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STO MEETING PROCEEDINGS **MP-SCI-318**

Space Domain and NATO Operations: A Critical S&T Review

(Domaine spatial et opérations de l'OTAN: une revue critique de la S&T)

Systems Concepts and Integration (SCI) Panel SCI Specialists' Meeting

held on 25 - 27 June 2019, Turin, Italy.

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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- 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 Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

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Space Domain and NATO Operations: A Critical S&T Review

(STO-MP-SCI-318)

Executive Summary

The SCI-318 Specialists' Meeting held from 25 – 27 June 2019 was hosted by the Army Education & Training Command, School of Applied Military Studies, Turin, Italy. The objectives of the event were to raise awareness of and assess the current space-focused collaborative program of work of the NATO Science and Technology Organization and to make recommendations for the future of space-focused efforts under the STO's guidance. The Specialists' Meeting participants conducted a technical tour of Thales Alenia Space and Altec to help set the tone for the technical discussions that followed. In addition, the participants reviewed presentations on the ongoing and planned work from five of the seven STO Panels which consisted of seven current and four planned space-focused activities across the STO's collaborative program of work. For context, this represents approximately 5% of the 300+ ongoing activities in the collaborative program of work. After the reviewing the current and planned activities, the participants broke out into syndicates to formulate recommendations for consideration by the STO and the nations that support its collaborative program of work. There were five major findings developed by the syndicates:

1. Standards form the foundation for interoperability, some minimum set of interface criteria that can be counted on by all nations to allow for collective or shared communications, PNT, ISR and C2 is essential for interoperability to be achieved.
2. Resiliency in the space segment of the NATO C2 architecture is the most that NATO as a stand-alone entity can likely achieve and requires an understanding of the space enabled C2 architecture in which NATO operates and an appreciation for the threats that NATO forces face in the space domain.
3. Space Domain Awareness (SDA) is not the same as Space Situation Awareness.
4. Training and education are foundational to the development of "space aware" Alliance leaders and contributors.
5. There are *real* advanced/disruptive technologies being introduced into the space domain.

Six major recommendations for NATO STO resulted from the Specialists' Meeting:

1. Commit to tracking the Space program of work in a coordinated way.
2. Initiate a Space Strategic Initiative in the next NATO STO strategic planning effort.
3. Establish a standing Space Technical Team to connect efforts across the STO.
4. Take on the immediate challenge of defining a Space Lexicon for NATO.
5. Purposefully develop a Collaborative Demonstration of Technology for a space focused application.
6. Ensure that the STO, through the space cognizant members of its program of work, influences the content of the NATO School space course and the NATO Staff College senior leader curriculum.

Domaine spatial et opérations de l'OTAN : une revue critique de la S&T

(STO-MP-SCI-318)

Synthèse

La réunion des spécialistes du SCI-318 s'est tenue du 25 au 27 juin 2019 au Commandement de la formation de l'armée, École des études militaires appliquées, à Turin, en Italie. Les objectifs de l'événement étaient de sensibiliser l'assistance au programme des travaux collaboratifs actuels, axé sur l'espace, de l'Organisation pour la science et la technologie de l'OTAN, d'évaluer ce programme et d'émettre des recommandations pour les futurs travaux axés sur l'espace dans le cadre des directives de la STO. Les participants à la réunion des spécialistes ont réalisé une visite technique de Thales Alenia Space et d'Altec qui a contribué à donner le ton des discussions techniques consécutives. De plus, les participants ont passé en revue les présentations des travaux en cours et planifiés provenant de sept commissions de la STO, qui consistaient en sept activités en cours et quatre activités planifiées axées sur l'espace parmi tout le programme des travaux collaboratifs de la STO. Nous précisons que cela représente approximativement 5 % des plus de 300 activités en cours dans le programme des travaux collaboratifs. Après la revue des activités en cours et planifiées, les participants se sont réunis en sous-groupes pour émettre des recommandations à destination de la STO et des pays qui soutiennent son programme des travaux collaboratifs. Les sous-groupes ont développé cinq grandes conclusions :

1. Les normes forment la base de l'interopérabilité, un ensemble minimal de critères d'interface sur lesquels tous les pays peuvent compter pour établir des communications collectives ou partagées. Les normes PNT, ISR et C2 sont essentielles à la mise en place de l'interopérabilité ;
2. La résilience dans le segment spatial de l'architecture C2 de l'OTAN est le maximum que l'OTAN, en tant qu'entité autonome, est susceptible d'atteindre. Elle nécessite une compréhension de l'architecture C2 rendue possible par l'espace dans laquelle l'OTAN opère et une appréciation des menaces que les forces de l'OTAN rencontrent dans le domaine spatial ;
3. La connaissance du domaine spatial (SDA) n'est pas la même chose que la connaissance de la situation spatiale ;
4. La formation et l'enseignement sont essentiels au développement de contributeurs et de chefs de l'Alliance « sensibilisés à l'espace » ;
5. De réelles technologies poussées/révolutionnaires sont en cours d'introduction dans le domaine spatial.

La réunion des spécialistes a abouti à six grandes recommandations pour la STO de l'OTAN :

1. S'engager à suivre le programme des travaux spatiaux de manière coordonnée ;
2. Lancer une initiative spatiale stratégique dans les prochains travaux de planification stratégique de la STO de l'OTAN ;
3. Établir une équipe technique de l'espace pour relier les travaux dans l'ensemble de la STO ;
4. Relever le défi immédiat de définition d'un lexique de l'espace pour l'OTAN ;
5. Élaborer volontairement une démonstration collaborative de technologie destinée à une application axée sur l'espace ;
6. Veiller à ce que la STO, à travers les spécialistes de l'espace de son programme des travaux, influence le contenu du cours sur l'espace de l'École de l'OTAN et le cursus des cadres supérieurs l'École d'état-major de l'OTAN.

Technical Evaluation Report

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1.0 INTRODUCTION

The North Atlantic Treaty Organization (NATO) is significantly dependent upon space services to conduct its military missions and related responsibilities. The results of 2013's SCI-238 Research Specialists' Meeting (RSM) on *NATO Space Dependencies* validated this assertion and identified several areas to enhance the resilience of NATO's use of space to ensure comprehensive mission success. The breadth of the potential solutions and concepts for resilient NATO space capabilities will benefit from the extensive technical experience resident in the membership of the NATO Science and Technology Organization's (STO) Panels as well as that found in other NATO organizations such as Allied Command Transformation (ACT) and the Joint Air Power Competency Center (JAPCC). This Specialists' Meeting (SCI-318) was designed to review, five years after SCI-238, the space science and technology (S&T) program of the STO by bringing together space experts from the NATO Alliance to assess NATO's current and future needs for affordable, resilient space capabilities. SCI-318 provided a basis for achieving shared awareness of the heritage of space S&T within NATO and the progress, although slow, in progressing toward greater depth and diversity of the NATO space S&T portfolio. SCI-318 seeks to identify the most appropriate technical investments and actions to be taken by NATO and the nations in underwriting the collaborative program of work (CPoW) for space carried out under the stewardship of the STO Collaboration Support Office (CSO).

SCI-318 attracted 75 researchers, operators, planners and space thinkers from 12 nations. The exchange of information will feed into the S&T community in an effort to assure that the work done by the space SMEs is coherent with NATO needs and requirements, and that the work supports the development of NATO's overarching strategy for space.

1.1 Military Relevance

This Specialists' Meeting was inherently focused on improving the relevance of the NATO space domain-related collaborative S&T activities to the NATO operator, decision maker and military planner. A shared awareness of the military requirements and potential challenges at the outset enhances the relevance of the resulting technical activities of the NATO S&T enterprise.

To highlight the military relevance of the Specialists' Meeting, LTG FUNGO (ITA A) provided insights on the value, and challenges, of space capabilities in their support to NATO operations. LTG FUNGO introduced "space as a place" where military forces operate and through which terrestrial forces derive great benefit from the five space mission areas: Communications, Precision Navigation and Timing (PNT), Meteorology, Intelligence and Missile Early Warning. The significant take away from LTG FUNGO's introduction was that space capabilities, though essential, can be fragile, and it is imperative that the nations commit to delivering space capabilities to NATO forces that are resilient in the face of the threat and available when and where they are needed by terrestrial forces. LTG FUNGO also drove home the point that space must play a prominent role in joint exercises and must be an element of the training regimen of operators from all domains.

1.2 Scientific Objectives

The scientific objectives of SCI-318 included the following:

1. Developing a shared awareness of NATO's future space capability needs to enhance Alliance

forces under increasingly stressing operational environments (threats and environmental risks).

2. Identification of critical scientific and technical challenges that would benefit from focused NATO S&T attention via STO technical activities; including cross-panel collaborative efforts that maximize the broad technical depth of expertise across the STO panels.
3. Identification and development of critically important relationships among the NATO technical, operational, and policy communities involved in or responsible for NATO's success in the space domain.
4. Promotion of a NATO-wide community of interest focused on NATO's future operational and technical requirements to maximize successful space domain endeavors.

The importance of the scientific objectives and the value of S&T to the space domain were highlighted by the keynote presentation by Professor BUSSOLETTI, who eloquently detailed the evolution of the space sector as well as the current and future lines of research and development effort in the space domain. One of the main points that Prof BUSSOLETTI highlighted was that the space sector represents a high-technology niche that employs around 1 million people, and growing, in the public and private sectors. The sector is democratizing, highly competitive, and growing in importance in areas where S&T is essential to success. These areas include the space manufacturing area for boosters, space craft, ground support systems and services, but also in new and emerging areas such as proliferated small-satellite constellations, on-orbit servicing and in-space manufacturing.

1.3 Achievements

Because of its cross-panel participation, this activity is inherently synergistic amongst those STO panels that are engaged in technical activities associated with enhancing and protecting NATO operational activities supported by the space domain. In addition, this Specialists' Meeting included military operators along with elements responsible for providing space services to the Alliance, which will add significant relevance to the dialog and output of the activity. Participation by NATO representatives from bodies and agencies such as Allied Command Transformation (ACT), NATO Communications and Information Agency (NCIA), and Joint Air Power Competency Center (JAPCC) as well as the European Union's Satellite Center (EU SatCen) will enable further synergies.

1.4 Exploitation and Impact

The output of this Specialists' Meeting will serve, in part, as a roadmap for future NATO STO space-related activities, demonstrations, field trials and experiments. The technical content of this activity can support technical training and education on the space domain as well as provide a contributing basis to future NATO space support requirements that can guide its member nations in their planning, acquisition and implementation of space solutions and capabilities throughout the Alliance. The ultimate exploitation goal is the achievement of resilient, effective, efficient and affordable capabilities as well as the effective operational application of those capabilities throughout the Alliance.

An area where significant impact can be achieved early on from the findings of SCI-318 is in the development of NATO's overarching space policy, where the STO, through its outreach efforts, can have an immediate and lasting impact on the development of that policy. In addition to impacting NATO space policy, the STO and its representatives can and should exploit the CPoW for space in a consultancy role in NATO exercises such as Trident Juncture and Trident Javelin. Finally, NATO efforts such as the Strategic Foresight Analysis and Framework for Future Alliance Operations must begin to address the significant capabilities and challenges of the space domain in their military advice on future requirements to NATO leadership. These are three critical areas for exploiting the STO CPoW for space, its participants, and the STO network of experts for maximum impact across the spectrum on NATO policy, training and exercises,

and future planning efforts.

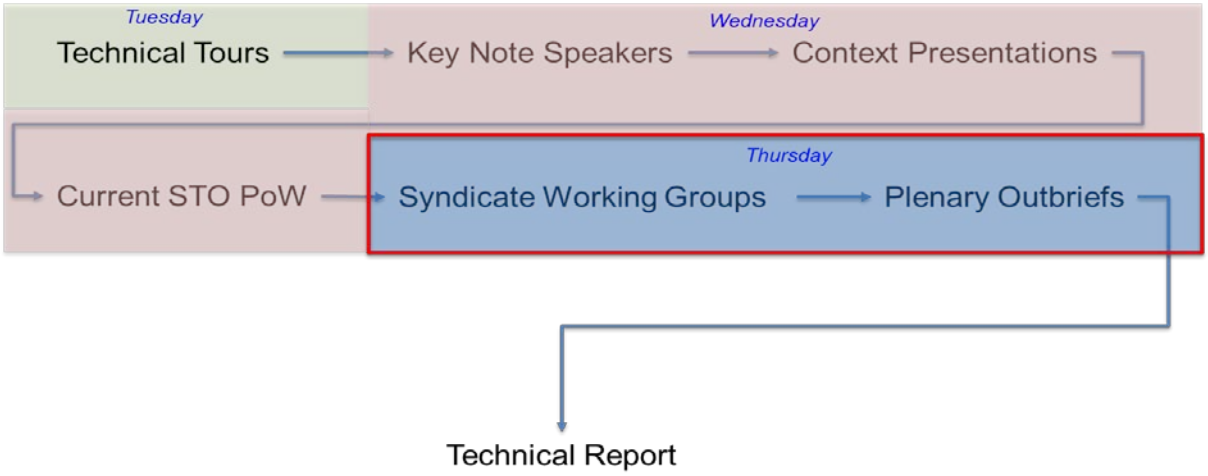

Figure 1: Overall Flow of the Specialists' Meeting

2.0 OVERALL CONDUCT OF THE SPECIALISTS' MEETING

SCI-318 was held, with exceptional support from MG CUOCI its commander, at the Army Education & Training Command, School of Applied Military Studies, Turin, Italy, 25 – 27 June 2019. The meeting followed the flow shown in below.

The following is a short synopsis of the three days over which the Specialists' Meeting was held. A copy of the agenda and associated Specialists' Meeting guidance charts are provided in the Appendix A.

Day 1: Technical Tour
The first day was conducted in a technical tour format to provide an overview of space science and engineering activities, and was graciously sponsored by Thales Alenia Space and Altec. Their intent was to help focus all the participants on a cross-section of leading-edge space topics and provide the motivation to get ideas flowing for the following two days.

The sponsors afforded all the participants an opportunity to visit the Thales Alenia Space Italy technology labs and integration halls in the morning and tour the Altec facility, which included their lunar rover laboratory, in the afternoon. The outcome of the technical tour was an inspired group of participants who were expose to several emerging or developing new space technologies that could find their way into solving space resiliency issues for NATO.

Day 2: Symposium
The second day was conducted in a symposium-style format with invited keynote speakers representing the operational side of NATO and the civil space perspective. The intent of these presentations was to create awareness among the participants of the breadth of space capabilities and their relevance to NATO operations and provide a glimpse at the massive changes occurring in the commercial space sector. The speakers helped establish a clear set of requirements, limitations, and recommendations for both warfighters and space capability providers.

The day continued with presentations on S&T activities sponsored by five of the seven NATO STO panels who presented a summary of the space-focused efforts, past and present, in their collaborative program of work. These presentations, though not exhaustive, provided a good cross section of the NATO STO space

portfolio.

Overall, the symposium provided the participants with a shared awareness of the breadth of NATO space capabilities, as well as limitations. From these initial seeds, perceived requirements for S&T solutions could be derived. The day ended with an open floor discussion about observations from the day's presentations framed by the following questions:

1. What have you found new or interesting?
2. What have you found disturbing or of concern?
3. What important topics / issues were not addressed?
4. Do you have any questions for the group?
5. What must get discussed tomorrow?

These primers allowed an open dialogue that started the preparation for the syndicate work of the following day.

Day 3: Syndicate Work

The third day was dedicated to syndicate break-out work that was facilitated and recorded by members of the organizing committee. The syndicates were engineered to leverage the expertise of the participants and their diverse areas of expertise. The discussion was guided by the following questions provided to all five of the break-out sessions:

1. Major challenges facing NATO's access to and use of the space domain
    a. Operational (military and space system operations)
    b. Institutional (policy, sociology, economics, governance, …)
    c. Science & Technology / engineering / technologies
    d. Threats and risks
2. Review of NATO STO Program-of-Work on Space
    a. Accomplishments
    b. Gaps and shortfalls
        i. Technical topics
        ii. Nature of participants
        iii. Engagement with other NATO organizations / activities
3. Areas for NATO STO "technical" focus in the future
    a. Space mission areas
    b. Space system capabilities
    c. Support to the NATO operators
4. Implementation recommendations – how to make real progress?
    a. Ideas for activities, e.g. task groups, specialist's meetings, lecture series, etc
    a. Nations and NATO organizations interested in supporting
    b. NATO activities for NATO STO engagement (exercises, studies, …)

The goal of the syndicate sessions was to elicit feedback on the current content of a STO's collaborative program of work (CPoW) for space as well as to provide expert community guidance and direction on the future content of the CPoW for space. The syndicates culminated with briefings to the participants in plenary session. A summary of the recommendations of the syndicates will be presented in the Syndicate Findings and Recommendations section, and the content of the briefings can be found in Appendix B.

3.0 ASSESSMENT OF THE CURRENT AND PLANNED STO PROGRAM OF WORK

3.1 Current STO space program of work

Representatives from five of the seven STO S&T panels presented their CPoW activities in support of the space domain of operations. Of the 300+ activities in the overall STO CPoW, there are only on the order of 11 current or planned activities directly related to the space domain spread amongst five of the seven STO panels and group, this number represents only about 3% of the overall CPoW. This number seems inadequate considering the fact that space is a highly technical mission area with significant research and development activity in the Alliance nations, and the fact that NATO is exceedingly dependent on space delivered capabilities. There are additional activities that are tangentially related to space or that could include space-relevant findings, but a comprehensive review of those activities was apparently beyond the ability of the participants from the STO panels that participated. It was apparent from its sponsorship of this Specialist's Meeting that the SCI panel is the de facto home for the CPoW for space within the STO. The following summary of the STO S&T panels' current space program of work highlights what is either currently or planned to be in work in this area:

3.1.1 Advanced Vehicle Technologies (AVT) Panel

The AVT panel has a long history of aerospace S&T activities, many of which involve direct and indirect application to the space domain. Most recently the panel has focused on the areas of small satellites, additive manufacturing, and electric propulsion.

1. AVT-336 RSM - Enabling Platform Technologies for Resilient Small Satellite Constellations for NATO Missions. The goals of AVT-336 are to investigate the state-of-of-the-art, gaps, opportunities and benefits to be derived by infusing new platform technologies for resilient small satellite constellations.
2. AVT-294 RTG - Towards Improved Computational Tools for Electric Propulsion
3. AVT-ET-189 Future Directions for the use of Additive Manufacturing in NATO Operations

3.1.2 Information systems technology (IST) Panel

IST Research activity is generally indirectly related with the Space Domain and covers the following broad topics of relevance:

1. Communications, networking and network management
2. Spectrum analysis & management
3. Security & Cyber defense
4. Multisource data fusion Data/image analytics
5. Artificial Intelligence & Autonomous systems

IST specific Space-related activity:

1. IST-172 RTG - Airborne Beyond Line of Sight (BLOS) Communication Network

a. Major role of BLOS communications in connecting forces out-of-theater but also in-theater

b. Airborne BLOS network as an additional option to SATCOM or HF

c. A network of multiple airborne relay nodes provides added resiliency in a hostile communications environment

3.1.3 Systems Analysis and studieS (SAS) Panel

SAS Research activity is generally indirectly related with the Space Domain and covers the following broad topics of relevance for potential cooperation:

1. Integration of Space domain into new concepts of operations
2. Impact of Space Domain on Deterrence (follow-on of SAS-141)
3. How to make the best use of Space Domain
4. Deploying effectively space assets
5. Integration of advanced data analytics on the space domain
6. Impact of Space Domain on Urban Operations
7. Cost and risk analysis of the loss of Space Domain

Of the activities presented by the SAS Panel, the two that follow showed the most direct linkage to the Space CPoW, though in both cases the context is significantly broader than the space domain of operations.

1. SAS-149 RLS - Basics Of Complex Modern Urban Functions And Characteristics
2. SAS-ET-ED - Developing A Standard Methodology For Assessing Multinational Interoperability

3.1.4 Systems concepts and integration (SCI) Panel

The SCI panel is the *de facto* home of space activities within the STO's CPoW. SCI is where the members at large for space find their home and has the largest collection of space cognizant members within the collaborative network. The current and future work by SCI focuses on the broad areas of space domain awareness and the space environment.

1. SCI-279 RTG - Enabling Technical Considerations for a NATO-Common Space Domain Operating Picture
2. SCI-229 RTG - Space Environment Support to NATO SSA
3. SCI-ET-036 - Collaborative Space Domain Awareness Data Collection and Fusion Experiment

3.1.5 Sensors and Electronic Technology (SET) Panel

The SET panel focuses on systems, technologies and applications that find value in the space domain but are not necessarily targeted on space applications. Sensor technology is as relevant to terrestrial applications as it is to space. That said, SET has a history of looking at space through a long lens and continues to find space relevance for its activities.

1. SET-279 RTG - Space-based SAR and Big Data Technologies to support NATO Operations
2. SET-ET-115 - RF and RF/EO Technology for Space Situational Awareness

Overall, the review of the current Space CPoW provided to the SCI-318 participants established a basic understanding of the current STO activities. The goal being that during the third day of the meeting, the SMEs and practitioners could break out into their syndicates and attempt to address four broad questions

meant to guide the groups to conclusions about the future direction for the STO's space-related CPoW.

4.0 SYNDICATE FINDINGS AND RECOMMENDATIONS

During the course of day three, the participants broke into five syndicates, each with the goal of addressing the four guiding questions that are at the core of the outcomes of the Specialists' Meeting. The results of that effort are summarized in the following sections as they were reported in the final briefings of each of the syndicates. The full text of the syndicate briefings can be found in Appendix B.

The guiding questions are restated here, and they are followed by a summary which distills the consistent themes from the raw syndicate results. The findings are:

1. What are the major challenges facing NATO's access to and use of the space domain?
    a. The Space S&T community lacks a guiding element within NATO as well as an overarching strategy for space, which in turn inhibits coherency in the program of work for the STO.
    b. Standards for data sharing are needed in multiple areas to include: interoperability, Space Domain Awareness, sensor data, common operating picture, architectural interfaces.
    c. A lack of common understanding of the space domain and the threats therein among the Nations that is demarcated by the line between spacefaring and non-spacefaring nations. The provision of a technical definition and common language for the space domain could help this understanding, at least in the S&T community.
    d. Space is evolving very quickly from a benign domain to a warfighting domain and from military/government actions to commercial use.
2. What was your assessment of the NATO STO Program-of-Work on Space?
    a. Past activities need to progress to demonstrations and then to adoption by the Nations.
    b. Space crosses technical domains, but it is not especially cross-panel within the STO. SET and SCI are making some progress in this regard.
    c. The Space CPoW is relatively small compared to the Air, Land and Sea domains, and it has no clear mandate within NATO.
    d. There is an apparent need for a central guiding element for the STO's Space CPoW.
3. In which areas should the NATO STO "technical" focus be in the future?
    a. Space Domain Awareness in support of NATO Operators and the safety of flight (debris, threats, space weather, etc.) for the space systems of the Nations.
    b. Space systems modeling and simulation is conspicuously absent from the CPoW.
    c. Enhancement of the training and education of NATO as a command structure and of the NATO operators in non-space domains to raise awareness of space capes and threats.
    d. Standards development for interoperability and data and information sharing.
        i. Continue efforts such as SCI-311 to enhance data sharing and interoperability.
    e. Space systems resiliency to include cyber, weather, and fighting through hostile actions.
    f. Develop a common understanding of threats space systems face now and in the future.
4. Implementation recommendations – how can the STO make real progress?
    a. Establish an 8th panel focused on Space as a cross-technical-domain community of

interest.

i. An alternative could be a standing technical team similar to the Flight Test Technical Team already sponsored by the SCI panel.

b. Develop a Lecture Series to help with the development of NATO's Overarching Space Policy and Doctrine.

ii. RLS might include common lexicon, space fundamentals, and legal aspects.

iii. Ensure the RLS targets the NATO ACT Strategic Foresight Analysis and Framework for Future Alliance Operations communities to introduce space to ACT's future capability planning processes.

c. Identify relevant space CPoW activities for graduation to Collaborative Demonstrations of Technology.

d. Explore the implications of Space Traffic Management for NATO operations.

e. Leverage the community of space experts within the STO to enhance the space content of NATO exercises, use this as an opportunity to put the CPoW products to action.

5.0 AGGREGATED FINDINGS AND RECOMMENDATIONS

The assessment of the Technical Evaluator and Rapporteur after reviewing the STO space CPoW, participating in the syndicate work and reviewing the results presented in the syndicate briefings is captured in five broad thematic areas:

1. Standards form the foundation for interoperability. Standards in the sense of the NSN may not be the answer, but some minimum set of interface criteria that can be counted on by all nations to allow for collective or shared communications, PNT, ISR and C2 is essential for interoperability to be achieved.
2. Resiliency in the space segment of the NATO C2 architecture is the most that NATO as a stand-alone entity can likely achieve unless NATO commits to "owning" space capabilities. Resiliency is only a catch phrase unless there is an understanding of the space enabled C2 architecture in which NATO operates and an appreciation for the threats that NATO forces face in the space domain.
3. Space Domain Awareness (SDA) is not the same as Space Situation Awareness. To achieve SDA, NATO and the nations of the Alliance must be able to:
    a. Develop an overarching space policy (OSP),
    b. Deal with characterizing threats that present minimal observable characteristics,
    c. Present a common operating picture (COP) for the space domain, in the absence of an OSP, a space COP will remain a national interest. In this pre-OSP period, the CPoW can still make contributions to the development of the COP.
    d. Space traffic management will remain a challenge that must be taken up by an international organization, most likely made up of the space fairing nations.
    e. Conceive of an STO project to address Space Domain Awareness in a coordinated way, i.e., a structured framework prepared by an advisory expert group on the subject, capable of stimulating new ETs, RTGs, SMs, LSs, whose outcomes are complementary and represent important tiles to build up a robust and effective STO Space Domain Awareness expertise knowledge platform.
4. Training and education are foundational to the development of "space aware" Alliance leaders and

contributors.

a. Training targeted and properly sequenced at national and NATO venues could be supported by efforts of the CPoW.

b. NATO exercises need to contain Space elements that are both realistic and stress the joint/coalition nature of NATO operations.

c. The CPoW could be leveraged to develop a Space 101 Lecture Series that would support a number of training and education thrust areas to include exercises and NATO military training venues such as the NATO School and the NATO Staff College.

d. A critical gap is in the area of knowledge transfer from the S&T realm to the operational and policy development domains. To date, STO has developed a set of very interesting results, but they are fragmented and difficult to be exploited in a NATO common framework.

5. There are *real* advanced/disruptive technologies being introduced into the space domain.

a. Additive Manufacturing is finding traction in the space domain, as is manufacturing in space using native materials from space.

b. On orbit servicing may provide a revolution in extending the operational life of space systems.

c. Several disruptive technologies such as quantum encryption, autonomous operations for lethal systems, and the characterization of small/dim objects using non-traditional means are showing promise. Disruptions of their nature can represent both threats and opportunities and warrant the focused attention of space technical committee within the STO structure.

d. The challenge presented by the fast-moving commercial space community will present challenges for the nations of the Alliance, as the commercial sector is driven by profit rather than military capability. Learning to harness these advances in the niche of military operations will remain a challenge as private industry takes an ever more leading role in technology development.

In response to these five broad areas, the following *Specific Actions for the Science and Technology Organization* are recommended:

1. Commit to tracking the elements of the Space CPoW across the seven technical panels/group in a coordinated way that crosses the stovepipes of the seven STO technical communities of interest (panels and group).
2. Initiate a Space Strategic Initiative in the next strategic planning effort, the initiative should be similar to previous STB initiated/endorsed strategic initiatives and should focus on influencing NATO's policy development, exercise planning and futures thinking.
3. Establish a standing Space Technical Team based on the model of the SCI Panel's Flight Test Technical Team with the charter of connecting the CPoW efforts across the STO and providing overarching care and guidance to what is currently an uncoordinated, yet active, community of interest.
4. Take on the immediate challenge of defining a Space Lexicon for NATO. This lexicon would be invaluable in the development of an Overarching Space Policy by the BiSC for Space and for the nations of the Alliance in their efforts to achieve a fundamental level of space interoperability.
5. Purposefully develop a Collaborative Demonstration of Technology (CDT) for a space focused application. This CDT must be well chosen, organized, and supported in order to ensure the

greatest impact of the effort and the resources it will require.

6. Ensure that the STO, through the space cognizant members of the CPoW, influences the content of the NATO School space course. A well-focused and in-depth lecture series on space capabilities and what they deliver for terrestrial operations, developed as part of the CPoW in collaboration with the NATO School and Staff College faculty, could form the nucleus for space-focused content at the NATO school and for the senior leaders curriculum the NATO Staff College.

It is clear that to maintain the focus on space, activities such as the SCI-318 are needed periodically to ensure that an appropriate degree of technical and threat vigilance is maintained and imparted to the NATO space community, especially in light of the on-going rapid evolution of the space domain of operations. Coordinating and informing the efforts of the various NATO organizations and agencies involved in space must continue in order for *Space as a Warfighting Domain* to be properly served by the S&T community. As such, this activity finds that a standing Space Technical Team for space should be formed immediately to lead and leverage not only the NATO S&T community but the planning and operational communities as well.

In closing, this final thought, gleaned from a conversation overheard between an aviator and an exercise planner, seems to capture the challenge for the space operational domain in a warfighting context. The aviator said: *"The challenge as I see it, from a non-space operator's point of view, is for space to deliver its full suite of enabling capabilities when and where they are needed, period."* The comment was made during a discussion about joint exercises where the aviator was lamenting how during exercises, space capabilities were "taken away" in order to prepare participants for operations without the war winning capabilities that space enables. The point he made is that training and exercising for joint and combined operations should not focus on terrestrial operators executing their missions without space capabilities; rather, they should have the full suite of space capabilities at their disposal to "train like you fight". Space capabilities should not be so brittle that they are lost at the outset of hostilities, otherwise why have them at all. From the space operations point of view, space operators should exercise fighting through attacks to ensure they deliver their war-winning capabilities when and where they are needed to win on the land, in the air and at sea. To reach this level of proficiency, all domains of warfighting must strive to sustain resiliency in the face of significant adversarial threats. The NATO STO has a prime opportunity to influence these desired outcome and have an impact through exploiting the findings of this specialist's meeting as soon as possible.

APPENDIX A

25 June - Day 1 – Technical Visits

08:00 Registration at the Arsenale Palace, The Army Education & Training Command and School of Applied Military Studies (Comando per la Formazione e Scuola di Applicazione dell'Esercito)

08:30 Departure by bus

09:00 Visit of THALES ALENIA Space Claudio CASACCI, Roberto PROVERA, THALES ALENIA Space, ITA

14:00 Visit to ALTEC, Armando CIAMPOLINI, ALTEC SPACE, ITA

26 June - Day 2

08:30 Registration at the Arsenale Palace

09:00 Welcome Ceremony by Specialists' Meeting Chairs and Host

Lt Col (ITA A) Giovanni SEMBENINI, MoD, Secretariat General of Defence and National Armaments Directorate, ITA

Dr Donald LEWIS, Aerospace Corporation, USA

09:10 Welcome by Gen. D. Salvatore CUOCI (ITA A), Commander - Army Education & Training Command, and School of Applied Military Studies, ITA

09:15 Introduction to the NATO STO CSO, Lt Col (USA AF) Ryan SNIDER SCI Panel Executive

Keynote Speeches

09:20 Introduction of Keynote Speaker 1, SCI-318 Co-chair

09:25 Keynote Speech 1, LTGEN Giovanni FUNGO (ITA A), Comandante per la Formazione e Scuola di Applicazione dell'Esercito, ITA

09:50 Introduction of Keynote Speaker 2, SCI-318 Co-chair

09:55 Keynote Speech 2, Professor Ezio BUSSOLETTI, Ministry of Infrastructure & Transport, ITA

10:20 Overview of NATO STO / CSO, Lt Col (USA AF) Ryan SNIDER, SCI Panel Executive, NATO CSO

10:30 BREAK

11:00 Introduction to NATO STO Space & Specialists' Meeting Objectives

Dr Donald LEWIS, Aerospace Corporation, USA

11:25 Threat briefing, Lt. Col. Tim VASEN (DEU AF), NATO JAPCC

11:45 NATO Space Support in Operations - BiSCSWG / Policy and Training, Lt Col (FRA AF) Stephanie VRAC, NATO ACT

12:05 NATO Space Support in Operations – Exercises, Lt Col (FRA AF) Stephanie VRAC, NATO ACT

12:25 European Satellite Centre SATCEN SSA Activities, Mr Joao ALVES, EU SATCEN

13:00 LUNCH

14:00 NATO STO - SCI Panel Space Activities, Dr Donald LEWIS, Aerospace Corporation, USA

14:25 SCI-311 Task Group on Collaborative Space Domain Awareness Data Collection and Fusion

Experiment, Ms Carolyn SHEAFF, USAF AFMC AFRL/RIED, USA

14:45 NATO STO - AVT Panel Space Activities, Prof. Dr Alim ASLAN, Istanbul Technical Univ, TUR

15:10 NATO STO - SET Panel Space Activities Prof. Marco MARTORELLA, University of Pisa, ITA

15:35 BREAK

16:05 NATO STO Space Environment Prof. Mauro MESSEROTTI, INAF-Astronomical Observatory of Trieste / Department of Physics, University of Trieste, ITA

16:20 Group Discussion

16:50 Introduction to Day 2 Activities

17:00 End of Day 1

27 June - Day 3 – Syndicate Working Groups

09:00 Day 2 Administrative Remarks,

Dr Donald LEWIS, Aerospace Corporation, USA

Lt Col Giovanni SEMBENINI (ITA A), MoD, Secretariat General of Defence and National Armaments Directorate, ITA

09:05 Syndicate Instructions and Work Assignments in Plenary Session,

Dr Donald LEWIS, Aerospace Corporation, USA

09:15 Syndicate Task 1: Review Session (All)

10:00 Syndicate Task 2: Critical review of STO Program of Work (All)

11:00 Syndicate Task 3: S&T opportunities (All)

12:00 Syndicate Task 4: Implementation - Making it Real (All)

13:00 LUNCH

14:00 Plenary Preparation

14:30 Syndicate Briefings (All)

15:45 BREAK

16:15 Plenary Discussion

16:45 Technical Evaluation Report (TER) Briefing, Dr James GREER, The Aerospace Corporation, USA

16:55 Closing Remarks

17:00 End of Specialists' Meeting

APPENDIX B

B1. SYNDICATE A

1. Major challenges facing NATO's access to and use of the space domain
    a. Operational\Institutional Challenges:
        i. Avoid those areas where S&T cannot influence or control the outcome
        ii. Hinders scientific progress
        iii. Country Specific agreements (Bi-lats, multi-lats, PAs)
        iv. Institute\embed approvals into processes
    b. STANAGs for space data sharing (4676 potential?) - Interoperability Standard?
    c. CSO\STO Coordinator for Space S&T
    d. Science & Technology \ engineering \ technologies
        i. Identify and provide architecture\system that is fully resilient or degrades gracefully
        ii. Cases \ Challenges to interoperability
    e. Data Sharing \ Data streaming \ Interfaces
    f. Threats & Risks – see JAPCC briefing for list of threats
        i. Irreversible Effect vs Irreversible Action : Discussion centers on whether threat is reversible or not to the satellite vs the mission the satellite supports
        ii. Risk - Data Corruption: Identified and unidentified (Malicious\Intentional and Unintentional)

Review of NATO STO Program-of-Work on Space

    f. Gaps & Shortfalls
        iii. Technical topics
        iv. Nature of participants
        v. Engagement with other NATO organizations

Areas for NATO STO "technical" focus in the future

    g. Space System Capabilities
        vi. RF Spectrum Allocation & Management
    h. SSA Challenges
        vii. Revisit rates on objects
        viii. Cooperative Collection
        ix. Collection on small\dim objects
        x. Space Traffic Management – effect of small sat clusters on military sensors
    i. Debris Population

xi. Mapping \ Cataloging

xii. Mitigation strategies

j. Support to NATO Operators

xiii. Need for Modelling & Simulation capability and tools - Effects on operations

xiv. Need for understanding of space support – what does it provide and why do I care

xv. Space providers\operators\coordinators need to be realistic exercise components

xvi. Need for Training and education

Implementation recommendations – how to make real progress?

k. Leverage existing sensor assets to address issue of small\dim objects and debris

l. Effort to quantify impact of available data (massive) from commercial sensors on military operations. How does this affect the balance of power ?

m. Identify procedures and techniques for degradation of services

n. Increased involvement in military exercises

xvii. Realistic component

xviii. Put studies into action

xix. Include both spectrums: Degradation of space services and overloading forces with space-based information & products

o. Organizations interested in supporting

p. Nato Activities for NATO STO engagement (exercises, studies)

xx. Pipeline for involvement in existing exercises, e.g. TRIDENT Juncture

B2. SYNDICATE B

1. Major challenges facing NATO's access to and use of the space domain

a. There are many opportunities for space collaboration

b. A common understanding of the influence of space assets

c. Investigate bridging the gap between the space and cyber domains

d. Promote Research Lecture Series beyond S&T community

i. For example, to NATO military personnel, mission planners, exercise coordinators, etc.

e. To what extent has STO coordinated all expertise and assets to contribute to effectively protecting critical infrastructure in the theatre from space-originated threats on mission operations?

f. To what extent has STO promoted the analysis and development of comprehensive Space Domain data fusion and assimilation techniques capable to evaluate the extent of mission success?

g. To what extent has STO considered mission analysis techniques for impacts by Space Domain perturbations?

h. To what extent has STO considered the coding of knowledge on Space Domain

perturbations, their sources and impacts as a fundamental conceptual and operational tool to support the interpretation of the phenomenological scenarios and relevant impacts on mission success?

2. Review of NATO STO Program-of-Work on Space
    a. There is no clear role of STO in NATO space domain:
        i. Should SCI lead in coordination of all space tasks?
        ii. SCI & SET starting coordination with joint space session at fall panel meeting
3. Areas for NATO STO “technical” focus in the future
    a. Education and training on the influence of space assets on the warfighter:
        i. Which information coming from space is used for what and what happens if the space information is degraded or not available?
    b. Standardized calibration techniques for sensor measurements:
        i. Purposes include SSA, imagery fusion, collision avoidance, etc.
    c. Standardized format for data information sharing
    d. Standardized format for sensor data
    e. Spacecraft hardware and software resiliency mitigating factors:
        i. Collaboration with external agencies (EU for example)
        ii. Coordination with external agencies on research priorities
    f. Space traffic control guidelines
    g. What does NATO's space architecture look like?
4. Implementation recommendations – how to make real progress?
    a. *Why the Space Domain* Lecture Series with tri-fold pamphlet
        i. Target audience would be HQ military staff, ACT SFA & FFAO
    b. Standardization of data info sharing between spacefaring nations:
        i. Specialists’ Meeting with outcome of Lecture Series
    c. Lecture Series for spacecraft resiliency enhancing factors
    d. Exploratory Teams to discuss:
        i. Collaboration with external agencies (EU for example)
        ii. Coordination with external agencies on research priorities
    e. Implications of Space Traffic Management to NATO operations
    f. Exploratory Team to investigate low-cost satellite swarm implications to NATO's military operations (space architecture)
    g. Convene an Exploratory Team (ET) to create a roadmap for the RTG that follows
        i. Create a Research Task Group (RTG) to review all expertise and assets that may contribute to effectively protecting critical infrastructure in the theatre from space-originated threats on mission operations
    h. Convene an ET first to survey the existing data relevant to the Space Domain

i. Create an RTG that will then identify the optimum schemes for data fusion and assimilation

i. Create an RTG that will analyze techniques for evaluating mission impacts caused by Space Domain perturbations

j. Create an RTG that will survey the existing knowledge and expertise on space domain perturbations to be coded in a way that can be managed at the human and machine levels in support to the interpretation of the phenomenological scenarios and relevant impacts on mission success

k. Convene an ET to investigate methods of bridging the gap between the space and cyber domains

B3. SYNDICATE C

1. Major challenges facing NATO's access to and use of the space domain
    a. Operational
        i. Interoperability important – need more details with common understanding
        ii. standardization is a means to interoperability
        iii. How to transfer new knowledge or technologies generated to NATO operations
    b. Technologies
        i. Quick launch capability for resiliency
        ii. In-orbit servicing is important
        iii. Additive manufacturing in space for in-orbit servicing
        iv. Manufacturing in space using re-entry vehicles
        v. Resident Space Object characterization – share information regarding space threats
        vi. Space debris removal – active removal
        vii. On board propulsion and maneuvering capabilities
        viii. Formation flying and constellations
    c. Threats and Risks
        i. Commercial and military space traffic management
        ii. Easy access to space-based products by red forces from commercialization of space
        iii. How to deal with Intellectual Property Rights (IPR) related to open innovation
2. Review of NATO STO Program-of-Work on Space
    a. Space is covered by number of panels
    b. Based on current STO structure need for cross panel activities as 'space' involves highly integrated systems
    c. Space related work is very limited compared to air, land or sea
    d. Topics to be included or expanded in CPoW

i. Cyber
ii. Airborne launches and sea launches
iii. High Altitude Platforms
iv. Quantum technologies

e. Attract more institutions and encourage experts to participate
f. How to benefit from cutting edge technology in the commercial and academic sectors

3. Areas for NATO STO “technical” focus in the future
   a. S&T Needs
      i. Quantum
      ii. High altitude vehicles
      iii. Increase cyber security
      iv. Space weather for higher latitude with easy sharing
   b. Operational Needs
      i. Prepare a strong basis for interoperability
      ii. Having multinational agreements and processes to space share products among nations
      iii. Impact of adversarial space threats for NATO nations e.g. Jamming
      iv. STO should try to feed FMN (Federation Mission Network) initiative to operationalize S&T outcomes, in particular to space
4. Implementation recommendations – how to make real progress?
   a. Ability for NATO to access to commercial space-based products directly, without going through individual nations
   b. Generate a 'real' cross panel activity for space or a new dedicated panel specific to space area
   c. Suggested tasks for this new space technical team
      i. Identification of enabling 'integrated ' space technologies for future military needs
      ii. Track 'New Space' activities for future exploitation for military advantage or threats
      iii. Develop a process to prioritize and expand research in critical areas eg. quantum, high altitude vehicles etc
      iv. Maintain a comprehensive list of activities in space, which should be regularly updated
      v. Develop a process to distribute information to the space community efficiently
      vi. Regularly review and update the program of work against high priority topics

B4. SYNDICATE D

1. Major challenges facing NATO's access to and use of the space domain
    a. Experiments (Action) -Too few, need results
    b. Importance of Interoperability -NATO has a role
    c. Definition of Space Domain needed -technical definition, not policy
        i. Includes ground station?
    d. What is the NATO action plan for space?
        i. Need common language, space is international
        ii. Quite vague, not specific, very broad
    e. Interdependencies between technical/policy/legal
        i. Need operational perspective, need operational benefit, specific
        ii. Better defined relationship between technical and operational
        iii. Why is this important to the operator? Operator should be in the lead!
        iv. Importance of training → awareness of threat
2. Review of NATO STO Program-of-Work on Space
    a. Experiments (Action) -Too few, need results
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        i. Need operational perspective, need operational benefit, specific
        ii. Better defined relationship between technical and operational
        iii. Why is this important to the operator? Operator should be in the lead!
        iv. Importance of training → awareness of threat
3. Areas for NATO STO "technical" focus in the future
    a. Dedicated panel? Pros & cons
    b. Space effort seems fractured within STO
    c. Data Fusion initiative is valuable
        i. Need for interoperability
        ii. Important for NATO to focus on (more focus!)
    d. More experiments & exercises
        i. Helps with training of operational understanding

e. Event on the intersection between defense & scientific mission (example: space weather)
f. Need for managed datasets for academia
g. Common Situational Awareness picture
    i. Data Fusion & Interoperability
h. Operational experience focused event for the STO academic & industry comunities
i. Opportunity to engage with NATO school, which offers space classes
j. Need for space language education
k. Modeling is an opportunity
l. Ground stations – affordability opportunity?
m. Pre-meeting readings to make the face-to-face time more efficient
n. Identify Key Space Gaps
    i. Interoperability/data standards (need industry engagement)
    ii. Pace: Need faster way for considering system updates than STANAGs
        1. Can technology solution help? (shared middleware for example)
    iii. Resiliency: Resistant to cyber threats & jamming
        1. Actionable for NATO?
    iv. Threats: What are they?
    v. Modeling & Simulation (like a space simulator)
        1. Help with shared understanding
        2. Coordinate with ground stations
        3. Exercise scenarios
        4. Training-operational & technical communities
    vi. Network of smallsats analysis

4. Implementation recommendations – how to make real progress?
    a. Separate panel for Space? -No?
    b. Focus of investments
        i. European R&D Strategy will be published in next 18 months. How will this impact the plan? The strategy is R&D, including Space.
    c. Develop NATO Space Doctrine
    d. Lecture Series: Common language for space domain
    e. Dataset event – step forward towards domain interoperability
    f. Focus specialist meeting with read-aheads
    g. Event with user on the ground -perspectives, challenges & experiences
        i. Voice of the Customer Workshop
        ii. Feedback from exercises (like Trident Juncture)

h. Challenge Event -multiple places (students) working in parallel
    i. Threats – Red-teaming (probably challenging politically)
    ii. Solutions – Innovation focused

B5. SYNDICATE E

1. Major challenges facing NATO's access to and use of the space domain
    a. Space is evolving very quickly:
        i. Technology, commercial, etc
    b. Paradigm change: from System of Infrastructures to System of Information to be categorized and integrated (kind of Data Repository)
    c. NATO does not own satellites
    d. Information driven Warfare
    e. Changing theatres of operations (e.g. Arctic, information)
2. Review of NATO STO Program-of-Work on Space
    a. Current CPoW relevant.
    b. Do further step to Implement the results of previous activities; refer to Task 4 chart
    c. More cross panel activities and results sharing
3. Areas for NATO STO "technical" focus in the future
    a. Capabilities available but data sharing and infrastructure control policy is a challenge (interoperability)
        i. Big data analysis and AI
    b. Resiliency very important topic
    c. Cyber Security for Space Systems
    d. Arctic
    e. Education
4. Implementation recommendations – how to make real progress?
    a. Resilience: SCI 308 follow on
        i. Technical Analyses of key topics (AVT)
        ii. Capability (ISR, SATCOM, PNT, SSA) perspective (SCI)
    b. The changing Arctic and its challenges
        i. Infrastructure (SATCOM, ISR, Space Wx)
        ii. Cross-panel activity
    c. Interoperability
        i. What information do we need? What information is available, what do we lack? (TM)
        ii. How to share data for efficient information extraction (WS involving external

entities e.g. Space agencies, Commercial entities, etc)

NATO STO SCI Panel
Specialists' Meeting SCI-308

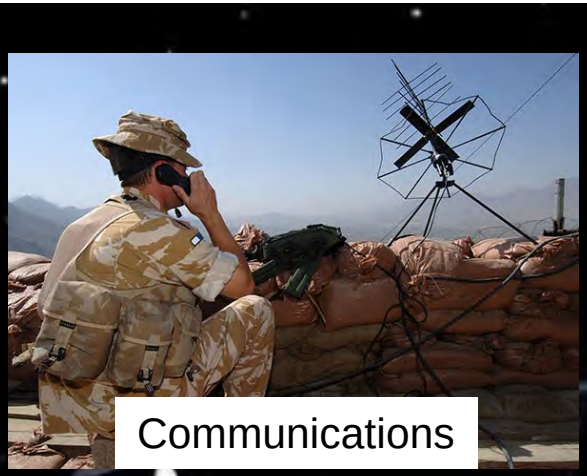
The Space Domain and NATO Operations: A Critical S&T Review

Lieutenant General Giovanni FUNGO
Education and Doctrine Command
Commander

Turin, 26 June 2019

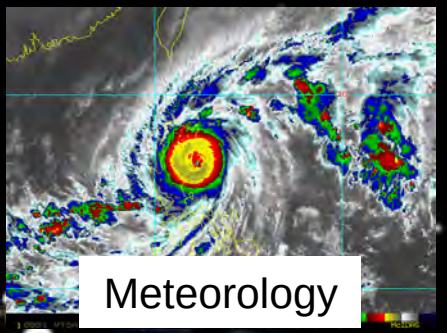
Space Domain

Space is a place



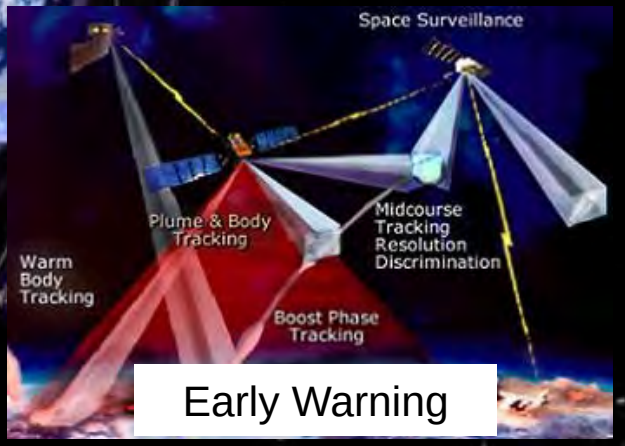
Communications

Precision Navigation & Timing



Meteorology

Intelligence



Early Warning

If space is a ‘place’ similar to other domains, it can be escalated as air, land, and sea

Space support in NATO Operations

Satellite Communications (SATCOM)

- provide global coverage and connectivity
- obtain strategic situational awareness
- enable maneuver of forces Beyond Line of Sight (BLOS)
- NATO does not own any SATCOM satellites
- NATO owns fixed and deployable ground terminals

Satellite Communications (SATCOM)

Advantages

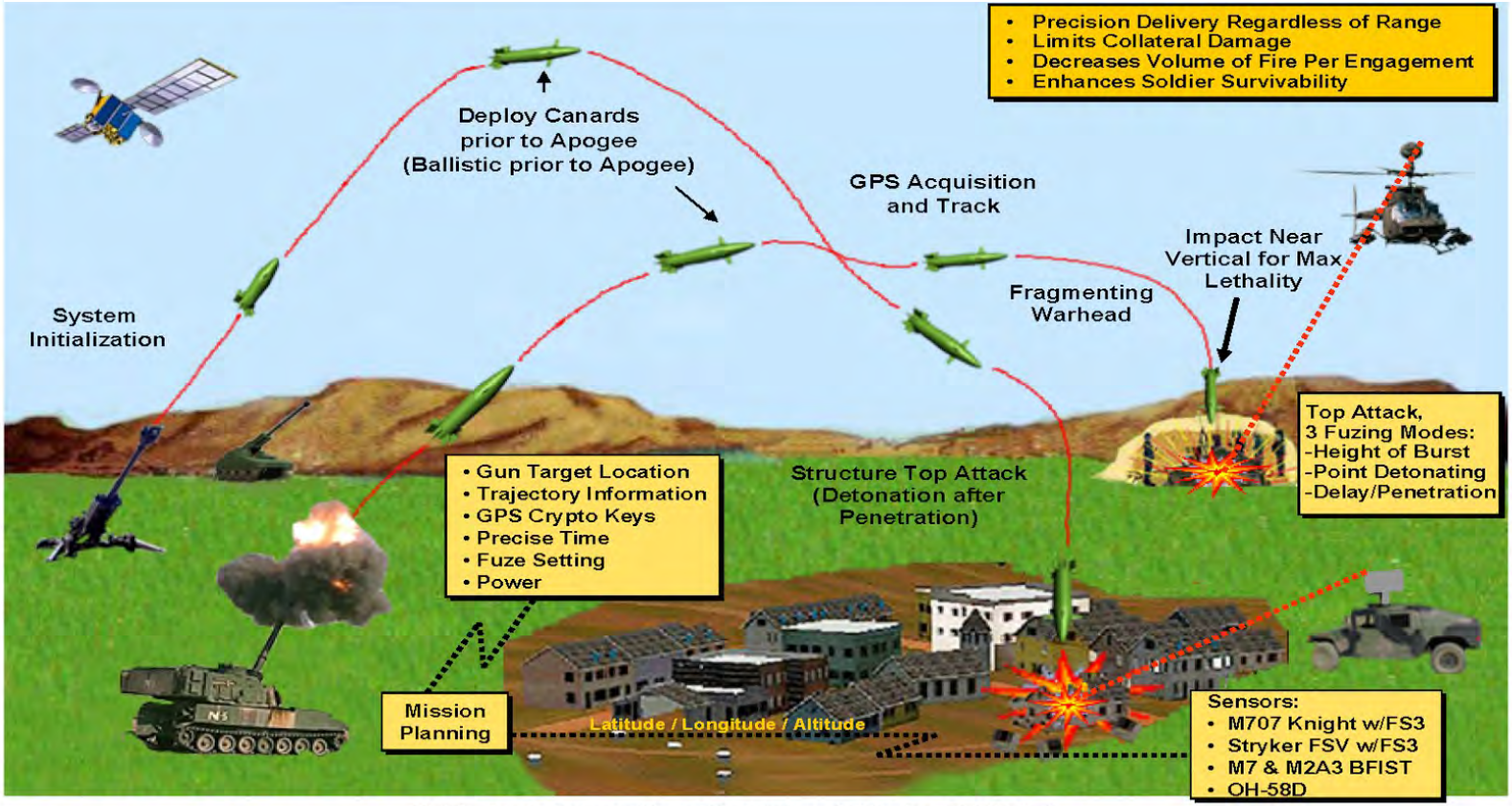
- real time BLOS transmission with no need for ground communications architecture

