THERMAL

GRACE

Comfort-as-a-Service
Perceived Thermal Comfort Sensing & AI-Driven Insights

01

Vitality HUB Fontys ICT Delta 2025–2026

RESEARCH FOUNDATION

PERCEIVED THERMAL COMFORT IOT SYSTEM

Literature Study: Thermal comfort research (TUe, Delft, academic institutions)

Key Parameters: PMV/PPD algorithms from ISO 7730 standards

Sensor Requirements: Derived from PyThermalComfort library research papers

02

PROJECT EVOLUTION

S6 (SPRING-SUMMER 2025)

UX research with 3Beam AIoT LED Blackboard

S7 (AUTUMN-WINTER 2025-2026)

Rapid prototyping, verification and validation

01 Initial Pivot: From 3Beam to "Beets" modular components

02 Strategic Refocus: Thermal comfort as primary use case

03 Current Stage: Full-stack development with MVP hardware & software

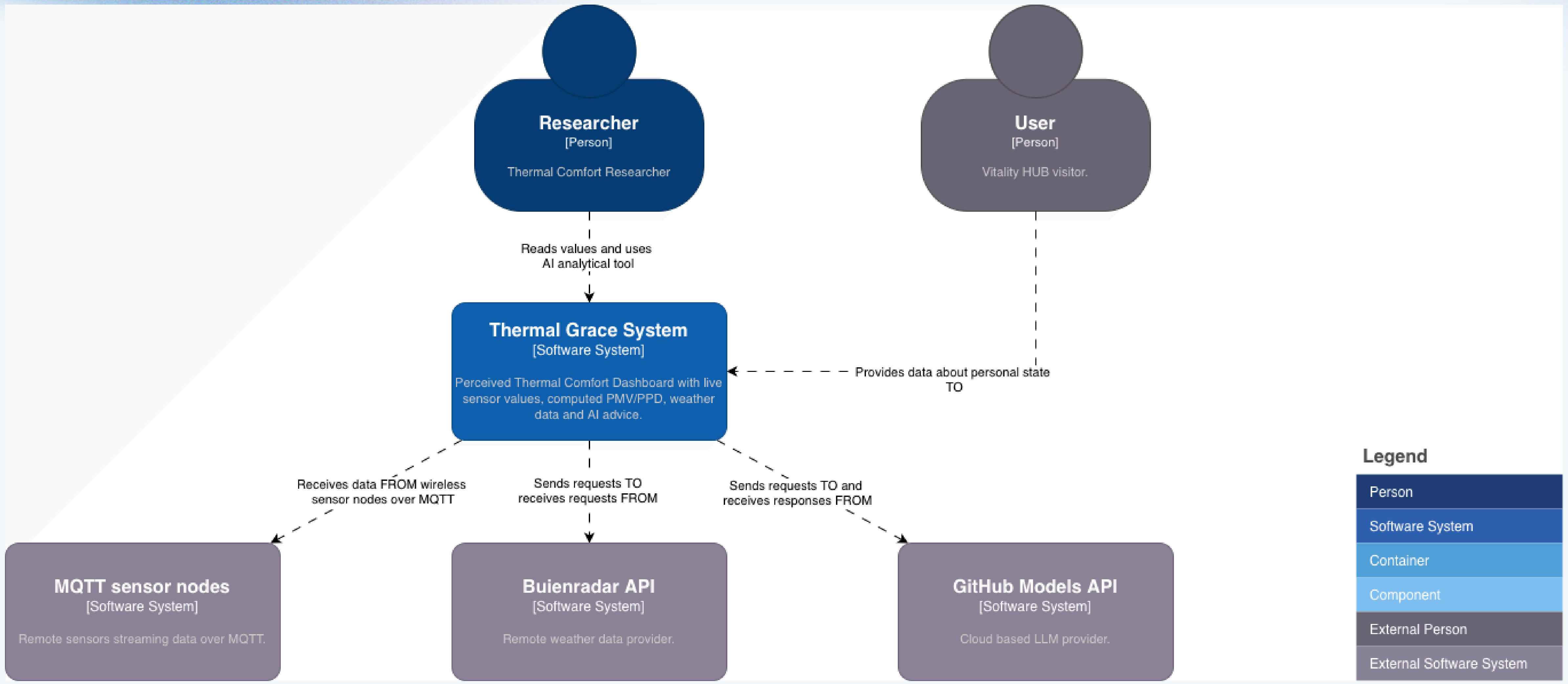
PROBLEM & CONTEXT

LACK OF REAL-TIME, DATA-DRIVEN THERMAL COMFORT MONITORING IN COMPLEX ENVIRONMENTS

- No integrated system for environmental sensing + user feedback
- Manual HVAC adjustment without scientific basis
- Limited validation platforms for comfort algorithms
- Gap between academic research & practical implementation

