Prediction of Physiological and Psychological Crew Performance under Various Thermal Conditions

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Outline

- Background and Aim
- Method
- Results
- Work in Progress
- Conclusion & Future Work

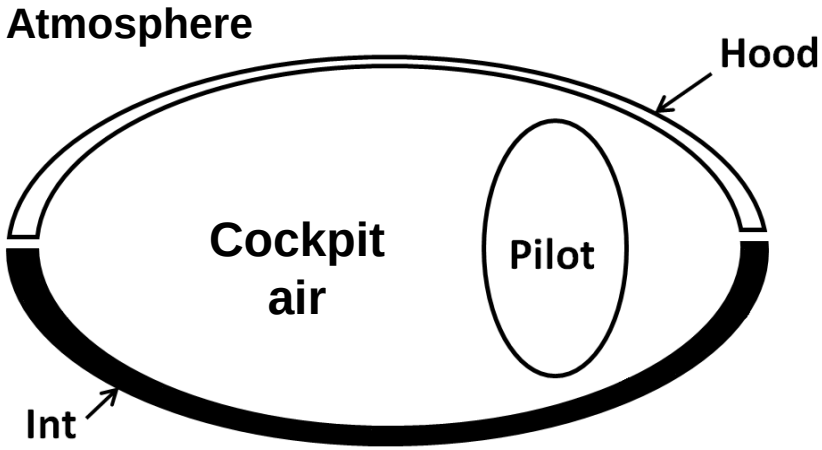
Background and Aim

- aircrafts are exposed to a wide range of thermal conditions
- if thermal comfort is not ensured the pilot can suffer from significant heat stress
- the project was initiated in order to increase the understanding for the thermal comfort in a cockpit for long endurance flights
- the aim of the present work is to develop a model for the thermal environment in the cockpit, and combine it with a thermoregulatory model of a human

Method

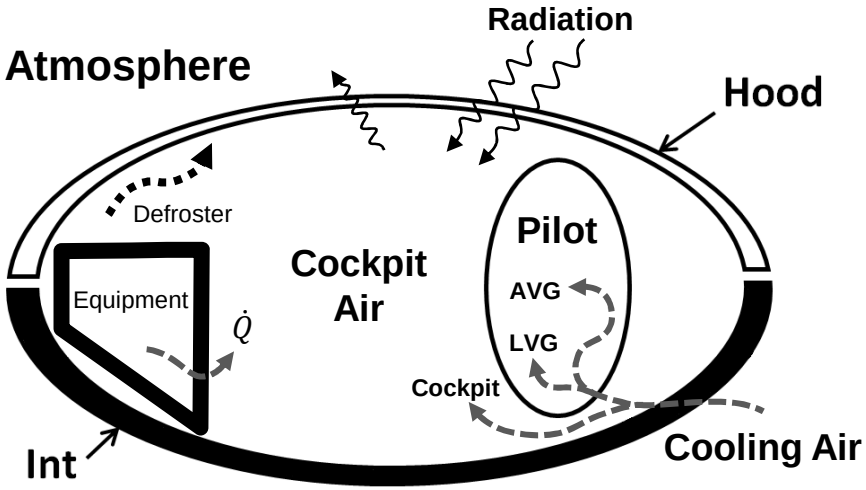
Combined cockpit-pilot model

- the model combines the thermodynamics in a cockpit with a human thermoregulatory model representing the pilot
- the combined model consists of five sub-models, or parts presented in the figure
- the model combines lumped systems with finite difference modelling



Method

Heat exchange mechanisms



$$\dot{Q}_{cp} = \dot{Q}_{conv,int} + \dot{Q}_{conv,pilot} - \dot{Q}_{conv,hood} + \dot{Q}_{equpiment} + \dot{Q}_{defroster} - \dot{Q}_{cool,pilot} - \dot{Q}_{cool,cockpit}$$

$$\dot{Q}_{int} = \dot{Q}_{conv,int} + \dot{Q}_{rad,in} - \dot{Q}_{rad,out} + \dot{Q}_{equpiment} - \dot{Q}_{cool,int}$$