Disadvantages

- NATO supplement limited SATCOM capacity with national and civil systems
- big antennas reduce mobility
- SATCOM systems are susceptible to jamming
- bad weather degrades the signal

Space support in NATO Operations

Positioning, Navigation and Timing (PNT)



Space-based PNT systems support strategic, operational, and tactical missions by providing precise three-dimensional location and navigation capability in all physical domains (Land, Maritime, Air and Space)

Space support in NATO Operations

ESERCITO

Positioning, Navigation and Timing (PNT)

Advantages

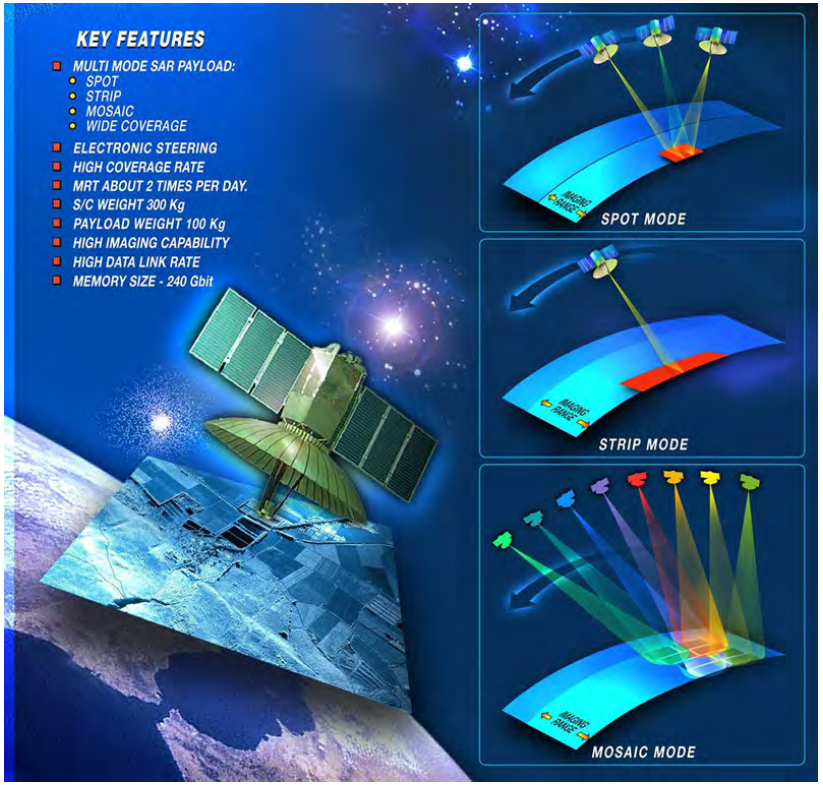
- provides continuous global service
- provides continuous real-time information to a potentially unlimited number of users

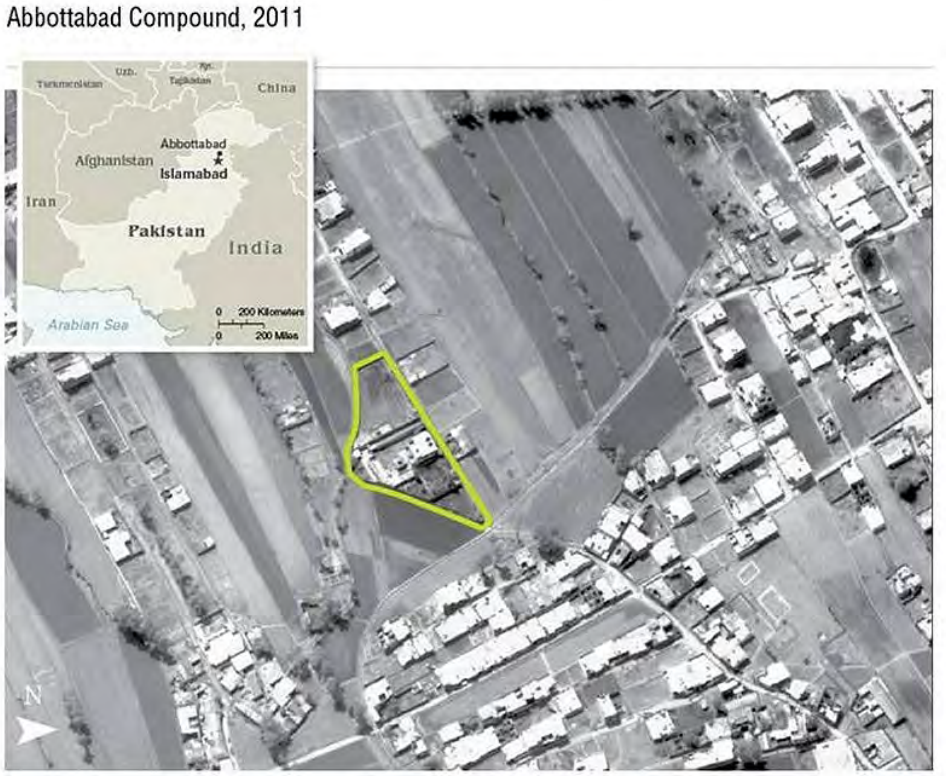
Disadvantages

- the adversary can exploit the service and reduce the NATO military advantage
- the signal is very susceptible to jamming
- the adversary could generate false signals to mislead the user (spoofing)
- the signal is susceptible to vegetation or steep terrain

Space support in NATO Operations

Intelligence, Surveillance and Reconnaissance (ISR)

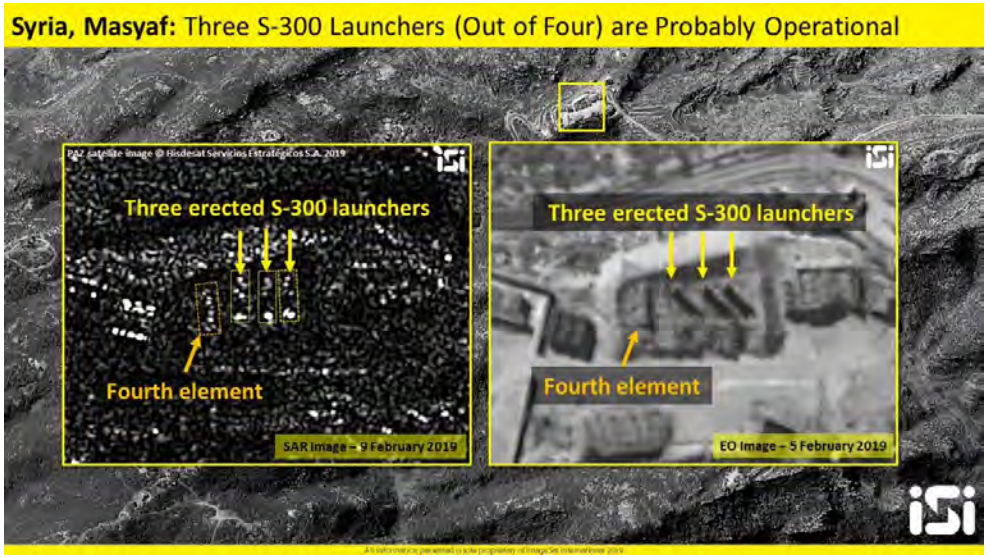




ISR systems enable to obtain information about activities and resources of an adversary and to secure data concerning the geographic characteristics of a particular area of interest where no data can be obtained from other sources without putting at risk personnel and means

Space support in NATO Operations

Intelligence, Surveillance and Reconnaissance (ISR)



Advantages

- Global coverage over denied areas
- enhance planning capabilities by providing updated information

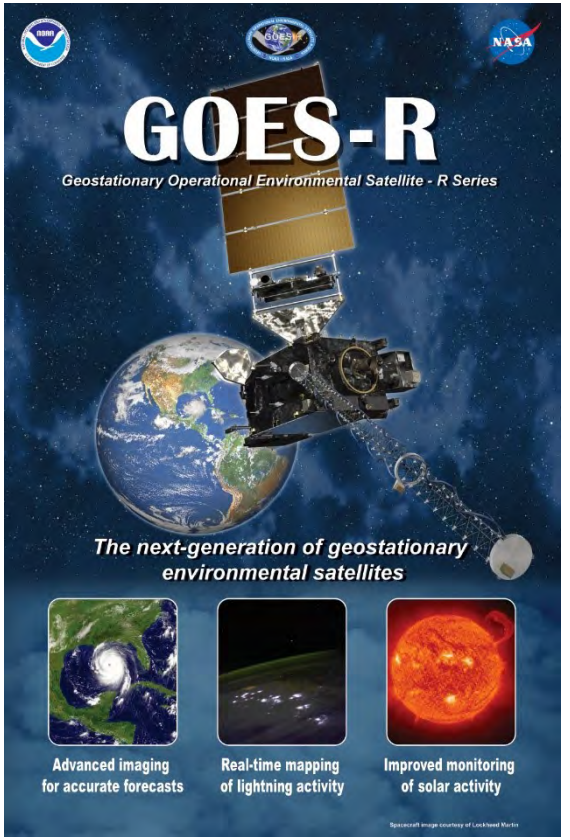
Disadvantages

- Satellite revisit times are predictable
- EO and IR sensors have limits (daylight and good wather), less for radar sensors
- Atmospheric disturbances affect imaging systems
- Anti-satellite (ASAT) weapons and space debris represent vulnerabilities

Space support in NATO Operations

ESERCITO

Meteorology and Oceanography (METOC)

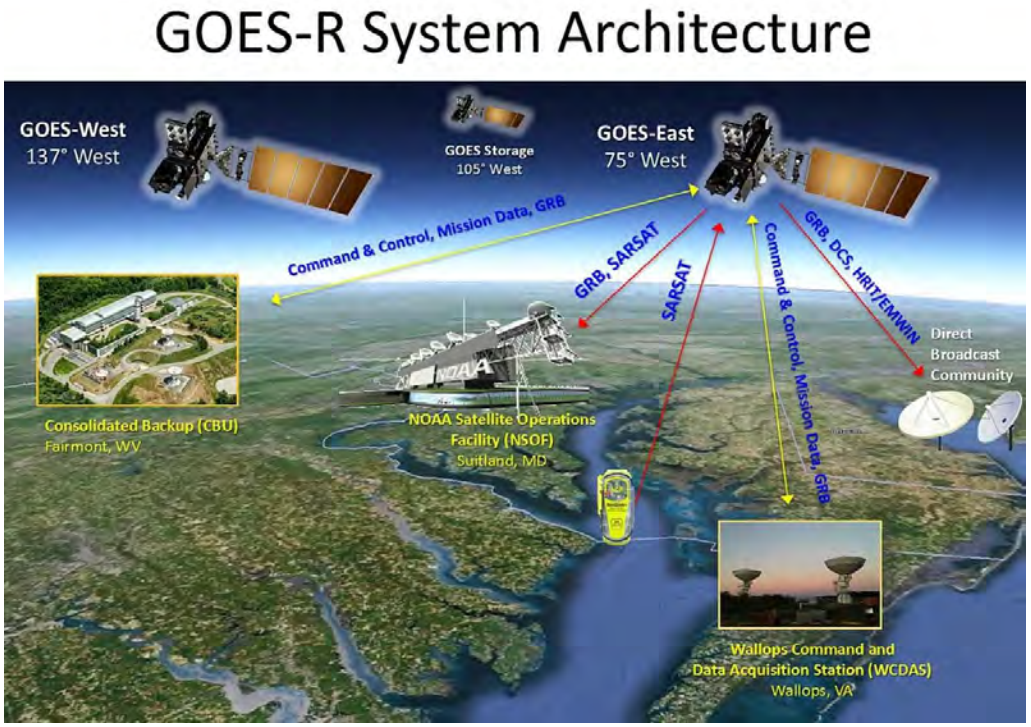


Environmental monitoring satellites provide terrestrial environmental monitoring, which include both atmospheric and oceanographic assessments.
Understanding METOC-derived information is crucial for operational planning.

Space support in NATO Operations

ESERCITO

Meteorology and Oceanography (METOC)



Advantages

- Satellites gather data in areas, where no data can be obtained via other means

Disadvantages

- Polar-orbiting satellites have limited time over target but provide HD data
- Geosynchronous satellites provide low res images, but constant view of target

Space support in NATO Operations

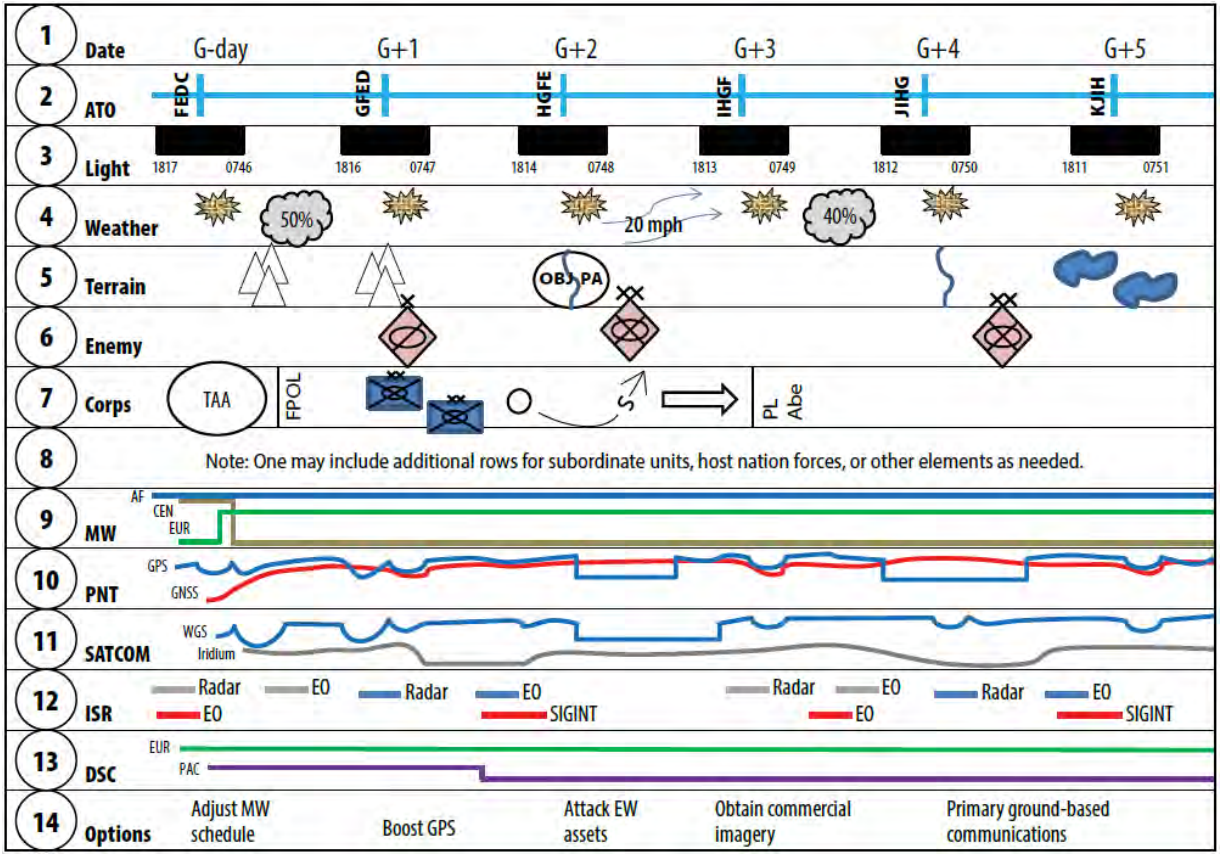
ESERCITO

Shared Early Warning (SEW)

USA is the only NATO Nation with dedicated Space-based assets for missile warning. NATO and USA have an established SEW policy, which assures that USA will provide Integrated Threat Warning and Attack Assessment (ITWAA) for all European NATO territories and forces.

Synchronization of Space Systems

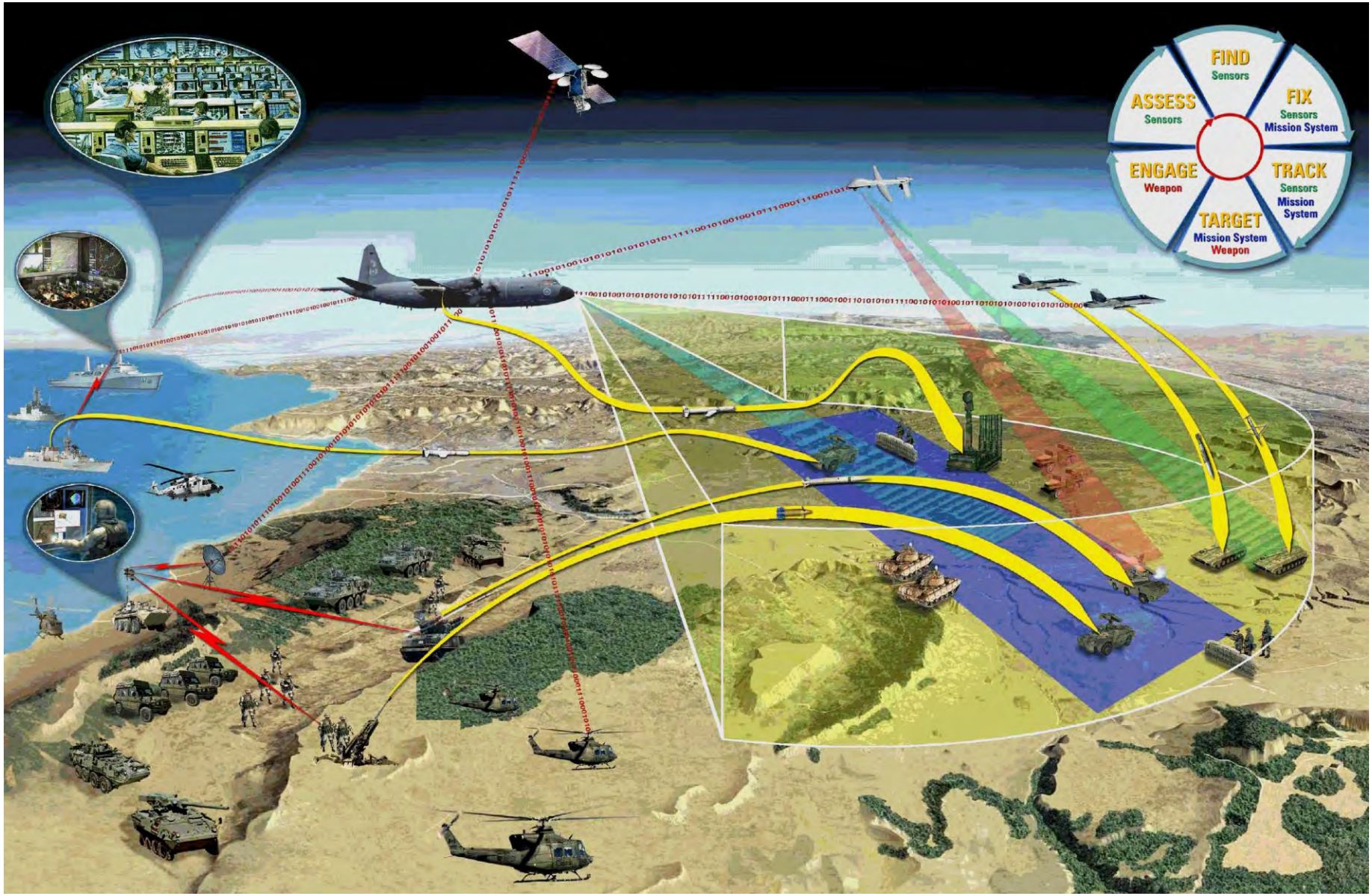
Visualizing the Synchronization of Space Systems in Operational Planning



- NATO will not enjoy uninhibited access to space systems in future conflicts
- NATO must visualize how friendly, enemy, and neutral space systems will affect the operational environment.
- Maintaining a relative advantage in such an environment require the synchronization of tactical actions across all domains including space

Sensor-to-shooter time

ESERCITO



Denied Degraded Disrupted Space Operational Environment (D3SOE)

Offensive operations against space-enabled operational systems are expected

Denied Degraded Disrupted Space Operational Environment (D3SOE)

Commanders and staffs need to be trained and prepared

Analog Radio

HUMINT

Analog Battle Tracking

Target Acquisition

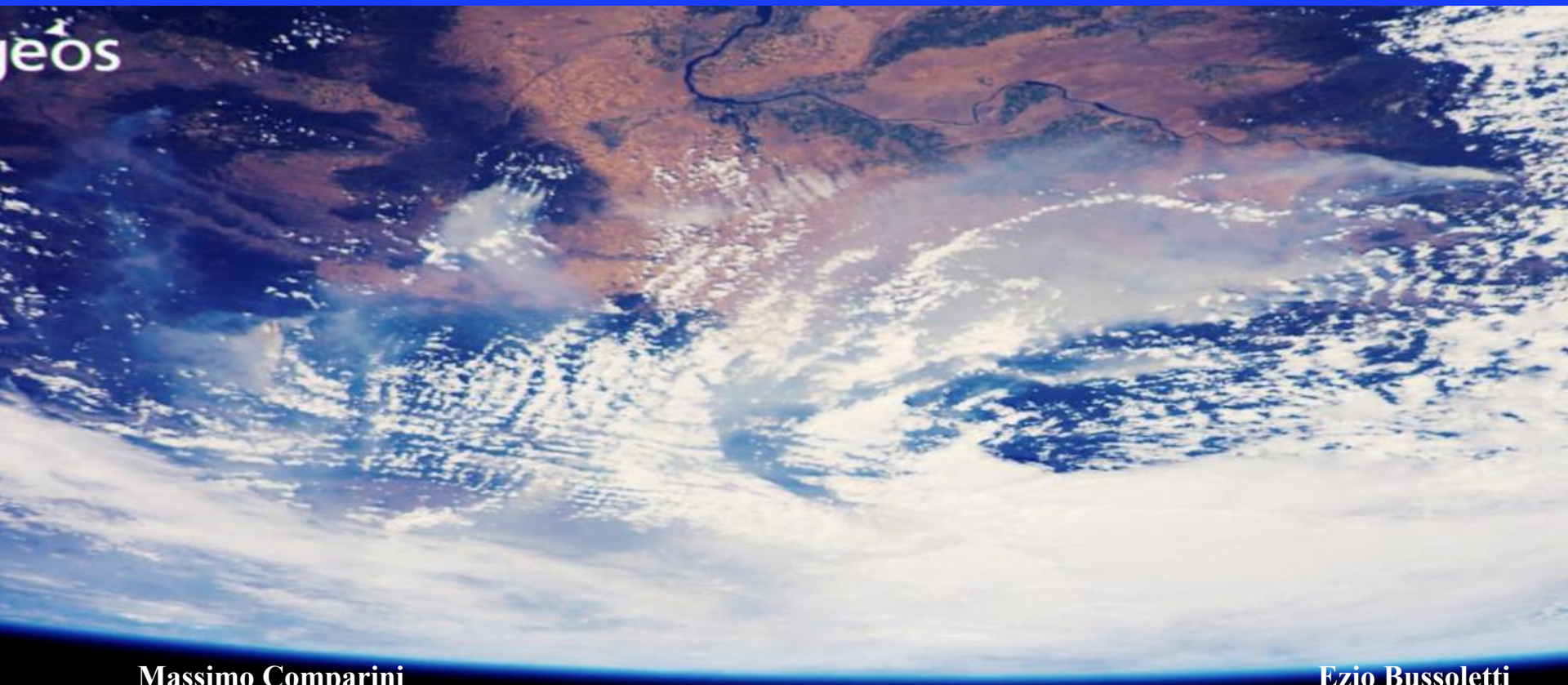
Land inertial navigation and pointing system

Conclusions

- Space-based assets provide capabilities that shift the balance of forces
- Space constitutes an enabler of the traditional land, sea and air domains
- Space enables to deliver overwhelming firepower and dominant maneuver on land
- Adversaries can jam/destroy satellites or limit their effectiveness
- Prepare contingency plans in case of a D3SOE

Pheidippides

The Space Sector today and in the near future



Massimo Comparini

e-GEOS – Chief Executive Officer
Telespazio – Director Line of Business GeoInformation
Chairman - Space Innovation in Itaty

Ezio Bussoletti

Coordinator
Space & Aeronautics Area
PNR MIUR

Space Phases Evolution

First Space wave

Space as Political Power Cold War

Moon landing 1969

JFK Speech 1962

2° Space wave

Science and Exploration Early Comms

inmarsat

1979

Navstar 1 1978

INTELSAT

3° Space wave

DAB DBS HTS Comms LEO/MEO Earth Observation Navigation Systems

2007-2010

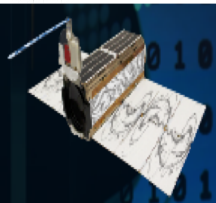
COSMO SkyMed

mid 90's

mid 2010's

OneWeb

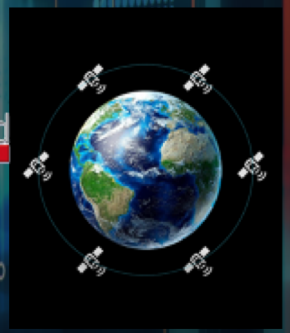
Globalstar



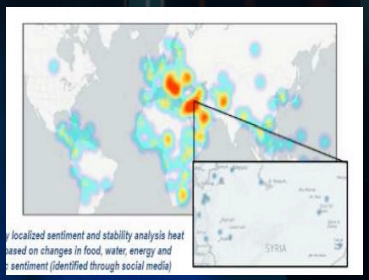
4° Space wave

Democratization Sharing Economy In Space

Earth Digital Twin

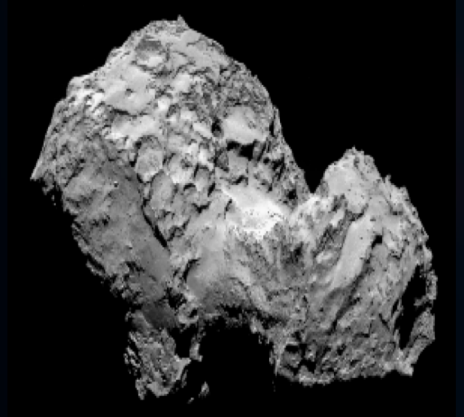


Pattern of life



THE SPACE SECTOR

- *Attractive strategic goal*,
- The number of countries and companies and their *downstream applications continues to grow*
- Space often is considered as expensive though national investments represent very small percentage relative to GDP in all G20 countries
- High-technology niche: it employs about One million *persons*: public administrations (space agencies, space departments in civil and defense-related organizations), the space manufacturing industry (launchers, satellites, ground systems); direct suppliers to this industry (components), and the wider space services sector (commercial satellite telecommunications, navigation and raising earth observation).



UNITED NATIONS
Office for Outer Space Affairs

Space for the 2030 Agenda

Adopted by all UN Member States in **2015** provides a shared blueprint for **peace and prosperity** for people and the planet, now and into the future.

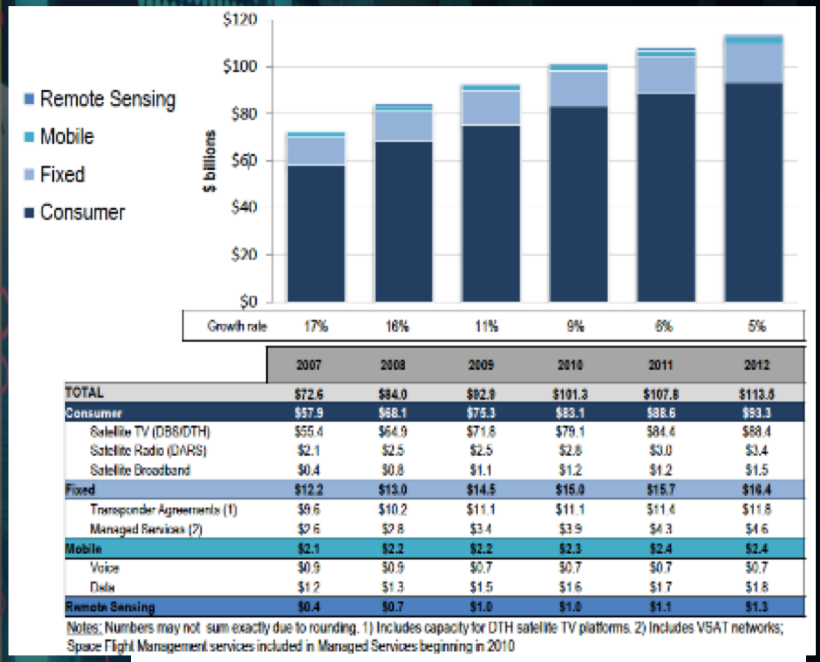
The 17 Sustainable Development Goals (SDGs) are an **urgent call for action** by all countries – in a global partnership

65 of the 169 SDG targets are reliant on the use of Space

SPACE4SDGS

THE SPACE SECTOR ECONOMY

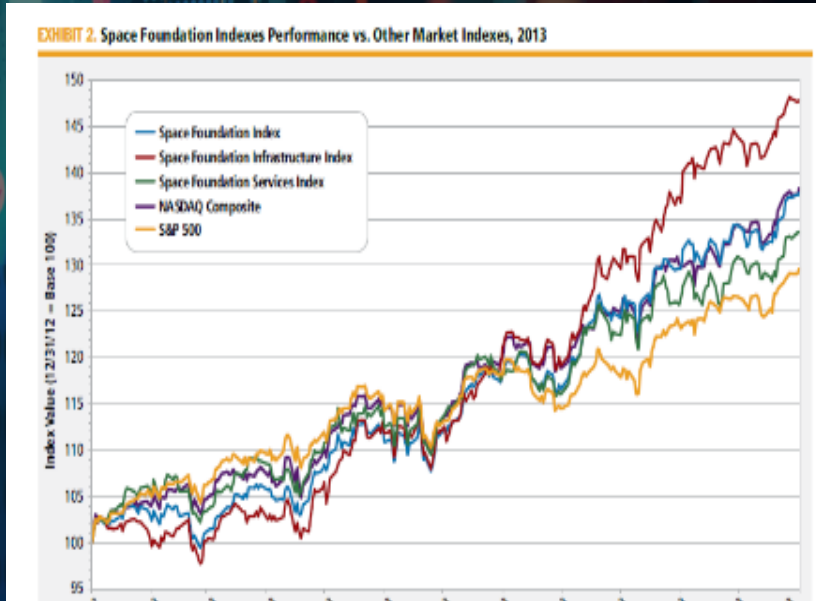
- Traditionally strongly dependent from public budgets, it has today achieved commercial maturity (in Telecom/Broadcasting and, recently, global navigation and Earth Observation)
- Public funding still represents a significant source for large space programs
- in the last few years pushing technology development across the whole industrial chain has injected an impressive amount of resources by private global industrialist and billionaires (Musk, Branson, Bezos, Zucken, ….)
- Today private funding (industry / market) accepts to support initiatives due to adequate financial return
- Investors confidence in the outlook for Space companies (robust performance of the Space Foundation Indexes)



	2007	2008	2009	2010	2011	2012
TOTAL	$72.6	$84.0	$92.9	$101.3	$107.8	$113.6
Consumer	$57.9	$68.1	$75.3	$83.1	$88.6	$93.3
Satellite TV (DBS/DTH)	$55.4	$64.9	$71.8	$79.1	$84.4	$88.4
Satellite Radio (DARS)	$2.1	$2.5	$2.5	$2.8	$3.0	$3.4
Satellite Broadband	$0.4	$0.8	$1.1	$1.2	$1.2	$1.5
Fixed	$12.2	$13.0	$14.5	$15.0	$15.7	$16.4
Transponder Agreements (1)	$9.6	$10.2	$11.1	$11.1	$11.4	$11.8
Managed Services (2)	$2.6	$2.8	$3.4	$3.9	$4.3	$4.6
Mobile	$2.1	$2.2	$2.2	$2.3	$2.4	$2.4
Voice	$0.9	$0.9	$0.7	$0.7	$0.7	$0.7
Data	$1.2	$1.3	$1.5	$1.6	$1.7	$1.8
Remote Sensing	$0.4	$0.7	$1.0	$1.0	$1.1	$1.3

Notes: Numbers may not sum exactly due to rounding. 1) Includes capacity for DTH satellite TV platforms. 2) Includes VSAT networks; Space Flight Management services included in Managed Services beginning in 2010

Source: SIA State of the Satellite Industry Report October 2013



EXAMPLES OF PRIVATE ENGAGEMENTS

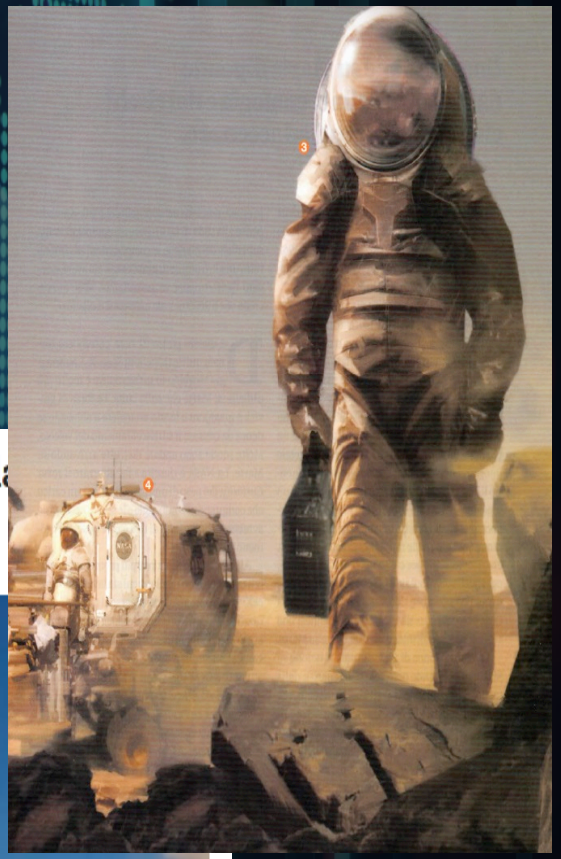
FARNBOROUGH INTERNATIONAL AIRSHOW

Virgin Galactic spinoff Orbit to launch rockets from the UK with space deal

- Virgin Orbit sealed a deal with the U.K. Space Agency to launch its LauncherOne rocket via Cosmic Girl, a modified Boeing 747-400 plane.
- Virgin said Monday the agreement meant Orbit would be the first firm to operate flights to space from British soil.

Ryan Browne | @Ryan_Browne_
Published 7:35 AM ET Tue, 17 July 2018

CNBC



Blue Origin successfully tests escape system in l… Shepard launch

by **Jeff Foust** — July 18, 2018

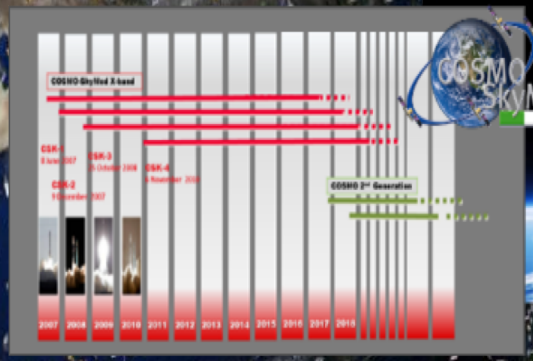
THE SPACE SECTOR ECONOMY

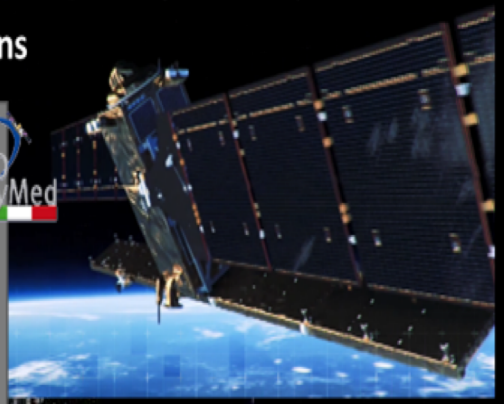
Constellations will account for 70% of the future demand

Smallsat demand is experiencing a increase **x7**

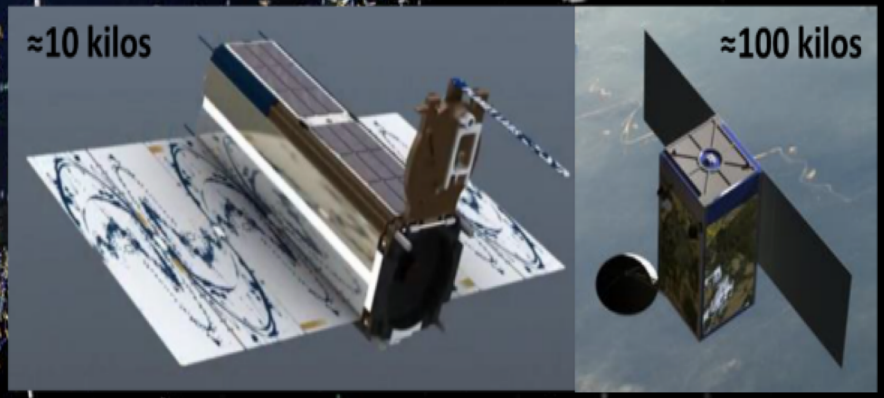
evolution of large infrastructure (high end sensors few sats)

≈2 tons





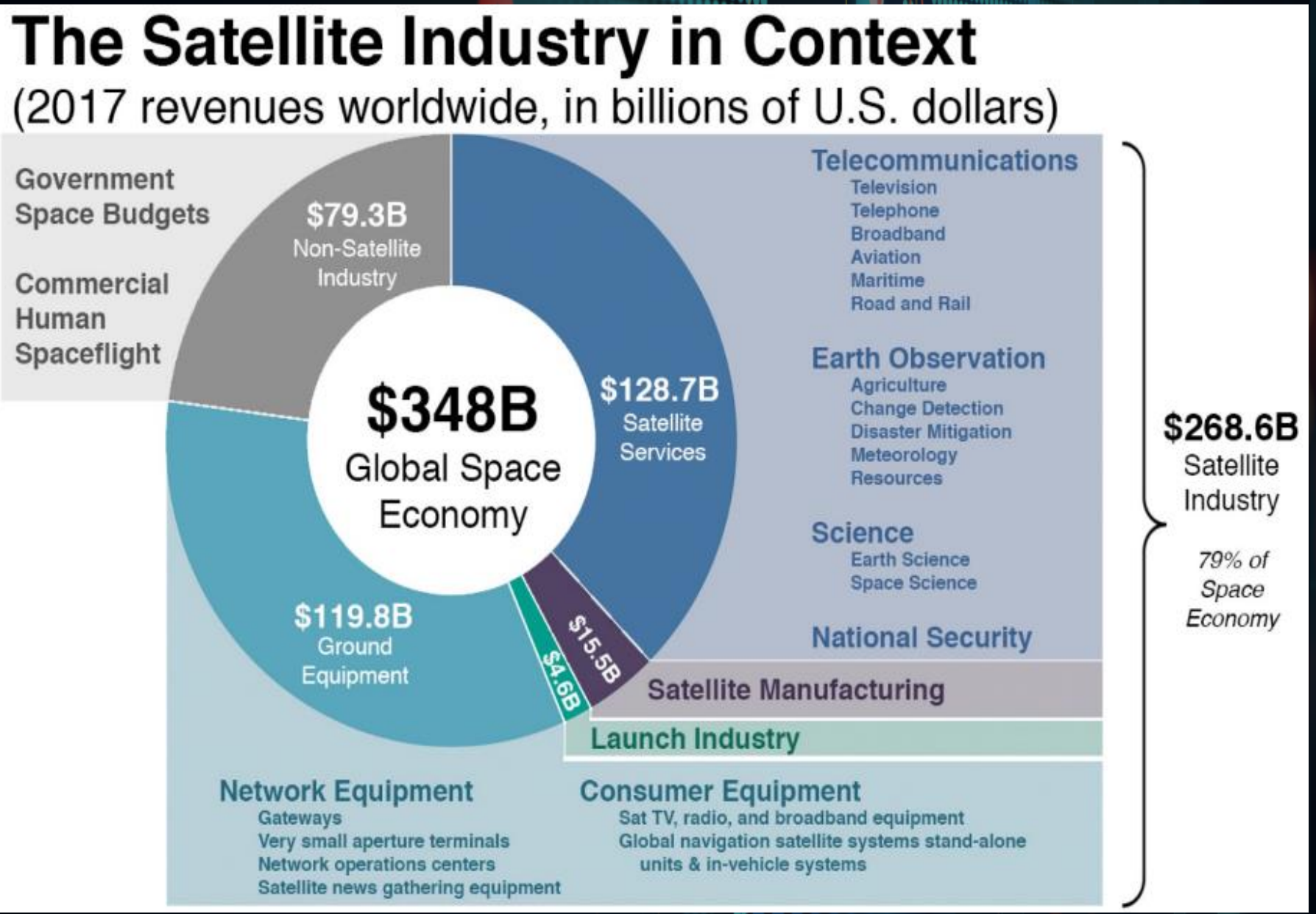
emerging constellations (low end sensors/many sats)



THE SPACE SECTOR ECONOMY

- Industry shareholding shifted from public to private over the years, some still under "public surveillance" (through governance or ad hoc regulation) but a number of new companies raised up in the last few years
- Mostly employing dual technologies, predominantly "user driven" as opposite from original "technology push" approach,
- More emphasis to applications and service development
- A new *Space Economy* is emerging much wider than the space sector itself and can be defined using different perspectives.
- It can be defined by its products (e.g. satellites, launchers…), its services (e.g. broadcasting, imagery/data delivery), its programmatic objectives (e.g. military, robotic space exploration, human spaceflight, Earth observation, telecom…), its actors/value chains (from R&D actors to users), and its impacts (e.g. direct and indirect benefits…).

THE SPACE SECTOR ECONOMY



Space Democratization

- Decreased costs, increased capabilities and path breaking innovations are making satellites and space applications and services more relevant to businesses and public good
- Satellites transform businesses and quality of life today much more than ever, associated technologies have expanded at an exponential speed
- This dynamic known as "Democratization of Space", implies that more people and new organizations are part of the industry
- IT'S NOT AT ALL ONLY A TECHNOLOGY EVOLUTION
  IT'S A CULTURAL PARADIGN SHIFTS

New space race where the players, technology, and services are as diverse as innovative

Global connectivity

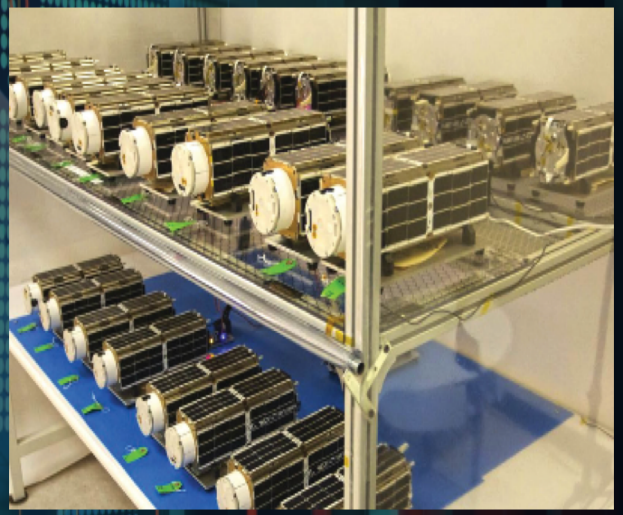
Global geospatial

Space Democratization

- **The rapid evolution of technology** (Improvements in launch systems, sensors, other input technologies and innovations such as the smallsat architecture) **drives down costs.**

- **More sensors** and a **greater diversity** of their types mean **greater performances** (spatial resolution, higher temporal cadence & richer spectral coverage)

- **The combination of decreased cost and increased capabilities opens up new use cases, new industrial births and applications for businesses**



Space Democratization

- **Transformation** of the space industry largely **driven by new services and applications** (innovations in launch and satellite manufacturing technology & new applications)
- **"NewSpace":** rapid inventions and developments, lower costs, commercially available parts and incremental development
- **Shift from large players** (governments and big corporations) who operate satellites, distribute data and supply services, **to the market which includes many startups** that deploy new technologies to support traditional applications and develop new applications
- **The sharing economy in Space** (a double-digit B$ industry), **is one of the key running transformations**.

Cadillac 60s

Saturn late 60s

Tesla mid 10s

SpaceX reusable rocket

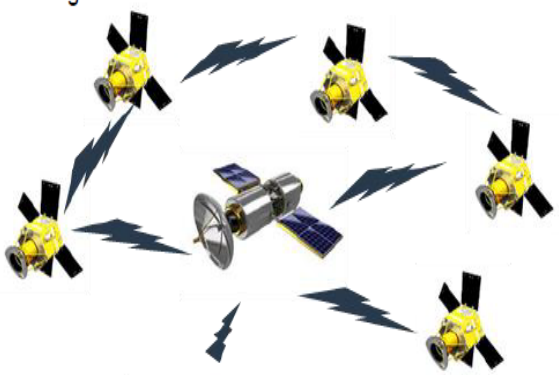
Space Democratisation

4 Small-Satellite Clusters Replacing Large Satellites

With low manufacturing cost and not mandating dedicated launch vehicles, small satellite clusters are beginning to set the trend of realizing improved space capabilities also enabling penetration into densely populated orbital space.

Formation flying and fractionated satellite architecture: navigation and formation control, modularity and open-architecture for expansion of existing clusters

Micropropulsion systems: MEMS-based miniaturized propulsion systems, precise attitude control for formation



Inter-satellite connectivity: distributed processing, advanced data routing protocols, faster relay, high data rate

Reconfigurable on-board electronics: post-launch system upgrade capability (software)

Small-satellite launch capability: dedicated launch vehicles, secondary payload adapters

2030 Small-Satellite clusters delivering complex-higher capability multi-missions at low cost

Future Apps

- **Multi-point imagery = Advanced ISR / Cartographic Imagery / Digital Maps**
- **Stand-Alone / Integrated Communication**
- **Timed multi-point data gathering = Advanced EO / Remote sensing**

Benefits

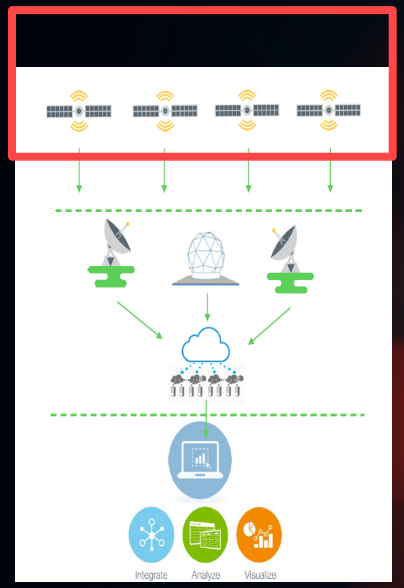
Reduced financial risk: Low cost satellite missions delivering enhanced mission capabilities across extendable mission life .

Improved capabilities: Reduced time-Improved quality data gathering (multi-point imaging), low-light imaging, system reliability (through redundancy)

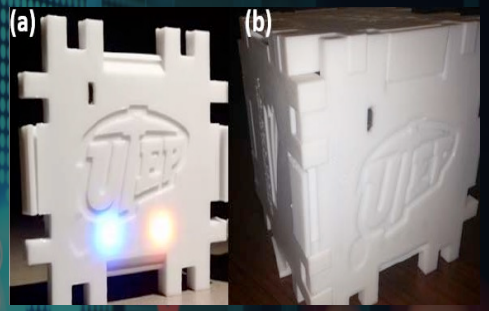
Multi-Mission Satellites: Modular and flexible architecture generating multi-mission opportunities.

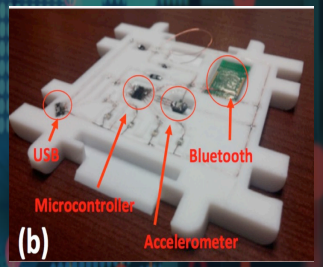
Increasing adoption: Enhanced functionalities and new applications at an 'affordable' cost to create new genre of satellite owners- both Military & Commercial

Space Democratization



- Constellations/Mega Constellations
- Trains
- Clusters
- Nanosatellites
- Fractionated spacecraft
- Hosted payloads
- Formation flying
- Additive Manufacturing
- Sat systems parallel computing
- Autonomous cooperative systems



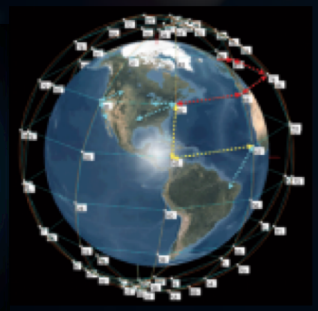


Additive Manufacturing

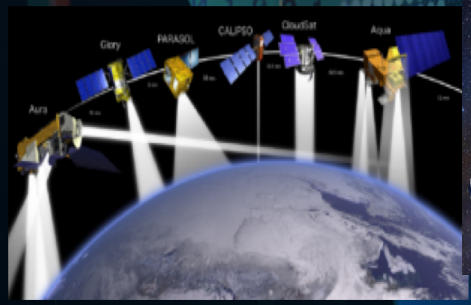
3D Printed Electroncis

Cubesat

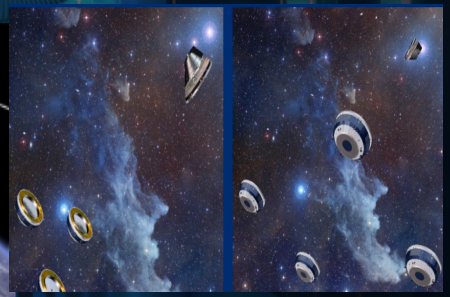
Const's



Megaconst's



Trains



Clusters

Swarms

Space Democratization

Globalization

Higher Competition level

- ***Globalisation is affecting the space economy*** **at different levels.**
- **In the 80s, only a limited group of countries had the capacity to build and launch a satellite. Many others are presently engaged in Space related activities with increasing trend**
- ***Supply chains*** **(development and operation of Space systems) are increasingly evolving at the international level, though the sector remains heavily influenced and shaped by strategic considerations.**
- ***Many Space technologies are dual use*** **which tends to constrain international trade though the research on global value and supply showsa rapid internationalization process**

- **More actors seek to enter global value chains, then competition on the relatively small commercial open markets is more difficult for incumbents.**

Space Democratization

Mega Trends

New Innovation Dynamics

R&D Centers Universities stronger impact

- Scientific and technological innovations render Space applications more accessible
- New Actors (Research Center and Universities) now can buy off-the-shelf technologies and equipment to build micro-satellites with growing complexity functionality.
- Innovative cross cutting industrial processes are promising to potentially inject disruptive breakthroughs in the Space manufacturing.
- This, coupled with globalization, could increasingly impact the Space activities particularly for incumbent industrial actors.

