# Handheld Infrared Camera for Medical Diagnoses

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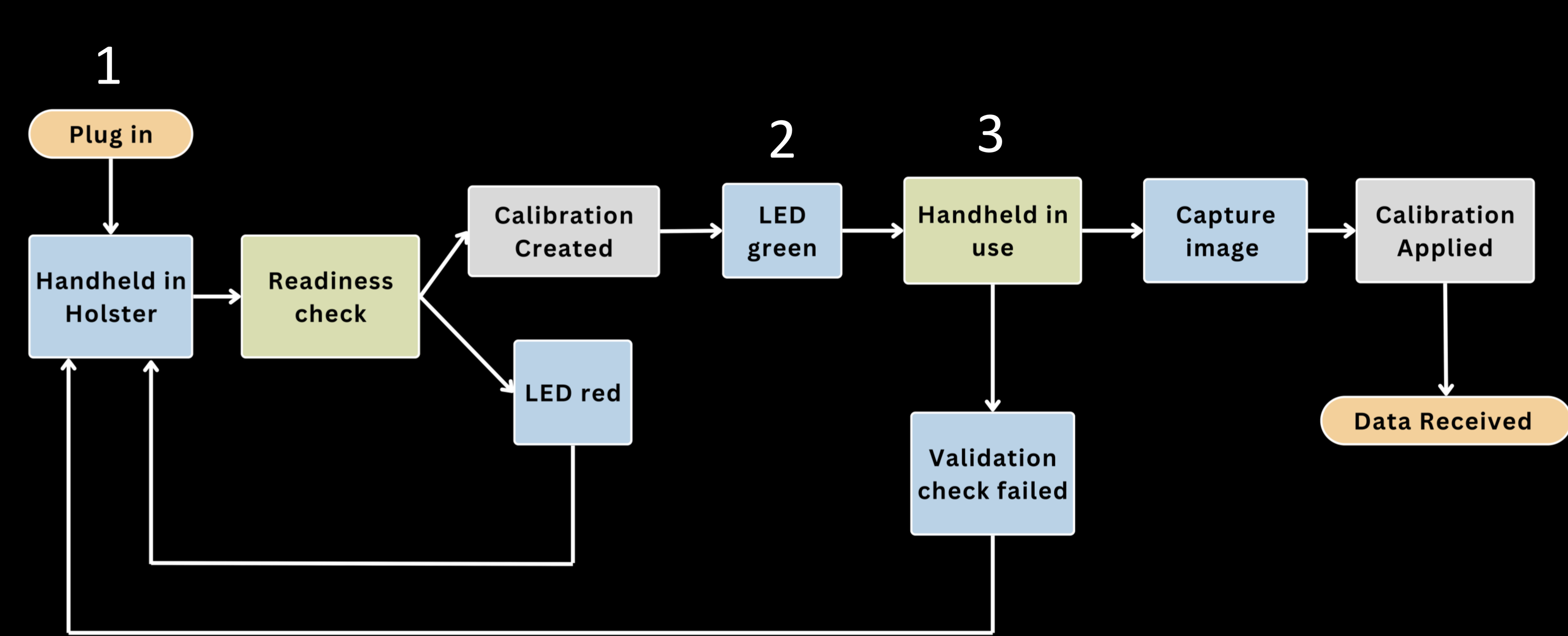
## Abstract

According to the CDC, millions of Americans live with undiagnosed health conditions. PulsIR enables painless, affordable early detection of diseases – ranging from diabetes to tumors – by capturing subtle blood flow disruptions through skin temperature. It offers a proactive diagnostic tool that fits seamlessly into routine checkups.

