Technical Evaluation Report

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1.0 INTRODUCTION

This report is the technical evaluation report of the North Atlantic Treaty Organization (NATO) Research and Technology Organization (RTO) Human Factors and Medicine (HFM) symposium HFM-124/RSY, entitled "Strategies to Maintain Combat Readiness during Extended Deployments – A Human Systems Approach".

1.1 Theme

Human Systems Integration is the integration of the areas of Human Factors, Personnel, Training, Systems Safety, and Health Hazards into the material lifecycle and operational doctrine to ensure safe and effective operability and supportability. The goals of HSI in the materiel lifecycle are to:

1. Incorporate effective human system interfaces,

2. Minimize life-cycle costs, and

3. Manage risk of loss or injury to personnel, equipment or environment, by assessing and managing the impact of system design on the HSI domains from the earliest stages of materiel acquisition; assessing and managing the impact of the HSI domains on the system design and total life-cycle costs from the earliest stages of materiel acquisition; achieving the required levels of human performance, and making economical demands upon personnel resources, skills and training.

By applying HSI principles to acquisition and support the Human Factors and Medicine Panel is endeavoring to alter how NATO countries currently view systems design and development from one of a "technology" driven society to a "people-technology" driven culture.

1.2 Objectives

The symposium call for participation indicated that the meeting would use current operations as a HSI use-case baseline for future NATO operations, and:

1. Identify the origin of problems confronted by NATO and Partners for Peace (PfP) troops that affect performance;

2. Endeavour to provide strategies to mitigate those outcomes which diminish operational effectiveness;

3. Identify *Human Systems Integration* tools, processes and;

4. Offer recommendations with respect to future R&D support of human capabilities for future deployments.

1.3 This Document – the Technical Evaluation Report (TER)

As stated in the NATO RTO guidelines, a symposium TER is intended to review the work presented as an entity, to place the papers in their correct relation to one another, to assess the overall technical situation in the symposium subject as it emerged from the meeting, to draw conclusions and to make recommendations for further action.

Guidelines to the Technical Evaluator provided by the RTO emphasize the importance that the TER deal thoroughly with the inter-relations of the work presented at the symposium. Instructions clearly indicate that the evaluation focus on the overall technical-scientific situation in the chosen subject areas and NOT be a succession of unrelated individual presentation summaries.

2.0 EVALUATION

This section of the report details the evaluation of the symposium.

2.1 Evaluation of Meeting Relevance

Throughout the workshop, the papers presented clearly indicated the importance of human centred R&D within NATO operations. A general summary of the discussions which took place during the 3 day symposium would imply that:

> *Coalition forces are operating for extended durations, against asymmetric threats, using new classes of platforms/systems, in harsh physical environments, within military force structures that are themselves transforming, with a shortage of personnel to staff those structures, resulting in even higher operational tempo.*

The presentations made, and the related discussions, indicated that NATO's ability to MANAGE HUMAN PERFORMANCE is key to operational success, and ongoing R&D is critical to shape our ability to maintain combat readiness.

2.2 Evaluation of Meeting Structure vs Core Constructs in the Symposium Title

The title of the symposium identified three core constructs, namely:

1. Human Systems Integration
2. Combat Readiness
3. Extended Deployments

Evaluation activities were conducted to determine the extent to which these three constructs were defined, and then addressed in the presentations given and the discussions that were held.

2.2.1 Human Systems Integration

The construct of Human Systems Integration was defined several times early in the symposium. These definitions generally focused on the "official" definitions of HSI that were first created in NATO meetings in 1994, and which have been tailored since then to meet the needs of individual NATO nations.

A typical baseline HSI definition would be "the integration of human factors engineering, health hazard assessment, system safety, training, manpower, and personnel in the acquisition and development of military systems". Extensions to that base definition would be the inclusion of survivability and/or protection by some nations.