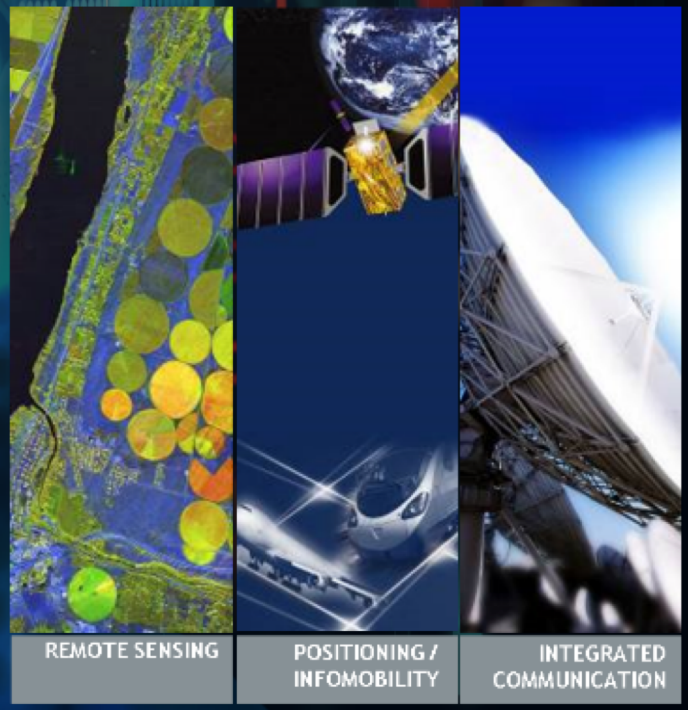
Space Democratization

- **The downstream sector:** satellites operators and providers of Space products and services with/in complement to other forms of enabling infrastructures and/or services

- **Services use a specific satellite capacity** (bandwidth or imagery) as inputs to provide a more global service to consumers (business, government or retail)

- **Downstream services** are various and are traditionally **divided into 3 application domains:**

  - a) TELECOMMUNICATIONS
  - b) EARTH OBSERVATIONS/REMOTE SENSING
  - c) NAVIGATION

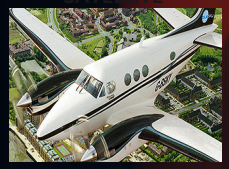


Space and Democratization

From data → Generating info → To customized platforms

GEOSPATIAL

SATELLITE


AERIAL / UAV

NAVIGATION

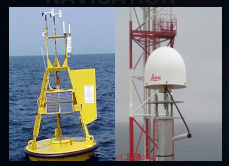

IN SITU SENSORS

IMAGE CONTENT

REPORTS

GEO CONTENTS

LAND

DEFENCE

MARITIME

AGRICULTURE

EMERGENCY

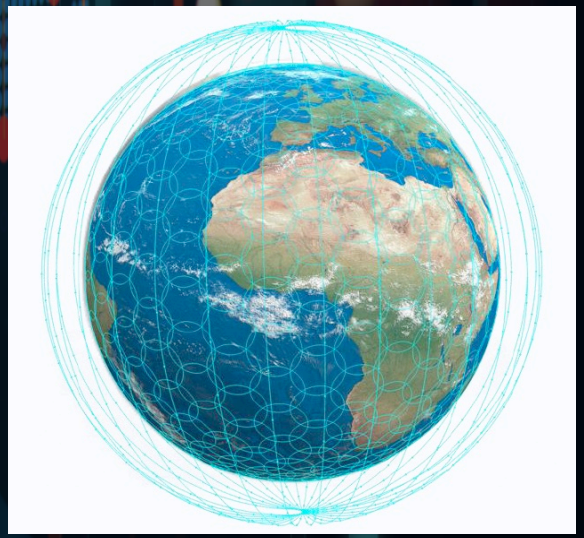
ENVIRONMENT

The new Space race – Global Connectivity

- The Demand for ever-faster broadband internet connections setts new architecture and technology limits towards increasingly powerful *High-Throughput Satellites* (HTS)

- The dominance of geostationary HTS is tested by the emerging *mega constellations*, fleets of hundreds or even thousands of relatively small satellites orbiting at significantly lower altitudes.

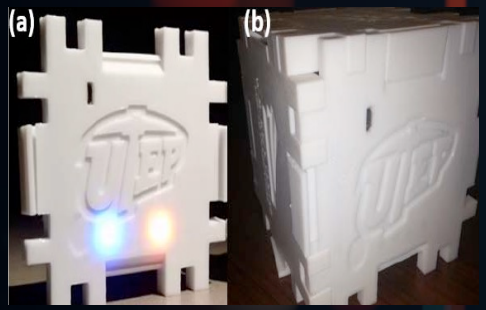
- LEO & MEO broadband satellites promise nearly fiber-optic speeds and global coverage with low latency, fully integrated in hyper connected systems

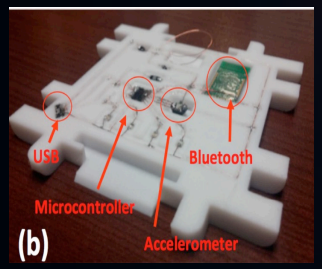


Mega constellations are a fundamental tool in Space democratization and an opportunity to contribute to Space activities for a broad range of institutions, including emerging innovative Startups, Research Centers and Universities.

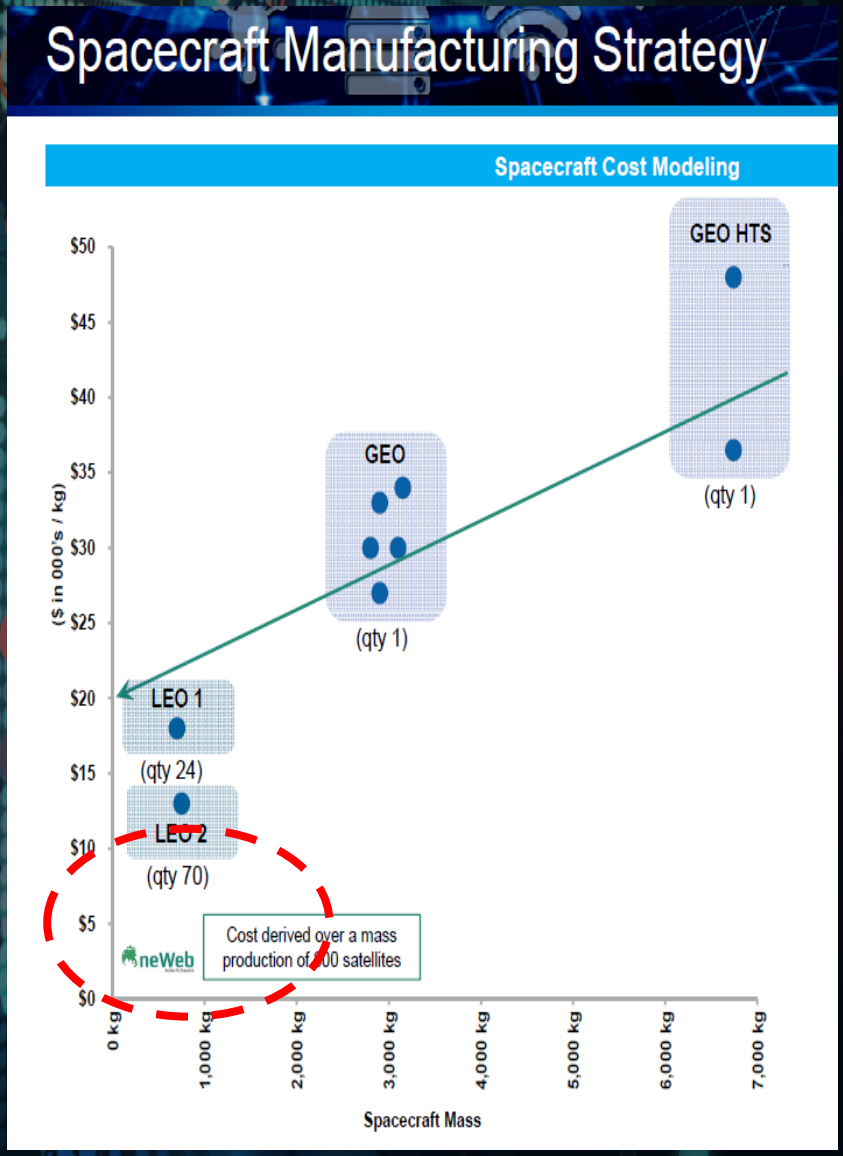
The new Space race – global connectivity

- **A new class of Space services and applications allow to build cost effective microsatellite constellations and clusters**
  (miniaturization of on board functions)





Additive Manufacturing
3D Printed Electroncis
Cubesat



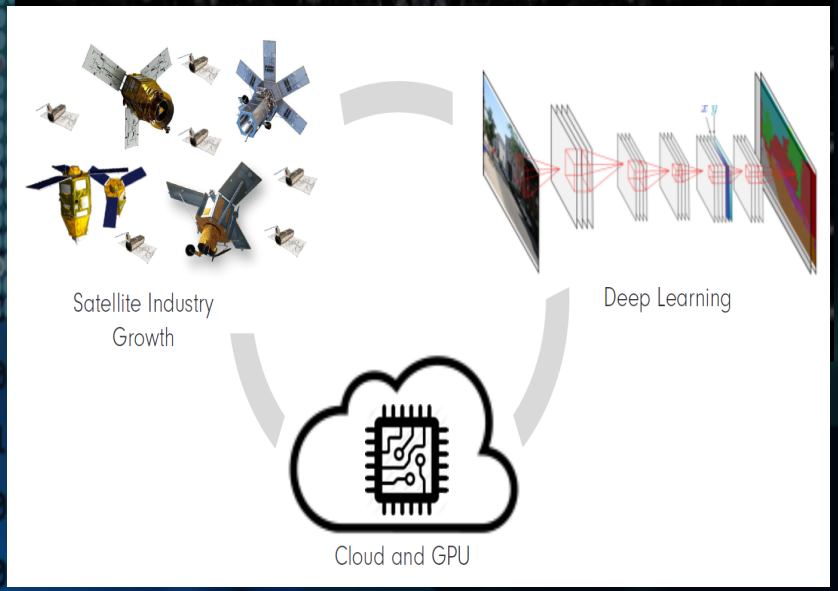
The new Space race – global geospatial

- Complementing EO Space systems based on large Space infrastructure and very high performance payloads and sensors allows:
  - to conceive very high revisit observation capabilities,
  - to obtain a quasi-persistent surveillance in perspective
  - to feed a new generation of service and application platforms with an exponentially growing amount of data

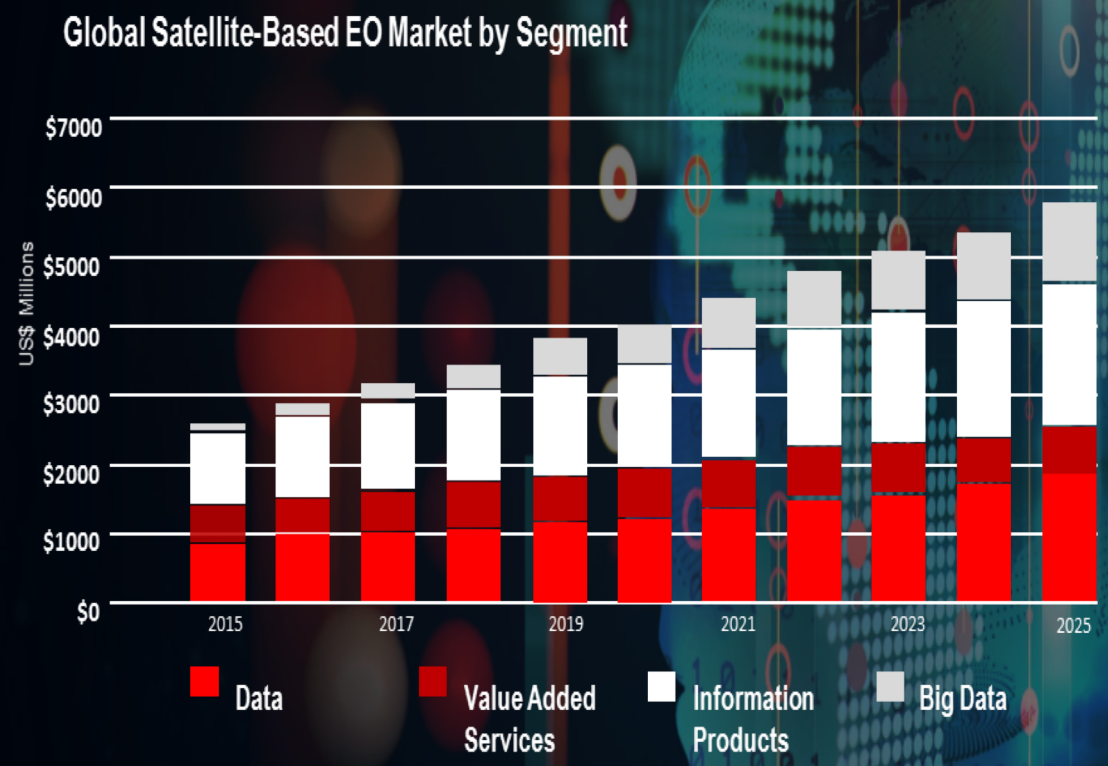
- Data, more and more, are just a part of the game

- Convergence with IT and data analytics boosts a new information driven market

- EO Geospatial business is today an inherent part of IoT



Geospatial Information Market Trends



high growth rate in information products and big data analytics

- Price of the **Optical** data is decreasing
- Use of **Radar** technology is growing
- **Number** of satellites is growing, with a large variety of sensors
- **Constellations** add temporal resolution dimension
- Huge amount of EO space data is generated
- **Big Data and Data Analytics** is fully integrated in geo-information applications

New Space Trend

From data **Generating info** **To customized Information Products and BDA**

Orbital Insight

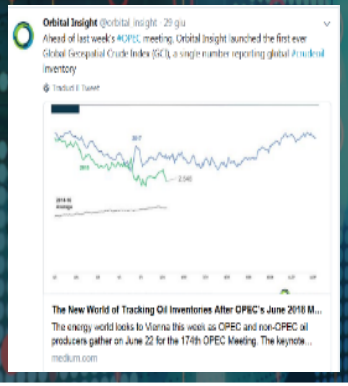
Orbital Insight Data Now Available on the Bloomberg Terminal

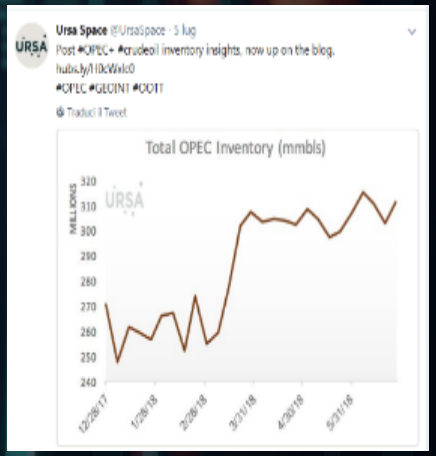
Bloomberg Terminal subscribers can now access daily geospatial analytics to make more informed investment decisions

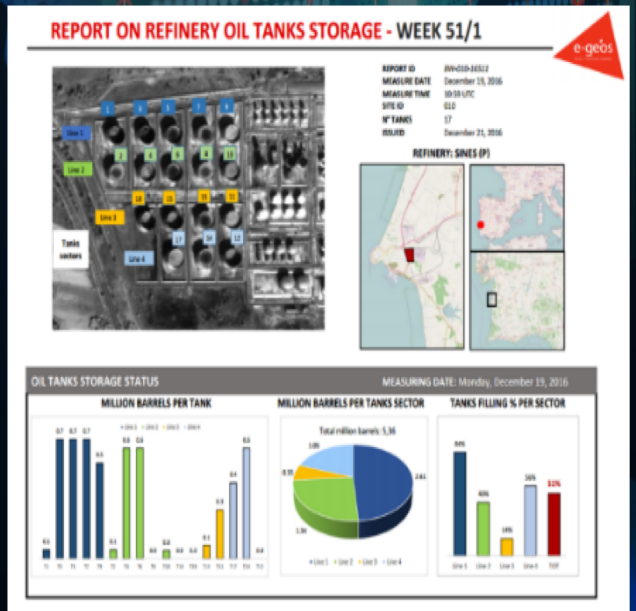
PALO ALTO, Calif., July 18, 2018 (GLOBE NEWSWIRE) -- Orbital Insight, the leader in geospatial analytics, announced today that its U.S. Consumer Retail product is now available via the Bloomberg Terminal. Bloomberg subscribers can now access daily car counts for 80 U.S. retailers. Year-over-year comparisons for the past five years are also available to better contextualize changes.

"The financial services industry relies on the Bloomberg Terminal for trusted data, and geospatial analytics adds a timely and accurate source that brings additional value," said A.J. DeRosa, Orbital Insight's Executive Vice President and Head of Global Sales. "With this integration, we can better meet the needs of buy side traders, analysts, risk professionals, and others who are looking to generate alpha."

Subscribers can download Orbital Insight's data or use data visualizations directly on the Bloomberg Terminal to measure against traditional investment metrics by accessing ORBT <GO>.







THE VALUE CHAIN FOR THE NEW VALUE ADDED SERVICES

More value addition/processing to the raw data

High

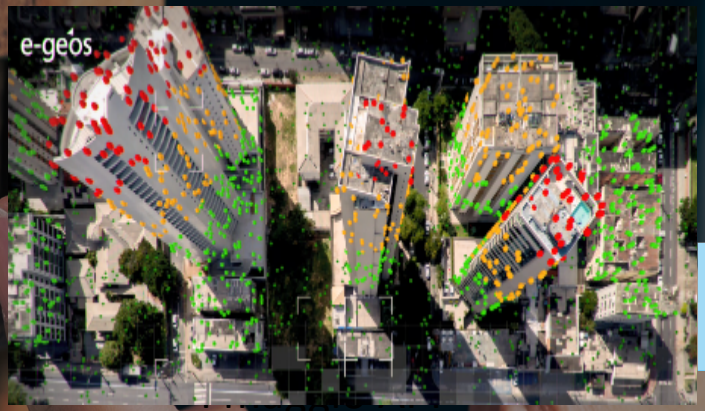
Big data analysis

Information Products

Value Added Services

Data

Low



Services for Financial user comunity

THE BIG DATA PROMISE – DATA IS THE NEW OIL

GEO Big Data + IA + Analytics are changing the game in the data consumption

AI

Machine learning

Deep learning

Big Data

Self Program

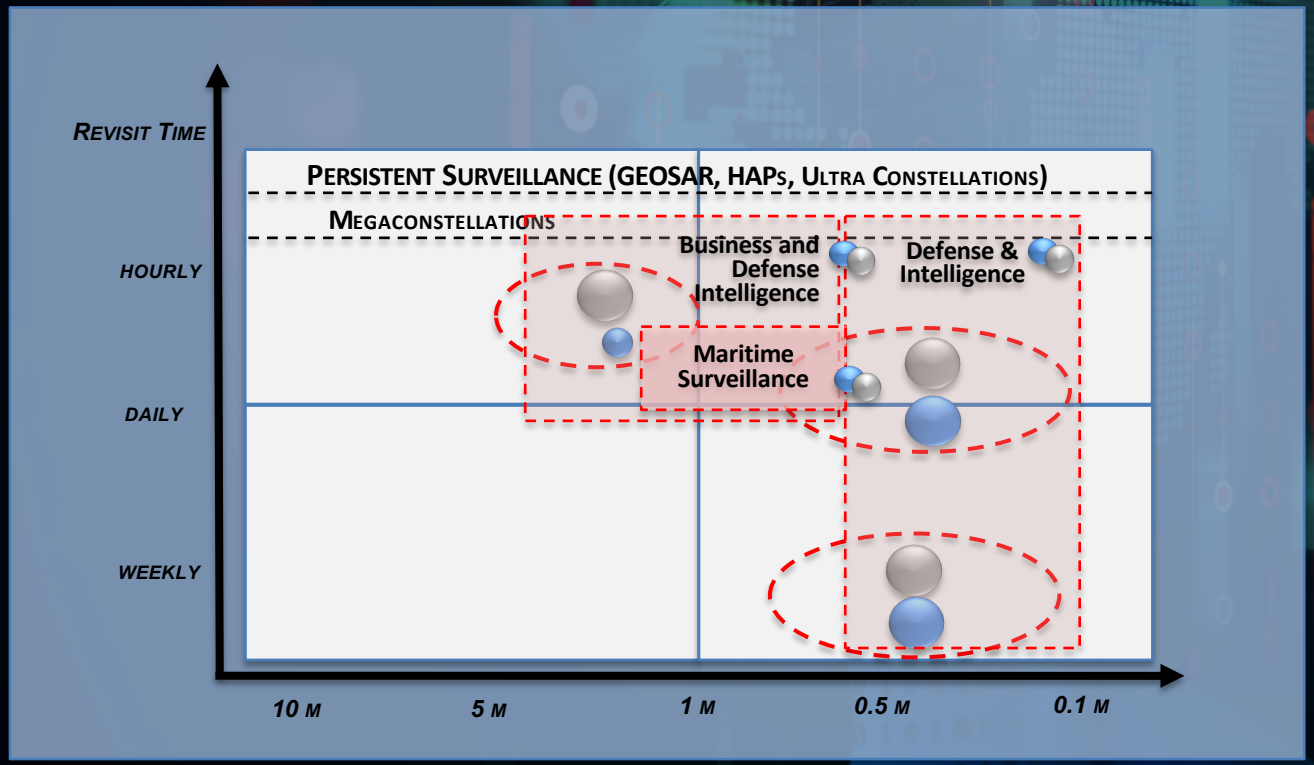
Predictive Analysis

Prescriptive Analysis

Automated action

- **Big Players envisage a role to the Geo-Information Analytics driven solutions in their business model and plan significant investments**
- **New information driven markets (big data, data analytics apps) drive increase in revenues for sat operators**
- **Industrial landscape is going to have a strong evolution with consolidation in place and a growing strong momentum in the evolution of partnership models**

Defense & Intelligence will largely benefit from a higher data variety as well as of advanced methods to derive timely information flow



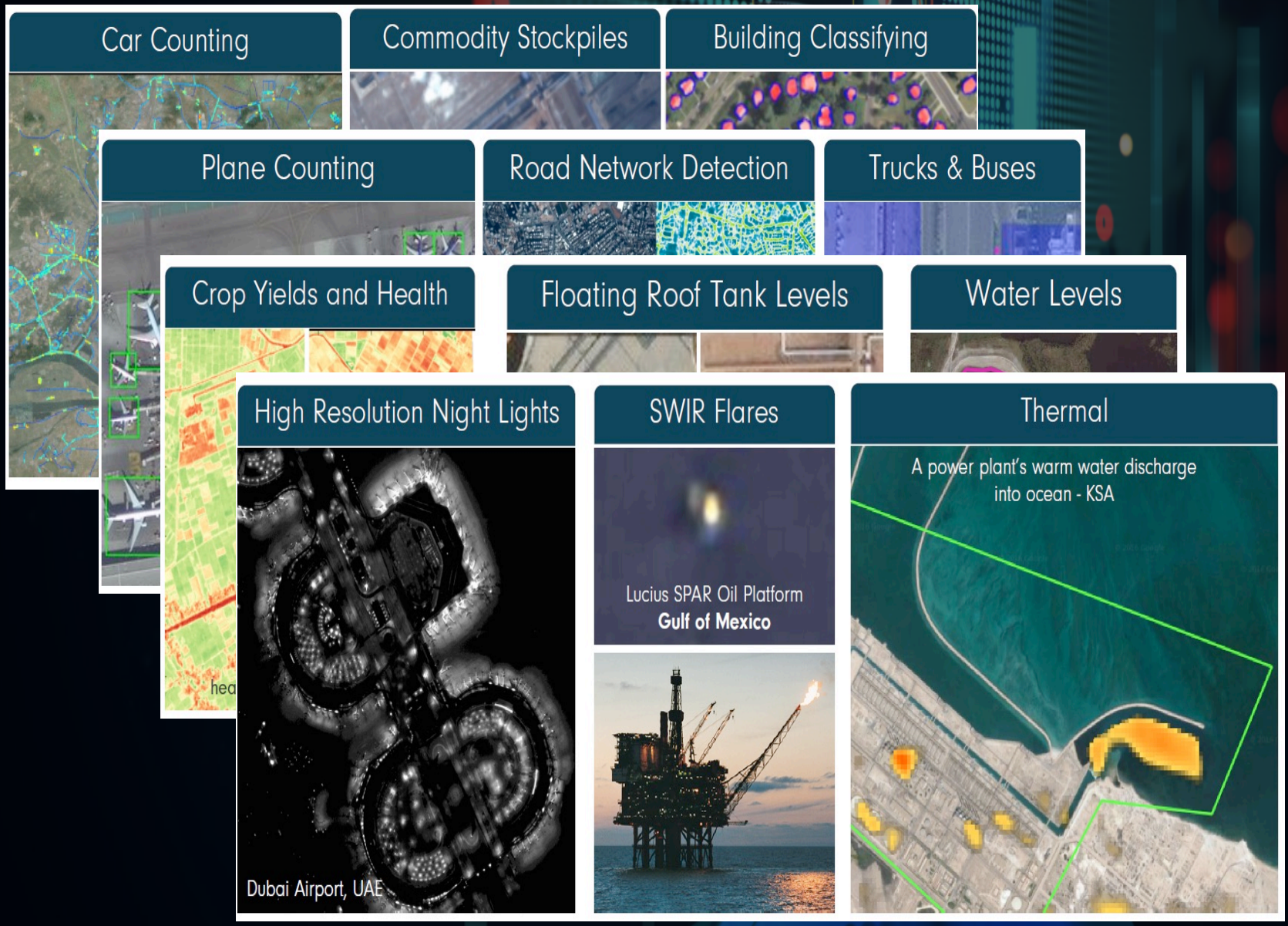
monitor daily

discover trends

deliver insight

e-geos

Space Democratization

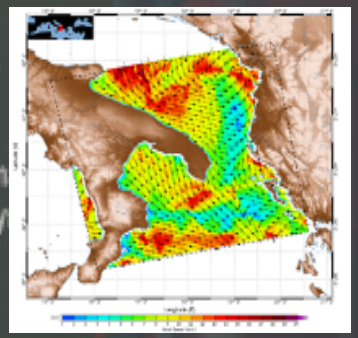


Space Democratization

Vessel detection

Oil Spill Detection

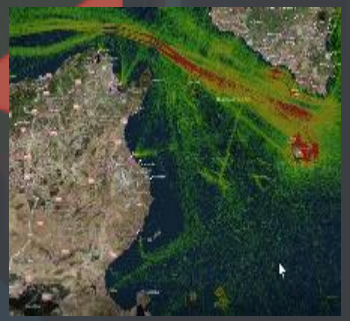
Wind & Wave



Activity Report

Geospatial Analysis and Alert Notifications

Exact Earth



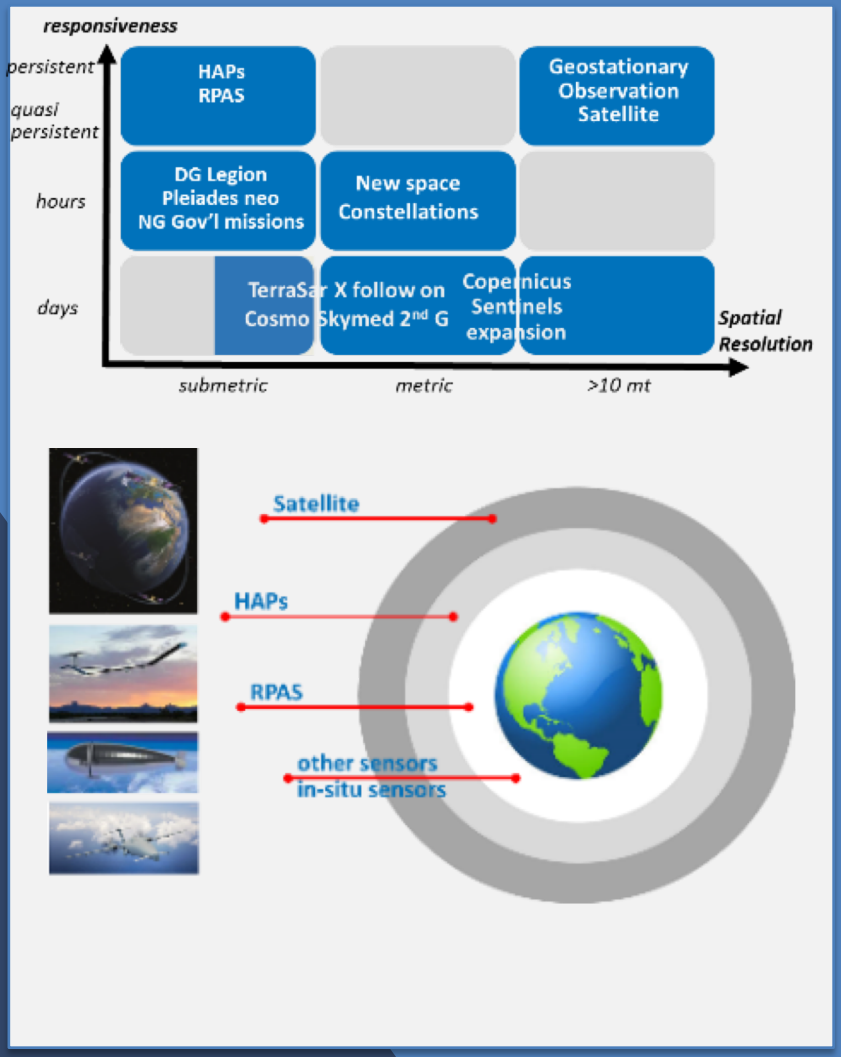
PIATTAFORME STRATOSFERICHE D'ALTA QUOTA
HAP (High Altitude Platforms)
LE SFIDE TECNOLOGICHE

A range of geospatial application platforms leverage the federation and data fusion from satellite - radar, optical and other sensors - and other platforms including UAV and in perspective HAPs

A major goal is to benefit of the complementary features to address e persistent or quasi-persistent surveillance mostly for D&I users

Services enabled by asset federation on specifically by Satellite/HAPs data fusion are image intelligence and surveillance in maritime, land, border control, critical infrastructure, territory and industrial monitoring

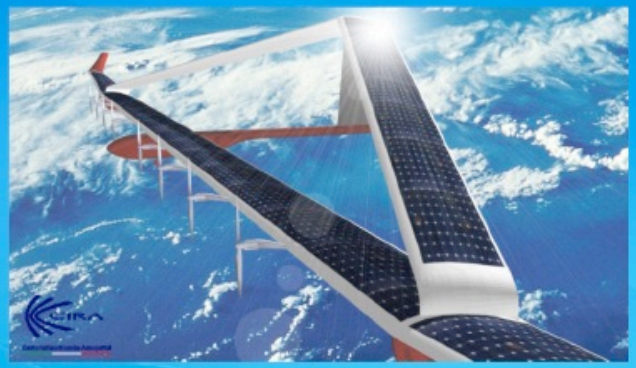
Those services are in the intereset fo EU entrusted entities (EMSA, Frontex, EU SatCen), National and International Military organization ad finally industrial sector



PIATTAFORME STRATOSFERICHE D'ALTA QUOTA

LE SFIDE TECNOLOGICHE

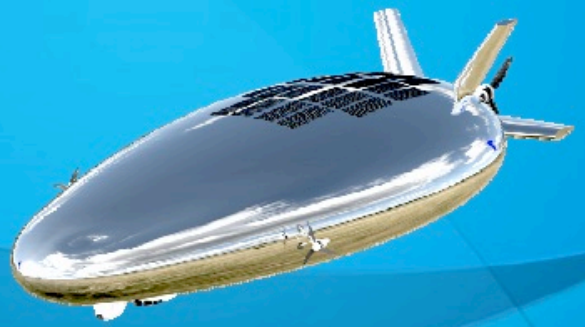
2002-2010
Heavy Lift Stratospheric Balloon Test



2006-2008
LVR –HALE project
Preliminary design of a HAPS Joined-wing

CIRA Activity on HAPS

New CIRA Project
2016-2021
HA² - High Altitude Hybrid Airship
Design, Realization and Flight-Demostration of a new concept of High Altitude Pseudo-Satellite



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PIATTAFORME STRATOSFERICHE D'ALTA QUOTA

LE SFIDE TECNOLOGICHE

Study on Application Requirements

Analysis of Payload Requirements

Optical – Hyperspectral – Infrared – Radar

Platform Requirements

Platform Requirements

Payload	100 kg (12 % MTOW)
Altitude	20000 m
Energy System	Rechargeable Batteries with Solar Energy
Power	Propellers powered by Electric Engines
Cruise Airspeed	16 m/sec
Night Duration	15 h
Mass category	< 1000 Kg
Mission Duration	4 months

Operative Environment →

Airworthiness →

← Safety First

← Easy Operation

← Low Cost

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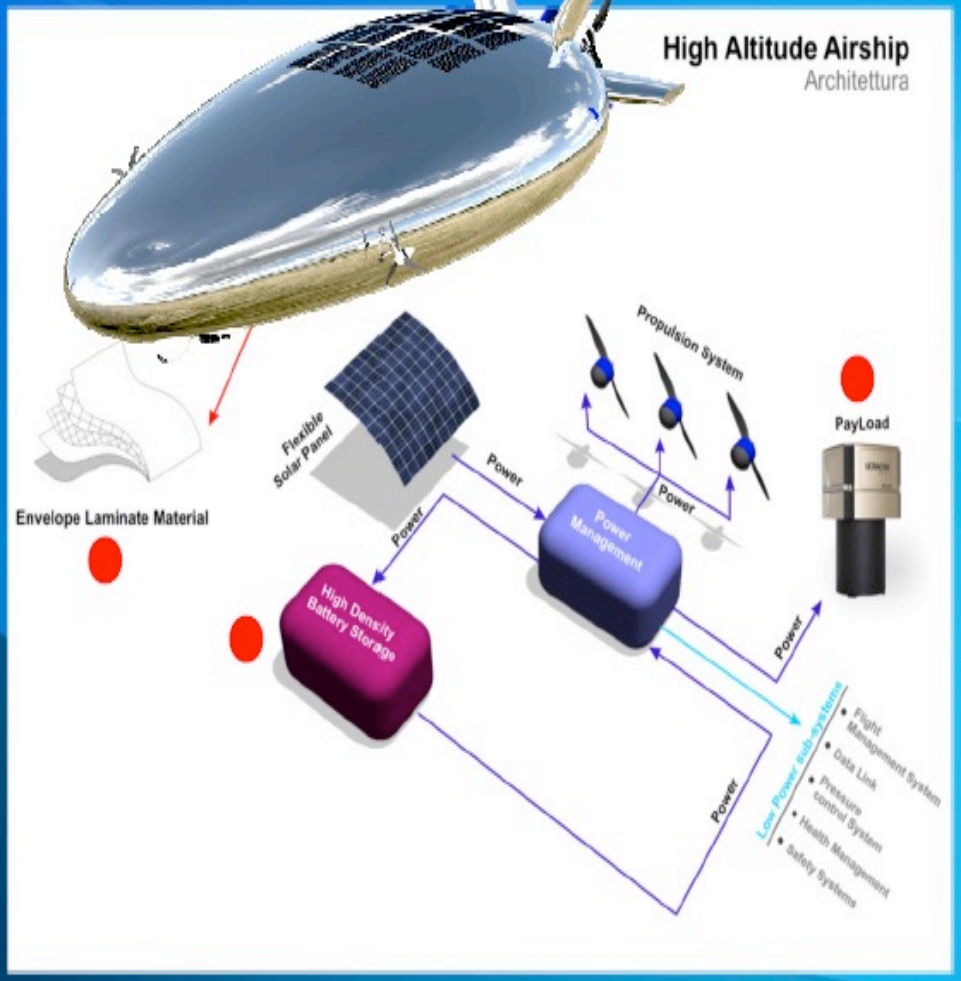
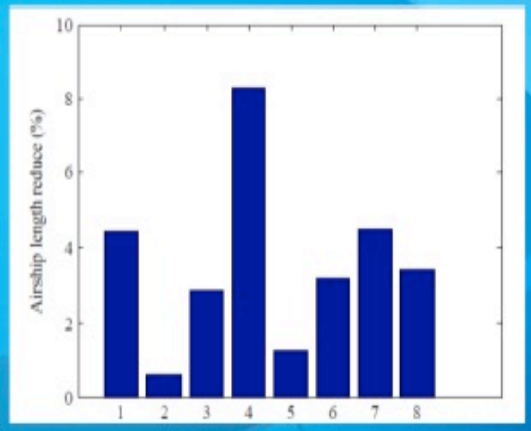


Mark	Component
1	Envelope mass/area ratio (g/m^2)
2	Air-filled ballonet mass/area ratio (g/m^2)
3	Solar cell mass/area ratio (g/m^2)
4	RFC energy/mass ratios (Wh/kg)
5	Propeller power/mass ratios (W/kg)
6	Solar cell efficiency (%)
7	RFC efficiency (%)
8	Propeller efficiency (%)

Key Technologies



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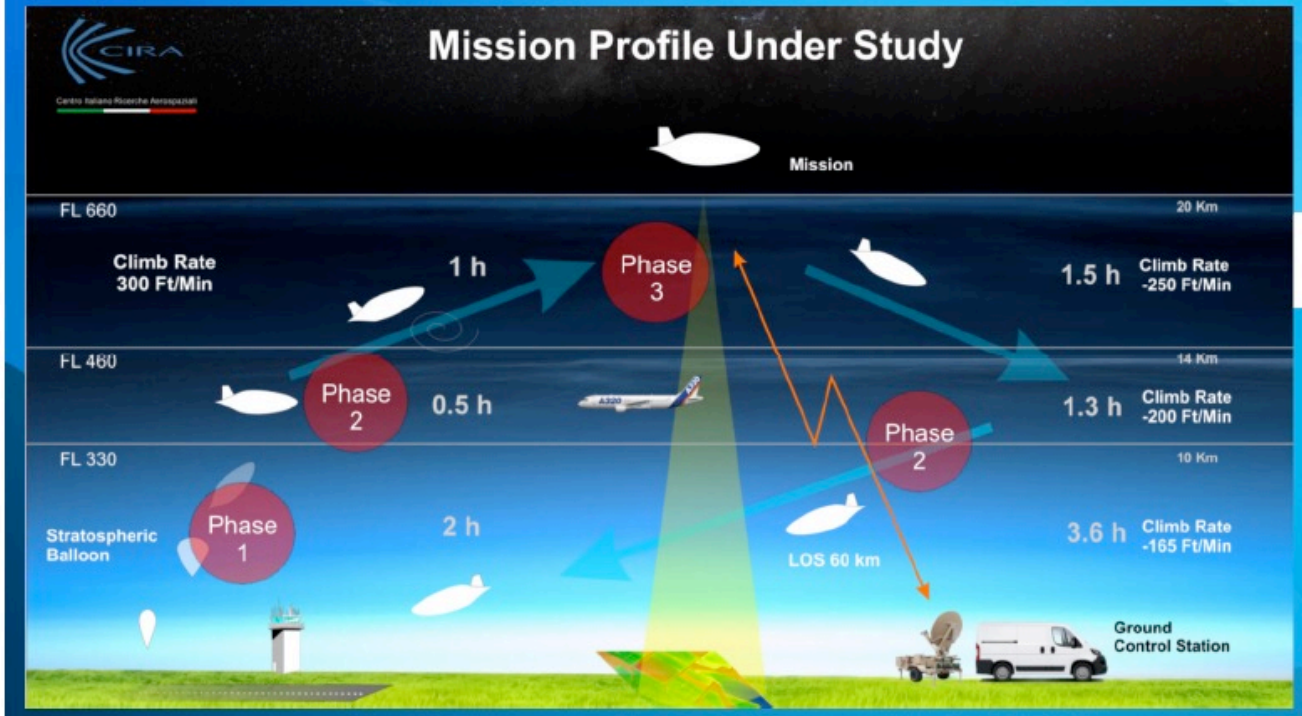
PIATTAFORME STRATOSFERICHE D'ALTA QUOTA

LE SFIDE TECNOLOGICHE



Operational Aspect

Advantages in the Employment of Hybrid Airships as HAPS

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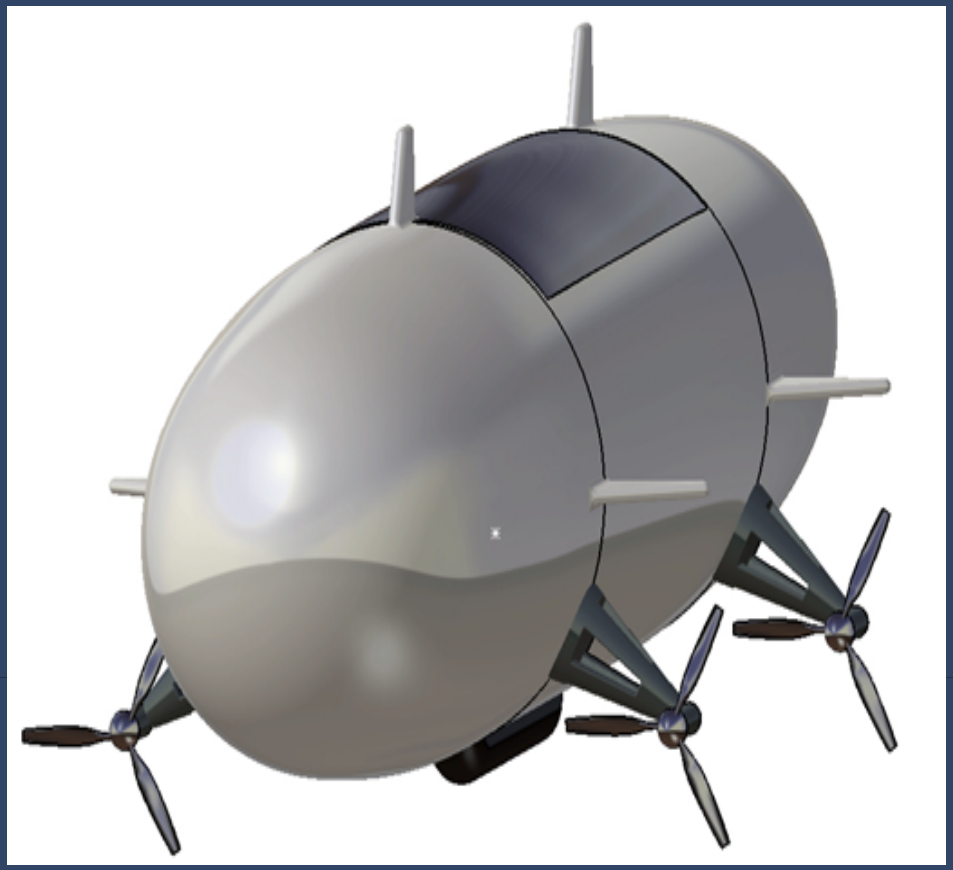
HAAP-SI
(High Atmosphere Air-ship Platform - Space Italy)

Piattaforma Stratosferica Stazionaria HAAP-SI T

(Osservazione Elettro-Ottica, Radar, IR, Campi e.m., Data Relay, ecc.)

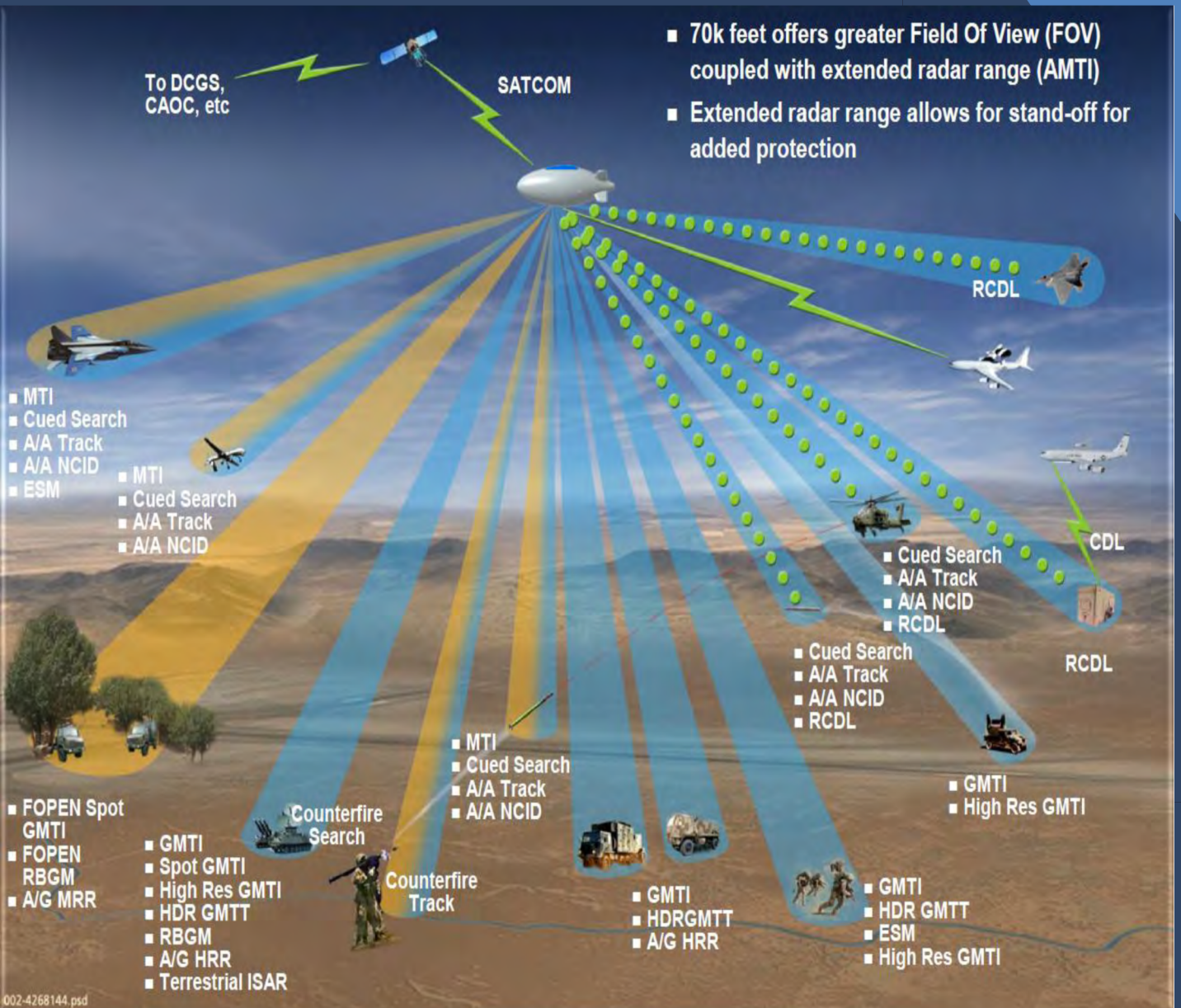


CARATTERISTICHE PRINCIPALI

	HAAP-SIT
Massa PL (Kg)	100
Pot. Elettr PL (Kw)	3
Lung. In quota (m)	66
Lung. al suolo (m)	46
Diametro(m)	22
Endurance Mission (mesi)	> 6

SPACE ITALY

HAAP
POSSIBILI APPLICAZIONI IN SETTORI DIFESA



Prepared by

the Office of the Assistant Secretary of US Defense for Research and Engineering, Rapid Reaction Technology Office- 2012

-LIGHTER-THAN-AIR VEHICLES

SPACE ITALY

THANK YOU

Massimo Comparini

e-GEOS – Chief Executive Officer
Telespazio – Director Line of Business GeoInformation
Chairman - Space Innovation in Italy

Ezio Bussoletti

Area Coordinator
Space & Aeronautics,
National Research Plan
MIUR

UNITED NATIONS
Office for Outer Space Affairs
www.unoosa.org • @UNOOSA

APPLICAZIONI

Le principali applicazioni di HAAP-SI sono:
- Settore ICT (es. Telecomunicazioni) e
- Remote Sensing, sia militare sia civile (es. Osservazione, Identificazione emissioni elettromagnetiche).

VANTAGGI ICT

- Rispetto alle stazioni di Terra hanno una più larga copertura, minore interferenze dovute agli ostacoli (edifici e rilievi montuosi)
- Rispetto ai satelliti hanno minore latenza del segnale (ritardo del segnale) e la possibilità di una manutenzione periodica poiché la piattaforma può ritornare a Terra.

VANTAGGI REMOTE SENSING

- Le Piattaforme stratosferiche operano a quote più basse dei satelliti con la possibilità di rimanere in posizione stazionaria sulla stessa area
- Immagini a più alta risoluzione in quanto più vicine al target.

PIATTAFORME STRATOSFERICHE D'ALTA QUOTA

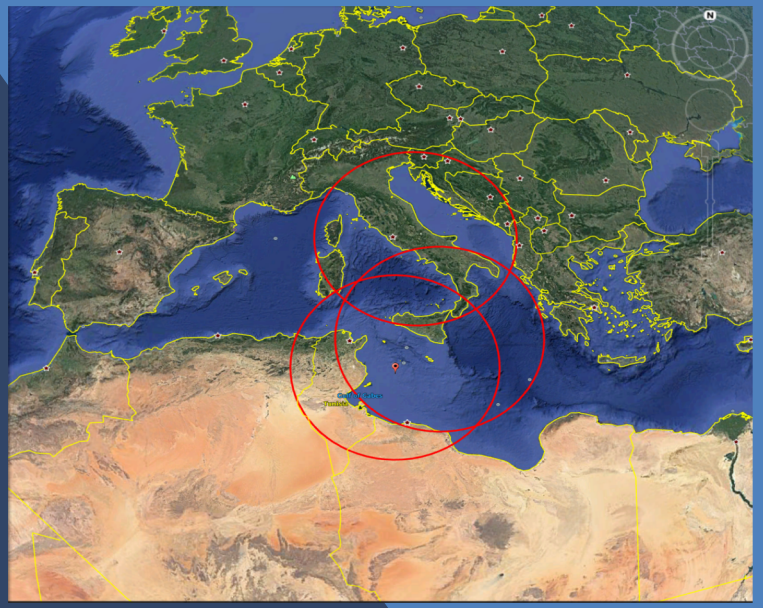
LE SFIDE TECNOLOGICHE

La realizzazione di una piattaforma stratosferica tipo AIRSHIP necessita di nuove tecnologie

I tentativi di sviluppo di vari paesi, anni 2000-2008, non sono stati di successo

Dal 2013 ripartite nuove iniziative tutte nazionali (Russia, Cina, Francia,…) ancora in corso utilizzando tecnologie comuni anche in settori diversi dall'Aerospazio:

- polimeri barriera e film rinforzati da fibre ad alte prestazioni
- batterie di nuova generazione
- celle fotovoltaiche ad alto rendimento
- microelettronica
- sistemi di guida e controllo per droni
- e molto altro…..



