

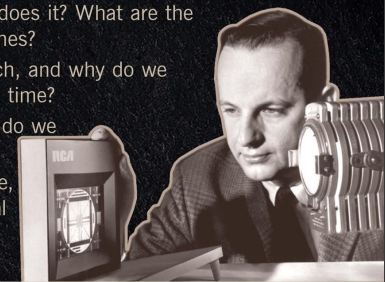
Team D4 – Vitaband

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1. What are we trying to do?
2. How is it done today and who does it? What are the limitations of the present approaches?
3. What is new about our approach, and why do we think we can be successful at this time?
4. If we succeed, what difference do we think it will make?
5. How long do we think it will take, and what are our mid-term and final exams? How much will it cost?



George Heilmeier
DARPA Director 1975-1977



Add your 12 slides after this slide... [remember, 12 min talk + 3 min Q/A]

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Make sure to cover

(refer to the Design Presentation Guidance):

- Use Case & Requirements
 - Remind us who is your customer, what product do they want to buy and quantitative reqs [keep it short]
- Quantitative Design Reqs
 - Map quantitative use case to quantitative design requirements
- Solution Approach
 - Remind us of solution path(s) ... and social, cultural, global .. factors; any changes since proposal ?
- Block Diagram
 - Detailed design: incorporate flow diagrams, state diagrams, protocols
- Implementation Plan
 - include Design Trade Study(ies) here; what will YOU develop ? vs buy/download/reuse ?
- Testing, Verification and Metrics
 - including quant metrics; how you will test and what is passing; failed tests ? Risk mitigation ?
- Project Management
 - WHO is going to do WHAT and WHEN ?

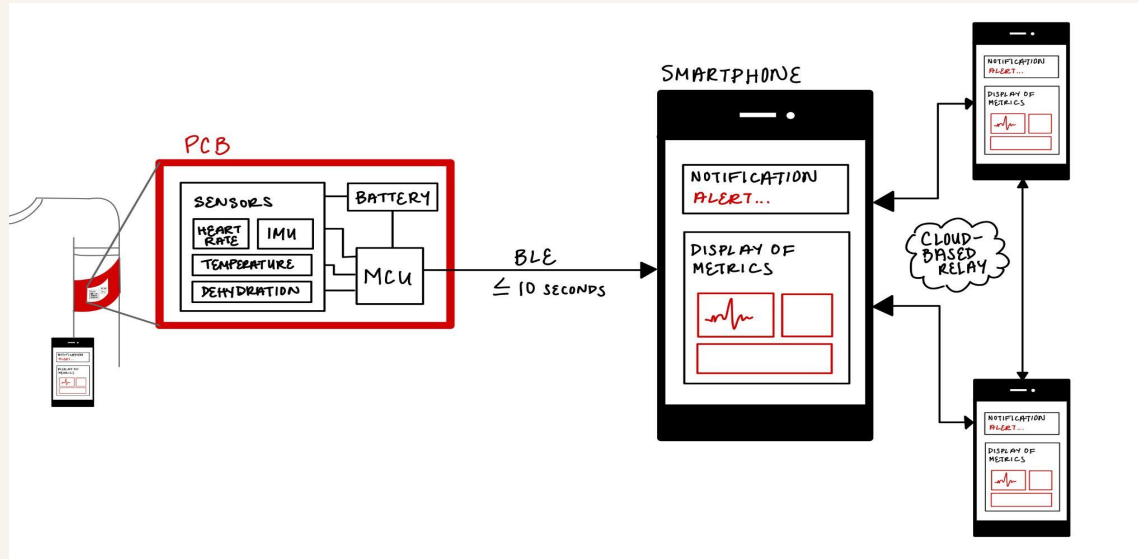
Consider that this slide already works as a introduction slide so use your first slide wisely

Remember – Relevant figures (and tables) can be worth
“a thousand words”!

Use Case

Problem:

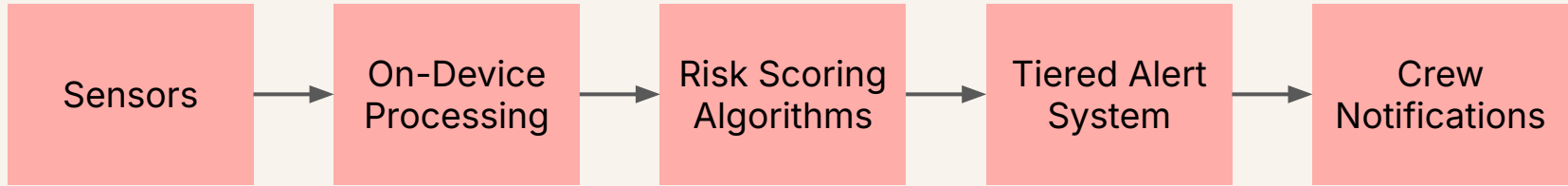
- Outdoor jobs are highly physically demanding
- workers are at risk of heat stroke, overexertion, and falling.