Regrettably, the symposium program did not cover the full range of formally defined HSI topics. For example, the following issues were not addressed by the papers presented:

- R&D on Training or Mission Rehearsal Methods or Techniques
- R&D on Personnel Impact Analysis Methods or Techniques
- Many Areas of Health Hazards
- System Safety as it Relates to Human Error

In addition, the symposium content did cover very relevant human performance research areas outside of the formal HSI definition, such as:

- Human in command, psycho-social issues
- Post-traumatic stress
- Medicine
- Performance sustainment medical research

The current HSI definition notwithstanding, these issues, and their inter-relationships must also be considered when conducting a "human systems" approach to advance human performance in combat.

2.2.2 Combat Readiness

The construct of Combat Readiness was defined in one paper as consisting of material readiness, personnel readiness and training level, and then went on to describe a research program investigating the psychosocial influences on personnel readiness as one set of many influencers. There is opportunity here for a more systematic definition of personnel readiness to be developed and defined by the community, building upon this work presented.

2.2.3 Extended Deployments

The construct of Extended Deployments was never defined in the meetings. No discussion was held regarding what an "extended deployment" consisted of, while the papers presented discussed research activities related to human performance ranging from 6 weeks in the field through to many years of field operation across multiple deployment rotations.

The lack of definition did not hamper the meeting in any way, it simply resulted in a broad range of research being presented with vastly different durations of soldier deployment being used as the context for the research.

It was clear, however, that in order to fully appreciate the inter-relationships of all human systems research domains on human performance, that "extended deployment" should be defined in the future as "military operations that span multiple rotation cycles, or a single rotation extended in its duration". Using this type of definition, the inter-relationships of all human research domains can be more fully appreciated. Interrelation examples include:

- The duration of any one rotation cycle (whether 3 months, 6 months, or 12 months) into a deployed operation will vary by nation and their ability to staff an extended rotation cycle.
- The duration of the rotation appears to impact the overall mental health and both the cognitive and physical state of the soldier (based on the range of research presented).
- The duration of the rotation, and the activities that occur within it, affect the level of post-operation stress that a soldier experiences, which in turn affects the ability to recover from that stress.
- The length of time a soldier spends in "recovery" prior to being returned to the operation then determines the extent to which they enter their next operational rotation in a stressed state (in terms of physical or mental fatigue, or in terms of social stresses from family or other domestic issues which may be stressed by the rotation cycle). Examples as extreme as year long postings with less than 6 months at home followed by another year long operational rotation where mentioned in research papers.
- These soldiers entering second, third, or more rotations during "extended deployments" would appear to be operating in a degraded state (based on a range of the research presented), which then means that the human factors research that affects the design of weapons platforms, the training research that affects in-theatre mission rehearsal training requirements, the bio-medical research regarding performance sustainment pharmaceuticals, etc. all must be conducted with a full consideration of this soldier in their 2nd or more rotation. Research should not be based on a well rested, garrison base state, soldier. Such considerations have the potential to affect all domains of human systems research as all NATO agencies plan future R&D work streams.

2.3 Evaluation of Meeting Sub-topics

This section of the report reviews the collection of research within each of the meetings six (6) sub-topic areas. Section 2.3 then reviews the overall integration of the research presented across all topic areas combined.

2.3.1 Human Systems Integration/Human Factors Engineering

This session included the Key Note presentation for the symposium. The papers included two solid presentations of Human Systems Integration programs, one in the army domain from US Army MANPRINT and one from the naval domain from US Navy SEAPRINT. These program papers outlined how HSI programs are increasingly becoming structured and process based. The main "take away" from these papers from an R&D perspective is that HSI programs a key exploitation path for integrated human performance R&D, allowing the results of research to be integrated and applied across all HSI domains in the definition, design, development, and deployment of military systems and capabilities.

The session included an excellent US Air Force paper that applied an HSI approach to the investigation of root causes of Unmanned Aerial Vehicle (UAV) mishaps in the US Army, Navy, and Air Force communities.

