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National Military Space Operations Centres

Requirements on National Centres with Respect to NATO Needs

Joint Air Power Competence Centre

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The Assistant Director of the Joint Air Power Competence Centre (JAPCC)

SUBJECT:

National Military Space Operations Centres –
Requirements on National Centres with Respect to NATO Needs

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NATO does not have space-based resources of its own; however, the organization is heavily and increasingly dependent on space data, products and services to conduct military operations, missions and other activities, as well as executing training and exercises. Several NATO member nations operate satellites, which provide such needed capabilities. However, these assets are operated under national Command and Control (C2), and nations are not willing to place them under NATO C2 and NATO is not aiming to become an autonomous space actor with assets of its own. On the other hand, some space-faring allies are able to offer and provide data, products and services to NATO on a voluntary basis. As a result, NATO is totally reliant on external sources in the space domain, especially on its member nation's, willingness to share and the supply of commercial providers.

To guarantee the process of exchanging data, products and services, some mechanisms and regulations have to be in effect. The purpose of this report is to set out the framework conditions for a National Military Space Operations Centre and outline the conditions for the needed exchange mechanism to assure continuous space support in line with NATO's needs.

This study will focus on requirements for information in NATO's newest Operational Domain 'Space' and will form a basis for defining generic structures as well as procedures for future (or) planned national Space Operation Centres of NATO member nations as the potential national focal point of space-based information.

Among many sources, this publication is based on data collected by a JAPCC questionnaire from member nations of NATO, which are summarized here in Annex E. These findings are also used in the JAPCC publication 'Resiliency in Space as a Combined Challenge for NATO', published in August 2021, so that both publications can be read in context at the time of writing.

I invite you and your staff to read this study. We welcome thoughtful insights and comments from our readers. In this regard, feel free to contact the Space Branch via e-mail at space@japcc.org.

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CHAPTER 1

Preface

Neil Armstrong's first step on the moon more than 50 years ago (21 July 1969) was the symbolic finale in a competition, a space race between the United States of America and the Soviet Union – the main actors at that time. Since then, more and more actors have started their venture into Space, nations as well as private companies. Today 40 national and regional space agencies are officially listed on the webpage of the United Nations Office for Outer Space Affairs (UNOOSA)[1], while other sources listed more than 70 national organizations.[2] The total number of active satellites grew to 3,372 by 1 January 2021[3], and since the beginning of the Space Age 11,139 objects have been launched.[4]

1.1 Background

Today's daily life without space-based products and services would be unimaginable for both civil and military purposes. Space is a Global Commons[5], or a Global Public Good (GPG) like Maritime, Air and Cyber. All of these are crucial enablers of international prosperity and security.

Higher dependency on space Data, Products and Services (DPS), provided by space-based services, more organizations, more rocket launches, more satellites and more space debris in various orbits, as well as more competition in Space among more players

present challenges today. In addition, ongoing trends, like mega-constellations, space tourism, future trends like Mars exploration, or asteroid mining, and a higher degree of commercialization will induce even great use of Space.

The military, as one part of a national security organization, is a very active player in Space in many nations worldwide. As a note, also NATO has operated space derived DPS since the 60's. Space-based assets are having an amplifying influence on military forces and their ability to project power. For decades Space has been an outstanding environment for enhancing military power and will be more so as various militaries all over the world increase their involvement in Space. As one of the latest major developments on the military front, on 4th December 2019, NATO's Heads of State and Government recognized Space as a distinct operational domain on par with Air, Land, Maritime and Cyberspace.[6] In doing so, they illustrated the growing influence of space-based assets on NATO's military warfighting capability and the importance for strengthening the Alliance in the future. However, this decision also confirmed that Space is developing into an environment for the projection of power, for competition and as a sphere of influence for space actors. It will be interesting to see if this will lead to a (further) militarization of Space. Nevertheless, today Space is an operational domain alongside Air, Land, Maritime and Cyberspace and this status may help NATO and all allies improve coordination and integration of this challenging domain with air, land and maritime operations and with greater speed, effectiveness and precision.

Declaration of Space as a distinct operational or warfighting domain acknowledged its status in NATO as a vital, not-to-be-neglected part of overall warfare. Space capabilities, or more precisely, the effects provided by those capabilities, have proven to be significant force multipliers or, in some cases, even critical force enablers when properly integrated into an operation. However, this does not mean that Space is the most important domain in the current of future conduct of war. It simply means that omitting space capabilities will throwback warfare to the era of the early days of the Cold War. In those days, air superiority at the beginning of a military conflict was key for all ongoing operations to ensure survival. Today, Space – in line with Cyberspace – will be the means of first-time operation, and their assets have to withstand first attacks in order to continue operating. Both are a cross-sectional challenge for all military operations. Therefore, increasing interdependencies between all domains require a new relationship of connected operations. For that reason, Space must be an integral part of the developing concepts of Multi-Domain Operations (MDO)[7], or Joint All Domain Operations (JADO)[8], because of its effects on all domains. Consequently, NATO's potential adversaries are developing means in precisely these areas to be able to deny, degrade and disrupt NATO's space capabilities.

NATO's operational capabilities are enabled by space-based capabilities, among others; therefore, they are a decisive factor in today's activities of NATO. In spite of that importance, NATO as an organization does not have integral capabilities in Space; it coordinates those services provided by nationally controlled assets and, therefore, it is highly reliant on its 30 member nations[9] for contributing their individual share of DPS, as well as best-trained space professionals. Nations are the capability providers for NATO, they have the toolset. Thus, the nations play a significant role in how and to what extent NATO is able to integrate the space domain across the spectrum of conflict.[10] On the other hand, NATO must take space capabilities into account and must integrate the desired effects into relevant policies, plans, doctrines and strategies at the joint and single service levels of planning and execution.

This study will describe and evaluate national contributions and procurement via commercial partners of space-based DPS to NATO, particularly a national military Space Operations Centre (Nat mil SpOC) as the possible focal point of all national military space activities and the main link to NATO. From NATO's point of view and for their need for information, this study will try to develop these requirements as a basis for the potential organization of a Nat mil SpOC. These findings may give some input to nations in their efforts for adequate adjustments of their own Space Operations Centres (SpOC). It may also be of assistance

to newcomers without integral or little space capacities, NATO member nations as well as cooperating nations, for their contribution to NATO's dependency on national support.

A focus will be on facilitating the development of the compatibility, on interoperability between Allies and on the alignment of procedures.

The operational environments in Space have changed over the last few decades, from a mainly undisturbed setting, to the congested and contested domain we see today. Nascent and re-emerging peer-level competitors realized NATO's and Alliance member nations' military and economic advantages enabled by space capabilities. They are undertaking a significant effort to negate those advantages through denial, disruption, degradation and possible destruction of western nations' space systems. Space is now an operational, or warfighting domain and NATO – within agreed upon limitations – must be prepared by arrangements with the nations, to have access to, fight in, from and through Space to protect and finally to defend their interests in this domain. It is a reality today that tensions, even to the degree of confrontation, between nations are being manifested in Space. As a result, NATO and nations are forced to provide safety and security in and for the space domain.

Looking into the future, the space environment and the military domain, including for the systems, applications and widespread area of human activities will be a sphere of ongoing explosive scientific and technological progress. This will present nations with enormous challenges for the implementation and integration of space assets into military service, to benefit from their use.

For NATO, recognizing Space as an operational domain was not only the culmination of a prolonged effort that started with integration into the military organization. Foremost it was the starting point for initiating additional work, like the development of specific terms and definitions, which may become a common basis for all national supporting entities, from DPS to the coordination of effects and information through the provision of general space awareness and understanding. However, details on these newest developments are mainly still in development and predominantly not published yet.

1.2 Aim

The aim of this study is to provide NATO, its member nations and interested persons or organizations with basic knowledge and requirements about Nat mil SpOCs in their specific role in NATO's need for DPS as well as to provide some baselines for the development of processes for mutual exchange and the need for agreements as one prerequisite for interoperability. In this regard, Space is only one piece in the overall effort to integrate national military capabilities of NATO member nations with NATO's comprehensive approach.

1.3 Assumptions

Use of modern, sophisticated space technologies in the current and future civil and military environment is not only a question of technology; it also requires a combination of personnel, organizations, procedures, operations, and especially finance. In the context of this study, the recommendation is to achieve a common will and understanding of mutual objectives within NATO and the Alliance.

1.4 Methodology

How will NATO fight in the future, and how do we incorporate possible future challenges into today's solutions? The answers to these questions are in analysing the threats, identifying gaps, setting requirements for filling these gaps as well as fostering technical innovation especially in this domain.

The study consisted mainly of document research from primarily open sources, key stakeholder engagement and on critical analysis of programs, processes and policies, as well as own experiences.

This explanation of the study starts in chapter 2 by framing today's situation and delineating a possible scenario within the changing geopolitical landscape. The opening also includes what key technology is feasible. Subsequently, the anticipated conditions are compared to the type of conflicts that NATO might face and the NATO capabilities, which are expected to be requested. In addition, a brief insight into the organizational structure of NATO and the relationship with the member nations is outlined in this chapter, as are the space capacities of these nations, especially in the military sector.

Chapter 3 explains NATO's position with respect to the reliance on DPS, as well as the regulations for information sharing, organization and processes, and finally Education and Training (E&T).

The specific legal framework is described in chapter 4, followed by the main chapter (5), which will look at specific requirements in detail, such as organizational, technological, physical and human. This chapter is the focal point of the investigation. Technological aspects and Information Technology (IT) aspects are determinant factors for Space and are heavily interconnected. Due to a variety of different factors, they are discussed separately within the study.

Chapter 6 will include a basic overview of existing SpOCs in NATO member nations and will highlight specifics regarding the exchange of DPS to NATO and allies. Chapter 7 will show new developments and ideas in the space sphere based on military relevance for the near future and the final chapter, 8, will conclude this paper with a look into the future.

Recommendations on the requirements for a Nat mil SpOC, which explained within the structure of the NATO DOTMLPF-I[11] process, are listed in Annex A. Additional annexes provide more detailed information on specific subjects.

1.5 Key Definitions[12]

The central theme of this paper is *Interoperability*. It is defined as 'The ability to act together coherently, effectively and efficiently to achieve Allied tactical, operational and strategic objectives'.

Achieving effective interoperability has been a major challenge for NATO since its early days. Interoperability is the key to NATO's success, especially with today's modern forces; therefore, it is one of NATO's top planning priorities. For this study, interoperability with respect to procedural, technical and human aspects is the main focus area.

In addition, *Cooperation*, is defined as 'The process of groups of organisms working or acting together for common, mutual, or some underlying benefit, as opposed to working in competition for selfish benefit' (as used in social sciences), is closely linked with interoperability; both are mutually dependent. Cooperation does not only imply technological aspects, but it also refers to the function of the organization and even to intellectual skills. Today's cooperation will be tomorrow's integration.

Concentration, another keyword in this area, is not specifically defined in this context. However, a general description is a conglomerate of forces as a measure to make optimal use of scarce resources (especially personnel or financial) in order to target various efforts.

Besides these commonly used definitions, further specific elements, especially in the space domain, remain undefined; even a definition and a common understanding of Space have not been agreed upon. The United Nations (UN) is merely setting general rules, while leaving the definition of Space to the individual nations.

1.6 Limitations

NATO's recognition of Space as an operational domain influenced the writing of this paper. However, statements from recently provided documents were not taken into consideration, mainly due to their actual status as draft documents, as well as their classification. Nevertheless, these papers show the

way forward and call for actions to be taken by the highest NATO authorities, as well as the nations.

JAPCC prepared and circulated a questionnaire to all NATO member nations that addressed aspects of this study, as well as another JAPCC study entitled *Resiliency in Space as a combined Challenge for NATO* that was published in August 2021.[13]

Other NATO documents with regard to the space domain have been published more recently but are classified 'NATO RESTRICTED'. Specific content from these documents has been included in this whitepaper, but in a manner that ensures classified information is not disclosed, and this study can remain at the UNCLASSIFIED level to allow for broader dissemination. Conclusions that are more specific can be found in the cited documents. A list of referenced literature is attached in Annex G.

