NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

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RTO TECHNICAL MEMORANDUM **TM-SPD-001**

2004 Space Report: Environment and Strategy for Space Research at NATO's Research and Technology Organisation (RTO)

(Compte rendu Espace 2004 : Environnement et stratégie de la recherche spatiale de l'Organisation pour la recherche et la technologie de l'OTAN)

Prepared by the RTA Strategy and Planning Division.

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Prepared by the RTA Strategy and Planning Division.

by

Jessica A. Woods-Vedeler

The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote co-operative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective co-ordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also co-ordinates RTO's co-operation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of co-operation.

The total spectrum of R&T activities is covered by the following 7 bodies:

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

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier co-operation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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List of Acronyms

ACT	Allied Command Transformation
AG	Activities Group
AGARD	Advisory Group for Aerospace Research and Development
AGS&R	Aerospace Ground Surveillance and Reconnaissance
ASAR	Advanced Synthetic Aperture Radar
ASAT	Anti-Satellite
ATI	Automatic Target Identification
AVT	Applied Vehicle Technology
CAESAR	Coalition Aerial Surveillance and Reconnaissance
CCMS	Committee on the Challenges of Modern Society
CFSP	Common Foreign and Security Policy
CSD	Coalition Shared Database
DoD	Department of Defense
DRG	Defense Research Group
EC	European Commission
EHF	Extremely High Frequency
EMP	Electro-Magnetic Pulse
ENVISAT	Environment Satellite
EO	Executive Officer
ERS	European Remote Sensing
ES	Executive Session
ESA	European Space Agency
ESDP	European Security and Defense Policy
ESM	Electronic Support Measures
ESRP	European Space Research Program
EU	European Union
GLONASS	Global Navigation Satellite System
GMES	Global Monitoring for Environment and Security
GMTI	Ground Moving Target Indicator
GPS	Global Positioning System
HFM	Human Factors and Medicine
IMU	Inertial Measurement Units
IPM	Inter-Panel Meeting
ISAF	International Security Assistance Force
ISAR	Inverse Synthetic Aperture Radar
IST	Information Systems Technology
ISTAR	Intelligence, Surveillance, Target Acquisition and Reconnaissance
Kbps	Kilobits/second

LADAR	Laser Radar
LANDSAT	Land Satellite
LEO	Low-Earth Orbit
LIDAR	Laser Imaging Detection and Ranging
M&S	Modeling and Simulation
MAJIIC	Multi-Sensor Aerospace-Ground Joint Interoperable Intelligence Surveillance and Reconnaissance Coalition
MAS	Mission Application Study
MC	Military Committee
MEM	Micro-Electro-Mechanical
MEO	Mid-Earth Orbit
MERIS	Medium Resolution Imaging Spectrometer
MMW	Millimeter Wave
MTI	Moving Target Identification
NAC	North Atlantic Council
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVWAR	Navigational Warfare
NC3A	NATO Consultation, Command and Control Agency
NC3B	NATO Consultation, Command and Control Board
NCTI	Non-Cooperative Target Identification
NCW	Network Centric Warfare
NEC	Network Enabled Capability
NMSG	NATO Modeling and Simulation Group
NURC	NATO Underwater Research Center
OA	Operational Analysis
OS	Open Service
PASR	Preparatory Action in the field of Security Research
PNT	Position, Navigation and Timing
PBM	Panel Business Meeting
PRS	Public Regulated Service
R&T	Research & Technology
RADARSAT	Radar Satellite
REA	Rapid Environmental Assessment
RF	Radio Frequency
RNSS	Radio Navigation Satellite Service
RSG	
RTA	Research and Technology Agency
RTB	Research and Technology Board
RTO	Research and Technology Organization
SAG	Space Advisory Group
SAR	Synthetic Aperture Radar

SAS	Studies, Analysis and Simulation
SATCOM	Satellite Communication
SCI	Systems Concepts and Integration
SDR	Software Defined Radios
SEC	Space Expert Consultants
SET	Sensors & Electronics Technology
SHF	Super High Frequency
SPD	Strategic and Policy Division
SPS	Strategic Planning Session
SRTM	Shuttle Radar Topography Mission
TG	Task Group
UAV	Unmanned Aerial Vehicles
UAV	Unmanned Autonomous Vehicles
UHF	Ultra High Frequency
US	United States
VNC	Voluntary National Contribution
WG	Working Group

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2004 Space Report: Environment and Strategy for Space Research at NATO's Research and Technology Organisation (RTO)

(RTO-TM-SPD-001)

Executive Summary

This report describes the motivation for and a strategy to enhance the NATO Research and Technology Organization's (RTO) current space research effort to reflect NATO's growing military dependence on space systems. Such systems and services provided by these systems are critical elements of military operations and are vulnerable to disturbance by adversaries and environmental effects. Data from these systems should be more fully exploited. NATO's involvement with space systems includes an interoperability simulation involving a suite of sensors on land, air and space platforms; acquisition of NATO's next generation satellite communications capability; participation in the resolution of the frequency overlap between the GALILEO and GPS radio navigation satellites; a project involving the use of satellite-based internet access to promote stability in the Caucasus region; and training for NATO operational planners focused on use of space system assets. NATO has used space systems operationally in Kosovo and Afghanistan. A quantitative analysis of work related to space in the NATO RTO showed that during the period of 1998-2004, 5% of the research pursued in the NATO RTO has been clearly focused on space applications. The environment and barriers for space research were considered. Space capability is considered of high importance to meeting the civil and military goals of the European Union (EU). The US is challenged with maintaining superior space capability and international cooperation to meet future needs. A national trend towards "requirements based research" rather than "open-ended basic research" leads to a cost vs. return perspective that limits researcher participation in RTO forums. Organizational barriers to more focused attention on space research include lack of sufficient space expertise representation on panels, the military sensitivity of space, current panel work loads and the need for specific technical recommendations from peers. A strategy for enhancing space research in the RTO is to create a limited-life Space Advisory Group (SAG) composed of Space Expert Consultants who are panel members with appropriate expertise and additional expertise from the nations. The SAG will recommend and find support in the nations for specific technical activities related to space in the areas of Space Science, Remote Sensing Data Analysis, Spacecraft Systems, Surveillance and Early Warning, Training and Simulation and Policy. A request for formalization RTO Space Advisory Group is being sought from the RTB. Failure to approve formation of a Space Advisory Group sends a message to RTO community and nations that space is NOT among the many priorities for RTO research and the RTO will not be recognized as a forum for trans-Atlantic defense space research. In summary, the formation of a Space Advisory Group is recommended to provide an organizational mechanism for the RTO to enhance space research activities.

Compte rendu Espace 2004 : Environnement et stratégie de la recherche spatiale de l'Organisation pour la recherche et la technologie de l'OTAN

(RTO-TM-SPD-001)

Synthèse

Ce compte rendu décrit la motivation et la stratégie d'amélioration des efforts actuels de l'Organisation pour la recherche et la technologie de l'OTAN (RTO) dans le domaine de la recherche spatiale en vue de refléter la dépendance militaire croissante de l'OTAN par rapport aux systèmes spatiaux. Ces systèmes, et les services qu'ils offrent, constituent des éléments critiques des opérations militaires et sont vulnérables aux perturbations dues à l'adversaire et aux effets environnementaux. Les données fournies par ces systèmes doivent être exploitées de manière plus complète. L'engagement de l'OTAN dans les systèmes spatiaux comprend une simulation d'interopérabilité impliquant une série de capteurs installés sur des plates-formes terrestres, aériennes et spatiales, l'acquisition des capacités de communications des satellites de prochaine génération de l'OTAN, la participation à la résolution du recouvrement de fréquence entre GALILEO et les satellites de navigation radio GPS, un projet impliquant l'utilisation d'un accès Internet par satellite afin d'améliorer la stabilité dans la région du Caucase, et la formation de planificateurs opérationnels de l'OTAN axée sur l'utilisation des moyens des systèmes spatiaux. L'OTAN a utilisé les systèmes spatiaux en opérations au Kosovo et en Afghanistan. Une analyse quantitative des travaux liés à l'espace au sein de la RTO de l'OTAN a montré que, durant la période 1998-2004, 5 % de la recherche effectuée par celle-ci était clairement axée sur les applications spatiales. L'environnement et les barrières de la recherche spatiale ont été pris en compte. Les capacités spatiales sont considérées comme très importantes pour la réalisation des objectifs civils et militaires de l'Union Européenne (UE). Les États-Unis sont confrontés au défi que représentent le maintien de la supériorité spatiale et la coopération internationale en vue de répondre aux besoins futurs. Une tendance nationale vers une « recherche axée sur les besoins » plutôt que vers une « recherche globale ouverte » conduit à une perspective coût-retour qui limite la participation des chercheurs aux forums RTO. Les barrières organisationnelles à une attention plus ciblée sur la recherche spatiale incluent le manque d'une représentation suffisante de l'expertise spatiale dans les commissions, la sensibilité militaire de l'espace, les charges de travail des commissions actuelles et le besoin de recommandations techniques spécifiques de la part de pairs. Une stratégie d'amélioration de la recherche spatiale au sein de la RTO consiste à créer un Groupe consultatif spatial (SAG) limité dans le temps, composé de consultants experts dans le domaine spatial qui sont membres de la commission, avec une expertise appropriée et une expertise complémentaire de la part des nations. Le SAG émettra des recommandations et recherchera un soutien national pour les activités techniques spécifiques relatives à l'espace dans les domaines de la science spatiale, de l'analyse de données de détection à distance, des systèmes de véhicules spatiaux, de la surveillance et de l'alerte lointaine, de la formation et de la simulation et de la politique. Une demande de formalisation du Groupe consultatif spatial de la RTO est déposée auprès du RTB. Un refus d'l'approbation de la formation d'un Groupe consultatif spatial adresserait un message à la communauté RTO et aux nations signifiant que l'espace ne fait PAS partie des nombreuses priorités de la recherche RTO et que la RTO ne sera pas reconnue comme forum de la recherche spatiale de défense transatlantique. En résumé, la formation d'un Groupe consultatif spatial est recommandée afin d'offrir un moyen d'organisation permettant à la RTO d'améliorer les activités de recherche spatiale.

2004 Space Report: Environment and Strategy for Space Research at NATO's Research and Technology Organisation (RTO)

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1.0 OVERVIEW

This report describes the motivation for and a strategy to enhance the NATO Research and Technology Organization's (RTO) current space research effort to reflect NATO's growing military dependence on space systems. The motivation for increased consideration of space, a high-level description of how NATO currently uses space systems and the current environment is for space research is presented. A strategy for enhancing the capability of NATO's RTO to be responsive to changing military needs despite a challenging environment is proposed.

1.1 Motivation and Objective

Why does NATO RTO need to enhance space research efforts?

A presence in space gives military commanders the "high ground" and enables them to have a more effective and centralized way to assess and control multi-national actions on a battlefield covering large geographic regions [1]. As NATO and nations are facing increased global responsibilities for security and defense with smaller forces, the ability to meet objectives will increasingly depend on use of such integral, force-enhancing support from space [2].

The vulnerability of space systems to disturbance, however, provides adversaries with an excellent means to degrade combat efficiency and effectiveness due to our dependence on such systems [2]. Attack can be carried out asymmetrically by nations will little or no space capabilities and with little impact on their own force structure. Denial of access to satellite data such as radio navigation signals ('Navigational Warfare'), communication and imagery via jamming is another effective mechanism that can be used by adversaries from the ground or air. Such disturbances can also be caused by natural environmental events like solar and atmospheric activity. Thus, military dependence on space systems in a combat environment is dynamic and subject to change based on vulnerabilities due to dependence on such systems. Further, a need exists to improve integration and exploitation of data from multiple space sensors to produce more effective decision tools for the military commander.

Thus, the objective of pursuing space research in the NATO RTO is to enhance NATO security effectiveness by increasing national capability to achieve and maintain superiority via the use of modern space systems. Research to sustain, protect and advance space-based systems and related technologies and to assure that information from space-based systems is securely communicated, accessible and useful must be pursued. To meet this objective, a strategy is needed that will enhance the ability of RTO research panels to initiate and support space research that is consistent with NATO's capability needs and national interests.

* On Detail Assignment from the US National Aeronautics and Space Administration (NASA).

1.2 NATO and Space

What is currently going on related to space in the broad context of NATO and in the NATO RTO research panels?

A high-level discussion of how space systems are used in research and operations within NATO is presented with examples of on-going research activities at NATO Consultation, Command and Control Agency (NC3A), NATO Consultation, Command and Control Board (NC3B), NATO Underwater Research Center (NURC), NATO Science Committee and the NATO School. These examples include an interoperability simulation involving a suite of sensors on land, air and space platforms; acquisition of the NATO's next generation satellite communications capability; a discussion of NATO's role in the resolution of frequency overlap between the GALILEO and Global Positioning System (GPS) radio navigation satellites; a project involving the use of satellite-based internet access to promote stability in the Caucasus region; and a description of training for NATO operational planners focused on use of space system assets. Examples of NATO operational use of space systems are also presented for operations in Kosovo and Afghanistan.

In addition, a quantitative analysis of work related to space in the NATO RTO since 1998 is presented. As a summary, during the period of 1998 – 2004, 5% of the research pursued in the NATO RTO has been clearly focused on space applications. The research includes Hypersonic Vehicle Development (i.e. "Access to Space"), Solid Rocket Propulsion, Characterization of the Ionosphere, use of both Military and Civilian Space Systems in Military Operations and the development of a wide range of optical and navigational sensors and radars that could be used in space-based applications. Work is also being pursued in Network Centric Warfare and Network Enabled Capabilities, both of which may consider use of space system elements. By comparison to Advisory Group for Aerospace Research and Development (AGARD) activities, it is seen that the amount of research focused on space that the NATO RTO pursues has at best remained unchanged despite NATO's growing dependence on space systems and information obtained from such systems. Two areas that were pursued in AGARD, Spacecraft Development and Remote Sensing from Space, have diminished substantially.

1.3 Environment for Space Research

What are the current environment for space research and the perceived barriers to increasing the amount of space research RTO pursues?

The environment and barriers for space research are considered at international and national level and at the NATO RTO organizational level.

The international environment for space is discussed as it tends to set the tone for the level of collaboration that is achievable. In particular, the European community is currently undergoing rapid expansion and a period of policy reformation to achieve increased unification, efficiency and strategic independence. Space figures prominently among those issues considered of high importance to meeting the civil and military goals of the European Union (EU) in the future and much progress has been made in the last year to establish an EU space policy to establish priorities. However, the vision of a strategic independence for the EU is challenged as individual nations continue to pursue national visions for both civil and military defense through cooperation with the United States (US), Russia and, increasingly, China, India and Japan. Further, while global security benefits substantially from the US investment in military space, there is much concern in Europe regarding the perceived US intent to weaponize and control space and many doubts about whether the European community wishes to share similar objectives. Thus, the US is challenged with maintaining superior space capability and international cooperation to meet future needs.

In addition, a relatively new trend in national research priority and its influence on the NATO RTO research environment are discussed. In particular, the trend towards "requirements based research" rather

than “open-ended basic research” leads to a cost vs. return perspective that limits free participation in the RTO forums especially in research areas related to space which may be funded at lower levels.

Finally, organizational issues within the NATO RTO that appear to be barriers to more focused attention on space research are presented. In particular, it is noted that the technical skills and preferences of panel members are typically not related to space which makes it difficult to have such activities initiated and find sufficient support for success. Space is a highly sensitive technical area. As such, collaboration is typically limited to action under bi-lateral agreements. Thus, most panels view focused space research from only a dual-use perspective or peripheral to their main mission. In addition, panels have very full portfolios of work. Additional activities related to space compete directly with a large number of other priorities. Finally, technical recommendations and leadership are sought from among the technical peers of panel members not from within the Research and Technology Agency (RTA) staff. It is important that recommendations for space research activities come from Level 2 experts within the technical community.

Figure 1: NATO Integrated Communications (Image credit: Thales).

1.4 Strategy and Implementation Plan for Enhancing Space Research in the NATO RTO

What is the most effective strategy for energizing current space research and motivating more space research in the RTO?

Any strategy pursued for increasing space research in the NATO RTO must represent a solution despite the constraints of the current environment. While several solutions may be possible, an optimal path is recommended by which RTO space research can be enhanced.

A key element in considering space as an RTO application area is to more formally recognize the growing importance of space in the military domain. Thus, the need for attention to space research must be clearly indicated in the NATO R&T Strategy.

By organizational analysis, it was decided that an Inter-Panel level Space Advisory Group (SAG) should be established. The SAG is NOT a panel and does not have a formal panel structure. The SAG is a formalization of the Space Expert Consultants who are panel members with relevant expertise that are supplemented by space experts outside the normal RTO technical network. The outside experts infuse new ideas, experience and give access to new technical networks in the nations. These Space Expert Consultants are Level 2, are willing to participate in discussions related to defense space research and are

familiar with the space capabilities of their nations. Space Expert Consultants are being sought in technical areas including Space Science, Remote Sensing Data Analysis, Spacecraft Systems, Surveillance and Early Warning, Training and Simulation and Policy. The Group will have representation from as many nations as possible. Each panel will have at least one member with space expertise participating in the activities of the Space Advisory Group who will be an integral part of relaying Space Advisory Group recommendations back to his/her panel. Representation from other NATO bodies such as Allied Command Transformation (ACT), NC3A, NATO Science Committee and NURC will also be sought for increased visibility and feedback within the NATO community. A request for formalization of the Space Expert Consultants into an RTO Space Advisory Group will be sought from the RTO Research and Technology Board (RTB). The major responsibilities of the Space Advisory Group are summarized below:

- Map NATO needs and National interests to specific recommendations for cooperative defense research topics
- Identify sufficient support within at least 4 nations to support the topics BEFORE recommendations are made to the panels
- Provide recommendations for specific activities back to the panels for inclusion in individual panel planning processes
- Identify key Space Technology Watch areas including potential disruptive space technologies
- Promote visibility of NATO RTO as a forum for trans-Atlantic, collaborative defense space research
- Recommend renewal or transformation of Space Advisory Group to RTB at end of 2 years

An on-line *RTO WISE Forum* will provide a forum for communication and collaborative discussion related to defense space research and upcoming events. It will also be used to prepare for a *RTA Space Strategy Workshop* in June 2005. At this workshop, *invited* participants will formulate a vision for the RTO in space research. Specifically, the workshop participants will review national interests in defense and security space research and NATO capability needs to make an initial assessment of topics that may be of joint interest for cooperative research. The Space Advisory Group will meet again in December 2005 to add recommendations based on findings at the Systems Concepts and Integration (SCI) Panel's Space Symposium and to finalize recommendations to the panels. A timeline for the Implementation Plan is in the report.

Finally, it is important to note that failure to approve formation of a Space Advisory Group sends a message to RTO community and nations that space is NOT among the many priorities for RTO research. As described in the report, this has several implications. The most significant impact will be that the NATO RTO will not be able to position itself as a strong forum of choice for trans-Atlantic collaborative defense space research and NATO will miss an opportunity to facilitate improved relations and common defense among nations.

