Chapter 8 – CONCLUSIONS AND SUMMARY

Chapter Lead: J. Reising

Contributors: J Reising, R. Taylor

Force augmentation issues relevant to the human operator have been shown to exist on several levels, including individual UMV control station design, vehicle interoperability, and integration of UMVs with manned systems. On the basis of the material reviewed by the RTO HFM-078 Technical Team, and reported in detail in the preceding chapters, many topics, issues and conclusions related to UMV human factors have been raised. In an attempt to summarize this vast effort, five major issues were extracted that cut across several sections of this report. Each issue is followed by a representative sample of conclusions associated with it. These identified conclusions are not at all intended to be exhaustive. Rather they serve primarily to illustrate the general findings and understanding with regards to each issue.

8.1 ISSUE 1: HUMAN AUTHORITY AND RESPONSIBILITY IN DEALING WITH UMVs

In modern asymmetric warfare, well-organized belligerents ignore the legal requirement under international law to be readily distinguished from the civilian population. They merge with the civilian population, they do not travel in identifiable military vehicles and they use sophisticated deception tactics. Thus, in modern warfare, it is very difficult for an autonomous machine to discriminate between civilians and military targets.

8.1.1 Conclusion 1

Experienced human perception and judgment are needed to assess risks, to consider both the immediate and broader context, to judge the consequences and implications of action, and if possible, to anticipate, see through and counter any new deception tactics. Consequently, any autonomous system will remain dependent upon 'human-in-the-loop' targeting decisions, where a human makes the ultimate decision to engage a target.

8.1.2 Conclusion 2

Human involvement is required in military operations to direct and plan the use of military capability, and to ensure lawfully correct use of lethal force. This is achieved through the application of human command authority, responsibility and accountability, and competency. With autonomous UMVs, some of that responsibility is delegated to increasingly competent computer controlled machines, but the authority and accountability for the delegation ultimately remains with humans.

8.1.3 Conclusion 3

Methods for expressing detailed system automation level requirements (e.g., Pilot Authorisation and Control of Tasks (PACT)) maintain operators' authority by enabling them to delegate responsibility for tasks to the computer through a set of contracts that limit autonomy and bound the behavior of the aiding system, while maintaining the operators' authority through executive control.

8.1.4 Conclusion 4

Delegation approaches to interaction with intelligent yet subordinate human operators have worked repeatedly throughout history and, particularly, the history of warfare. Automation in the form of UMVs will increasingly take its place as one of those actors. Since we want it to be intelligent, capable and effective, yet remain subordinate, we will increasingly need methods for enabling it to interact with us in the ways that we trust and are familiar with. Since delegation is the primary method that fits that bill, it only makes sense to pursue delegation approaches to human interaction with automation.

8.2 ISSUE 2: THE ROLE OF HUMAN OPERATORS WITH ADVANCED AUTOMATED AND INTELLIGENT UMV SYSTEMS

A number of fundamental questions and key issues can be identified concerning the role of humans in advanced automated and intelligent systems. There is an inexorable trade off between higher levels of automation and unpredictability. In particular, there is uncertainty over how to optimize the use of human and computer decision resources, while preserving a human-centric system.

8.2.1 Conclusion 1

Automation must be designed to augment, not hinder, human capabilities. It is critical for appropriate use of automation that the user understand how the automation works and what mode the automation is in. Additionally, operator interfaces must provide rapid visibility into the current status and future plans of automation for shared human-automation situational awareness.

8.2.2 Conclusion 2

Intelligent decision support interfaces will need to be designed such as to allow independent operator assessment of the situation as well as the rationale for any automated classifications/recommendations.

8.2.3 Conclusion 3

The system should perform automatic activities as if they were completed by the operators themselves during automatic task execution. There will be less unattended actions of the system, which improves the operators' awareness and comfort, increasing total system safety and performance. Natural operation is particularly important when the operators have to override the automatic system by switching back to manual control.

8.2.4 Conclusion 4

Automation does not reduce operator workload per se; it may change the nature of the workload or may even increase it. The operators, as supervisors of automated systems, essentially become long-term monitors with periodic requirements to intervene when necessary. The cognitive workload associated with this supervisory control may well be higher than the workload of physical control.

8.2.5 Conclusion 5

All automation is not created equal. It can be brittle, unpredictable, and prone to bias. Knowing about these pitfalls is half the battle. A designer must carefully look at where and how the automation may fail and ensure the operators know the mission impact (if any) of the failure.

8.2.6 Conclusion 6

Human knowledge, experience and judgment provide unique capability to analyze safety risks and to think ahead in uncertain and novel situations. The challenge is to provide information and decision systems that protect and preserve the human operators' key role, and that augment and enhance the operators' cognition rather than replace the operators in complex decision making.

8.2.7 Conclusion 7

New approaches to the use of automation propose adjustable levels of computer autonomy with a strong socio-technical and cognition basis. These seem likely to provide sensible architectures for distributed, multi-agent intelligent systems that can be more readily appreciated by human operators than traditional automation approaches.