Una piattaforma a 20 Km di quota copre aree da 1000 km di diametro (cfr. cerchi in rosso)

The NATO Science & Technology Organization

Enabling Future Innovation and Capabilities

26 June 2019

Collaboration Support Office (CSO)
Lt Col Ryan SNIDER
Panel Executive

Agenda

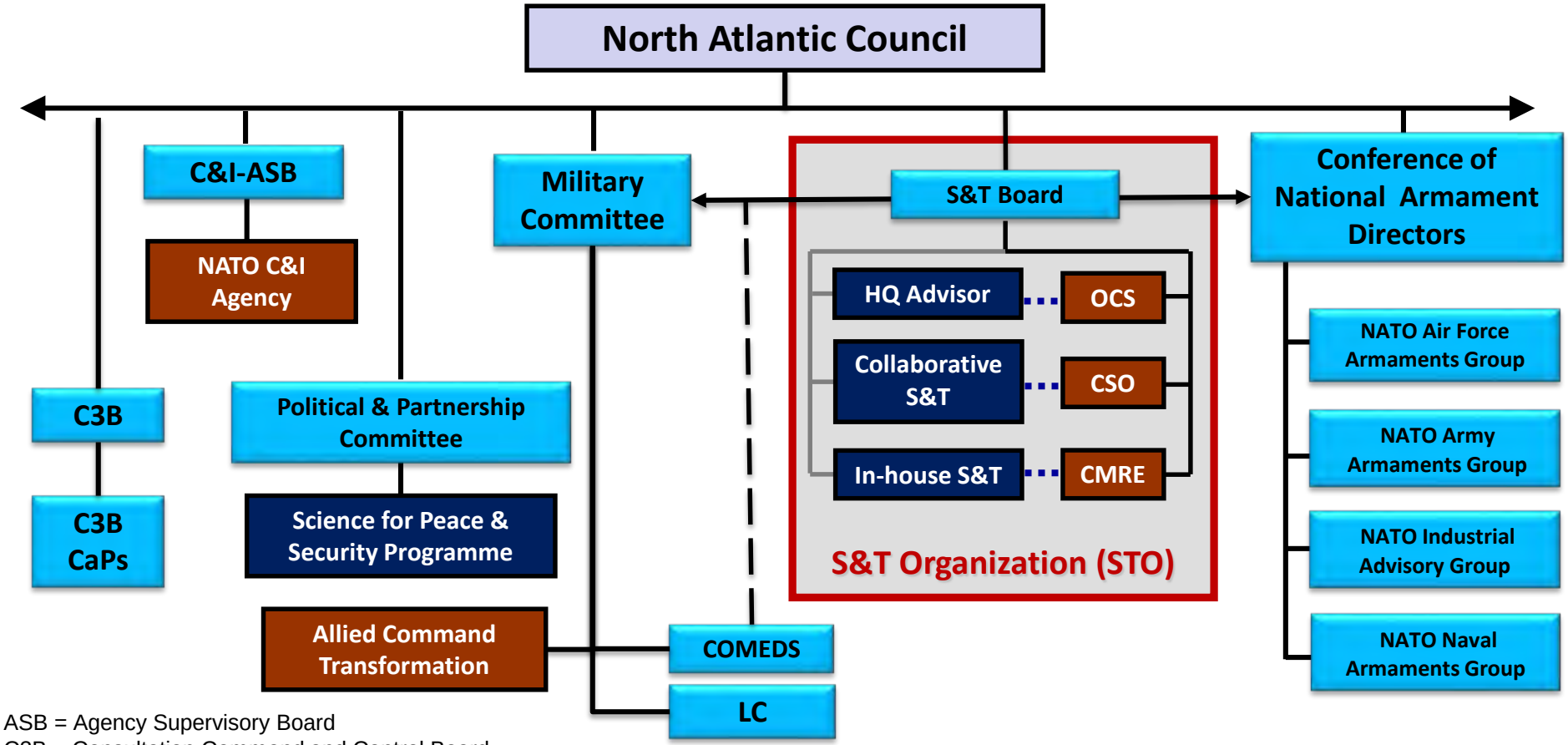
- *Why* Collaborative S&T in NATO?
- NATO S&T Community
- STO Collaboration Support Office (CSO)
- The Systems Concepts and Integration (SCI) Panel

Why Collaborative S&T in NATO?

- It **leverages scarce resources** while providing **synergies** and **interoperability** by:
  - Shorter delays in reaching conclusions
  - Benefiting from the best specialised resources in the Nations
  - Finding common solutions for increasingly complex problems
  - Enabling cost avoidance and cost sharing

Specialisation is a reality: no one has it all

The NATO S&T Community since 1 July 2012



ASB = Agency Supervisory Board
C3B = Consultation Command and Control Board
CaP = Capability Panel
C&I = Communications and Information
COMEDS = Committee of the Chiefs of Military Medical Services
LC = Land Command

NATO Nations in STO Program of Work

- –ALBANIA
- –BELGIUM
- –BULGARIA
- –CANADA
- –CROATIA
- –CZECH REPUBLIC
- –DENMARK
- –ESTONIA
- –FRANCE
- –GERMANY
- –GREECE
- –HUNGARY
- –ITALY

ESTIMATED SIZE OF MILITARY R&D IN NATIONS

- 70,000 (+) scientists
- From 100 (+) laboratories
- Investing 25B€ (+) yearly
- ~ 5,000 scientists in our Network

- **Partnership for Peace (PfP)**
  - **Enhanced Opportunity Partners (EOP): AUS, FIN, SWE**
- **Mediterranean Dialogue**
- **Istanbul Cooperation Initiative**
- **Global Partners**

- –LATVIA
- –LITHUANIA
- –NORWAY
- –POLAND
- –PORTUGAL
- –ROMANIA
- –SLOVAKIA
- –SLOVENIA
- –SPAIN
- –THE NETHERLANDS
- –TURKEY
- –UNITED KINGDOM
- –UNITED STATES

NATO S&T Strategy

Goals

- *Accelerate Capability Development*
- *Deliver Timely, Targeted Advice*
- *Build Capacity through Partnerships* ★

Lines of Effort

- Stay at the forefront of S&T
- Forge and nurture effective partnerships
- Promote prototyping & techology demos ★
- Enhance Alliance decision making
- Focus on Alliance needs to boost impact

Investment Areas

- Enhance the NATO S&T network of experts ★
- Intensify strategic comms
- Improve the S&T Programmes of Work
- Promote NATO S&T coherence

2017 NATO S&T Priorities

Precision Engagement
- Precision Control
- Weapons – Techniques & Systems
- Weapons – Effects
- Active & Passive EM/Acoustic/Optic Countermeasures
- Rules of Engagement, Legal, and Ethical Implications

Advanced Human Performance & Health
- Human Resiliency
- Medical Solutions for Health Optimization
- Enhanced Cognitive Performance
- Human/Machine Interfaces

Cultural, Social & Organisational Behaviours
- Social Influence
- Political Influence
- Cultural Communications
- Group & Organisational Behaviour

Data Collection & Processing
- Electromagnetic Sensors
- Non-Electromagnetic Sensors
- Sensor Integration &Networks
- Advanced Signal Processing

Information Analysis & Decision Support
- Human Decision Making
- Big Data & Long Data Processing and Analysis
- Multi-Domain Situational Awareness
- Planning & Managing Uncertainties

Communications & Networks ★
- Secure & Resilient Communications
- Trusted Multi-Domain Information Sharing
- Ad Hoc and Heterogeneous Networks

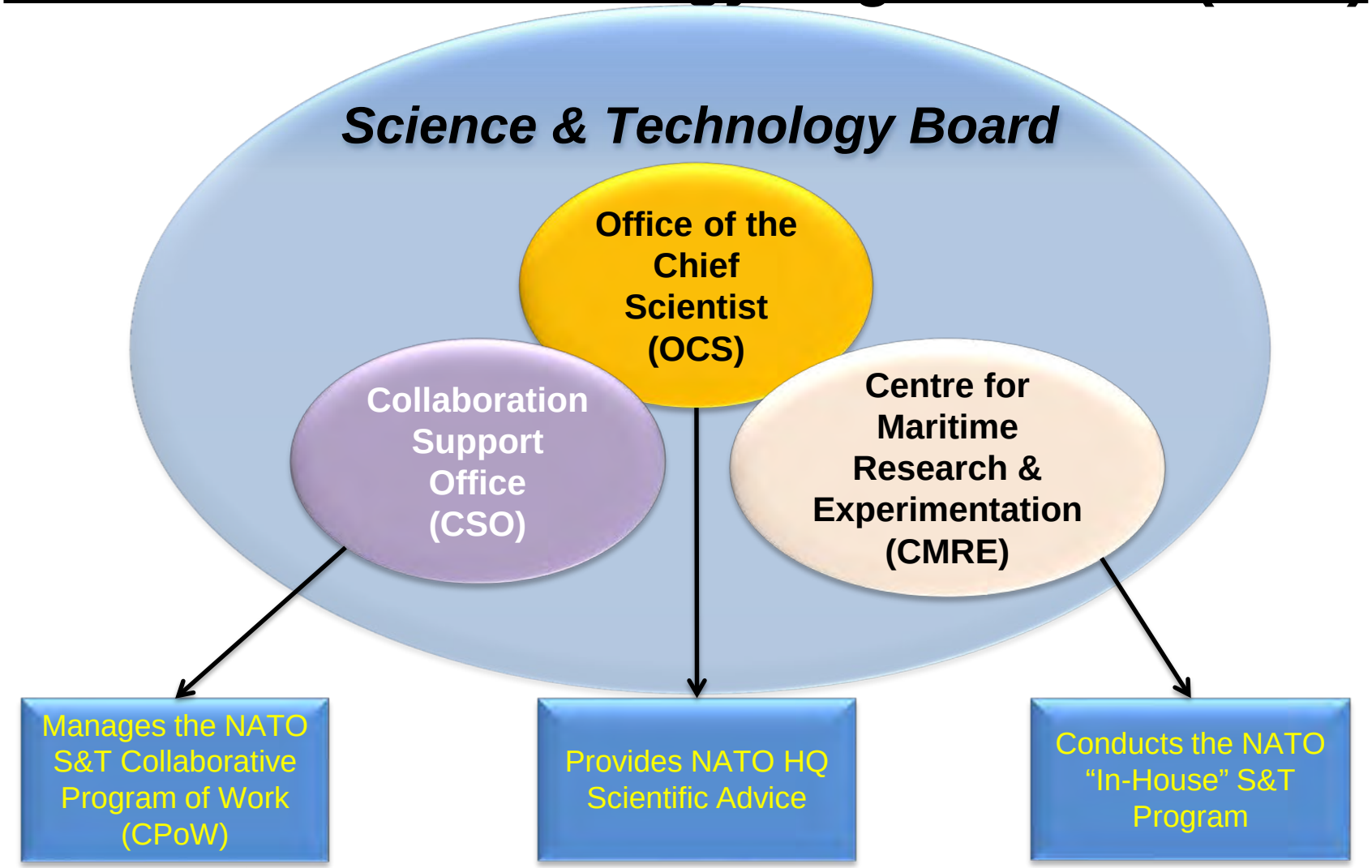
Autonomy
- Artificial Intelligence
- Mission Autonomous Systems
- Human-Autonomous Machine Teaming

Power & Energy
- Power and Energy Storage
- Alternative / Renewable Energy Sources
- Propulsion
- Enhanced Energy Efficiency & Management

Platforms & Materials
- Fast and Agile Platforms
- Unmanned Platforms
- Hypersonic Platforms
- Advanced and Adaptive Materials
- In-theatre Fabrication & Production of Equipment

Advanced Systems Concepts
- Integrated H-M Hybrid Force
- Clusters & Swarms
- Modular, Scalable Systems
- Efficient & Effective Logistics
- Integrating Live & Simulation Systems
- High Assurance Eng & Validation

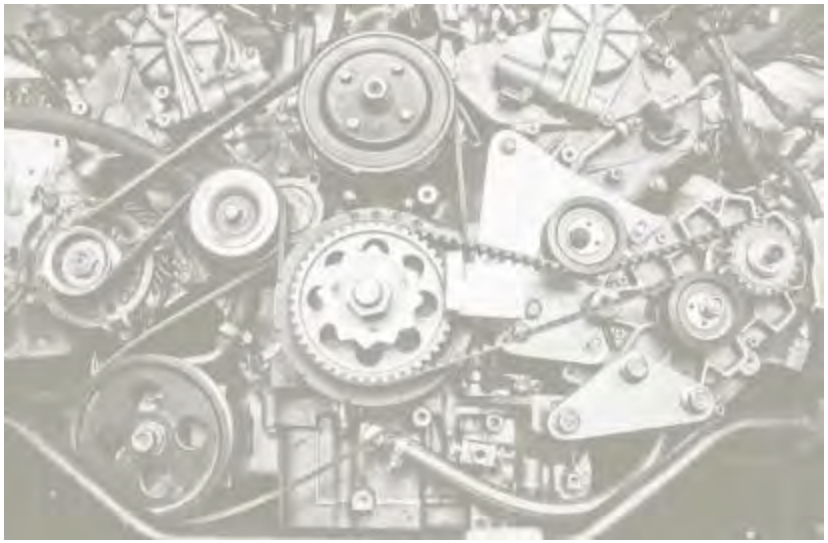
Science and Technology Organization (STO)



Collaboration Support Office (CSO)

"The Collaborative Production Engine of the STO"

- **Maintains Active Network of > 4,000 Scientists**
- **Manage > 200 Collaborative S&T Activities per year**
- **Supports 6 Technical Panels & 1 Group**



Collaborative S&T Activities

- **Exploratory Teams (ET)**
  (study group, 1 year max.)
- **Research Task Groups (RTG)**
  (study group, 3 years max.)
- **Research Workshops (RWS)**
  (selected participation, 2-3 days)
- **Research Specialists' Mtg (RSM)**
  (<100 people, 2-3 days)
- **Research Symposia (RSY)**
  (>100 people, 3-4 days)
- **Research Lecture Series (RLS)**
  (junior and mid-level scientists)
- **Research Technical Courses (RTC)**
  (specialised audience w/ops focus)

Research Specialists' Teams

Activity Lifecycle

Good Idea

Proposal (≥ 4 Nations)

Panel Approval (Unanimity) (≈ 20 Nations)

Board Approval (27 Nations) (≤ 6 Months☆)

Work / End Product (≤ 3 Years)

Distribution (REF: Proposal)

Your Activity Process Thus Far

An activity created and endorsed by the Panel *usually* starts as an Exploratory Team (ET)

ET

If the ET decides to follow on, it seeks the Panel's approval and STB's endorsement to become

SCI-318 RSM

RSM/RWS/RSY/RLS/RTG

which develops findings and produces a final

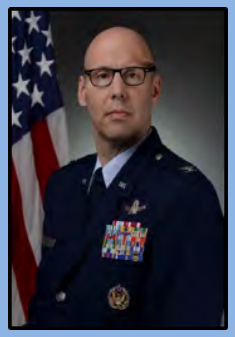
Product

You are here

STO Program of Work Management

Dr. Pavel Zuna
CSO Director

MGen (ret) Philippe Montocchio
Deputy Director



Col Daniel Gallton
Head, Operations and Coordination Division

Col (ret) Philippe Soete
Executive Officer, Advisor to the Director

	AVT	HFM	IST	NMSG	SAS	SCI	SET
Panel Chairs	MAJ David Lecompte (BEL)	Alison Rogers (GBR)	Michael Wunder (DEU)	Agatino Mursia (ITA)	Ana Barros (NLD)	Karin Stein (DEU)	David Blacknell (GBR)
CSO Panel Executives	Christoph Mueller (DEU)	LtCol Erik Laenen (NLD)	Col (ret) Philippe Soete (acting)	Cmdr Santiago Fernandez Dapena (ESP)	LTC Tim Povich (USA)	Lt Col Ryan Snider (USA)	LtCol Francesco Santoro (ITA)

6 Panels and 1 Group

AVT **Applied Vehicle Technologies**

Vehicle, platform, propulsion and power systems -- land, sea, air, and space

HFM **Human Factors and Medicine**

Optimize health, safety, well-being and performance of humans in operational settings

IST **Information Systems Technologies**

Information Warfare & Assurance; Information & Knowledge Management; Communications & Networks; Architecture & Enabling Technologies

SAS **System Analysis & Studies**

Studies & analyses of operations & technology; develop methods & tools

SCI **Systems Concepts & Integration**

System of Systems approach across spectrum of platforms & operating environments; integrated defense systems

SET **Sensors & Electronics Technologies**

Reconnaissance, Surveillance, & Target Acquisition; Electronic Warfare; Communications & Navigation; Multi-sensor integration/fusion

MSG **Modelling and Simulation Group**

Maximize the effective utilisation and co-ordination of M&S

SCI Panel Composition

57 Members
46 National Representatives
8 Members-at-Large (MaL)
(MaL for Space - Dr. Don LEWIS)
2 NATO Associate Members
(ACT, JEWCS and NCIA)

NATO Nations Represented (20/29)

BELGIUM	NORWAY
BULGARIA	POLAND
CANADA	PORTUGAL
CZECH REPUBLIC	ROMANIA
DENMARK	SLOVAKIA
ESTONIA	SPAIN
FRANCE	THE NETHERLANDS
GERMANY	TURKEY
GREECE	UNITED KINGDOM
ITALY	UNITED STATES

Enhanced Opportunity Partners (2)

Finland Sweden

SCI Panel – Leadership and Support Team

Chairmanship

CHAIR	VICE CHAIR
Dr Karin STEIN Fraunhofer IOSB	Mr Allan CHAN US Army Futures Command

Panel Office

EXECUTIVE	ASSISTANT
Lt Col Ryan SNIDER NATO STO (CSO)	Ms Carlotta ROSSI NATO STO (CSO)

Contact Info

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carlotta.rossi@cso.nato.int

Working Session A

CHAIR	VICE CHAIR
Prof Michael HENSHAW Loughborough University	Prof Victor LOBO Escola Naval

Working Session B

CHAIR	VICE CHAIR
Dr David TREMPER DARPA	Dr Jean FORTIN DRDC

Working Session C

CHAIR	VICE CHAIR
Dr Christian MOLDER US Air Force HQ AFTC	Dr Johann DAMBECK MBDA

SCI Panel – Strategy Areas

Systems Integration & Interoperability (Working Session A)	Integrated Survivability (Working Session B)	Enablers and Disruptive Capabilities (Working Session C)
• Coalition Operations Concepts/Capabilities • Systems of Systems • Architectures, Standards, & Interoperability • End to End Effects Chains • Human in Systems • Situational Awareness	• Force Protection Systems • Electronic Warfare (EW) • Camouflage, Concealment & Deception (CC&D), Denial & Deception (D&D) • Directed Energy Weapons (DEW)/Counter-DEW	• =>Space • Autonomy • System Verification & Validation (Flight Test Technical Team [FT3]) • Cyber – Internet of Things

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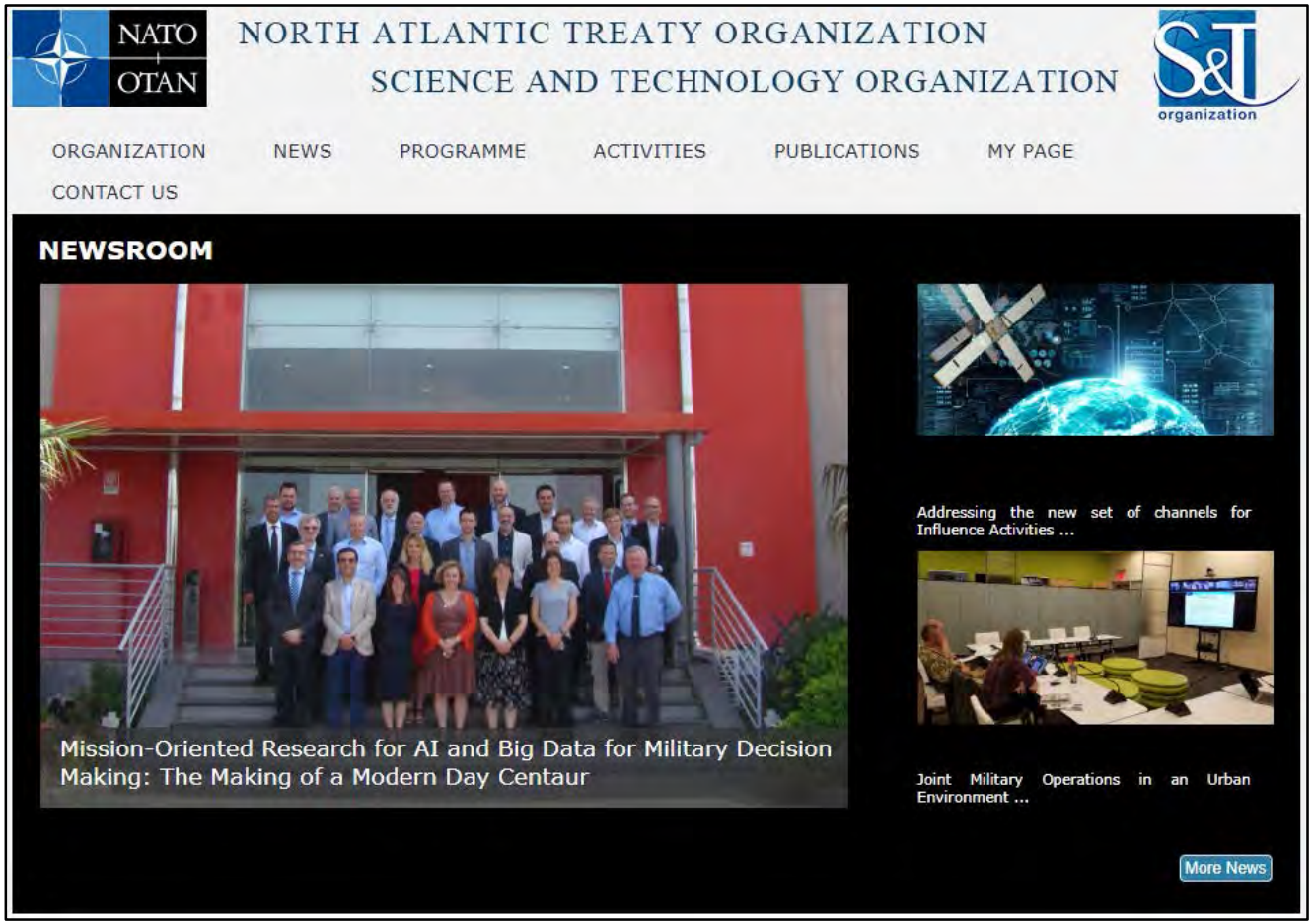

Questions?

Ask your Panel Office

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SCI Panel Executive
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Panel Assistant:

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Joint Air Power Competence Centre

Threats to NATO's Space Support in Operations

LtCol Tim Vasen (DEU A)
JAPCC

NATO UNCLASSIFIED releasable to AUS, SWE, FIN and SGP

About the JAPCC (1):

Joint Air Power Competence Centre

- NATO Centre of Excellence (CoE), dealing with the topic 'Joint Air and Space Power'
- MoU Organization funded by 16 NATO member nations
- <u>It consists of four branches:</u>
  - Training and Exercise
  - Combat Air
  - Air Operations Support
  - C4ISR + Space

FRA and **PRT** have been members in the past

NATO UNCLASSIFIED releasable to AUS, SWE, FIN and SGP

About the JAPCC (2):

Joint Air Power Competence Centre

- JAPCC Director is Com AIRCOM
- But it is not included in the NATO Command Structure
- There is a degree of 'academic freedom'
- The information does **not represent NATO policy**, rather the **author's opinion**, based on **doctrine, SOPs and experience**

FRA and **PRT** have been members in the past

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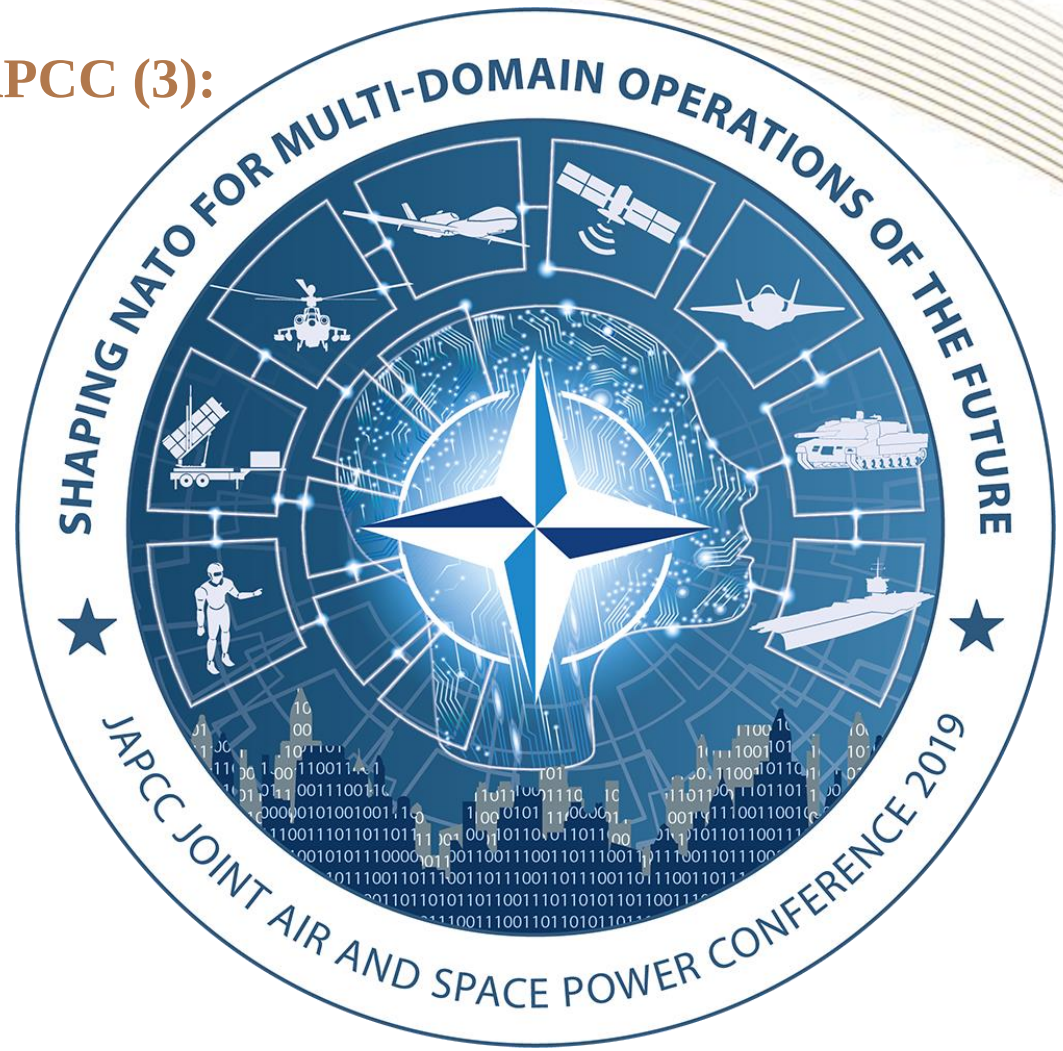
About the JAPCC (3):

Joint Air Power Competence Centre



JAPCC Conference

08th to 10th October 2019 in Essen, DEU

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Limiting factors for Space in NATO
(just some of them)

Joint Air Power Competence Centre

- NATO neither owns nor operates own satellites
- NATO owns Space systems (ground infrastructure etc.)
- NATO still struggling on the ‘paper work’
- Responsibility for Space is still in the hands of the operating nations
- NATO’s role is currently ‘just’ coordinating the service(s)

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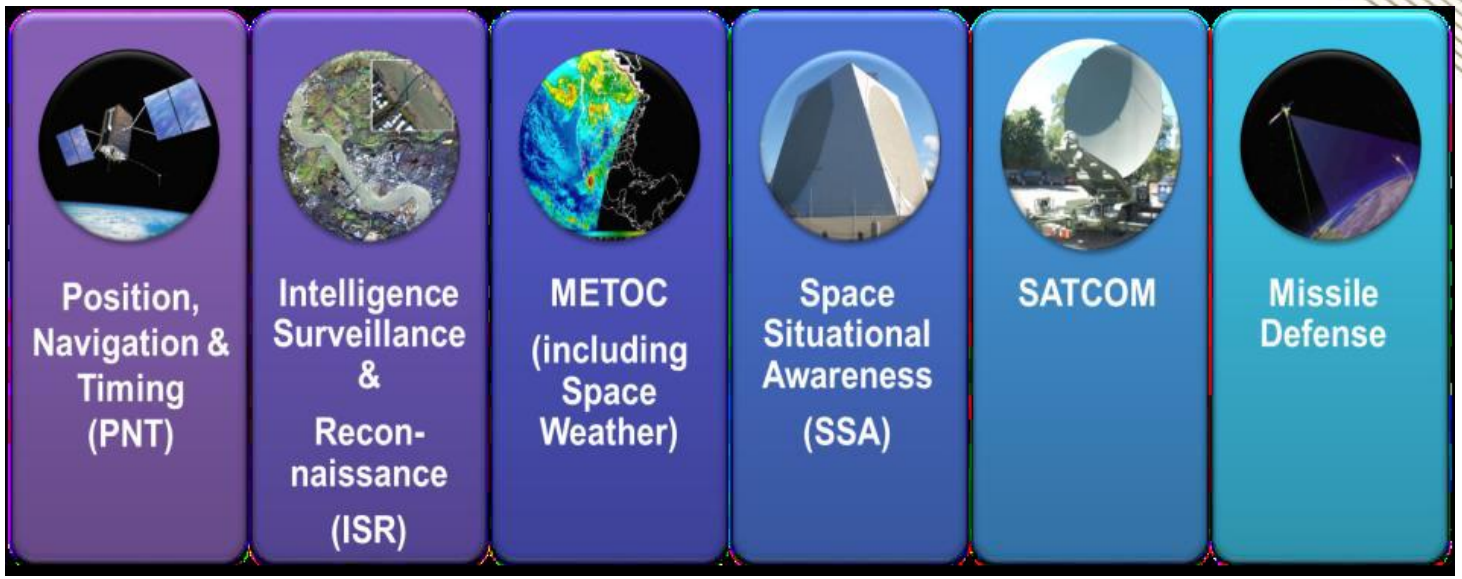
military usable Space services

Space is militarized , but not weaponized !

Joint Air Power Competence Centre



E-O
SAR
SIGINT (ELINT, COMINT, etc.)

or
SDA

OPIR

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Environmental threats:

Joint Air Power Competence Centre

- **Space weather influences (WX)**
  - Solar activity related electro-magnetic interference(s)
  - Spacecraft charging
  - Effects on: PNT, COM, ISR
- **Terrestrial weather**
  - cloud cover
  - heavy rain
  - Effects on: COM, ISR

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General man made threats:

Joint Air Power Competence Centre

- **Space Situation Awareness (SSA)**, Space debris
  - safe Spacecraft operations / collision avoidance
  - “Recognized Space Picture”
  - SATRAN as a product

  - includes Space INTEL
  - includes WX awareness

  - <u>Effect:</u>
    - allows ‘hidden’ operations
    - option to unveil hostile Space operations
    - option to secure/protect own Space assets

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General threats (1):
(treats to all kinds of Space Systems)

Joint Air Power Competence Centre

- Kinetic Threats to spacecraft
  - Direct ascent
    - collateral damage → debris clouds
    - irreversible
    - Deterrence
  - Co-orbital
    - collateral damage likely → debris...
    - usually irreversible
    - Deterrence if designated military system
    - 'on orbit servicing'
    - 'Kamikaze'
- Kinetic threats to the ground segment
  - anything Space related (C2 centers, antennas, etc.)
  - also against supporting infrastructure
    - reversible (changed antenna angle, pulled plug, …)
    - up to irreversible (destroyed building, antenna, power plant, etc.)

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General threats (2):

(treats to all kinds of Space Systems)

Joint Air Power Competence Centre

- Directed Energy Weapon (DEW)
  - high power laser/microwave/etc.
  - sends a high power impulse to Spacecraft
    - reversible up to irreversible depending on the power output
- Cyber attacks
  - likely against ground segment first
  - also against supporting infrastructure/elements
    - reversible up to irreversible
- Nuclear detonation in Space
  - EMP directly disables satellites
  - creates a massive WX effect
    - Spacecraft degrade over time
    - up to irreversible

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Threats to PNT (currently GPS):

Joint Air Power Competence Centre

- Jamming
  - against civilian, military (2+ channels) as well as protected receivers
  - Effect: degradation or loss of service
- Spoofing
  - Currently only against civilian (unprotected) single frequency receivers
  - Effect: receiver gains a false position an provides false navigation service
- Timing dependencies (mostly jamming effects)
  - Radar
  - Communication
  - Network synchronization
  - Civilian applications
- Overall mitigation approaches:
  - GPS: GPS-III satellite generation (M-Code as third protected frequency)
  - NATO: integration of EU-GNSS ‘GALILEO’

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Threats to ISR:

Joint Air Power Competence Centre

- Dazzling electro-optical payloads
  - continuous waveform laser
  - ‘flash light in the dark’
  - Reversible action
  - Effect: ‘passage mission kill’
- Jamming Synthetic aperture radar (SAR) payload
  - Effect: ‘passage mission kill’
- Dummies/decoys, camouflage
  - Advanced ones have IR, EO, SAR signature, as well as EW emitters
  - Effect: hard work for analysts, higher amount of ammunition
- ‘Commercial application factor’

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Threats to SATCOM:

Joint Air Power Competence Centre

- Uplink jamming
  - jamming of the satellite
  - prevent sending signals to the satellites
  - mobile as well as fixed (fixed usually more powerful)
  - large areal effect due to the direct impact on the satellite
  - Effect: reversible degradation of the satellite itself
- Downlink jamming
  - jamming of the receivers on the ground (ground as well as user segment)
  - usually requires 'higher' position (or airborne)
  - locally (and timely) limited
  - Effect: reversible degradation of the ground infrastructure/user segment
- 'Commercial applications factor'

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Threats to OPIR:

Joint Air Power Competence Centre

- comparable to ISR threat
- Space-based systems usually rely on IR-sensors
- ground based sensors get more relevance
- unlikely due to orbits and ‘deterrence’

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Commercial applications factor:

Joint Air Power Competence Centre

- Who will protect
  - who will compensate in the case of ‘man made failures’
  - will the company stay in the contract due to threats (peer opponent)

- What will be the costs
  - will need a ‘basic’ funding to get it, if needed (permanent costs)
  - commercial companies could (usually) earn more money when customers are wide spread → massive amount in comparison to ‘regular’ customer (USA observation and lessons learned out of there past…)

- Military ‘focus areas’ (AOO) always attracts several participants (3rd parties, media, NGO, etc.) that also need bandwidth
  → “**competition** for **capabilities** and **capacities**”

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Summary:

Joint Air Power Competence Centre

- There is no NATO operation without Space support
- Threats to Space services are always present
- ‘Protection’ of satellites belong to the operating nations
- Always keep the ‘commercial applications factor’ in mind
- Keep NATO’s role in Space always in mind
- Keep NATO’s role in Space always in mind

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Thank you for your attention

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EUROPEAN UNION
SATELLITE CENTRE
Analysis for decision making

Space Situational Awareness at the EU SatCen

SCI Panel: The Space Domain and NATO Operations: A Critical S&T Review

Turin, Italy, 26 June 2019

João Alves – Head of SSA
joao.alves@satcen.europa.eu

European Union Satellite Centre

SatCen
European Union Satellite Centre

Mission

To support the **decision making and actions of the Union** by providing products and services resulting from the **exploitation of relevant space assets** and collateral data, including satellite and aerial imagery, and **related services**

European Union Satellite Centre

SatCen
European Union Satellite Centre

Agency of the EU Council

HQ in Torrejón de Ardoz, Spain

EO Satellite Data – secure context

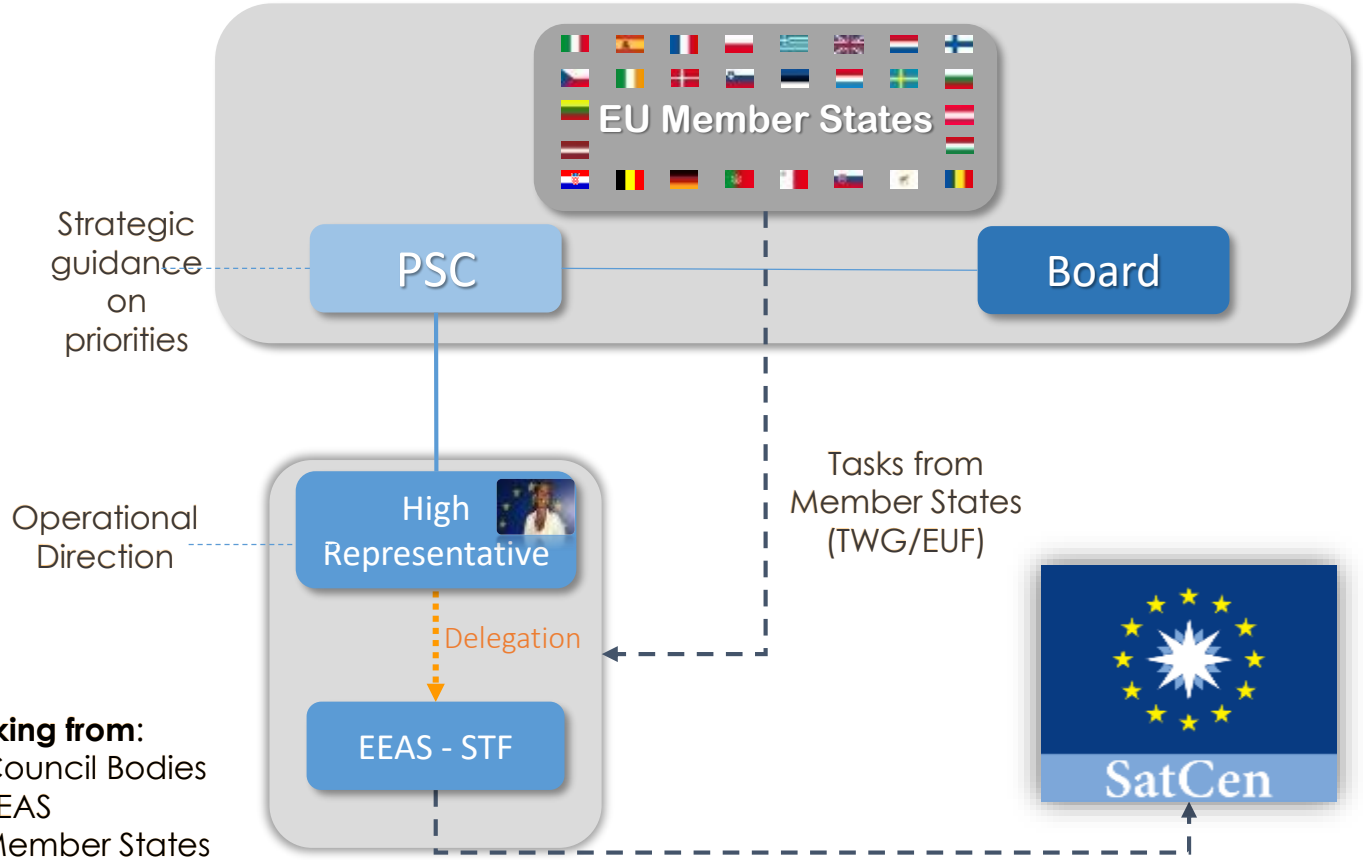
CFSP/CSDP

Council Decision 2014/401/CFSP

GEOINT Service Provider, 24/7 availability

SatCen

Governance



Approves

- Budget
- Work programme
- Cooperation (having regard to Council or Director responsibilities)
- Appoints Director

SatCen has legal personality

The Director:

- Is the legal representative
- Is responsible for day-to-day administration
- Executes the Centre's mission

Tasking from:

- Council Bodies
- EEAS
- Member States
- Commission
- Third States
- IOs (NATO, UN)

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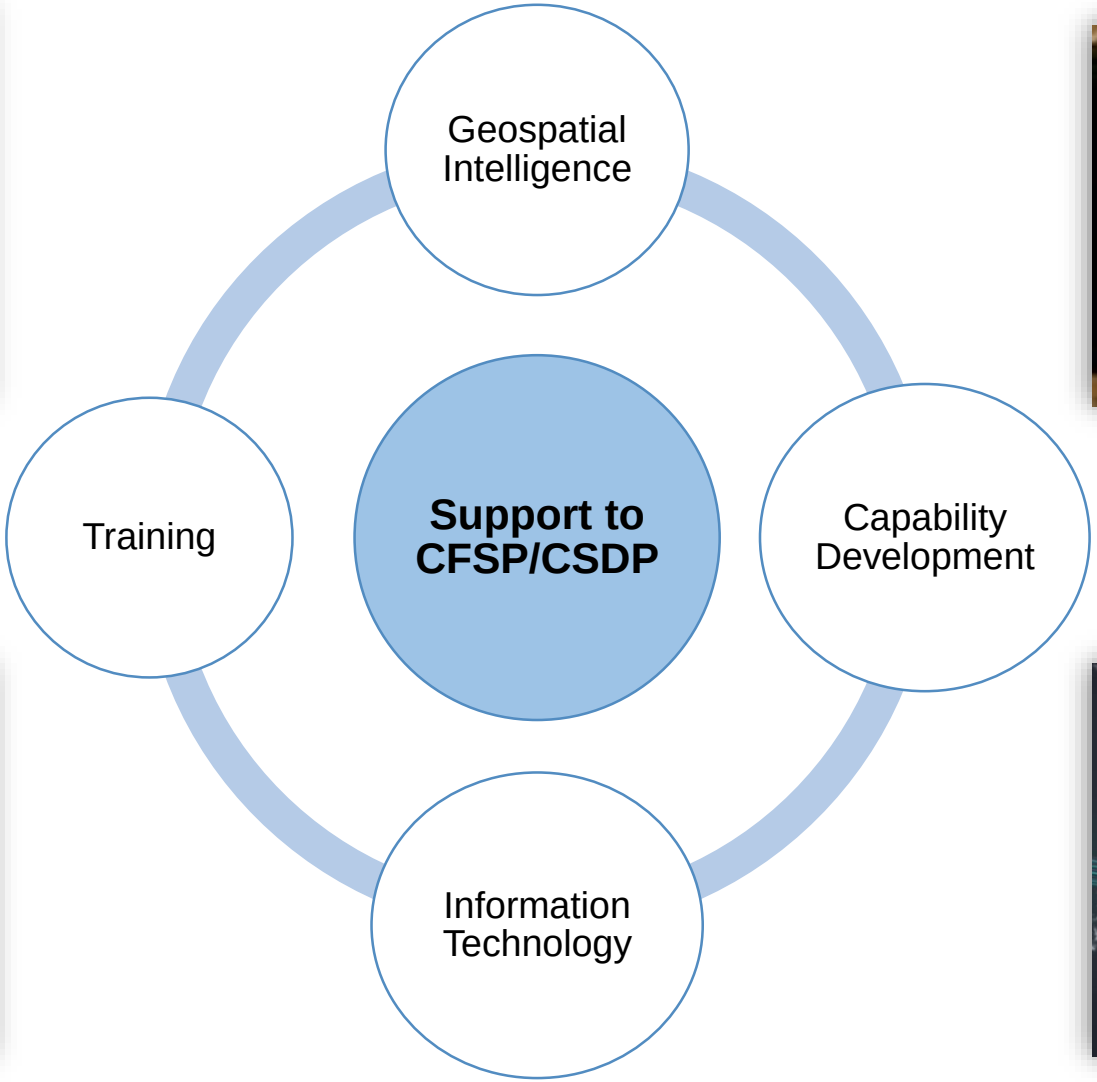
Activities



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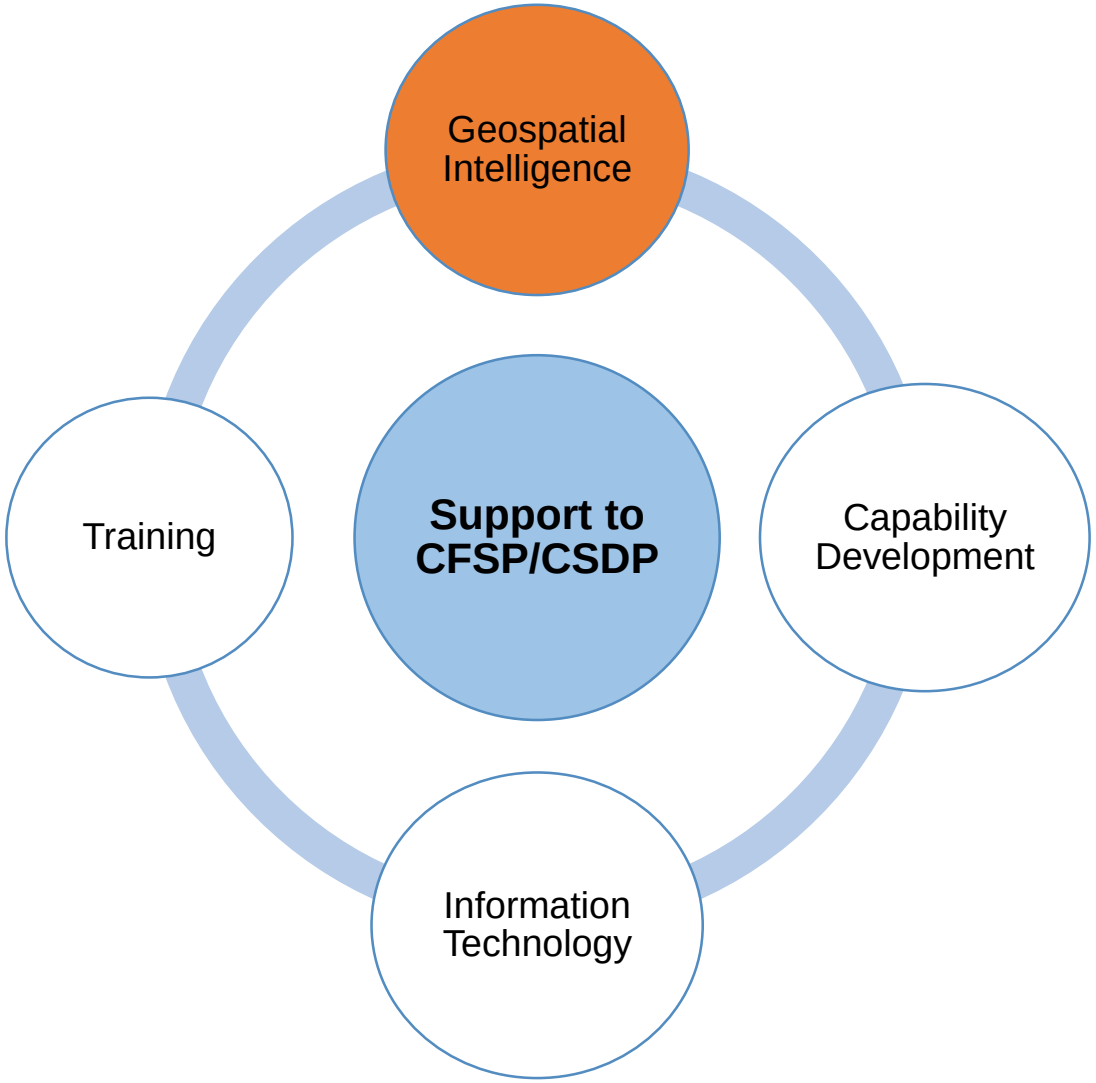
Activities



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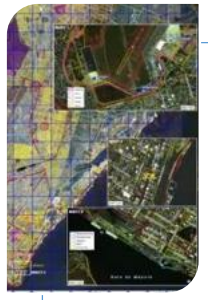
Main Analysis Domains

Security Surveillance

- *Treaty verification*
- *Border control*
- *Global terrorism*
- *Piracy and coastal analysis*



Contingency Planning

- *Support to evacuation operations*
- *Rapid mapping*

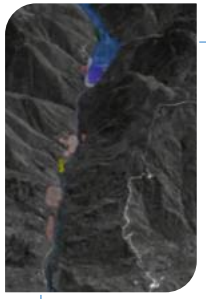
Standard driven

Quality oriented

Interoperability

Humanitarian Aid

- *Refugee camps / IDPs*
- *State failure and insurgency*
- *Man-made and natural disasters*



Critical Infrastructure

- *Elements-at-risk mapping*
- *Threat analysis and Vulnerability Assessment*

Users satisfaction

Military Capabilities

- *Analysis of military activity / deployed forces*
- *Battle Damage Assessment*

Weapons of Mass Destructio

- *Arms control and non-proliferation*
- *Chemical weapons*

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Users

- Council Bodies – EEAS
- Member States
- European Commission
- Third States
- International Organisations (NATO, UN, OSCE, OPCW)

Field Support | **Planning** | **Decision making**

Written Reports

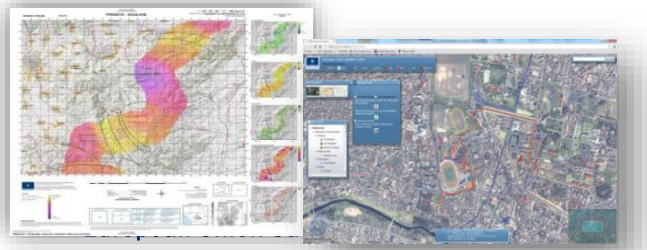
- **Planning operations**
- **Military activity**

Cartography

- **High detail maps**
- **Complex**

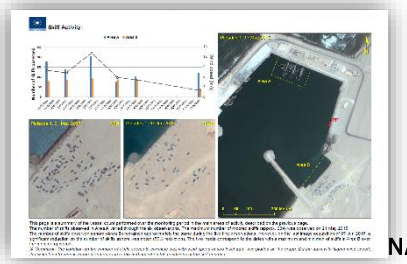
Spatial Analysis

- **Added value GI overlays**



Written Reports

- **Figures**
- **Statistics**
- **Simple**



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Support to EU Missions and Operations, EU Agencies and International Organisations

EUMM GEORGIA

Border monitoring, assessment of military facilities and analysis of military activity

EU NAVFOR MED-SOPHIA

Surveillance and assessment of human smuggling and trafficking networks

EU NAVFOR ATALANTA

Monitoring known Pirate Operating locations, maritime facilities and shoreline activity

OSCE SMM UKRAINE

Support in the verification of the Minsk Agreement. Analysis of military activity and equipment

FRONTEX

Monitoring of coast activity and external borders activity related to migration crisis

OPCW

Support to Fact Finding Teams and verification of Syrian Reports.

