Human Automation Integration for Supervisory Control of UAVs

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SUMMARY

With the increasing use of uninhabited military vehicles in air, land, naval (surface and underwater) roles, we need to know more about factors affecting operator "engagement" - cognitive/conative/behavioural task involvement - with systems exploiting virtual media technology, in particular for reach-back, remote supervision of operations involving use of lethal force. UK experience in operating Predator has led to concerns about the operator needing emotional connectivity to "feel the granularity of the battle-space", about the "morality of altitude", and the potential for the "playground bully" to become the mode of control. Research has demonstrated the difficulty of providing sustained levels of cognitive engagement for operators at remote control stations providing supervisory targeting veto. It may be possible to mitigate these risks and to augment human involvement and engagement strategies through operator selection, training and system design. Consideration is needed of the relevance of mission and decision enabling technologies for augmenting engagement. These enabling technologies include advanced human-computer interfaces, virtual media, multi-modal "immersive" synthetic environments, task and user monitoring and modelling, collaborative technologies and communication techniques such as semantic information/knowledge web approaches to decision effectiveness.

1. BACKGROUND

Virtual media studied from a socio-technical systems or human factors (HF) perspective, considers virtual technology as tools for human use, providing enabling and augmentation of human capability. In the military environment, virtual media technology is exploited extensively for training purposes and increasingly for prosecuting military operations under Network-Centric Warfare (NCW) concepts. A potentially useful framework, arising from tele-operations research (Leo van Breda, TNO, personal communication), is to consider virtual media by distinguishing between *virtual presence* (e.g. user emersion, synthetic visualisation of agents, robotic behaviour), *virtual cognition* (e.g. automatic detection/recognition systems, machine or artificial intelligence (AI), decision systems, agent oriented software), and *virtual communication* (e.g. digital/electronic vision and telecoms systems, synthetic speech, 3-D vision/sound, tactile interfaces, head mounted displays). A rapidly emerging NCW technology that exploits all of these dimensions of virtual media, both in military training and operations, is Uninhabited Air Vehicle (UAV) systems. In one recent research implementation, the US AFRL "Vigilant Spirit" Research UAV Control Station (UCS) supports supervision of automatic air-to-air refuelling of multiple UAVs by presenting the operator with variable synthetic views of the positioning of the UAVs with respect to synthetic views of refuelling tanker aircraft (Mark Draper and Greg Feitshans,

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US AFRL/HE, personal communication). UAVs are a class of Uninhabited Military Vehicles (UMVs). HF of UMVs have been studied under RTO HFM-078/RTG-017 Technical Team. This paper seeks to consider HF of virtual media in the context of the UAV/UMVs, as investigated by RTO HFM-078/RTG-017, and in particular the military relevance of UAV/UMVs. The Final Report of HFM-078/RTG-017, currently in press, will provide a broader and more detailed analysis of these UMV HF issues [1].

UAVs are enablers of military capability with clear endorsement at the highest level. Many NATO Nations have active programmes to develop and integrate UAV systems into the front line military force mix. UAVs are most commonly characterised as dealing well with 3-D tasks – dull, dirty and dangerous. They are used extensively in intelligence, surveillance and reconnaissance (ISR) roles, affording persistence in the provision of critical information, without risking lives. Increasingly, they are being considered for combat and support roles. Modern warfare needs military capability to respond to the threat of conventional hostile force and to the challenges of asymmetric conflicts, where political and military success relies on effects-based targeting and operations. In the age of NCW, or Network Enabled Capability (NEC), ISR information supplied by UAV systems can be a key combat multiplier in the hands of a commander**.** Automation technology and computer-based information processing are increasingly important for balancing affordability, capability and achievability with increasing pressures on scarce, skilled human resources. Important questions remain about what realistic effects can be expected to be achieved by UAVs in the uncertain, ambiguous and non-linear battle-space of the future, including how international law will interpret robotic warfare in the future. However, the main consideration of interest is not so much the military relevance of UAVs, since this seems mostly self evident. Rather, the key issue is to establish why HF are important military relevant issues with “unmanned” technologies. Since UAV technologies are expected to actually reduce human involvement in some tasks, it is not self evident why HF issues should warrant raised attention.