To provide a rough overview, this study will initially explain the relevance of Space in general to modern operations and the military significance for NATO in particular.

Collective Defence (CD) is only one of all the NATO Mission types[14], but it is the most demanding and challenging. Throughout the study, and where no other mission types are mentioned, this paper focuses mainly on Article V operations.

The statements and conclusions made in this paper are valid for conceptual and doctrinal work, Standardization, Cooperation and, lastly, Education, Training, Exercises and Evaluation (ETEE).

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6. NATO Summit, 3–4 Dec 2019 in London, UK, London Declaration, available from https://www.nato.int/cps/en/natohq/official_texts_171584.htm [accessed 16 Januar 2020].
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9. North Macedonia joined NATO as 30th ally on 27 March 2020, available from https://www.nato.int/cps/en/natohq/news_174589.htm [accessed 15 April 2020].
10. NATO, AJP-01, 2017.
11. Doctrine, Organization, Training, Material, Leadership, Personnel, Facilities, Interoperability.
12. For all terms, definitions and explanations see Annex C with respective sources.
13. JAPCC Whitepaper Resiliency in Space as a combined challenge for NATO, published August 2021 available at https://www.japcc.org/portfolio/resiliency-in-space/ [accessed 18 August 2021].
14. For detailed information, see AJP-3 Allied Joint Doctrine for the Conduct of Operations (Edition C, Version 1), February 2019 and AJP 3.4. (A) Allied Joint Doctrine for Non-Article 5 Crisis Response Operations, October 2010.

CHAPTER 2

NATO and Space

The increasing permeation of technology in our society today is evident in everyday life. Especially in the military, this trend is described by keywords such as digitization, automation, miniaturization, robotics, and Space. The complete and successful integration of the newly recognized domains of Cyberspace[1] and Space with the classic domains of Land, Maritime and Air present challenges for the future. Even today, Space, like Cyberspace, as a new domain of warfare, is often neglected in the planning, execution and assessment phases of military campaigns in the joint, land, air and maritime environments.

2.1 Space – A Changing Environment

The full integration of DPS, provided by space-based assets will raise the effectiveness of all military operations of NATO in all mission types. As the UK Ministry of Defence stated: 'Like air power, the attributes of space power are related to the ability to exploit the vertical dimension, albeit to a significantly greater degree, as space can provide a truly global capability.'[2] The just established Headquarters of the US Space Force declares, 'Space is the only physical domain capable of achieving a globally persistent and legal

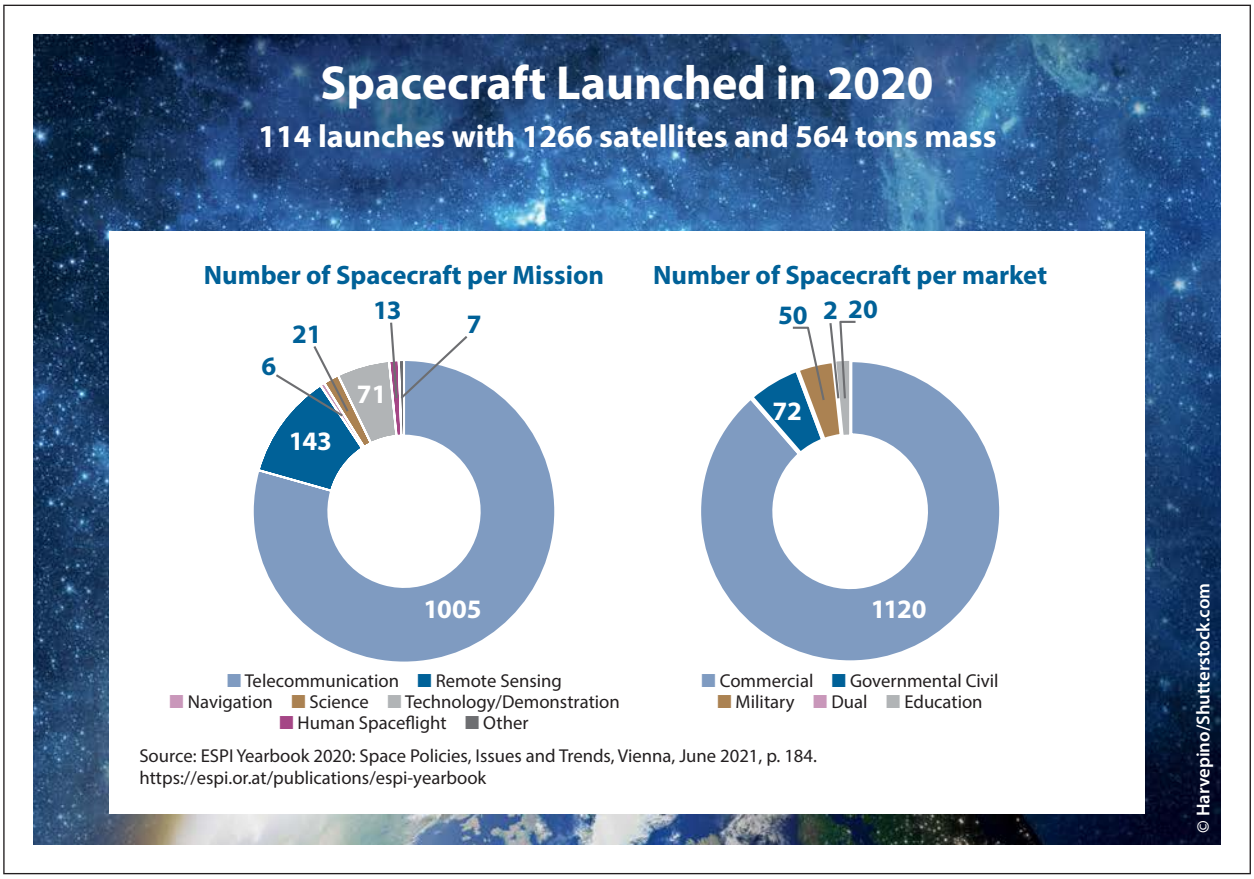

Figure 1: Spacecraft launched in 2020.

overflight military perspective of any location on the earth'.[3]

Today, Space is not as mysterious as it once was, and is of interest now not only to established space-faring nations, but also to many ambitious nations as well as civilian companies. The importance of space-based applications has increased in recent decades, and the main actors in Space have also changed. While in the early years of space exploitation there were only two world powers competing in this dimension, other nations have since stepped up to the stage and commercial participants are also significantly changing the list of participants.

Previous decades were characterized by a space industry mainly dominated by governments and specific public-sector institutions. Today we are undergoing a fundamental reorientation of the entire industry. New actors with innovative business models have shown up on the scene. The actual buzzword New Space[4] is associated with changes not only in technology, but also in finance and the economy. Key phrases in these realms are: small satellites, standardized satellites, mega-constellations, Commercial-off-the-Shelf (COTS) components, shorter design and mission lifetimes, modern forms of financing, serial production, as well as quick launch or launch-on-demand capabilities. These ongoing developments very clearly demonstrate the dual character of Space in various fields: military and civilian spheres; governmental entities and private companies; national responsibility and international cooperation.

The military, formerly a leading and determinant actor in Space, is in modern times only one of many stakeholders. Especially in colloboration with civilian enterprise, the military must realign

to a new role; the industry is setting the scene. On the other hand, new business models offer great opportunities for new forms of Public-private Partnerships (PPP).

This situation leads, among other things, to a huge increase in the number of objects in Space, especially in preferred orbits. Such objects contain not only the satellite itself, but also remnants of the means of transport or other space debris that has been lost or went out of control. In addition, crowding of preferred orbits may also cause some overlapping and, therefore, interference within primary radio frequencies and may limit their service.

All these increasing activities in Space require more and better coordination of orbit assignments than exist today. Current Space Situational Awareness (SSA), done only by some NATO Space-faring nations, is a passive effort for information delivery of the space environment, particularly for hazards like Collision Avoidance (CA), re-entry-warning, and space weather effects. This is no longer sufficient, active systems must be implemented for additional needs. A more comprehensive approach than SSA alone needs more input based on additional data, information and intelligence in order to locate, track and identify potential threats from, and in, Space. SSA includes all aspects in this domain, especially an adversary's capabilities and probable intentions. NATO recognized these aspects and identified Space Domain Awareness (SDA)[5] as a new responsibility to achieve a common understanding of all aspects associated with the space domain, this would include adversaries' threats as well as own vulnerabilities. Therefore, this new term demonstrates very obviously the changed assessment of Space from a merely physical domain to an operational domain with a specific military element.

In the long term, a Recognized Space Picture (RSP), analogous to a Recognized Air Picture (RAP), is highly valued militarily. Like organizing worldwide air traffic by means of Air Traffic Control (ATC), similar active means for managing movements in Space must be implemented; a first idea includes Space Traffic Management (STM).[6] These challenges and corresponding legal factors must maintain pace with technological innovation. Regulations governing use of airspace fall under national jurisdiction, while the International Civil Aviation Organization (ICAO), a specialized organization of the UN, manages international cooperation. Commonly accepted and agreed upon regulations regarding Space are necessary now to address future challenges and must be implemented by the UN as well as the only worldwide organization with the necessary span of influence in this regard. The United Nations Committee on the Peaceful Use of Outer Space (UNCOPUOS) would be the primary forum for discussion of these issues. However the status of this UN sub-organization is only at the committee level and comprises only 95 nations as members[7], in comparison to 193 members in other UN specialized agencies, like ICAO.[8]

2.2 Today's Significance of Space

The global space sector has become increasingly important to modern societies all over the world; it is an important part of modern daily life. Space technologies as well as space-based DPS are an integral and crucial part of modern economies as well as global security. This trend will continue in all developed and developing nations and they all rely increasingly on space-based assets. Therefore, space resources comprise the newest of national critical infrastructure and it seems they will be even more important to the needs of a growing earth population, which is expected to reach 9.7 billion in 2050.[9] Space-based assets will assist with better management of scarce resources, mainly water and minerals, will support the efficient use of energy and transportation and will offer even more improved communications, television, internet as well as navigation and timing to the population. In addition, space weather will also be included more in the risk management for future national weather forecasts.

Researchers in space technology and space exploration are looking for answers to basic scientific questions about the universe and about our own part on

our blue planet. Basic scientific research of Space addresses major challenges of today's society, such as climate change, pollution, food, loss of biodiversity and migrations. However, if talking about areas of Space, which are useable with today's technologies and a reasonable effort, you have to keep in mind we are talking about only a very small area around earth with a primary focus back towards earth.

Both points of view – basic research and user-related technology – have important economic aspects for space-faring nations; it helps in the determining a yearly percent increase of economic wealth and creates employment directly and indirectly within the space industry.

Space activities not only play an increasingly important role in all public and private activities, they are essential for national security and so a focus area for the military. In addition, due to their inherent dual-use-capabilities, civil and military space activities are using the same environment, shared as well with industry. Furthermore, both sectors often use the same infrastructure and they meet civil and defence goals simultaneously. Overall, a lot of interconnection between public, civilian and military space aspects exists, which must be taken into account when considering Space.

Space support in operations, missions and other activities are a significant part of military activities. This relationship was widely recognized and apparent to the public for the first time during the first Gulf War (1990/91), when its potential as a critical military enabler was obvious.[10] Today, no single operation will be planned or executed without space support! This does not mean that a lack of space capabilities will prohibit the execution of missions, but that it will downgrade the level of warfighting effectiveness to that of an earlier period of warfare and reduce NATO's technical advantage. Alliance forces would be less proficient in performing operations and missions and perhaps not fully achieve its political objectives.

Today, not only have the pioneering space-faring nations established national space strategies or military space strategies; some other NATO nations have also accomplished this and others are on their way to doing so. In contrast, some NATO member nations are not taking any action yet. What about NATO's own activities? Does it manage space activities of its own? As the premier intergovernmental military alliance between North America and the European countries, it constitutes of collective defence system, whereby its independent member states agree to mutual defence in response to an attack by an adversary?