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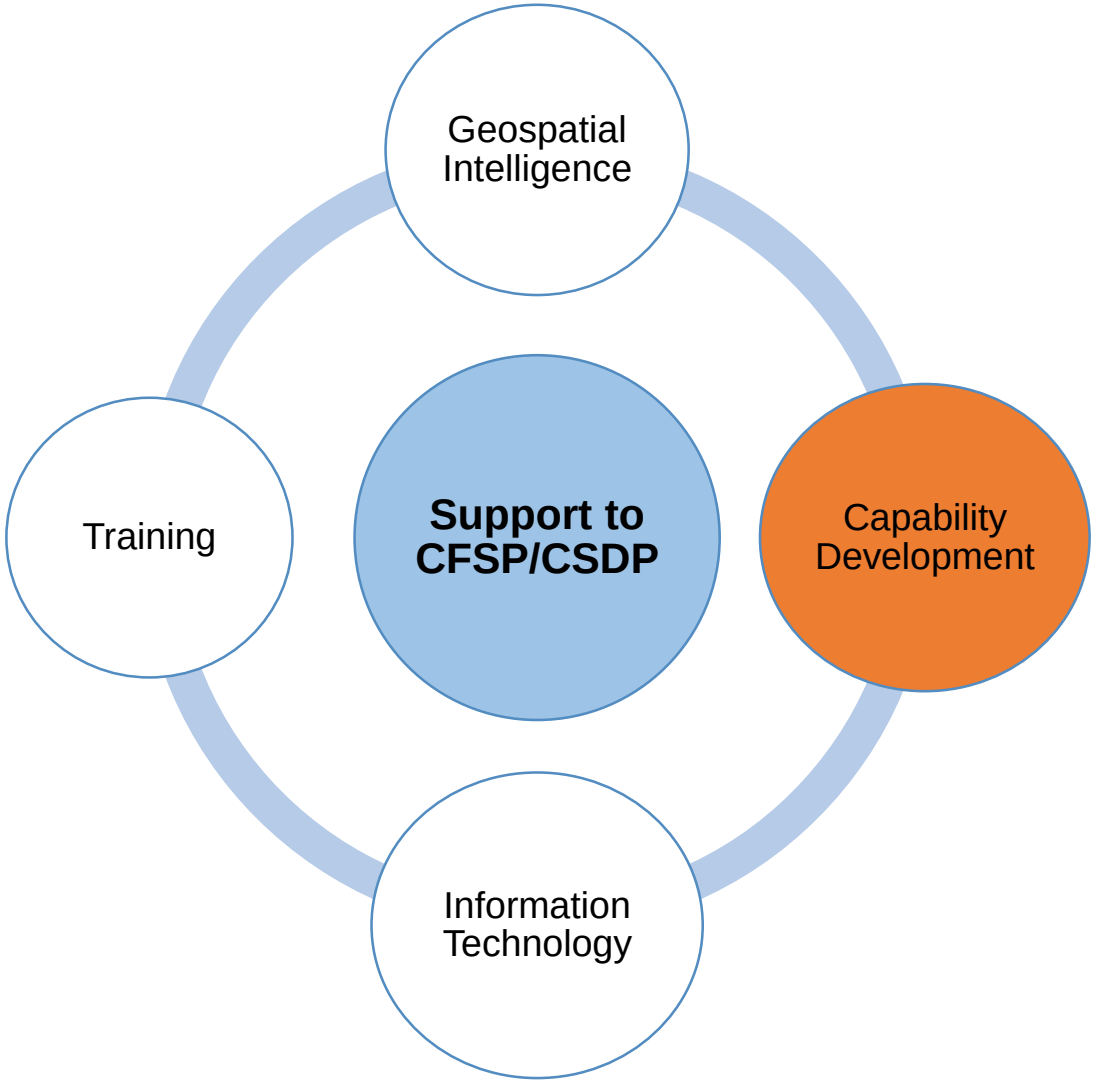
Activities



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Capability Development - Copernicus Security Services

SatCen

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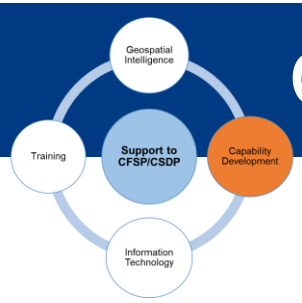


Capability Development – Space Surveillance and Tracking

© European Union

Cooperation

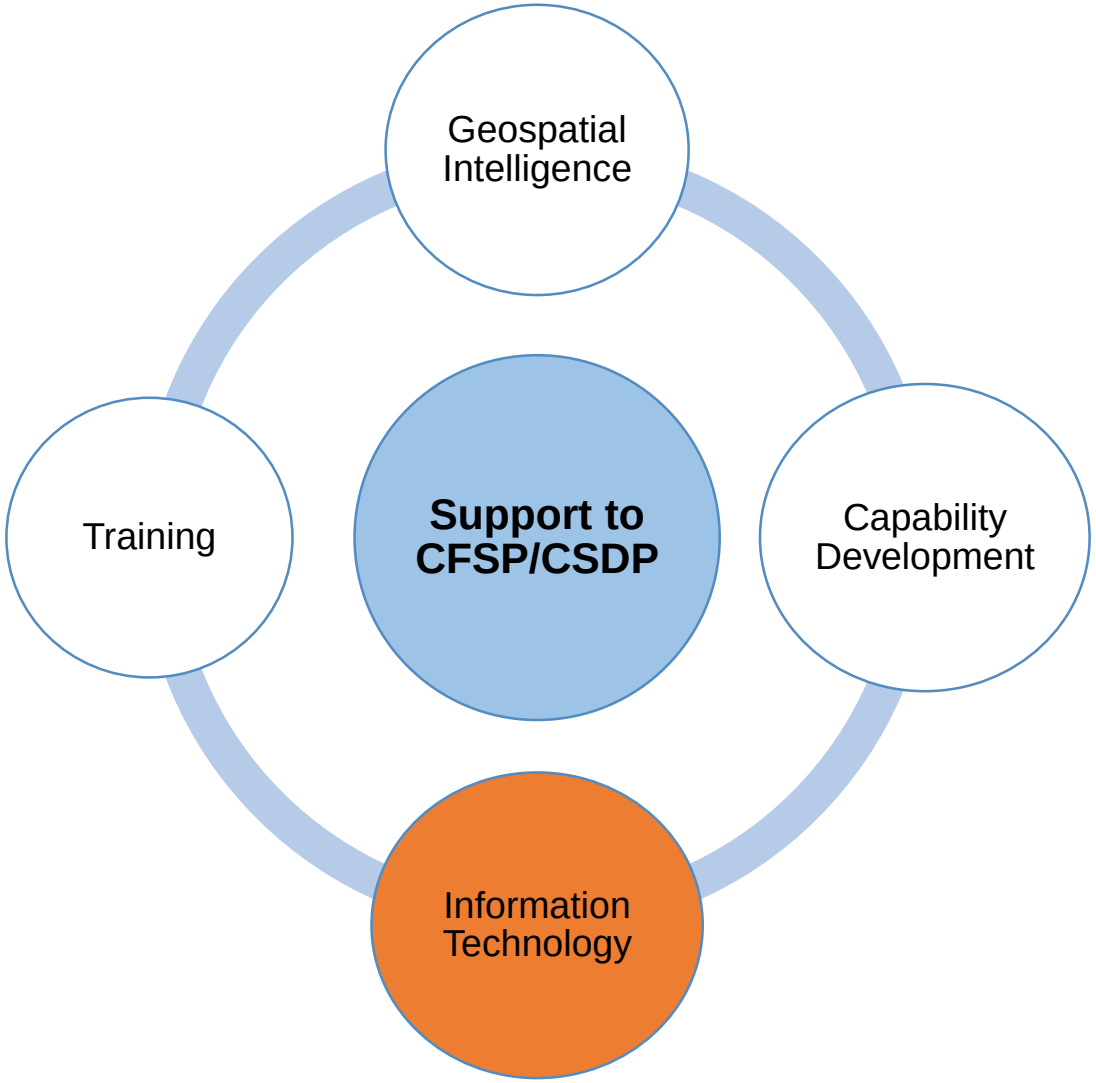
Article 2.3 of SatCen Council Decision

- *"…. **cooperate with the Commission and with Union agencies**, bodies or Member States, …. **maximising synergies and complementarity with other Union activities** …. in particular in the area of **space and security**"*

Proposal for a Regulation establishing the space programme of the Union and the European Union Agency for the Space Programme

- *" .. SATCEN will be **maximising synergies and complementarities** with other Union activities especially the **Programme and its components.**"*

Activities



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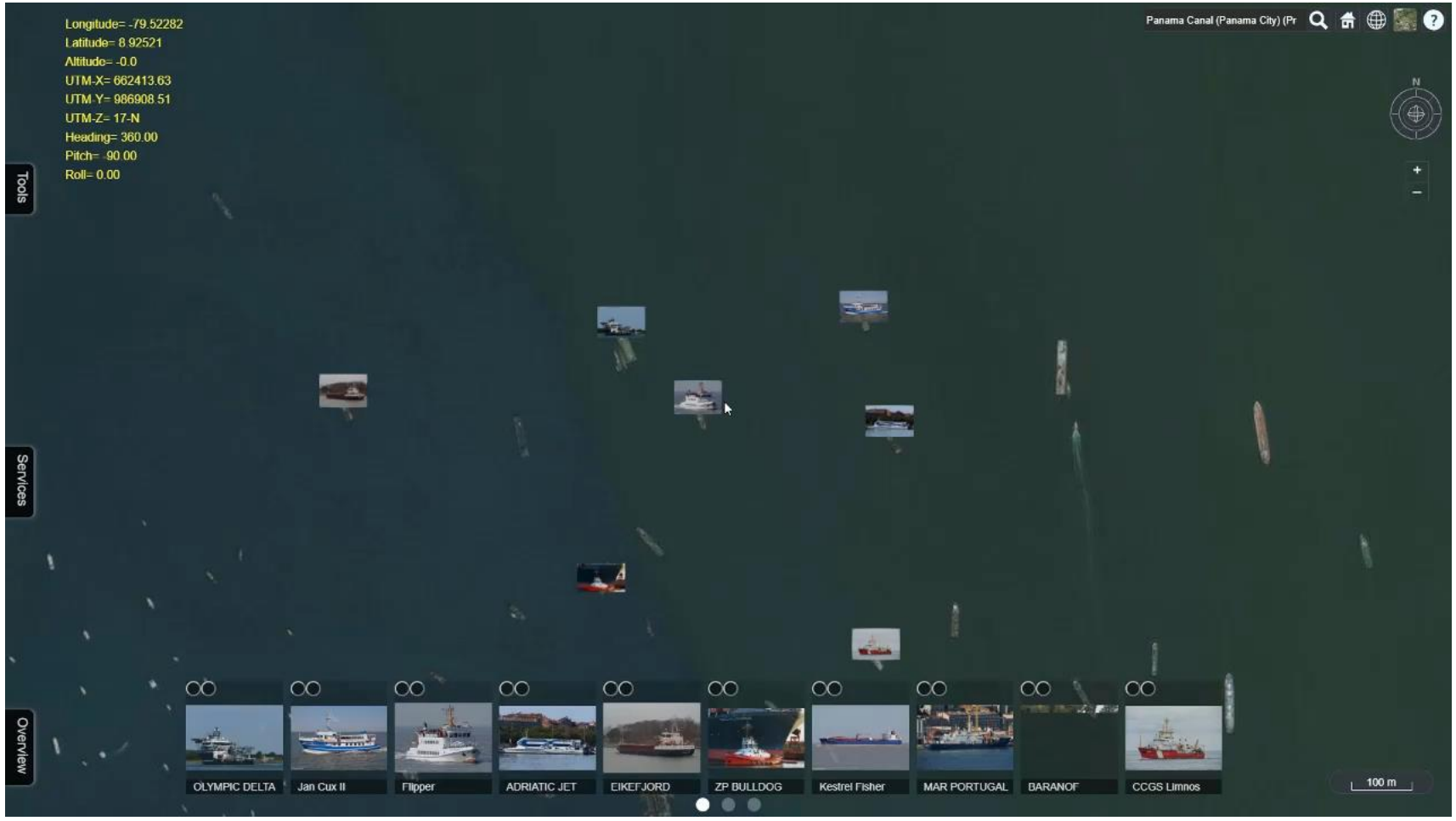
Information Technology



Operational Artificial Intelligence

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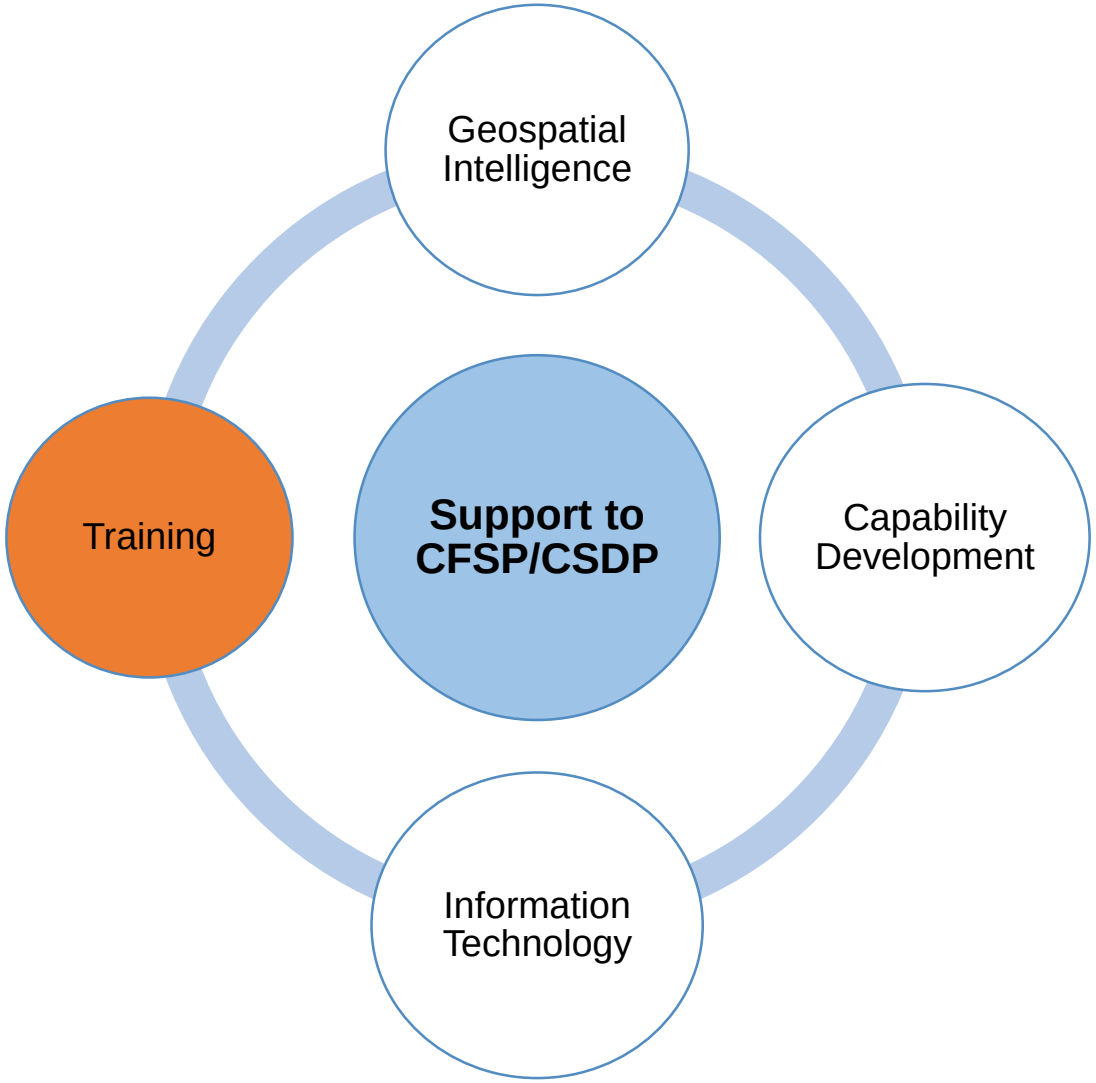
Activities



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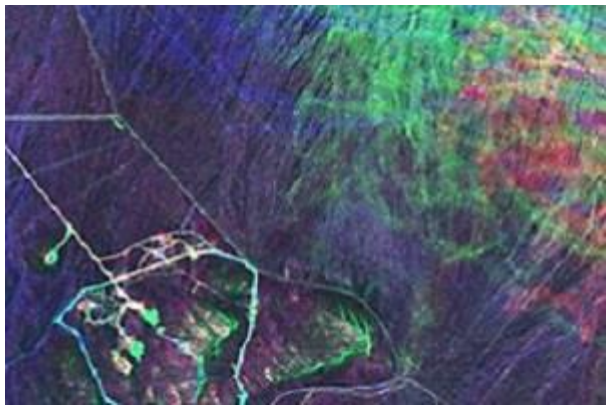
Training

GEOINT



SAR

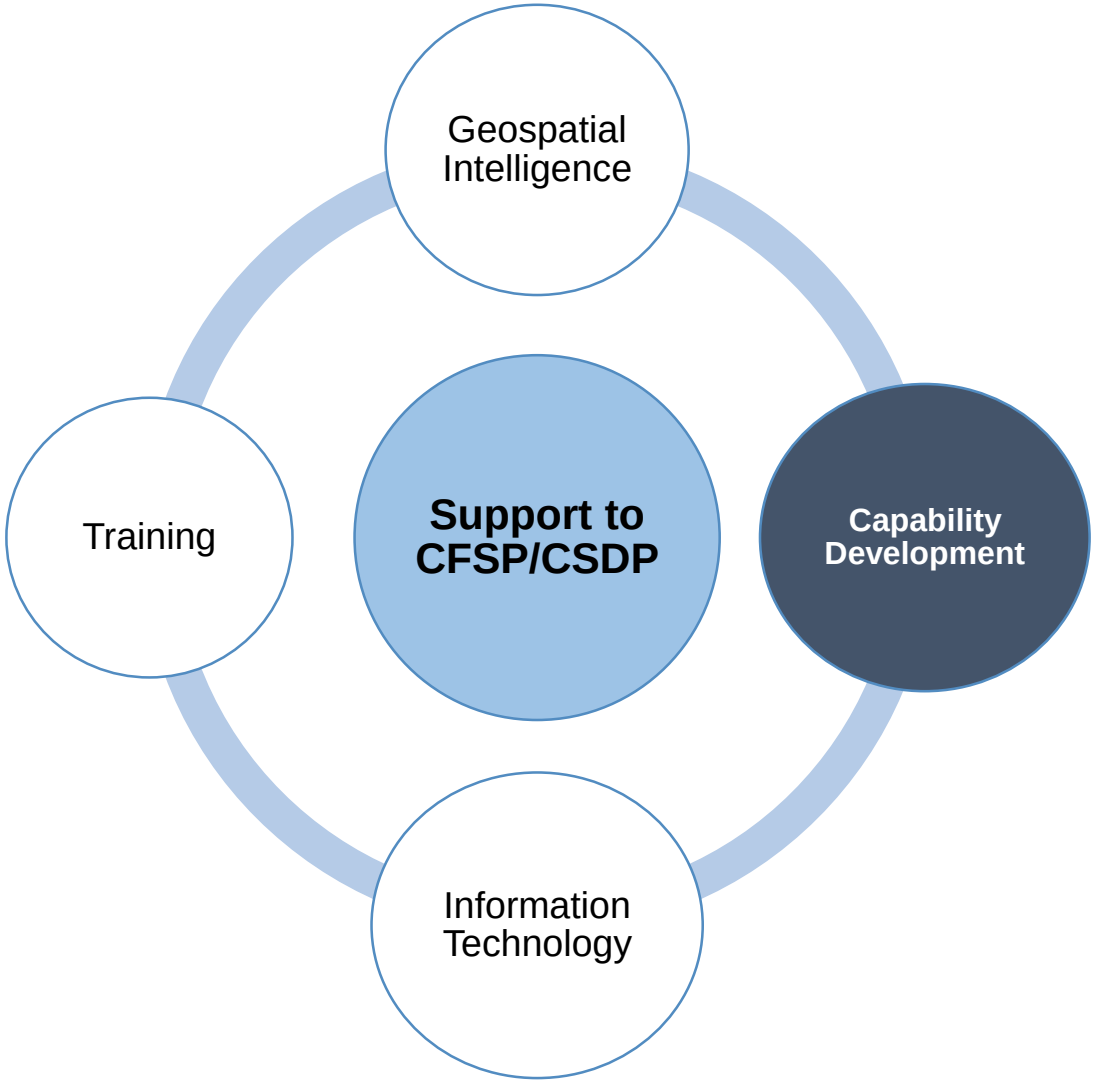
IMINT

NUCLEAR

INDUSTRIES

IN-SITU

Activities



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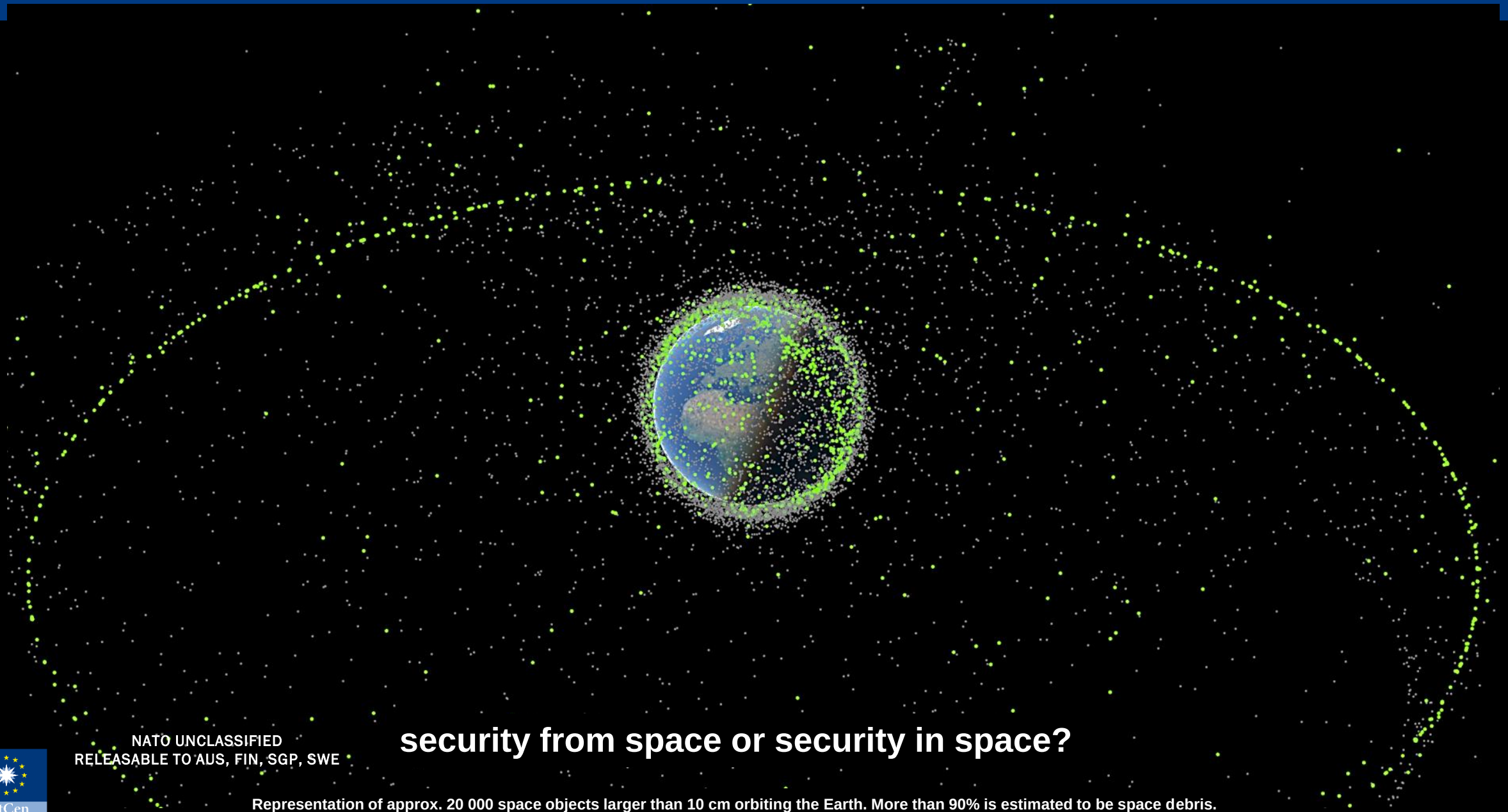
Congestion in Space



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security from space or security in space?

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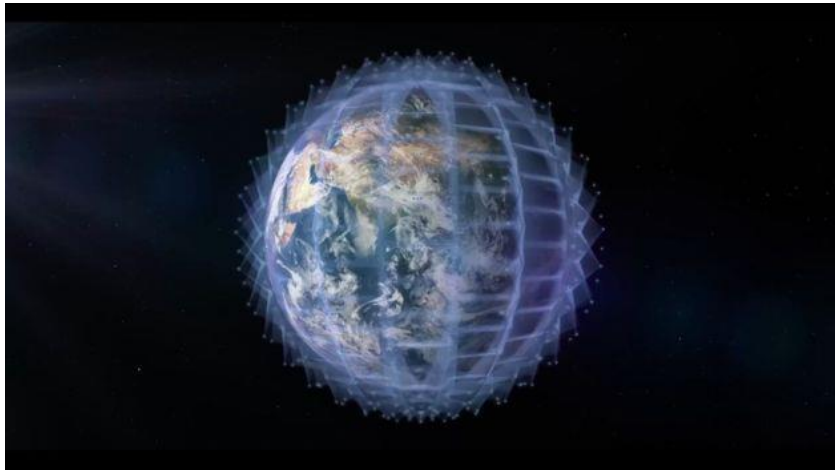
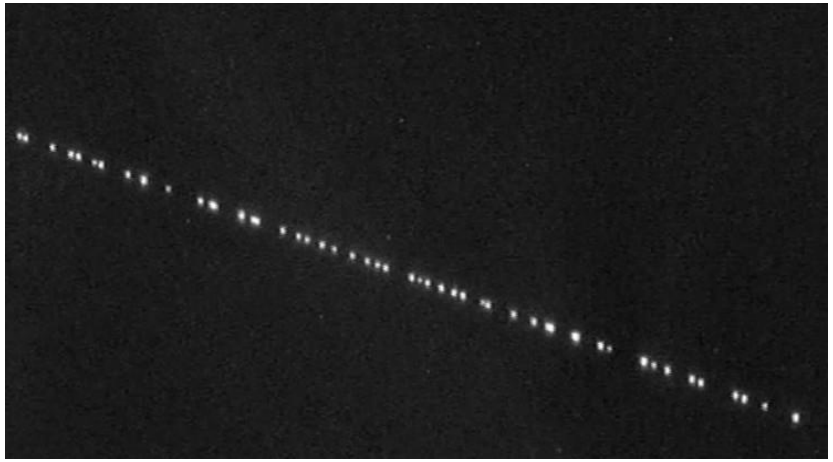
Representation of approx. 20 000 space objects larger than 10 cm orbiting the Earth. More than 90% is estimated to be space debris.

Competing in Space

Indian ASAT performed end of March
Credit: Government of India



Mega satellites constellations…
Credit: BBC



…becoming a reality (SpaceX Starlink fist launch of 60 satellites)
Credit: SatTrackCam Leiden

SatCen

Space security is strategic for Europe

Galileo/EGNOS

© European Union

Copernicus

© European Union

The Commission proposes to allocate the **€16 billion budget** for the 2021-2027 Space Programme, including Galileo/EGNOS, Copernicus, and the development of to develop new security components i.e. SSA, GOVSATCOM

"Over **10% of the EU's GDP** is already dependent on space-related services"

Vice-President of the Commission Maroš **Šefčovič**

EU SatCen and Space Situational Awareness

Why the EU SatCen is involved in SSA?

- Only EU agency with more than **25 years** of experience in the **Space** and **Security** domains
- "Its expertise in **handling classified information** in **a secure environment** and its **tight institutional links** with the **Member States** is an **asset** facilitating the handling and delivery of SST services" [SST Decision 541]

EU SatCen SSA activities started in 2011

First, with a set of studies and preparatory actions:

- FP7 Support to Precursor SSA Services (SPA) & Support to the development of a European SSA Capability (STEP)
- H2020 Preparation for the establishment of a European SST Service provision function (PASS)
- **Cooperation with EDA/pMS with the Recognised Space Picture study**

Currently, the EU SatCen is the interface for the delivery of operational EUSST Services

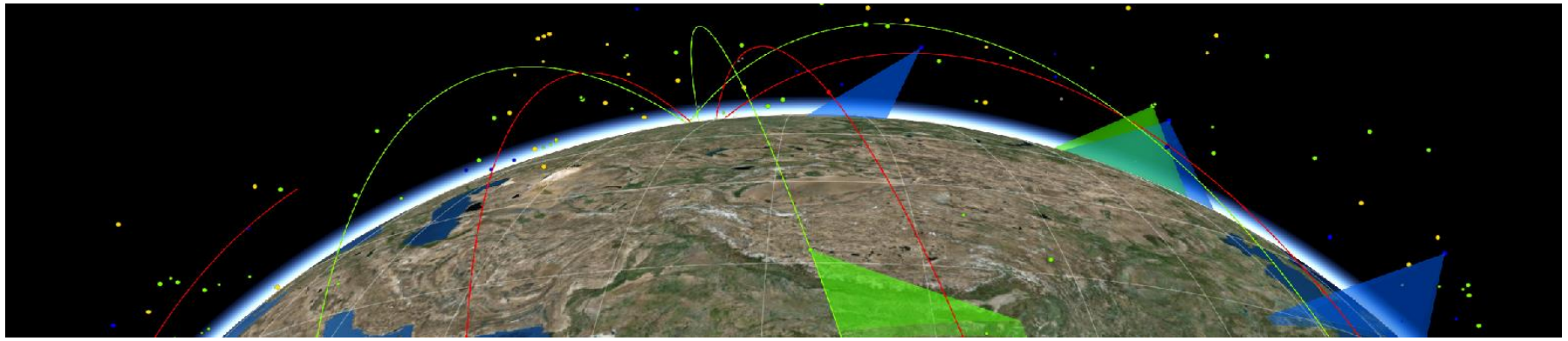
- **EU SST Support Framework implementation (SST-SF) in cooperation with the SST Consortium**

EU SatCen - EDA cooperation on SSA matters

EU SatCen - EDA past cooperation on SSA matters

- Participation in **EDA project team (PT SSA)** with an observer status
- Provision of technical expertise to EDA projects – Capability Armament & Technology: "Display and Data management for a Cooperative **Recognized Space Picture"**

Recognized Space Picture (RSP) Display Study



Fostered discussions between **EDA, EU SatCen and MS** to facilitate a common understanding on **what is RSP, as an objective of SSA/SST Specific Defence Services**

Decision of the European Parliament and of the Council of 16 April 2014 establishing a Framework for Space Surveillance and Tracking Support

« Ensuring the long-term availability of European and national space infrastructure, facilities and services which are essential for the safety and security of the economies, societies and citizens in Europe » (article 3)

With the aim to (article 4):

« Establish a **SST capability at European level** and with an **appropriate level of autonomy** » :

(a) The establishment and operation of a **sensor function** consisting of a network of Member State ground-based and/or space-based sensors, including national sensors developed through ESA, to survey and track space objects and to produce a database thereof;

(b) The establishment and operation of a **processing function** to process and analyse the SST data at national level to produce SST information and services for transmission to the SST service provision function;

(c) The setting up of a function to provide **SST services** as defined in Article 5(1) to the entities referred to in Article 5(2).

SatCen

Space Surveillance and Tracking Support Framework – SST Cooperation

SST Support Framework. supports the **networking and operations** of **SST assets owned by EU countries**, as well as the **EU SatCen**, in order to provide SST services

EU SatCen acts as the SST Front Desk, **the EU Element in the SST SF**, facing SST Users: all **EU MS, EU institutions, satellite owners and operators, and civil protection authorities**

Sensors → Processing → Service Provision

COO (FR)	GSSAC (DE)	ISOC (IT)	S3TOC (ES)	SSAC-PL (PL)	COpE (PT)	COSST (RO)	UKSpOC (UK)	Front Desk (SatCen)

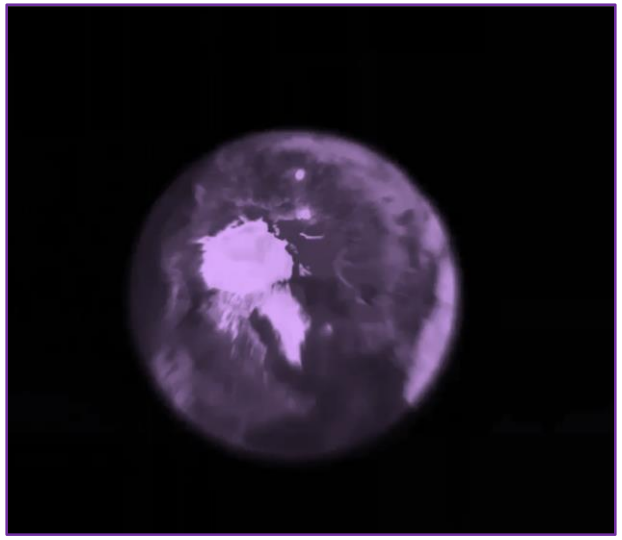
SST Services

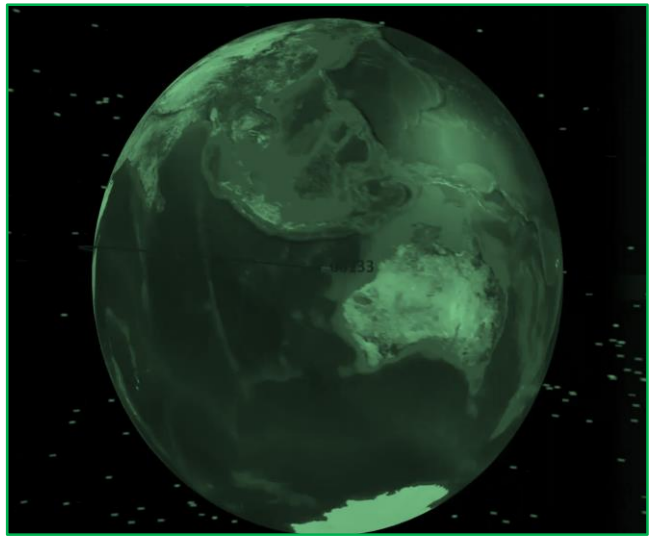
- « The **SST services referred to in Article 4 shall be of a civilian nature**. They shall comprise the following services:

- (a) the **risk assessment of collision** between spacecraft or between spacecraft and space debris and the generation of collision avoidance alerts during the launch, early orbit, in-orbit operation and disposal phases of spacecraft missions;

(b) the **detection and characterisation of in-orbit fragmentations**, break-ups or collisions;

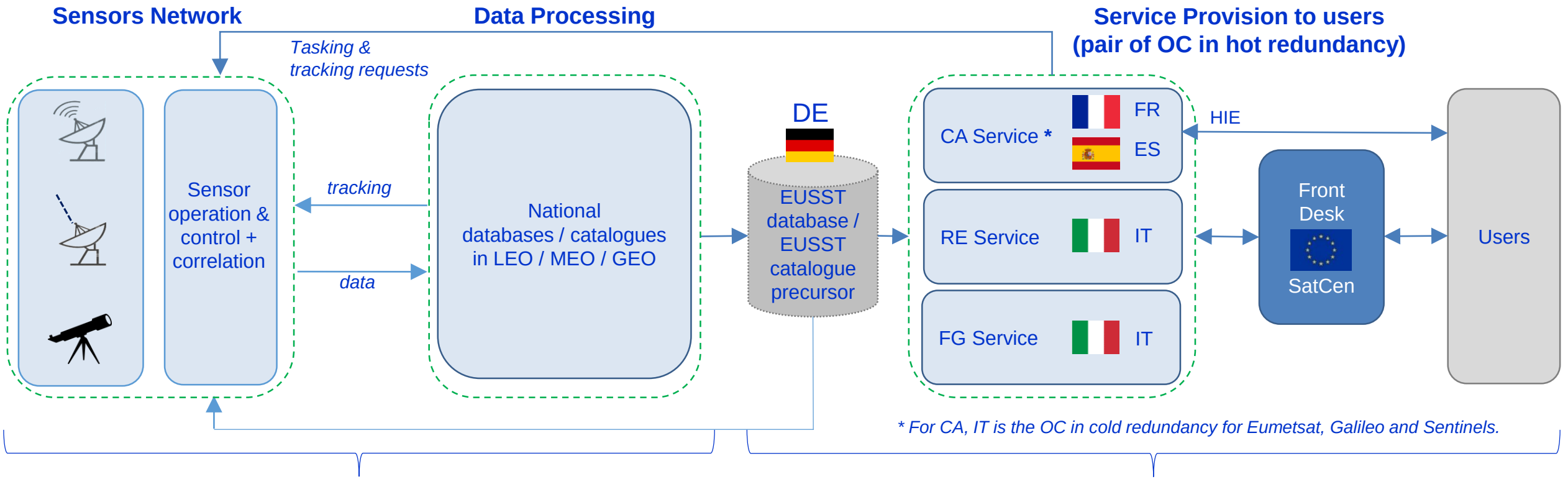
(c) the **risk assessment of the uncontrolled re-entry of space objects** and space debris into the Earth's atmosphere and the generation of related information, including the estimation of the timeframe and likely location of possible impact. **» (article 5)**





User Registration & Service Request :https://sst.satcen.europa.eu

EU SST Service Provision Model



Member States

SST Cooperation

Offline work

COO (FR) | GSSAC (DE) | ISOC (IT) | S3TOC (ES) | SSAC-PL (PL) | COpE (PT) | COSST (RO) | UKSpOC (UK)

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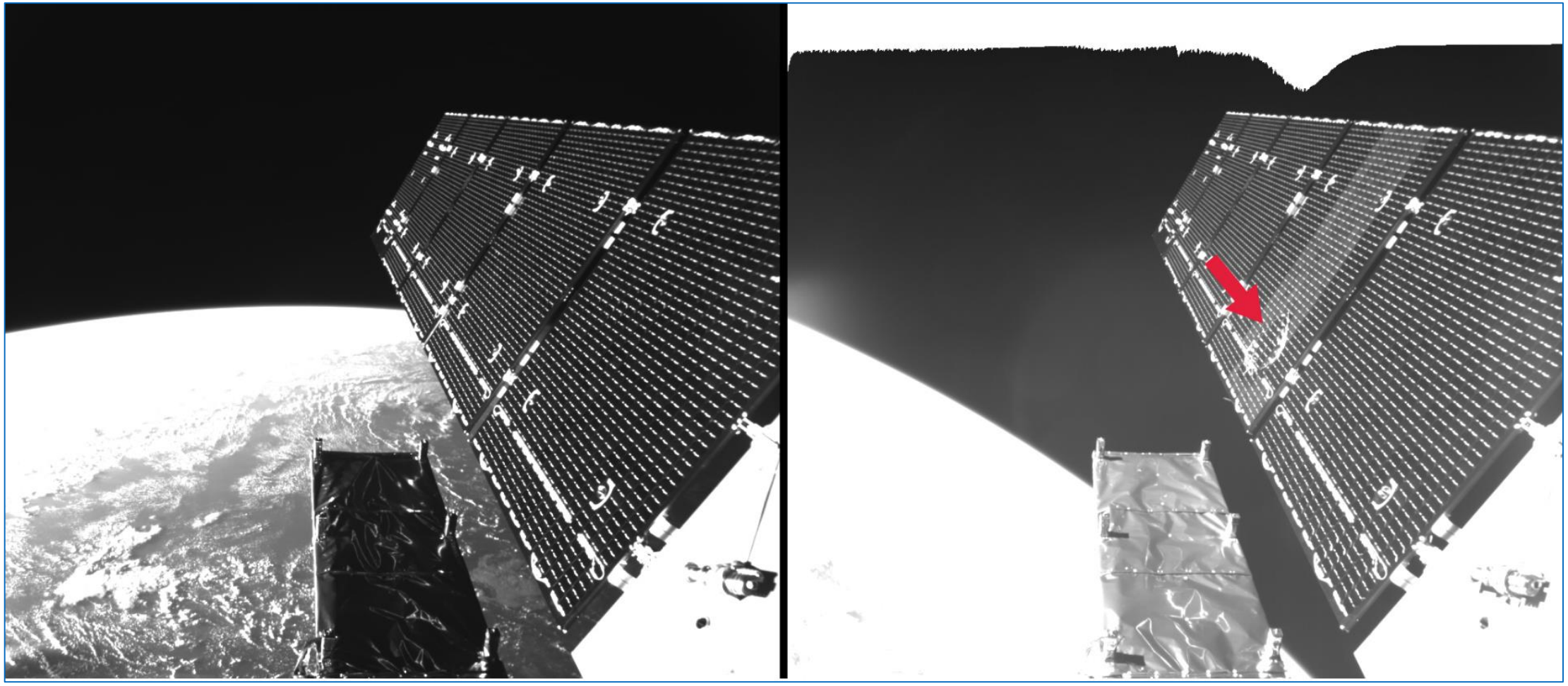
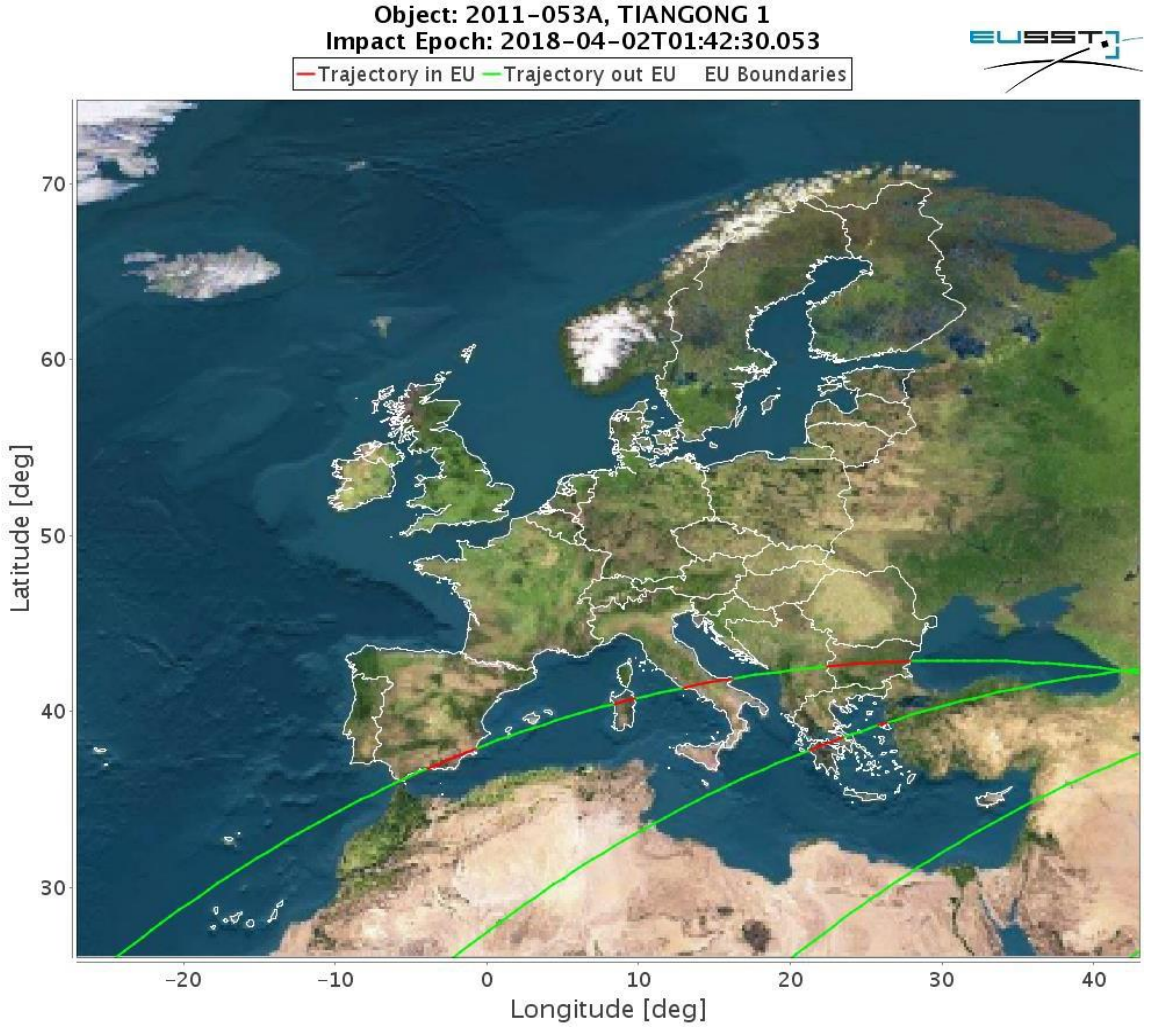
Sentinel 1A event - 2016/08/23

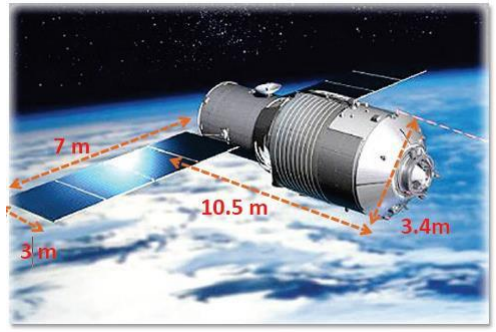


© ESA

Estimates indicate that the size of the particle was of a few millimetres…

Re-entry of Tiangong 1 - 2018/04/01

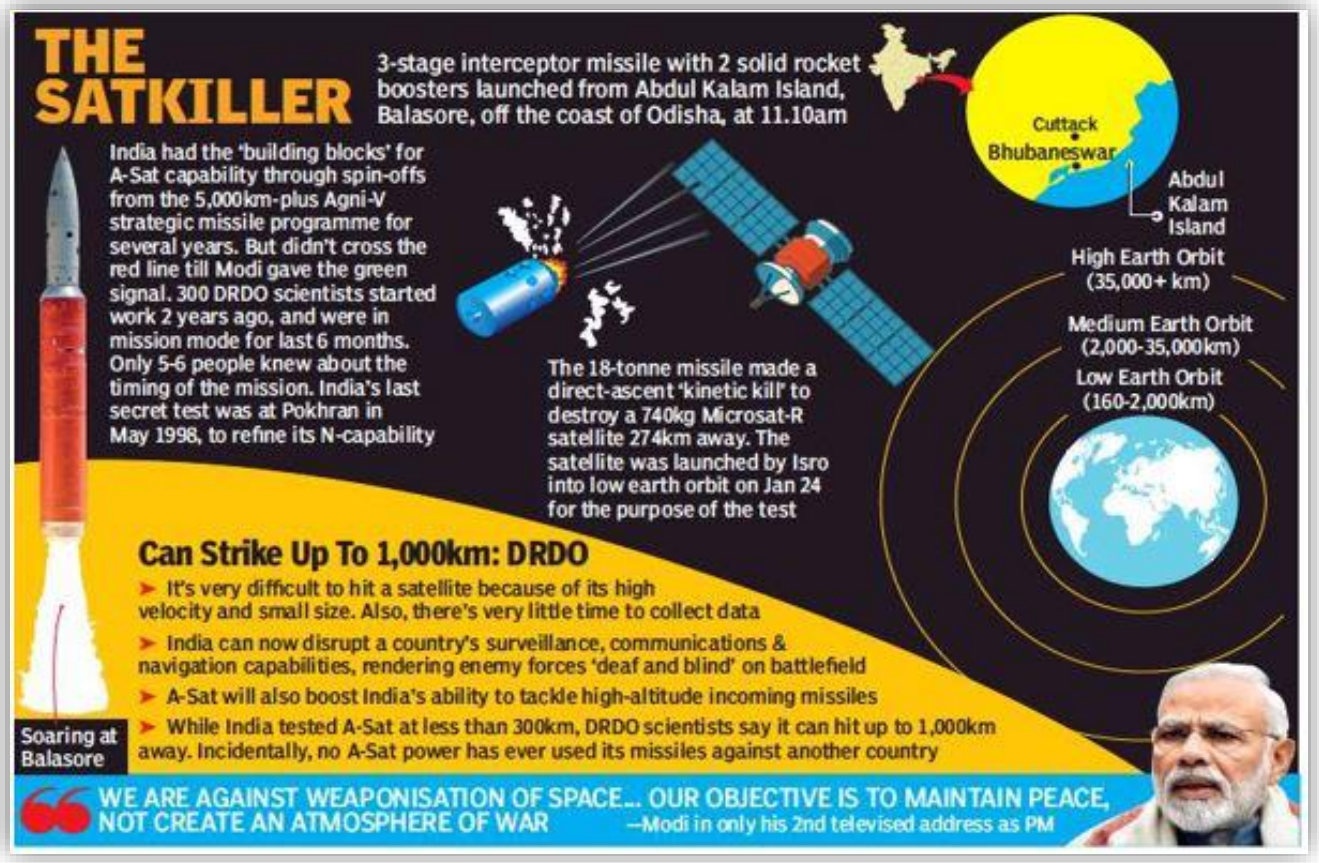




Object Description	
Type	Payload
Int'l Designation	2011-053A
NORAD Number	37820
Launched	30 September 2011 @ 03:16:03.507 UTC
Site	Jiuquan Satellite Launch Center, China
Orbit	197km x 344 km – 42,78 deg. (14 times re-orbited)
Mission	Tiangong-1, First Chinese Space Station
Mass	8500 kg at launch
Dimensions	10,5m x 3.4m x 17m
Solar panels	2 panels (approx. 7m x 3m)

Indian Microsat-R ASAT – 27/03/2019

Credit: Press Information Bureau Government of India



Credit: Times of India

Indian Microsat-R ASAT – 27/03/2019

WorldView-3, 11 Mar 2019
Pléiades-1, 28 Mar 2019
Previous missile launches scorch marks
Unidentified equipment
Nail mounted launch preparation shelter
Pléiades-1, 28 Mar 2019
Pléiades-1, 28 Mar 2019
Pléiades-1, 28 Mar 2019

João Alves
Head of SSA
joao.alves@satcen.europa.eu

NATO UNCLASSIFIED
RELEASABLE TO AUS, FIN, SGP, SWE

SCI-311 Research Task Group (RTG) Collaborative Space Domain Awareness (SDA) Data Collection and Fusion Experiment

Carolyn Sheaff
Information Directorate
Air Force Research Laboratory

SCI-311 RTG: Collaborative Space Domain Awareness (SDA) Data Collection and Fusion

Team Leader:	USA
Invited:	All NATO nations, plus PfP nations FIN, SWE, AUS
Willing:	DEU, ESP, FRA, GBR, ITA, NLD, POL, ROU, USA, JAPCC
Desired:	NCIA, ACT, ACO, JToES, BiSCSWG, JCGISR, SET, SAS, IST, MSG
Duration:	Apr 18 – Jul 20
Related Activities:	SCI-229 RTG, SCI-238 RSM, SCI-279 RTG, SCI ET-036, others

Objectives:

- Experimental demonstration effort to collect, share, and fuse SDA information among member nations

Topics/themes:

- Space Object Tracking
- Satellite Radio Frequency Interference (RFI)
- Space environment (weather) conditions affecting spacecraft
- Data fusion algorithms
- Decision Support communication concepts, tools and methods for communicating changes in the space domain

Impact and Exploitation:

- Identify, evaluate, extend, and validate common formats/standards needed to enable a basic space data exchange/storage capability across NATO, improve interoperability and overall SSA
- Explore and evaluate new collaboration tools, processes, and procedures to inform future investments and developments, including data fusion approaches
- Support Space Capability Preservation Long Term Aspect (LTA) requirement through improved SSA
- Provide knowledge and input to emerging NATO Space Policy

NATO Space Situational Awareness

NATO and military operations are becoming increasingly dependent on space-based capabilities

- NATO has established a Long Term Aspect (LTA) requirement for NATO Space Capability Preservation
- SSA is a key component of Space Domain Awareness (SDA) relevant to conducting effective space operations
- A shared Common Operating Picture (COP) of the space domain and a common integrated environment within the NATO space planning and operations domains is necessary:
  - Ensure timely exploitation of space-related data and products,
  - Facilitates improved SSA
  - Ensures robust SDA for NATO and its nation partners