In summary, creation of an administrative framework within RTO such as the Space Advisory Group for discussion and recommendation of space issues is proposed. The framework includes workshops, an on-line forum and creation of a board-approved Space Advisory Group that identifies, recommends and supports research appropriate for the NATO RTO.

2.0 INTRODUCTION

Since the inception of NATO in 1952, NATO has considered a presence in space and access to space as elements of military defense. A space presence enables superiority on the battlefield via a myriad of capability such as broad and secure communication, target sensing and identification, situational

awareness and environmental assessment. Space-based assets are already critical components in the integration of land-, sea- and air-based mission elements for tactical operations involving communications, navigation, meteorology and early warning. Thus, in modern times, space has become established as the fourth defense environment in addition to land, sea and air.

The objective of pursuing space research in the NATO RTA is to enhance NATO security effectiveness by increasing national capability to achieve superiority via the use of modern space systems. While NATO has pursued space research in the past, the scope of such research has been limited. NATO's research program has traditionally been dominated by focus and expertise related to land, sea and air applications, even during the times of AGARD and Defense Research Group (DRG). Thus, given increasing importance of space, the criticality and potential of more effectively using space assets to achieve NATO military objectives must be emphasized more fully in the current research program as one means of developing a superior common defense capability. Further, while the NATO defense community is clearly not interested in developing a NATO owned space system infrastructure, the research performed within the NATO RTO can be used to improve and protect data and services obtained via assured access to national systems.

During the 2003 Fall Executive Session in Ottawa, Canada, the US agreed to provide, as a Voluntary National Contribution (VNC), a Space Expert from the National Aeronautics and Space Administration (NASA) to serve as Space Research and Technology Executive Officer within the Strategic and Policy Division (SPD) of RTA. The objective was to define strategies for increasing space research within the NATO RTO. As such, this status report for 2004 recommends a Strategy for enhancing the capability of NATO RTO panels to pursue space research related to NATO needs and the interest of the nations.

First, the motivation and objective of enhancing space research in the NATO RTO will be presented. Next, the approach for information gathering will be presented followed by some examples of how NATO currently uses space systems. Results from a quantitative study on space research in the NATO RTO will also be presented. In addition, the external and internal environments for space research will be reflected upon. This includes discussion of the emerging European Union's Space Policy and the US Space Policy, trends in current national research priorities and barriers observed within the existing NATO RTO research panels. Finally, a Strategy will be recommended with an Implementation Plan that represents an optimal approach to enhance space research in the RTO given the current environment for research and the preferences of participants.

3.0 MOTIVATION AND OBJECTIVE

Why does NATO RTO need to enhance space research?

A presence in space gives military commanders the "high ground" and enables them to have a more effective and centralized way to assess and control multi-national actions on a battlefield covering large geographic regions [1]. Such a presence was critical in the Gulf War, regarded by many as the "First Space War," in which a fleet of 51 military and 12 commercial [3] geo-synchronous and Low-Earth Orbit (LEO) spacecraft provided rapid access to engaged troops, provided critical tactical and strategic information and performed complex operations such as retargeting strike aircraft and cruise missiles in flight [1][4]. More recently, in the US-led Operation Iraqi Freedom, use of space systems in battle reached a new level when GPS capabilities were paired with precision-guided munitions to find and hit their targets. Because of such demonstrated advantage, space will, for the foreseeable future, be a tool to provide a military advantage on the battlefield. And, as NATO and nations are facing increased global responsibilities for security and defense with smaller forces, the ability to meet objectives will increasingly depend on use of such integral, force-enhancing support from space [2].

The vulnerability of space systems to disturbance, however, provides adversaries with an excellent means to degrade combat efficiency and effectiveness due to our dependence on such systems [2]. Attack can be carried out asymmetrically by nations will little or no space capabilities and with little impact on their own force structure. For example, Anti-Satellite (ASAT) systems can be used that include direct ascent, co-orbital weapon systems and directed energy beams from ground or space. In particular, high-altitude detonation of nuclear devices launched on ballistic missiles can lead to electromagnetic disruption via widespread ionization, Electro-Magnetic Pulse (EMP) and artificial auroras. Tracking and targeting a satellite can easily be accomplished using relatively inexpensive commercial software packages to predict orbital mechanics using orbital parameters of satellites available on the Internet. And, because many satellites fly in similar orbits to cover the most highly populated regions on the planet, secondary satellite damage is likely to occur due to resulting orbital debris or presence of secondary satellites in the radius of attack. Denial of access to satellite data such as radio navigation signals ('Navigational Warfare'), communication and imagery via jamming is another effective mechanism that can be used by adversaries from the ground or air. Such disturbances can also be caused by natural environmental events like solar and atmospheric activity. Thus, military dependence on space systems in a combat environment is dynamic and subject to change based on vulnerabilities due to dependence on such systems.

Further, a need exists to improve integration and exploitation of data from multiple space sensors more effectively for use by the military commander. As many nations now rely on assured access to information from other nation's satellites, it is particularly important to facilitate integration and analysis of multi-national data to produce useful decision tools for the military commander.

Thus, the objective of pursuing space research in the NATO RTO is to enhance NATO security effectiveness by increasing national capability to achieve and maintain superiority via the use of modern space systems. Given the increasing dependence on space systems, space research must be emphasized more fully in the current RTO research program as one means of developing a superior common defense capability. Research to sustain, protect and advance space-based systems and related technologies and to assure that information from space-based systems is securely communicated, accessible and useful must be pursued. To meet this objective, a strategy is needed that will enhance the ability of RTO research panels to initiate and support space research that is consistent with NATO's capability needs and national interests.

4.0 APPROACH

In order to formulate a strategy for energizing more space research in the NATO RTO program, observations of the current environment must be made. First, it must be understood clearly what is motivating the need for change from the current status. If the current status is not clearly understood, it too, must be characterized in order to have a baseline for change. Further, external and internal influences that could facilitate or that may inhibit change must also be understood. Ultimately, through a thoughtful consideration of the alternative strategies in the context of the current environment, an optimal solution may be defined.

Thus, in this report four main questions are addressed in order to define a strategy that will have the highest probability of success within the constraints of the current environment.

1) *Why does NATO RTO need to pursue more space research?*
2) *What is currently going on related to space in the RTO research panels and in the broader context of NATO?*
3) *What are the current environment for space research and the perceived barriers to increasing the amount of space research RTO pursues?*

4) *What is the most effective strategy for energizing current space research and motivating more space research in the RTO?*

The information obtained in this report was the result of the Space Executive's efforts to understand the RTO research process and product in both a qualitative and quantitative sense. In particular, information was obtained by attending Panel Business Meetings (PBM), RTB meetings and several Task Group (TG) meetings. At these meetings, a top-level understanding of how new research activities and RTO initiatives are identified, formulated and approved was observed as well. The distribution of technical interest and expertise within each panel and barriers to change were also observed. In addition, the newly enabled RTO database was an invaluable tool used extensively to identify the types of activities historically and currently associated with each panel. Further, the Space Executive participated in a variety of discussions with researchers and officials within US and European communities to gain a better understanding of contemporary trends and political influences that affect the NATO RTO. Finally, an optimal solution was formulated based on a careful consideration of different organizational possibilities subject to many constraints imposed by the contemporary defense research environment and current RTO panel structures. In the end, the solution to what appeared to be an over-constrained problem was possible only via introduction of additional resources from the nations.

5.0 NATO AND SPACE

What is currently going on related to space in the RTO research panels and in the broader context of NATO?

The objective of this section is to describe NATO's current interest in use of space systems. As part of this, examples are presented that describe research NATO pursues involving these key network elements. The section is intended to be an overview of representative activities and is not exhaustive of all NATO activities related to space. Activities are presented for several NATO bodies including the NC3A, NURC, NATO Science Committee and the NATO School. In addition, overview information is presented on the importance of space systems in recent military operations.

5.1 NATO Use of Space

5.1.1 NATO Consultation, Command and Control Agency and Board (NC3A and NC3B)

At the NC3A at The Hague, NL and the NC3B at Brussels, BE, several activities have been underway for a number of years related to use of space systems. Several recent activities have had substantial visibility. These include the Coalition Aerial Surveillance and Reconnaissance (CAESAR) Project and acquisition of the SATCOM Post-2000 capability. In addition, the NC3 organizations played a role in resolution of the frequency allocation issues associated with the European radio navigation satellite constellation, Galileo.

5.1.1.1 CAESAR/ MAJIIC

Aerospace Ground Surveillance and Reconnaissance (AGS&R) assets are part of an overall Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) Architecture that includes a variety of platforms supporting sensors that make use of a wide range of the electromagnetic spectrum, from optical wavelengths to radar. Experience in development of such systems has shown, however, that use of advanced technology alone does not provide an enhanced capability to these systems. In fact, as recent as 1999, when the US Joint STARS and U2 and French HORIZON flew in the Kosovo conflict, they were unable to integrate into a true interoperable capability despite advanced sensor capability. In the next decade, it is projected that Canada, France, Italy and the UK will all deploy new Ground Moving Target Indicator (GMTI) and Synthetic Aperture Radar (SAR) platforms and processing capabilities and that the

US will continue to enhance existing capabilities. However, none of these nations will have a sufficient number of sensors to fully exploit a sustained, large-scale military operation. Thus, operational procedures and integration into existing processes will need to be established to gain maximum benefit from the use of these new technologies [5].

As a result, the NC3A and multiple nations have participated in a number of exercises to prove that AGS&R sensor and exploitation systems could interoperate in a realistic environment. In particular, the goal is to increase the air and ground commander's situational awareness by improving the ability to produce, disseminate, display, exploit and correlate GMTI and SAR imagery from multiple sensor platforms. These platforms include air, land and space-based platforms.

The most recent effort is the CAESAR Project. CAESAR is a multi-national activity led by the NC3A that is focused on demonstrating joint AGS&R capabilities. Seven nations participated in two combined joint simulation exercises held at the NC3A in 2003 and 2004. In these exercises, the application of a Coalition Shared Database (CSD) and various Standardization Agreements were used to successfully demonstrate interoperability [6].

A variety of platforms and sensors were included in the joint exercise as shown in Figure 2. Most of these platforms offer a "Synthetic Aperture Radar (SAR) sensor, which is capable of detailed imaging of the ground at considerable standoff distances and the detection and in some cases identification, of stationary targets. These SAR sensors operate in both a high-resolution Spot mode, where a small area is imaged in detail, and a wider-area, lower detail, Swath mode. Some sensors also include an Inverse SAR (ISAR) mode capable of imaging moving objects with high resolution. Either simultaneously or in an interleaved fashion, these platforms also offer a GMTI radar mode. This mode facilitates the detection of targets that are in motion at or near the surface of the earth, again, at a considerable standoff distance. The airborne platforms communicate with the ground stations over one or more system-specific medium and/or high-bandwidth data links" [6]. Also included are numerous ground-based exploitation capabilities for processing data.

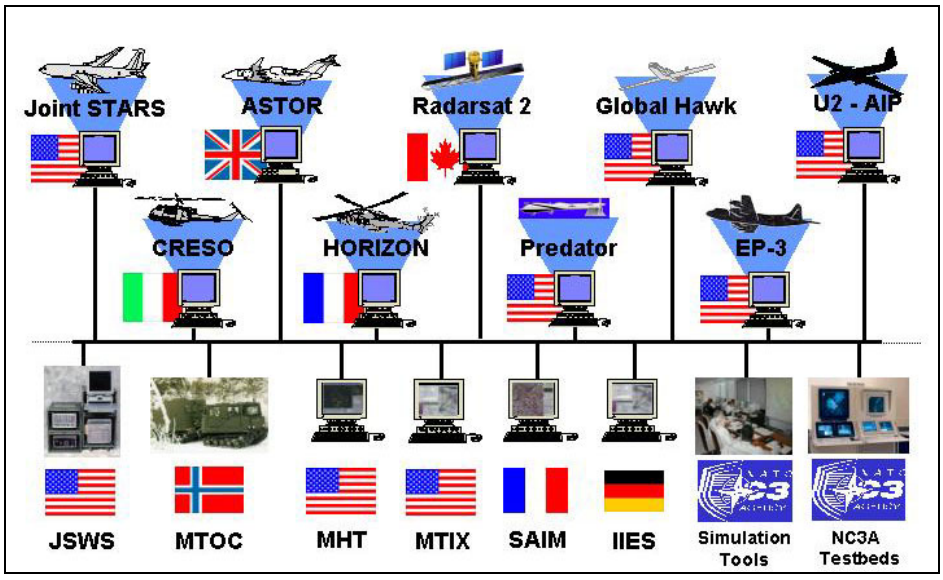

Figure 2: Systems Considered in CAESAR Interoperability Demonstration.

The simulation exercises with these systems have been highly successful. A follow-on project called the Multi-Sensor Aerospace-Ground Joint Interoperable Intelligence Surveillance and Reconnaissance Coalition (MAJIIC) project will be conducted in 2005 – 2009 to expand on the results of CAESAR.

The use of the Canadian RADARSAT shown in Figure 3 indicates a rather *defacto* recognition by the NATO community that space-based assets are a key element in the ISTAR network that must be integrated effectively with other resources to achieve full advantage. The RADARSAT instrument provides unique advantages over aircraft-based and optical satellites observations because of its superior ability to transmit and receive high quality images of Earth through all weather conditions and at any time of day [7][8]. Of further interest is that RADARSAT is a satellite developed by the Canadian Space Agency and the Canadian Center for Remote Sensing for civilian Earth science applications. Its mission is to monitor environmental change and to support resource sustainability. Thus, the willingness of nations to consider use of satellites for both civil and military use is apparent.

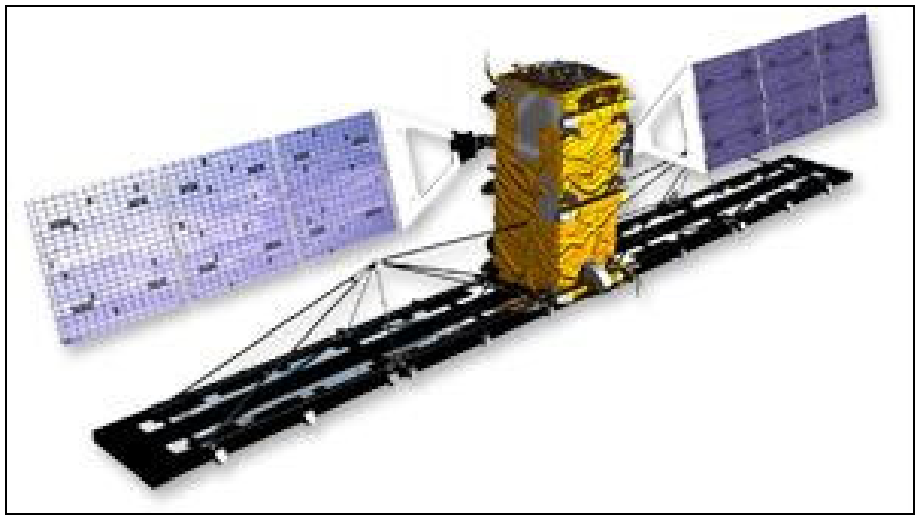

Figure 3: Canadian RADARSAT-2 Satellite to be Launched in 2005.

5.1.1.2 SATCOM Post-2000

For nearly 35 years, NATO has relied on a series of satellites to provide high-level communication between NATO leaders and forces. As the last two of NATO's currently owned NATO-IV satellites reach end of life, NATO is procuring improved services to meet future military SATCOM requirements. The goal is to not only replace the existing satellites but to ensure that NATO's SATCOM capability is compatible with its new role in global crisis management as defined at the 2003 Prague Summit and that NATO has the ability to support an increasing commitment to support rapidly deployable forces.

The NC3A completed the source selection for NATO's new satellite capability in the 'Microwave' or Super High Frequency (SHF) (6 – 20 GHz) and Ultra High Frequency (UHF) (0.2 – 1.6 GHz) bands in Summer 2004 [9]. Proposals were submitted by the US and a Joint Consortium of France, Italy and the UK. Under this procurement, it was hoped that requirements for Extremely High Frequency (EHF) (44 – 59 GHz) could also be met. However, neither team could meet technical requirements with current systems. Thus, those requirements are currently under review by NC3A for consideration at a later time.

As a result of the competition, the Joint Consortium was selected to provide the capability via a service provision arrangement at a price of nearly 0.5 Billion Euros. Under this agreement, NATO requirements will be met via use of current and near-term available national military communication satellites. In particular, the Joint Consortium will utilize capacity of the French SYRACUSE III satellite series, the Italian SICRAL constellation and the UK SKYNET 4/5 shown in Figure 4. SYRACUSE satellites are built by Alcatel Space in Paris, France. Alcatel also built the high resolution imaging optical imaging instruments for Helios I and II observation satellites and provided high resolution radars for the German SAR Lupe reconnaissance satellite constellation. SICRAL is built and provided by Alenia Spazio in

Rome, Italy. Finally, the SKYNET series is owned and operated by Paradigm Secure Communications in the UK. Paradigm will provide SKYNET 4 services in 2005, with a migration to SKYNET 5 services beginning in 2007. SKYNET satellites are built by EADS Astrium Ltd. Provision of NATO communication services by the Joint Consortium began at the end of 2004 and will continue for 15 years through 2019.

Figure 4: SKYNET Satellite.

5.1.1.3 GPS-Galileo

One of the most visible space issues in the past year has been resolution of a conflict between the European Union's upcoming Galileo Radio Navigation Satellite Service (RNSS) and the current US GPS.

GPS currently provides radio navigation services world-wide for both civilian and military applications, including NATO. In brief, radio signals sent from a constellation of orbiting satellites are collected by ground receivers. The combined signals from multiple satellites in the constellation are used to calculate the position, velocity and current time of the receiver.

The conflict involved a concern that the frequency bands associated with the Galileo Open Service (OS) and Public Regulated Service (PRS) would overlap with a GPS frequency band to be used in the future for military purposes [10]. The OS is for public use and the PRS has restricted use for EU law enforcement and security agencies. The interference would prevent use of a GPS military service referred to as M-Code. The M-Code is the central capability of military GPS for precision positioning, navigation and timing for use in Navigational Warfare (NAVWAR). NAVWAR involves denial via jamming of satellite navigation services in a conflict area to adversaries while preserving Allied capabilities. If the OS and PRS signals overlaid the GPS-M Code, jamming these signal frequencies would also jam the GPS military signal used by the US or NATO for military advantage. A negotiated agreement [11] between the US and the EU was achieved via difficult negotiations in June 2004 [12]. In this agreement, the overlap issue was resolved, thus, creating two independent systems (i.e. GPS and Galileo) for civil radio navigation services that do not interfere with GPS military operations.

Although, ultimately, the US and EU resolution was achieved outside of NATO, extensive discussions related to the resolution of this problem were handled by the North Atlantic Council (NAC). The discussions resulted in a tasking of the NATO C3 Board's Navigation Sub-Committee to evaluate the interrelationship between GPS and Galileo in terms of NATO military effectiveness. In addition, a study is being conducted for NC3A by the NC3B's Navigation Sub-Committee to address the impact of NAVWAR on NATO Network Enabled Capability (NEC), as the ability to provide accurate Position, Navigation and Timing (PNT) is a central element of NEC.

