Simulation-based Digital Shipbuilding Garment Design – Thermally Controlled PPE for Shipbuilders

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Textile Engineering, Chemistry and Science,
North Carolina State University

Justification for This Project

- ***Thermal Challenge***
  - Achieving comfort and burn prevention in harsh environments is challenging.
- ***Thermal discomfort and burns*** with traditional PPE can occur, while welding.
  - Welder working in sweltering summer heat…
  - …exacerbated by ***radiation hazard,*** especially in ***confined spaces.***
- ***A simulation-optimized digital PPE design process can prevent…***
  - ***welding-related burns*** through better insulating and fitting garments;
  - ***thermal discomfort*** through computerized thermal sensing and cooling technologies.





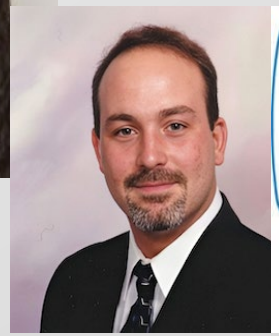
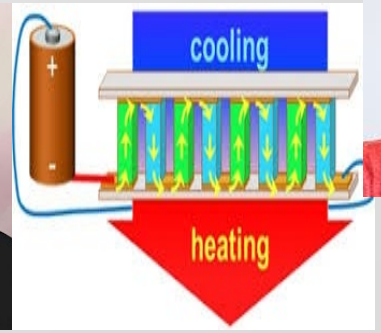
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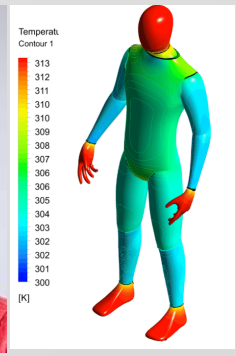
Team Composition

- PI: **Michel Audette, Ph.D.** Computer vision, ***medical simulation, human performance, deep neural networks***.
  - Associate Prof., Electrical & Computer Eng., GPD – Biomedical Eng., Old Dominion University.
- CoPIs:
  - **MyungHee Sohn, Ph.D.,** Apparel fit, apparel technology, ***apparel design process***.
    - Associate Prof.- Fashion Design, Family & Consumer Sciences, California State University Long Beach.
  - **Mia Joe, Ph.D**., Educational technology, instructional design, ***shipbuilding industry.***
    - Research Assistant Professor, Virginia Modeling, Analysis, and Simulation Center, Old Dominion University
  - **Christopher Paolini, Ph.D**., distributed processing & sensing, ***smart clothing, embedded cooling***.
    - Assistant Prof., Electrical & Computer Engineering, San Diego State University
- Consultant: **Emiel DenHartog, Ph.D.,** Clothing biophysics, ***textile testing, comfort models***.
  - Professor & Department Head Textile Engineering, Chemistry and Science, North Carolina State.



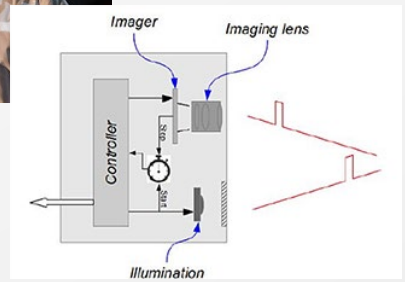


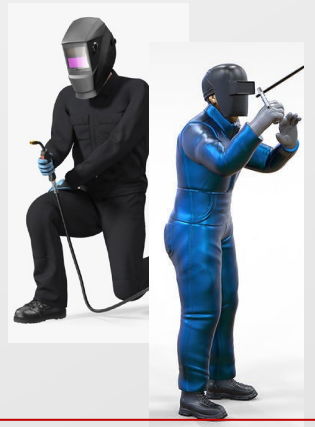



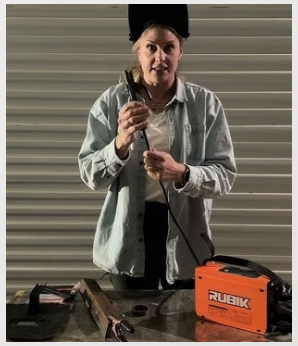
Clothing Simulation- Static 3D to Clo3D to FEA Pipeline











