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**STO MEETING PROCEEDINGS** **MP-HFM-217**

# Supervisory Control of Multiple Uninhabited Systems Methodologies and Human-Robot Interface Technologies

(Commande et surveillance de multiples systèmes sans pilote Méthodologies et technologies d'interfaces homme-robot)

STO Human Factors and Medicine Panel (HFM) Workshop

held in Prague, Czech Republic on 8-10 May 2012.

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**The HFM-217 Workshop on Supervisory Control of Multiple Uninhabited Systems Methodologies and Human-Robot Interface Technologies took place in Prague, Czech Republic, from Tuesday 8th May through Thursday 10th May 2012. The technical part of the program consisted of 2 keynote presentations, 13 interactive Technology Demonstrations followed by an overall summary/award presentation, a breakout session in three groups on Priority Research Challenges followed by a plenary presentation of the results and a subsequent consolidation of these, and a closing session. Approximately 50 researchers participated in this workshop**

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# The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses



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# Supervisory Control of Multiple Uninhabited Systems Methodologies and Human-Robot Interface Technologies

(STO-MP- HFM-217)

## Executive Summary

The HFM-217 Workshop on "Supervisory Control of Multiple Uninhabited Systems – Methodologies and Human-Robot Interface Technologies" took place in Prague, Czech Republic, from Tuesday 8th May through Thursday 10th May 2012. The technical part of the program consisted of 2 keynote presentations, 13 interactive Technology Demonstrations followed by an overall summary/award presentation, a breakout session in three groups on Priority Research Challenges followed by a plenary presentation of the results and a subsequent consolidation of these, and a closing session. Approximately 50 researchers participated in this workshop.

The primary purposes of this invitation-only workshop were:

- To review the recent advances in the areas of Multi-Uninhabited Military Vehicle (UMV) supervisory control methodologies and operator interface technologies, and
- To identify the next steps and critical research needed to achieve future NATO visions for multi-UV employment, and
- To exchange knowledge and ideas with fellow researchers.

The thirteen working demonstrators from HFM-170 that were brought together in one meeting place formed the core of this capstone workshop. The idea of putting them side-by-side was brilliant and created at atmosphere in which discussions were open, constructive, and hands-on, and that inspired the collective thinking about the new challenges that lie ahead of us.

A very well organized and extremely interesting workshop developed. After the interactive technology demonstrator sessions, three breakout groups were formed to respond to three questions:

- What is the highest priority research needs to enable future NATO UV visions?
- Who are the key researchers/laboratories in this area across NATO?
- What are future CONOPS to explore, and what are the most promising interface technologies?

The results were coalesced into a new candidate model of supervisory control that considers all high priority research facets.

There are two main sets of conclusions that can be drawn from this workshop and that can also be read as recommendations:

- The first conclusion is that models need to be developed and selected that can support the human factors engineers balancing act of deciding which type of task distribution in controlling multiple uninhabited vehicles best matches the real-world drivers. A model like that could also be instrumental in providing consistency in user interface design decisions around NATO.

- The second conclusion is based on the observation that the ongoing evolution of uninhabited systems reveals a rapid blurring of the boundaries between the roles of humans and machines as well as the difference between the notions of uninhabited systems and other automated process. Simply put, in the future we need not focus much more on Supervising Uninhabited Systems, but rather on the multi-faceted and reciprocal interaction between human and automated processes. That a particular system is uninhabited will be a disappearing notion. What we need to have is flexible/adjustable, trustworthy automation being operated under user sovereignty. This will likely require not just intense collaboration but potentially even a merge of the field of human factors engineering with other engineering fields such as process automation and computer science.

# Commande et surveillance de multiples systèmes sans pilote Méthodologies et technologies d'interfaces homme-robot

## (STO-MP-HFM-217)

## Synthèse

L'atelier HFM-217 « Commande et surveillance de multiples systèmes sans pilote – Méthodologies et technologies d'interfaces homme-robot » a été organisé à Prague en République tchèque, du mardi 8 mai au jeudi 10 mai 2012. La partie technique du programme a consisté en 2 interventions d'intérêt majeur, 13 démonstrations interactives de technologies suivies d'une synthèse d'ensemble et d'une remise de prix, une session divisée en trois groupes de discussion traitant des problèmes des recherches prioritaires suivie d'une présentation plénière des résultats qui ont ensuite été regroupés, puis d'une session de clôture. Cet atelier a reçu la participation d'environ cinquante chercheurs invités.