5.1.2 NATO Underwater Research Center (NURC)

5.1.2.1 Rapid Environmental Assessment (REA)

The NATO Undersea Research Center (NURC) conducts research and development using commercial satellite resources for Rapid Environmental Assessment (REA).[1]

In particular, the NURC is in the process of establishing an Earth Observation facility at their main site in La Spezia, Italy. In December 2002, under the auspices of the NATO security investment program, NURC began the procurement of a state-of-the-art satellite receiving ground station as shown in Figure 5. The X-Band ground station has been configured to receive MERIS and ASAR from ENVISAT as well as imagery from RADARSAT-1, TERRA-MODIS, AQUA-MODIS and LANDSAT-7-ETM as indicated in Table 1. It is expected to be completed by late 2004. An example of data received is shown in Figure 6. The X-band ground station is a critical building block of the NURC research program, providing real-time satellite reception capabilities on demand to the REA research thrust area.

Figure 5: X-Band Antenna Mounted on Mobile Ground System.

[1] Information provided in this section by Dr. Peter Ranelli, Head of the Rapid Environmental Assessment Branch, NURC.

Table 1: Satellite Sensor Data Received by X-Band Ground Station

Satellite	Sensor	Nation/ Operator	Wave-Length	Spatial Resolution
ENVISAT	A-SAR	European Space Agency (ESA)	C-Band HH & VV	0.3 - 5 km
ENVISAT	MERIS	European Space Agency (ESA)	0.4 - 0.9 mm	300m
RADARSAT	SAR	Canada/ RSI	C-Band HH	2 - 100 m
TERRA/AQUA	MODIS	US/NASA		
LANDSAT-7	Thematic Land Mapper	US/USGS/NASA	0.45 – 1.75 µm 10 – 12.5 µm 0.5 – 0.90 µm	Six 30 m One 60 m One 15 m
TERRA-SAR (2005)	X-Band SAR	Germany		

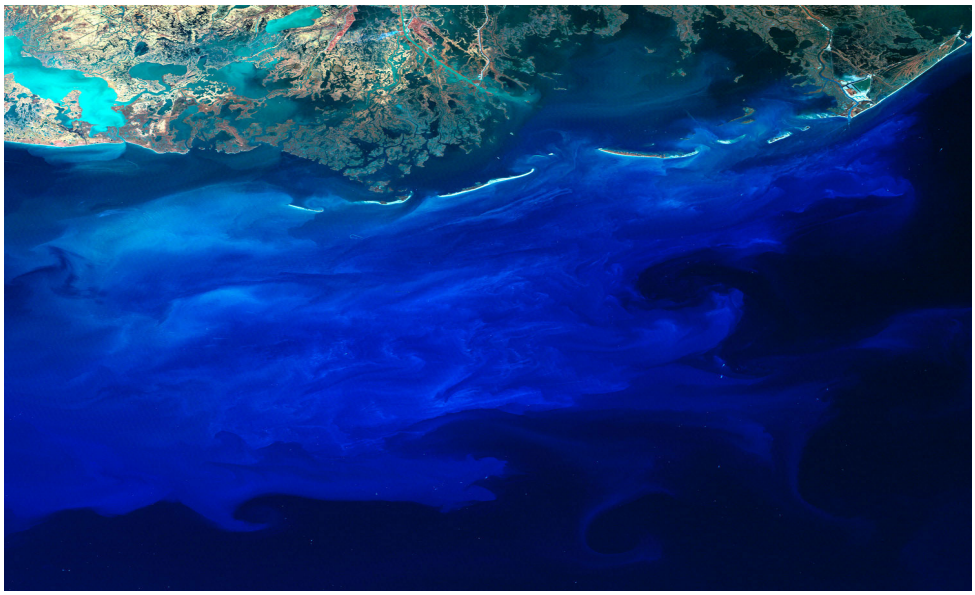

Figure 6: Image from ENVISAT/MERIS showing Coastal Conditions.

The overall goal of REA is to enable the generation of a timely environmental picture of the littoral battle-space, assisting the maritime commander to exploit the environment to strategic and tactical advantage. More specifically, environmental assessment involves a sequence of data collection, analysis and dissemination activities that begin in the early planning stage, become more detailed and time critical as an operation approaches, and require updating after an operation commences. This sequence is a Military Committee (MC) approved Concept of Operations for Maritime REA. The remote REA phase employs all sources of information including climatological data bases, satellite imagery and numerical forecast models for constructing the best historical picture of the tactical environment. The next phase consists of Precursor and/or Covert surveys involving high-resolution on-scene measurements by ships, aircraft, satellites and autonomous or remotely controlled vehicles as permitted in order to provide increased resolution as well as constraint models. These require rapid fusion of data into databases and decision aides. Even more rapid data fusion is required for the operational environmental assessment phase, which progresses while an operation is underway in order to keep the environmental picture and its supporting models up to date. Satellite remote sensing images are key and time critical to all the phases of REA.

Fusion of the data collected into operational and tactical decision aids and dissemination to operational commanders is key to successful REA operations.

However, the ability to predict and simulate the spatial and temporal variability of the environment in coastal, shallow and semi-enclosed areas is a formidable challenge. The scientific research goals and objectives for the exploitation can be summarized in the four sub-areas:

1) Ocean color and undersea visibility
2) Wind, wave observations and modeling
3) Multi-sensor data fusion and exploitation
4) Satellite data-model assimilation

To achieve the goal of REA, several projects have identified real-time satellite reception as a key component in facilitating a littoral observation, prediction and exploitation system. For example:

- Development of realistic tactical decision aids requiring time-critical environmental inputs and short delivery times through communication networks.
- Development of new adaptive sampling techniques. Guiding ship-towed and autonomous underwater vehicles for adaptive sampling of oceanographic features with greatest impact on accuracy of nowcasts/forecasts results. Of paramount importance are sampling of "short-lived" phenomenon (turbidity plumes, wind fronts, short waves) requiring concurrent in situ and remote sensing imagery.
- Assimilation of real-time remote sensing imagery data into meteorological, oceanographic and optical nowcast/forecast models.
- Demonstration of rapid deployment requirements and reception of imagery in remote locations inaccessible by other receiving stations.
- Transitioning of research results into operational products and applications.

In summary, the NURC is actively pursuing the development of processes and tools by which Earth observation data from military and civilian satellites can be conveyed rapidly and effectively to commanders for assessment of littoral environmental conditions during expeditionary operations.

5.1.3 NATO Science

5.1.3.1 NATO Science Committee

The NATO Science Committee [13] supports efforts for international cooperation among scientists. The objective is to sustain peace by fostering trust and understanding through the creation of enduring links between scientists in the Euro-Atlantic region. To achieve this objective, the NATO Science Committee administers the "Security Through Science" Program. In this program, the priority research topics of interest include Defense Against Terrorism, Countering Other Threats to Security and Partner Country Priorities.

One of the activities in this Program is the Virtual Silk Highway project [14]. In this project, the Science Committee's objective is to promote stability in the Caucasus region by providing a valuable tool for regional cooperation among scientists. More specifically, the 'Silk' project involves the installation of a satellite-based network to provide reliable and affordable internet access to members of the academic community in Central Asia and Caucasus countries. These countries include Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, Uzbekistan and, now, Afghanistan.

The Silk network configuration consists of satellite dishes and network equipment in participating countries, a central communication hub in Hamburg, Germany and a contract with a satellite vendor for internet access via a common satellite link. Services for the communications hub are donated by Deutsches Elektronen-Synchrotron and communications equipment was donated by CISCO. The technology used enables each nation to have a minimum bandwidth supplemented with unused bandwidth of other participating countries. The use of modern data caching techniques enables further improvement in the achievable bandwidth. As a result, bandwidth available ranges from 64 Kbps to 384 Kbps (Kilobits/second), an amount which is slightly better than what is available for the average Western European home. A goal is to increase this bandwidth to 3 Mbps in the near term.

Thus, the NATO Science Committee Virtual Silk Highway Project is using satellite resources to promote stability among Partner nations.

5.1.3.2 The NATO Committee on the Challenges of Modern Society

The aim of the Committee on the Challenges of Modern Society (CCMS) [15] is to address issues such as non-traditional threats to security, new and emerging risks that could cause economic, social and political instability, and conflict prevention in relation to resource-scarcity and environmental problems among others.

Several of the projects supported by CCMS utilize data available from satellite-based Remote Sensing instruments. For instance, in the "Waterway Observations for the Caspian Basin" project, sea-level topography derived from satellite measurements is used to infer information about the circulation of the Caspian basin water. Such information is used as an input for analytical models of the water system that will be used to assist decision makers in the management and recovery planning of the Caspian basin environment. This is a pilot project to show how such observations can benefit the region socio-economically.

Thus, remote sensing data is a recognized source of information for environmental understanding and decision making that, ultimately, impacts the security of a region. This may apply to changing land-use, treaty enforcement, pollution assessment and a myriad of other possibilities for the use of such data.

5.1.4 Training

NATO recognizes the space system component as an important tool for the military commander. As such, the NATO School [16] in Oberammergau, GE offers a NATO Secret course in the Operations and Plans Department to instruct commanders on how to include use of space in NATO operational planning and day-to-day operations. The course, N3-01 "NATO Space Operational Planning Course," provides military leaders with basic instruction and information they can use to understand the capabilities of space-based assets. Other courses related to Joint Special Operations also include discussion of space as a tool for the commander.

5.1.5 Operations

NATO has benefited from the use of Alliance space systems in conflict. In particular, NATO's role in the Kosovo conflict to end the abuse of human rights and the repression of the Kosovar Albanian minority was supported heavily by a number of space systems. Communication was provided by the UK's SKYNET satellites. These satellites were responsible for rapid and secure military and data transmissions between NATO member nations. The US GPS system provided navigation and timing support to coordinate actions of aircrews and naval forces for the delivery of precision munitions including air and sea launched cruise missiles [17]. Thus, NATO's use of space systems contributed significantly to bringing a resolution to the Kosovo conflict and continues to support NATO troops in the region. In 2003,

NATO took control of the International Security Assistance Force (ISAF) in Afghanistan to assist the government of Afghanistan in maintaining security in the region of Kabul. Recently, that control has been extended northward by UK, GE and NL Allied forces to influence security in the northern provinces of the country. The action is supported by Alliance satellites moved to temporarily provide coverage in this region [18].

In general, NATO benefits from space systems to give military commanders the "high ground" and to enable them to have a more effective and centralized way to assess and control multi-national actions on a battlefield covering large geographic regions [1]. Because of this, space will, for the foreseeable future, be a valuable tool to provide a military advantage on the battlefield.

5.1.6 Summary

NATO is currently viewing space system components as key security and operational defense network elements. NATO is using satellites to provide communication to developing partner nations to promote regional security. The growing potential of space systems in operational scenarios and threats to these important systems have spawned a need for research aimed at increasing interoperability with these elements, for effectively condensing the massive amounts of data available from space and for protecting these systems and their services. Thus, enhancing the capability within nations via the RTO to develop of national space assets used for NATO defense and security makes objective sense.

5.2 Space Research in NATO RTO (1998 – 2004)

5.2.1 Introduction

An analysis of the NATO RTO panel activities since 1998 was conducted to quantify the amount research being conducted related to Space. In this study, each panel's research activities were evaluated to determine if it could be considered either Space Focused or Space Related. *Space Focused* research is research clearly related to the development of space-based capabilities. The relevance is evidenced by substantial technical content or specific mention of such relevance. *Space Relevant* research involves generic technology developments that could be extended to space-based applications. In this second category, the space relevance may be specifically indicated but not a central focus of the activity.

This section describes the results of this study. Each part of this section commences with an introduction to the mission of each panel or group. This is followed by a summary of Space Focused and Space Related activities and a specific identification of which activities conducted have been Space Focused. In addition, the number of Space Focused activities relative to the number of other panel activities is compared. Specific activities in each panel that were categorized as Space Focused and Space Related are included in Annex B. Activities that could be applied to the Human and Robotic Exploration of Space are also identified as these activities may be of interest to some nations.

The RTO database, 1998 – 2003 Green and Blue Books and information available from individual panel archives were used to compile information regarding historical and on-going activities for each panel. Each RTO panel, via the panel Executive, was invited to review and revise the content of their report. This report reflects the status of activities as of December 2004.

5.2.2 AVT Panel

5.2.2.1 Introduction to AVT Panel

The Mission of the Applied Vehicle Technology (AVT) Panel is to improve the performance, affordability and safety of vehicle platforms, propulsion and power systems operating in all environments including land, sea, air and space, for both new and aging systems. The scope of activities in the AVT Panel is broad and includes design, analysis, testing, operations and environmental impact of such systems. Technical disciplines include fluid dynamics, structural and propulsive materials, vehicle and structural control, and experimental test methods.

5.2.2.2 Summary of Space Activities in the AVT Panel

Space Focused Research

The Space Focused research that the AVT Panel pursues is almost exclusively related to systems development of:

- Hypersonic Vehicles
- Solid Rocket Propulsion

Both the Hypersonic Vehicle and Solid Rocket Propulsion research contribute to a key military capability of "Access to Space". Table 2 contains a summary of Space Focused activities pursued within the AVT Panel since 1998.

Table 2: AVT Panel Space Focused Activities

Activity	Number	Title	Status
Exploratory Team*	AVT-ET23	Improved Hypersonic Performance Through Boundary Layer Transition Prediction	Completed
Lecture Series	AVT-116	Critical Technologies for Hypersonic Vehicle Development	On-going
	AVT-117	Heat Transfer and Inverse Analysis	On-going
	AVT-130	Flight Experiments for Hypersonic Vehicle Development	On-going
	AVT-142	Experiment, Modelling and Simulation of Gas-Surface Interactions for Reactive Flows in Hypersonic Flights	On-going
Specialist's Meeting	AVT-089	Advances in Rocket Performance Life and Disposal	Completed
Symposium	None		
Technical Courses	AVT-034	Measurement Techniques for High Enthalpy and Plasma Flows	Completed
	AVT-096	Internal Aerodynamics in Solid Rocket Motors	Completed
Task Group	AVT-007	Hypersonic Vehicle Propulsion Technologies	On-going
	AVT-008	Hypersonic Experimental and Computational Capabilities - Improvement and Validation	Completed
	AVT-016	Evaluation Methods for Solid Propellant Burning Rate	Completed

* Exploratory Team records not available before AVT-ET-021.

Research related to development of Hypersonic Vehicles has been very active over the years. As shown in Table 3, it has included at least 1 Exploratory Team, 3 Lecture Series, 1 Technical Course and 1 Task Group. The specific technical areas of interest include flight test methodology, propulsion system development, and characterization of high temperature reacting gas flows. In flight testing, test methodology and instrumentation for measuring critical aerothermodynamic parameters were developed. These parameters are relevant to systems for propulsion, thermal protection, navigation and control, and vehicle health management. Propulsion system research includes aerodynamic performance analysis for ramjet and supersonic scramjet configurations and flow physics analysis. Experimental methods for measuring high enthalpy and plasma flows were presented in a special course on high temperature reacting gas flows.

Table 3: Space Focused Activities as Percentage of Total Number of Activities in AVT Panel

Activity	Total	Space Focused	%
CDT	2	0	0
Exploratory Team*	28	1	4
Lecture Series	12	4	33
Specialist's Meeting	18	1	6
Symposium	22	0	0
Technical Course	9	2	22
Task Group	43	3	7
Workshop	7	0	0
Total	141	11	8

* Exploratory Team records not available before AVT-ET-021.

Activities related to Solid Rocket Propulsion include 1 Specialists' Meeting, 1 Technical Course and 1 Task Group. Research on Solid Rockets has focused on internal aerodynamics, methods for characterizing solid rocket propellant burn rate and identification of new propellants. In particular, aerodynamic studies include research on characterizing internal flows for both tactical rockets and large boosters for launch vehicles. Research has been conducted as well to better characterize solid propellant material properties in order to improve prediction of burn rates. New propellants for rocket motors have been studied with a focus on chemistry and performance parameters and a concern for environmental impact due to end of life disposal.

In addition, an Exploratory Team was initiated in 2003 on "Extended Satellite Life." The activity was focused on development of spacecraft propulsion systems for satellite life enhancement and reduction of operational cost. It was cancelled due to lack of participation.

Space Relevant Research

Approximately 21% of the research the AVT Panel has performed may be viewed as having potential for application to space-based activities and is considered to be Space Relevant. If activities related to Human and Robotic spaceflight are included, the percentage of Space Relevant research increases to 32%.

More specifically, the AVT Panel is actively involved in research that may be applied not only to atmospheric and terrestrial vehicles but also to spacecraft. Such research has been conducted in the following areas:

- Analysis:
  - Cost Reduction via Design and Analysis
  - Qualification by Analysis
  - Inverse Heat Transfer Analysis

- Control:
    - Control of Flexible Structures
    - Autonomy and Control for Unmanned Air Vehicles via Intelligent Systems
- Sensors:
    - Micro-electro-mechanical (MEM) Devices
    - Non-intrusive Measurement Techniques
    - Smart Actuators
- Structural Materials:
    - Nanomaterial Technology
    - Intelligent Processing and Manufacturing
    - Low Cost Composites
    - Cost Effective Application of Titanium Alloys
    - Combat Survivability
    - Multifunctional Structures

In addition, some of the research that the AVT Panel performs can be related to Human and Robotic Exploration of Space. While this type of research is not necessarily defense space related, it may be of specific interest to nations pursuing such efforts in the civil sector. Such research includes the following areas:

- Unmanned Autonomous Vehicles (UAV):
    - Fuel Cells
    - All Electric Vehicles
    - Micro-Air Vehicles
- Aging Vehicle Systems

Statistics

Table 3 presents Space Focused activities as a percentage of the cumulative number of activities since 1998[2]. Exploratory Teams, Specialists' Meetings and Task Groups that are clearly space focused account for about 4 – 7% of these activities. The percentages are about 33% for Lecture Series and Technical Courses. Overall, approximately 8% of AVT's past and current activities have been Space Focused.

[2] Historical count estimates are based on activities reported in the RTO database as of 6 December 2004. This is modified from July, 2004 estimates.

5.2.3 HFM Panel

5.2.3.1 Introduction to HFM Panel

The Mission of the Human Factors and Medicine (HFM) Panel is to optimize performance, health, well-being and safety of the human in operational environments with consideration of affordability. This involves understanding and ensuring the physical, physiological, psychological and cognitive compatibility among military personnel, technological systems, missions and environments. The scope of activities in HFM includes focus on human factors, operational medicine and human protection in adverse environments.

5.2.3.2 Summary of Space Activities in the HFM Panel

Space Focused Research

The HFM Panel has not conducted any Space Focused research as shown in Table 4.