The research included consideration of the full range of HSI domains, and was the single most complete application example of an HSI approach to technical research and development during the symposium.

Questions and answers during this period emphasized that HSI programs are lacking full consideration of psycho-social issues related to human performance, and that structured understanding of cost-benefit of an HSI approach is still missing throughout the NATO nations.

2.3.2 Psychological and Sociological Issues

This session focused on cognitive and sociological stressors and how they relate to human performance and operational readiness. There are extensive surveys being conducted by many nations to continue to define and measure cognitive and sociological stress within modern day military operations, and to research, develop, and evaluate a wide range of interventions to manage these stressors. In some cases, integrated research is being conducted that examines the physical stressor link to cognitive stressors.

Many studies document that cognitive stress is increasing, and there is a link to the nature of operations and the work/rest schedule that comes from the deployment and rotation cycle. More soldiers deployed into operational theatres are experiencing "combat" conditions, and deployments are growing in length and frequency resulting in less rest at home between deployments.

This has lead to different studies defining various aspects of Combat Stress Induced Cognitive Decline, whereby the core cognitive capability of the soldier is continually degraded across extended deployments that span multiple operational rotations. Applied research projects indicate that cognitive stress can degrade human performance more than alcohol or drugs (in colloquial terms "soldiers are deploying with degraded cognitive capabilities as if they were intoxicated").

Some R&D activities are investigating stress and psychological support that reflect deployment and rotation cycles, and involve both the soldier and the family, focusing on both individual and unit mission fitness levels.

Research indicates a link between psychological and physical fitness.

New training techniques are being researched and evaluated to mitigate the impact of combat stress induced cognitive decline, including virtual reality based techniques, to condition soldiers for battlefield traumatic situations.

Research continues on pharmacological methods to mitigate/prevent cognitive performance decrements associated with workload, time on task, hypoxemia fatigue, and sleep deprivation.

In addition to cognitive stressors, research continues to define social and cultural stressors and their negative impact on combat readiness and battlefield performance. Some novel methods were reported with new tools to analyze and train for multi-cultural operations. There would appear to be significant opportunities for ongoing R&D in this area .

A key technical observation from this session included the extremely important need to link the results of research on cognitive function decrease with the human factors design criteria that is used to define weapons platforms, tactics, techniques, and procedures, and the training needs analysis that defines the frequency for which training is required to maintain skills in-theatre. It would be expected that the literature on human capabilities used by human factors engineers and training development offices to define systems and training

programs is based on a "rested human in garrison", or even "university population research subject", which means there is likely a "higher than-should-be-expected cognitive function" being assumed by these professionals. Research on cognitive function decline resulting from combat stress and extended deployments needs to guide human design criteria used to shape next generation weapon platforms and training requirements. This would be a human systems approach.

2.3.3 Physiological Challenges

This session reported research on the impacts of physiological stressors such as heat or cold (mostly cold) on human performance, and methods to measure physical performance.

These papers were mainly single issue physical performance research papers, continuing to extend the body of knowledge of human physical performance.

The exception was a paper on strategies to reduce heat stress when wearing NBC protective clothing in the transition from MOPP 1 to MOPP 4 levels of protection. This physiological research paper was unique in that it showed an integrated, "human systems" approach to the research challenge whereby clearly human factors engineers involved in the design of next generation clothing systems, chemical/biological protection scientists, and physiologists where combining their various expertise to both (a) design new concepts for thermal management while providing chem/bio protection, and (b) design experiments that were relevant to the integrated human performance challenge.

2.3.4 Performance Management

During this session, presenters reported some evaluations of procedural interventions to manage work/rest and the associated impact of fatigue on cognitive and physical function. However, the focus was on the fact that due to operational tempo it is not possible to effectively utilize procedural methods (management or work/rest cycles) and that a range of pharmaceutical based interventions to assist with performance management are now available.

Research reported on a range of performance management interventions from caffeine through various pharmaceuticals with data reported on the ability to manage and sustain cognitive and physical function as a result.

