Chapter 1 – INTRODUCTION

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1.1 OVERVIEW AND SCOPE

Uninhabited Vehicle systems (UVs) are at the forefront of current battles and future thinking. A number of NATO countries are now using UVs to enhance their manned forces, especially in performing tasks that are dull, dirty, or dangerous. While several projects are focused on increasing the level of autonomy for future UVs (and thus enabling supervisory control), there is a dearth of information as to how best to couple this intelligent autonomy with human decision-making abilities. With highly automated UVs, the operator's role is supervisory in nature, overseeing the automated activation of programmed events (e.g., making sure the appropriate event is activated at the appropriate time) and managing unexpected changes to the automated mission plan. Associated operator interfaces must take into account issues associated with automation management, including vigilance, attention management, clumsy/brittle automation, etc. Continuing this trend beyond the current state-of-the-art, a vision exists for a new interface paradigm for controlling next-generation UVs. This envisioned interface system involves multiple autonomous UVs being controlled by a single supervisor. These UVs will have the capability to make certain decisions independent of operator input and pre-defined mission plans. This capability of the UV to 'decide' constitutes a whole new set of challenges for UV operators, as they will be required to rapidly judge the appropriateness of these decisions and assess their impact on overall mission objectives, priorities, etc.

Given the current progress of technological developments and operational concepts regarding UVs, a strong and combined effort of NATO-countries is essential to resolve the unique human-system issues associated with augmenting the existing force with these vehicles. Since the trend is very clearly on the development of more autonomous UVs, the time is right to address the critical human factors issues involved. Human factors design guidelines will have the greatest impact if they are identified before wide scale NATO design and procurement of highly autonomous UVs occur. Given the possibility that future operators may control multiple UVs simultaneously, additional human factors challenges will be to maintain situation awareness, a reasonable workload level, and high system performance and safety across several managed assets. New principles for supporting the operator in such scenarios, which focus on supervisory control design methodologies and novel situation assessment/decision support aids, need to be developed and evaluated. Additionally, standard operator interface design guidelines associated with UV supervisory control need to be identified so as to facilitate interoperability across unmanned platforms. The ultimate goal of HFM-170 was to increase NATO's successful operations utilizing highly automated UVs; however, the specific goal was to provide a single point of focus for identifying, prioritizing, and addressing human factors challenges associated with UV supervisory control.

HFM-170 team members developed and demonstrated pertinent supervisory control human-system interface design practices and concepts for UV network-centric operations. It directly leveraged HFM Task Group HFM-078/RTG-017 [1], which developed a comprehensive review of uninhabited military vehicle human

factors issues across a wide variety of human effectiveness areas and potential military applications. Building off this acquired knowledge, HFM-170 concentrated on the identification and demonstration of successful supervisory control methodologies and interface design practices for enabled single operator control of multiple UVs, with various degrees of autonomy (including highly autonomous UVs).

Several relevant issues and challenges addressed included:

- Supervisory Control Issues and Methodologies:
  - Human-automation challenges and mitigation techniques.
  - Human-automation problem solving/cooperative dialog.
  - Networked telepresence.
  - Manned/unmanned collaboration.
  - Flexible (adaptive) level of automation.
  - Optimization of human/vehicle ratio.
  - Heterogeneous systems.
- Control Station Design – Decision Support Interfaces:
  - Situation assessment aids, augmented feedback of action impact.
  - Task switching, interruption and prioritization methods.
  - Predictive / “look ahead” tools, anticipatory support.
  - Intelligent aiding, time-critical decision making.
  - Multi-modal interfaces, intuitive interfaces, natural language speech enabled interfaces.
  - Commonality of supervisory control interface design components supporting interoperability.
  - Augmented remote world.

A unique aspect of HFM-170 was the process followed. The team was given explicit instruction to operate in a more collaborative manner, with more demonstrations versus discussions of research papers. The next section discusses a novel approach that the group settled on to attempt to maximize collaboration and tech demos without compromising each researcher’s research priorities.

1.2 HFM-170 PROCESS: MAXIMIZE COLLABORATIONS AND TECHNOLOGY DEMONSTRATIONS

Given the direction from the HFM Panel for the Task Group to focus on increasing team collaborative efforts and hosting high-fidelity Technology Demonstrations (TDs) versus strictly discussing lab research findings, the team needed to formulate a new approach to facilitate these objectives. However, the dilemma was how to accomplish true collaboration within the obvious limitations that exist with NATO teams (e.g., no additional resources provided, conflicting schedules, international restrictions, the continuing need for team members to accomplish their own national research agenda). HFM-170 Team Members thus formulated a new process by which to formally identify, develop and ascertain NATO collaboration potential for specific UV-related TDs that would be occurring within each individual country over the time-course of the Task Group. This process is summarized below.

