MODEL OF PHYSIOLOGICAL RESPONSES DURING SPATIAL EXTRA-VEHICULAR ACTIVITY

Françoise THELLIER *, Françoise MONCHOUX *, Jean-Louis BONIN * and Gilles CLÉMENT **

* LESETH - Université Paul Sabatier - **118,** route de Narbonne - 31062 - Toulouse Cedex - FRANCE
** MEDES - Hôtel Saint-Jacques - 2, Rue de la Viguerie - 31052 - Toulouse Cedex - FRANCE

INTRODUCTION

Extra Vehicular Activities (EVA) are a main component of in-orbit operations for manned space flight. These activities raise a number of technical challenges such as the design of a highly performing space suit as well as the understanding of human behaviour under microgravity such as the astronaut's psychological and physiological reactions to his environment.

The simulation of human physiological functions, such as thermoregulation and cardiopulmonary responses, in the form of a software model, has been developed. The use of mathematical models of human biological systems is not a new phenomenon, but the majority of the available models are limited to one physiological function, and do not consider the interactions between functions. The purpose of this integrated model was to link the different submodels to obtain a highly representative and flexible Human Physiological Model (HPM).

METHOD

The Human Physiological Model is made up of three submodels : a thermoregulation submodel, which represents the core of the model, a respiratory submodel, and a cardiovascular submodel. Currently the integrated model simulates the physiological responses of a healthy 'standard man' (height: 1.75 m; weight: 74 kg; *skin* surface: 1.89 m^2), aged 35, placed in either micro gravity or Earth gravity conditions. Fat and muscles proportion is normally distributed, respiratory coefficient is *0.82,* heart rate at rest ranges from 60 to 80 beats/min.

Thermoregulation model.

The thermoregulation submodel is based on the 25-node human model developed for indoor comfort MARCL [1]. It gives the thermo-physiological parameters (skin temperatures, wettedness, sweating...) of the body. It is divided into a passive and an active part. The passive part represents 6 segments (**head,** trunk, arms, **hands,** legs, feet), each of them **composed** of four layers and linked together by the blood Metabolic heat is produced in each compartment, and then transfers to the outside through tissular conduction and blood convection. There are heat losses towards environment through respiration and skin heat exchanges with space-suit. The active part of the submodel simulates the physiological reactions of the body to thermal strain. It modifies the sweat rate, the *skin* blood flow and the increase of heat production due to shivering.

We adapted this model to fulfil the micro gravity conditions starting from the following assumptions :

• heat exchanges through respiration are calculated as a function of the gas volume inspired. During EVA, the gas inspired is assumed to be pure oxygen;

• compared to Earth conditions, blood flow is decreased by 20% in the lower **limbs** due to the absence of gravity;

• muscles of upper limbs are highly active during EVA;

• skin heat exchanges are calculated through the space-suit modelling.

Cardiovascular and respiratory models.

A cardio-vascular submodel **and** a respiratory submodel were created from real **data** collected on Russian cosmonauts and volunteers from real EVA or from simulated EVA in a Earth-based vacuum chamber. Collected measurements were averaged among subjects or sessions over a period of 60 minutes. Simple linear and multiple regression coefficients were then calculated corresponding to the relationship between the physiological parameters (heart rate, respiratory rate, O_2 volume consumption and CO_2 volume generation), the activity and the mean body temperature.

Space-suit model

The first results showed that body temperatures are highly sensitive to the heat exchange. Then, while the purpose of this study was not the space suit modelling, the thermal environment of the astronaut must be described with a sufficient accuracy. The mathematical representation of the space-suit roughly evaluates heat exchanges between the Oxygen Ventilation Network (OVN), the Liquid Cooled Garment (LCG) and the *skin.*

Integrated model

The coupling between all submodels of HPM and the space suit determines the thermal state of the body **and,** consequently, the cardio-vascular state (Fig. 1). Inputs are the activity of the astronaut for HPM, and inlet temperatures of water and oxygen for the space suit.

RESULTS

Tests allowed to check how the physiological submodels interact together, comparing the data predicted by HPM with those collected during simulated or actual EVA. Figure 2a shows some results obtained in an Earth thermal chamber. The measured ear temperature is compared with predicted mean skin head temperature. Both are oscillating around 37°C. This means that the estimated cooling power of the simulated space suit is rather good. Differences about variations are provided by the fact that the calculated temperature follows water temperature variations while the ear temperature thermometer, which is rather insulated, indicates a more internal (and constant) temperature. A better fit is obtained comparing ear temperature to the HPM mean body temperature [2]. Comparison of skin temperatures is highly linked to the measurement point.