LTA Framework for NATO Space Capability Preservation

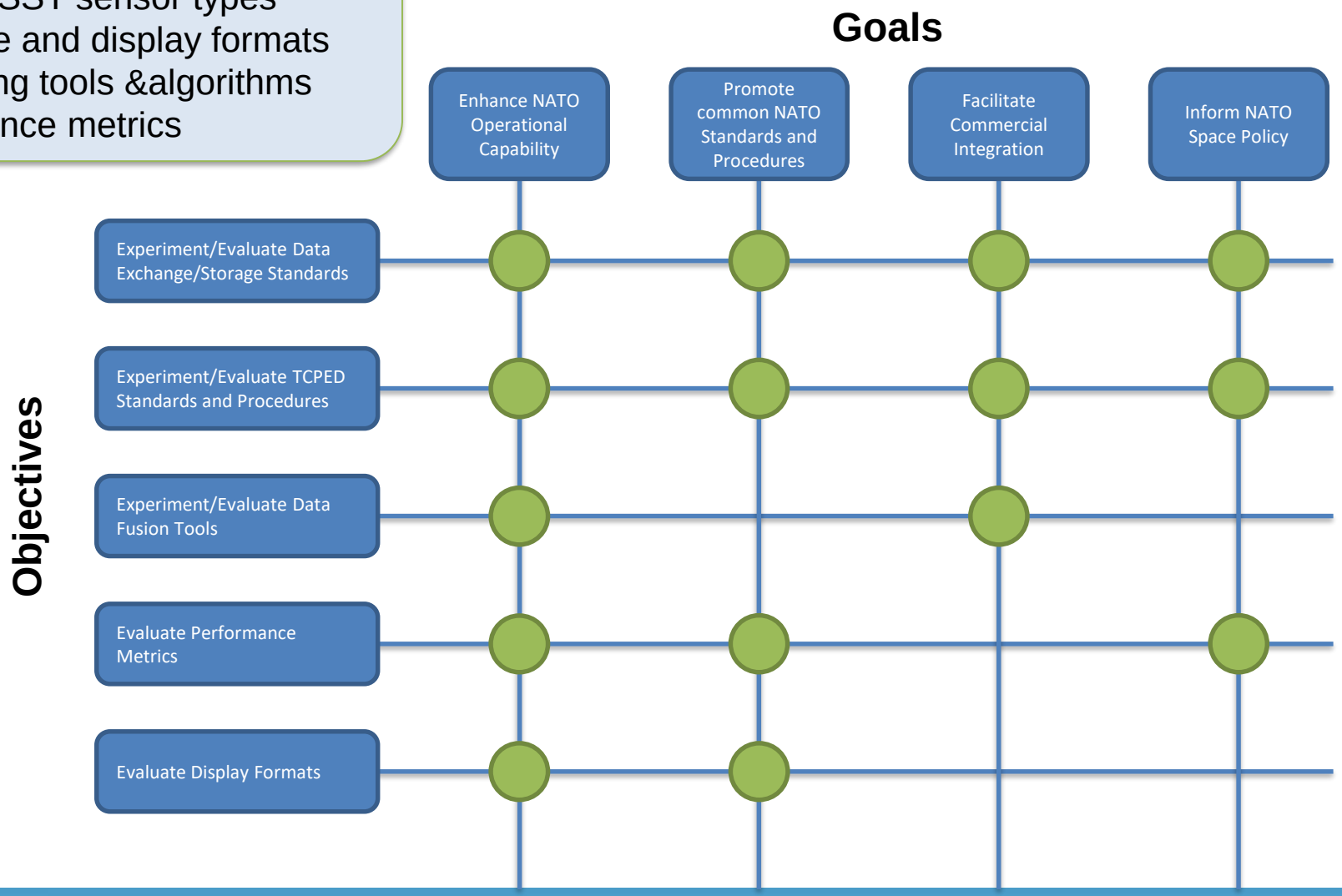
Equity and Dependency	Risk and Threat	Accommodation / Reconstitution
• NATO-wide dependency analysis – Identification of critical current and anticipated NATO space dependencies • Assess implications of loss of critical NATO space capabilities – Characterize required attributes for mitigating solutions	• Current and future risks and threats – Environmental – Unintentional interference – Hostile threats • Space situational awareness and operational threat characterization – NATO-common SSA operational picture – Warning and assessment functions – Attack and interference attribution	• Functional prioritization – Priorities for mitigating courses of action • Effects mitigation (a priori) – Debris effects minimization – Blue force status monitoring – CONOPS (non-material solutions) • Contingency measures (a posteriori) – Mutual assistance planning – Non-space functional surrogates • Functional Reconstitution – Responsive space – Non-space options

NATO Science and Technology Organization (STO), Collaboration Support Office (CSO), Systems Concepts and Integration (SCI) Panel SSA Activities

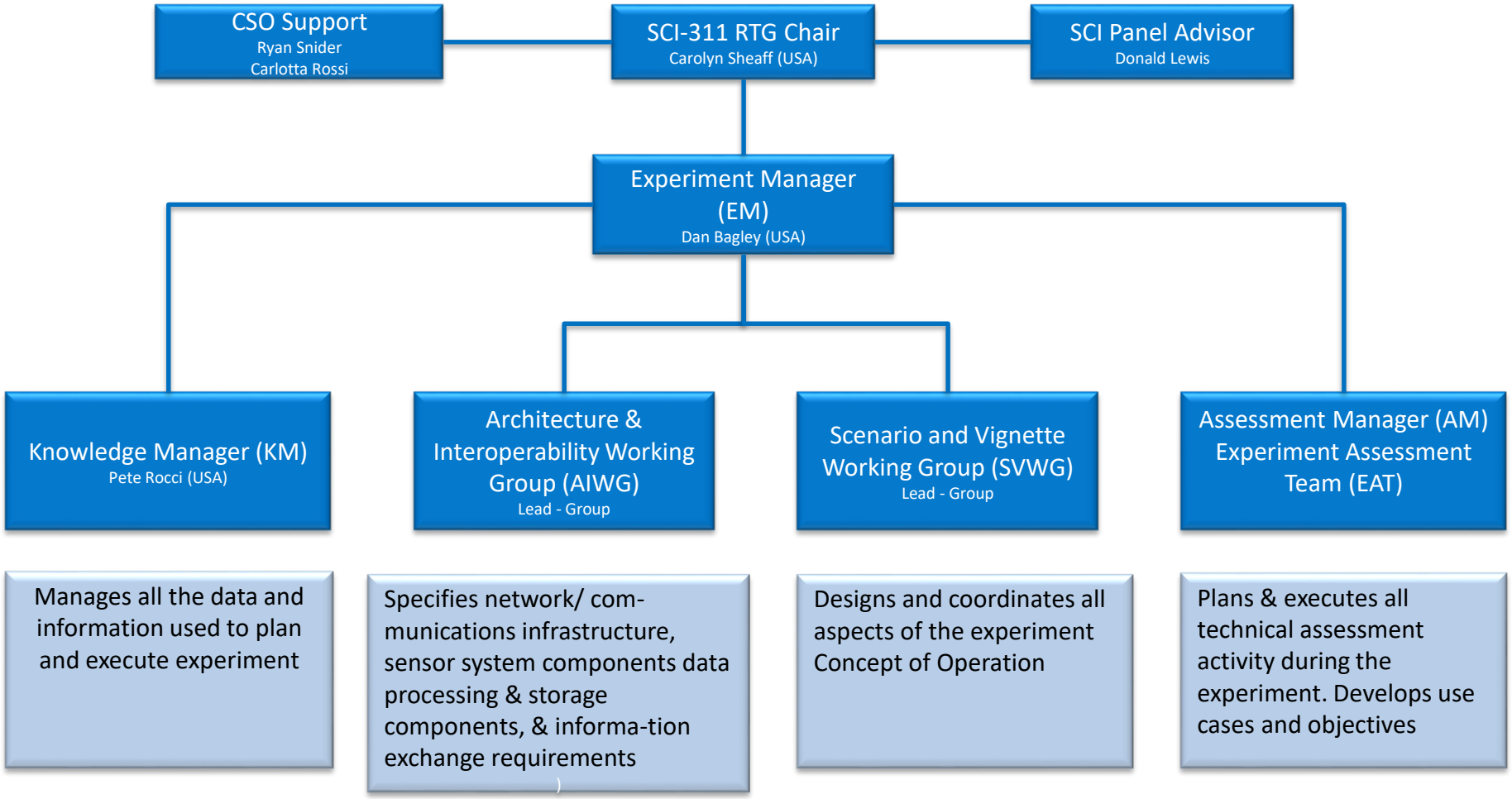
- **NATO SCI-279 RTG:** "Requirements for a NATO Common Space Domain Awareness (SDA) Operating Picture"
  - Recommended NATO begin experimenting with collaborative collection, processing, and analysis efforts
- **NATO Exploratory Team (ET-036):** "Collaborative Space Domain Awareness Data Collection and Fusion" formed to:
  - Assess the realistic opportunities for national-level space domain data to be shared within NATO
  - Recommended the formation of a new Technical Activity Proposal (TAP), which subsequently was approved as the SCI-311 RTG
- **NATO SCI-311 RTG:** Collaborative Space Domain Awareness (SDA) Data Collection and Fusion Experiment"
  - Mutually agreed-upon collaborative activity that involves the collection and exchange of SDA data and information.
  - Addresses the basic technologies and approaches necessary to conduct collaborative space object tracking, orbit determination, orbit prediction, conjunction analyses, re-entry analyses, maneuver detection, and data fusion
  - Globally-distributed ground sensors and processing, storage, and visualization capabilities

Collaborative space object tracking
- Different SST sensor types
- Exchange and display formats
- Processing tools &algorithms
- Performance metrics

SCI-311 RTG Traceability Matrix



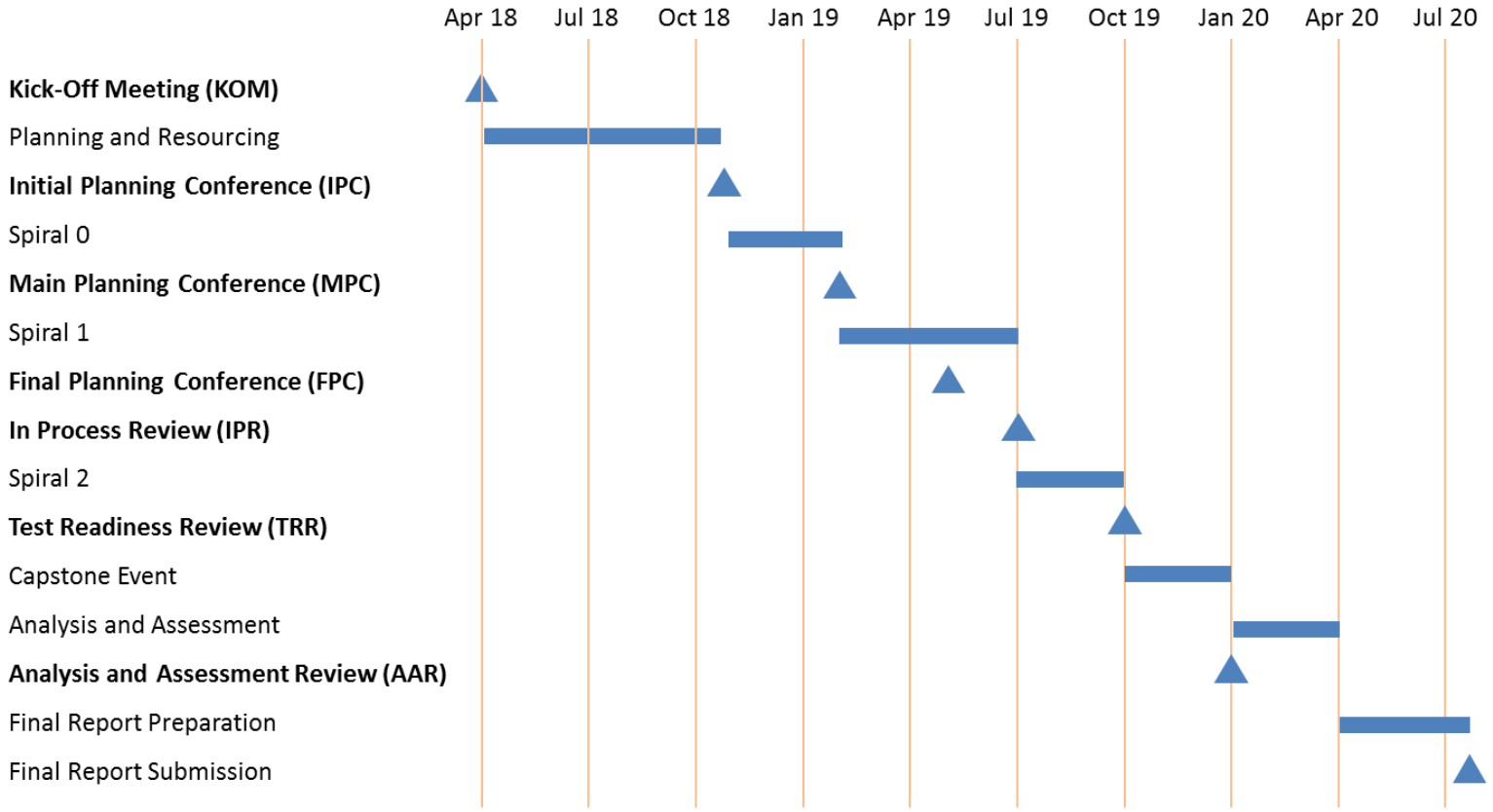
SCI-311 RTG Experiment Management Team



SCI-311 RTG Schedule

Structured as three incremental Spirals and a single Capstone Event:

- **Spiral 0** – Data Exchange Validation, Oct 2018 – Feb 2019
- **Spiral 1** – Medium Earth Orbit (MEO) Sensor Calibration and Tracking, Feb – Jul 2019
- **Spiral 2** – Geostationary Earth Orbit (GEO)/Low Earth Orbit (LEO) Sensor Calibration & Tracking, Aug-Oct 2019
- **Capstone Event** -- Oct – Dec 2019



Spiral 0 – Data Exchange Validation
Execution Period: Oct 18 – Feb 19

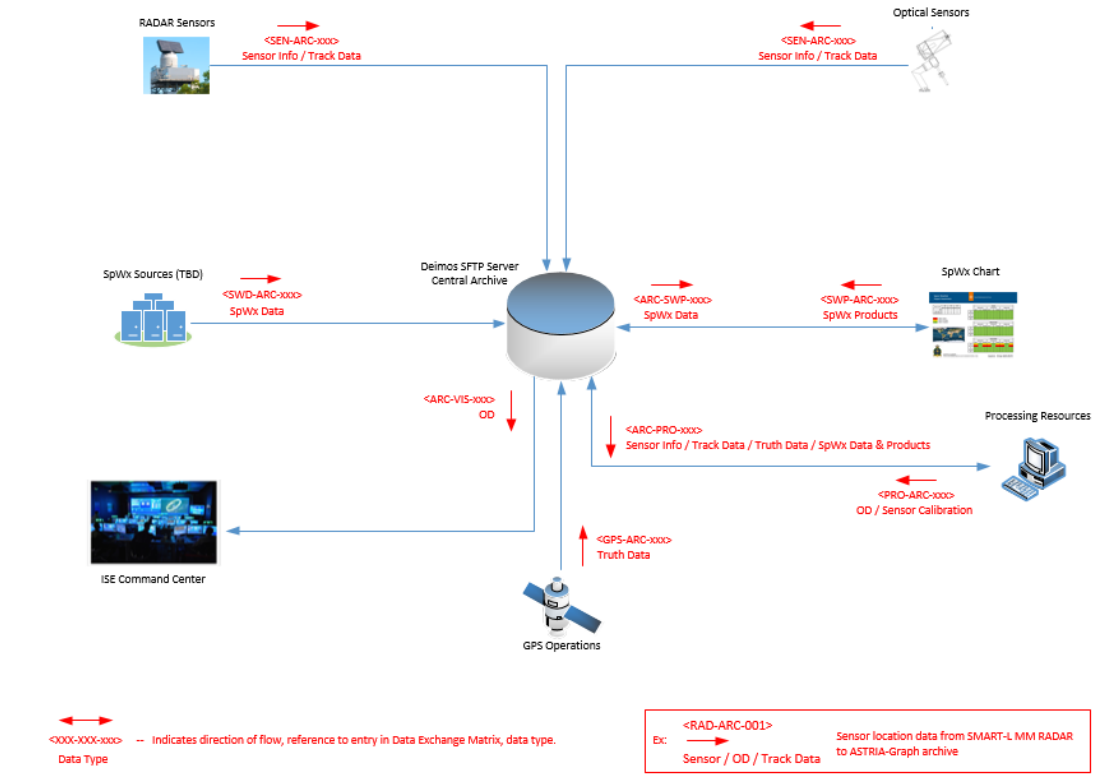
Description

- Simple data exchange validation
- Use Deimos SFTP Server as central repository
- Single Master Data Asset Characteristics (MDAC) Excel spreadsheet
- Common data formats specified for each data type/standard naming conventions established
- Use existing or simulated data (no new collections)
- Spiral 0 Data Evaluation and Assessment Spreadsheet (DEAS)

Measure of Performance (MOPs)

- Interoperability Measurement and Assessment
  - Ability to exchange (post and ingest) other providers' data
  - Ability to use (compute and/or display) other providers' data
  - Annotate Spiral 0 results in Data Evaluation and Assessment Spreadsheet (DEAS)

Spiral 0 Architecture



Spiral 0 – Data Exchange Validation
Execution Period: Oct 18 – Feb 19

Findings

- A significant portion of the specified data exchange validations were not accomplished as scheduled. Weather played a large role
- Some participants could not access the central archive directly, due to firewall and other issues
- Some participants did not post their data using the agreed SCI-311 RTG file naming convention
- The Consultative Committee for Space Data Systems (CCSDS) Tracklet Data Message (TDM) standard may not be sufficient for all situations
- Some sensor systems implemented TDM 2.0 (which requires magnitude), while others used TDM 1.0 (which does not allow reporting of magnitudes)

Spiral 0 Data Evaluation and Assessment Spreadsheet (DEAS)

To do	For Data Sources: Fill in respective cells, indicating whether data was uploaded successfully For Processing Resources: Fill in respective cells to indicate if data was found and processed successfully

			Data Sources				Airbus Robotic Telescope (ART) Processing (DEU)						DLR Processing (DEU)					
	Data Type	Architecture Designator	Source	Expected Data Format	Data Uploaded?	Remarks	Architecture Designator	Access?	Find?	Downld?	Process/ Display?	Remarks	Architecture Designator	Access?	Find?	Downld?	Process/ Display?	Remarks
	Sensor Location and Characteristics						ARC-PRO-001						ARC-PRO-002					
			0	0	Y													
	Tracklets																	
		SEN-ARC-001	ART (DEU)	CCSDS TDM (KVN)	S	SCI-311 RTG filename convention not used	ARC-PRO-009						ARC-PRO-041	Y	Y	Y	N	no magnitude given
		SEN-ARC-002	DLR Sensor1 (DEU)	CCSDS TDM (KVN)	S	SCI-311 RTG filename convention not used properly. SMART-01-B	ARC-PRO-010						ARC-PRO-042					
		SEN-ARC-003	DLR Sensor2 (DEU)	CCSDS TDM (KVN)		nothing uploaded	ARC-PRO-011						ARC-PRO-043					
		SEN-ARC-004	DLR Sensor3 (DEU)	CCSDS TDM (KVN)		nothing uploaded	ARC-PRO-012						ARC-PRO-044					
		SEN-ARC-005	DeSS Centu1 (ESP)	CCSDS TDM (KVN)	S	SCI-311 RTG filename convention not used. Cannot determine sensors from names	ARC-PRO-013						ARC-PRO-045	Y	Y	Y	Y	naming convention incorrect
		SEN-ARC-006	DeSS Tracker1 (ESP)	CCSDS TDM (KVN)	S		ARC-PRO-014						ARC-PRO-046	Y	Y	Y	Y	naming convention incorrect
		SEN-ARC-007	DeSS Tracker2 (ESP)	CCSDS TDM (KVN)	S		ARC-PRO-015						ARC-PRO-047	Y	Y	Y	Y	naming convention incorrect
			ANSY		S									Y	Y	Y	Y	naming convention incorrect
		SEN-ARC-008	SST E2E (ESP)	CCSDS TDM (KVN)	S		ARC-PRO-016						ARC-PRO-048					
		SEN-ARC-009	SMART-L MM (NLD)	CCSDS TDM (KVN)	S	SCI-311 RTG filename convention not used ("THALES" stationID versus specified "SMARTL", underline in sensorname)	ARC-PRO-017						ARC-PRO-049	Y	Y	Y	N	angle1 is given twice
		SEN-ARC-010	PST2 (POL)	CCSDS TDM (KVN)		nothing uploaded	ARC-PRO-018						ARC-PRO-050					
		SEN-ARC-011	Polonia1 (POL)	CCSDS TDM (KVN)		nothing uploaded	ARC-PRO-019						ARC-PRO-051					
		SEN-ARC-012	SOLARIS 2 (POL)	CCSDS TDM (KVN)		nothing uploaded	ARC-PRO-020						ARC-PRO-052					
		SEN-ARC-013	SOLARIS 3A (POL)	CCSDS TDM (KVN)		nothing uploaded	ARC-PRO-021						ARC-PRO-053					
		SEN-ARC-014	SOLARIS 3B (POL)	CCSDS TDM (KVN)		nothing uploaded	ARC-PRO-022						ARC-PRO-054					
		SEN-ARC-015	Penoptes-PIRATE (POL)	CCSDS TDM (KVN)		nothing uploaded	ARC-PRO-023						ARC-PRO-055					
		SEN-ARC-016	Penoptes-COAST (POL)	CCSDS TDM (KVN)		nothing uploaded	ARC-PRO-024						ARC-PRO-056					
		SEN-ARC-017	Penoptes-MAM (POL)	CCSDS TDM (KVN)		nothing uploaded	ARC-PRO-025						ARC-PRO-057					
		SEN-ARC-018	TO-30 BITNET (ROU)	CCSDS TDM (KVN)	S	SCI-311 RTG filename convention not used properly.	ARC-PRO-026						ARC-PRO-058	Y	Y	Y	N	magnitude missing
		SEN-ARC-019	TO-30 AROAC (ROU)	CCSDS TDM (KVN)	S	SCI-311 RTG filename convention not used properly.	ARC-PRO-027						ARC-PRO-059	Y	Y	Y	N	magnitude missing
		SEN-ARC-020	L5.6 BITNET (ROU)	CCSDS TDM (KVN)		nothing uploaded	ARC-PRO-028						ARC-PRO-060					
		SEN-ARC-021	L5.6 AROAC (ROU)	CCSDS TDM (KVN)		nothing uploaded	ARC-PRO-029						ARC-PRO-061					
		SEN-ARC-022	S. AUS 1 TASKABLE (USA)	CCSDS TDM (KVN)	Y	will be updating with real data	ARC-PRO-030						ARC-PRO-062	Y	Y	Y	N	no station coord given, and all the same
		SEN-ARC-023	S. AUS 2 TASKABLE (USA)	CCSDS TDM (KVN)	Y	will be updating with real data	ARC-PRO-031						ARC-PRO-063					
		SEN-ARC-024	S. AUS 3 FIXED (USA)	CCSDS TDM (KVN)	Y	will be updating with real data	ARC-PRO-032						ARC-PRO-064					

Spiral 1 – MEO Sensor Calibration and Tracking
Execution Period: Feb 19 – Jul 19

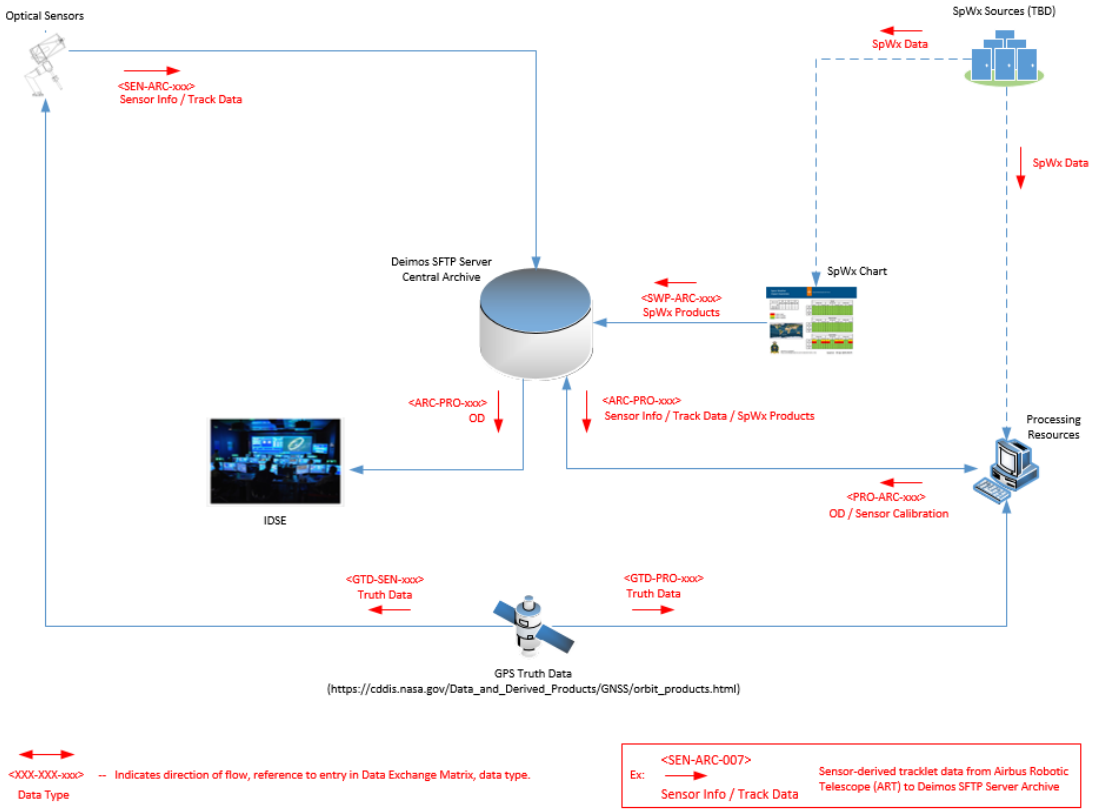
Description

- Sensor location and characteristics information consolidated into a single Master Data Asset Characteristics (MDAC)
- Common data formats, standard naming conventions
- Deimos SFTP Server as central repository
- Calibrate sensors using GPS targets and publicly-available GPS truth data
- Orchestrated collaborative collection on select GPS target satellites,
- Formulate tracklets - Perform Orbit Determination (OD)
  - Use Cases:
- Multiple sensors tracking same object during same time period
- Multiple sensors tracking same object during different parts of its orbit (coordinated “hand-off”/blended solution)

Measure of Performance (MOPs)

- Precision/accuracy of orbit solutions
  Percentage of given satellite orbit that is observable

Spiral 1 Architecture



Spiral 2 – GEO/LEO Calibration and Tracking Overview

- Conduct collaborative GEO/LEO tracking effort
  - Plan and conduct orchestrated collection on select target satellites, formulate tracklets
  - Perform Orbit Determination (OD) from tracklets provided by multiple sensors across several processing resources, compare the results
  - Use Cases:
    - Multiple sensors tracking same object during same time period, compare results
    - Multiple sensors tracking same object during same time period, some type of blended solution
    - Multiple sensors tracking same object during different parts of its orbit (with coordinated "hand-off"), some type of blended solution

- Measures of Performance (MOPs)
  - Precision/accuracy of orbit solutions (via observation by multiple sensors, geographic diversity, filtered solutions)
  - Percentage of given satellite orbit that is observable (increased coverage due to use of multiple, collaborative sensors vs a single sensor)
  - Other possible MOPs To Be Determined

SCI-311 RTG Recap

Experiment	A trial-and-error process in search of a good solution for the left side of the hypothesis paradigm to fill a capability gap. Typical experiment questions are expressed as ”Does this approach produce a favorable outcome?’’ and ‘‘Can this problem be solved with X?’
Collaboration	Two or more entities working together to realize or achieve a shared goal.
Consensus	•Multiple views are expressed and discussed among the collaborating parties •A solution or decision is proposed, based on a preponderance of appeal (general agreement) evident in one particular option •Consensus is reached when everyone can answer “yes” to the question: “Can you live with it?”
Transition	Follow-on developments and demonstrations to further advance technology and/or procedures

Systems Concepts and Integration Panel, SCI-318 Specialists' Meeting on

'The Space Domain and NATO Operations
A Critical S&T Review'

Army Education & Training Command, and School of Applied Military Studies
Turin, Italy, 26 June 2019

NATO STO - AVT Panel Space Activities

Prof. A. R. Aslan, Dr. V. Wickramasinghe and Dr. W.K.Belvin
AVT-336 Co-Chairs

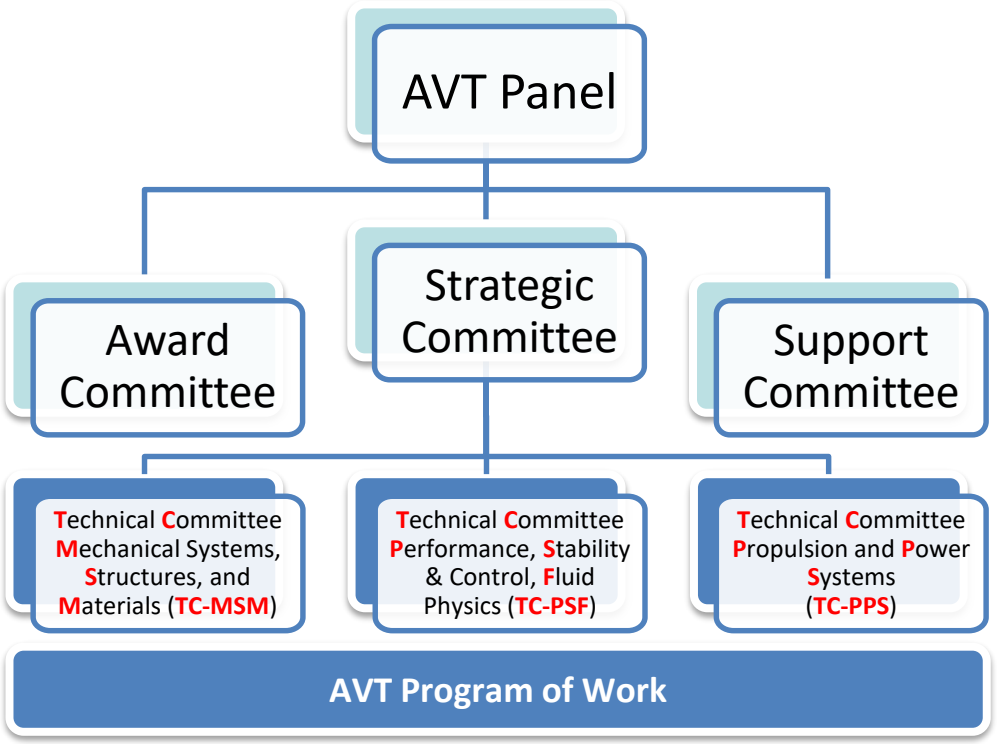
As one out of seven STO expert panels AVT works platform relevant technologies from the 'cradle to the grave' in all domains.

"Improve **performance**, **affordability**, and **safety**

of **vehicle**, **platform**, **propulsion** and **power systems**

operating in **all environments** for **new** and **ageing systems**

through **advancement** of **appropriate technologies**"



The Technical Committees are the engine of AVT's Programme of Work,…

*"The TC **Mechanical Systems, Structures & Materials** covers all technical aspects (…) concerning the full range of technologies relevant to **vehicle and platform mechanical systems and structures**.*

vehicle and platform concepts and design / multidisciplinary design and optimization / structural loads and dynamics / structural aspects of aero elasticity and fluid structure interaction / structural aspects of stability and control / noise and vibration control / structural materials and manufacturing processes / smart and multifunctional materials and structures / non-structural materials / environmental effects / corrosion, fatigue and other degradation mechanisms / failure mechanisms, life prediction and health monitoring / (non destructive) inspection, certification and safety / reliability maintenance and repair / affordability, availability, survivability and supportability / test facilities, techniques and instrumentation"

ToR TC MSM

Forward Looking Topics worked by MSM

- Autonomous Ground Mobility
- Advanced Materials and Manufacturing
- Integration of Augmented Reality in vehicle designs
- Proactive maintenance technologies
- Platform technologies for Small Satellite Constellations
- Anti-tamper protective systems

Where we would like to do more

- Cyber-Physical Systems
- AI enabled Material & Structure design
- Consequences of increased level of autonomy on platforms
- Robotics / Exoskeletons
- Novel structures

…by providing a forum for subject matter experts with a minimum bureaucratic burden…

*"The TC **Performance, Stability & Control, Fluid Physics** covers all technical aspects (…) concerning **Performance, Stability & Control as well as Fluid Physics.***

Multidisciplinary Vehicle Design and Analysis / Mission Performance Enhancement / Stability and Control / Aero- and Hydro-dynamics / Theoretical, Experimental and Computational Fluid Dynamics / Aerothermodynamics / Aero- and Hydro-acoustics / Aeroservoelastics / Fluid-structure interactions / Integration of Propulsion Systems with Vehicle / Vehicle Dynamics"

ToR TC PSF

Forward Looking Topics worked by PSF

- Virtual design Validation & Verification of air and sea platforms
- Set-based design
- Advanced IR and aero-acoustic modelling & integration
- Future Vertical Lift
- Hypersonic flow physics
- Innovative Control Effectors

Where we would like to do more

- Human-Machine-Teaming
- Miniaturization

…the AVT Panel allows its members to focus on the development of activities and the review of specific scientific contents.

"The TC PPS covers all technical aspects (…) concerning both ***legacy and new propulsion, (electrical) power and thermal as well as energetic systems.***

air-breathing (e.g. piston, gas turbine, ramjet, scramjet) / air-independent, solid and liquid propellant rocket / electric drive and hybrid systems / electrical generation (e.g. shaft driven generators, fuel cells and photo voltaic cells) / electrical distribution systems (including conversion and protection) / air, liquid and two-phase environmental conditioning systems / energy storage devices (e.g. batteries and super-capacitors) / materials, pyrotechnics, explosives and propellants used in munitions and rocket motors / standard and alternative fuels"

ToR TC PPS

Forward Looking Topics worked by PPS

- Advanced Health Management Systems
- Alternative fuel & energy sources
- Hybrid- / electrical aero-propulsion
- Scarcity of raw materials & pre-cursors
- New energetic materials
- Hypersonic Operational Threats

Where we would like to do more

- Adaptive / Variable Cycle Engines
- Air-Breathing Engines
- Energy Storage & Distribution

SPACE DOMAIN TECHNICAL WORK in AVT

AVT #	TITLE	YEARS
AVT-ET-078	Lightweight Multifunctional Space Structures for Micro Satellites and Space Vehicles	10.2006-10.2007
AVT-ET-079	Small Spacecraft Technologies	10.2006-10.2007
AVT-ET-087	Systems Requirements Review for Small and Multifunctional Spacecraft	10.2007-10.2008
AVT-171 (RWS)	Multifunctional Structures and System Technologies for Small Spacecraft	04.2009-12.2010
AVT-ET-110	Risk and Reliability Assessment and Validation for Small Spacecraft	10.2010-10.2011
AVT-210 (RSM)	Risk and Reliability Assessment and Validation for Small Spacecraft	01.2012-12.2013
AVT-ET-138	Small Satellite Performance Validation Concepts and Approaches	10.2013-10.2014
AVT-257 (RSM)	Best Practices for Risk Reduction for Overall Space Systems	01.2015-12.2016
AVT-ET-181	Investigation of NATO Mission Priorities for Small Satellite Constellation Platform Technologies	10.2017-10.2018
AVT-336 (RSM) (SCI)	Enabling Platform Technologies for Resilient Small Satellite Constellations for NATO Missions	01.2019-12.2020

SPACE DOMAIN TECHNICAL WORK in AVT

AVT #	TITLE	YEARS
AVT-ET-152	Assessment of Capabilities for First-Principles Simulation of Spacecraft Electric Propulsion Systems and Plasma Spacecraft Environment	10.2014-12.2015
AVT-LS-262	Space Debris Reentry and Mitigation	10.2014-12.2015
AVT-LS-263	Electric Propulsion Systems: From Recent Research Developments to Industrial Space Applications	10.2015-12.2016
AVT-267 (RWS)	Future of Manufacturing for Military Applications	01.2016-12.2018
AVT-271 (RWS)	Research Directions for First-Principles Simulation of Spacecraft Electric Propulsion Systems and Plasma Spacecraft Environment	10.2015-12.2016
AVT-294 (RTG)	Towards Improved Computational Tools for Electric Propulsion	01.2018-12.2020
AVT-ET-189	Future Directions for the use of Additive Manufacturing in NATO Operations	01.2019-12.2019

AVT BACKGROUND on SPACE

- **Since early 2000s the AVT panel has been actively engaged in assessment of Smallsats for efficient use in NATO military operations.**
- **In 2010 in Antalya, Turkey, the AVT 171 technical team held a Workshop on "*Multifunctional Structures and Systems Technologies for Small Spacecraft*", and identified a number of important technologies that must be developed to realize the full capability and value of the use of small satellites.**
- **The primary technology identified in order to meet mission objectives and performance at optimum cost was verification of the system in light of the mission defined risks and required reliability.**

BACKGROUND on SPACE

- **A follow on ET (AVT-ET-110) and a Technical Team (AVT-210) is established to investigate "*Risk and Reliability Assessment and Validation for Small Spacecraft*".**
- **The ET-110 has identified the need for new approaches and techniques for validation in order to more completely access the benefits of Smallsats and proposed a plan to identify the elements of these new approaches through a follow-on Technical Team AVT 210.**
- **A mini-workshop was held in 2012 to define the key technology topics around which to focus the investigation.**

BACKGROUND on SPACE

- **Once the scope of AVT-210 was obtained, it was decided to hold a Specialist's Meeting in order to assess the state of the art and emerging technologies and processes of NATO's small space vehicle community.**
- **The objective of the Specialist's Meeting was to investigate best practices used and concepts proposed in current small sat programs to assess and evaluate risk and the associated reliability to tailor design and verification standards for low cost spacecraft.**
- **The Specialist's Meeting was designed to promote the exchange information among the NATO small satellite community. As a result, Five (5) key recommendations were drawn from the discussions:**

BACKGROUND on SPACE

1. **Risk must be established based on mission requirements**
   - Must reflect military needs
2. **Need to establish standards for Smallsats**
   - should be international
   - Should be tailorable
3. **Need to promote utilization of plug and play architecture**
4. **Need to perform trade-off studies of design, analysis, test**
   - Establish best practices from which to choose
5. **Need for available and accessible low cost launch vehicles**
   - Provide replacement for non-successful launches or S/C failures

BACKGROUND on SPACE

- **Based on the recommendations of AVT-210 Specialist Meeting on "Risk and Reliability Assessment and Validation for Small Spacecraft" a new ET is proposed.**
- **This ET named "AVT-ET-138, Small Satellite Performance Validation Concepts and Approaches" reviewed the results and recommendations of this Specialist Meeting together and develop a plan to implement the recommendations in order to improve confidence in verification of reliability for cost and time effective Smallsats by considering whole life cycle of spacecraft.**

BACKGROUND on SPACE

- As a result a follow on TT AVT 257 "Best Practices for Risk Reduction for Overall Space Systems" was established with a goal to investigate the most effective means to enhance the projected performance of Small satellites (including Microsats, Nanosats and Picosats) for NATO missions while achieving savings in cost and schedule.
- The primary objective was to bring together experts in relevant fields to review and assess the current state-of-the-art in key technical areas, identify the gaps in technology and define the required next steps.
- A Specialist Meeting was organized and conducted to specifically address three key issues to change the level of risk aversion while enhancing performance of space systems:

BACKGROUND on SPACE

- **Subsystem Compatibility and Integration**: **New interface standards and protocols, including component interchangeability at the unit level based on Commercial-off-the-Shelf (COTS) technology to enable rapid integration with confidence.**
- **Functional Design and System Implementation**: **New system implementation approaches, particularly as a system of spacecraft systems (constellations, co-operation of systems and swarms) including the use of advanced deployable structural concepts, thermally stable structures and other new concepts to provide enhancements in function and performance.**
- **Verification and Validation**: **New lean and agile validation approaches through analysis, simulation and test to achieve acceptable mission risk and to reduce cost to save time. Opportunities to simplify the design and validation of Smallsats hardware at the subsystem, system and system of system levels to more effectively validate the design as implemented to achieve success of the required mission.**

BACKGROUND on SPACE

- **The AVT-257 Technical Team has established the state-of-the-art in key areas for space systems technologies and identified a number of key recommendations to enhance the capability and availability of Smallsats for NATO missions to improve performance and cost effectiveness, and benefit the NATO war fighter.**
- **The advice from other NATO user groups deemed to be necessary to prioritize and act upon these recommendations to enhance the value and responsiveness of Smallsats to the war fighter to be developed in a timely fashion to support future NATO missions.**
- **An Exploratory Team ET-181 was established under AVT Panel to seek input from NATO nations and organizations on the priority of technology development for small satellite constellation platforms based on NATO mission needs.**

BACKGROUND on SPACE

- **A letter was formulated by the team and sent to relevant NATO organizations and national institutions with specifically targeted questions to obtain organizations.**
- **After reviewing and analyzing the responses, a number of platform technologies were identified to effectively operate small satellite constellations.**
- **A Technical Team, AVT-336, is proposed to further communicate and advance enabling platform technologies for resilient small satellite constellations for NATO missions by organizing a Specialized Meeting in 2020.**

To: NATO Allied Command Transformation Group (NATO ACT)
NATO Allied Command Operations (NATO ACO)
NATO Industrial Advisory Group (NIAG)
NATO STO CSO Systems Concepts and Integration Panel (SCI)
NATO STO CSO System Analysis and Studies Panel (SAS)
NATO STO CSO Sensors and Electronics Technology Panel (SET)
NATO STO National Point of Contacts
Subject: Input on technology development for Smallsats

A Technical Team AVT-257 was established under the Applied Vehicle Technology (AVT) Panel to investigate the most effective means to enhance Smallsat platforms for NATO missions while achieving savings in platform cost and schedule. As part of the activity of AVT-257, a Specialist Meeting on “Best Practices for Risk Reduction for Overall Space Systems” was held in October 2016. A key observation repeated during the meeting and reinforced during the plenary discussion was the need to actively engage the user community and S&T subject matter experts early in the process of identifying needs and opportunities for technology advancement.

To accomplish this task, it was also identified that there is a strong need for collaborative work in this area. A follow up Exploratory Team AVT-ET-181 has been established to seek this input, on the priority of technology development for Smallsat constellation platforms for efficient NATO missions, from other NATO organizations. To this end, we request the following information from your organization:

1. Is your organization actively involved in the use or operation of space based assets? If yes, if possible, please give a brief list of those assets/capabilities.
2. What further capabilities are needed from space assets to carry out their missions?
3. In the past, now or near future, have you considered small satellite constellations as a viable approach to meet NATO mission requirements (nation-wide or NATO-wide)? (GPS is an example of a constellation of large satellites). If yes, would you provide a point of contact to discuss details of instruments and platform?

Collected information will be used to prepare a plan for implementation of recommendations, to be used within NATO. Would you kindly send your responses to AVT Office before February 15, 2018?

AVT Panel Chair

Sender	Date	PoC	Country
SCI	12.11.2017	Donald A Lewis <donald.a.lewis@aero.org>	SCI/STB/NATO
Danish Ministry of Defence	20.11.2017	fmi-ma-cho@mil.dk	Denmark
Airbus Defence and Space S.A.U	29.11.2017	paula.saameno@airbus.com	Spain
NCI	7.12.2017	esben@mil.dk	Denmark
IABG mbH (DEU)	11.12.2017	Fokken@iabg.de	Germany
Dutch MoD	12.12.2017	JB.Buijs.02@mindef.nl	Netherlands
Newtec Cy n.v.	20.12.2017	kwil@newtec.eu	Belgium
DSTL	26.0.2018	Michael O'Callaghan	UK
Defenceinovation	1.02.2018	James White <james@defenceinnovation.eu>	EU
FFI	1.02.2018	richard.olsen@ffi.no	Norway
VKI	2.02.2018	masutti@vki.ac.be	Belgium
RHEA	15.02.2018	a.pidgeon@rheagroup.com	Belgium
INTA	16.02.2018	martinefc@inta.es	Spain
SSTL	19.02.2018	m.pointer@sstl.co.uk	UK
AVT	20.02.2018	Technical Observations on Space Support to Operations in TRIDENT JAVELIN 2017'	AVT
ACT	23.02.2018	Robert.kroeger@act.nato.int	NATO ACT
NRC	1.03.2018	Wickramasinghe, Viresh <Viresh.Wickramasinghe@nrc-cnrc.gc.ca>	Canada
NASA LANGLEY	1.03.2018	w.k.belvin@nasa.gov	USA
MSB	1.03.2018	aslanr@itu.edu.tr	Turkey

Recommendations

As a subset of the respondents' survey information, recommendations to consider for Smallsat platform development under AVT include:

- **Spacecraft autonomy to reduce operational burden and ground station vulnerability**
- **Enhanced on-board power/efficiency to enable onboard processing, higher transmission power and higher download rates**
- **More efficient and capable platform systems to devote more resources of power, mass and size to mission payloads**
- **Enhanced spacecraft positional knowledge and control to improve instrument resolution and constellation interoperability**

Possible Impact of the Technology on a Military Capability Blue force implications

- **Smallsats support many different military capabilities as they are able to perform military missions that once were reserved for large spacecraft. There are a number of roles that Smallsats could perform in future military operations.**
- **While it is very unlikely that Smallsats will replace the sub meter (below 0.5m) ISR capabilities of very large spacecraft in the near future, a more realistic possibility is that Smallsats would increase time resolution considerably. The current state of technology may be sufficient to have this.**
- **Today, Smallsats of different size and degrees of autonomy are already used for intelligence, reconnaissance and surveillance missions, taking advantage of the fact that Smallsats can have very short revisit times and can be positioned flexibly near potential targets.**

Red force implications

- **Since Smallsats can be developed in short times and with affordable budgets they may also be used as a threat to NATO space assets.**
- **The real cost is placing the Smallsats in relevant orbits requiring launch vehicle capability which is today only owned by a small number of space fairing nations.**
- **The launch capacity may be obtained through Russia and China. All launches being monitored closely by international community gives time to counter act.**

AVT 336 Technical Team/Programme Committe

CAN: Viresh Wickramasinghe (Co-chair)

TUR: Alim Rüstem Aslan (Co-chair)

USA: W. Keith Belwin *(Co-chair)*

DEN: C. Wiin Havsteen

DEU: A. Wagner, T. Neff

ITA: G. Sembenini (SCI)

NLD: A. Van Kleef

PRT: A. Suleman

TUR: A. Ozyıldırım

USA: Donald Lewis (SCI)

AUS: S. Tuttle

SWE: P. Goede

NZL: W. Coldicutt

Panel mentor: M. Huggins (USA)

- **Cross panel activity with SCI**
- **TechWatch Card**
- **Report on exploiting enabling platform technologies for resilient small satellite constellations in order to enhance the quality and timeliness of information provided to NATO warfighters**

Mission and Scope

The TT will investigate the state-of-of-the-art, gaps, opportunities and benefits to be derived by infusing new platform technologies for resilient small satellite constellations. More specifically, the potential topics to be addressed will include, but not limited to, the following technologies such as

- **Increasing resilience, increasing responsiveness,**
- **platform implications for BD&AI,**
- **supporting technologies including thermal management, deployable structures, propulsion and manoeuvring, high speed communication architectures, in-orbit survivability, multi-spacecraft architectures, mission level autonomy, disposal and high volume manufacturing techniques.**

Timeline for RSM

- Kick-off meeting – May 2019
- Approval of call for papers by TT Aug 2019
- Distribute call for papers – Sep 2019
- Abstracts due – Dec 2019
- Inform Authors – Feb 2020
- Confirm program schedule – PBM 27 April – 1 May 2020
- Identify Technical Evaluator and Keynote Speakers - PBM 27 April – 1 May 2020
- Submit papers – End of Aug 2020
- RSM – Fall 2020 in Sweden (20-25 paper for 2.5 days)
- Final Report – Dec 2020

Primary Topics for Call for Papers

- **Theme: Responsive, Resilient, Reliable and Affordable**
- **Constellation Level**
  - Multi-spacecraft, interoperable, architectures
  - Mission level autonomy for constellations
  - Survivability of mission capability
  - Quick launch and multiple launch capabilities
- **Satellite (System) Level**
  - Command, communication and control
  - High volume manufacturing techniques
  - Propulsion and manoeuvring
- **Subsystem Level**
  - Thermal management in small volume
  - Improved on-board processing capability
  - Deployable apertures for power and RF antennas
  - High speed communication architectures (Ground segment and Intersat comms)

Primary Topics - Constellation Level

- **Multi-spacecraft, interoperable, architecture**
  - Mission Design and Multi-spacecraft Architecture
    - Distributed satellites with same or diverse functionality
  - Communication interface
  - Control implications
- **Mission level autonomy for constellations**
  - Mission optimization, low requirements for human interaction
  - Automatic collision avoidance
- **Survivability of mission capability**
  - New redundancy concept
  - Improve resiliency through spacecraft redundancy
  - Embedded deorbit technologies
- **Use of commercial constellations to host military payloads**
  - Higher risks, reduced costs?
- **Quick launch and multiple launch capabilities**
  - Multi Satellite rapid launch capability
  - Standard interfaces for bus and payloads

Primary Topics - Satellite (System) Level

- **Communication**
  - Satellite to ground communication, Satellite-to-satellite or satellite-to-aircraft
  - High bandwidth communications
  - Secure comms
- **Command and control**
  - Autonomy
  - Safety and security
- **High volume manufacturing techniques**
  - Cross industry training
  - Just in time manufacturing
  - Modularity, Assembly and 3-D Printing
- **Processing of raw data to generate information for the warfighter**
  - On-board processing for data reduction and fusion
- **Propulsion and maneuvering**
  - High precision thrusters
  - Electric propulsion, ion propulsion, FEEP, PPT
  - Cold gas and resisto jet

Primary Topics – Subsystem Level

- **Thermal management in small volume**
  - Depend on the application
  - Passive or active use of heat pipes HPs or LHPs
  - Duty cycle adjustment but not suitable for military applications
- **Rapid insertion of latest technology advances**
  - Improved on-board processing capability with COTS systems
  - Insertion of new technology for performance and efficiency
  - New materials
- **Modular plug-and-play subsystems**
- **Apertures for increased power, comm, sensing**
  - Deployable booms, antennas and reflectors
  - Miniaturization and packaging for launch
- **Precision positioning, navigation and timing (PNT)**
  - Sensors and algorithms
- **Deorbit systems**
- **Resiliency to environment**
  - Radiation
  - MMOD

THANK YOU

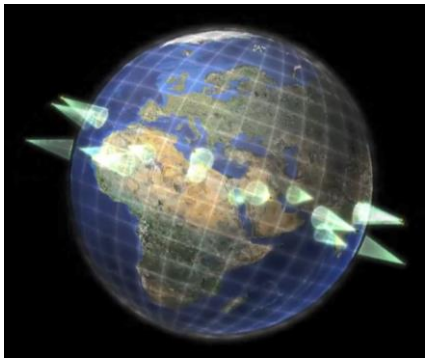
Contact information

aslanr@itu.edu.tr Viresh.Wickramasinghe@nrc-cnrc.gc.ca w.k.belvin@nasa.gov

QUAD CHARTS

NATO Unclassified+AUS+FIN+SWE+SIN

AVT 336 (RSM) : Enabling Platform Technologies for Resilient Small Satellite Constellations for NATO Missions



Team leader(s):	**A.R. Aslan (TUR)** **V. Wickramasinghe (CAN)**
Panel Mentor:	**K. Belvin (USA)** **M. Huggins (USA)**
Members:	**AUS, CAN, DEU, DEN, ITA, NLD, NZL, PRT, SWE, TUR, USA**
Duration:	**Jan 2019 - Dec 2020**
Coordination:	**SCI Panel, NATO Organizations**
Related activity	***SCI 318, AVT-ET-181, AVT 257***

Objectives:

A Technical Team is proposed to further communicate and advance enabling platform technologies for resilient small satellite constellations for NATO missions by organizing a Specialized Meeting in 2020.

