Technical Evaluation Report

Prof Yvan Baudoin
Dept Mechanical Engineering
Royal Military Academy
30 Av de la Renaissance
BE 1000 Brussels
BELGIUM

Yvan.baudoin@rma.ac.be

1. INTRODUCTION

The modern military (ground, air, sea) combat/ transport vehicles, not only depending on increasing information/communication systems and increased mobility in various and quite different environmental conditions over the world, must also be characterised by a high **manoeuvrability** and a even high **reliability**: that implies an optimised design, based on the modern analytical tools at disposal of the Engineers. But the military vehicles also have to offer an optimal **comfort** to the crew and the passengers in charge of the execution of their specific tasks or missions: and that implies a mastering of the **noise, vibration and motion** induced by the various (land, air, sea) driving conditions: a great challenge due to the highly non linear dynamics of those three potential sources of disturbing impacts on the performance of the Human Operators.

Three categories of impacts, and consequently three categories of Engineering Techniques, may be considered when the habitability (influenced by noise, vibration and motion) of combat / transport-vehicles is concerned:

- The kind of missions entrusted to the Armed Forces with, as primary consequence, the type of vehicle (ground, air, sea, undersea) that will be used, and obviously the accotrding environmental influences (off-road terrain, roadway roughness, tyre-soil interaction of aircrafts on runways, aerodynamic forces, shock loads on eavy seas…) and their specific noisy frequency-range (**Environmental impact**).
- The design and technology (structures, materials, engine, suspension, transmission, armour,control devices,..) leading to the whole vehicle concept and its sub-systems/components , each of them inducing particular periodic or random disturbances (**Technical Impact**).
- The ergonomical factors aiming a performant human-machine, environment-interface (computer displays in moving vehicles, hearing protection systems, Health Hazard assessment methodologies, traning on advanced simulators...) (**Ergonomical Impact**).

According Engineering Techniques allow to face the aforementioned direct or indirect impacts on the Human performances. The **Environmental Engineering** is defined as the study of the resistance of the products (in this case the vehicles or parts of those ones) against the aggression of the environment: the aerodynamic forces and the aircraft-runway or tyre-soil interactions for airplanes, the ground-wheels or tracks contacts for ground-vehicles, the ship motions in different seaways for ships , resulting in vibrations, shocks and noise which have an impact on the structures and the various electromechanical components of the vehicles (as well on the Human Crew). The design of new systems as well as their (predictive) maintenance impose a good knowledge of the environmental parameters: g-loads, speeds, and forces acting on the vehicles, a.o., have to be measured in order to develop valid models and statements on ride comfort. Such data will also validate the results of simulation tools as well as possible virtual tools allowing a comprehensive treatment of human behavioral problems.

Obviously there is no rigid frontier between the environmental engineering and the **Technical** (today mechatronical) E**ngineering** that will bring solutions to the problems caused by the expected environmental disturbances (for instance, by equipping land vehicles with an adaptive suspension, by choosing an adequate disturber-intake assembly decreasing the disturbance to the vortex flow of aviation power units, use of composite material fuselage, ….) , nor between the Environmental Engineering or the Technical Engineering and the **Human Factors** E**ngineering** that will allow the Crew to fill its mission despite the remaining disturbances, through performant Human-Machine-Environment Interfaces or Tools (design of hearing protection devices, development of specific relaxation therapies, …) : several papers of this AVT110 symposium were dealing with a global or specific analysis of the three aspects (impacts and/or corresponding engineering techniques) , the major key-words of this Conference being **Design** (of the vehicles and their subsystems), **Control** (of the vehicle, i.e. active vibration/noise/motion control, or of the mission , i.e. tasks entrusted to the Crew, **and Performance** (of the Crew): the performance of the military people remaining obviously, as B.Sicard reminded it by concluding the key-note 2, the major objective.

2. ANALYSIS OF THE PRESENTED AVT-110 NOTES

Human Factors: from a military operational perspective, there is a great interest in identifying circumstances in which Human performance is degraded and identifying approaches or measures that can be used to mitigate any performance degradation, through real (on-the-field) or virtual (simulation) testing procedures., or virtual tools allowing a comprehensive treatment of human behavioral problems The papers 1, 11, 13, 27, a.o. illustrate some approaches and corrective tools, a.o. in the domain of the communication means.

Technical Factors: since military ground vehicles are by nature often operating at rough terrain , aircrafts by nature submitted to aerodynamic loads, landing shocks and ships exposed to varying sea-conditions during their relatively long missions , the question of vibration reduction is of great importance, not only for reducing the excitation of the mechanical structures and parts of the vehicle but also to ensure a high ride comfort especially necessary for fatigue-free driving over long distances : (semi-) active vibration/noise control techniques play here an essential role: a quasi-exhaustive description of those techniques are given in the paper 2, while specific approaches may be consulted in the papers 4, 5, 6, 17, 18, 20, 22, a.o.

Environmental Factors: the interactions between environmental factors (mission profile, terrain, …) and internal noise/vibration sources (engine, transmission, structures and material,…) are complex, implying the use of specific filtering techniques as well as the implementation of a comprehensive network of measurement devices near the sources and inside the crew compartments. Useful informations on practical methodologies have been presented ,a.o., in papers 8, 9, 10 , 11, 12, 18, 31.

