600
16. You should see temperature values by C1, C2, C3 and no error messages

GoPro Install:

1. Decide on placement of GoPros


Figure 13 – GoPro Placement

2. Splice together 5v fans so that they share a USB plug (depending on distance between GoPros, additional cable may need to be added)
3. Run the USB-C Power cables and decide on routing
4. Plug USB for fans into the inverter and USB-C cables into power brick connected to inverter

Test Equipment:

1. With everything plugged in and secured, start the bulldozer
2. The inverter should beep when the dozer is started, and the left LED should blink briefly upon the dozer being powered on
3. To test the thermocouples and LEDs, take a lighter or heat gun an heat up the end of the thermocouples, the corresponding LED for each thermocouple should light up
4. Turn on the GoPros and start recording, allow to run for a few minutes to ensure they are working properly
5. Note: The GoPros will shut off if the dozer is powered off. If this occurs, the next time you turn on the GoPros you will briefly see a message saying repairing file, this is ok and expected if the GoPros were not manually shut off before the dozer.

Tuning Threshold Temperatures:

1. Plug Arduino into laptop, ensure that power is disconnected
2. To modify threshold temperatures, start by opening the most recent version of the sketch
3. Each thermocouple has its own threshold temperature, labeled leftsidethresholdTemp, underneaththresholdTemp, and rightsidethresholdTemp

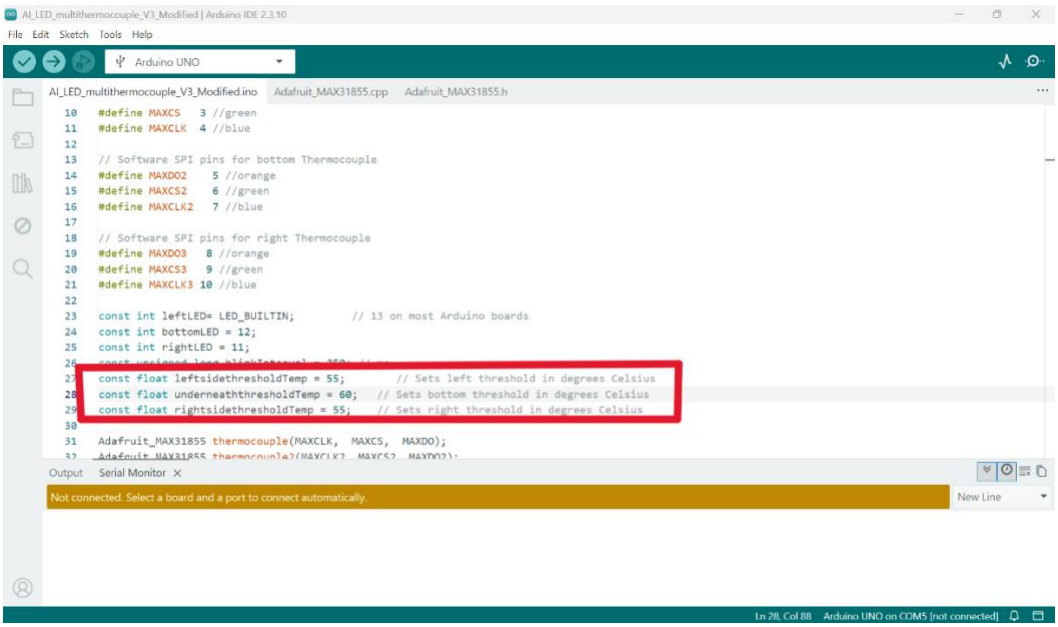


Figure 14 – Variables to change

4. To adjust the threshold simply replace the number with whatever new threshold temperature you want to set in Celsius
5. Once temperatures have been set, click verify sketch, if it compiles without error, then click upload sketch
6. Once Sketch uploads, open serial monitor and that system is reading values, also watch LEDs to ensure temperatures are not too low.

I. Health and Safety Warnings

1. Electrical

- When working on electronic components, they should be unplugged
- Electrical components present a shock hazard as well as a fire hazard if improperly handled

2. Heat

- When installing the system, the temperature inside the dozer can be greater than the temperature outside of the dozer, ensure that anyone installing the system stays hydrated.

3. Tools

- Installing the system requires the use of tools including, but not limited to, a soldering iron, heat gun, hot glue gun, wire clippers, and scissors. Always follow proper safety procedures when using these tools.
- When using a soldering iron, avoid inhaling fumes

J. References

1. Wu, S., Petrilli, A., Grob, I., & Zemek, P. (2022). *Bulldozer Burnover Study.* U.S. Department of Agriculture, Forest Service National Technology and Development Program.

K. Acknowledgements

The authors would like to acknowledge Alamaba Forestry Commission, Montana Space Grant Consortium, and NASA Wildland Fire Program

L. Appendix

Attachment 1 – Link to instructions for Installing Arduino IDE

Due to instructions changing over time and different operating systems, a link to the official instructions is included.

Link:
https://support.arduino.cc/hc/en-us/articles/360019833020-Download-and-install-Arduino-IDE

Attachment 2 – Links to additional resources

- Proto Screw Shield Tutorial
  - https://learn.adafruit.com/adafruit-proto-screw-shield
- Adafruit Thermocouple Tutorial
  - https://learn.adafruit.com/thermocouple/