Technical Evaluation Report

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ABSTRACT

The Applied Vehicle Technology Panel (AVT) and the Systems, Concepts and Integration Panel (SCI) of the Research and Technology Organization (RTO) of NATO organized a joint symposium on "Platform Innovations and System Integration for Unmanned Air, Land and Sea Vehicles" which met from 14-18 May 2007 in Florence Italy. The objective of the symposium was to focus on key technologies that permit the increased performance potential offered by autonomous or semi-autonomous systems to be fully exploited throughout the battlespace.

The papers presented at the symposium were technical papers of air, land, sea, and undersea unmanned vehicles which focused on key technologies for these systems. The papers ranged in topics from current systems in use to micro systems mimicking insects in flight. The following list of sessions describes the content of the symposium: Platform Mobility, Autonomous Control, Platforms and Control, Multi-Vehicle Control, Mobility and Control, Vision and Platforms, Advanced Concepts.

EXECUTIVE SUMMARY

The objective of this joint AVT-SCI symposium was met. Excellent papers were received and presented addressing key inter-disciplinary technologies needed to increase the performance of autonomous vehicle systems. The symposium was well balanced in that it included papers that were top level systems engineering papers on current systems in development and some advanced concepts along with papers that were more relevant in specific technical areas like autonomous control theory. The authors were well balanced in their discussions in that they discussed not only their successes but also some of their failures.

The authors gave very good presentations of their papers. Many inserted video clips in their presentations that brought their presentations to a higher level that cannot be captured in their papers. The organizing committee is to be commended for not only their balance of subjects: air, land, sea and undersea but also for not scheduling sessions by type of unmanned systems but presenting air, land, sea vehicles in all sessions.

Innovative technologies were presented dealing with swarm concepts of UAVs and UGVs, control architectures and strategies including multi-vehicle control by a single operator, optimum task assignment and scheduling of UAVs, mission planning in dynamic scenarios including adaptive control for obstacle avoidance, decking of UAVs on a ship at rough sea state, biologically inspired designs, morphing vehicles etc.

The common problems across all systems could be topics of consideration for future RTO symposiums or specialist meetings. The general topics across the papers presented are: level of autonomy, navigation, mission control / mission planning, data transfer, systems integration, man/machine interface, and communications.

For these topics to be discussed at the proper level would require joint panel meetings like this one. An example of such a meeting would be entitled “Routine Operation of UAVs in National and International Airspace”. A meeting on this subject would require input from not only most of the panels but also military and civilian operations and national regulatory agencies.

Unmanned vehicles are the next revolution in military capability. Although they were initially accepted very slowly by the military operations, they are now being widely used. Use of unmanned systems will continue to grow and RTO symposiums and specialist meetings should be held on a continuing schedule to discuss and disseminate current technology and innovative concepts.

The cross-fertilization of the AVT and SCI communities sparked excellent and fruitful discussions. The good balance between established programs and emerging technologies generated numerous ideas and initiatives for future co-operative research work. As on over 130 participants note it on the questionnaire: “This event had been waited for”.

INTRODUCTION

Background

Since in 1997, NATO decided to set up the RTO with the mission “To conduct and promote co-operative research and information exchange within NATO and with its Partners”, the technical Panels, very quickly, identified the importance of unmanned vehicles in modern warfare scenarios, including peace enforcement and countering terrorism. An evidence of this is the large number of technical activities, listed in Annex 1, dealing with unmanned systems. However, when looking at the contents of the published documents, it appears that, in most of the cases, the emphasis is led on the particular expertise available in the individual panels and narrowly streamlined with the terms of reference of that panel. Further development of more efficient, safer and more affordable autonomous systems can only be realized following a multi-disciplinary approach. This was the motivation of the AVT and SCI Panels to set up this joint symposium on “Platform Innovations and System Integration for Unmanned Air, Land and Sea Vehicles”.

Scope and Theme of the Symposium

The scope of the symposium is to focus on key inter-disciplinary technologies that are necessary for increased performance potential offered by autonomous or semi-autonomous systems in the battlespace covering land, sea and air domains. The difficulty, however, is that the list of such inter-disciplinary technologies is too long and impossible to cover in one symposium. Therefore, the theme of the present symposium is to address some of the critical challenges including:

- Innovative platform design for improving autonomy;
- Methods for reliable situational awareness;
- Multi-vehicle cooperative control as a force multiplier;
- Biologically inspired designs; and
- Human interactions with autonomous platforms.