Use Case Requirement	Design Requirements
12 hr battery life	avg system current $\leq \sim 40$ mA (battery life= capacity/avg current) $12 \text{ hr} \leq 500\text{mAh} / I_{\text{avg}}$ $I_{\text{avg}} \leq 41.6$ mA
HR accuracy	PPG sampling ≥ 1 Hz Bandpass filtering 0.7-3.5 Hz and motion/noise rejection Dropped samples $< 0.1\%$ HR output update rate 1 Hz with 5-10 s estimation window
Temperature accuracy	Skin temperature sensor accuracy $\pm 0.5^\circ\text{C}$ over 30-42C Ambient temperature accuracy $\pm 1.0^\circ\text{C}$ over Pittsburgh range. Thermal placement requirements: skin sensor must be in contact region, ambient sensor must be isolated/vented to reduce body bias
BLE range/reliability	Maintain BLE connection with packet success rate $\geq 95\%$ at 10 m Antenna keepout, edge placement on pcb

Solution Approach: Overview

Multi-layered safety system for real-time worker health monitoring in hazardous environments



Key Design Decisions

- Continuous multi-sensor monitoring for real-time response and reduced false positives
- On-device risk scoring enables offline operation and protects data privacy
- Tiered alerting (ok→warning→critical→emergency) reduces alert fatigue
- Contact list-based crew notifications + manual emergency override

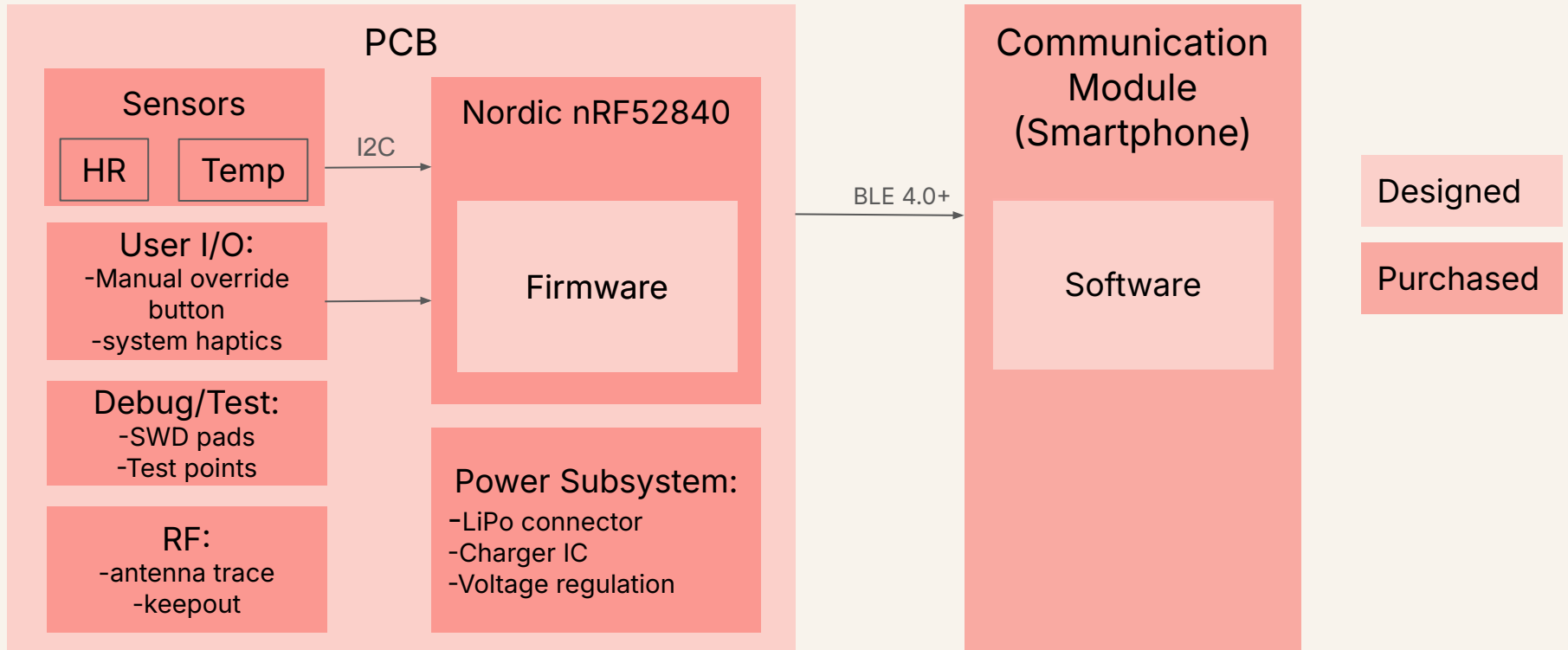
Solution Approach: Evolution & Design Requirements