2. UAV HUMAN FACTORS

UAVs are valued variously as force-multipliers, as augmenters of the force, and as adding a new component to the military force mix. But ultimately, UAVs are tools for human use. Human effectiveness is the key to all military capability. UAVs are enablers of human effectiveness and military capability. Human involvement in UAV systems is of paramount importance. HF issues need to be in the sharpest focus to mitigate the unacceptable risks of de-humanisation of decision-making in warfare.

Human factors issues are crucial to the successful operation of UAV systems. Recent USAFRL flight safety analysis data show HF to be a causal factor in 70% of UAV accidents. HFM-078/RTG-017 identified that force multiplication can be achieved by addressing the following human factors issues and challenges for UMV systems including UAVs:

- Collaborative Work – Optimal Task Distribution
- Virtual team performance
- Manned/Unmanned collaboration
- Interoperability
- Flexible level of automation
- Optimization of operator/vehicle ratio
- Control Stations – Intelligent Operator Support
- Operator functional state assessment
- Intelligent adaptive interfaces
- Cognitive cooperation
- Knowledge management systems

From a high level military perspective, Air Chief Marshall Sir Brian Burridge, Commander in Chief, Strike, of the Royal Air Force (RAF) believes that in order to appreciate the capability of UAVs, we need to appreciate their limitations and benefits, but that understanding of the human dimension is the most important of all – knowing how to use them, task them and to integrate them [2]. Use of UAVs is generally justified on grounds of capability, affordability and safety. UAVs can make certain tasks safer by reducing human involvement and risk to life, allowing the possibility of human resources being re-deployed more efficiency and effectively. This produces complex changes in the balance and priority of HF issues for UAV systems. Paradoxically, for many aspects of UAV system engineering and operation, the proper consideration of HF has even greater military relevance. Human involvement remains essential throughout the UAV system life cycle, including UAV operations. As a discipline, HF provides the tools for understanding and ensuring the correct human involvement in the UAV system life cycle. Obviously, UAV habitability is not a concern. However, vehicle maintenance is still needed. Vehicle control and safety becomes a complex issue, especially when mixing UAVs with manned vehicles and "dismounted" forces. Increasing levels of UAV autonomy are expected to reduce the need for human intervention in operations. However, UAVs are not a substitute for human involvement in the battle-space. Crucially, human control of UAVs is axiomatic for military relevance. Consideration of the technological viability of autonomous systems, and the legal constraints, suggests that a "human-in-the-loop" system, with virtual media providing the human-UAV interface, will be the most likely mode of operation to provide the required supervision and discrimination.

3. SUPERVISORY CONTROL

In warfare, the problems and outcomes are complex, dynamic, uncertain and risky, and the application of critical judgement and decision making is crucial to successful conflict resolution. Context sensitivity is important for assessing the quality of military decision making. Humans encode context naturally and handle decision making adaptively with incomplete, partial and uncertain information. This provides decision making capability not easily matched by AI in computers, or supported by virtual media. However, to exercise good military judgement, humans need to feel the texture and "granularity of the battle-space". Achieving the required level of immersion and engagement remotely with virtual media presents significant technical challenges with validation and measurement issues, which must ultimately be judged by the effectiveness of resultant human decision making. UAV operators removed from the immediate context of use, and dependent on virtual media for communication and presence, risk losing operator context sensitivity and system adaptiveness. Air Chief Marshall Sir Brian Burridge refers to this as the need for "emotional connectivity of the battle-space" [2]. For autonomous UAV operations, dependent on virtual cognition, the detailed level of operator supervision required is likely to be dependent on the individual mission context and the Rules of Engagement (RoE). This can be difficult or impossible to anticipate fully in advance. As a minimum, the operator needs virtual media to be enable him/her to discriminate between what is a valid military target and what is not.

Technological limitations and legal and moral constraints suggest that some form of human-in-the-loop control always will be required [1,2]. Currently, with manned vehicles, the human operator provides the flexibility to adapt to constraints on functioning arising from system design, creates on-line tolerance of variability and uncertainty in the external environment, and offers adaptation to changing dynamic mission context. The requirements for human-in-the-loop control of UAV operations, either remote or reach-back, can be considered as occurring at a number of levels depending on the level of automation e.g. tasks, functions, tactical and strategic mission goals. Classes of control can be characterised as either manual, semi-automatic, and fully autonomous (cf virtual presence with virtual cognition), with and without human supervisory control. Generally, automation best serves human purposes by enabling higher levels of human control i.e. automate routine 3-D tasks and support human supervisory control at tactical and strategic levels. The challenge is to determine the precise level of supervision required, and to identify the detailed user requirements and HF engineering solutions, for efficient and effective supervisory control [3].