Les principaux objectifs de HFM-217 étaient:

- l'examen des progrès récents dans le domaine des méthodologies de commande et de surveillance et celui des technologies d'interfaces opérateur pour de multiples véhicules militaires sans pilote (UMV) ;
- l'identification des prochaines étapes et des recherches essentielles nécessaires à la réalisation des ambitions de l'OTAN vis-à-vis d'une utilisation multi-UV ; et
- l'échange de connaissances et d'idées entre chercheurs.

Les treize modèles fonctionnels de démonstration issus de l'HFM-170 avaient été regroupés sur un seul lieu de réunion et ont constitué le cœur de cet atelier fondamental. Les disposer les uns à côté des autres s'est avéré être une excellente idée qui a généré une ambiance propice à des discussions ouvertes, constructives et pratiques ; cela a inspiré une réflexion collective sur les nouveaux défis qui nous attendent.

Un atelier très bien organisé et extrêmement intéressant s'en est suivi. Après les sessions de démonstration des technologies interactives, trois groupes de discussion ont été constitués pour répondre à trois questions :

- Quelle est la priorité la plus importante pour que la recherche puisse permettre de progresser vers les visions futures de l'OTAN en matière d'UV ?
- Quels sont les chercheurs/laboratoires les plus en pointe dans ce domaine au sein de l'OTAN ?
- Quels sont les futurs concepts d'opération (CONOPS) à explorer, et quelles sont les technologies d'interface les plus prometteuses ?

Les résultats ont été réunis en un nouveau projet de modèle de commande et surveillance qui tient compte de tous les aspects de recherche prioritaire.

Deux conclusions principales peuvent être tirées de cet atelier et servir de recommandations :

- La première reflète la nécessité de développer et sélectionner des modèles qui peuvent aider les ergonomes à équilibrer le choix du type de distribution des tâches de contrôle de multiples véhicules sans pilote qui correspond le mieux à des pilotes réels. Un tel modèle pourrait également contribuer à la cohérence des décisions dans l'OTAN en matière de conception des interfaces utilisateurs.
- La deuxième est basée sur une observation qui souligne que l'évolution continuelle des systèmes sans pilote brouille en fait rapidement, d'une part, la frontière entre le rôle de l'homme et celui de la machine, et d'autre part, la différence entre la notion de systèmes sans pilote et celle d'autres processus automatisés. En bref, il n'est pas nécessaire de nous concentrer davantage sur la surveillance des systèmes sans pilote mais plutôt sur les interactions multiformes et réciproques entre l'homme et les processus automatisés. Dire qu'un système particulier est sans pilote est une notion vouée à disparaître. Ce à quoi nous devons parvenir est un système automatisé fiable, souple ou ajustable qui fonctionne sous la responsabilité de son opérateur. Une simple collaboration intensive risque de ne pas suffire et une fusion sera probablement nécessaire entre le domaine ergonomie et d'autres domaines d'ingénierie, comme l'automatisation des processus ou l'informatique.

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# Workshop on Supervisory Control of Multiple Uninhabited Systems – Methodologies and Human-Robot Interface Technologies

## Technical Evaluation Report

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### *ABSTRACT*

*About 50 human factors researchers gathered in Prague in May 2012 for a workshop to discuss human factors aspects of uninhabited systems. More specifically, they focussed on supervisory control of multiple uninhabited systems. The workshop was strongly enriched by the presence of 13 interactive technology demonstrators from the different nations. Lively and inspiring discusssions ensued and the collective thinking and insight was raised to new levels. Two important conclusions can be drawn from this workshop. First, there is a need of adequate models that can support engineers (during design) and operators (during missions) to decide which type of task distribution in controlling multiple uninhabited vehicles best matches the real-world needs and constraints. This needs to be developed. Second, we need not focus much more on Supervising Uninhabited Systems as such, but rather need to turn our attention to the multi-faceted and reciprocal interaction between human and automated processes. That a particular system is uninhabited will simply be a disappearing notion. What we need to have is flexible, adjustable, trustworthy automation being operated under user sovereignty. This will likely require not just intense collaboration but potentially even a merge of the field of human factors engineering with other engineering fields such as process automation and computer science.*