- the thermal response of the pilot is computed by the thermo-regulatory model which receives its input values from the cockpit model

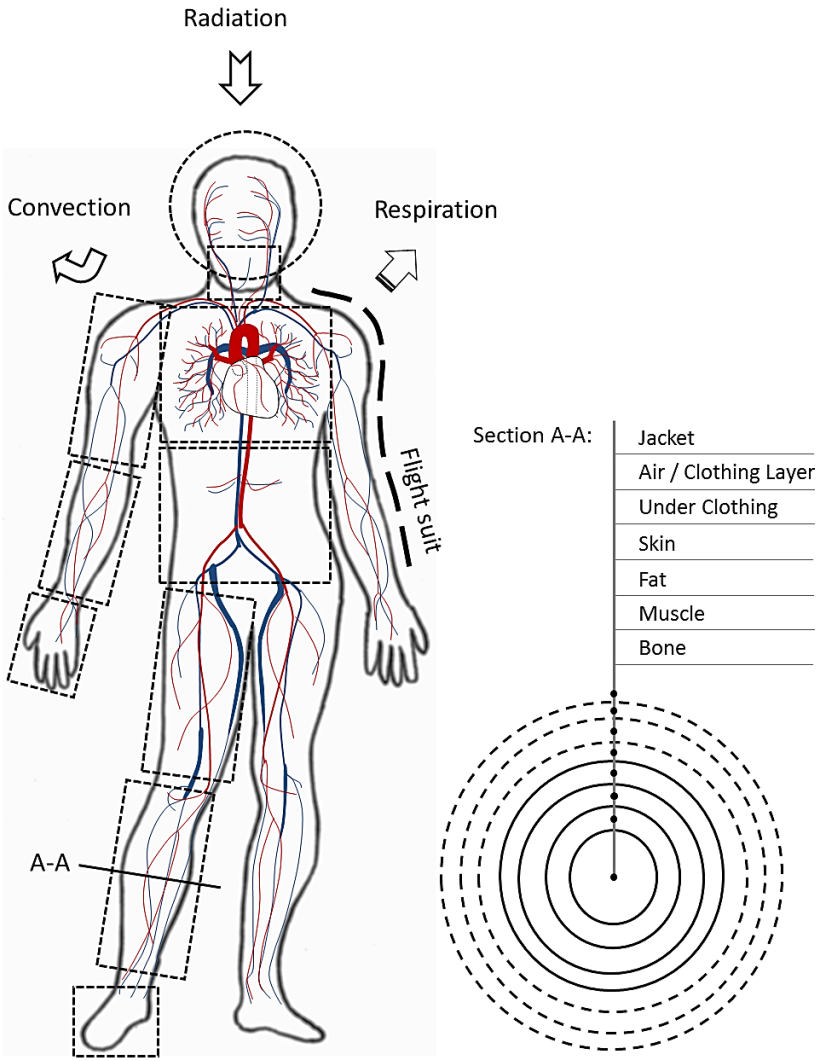
Method

Thermoregulatory model of the pilot

- the model is based on Westin's 16 segments thermoregulatory model [1]
- the model consists of two systems:

  I. Passive: the heat transport within the human body plus the heat exchange between the pilot and the cockpit

  II. Active: control system which senses thermal changes in the body and responds with shivering, sweating, vasodilation, vasoconstriction, and respiration