Shipbuilder Feedback

Shipbuilder static range captures & digital models

Shipbuilder avatar canonical poses

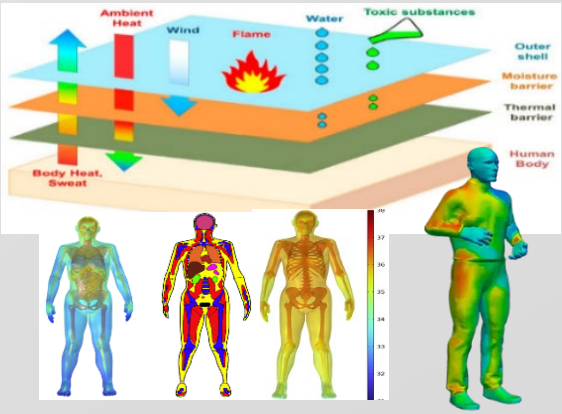
CLO3D

Garment designs in canonical poses

FEA thermal simulation study







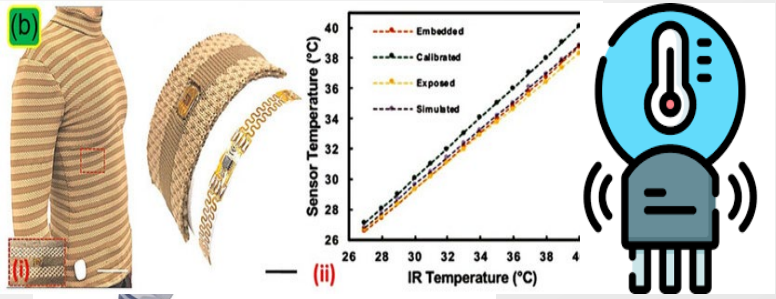
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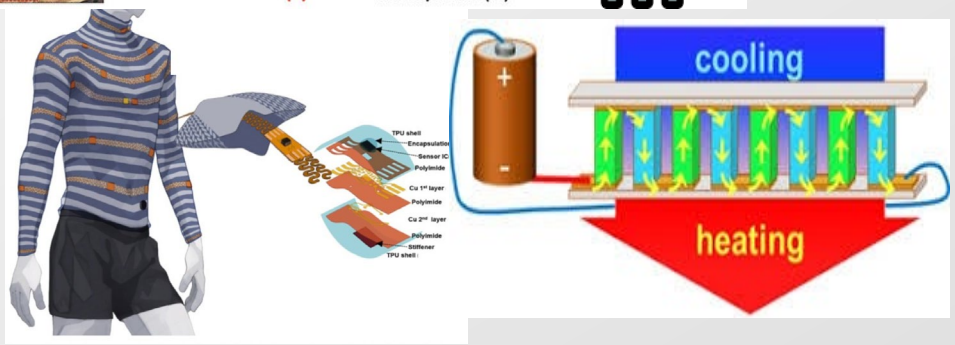
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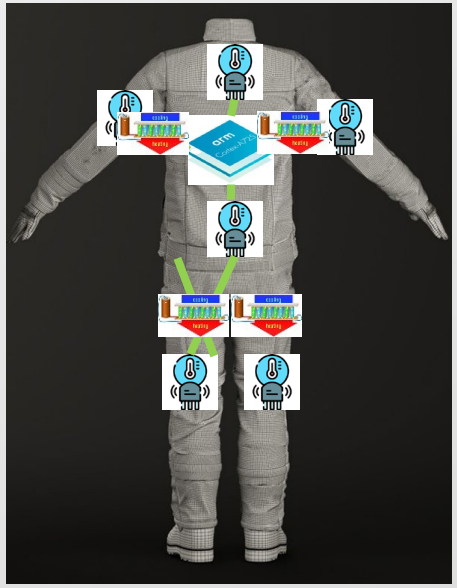
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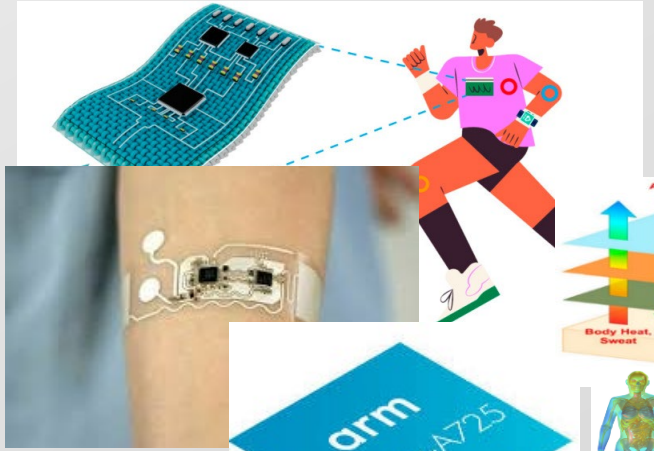
Sim-based Insulative & Thermally Controlled Clothing