8.2.8 Conclusion 8

Automation has often been approached from the bottom up, starting with the system components. An alternative is to approach the problem from the top down, using the requirements to joint system performance as a starting point. In this approach the emphasis is on operators being in control. A multi-layered Extended Control Model (ECOM) provides a good basis for understanding the consequences of automation and the needs of various types of information to support views of the past, present, and future.

8.3 ISSUE 3: INTEROPERABILITY OF UMV SYSTEMS

Migration of operator control is currently regarded as one of the most complex and risky phases of UMV operations. Because it includes changes in the locus of control within functional, temporal, or physical domains, many system parameters may be changed and difficult procedural and technical issues can be involved. For instance, in current long endurance UAV operations, control may be transferred between operators in a control station (e.g., crew changeover), between control stations (e.g., vehicle handoff), or among members of a crew (e.g., task execution). Migrating control between dissimilar systems is particularly difficult because of issues of system synchronization.

8.3.1 Conclusion 1

The control system will need to be designed to allow for system synchronization and facilitate operators' achieving an adequate level of situational and system's awareness so a handover can be safely performed.

8.3.2 Conclusion 2

UAV interoperability requires development of a standard set of control station design specifications and procedures to cover the range of potential UAV operators and applications across military services and countries.

8.3.3 Conclusion 3

Resolving issues associated with connectivity, knowledge and action consistency, and transfer of control must be addressed during the early stages of systems engineering to ensure proper human-centered development of UMV systems within a system-of-systems architecture.

8.3.4 Conclusion 4

Migration of control between operators at physically dispersed locations may require initiation and alignment of systems, one or more data and communications links, and possibly even cryptological equipment. It may also require coordination with external command and control agencies. This situation may be made more complex if a face-to-face debrief is not possible.

8.3.5 Conclusion 5

Migration of operator control needs to be coordinated prior to the actual event. This means the specific procedures and information to be exchanged should be identified during the mission planning process. The procedures should be available in checklist form and should have been previously validated to minimize the unintended effects of operator input errors as well as be applicable to both nominal and off-nominal situations.

8.3.6 Conclusion 6

Since migration of operator control of UMVs demands a high level of crew coordination, all involved personnel should have initial and recurrent proficiency training in control transfer procedures as well as crew coordination.

8.3.7 Conclusion 7

Team performance directly correlates with team members' levels of situational awareness (SA). Accordingly, in order to safely migrate operator control, it is imperative the operators gaining control have at least the same level of SA as the operators releasing control. Operators should strive for the highest level of SA (e.g., level 3 SA) prior to assuming control of a UMV. Level 3 SA is defined as prediction of the future status of one's own situation and the surrounding elements. SA may need to be achieved at the system, operational, and mission levels.

8.4 ISSUE 4: CONTROL STATION DESIGN

There is a vast expanse of data that is available to UMV operators in a network centric environment. Coupled with the limitations of human information processing, autonomous UMV supervisory control issues, and the impact of environmental stressors on cognitive performance, control station designers face a huge challenge to provide a user centered design.

8.4.1 Conclusion 1

It is important that any UMV operator interface design follow a multi-disciplinary user-centered design process. The goal of user-centered design is to ensure the final design meets the users' needs and expectations. The process of requirements definition (user profiles, work flow, task analysis, and information architecture) and repeated interface design development and iteration (through multiple usability assessments and formal evaluations) will increase the likelihood of obtaining fully functional and easy-to-use interfaces.

8.4.2 Conclusion 2

It is important to recognize the unique challenges levied upon the UMV operators including the effects of system time delays, bandwidth limitations (which can be intermittent), datalink degradations/dropouts, and the

loss of multi-sensory information often afforded to onboard operators. However, the physical separation of crew from vehicle might also offer some unique benefits that should be exploited. Besides the obvious benefit to crew safety, it is quite likely that available bandwidth and the variety of available information sources might be, in certain cases, far greater for a geographically-separated UMV crew than for onboard operators, potentially resulting in more situational awareness rather than less.

8.4.3 Conclusion 3

As technology advances, the role of the UMV operators must change as well. Therefore, UMV operator interfaces must be tailored to match the capabilities and limitations of the host system and intended mission. These operator interfaces must take into account issues associated with automation management, including vigilance effects, brittle/clumsy automation, sudden workload spikes, etc.

8.4.4 Conclusion 4

In the future, a new interface paradigm for controlling next generation UMVs may be required to enable a single supervisor to control multiple semi-autonomous UMVs. Because these UMVs will have the capability to make certain higher-order decisions, independent of operator input and pre-defined mission plans, operators will face a new set of challenges. Specifically, they will be required to rapidly judge the appropriateness of these decisions and assess their impact on overall mission objectives, priorities, etc. Future operator interfaces will need to be tailored for multi-UMV control and to allow the operator the capability to easily inspect/override the autonomous UMV decision-making logic. These interfaces will also need to provide information fusing/filtering algorithms, intelligent prioritization/cueing logic, and possibly some form of adaptive task allocation in response to rapidly changing events and/or workload levels.

