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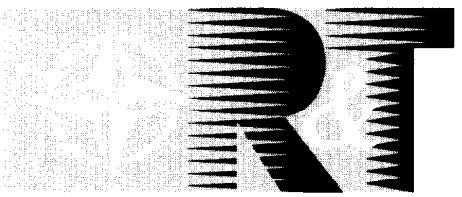

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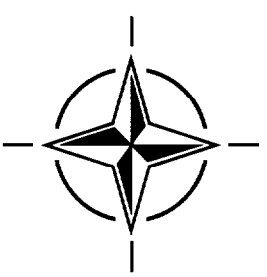
Models for Aircrew Safety Assessment: Uses, Limitations and Requirements

(la Modélisation des conditions de sécurité des équipages : applications, limitations et cahiers des charges)

Papers presented at the Specialists' Meeting of the RTO Human Factors and Medicine Panel (HFM) held at Wright-Patterson Air Force Base, Ohio, USA, 26-28 October 1998.



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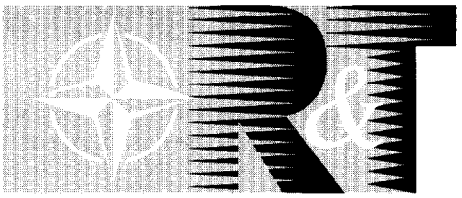

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RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote cooperative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective coordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also coordinates RTO's cooperation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of initial cooperation.

The total spectrum of R&T activities is covered by 7 Panels, dealing with:

- SAS Studies, Analysis and Simulation
- SCI Systems Concepts and Integration
- SET Sensors and Electronics Technology
- IST Information Systems Technology
- AVT Applied Vehicle Technology
- HFM Human Factors and Medicine
- MSG Modelling and Simulation

These Panels are made up of national representatives as well as generally recognised 'world class' scientists. The Panels also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier cooperation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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Models for Aircrew Safety Assessment: Uses, Limitations and Requirements

(RTO MP-20)

Executive Summary

The Human Factors and Medicine Panel (HFM) of the Research and Technology Organization (RTO) held a Specialists' Meeting on "Models for Aircrew Safety Assessment: Uses, Limitations and Requirements" at Wright-Patterson Air Force Base (WPAFB), Ohio, US, 26-28 October 1998. The Meeting was held to honour Dr Henning E. von Gierke, Director Emeritus, Human Effectiveness Directorate, Air Force Research Laboratory, WPAFB for his pioneering work in biodynamics and his extensive service to NATO/AGARD*.

Technological advances in computer speed and power have made modelling a feasible research and design tool. Computer simulations are being used extensively by safety experts to predict human physical and physiological responses, to reduce testing requirements, and to perform human safety-systems analyses. This Specialists' Meeting covered modelling of human body responses to environmental stressors, and the systems with which the body reacts for: impact, emergency escape, sustained acceleration, motion sickness, high altitude, mechanical shock, vibration, blast, extreme thermal conditions, directed energy and live fire. These studies impact on NATO aircrew safety issues in that they provide:

- new information on the extensive developments made in collecting biodynamic data for model development from animal and volunteer human testing for the past 30 years;
- further realization of the importance of good model and data-base validation and verification procedures, and the importance of standardization of recording systems and data bases to exchange data sources;
- confirmation of the significance of finite-element analysis, often when it is coupled with rigid-body modelling, for analyzing human-systems interaction during crash and other loading conditions;
- important new efforts in the human-systems integration of cardiovascular and cerebrovascular responses with the dynamics of anti-G protective hardware to sustained acceleration to address safety design issues; and
- new models and methods for describing or predicting:
  - mechanical shock that rely on biomechanical analysis rather than signal-processing techniques;
  - motion sickness that relate sensory information conflict between sensed and subjective (from past experiences) gravitational accelerations;
  - altitude decompression sickness that combine gas-bubble growth models with survival-analysis techniques;
  - impact of battlefield trauma on predicted task performance as exemplified by the Operational Requirement-based Casualty Assessment (ORCA) computer code for exposure to penetrations, blast, laser energy, and chemical, thermal and accelerative loading; and
  - body responses to vibration, radio frequency radiation, burns and blast overpressure.