Recommendations

From the early start of their work, the members of the Program Committee were aware of the very large scope of the conference. This was the reason why the decision was taken to focus the symposium on really critical challenges as mentioned above. Although all these domains have been covered and the large majority of the papers are of a high scientific level, there are ways for improvement by further fine-tuning the scope so as to concentrate on a still more limited number of technical domains.

Not all authors seem to be aware of the mission statement of the RTO: *To conduct and promote co-operative research and information exchange within NATO and with its "Partners"*). The evaluators have seen a few number of papers and presentations, illustrating remarkable results of outstanding scientific work performed at the organizations of the authors, but with very little technological spin-off towards the audience.

For unmanned systems in particular, there is a need for an inter-disciplinary approach. This has been fully understood by the Program Committee and they are encouraged to do so in the future. This symposium was the fruit of a co-operation between the SCI and the AVT Panel. We are confident that in the future also other Panels would contribute positively. This is for instance the case for SAS, SET and the MSG.

Effectiveness, operational readiness, survivability, maintainability, safety and affordability are extremely important issues in the context of modern war fighting and peace keeping scenarios. Autonomous or semi-autonomous vehicles become more and more complex, have already or will soon have onboard intelligence and decision making software. Therefore we should train ourselves not to speak any longer about *vehicles* but about *systems*.

Participants are also encouraged to participate or to follow as closely as possible the activities organized by the JCGUAV (Joint Capability Group on UAVs (under the CNAD)) and the UAV work performed by the JAPCC (Joint Air Power Competence Center).

Last but not least, based on the technology level of the papers and presenters, on questions and comments from the audience after each presentation and on "off the record" discussions during coffee breaks and luncheons, we would strongly recommend another joint symposium or preferably a real inter-panel (multi-track) activity in the next two or three years.

EVALUATION

SESSION 1: Unmanned Vehicle Operations

The session was initiated by Keynotes 1 and 2 on "Predator Current Operations" and "UAV Operations: from autonomous navigation to multi-platform cooperation", which were an excellent introduction to Papers 1 and 2, the only papers of this session. Approximately 75 people were at the beginning of the session and approximately 55 were present for the second paper.

Paper 1: Embedded System Technology as Enabler for Innovative Swarm Concepts

This TNO (NTL) paper gave an interesting view on the potentialities of smart control of aerial swarms for new ways of warfare scenarios. In this context an innovative mobile swarm concept is defined as a system exchanging information between members who are cooperating to perform coordinated tasks. Embedded MEMS technology and wireless information exchange between the members are key to realizing such innovative scenarios.

The presentation was illustrated by a video-movie showing a derivative of the DELFLY flapping wing concept, developed by Delft TU.

Paper 2: Optimal UAV Task Assignment and Scheduling

A USA paper addressing the complex optimization problem of task assignment and scheduling for UAVs, operating in a semi-autonomous manner with a single operator controlling the multi-vehicle team.

The author proposes a MILP (Mixed-Integer Linear Programming) technique but addresses the primary limitation of MILP which is the computational complexity and computation time. Therefore he suggests a two step approach by:

- Using a simpler cost function reducing the computational complexity and required solution times; and
- Constraining the allowed time for task completion such that any feasible solution will result in acceptable mission performance.

The paper includes a convincing illustration of the MILP with decision variables, cost functions and constraints applied to a team of heterogeneous UAVs performing attack or verification tasks on ground targets. The involvement of the human supervisor in the decision adequately addressed.

SESSION 2: Platform Mobility I

Approximately 50 people attended this session. Of the 4 papers presented in this session, 2 were on systems already in some phase of development and the other 2 were concept papers.