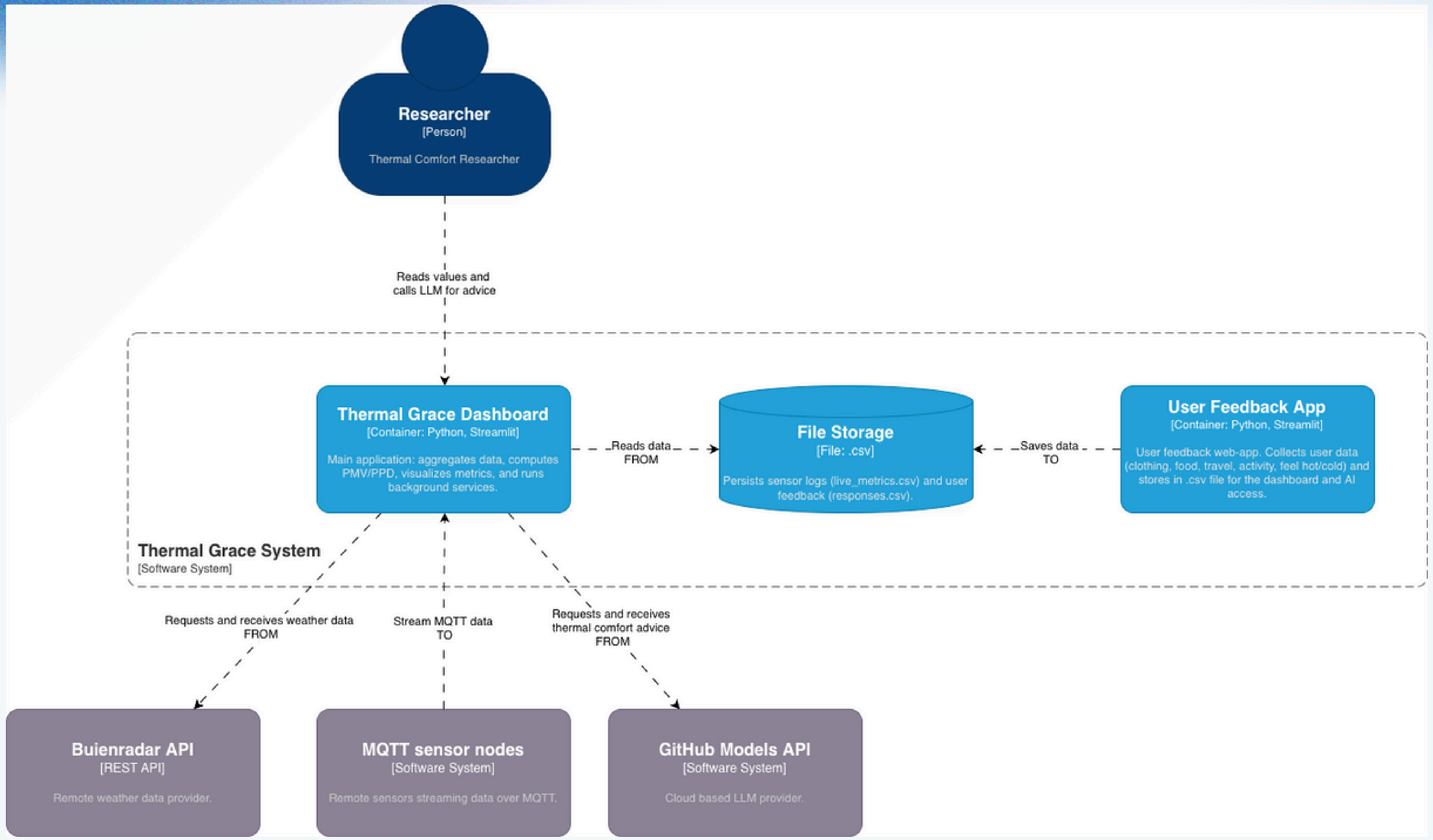
03

SYSTEM ARCHITECTURE (C4)