With the increased emphasis on simulation and modelling in aircrew safety design, and the requirement for greater international collaboration, the recommendation is made that the RTO/HFM Panel assess the feasibility of establishing a series of biodynamics and trauma-injury data bases that would capture the relevant data available in the different aircrew environments. These data bases and any analogous pre-competitive modelling techniques, tools and ideas would conform to accepted procedures of standardization, validation and verification, and be available to all NATO nations conducting collaborative research and design.

* AGARD, the Advisory Group for Aerospace Research and Development, which merged with the NATO/DRG to form the RTO.

La modélisation des conditions de sécurité des équipages : applications, limitations et cahiers des charges

(RTO MP-20)

Synthèse

La commission des facteurs humains et médecine (HFM) de l'Organisation pour la recherche et la technologie de l'OTAN (RTO), a organisé une réunion de spécialistes sur « la modélisation des conditions de sécurité des équipages: applications, limitations et cahiers des charges » sur la base aérienne de Wright Patterson (Ohio USA), du 26 au 28 octobre 1998. Cette réunion a permis de rendre hommage au Docteur Henning E. von Gierke, Directeur émérite de la Direction des études sur l'efficacité humaine, au laboratoire de recherche de WPAFB, pour ses travaux novateurs dans le domaine de la biodynamique, et pour les nombreux services rendus à l'AGARD* dans le passé.

Les avancées technologiques en matière de vitesse et de puissance de calcul ont fait de la modélisation un outil pratique pour la recherche et la conception. Les simulations numériques sont largement utilisées par les spécialistes de la sécurité pour prévoir les réponses humaines, physiques et physiologiques, pour alléger les procédures d'essais et pour analyser des systèmes de protection individuelle.

Cette réunion de spécialistes a porté sur la modélisation des réponses du corps humain aux facteurs d'agression, ainsi que sur les systèmes avec lesquels le corps réagit en cas d'impacts, d'évacuation d'urgence, d'accélérations soutenues, de nausées liées aux mouvements, de vol à haute altitude, de chocs mécaniques, de vibrations, de souffle, de conditions thermiques extrêmes, et d'exposition à l'énergie dirigée et aux tirs réels. Ces études ont une incidence sur la sécurité des personnels militaires de l'OTAN dans la mesure où elles fournissent :

- de nouvelles informations sur les progrès considérables réalisés dans le domaine de la collecte des données biodynamiques pour le développement de modèles, basés sur les résultats d'essais effectués au cours des trente dernières années sur des animaux et des bénévoles humains;
- une nouvelle prise de conscience de l'importance des procédures de vérification et de validation pour les bases de données et les modèles, comme de la nécessité de disposer de bases de données et de systèmes d'enregistrement normalisés pour permettre un meilleur échange entre sources de données;
- la confirmation de l'intérêt de la méthode d'analyse des éléments finis, surtout lorsqu'elle est associée à la modélisation de corps rigides, pour l'analyse des interactions homme-système en cas d'écrasement ou de surcharge;
- d'importants efforts nouveaux visant l'intégration homme-système des réponses cardiovasculaires et cérébrovasculaires dans la dynamique des équipements de protection contre les forces d'accélération soutenues, afin de résoudre les problèmes de conception des équipements de protection individuelle et,
- de nouveaux modèles et de nouvelles méthodes pour la description et la prévision :
  - de chocs mécaniques; ces modèles et méthodes sont issus d'analyses biomécaniques plutôt que de techniques de traitement du signal;
  - de nausées liées aux mouvements, qui décrivent la perception d'informations sensorielles contradictoires relatives à des accélérations dues à la pesanteur, qu'elles soient senties ou subjectives (précédemment vécues)
  - du mal de décompression en altitude, qui associe des modèles d'accroissement des bulles de gaz aux techniques d'analyse de la survie;
  - des informations concernant l'impact des traumatismes subis sur le champ de bataille sur les prévisions en matière d'exécution des tâches, comme dans le cas du code de calcul de la méthode d'estimation du nombre des victimes par rapport aux besoins opérationnels (ORCA), relatif à l'exposition aux pénétrations, au souffle, à l'énergie laser, aux charges chimiques, thermiques et liées aux accélérations et les réponses du corps humain aux vibrations, aux rayonnements RF, aux brûlures et à la surpression due au souffle.