Paper 3: Withdrawn

Paper 4: Intelligent Mobility Research at Defence R&D Canada for Autonomous UGV Mobility in Complex Terrain

This paper addressed the mobility problems of UGVs operating in complex urban environments including bomb damaged roads and facilities. The paper discussed several locomotion concepts including deliberate dexterous, variable geometry, and dynamic reactive locomotion. There was an excellent discussion on what type of control system is necessary for operating in ground terrain which is not known before the vehicle enters it. The paper identifies distinct mobility paradigms that facilitate research in areas of control, sensing, and learning necessary for UGVs to successfully operate in complex urban environments.

SESSION 3: Platform Mobility II

This session was attended by approximately 50 people. Of the three papers presented, two were top level program manager briefings and the other was a very good overview of basic research of UGVs with complimentary semi-& autonomous mobility behaviors. Papers 6 and 7 are important contributions as they demonstrate the high quality research being accomplished at Universities and small companies in areas outside of basic military research but are applicable to some of the militaries problems.

Paper 5: Aerial Multirole 120mm Robot Horus

This paper is a program overview of the 120mm Robot Horus system. It describes the basic system and its capabilities. As the title implies, it is being designed to be launched from a 120mm barrel but later development will provide other versions. No questions were asked at the end of this presentation.

Paper 6: Design of Multi-Role Springer Unmanned Surface Vehicle

This paper is a technical overview of a specific system. It is a good discussion of systems integration and design. The paper initiated a good discussion on the design of navigation, guidance, and control subsystems but the designs are current state of the art. Although state of the art, the paper is an excellent overview of well integrated systems design and what an integrated design team is capable of accomplishing.

Paper 7: Articulating and Morphing Unmanned Ground Vehicles Controlled with Complimentary Semi- & Autonomous Mobility Behaviors

The paper presented a good overview of the work being accomplished in Universities on small autonomous ground vehicles. In particular, the paper described the innovative work that is being accomplished by highly motivated student engineering design teams. It starts with basic system requirements. The paper then goes into detail describing the development of an overall algorithm using a vision based sensing subsystem. The final design was then used in a design competition where it came in fourth of 28 vehicles where vision based navigation was used.

SESSION 4: Autonomous Control I

This session was attended by approximately 60 people. Two papers were presented in this session. The first paper was a good presentation on the problem of locating sea mines. The second paper was outstanding in that it explored the system of systems problems of combined autonomous air and sea operations.

Paper 8: Implementation of Autonomous Mission Control for Mine Reconnaissance AUVs

This paper was a logical discussion of the requirements for a mine reconnaissance vehicle. It starts with understanding the requirements and defines these requirements. The current state of the art for each of these requirements is baselined. The paper then goes into the development of a mission controller based on several different levels of autonomy. This is an excellent paper on systems engineering and the decomposition of system requirements into a design.

Paper 9: Mixed Innovative Control of Unmanned Air and Ocean Going Vehicles: Models, Tools, and Experimentation

This paper should be read by all as it is the first system of systems effort that truly address a combined air and sea operations at the R&D level. The paper concentrates on the control aspects of a mixed force starting with defining the control framework including both system and control concepts and ending with operational deployment concepts. This research will lead to innovative operational concepts and should be the catalyst for other countries to pursue like research.

SESSION 5: Autonomous Control II

35 people were in attendance for session 5. This session had several outstanding presentations.

Paper 10: A Pseudospectral Method for Real-Time Mission Planning and Obstacle Avoidance

This is an outstanding paper on the optimal control problem of ground vehicles negotiating a path through an area with many obstacles present. Obstacles of arbitrary number, size, and type are modeled in the form of path constraints. The authors have an outstanding presentation detailing their methods and providing a gradual

build up to the final application of optimal control techniques against a 32 obstacle environment with circular obstacles.

Paper 11: German Research Program about Key Technologies for AUVs

This is an overview paper on the key technologies for under water autonomous vehicle. The key technologies identified are: dynamics and stability; navigation; sensors; communication and autonomy. The authors discuss current technology level in each of these areas and then give a brief discussion of planned research in each of these areas for the German navy.

Paper 12: UAV Autonomy – Which Level is Desirable? – Which Level is Acceptable? Alenia Aeronautics Viewpoint

This is an outstanding paper and addresses the main problem facing the growth of unmanned air vehicles in the national airspace. The paper presents the thought and views of Alenia Aeronautica but it is a good starting point for discussion in this area. In fact, this topic could be a future symposium or at least a specialist meeting including other government agencies concerned with air vehicles operating in the national airspace. The paper also discusses autonomous applications in all phases of a mission. The paper ends with discussion of current and future applications of autonomy in Alenia systems.