When discussing Space and all benefits of this domain for the warfighter, we first must define where Space begins. Against all expectations, there is no official definition according to international law about Space. Most experts, as well as lawyers, agree that an altitude of 100 km is the beginning of Space, as set by the Federation Aeronautique International and referred to as Karman-Line.[11] With no official definition, each nation could determine its own horizontal limit for both sovereign airspace (with own sovereign rights) and Space (free from national sovereignty). This is a critical geo-political factor especially in relation to national activities and engagement, e.g. military engagements like self-defence at specific altitudes. In addition, NATO accepts the Karman-Line as acommonly viewed limit where aerospace ends and Space begins.[12]

Some leading space-faring nations have at least created a definition of space power. For example, the United Kingdom defines space power as 'Exerting influence in, from, or through, space'.[13] Up to now, NATO has avoided approving a definition.

After recognising Space as an operational domain, NATO is working on its own definitions or taxonomy for Space. This should also include a clear understanding on space power, to set the scene and the limitations about their planned future activities in this domain. A common understanding for the assessment of an attack on space-based objects, whatever kind of attack this may be, is essential. Nevertheless, the individual right of self-defence for all NATO missions types, Article V operations as well as

expeditionary missions like International Security Assistance Force (ISAF) or Resolute Support (RS), is indisputable.

Declaring Space as an operational domain by NATO is not the last step of all recent developments, it is mainly a starting point for NATO and its member nations for future efforts to fill its newest domain with the substance to ensure that the Alliance has reliable access to space products and services, when and where necessary.[14]

With the growing significance of the space domain, NATO clarified its objectives to ensure access to, and freedom of manoeuvre within Space for the Alliance. NATO, enabled by the nations, will accomplish its operational objectives by gaining and maintaining the operational advantage within the space domain in order to enable operations, missions, and other activities to achieve deterrence.

2.3 Space Threats

NATO is an intergovernmental, political alliance of 30 independent nations with a military arm that aims to establish a system of collective defence against any attack by an external party. In ongoing preparation for all manner of attacks, NATO takes into account all possible adversaries and their military potential. The assessment of these threats must be comprehensive and, therefore, must include Space as a potential area of threat. These threats are to be divided into natural and man-made threats, in and from Space; both types could be either intentional or unintentional. The ongoing evolution in space-related matters, especially rapid advances in space technology, creates new opportunities on one hand, yet on the other hand, generates new risks, vulnerabilities and potentially new threats. All these types of threats have different levels of importance and relevance for a military assessment.

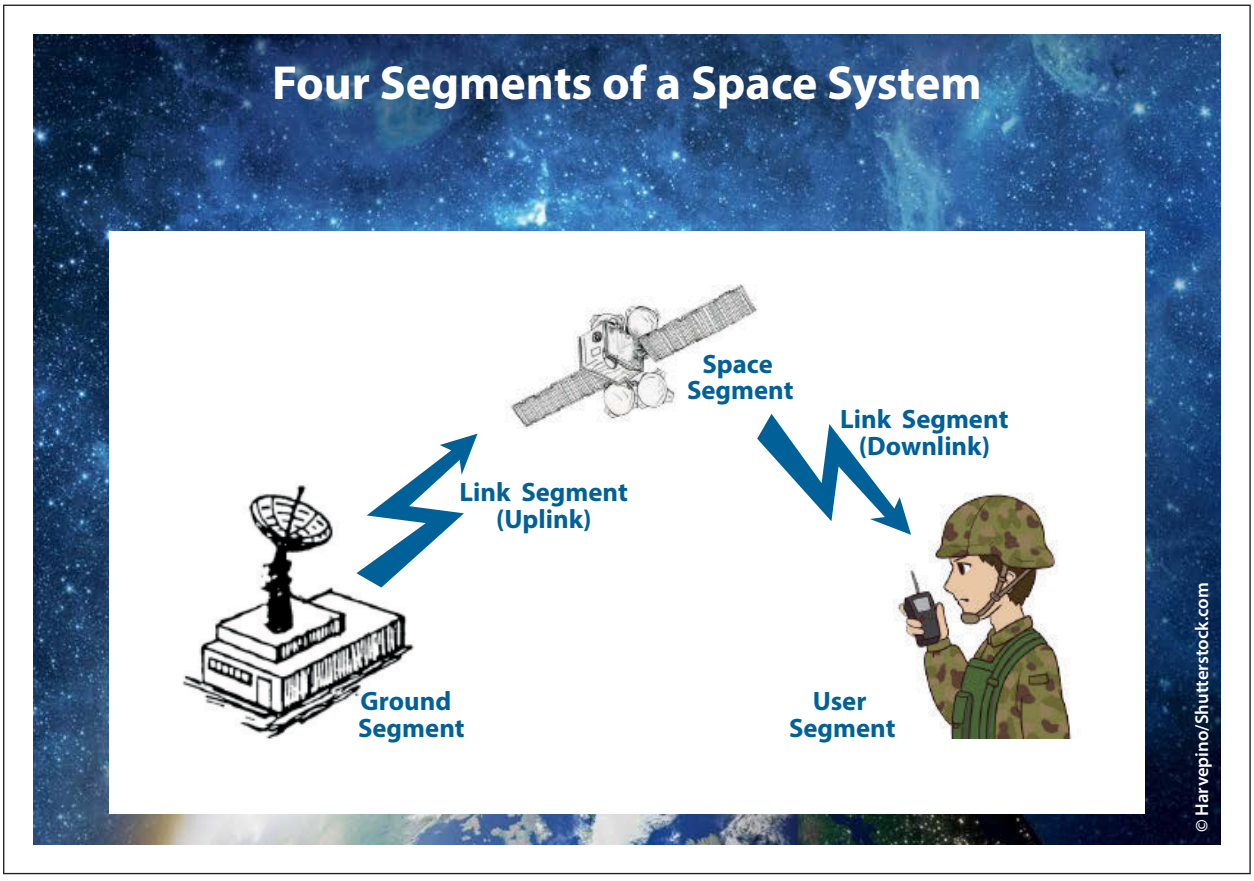

Figure 2: Space System Segments.

If talking about threats, we always have to analyse which part of a space system may be threatened. A holistic space system is designed of numerous parts, which are grouped into four major groupings: the space-, ground-, user- and link- segment (Figure 2). Each individual segment is of special significance and has vulnerabilities of its own, but is indispensable for operation of the total system.

For the sake of completeness, the launch segment should be mentioned explicitly, as it is sometimes seen as part of the ground segment, but sometimes also as an independent segment.

Natural threats are physical, based on space weather effects and are mainly generated by solar activity, which includes solar flares, coronal mass ejections and solar energetic particles. In addition, galactic cosmic rays are of importance. All these threats are indicated by electro-magnetic noise, interference and energy charged particles that could have a negative effect by temporarily degrading the link segment (signals or data transmission), by damaging electronic components of satellites or causing physical damage to the satellite's surface. Space weather may even affect satellite orbits. The earth has some natural protection mechanisms. For example, the atmosphere acts as a filter for material and radiation from Space. Only from strong forces would this protection no longer be sufficient and have negative impacts on both technology as well as for humans.[15]

Man-made threats are those threats emanating from artificial objects, which pose hazards to some or all space segments, either originating from Space or from earth. This encompasses mainly:

- Space debris, defined as man-made objects, including fragments and elements thereof, which are not functional;
- Direct ascent attacks like missiles targeting orbiting satellites (ASAT);
- Electronic forms of attack like spoofing and jamming;
- Attacks on the ground infrastructure;
- Optical forms such as blinding via laser or even using directed energy to damage or disable satellites;
- Co-orbital threats, defined as operations of a satellite close to another to manoeuvre into it, grab it or explode near to it;
- Nuclear detonation in Space.[16]

NATO's adversaries are using space-based capacities with almost the same capabilities at their disposal like some NATO member nations. To ensure NATO has the ability to operate, the Alliance relies on offensive and defensive counter-space operations (OCS, DCS), planned and executed by the member nations to minimize the likelihood of a successful attack from any adversary.[17] In addition to these threats, cyber is also a method of choice.

Potential adversaries have made a lot of progress within the last decade in developing counter-space systems to threaten NATO member nations' space systems in Space as well as from Space.[18] These specific threats represent a threat to Allies' security and defence in general and are a potential vulnerability to space capabilities specifically. Active disabling of satellites in orbit is no longer fiction; some nations have already conducted these ASAT operations. The first successful tests were conducted by the USA, Russia, China and India.[19] Although the targets of these ASAT tests were non-functioning satellites in Low Earth Orbits (LEO), these nations demonstrated their ability for offensive action in Space and created, in public opinion, a *Star wars-effect*. However, these tests revealed a capability that is a real risk; therefore, the implications of offensive operations in Space have to be analysed carefully, and mitigation measures initiated immediately.

ASAT tests against satellites in orbits other than LEO are very likely, and a Chinese launch in May 2013 into a nearly GEO altitude may have been just such a test.[20]

Electronic and optical forms, as well as co-orbital threats are currently being intensively researched by

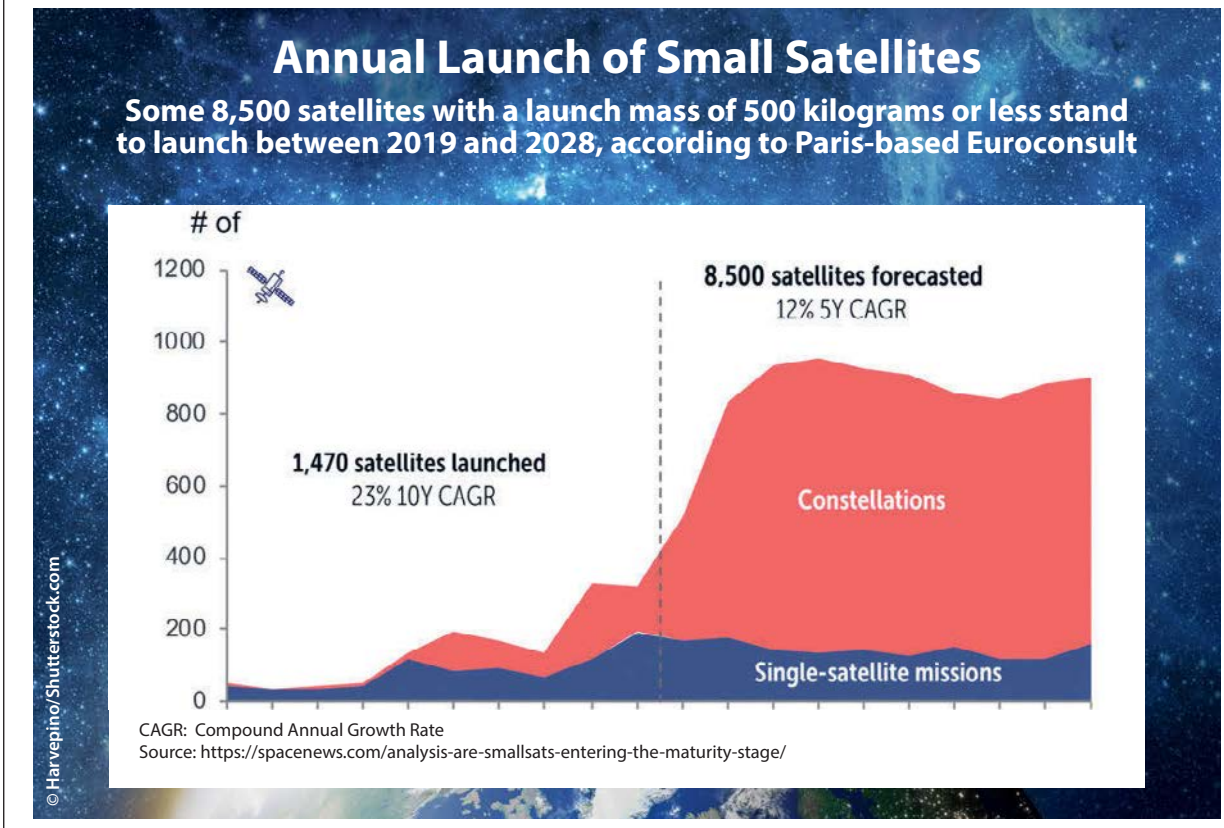

Figure 3: Annual Launch of Small Satellites: 8.500 satellites with a launch mass of 500 kg or less stand to launch between 2019 and 2028.

potential adversaries of NATO and are being brought to operational status as they have recognized NATO's significant dependence on space-based systems. In addition, a significant increase, especially in the number of small satellite deployments by new space-faring nations and private companies in the area of LEO, has been observed over the last few years. On the one hand, this leads to a democratisation of Science and Technology as well as the commercialisation of Space.[21] On the other hand, both their quantity and quality, characterized by their small size, makes it more difficult to detect and identify these objects. This increases the already contested number of orbits, the risk of collision and requires that active control be implemented. The number of operating satellites will grow over the coming years, mostly in LEO. Figure 3 depicts the especially enormous increase forecasted for satellites below 500 kg launch mass within this decade; if that trend continues it may result in overcrowded and congested orbits requiring a totally new solution for the allocation of orbits.