The team first identified a series of TDs that would occur throughout the follow-on Task Group period of performance. Each participating Nation was allotted at least one TD if they so desired. A total of 15 Technology Demonstrations (TDs) were eventually agreed upon across 8 countries. These TDs focused on a broad range of pertinent human factors issues associated with supervisory control of multiple unmanned systems (see next section and the following chapters). Several candidate supervisory control frameworks were subsequently conceived in an effort to integrate these TDs into a common supervisory control framework (see Chapter 2).

After identification of the official list of TDS, each TD was considered in-turn for potential level of NATO collaboration. Since higher levels of international collaboration requires a significant amount of lead time for planning and orchestrating, this discussion of potential collaboration opportunities took place at the initiation of the Task Group. Collaboration among each of the participating TG NATO Nations was considered along a graduated scale (Figure 1-1). This scale defaults at 'no collaboration', which is applicable to many situations given constraints placed on programs and costs of collaboration. As collaboration level increases, the scale rises to "coordination" (information sharing, schedule coordinating, witnessing the TD, etc.), then to "cooperation" (structuring similarly focused tech demos to enhance effects, maximize information gathering, data collection) and finally to full "collaboration" (multiple NATO Nations combine resources to produce a truly integrated TD). Full collaboration was achieved in one instance within this Task Group, and is described in Chapter 9.

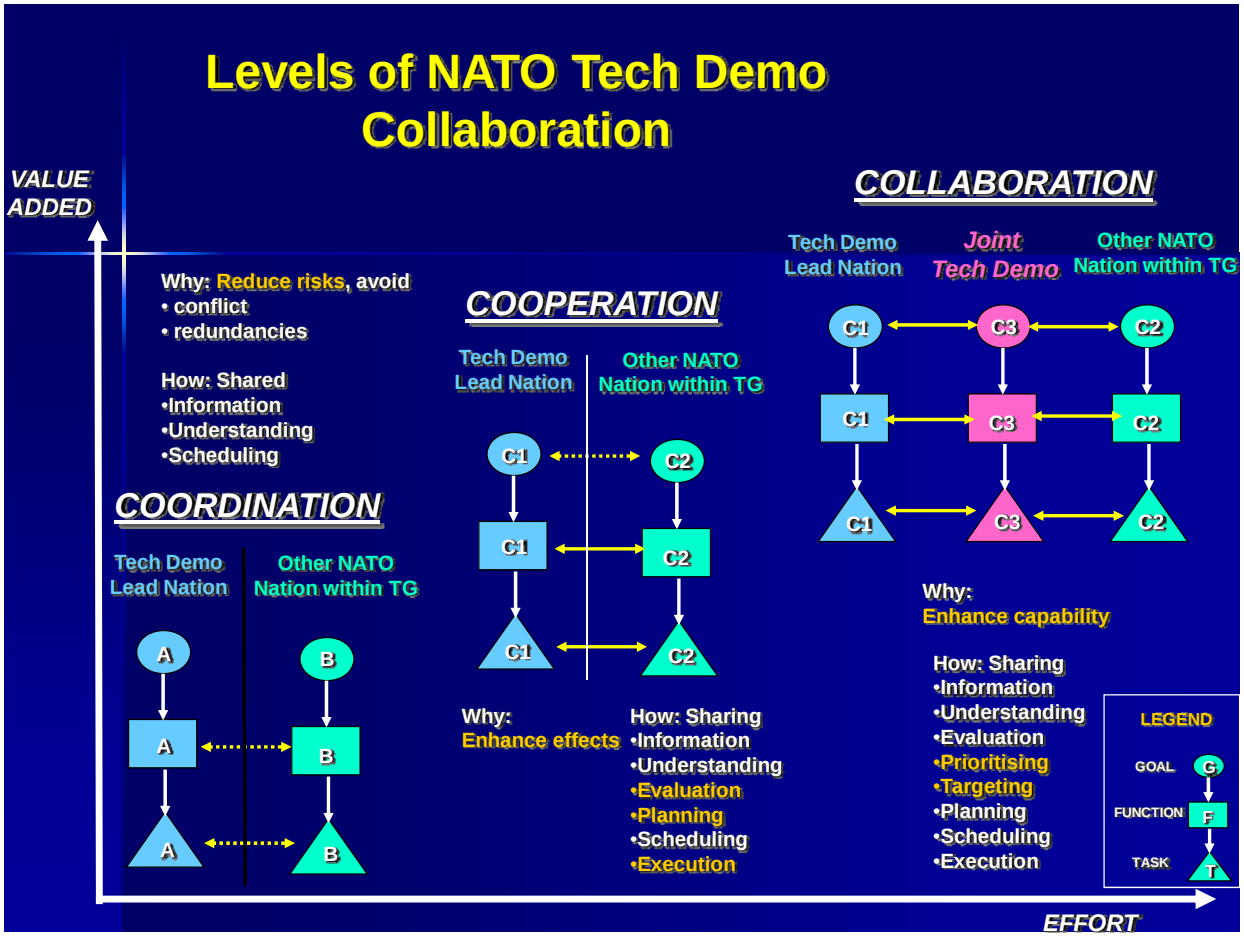

Figure 1-1: Levels of NATO Technology Demonstration Collaboration for HFM-170.