Overall the session presented high quality experimental research, clearly demonstrating there are a range of efforts across NATO in these areas which is critical for the maintenance of high operational tempo.

Most studies, however, focused on performance over several days only, and not on the "extended deployment" focus of the meeting. This was likely due to an experimental design issue, as research in this area is focused on shorter duration studies early in the R&D process.

It would be an obvious extension to this research to evaluate the effectives of these interventions on a soldier that is not a "local lab subject", but that is a "recently returned veteran experiencing Combat Stress Induced Cognitive Decline", linking research in the psychological performance domain to the performance sustainment domain (see Section 2.3.2), thereby taking a more complete human systems approach and increasing the operational relevance of the research.

2.3.5 Occupational Health and Protection

This session reported on research related to occupational health and protection during operations.

Many papers indicated the important role of perceived health threats, the limited significance of real exposures, and the importance of unions/families/public opinion being managed through ongoing assessment, analyses, and associated communication.

A number of papers reported on methods to investigate occupational health hazards in the field, with some operational field research results from different operations using different assessment methods.

Participants commented that future research in these areas should study the link between health and medical issues and the impact on military performance and military capability (link occupational health and protection issues with military performance to better inform the military customer).

2.3.6 Current HFM Activities Related to Sustainment of Military Operations

Four related HFM panels were asked to present papers to summarize their activities, to add to the "human systems" aspect of the meeting, and the importance of developing a common understanding of the state of human performance research issues.

The four presentations included:

1. Physical Fitness Standards for Army Tasks
2. Multi-National Operations and Inter Cultural Factors
3. Protection Against Adverse Effects of Toxic Hazards
4. Unmanned Military Vehicles: Human Factors Issues in Augmenting the Force

2.4 Evaluation of the Level of Integration and Interrelations across the Research Domains

This section of the report address the level of "integration" of "human systems" domains that was evident in the research presented, as this was a core driver in the theme of the meeting.

Three levels of "integration" were evident in the papers presented:

1. Historical, Non-Integrated R&D in Human System Domains
2. Partial Human Systems Integration Approaches
3. Full Human Systems Integration Approaches

Each of these levels of integration is addressed in the following sub-sections.

2.4.1 Historical, Non-Integrated R&D in Human Systems Domains

Historically, human research in defence labs across NATO has been conducted in a primarily non-integrated fashion, whereby research was conducted within a single domain. Examples of these domains might include R&D that was conducted to:

- Define the capabilities and characteristics of the human in areas such as:
  - Anthropometrics
  - Biomechanics
  - Basic Physiological Response & Training Effects
  - Response at Altitude and Depth and Under G-force
  - Health Hazards with weapons, in vehicles, under extreme environmental conditions
  - Sensory characteristics (visual, auditory, tactile) and attentional capability
  - Decision Making, under Stress
- Develop Techniques to Shape Human Capabilities in areas such as:
  - Personnel Selection
  - Training Methodologies, the role for Simulation
  - Medical Treatment Techniques
- Develop Applied Analysis Methods to Shape Human-System Design in areas such as:
  - Human Factors Engineering
  - Information Display

Often this R&D was military environment specific, with papers focusing on a Land, Air, or Maritime application domain.

Clearly, there is still a requirement for this type of research, with 46.5% of the papers presented at this "human systems" focused symposium being single human system domain focused (see Figure 1).