3. SOME RECOMMENDATIONS

3.1. Requirements, Test and Evaluation, Standards (Human Factors Engineering)

Additional work needs to be done to standardize measures for use in research environments and in field environments. As an example, correlations between specific and objective vibration measurements prescribed by the ISO 2631 (comfort of seated person) have still to be correlated with the global expected dynamical behaviour or properties of the vehicle, then with the functional requirements or guidelines leading to technical design requirements; same ISO 2631 should be adapted to take into account with the high accelerations (shocks) . In the frequency range 20 Hz/20 KHz, noise measurements as prescribed by the ISO 532 (noise level) have still to be refined and completed by other metrics related to the other characteristics and fatigue effects of the noise.

A large low frequency content of the noise spectrum characterises most military Ground vehicles, that can not easily lead to an efficient hearing protection (communication headsets design) and that also disturb the communications (paper 10, a.o.)

Based on their measurements , some authors (paper 11, a.o.) also a need to establish specific guidelines for human exposure in military propeller-driven aircraft, particularly with regards to comfort and performance.

Finally the last contributions of the symposium, focusing on the Naval Systems, also described or proposed specific prediction tools and performances evaluations procedures.

3.2. Requirements, Test and Evaluation, Standards (Technical Engineering)

Design

Functional performances such as noise, vibration, shocks, engine emission, reliability, safety, survivability, etc.., are increasingly imposed by the international legislation. Two approaches may be considered: the so-called palliative approach consisting into the research of the most incriminated sources of vibrations, acoustic noise, lack of safety,…and resulting into adaptive corrections of existing vehicles (the so-called re-engineering) (papers 4, 22,..) or the enhancement of analytical models and simulation tools leading to the treatment of the aforementioned performances at the earliest possible stage of the design process (the so-called integrated Design Approach) (papers 3, 21, 22, 25, 32,..).

Simulation and virtual prototyping

The building of prototypes or the substantial modification of existing vehicles (varying missions) should be preceded, for cost-effectiveness reasons, by development studies based on virtual prototypes of the intended vehicle: that implies the use of multibody simulation models (papers), FEM (Finite Element Method), BEM(Boundary..) , SE (Super Element) , CMS (Component Mode synthesis) ,…It's however still essential to apply the correct loads to the simulation models , by collecting realistic data on similar systems and even essential to test and evaluate the builded prototype before launching the production of pre-series or series vehicles. It is even essential to take into account with the drawbacks of such simulation tools, a.o. the impossibility to include all the effects of the noisances on the human : simulators could realise the link between both virtual tools and on-the-field measurements: the paper 12 of DLR suggest some assessable solutions.

3.3. Requirements, Test and Evaluation, Standards (Environmental Engineering)

The setting of standards impose the development of interactive models (man-machine-environment). Some analytical methodes have been proposed and may be considered as promising tools for refining existing standards: examples: the paper 19 leading to correctly define isolation systems in the particular case of seating crews, the methods developed at ONERA allowing to deal with external and internal vibroacoustic problems of complex structures in LF (low frequency), MF and HF domains and their applications to aeronautical structures have been presented in the paper 23, the excellent model-based (sea, ship) analysis presented in the paper 30, combined with the design rules introduced in the paper 31 and the next ones allowing the development of criteria dealing with the treatment of the environment (manoeuvring) as well as with the design of the vessel and the improvement of human performances.

4. CONCLUSION

The requirements for performant military vehicles are often limited to three important parameters: the mobility (manoeuvrability performances) , the survivabilty (protection of the vehicle) and the lethality (weapon systems) . The habitability, as it has been defined during this first symposium devoted to driving safety and the ride comfort of the Military Operators, is even often considered as secondary, with, as consequence, a real degradation of the Human performances. Some worrying values of noise levels (SPL from 80 to more than 110 dbA inside High Mobility Vehicles , Light and Heavy Tanks – Propellor, Jet aircrafts or Helicopters) , only compensated by the development of hearing protection systems leading, at the latest, to a 25dBA attenuation , impose a lot of engineering efforts exploiting the structural properties of adapted isolation materials/shapes that have to be taken into consideration by the begin of the design procedure of the future military platforms. Concerning the vibrations/shocks sollicitations, the most critical behaviour is observed by the Land Vehicles: they are tested on various test tracks and it results from several studies that the future vehicles have to integrate active vibration/chassis control systems. We nevertheless observe that no any methodology is proposed to combine the results of vehicles tested on different tracks , a global combination that could lead to an index of global hability satisfaction. Such an index has still to be defined : may-be could it be interesting to invite an AVT Exploratory Group to focus on habitability criteria, modeling, for instance, its work on the this of the WG that has developed the Stanag 4154 (Marine, see paper 34).

This first symposium covered a lot of important, often negelected, factors that can improve the operationability of the Armed Forces: we are convinced that such a symposium may be followed by a second ‘broad-band one ‘ merging the experiences of Land, Air and Sea Experts and allowing a fruitful exchange of methodologies. Beside this general symposium, now that an existing expertise emerges, should it be indicated to foresee two Specialists meetings, one focusing on ‘Enhancement of Nato Mil Veh Habitability by management of Design/Re-engineering Models/Tools’, another one specifically devoted to ‘Enhancement of Nato Mil Veh Habitability by management of Human Factors Engineering Techniques’.