Not only are established space-faring nations using this evolving domain, newcomers to Space (governmental, military, commercial, scientific entities) have also started or expanded their activities in Space. Ongoing scientific and technological progress is resulting in an exponential rise of the number of objects in Space, creating additional challenges. Many more satellites are orbiting on a few specific orbits, the amount of space debris (parts of rockets, unserviceable satellites, wreckage of explosions or collisions) is rising and the risk of additional collision is increasing, the so-called Kessler Syndrome.[22] As all these developments are advancing at a progressively faster rate, and therefore, as the space environment is presenting more challenges for safe traffic and higher risks to our freedom of action, the UN also assesses Space today

as a contested, congested and competitive environment.[23]

Although the Kessler Syndrome is currently mainly a problem for LEO objects, the GEO presents a similar problem. Even if the circular track is larger than that of LEO, vertical variance is very low and the space available is becoming scarce. This crowding results in the allocation of boxes and, in particular, in the regulation of orbital bands to prevent close approaches and interference.

Electromagnetic interference is also carefully monitored and analysed. Due to the high number of objects, especially in LEO, there is a high probability of unintended interference, though some interference may actually be intentional. If it is unintentional, cooperation with the operator of the source is an indispensable and appropriate mechanism for resolution. Intentional electromagnetic interference could be an initial indication of an attack by an unknown adversary and, if this is the case, an immediate investigation is all-important. Due to the high number of active satellites, as well as space debris in LEO, a verification of parts and/or interference could not be accomplished manually by a single operator. Automated services by Big Data and Advanced Analysis, mainly based on Artificial Intelligence (AI), could provide additional solutions.

Space-based assets – as well as Cyberspace – are force enablers and/or multipliers supporting other domains to achieve greater effectiveness. Therefore, these domains are primary targets for adversaries in order to hamper or degrade NATO's ability to achieve its goals and objectives and to minimize the effectiveness of operations. Space assets will be targets in the first minutes of a war, possibly integrated with Cyberspace attacks. However, some unfriendly preliminary adversary actions could be executed even prior to an apparent attack, prior to Day Zero.[24] While the strategic balance was once based on defence, it is now shifting in favour of offense because in the digitally interconnected world, cyberattacks may become the devastating weapon of the first hour by eliminating critical infrastructure. Without a doubt, Space is part of critical infrastructure, therefore any attack on space capabilities in orbit or anywhere else is an attack on a nation's sovereignty, prosperity and is a major threat to security and peace regionally (if not globally).

All these threats and challenges set the conditions for greater risk to NATO's freedom of action in all aspects of space operations. This raises the question of how NATO, with respect to the allies, would be able to operate in this scenario. Additionally, aspects like the protection of satellites, including their active defence, as well as resilience and redundancy of space systems in general, have to be taken into consideration.

It can be said concisely, that the increasing importance of space assets worldwide will challenge NATO in many ways. Consequently, decisive and future-oriented solutions in this newly recognized domain are essential for more robust capabilities in deterrence and defence of the Alliance. The implementation of specific tools and responsibilities to assess the threat to all four segments of a space system needs to be discussed on the NATO side. The Nations are covering a wide range of capabilities, based on their individual access to collect and analyse their data. One important question in this realm is, due to the high level of classification, how NATO will align the responsibilities for Intelligence from Space as well as Intelligence of Space between national inputs and the Alliance's part including their mutual relationship and exchange.

2.4 Operating Environment with Special Attention to Space

In modern societies, a drastic change in daily life, especially in technological, sociological, and cultural areas must be managed. These areas influence all governmental roles and responsibilities, so – in the context of this study – the broader area of security and, therefore, the military. Individual national interests, roles and responsibilities of armed forces vary among allies; even after more than 70 years of NATO's existence, armed forces are mainly nationally focused. Nonetheless, it is indisputable that future warfare will

be characterized by multi-domain, multi-regional, joint, combined, and cooperative civil-military operations at high velocity. These characteristics must be taken into account in shaping the structure of tomorrow's armed forces.

Main trends in the space domain within western, liberal democracies are influenced by more actors, commercialisation by new space start-up companies, and large constellations of small satellites. On the other hand, resurgent Russian activities and rising Chinese ambitions cannot be neglected. Both of these trends will influence the character of the space domain in the near future.[25]

NATO as an organization, established on the concept of collective defence and common ideals is predicated on solidarity and unity as well as diplomatic and military powers. To demonstrate the full scale of its unique power, NATO must establish clearly articulated levels of Integration, Interoperability, Jointness, and Coordination. Ultimately, this is the basis for the principle of Unity of Command, these principles apply equally to the space domain.

Initial work on these aspects led to the official documentation of space specifications and standards for NATO's way ahead. The latest classified publications postulate a centralized NATO Single Point of Contact (PoC) for Space aspects, which was put into effect by the NATO Defence Ministers In Oct 2020. They agreed on the creation of a Space Centre at AIRCOM in Ramstein for increasing NATO's awareness of the challenges in Space.[26] Tasks, roles, responsibilities, cooperation, linkage, and many more aspects of this future focus of NATO's Space activities are being considered at the moment. However, it can be said that the establishment of a Space Centre is a major step forward in meeting the demand for Integration, Interoperability, Jointness and Coordination in military operations, but it is not yet clear to what extent this can be achieved.

NATO does not execute space operations because it does not possess its own assets or capabilities in Space, other than a mere few SATCOM ground stations and some user equipment owned by NATO Communications and Information Agency (NCIA) and three NATO signal battalions. The Alliance only administers or coordinates aspects of space-related assets to support its missions. Space Subject Matter Experts (SME) within the NATO Command Structure (NCS) are managing how Space DPS is integrated into the planning processes of operations, missions and activities – the What. Operational experts in the planning division of these NCS HQs are communicating and translating this in the Operational Planning Process (OPP), the So What, into different options and recommended courses of action for the commander. Today, and for the foreseeable future, NATO will not be operating in Space, but will integrate its DPS into all operational aspects. Therefore, a terminus like SpOC may be too ambitious for NATO at this early stage in the development of the domain. Nevertheless, the need for some kind of coordination centre is widely accepted, and its title should express the supporting role of Space in NATO's operations, as it is done with the naming of the Space Centre.

In today's NATO structure, commander AIRCOM acts as the primary Air and Space Advisor to the Supreme Allied Commander Europe (SACEUR).[27] Consequently, the new top space organizational module within NCS as installed at HQ AIRCOM to coordinate, synchronize and prioritize all aspects of Space Support from Baseline Activities in Current Operations (BACO), and through crisis to Maximum Level of Effort (MLE). As a first step, the number of Space SMEs within AIRCOM staff was increased with the latest NCS adaptation phase and ongoing efforts will see the staffing of the Space Centre as a dominant hub for all space-related aspects as NATO moves toward full implementation of Space as a Domain.

Still some dissenting opinions for establishing a cell at the Operational Level (Joint Forces Command (JFC) Brunssum, JFC Naples, and JFC Norfolk) for truly Joint Operations do exist. This may be because the operational level requires a centre to be prepared and enabled to receive and synchronize the DPS provided by nations for their specific operational needs. Of course, this requires a different structure with additional personnel. Therefore, the centralization at a single point

in the organization is the right decision; particularly as such an organization already exists with AIRCOM as the hub and additional Space Support Coordination Elements (SpSCE) at the JFCs and Single Service Commands on LANDCOM and MARCOM levels. The details of cooperation with the new Space Centre must be defined.

Additionally, at the strategic level (SHAPE), some expertise must be provided, especially for completing the strategic and doctrinal tasks that govern the preparation and execution of operations, e.g. establishing a Memorandum of Understanding (MoU) with volunteering nations for providing space support to NATO or developing NATO accepted exchange mechanisms.

In recent decades, the space domain evolved from being exclusively strategic level support through intelligence gathering, early warning and targeting of deterrent forces to now include the operational-tactical level and even down to the individual warfighter by providing direct support with communication, positioning and navigation and remote sensing.[28] Therefore, it is critical to determine the extent to which these levels must also be equipped with space expertise for principal or additional duties.

For more than two decades, NATO has focussed on Non-Article V operations far away from its home bases. However, in the last few years, geopolitical changes have necessitated the re-emphasis on Article V operations. In particular, the extent to which space assets have been used, as well as how they are employed is significantly different. In recent out-of-area operations against opponents, which are hopelessly inferior in conventional warfare capabilities, let alone in the field of Space, NATO was able to execute missions without fear of enemy action in the space domain. On the other hand, future Article V operations with a peer or near-peer adversary will not be without comprehensive influence against NATO's own space systems. Operations falling under this article must include an assessment about offensive measures against adversary space capacities. Both passive and active measures require much more attention to space-specific aspects and, in particular, full integration of space capabilities into all aspects of future warfare. One of the first steps has already been taken with the recognition of Space as an operational domain, but the detailed work has only just begun.

The results of this process were incorporated into the NATO Space Centre. The final structure, scope, personnel, communication relations, and other aspects are the result of a more detailed investigation done mainly by AIRCOM, today's and tomorrow's NATO centre of gravity for Space.

Besides the integration into the NCS space structure, this future NATO Space Centre has to be seen as the spider in a web of national Space Centres, as their central coordination and integration element. The final results once worked out, could additionally foster discussion for an enlarged NATO space structure within the NCS and the extended Lines of Communication (LoC) to nations.

2.5 NATO's Space Capabilities

As with national armed forces, the NATO alliance is dependent on space-derived DPS in peacetime, crisis and conflict. NATO's efforts to increase the Alliance's effectiveness include space-based capabilities – as with all other capabilities – in their planning for its three core tasks: Collective Defence (CD), Crisis Management (CM) and Cooperative Security (CS).[29]

Since their foundation, NATO's doctrine and organization was oriented in the classical three domains of Land, Maritime and Air. The revolutionary changing of IT, concomitant with current new Communication and Information Systems (CIS), as well as the need for their protection, has seen Cyberspace emerge as a critical component of missions. This significant emergence led to the declaration of Cyberspace as its own operational domain in 2016 – the fourth domain.[30]

Similar to Cyberspace, sophisticated space technologies as well as worldwide use of space-based assets are rapidly evolving, changing traditional processes of

thinking and operating. Recent developments in the space industry led to a continuous increase in the number of actors as well as satellites in Outer Space. These ongoing developments encouraged NATO and its member nations to formalise their approach to operations in and from Space – a reality which has been emphasised by the Alliance's formal recognition of Space as an operational domain in December 2019 – the fifth domain.[31]

In this realm, military space capabilities and systems are force multipliers and, in some cases, even force enablers. The employment of space systems is considered able to increase the effectiveness of warfighters in all other domains (land, maritime, air, and Cyberspace). Meanwhile, the utilization of space-based capabilities is an established part of modern military operations.