Table 4: HFM Panel Space Focused Activities

Activity	Number	Title	Status
Exploratory Team	None		
Lecture Series	None		
Specialist's Meeting	None		
Symposium	None		
Technical Courses	None		
Task Group	None		
Workshop	None		

Space Relevant Research

Approximately 23% of the research that the HFM Panel has performed may be viewed as having 'dual-use' potential for application to Human and Robotic Space Exploration. That is, the research performed has generic application to both soldiers and the space explorer. Such research includes areas such as flight medicine, radiation effects and modeling and simulation of humans in virtual aerospace environments.

Areas of research that have been conducted in the HFM Panel with such relevance include:

- Flight Medicine and Physiology:
  - Effects of aging on performance and safety
  - Cardiopulmonary aspects of aerospace medicine
  - Effects of medication on crew performance
  - Prevention of motion sickness and spatial disorientation
  - Effects on humans of highly maneuverable aircraft
  - Effects of rest on crew performance
  - Sleep deprivation and management

- Effects of Weapons on Humans:
  - Radiation injury and countermeasures
  - Effects on and defense for pilots against directed energy weapons
  - Bio-effects of lasers and human protection strategies

- Modeling and Simulation of Humans:
  - Characterizing the predictability of human performance
  - Safety system models involving humans
  - Simulations of crew performance
  - Modeling human behavior in constructive control methods

- Human Interfaces with Technology:
  - Telemedicine
  - Role of humans in intelligent and automated systems
  - Evaluation of alternative technologies for vehicle control in aerospace environment
  - Virtual environments for human/system interaction
  - 3D audio display and speech communication

Statistics

Table 5 presents Space Focused activities as a percentage of the cumulative number of activities since 1998[3]. Clearly, other than Space Related activities, HFM has not conducted any Space Focused activities.

Table 5: Space Focused Activities as Percentage of Total Number of Activities in HFM Panel[4]

Activity	Total	Space Focused	%
CDT	0	0	n/a
Exploratory Team	35	0	0
Lecture Series	7	0	0
Specialist's Meeting	7	0	0
Symposium	17	0	0
Technical Courses	4	0	0
Task Group	38	0	0
Workshop	8	0	0
Total	116	0	0

[3] Historical count estimates are based on activities reported in the RTO database as of 6 December 2004. This is modified from July 2004 estimates.

[4] Task Group count includes activities with non-specific designations.

5.2.4 IST Panel

5.2.4.1 Introduction to IST Panel

The Mission of the Information Systems Technology (IST) Panel is to maintain expertise and foster information exchange and coordination with other panels in the areas of Information Warfare and Assurance; Information and Knowledge Management; Communications and Networks; and Architecture and Enabling Technologies.

5.2.4.2 Summary of Space Activities in the IST Panel

Space Focused Research

The Space Focused research that the IST Panel pursues is related to:

- Characterization of the Ionosphere.

The activities related to Characterization of the Ionosphere include one Exploratory Team and a newly formed Task Group. A Specialists' Meeting is planned for 2006. This work involves modeling the global, small-scale and large-scale structure of the ionosphere and propagation through the ionosphere for applications such as satellite communications, space surveillance, satellite-based navigation systems and space weather.

Table 6 contains a summary of related Space Focused activities within the IST Panel since 1998.

Table 6: IST Panel Space Focused Activities

Activity	Number	Title	Status
Exploratory Team	IST-ET-023	Characterization of the Ionosphere	Completed
Lecture Series	None		
Specialist's Meeting	IST-056	Characterization of the Ionosphere	on-going
Symposium	None		
Technical Courses	None		
Task Group	IST-051	Characterizing the Ionosphere	on-going
Workshop	None		

Space Relevant Research

Approximately 22% of the research the IST Panel has performed may be viewed as having potential for application to space-based activities. If activities related to human and robotic spaceflight are included, the percentage of Space Relevant research increases to 38%.

Much of the Space Relevant research is associated with areas such as antenna development, information system assurance and security, communication technologies, data visualization and fusion and video surveillance. This research is broad enough to be applied to network centric systems that include secure communication with space-based sensors and antennas and also to the interpretation and analysis of data from such technology.

The research related to development of Smart Antennas is strongly Space Related. One Symposium has been held on the subject of Smart Antennas. Another Symposium is planned for 2006. While the research is primarily focused on conformal phased array antennas for aircraft, it includes research in the development of antennas for communications between high speed aircraft and satellites. Further, the understanding of how structural deformations in antenna structures affect the performance and of how to compensate for errors

resulting from such deformation is of importance to the development of large, ultra-lightweight space antennas.

The IST Panel has pursued the following topical areas of research:

- Information assurance and security:
    - Technologies and tools for real-time intrusion detection of mission critical systems
    - Measures for protecting information in systems and infrastructures against accidental or malicious attacks
    - Exploitation of weaknesses in information infrastructure
    - Information system survivability and intrusion tolerance
    - Information management and security standards for commercial systems
    - Cryptography
    - Dual use of high assurance technology

- Communications:
    - Wireless communications:
        - Mobile communications via satellite linkage
        - Modeling and simulation
    - Frequency allocation for aerospace communications
    - Adaptive information management schemes to overcome effects of low and variable throughput and unreliable connectivity to Command and Control nodes
    - Adaptive algorithms, signal processing and design for conformal antennae
    - Network Centric Warfare (NCW)
    - Network Enabled Capability
    - Software Defined Radios (SDR)

- Visualization methods and technology for large data sets and network analysis:
    - Performance evaluation of visualization methods
    - Search engines and algorithmic processes
    - Data fusion and architectures for Command and Control
    - Multi-media information discovery, presentation and interaction
    - Visualization of relationships and dynamically evolving systems
    - Human-machine interaction aspects of visualization
    - Structural network analysis

- Video-based surveillance systems (i.e. application to space-based surveillance and monitoring of spacecraft and other objects of interest):
    - Multi-sensor data processing and communications
    - Real-time tracking of multiple mobile objects

Some of the research that the IST Panel performs can be related to the presence of humans and robots in space. While this type of research is not necessarily defense related, it may be of specific interest to nations pursuing such efforts in the civil sector. Such research includes the following areas:

- Speech systems technology and processing

- Robotic and multi-robotic systems:
  - Human and robotic interaction requirements
  - Techniques for evaluating effectiveness of robotic systems
  - Use of robots in missions such as reconnaissance, surveillance, transport and communication networks

Statistics

Table 7 presents Space Focused activities as a percentage of the cumulative number of activities since 1998[5]. The Exploratory Team and Task Group that are clearly Space Focused account for about 4% of these activities. Overall, about 4% of the IST Panel activities have been Space Focused.

Table 7: Space Focused Activities as Percentage of Total Number of Activities in IST Panel

Activity	Total	Space Focused	%
CDT	1	0	0
Exploratory Team	25	1	4
Lecture Series	2	0	0
Specialist's Meeting	1	1	100
Symposium	14	0	0
Technical Course	0	0	n/a
Task Group	27	1	4
Workshop	9	0	0
Total	79	3	4%

[5] Historical count estimates are based on activities reported in the RTO database as of 6 December 2004. This is modified from July 2004 estimates.

5.2.5 NMSG

5.2.5.1 Introduction to NMSG

The Mission of the NATO Modeling and Simulation Group (NMSG) is to provide readily available, flexible and cost-effective means to dramatically enhance NATO operations in the application areas of defense planning, operational planning, training and exercises, support to operations and modernization. This goal is accomplished by providing a NATO-wide co-operative effort that promotes interoperability, reuse and affordability of Modeling and Simulation (M&S) tools. The scope of NMSG includes M&S standardization, education and associated science and technology. Additionally, the Group provides M&S expertise in support of the tasks and projects within the RTB and from other NATO organizations.

5.2.5.2 Summary of Space Activities in the NMSG

Space Focused Research

The NMSG has not conducted any Space Focused research activities.

Space Relevant Research

Approximately 26% of the research the NMSG has performed may be viewed as having "dual-use" potential for application to modeling and simulation of space-based systems and components and is considered to be Space Relevant. In particular, the NMSG is involved in developing simulation environments and resources for interoperability studies that may be extended to include space-based elements. Research is also being conducted to investigate use of simulation to reduce cost and time in system design and acquisition programs. In summary, Space Relevant research has been conducted in the following areas:

- Modeling and Simulation for Interoperability:
  - Data and Simulation Standards
  - High Level Architecture (HLA) Development
- Simulation-Based Design and Virtual Prototyping

Statistics

Table 8 presents Space Focused activities as a percentage of the cumulative number of activities since 1998[6]. No Space Focused activities have been conducted.

Table 8: Space Focused Activities as Percentage of Total Number of Activities in NMSG

Activity	Total	Space Focused	%
CDT	1	0	0
Exploratory Team	14	0	n/a
Lecture Series	0	0	n/a
Specialist's Meeting	0	0	n/a
Symposium	6	0	0
Technical Course	2	0	n/a
Task Group	22	0	0
Workshop	1	0	n/a
Total	46	0	0

[6] Historical count estimates are based on activities reported in the RTO database as of 6 December 2004. This is modified from July 2004 estimates.

5.2.6 SAS Panel

5.2.6.1 Introduction to SAS Panel

The mission of the Studies, Analysis and Simulation (SAS) Panel is to conduct studies and analyses of an operational and technology nature, to exchange information on Operational Analysis (OA) technology, to advance the development of OA methods and tools and to provide a forum for NATO M&S oriented towards operational issues. The scope of SAS includes conducting studies linking technology and operations, conducting analysis focused on the operational effectiveness of forces and systems, and performing operations simulation.

5.2.6.2 Summary of Space Activities in the SAS Panel

Space Focused Research

The Space Focused research that the SAS Panel has conducted is related to:

- Ground Surveillance

As listed in Table 9, Ground Surveillance via satellites was considered in a Mission Application Study (MAS) comparing several types of surveillance system platforms (i.e. satellite constellations, high-altitude drones and aircraft) against a specific set of requirements including those associated with Moving Target Identification (MTI). A result of this study was that satellite systems were not considered to be technically and financially competitive against high-altitude drones for theatre surveillance.

Table 9: SAS Panel Space Focused Activities

Activity	Number	Title	Status
Exploratory Team*	None		
Lecture Series	None		
Long Term Systems Study	None		
Mission Application Study	SAS-021	Long-Term Technologies for Alliance Ground Surveillance	Completed
Specialist's Meeting	None		
Symposium	None		
Technical Courses	None		
Task Group	None		
Workshop	None		

*Exploratory Team records not available before SAS-ET-K

Space Relevant Research

Approximately 6% of the research the SAS Panel has performed may be viewed as having potential for application to space-based activities and is considered to be Space Relevant. More specifically, the SAS Panel is involved in research that may be applied to spacecraft systems development. Such research has been conducted in the following area:

- Life Cycle Cost:
  - Cost Structure
  - Methods and Models

Statistics

Table 10 presents Space Focused activities as a percentage of the cumulative number of activities since 1998[7]. Only one Mission System Study was identified as Space Focused. This represents approximately 1% of SAS's past and current activities.

Table 10: Space Focused Activities as Percentage of Total Number of Activities in SAS Panel

Activity	Total	Space Focused	%
CDT	1	0	0
Exploratory Team*	14	0	0
Lecture Series	3	0	0
Long Term Systems Study	11	0	0
Mission Application Study	8	1	13
Multi-National Exercise	1	0	0
Specialist's Meeting	1	0	0
Symposium	11	0	0
Technical Course	0	0	n/a
Task Group	20	0	0
Workshop	0	0	n/a
Total	70	1	1

[7] Historical count estimates are based on activities reported in the RTO database as of 6 December 2004. This is modified from July 2004 estimates.

5.2.7 SCI Panel

5.2.7.1 Introduction to SCI Panel

The Mission of the Systems Concepts and Integration (SCI) Panel is to advance knowledge related to systems, concepts, integration, engineering techniques and technologies across the spectrum of platforms and operating environments to assure cost-effective mission area capabilities. Integrated defense systems include manned and unmanned air, land, sea and space systems. The panel activities focus on NATO and national mid- to long-term system level operational needs. The technical scope of SCI Panel activities is multi-disciplinary and covers a range of theoretical concepts, design, development and evaluation methods applied to integrated defense systems. This includes systems involving weapons and countermeasures, system architectures and mechanization, vehicle integration, mission management and systems engineering.

5.2.7.2 Summary of Space Activities in the SCI Panel

Space Focused Research

The Space Focused research that the SCI Panel pursues is related to:

- Satellite Navigation
- Military Use of Space Systems

Table 11 contains a summary of Space Focused activities within the SCI Panel since 1998.

Table 11: SCI Panel Space Focused Activities

Activity	Number	Title	Status
Exploratory Team	SCI-146	Commercial Space System Capabilities and Military Requirements	on-going
Lecture Series	SCI-029	System Implications and Innovative Application of Satellite Navigation	Completed
Specialist's Meeting	None		
Symposium	SCI-058	Precision Time-Space, Positioning and Navigation (Integrated Navigation Systems)	Completed
	SCI-098	Use of Space Systems in Integrated Military Missions	Completed
	SCI-150	Integration of Space-Based Assets Within Full Spectrum Operations	on-going
Technical Courses	None		
Task Group	None		
Workshop	None		

Research related to Satellite Navigation included one Exploratory Team and one Lecture Series. Specifically, the research was related to the theory and design of inertial navigation systems and to the technical performance evaluation of satellite-based navigation systems such as the GPS and GLONASS.

Military Use of Space Systems is an area that addresses the integration of both commercial and military space-based assets into military operations. Panel activities related to this include one Exploratory Team and two Symposiums. In particular, the purpose of these activities is to identify military requirements related to use of space-based assets by creating a forum for discussion among operational users.

Space Relevant Research

Approximately 20% of the research the SCI Panel has performed may be viewed as having potential for application to space-based activities. If activities related to human and robotic spaceflight are included, the percentage of Space Relevant research increases to 24%.

The Space Relevant research is associated with areas such as vehicle flight dynamics and control, Radio Frequency (RF) applications, system development and multi-platform operations involving Unmanned Aerial Vehicles (UAV). Activities in these areas may be applied to spacecraft vehicle control, to address vulnerability of a spacecraft system or to include a space mission element in a network-centric operation.

In summary, the SCI Panel has pursued the following topical areas of Space Related research:

- Vehicle Flight Dynamics and Control:
    - Robust Control
    - System Level Integration of Control Systems
    - Automation of Flight Control
    - Optical gyros
- RF Applications:
    - High Power Micro-Wave Effects on Electronic Components
    - Imaging Radar:
        - Vulnerability to Electronic-Countermeasures
        - Image Processing for Search and Target Acquisition
    - Susceptibility of Wireless and Mobile Tactical Radio Systems
- Unmanned Aerial Vehicles (UAVs):
    - Multi-Platform Operation (including space-based assets)
- Systems Development:
    - Testing
    - Simulation
    - Signal Processing

In addition, some of the research that the SCI Panel performs can be related to the presence of humans and robots in space exploration. While this type of research is not necessarily defense related, it may be of specific interest to nations pursuing such efforts in the civil sector. Such research includes the following areas:

- Unmanned Aerial Vehicles (UAVs):
    - Technologies
    - Flight Testing
- Robotic Systems:
    - Control Design
    - Computational Models of Human Vision (Search and Target Acquisition)

Finally, it is noted, that most of the satellite navigation, navigational sensors and flight controls research activities related to space are carryovers from AGARD's Flight Controls Panel. In particular, the SCI-029 Lecture Series on Satellite Navigation was held in 1996 and was completed under SCI. Participation in

both carry-over and new space related activities declined as relevant panel expertise declined. For instance, several activities that would be considered Space Focused were initiated since 1998. These activities were cancelled due to lack of participation and/or leadership. They include:

- SCI-035 – Space Systems Testing
- SCI-111 – Future Global Positioning and Timing Systems

Statistics

Table 12 presents Space Focused activities as a percentage of the cumulative number of activities since 1998[8]. Exploratory Teams that are clearly Space Focused account for about 4% of these activities. 10% of Lecture Series and 14% of Symposiums were Space Focused. Overall, 4% of the SCI Panel activities were Space Focused.

Table 12: Space Focused Activities as Percentage of Total Number of Activities in SCI Panel

Activity	Total	Space Focused	%
CDT	1	0	0
Exploratory Team	23	1	4
Lecture Series	10	1	10
Specialist's Meeting	0	0	n/a
Symposium	22	3	14
Technical Course	1	0	0
Task Group	64	0	0
Workshop	12	0	0
Total	133	5	4

* Task Group count includes TG, WG, AG and RSG

[8] Historical count estimates are based on activities reported in the RTO database as of 6 December 2004. This is modified from July 2004 estimates.

5.2.8 SET Panel

5.2.8.1 Introduction to SET Panel

The Mission of the Sensors & Electronics Technology (SET) Panel is to advance technology in electronics and passive/active sensors as they pertain to reconnaissance, surveillance, target acquisition, electronic warfare, communications and navigation; to enhance sensor capabilities through multi-sensor integration/ fusion; and to explore multi-sensor applications and the role of sensor fusion. The scope of activities in the SET Panel includes a primary focus on electro-optic and RF sensors, system components related to such sensors, processing of sensor data and electromagnetic compatibility.

5.2.8.2 Summary of Space Activities in the SET Panel

Space Focused Research

The Space Focused research that the SET Panel pursues has almost exclusively been related to development of:

- Space-Based Radar
- Navigational Sensors
- Electro-Optical Sensors

Table 13 contains a summary of space focused activities within the SET Panel since 1998.

Table 13: SET Panel Space Focused Activities

Activity	Number	Title	Status
Exploratory Team	SET-ET10	Spacebased Radar Experiment Planning	SET-045
	SET-ET14	Advancement in Inertial Sensors and their Application to Navigational Systems	SET-050/-054
	SET-ET35	Emerging Technologies for Sensors Front-ends	Complete
Lecture Series	SET-064 a and b	Advances in Navigation Sensors and Integration Technology	Complete
Specialist's Meeting	None		
Symposium	SET-039/RSY08	NATO/Military Sensing Symposium	Complete
	SET-037/RSY06	Spacebased Observation Technology	Complete
	SET-050/RSY11	Emerging Military Capabilities Enabled by Advances in Navigation Sensors	Complete
	SET-094/RSY-019	Emerging EO Phenomenology	On-going
	SET-095/RSY-020	Bistatic and Multistatic Radar and Sonar Systems	On-going
Technical Courses	None		
Task Group	SET-045/RTG26	Spacebased Radar Technology for Military Applications	On-going
	SET-054/RTG30	Emerging Military Capabilities Enabled by Advances in Navigation Sensors	Complete
	SET-084/RTG-048	Emerging Technologies for Sensors Front-Ends	On-going
	SET-087/RTG-050	Vibrating Antennas and Compensation Techniques	On-going

Studies related to development of space-based SAR included one Exploratory Team and an on-going Task Group. The study is contributing to the evaluation and development of military space-borne radar sensors for

3-dimensional imaging capability with day/night and all weather operation. Technical areas addressed involve cartography, 3D-mapping, 3D-signature analysis, data fusion, change detection, SAR interferometry and polarimetry and evaluation of SAR performance and simulation tools. Fusion of data acquired from civil space-based SAR (i.e. Shuttle Radar Topography Mission (SRTM), European Remote Sensing (ERS) Satellite, RADARSAT and ENVISAT) is also under investigation. Bi- and multi-static radar on space-based platforms will be addressed in an upcoming symposium.