How we evolved:

- Narrowed the scope by eliminating dehydration and fall detection for MVP
- Contact-based crew notification list instead of GPS to save power
- Physical emergency button added to improve safety

Design Requirement	Solution Approach
Successful power management	Duty cycling to keep the MCU in a sleep mode between tasks
Accurate heart rate processing	High frequency sampling (≥ 100 Hz), bandpass filter to eliminate noise, and DMA to avoid interrupt interference with the data
Effective thermal sensor design	Direct skin contact, ambient sensor isolation and venting, and calibration
Reliably maintain BLE connection	Impedance matching between antenna and BLE SoC to maximize power transfer

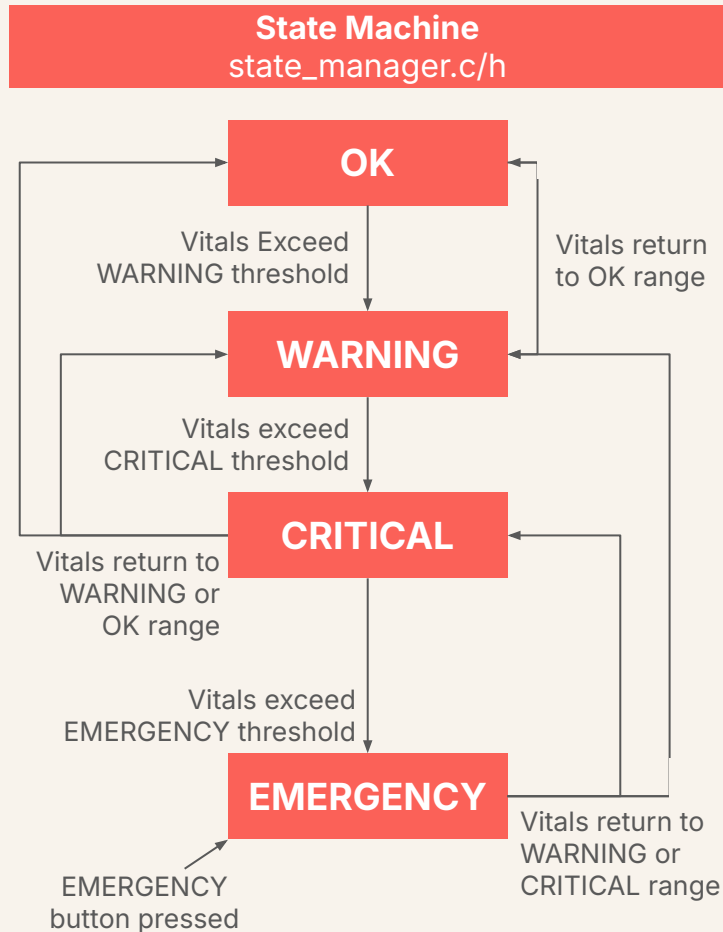
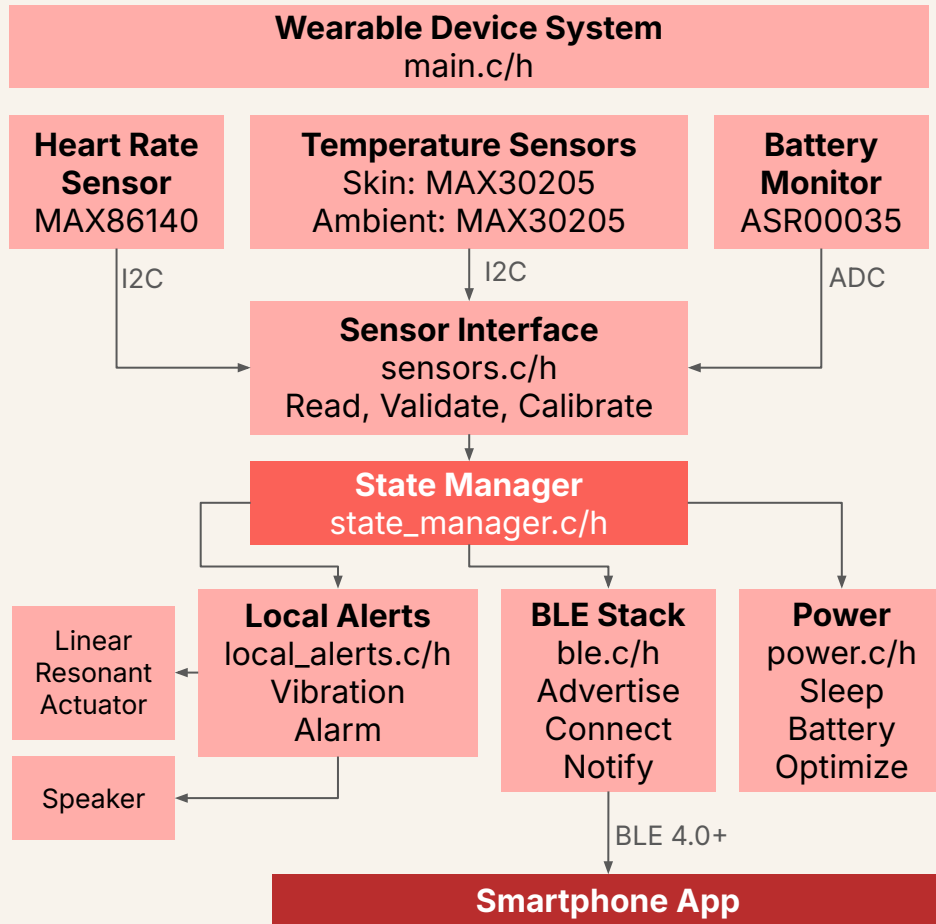
Block Diagram: High Level System Overview



