



Protective Responsive Outer Shell for People in Industrial Environments



Outline

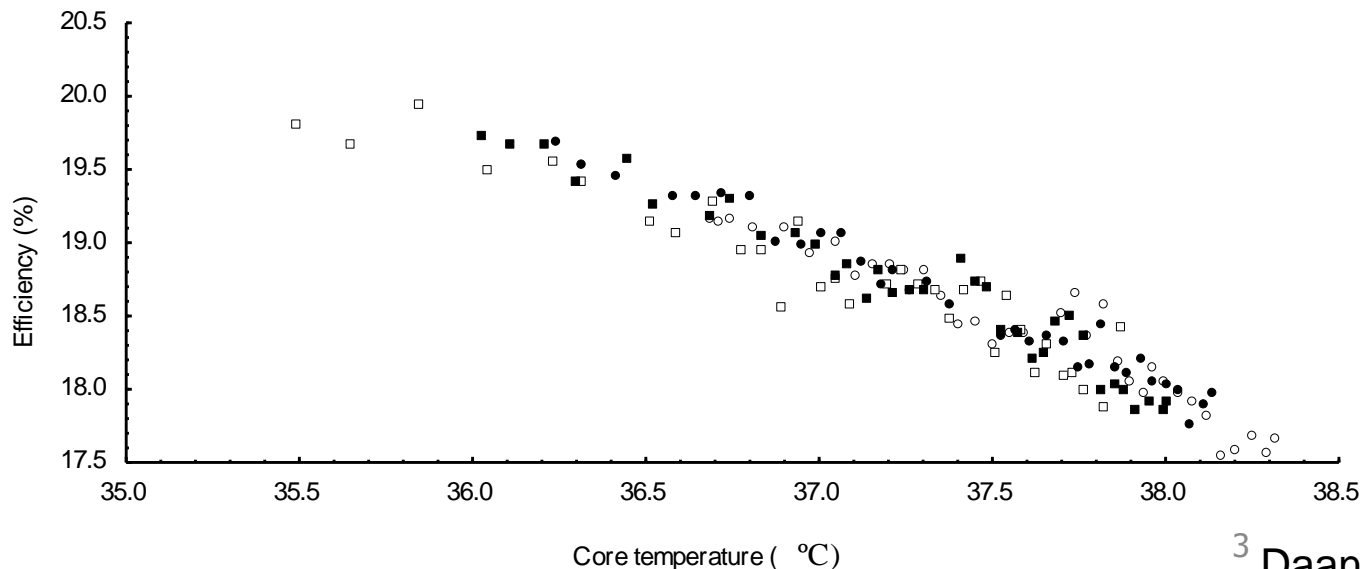
- Challenge
- Goal of Prospie
- Work packages
- Cooling
- Warning
- Criteria
- Conclusions



Challenge



- Humans are “tropical animals” and can cool through sweat evaporation
- This mechanism is compromised during work in PPE
- Heat strain leads to a drop in work efficiency and vigilance
- Heat strain may lead to heat illness



Goals of Prospie



- Development of Personal Protective Equipment prototypes
- Incorporating cooling
- Use physiological monitoring systems to generate warnings for thermal strain for the worker and industrial safety systems
- Incorporate ease-of-use, cleanability etc. in the design considerations



Prospie work packages



WP1 – Cooling systems

WP2 – Smart warning system

WP3 – Thermophysiological algorithms

WP4 – Integration

WP5 – Production

WP6 – Testing in industry

WP7 – Standardization and dissemination



Prospie cooling systems



PROSPIE

Absorbing endothermic salts inside of garments

Extra evaporative cooling power

Only activated at high relative humidity

Option for forced ventilation

PCM salt heat shield as a thermal buffer

Seperate vest

Applicable for ceramics, metal industry,..