Research in the area of navigational sensors was initiated via an Exploratory Team followed by a Task Group. These activities produced a Lecture Series and Symposium. The navigational sensor activities that were Space Focused included use of advanced low-cost navigation sensor technologies for spacecraft including Inertial Measurement Units (IMU), gyroscopes, GPS, strap-down systems and MEM devices. The 'dual use' implementation of navigational technologies was emphasized in a symposium focused on air and land vehicles. Issues addressed included precise targeting, situational awareness, navigation, flight path guidance stabilization and control, smart munitions, tactical missiles, robust sensor platforms and personal navigation systems.

The SET Panel held a very comprehensive Space Observation Technology symposium at which many aspects of space-based observation were discussed. This included discussion of operational requirements and trade-offs; space-borne radar technology including SAR; surveillance; on-board and real-time processing; ground support systems; and sensor systems.

Included also in the Space Focused area for SET is technology research that is very strongly dual-use for both atmospheric and space applications. A Military Sensing Symposium included development and use of these sensors for missile defense targeting, navigation, target identification, surveillance and reconnaissance. A Task Group is also planned to survey emerging technologies for optical and RF sensor front-ends. Issues relating to the use of RF antenna systems are being studied. A currently active Task Group is investigating how structural deformations in antenna structures effect measurements and how to electronically and mechanically reduce such effects.

Space Relevant Research

Approximately 45% of the research that the SET Panel has performed may be viewed as having 'dual-use' potential for application to space-based sensors. That is, much of the research associated with the sensor development is generic such as the establishment of sensor performance metrics, image processing algorithms, sensor models or multi-sensor data fusion.

More specifically, the SET Panel is actively involved in developing tools and techniques for electro-optical (LIDAR and micro-scanned thermal imaging), RF (SAR, MMW, multi- and bi-static radar), and multi-sensor (LADAR) systems. Theoretically, all of these sensors may be demonstrated on a space-based platform with further, specific development for such an application. Areas of research that have been conducted in the SET Panel with such relevance include:

- Theory of polarimetric and interferometric radar in reconnaissance and surveillance
- Modeling, validation and simulation of target, sensor and environment models
- Experimental performance assessment and measurement techniques
- Image degradation due to atmospheric and background effects, low contrast, noise and laser dazzling
- Target detection and classification:
    - Low observable air and maritime targets radar imaging
    - Aircraft radar images

    - Non-Cooperative Target Identification (NCTI)
    - Automatic Target Identification (ATI)
- Surveillance and Reconnaissance
- Signal/image processing:
    - Complex signal processing algorithms and software radars for data fusion
- High speed electronics
- Multi-sensor fusion
- Dual-use (space and terrestrial) sensor suites

In addition, the SET Panel has been addressing some issues related to atmospheric modeling that will facilitate modeling sensor performance from orbit. This research includes the modeling of adverse weather conditions, air mass characterization, modeling propagation of missile exhaust plumes and coastal aerosols.

Statistics

Table 14 presents Space Focused activities as a percentage of the cumulative number of activities since 1998[9]. Exploratory Teams and Task Groups that are clearly space focused account for about 6 – 8% of these activities. Twenty-two percent of Lecture Series and 36% of Symposiums were considered to be Space Focused. Overall, approximately 12% of SET Panel activities have been space focused.

Table 14: Space Focused Activities as Percentage of Total Number of Activities in SET Panel

Activity	Total	Space Focused	%
Exploratory Team	32	3	9%
Lecture Series	9	2	22%
Specialist's Meeting	3	0	0%
Symposium	14	5	36%
Technical Course	0	0	n/a
Task Group	50	4	8%
Workshop	5	0	0%
Total	113	14	12

*1 CDT in conjunction with SCI-152.

[9] Historical count estimates are based on activities reported in the RTO database as of 6 December 2004. This is modified from July 2004 estimates. The result is a higher percentage of Space Focused activities due to the inclusion of activities that were considered to be very strongly 'dual-use' for space.

5.2.9 Comparison to AGARD Activities (1995 – 1998)

A comparison was made to the level of space research activity in AGARD during the most recent period of 1995 – 1998. Detailed activity information was not as readily available for a direct comparison, so only Space Focused publications were identified and counted relative to other publications during the same period [19]. In particular, out of 1879 publications, 95 were Space Focused or 5% of the total, not including work related to Hypersonic Vehicles and sensor system development. These publications were primarily in the area of Spacecraft Design, Testing and Performance and in Remote Sensing. The RTO research in either of these topical areas has diminished significantly. Thus, during AGARD's final years, very little space research was pursued aside from Access to Space via Hypersonic Vehicles and sensor system development.

5.2.10 Summary of Activities

As summarized in Table 15, 5% of the research pursued in the NATO RTO since 1998 has been Space Focused including Hypersonics and sensor system development. In AVT, this research has been concentrated on "Access to Space" via Hypersonic Vehicle development and Solid Rocket Propulsion. IST space activities focus on Characterization of the Ionosphere. IST is also pursing work in Network Centric Warfare and Network Enabled Capabilities, both of which may consider use of space system elements. SAS has conducted a study to evaluate use of satellite platforms with other types of surveillance system platforms. SCI has been actively considering the use of both military and civilian space systems in military operations and also addressing issues related to satellite navigation. Finally, the SET Panel has pursued the development of a wide range of optical and navigational sensors and radars that could be used in space-based applications. By comparison to AGARD activities, it is seen that the amount of Space Focused research that the NATO RTO pursues has at best remained unchanged despite NATO's growing dependence on such systems. Two areas, in particular, Spacecraft Development and Remote Sensing from space have diminished significantly.

Table 15: Summary of NATO RTO Space Focused Activities (1998 – 2004)

Activity	Total	Space Focused	%
CDT	6	0	0
Exploratory Team	171	6	4
Lecture Series	43	7	16
Long Term Scientific Study	11	0	0
Military System Study	8	1	13
Multi-National Exercise	1	0	0
Specialists' Meeting	30	2	7
Symposium	106	8	8
Technical Course	16	2	13
Task Group	265	8	3
Workshop	42	0	0
Total	**699**	**34**	**5**

6.0 THE ENVIRONMENT FOR SPACE RESEARCH

What are the current environment for space research and the perceived barriers to increasing the amount of space research RTO pursues?

In this section, the environment and barriers for space research are considered at the NATO RTO organizational level and in the much broader national and international level. In particular, the international environment for space is discussed as it tends to set the tone for the level of collaboration that is achievable. In addition, a relatively new trend in national research priority and its influence on the NATO RTO research environment are discussed. Finally, organizational issues within the NATO RTO that appear to be barriers to more focused attention on space research are presented.

6.1 International Environment for Space

National policies that seem to differ on how space should be used create a challenging environment for cooperation. However, recognition of different perspectives among nations is an important step towards finding common capability needs that will ultimately lead to the most effective use of resources to develop new capabilities for a stronger Alliance. Thus, while the US is currently recognized as having a powerful military presence in space, it is important to consider the priorities of both North American *and* European Allies as indicators of where enhanced trans-Atlantic cooperative research may be achieved for progress within NATO. Thus, recent actions within Europe to define priorities via an EU space policy are summarized and a very brief discussion of the US Space Policy is presented. This discussion is followed by several observations on the current state.

6.1.1 EU Space Policy

The European Union is currently undergoing rapid expansion and a period of policy reformation to achieve increased unification, efficiency and strategic independence. Space figures prominently among those issues considered of high importance to meeting the goals of the European Union in the future.

In January 2002, the European Parliament requested that the European Commission (EC) provide leadership in the establishment of a European Space Policy. In response, The EC set up a Joint Task Force involving the EC the European Space Agency (ESA) to consult within the European community on the subject of space policy. The consultancy involved a series of topical workshops and an active internet forum. Participation was strong in the eight workshops held between March and June 2003, with over 1400 participants. The workshops covered topical areas including: Industrial View; Scientific Community View; Institutional, Security and Defense Aspects; Operator and Service Provider's View; and International Cooperation.

Of particular interest was the workshop held in May 2003 which was dedicated to security and defense issues. In this workshop, focus on the following space-based capabilities was recommended:

- Independent Access to Space
- Global monitoring
- Global reconnaissance, monitoring and surveillance, including image intelligence and electromagnetic signal analysis
- Meteorology and oceanography
- Telecommunications
- Intelligence information and verification
- Global command, control, communications and Information
- Global positioning, navigation and timing

- Mapping
- Space-based surveillance
- Early warning and distant detection
- Search and rescue

As a result of this consultancy, the Joint Task Force was able to formulate a Green Paper describing the European expectations with regard to space [20]. The Green Paper was used as a reference for the White Paper on Space [21] that is an Action Plan to implement the new European Space Policy goals. The Action Plan was adopted by the European Commission in November 2003. In general, the White Paper emphasizes that European Policy should exploit the real benefits that space technologies can offer to meet European goals including faster economic growth; job creation and industrial competitiveness; European Union enlargement and cohesion; sustainable development; and security and defense. In particular, the following five actions were laid out in the Action Plan.

6.1.1.1 Deploy a European Asset for Satellite Navigation, Timing and Positioning

Proposed by the European Commission in 1999, GALILEO, as shown in Figure 7, is the first major space project launched under the auspices of the EU in partnership with private industry. GALILEO will provide Europe with independent navigation, timing and positioning information. As such, it is an important strategic asset and element of the European space policy. GALILEO is a constellation of 30 satellites and associated ground stations designed to provide global radio navigation services by 2008. The Mid-Earth Orbit (MEO) satellites will be in 3 orbital planes at 56° inclination. With GALILEO, the EC seeks to tap into the rapidly growing commercial demand and economic benefits for a wide range of satellite navigation services and derived products.

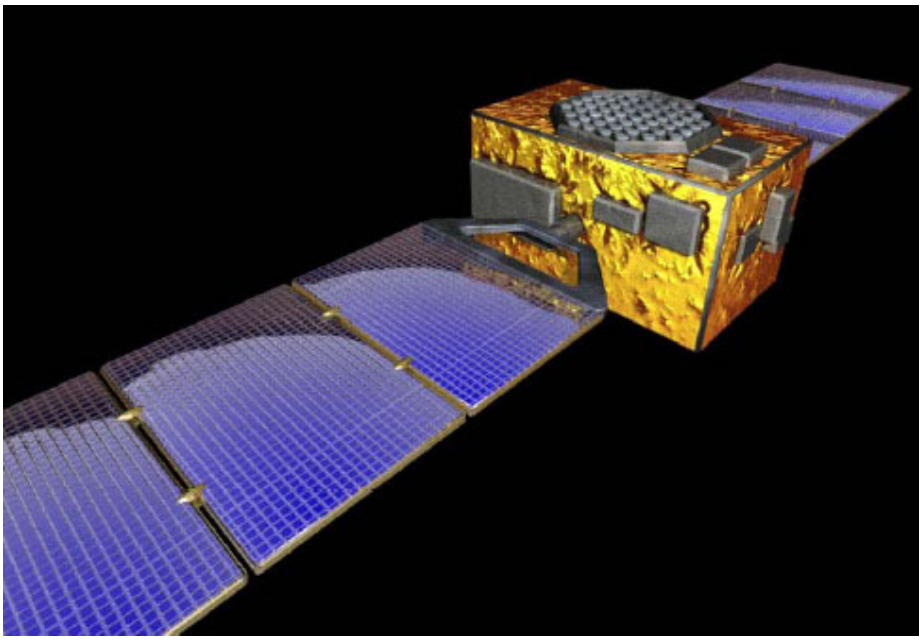

Figure 7: GALILEO Spacecraft.

6.1.1.2 Provide Global Monitoring for the Environment and Security (GMES)

At the Gothenburg Summit of 2001, the European Council adopted a strategy for sustainable development that called for a European capacity for Global Monitoring for Environment and Security (GMES). GMES

is a pan-European partnership aimed at delivering sustainable, shared data and information services provided by observation systems in space, land, air and sea. It relies upon use of a variety of space-based Earth observation systems including "high- and medium-resolution, optical and radar imagers for land surface, coastal zone and ocean monitoring; advanced optical and microwave sensors for atmospheric composition measurements and advanced active and passive microwave instruments for ocean monitoring" [21]. The promotion of interoperability among existing and near-term systems, such as GALILEO, via coordinated data policies and standardized spatial data infrastructures is of particular interest. Thus, space-based systems provide the tools for addressing not only military needs and but also humanitarian objectives like aiding development, fighting poverty, early warning and management of natural disaster. As such, GMES supports EU military objectives linked to the implementation of a Common Foreign and Security Policy (CFSP).

6.1.1.3 Use Space as a Contribution to the CFSP

The European Union seeks to have a more effective role in global security via a stronger CFSP that is supported by a European Security and Defense Policy (ESDP). In particular, it is desirable for the ESDP to have more reliable access to space-based systems and services for strategic advantage and to enable a capacity for independent and informed decision making. The White Paper recommends additional study into how EU Space Policy can embrace security and defense more fully. In particular, there is a need to reconcile procedures for the military and civil sharing of nationally owned, dual-use space assets. This includes a need for policy to govern how to maintain control of certain types of data from civilian assets and how to use such assets in real-time for military applications. It also includes a need to better define the respective roles of the EU Satellite Center and the multi-national ESA for EU military needs. ESA's charter prohibits participation in military space development. However, talks are now underway to make ESA the EU's resource for civilian *and* military space under the EU-ESA Framework Agreement [22]. Finally, in order to build a comprehensive EU space-based security capability, the report recommends developments in the areas of:

- Global monitoring, positioning, navigation and timing
- Communication
- Signals intelligence to monitor electromagnetic activities
- Early detection of activities leading to missiles proliferation
- Space surveillance for detection and identification of space objects
- Space environment monitoring for solar events, near-earth objects and space debris

6.1.1.4 Bridge the "Digital Divide"

Investment in satellite communications allows the European community to more fully participate in the 'knowledge economy' to strengthen economic growth and build cohesion among EU nations. The EU seeks to bridge the "digital divide" and foster development of the new Member states with expanded internet access via the provision of broadband communication services.

6.1.1.5 Develop International Partnerships

Finally, the White Paper recommends that the European Union take advantage of international cooperation to leverage European capability and investment. Such cooperation is encouraged among nations at the EU level, as it is recognized that no EU nation has the resources to independently develop all the space capabilities needed. Cooperation is also encouraged via long standing relationships with the US and Russian and through partnership with other emerging space nations.

To meet the five goals of the EU Space Policy, space technologies and infrastructures must be available via a European capacity to launch and maintain satellites providing global communications, positioning and observation. To meet these objectives, the White Paper strongly recommends an increase in funding by the EU to develop and deploy applications and to support space research and development, technology and infrastructures[10]. With the adoption and implementation of the White Paper recommendations by the EC and, specifically, the ensuing increase in funding for space systems and science, an increasing interest in space research should be observed in the future. The White Paper also recommends more consolidation and coordination of the scientific and technical basis for currently existing space activities and warns that if the proposed approaches to space policy are not adopted, that European competitiveness in the world space market will seriously decline.

In summary, the European Union is currently undergoing an evolution to a more unified state with focused goals. The military, security, humanitarian and economic advantages of strengthening the existing space capability of the EU have been thoughtfully considered and found to be one of the keys to successfully meeting EU goals. As such, EU decision-makers have been encouraged by members of the space community to reinforce the importance of space technologies in support of security and defense policy requirements.

6.1.2 US Space Policy

In the US Space Policy [23], the US recognizes its current global leadership role in exploration and use of space for meeting goals of national security, foreign policy, economic growth, environmental stewardship and scientific and technical excellence. Assuring access to space and a continuous presence in space are indicated as key elements for peacekeeping and maintaining US national security. Use of space assets to meet humanitarian needs is a recognized part of security and is integral to the US responsibility as a global space power. The Policy also seeks to pursue international cooperation to ensure the peaceful exploration and use of space.

More specifically, the goals of the US space program are to [23]:

- Enhance knowledge of the Earth, the solar system and the universe through human and robotic exploration
- Strengthen and maintain the national security of the United States
- Enhance the economic competitiveness and scientific and technical capabilities of the United States
- Encourage State, local and private sector investment in, and use of, space technologies
- Promoting international cooperation to further US domestic, national security and foreign policies

In addition, the US Space Policy mirrors the United Nations Treaty on the peaceful use of outer space [24] in rejecting sovereignty of any nation over areas of space or celestial bodies. It further recognizes space systems of any nation to be national properties having the right of unrestricted passage and uninterrupted operations in space, including operations involving data collection. As a result, the US regards interference

[10] In fact, such funding is beginning to appear under the European Commission's Preparatory Action in the field of Security Research (PASR) as a first step towards a European Space Research Program (ESRP). While the amount of funding for space research is expected to be a small part of the PASR at first, funding (15M Euros in 2004 and 24M Euros in 2005) has already been made available for research in the following areas:
- Optimising protection of networked systems
- Protecting against terrorism
- Enhancing crisis management
- Achieving interoperability and integrated systems
- Improving situation awareness

Source: http://europa.eu.int/comm/research/security/index_en.html

with space systems as an infringement on sovereign rights. The US uses space systems for the purpose of national security to improve "US ability to support military operations worldwide, monitor and respond to strategic military threats, and monitor arms control and non-proliferation agreements" [23].

The US Space Policy delineates several relevant sectors including National Security, Defense, Intelligence and Commercial interests.

In the National Security sector, the Policy specifically indicates the need for pursuing space activities that support the US right to self-defense and the defense of allies; deterring and warning against attack; preventing and countering use of space by hostile forces; enhancing the operation of US and allied forces; and ensuring the ability to conduct military and intelligence related space activities.

In the Defense sector, US Space Policy emphasizes the need to assure a national capability for executing space missions for the space support, force enhancement, force application and space control. The US Department of Defense (DoD) is tasked with protection of critical space-related technologies and missions. DoD is also responsible for launching space systems for the defense and intelligence communities and for maintaining such launch capabilities. DoD is also responsible for maintaining the effectiveness of the US space control capability consistent with treaty obligations to ensure freedom of action in space or, in conjunction with diplomatic or legal measures, to deny freedom of action to adversaries or prevent hostile use of space systems. The US Space Policy also requires that the US will maintain a space surveillance capability to monitor and classify intent of potential threats. Finally, the Policy indicates that the US should pursue a missile defense program to provide for an enhanced theater missile defense capability, for defense against long-range ballistic missile threats to the US and for related technology development.

Responsibility related to exploration of the universe, including Earth, is mostly delegated to NASA for implementation. NASA is the US civil agency for research and development related to physical and space science; Earth observation for global change and the impact of humans on the environment; human and robotic space flight and space exploration; and the development of space technologies to meet US government and commercial needs. NASA's role in civil space exploration gained additional attention in January 2004 when the President announced his new "Vision for Space Exploration Program" [25] to explore the Moon, Mars and beyond.