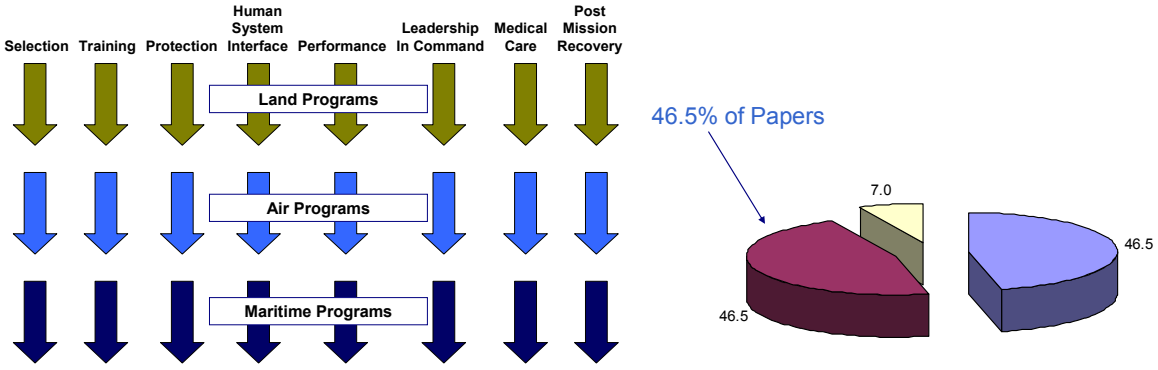

Figure 1: Single Issue Papers

2.4.2 Partial Human Systems Integration Approaches

There is increasing evidence that an "integrated" human systems approach to R&D and the application of knowledge about human performance in the design and operation of military systems and capabilities has value.

This is evident in the growth of Human Systems Integration (HSI) programs in many NATO nations, whereby the applied science workforce that attempts to deal with human systems issues addressed by:

- Human Factors Engineering Experts
- Health Hazard Experts
- Safety Experts
- Training Experts
- Personnel Experts

This focus on human systems integration is starting to be realized in the growth of R&D that includes considerations across multiple human system domains in the design of the R&D studies and the application of the results.

This was evident during the symposium in that 46.5% of the papers illustrated a partial human systems integration approach, whereby at least two different human system domains were involved in the R&D activity (See Figure 2).

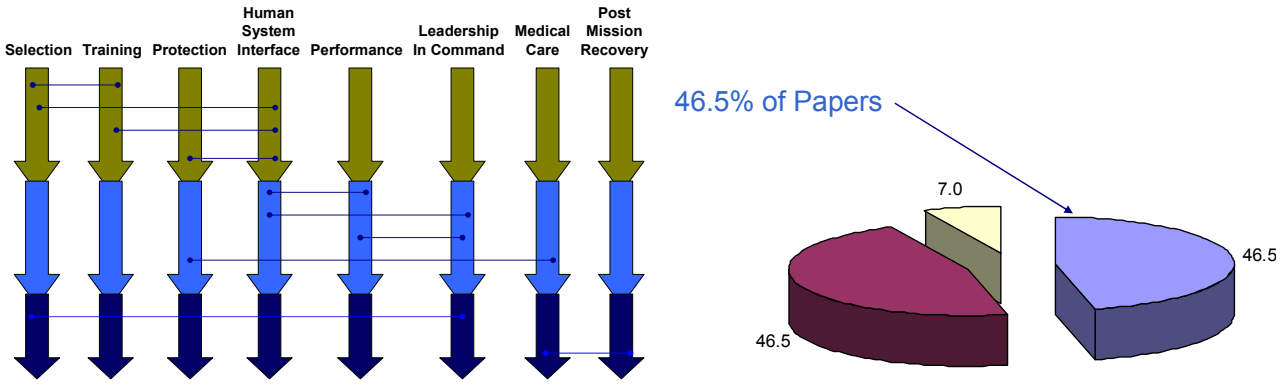

Figure 2: HSI Papers Addressing at Least 2 Domains

2.4.3 Full Human Systems Integration Approaches

It is clear that the complexity of systems-of-systems operations, within a high operational tempo, with high levels of combat stress now introduces the requirement for an even more complete and well rounded "human systems" approach to research on human performance and the application of the results in the design and operation of military systems and capabilities.

R&D is only just beginning to take a full HSI approach. Only 7% of the papers at the symposium took this approach, with the majority of those being HSI program papers (see Figure 3), and really only one paper (the UAV study discussed in Section 2.3.1) being a true scientific analysis considering the full range of HSI domains in a systematic study of human performance and its contribution to overall system performance.