8.4.5 Conclusion 5

The ‘T’ arrangement of the airspeed, altitude and heading in aircraft cockpits has led to a standard arrangement in manned aircraft. This has allowed pilots to move from one aircraft to another with minimum levels of negative transfer. No such standards exist for UMV control station design. This has led to vastly different designs by each manufacturer and the result that operators must be trained very specifically on each platform control station, with little or no advantage of previous learning. This lack of standard design components, at least for fundamental information, must be addressed for UMVs to reduce training costs, logistics and operation errors.

8.4.6 Conclusion 6

UMV operator interfaces need to be designed with an understanding of where the human information processing bottlenecks occur in a task flow. As a result, the operator must be given information in a form that is easily perceived, interpreted, and responded to.

8.4.7 Conclusion 7

Since UMV operators are currently limited to a reduced stream of sensory feedback delivered almost exclusively through the visual channel, there is reason to believe that situational awareness and performance may be improved through multi-sensory interfaces. These improvements might stem from an increase in the operators’ sense of presence in the remote environment, from increased information throughput provided by multi-sensory stimulation, and/or a more intuitive presentation/control of information. The result can be

improved performance over conventional visual interfaces. Technologies such as spatialized audio, haptic/tactile stimulation and speech recognition systems appear especially relevant to multi-UMV operations.

8.4.8 Conclusion 8

The sense of presence (i.e., "being there) is often concomitant with engagement on the part of the operators, and this may be critical when the operators take on a supervisory role over semi-autonomous UMVs. In this situation, there exists the potential that the operators will 'fall out' of the control loop and may have difficulty re-entering when necessary. Immersion in a virtual environment (i.e., the UMV operator interface) may facilitate intuitive interaction and ensure that the operators remain engaged in the mission even if not directly flying the vehicle.

8.5 ISSUE 5: OPERATOR SELECTION AND TRAINING

UMVs are new technologies for most militaries around the world, and potentially require new jobs, positions, occupations, and units to command and control these assets. On the other hand, militaries have similar manned vehicles with similar payloads. The personnel that operate these vehicles are highly skilled and knowledgeable, and these skills and knowledge are potentially transferable to operating UMVs. Moreover, if UMVs were highly "intelligent" or "autonomous" then perhaps only general skill and knowledge levels would be required to operate the vehicles and their payload.

8.5.1 Conclusion 1

The best way to prevent the loss of operators' skills is to periodically give the operators dedicated training. Another possibility is to require the operators to perform skill critical tasks manually at certain times, even though the task may have been allocated to the automated system.

8.5.2 Conclusion 2

Experience improves operators' cognitive throughput, allowing them to devote limited attentional resources to future problems while automatically attending to immediate perceptual and motor tasks.

8.5.3 Conclusion 3

Teams comprising fundamental knowledge, skills, and abilities (KSAs) are better equipped to fulfil mission goals. KSA requirements are not completely transferable from in-person teams to virtual (distributed) teams and vice versa. The densely computer-mediated communication environment of the virtual realm requires a heightened adeptness at managing digital conflict, text-intensive interactions, and media selection.

8.5.4 Conclusion 4

Relative to virtual teams, social control is particularly valuable when the need for sharing tacit knowledge increases over socially impoverished channels of virtual communication, where conflict may escalate due to teamwork issues engendered by cultural difference in communication and problem-solving styles and approaches.

8.5.5 Conclusion 5

Teams need environments which facilitate efficient and effective command and control information sharing. When team members trust each other and the team infrastructure, are educated about organizational structure and processes, and understand information processing, fluid communication is enabled.

8.5.6 Conclusion 6

Team members need to quickly identify individual and team information needs, fulfil the needs, and disseminate, synthesize, and integrate that knowledge into mission activities. Consequently, situational awareness requirements can be addressed by supporting social networks with access to databases, human capital, and technology.

8.5.7 Conclusion 7

The transfer of skills and knowledge, and the requirement for general skill and knowledge levels will contribute to Force Multiplication by drawing from an existing, broader pool of people that can operate UMVs.

8.6 SUMMARY

A review of the many issues identified throughout this report highlights two major emphasis areas for future NATO RTO focus. The first area involves the study of tools and techniques for distributive collaboration/ command and control of UMV teams. Issues of virtual teaming, communication bandwidth, collaboration methods and responsibility/authority are a few aspects of this important area. The second area centers on the methodologies and technologies to enable flexible human supervisory control of multiple, highly-automated UMV assets. Issues with this key area include human-automation challenges and mitigation techniques, flexible levels of automation, situation assessment and decision support tools for human-robot systems, multi-modal interfaces, and anticipatory support aids.