## From ±5 °C to ±0.5 °C

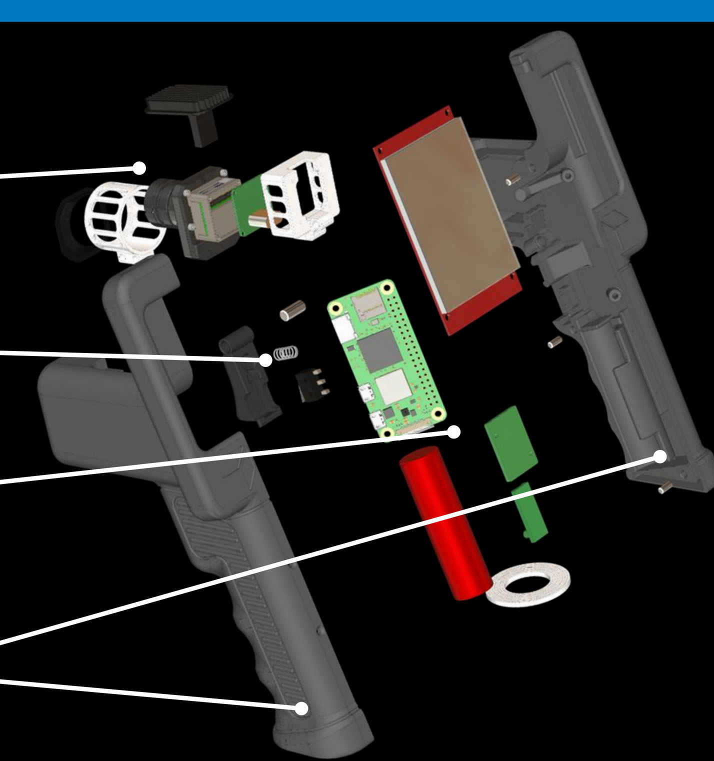
PulsIR is a handheld medical device that integrates a FLIR Boson+ thermal camera to deliver accurate skin temperature measurements. To improve temperature accuracy, the team developed a custom calibration framework with an integrated black body reference. The PulsIR system was effective in reducing the measurement error from ±5 °C to ±0.5 °C.