In highly autonomous operations, communications permitting, humans can retain high level supervisory control through setting and monitoring of tasks and goals, and through authorisation of safety critical actions and use of lethal force. However, experience of automation supervision elsewhere, in particular in the process control industry and with flight deck automation has shown that reliable and robust human supervisory control is inherently difficult to achieve. Dependence on human supervisory control is risky for safety critical events and tasks. Limitations on cognition (perception, learning, memory and reasoning) mean that it is inherently difficult for humans to perform supervisory control in a consistent and reliable manner, particularly during sustained operations requiring vigilance and unpredictably intermittent high levels of attentional engagement. Ultimately, there is a risk that the over-use of automation may reduce human authority, responsibility and competency. Crucially, over-use of automation risks de-skilling the user in the important cognitive domain, reducing the essential human capability for exercising critical judgement and decision making in the appropriate use of lethal force.

Supervisory control requires robust and reliable communications with the battle-space. The realities of military communications present a real dilemma for the supervisory control paradigm. In practice, communications technology limitations (e.g. line-of-sight and bandwidth restrictions, information quality, latency) and communications breakdown (e.g. hostile interference, electronic countermeasures) can limit feedback on mission performance and prevent real-time mission intervention during remote control operations. This may necessitate detailed mission planning, including contingencies for restricted autonomous operations when human supervision and authorisation is denied.

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 UAVs, some of that responsibility is delegated to increasingly competent computer controlled machines, but the authority and accountability for the delegation ultimately remains with humans. Ensuring the correct human involvement in UAV operations provides issues for Command and Control (C2), concept of operations (CONOPS), ROE and for the specific information display and control requirements in the context of use i.e. ISR, combat, or support roles. For military relevance, UAV autonomy concepts must be integrated with the C2 requirements of both national and international C2 infrastructures (joint and coalition operations). C2 is rooted in human authority, responsibility and accountability, will, leadership and competency in judgement and decision making. The potential for fully autonomous UAV operations presents significant challenges for concepts and principles of military C2. UAV control requirements need to be integrated with C2 frameworks and architectures (information flows, decision nodes, and dynamic interactions), chains of command and CONOPS. This is to ensure leadership and the correct delegation of human authority, responsibility and accountability, and the necessary dynamic human interactions, with appropriate levels of trust.

COGNITION, CONATION, MORAL AND ETHICAL ISSUES.

UAVs are used extensively to gather information in ISR roles for human interpretation. ISR information is inherently incomplete and uncertain. Fundamentally, computer-based information processing systems are limited in that they can not comprehend the meaning of information in both human cognitive (e.g. apply knowledge, understand, judge consequences) and human conative terms (feel truth, appreciate human implications, experience emotions, and moral and ethical values). Critical military judgement is needed to interpret the meaning of ISR information. Crucially, UAVs can not appreciate the effects of use of lethal force. An “emotional connectivity” is needed to appreciate the “moral value of killing and the value of human life” [2]. Critical military judgement is needed for decisions on use of lethal force. Failure to ensure proper human involvement risks rendering UAVs as unusable tools for military purposes.

The study of moral issues (ethics) is “*concerned with or relating to the distinction between good and bad or right and wrong behaviour*” (based on the definition of ‘moral’ from the Oxford English Dictionary).

In considering moral issues of using autonomous UCAVs, Air Chief Marshall Sir Brian Burridge refers to the term "*morality of altitude*" that was coined in to reference the disconnection of the pilot at 10,000 feet from the destruction caused by bombing on the ground [2]. This disconnection led to a lower incidence of psychological problems amongst USAF pilots than their US Army colleagues on the ground during the Vietnam conflict. He believes that the "*morality of altitude*" is at the heart of the debate of how international law will interpret robotic warfare in the future. He concludes that "*Feeling the granularity of the battle-space is the key issue in interpreting the Rules of Engagement*".