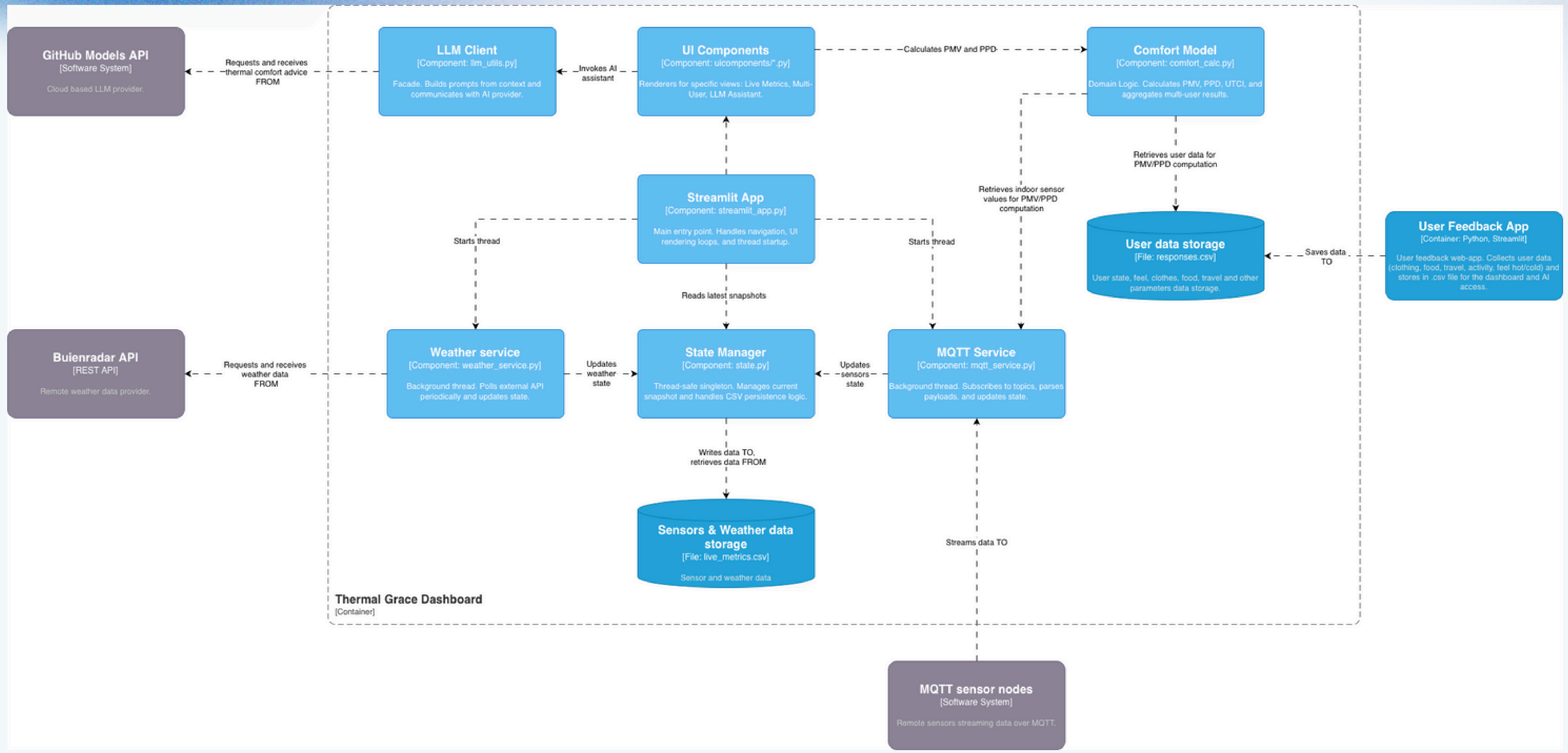
C4 diagram level 1 – context

SYSTEM ARCHITECTURE (C4)



C4 diagram level 2 – container

SYSTEM ARCHITECTURE (C4)