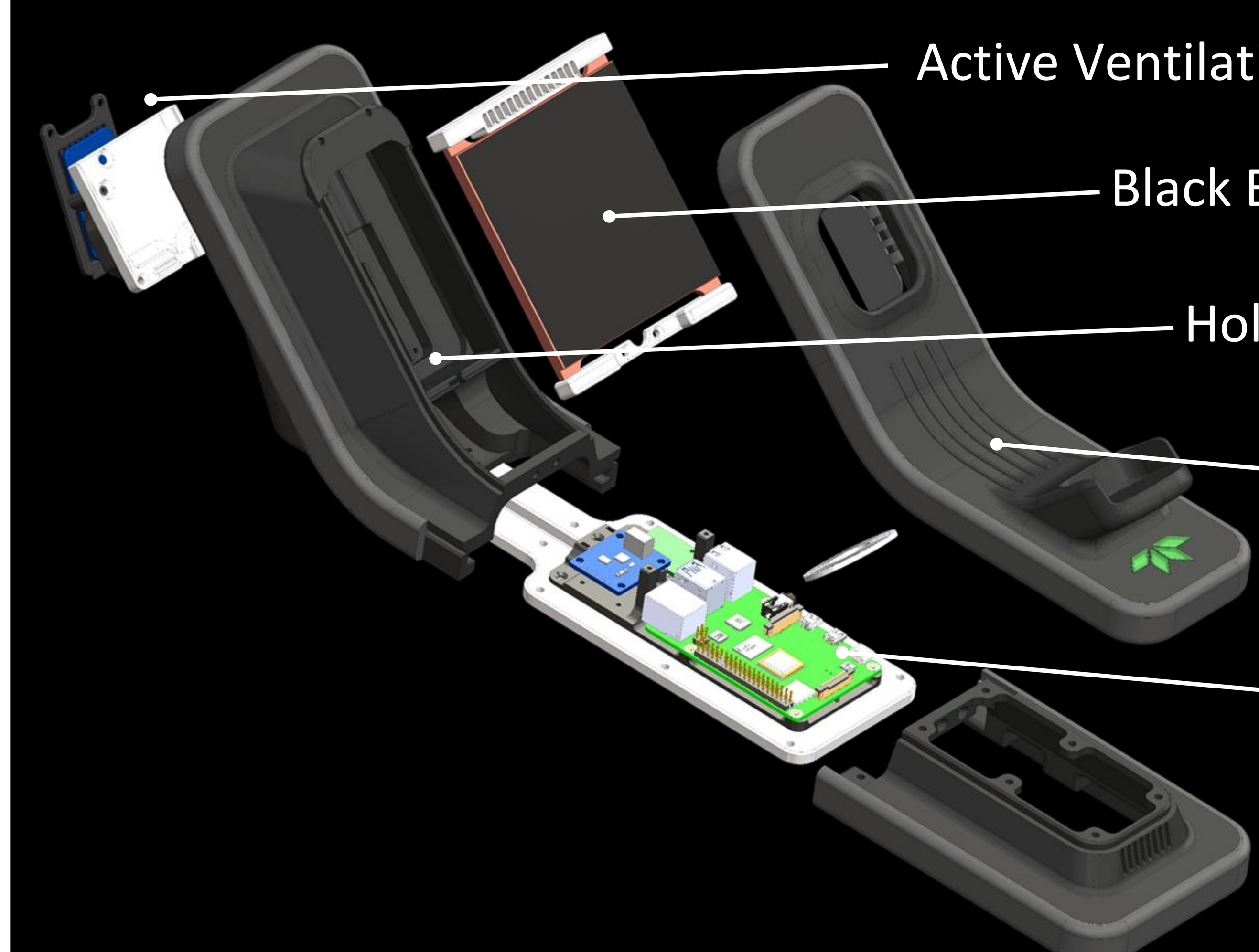
## Use Case Flowchart



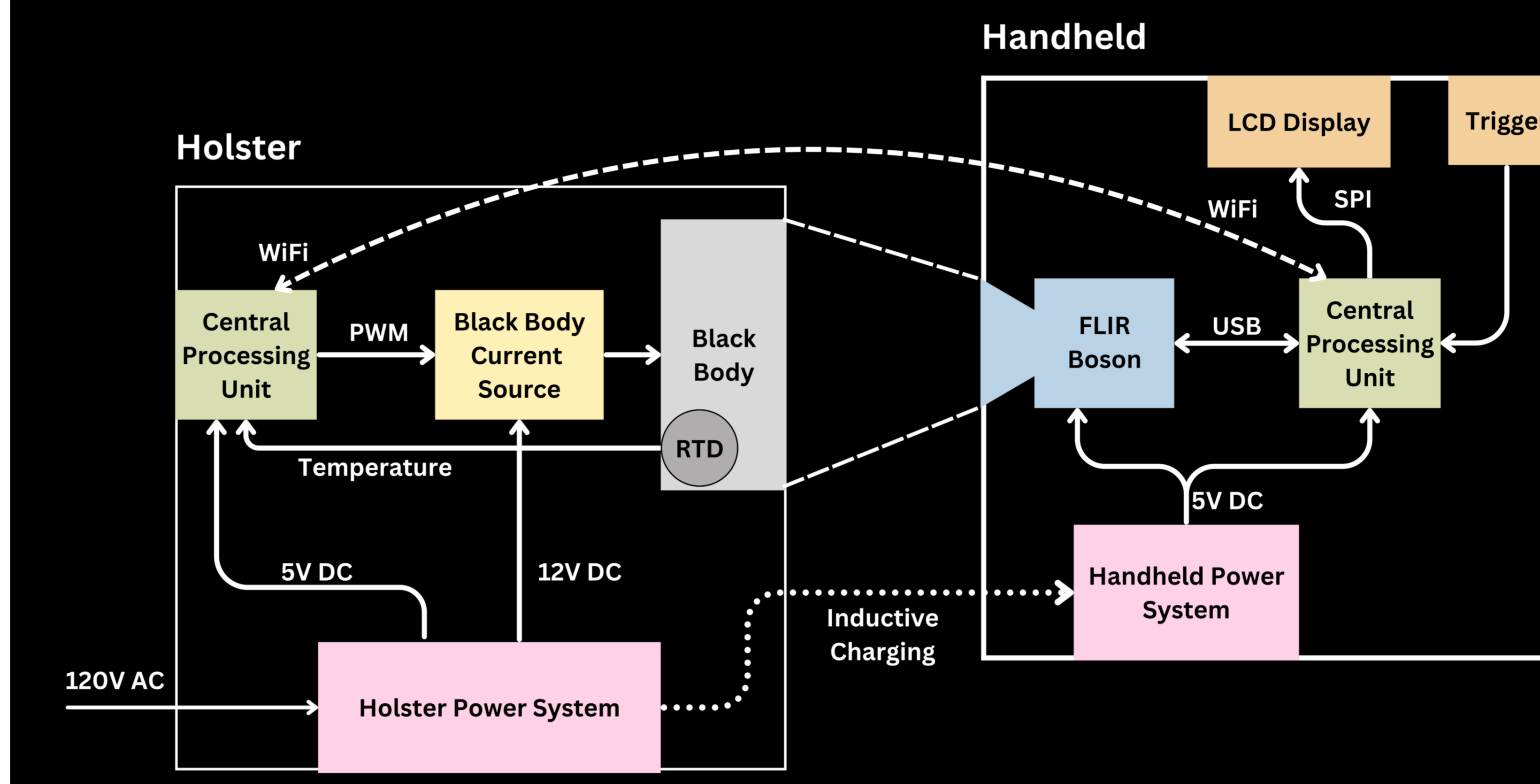

1. Plug holster in
   - Black body begins to heat to operating temperature
   - Handheld receives wireless power to charge
2. Green status light signals system readiness
   - Handheld, black body, and Wi-Fi connection nominal
3. Remove the handheld and capture thermal maps