In an actual EVA (Fig. 2b), a fairly constant difference appears between the same temperatures. The explanation seems to be a bad representation of the space suit in space : sun, radiations were not taken into account; besides, the length and the distribution of LCG pipes had been modified. The calculated heat removal is too high, inducing a lowered calculated skin temperature.

CONCLUSION

The HPM model permits evaluation of a "standard astronaut status during EVA. Assumptions have been done about distribution of muscular activity and blood flow. Strong influence of thermal environment has been shown. Complementary improvements have to be done about space suit modelling and determination of physiological parameters that can be compared..

ACKNOWLEDGEMENTS

REFERENCES

1. Monchoux F., Serin G. and Thellier.F., Cordier A., Galéou M. 1992. *"Des logiciels pour l'analyse et la gestion du confort thermique "*. Revue Générale de Thermique, No 371, 616-620.
2. Monchoux F., Thellier.F., Bagiana F., Barer A. 1994."*Human Physiological* Model *during Extra Vehicular Activities"*. 5th European Symposium on Space and Environmental Control Systems, Friedrichshafen.
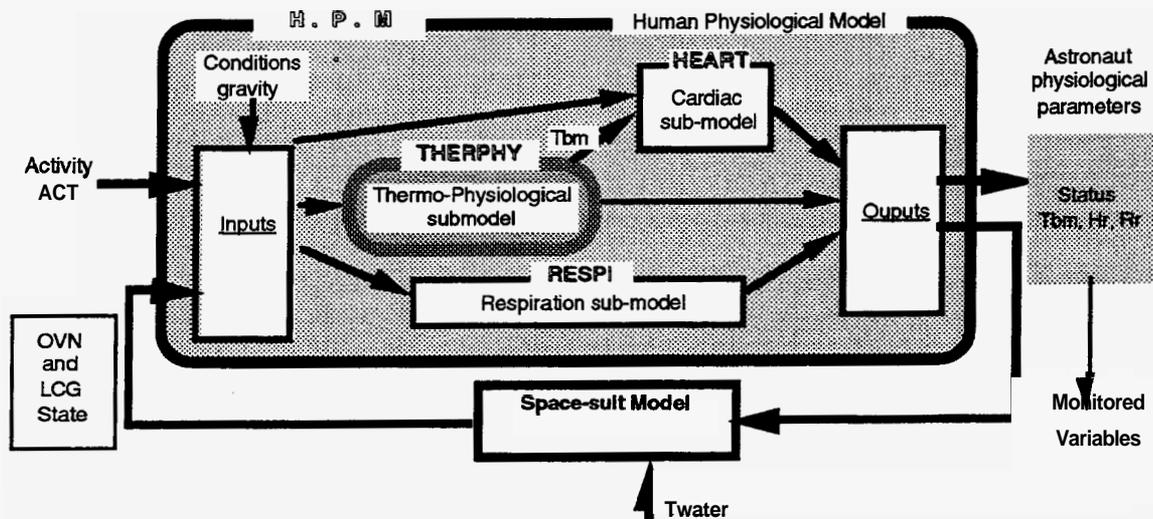

Fig. 1 - Diagram of the integrated model
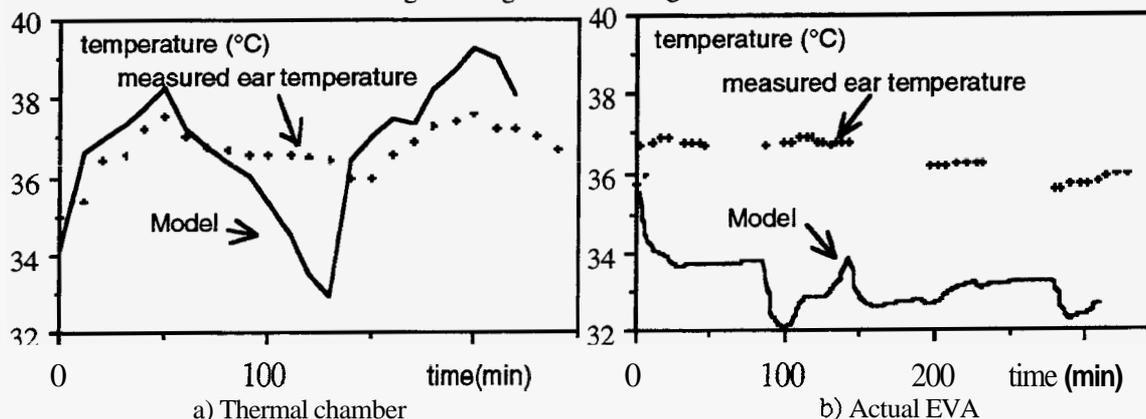

a) Thermal chamber

b) Actual EVA

Fig. 2 - Comparison between measured ear temperature and simulated head temperature versus time.