SESSIONS 6 + 7: Platforms and Control I and II

The session was introduced by a third Keynote "Unmanned Naval Operations", a Canadian contribution. All planned papers were presented to an audience of 50 observers.

Paper 13: The Use of Simulation in De-risk Maritime UAV Operations

This paper is on the application of the UK Ship/Air Interface Framework (SAIF) project, developed for manned aircraft, for MUAV simulation experiments. SAIF has developed a networked simulation architecture for the purposes of studying the dynamic interface between an air vehicle and the ship from which it operates. The very interesting and well structured paper gives an assessment on the feasibility and benefits of modeling MUAV operations within the modified architecture, complemented by modules taking the recovery system, the MUAV, the UAV controller and the MUAV into account.

Paper 14: Development and Tests of an Automatic Decking System Demonstrator of VTOL UAV on Naval Platform

The purpose of the paper was to highlight the potentialities of an automatic decking system bringing a UAV, without operator remote control, on the ship landing platform, in severe sea state conditions. A system demonstrator has been developed and various levels of tests have been performed including numerical simulations, physical simulations at reduced scale as well as physical simulations at full scale with a real unmanned helicopter decking on a frigate with platform motions representative of sea state 5 and with various wave incidences. During the presentation convincing video-movies illustrated the performances of the demonstrator.

Paper 15: Biological Inspiration for Agile Autonomous Air Vehicles

A very well written paper providing insight into the biology and dynamics of insects, birds and bats. It has the potential to serve as a guide for the design of new manmade systems. The author underlines the requirements

for MAVs ensuring agile maneuvering within confined airspace while using small but efficient sensors for mission accomplishment. Research areas of potential biology contributions are identified:

- Understanding aero-elastic flapping wing flight at low Reynolds numbers, morphing wings;
- Exploring sensory-rich multi-scale feedback associated with biological flight;
- Robustness and fault tolerance of biological systems; and
- Understanding the body sensing system of flying insects.

Paper 16: The Oshkosh-VisLab Joint Efforts on UGVs: Architecture, Integration and Results

This contribution is the result of collaboration between a USA company and an Italian university. It is concentrated on the response the partners gave to the DARPA Grand Challenge, in which the autonomous vehicles of participating teams are expected to run a distance of 220 km within 10 hours in unknown terrain. Among 200 teams that signed in for the competition, 42 were selected but only 5 reached the finish line. A very interesting presentation of the paper, including convincing video movies highlighting the challenges of the competition and remarkable results obtained by the team. However, the amount of valuable technical information given to the audience was limited. This is probably due to the confidentiality of the innovative solutions used for the successful accomplishment of this highly demanding competition.

Paper 17: Design and Testing of a Morphing Wing for an Experimental UAV

An excellent and detailed (35 pages) description of the analysis of the aerodynamic and structural problems associated with a morphing wing making use of a flexible skin. The morphing wing has span and chord expansion capability and the design is done using aerodynamic shape optimization and a coupled aero-structural analysis. Very detailed information is given on the rib and span extension mechanisms. The paper includes wind tunnel testing results for several wing planform configurations.

This research was sponsored by the RTO/AVT Support Committee with Canada and Portugal as respectively the supporting and the supported Nations.

SESSION 8: Multi-Vehicle Control

In presence of 45 observers all three papers of this session were presented.

Paper 18: Multi-Vehicle Flight Testbed for Extended Mission Analysis and Fault Isolation and Recovery

The paper presents a multi-vehicle testbed, named RAVEN, enabling investigations of long-duration missions in a controlled environment. RAVEN is comprised of both aerial and ground vehicles and is controlled by a single operator. The main objective of the testbed is to test and demonstrate multi-vehicle mission management algorithms that embed the fleet and vehicle health state into the mission and UAV planning using real hardware. It allows researchers to conduct tests for a wide variety of mission scenarios. Also perching and tracking missions were executed with success. The paper is illustrated by several video-films available on the Internet.