C4 diagram level 3 – components

06

Thermal Grace

VHUB, Fontys Delta

HARDWARE TOPOLOGY

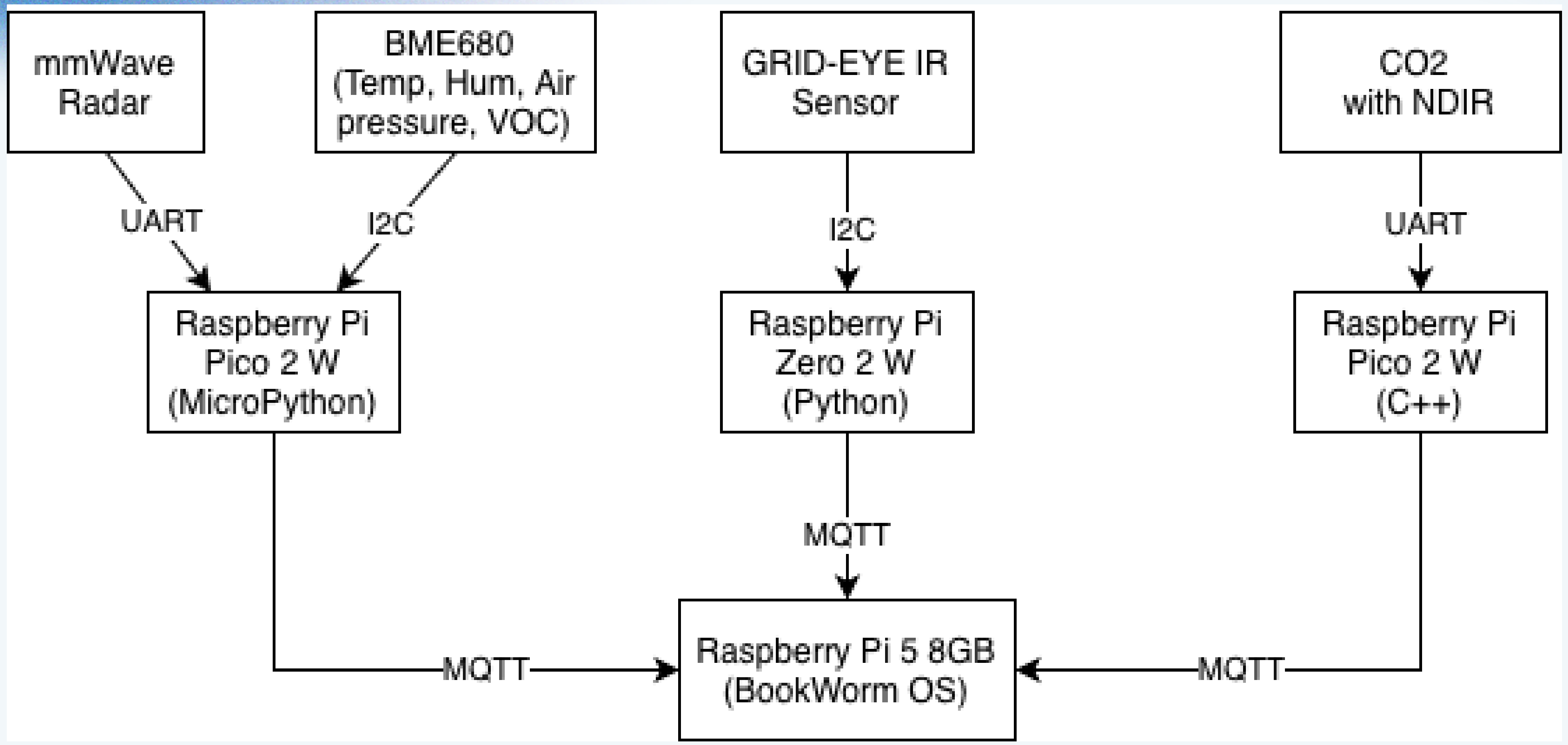
01 **Remote Node 1:** Raspberry Pi Pico 2 W + CO2 NDIR sensor (air quality)

02 **Remote Node 2:** Raspberry Pi Pico 2 W + BME680 (temp, humidity, pressure, VOC) + mmWave radar (occupancy)

03 **Remote Node 3:** Raspberry Pi Zero 2 W + Thermal sensor array (spatial heat mapping)