Nevertheless, NATO does not have satellites, nor other space-based assets of its own at its disposal; rather, it merely operates some ground-based assets for Satellite Communication (SATCOM). For the foreseeable future, the Alliance does not intend to become an independent actor in Space and has no intention to build or procure its own capabilities. NATO states very clearly that the organization will not become an autonomous space actor. [32] It is not interested in operating its own space activities and possesses neither the organization, nor the authorities of the NCS to play an active role in operating space assets; including Command and Control (C2). Consequently, NATO does not conduct space operations in the above-mentioned sense, space-faring member nations do. However, the planning and execution of operations in today's world is heavily dependent on DPS provided by modern space systems. For this reason, NATO – as an actor of its own – must know and understand the space capabilities of the contributing nations, their availability and how to integrate these national capabilities with their inherent limitations into its own activities, ever cognizant that contributions in this domain are provided from the nations on a strictly voluntary basis and that they are not guaranteed. Consequently, most of the decisions still need to be made and plans approved by the nations. To put it clearly: a NATO commander does not have the authority to request space forces, nor may the commander request space capabilities. Instead, the request must be made for space DPS for specific objectives. The overall objectives should be a starting point for allies in setting priorities in their contribution to NATO and in weighting apportionment of their national space systems.

It remains to be said that not all NATO member nations are space-faring nations, nor do they possess their own capabilities. Only some of the 30 allies are using military space assets and can offer respective DPS or other space capabilities to NATO. Despite that fact, an impressive 60 % of the world's available satellites are owned by NATO nations and the USA is the leading nation among all NATO allies in this context (Figure 6 – see page 22).

The provision of national space DPS to NATO requires significant effort to integrate these contributions into NATO's organization, structure and plans, as well as to coordinate these in support of NATO Operations. Some conditions must be met for this integration to succeed, both sides, NATO and the nations must agree on these procedures.

To fulfil its requirements, NATO's first and foremost used sources are purely national military sources. The provision of these DPSis solely at the individual nation's discretion and controlled by respective national military command authorities. If two or more NATO member nations provide and control these assets collectively, more parties could be involved.

Potential sources of service, other than those under the sovereign control of a NATO member nation, are commercial providers and organizations under commercial contracts. However, the use of these sources introduces both opportunity and risk. Under normal circumstances, a customer can choose between several commercial competitors with different products and costs, but NATO competes with other customers. The opportunity for the best choice between several suppliers can lead to tailor-made and needs-based offers, but also may lead to higher costs due to a higher level of demand. There is also the risk that there may

be a dependency on only a few or even one provider, which can impact on the nature and scope of the services provided. High demand from other customers could raise the price or lead to NATO's exclusion from the services. The ability to include additional parameters in requirements are crucial, especially for NATO's military needs. On the one hand, delivery of DPS must be guaranteed at all times, especially in times of crises and war. On the other hand, it must be ensured that NATO opponents or possible adversaries do not benefit from the same commercially provided sources. In a theoretical construct, it could be that both NATO and their adversaries are using the same provider and the same source.

A third source of space services might be provided from the international open market, as there are service providers broadly available with no restrictions or fees for service, like the European Union's Copernicus and Galileo Programmes.[33]

Due to their characteristics, space systems are inherently vulnerable. Even if the Alliance member nations or NATO structure itself are not involved in any terrestrial conflict directly, their space-based assets could be affected if the hostilities commence in Space. Therefore, a broad approach for awareness and protection is an absolute necessity.

In addition, NATO's potential adversaries are persistent in their intensive endeavour to develop modern Counter-Space technologies to weaken NATO's freedom of manoeuvre and, therefore, projection of power in Space.[34] Consequently, NATO member nations must also develop, especially in the area of Indications and Warnings (I&W), additional measures for timely detection of threats and/or attacks. Space-based assets may provide this capability.

Declaring Space an operational domain was the latest step in the evolution of Space within NATO. The start of the process of integrating Space into NATO's warfare began with the initial lessons learned from ISAF operations in Afghanistan, as well as experience from activities like the Schriever-Wargame. In recognition of the growing significance of Space in NATO (mainly space assets owned by nations, NATO's need for DPS, and increasing threats of potential adversaries) a working group was established at the strategic level (ACT and ACO). Participants range from among the NATO NCS and commercial entities involved in space activities as well as voluntary nations; this collection of offices was established as the Bi-Strategic Command Space Working Group (BiSCSWG) in 2013.[35] This was the first step for coordination and cooperation and provided a unique forum for discussion of all operational matters of Space below the political level. Guided by a Program of Work (POW), this group started their work, and due to the success of the efforts and progress of this group was acknowledged by the mandate being extended in 2016 up to 2021 and an updated POW was created.

The main progress and achievements of the BiSCSWG were made in the area of Space Support in Operations, a crucial part of NATO activities. To formalize the support provided by nations to NATO, which had yet to be done, some guidance and policies were completed. In particular:[36]

- Space Handbook;
- Policy for Space Support to NATO Operations;
- Overarching Space Policy;
- Advice Paper on Space as an operational domain.

Yet, while the BiSCSWG is a group of NATO and national space experts working together in exchanging experience, ideas and visions, it's not a permanent NATO body, nor has this or any other space agency been established at the highest political level in NATO HQ.

After Space was declared an operational domain, the BiSCSWG is working on the first measures for meeting the requirements to achieve full integration of Space into NATO via a broad approach of guaranteeing NATO's unhindered access to, freedom of manoeuvre through, and unfettered utilization of Space.[37]

In addition, it must be stated that there is a general lack of knowledge among personnel working indirectly with space topics in the NCS, on how space DPS

Figure 4: Structure of NATO's Space Capabilities until 2020.

could be integrated with operations and might benefit NATO. As these shortfalls had been recognized previously, the number of Space SMEs in NCS had already been increased slightly in the latest adaptation in 2019; some of the positions are multi-hatted, assigned with non-space responsibilities as well. A further increase in the number of positions since its recognition as an operational domain will emerge as a requirement again.

NATO has made the first steps in recent years in adapting to the growing influence of space assets, however it must be recognized that more work must be done to fully adapt space strategic and operational plans into the tactical execution of operations, to exploit critical capabilities for mission accomplishment.

Additionally, the ongoing detailed integration of space aspects into the next NATO Defence Planning Process (NDPP) 2022–2026 will represent a big step forward. By means of the NDPP, as one of NATO's fundamental planning instruments, the alliance identifies the capabilities it requires and Allies align their military development and acquisition to NATO needs. Overall, this process will better harmonise NATO and national defence planning and, finally, guarantee the provision of the required forces and capabilities for NATO's missions.

However, in recent years, NATO has made some progress integrating space-related issues into their daily work; basic principles have been generated, and categories within the entire spectrum of space capabilities have emerged from working practice. Focused on specific purposes, NATO structured all space support activities into six single categories so-called space Capabilities or Space Functional Areas (Figure 4). In general, these capabilities support the execution of

NATO's operations, missions and other activities across all domains and in all mission types.

Full awareness of the completely operational domain of Space is a must for every NATO Force commander at every level. A commander and his/her staff must be aware of the capabilities of Space Support and the specific impact on operations in their respective Areas of Responsibility (AOR).

In a typical NATO staff construct, specific responsibilities for space-related tasks have grown and been demarcated over the years. In accordance with their designated responsibilities, respective staff elements have adopted the newly added contribution of space services to encapsulate all subject matter areas.

Military planning and execution are critically dependent on timely and accurate information. ISR platforms are one means for collecting data, e.g. real-time, high definition images or video. Typically the national or NATO Staff J2 is responsible for all aspects of ISR and, therefore, for the newly established space-related ISR. The Request for Information (RfI) is the normal means by which ISR- and Intelligence-related information is requested by planners. The Intelligence staff will endeavour to answer these requests as precisely and comprehensively as possible; those submitting the RFI does not influence the selection of the source of this information, e.g. whether airborne, Space or any other asset. Therefore, the source of information is not relevant and the manner of collecting the data, in order to perform the Intelligence assessment to answer the request is an internal intelligence (INTEL) issue; J2 SMEs will select the most suitable or, sometimes the only available, source. Space assets must be included among the resources in the existing INTEL community toolbox. Inside NATO, INTEL aspects are well planned and orchestrated in existing staff structures. In fact, the NATO Intelligence Fusion Centre (NIFC) was established in 2006 to contribute to INTEL activities of NATO staffs for planning and execution of operations..[38] This agency should also include space INTEL, the integration of information from Allies' space-based assets as well as assessment of adversaries' space capabilities. As a typical NATO MoU organization, NIFC is dependent on the contribution from member nations' sources, which are often classified, as well as information from open sources and private organizations.

Shared Early Warning (SEW) is a high priority responsibility of the J 3 Staff; they manage all aspects of Missile Defence (MD) and Integrated Air and Missile Defence (IAMD). Data from SEW satellites contribute to this time sensitive responsibility, which is well established in the NATO Integrated Air and Missile Defence System (NATINAMDS). Space-based infrared sensors (currently held only by the US) detect the launch of ballistic missiles and, via specialized alert lines, forward this information directly to NATO and Allies with the highest urgency to facilitate an appropriate response. This includes active as well as passive defence options, by alerting military and civilian authorities.

Today's modern communication lines are widespread: one of the drivers for SATCOM capabilities is the need for connectivity of Beyond Line of Sight (BLOS) operations, including communication to Unmanned Aerial Systems (UAS) to maritime and aero assets, as well as Communications-On-The-Move (COTM). The use of real-time, high-quality communication throughout all regions of the world, in combination with the high bandwidth for operating complex sensors and video streaming requires extensive planning for execution. The responsibility for planning to meet communications requirements within the military structure, including the use of SATCOM, normally rests within the J6 staff element.

These three examples clearly demonstrate that additional capabilities brought to the warfighter by new technologies may be integrated into existing staff structures and do not necessarily require the creation of new departments within the staff.

The integration of space weather and the associated intricacies into a NATO staff is typical of the discussion necessary to integrate overall space capabilities into a staff. The analysis of space weather specifics gives us a better understanding of the dynamic system powered by our sun and the manifestations on, and near,

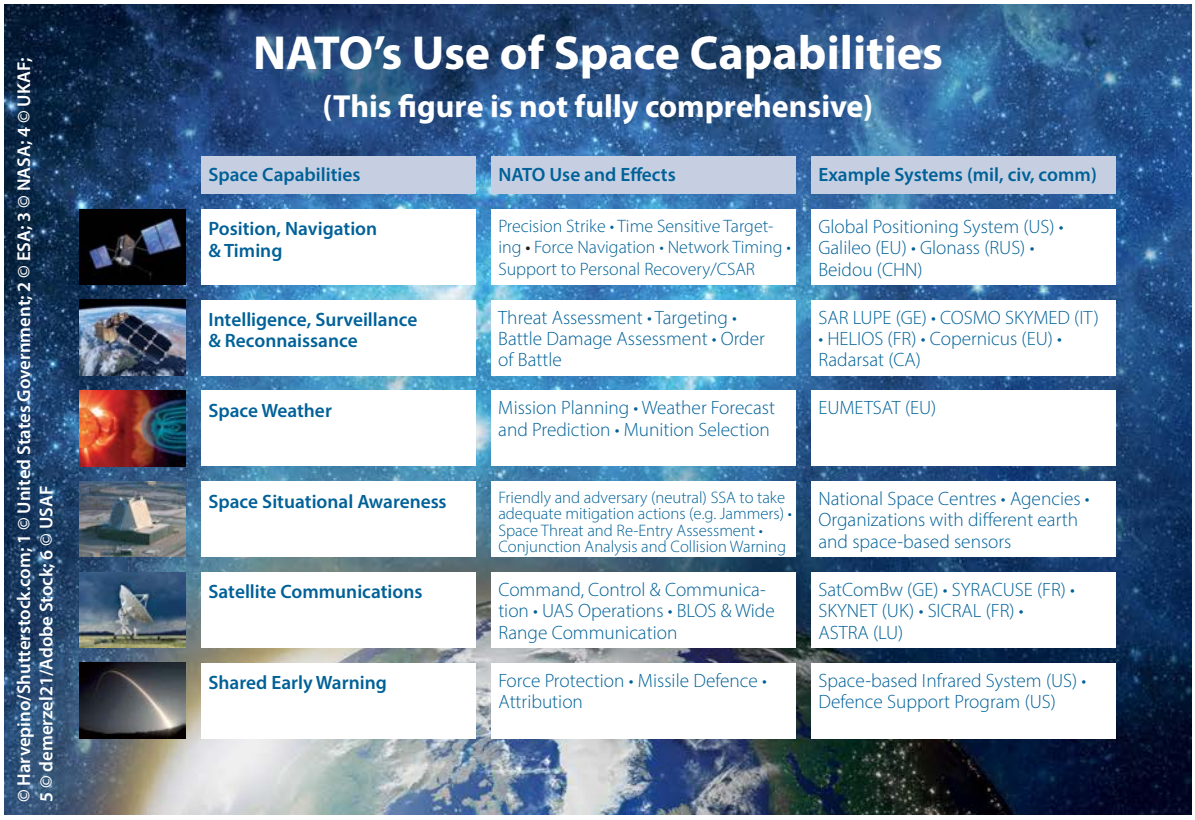

Figure 5: NATO's use of Space Capabilities (Examples).

the earth. An understanding of space weather helps us to predict and mitigate its effects on spacecraft and humans, not only in Space, but also on earth and hence it is prerequisite information for all military activities. For that reason, an SME with the responsibility of forecasting space weather effects and integrating its possible impacts on the planning cycle should be integrated into the Meteorology and Oceanography (METOC) part of the staff and space weather should be part of their portfolio.