Component Tradeoffs

Component	Alternative	Justification
MCU: Nordic nRF52840	ESP32-C3	Nordic has better BLE reliability and is ultra-low power, larger community for wearables. ESP would use much more power and has a larger PCB footprint
PPG sensor: MAX86141	MAX30102	Medical-grade performance, designed for wearable HR, low power modes, good motion artifact rejection, high accuracy. 86141 has more robust filtering.
Skin temperature sensor: TMP117	MAX30205	Medical-grade performance, 0.1C accuracy, very low drift, 12C simple integration, ultra low power. TMP much more low power than MAX and can be used for both skin and outside temp due to its wider range
Ambient Temp/Humidity: SHT31	TMP117	SHT offers combined temp and humidity readings to compute heat index, low power, I2C simple. TMP can't measure humidity.
Charging IC: MCP73831	BQ24074	Simple LiPo charger, small, cheap, and easy to integrate. No need for more advanced power path offered by BQ

Implementation Plan: Firmware



Implementation Plan: Equations and Logic

Core temperature computation:

$$T_c(t) = T_{c,0} + B_T(T_{arm}(t) - T_{arm,0}) + B_H(HR(t) - HR_0)$$

PSI computation:

$$PSI(t) = 5 \cdot (T_c(t) - T_{c,0}) / (39.5 - T_{c,0}) + 5 \cdot (HR(t) - HR_0) / (180 - HR_0)$$