04 **Central Hub:** Raspberry Pi 5 (data aggregation, processing, dashboard hosting)

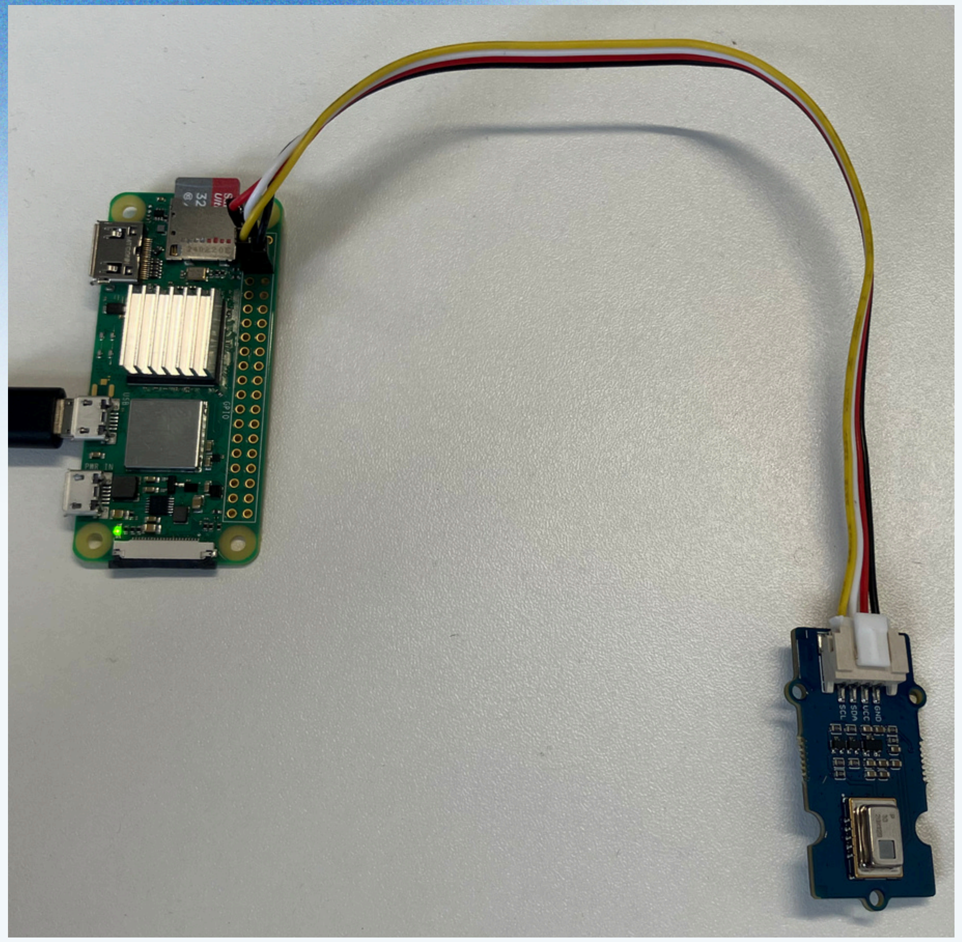
HRADWARE ARCHITECTURE



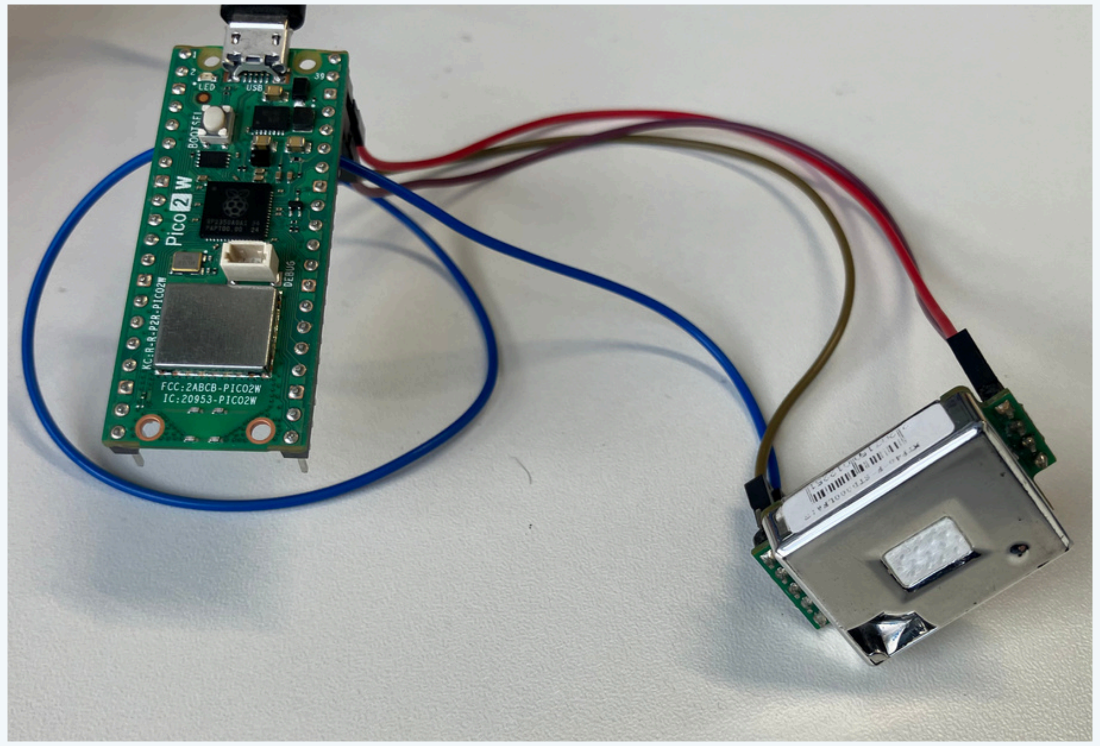