Finally, SSA and PNT are the sole remaining areas for a Space SME in a space-specific section within a staff.

PNT services offer ubiquitous capabilities for air, maritime and ground navigation and provide additional benefits, e.g. in Blue Force Tracking (BFT), employment of Precision Guided Ammunition (PGM) or avoiding collateral damage and civilian casualties. Additionally, PNT services provide timing signals to synchronize networks and radar sensors.

These capabilities cannot be assigned to already existing staff elements; they will most likely lack the expertise. The specialized functions typical of space systems demand a specific level of expertise in space, which must be integrated as a Space Support Element, in whichever manner, into a NATO staff.

Not only does the functional responsibility of these six Space functional areas have to be considered, but two additional aspects must be taken into account. The staff element supporting space activities will be the single point of contact to address all overarching questions and challenges regarding Space, not only for internal staff coordination, linkages and interrelationship, but also as the primary adviser for the commander. Plans, concepts and other fundamental

documents will be the primary responsibility for a Space SME, merging all single interests under common direction – the space perspective. The space experts will work together with land, air, maritime and cyberspace experts to integrate space-specific aspects in all domains; vice versa, it must be ensured that all domain experts are able to provide their support to the space domain staff is in line with operational and mission-specific requirements. Figure 5 opposite lists some examples of NATO's use of space capabilities and examples for relevant systems.

Full integration of space dependencies in all staff activities means that each staff member needs at least a foundational knowledge of Space and the relationship to his/her specific area of responsibility. Space SMEs can provide these lectures internally because of their E&T knowledge in this domain.

For NATO and its respective Headquarters (HQ), the Mission Command and Control Centres, or other operation cells are the coordination element for all aspects of the execution of a mission, including Space. The utilization of their capabilities is an indispensable part of modern military operations, and in many cases, has already been integrated. This integration is described in chapter 3.

Finally, NATO must analyse and identify its own strengths and capabilities, as well as its weaknesses, shortfalls or gaps within the new space domain. It must also provide appropriate recommendations and set the scene for the accomplishment of allies' national portions. This requires a purposeful, but also a careful reveal of NATO's space strengths; too little effort maybe an ineffective contribution to NATO's deterrence posture, and not suppressing activity may allow escalation and lead to a new arms race in Space.

2.6 NATO Nations Space Capabilities

In the early days of space exploration, high costs and technological complexity allowed only a few nations to possess their own space activities. However, the ongoing commercialization and proliferation of space technologies in recent years has significantly widened this exclusive circle. Many Nations have increased their presence in, and access to, Space. Today, over 50 nations or multinational organizations own or operate space assets.[39] This may raise the question of the need for a national SpOC or, for solely military purposes, the need for a national military SpOC?

NATO as an organization does not own complete space systems or even capabilities of its own (other than some SATCOM ground equipment), as previously mentioned. However, as an Alliance, individual sovereign nations provide their national capabilities to NATO, but they retain the full authority and sovereignty of their space assets. In summary, all members of the Alliance contribute to creating the biggest space player worldwide, operating approximately 60 % of all space activity (Figure 6 – see page 22). On the other hand, only a few nations have the resources to operate in all different space capabilities independently. Some nations do possess specific military space systems; however, the majority of them rely on commercial, civilian and sometimes 'dual-use' space systems. Therefore, a broad multinational and multi-agency collaboration effort is necessary to generate a broad range of services for NATO's needs. The mutual exchange of space DPS between NATO and nations as well as between individual nations, is crucial to minimize vulnerabilities and increase strengths.

As mentioned above, NATO partners delivering space-based DPS are numerous: national contributors, commercial partners as well as open sources.

We see the same situation on the national side; they also have different origins for space-based DPS. First of all, own military capabilities of national armed forces are a principal source. In addition, government and civilian sources from other national government sectors are secondary sources. Lastly, individual nations purchase products on the commercial market (national and international), and use open sources.

However, a distinction must be made between which product or service is needed, e.g. SATCOM services are offered on the commercial market for different areas

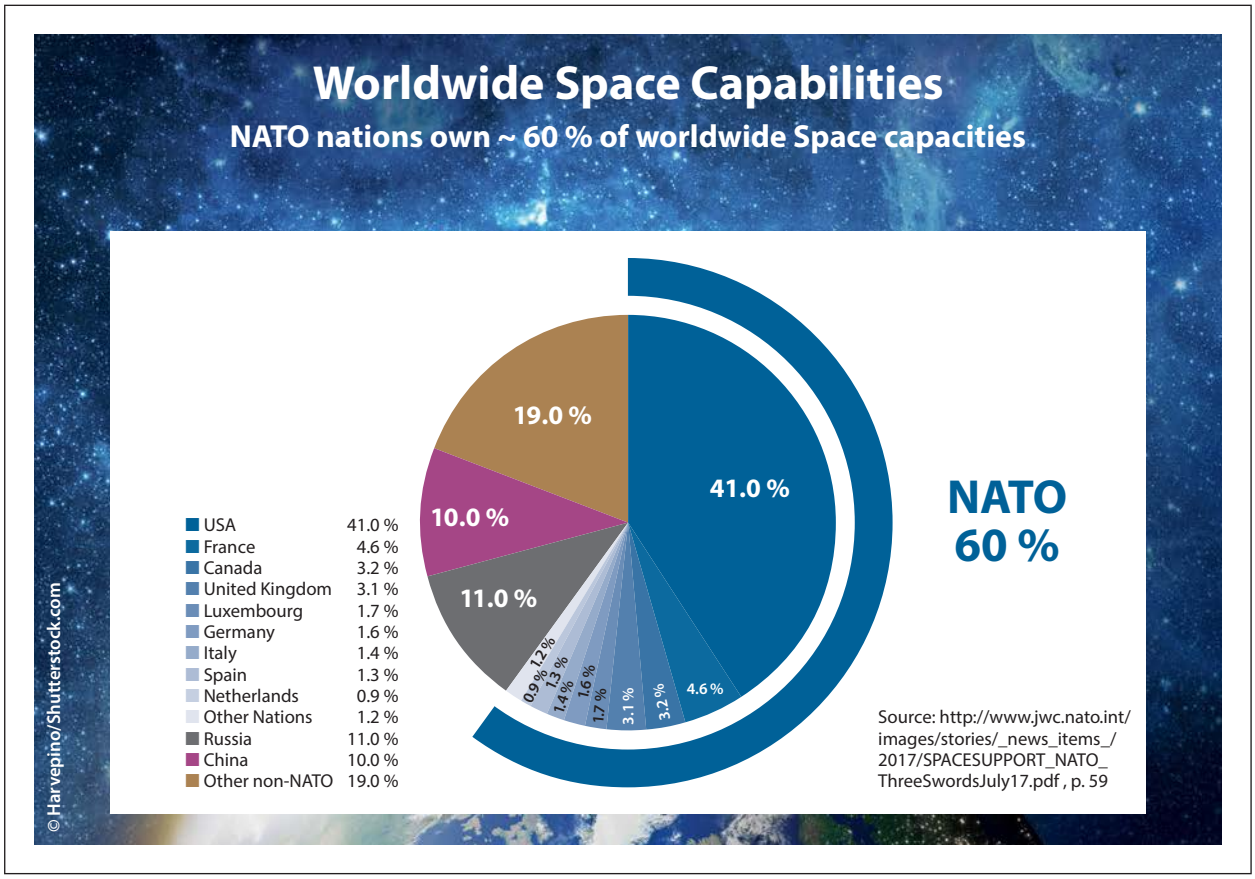

Figure 6: Worldwide Space Capabilities.

in specific bandwidths and frequencies. It must be analysed critically whether specific military needs will be fulfilled, especially whether the service is guaranteed in times of tension and war. ISR products, especially those that must meet specific military requirements, are often a product provided by the nation's military only under stringent conditions and restrictions. Nevertheless, private contributors are also available and the European Copernicus programme even provides specific data of Earth Observation (EO) free of charge[40]; however, this data may be of limited use for military requirements.

Nations are providing the majority of NATO's needs. However, the 30 allies have very different space activities and programs, from nothing to the top world leader. Therefore, their endeavours are also varied. As a consequence of NATO's common understanding of the space domain, the benefits and drawbacks may be divergent between space-faring and non-space-faring nations. At the moment, only very limited and basic concepts are generally agreed upon and are included in national positions and policies.

Space-faring nations have significantly different approaches to integrating space capabilities in military operations. For example, in 2018, the US[41], followed by France in 2019[42] announced their intention to strengthen their efforts in Space. While the US established its own Space Force (United States Space Force (USSF)), France reorganized and renamed its Air Force into Air and Space Force (Armee de l'air et d'espace). These two examples illustrate the push forward to establish real, not only symbolic, Space Power. Besides organizational, financial and personnel changes, this includes a variety of measures in the new domain, from active capabilities in the protection of satellites to passive means such as powerful ground-based

lasers to be used to track enemy spacecraft. The consequences of these developments have not been seen yet. However, it clearly demonstrates national efforts and raises concerns to many about the high degree of militarization, or even weaponization, of Space.

National advanced technical space programmes, with appropriate national funding, demonstrate their importance for own national critical infrastructure and the contribution to national security, as well as control in technology transfer of high-tech products, but are solely national activities and only occasionally shared in close cooperation with hand-selected partners. Because of national sensitivities, these activities are classified, which leads to many restrictions to prevent the uncontrolled spread of this expertise; however this also limits wider cooperation.

This attitude seems to be slowly changing, at least between NATO member nations and within the European Union (EU). The reasons for this may be manifold. Primarily, there is widespread acceptance of the resurgence of old NATO adversaries and the emergence of new ones that threaten the Alliance in Space. Additionally, allies realize the absolute necessity of a common NATO concept combined with the constant need to reduce costs and, ultimately, the realization of the general need to strengthen international organizations.

For example, the EU's 'Common Security and Defence Policy' is not an antipode to NATO; it is taking into consideration European specific characteristics.

National space capabilities are manifold and specific information about security and military space assets are classified and beyond the scope of this paper to disclose. However, the growth of national space capabilities will be substantial in the short and mid-term; the question is whether NATO will benefit from them.

In general, national space capabilities are being used for:

- National objectives;
- Voluntarily national contribution to NATO, the EU, and other international organizations;
- Voluntarily national contribution to other partner nations (e.g. AUS, AUT, JPN, NZL) under bilateral/multilateral contracts;
- Commercial purposes.