Deliverable:

Report on exploiting enabling platform technologies for resilient small satellite constellations in order to enhance the quality and timeliness of information provided to NATO warfighters

Impact and Exploitation

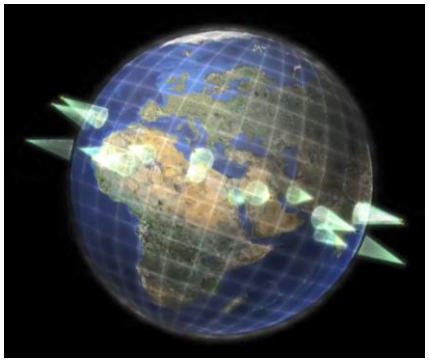
• **DOTMLPFI**

• Directly advances technology for two Long Term Aspects defined in the 2015 STB Science & Technology Priorities, i.e. “Intelligence Surveillance and Reconnaissance (ISR) Collection Capability” and “Space Capability Preservation.”

• Enhances space capability and availability of Smallsats, for various NATO missions including communications, geo-positioning and ISR

• Identifies viable new approaches and techniques consistent with SmallSat Constellation Platform Technologies to more completely access the benefits of Smallsats to support the warfighter

AVT ET 181: Investigation of NATO Mission Priorities for Small Satellite Constellation Platform Technologies



Team leader(s):	**A.R. Aslan (TUR)** **V. Wickramasinghe (CAN)** **K. Belvin (USA)**
Members:	**CAN, DEU, ITA, NLD, PRT, TUR, USA, SWE, AUS**
Duration:	**OCT 2017 - OCT 2018**
Cooperation:	**NATO Organizations, STO Panels**
Related activity	***AVT-257***

Objectives:

The Exploratory Team will develop a plan for implementation of some or all of the recommendations from AVT-257 to gain the benefit for Smallsats to achieve NATO mission requirements. The Exploratory Team will seek input from other NATO organizations on the priority of technology development for Smallsats constellation platforms in order to implement the most important recommendations based on NATO mission needs.

Deliverable:

Plan for implementation of recommendations of AVT-257 through a TAP for a follow-on Technical Activity.

Impact and Exploitation

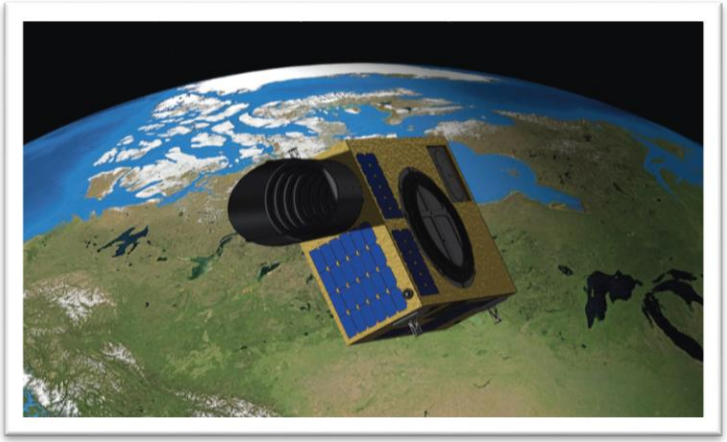
• **DOTMLPFI**

• Directly advances technology for two Long Term Aspects defined in the 2015 STB Science & Technology Priorities, i.e. “Intelligence Surveillance and Reconnaissance (ISR) Collection Capability” and “Space Capability Preservation.”

• Enhances space capability and availability of Smallsats, for various NATO missions including communications, geo-positioning and ISR

• Identifies viable new approaches and techniques consistent with Small Satellite Constellation Platform Technologies to more completely access the benefits of Smallsats to support the warfighter

AVT-257 RSM-041 (MSM) on "Best Practices for Risk Reduction for Overall



Team leader(s):	**Dr D.G. ZIMCIK (CAN)** **Prof A.R. ASLAN (TUR)**
Members:	**CAN, DEU, ITA, NLD, POL, POR, TUR, USA**
Partners:	**SWE, AUS, NZL**
Duration:	**JAN 2015 - DEC 2016**
Cooperation:	**SCI, SET**
Related activities:	**SCI-268**

Objectives:

- The Technical Team (TT) will investigate the most effective means to enhance the performance of Smallsats for NATO missions while achieving savings in cost and schedule**.**

Topics:

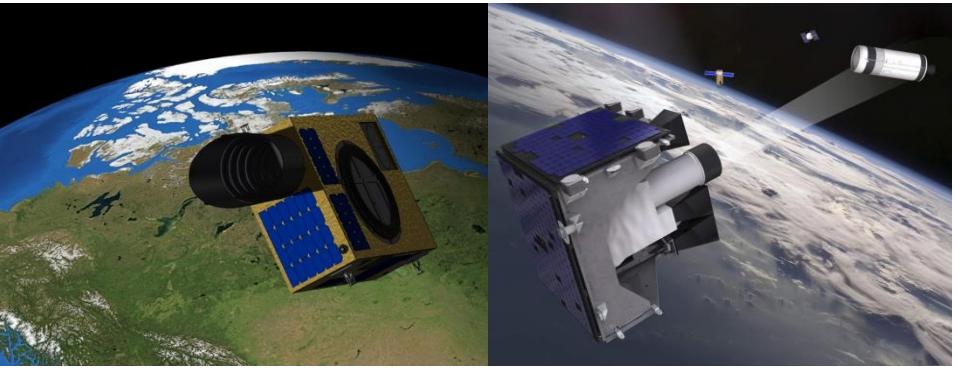
- The TT will address the following three key issues to change the level of risk aversion while enhancing performance:
  - Subsystem Compatibility and Integration
  - System Implementation Opportunities
  - Verification and Validation Rationalization

Impact and Exploitation:

- More responsive and resilient space assets
- Reduced cost and schedule for implementation of space assets
- Improved spatial resolution of remote sensing imagery from space
- Improved timeliness and latency of remote sensing imagery from space
- Overall greater support for the warfighter in the field

Recommendations will be exploited by national programs to support NATO missions

AVT-210 RSM-031 on "Risk and Reliability Assessment and Validation for Small Spacecraft"



Team leader(s):	**Dr D.G. ZIMCIK (CAN)** **Prof A. R. ASLAN (TUR)**
Members:	**CAN, DEU, ITA, POL, PRT, TUR, USA**
Partners:	**SWE**
Duration:	**MAR 2012 - DEC 2013**
Cooperation:	**SAS, SCI, SEI**
Related activities:	**AVT-171**

Objectives:

- to assess and evaluate reliability and the associated risk to tailor design and verification standards for low cost spacecraft
- to validate and qualify concepts to meet performance requirements of a small satellite in order to assess the true cost and value of the process
- to be able to understand the value of current methods and proposed concepts of risk and reliability assessment in terms of benefits in cost and availability, and the means to enhance the value to be derived from small spacecraft

Exploitation of the results:

- support of LTCR #34 *"Capable of preserving space as a sanctuary for NATO assets*"
- knowledge on risk and reliability assessment was shared among NATO nations
- five key recommendations were drawn from the discussions and the relevance to NATO was elaborated
- results could have an revolutionary impact on program decision making → reassessment necessary in a few years
- follow on activity on *"Small Satellite Performance Validation Concepts"* is proposed to implement recommendations to improve confidence in

AVT 171 Multifunctional Structures and System Technologies for Small Spacecraft

Objectives

- Assess the state-of-the-art in small satellite component and system technologies
- Assess the potential military applications to define requirements for small sat technologies
- Interact with RTO Technical Teams to clarify and validate requirements
- Hold a Workshop in Spring 2010 to assess status, projections and challenges related to key technology areas

- **Nations Willing to Participate**
  BEL(TBC), CAN, DEU, GBR, ITA, NLD(TBC), POL, TUR, USA
- **Chair(s) and Panel Mentor**
  Dr. D. Zimcik (CAN), Dr. M. Sinapius (DEU),
  Mentor Mike Huggins (USA)

- **Type**
  Technical Team
- **Origin**
  ET 087
- **Classification**
  NU
- **Start**
  04/2009
- **End**
  12/2010

AVT 171: Technology Topics Matrix Elements

- **:Multifunctional and modular structures**
  - Deployable Structures, incl. sensing instrument apertures
  - Platform structures and payload interfaces
  - Adaptive-Multifunctional Structures and Materials
  - Spacecraft protection (environmental, man-made)
  - De-orbiting systems
- **Guidance, Navigation and Control including propulsion**
  - Attitude and orbit control sensors
  - Actuators for Control
- **Thermal Management**
  - Radiative cooling, limited araa
  - Advanced heat pipe systems
- **Power Generation and Storage**
  - 100 minute orbit, 100,000+ charge/discharge cycles
  - High efficiency, radiation tolerant photo voltaic systems
- **Onboard Intelligence, Autonomy**
  - Interoperability
  - Data storage and transmission, incl. wireless data transmission
  - communication incl. inter-satellite links
  - Secure operation
- **Assembly, Integration and Test**
  - Verification and Validation
  - Risk tolerance

AVT-ET-152 (PPS) on "Assessment of Capabilities for First-Principle Simulations of Spacecraft Electric Propulsion Systems and Plasma Spacecraft Environment"

Team leader(s):	**Dr Jean-Luc CAMBIER (USA)** **Dr Anne BOURDON (FRA)**
Panel Mentor:	**Mr Mike HUGGINGS (USA)**
Members:	**USA, FRA, DEU, ITA, BEL**
Partners:	**AUT**
Duration:	**OCT 2014 - OCT 2015**
Cooperation:	**None**
Related activities:	**None**

Objectives:

Extend lifetime and usefulness of orbital assets, help identify the source of malfunctions, and provide real-time or forensic evidence of hostile actions, as opposed to natural effects from the self-generated or ambient environment.

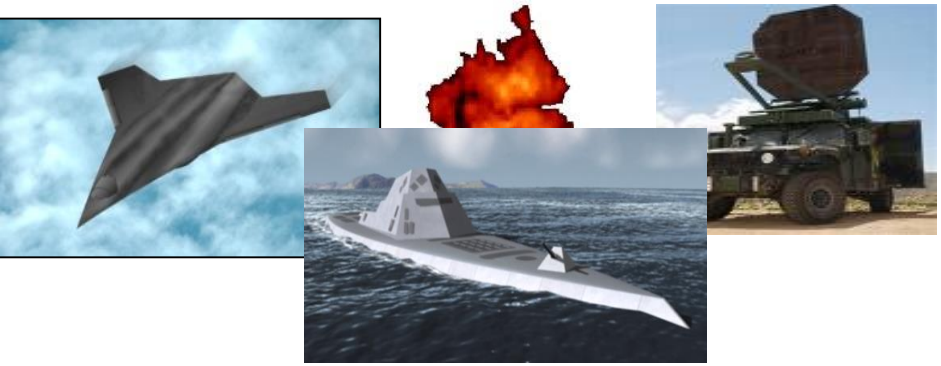
Topics:

- Developing a virtual space environment simulation capability
- Evaluate the state-of-the-art in numerical methods for multi-scale plasma simulations
- Neutral and charged particle interactions with materials at low and high energies

Impact and Exploitation:

- Determination of hostile action and its impact
- Space situational awareness

AVT-226 RTG-075 on "Validation of Thermal Models for Air, Land, Sea and Space Vehicles"



Team leader(s):	**Ir. Bart EUSSEN (NLD)** **Dr Mark SPECTOR (USA)**
Members:	**BEL, CAN, CZE, NLD, TUR, GBR, USA**
Partners:	**AUS, all PFP nations invited**
Duration:	**JAN 2014 - DEC 2016**
Cooperation:	**None**
Related activities:	**AVT-148**

Objectives:

- Assess thermal validation methodologies in order to establish thermal design practices for future military platforms.
- Develop an understanding and quantification of uncertainty as it influences the validation process.

Topics covered:

- Development of a common test bed for characterization
- Thermal model for test bed verification
- Component model validation
- Quantification of uncertainty as it influences the validation process
- Test methodology and instrumentation comparison

Impact and Exploitation – DOTMLPFI

- Validated thermal tools will ensure operation of platforms to their design specifications
- Avoid operational restrictions needed to stay within thermal limits
- Enhance platform efficiency
- Educate practitioners and decision makers on best practices for thermal system development and acquisition.

AVT-227 RTG-076 on "Balancing energy storage with safety in large format battery packs"

Team leader(s):	**Dr Ian HILL (CAN)** **Mr Kevin David POINTON (GBR)**
Members:	**CAN, DEU, NOR, TUR, GBR, USA**
Partners:	**None**
Duration:	**JAN 2014 - DEC 2016**
Cooperation:	**SET**
Related activities:	**SET-206**

Objectives:

- to establish guidelines for specifying the best battery chemistry for a given application
- to establish what is known and what is not known about failure modes in advanced batteries
- to analyse strategies for safer high energy density battery components and protection systems
- to recommend directions for battery architectures and for platform designers, in order to influence the balance between performance and safety

Topics covered:

- Nature of cell chemistries (lithium titanate, lithium iron phosphate, lithium metal oxides)
- Scaling factors and different environmental conditions
- Active and passive protection systems
- Failure modes and emissions (FTIR of gases)

Impact and Exploitation – DOTMLPFI

- Potential impact on NATO policy with respect to the risk associated with chosing a particular battery for a given application
- Educate users and decision makers regarding the safe and reliable operation of advanced batteries
- Reduce the logistics burden through the use of longer life and higher energy density batteries

AVT-258 RSM-042 (MSM) on "Additive manufacturing for military hardware"

Team leader(s):	**Dr L. 't HOEN (NLD)** **Dr P. WANJARA (CAN)**
Members:	**CAN, DEU, EST, FRA, GBR, ITA, NLD, NOR, USA**
Partners:	**AUS, NZL, SWE**
Duration:	**JAN 2015 - DEC 2016**
Cooperation:	**None**
Related activities:	**ET-139, AVT-163, TechWatch topic Additive Manufacturing**

Objectives:

- Analysis of state of the art in additive manufacturing for repair and replacement components in military platforms.
- Identify technology gaps that compromise the application of additive manufacturing

Topics:

- Additive manufacturing for replacement components
- Additive manufacturing for repair
- Process and design optimization
- Microstructure and performance
- Materials (metals and polymers)
- In-service experience

Impact and Exploitation (DOTMLPFI):

- Identification of technology gaps can be used to plan future research on additive manufacturing to mature the processes and enable application of the technology
- Application of additive manufacturing for replacement components can:
  - Reduce logistical footprint
  - Increase support chain flexibility
- Additive manufacturing can enable repair of components that are beyond current repair technologies, leading to:
  - More efficient use of components
  - Lower need for spare parts

AVT-262 RLS-039 (MSM) on "Space Debris Reentry and Mitigation"

Team leader(s):	**Dr Jean MUYLAERT (BEL-VKI)** **Prof Thierry MAGIN (BEL-VKI)**
Members:	**BEL, NLD, FRA, GBR, USA, DEU**
Partners:	**None**
Duration:	**DEC 2014 - DEC 2015**
Cooperation:	**None**
Related activities:	**None**

Objectives:

- Discussion on design and validation of prediction tools
- Disseminate information on ongoing and future projects
- Consideration of debris demise and mitigation
- Course addressed to professionals and students from industry, space agencies and defense programs

Topics:

- Legislation, origin of debris
- Numerical tools
- Present and future projects
- Uncertainty quantification

Impact and Exploitation:

- Continuous education
- Set of Lecture Notes for further dissemination

AVT-263 RLS-040 (PPS) on "Electric Propulsion systems: from recent research developments to industrial space applications"

Team leader(s):	**Prof Thierry MAGIN (BEL-VKI)**
Panel mentor:	**Prof Tony ARTS (BEL)**
Members:	**BEL, NLD, FRA, GBR, USA, DEU**
Partners:	**None**
Duration:	**DEC 2014 - DEC 2015**
Cooperation:	**None**
Related activities:	**AVT-ET-152**

Objectives / Topics to be addressed by the course:

- Current technologies and technological challenges
- Physico-chemical models and CFD methods for engineering predictions
- Experimental facilities, measurement techniques and flight data
- Review of ongoing and future projects

Covering:

- Electrostatic, electromagnetic/electrostatic, electromagnetic and electrothermal engines
- Experimental and numerical methods

Impact and Exploitation:

- Continuous education
- Set of Lecture Notes for further dissemination

Future of Manufacturing for Military Applications

AVT-267 (RWS)

Team leaders	T'HOEN-VELTEROP, Ludmila (Dr.), WANJARA, Priti (Dr.)
Participating	CAN FRA DEU GRC NLD NOR GBR USA
Authorized	STOEOP
Desired	
Duration	01 Jan 2016 - 31 Dec 2018
Classification	NATO Unclassified
Related activities	AVT-139, AVT-163, AVT-258, AVT-264

Objectives:

Providing a forum for manufacturing process specialists to discuss the future of their specialty (e.g. forging, casting, machining, coating, welding, digital manufacturing) in light of the availability and rapid development of additive manufacturing and the general transition towards automation, robotics and intelligent/advanced materials and technologies.

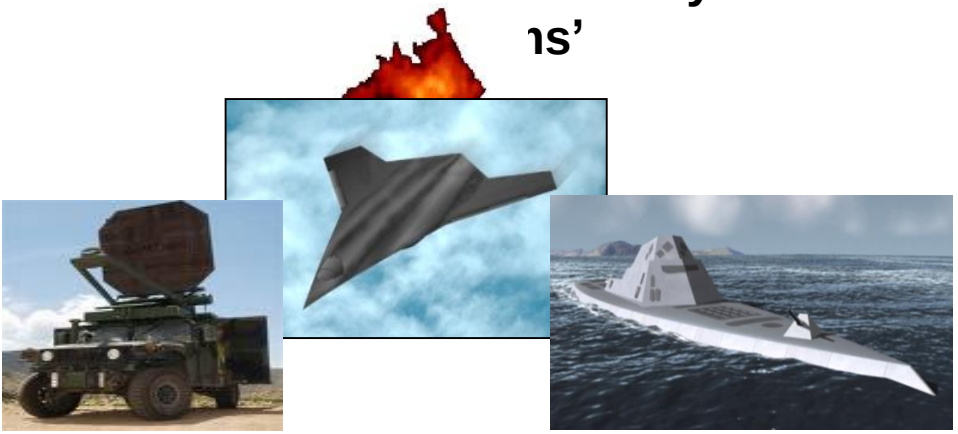
Topics:

Micro-machining // Robotics and adaptive automation // Prognosis of machine failure // Manufacturing precision enhancement // Manufacturing process simulations // Low cost tooling // Surface engineering // Virtual manufacturing // Advanced materials processing

Exploitation:

The outcome of this activity will positively impact on the preparedness of the defence industry supporting NATO nations in advanced manufacturing. Recommendations provided to the AVT Panel will be utilsed by the defence industry in advancing the identified technologies.

AVT-270 RWS (PPS) on 'Validation of Thermal Models for Military Power ıs'



Team leader(s):	**Dr. Mark Spector (USA)** **Ir. Bart Eussen (NLD)**
Panel mentor:	**Mr. James Macleod (CAN)**
Members:	**BEL, CAN, DEU, GBR, NLD, TUR, USA, AUS**
Partners:	**CHE**
Duration:	**JAN 2017 - DEC 2017**
Coordination:	**None**
Related activities:	**AVT-178, AVT-226**

Objectives:

This workshop will provide an opportunity to present, discuss and assess the thermal validation methodologies developed in AVT-226. Experts in thermal system design and modeling will present papers on quantification of uncertainty and its influence on design practices for military platforms.

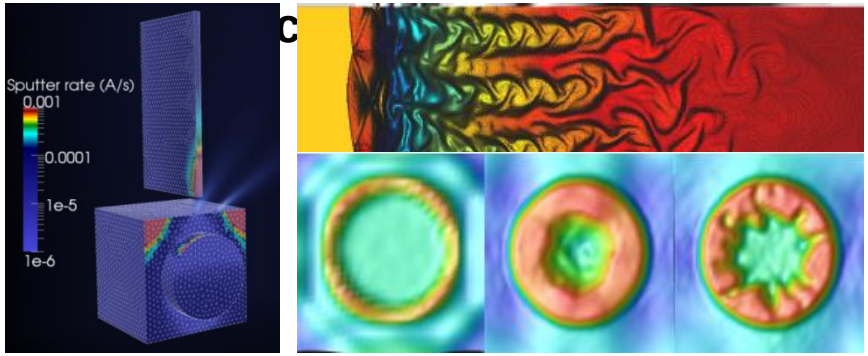
Topics covered:

- Modeling and simulation tools for steady state and transient thermal system design
- Quantification of uncertainty as it influences the validation process
- Metrics for capturing thermal performance
- Sensitivity requirements for component models to off-design conditions and installation/component variability

Impact and Exploitation: DOTMLPFI

- Validated thermal tools will ensure operation of platforms to their design specifications
- Avoid operational restrictions needed to stay within thermal limits
- Enhance platform efficiency
- Educate practitioners and decision makers on best practices for thermal system development and acquisition

AVT-271 RWS (PPS) on "Research Directions for First-Principles Simulation of Spacecraft Electric Propulsion Systems and Plasma C



Team leader(s):	**Dr. Justin Koo (USA)** **Dr. Anne Bourdon (FRA)**
Members:	**Giovanni Lapenta (ITA), Thierry Magin (BEL), Manuel Torrilhon (DEU), Jean-Luc Cambier (USA)**
Partners:	**None**
Duration:	**OCT 2015– OCT 2016**
Coordination:	**TBD**
Related activities:	**ET-152**

Objectives:

- Expand work of AVT-152-ET to refine assessment of technical challenges to first-principles plasma simulation in regimes of interest
- Document assessment and prioritize a small number of focused efforts for multi-year RTG effort.

Topics covered:

- Multiscale methods for numerical simulation of partially ionized magnetized plasmas
- Recent trends in relevant algorithms, mathematical approaches and computing hardware
- Review of physical and chemical databases and relevant validation experiments

Impact and Exploitation – DOTMLPFI

- Potential impact on research strategy of NATO nations by identification of most relevant technical challenges to improving modeling and simulation
- Will enable RWS members to exploit greater opportunities for collaboration on algorithm/numerical model development and experimental campaigns to tackle these challenges.

Future directions for the use of Additive Manufacturing in NATO operations

AVT-ET-189 (ET)

Team leaders	THORVALDSEN, Tom (Dr), T'HOEN-VELTEROP, Ludmila (Dr.)
Participating	CAN DEU ITA NLD NOR ESP TUR
Authorized	STOEOP
Desired	
Duration	01 Jan 2019 - 31 Dec 2019
Classification	NATO Unclassified
Related activities	AVT-ST-006, AVT-267

Objectives:

Explore a way forward of AM Technology and Implications in the NATO S&T framework

Topics:

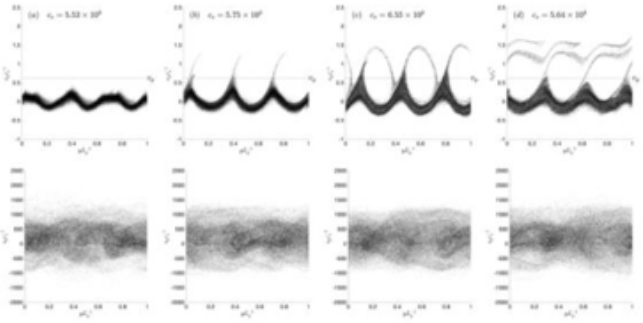
Developing NATO requirements / ”standards” and recommendations for the set of materials and production processes used in NATO operations // Establishing a NATO digital library for spare parts // Establishing routines for material characterization and test set-up for quality assurance of printed parts used in NATO operations // Setting the framework for establishing the infrastructure for NATO joint logistic operations // Support science and technology collaboration and information exchange within NATO

Exploitation:

The ET is considered as the next step to gain a better understanding of national capabilities and future needs and plans for AM in military operations. In addition, it is important to define NATO’s role and the added value to national efforts in AM. NATO’s integrating role can deliver interoperability and streamline digital standardization or repository management.

Towards Improved Computational Tools for Electric Propulsion

AVT-294 (RTG)



Team leaders	BOURDON, Anne (Dr.), KOO, Justin (Dr)
Participating	BEL CAN FRA DEU ITA USA
Authorized	STOEOP
Desired	
Duration	01 Jan 2018 - 31 Dec 2020
Classification	NATO Unclassified
Related activities	AVT-271

Objectives:

Leverage the research efforts of NATO member nations to develop advanced electron transport models, push the boundaries of high fidelity simulation capability, and investigate model reduction schemes to make computationally tractable the critical behaviour of complex EP plasma simulation.

Topics:

Physics Model Development / Advanced Theory – develop new theoretical models for cross-field electron transport // High Fidelity Simulation – Push limits of computational simulation and low-diffusion kinetic methods to generate "truth" simulations // RBM and UQ – Accelerate code and quantify uncertainty to deliver enhanced systems engineering impact

Exploitation:

The product of this RTG is not a particular software product or set of algorithms, although these will likely be developed during the course of the technical effort. Rather, this RTG seeks to coordinate and accelerate NATO progress towards the development of a whole family of numerical models, beginning with simplified electron transport models but extending all the way to coupled HET simulations including realistic spacecraft geometries and boundary condition physics. The final conclusions of this RTG will be disseminated through a technical reference document detailing progress by the team (and surveying progress of the broader community) towards the development of improved physics-based cross-field electron transport models.

NATO STO - SET Panel Space Activities

Marco Martorella
m.martorella@iet.unipi.it

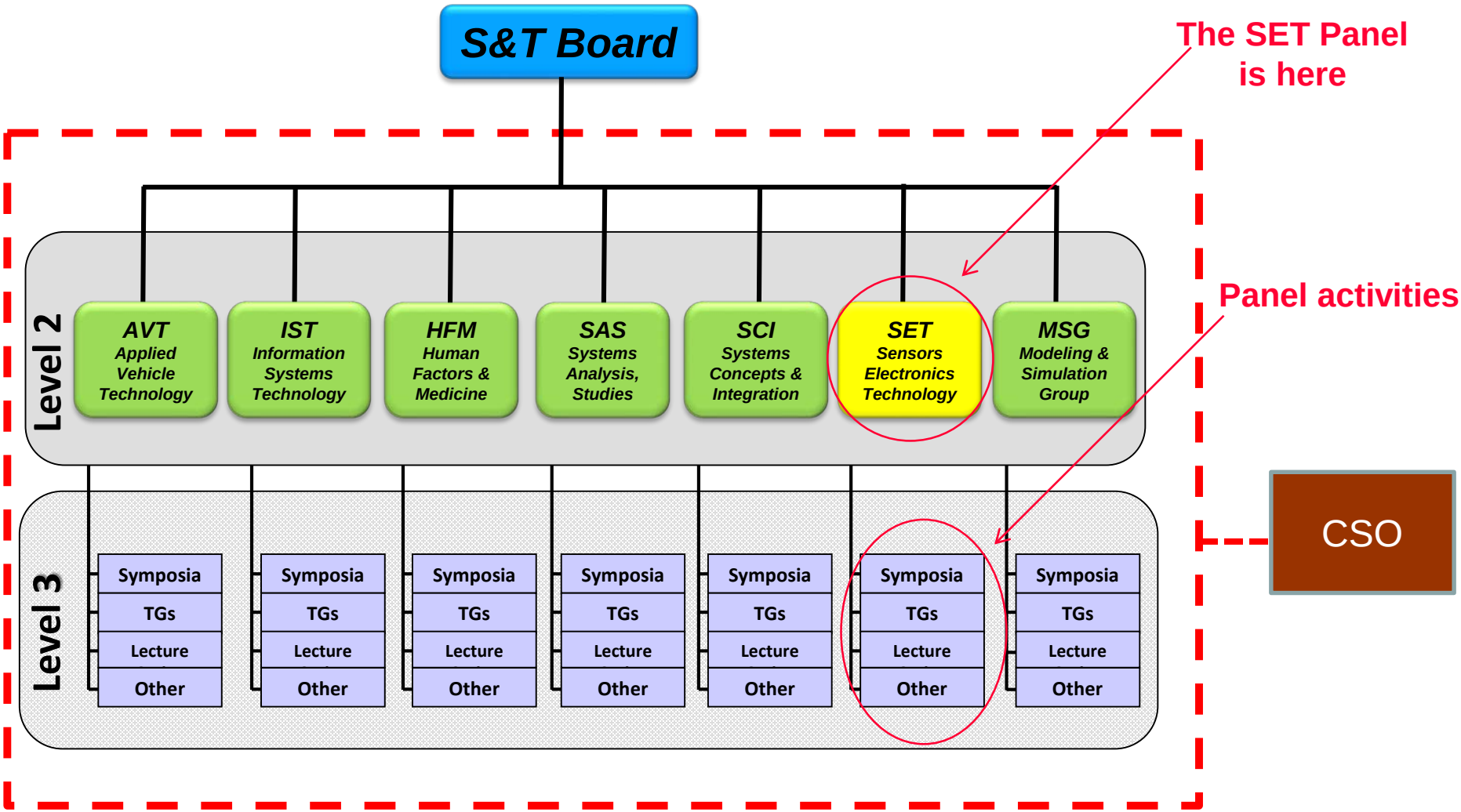
SCI-318 RSM
The Space Domain and NATO Operations: A Critical S&T Review

Army Education & Training Command, and School of Applied Military Studies
Turin, 25-27 June 2019

Outline

- SET Panel
- SET Panel activities in Space
  - Past
  - Current
- Conclusions

SET Overview



Sensors and Electronics (SET) Panel

PANEL MISSION:

To foster co-operative research, exchange of information, and the advancement of **science and technology** among the NATO Nations in the field of **sensors and electronics** for defense and security.

PANEL SCOPE:

The SET Panel addresses electronic technologies and passive and active sensors as they pertain to **reconnaissance**, **surveillance** and **target acquisition** (RSTA), **electronic warfare** (EW), **communications** and **navigation**, and the enhancement of sensor capabilities through **multi-sensor integration and fusion**.

- **Optical Technology Focus Group**
- **Radio Frequency Technology Focus Group**
- **Multi Sensors and Electronics Focus Group**

SET Panel – Thrust Areas

Optical Technology Focus Group

- Infrared and Spectral Sensing
- Laser Radar Technology
- Performance Modeling
- Target Signatures
- Optical countermeasures
- Computational Imaging

Radio Frequency Technology Focus Group

- Radar*
- ATR/NCTR
- Radar and SAR Imaging
- Radar Signatures
- Resource and Spectrum Management

*Active, Passive, SAR, Noise, Cognitive, Multi- and Bi-static, Multi-function, Software Defined

Multi Sensors and Electronics Focus Group

- Application areas:
  - C-IED;
  - Swarms;
  - Navigation;
- Sensors
  - Multi-sensor fusion
  - Acoustics
  - CBRNE
  - Quantum Sensing.

Military Relevance of the SET CPoW

- Increased Situational Awareness
- Enabling operations in hostile/denied environments
- Precision Engagement (targeting, fire control and countermeasures)

SCIENCE AND TECHNOLOGY ORGANIZATION

SENSORS & ELECTRONICS TECHNOLOGY PANEL

CHAIR

David BLACKNELL GBR

VICE-CHAIR

Frank VAN DEN BOGAART NLD

PANEL OFFICE

Francesco SANTORO ITA EXECUTIVE

Ewelina GLINSKA-LEWIS POL ASSISTANT

NATO NATION PANEL MEMBERS

Olimpjon SHURDI ALB

Xavier NEYT BEL

Eric APPELDOORN BEL

Kamen ALEKSANDROVA BGR

Angel GENCHEV BGR

Alexandre JOUAN CAN

Peter MASON CAN

Ivana CAPAN HRV

Mladen VIHER HRV

Jan LEUCHTER CZE

Vojtěch STEJSKAL CZE

Jiri VESELY CZE

Henning HEISELBERG DNK

Steen SONDERGAARD DNK

Veljo RAIDE EST

Kaarel PIIP EST

Etienne LERAY FRA

Patrick GREMILLET FRA

Marie Thérèse VELLUET FRA

Reinhard EBERT DEU

Klaus HRUSCHKA DEU

Sven KUPFER DEU

Marios LOUPOS GRC

Christos MARMALIDIS GRC

Tibor BUZASI HUN

Marco MARTORELLA ITA

Mauro Varasi ITA

Oskars KRIEVS LVA

Arturas JUKNA LTU

Frans CLAESSENS NLD

Frank VAN DEN BOGAART NLD

Øyvind SJØVIK NOR

Borge TORVIK NOR

Pawel PNIEWSKI POL

Jerzy PIETRASINSKI POL

Maciej SMOLARCZYK POL

Joao NEVES PRT

Florent ROMAN ROU

Florin SERBAN ROU

Ioan NICOLAESCU ROU

Jan OCHODNICKY SVK

Sandi BOGATAJ SVN

Javier GARCIA FOMINAYA ESP

Ozgur BIRDAL TUR

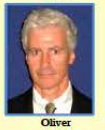
Poyraz ONER TUR

Fatih SAY TUR

David BLACKNELL GBR

Peter HARVEY GBR

William STAFFORD GBR

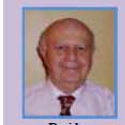


Oliver ALLEN USA

Bryce SCHUMM USA

Donald A. REAGO USA

PARTNER NATION PANEL MEMBERS



David ROBERTS AUS

Paavo RAERINNE FIN

Jukka RUOSKANEN FIN

Per ANDERSSON SWE

Hans FRENNEBERG SWE

Peter WELLIG CHE

MEMBERS AT LARGE

Wolfgang KOCH DEU

Frank EHLERS DEU

Peter KNOTT DEU

Gianni BARANI ITA

Andrea DE MARTINO ITA

Alexander VAN EIJK NLD

Krzysztof KULPA POL

Hugh GRIFFITHS GBR

Kenneth MCEWAN GBR

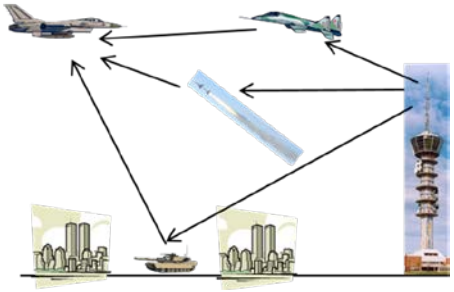
Tien PHAM USA

Baruch LEVUSH USA

A.Way FOUNTAIN III USA

Current and Future Focus

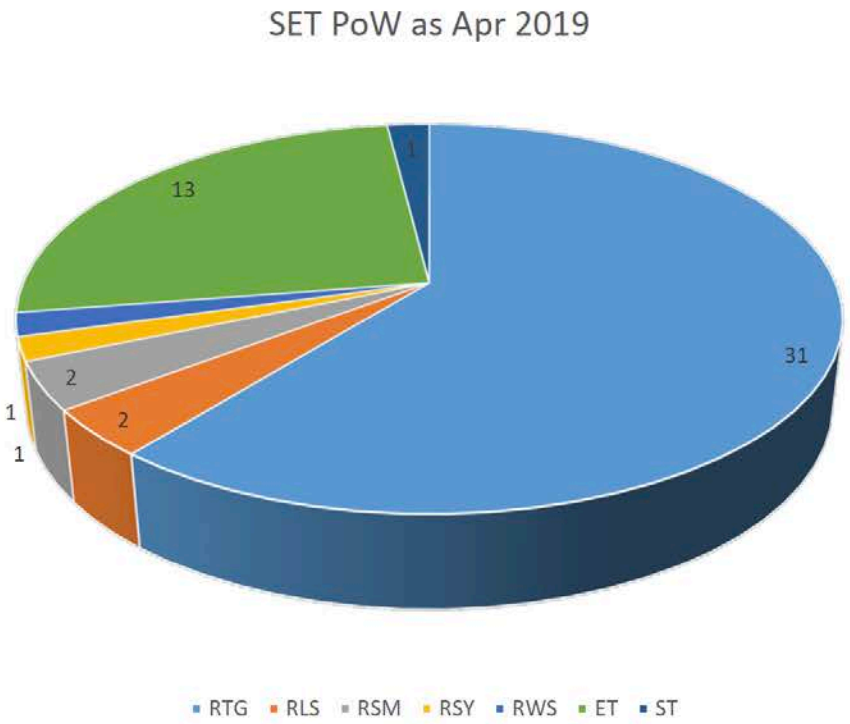
- **Current focus**
  - Passive/Active Radars (and Countermeasures)
  - Automated Target Recognition/Non-Cooperative Target Recognition (ATR/NCTR)
  - Compressive Sensing (RF and EO/IR)
  - Laser Countermeasures
  - Computational Imaging
  - Sensor Networks
  - Swarm Systems
- **Future focus**
  - **RF and RF/EO Technology for SSA**
  - Mid –Infrared Laser Technology
  - Quantum Navigation
  - Wide Area Surveillance (WAS) Capability



SET Panel – Current Programme of Work

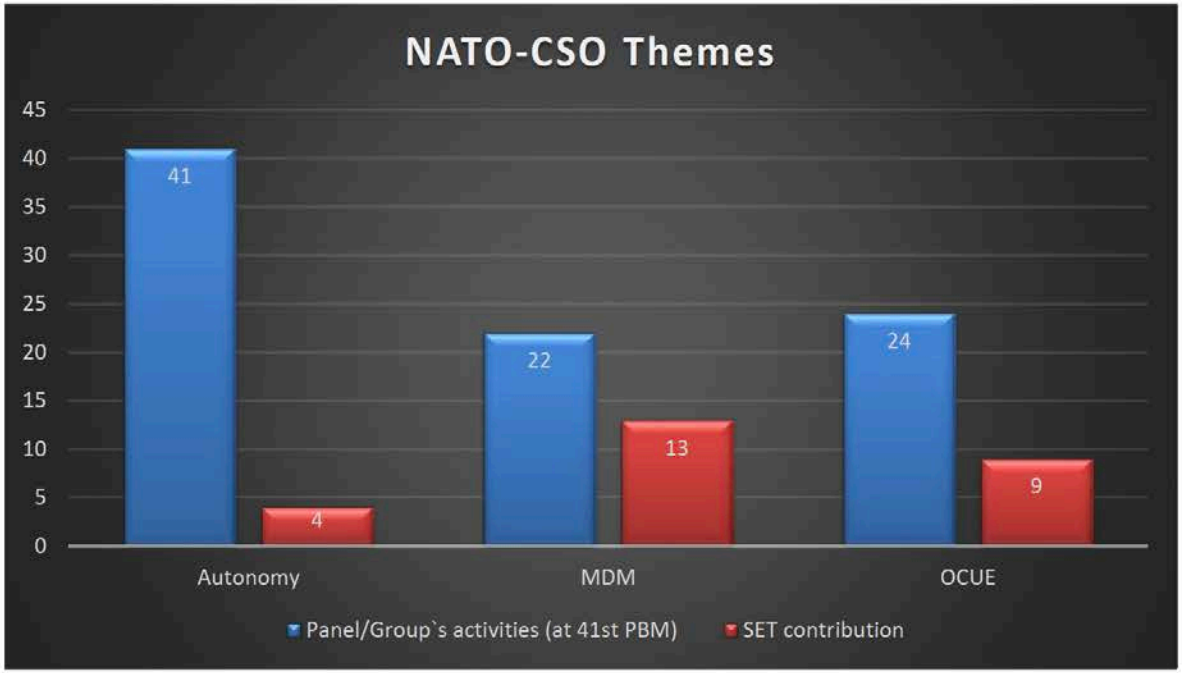
OVERALL

- **51 Current Activities**
- 31 Task Groups (RTG)
- 2 Lectures Series (RLS)
- 2 Specialists' Meetings (RSM)
- 1 Symposia (RSY)
- 1 Workshop (RWS)
- 13 Exploratory Teams (ET)
- 1 Specialist Team (ST)



STO-Themes involvement

- **CSO Themes – SET contribution**
  - ✓ Autonomy: 3 RTGs, 1 ET;
  - ✓ BD&AI, MDM: 7 RTGs, 2 RSM, 4 ET
  - ✓ OCUE: 6 RTGs, 1 RWS, 2 ET



Space-related activities

- **Recent Past**
  - **SET-145 RTG -** Extraction of Geospatial Intelligence Information from Space-borne SAR Sensors
  - **SET-220 RTG -** Geospatial Information Extraction from Space-Borne SAR-Images for NATO-Operations

- **Current**
  - **SET-279 RTG -** Space-based SAR and Big Data Technologies to support NATO Operations
  - **SET-115 ET -** RF and RF/EO Technology for Space Situational Awareness

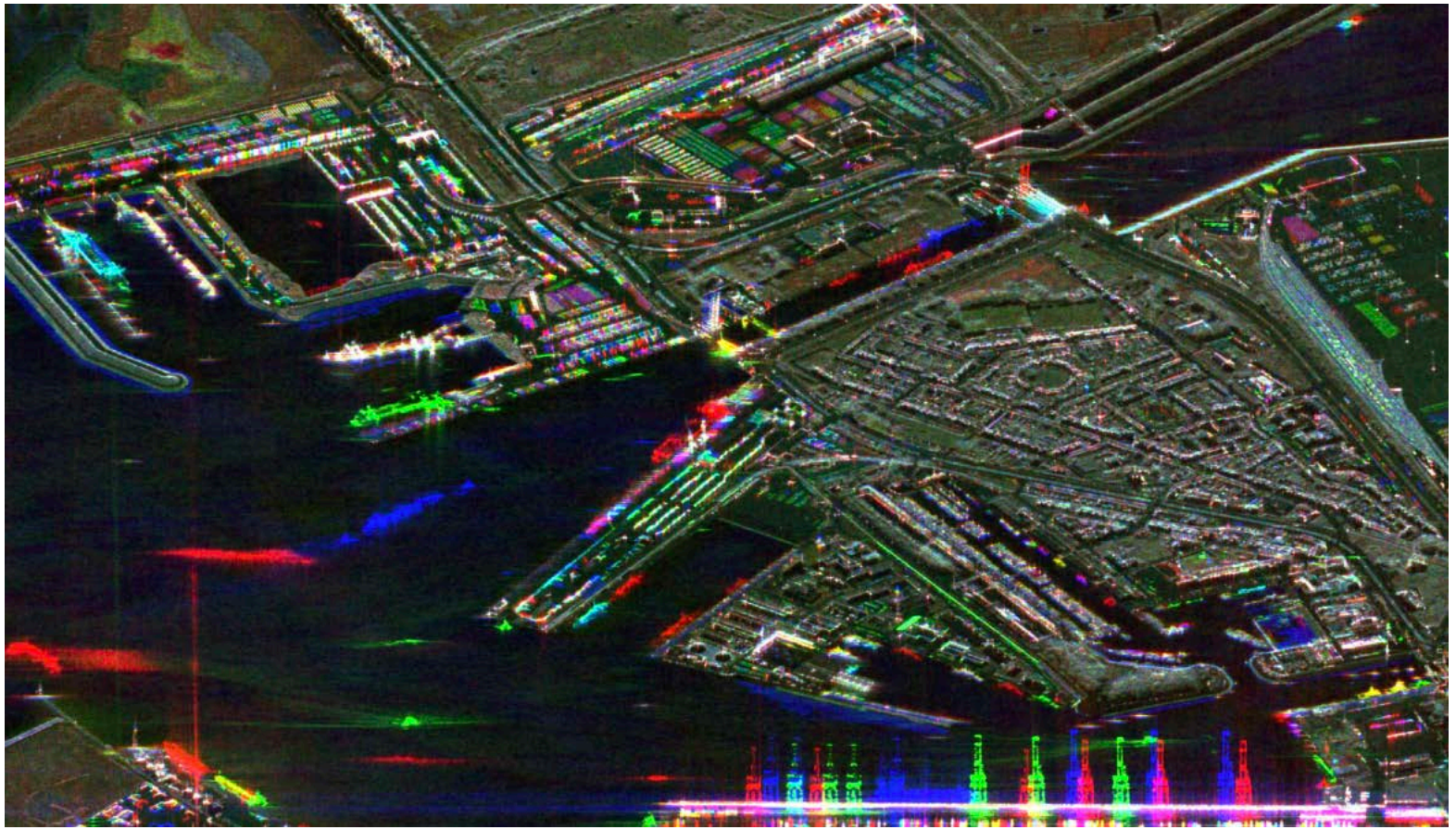
Space-related past activities

- **SET-145 RTG - Extraction of Geospatial Intelligence Information from Space-borne SAR Sensors**

  - Stressed the importance of geospatial information for NATO strategic and tactical operations

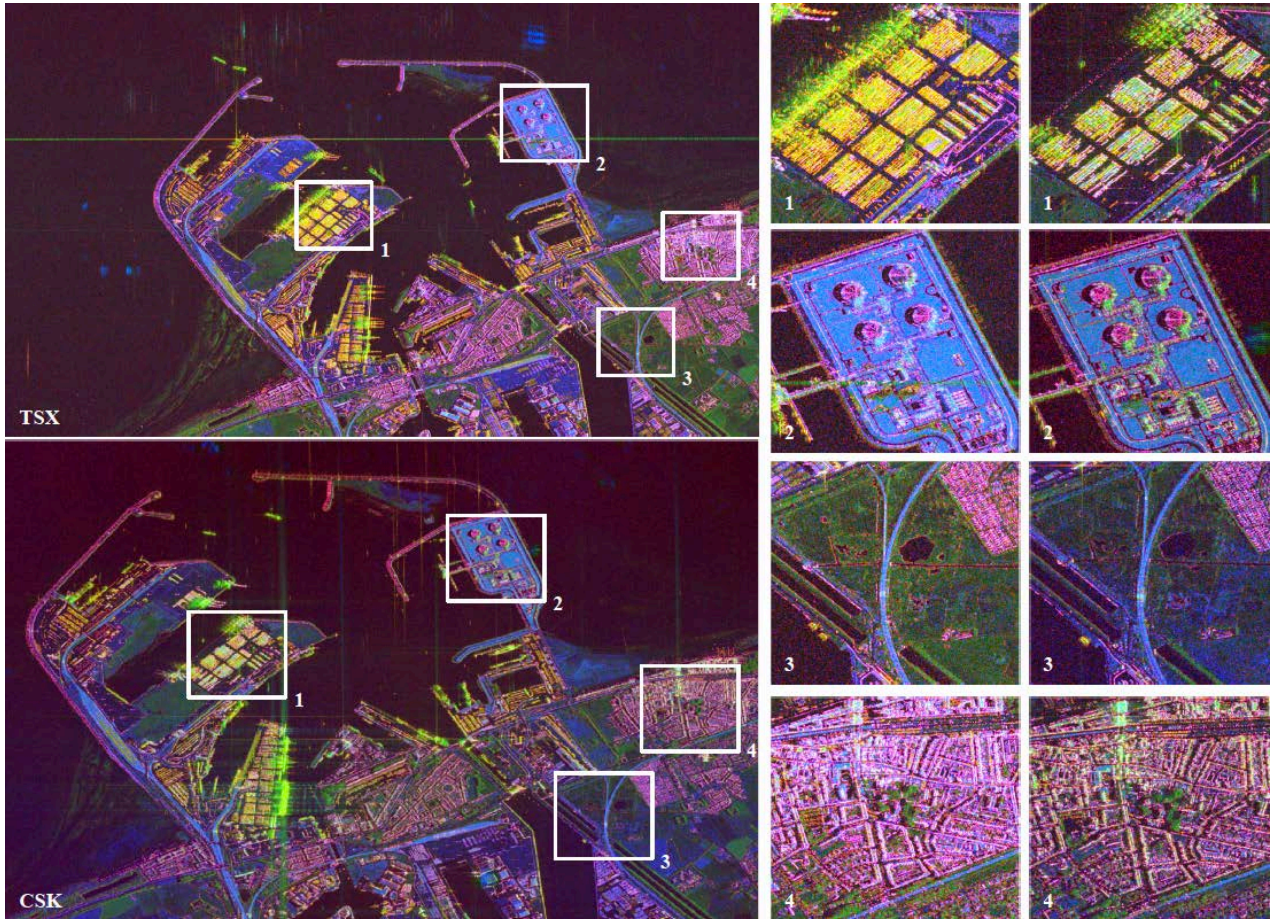
  - Main topics addressed:
    - change-detection
    - visual presentation of space-borne radar images
    - Military requirements of space-borne radar systems for Maritime domain awareness

SET-145 RTG



Each color (red-blue-green) is associated with a SAR image taken from different systems at different times

SET-145 RTG



Coefficient of variation – Amplitude intensity – Interferometric coherence (CovAmCoh) representation

Space-related past activities

- **SET-220 Geospatial Information Extraction from Space-Borne SAR-Images for NATO-Operations**
  - Analysis of the potential of extracted geospatial information using space-borne SAR sensors. Specific goals
    - Contribution to the intelligence preparation of the battle space (IPB)
    - Demonstration of SAR-capabilities for reconnaissance purposes during the NATO trial Unified Vision 2014
    - Integration of the extracted geospatial information into an interoperable environment (e. g. CSD)
    - Application of the lessons learned to Unified Vision 2016

NATO SET-220 on "Extraction of Geospatial Intelligence Information from Space Borne SAR-Sensors for NATO Operations"

Technical Achievements Poster for SET Panel / 42th PBM 07.11.2018

Start Date: January 2014 - End date: January 2017

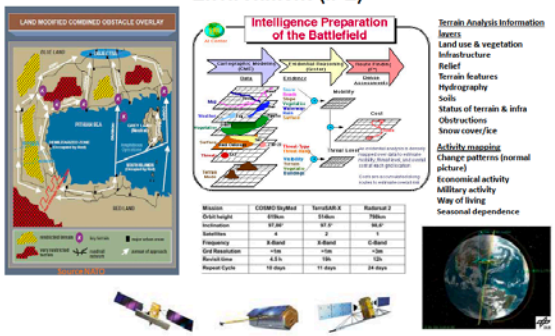
Military relevance, originality & recommendation

- Use of space-borne SAR-systems for the preparation of the operational environment
- Collection and processing of relevant data sets acquired under nearly operational conditions
- Generation of information layers (e. g. DEMs, infrastructure maps, land use maps)
- Time series of data for areas of interest for military and security purposes
- Detection and characterisation of changes
- Operational methods for NATO use up to a TRL 5
- Results to support a future combined use of space-borne information for intelligence topics

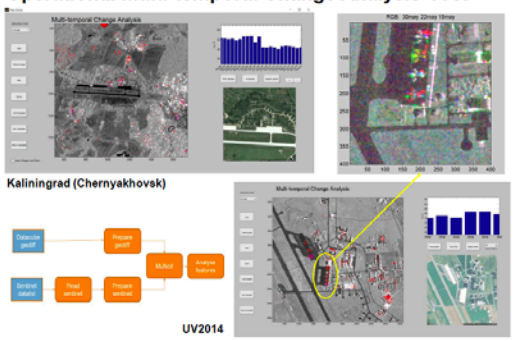
New TG: Application of Big Data technologies to support NATO Operations

- Intelligence preparation of the battlefield (NATO AJP 2.1)
- Automated production of relevant multi-temporal changes in (radar) satellite image data stacks
- Fusion of changes with foundation data such as GIS context information
- Use of open source information and big data analysis to produce operational intelligence alerts
- Workshop with practical applications for possible operational NATO users

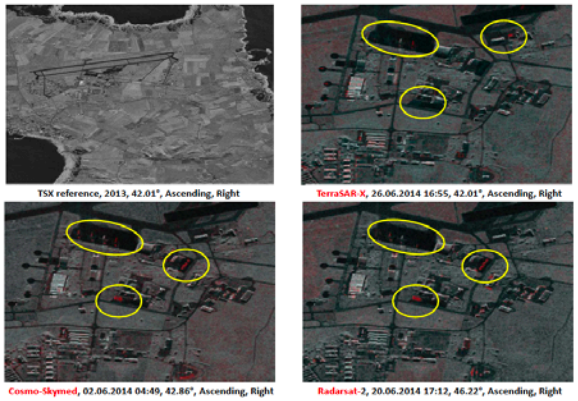
Information Layers for the Intelligence Preparation of the Environment (IPE)



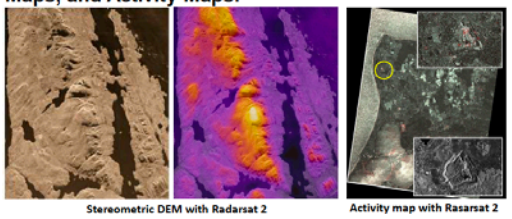
Operational Multi-temporal Change Analysis Tool

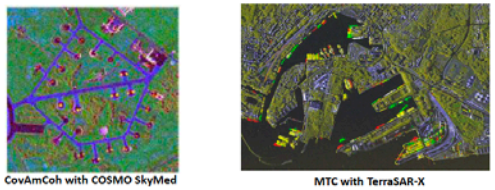


Temporal Series of SAR-images acquired with TerraSAR-X, Cosmo SkyMed and Radarsat 2 (UV2014)

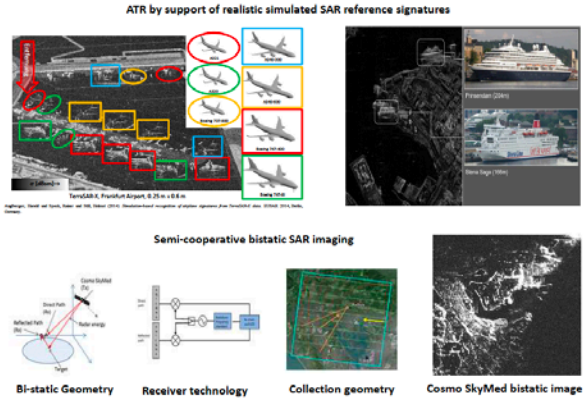


Information layers: Digital Elevation Data, Land Use Maps, and Activity Maps.