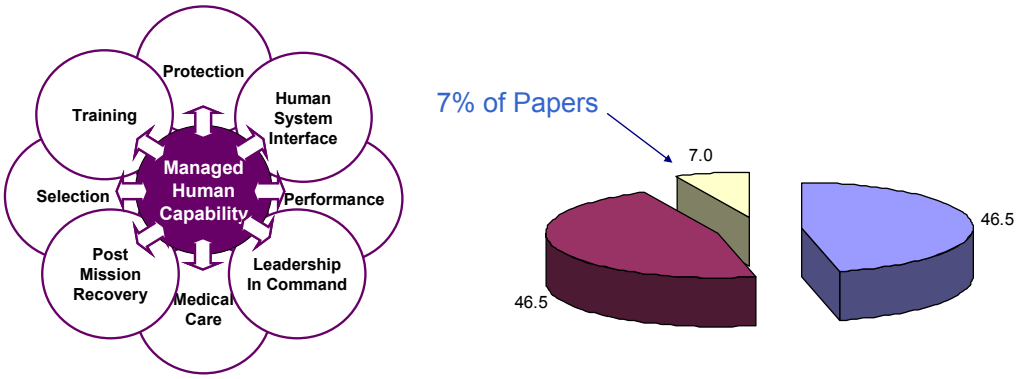

Figure 3: Full Consideration of Human System Issues

2.5 Research Contributions Absent from the Symposium

In order to completely address the full scope of the symposium, thereby addressing the entire Human Systems Integration approach to Combat Readiness, additional research contributions are required. Research contributions notably absent included:

- Personnel
- Training
- Additional Health Hazards (heat, light, noise, vibration, etc)
- Applied Methods, or Integrating Methods that bring human system domains together.

2.6 The Need to Sell the Relevance of Human Performance Research

The very high volume of papers presented at this symposium afforded the opportunity to see how the different NATO Nations frame and present their human centred R&D activities.

It is apparent that only a portion of the NATO community is generally aware that, while human performance issues are increasing in importance, there is still a strong requirement to continually show relevance and to essentially "sell" the value of human related research in a military community that is often dominated by the excitement of "systems" and their operational impact. Properly addressing all aspects of the "Human System" is therefore absolutely essential.

Any applied R&D activity within the military community must address the components listed down the left side of Figure 4 in the design of the research study, and therefore the resulting presentation of that research must include the "story line" that is illustrated down the right side of Figure 4. In many cases the authors/presenters only told a small portion of the necessary story line, such as "..this is our study, and this is what we found and have concluded..". It is very important that this human performance R&D community

continually tell the full story, especially the military relevance component, even when solely in the company of other human performance specialists, to both (a) practice linking the relevance of human research to military operations at all times, and (b) to learn from each other how to best illustrate that relevance.