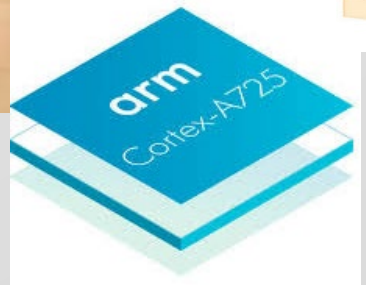
- ***Insulative & actively cooling*** technologies: - ***resistance temperature detectors*** (RTDs), woven into fabrics;
  - ***Aerogel & graphene*** insulators; - Textile-embedded ***processors***; - Wearable ***thermoelectric cooling***.
  - ***Embedded physiological sensors*** (heart rate, temperature, etc.) also feasible.
- Dr. Sohn can ***design garment pattern blocks that accommodate integration of flexible RTDs***, ensuring that seam placement and fabric tension do not interfere with ***sensor functionality or wearer comfort.***
- Dr. Paolini is an expert in ***distributed sensing & computing***, featuring ***wearable PCBs*** & ***low-power CPUs.***
- Dr. DenHartog: expert in finite elements analysis of textiles ***for thermal response*** (based on firefighter PPE).

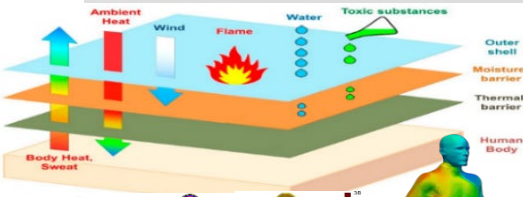


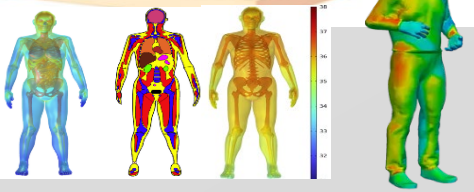












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Deliverables & Customer Involvement

Deliverables:

- Simulation-based thermally controlled PPE design methodology, digital files, & software for NSRP members.
- Thermal finite-element framework for evaluating garment layers, sensing, cooling, and heat rejection.
- Wearable sensing/control electronics prototype integrating RTDs, processor, and Peltier cooling.
- One thermally controlled upper-body PPE prototype.
- Follow-on technology-transition plan for other PPE components, manufacturing, and scale-up.

Customer involvement:

- Norfolk Naval Shipyard will serve as the primary shipyard/user point of contact.
- Colonna's Shipyard is supportive of proposed effort & relevance to broader shipbuilding industry.