Hardware architecture diagram

PROTOTYPE V.1

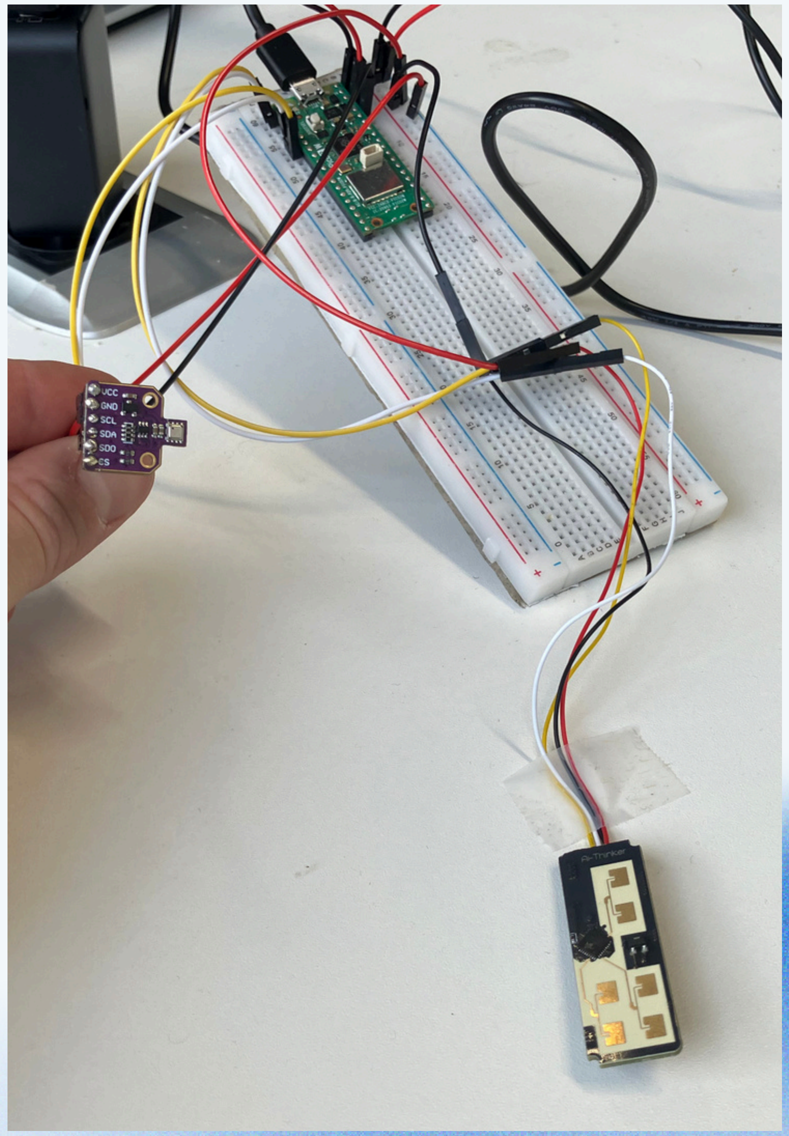
Raspberry Pi 5 Central computer, Server with Thermal Grace Dashboard