In the Intelligence sector, the US policy requires that timely information and data is provided by space systems to "support foreign, defense and economic policies, military operations, diplomatic activities, indications and warning, crisis management and treaty verification." Strict and detailed guidelines are indicated for the classification and public release of data from such systems, in particular, satellite reconnaissance data. Restrictions on the dissemination of commercial remote sensing data are also indicated but covered under a separate document [26].

The Commercial space sector is also viewed as an importance element of the US Space Policy as it benefits the US economically while also supporting US national security and foreign policy interests.

Finally, in support of US Space Policy are extensive doctrines on International Cooperation; Space Transportation; Space-Based Earth Observation; Non-proliferation; Export Controls; and Technology Transfer.

6.1.3 Challenges

Both the EU and US face tough challenges.

In particular, while the EU is working diligently to formulate a pan-European strategic military space policy, the current environment for space research in Europe does not appear to be highly coordinated and

is not well funded [27]. In fact, the European military space development effort is still widely recognized as being primarily based on the initiatives of individual nations. Thus, while space technology is viewed as a strategic priority by the EU and nations have significant space capabilities available, consolidated acquisition planning is currently lacking and much duplication exists in development efforts. In addition, the vision of a strategic independence for the EU is challenged as individual nations continue to pursue national visions for both civil and military defense through cooperation with the US, Russia and, increasingly, China, India and Japan.

The US is not exempt from tough challenges. While global security benefits substantially from the US investment in military space, there is much concern in Europe regarding the *perceived* US intent to weaponize and control space and many doubts about whether the European community wishes to share similar objectives. Further, the impact of strict US Export Control laws [28] was cited as a reason in the EU Space Policy for increased international cooperation. The EU hopes to dilute adverse effects of these laws incurred by the European community via international cooperation with other space powers to the extent possible as they view these laws as an attempt to constrain commercial growth in the international space market. Thus, the US is challenged with maintaining superior space capability *and* international cooperation to meet future needs.

While the issue of policy formulation is out of the scope of NATO's RTO, policy implementation dictates national research investment that does impact RTO research. National policies clearly limit the ability of researchers to freely participate in joint research activities. And because space remains a highly sensitive technical area, nations will continue to be cautious about which technical areas they choose to contribute in order to maintain their national priorities for defense and security.

6.2 Trends in National Research Priorities

NATO RTO's predecessor organization, AGARD, was formed in 1952 at the request of Dr. Theodore von Kármán. von Kármán had the vision of a science and engineering community that performed collaborative research across national boundaries on common defense issues faced by NATO nations. The exchange of information and use of existing research and development resources could be used for mutual advantage without affecting the principles of national policy [29]. The success of his vision was further based on the premise that a researcher's primary motivation for achieving excellence was pursuit of knowledge, that working in an international community enhanced the research experience and that those who participated were free to form their own programs of work. Thus, researchers could become technical ambassadors promoting cooperation throughout NATO. After more than 50 years, the NATO research community has proven this concept and the research organization continues to draw impressive expertise from within the NATO community.

In 2004, the environment for research is radically different than it was even ten years ago. A major reason for this is a shift towards "requirements based research" rather than "open-ended basic research". The philosophy behind open-ended basic research is that the creative process of the free scientific mind can be more innovative without administrative interference. However, the need for fiscal efficiency and hunger for results in organizations around the world has led research agencies and companies to become more restrictive of research activities. Now, more than ever, for research to be funded, it must be tied to finding solutions that meet the mission requirements of organizations.

Because researchers who contribute to the NATO RTO work for the civil and defense organizations undergoing this shift, their participation in the RTO is affected because researchers are no longer quite as free to define and follow-through with their own program of work. Thus, the participation in the RTO activities is no longer solely based on the principal of scientific fraternity but is an expression of national and corporate investment priorities. Because budgets are tight, specific research areas must be strongly coupled with commercial and government funded activities. The cost vs. return perspective of investment

leads to a prioritization of research activities and the cost of conducting research. This includes limiting travel and work-time that would allow free participation in RTO.

This is particularly important for defense space research. In general, defense space research is regarded as a much lower funding priority than other, more traditional areas of research such as in land, sea or air operations despite its growing importance in military operations. As an example of this, one large NATO nation has recently privatized many of its government research labs. It is now very difficult for former government space researchers, now in the private sector, to gain funding for participation in space related RTO activities that don't clearly support new organizational objectives. The tightening of resources can be observed for other organizations throughout the US and Europe that are undergoing a similar shift towards requirements based research and fiscal efficiency.

6.3 NATO RTO Organizational Observations

Finally, several observations were made regarding the preferences of RTO research panels. It is important to understand these preferences in order to offer a strategy for, perhaps, influencing panels to expand their scope of work. The following is a summary of key observations.

The technical skills and preferences of panel members are typically not related to space. This was reflected in the panel overviews that showed few RTO activities focused on some aspect of space systems or science. In fact, the NATO RTO lacks a "critical mass" of experts with space science and technology expertise. Most panel members have a lack of access to national networks involved in space systems development and science. As a result, they are largely unaware of capabilities or national interests in these areas. The impact is that space focused activities are only infrequently proposed and rarely find sufficient (i.e. 4 nations) support within the panel or the nations for success.

Space is a highly sensitive technical area. As indicated earlier, the influence of the external environment clearly influences panel decision making. The preference for major nations to prefer bi-lateral agreements in sensitive areas of research that may be of interest to panels is mutually exclusive with the RTO requirement for multi-national cooperation. Thus, while the RTO may occasionally spawn bi-lateral or even tri-lateral activities in space research, these activities are not tracked by RTO panels. In the end, as shown in the panel activity analysis, if the panels consider space related work at all, most would view it only as dual-use of technologies being developed for other applications and peripheral to their main mission.

In addition, many of the **panels have very full portfolios of work**. The suggestion that space should be considered as an application area carries with it the question regarding what the right proportion of research is among land, sea, air and space research since space activities compete directly with a large number of other priorities delivered by NATO or national interests. Panels are reluctant to change the current balance without clear motivation from the NATO Research & Technology (R&T) Strategy, RTB, NATO Capability Needs or national interests.

Finally, it was important to understand how the role of an Executive Officer (EO) from the RTA Staff is perceived by the research panels. In general, the RTA is regarded by panel members as an administrative organization. The EO role, then, is to provide administrative support to panel members to facilitate research activities. **Technical recommendations and leadership are sought from among the technical peers of panel members not from within the RTA staff** except for higher-level NATO directives conveyed via RTA staff members.

7.0 STRATEGY FOR INCREASING SPACE RESEARCH IN NATO RTO

What is the most effective strategy for energizing current space research and motivating more space research in the RTO?

Any strategy pursued for increasing space research in the NATO RTO must represent a solution despite the constraints of the current environment discussed in the preceding section. It must also fit within the organizational constraints imposed by the RTO. While several solutions may be possible, this section describes an optimal path to achieve the desired result. It is also the simplest solution, as a simple solution is often the most successful in a complex environment. The solution will enable NATO to enhance its security effectiveness by increasing national capability to achieve superiority via the use of modern space systems.

This section begins with the formulation of a strategy. In this formulation, the need for space research to be clearly endorsed at the highest level in the NATO R&T Strategy is recognized as a precursor to success. Next, a comparison of Organizational Strategies that could be considered to increase space research within RTO is made. From these possibilities, one is selected that optimally satisfies the constraints imposed by the current environment. Finally, an Implementation Plan is presented that defines elements of the strategy and maps out a course for success.

7.1 Strategy Formulation

7.1.1 NATO R&T Strategy Revision

A key element in considering space as an RTO application area is to more formally recognize the growing importance of space in the military domain. In order for the RTO research community and NATO nations to embrace study in this area, it must be specifically indicated in the NATO R&T Strategy. The NATO R&T Strategy is a document that provides guidance to panels regarding issues of the highest importance to NATO and is used by panels in the program planning process. Thus, recognition of a military dependence on space and the need to pursue research related to space must be clearly indicated in the NATO R&T Strategy.

7.1.2 Comparison of RTO Organizational Strategies

The current organization of RTO is defined by six research panels and a one research group and is administered by the RTA. To address the issue of whether another organizational unit should be established for space, a trade matrix was drawn with the different options. This matrix is presented in Table 16.

Table 16: Potential RTO Structures for Space Research

Option	Organization	Description	Chairman	Pros	Cons
1	Pursue research via existing research panels	▪ Membership remains in panels ▪ New activities related to space introduced via normal panel procedure	No	▪ No technical isolation of panel members	▪ Rebalance or reduction in current research efforts may be required in panels to accommodate additional activities ▪ Most panels unable to appoint sufficient members with expertise to initiate or support space research activities ▪ Difficult to coordinate space activities among panels
2	***Space Advisory Group***	▪ Membership remains in panels but is 'borrowed' by the group ▪ Membership augmented with external space expert consultants ▪ Inter-panel level ▪ Coordinated recommendations for space research topics made to panels by peers ▪ Group members identify expertise in nations to support ideas BEFORE making recommendations to panels	Chairman	▪ No technical isolation of panel members ▪ May add external membership ▪ RTA space executive officer to support Space Advisory Group ▪ Limited-life (2 years w/ possibility of renewal or transformation)	▪ Rebalance or reduction in current research efforts may be required in panels to accommodate recommended activities
3	***Space Panel***	▪ Same as Space Advisory Group except that space activities are consolidated under separate administration ▪ Initiates and conducts own space research activities	Chairman	▪ May add external membership ▪ Separate panel executive and panel assistant	▪ Difficult to separate space activities that might involve dual-use technologies from other panels ▪ Potential technical isolation as multi-disciplinary group may not attract technical specialists ▪ Additional cost of panel assistant ▪ Indefinite life
4	***NATO Space Group***	▪ Analogous to NMSG ▪ Resident RTA staff Space experts to conduct quick response studies for NATO ▪ Consolidation of space expertise and tasks from current panel activities to Space Group ▪ Initiates and conducts own space research activities	Chairman	▪ May add external membership ▪ Separate panel executive and panel assistant	▪ Difficult to separate space activities that might involve dual-use technologies from other panels ▪ Potential technical isolation as multi-disciplinary group may not attract technical specialists ▪ Additional cost of panel assistant ▪ Indefinite life ▪ The need for quick studies related to space may already be fulfilled by NC3B sub-committees in conjunction with NC3A

Option 1 is the current panel structure. In this option, panel members remain among their technical peers and consider additional activities focused on space. This is the current model. It is subject to the barriers previously identified in Section 6.2 and represents an over-constrained situation in terms trying to infuse additional space research into panel programs.

Option 2 is a more flexible option. In this option, an inter-panel SAG is defined in which appropriate panel members are supplemented by space experts outside the normal RTO technical network. The outside experts infuse new ideas, experience and give access to new technical networks in the nations. The SAG is NOT a panel. It establishes topics of importance to NATO and the nations and provides recommendations for specific activities back to the panels. Thus, recommendations are made to panels via their technical colleagues to maximize the credibility of the recommendations. The SAG further takes responsibility for identifying sufficient support within at least 4 nations to fulfill the tasks BEFORE recommendations are made to the panels. The SAG takes the responsibility for identifying key Space Technology Watch areas including potential disruptive space technologies. SAG is responsible for increasing visibility of NATO RTO as a forum of choice for trans-Atlantic cooperative defense research. In this model, however, panels may still need to consider a rebalancing or reduction in current research efforts to accommodate additional activities that may be recommended. Panels are welcome to adopt members of Space Advisory Group as Panel Members or Members at Large. The SAG has a finite life-time of 2 years with the possibility of renewal or transformation to another organizational structure at the end of that period of time. The Space Advisory Group will make a recommendation regarding such continuance to the RTB.

Option 3 involves setting up a permanent Space Panel. Option 3 is similar to Option 2 except that it has its own program planning and administration for space activities. Existing space activities in other panels are consolidated in the Space Panel. Similar to Option 2, space experts outside the current RTO technical network become involved. The key advantage is the relief of the administrative burden on panels due to an increased number of activities. A strong disadvantage is the difficulty in separating space activities from other panels that may involve development of strongly dual-use technologies. In addition, highly multi-disciplinary groups may not be attractive professionally to the technical specialists that are needed.

Option 4 is the formulation of a Space Group analogous to the NMSG. The Space Group would have RTA Staff Experts available to perform space related studies for broader NATO needs. Similar to Option 3, experts outside the current RTO technical network would need to become involved; the group would have its own program planning and administration; and existing space activities in other panels would be consolidated in the NATO Space Group. Disadvantages to Option 4 include those associated with Option 3. In addition, the need for quick studies related to space may already be fulfilled by NC3B Sub-Committees in conjunction with NC3A.

The current operating structure of the RTO and RTA is the result of a transformation of technical programs from the former two organizations AGARD and DRG. Thus, much thoughtful consideration has been given to formulation of the current organization. As a result, it has been emphasized that the success of any new initiative at this time in the NATO RTO will be closely connected with how well it conforms to the recently established organization and associated procedures.

As a result, it is unlikely that the formation of a permanent group related to space will be acceptable. Thus, Options 3 and 4 for defining separate research groups can be eliminated from consideration. On the other hand, it is not likely that the current research groups will spontaneously embrace additional topics related to space given their current technical demographic and priorities. The conclusion, then, is that Option 2 must be seriously considered, that is, the formation of a SAG.

7.2 Implementation Plan

In this section, an Implementation Plan for the Option 2 strategy is presented. The first step is participation in the NATO R&T Strategy Revision followed by identification of Space Expert Consultants in the nations and details describing formulation and actions of a Space Advisory Group.

7.2.1 NATO R&T Strategy Revision

In 2004 – 2005, the NATO R&T Strategy is being revised. It is revised only every few years to add or modify priorities that NATO may need to see reflected in the research program. By taking advantage of the timely revision, a recognition of the growing use of space systems as a key element of military operations was added. A clear statement should be included indicating the need for research to sustain, protect and advance space-based systems and related technologies and, further, to assure that information from space-based systems is securely communicated, accessible and useful. While the document revision is underway, it is important that the statement on space retain a useful wording and not be diluted to a mere observation of emerging technologies. In this way, the statement will provide justification for promoting RTO research related to use, protection and development of space systems.

7.2.2 Identification of Initial Key Areas of Space Research and Technology

The matter of increasing space research in the RTO research panels presents a “chicken and the egg” situation.[11] In order to consider what activities might be appropriate for research in the NATO RTO related to space, knowledgeable people with technical expertise in space science and technology should be consulted for input. Unfortunately, as was mentioned earlier, the current NATO RTO network lacks a “critical mass” of such people. Thus, in order to jumpstart the process of locating experts within the nations, a list of potential Space Focused Technical Areas was generated and used as a tool in the next step.

As shown in Table 17, the content of the list is a combination of technical areas currently being addressed by panels, NC3A or URC and additional technical areas which may need to be addressed. The technical areas include Space Science, Remote Sensing Data Analysis, Spacecraft Systems, Surveillance and Early Warning, Training and Simulation and Policy related to international cooperation. The presence of Remote Sensing Data Analysis is particularly important as many nations use data from satellites under ‘assured access agreements’ to products from other country’s space-based assets but the NATO RTO has almost no research activity supporting this technical area. In general, the list is being used as a starting point. It is anticipated, however, that the Space Focused Technical Areas will be modified according to input received from Space Experts during upcoming planning activities.

[11] Which came first, the chicken or the egg?

Table 17: Space Focused Technical Areas

Space Science	Space weather, upper atmospheric research and space debris
Remote Sensing Data Analysis	Use and fusion of commercial satellite data products and deployable ground stations
Communications	Areas such as information security and space-based electronic systems development, antennas
Spacecraft Systems	Guidance and navigation, spacecraft vulnerability and defense, advanced structures and materials, radiation shielding, small satellites, apertures, re-entry physics and access to space
Surveillance and Early Warning	Space-based optical imaging, radars, hyper-spectral imaging, Electronic Support Measures (ESM), MTI, detection and other related technologies
Training and Simulation	Use of existing simulations of spacecraft, spacecraft-mounted instrumentation and communications networks for operations training and risk management studies
Policy	Policy issues related to international cooperation and technology exchange in space research and development

7.2.3 Identification of Space Expert Consultants

The first step in achieving a Space Advisory Group is to identify Space Experts within the nations to consider space related issues of importance to NATO as the RTO research program is defined by the researchers who contribute to it. As was shown in the RTO research activity analysis presented earlier, however, there is strong indication that expertise related to space is not represented sufficiently among the panel membership to sustain substantial space research activity. As a result, few activities related to space have been conducted since 1998. Of those that have been proposed, a number of them have failed to receive sufficient support in the panel or in the nations to proceed and were cancelled. The issue then becomes one augmenting the current technical network with senior level technical professionals who can assist in identifying specific technical activities of relevance to the RTO and who can provide access into national space research networks to find support for these activities.

The Space Expert Consultants (SEC) being sought have expertise and current, senior level responsibilities in one or more space related technical areas as indicated in Table 2. These Consultants may be panel members and, as a group, represent as many nations as possible. They are willing to participate in discussions related to creating a stronger vision for RTO in defense space research and are familiar with space related capabilities of their nations.

The process of identifying the SEC first involves taking advantage of the existing technical network within RTO panels for recommendations. While panel members themselves may not have the relevant expertise required, panel members may be aware of colleagues who do. This is an important step in the identification of SECs as it invites panel members to participate or to decline to participate in the process. This avoids overlooking any panel member who may have relevant interest and also creates an initial 'buy-in' for recommendations from the SECs that may come back to the panel later. A formal letter of request for panels to make SEC recommendations was sent to the Panel Chairmen from the Space Executive Officer via the RTA Director.

Because many panel members are not connected with space research networks within their nations, it is also important to follow other avenues of identifying SECs. Following panel response to the RTA Director's letter from the panels, the Space Executive worked with National Coordinators to supply contacts for

underrepresented technical areas or nations. The Space Executive will also provide recommendations based on interaction with senior space officials in the nations. In all cases, all recommendations from the nations from any source will be provided to the National Coordinators for approval. This will be followed by a formal letter of invitation to participate in RTO space strategy activities.

7.2.4 NATO RTO Space Forum

To begin the process of building communication among the Space Expert Consultants, an on-line WISE Forum is being set up at the NATO RTA. The Forum will provide a mechanism for collaborative discussion on questions related to defense space research and the NATO RTO. Such discussion will become the basis for future decision making within the Space Advisory Group and, thus, ultimately contribute to recommendations made to RTO panels. It will, in addition, be used to communicate information regarding events of interest to the trans-Atlantic defense space research community. Such information will not only benefit the Space Expert Consultants but bring increased participation in and coordination of on-going RTO space activities. The Forum will be moderated by the RTA Space Executive.

7.2.5 Formation of Space Advisory Group

As described above, an effort is underway to supplement space expertise within the RTO panels with additional space expertise in the nations through the identification of Space Expert Consultants. It is very important to identify the right people with the right skills to participate in defining a vision for the NATO RTO in space. However, it is equally important that the RTO give back to them the opportunity to be recognized for their contributions and supported by their nations and for their recommendations to be seriously considered by the RTO research panels. Thus, a request for formalization of the Space Expert Consultants into an RTO Space Advisory Group is being sought from the RTO RTB.