### *KEYWORDS*

*Uninhabited Military Vehicles, Unmanned Vehicles, Supervisory Control, Human-Machine Symbiosis, Human-Robot Interaction, Cooperative Automation, Mixed Teams, Advanced Operator Interfaces, Swarms*

## 1. INTRODUCTION

### 1.1 Purpose and Scope

The history of the group of scientists and engineers that organised this workshop dates back to 1988 when EOARD sponsored conferences on the topic of a "*Human-Electronic Crew*". After that, NATO RTO followed with the HFM-078 taskgroup on "*Uninhabited Military Vehicles: Human Factors in Augmenting the Force"*. They organised a workshop in Leiden, The Netherlands in 2003, and also a concluding symposium in Biarritz, France in 2006 entitled "*Human Factors of Uninhabited Military Vehicles as Force Multipliers*" (HFM-135). After that, the group continued as taskgroup HFM-170 "*Supervisory Control of Multiple Uninhabited Systems – Methodologies and Enabling Human-Robot Interface Technologies.* With this, their center of attention shifted forward towards the challenges of supervising *multiple* uninhabited systems by a single operator. The focus of their work was on creating high-fidelity technology demonstrators, when possible as a collaborative effort between the nations. These 13 demonstrators from HFM-170 brought together in one place formed the core of this capstone workshop. The workshop announcement text can be found in Appendix A.

The primary purposes of this Workshop were

(1) To review the recent advances in the areas of multi-Uninhabited Military Vehicle (UMV) supervisory control methodologies and operator interface technologies, and

(2) To identify the next steps and critical research needed to achieve future NATO visions for multi-UMV employment, and

(3) To exchange ideas with fellow researchers.

### 1.2 Symposium Program & Participation

The HFM-217 Workshop on "*Supervisory Control of Multiple Uninhabited Systems – Methodologies and Human-Robot Interface Technologies*" took place in Praque, Czech Republic from Tuesday 8th May through Thursday 10th May 2012. The technical part of the program consisted of 2 keynote presentations, 13 interactive Technology Demonstrations followed by an overall summary, a breakout session in three groups on Priority Research Challenges followed by a plenary presentation of the results and a subsequent consolidation of these, and a closing session which included the TER summary presentation of which the current paper is the written version. The detailed program can be found in Appendix B. About 46 participants from a range of nations and affiliations participated in the – invitation only – workshop.

## 2. OBSERVATIONS

My observations are presented below in three separate sections reflecting the overall structure of the workshop.

### 2.1 Overall Impression

The idea of bringing all 13 Technology Demonstrators together in one place was brilliant and created an atmosphere in which discussions were open, constructive, and hands-on, and that inspired the collective thinking about the new challenges that lie ahead of us. A very well organized and extremely interesting workshop developed. The organisers certainly achieved their goals. It must also be said that both keynote presentations contributed strongly to the sense of relevance of the topic, both in scientific terms (Chris Miller) as well as in operational terms (Jeffery Eggers).

### 2.2 Technology Demonstrations

#### 2.2.1 Process

The 13 Technology Demonstrators are described in detail in a publication by HFM-170. During the workshop they were presented briefly in a plenary session. After that, all participants moved to a hall in which the demonstrators had been set up. They were led in small groups in *round-robin* style around the demonstrators in such a way that everyone got to experience all demonstrators. This led to a very intense experience, a hall vibrant with activity.

Taken together, the set of demonstrators displayed a great mixture. Some reflected a single study where others could be seen as the culmination of decades of work of many people. Some demonstrators had been used in field trials or even in large collaborative trials whereas others were laboratory studies. And some demonstrators explored new or future interaction approaches while others performed formal lab evaluations of different existing interaction designs.