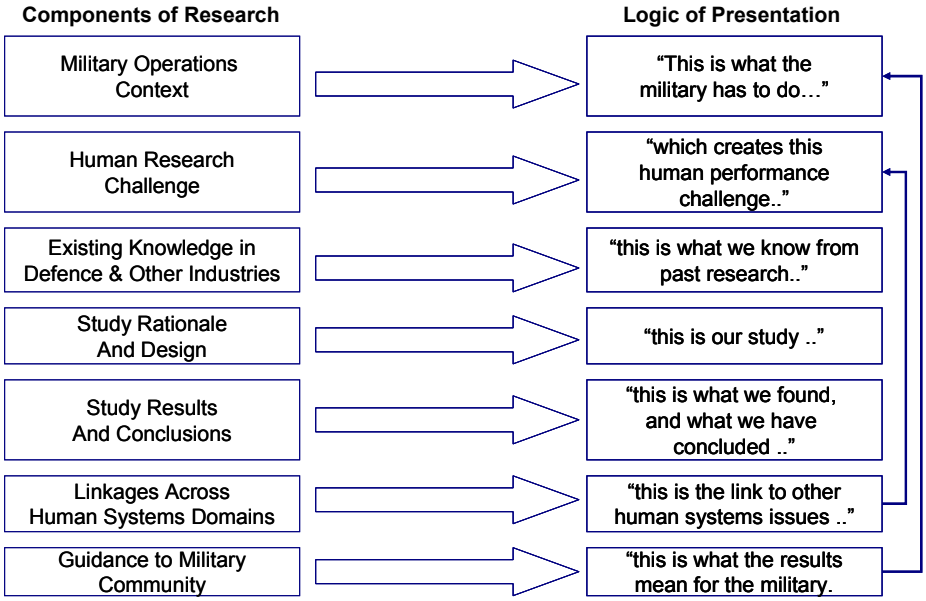

Figure 4: Logic and Structure of Human Research R&D Presentations

3.0 CONCLUSIONS AND RECOMMENDATIONS

The HFM Community obviously needs panels, work groups, symposia, etc. that address narrow human performance issues and it is expected that the established R&D programs in single domains will continue to effectively achieve this aim.

The HFM Community needs to also continue the theme of this meeting, and have sessions that attempt to view human performance from a HUMAN SYSTEMS INTEGRATION perspective. These HSI level meetings need to summarize the state of knowledge in the areas of science that the HFM community is responsible for, such as (but not limited to):

- Hazards (Heat, Light, Noise, Vibration, CBR, Blast, Fatigue)
- Human Factors/Human Computer Analysis & Design Methods
- Psychological and Sociological R&D
- Development of Human Systems Integration Methods

In order to achieve the necessary summary of R&D in this human systems areas, sessions longer than 15 minutes in duration would be warranted. The 15 minute duration of sessions during this symposium was well

managed by the chairs, but it did limit full coverage of the topics and many authors and attendees expressed concerns with the abbreviated time slots.

These HSI level meetings need to point to integrating R&D, and integrated applied solutions that are deployable to MANAGE human performance in the field. In consideration of this Human Systems objective, there were R&D areas missing from this meeting:

- R&D related to specific health hazards were missing.
- Training Methodology R&D was missing.
- Personnel Impact Analysis R&D was missing.
- Human Error R&D was minimal.
- Integrated analysis and application methods R&D was missing.

Outreach to these communities would be beneficial when conducting Human Systems level sessions, to help integrate R&D in the future. Ensuring that this R&D considers personnel operating in a coalition context (a stressor on psychosocial aspects particularly) extended the historical "systems approach" to now include full consideration of how different nations operate with each other.

To assist this necessary integration of human systems research within a NATO coalition context, it essential to:

- Develop a map, that outlines areas of human performance research and how they relate to an integrated human systems understanding.
- Develop a roadmap, that tracks what we know and have documented, and what we still need to "figure-out" based on the future operational context we see.

R&D is still required about the tradeoffs across Human Systems domains. This should be included in future sessions. Illustrated example questions that rose from this meeting, that would contribute to future "integrated" human system research might include:

- As the prevalence of Combat Induced Cognitive Decline increases, is there a requirement to alter the baseline human characteristics used to guide human factors and training development professionals?
- As we increase automation to reduce workload what impact are we having on selection and training requirements?
- As we sustain performance with caffeine or some pharmacological aid, is there is a change in sensory performance that should be accommodated in interface design?
- Are human error assumptions in safety system calculations based on optimal cognitive states, which are now compromised by operational tempo and/or performance sustainment interventions?
- Does caffeine (or other interventions) affect interaction effectiveness or tolerance of other cultures in a command centre under stress?

In order to continually insert the results of Human Systems related R&D, it is important for the global defense community to recognize the importance of the human as part of the system, and the overall capability, during both acquisition and life cycle management. To ensure effective consideration of the human, Human Systems Integration teams should be a component of the Integrated Project Teams (IPTs) established across the defence materiel life cycle.