Prospie warning system

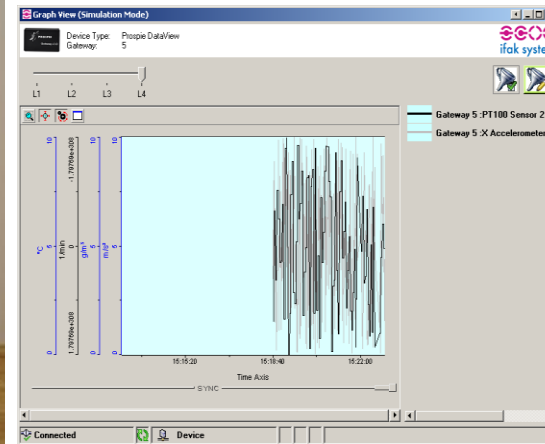
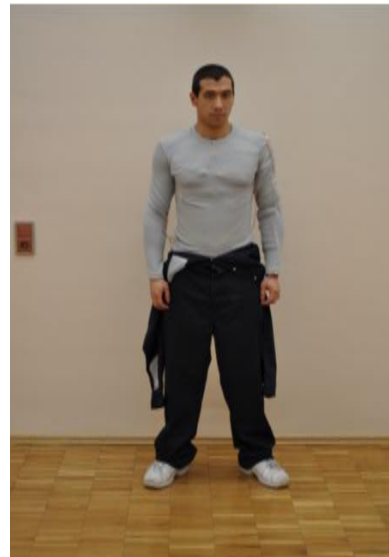
Temperature + humidity skin & clothing sensors

Heart rate & acceleration sensor (movement)

Bluetooth connection & data logging

Modular outer sensors (e.g. CO₂)

Subject warning and central warning



Warning criteria



- Model development
 - Provide a thermophysiological model of a worker
- Model individualisation
 - body size and composition
 - acclimatisation status
 - physical fitness
- Model validation
 - Comparisons measured data

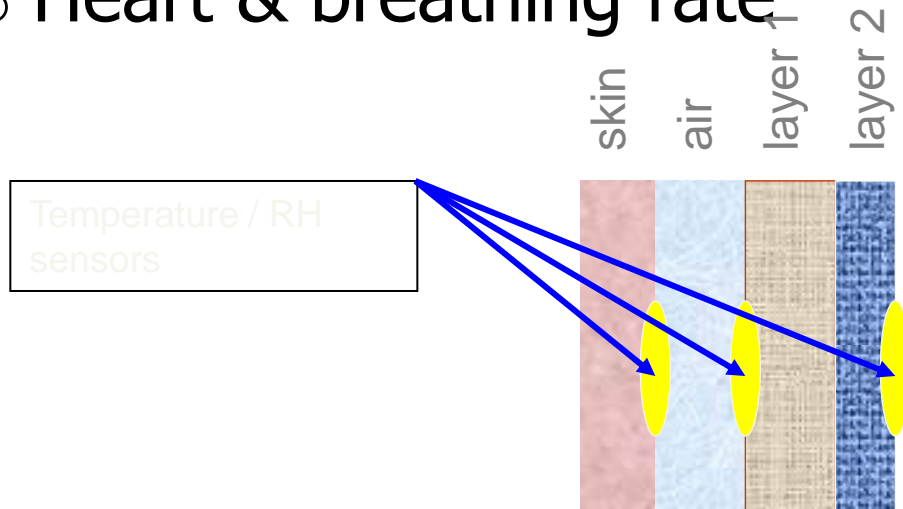
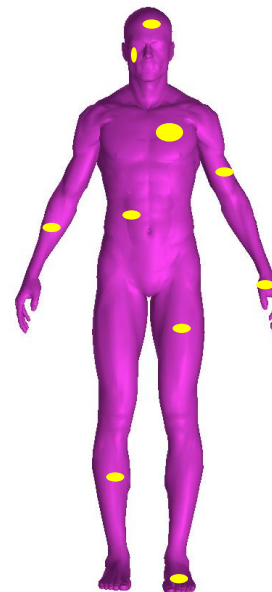