The Space Advisory Group will have a somewhat flexible membership. It is NOT a panel and does not have a formal panel structure. It should, however, have representation from as many nations as possible in areas of technical relevance to the NATO RTO and space. Initially, these areas are as specified in Table 17, but can be expanded as needed by the Space Advisory Group to include other technical areas. In addition, each panel should have at least one member with space expertise (hopefully many more) participating in the activities of the Space Advisory Group. This member will be an integral part of relaying Space Advisory Group recommendations back to his/her panel. Representation from other NATO bodies such as ACT, NC3A, NATO Science Committee and NURC will also be sought for increased visibility and feedback within the NATO community.

The major responsibilities of the Space Advisory Group are as indicated in Section 7.1.2 in the discussion of Option 2 of the Organizational Strategies and are summarized below:

- Map NATO needs and National interests to specific recommendations for cooperative space defense research topics
- Identify sufficient support within at least 4 nations to support the topics BEFORE recommendations are made to the panels
- Provide recommendations for specific activities back to the panels for inclusion in individual panel planning processes
- Identify key Space Technology Watch areas including potential disruptive space technologies
- Promote visibility of NATO RTO as a forum for trans-Atlantic, collaborative defense space research
- Recommend renewal or transformation of Space Advisory Group to RTB at end of 2 years

With regard to visibility, it should be recognized that the NATO RTO has an opportunity to become a stronger forum for international collaboration in space research. However, it is important for the RTO to position itself to become a forum of choice for, in particular, trans-Atlantic collaboration among the US, Canada, EU and other European nations. This is not to compete with collaborative forums that the EU must establish for its own internal, defense space research. To capture the opportunity to become a stronger forum for space research, the RTO must be prepared with a visible and credible mechanism such as the Space Advisory Group. If there is not recognizable interest within RTO to embrace the role of collaborative space research, nations will move towards formation of other suitable forums and NATO will miss an opportunity to facilitate improved relations between nations. Thus, a need exists to build awareness of NATO RTO to serve as a forum for trans-Atlantic collaborative space defense research. Nations interested in only bi-lateral agreements for space research may decide to not take full advantage of what the NATO RTO offers. However, as in the past, the NATO RTO can still be instrumental in promoting international confidence building and communication.

7.2.6 Space Advisory Group Activities

Several activities are planned in order for the Space Advisory Group to fulfill its role.

7.2.6.1 RTA Space Strategy Workshop

The first and key event for the Space Advisory Group will be an RTA Space Strategy Workshop. The workshop will be held in June 2005 at the RTA in Paris, France. At this workshop, *invited* participants will formulate a vision for the RTO in space research. Specifically, the workshop participants will review national interests in defense and security space research and NATO capability needs to make an initial assessment of topics that may be of joint interest for cooperative research. The workshop format will include a plenary session followed by facilitated parallel session discussions in specific technical areas to "brainstorm"[12] initial recommendations for specific technical activities. Following reports back from break-out groups to a plenary session, initial recommendations will be prioritized in parallel sessions and the process of identifying national support will be initiated. Final recommendations will be presented in plenary session.

Preparation for this workshop will occur mainly via discussion on the RTA Space Forum discussed previously. In particular, during a fixed period of 2 months prior to the workshop, the Forum will be used to raise and discuss issues related to specific technical areas; address planning issues related to the workshop; and share information regarding upcoming events of common interest. The forum will also be used to generate a Technology Watch list for emerging or potentially disruptive space technologies. Participation by the Space Advisory Group in this Forum is very valuable to the success of the workshop.

As a note, the reader may notice that this approach is similar to the very successful approach being taken in formulation and implementation of European Union Space Policy by the EC/ESA Joint Task Force, albeit on a much smaller scale. In particular, this includes the use of an on-line forum for collaborative discussion and communication, the establishment of a recognized group of experts to establish priorities and participation in workshops. Thus, members of the European space community are already familiar with such an approach.

7.2.6.2 SCI-150 Symposium

A second activity to be held is the SCI-150 Symposium "Integration of Space-Based Assets within Full Spectrum Operations" at Colorado Springs, Colorado, October 2005. Members of the Space Advisory Group are very welcome to attend this event but it is not required. The objective of this symposium will be to bring together Operational Users with scientists and technologists to discuss the use of space systems in

[12] *Brainstorm* = generate many ideas for consideration

integrated military operations. Portions of this meeting are classified up to NATO Secret. An outcome of this meeting will be specific research areas of interest to the operational community.

7.2.6.3 RTA Space Strategy Meeting

A limited-attendance meeting will be required to finalize the list of recommended activities to the panels. Recommendations from the SCI-150 Symposium will be appended to the list generated during the RTA Space Strategy Workshop. At the December 2005 meeting, support of each recommendation from the nations will be actively sought if not already identified. No recommendation will be moved forward without support committed from at least four nations in order to maximize the probability of success within the panels.

7.2.6.4 Reporting

The Space Advisory Group will report recommendations to the RTB, in Spring 2006, in order to keep them informed of the Space Advisory Group progress. Members of the Space Advisory Group will then report recommendations to the panels and NMSG at their Spring Business Meetings for inclusion in the panel program planning process. Members of the Space Advisory Group will monitor progress of the activities and remain available to facilitate support of recommendations in their nations.

7.2.6.5 Renewal

In 2007, the Space Advisory Group will recommend renewal or transformation of Space Advisory Group at the Spring RTB Meeting. A limited attendance meeting for discussion of this may be required prior to the Spring RTB.

7.3 Strategy Summary

In summary, creation of an administrative framework within RTO such as the Space Advisory Group for discussion and recommendation of space issues is most appropriate. The framework includes workshops, an on-line forum and creation of a board-approved Space Advisory Group that identifies, recommends and supports research appropriate for the NATO RTO.

Table 18 is a summary of the recommended strategy per year including preparatory activities that occurred in 2004. As of this writing, the work indicated in 2004 has already been completed and the process to identify Space Expert Consultants in the nations has begun.

Table 18: Summary of Strategy Implementation Plan

2004

- Revise RTB Strategy to include statement motivating the need for space research in RTO
- Observe panel program planning procedures and technical expertise/preferences
- Review RTO records for past and current efforts related to space
- Begin building community of Space Expert Consultants from nations and panels
- Identify initial key areas of space research and technology

2005

- Complete building community of Space Expert Consultants from nations and panels
- Provide communication and promote discussion via on-line Space Forum in NATO RTO WISE
- RTB formally approves Formalization of Space Advisory Group
- Endorsement of Space Advisory Group included in Strategic Planning Session (SPS) and Executive Session Decision Sheets
- Formalization of Space Expert Consultants into Space Advisory Group
- Space Advisory Group maps NATO needs and National interests to specific cooperative defense research topics during Space Strategy Workshop (June 2005)
- Specific research topics from operational users identified during SCI Space Symposium (October 2005)
- Space Advisory Group finalizes recommendations to panels on specific areas of research (December 2005)
- Space Advisory Group creates visibility for RTO as forum for trans-Atlantic defense space research

2006

- Space Advisory Group takes responsibility to identify and gain support for expertise within nations to enable research topics
- Space Advisory Group briefs Panel Chairmen at IPM and RTB Members on recommendations at Spring Meetings
- Space Advisory Group presents recommendations to panels during Spring Panel Business Meetings
- Panels include recommendations for activities in their individual program planning processes
- Space Advisory Group creates visibility for RTO as forum for trans-Atlantic defense space research

2007

- Space Advisory Group monitors progress of research and provides assistance as needed
- Space Advisory Group recommends decision for renewal or transformation to RTB

8.0 RECOMMENDATION

This section summarizes the recommendation to be made to the 18th RTB SPS and Executive Session (ES) to be held at Paris, France, March 2005. The impact of not approving the recommendation is also included.

8.1 Summary

- Formal approval of Space Advisory Group and its responsibilities by RTB

8.2 Impact of Not Approving Recommendation

Failure to approve formation of a Space Advisory Group has several implications. In particular, it sends a message to RTO community and nations that space is NOT among the many priorities for RTO research. Further, lack of formalized Space Advisory Group will be viewed as not having endorsement of RTB and recommendations and efforts of Space Expert Consultants may not be recognized by panels. It also promotes a weak message from the RTB regarding their intent relative to increasing space activities within RTO. Finally, having no formalized Space Advisory Group makes it very difficult to attract and recognize the efforts of participants who must gain national support for participation. The overall result will be that the NATO RTO will not be able to position itself as a strong forum of choice for trans-Atlantic collaborative defense space research and NATO will miss an opportunity to facilitate improved relations and common defense among nations.

9.0 FINAL REMARKS

Despite the difficult environment for space, space continues to be inspirational to researchers whether the application is civil or military, independent of national affiliation. It is the inspirational aspect of space and potential for space to enhance defense capabilities that will be fundamental to the success of the current effort. As a result of these efforts, in the very least, NATO RTO will begin gaining recognition within the international defense space community as a collaborative environment for confidence building and exchange information. In the event that the international political environment precludes significant collaboration, cooperative civil space efforts will continue to pave the way until the international community is prepared to embrace military space cooperation more fully.

10.0 REFERENCES

[1] Huybrechts, S.M., Presler, R.G. and Ott, M., *The High Ground*, Military Thought and the Essence of War, Seminar M, National Defense University, http://www.ndu.edu/library/n4/n045602M.pdf.

[2] Caton, J.L., *Joint Warfare and Military Dependence on Space*, **Joint Forces Quarterly**, Winter 1995.

[3] Ashy, J.W., *Desert Storm: The First Space War*, http://www.au.af.mil/au/awc/awcgate/grayspc/dstorm/dstorm.html

[4] United States Department of Defense, Report of the Secretary of Defense to the President and the Congress, Washington GPO, February 1992, 85.

[5] Kreitmair, T. and Ross, J., *The Coalition Aerial Surveillance and Reconnaissance (CAESAR) Simulation Exercise 2003: Results and the way ahead*, 2004 Command and Control Research and Technology Symposium, San Diego, CA, USA, 2004.

[6] Ross, J., *The Coalition Aerial Surveillance and Reconnaissance (CAESAR) Approach to Enhancing the Interoperability of Coalition Ground Surveillance Systems*, NC3A, 2004.

[7] http://www.ccrs.nrcan.gc.ca

[8] http://radarsat.space.gc.ca

[9] NATO Press Release (2004) 072, 5 May 2004.

[10] Saulay, J.P., *Report on the Activities of the Navigation Sub-Committee (SC/8)*, 15 November, 2004, NATO C3 Board.

[11] http://www.useu.be/Galileo/

[12] *US and EU to Sign Landmark GPS-Galileo Agreement*, US Department of State Press Release, 2004-06-04.

[13] http://www.nato.int/science/

[14] http://www.nato.int/science/virtual_silk/index.htm

[15] http://www.nato.int/ccms/info.htm

[16] http://www.natoschool-shape.de/

[17] *Space Role in ALLIED FORCE Extensive – Effective United States Space Command*, News Release No. 11-99, June 17, 1999, http://www.globenet.free-online.co.uk/ethics/srole.htm

[18] *NATO in Afghanistan Factsheet*, 17 December, 2004, http://www.nato.int/issues/afghanistan/040628-factsheet.htm.

[19] *AGARD: Index of Publications 1995 – 1998*, April, 2000.

[20] *Green Paper on European Space Policy: Report on the Consultation Process*, BR-208, October 2003.

[21] *White Paper – Space: a new European frontier for and expanding Union: An action plan for implementing the European Space Policy*, Commission of the European Communities, Com (2003) 673, November 2003.

[22] http://europa.eu.int/comm/space/news/article_1701_en.html

[23] *Fact Sheet: National Space Policy*, The White House National Science and Technology Council, September 19, 1996.

[24] *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, United Nations Resolution 2222 (XXI), Annex.

[25] *President Bush Announces The Vision for Space Exploration*, US White House Press Release 20040114-3, January 14, 2004.

[26] http://www.au.af.mil/au/awc/awcgate/space/2003remotesensing-ostp.htm

[27] Selding, P.B., *EU Faces Space Budget Duplication, Consolidation Concerns*, **Space News**, December 13, 2004.

[28] *The International Traffic in Arms Regulations (ITAR) 22 C.F.R. 120-130*, U.S. Government Printing Office, April 1, 2004.

[29] Van der Bliek, J., *AGARD: The History 1952 – 1997*, p. xi, NATO RTA, Neuilly-sur-Seine, France, 1999.

Annex A – RTA DIRECTOR'S LETTER TO PANELS REQUESTING IDENTIFICATION OF SPACE EXPERT CONSULTANTS

RTA/DIR(2004)143 7 October 2004

TO: RTO Panel and NMSG Chairmen

COPY: RTB Chairman
IMC Chairman
RTA Executive Staff

FROM: The Director

SUBJECT: **Space Expert Consultant List**

The purpose of this memo is to clarify the RTA plan and Panel support needed in the development of a Space Expert Consultant List. In reference to the presentation given by the RTA Space Executive at the Istanbul IPM and to the ensuing discussions, the RTA requests assistance from the Panels to identify Level 2 experts in space within the Nations and on the Panels. Panel Chairs are asked to bring this request to the attention of Panel Members during their Fall Panel Business Meetings.

The Space Expert Consultant List will be used as a resource by the RTA during activities related to defining an RTO vision for space. In the near-term, these activities involve 1) network building and communication via an on-line Forum moderated by the RTA Space Executive and 2) participation in a 2005 RTO Space Strategy Workshop. Further information regarding the workshop will be distributed in early 2005. In the long-term, the Space Expert Consultant List and network will be a resource to panel members and allow nations to more fully propose and support activities focused on space applications.

Individuals sought for the Space Expert Consultant List should have expertise and current, senior level responsibilities in one or more of the "Space Focused Technical Areas" that are relevant to the Panel Mission. These areas are described in the attached presentation. The Expert Consultants identified may include panel members and should represent as many nations as possible. These individuals should be willing to participate in discussions related to creating a vision for RTO in space defence research. They should also be familiar with space related capabilities of their nations.

Contact information for each Expert Consultant (eg. Name, Title, Organization, Nation, Phone, Fax, Email, Mailing Address, Space Focused Technical Area) should be provided to the RTA Space Executive. Panels are kindly asked to notify the RTA if there are nations unable to provide names or that would prefer to provide names via a nationally coordinated response.

The level of effort associated with this activity for panel members is intended to be very limited. However, results are needed within a reasonable period of time following the Fall Panel Business Meetings in order for the RTA to effective begin planning for the upcoming Space Strategy Workshop. Thank you for your assistance.

[ORIGINAL SIGNED BY DR ÜÇER ON 7 OCTOBER 2004]

Dr A.S. Űçer

Attachment: 1. Space Presentation for Panels

Annex B – LIST OF SIGNIFICANT SPACE FOCUSED AND SPACE RELATED RTO ACTIVITIES BY PANEL 1998 – 2004

B.1 AVT PANEL

B.1.1 AVT Space Focused Activities

AVT-007/ RTG-010	Hypersonic Vehicle Propulsion Technologies
AVT-008/ RTG-001	Hypersonic Experimental and Computational Capabilities – Improvement and Validation
AVT-016/ RTG-005	Evaluation of Methods for Solid Propellant Burning Rate Measurement
AVT-096/ RTC-003	Internal Aerodynamics in Solid Rocket Motors
AVT-116/ RLS-010	Critical Technologies for Hypersonic Vehicle Development
AVT-117/ RLS-011	Heat Transfer and Inverse Analysis
AVT-130/ RLS-013	Flight Experiments for Hypersonic Vehicle Development
AVT-034/ RTC-004	Measurement Techniques for High Enthalpy and Plasma Flows
AVT-089/ RSM-011	Advances in Rocket Performance Life and Disposal
AVT-142/ RLS	Experiment, Modelling and Simulation of Gas-Surface Interactions for Reactive Flows in Hypersonic Flights
AVT-ET-023	Improved Hypersonic Performance through Boundary Layer Transition Prediction

B.1.2 AVT Space Related Activities

AVT-001/ RSY-001	Missile Aerodynamics
AVT-021/ RWS-001	Intelligent Processing of High Performance Materials
AVT-048/ RSY-008	Active Control Technology for Enhanced Performance Operational Capabilities of Military Aircraft, Land Vehicles, and Sea Vehicles
AVT-076/ RSM-007	Low Cost Composite Structures in Military Platforms
AVT-077/ RSM-008	Cost Effective Application of Titanium Alloys in Military Platforms
AVT-078/ RTG-019	MEMS Applications for Land, Sea and Air Vehicles
AVT-087/ RSY-012	Combat Survivability of Air, Space, Sea and Land Vehicles
AVT-090/ RSY-013	Reduction of Military Vehicle Acquisition Time and Cost through Advanced Product Simulation
AVT-092/ RTG-025	Qualification by Analysis
AVT-093/ RTG-026	Integration of Tools and Processes for Affordable Vehicles
AVT-095/ RTC-002	Intelligent Systems for Aeronautics
AVT-122/ RSM-016	Nanomaterials Technology for Military Vehicle Structural Applications
AVT-124/ RSM-017	Recent Developments in Non-Intrusive Measurement Technology for Military Application on Model-and Full-Scale Vehicles
AVT-129/ RLS-012	Nanotechnology Aerospace Applications
AVT-134/ RTG	Multidisciplinary Optimization for Propulsion and Power Systems for Air, Land and Sea Vehicles
AVT-135/ RSY	Innovative Missile Concepts
AVT-136/ RTG	Assessment and Experimental Calibration of Aerothermodynamic Flight Prediction Tools
AVT-139/ RSM	Net-Shape Processing
AVT-141/ RSM	Multifunctional Structures/Integration of Sensors and Antennas
AVT-143/ RLS	Design, Analysis and Experimental Investigation of High Speed Plumes Cost Through Advanced Product Simulation

AVT-ET-008	Propulsion Systems for Land, Sea, Air and Space
AVT-ET-021	Survivability of Air, Space, Sea and Land Vehicles
AVT-ET-022	Reduction of Military Vehicle Acquisition Time and
AVT-ET-027	Novel and Emerging Vehicle and Vehicle Technology Concepts
AVT-ET-033	Inclusion of Lethality Aspects in the Scope of the AVT Panel
AVT-ET-042	Active Controls
AVT-ET-054	Tools and Processes for Affordable Weapon Systems
AVT-ET-066	MEMS
AVT-ET-067	Low Cost Composites
AVT-ET-069	Cost Effective Application of Titanium Alloys