   - Calibration is applied to capture image on the holster
   - Final image is sent to application for analysis

## Final Product



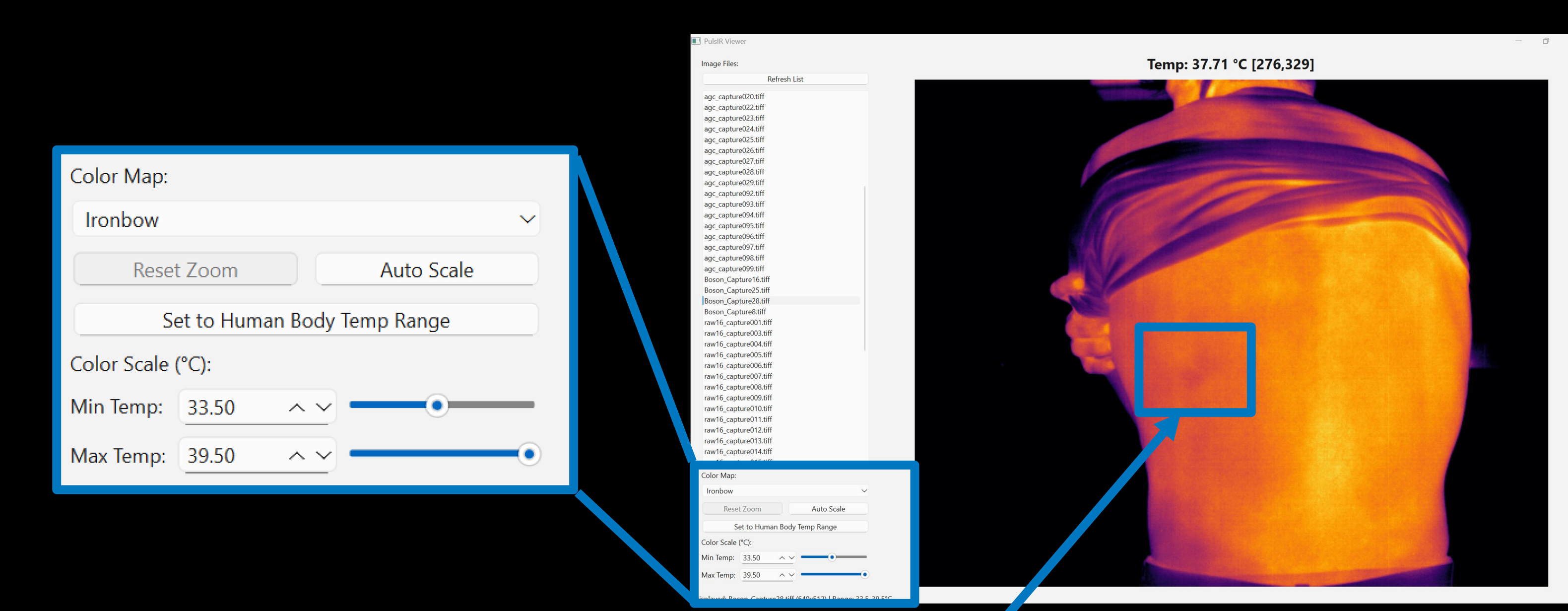




## Full System Block Diagram




## PulsIR Viewer

PulsIR Viewer enables users to view and analyze data with ease. Key features include temperature display at the cursor, zoom functionality, adjustable display ranges, and multiple color palette options.