The Air Chief Marshall poses the future possibility of the "Play Station" operator who may never have had actual combat experience, no connections with other operational units, and no shared operational experiences [2]. Furthermore, he expects that future highly autonomous systems will be reliant on an experienced programmer for their autonomy, who may not have any experience of combat operations in a manned platform. He notes that this will "*further remove the remote pilot from the system and place him within the industrial or military support base*". The Air Chief Marshall discusses how this exacerbates "*the disconnection of air power from the shared battle-space".* In considering the increasing lethality and persistence of UAVs, he questions how we stop the "*Play Station*" generation becoming the "*playground bully*" of the battlefield? He asks if this disconnection exacerbates the potential for the "*play ground bully*" in all of us to emerge. He contrasts the simplicity of "*drop and drag*" mouse actions on a lap top during remote reach-back operations, with the consequences on the other side of the world. One of the implications of these issues is that there with the emergence of increasingly autonomous UMVs, there is an increasing need to prioritise both cognition and conation as human dimension drivers of HSI.

4. HUMAN SYSTEM INTEGRATION

As a speciality, HF is traditionally concerned with the study of the man-machine interface. This also includes consideration of the equipment, the physical environment, the tasks and the individuals who do the work. Humans are involved throughout the UAV life cycle, from conceptualisation, specification, design and development, through command, control, operation and maintenance, to decommissioning. The term Human Systems Integration (HSI) is increasingly used in NATO nations to cover the broad scope of human considerations needed from a human-centred approach to systems engineering (or in a system-of-systems approach). The following definition of HSI has been agreed by NATO NSA Aircrew Integration Panel for addition to AAP-45 (NATO Glossary of Aircraft – Aircrew Integration (AI) Specialist Terminology and Abbreviations): *The technical process of integrating the interdependent elements of Human Factors Engineering, Manpower, Personnel, Training, System Safety, Health Hazards, Survivability, and Habitability into the system acquisition process to ensure the safe and effective operability and supportability with minimised Life Cycle Cost (LCC).* UAVs change the challenges of system safety, health hazards, survivability and habitability, reducing risks compared with manned vehicles, particularly for remote "reach-back" operations. Otherwise the HSI domains of HF Engineering, Manpower, Personnel, Training, remain as ever highly relevant for the UAV system life cycle. Notwithstanding, achieving the correct human–automation integration is a key HSI challenge for UAVs, with significant implications for HF Engineering, Manpower, Personnel and Training.

5. MANNING

Generally, UAVs are expected to augment the force and to create potential savings in human resources, manning levels and training. However, Air Chief Marshall Sir Brian Burridge, describes how the current manpower burden of remotely piloted operations is significant, and should not be underestimated [2]. The Air Chief Marshall reports that as part of the Predator Task Force at Nellis Air Force Base, the RAF mans a single Predator A Orbit in support of the coalition intelligence, surveillance and reconnaissance effort. This RAF unit, 115 Flight, totals 44 RAF personnel. He explains that a Predator A can orbit for 20 hours and requires 2 crew who operate for 8 hours each, totalling 6 crew for a single Predator. In addition, the operation involves analysts, data link managers, engineers in the deployed location, and the crews required to launch and to recover the UAV in theatre. This corresponds to a considerable manpower intensive effort, in stark contrast with the current aspiration of UAVs to reduce the manpower burden. In the future, UMVs may be expected to operate with increased levels of autonomy, with concomitant reductions in human involvement in platform control. Estimates of savings require comparisons with manned aircraft operations providing the same level of persistence. But on the evidence from Predator A operations, we should be careful not to underestimate the human resources requirements of UAV operations.

The Global Hawk High Altitude Endurance UAV system, with relatively higher levels of autonomous functioning compared with Predator, has ground control facilities comprising two elements, the Launch and Recovery Element (LRE) and the Mission Control Element (MCE). The LRE accommodates two persons and is responsible for pre-flight and post-flight ground operations and the takeoff and landing phases of flight. The MCE accommodates four persons and is responsible for the mission portion of the flight, when the vehicle is at cruise altitude.

Currently, it is a priority in many NATO Nations UAV research programmes to reduce the manpower burden by reducing the ratio of operators to vehicles for flight and mission control. A common aim is to increase operator effectiveness by enabling a single operator to control multiple UAVs simultaneously (typically up to four) by introducing increased levels of automation, operator decision aiding and advanced human-computer interfaces (HCI).