Space assets are an integral part of national infrastructure, their value to gross national product is significant and they are highly vulnerable. Therefore, nations must ensure the safety and security of their space capabilities; this includes the ground and link segments and the responsibility for the protection of the space segment. If the user segment is not part of the national infrastructure, their protection is not a governmental responsibility because of its possible worldwide use outside national boundaries.

For those NATO member nations that do not have their own space capabilities, nor space-based assets or direct access to some DPS, sharing the use of resources and helping them learn from experienced nations and/or organizations could help these nations in their individual efforts to start their own activities in Space. For these nations, working with the Alliance could be an opportunity to contribute to goals collectively, that they cannot fulfil individually. Additionally, the widespread collaboration will make NATO stronger because more members bring in more knowledge, activities and, in the end, more capabilities. The crucial question is mainly whether there is the political will to overcome national self-reliance and contribute to a common goal. In addition, strengthening the political and military branches of the Alliance will lead to reduced costs for nations with respect to military procurement and to increased efficiency, effectiveness, interoperability and resilience.

Some adversaries and foreign competitors are developing and deploying their own space systems, of high-quality and in high numbers.[43] Offensive systems create specific threats and will force NATO, as well as their member nations, to analyse these threats and develop options to counter these risks. Countermeasures could be passive (hardening, shielding), organizational (reserves, launch on demand) as well as active means (attack options via cyber, electronic or kinetic measures). In these areas of activities, NATO is

split, with only a few nations capable and willing to commit resources to research and development (R&D) of Counter-Space Capabilities.

NATO and the nations must realize that due to the complexity and quantity of ongoing challenges in the space domain, no single nation can manage all these efforts alone. The fundamental principle of NATO, as a system of collective and mutual defence, offers a lot of chances for burden-sharing and return on investment and contributions.

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CHAPTER 3

NATO's Need for Data, Products and Services

NATO is in a state of constant evolution in order to meet the changing geopolitical security environment in the best way possible. Mainly, recent NATO summits have set the course for necessary doctrine and policy adjustments. Highly capable, deployable and trained forces are one appropriate answer to the current security threats. Due to the broad geographic reach of modern military capabilities and the data requirements of today's modern weapon systems, such as high precision weapons and Unmanned Aerial Systems (UAS); accurate and timely information is indispensable. This demand for information is universal in all conflicts and reinforces the importance of space assets have toward achieving information superiority.

In particular, the recognition of Space as an operational domain forces NATO to gain and maintain an advantage to ensure free access to and use of the space domain through developing SDA, providing Operational Space Support (OSS) and conducting Space Domain Coordination (SDC).[1]

3.1 How Can Space Capabilities Support NATO?

Since the London Summit in December 2019, when Space was declared an operational domain, Space has become a new focal point for NATO.

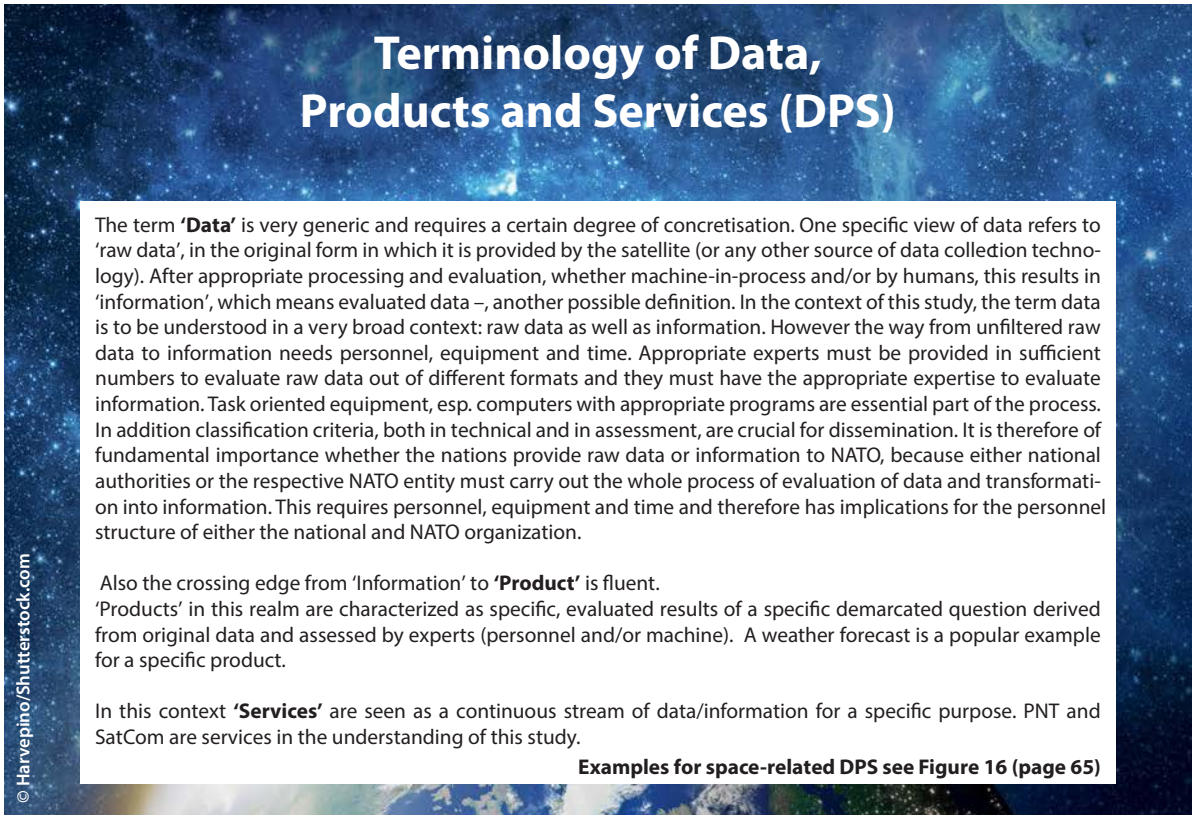


Figure 7: Terminology of Data, Products and Services (DPS).

What does Space represent in this regard for NATO? The Alliance has agreed not to develop any own space capability now or in the near future. For military purposes, the space domain may be divided into two principle fields. The first field is Near Earth, the physical area that first was the target of scientific research, but very quickly became an area for stationing satellites in order to take advantage of the special characteristics of the orbits therein and which is widely used for military activities today. The other field Outer Space, the interplanetary area beyond Near Earth and between celestial bodies, which is not yet usable for the military and so not of primary interest.

Over decades, new multi-layered technologies have emerged for the benefit of humanity, and which NATO has divided into the following six functional areas, each with specific objectives (Figure 3 – see page 12):

- Position, Navigation and Timing for precise and synchronised operations;
- Intelligence, Surveillance, and Reconnaissance, for strategic, operational, tactical decision support, planning and assessment;
- Meteorological, oceanographic, space environment monitoring and forecast for planning and execution of operations;
- Space Situational Awareness, for understanding the operational environment;
- Satellite Communication (SATCOM), for consultation, command and control (C3);
- Shared Early Warning, for prompt reaction to missile threats.

In short, NATO uses the physical sphere of Space to enable, support or maximise their military power, and for this reason, Space is an operational area for the purposes of warfare. NATO needs space DPS and information

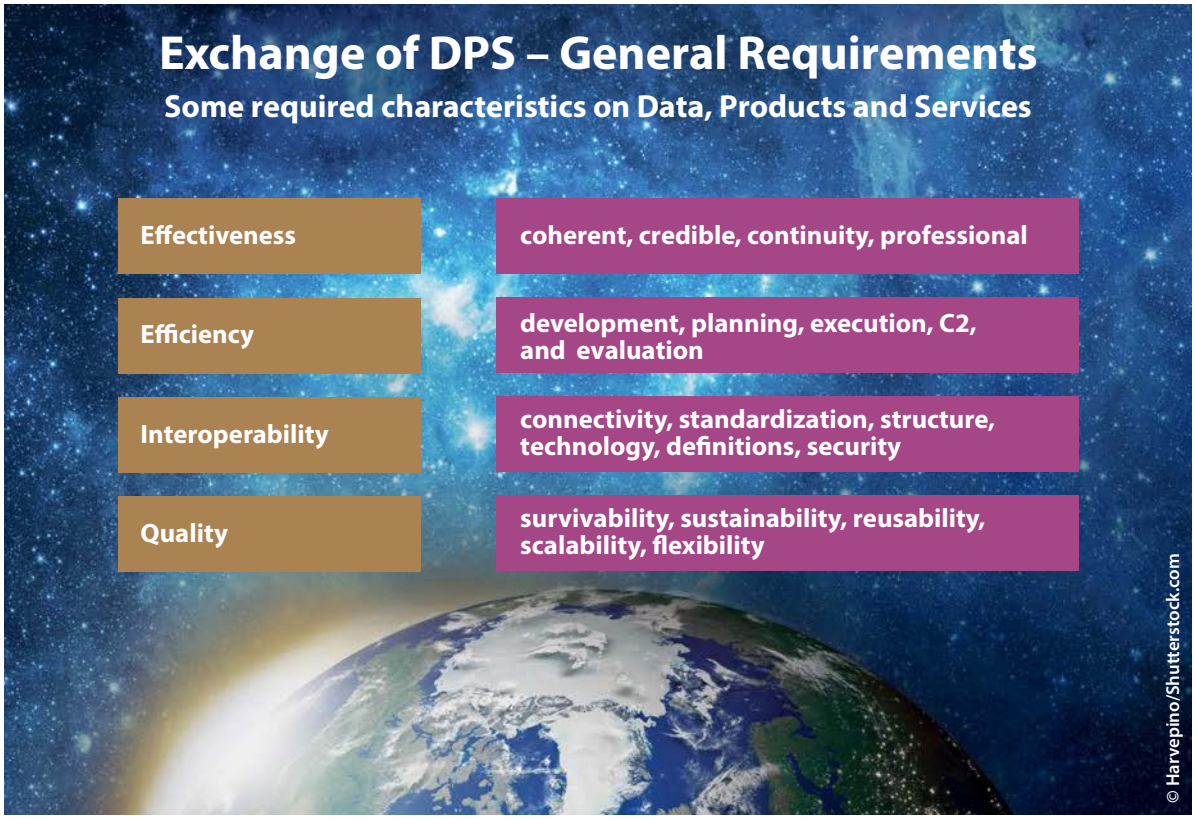


Figure 8: Exchange of DPS – General Requirements.

in support of their operations and it is used as a force enabler or multiplier for warfighting actions in all other domains. However, basic laws of physics and orbital mechanics dictate the rules for the use of space assets.[2]

NATO commanders within the NCS are allocating forces to conduct operations based on decisions made collectively by member nations. For this purpose, comprehensive situational awareness is essential within the decision-making process to support the conduct of operations in the respective Area of Operations (AOO). A critical component of this reservoir of information includes details on the space domain.

Which information related to own and adversaries' space assets, as well as DPS provided by national space systems do these commanders need in detail? To answer this question, it is necessary to discuss what NATO's objectives are in Space.

In all future conflicts, space-based satellites, as well as corresponding ground facilities, are likely to be the first infrastructure to be attacked; initially by cyber-attacks followed by kinetic attacks. Therefore, the space systems must be able to withstand these attacks in order to continue allowing all other domains (land, maritime, air, cyberspace) to fight. Space capabilities are presented as enablers, which enable other domains to be effective. This reliance is why NATO's potential adversaries are so keen to be able to effectively disrupt this capability first. Understanding this vulnerability requires a strategy for the 'survival' of space systems against attack. These aspects are currently discussed under the term 'resilience'.[3]

In the cold war era, Air Superiority was a prerequisite for all further operations. Today space superiority has secured its own place as a precursor for successful missions. In fact, Space has been the foundation upon

which NATO has achieved technological dominance for decades.