En raison de l'importance accrue accordée à la modélisation et à la simulation dans la conception liée à la sécurité des équipages, et étant donné que le besoin d'une plus grande collaboration internationale se fait sentir, il est recommandé à la commission RTO/HFM d'évaluer la réalisation d'une série de bases de données biodynamiques et de traumas/lésions, pour saisir les données pertinentes existantes dans les différents environnements opérationnels. Ces bases de données, ainsi que tout autre outil, technique ou concept concurrentiel analogue, se conformeraient aux procédures de vérification, validation et normalisation agréées, et seraient mises à la disposition de l'ensemble des pays membres de l'OTAN engagés dans la recherche et la conception collaboratives.

* NATO/AGARD, le Groupe consultatif pour la recherche et les réalisations aérospatiales, qui a fusionné avec le NATO/GRD, pour former la RTO.

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SESSION IV: SUSTAINED GZ ACCELERATION: MODELLING HUMAN RESPONSES TO ANTI-GZ PROTECTION STRATEGIES

Preface

This Specialists' Meeting reviewed a variety of models applicable to the field of aerospace physiology and aircrew safety. These included lumped-parameter, rigid-body, finite-element, statistical, physiologic, and empirical models. These models described the human-body responses to environmental stressors, and the systems with which the body interacts. Also considered were the data bases and tolerance criteria used with these models. Special presentations focussed on the validations, limitations, and appropriate applications of different models.

The following topics were addressed:

- modelling human responses to impact and ejection accelerations:
  - biodynamic data-base development of material properties and mechanical characteristics of human tissue,
  - head/neck/spine responses and models,
  - finite-element model of upper extremity for assessing arm-airbag interaction, and
  - validation of the MADYMO mathematical-dummy model against Hybrid II and Hybrid III test dummies;
- modelling human-systems interaction during ejection and impact:
  - combining wind-tunnel data with the ATB occupant model to evaluate ejection-seat/crew-member interactions,
  - head protection against windblast, and
  - using airbags and optimal seating strategies to reduce injuries;
- modelling human-systems responses to sustained Gz acceleration for:
  - cardiovascular and cerebrovascular functions,
  - baroreceptor (pressure sense organ) function, and
  - anti-G protection strategies; and
- modelling human responses to harsh air environments in regard to:
  - mechanical shock based on human-response data,
  - whole-body vibration,
  - motion sickness as a conflict between subjective (from mental stores of past experiences) and sensed gravitational vectors,
  - altitude decompression sickness from gas-bubble and survival-analysis considerations, and
  - battlefield trauma (penetration, blast, laser, chemical, thermal and accelerative loading) by an Operational Requirements-based Casualty Assessment (ORCA) computer code in terms of predicted task performance.

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Human factors engineering
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Finite element analysis
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Safety engineering
Stress (physiology)
Push-pull effect
Protective clothing
Anti-g suits
Battlefields
Traumatic disorders
Data bases
Dummies
Ejection seats
Anthropometry
Biomechanics
Casualties
Evaluation
Windblast
Directed energy
Live fire

14. Abstract

These proceedings include the Technical Evaluation Report, a tribute to Dr. Henning E. von Gierke, Director Emeritus, Wright-Patterson Air Force Base (WPAFB), OH, three Keynote Addresses and 32 invited papers of a Specialists' Meeting sponsored by the NATO/RTO Human Factors and Medicine Panel. It was held at WPAFB from 26-28 October 1998.

Significant advances have been made in modelling human physical and physiological responses to extreme environments. Technological advances in computer speed and power have made modelling a feasible research and design tool. Computer simulations are being used extensively for predicting human physical and physiological responses, for reducing testing requirements, for rapidly designing improved protective systems, and for performing human safety-systems analyses. A variety of models were reviewed at this Specialists' Meeting including lumped-parameter, rigid-body, finite-element, statistical, physiologic, and empirical models. Topics covered included modelling human-body responses to environmental stressors, and the systems with which the body interacts to: impact, emergency escape, sustained acceleration, vibration, mechanical shock, motion sickness, high altitude, blast, extreme thermal conditions, directed energy and live firing.

These proceedings will be of interest to military and civilian scientists and engineers interested in exploiting data bases, tolerance criteria, and new models and methods in the research of physiological systems and in simulating the design, test set up and evaluation of safety systems.

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