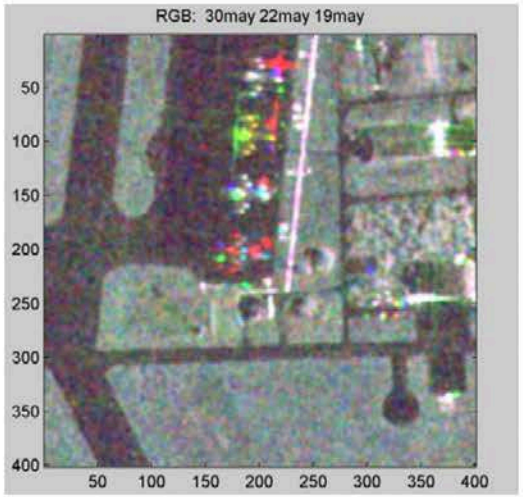




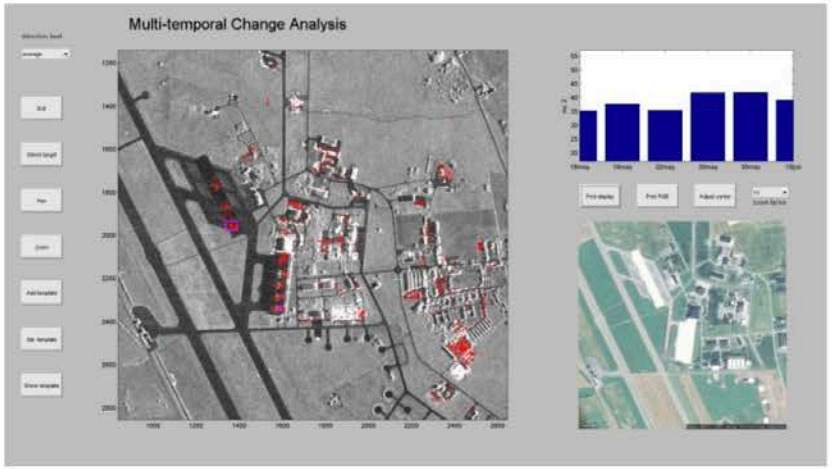
Automatic Target Recognition and New Technologies

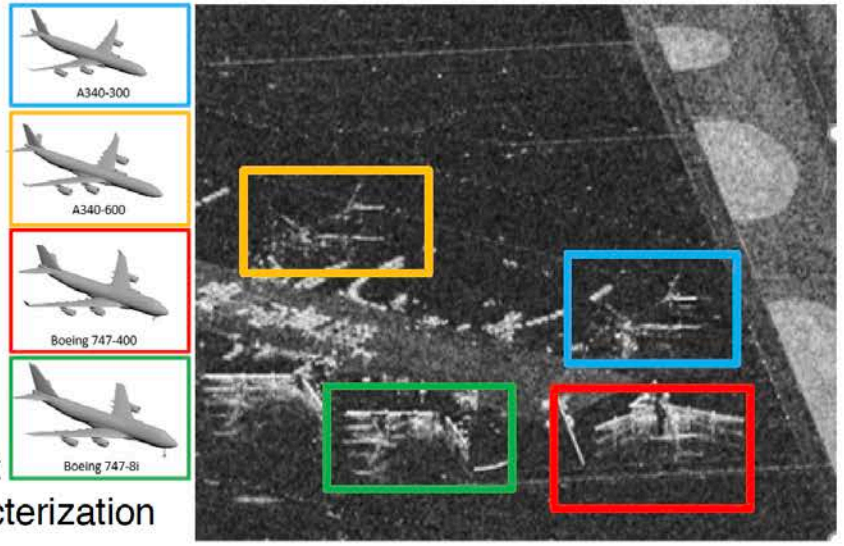


Poster highlights

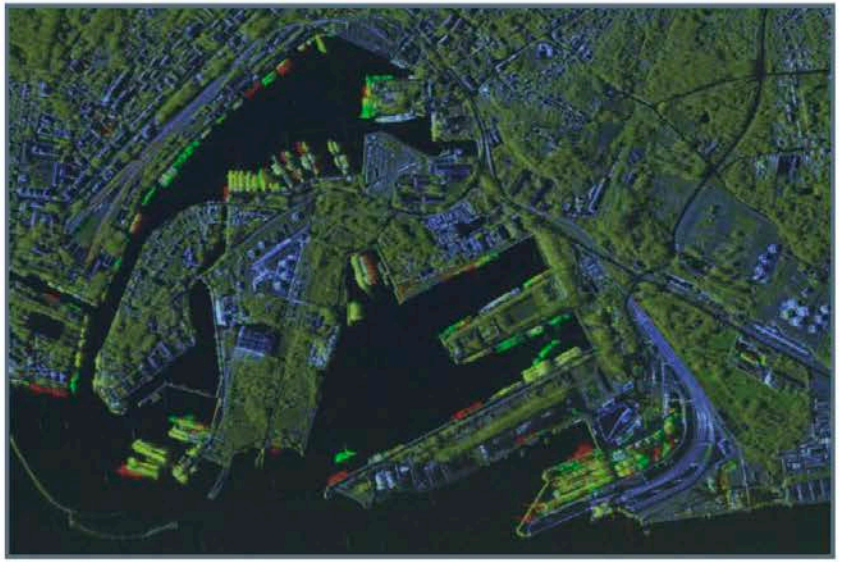


Multi-temporal change analysis





Object characterization



Change characterization

Space-related current activities

- **RF and RF/EO Technology for Space Situational Awareness**
  - This ET is investigating opportunities and possibilities to establish a NATO SET RTG on SSA-related topics.
  - Two meetings have taken place already (Paris and Sardinia) and two main leads have been identified that are of common interest among six nations (so far)
    - Long baseline bistatic radar experiment for GEO object detection and tracking
    - RSO characterisation at LEO with radar systems

Space-related current activities

- **Space-based SAR and Big Data Technologies to support NATO Operations**
  - Focus on intelligence preparation of the battlefield (NATO AJP 2.1) •
  - Automated production of relevant multi-temporal changes in (radar) satellite image data stacks •
  - Fusion of changes with foundation data such as GIS context information •
  - Use of open source information and big data analysis to produce operational intelligence alerts •
  - Workshop with practical applications for possible operational NATO users

Other recent contributions to *Space*

- One session on SSA at the RSM «Vectors in Radar» - Spring 2018
- More than ten papers published in NATO SET RSM/RSY dedicated to space, both in terms of Space-based sensors and SSA
- Two educational notes

Conclusions

Future activities

- Next RTG on SSA
- Joint SCI/SET session on SSA at the SCI/SET PBM in Fall 2019
- SET TWC on the role of radar for SSA to appear soon

Remarks

- Space domain is complex, SET can provide technology improvement and new capabilites
- There is a need for more synergies with other Panels regarding this topic
- A clear strategic vision is needed to focus and shape SET activities

Information Systems & Technology Panel

NATO STO – IST Panel Space Activities

Carlo Guglielmini - Leonardo SpA
Gian Luca Foresti - University of Udine, Italy

Turin 25-27 June 2019
SCI-318 Specialists' Meeting on "The Space Domain and NATO Operations: a critical S&T review"

Topics

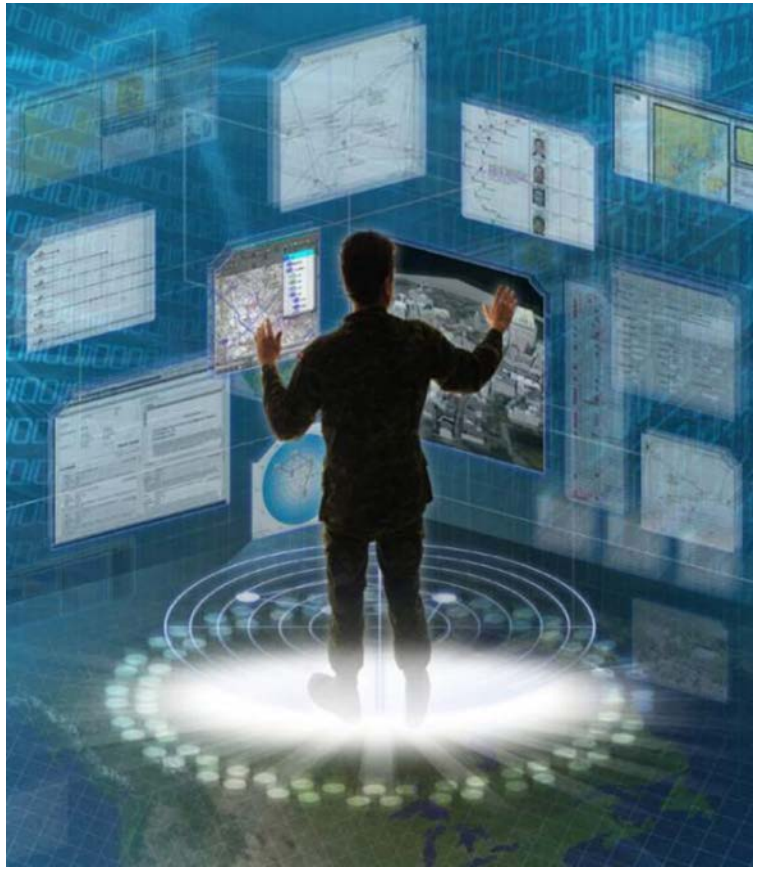
IST Panel

- **Mission, Organization**
- **Current Focus**
- **Technology Trends**
- **Partnership & Collaboration**

Space Activities

- **Space related**
- **Activities of interest**

IST Panel Mission



Advance and exchange techniques and technologies in order to

- improve C3I systems, with a special focus on **AI**, Interoperability, Decision Support, Network Connectivity, and Cyber Security;
- provide timely, affordable, dependable, secure and relevant information to war fighters, planners.

IST Panel Organization

Fall 2018 42nd IST-PBM Lisbon-Portugal

Spring 2019 43rd IST-PBM Budva-Montenegro

Fall 2019 44th IST-PBM Budapest-Hungary

Panel Chair:
Dr. Michael WUNDER

Vice-Chair:
Col. Dr. Nikolai STOIANOV

New Panel Executive
Col (rtd) Philippe Soète (interim)

Panel Assistant:
Mrs. Aysegül APAYDIN

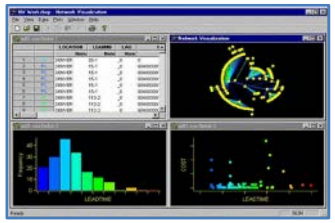
45 Members from 26/30 NATO Nations

+ 2 Partner Nations (**FIN** & **SWE**)

+ 3 Associate Members: **ACT, NCIA, CMRE**

2 Members at Large: GBR, TUR

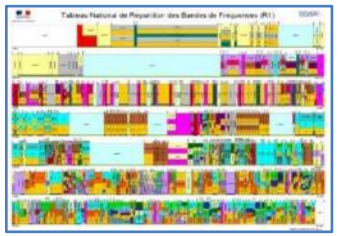
IST Focus Groups



AI2S: Architecture & Intelligent Information Systems

Knowledge Management for NATO Warfighter, **Decision Support** and **Interoperability**.

Chair: Pontus Hoerling, SWE
Vice-Chair: Hervé Le Guyader FRA



COM: Communications and Networks

Networks and Communications for **Connectivity Across All NATO Command Levels**.

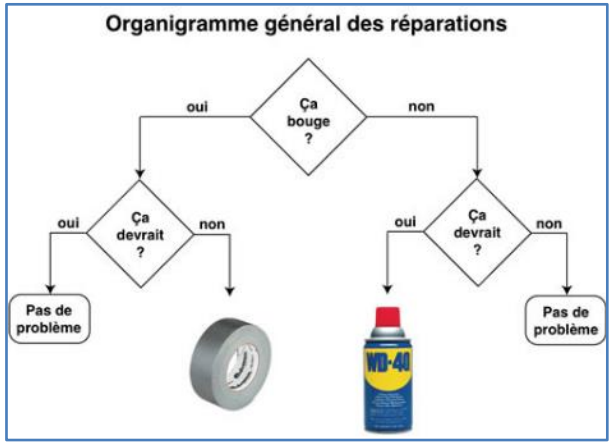
Chair: Risto Maatta, FIN
Vice-Chair: Simon Baker GBR

IWA: Information Warfare and Assurance

Protecting Information for NATO **Information Dominance**, accomplish **security & trust**.

Chair: Nazife Baykal, TUR
Vice-Chair : Candice Bedell, USA

Current Programmatic Focus I
Decision Making



Lightweight information mixed with facts → Social Media

- important source, Social Media Exploitation and for C2

Information Filtering and Fusion

- Sensor data, Social Media, DB

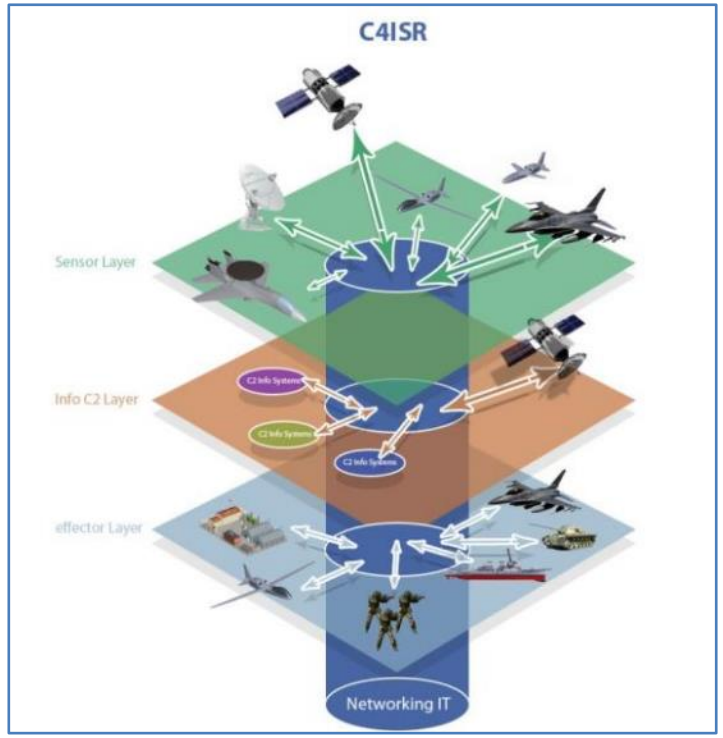
Autonomy of a multitude of devices

- swarms, autonomous impact assessment
- human-machine teaming

Machine Learning

- Capacities, op. demands, guidelines and consequences

Current Programmatic Focus II
Improve Communications



Connectivity Across All NATO Command Levels

- across heterogeneous networks and all levels and domains
- IoT

Optimize Usage of available Bandwidths

- Electromagnetic spectrum mgmt. and increasing spectral efficiency
- Cognitive radio and radio networks
- 5G mobile networks

Electronic Warfare

- Situational awareness, Command and control of the spectrum

Current Programmatic Focus III

Increasing relevance: Cyber Defense

Protect NATO Information Systems and Networks

- Multidomain Cyber Attacks

Cyber Awareness, CybOP

- Low cost, high speed, high impact, anywhere
- little reaction time → Prediction important
- Simulate and evaluate Cyber Attacks

Trust

- Single components and full integration
- Software, chips and algorithms

Technology Trends

Cyber Domain

- Cyber intelligence, Hybrid Warfare, aggressor patterns with AI
- Prediction, early warning against narratives/propaganda in social media
- Trust in complex, networked, automated, autonomous systems

Autonomy

- AI for global situation awareness
- Big Data, OSINT, Predictive Analysis, Visualization
- Interoperability of UAVs and with Command and Control

Future Networks

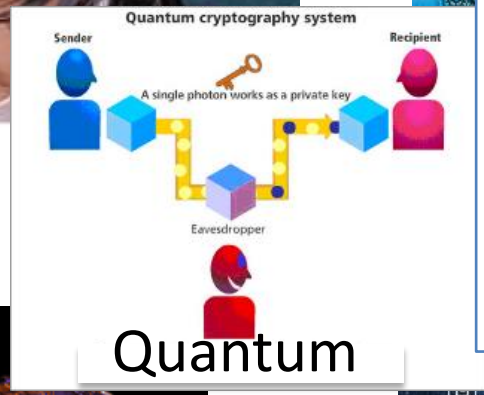
- Cognitive networks, Software defined networks (SDN)
- Hybrid Tactical Networks, 5G technology, Full Duplex Radio
- Airborne communications nodes

Stay at the Forefront of S&T

Technology Watch

Current IST TW Activities are focused on:

- **Real Avatars**
- **Digital Twins**
- **Quantum-safe Cryptography**
- **Blockchain and Distributed Ledger Technologies**
- **Terahertz Communications**
- **Trust in AI**
- **Legal, ethic AI**



Forge and Nurture Effective Partnerships

- IST benefits of Associate Members from **ACT** , **NCIA** and **CMRE**
- Trying to get connected with the NATO CCD CoE (**Cooperative Cyber Defence Centre of Excellence**) in Tallinn, Estonia
- IST organizing its Spring PBMs in coordination with the ICMCIS (**International Conference on Military Communications and Information Systems**)
  - Spring 2020: PBM colocated in Amsterdam, The Netherlands, 12-13 May 2020
- IST also connected via its members with the IEEE (**Institute of Electrical and Electronics Engineers**)

IST Space Activities

IST Research activity is mainly indirectly related with the Space Domain:

- **Communications, networking and network management**
- **Spectrum analysis & management**
- **Security & Cyber defense**
- **Multisource data fusion Data/image analytics**
- **Artificial Intelligence & Autonomous systems**

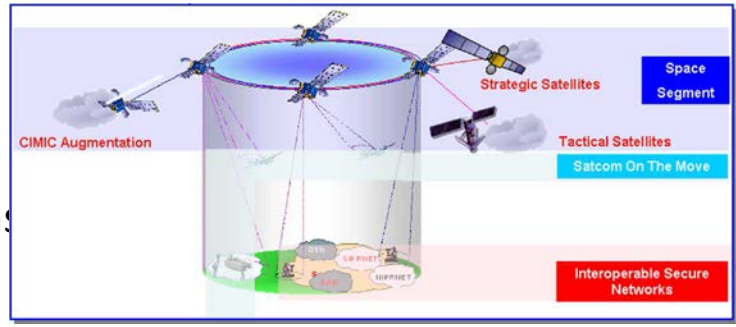
Still there are specific Space-related research topics being looked at:

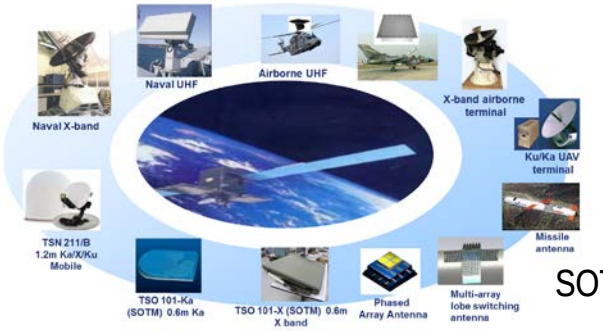
- **Satcom & Satcom like technologies**
- **New technologies**

Specific Space-related activities

NATO NEC over SATCOM (IST-113 RTG - Report Pub. 2018)

- Increasing requirement for suitable tactical satellite communication in military operations
- Solutions for some of the main challenges in NEC operational scenario:
  - direct and seamless interoperability between the Nations assets/capabilities
  - availability of tactical mobile SATCOM narrowband and wideband communications with improved mobility (SOTM)
  - spectrum congestion and global coverage issues including the Polar Regions





SOTM

Airborne Beyond Line of Sight Communication Network (IST-172 RTG 2019-22)

- Major role of BLOS communications in connecting forces out-of-theater but also in-theater
- Airborne BLOS network as an additional option to SATCOM or HF
- A network of multiple airborne relay nodes provides added resiliency in a hostile communications environment

Space-related new and future activities

Terahertz-band Communications and Networking

- High impact on future military operations: THz band supports huge transmission bandwidths (Tbps)
- Supports massive-data sharing for transformative applications in ground, air and space systems
- extremely robust and secure long range air-to-air links, space cross links and short range communications

Hyper Sonic Communications

- Research, development and testing have increased rapidly in Hypersonic area
- Enabling communications may significantly increase the capability offered by hypersonic “vehicles”

5G Technology Investigation

- 5G will support innovative capabilities and several others are targeted for major enhancements.
- Many have potential value in defense scenarios: eg extreme long range coverage in low density areas, self-backhaul, the inclusion of satcom, network slicing, diverse mobility management

Operation in arctic and high latitude areas

- Increasing military relevance of these areas require a specific focus to solve the criticalities that affect current satcom and radio communications

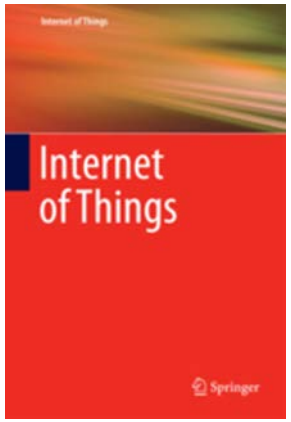
Activities of potential interest

Electromagnetic environment situational awareness for NATO (IST-146 RTG 2017-20)

- Radio Environment Map (REM) to provide situational awareness of spectrum in time, space and frequency

Cognitive Radio Networks (IST-140 RTG 2015-18)

- Transition towards full networking requires information exchange in unknown and hostile spectral environments
- Cognitive Radio Network technology is a promising solution for achieving this adaptability.



Software defined network architectures for FMN (IST-142 RTG 2016-20)

- Assessing new networking technologies (SDN, CCN) and assuring a smooth migration of the architecture

Military Applications of Internet of Things (IST-147 RTG 2016-19)
Federated Interoperability of Military C2 and IoT-Systems (IST-176 RTG 2019-22)

- Follow-on of RTG on Military Applications of Internet of Things (IST-147), Internet of Things (IoT) has a significant role to play in future Military Operations and Collaborative Resilience

Activities of interest

Cyber security of military Systems (IST-151 RTG 2016-19)

- Military systems and platforms are targets of choice for cyber attacks because of their potential strategic impact.
- Sharing and applying methodologies, processes, tools and technologies to assess military systems' cyber security.

Intelligent Agents for Cyber Defence & Resilience (IST-152 RTG 2016-21)

- Artificial cyber hunters – intelligent, autonomous, mobile agents specialized in active cyber defense.
- Agents will stealthily patrol the networks, detect the enemy agents while remaining concealed, and then destroy or degrade the enemy malware. They will do so mostly autonomously, because human cyber experts will be always scarce on the battlefield

Cyber Monitoring and detection capability for Military Systems (IST-162 RTG 2018-20)

- Improve military systems protection by incorporating a Cyber 'Monitoring and Detection' capability

Cyber Security Science and Engineering 2.0 (IST-170 RLS 2019-20)

- Supporting NATO member states and their national cyber security strategies through cyber security education.
- Disseminating knowledge on Cyber Security Science, Cyber Security Architecture and Cyber Security Engineering

Activities of interest

Network Management & Cyber Defence for FMN (IST-180 RTG 2020-22)

- Federated Mission Networking (FMN) is the leading concept for collaboration in NATO missions
- Development of Network Management and Cyber Defence (NMCD) to ensure safe and robust information exchange under the ever growing cyber threat

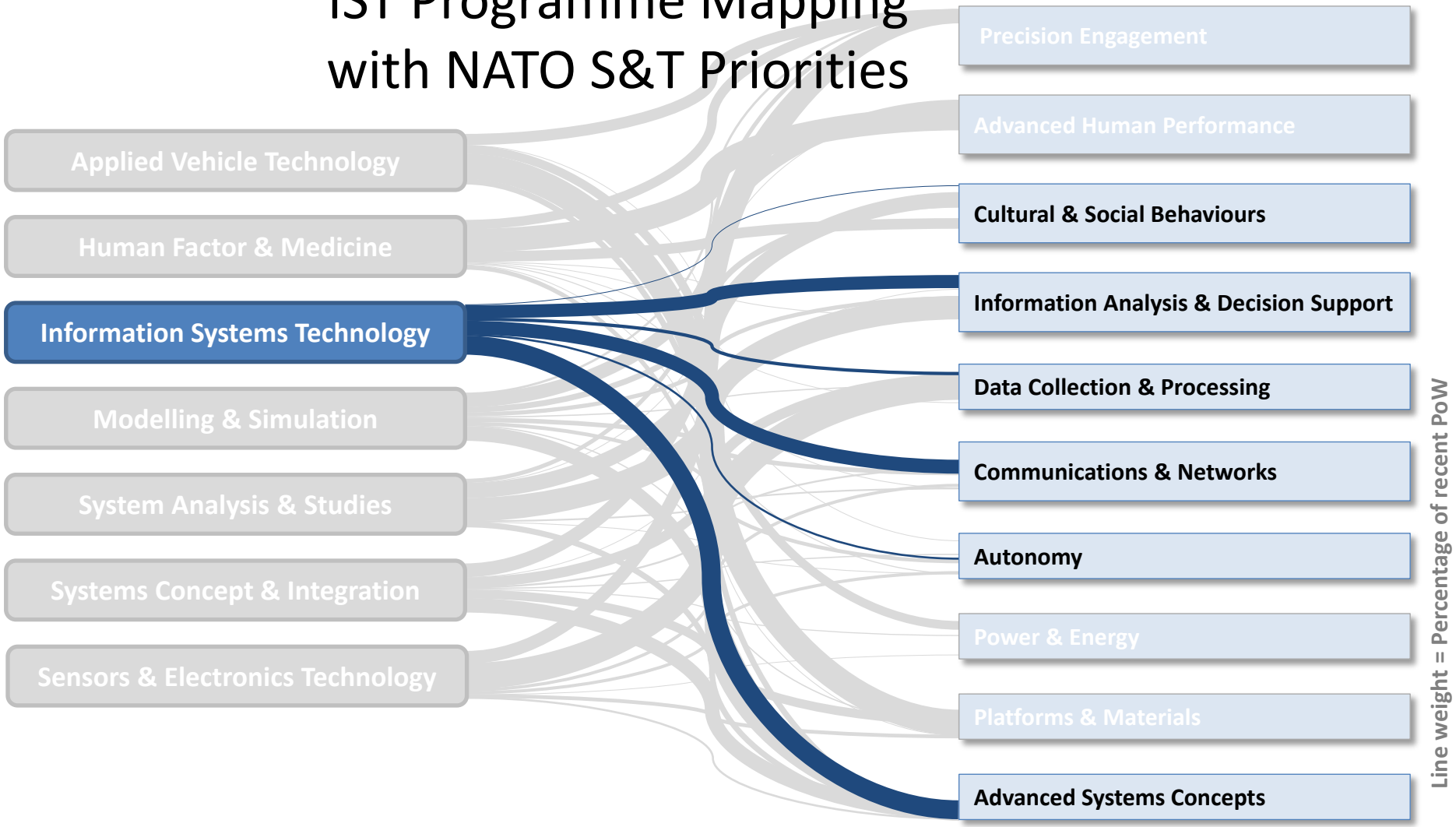
Blockchain Technology for Coalition Operations (IST-ET-110 2019-20)

- Potential to provide integrity, availability and authenticity
- The integrity of information gains more importance in case of a coalition force, where each nation has various technologies with different types and specifications of command and control systems

Unsupervised Machine Learning in the Military Domain (IST-P43-09 2019-2020?)

- Several military applications requiring AI approaches suffer of limited amount of labelled data
- Innovative solutions can reach appropriate intelligent solutions without the need of large amount of labelled data and can support intelligent transfer learning using available (also civil) data sets

IST Programme Mapping with NATO S&T Priorities



Thank you for your attention
Questions?
... suggestions?

System Analysis and Studies Panel

"Expert analytical support for better decisions in NATO operations and capability development"

23 June 2019

Lt Col Alessandro ALTOMONTE
SAS Panel
SCI-318 Torino (ITA)

System Analysis and Studies (SAS) Panel

"Expert analytical support for better decisions in NATO operations and capability development "

- The SAS Panel mission is to provide operations research and analysis support **to inform decision making by the NATO Alliance members and partners**. The main activities consist of among others:
  - **Conducting studies and analyses of an operational and technological nature**
    - Usually, exploring how operational capability can be enhanced through the exploitation of new technologies, new forms of organisation or new concepts of operation
  - **Promoting the exchange and development of methods and tools for operational analysis as applied to defence problems**

Panel Leadership and updates

Chair:
Dr. Ana Barros
(NLD)
TNO

SAS Panel Office
Panel Executive: LTC Tim Povich (USA)
Panel Assistant: Mr. Jeroen Groenevelt (NLD)

Vice Chair:
Mr. Espen Skjelland (NOR)
FFI

Programme Development Team
(Vice Chair + 6 Nations, ACT, Panel Exec)

Trial Programme Exploitation Team
(Tiger Team)

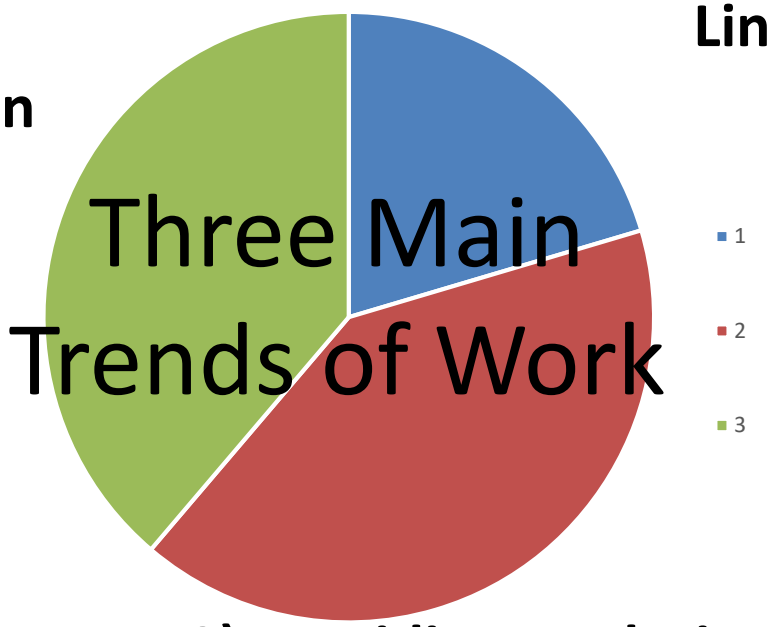
Awards Committee
Dr. George Akst (USA)
to retire, new Chair
Mr Goran Kindvall (SWE)

48 Members
- **43 National Representatives (23 Nations)**
- **2 PfP Nations + 1 Global Partner**
- **4 Associate Members: ACT, JALLC, OCS, NCI Agency**

SAS @WORK

3) Development of Methods and Tools to Enable Scientific Support to Decision Making (19/49)

- Systems Integration & Interoperability (Working Session A)
- Integrated Survivability (Working Session B)

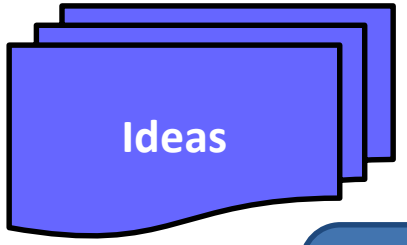


1) Evaluating S&T: Linkages between Technology and Operations (10/49)

- Enablers and Disruptive Capabilities (Working Session C)

2) Providing Analysis and Recommendations to Enhance Operational Effectiveness and Cost of Forces and Systems (20/49)

SAS Activity Development Process



Program development team (PDT)*

- facilitate development of new activities
- Identify topics of interest
- Recommends cross-panel activities

ET / ST TAP

Technical Team

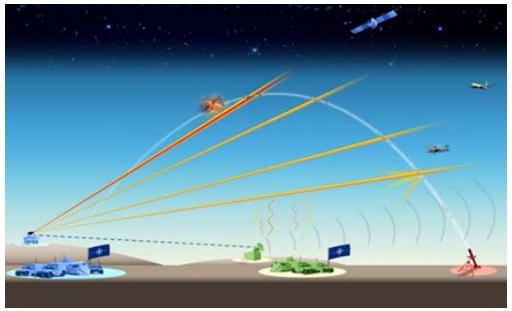
***Different from most Panels and Group!**

Stay at the Forefront of S&T:

Determining the Operational Impacts of New Technologies

Anti-Access, Area Denial (A2/AD)

- Assessing the challenges posed by adversary A2/AD capabilities in the short, medium, and long term and identify potential solutions encompassing technical, tactical, operational and strategic means. (SAS-147)



Directed Energy Weapons

- Providing analytical and operational inputs for a future Directed Energy Weapons (DEW) concept of employment encompassing all defence Lines of Development (such as covered by DOTMLPFI) (SAS-140)

Assessment/analysis support to facilitate the introduction of Non-lethal Weapons (NLW)

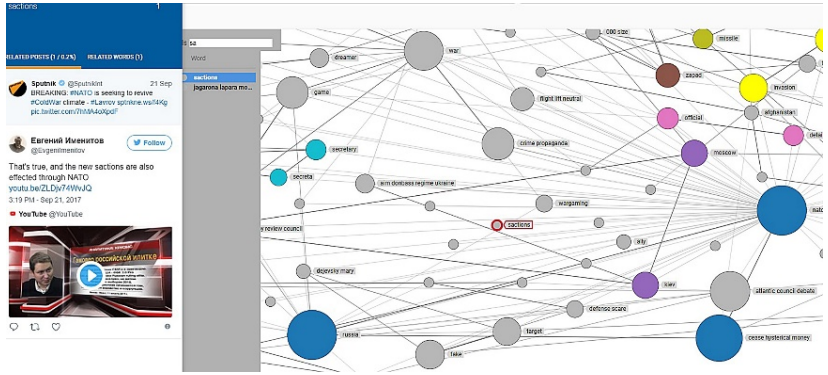
- Facilitating the introduction of NLW by addressing obstacles to development, acquisition, deployment, and employment by NATO and its member nations (SAS-133)
- Solutions Enabling Intermediate Force/Non-lethal Weapon Contributions to Mission Success (SAS-151)

Stay at the Forefront of S&T:

Winning in the Information Environment

Social Media Exploitation

- Determined rational and effective ways of exploiting social media as a source for intel purposes and investigated potentially relevant methods and tools for use by intel analysts when exploiting social media sources (SAS-IST-102)
- Evaluating the different social media exploitation tools to determine the best uses for exploiting the internet for intelligence purposes (SAS-142)



Information Operations for Influence

- Examined emerging threats in the information environment (IE), issues related to adversary exploitation of the IE and the employment of non-linear/hybrid warfare
- Identified capability gaps required to counter adversary asymmetric advantage in the information domain (SAS-117)

Making the best use of operational (big) data

- Data Collection and Management Handbook (SAS-111)
- Identification and requirements for “Big Data” Analytics (SAS-150, SAS-124)
- Coalition Sustainment Interoperability Study (SAS-ET-EH)

Forge and Nurture Effective Partnerships:

Engaging the NATO Operational Community

- **NATO Commands**
  - Casualty Estimation (SAS-ET-EC), A2/AD (SAS-147), Energy Efficiency and Security (SAS-118/119), Conducting Survey Research (SAS-144), Wargaming and COA Analysis (SAS-130/139), Operations Assessment in Complex Environments (SAS-110), Making the best us of operational data (SAS-111)

- **NATO Centers of Excellence**
  - Cyber Defence/Resilience(SAS-129, SAS-116), Energy Efficiency (SAS-119), Command and Control (SAS-104, SAS-143)

- **National and NATO Intelligence Communities**
  - Open Source Intelligence (SAS-IST-102, SAS-117, SAS-114, SAS-142), Communicating Uncertainty in Intelligence (SAS-114)

Forge and Nurture Effective Partnerships:

Engaging Academia and NATO Organizations

- **Partnership with Academia**
  - Comparison of Acquisition Systems (SAS-125), Deterrence and Assurance (SAS-141), Gamification of Cyber Defence/Resilience (SAS-129), Threshold Concepts (SAS-131) , Communicating Uncertainty in Intelligence (SAS-114)

- **Conference of National Armament Directors and Subgroups**
  - Risk Analysis in Acquisition (SAS-109), Comparison of Acquisition Systems (SAS-125), Soldier System Weapon & Equipment Tool (SAS-145)
  - Started exploration of potential alignment of PoW with NIAG and MCDC

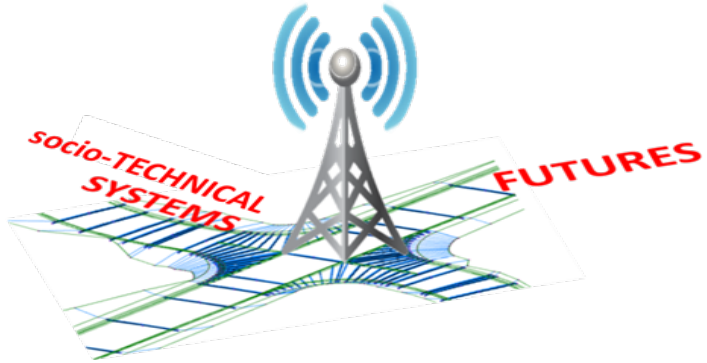
- **Other NATO Bodies and NATO HQ**
  - Communicating Uncertainty in Intelligence (SAS-114), Conducting Survey Research (SAS-144), Hybrid Warfare (SAS-121, 127), Non-lethal weapons (SAS-133), Comparison of Acquisition Systems (SAS-125), Data Collection and Management for Operations (SAS-111)

Promote Technology Demos:

Engaging Expert Communities of Interest

Futures Assessed Alongside socio-Technical Evolutions

- Conducted a trial of the FATE Method with non-members of the research team from Defense Science and Technology Lab, UK (Dstl) to work with practitioners and get feedback to assess and improve the method (SAS-123)



Non-lethal Weapons for Counter-UAS

- Supported the 2018 NATO Non-Lethal Technology Exercise Counter-UAS (NNTEX-18C) sponsored by the NATO Defence Against Terrorism Non-Lethal Capabilities (DAT-NLC) which educated attendees on the potential threats posed by small UAS and the challenges in defeating them and demonstrated new cUAS technologies. (SAS-133)

Promote Technology Demos:

Engaging Expert Communities of Interest (Upcoming)

Development of an internet exploitation grading system

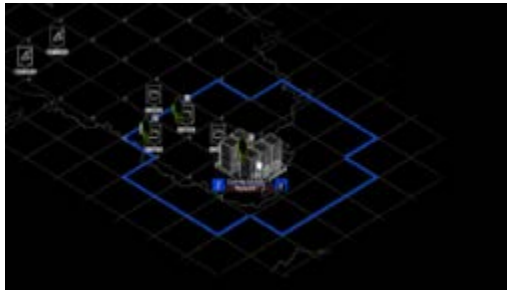
- Demonstration and trial of internet exploitation grading system in practice with an Intelligence Community of Interest (SAS-142)

NATO Analytical War Gaming - Innovative Approaches for Data Capture, Analysis and Exploitation

- Currently planning a wargame demonstration and data collection event in 2019 (SAS-139)

Gamification of Cyber Defence/Resilience

- Held a Cyber Security Serious Game Workshop at the 35th National Informatics Congress in Ankira, Turkey where they trialed their cyber defence serious game to an audience of military, industry and academics
- Future demonstrations planned with German and Dutch Armed Forces and as a syndicate at the NATO OR&A Conference (SAS-129)

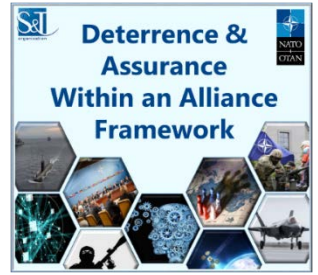


Enhance Alliance Decision Making:

Innovation in Deterrence and Defence

Deterrence and Assurance Symposium

- Reviewed NATO's concepts of Deterrence and Assurance (D&A) so as to underpin new approaches to planning, education and training to enable comprehensive planning, execution and assessment of D&A activities, ensuring that the Alliance remains effective in the face of evolving threats (SAS-141)
- Contributing to a future NATO Deterrence Concept



Threshold Concepts for Smaller Nations

- Introduced the novel concept "Conventional Threshold" for analyzing the different roles that armed forces in small states need in order to deter and defend against aggression (SAS-131)
- Conceptual Framework for Comprehensive National Defence System (SAS-152)

Renewing our Planning Capabilities for new Threats: Wargaming and COA Analysis

- Advancing strategic and operational decision making and synchronization in NATO by improving course of action analysis and developing analytical war gaming capabilities (SAS-130 and SAS-139)

Enhance Alliance Decision Making:

Handling Risk and Effectively Managing Cost

Risk Analysis in Planning and Acquisition

- Developed a NATO Risk Assessment Guidebook documenting the conceptual framework for risk and trade space analysis of defence acquisition programmes to help the Alliance manage risk in acquisition (SAS-109)
- Developed a risk-based framework to complement strategic (long term) defence planning for NATO and member nation(SAS-093)

Cost Analysis

- Defining best practices and guidance for Information and Communication Technology (ICT) cost analysis (SAS-153)
- **Understanding the cost implications of implementing autonomous systems (SAS-146)**
- Optimizing Investment in Simulation-Based Training (SAS-136)

Enhance Alliance Decision Making:

Adapting Operational Frameworks to new Technologies

Hybrid Warfare

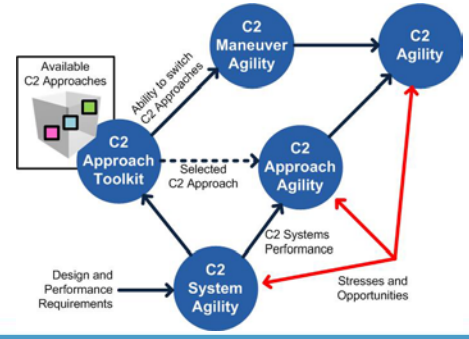
- Developed a case study of the Ukraine Crisis with an analysis of NATO Implications which is helping inform NATO decision makers and planners on hybrid warfare (SAS-121/127)
- Countering the Tactics of Hybrid Warfare: Military Aspects (SAS-ET-EK)

Cyber Warfare

- Provided a platform to investigate strategic level requirements for decision support in cyber defence (SAS-116)
- Developing innovative ways to educate commanders and decision makers as cyber security leaves cyber space and moves into the modern battlefield (SAS-129)

Command and Control

- Improved Awareness and Applications of C2 Agility Theory with NATO and helped inform NATO Concepts on C2 (SAS-104)
- Extending C2 Agility theory to Multi-Domain Operations (MDO) and the present challenges for C2 brought by autonomy and non-human intelligent collaborators (SAS-143)



Focus on Alliance Needs to Boost Impact (Theme's)

Basics of complex modern urban functions and characteristics (OCUE Theme)

- Articulate the importance of urban operations and the evolution of threats;
- Inform participants on the nature of urban complexities;
- Set the conditions for participants to identify challenges and gaps on military capabilities and S&T (SAS-149)

Cost Implications of Autonomy (Autonomy Theme)

- Facilitate awareness of the potential cost effects of the introduction of autonomy in military operations
- Explore relationship between costs and autonomy, to include aspect of cost-effectiveness
- Identify the second and third order costs that will result from the introduction of autonomy (SAS-146)

Multi-domain AI & BD for military decision making **(AI&Big data Theme)**

- SAS Co-chairing IST-173: Multi-domain AI & BD for military decision making S&T roadmap
- Autonomy to Accelerate the Intelligence Cycle (SAS-ET-EG)
- Employing AI to Federate Sensors in Joint Settings (SAS-ET-EI)

Potential cooperation: SAS topics related to the Space Domain

- Integration of Space domain into new concepts of operations
- Impact of Space Domain on Deterrence (follow-on of SAS-141)
- How to make the best use of Space Domain
  - Deploying effectively space assets
  - Integration of advanced data analytics on the space domain
- Impact of Space Domain on Urban Operations
  - SCI contribution to upcoming Lecture series SAS-149
  - ….
- Cost and risk analysis of the loss of Space Domain

Systems Concepts and Integration (SCI) Panel
SCI-318 Specialists' Meeting (RSM) on
'The Space Domain and NATO Operations: A Critical S&T Review'
Army Education & Training Command, and School of Applied Military Studies
Turin, Italy, 25 - 27 June 2019
NATO UNCLASSIFIED open to NATO Nations,
Australia, Finland, Sweden and Singapore

25 June - Day 1 – Technical Visits

08:10	Registration
08:30	Departure by bus
09:00	Visit of Thales Alenia Space
13:00	**LUNCH**
14:30	Visit of ALTEC S.p.A. (Aerospace Logistics Technology Engineering Company)
16:30	Bus leaves to return to RSM Premises - Arsenal Palace (*Palazzo dell'Arsenale)*
18:00	Ice Breaker at Arsenal Palace

26 June - Day 2

08:30 Registration, Arsenal Palace

09:00 Welcome Ceremony by Specialists' Meeting Chairs and Host
Lt. Col. Giovanni SEMBENINI, MoD, Secretariat General of Defence and National Armaments Directorate, Italy, Dr Donald LEWIS, Aerospace Corporation, United States

09:10 Welcome by the Commander of the Army Education & Training Command and School of Applied Military Studies
Major General D. Salvatore CUOCI, Army Education & Training Command, and School of Applied Military Studies, Italy

09:15 Introduction to the NATO Science and Technology Organization (STO) Collaboration Support Office (CSO)
Lt. Col. Ryan SNIDER, SCI Panel Executive, NATO Collaboration Support Office (CSO)

Keynote Speeches

09:20 Introduction of Keynote Speaker 1
Lt. Col. Giovanni SEMBENINI, MoD, Secretariat General of Defence and National Armaments Directorate, Italy

09:25 KN1 Space Support in NATO Operations
Lieutenant General Giovanni FUNGO, Commander for Army Education and Doctrine, Italy

09:50 Introduction of Keynote Speaker 2
Lt. Col. Giovanni SEMBENINI, MoD, Secretariat General of Defence and National Armaments Directorate, Italy

09:55 KN2 The Space Sector Today and in the Near Future
Professor Ezio BUSSOLETTI, Area Coordinator for Space and Aerospace, National Programme for Research, Ministry of Education and Research, Italy

10:20 Overview of NATO STO / CSO
Lt. Col. Ryan SNIDER, SCI Panel Executive, NATO Collaboration Support Office (CSO)

10:30 **BREAK**

11:00 Introduction to NATO STO Space & SM Objectives
Dr Donald LEWIS, Aerospace Corporation, United States

11:25 Threats to NATO's Space Support in Operations
Lt. Col. Tim VASEN, NATO JAPCC

11:45	NATO Approach to Space CDR Stephanie VRAC, NATO ACT, Lt. Col. Heiner GREST, NCIA
12:05	Space Support in NATO Exercises CDR Stephanie VRAC, NATO ACT, Mr Flavio GIUDICE, NATO Communications and Information Agency (NCIA)
12:25	Space Situational Awareness at the European Satellite Centre Mr Joao ALVES, EU SATCEN
13:00	**LUNCH**
14:00	NATO STO - SCI Panel Space Activities Dr Donald LEWIS, Aerospace Corporation, United States
14:20	SCI-311 Task Group on Collaborative Space Domain Awareness Data Collection and Fusion Experiment Ms Carolyn SHEAFF, USAF AFMC AFRL/RIED, United States
14:40	NATO STO - AVT Panel Space Activities Prof. Dr Alim ASLAN, Istanbul Technical University, Turkey
15:00	NATO STO - SET Panel Space Activities Prof. Marco MARTORELLA, University of Pisa, Italy
15:20	NATO STO - IST Panel Space Activities Ing. Carlo GUGLIELMINI, Leonardo SpA, Prof. Gian Luca FORESTI, University of Udine, Italy
15:40	**BREAK**
16:00	NATO STO - SAS Panel Space Activities Lt. Col. A. ALTOMONTE, Ministry of Defense, Italy
16:20	Group Discussion
16:50	Introduction to Day 2 Activities
17:00	End of Day 1

27 June - Day 3 – Syndicate Working Groups

09:00	Administrative Remarks Dr Donald LEWIS, Aerospace Corporation, United States Lt. Col. Giovanni SEMBENINI, MoD, Secretariat General of Defence and National Armaments Directorate, Italy
09:05	Syndicate Instructions and Work Assignments in Plenary Session Dr Donald LEWIS, Aerospace Corporation, United States
09:15	**Syndicate Task 1:** Review Session (All)
10:00	**Syndicate Task 2:** Critical review of STO Program of Work (All)
11:00	**Syndicate Task 3:** S&T opportunities (All)
12:00	**Syndicate Task 4:** Implementation - Making it Real (All)
13:00	**LUNCH**
14:00	Plenary Preparation
14:30	Syndicate Outbriefs
15:45	**BREAK**
16:15	Plenary Discussion
16:45	Technical Evaluation Report (TER) Outbrief Dr James GREER, The Aerospace Corporation, United States
16:55	Closing Remarks
17:00	**End of Specialists' Meeting**

REPORT DOCUMENTATION PAGE

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North Atlantic Treaty Organization
BP 25, F-92201 Neuilly-sur-Seine Cedex, France

6. Title

Space Domain and NATO Operations: A Critical S&T Review

7. Presented at/Sponsored by

Systems Concepts and Integration (SCI) Panel SCI Specialists' Meeting held on 25 - 27 June 2019 Turin, Italy.

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10. Author's/Editor's Address	**11. Pages**
Multiple	

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ASAT, C2, GPS, IST, Jamming, Lasers, Radar, SATCOM, Satellites, SATNAV, Space, Space Domain Awareness, Space Environment, Space Launch, Space Weather

14. Abstract

The SCI-318 Specialists' Meeting held from 25 – 27 June 2019 was hosted by the Army Education & Training Command, School of Applied Military Studies, Turin, Italy. The objectives of the event were to raise awareness of and assess the current space-focused collaborative program of work of the NATO Science and Technology Organization and to make recommendations for the future of space-focused efforts under the STO's guidance. The Specialists' Meeting participants conducted a technical tour of Thales Alenia Space and Altec to help set the tone for the technical discussions that followed. In addition, the participants reviewed presentations on the ongoing and planned work from five of the seven STO Panels which consisted of seven current and four planned space-focused activities across the STO's collaborative program of work. For context, this represents approximately 5% of the 300+ ongoing activities in the collaborative program of work. After the reviewing the current and planned activities, the participants broke out into syndicates to formulate recommendations for consideration by the STO and the nations that support its collaborative program of work.