Sensors:model input

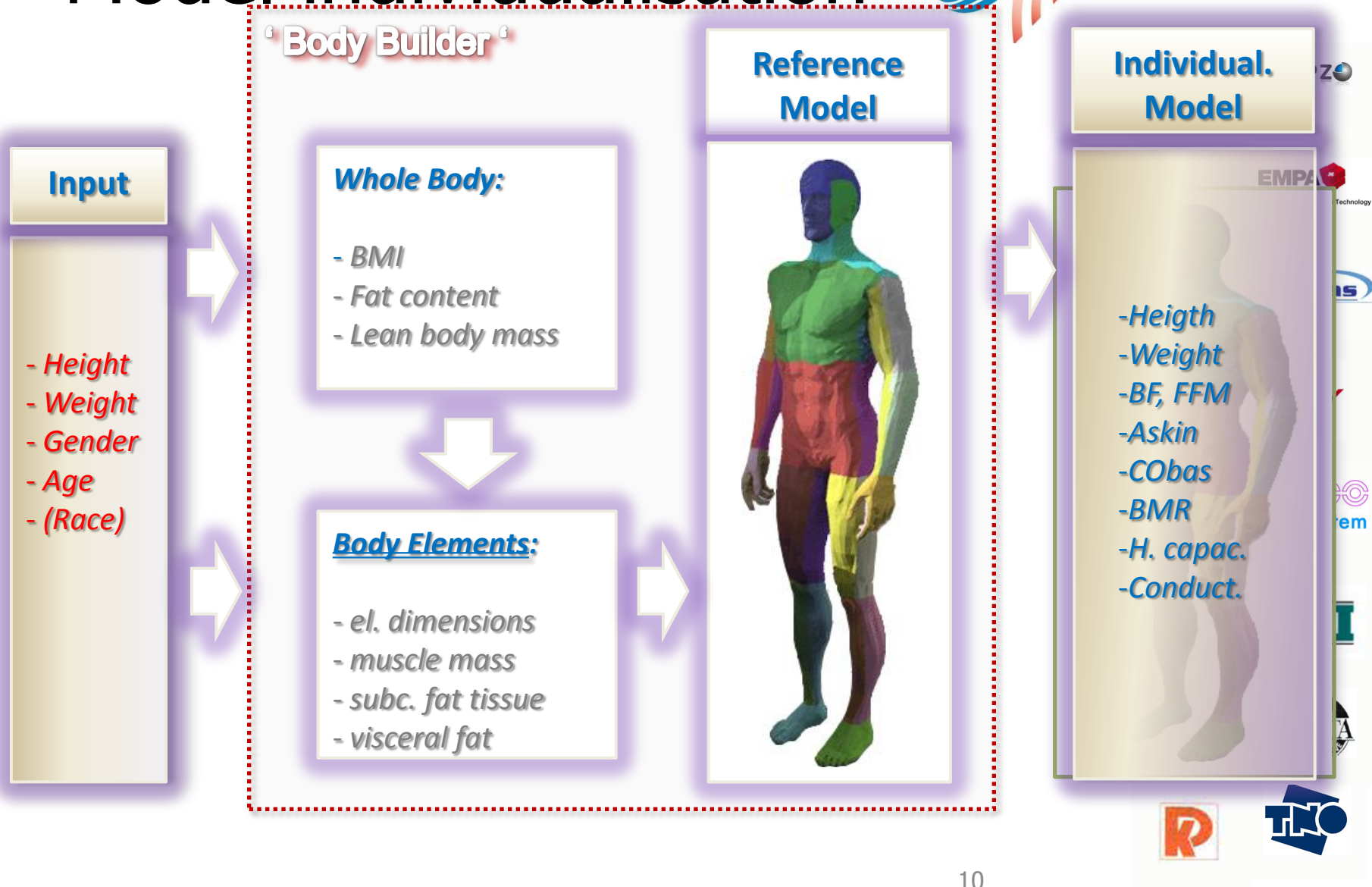


Sensor types:

- Skin: temperature
- Clothing micro-climate
- Heart & breathing rate



Model individualisation



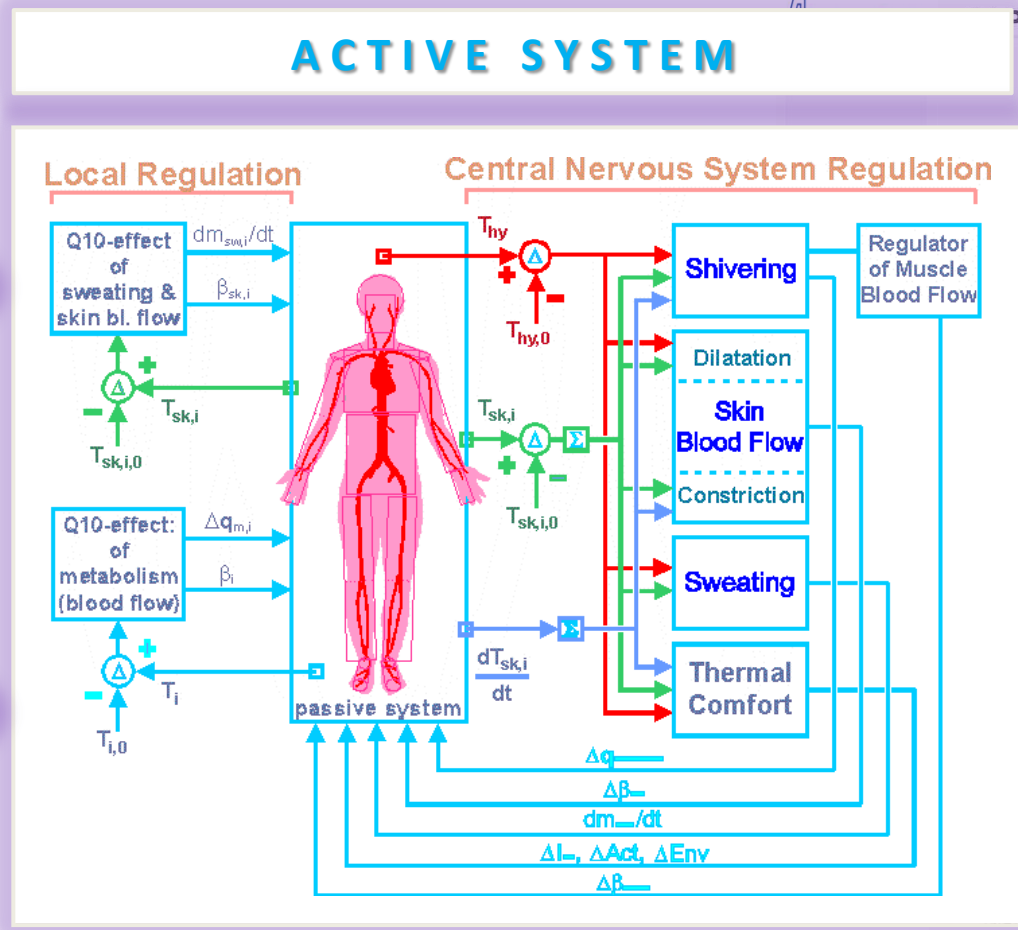
Thermoregulatory model

Input:

- Acclimatisation (days)
- Fitness (VO_{2max})

Passive System Variations:

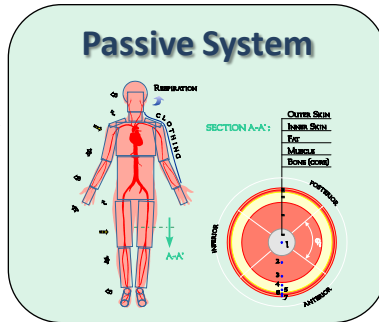
- Surface area,
- Weight (heat capacitance)
- Fat content (th. conductance)
- Basal Metabolism
- Basal Card. Output



Total model overview

Individualisation parameters:

- Height
- Weight
- Sex
- Age



Boundary Conditions

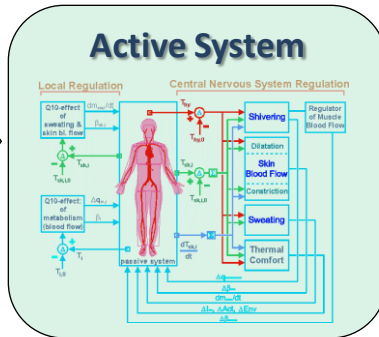
- Environment (t):**
 - T_a , T_r , v_a , rh , Q_s
- Personal (t):**
 -Clothing
 -Metabolic rate



Simulation engine



- Fitness
- Acclimat.