Thermal image heatmap sensor node



Remote CO2 with NDIR sensor node



Environmental data and mmWave

DEMO

VIDEO:

General demo:
https://youtu.be/vrhQb1QjbCg

Multi-user functionality:
https://youtu.be/Dp8xyD23VpI

TECHNICAL DECISION RATIONALE

THE MAKING PROCESS

Fontys ICT Delta 2025-2026

Streamlit vs. Home Assistant
HA: OS-level OS bloats dev; custom UI needs JS cards; indirect log parsing
✓ Streamlit: Python integration, fast iteration, native UI features, direct data forwarding

Raspberry Pi vs. ESP32
ESP32: Sensor compatibility issues, debugging delays (hours)
✓ Pi Ecosystem: Stable sensor integration, reduced debugging to minutes

11

THERMAL COMFORT MODEL

PMV (Predicted Mean Vote): ISO 7730 standard comfort scale (-3 to +3)

PPD (Predicted % Dissatisfied): Percentage of population dissatisfied at given PMV

Inputs: Temperature, humidity, air velocity, clothing, metabolic rate, occupancy

Implementation: PyThermalComfort library methods

CURRENT STAGE

STATUS

A Integrated LLM Assistant capable to analyze data from multiple sources

B Hardware nodes deployed & streaming data via MQTT

C Central hub receiving & aggregating sensor streams

D Streamlit dashboard with real-time visualizations

E PMV/PPD computation integrated with live sensor data

F User feedback app for validation data collection

A BALANCED PERSPECTIVE

3

BUILDING IT RIGHT & BUILDING RIGHT SYSTEMS

VERIFICATION

- **Design Conformance:** Hardware architecture matches specification document
- **Implementation Compliance:** Code meets requirements (sensor accuracy, MQTT reliability, data pipeline)
- **System Behavior:** Does delivered prototype perform as specified?
- **Data Quality:** Sensor calibration, MQTT message integrity, CSV logging consistency

VALIDATION

- **Stakeholder Needs:** Does system address Vitality HUB requirements?
- **Algorithm Accuracy:** PMV/PPD calculations vs. ground truth thermal comfort surveys
- **Use Case Testing:** Real-world deployment at Fontys facility
- **User Acceptance:** Researcher satisfaction with dashboard & recommendations

V&V TESTING PLAN

4

FOUR PHASES:

UNIT TESTS

Sensor calibration, PMV function accuracy, MQTT delivery, LLM accuracy

SYSTEM TESTS

Multi-node deployment, concurrent users, 48-hour stability, battery powered

INTEGRATION TESTS

End-to-end data flow, dashboard updates, API calls, new sensors & access points

ACCEPTANCE TEST

User comfort surveys, stakeholder interviews, feedback validation

15

Fontys Ict Delta

2025-2026

01 Sensor calibration & unit test execution

02 Integration & system testing (multi-environment)

03 User acceptance testing at Vitality HUB

04 Comprehensive V&V report with metrics & recommendations

PATH FORWARD

NEXT STEP: FORMAL V&V TEST PLAN DOCUMENTATION (ALIGNED WITH V-MODEL)

16

TECHNICAL DELIVERABLES

Hardware Specification: Architecture design document with diagrams

Software Specification: C4 context/container diagrams, API documentation

V&V Plan: Test cases, success criteria, traceability matrix

Validation Report: Test results, discovered issues, recommendations

RESEARCH APPLICATIONS

- Validation platform for thermal comfort algorithms (academic collaboration)
- Real-world data collection for comfort model refinement
- Modular architecture extensible to other environmental sensing domains
- Bridge between theoretical research (TUe, Delft) and operational systems

THANK YOU

CONTACTS

a.kraskov@student.fontys.nl
b.kaszuba@student.fontys.nl

Thermal Grace

FHICT Delta
2025-2026