Paper 19: Mission Planning for a Team of UAVs in a Dynamic Scenario

In this paper the authors study the mission planning problem of co-operating autonomous vehicles in a scenario which evolves and features moving targets, moving obstacles and pop-up threats. It is explained why a MILP (Mixed-Integer Linear Programming) approach is not suited for such dynamic situations. The paper proposes a clustering procedure in order to obtain a more global view of the scenario. This means grouping the targets into many clusters and then performing the assignment between the vehicles and the clusters. Doing this the assignment procedure is run on a smaller size system and moreover the vehicles get a more global view of the targets configuration.

Paper 20: A Generic Architecture for Autonomous Uninhabited Vehicles

The paper focuses on the ProCoSA software package, used by ONERA for controlling and monitoring highly autonomous systems. This software allows the development of decision architectures for any type of autonomous vehicles performing in a partially known and dynamic environment. The paper includes an overview of the software components and their individual functions. The decision architecture has been tested in the lab, at sea and in the air.

A tutorial example is included in the paper explaining how to program an embedded decision architecture using ProCoSA.

SESSION 9: Autonomous Control III

From three papers planned only two were presented to an audience of about 55 observers. Paper 22 was withdrawn.

Paper 21: VTOL Landing at Unusual Attitudes

The paper deals with the problem of a helicopter landing on a ship deck during rough sea and presents control issues associated with VTOLs. It describes technical approaches tailored to the two control design frameworks currently used at Georgia Tech. Impressive is the implementation of the dynamic inversion framework on a three degree-of-freedom helicopter to perform an aggressive landing on a vertical wall.

Paper 23: Transitioning Intelligence to Embedded Platforms

The paper addresses the work with the Open Control Platform (OCP) along with hardware and software to enable its use on testbeds and platforms which are better suited for embedded processors and more affordable for research teams. The work has been to separate the archaic build process from the execution platform, opening up the computational venue to machines which are closer to embedded platforms than general computing platforms, and more accessible to researchers and to integrate a desktop simulation environment for small UAVs. It will reduce the overhead required for an institution with interesting algorithms for autonomous behavior, to step into the domain of testing.

SESSIONS 10 + 11: Modeling and Control I and II

In total, five papers were selected for these sessions, however only four were presented to an audience of 50 observers. Paper 28 of Session 11was withdrawn.

Paper 24: Modeling Team Adversarial Actions in SEAD Operations

This paper deals with the problem of modeling the operations of opposing forces in a battlefield. The authors explain why classical game theory techniques frequently used to model human decision making in competitive situations are not appropriate to deal with the challenges posed by real operations. Decisions must be made taking into account that the information is limited, that the situation is highly dynamic and that the interactions are often very complex. The subject is discussed in the context of the attack of a Blue Force of UCAVs against a Red Force of SAM sites and radars.

Paper 25: Flight Control System Integration on Micro/Mini UAV Platforms

The paper presents the activity performed at the Politecnico di Torino under the Micro Hawk Research Program. The aim is to provide these platforms with autonomous flight capabilities. It is concentrating on work done on the integration and tuning of a commercial autopilot (weighting only 28 g) to achieve high performance autonomous flight. The paper is recommended to students and researchers involved in the MAV arena. The authors have included a long list of references dealing with the subject.

Paper 26: Control Strategies for Co-operating UAVs Guidance

The motivation of the authors is the need for tactical re-planning for a swarm of mobile sensors assets in reaction to complex adversarial environments, including pop-up threats. Key issues addressed are:

- Improvement of reactive re-planning of trajectories;
- To perform these in a safe way;
- Complying with requirements of collaborative operations of the swarm; and
- Sustained operation despite flight critical faults and failures.

Paper 27: An Overview of MAV Research at Brigham Young University

The paper describes the work related to the control of MAVs. It is focused on the following areas:

- Path following trajectories in urban canyons;
- Resistance to wind gusts;
- Precision landing;
- Target localization;
- Obstacle detection;
- Obstacle avoidance; and
- Aircraft control.

Quaternion based navigational algorithms for hover position hold, level flight waypoint tracking and transitions between these two modes have been developed for a fixed wing MAV.