- Sensors (t):**
 - T_{sk} (T_{cl})
- Personal (t):**
 -Met (br, ecg, acc)



Simulation Output (t):

- T_{re} , T_{oe} , ..
- T_{skm} , T_{ski}
- SW
- DL
- SH
- CS
- DTS
- PPD
- Q_{sk}
- q_{sk}
-

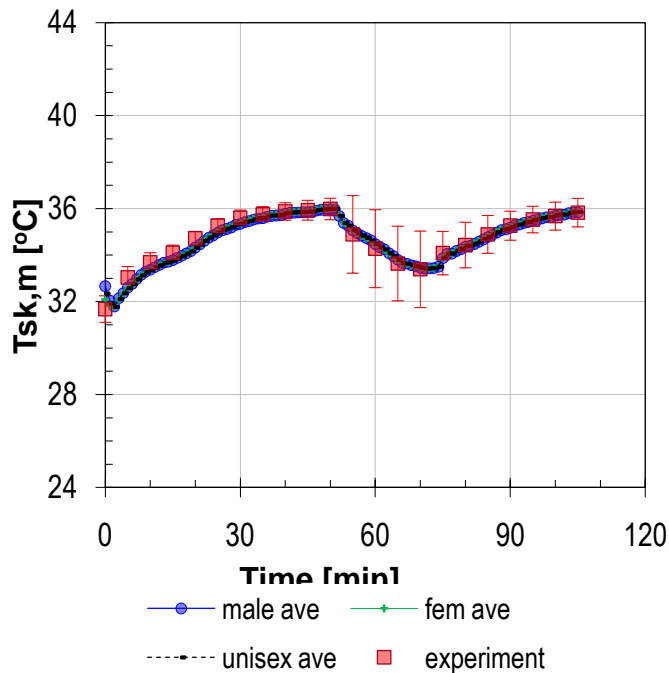


Validation: exercise in 40°C

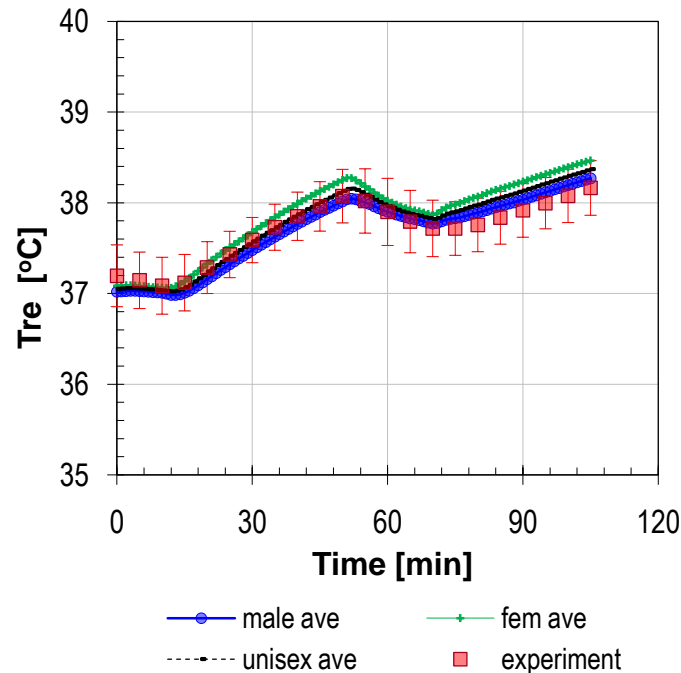


PROSPIE

Body skin Temperature (A)



Body Core Temperature (B)



Conclusions



Cooling strategies developed using absorbing endothermic salts

Warning system built in underwear and work suit

Thermal model used for prediction of core temperature (accuracy $0.03\text{ }^{\circ}\text{C} < \Delta T_{\text{co}} < 0.33\text{ }^{\circ}\text{C}$, typically: $\sim 0.2\text{ }^{\circ}\text{C}$)

Core temperature compared to criterion of 38.5°C

Now focus on integration and further development



Further information



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