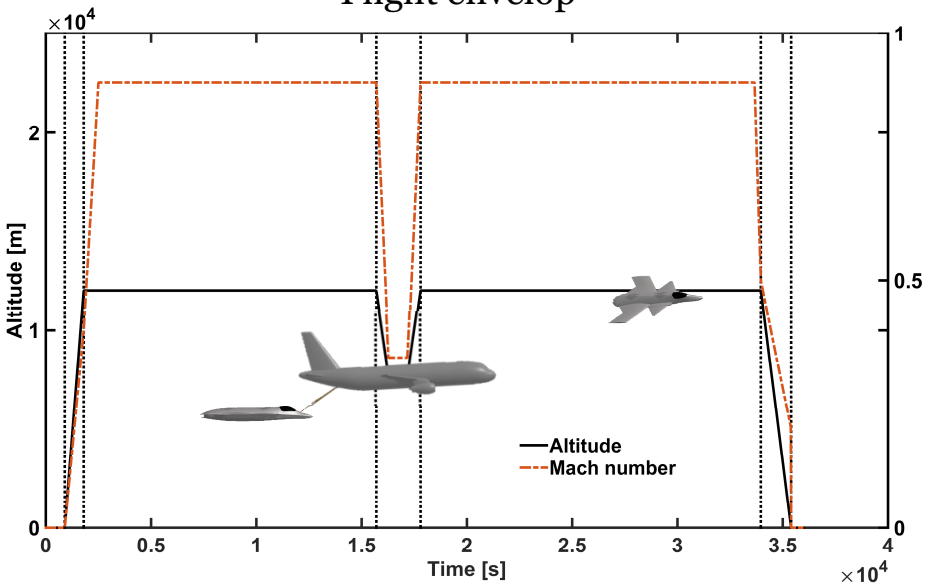
[1] Johan K. Westin. An improved thermoregulatory model for cooling garment applications with transient metabolic rates. PhD thesis, University of Central Florida, Orlando, Florida, 2008.

Results outline

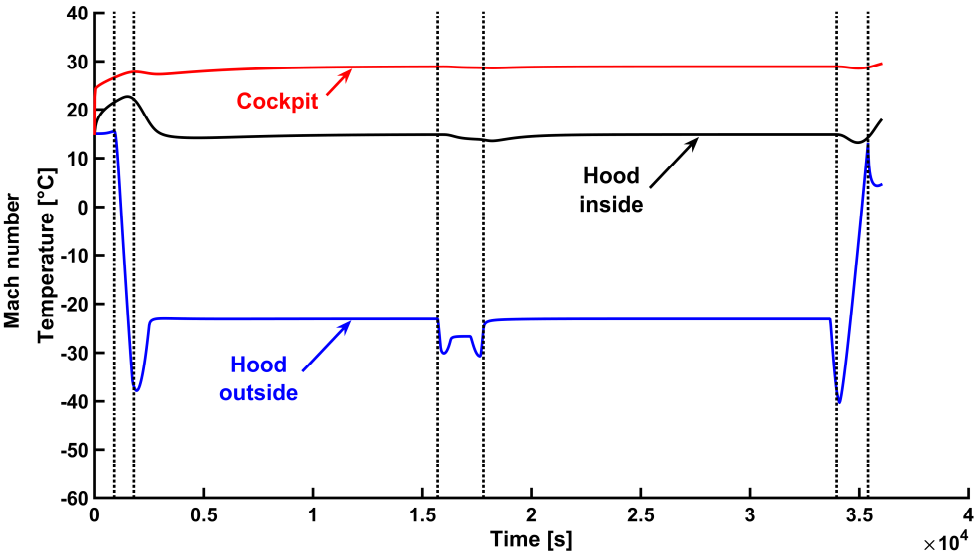
- Results:
  - ✓ simulation of a long endurance ferry flight including aerial refueling of a generic fighter aircraft, pilot-cockpit interaction
- Work in Progress:
  - ✓ Validation
  - ✓ Pilot interview
  - ✓ Crew performance modeling