The similarity between these Supervisory Control demonstrators was that all of them (1) took the viewpoint of the operator work environment and (2) dealt with positioning (multiple) vehicles and/or observation tasks. This is obviously a reflection of the typically usage of UMVs now and in the near future. However, there are other viewpoints and tasks that need Human Factors attention. For example, what knowledge do we need to support the supervisor of a future autonomous fuel transport convoy? What do we need to be able to support soldiers that – in theatre – encounter UMVs (or swarms of them) that are supervised by someone elsewhere? And what are the human factors implications of supervising UMVs or multiple UMVs that perform actions beyond moving and observation tasks, such as weapon usage or target designation? Certainly these topics need to be considered too.

The feedback forms which were handed out during the demonstration tour were used to summarise the event, an effort that was elegantly carried out by Mr. Harry Funk. A group voting procedure was also part of the process. Awards were given for scientific achievement (GER-1), near-term impact (US-1) and innovation (FRA-1).

### 2.2.2 Distributing Control

The main topic of this workshop is supervisory control and it is therefore relevant to look at the way in which the different demonstrators had chosen to distribute control between human and machine. To be able to investigate this, I plotted all 13 demonstrators on two axes in Figure 1. The horizontal axis describes at what point in time the decision was made concerning the distribution of control between human and machine for that specific demonstrator. This *when*-axis has three categories: the task distribution was either fixed at design time, set during mission preparation, or adjustable during mission execution. The vertical axis describes the type of entity that drove the task distribution. This *driver*-axis has four categories: task-based, depended on operator resources, driven by operator attention, or depended on the abilities of the operator (skills) and the availability of machine autonomous behaviours. The demonstrators could easily be plotted in this matrix, see Figure 1 below.

Many demonstrators showed a task distribution approach that simply assigned certain types of tasks to the operator and other types of tasks to an automated process (first row in Figure 1). Tasks were systematically distinguished using different task models, such as OODA-loop or State2Campaign. In two of these cases (FRA2 and PT) the choice between human and machine was made during mission preparation time (i.e., was fixed for the mission).

In three cases (US1, US4, GER) the task distribution was flexible during the mission and driven by operator resources (second row). In the two US demonstrators it was basically left to the operator to take control whenever s/he had time or felt it was needed; the GER demonstrator featured an elaborate workload model that used estimators and measurements to optimally redistribute tasks.

| When is the choice made → / What drives the choice ↓ | System Design Time (fixed) | Mission Preparation Time | Run Time (flexible) |
|---|---|---|---|
| **Task** (OODA, State2Campaign, ..) | SWE; UGVs [MiSeg]<br>US3; roboleader [MiSeg]<br>NL; telepresence [-]<br>US2; playbook [MiPack]<br>FRA1;swarms [MiPack] | FRA2; predefined Modes [OODA]<br>PT; consoles selected dep. #UAVs [OODA] | |
| **Operator Resources** (workload, senses, ..) | *Probably often implicitly underneath choices based on task* | | US1&4;multi UA/SV;let it go briefly" - principle<br>GER; workload driven (model & measure) |
| **Operator Attention** | *Not possible?* | | NL-planned; select "move to waypoint behaviour" when needed) |
| **Ability** (skills, expertise, ..) | *Probably always implicitly underneath choices based on task* | CAN-1; time criticality in sense&avoid situations | |

**Figure 1: How is control distributed?**

Much more can be said about this, but for here it is interesting to note that the demonstrators (or really: their human-machine interfaces) can be categorised easily and insightfully using these two dimensions. Beyond that, however, it is very relevant to note that in setting up these demonstrators limited systematic attention had been given to the *particular* choice of task distribution for each individual demonstrator. Obviously, for actual operational systems such choices will typically be driven by real-world drivers such as cost, performance, acceptance, reliability, etc... However, to translate these real-world drivers systematically and explicitly into decisions about how and when tasks should be distributed between human and automated process in controlling multiple uninhabited vehicles is not an easy task, and requires the development and selection of appropriate models.

## 2.3 Highest Priority Research Challenges

### 2.3.1 Process

After the interactive technology demonstrator sessions, three breakout groups were formed to respond to three questions:

- What are the highest priority research needs to enable future NATO UMV visions?
- Who are the key researchers/laboratories in this area across NATO?
- What are future CONOPS to explore, and what are the most promising interface technologies?