An interesting illustration of cooperative control of three UAVs, flying from loiter locations to their destination, coordinating their flight trajectories to arrive simultaneously is also included in the paper.

Paper 28: Withdrawn

SESSION 12: Vision and Platforms I

This session was the start of track II. None of the sessions in track II were well attended. Each session averaged approximately 10 people. When you subtract the authors, session chairman, and technical evaluator, it does not leave many people in the audience that did not have to be there. This was not fair to the authors. This track had several outstanding papers in the sessions. Strongly suggest to Panel members that the two track format not be used again especially on the last day when everyone is programmed to go into the main meeting room.

Paper 29: Meeting Unmanned Air Vehicle Platform Challenges Using Oblique Wing Aircraft

The data in this paper has been previously presented several times for manned aircraft. Since this is basically an aerodynamic effect, the results and conclusions are the same as for a manned aircraft.

Paper 30: Mission Management System for UCAV

This paper is an outstanding example of systems engineering techniques. It starts with requirements definition followed by systems architecture definition and implementation and finally systems integration and evaluation. There is a good discussion of general UCAV requirements followed by a discussion of the requirements for UCAVs flying in formation. Once requirements are defined, a technology assessment is undertaken before converging on a system architecture. The paper finishes with results from a very good simulation which includes pilot comments.

Paper 31: Comparing Organic vs. Assigned UAV Support to the Maneuver Company

This paper documents a systems study that started as a student project at the US Military Academy and was carried to completion by the student's professors. It is a good tutorial on how to properly conduct a system concepts study. The methods used are well documented and as in previous studies of this nature defining the correct evaluation criteria and their weighting functions are the most important part of the process.

SESSION 13: Vision and Platform II

Paper 32: Optimal Control Strategies for a Ducted RUAV

This paper presents an excellent program management level discussion of a Ducted Rotor UAV flight control design. The paper also discusses the basic aerodynamics of the design and continues with a brief discussion about the manufacturing processes used to build the vehicle.

Paper 33: Vision-Based Autonomous Surface Vehicles and Autonomous Aerial Vehicle Relative Positioning and Cooperation

This paper was another outstanding example of systems engineering but went one giant step farther by combining the requirements of an unmanned airborne system with the requirements of a water system to complement each others capabilities towards the prosecution of a single mission. The paper contains a very good discussion of a vision based positioning subsystem which was used to determine air vehicle relative position in regard to the surface one. Although this was an experiment it does provide valuable in site into cooperative autonomous air/naval operations.

Paper 34: The Flight Control System of the HoverEye VTOL UAV

The HoverEye is a ducted fan VTOL UAV short range reconnaissance with an electro-optic day/night camera payload. This again is an excellent systems engineering discussion of the design of the system including vehicle shape and aerodynamics, avionics selection, sensors, automatic code generation, control allocation, and navigation and guidance.

SESSION 14: Advance Concepts I

Paper 35: Recent Progress Towards Developing an Insect-Inspired Flapping-Wing Micro Air Vehicle

This is an outstanding paper because of the innovations and ingenuity of the authors. Although flapping wing technology has been discussed at other meetings, this is the first research in this area that is being complemented with a wind tunnel effort with real insects. This data is not included in the final paper but the existence of the data makes this paper all the more relevant.

Paper 36: Special Weapons Observation Remote Reconnaissance Direct Action System

Due to extenuating circumstances, this paper was not presented at the symposium but it will be included in the proceedings.

Paper 37: Unsteady Aerodynamics of Different Wing Profiles at Low Reynolds Number

This paper documents the results of a study looking at the importance of the shape thickness of the 2D wing profile on the aerodynamic force coefficients of a flapping airfoil. Elliptical and NACA 00 series profiles of 9 and 12 % thickness were studied. Standard comparisons are discussed between the two basic airfoil shapes and the results between the different profiles were not significant.

SESSION 15: Advanced Concept II

Paper 38: Fixed-Wing Micro Air Vehicles with Hovering Capabilities

This paper presents the results of basic wind tunnel research on the best wing platform for micro vehicles which maximizes lift while maintaining good lift to drag ratio. From this part of the study the following conclusions are made: Platform is of great importance; aspect ratio should be kept under 1.7 and moderate camber should be used. The paper then discusses two prototypes: a biplane and a VTOL vehicle. The rest of the paper discusses the development of a state of the art flight control subsystem for the VTOL prototype.