Lipoma (fatty tumor) visible with PulsIR Viewer's Smart Dynamic Range

## Results

Using PulsIR, subdermal features such as veins, lipomas, and inflammation sites can be observed, making a significant advancement in non-invasive diagnosis. We achieved a blackbody uniformity of ±0.15 °C, and our custom calibration framework significantly improved the system's temperature accuracy from an initial ±5 °C down to ±0.5 °C.

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pulsIR

# Calibration and Thermal Systems

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## Thermal Analysis

**Challenge**: The accuracy of our calibration relies on the Boson's internal temperature remaining low and stable, which ensures optimal performance. Without thermal management, the Boson running at 30 FPS reached 59 °C, significantly higher than the desired temperature.

30 FPS Boson without heatsink:
Empirical = 59°C

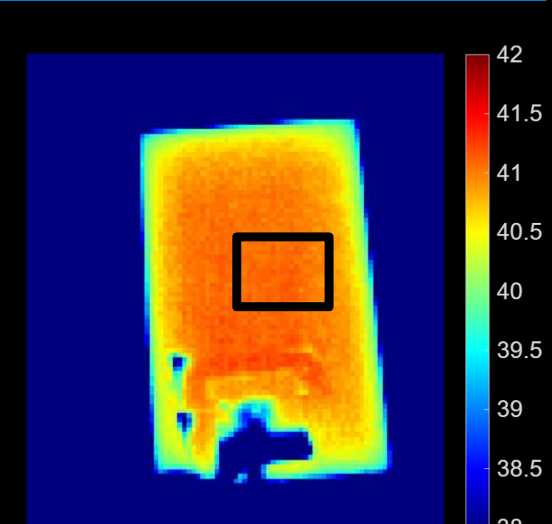
30 FPS Boson with heatsink:
Sim = 48.85°C
Empirical = 49.0°C

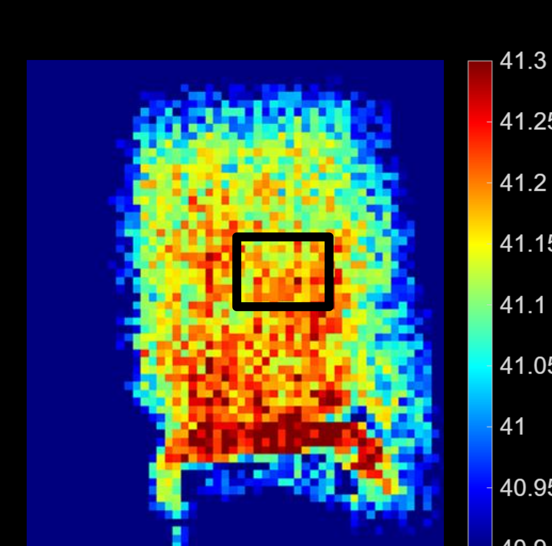
10 FPS Boson with heatsink:
Sim = 42.45°C
Empirical = 42.3°C

**Our Solution:** We implemented a strategic insulation approach and a custom-designed heatsink to establish a controlled thermal path for heat dissipation. Paired with a power-saving strategy that reduced the frame rate, this solution lowered the Boson's steady-state temperature to 42.3 °C.