The amount of ideas and collective insights was overwhelming. All results were presented plenary and the research priorities were then coalesced by Prof. Gilles Coppin into a new candidate model of supervisory control that considers all high priority research facets. This model puts the OODA-loop into the centre and groups all research topics around it in four blocks: people, architecture, automation, and interaction. This model certainly deserves to be worked out in more detail in an effort to help us all categorise the elements of our common research future. The workshop did not attempt to prioritise the material due to lack of time and guidelines and also due the overwhelming scope and volume of the material that was collected.

### 2.3.2 Human-Machine Symbiosis

The range of research ideas and conops that was brought to the table was huge. For instance, for interface aspects someone recapitulated it as the need to have distributed, collaborative, hybrid, service-oriented, ad hoc, hand-held [or even body-integrated] types of control of partly autonomous vehicles and their payloads and just about everything else too. Mention was made of future robots that would necessarily control humans as much as the other way around; of adversaries that control robots possibly including our own; of autonomous schoolbuilding robots; or even of the ultimate “Please win this part of the war for me”-robots. It was also envisaged that autonomous behaviours (military or not) will become omni-present in public environments as well as on the battle field. It was pointed out that in the near future open access to billions of live civil HD sensors streams radiated from mobile phones and the like might become a game changer in the military theatre as well, pushing the observation roles of UMVs into other niches.

To be able to report on this spectrum of results I’ve looked at them from the perspective of a symbiosis between human and machine. I’ve taken this viewpoint because although we do speak of supervisory control, which implies hierarchy, everything that was said during the session suggests a future in which we are much better off approaching the interaction between human and machine from both sides.

From biology we can learn that for any symbiosis to work, one needs to consider the relationship between the parties involved, the context or environment in which it takes place, and the desired outcomes of the symbiosis. In Figure 2 below I’ve listed a high-level summary of the research elements that came forward in the session. Under the heading “supervisory control relationship” you find topics such as natural interaction, mutual trust, etc. For instance, the topic “mutual state knowledge” means that for optimal collaboration both the supervisor and the supervised need to be aware of the current state of the other. It makes sense for a decision support tool to have an estimate of the commander’s current knowledge of the mission progress just as well as it makes sense for the commander to know whether, for example,  a controlled autonomous fuel convoy is capable to self-sustain its mission. Under the heading “environmental context” we see a topic like social interaction which is meant to denote the need for future UMVs to develop the capability to interact socially with the soldiers in the field, or possibly even with the citizens in the villages. Under the heading “Process Output” there is just one topic which has been put there as an example. It denotes the need for a close symbiosis with automated systems including UMVs in order to leverage the information gathering and processing needed to achieve decision superiority.

| Supervisory Control **Relationship** | Environmental **Context** | Process **Output** |
|---|---|---|
| • Language, Semantic Gap, Dialog<br>• Natural Interaction<br><br>• Mutual Transparency<br>• Mutual State Knowledge<br>• Mutual Learning, Adaptation<br>• Mutual Trust, Reliance<br><br>• Flexibility<br><br>• Ad hoc relationships<br>• Multiple relationships<br>• Are you ready for a relationship | • Environment Understanding<br>• Social Interaction<br>• Pervasiveness of Autonomous Behaviours<br>• Civil sources | • Need for leverage on information processsing (e.g. image analysis assistance) to achieve decision superiority |

**Figure 2: Some critical success factors for human-machine symbiosis.**

In much of the above the old differences between the roles of humans and machines as well as the difference between the notions of uninhabited systems and other automated processes is absent. Simply put, in the next future we need not focus much more on Supervising Uninhabited Systems but rather on the multi-faceted and reciprocal interaction between human and automated processes. That a particular system is uninhabited will be a disappearing notion. It will be treated like any other automated process, like image analysis. This will have a profound influence on the way we need to approach these interactions. No longer can this be approached from a human factors engineering point of view. Rather, we need to melt human factors engineering together with other engineering fields such as process automation and computer science to be able to create those systems that are needed for NATOs future UMV operations.

## 3. CONCLUSIONS & RECOMMENDATIONS

An important conclusion I'd like to draw is that putting in the effort of bringing a large number of working demonstrators from different nations together in one meeting place is very rewarding. It stimulates the discussion and thought exchange tremendously and creates a very vivid working atmosphere. Even though the cost turned out to be prohibitive in some cases for bringing everything that was envisioned, the gist was always conveyed easily, even with simpler means. I recommend the use of this approach more often.