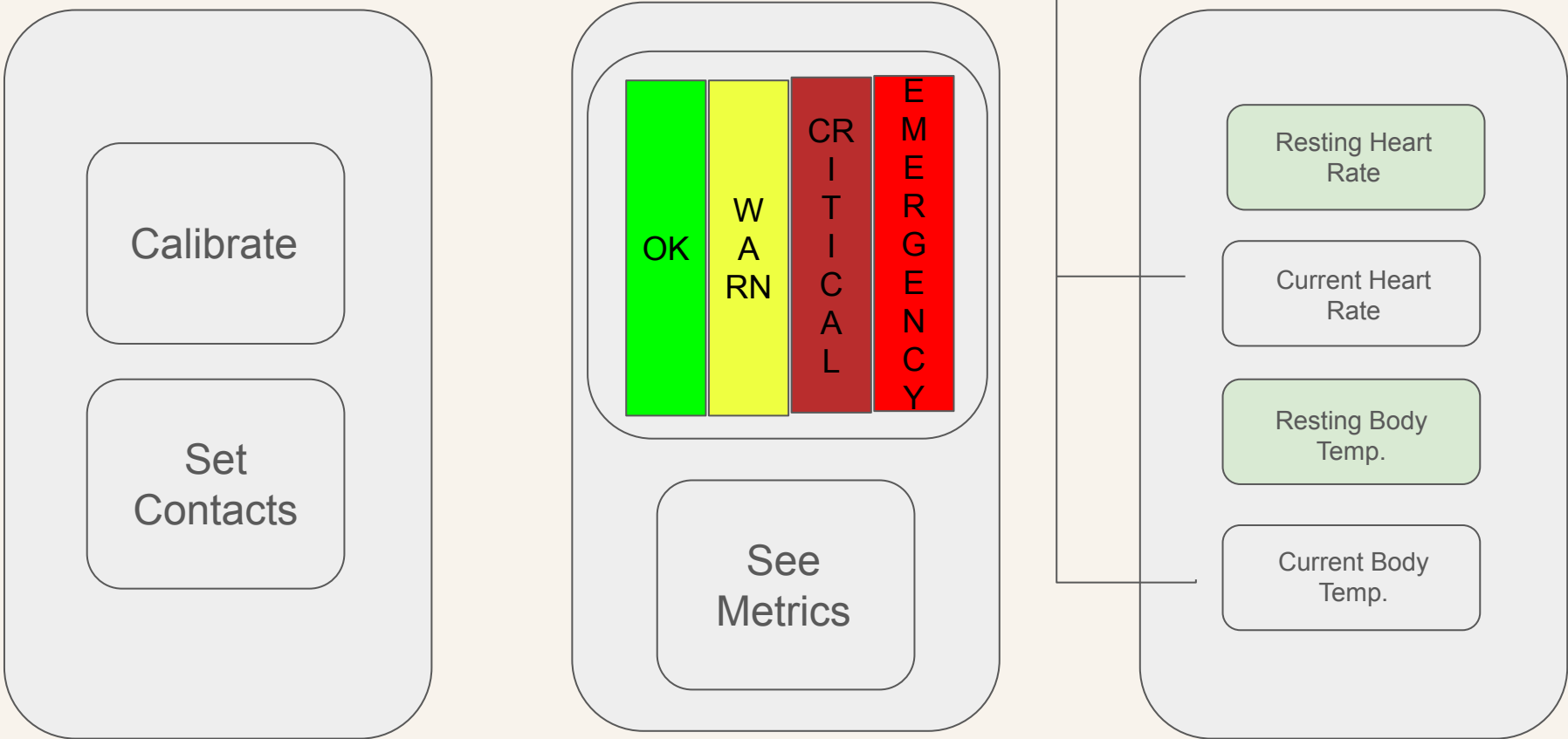
Alert Logic:

- PSI is evaluated at 1Hz
- WARN threshold: $PSI \geq 3$
- CRITICAL threshold: $PSI \geq 7$

State Transition Diagram

OK→WARN	$PSI \geq 3$ for 30 s
OK→HIGH	$PSI \geq 7$ for 10 s
WARN→HIGH	$PSI \geq 7$ for 10 s
HIGH→WARN	$PSI \leq 6.5$ for 15 s
WARN→OK	$PSI \leq 2.5$ for 30 s
EMERGENCY→ CRITICAL	$PSI \geq 7$ for 10 s
EMERGENCY→ WARN	$PSI \geq 3$ for 30 s

App User Interface



Testing, Verification, & Metrics

Sensors

- Test temperature and heart rate against clinical reference devices
 - Mean average error for heart rate: $\leq 5\text{bpm}$
 - Mean average error for heart rate: $\leq 0.5^\circ\text{C}$
 - Mean average error for core temperature estimate: 0.5°C

Alert Performance

- **Test inputs: Resting metrics from potential users, testbenches for HR elevation and temperature change**
 - **system should correctly assert the correct state for $\text{PSI} \geq 95\%$ of the time**
 - **$\leq 5\%$ false alerts during baseline activity**
 - **CRITICAL alert $\leq 10\text{s}$, WARN alert $\leq 30\text{s}$**

Wearability & Comfort

- Continuous runtime ≥ 12 hours under standard sampling conditions
- Packet success rate $\geq 95\%$ at 10 meters
- Alert delivery latency ≤ 1 second at 10 meters during HIGH condition trigger

Project Management