Paper 39: An Overview on Portable Human Machine Interfaces for Tele-Operation Control of Robotic Swarms

This is an outstanding tutorial on man machine interfaces for controlling unmanned vehicles. The paper starts with defining different operational scenarios, levels of interaction required for each scenarios and numbers of vehicles under the direction of one operator. It then defines an interface efficiency factor based on situational awareness of the operator. The paper then discusses the proper design of an operator's control unit such that the operator has optimum situational awareness that he can effectively monitor and control more than one unmanned vehicle. The principles of man / machine interface discussed in this paper are applicable to all systems.

Annex A – OVERVIEW ON RTO WORK ON UNMANNED SYSTEMS

APPLIED VEHICLE TECHNOLOGY PANEL (AVT)

AVT-033 Development and Operation of UAVs for Military and Civil Applications. TC 1999
AVT-049 Unmanned Vehicles for Aerial, Ground and Naval Military Applications. SY 2000
AVT-101 Low Reynolds Number Aerodynamics of Micro/Mini and High Altitude Vehicles. TG 2004-2006
AVT-104 Low Reynolds Number Aerodynamics on Aircraft including Applications in Emerging UAV Technology.LS 2003
AVT-138 Nanotechnology for Autonomous Vehicles, TG 2006-2008
AVT-145 Design Concepts, processes and Criteria for UAV Structural Integrity. WS 2007
AVT-146 Platform Innovations and System Integration for Unmanned Air, Land and Sea Vehicles. SY 2007
AVT-149 Micro Air Vehicles Unsteady Aerodynamics. TG starting this week

HUMAN FACTORS AND MEDICINE PANEL (HFM)

HFM-078 Unmanned Military Vehicles: Human Factor Issues in augmenting the Force. TG 2001-2005
HFM-103 Unmanned Military Vehicles as Force Multipliers. WS 2003
HFM-135 Human Factors of Uninhabited Military Vehicles as Force Multipliers. SY 2006

SYSTEMS CONCEPTS AND INTEGRATION PANEL (SCI)

SCI-023 Integrated Mission Concepts and Technologies for Future Unmanned Combat Applications. TG 2002
SCI-100 Architecture for the Integration of Manned and Unmanned Aerial Vehicles. WS 2001, pub available
SCI-105 Unique Aspects of Flight Testing of Unmanned Aerial Vehicles/ Unmanned Combat Aerial Vehicles. AG active
SCI-109 Applications, Concepts and Technologies for Future Tactical Unmanned Aerial Vehicles. LS 2002, Pub available
SCI-124 Architecture for the Integration of Manned and Unmanned Aerial Vehicles. TG 2007 pub pending
SCI-138 Applications, Concepts and Technologies for Future Tactical UAVs. LS 2003 (240 p)
SCI-175 System Control Technologies, Design Considerations and Integrated Optimization factors for Distributed Nano-Unmanned Air Vehicle Applications. LS 2007
SCI-186 C2 Architectures for Operations with Manned and Unmanned Air Vehicles. TG 2007
SCI-195 Advanced Autonomous Formation Control and Trajectory Management Techniques for Multiple Micro UAV Applications. LS 2008

SENSORS AND ELECTRONICS TECHNOLOGY PANEL (SET)

SET-073 Enabling Technologies of the EW Systems for Years 2010 and Beyond
SET-090 Sensors for Urban Operations

SET-092 Advanced Sensor Payloads for UAV
SET-106 Future Low Cost Threat Warning and Protection Systems for Ground and Air Vehicles
SET-107 Battlefield Acoustic Sensing for ISR Applications
SET-116 Low Cost Navigation Sensors and Integration Technology
SET-123 Nanomaterials for Sensors, Sources, and EM Manipulation
SET-125 Sensors and Technology for Defence against Terrorism
SET-126 Power Systems Optimization for the NATO Warfighter
SET-127 Enabling Technologies of the EW Systems for the years 2010 and beyond