B.1.3 AVT Activities Related to Human and Robotic Exploration of Space

AVT-023/ RWS-004	Fatigue in the Presence of Corrosion
AVT-033/ RTC-003	Development and Operation of UAVs for Military and Civil Applications
AVT-047/ RTG-015	All Electric Combat Vehicles (AECV) for Future Applications
AVT-049/ RSY-009	Unmanned Vehicles for Aerial, Ground and Naval Military Operations
AVT-060/ RWS-005	Magnetic Materials for Power Applications
AVT-085/ RSM-009	Life Management Techniques for Ageing Air Vehicles
AVT-098/ RTG-028/CDT	All Electric Combat Vehicle (AECV) for Future Applications – Co-operative Demonstration of Vehicle Performance
AVT-103/ RTG-031	Fuel Cells for Land, Sea and Air Vehicles
AVT-105/ RLS-009	MEMS Aerospace Applications
AVT-137/ RTG	Corrosion and Maintenance Data Sharing
AVT-138/ RTG	Nanotechnology for Autonomous Vehicles
AVT-140/ AG	Corrosion Fatigue and Stress Corrosion Cracking in Ageing Military Vehicles
AVT-ET-025	Fuel Cells for Land, Sea, Air and Space Applications
AVT-ET-040	All Electric Vehicles
AVT-ET-041	Uninhabited Vehicles

B.2 HFM PANEL

B.2.1 HFM Space Focused Activities

None

B.2.2 HFM Space Related Activities

None

B.2.3 HFM Space Related Activities: Human and Robotic Exploration of Space

HFM-001/ SY-001	Collaborative Crew Performance in Complex Operational Systems
HFM-003/ SM-001	Computer Models for Aircrew Safety Assessment Uses: Limitations and Requirements
HFM-004/ WS-002	Individual Differences in the Adaptability to Irregular Rest-Work Rhythms/Status of the Use of Drugs in Sleep-Wakefulness Management
HFM-005/ WS-003	Aeromedical Aspects of Aircrew Training
HFM-007/ LS-001	Alternative Control Technologies: Human Factors Issues
HFM-013/ WG-25	Alternative Control Technologies in Aerospace Environment (AMP WG-25)
HFM-014/ WG-26	Screening Protocol for Aeromedical Medications in Aviation Medicine
HFM-021/ RSG-028	Human Factors in Virtual Reality Applications
HFM-028/ SC-003	Cardiopulmonary Aspects of Aerospace Medicine
HFM-029/ SY-003	Countering The Directed Energy Threat: Are Closed Cockpits the Ultimate Answer?
HFM-030/ SY-004	Operational Issues of Aging Crew Members
HFM-031/ WS-004	Human Reliability in Safety Critical Systems
HFM-052/ LS-220	Human Consequences of Agile Aircraft
HFM-054/ AG-341	The Requirements for an Emergency Breathing System (EBS) in Over-Water Helicopter and Fixed Wing Aircraft Operations
HFM-058/ WS-007	What is Essential for Virtual Reality Systems to Meet Military Human Performance Goals?
HFM-084/ SY-009	The Role of Humans in Intelligent and Automated Systems
HFM-118/ RTG-039	Ground-based Spatial Orientation Training
HFM-121/ RTG-042	Virtual Environments for Human/System Interaction
HFM-130/ RTG-047	Development of an Assessment Methodology for Demonstrating Usability, Technical Maturity, and Operational Benefits of Advanced Medical Technology
HFM-131/ RTG-048	Validation of Medical Surveillance Algorithms
HFM-135/ RSY-018	Unmanned Military Vehicles as Force Multipliers
HFM-136/ RWS-013	Virtual Media for Military Applications
HFM/ET-034	Non-Ionising Bio-effects: Emerging Laser Threats and Human Protection Strategies
HFM/ET-040	Representation of Human Behaviour in Constructive Simulation
HFM/ET-041	Virtual Environments for Human/System Interaction
HFM/ET-051	Applications and Assessments for Telemedicine (TMED) Support to NATO Response Force
HFM/ET-054	Virtual Media for Military Applications

B.3 IST PANEL

B.3.1 IST Space Focused Activities

IST-051/ RTG-023	Characterising the Ionosphere
IST-056/ RSM	Enhancements on the Understanding of the Structure and Modelling of the Ionosphere
IST-ET-023	Characterisation of the Ionosphere

B.3.2 IST Space Related Activities

IST-002/ SY-002	Frequency Assignment, Sharing and Conservation in Aerospace Systems
IST-009/ SY-003	Tactile Mobile Communications
IST-010/ SY-004	Protecting NATO Information Systems in the 21st Century
IST-015/ RTG-004	Information Fusion
IST-021/ RTG-007	Multimedia Visualisation of Massive Military Datasets
IST-023/ RSY-008	Military Communications
IST-036/ RWS-005	Massive Military Data Fusion and Visualisation: Users Talk with Developers
IST-039/ RSY-011	Smart Antennas
IST-040/ RSY-012	Military Data and Information Fusion
IST-045/ RTG-017	Network Centric Operations Security
IST-047/ RTG-019	Building Robust Systems with Fallible Construction
IST-053/ RTG/CDT-001	Content Based Information Security (CBIS)
IST-059/ RTG-024	Visualisation Technologies for Networks Analysis
IST-035/ RTG-015	Awareness of Emerging Wireless Technologies
IST-054/ RSY-015	Military Communications
IST-048/ RTG-020	Dual Use of High Assurance Technology
IST-061/RTG-027	Information Infrastructure supporting Net Centric Warfare Communications
IST-060/ RTG-026	Advanced Multi-Sensors Surveillance Systems for Counter-Terrorism
IST-ET-003	Information Fusion
IST-ET-018	Smart and Adaptive Antennas in Military Communications
IST-ET-020	Awareness of Emerging Wireless Technologies
IST-ET-033	Software Defined Radio

B.3.3 IST Space Related Activities: Human and Robotic Exploration of Space

IST-029/ RTG-011	Use of Intelligent Agents in Virtual Reality
IST-032/ RTG-014	Multi-Robots Systems in Military Domains
IST-037/ RLS-238	Speech and Language Technology in Military Applications
IST-052/ RWS-008	Short-Term Realisable Multi-Robots Systems in Military Domains
IST-057/ RWS-009	Military Applications for Multi-Robots Systems
IST-058/ RTG-025	Military Applications for Multi-Robots Systems
IST-ET-013	Use of Intelligent Agents in Virtual Reality
IST-ET-015	Multi-Robots Systems in Military Domains

B.4 NMSG

B.4.1 NMSG Space Focused Activities

None

B.4.2 NMSG Space Related Activities

MSG-003/ RTG-003	M&S Technology In Support Of Simulation Based Acquisition
MSG-006/ RTG-006	M&S Support to Assessments of Extended Air Defence C2 Interoperability
MSG-012/ RTG-009	Recommendations on the Establishment of a NATO Simulation Resource Library
MSG-019/ RTG-016	Verification, Validation and Accreditation (VV&A) Of Federations
MSG-027/ RTG-020	Pathfinder: Integration Environment for Multi-Purpose Application of Distributed Networked Simulation
MSG-033/ RTG-024	High Level Architecture STANAG Development
MSG-034/ RTG-025	Data Standardisation: SEDRIS Technologies
MSG-038/ RTG-026	NATO Library of FEDEP Tools: Maintenance and Evolution
MSG-039/ RTG-027	M&S Support to Assessment of EAD C2 Interoperability
ET-002	Validation Verification and Accreditation of Federations
ET-009	PATHFINDER Integration Environment for Multi-Purpose Application of distributed networked Simulation

B.4.3 NMSG Space Related Activities: Human and Robotic Exploration of Space

None

B.5 SAS PANEL

B.5.1 SAS Space Focused Activities

SAS-021/MAS-005	Long-Term Technologies for Alliance Ground Surveillance

B.5.2 SAS Space Related Activities

SAS-054/ RTG-015	Methods and Models for Life Cycle Costing
SAS-028/ RTG-007	Cost Structure and Life Cycle Costs (LCC) For Military Systems
SAS-036/ RSY-006	Cost Structure and Life Cycle Cost (LCC) For Military Systems

B.5.3 SAS Space Related Activities: Human and Robotic Exploration of Space

SAS-007/ LTSS-003	Life Cycle Cost of All-Electric Combat Vehicles

B.6 SCI PANEL

B.6.1 SCI Space Focused Activities

SCI-058/ SY-003	Precision Time-Space, Positioning and Navigation
SCI-098/ SY-009	Use of Space Systems in Integrated Military Missions
SCI-146/ ET-026	Commercial Space System Capabilities and Military Requirements
SCI-150/SY-015	Integration of Space-based Assets Within Full Spectrum Operations

B.6.2 SCI Space Related Activities

SCI-019/ RSG-12	Tactical Implications of High Power Microwaves
SCI-030/ RSG-14	Communication, Electronic Warfare Control and Coordination
SCI-036/ AG-300T	Flight Testing of Radio Navigation Systems
SCI-042/ AG-339	Optical Gyros and their Applications
SCI-044/ SY	Non-Cooperative Target Identification Using Radar
SCI-053/ TG-004	Vehicle Dynamics, System Identification, Control and Handling Qualities
SCI-060/ LS-216	Application of Mathematical Signal Processing Techniques to Mission Systems
SCI-066/ TG-013	Countermeasures to Imaging Radars
SCI-081/ ET-012	Systems Engineering and Test Technology
SCI-083/ SY-006	Integration of Simulation with System Testing
SCI-107/ TG-022	Susceptibilities of Mobile Tactical Radio Systems
SCI-119/ WS-010	Tactical Implications of High Power Microwaves
SCI-120/ SY-011	Challenges in Dynamics, System Identification, Control and Handling Qualities for Land, Air, Sea and Space Vehicles
SCI-132/ TG-029	High Power Microwave Threat to Infrastructure and Military Equipment
SCI-137/ SY-013	Architectures for Network-Centric Operations
SCI-140/ TG-035	Vulnerability of Imaging Radars to Electronic Countermeasures
SCI-142/ LS-236	Robust Integrated Control System Design Methods for 21st Century Military Applications
SCI-143/ ET-024	Design Considerations for Theater Air Defense Systems
SCI-143/ WS-013	Design Considerations for Theater Air Defense Systems
SCI-144/ TG-037	System-Level Integration of Control, Plus Automation
SCI-152/ LS-239	Advances in Missile Guidance and Control
SCI-159/ TG-007	Reconnaissance and Neutralization of C3I Systems
SCI-166/ LS	Achieving Successful Robot Control Systems Design for 21st Century Military Applications, Part II, P-I
SCI-169/ TG	UAVs in a Multi-Platform Configuration for EW-Purposes
SCI-170/ TG	Trials to Investigate the Susceptibilities of Wireless and Mobile Tactical Radio Systems, P-N
SCI-173/ ET-119	The Evaluation of Complex Thermal Infrared Targets in Complex Backgrounds

B.6.3 SCI Space Related Activities: Human and Robotic Exploration of Space

SCI-023/ WG-05	Integrated Mission System Concepts and Technologies for Future Unmanned Combat Applications
SCI-045/ WS-001	Search and Target Acquisition
SCI-105/ AG-300E	Unique Aspects of Flight Testing of Unmanned Aerial Vehicles/ Unmanned Combat Aerial Vehicles

SCI-109/ LS-224	Applications, Concepts and Technologies for Future Tactical Unmanned Aerial Vehicles
SCI-118/ TG-025	Automation Technologies and Application Considerations for Highly Integrated Mission Systems
SCI-138/ LS-237	Applications, Concepts and Technologies for Future Tactical Unmanned Aerial Vehicles

B.7 SET PANEL

B.7.1 SET Space Focused Activities

SET-037 /RSY06	Space-based Observation Technology
SET-039/ RSY08	NATO / Military Sensing Symposium (4th MSS Symposium)
SET-045/ RTG26	Space-based Radar Technology for Military Applications
SET-050/ RSY11	Emerging Military Capabilities Enabled by Advances in Navigation Sensors
SET-054/ RTG30	Emerging Military Capabilities Enabled by Advances in Navigation Sensors
SET-064/ RLS-232	Advances in Navigation Sensors and Integration Technology
SET-064b/ RLS-232b	Advances in Navigation Sensors and Integration Technology
SET-084/ RTG-048	Emerging Technologies for Sensors Front-Ends
SET-087/ RTG-050	Vibrating Antennas and Compensation Techniques
SET-094/ RSY-019	Emerging EO Phenomenology
SET-095/ RSY-020	Bistatic-Multistatic Radar and Sonar Systems
SET-ET/ ET10	Space-based Radar Experiment Planning
SET-ET/ ET14	Advancement in Inertial Sensors and their Application into Navigation Systems
SET-ET/ ET35	Emerging Technologies for Sensors Front-ends

B.7.2 SET Space Related Activities

SET-001/ RSY01	E-O Prop., Sig. & System Performance Under Adverse Meteorological Conditions Considering O-o-A Ops
SET-007/ RTG01	Multi-Sensor Image Fusion for the Detection of Targets in the Battlefield of the Future
SET-010/ RTG04	Military Applications of Millimetre Wave Imaging (P03 RSG 20)
SET-012/ RTG20	Smart Antenna Structure
SET-015/ RTG12	The Characterization and Optimization of Advanced Thermal Images
SET-020/ RTG08	Detection and Tracking of Low Altitude Low RCS Air Vehicles
SET-022/ RTG10	Multi-sensor Image Exploitation
SET-026/ RSY04	High Resolution Radar Techniques
SET-028/ RWS01	Detection and Tracking of Low Level RCS Vehicles
SET-033/ RTG17	Missile and Aircraft E-O Signature Modeling
SET-040/ RTG22	Generation of Synthetic Data Bases for Non Cooperative Air Target Identification by Radar
SET-047/ RSY09	Passive and Low Probability of Interception (LPI) Radio Frequency Sensors
SET-049/ RSY10	Complementarity of Ladar and Radar
SET-053/ RTG29	Ground Target Automatic Recognition by Radar
SET-057/ RLS228	Military Application of Space-Time Adaptive Processing
SET-058/ RLS229	Optics-Microwave Interactions
SET-059/ RSY13	Target Tracking and Sensor Data Fusion for Military Observation
SET-060/IST-039/RSY14	Smart and Adaptive Antennas
SET-062/ RSM01	The Impact of Emerging Technologies and New Techniques on Air Defence Radars
SET-063/ RLS233	Knowledge-Based Radar Signal & Data Processing
SET-063b/ RLS233b	Knowledge-Based Radar Signal & Data Processing
SET-065/ RTG33	Multiband and Broadband Infrared Sensor Performance
SET-066/ RTG34	Frequency Sharing between Communication and Radar Systems

SET-068/ RTG36	Modelling, Analysis and Recognition of Radar Signatures for Non-Cooperative Aircraft Identification
SET-072/ RTG40	Modeling of Active Imaging System
SET-075/ RTG43	Polarimetric Signatures of Maritime Targets
SET-077/ RTG45	N-Dimensional Eye-Safe LADAR Imaging
SET-078/ RTG46	Multi-Band Radar Data Base for Air Defense Systems
SET-080/ RSY17	High Resolution Radar Signatures of Air Targets
SET-081/ RLS240	Radar Polarimetry and Interferometry
SET-082/ RWS	Stand-Off Detection of Biological Agents
SET-083/ RTG-047	High Performance Passive Millimeter Wave Imaging
SET-085/ RTG-049	Radar Signature Prediction of Cavities on Aircrafts, Vehicles, and Ships
SET-086/ LS	Advanced Radar Systems, Signal and Data Processing
SET-089/ RWS-005	Use of LWIR Hyperspectral Systems for Military Target Detection
SET-096/ RSM-002	MMW Advanced Target Recognition and Identification Experiment
SET- ET01	Atmospheric Propagation Effects on E-O Systems
SET- ET03	Data Fusion for Low Observable Targets
SET- ET06	Multi Sensor Fusion for Littoral Surveillance Systems
SET- ET07	Multi Sensor and Sensor Data Fusion
SET- ET13	Ground Target Automatic Recognition
SET- ET20	Mobile Telephones/Military Radars: Frequency Sharing
SET- ET22	Analysis of Hyperspectral Imagery for Target Detection
SET- ET23	Modeling of Active Imaging Systems
SET- ET24	Multiband and Broadband Infrared Sensor Performance
SET- ET26	Sparse Aperture and Aperture Synthesis Techniques for UAVs Ground Imagers
SET- ET28	Investigation of Software Radar Concepts
SET- ET29	Polarimetric Signatures of Maritime Targets
SET- ET32	N-Dimensional Eyesafe LADAR Imaging
SET- ET33	Validation of Multi-Sensor Models
SET- ET34	Data Base Generation in Support of Model Generation for Multi-band AD Radar System

B.7.3 SET Space Related Activities: Human and Robotic Exploration of Space

No activities uniquely related to Human and Robotic Exploration of Space.

Annex C – CALENDAR OF SIGNIFICANT NATO SPACE EVENTS IN 2005 – 2006

C.1 2005

April 27-29	NURC Remote Sensing Symposium	La Spezia, IT
May 9-13	AVT-130 Lecture Series on Hypersonic Vehicles Development	BE
June 9-10	RTA Space Strategy Workshop	Paris, FR
October 10-12	SCI-150 Symposium "Integration of Space Based Assets in Full Spectrum Operations"	Colorado Springs, CO, US
October 10-11	SET-094 Symposium "Emerging EO Phenomenology"	GE
December	RTA Space Strategy Follow-up Meeting	TBD

C.2 2006

August	IST-056 Specialist's Meeting "Enhancements on the Understanding of the Structure and the Modelling of the Ionosphere"	Fairbanks, AK, US

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Characterization of the ionosphere	Navigation satellites	Space research
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EU space policy	Operations research	Space-based radar
Force enhancer	Remote sensing	Spaceborne detectors
Government policies	Requirements	Spaceborne radar
Ground surveillance	Reviewing	Spacecraft
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Hypersonic vehicles	Satellite navigation	Strategy
Joint operations	Security	Surveillance and early warning
Military applications	Solid rocket propulsion	Training and simulation
Military planning	Space advisory group	US space policy
Military use of space systems	Space focused	

14. Abstract

This report describes the motivation for and a strategy to enhance the NATO Research and Technology Organisation's (RTO) current space research effort to reflect NATO's growing military dependence on space systems. Such systems and services provided by these systems are critical elements of military operations. NATO uses space systems for operational planning and support, communication, radio navigation, multi-sensor and multi-domain demonstrations. Such systems are also used to promote regional stability. A quantitative analysis of work related to space in the NATO RTO showed that during the period of 1998 – 2004, 5% of the research pursued in the NATO RTO has been clearly focused on space applications. Challenging environmental and organizational barriers for increasing RTO space research were identified. In part, these include lack of sufficient space expertise representation on panels, the military sensitivity of space, current panel work loads and the need for specific technical recommendations from peers. A strategy for enhancing space research in the RTO is to create a limited-life Space Advisory Group (SAG) composed of Space Expert Consultants who are panel members with appropriate expertise and additional expertise from the nations. The SAG will recommend and find support in the nations for specific technical activities related to space in the areas of Space Science, Remote Sensing Data Analysis, Spacecraft Systems, Surveillance and Early Warning, Training and Simulation and Policy. An RTO Space Advisory Group will provide an organizational mechanism to gain recognition of RTO as a forum for trans-Atlantic defence space research and to enhance space research activities.

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