For each TD, the eventual level of collaboration for each country/representative was dependent upon several variables including level of mutual research interest, availability of resources, alignment of resources, timing, value added, etc. The method for identifying and characterizing instances of collaboration is described next.

Each TD "owner" was required to complete a collaboration matrix (see Figure 1-2 below) that conveyed how much collaboration was desired (and in what area of the TD). One dimension of the matrix consisted of 3 levels of collaboration while the other represented 3 different phases of a TD. For each TD, this completed matrix was presented along with a discussion of the TD (objectives, approach, design, etc.), after which each country was prompted to state their level of interest (using the same collaboration matrix structure) in collaborating with that TD. In this way, the group was able to systematically identify and then track collaborations across a wide spectrum of collaboration levels and groups involved. Some TDs resulted in few to no collaborations while other TDs had much interest from various countries and one resulted in a new joint TD between the Netherlands and the US.

	Planning/Design	***Execution***	***Analysis***
Communication			
Coordination			
Collaboration			

Figure 1-2: Collaboration Matrix for Each TD.

The follow-on meetings occurred approximately every 6 months, over a three year period. Meetings centered around one or more tech demos associated with the host country. Many TDs were actual live tests using real assets in air or on ground or on water, providing needed realism and hands on experience. The tech demo researchers presented the TD(s), invited specialists as desired, and used the available time to discuss and critique the demo specifics. Contrasting approaches/concepts were also discussed.

As a means to disseminate the results and lessons learned from this Task Group, a NATO "Technology Forum" Workshop (RWS-217) is organized at the end of this effort. This forum presents summaries of all TDs conducted throughout the TG period through posters, videos, and hardware demos/simulations. Discussions center around lessons learned and the way forward regarding multi-vehicle control by a single operator.

1.3 SUMMARY

A total of 15 TDs were included as part of HFM-170. These TDs are listed in Figure 1-3, along with the Host country. TDs focused on many critical issues including multi-vehicle control, manned-unmanned teaming, human-automation interaction, telepresence interfaces, delegation interfaces, vehicle hand-offs, operator workload adaptive systems, variable levels of autonomy, authority sharing, situation awareness aids, cognitive workload assessment, swarming interface technology, and dynamic mission management.

Technology Demonstration	Title	Host Country
1	Multi-crew Control of a Single Unmanned Aircraft	Canada
2	Behaviour based Collision Avoidance and Formation Control of Multiple Unmanned Vehicles	Canada
3	Supervisory Control: OmniSense	Canada
4	Interacting with Multi-agent Systems / UAV Swarms	France
5	PEA Human Factors and Authority Sharing	France
6	Cognitive and Cooperative Automation for Aerial Manned-Unmanned Teaming Missions	Germany
7	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	Netherlands
8	Supervisory Control: Optimal Distribution of Workload Among Operators for Mixed Initiative Control of Multiple UAVs	Portugal
9	Task Switching for Multi-UGV Control	Sweden
10	Supervisor Control of UGVs for Tactical Reconnaissance	Sweden
11	Dynamic Airborne Mission Management Capability Concept Demonstrator	United Kingdom
12	Multi-UAV Supervisory Control Interface Technology (MUSCIT) Demonstration	United States
13	Delegation Control of Multiple Unmanned Systems (DELCON)	United States
14	Intelligent Agents as Supervisory Assets for Multiple Uninhabited Systems: RoboLeader	United States
15	Unmanned Surface Vehicle Control & Monitoring Human-Computer Interface for Amphibious Operations	United States

Figure 1-3: HFM-170 Technology Demonstrations.

The following chapters begin with an extensive review of the efforts undertaken by HFM-170 to identify supervisory control frameworks by which to describe the research being done in this area, including but not limited to the TDs. This is followed by a summary of each TD including its goals, approach, and results/ lessons learned.

1.4 REFERENCES

[1] *Uninhabited Military Vehicles (UMVs): Human Factors Issues in Augmenting the Force*. 2007. NATO-RTO-TR-HFM-078. Neully-sur-Seine: NATO-RTO.