## Black Body Uniformity

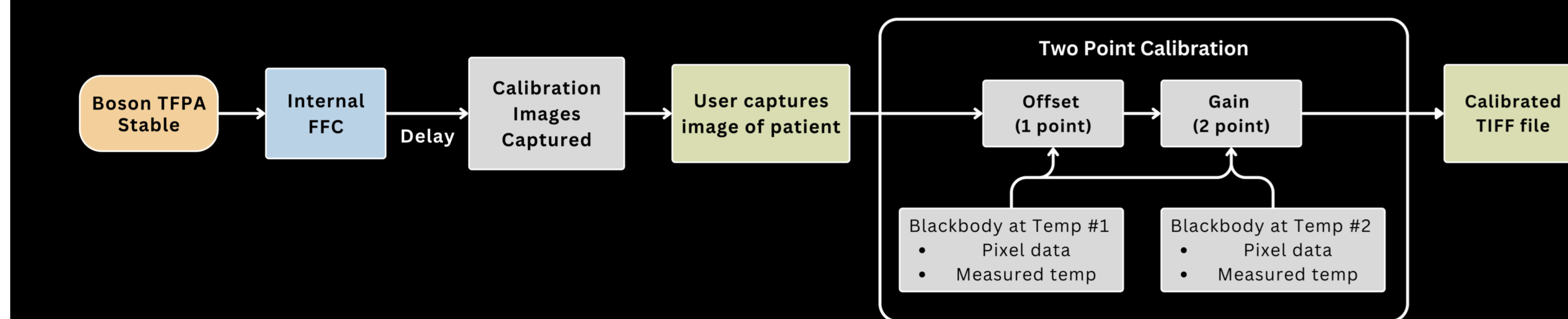
Our custom black body serves as a uniform temperature source for calibration, making it crucial to quantify temperature variation within the Boson's field of view (see black box to the right). By applying forced convection, we reversed the natural convection gradient and achieved a temperature uniformity of ± 0.15 °C. To further improve uniformity, future improvements include positioning the blackbody horizontally to minimize convection effects and using relative thermocouple voltage to dynamically control fan speed across the surface.