There are two main sets of scientific conclusions that can be drawn from this workshop and that can also be read as recommendations.

1. The first conclusion relates to the words *supervisory control* in the title of the workshop and became apparent after experiencing the 13 demonstrators and the associated research programs. It turned out that for each of these demonstrators implicit decisions had been made about the particular distribution of control between human and machine. Along the *when*-dimension the task distribution was either fixed at design time, set during mission preparation, or adjustable during mission execution. The

elements that drove the task distribution were either task-based, depended on operator resources, were driven by operator attention, or were depended on the abilities of the operator (skills) and the availability of machine autonomous behaviours. All demonstrators (and therefore all their human-machine interfaces) could be mapped onto these two dimensions, which is interesting in itself. However, it also became clear that limited systematic attention had been given to the *particular* choice of task distribution for each individual demonstrator. Obviously, for actual systems such choices will typically be driven by real-world drivers such as cost, performance, acceptance, reliability, etc... The first conclusion is therefore that models need to be developed and selected that can support the human factors engineers balancing act of deciding which type of task distribution in controlling multiple uninhabited vehicles best matches the real-world drivers. A model like that could also be instrumental in providing consistency in user interface design decisions around NATO.

2. The second set of conclusions relates to the future of Human Factors of Uninhabited Systems as a research field. The workshop sessions on *highest priority research needs to enable future NATO UMV visions* revealed a wealth of ideas. But the main outcome for me is that the difference between the roles of human and machine as well as the difference between the notions of uninhabited systems and other automated process will blur. Simply put, in the next future we need not focus much more on Supervising Uninhabited Systems but rather on the multi-faceted and reciprocal interaction between human and automated processes. That a particular system is uninhabited will be a disappearing notion. In a sense, a future HFM taskgroup might be focused on Affective Control of Multiple Human Effectors. But really, what we need to have is flexible, trustworthy automation being operated under user sovereignty. This will require not just intense collaboration but potentially even a merge of the field of human factors engineering with other engineering fields such as process automation and computer science.

# APPENDIX A:
# Original Workshop Meeting Announcement Text

## Supervisory Control of Multiple Uninhabited Systems - Methodologies and Human-Robot Interface Technologies

### A Workshop Examining the Human Factors of Multi-Uninhabited Vehicle Supervisory Control

The primary purposes of this Workshop, which is by invitation only, are to 1) review recent advances in the areas of multi-Uninhabited Military Vehicle (UMV), supervisory control methodologies and operator interface technologies, and 2) to identify the next steps and critical research needed to achieve future NATO visions for multi-UV employment. A key aspect of this workshop will be the detailed presentation, discussion, and critique of 10 to12 independent Technology Demonstrations (TDs) associated with UV supervisory control. These TDs have occurred within the past three years across eight NATO nations and associated with NATO Research and Technology Organization (RTO) Human Factors and Medicine (HFM) Technical Task Group 170. Many of the demonstrations will be interactive, with time allotted to allow informal detailed discussions to take place between participants and demonstration leads in order to get a more complete understanding of the specific research challenges and lessons learned. Using knowledge gained from these TD discussions, this workshop will then seek to identify additional research required to achieve true multi-UV supervisory control for future NATO operations. This workshop will also identify key programs and individuals (researchers, engineers and scientists) who are contributing to the UV human factors area from NATO countries and it will provide a valuable forum for the experts of several countries to measure progress in this critical technical area. It will also foster for the exchange of new ideas, concepts, and data relative to the supervisory control of multiple semi-autonomous entities.

This workshop will bring together experts representing Uninhabited Military Vehicle (UMV) operator control station design, automation, adaptive interfaces, multi-sensory interfaces, decision support systems, and networked operations to wrestle with unresolved issues such as:

*Supervisory Control Frameworks*

*Advanced UMV Operator Control / Display Interface Technologies*

*Supervisory Control Decision Systems Concepts*

*Application of Adjustable Levels of Automation*

*Networked UMV Applications and Systems of Systems*

The workshop will be unclassified, and will include overview presentations, technology demonstrations from HFM-170 Task Group members, posters, and group / workshop discussions. All invitees are expected to contribute through participation in discussion groups and group reports, leading to the development of an advisory report to NATO RTO.