Results

Flight envelop



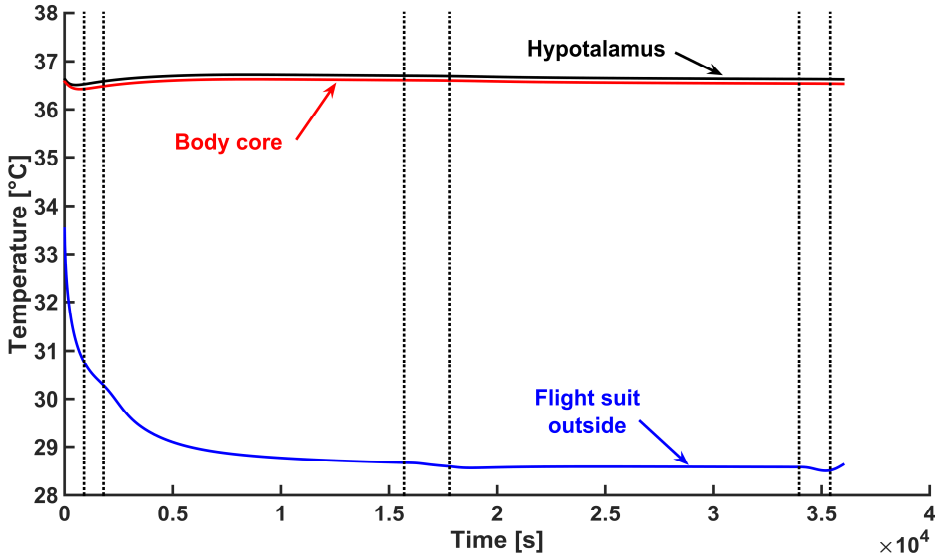
Cockpit temperaturers



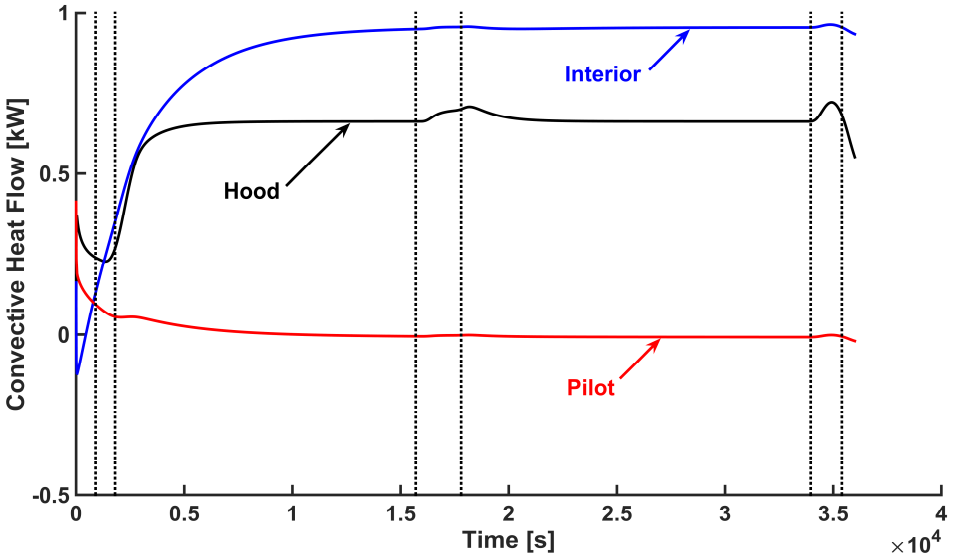
- decent for refueling only leads to minor reactions of the cockpit temperature
- temperature changes caused by change in Mach number and altitude are most distinct at the outside hood surface whereas the inside surface temperature remains relatively unaffected