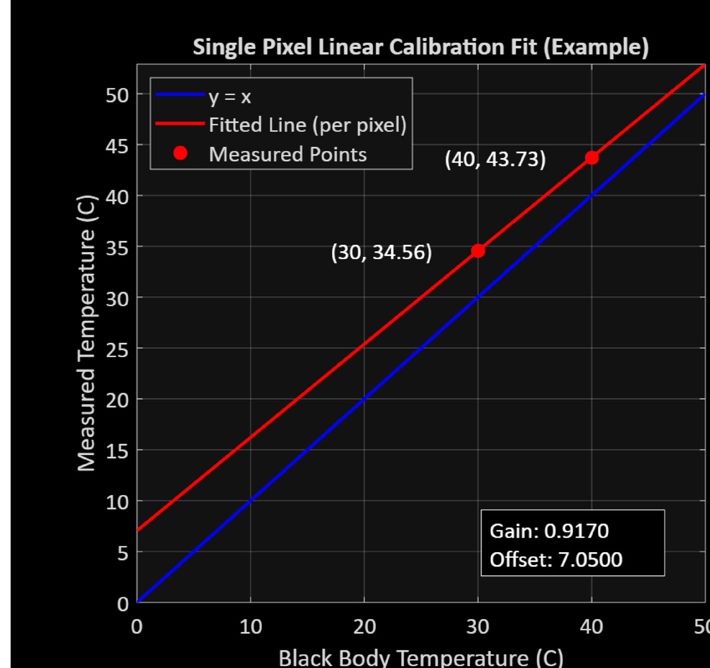



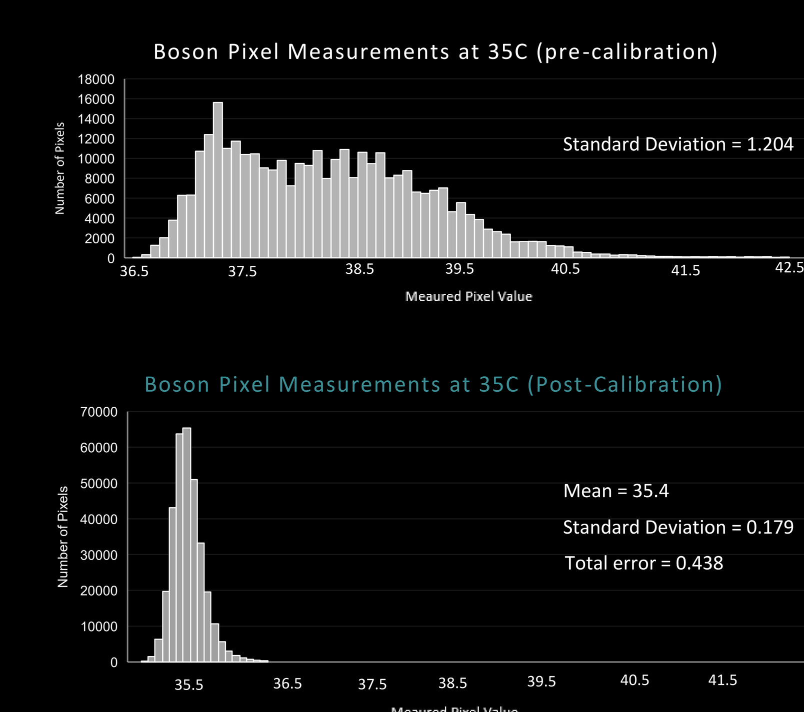

## Calibration Framework

**Two Point Calibration:** Using a blackbody reference, we generate offset and gain maps by comparing known and measured pixel temperatures, improving overall image accuracy.




- While Boson TFPA remains stable an internal FFC is completed to reset camera to factory standards
- Two blackbody images at different temperatures are used to compute per-pixel linear offset and gain corrections
- Correction file is saved and later applied to subject images to improve accuracy




**Results:** The image above (left) shows a linear fit example for a single pixel. Gain and offset values are derived from two calibration images. These values are used to generate gain and offset maps, with unique values for each pixel, which are then applied to subsequent images. Our two-point calibration method achieved a temperature measurement accuracy of ±0.438 °C.

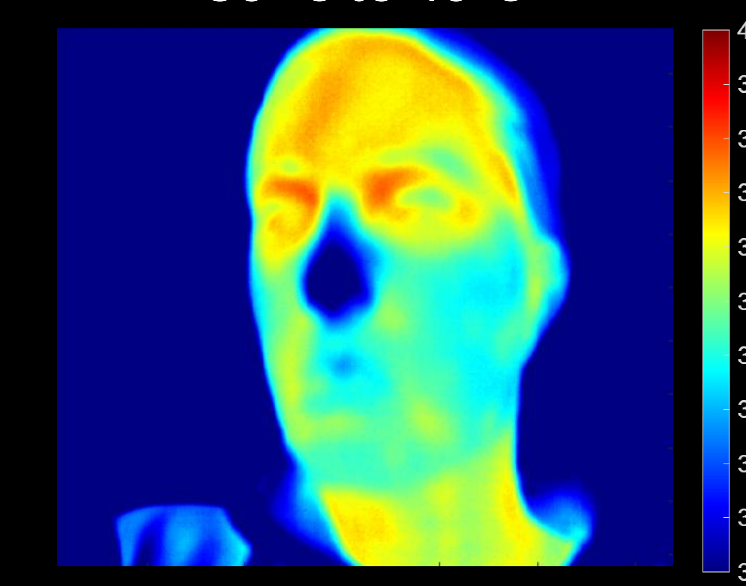
## Error Analysis

- RTD and RTD Amplifier: 0.2 °C
- Black Body Uniformity: 0.15 °C
- Calibration Error: 0.4 °C
- Noise Error: 0.18°C