Air Chief Marshall Sir Brian Burridge considers that softer human issues associated with operator selection and training need to be addressed urgently, ahead of some of the technological issues. Predator is remotely operated by a pilot and a sensor operator. Other UAVs use a computer operator. The Air Chief Marshall expresses concern that without proper training, operators "could be faced with the very real possibility of unwrapping one of these systems for the first time on operations". Integration and interaction with civilian airspace constraints is a key training issue. He emphasises the importance of previous military experience gained in operations. The experience of operating manned platforms enables them to interact with other units and to operate safely within airspace. He notes that they understand the needs of other units through this shared connection. Solutions may need to be found in the selection of personnel with appropriate operational experience, and in creating an appropriate work context for proper operator task engagement through a combination of HF engineering, HCI and training in RoE and effects appreciation.

6. INCREASED COGNITIVE COMPLEXITY

In the future, the possibility of increasingly autonomous UAVs can be expected to place greater cognitive demands on the operator, with little or no manual control required. Basic military skills and knowledge will continue to be important, such as airmanship and seamanship. But UAV system user requirements are driving UCS specifications to allow one operator to control multiple UAVs (typically 4 UAVs per operator is the design aim for advanced systems). Thus, the role of psychomotor abilities will become diminished. Performance of tasks that are likely to be required include:

- Managing and controlling multiple UAV missions
- Co-ordination and de-confliction of multiple UAV assets
- Interpreting and integrating command strategic intent, RoE and mission control requirements
- Recognizing and dealing with degraded system functionality
- Regaining SA after loss of UAV data links
- Interpreting displays containing multiple UAV perspectives
- Shift of system control to other team members or control stations
- Team-working and interpersonal interaction

The emphasis will be on the UAV operator as a mission manager, on multi-task management and performance, on judgement and decision-making skills, and on the cognitive ability to integrate and interpret dynamic, complex data, in order to make rapid and effective decisions.

7. REMOTENESS AND CONNECTIVITY

From a system-of-systems point of view, the term “unmanned” is potentially misleading. It is most certainly inappropriate from an HF engineering perspective. It suggests an absence, or a reduction, in human involvement, and consequently a lack of, or a lessening, in human system issues. This is particularly unfortunate since the opposite is probably nearer the truth. UAVs remove humans from the vehicle (or platform) and the hazardous operating environment. However, UAVs do not remove humans from the system of use. At the present time, with human-in-the-loop control, advances in autonomous vehicle technologies are worthless without an effective and efficient operator remote control/display interface.

Generally, separating operators from the context of use risks disconnection from the battle-space, reduced SA, and creates difficulty in decision making and in maintaining the level of control and feedback on the effects of use. Rather than reducing the human system issues, increasing remoteness may risk reducing the operator’s capability to provide effective task engagement, situation appreciation and timely interventions. Increased levels of autonomy may reduce some of the human-in-the-loop workload, but autonomy risks the effects of disconnection identified above. Research is needed both on AI techniques for autonomy and on HF of supervisory control. The risk of disconnection raises the importance of HF engineering for enabling supervisory control and for exploiting the potential mitigations afforded by advanced HCI design, augmented cognition technologies, SA tools and operator decision support aids. HCI style guide information is available for interoperability between UCS in NATO STANAG 4586. HCI is a rapidly advancing field and research is needed to provide properly validated advanced HCI solutions for future improved UCS.

8. RESPONSIBILITY AND ACCOUNTABILITY

It has been suggested that UAVs may shift the balance of responsibility and accountability for UAV behaviours and effects from users’ decisions during systems operation towards engineers’ decisions during system design. The development of this argument could depend on technological developments affecting the future possibility of machines that never make mistakes, the levels of automation employed, and the methods of supervisory control of operations and effects. International humanitarian law on military use of lethal force in conflict seems likely to keep responsibility and accountability firmly with the user/commander [2, 3]. So, with increasing levels of autonomy, the need for system transparency and SA could grow. User involvement in systems requirement specification will become increasingly important to ensure that critical military judgement can be properly exercised in the context of use. This could necessitate real time user/commander control of the level of automation (i.e. adjustable, variable levels of automation), in addition to supervisory control of the specific UAV operations and effects.