Results

Body temperatures



Convective heat flows

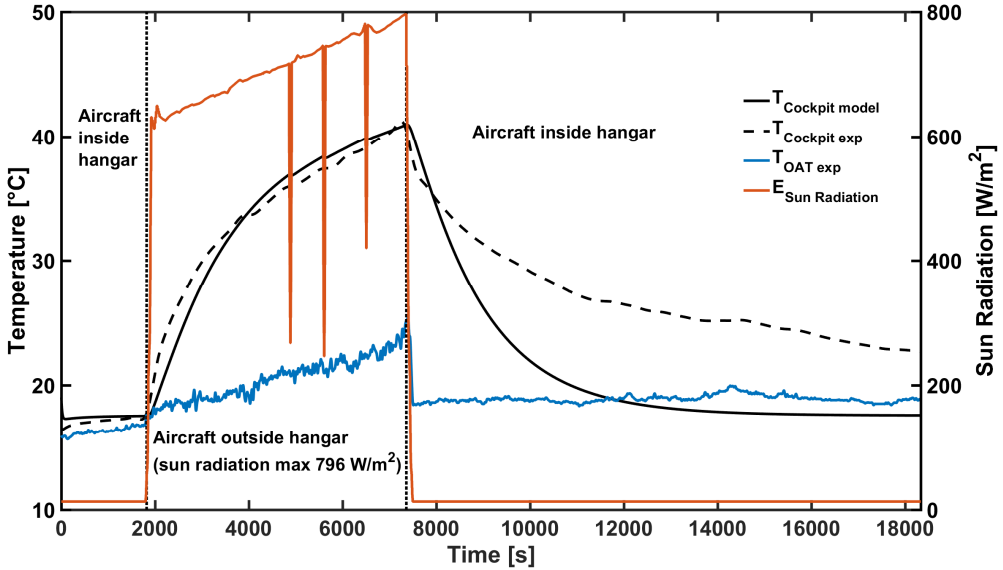


- both the cockpit and the pilot model are able to maintain a constant cockpit temperature over a long time
- the model returns to return to its original values after a temporary deviation.

Work in Progress

Validation

Cockpit temperature



Experimental Setup

- comparison to first on ground measurements looks very promising
- further analysis and fine tuning of model input parameters are in progress

Work in Progress

Pilot Interviews

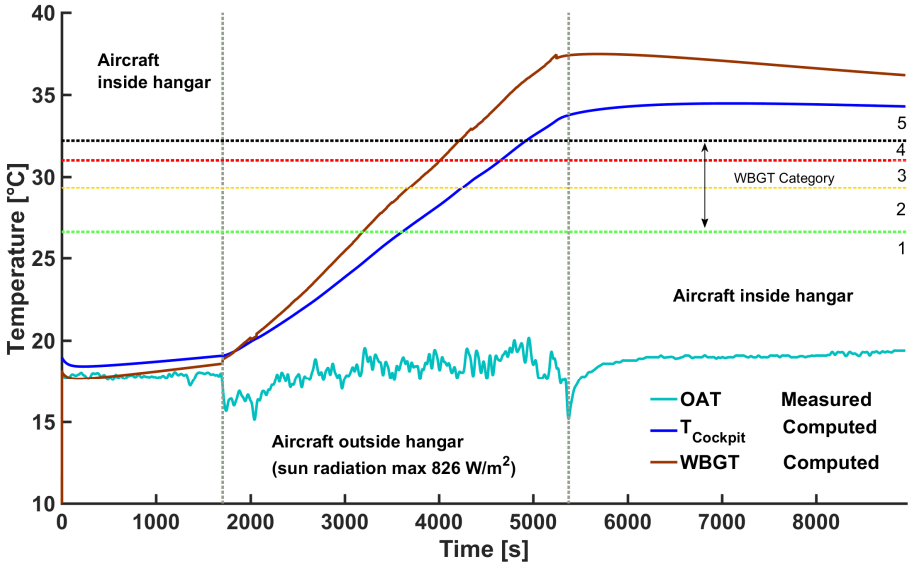
- the interviewed pilots are test pilots from SAAB and FMV
- the survey is still ongoing but first results show that the pilots statements support the need for simulation based cockpit thermal comfort studies and heat stress related crew performance modeling on ground and during flight

Picture credits to: Saab AB

Work in Progress

Performance Modeling

Crew performance estimation



Experimental Setup

- heat related physiological and psychological crew performance limits can be estimated by modeling different hat stress indices, e.g. Wet Bulb Globe Temperature (WBGT)

Conclusions

- a comprehensive cockpit-pilot model was implemented
- the first cockpit model validation results point in the right direction
- the cockpit model is suitable for pilot comfort related studies
- the combined model is applicable for simulating long range flight missions within a reasonable time

Future Work

- further development and validation of the pilot model
- Simulation of the pilots' cognitive capability depending on cockpit climate
- ECS model connection
- pilots' liquid and energy demand depending on temperatures and mission duration

Thank you for your attention!

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