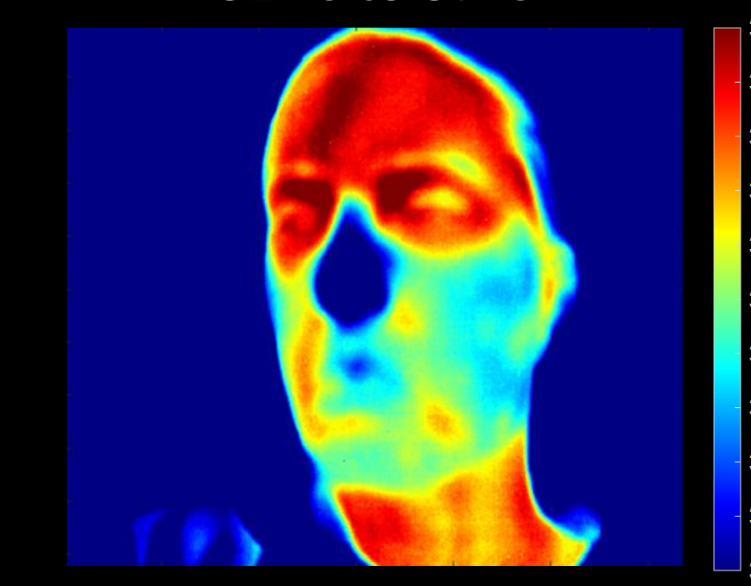
- **Total Error (RMS): 0.5 °C**

## Dynamic Range

30 °C to 40°C

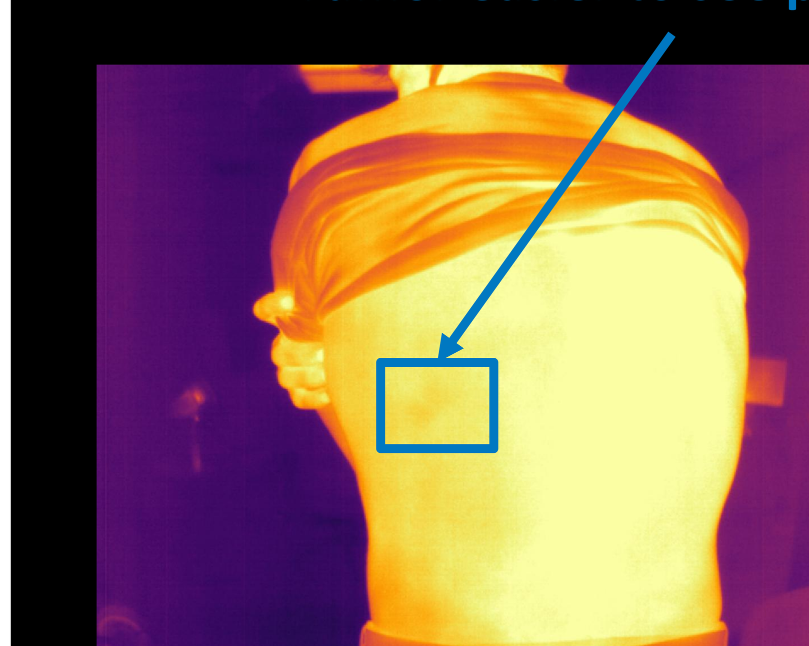


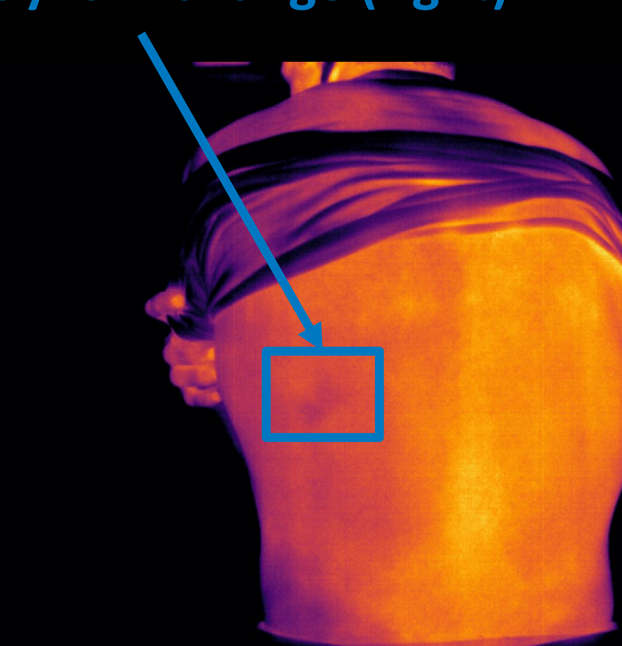

32 °C to 37°C




Adjusting the display temperature range enhances image contrast, making subtle differences in skin temperature more visible. Since skin temperatures typically range from 32–38°C, narrowing the camera's focus to this range improves diagnostic accuracy.

Tumor easier to see post dynamic range (right)





## Future Improvements

1. **RTD Temperature Measurement:** Improve accuracy in RTD readings by upgrading reference resistor in the RTD amplifier. Selecting a resistor with tighter tolerance (± 0.01%) will enhance calibration performance.
2. **Thermoelectric Boson Regulation:** Explore the integration of thermoelectric thermal management to actively regulate Boson temperature.
3. **Design Refinement:** Migrate from prototyping platforms to custom designed printed circuit boards. Refining PCB layout will minimize noise and enhance thermal dissipation paths.

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