# APPENDIX B:
# Detailed Workshop Program

**Monday, 7 May 2012**

- 18:00 – 22:00 (Optional) Technology Demonstration set-up

**Tuesday, 8 May 2012**

- 08.30 – 09.00 Welcome / Introductions by Mark Draper/Leo van Breda
- 09.00 – 10.00 Keynote Presentation : "*Supervisory Control Frameworks: Cheaper by the Dozen*" by Chris Miller & Gilles Coppin
- 10.00 – 10.30 Break
- 10.30 – 12.30 Technology Demonstration Summaries
  - *CAN-1: Dr. Siu O'Young – Multi-crew Control of a Single Unmanned Aircraft*
  - *CAN-2: Dr. Geoff Ho – Supervisory Control: OmniSense*
  - *FRA-1: Prof. Gilles Coppin – UAV Swarm Control - SMAART Project "Interacting with multi-agent systems / UAV swarms"*
  - *FRA-2: Dr. Angélica Léal – PEA "Human Factors & Authority Sharing" (FHPA)*
  - *GER-1: Prof. Dr. Axel Schulte – Cognitive and cooperative assistant system for aerial manned-unmanned teaming missions*
  - *NL-1: Dr. Chris Jansen – Remote auditory target detection using an unmanned vehicle – comparison between a Telepresence headtracking 3D audio setup and a joystick-controlled system with a directional microphone*
  - *PT-1: Mr. Gil Gonçalves – Supervisory Control: Optimal Distribution of Workload Among Operators for Mixed Initiative Control of Multiple UAVs*
  - *SWE-1: Dr. Peter Svenmarck – Task Switching for Multi-UGV Control ; Supervisor Control of UGVs for Tactical Reconnaissance*
  - *UK-1: Mr. Robert Taylor – Dynamic Airborne Mission Management*
  - *US-1: Mr. Tom Hughes – Multi-UAV Supervisory Control Interface Technology (MUSCIT) Demonstration*
  - *US-2: Mr. Jay Shively –Delegation control of Multiple Unmanned Systems (DELCON)*
  - *US-3: Mr. Michael Barnes – Intelligent Agents as Supervisory Assets for Multiple Uninhabited Systems: RoboLeader*
  - *US-4: Dr. Glenn Osga – Unmanned Surface Vehicle Control & Monitoring Human-Computer Interface for Amphibious Operations*
- 12.30 – 13.30 Lunch
- 13.30 – 15.00 Technology Demonstrations: Interactive Demos and Critique

- 15.00 – 15.30 Break
- 15.30 – 17.10 Technology Demonstrations: Interactive Demos and Critique
- 17.10 – 17:15 Wrap Up
- 17.15 – 19.00 Early-Evening Informal Social

**Wednesday, 9 May 2012**

- 09.00 – 10.30 Consolidated Review and Discussions of Technology Demonstrations by Mr. Harry Funk & Mr. Tim Barry
- 10.30 – 11.00 Break
- 11.00 – 12.00 Keynote Presentation: "*Vision for Future NATO Unmanned Vehicle Control & Operations*" by Col. Jeffery Eggers
- 12.00 – 13.30 Lunch
- 13.30 – 13.40 Charge to Work Groups by Dr. Mark Draper & Mr. Jay Shively
- 13.40 – 15.30 Breakout Group Discussions: Priority Research Challenges to Meet Future Vision for NATO UVs (WORKING GROUP LEADS: Jasper Lindenberg, Ruben Strenzke, and Angélica Léal)
- 15.30 – 16.00 Break
- 16.00 – 17.00 Breakout Group Discussions <continued>

**Thursday, 10 May 2012**

- 09.00 – 10.30 Group Presentations on Results of Breakout Meetings (30 min each)
- 10.30 – 11.00 Break
- 11.00 – 12.00 Research Priority Consolidation/Discussion by Prof Gilles Coppin
- 12.00 – 12.30 TER Summary by Dr. Hendrik-Jan van Veen
- 12.30 Closing Comments by Dr Leo van Breda & Dr. Mark Draper