9. ASSISTANT TECHNOLOGY

In the future, rather than coping with unreliable human supervisory control, or simply removing the operator from the control loop entirely, the paradigm for operator control will need to progress to one based on human-computer co-operation, as implemented in advanced pilot assistance systems. Future UAVs will contain associate systems (cf virtual cognition) that will enable the UAV operator and the associate to form a team of two crewmembers – one human and one electronic. This partnership is *cognitive co-operation* [5]. Ensuring the success of this necessary partnership presents significant challenges for HF of UAV systems. Research has shown how real-time HF engineering of variable levels of automation or adjustable levels of autonomy are important for controlling multiple autonomous UAVs, and provide the key to developing an adaptive human-computer decision partnership. Consideration is needed of the relevance of mission and decision enabling technologies for augmenting engagement. These include advanced human-computer interfaces, multi-modal virtual media “immersive” synthetic environments, task and user monitoring and modelling, collaborative technologies and communication techniques such as semantic information/knowledge web approaches to decision effectiveness. Visualisation of UAVs, such as in the US AFRL “Vigilant Spirit” Research UCS support for air-to-air refuelling, can be provided to augment operator task engagement, enhance operator situation awareness and trust in automation through direct virtual perception, and provide intuitive and integrated pictorial information to support operator supervision and intervention decision making.

10. CONCLUSION

Virtual media are extensively exploited by UAV systems. Virtual media support user interaction with UAV systems to enable UCS supervisory control. Increasing levels of autonomy are being implemented in UAV systems. High levels of autonomy present challenges for maintaining effective supervisory control with virtual media UCS. Ideally, a flexible approach is needed that allows a variable level of human intervention and autonomy, with the need for “drill-down” judged in real-time. For efficient and effective mission supervision and discrimination, the operator/supervisor needs to be able to bring added value to the understanding of the situation. To add value, he/she will need to be able to use knowledge (e.g. RoE, situation awareness, tactics) and to take into account additional contextual decision information not available to the UAV information processing system. Otherwise, the level of supervision may be uncritical and lack any real operator decision input, with the resultant legal implications. One example to avoid would be authorising target prosecution for autonomous UAVs based only on pre-set automatic target recognition (ATR) criteria without independent operator verification of the target context RoE. To mitigate this, the C2 system, UCS and virtual media need to provide a rich operating picture for mission assessment and appropriate mission performance critiquing tools.

Force augmentation issues relevant to the human operator have been shown to exist on several levels, including individual UAV control station design, vehicle interoperability, and integration of UAVs with manned systems. For UAVs to be successful, they must be fully integrated with manned systems so as to enhance the strength of the overall force. The HFM-078/RTG-017 Technical Team have identified the following priority areas requiring further research to determine how UMV systems, including UAVs, can be developed and improved further as force multipliers.

Interoperability

- Influence of the environment;
- Accessing and navigating large data sets;
- Common intent;
- Data latency and trust;
- Migrating control between operators and teams;
- Operator skills & embedded training;
- Commonality in control/display interfaces;
- Standardised communication protocol;
- Common machine understanding

Framework for force multiplication

- Control theory;
- Hierarchy;

- Sensing world/own state, other actors, and understanding mission objectives;
- Descriptive analyses;
- Design philosophy & guidelines

Control stations – Intelligent operator support

- User-centred design;
- Mission specific multi-modal interfaces;
- Intelligent displays;
- Human-automation shared SA & intent;
- Knowledge based operator assistant systems

Collaborative work

- Coalition history;
- Control of UAVs - locus of control now centrist, future distributed;
- Collaborative work environments - tools, self synchronisation, teaming;
- Intelligent cooperative systems – collaborating, automation as team member;
- Nano cognetics – bottom-up, emergent organising principles based on least parsable information exchanges

Controlability

- Automation is not the same as autonomy, since the latter implies that control is relinquished.
- A high level of automation does not mean a low level of interaction, but it opens the possibility of interacting and controlling at higher levels.
- In order to maintain military relevance, it is necessary that humans remain in charge. This is the axiom of human control.
- Since every mission must consider how events develop over different time frames, control always takes place on several levels simultaneously.
- Humans are more important for coordination between layers than for action within each layer.
- The possible contradiction between automation assistance and human ability to maintain control must be prevented by a human-centred system design.

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