'Winning the battle in space may not lead directly to winning the war. But if you lose in Space, you are guaranteed to lose the war.'[4]

This statement clearly illustrates that Space must be factored into all the planning and executing cycles of the other military domains in NATO's space-faring member nations, but also in the military activities of non-space-faring nations.

Provision of DPS varies in criticality for each NATO operation, mission or other activity. The loss or degradation of specific DPS may range from little to no impact, moderate to significant impact, or even critical impact in terms of consequences on a specific mission or parts of an operation.

A critical evaluation of all space factors is indispensable in mission planning. Both the individual capabilities, in relation to specific missions, and parts thereof, must be evaluated at all times. Furthermore, alternative services should be available on a permanent basis and implementable in a timely manner. These alternatives may not necessarily be space alternatives; in some cases, other means may provide adequate solutions.[5] In general, having alternative sources corresponds to the general military demand for contingency options.

In all 15 of NATO's military mission types, space support is indispensable. However, there is a difference between Article V and Non-Article V operations. Generally speaking, in Article V operations, space support is critical to successfully defend NATO territory against an aggressor. In competition with a peer or near-peer actor, the whole set of capabilities, including redundancies, alternatives as well as reserves, is essential to mission success. This level of redundancy is the greatest challenge for NATO and this level of a conflict is the strategic benchmark for efforts to organize, train and equip NATO forces as a whole.

Non-Article V operations require only selected elements of armed forces and in specific, limited roles. This can usually be achieved by a subset of a larger force, but may also require special equipment and training. Opposing forces in typical Non-Article V scenarios do not generally have the potential to seriously endanger NATO nations' existence, but they are capable of particular, even serious and painful strategic successes. Adversary space capabilities do not compare to those of the Alliance, neither in their nature, scope, nor in number and so do not pose an immediate threat to NATO's capabilties' existence. If during Non-Article V operations, space capabilities are not available, this may hamper the successful achievement of some specific objectives (e.g. forward deployment, synchronized communication, precision guided munitions), but will not jeopardize an operation in its entirety.

The intellectual work for planning and executing missions and operations is conducted in a C2 Cell or an Operations Centre. The generic term is Command Post (CP), which is defined as a location from which command is exercised.[6] Size, structure, equipment and personnel vary depending on the task, location and threat, among many other factors; a classic centralized organization versus one that is virtual and decentralized is determined by the management philosophy desired. CPs within the NCS are known as HQs and are an integral, fully manned part of NATO's Peacetime Establishment (PE). In crisis and war additional functions, tasks and personnel may reinforce these HQs.[7]

NATO does have a modest number of qualified personnel in their HQ to execute space-specific tasks and meet objectives. The Allied Joint Publication (AJP) 3.3 (B) provides some instructions on how to coordinate and integrate space capabilities in NATO. It stipulates in chapter 5: 'The space support coordination function describes the responsibilities and tasks for selected staff personnel who will serve as the commander's primary advisors for space support to operations. The space coordination function will have responsibility for planning the integration of space force enhancement tools and capabilities; the integration and coordination of space control and space situational awareness activities; and provides space analysis expertise and space-related products to the staff and

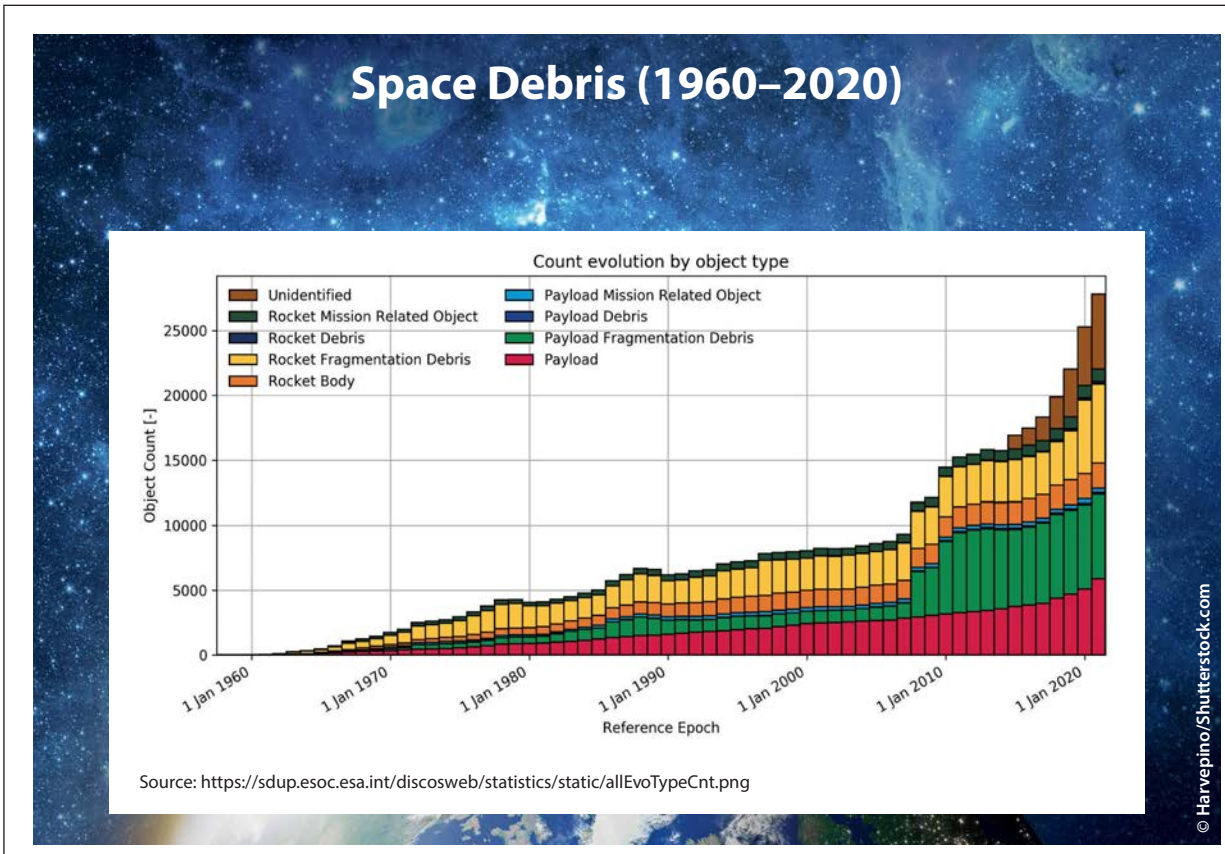


Figure 9: Space Debris.

subordinate elements. The space support coordination function will not compete or interfere with well-established space-related functions within the organization such as SATCOM apportionment, ISR collection planning, etc.'[8]

However, current efforts are ongoing to implement Space as a new domain within NATO's overall warfare efforts. In particular, the classified 'Space Domain Action Plan' provides a detailed way ahead for the implementation of the space domain in NATO. This document was published after approval at the highest NATO levels in fall 2021.[9] Nevertheless, integrating space DPS in operations, as well as synchronizing and coordinating these contributions from volunteering member nations into NATO staff, will require significant effort in modification of the organization, personnel, procedures, definitions, and others. The top priority in all this planning must be to achieve the ultimate impact – the effect on the battlefield. The more that nations are willing and able to integrate and coordinate their space capabilities in support of a NATO operation, the less capability and effort NATO will be required to commit to make use of them efficiently. Nevertheless, there may be occasions when a NATO commander may not receive the desired space support. This worst-case scenario must be prevented, and this can be achieved through timely and comprehensive preparation.

3.2 Space Situational Awareness as a Starting Point for Support

On 4th October 1957, the Space Age began with the launch of Sputnik 1. At that early stage, the many useful applications were not even predictable; today, no modern society can do without them. Nevertheless,

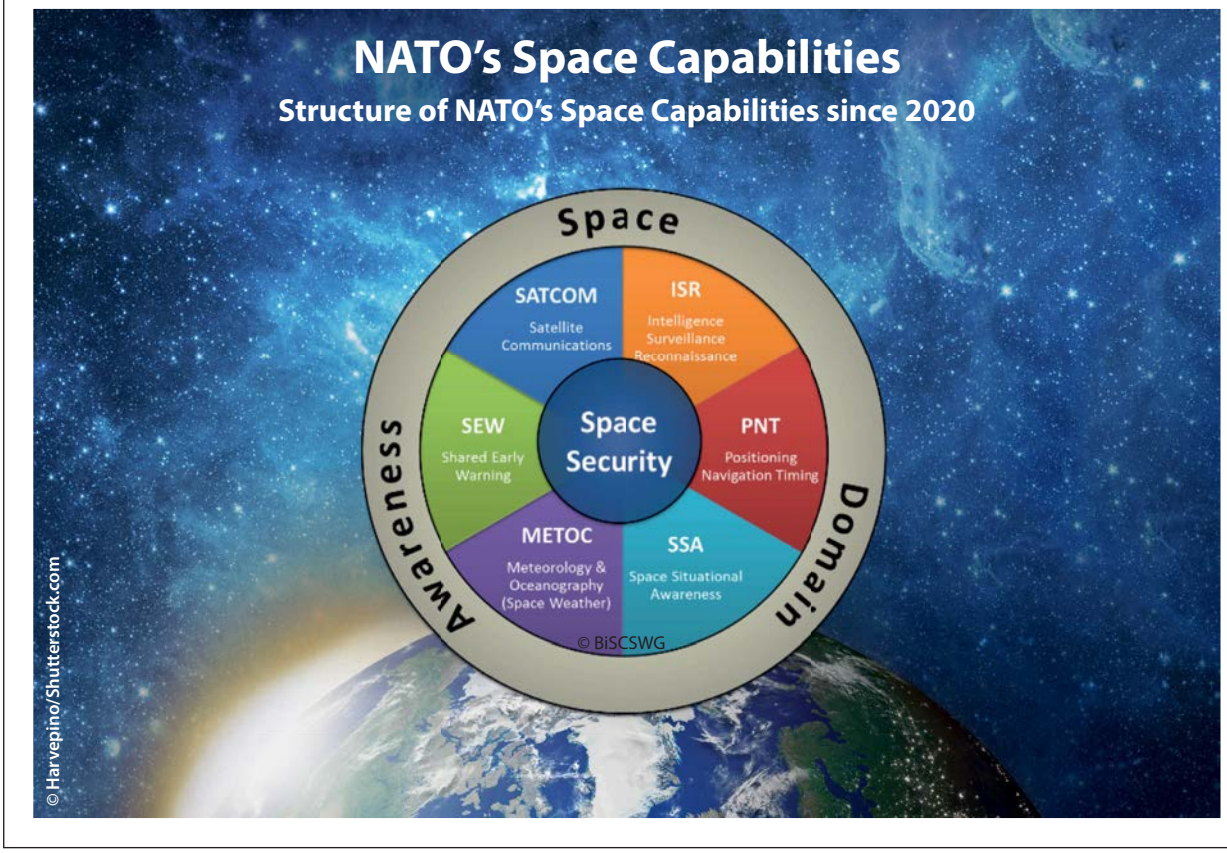


Figure 10: Space Domain Awareness (SDA).

their potential was unpredictable. Since 1957 about 6,100 rockets have been launched, placing almost 12,020 satellites into earth orbit, of which about 7,520 are still in orbit, and about 4,600 are still active and actively controllable. In addition, there are a myriad of remnants of space debris (see Figure 9, page 29), more than 9,500 tons of total mass, about 29,200 regularly tracked large objects by Space Surveillance Networks and maintained in their catalogue. The total amount of space debris can only be estimated using statistical models; as of August 2021, there are almost 129 million objects greater than 1 mm in size.[10]

Space is a zone used and populated with satellites by many nations, organizations, and commercial companies. Operating in this contested, congested and competitive environment necessitates a comprehensive understanding of all aspects of operations in this domain.

Space-related activities, from the NATO perspective, are categorized according to six groups of capabilities as seen in Figure 4 (see page 18) and adapted in 2020 (Figure 10 above).

The objective of SSA is to provide timely and precise data about the space environment and particularly about hazards and threats. This includes, for the most part:

- Space objects analysis (supported by Space Intel and Space Object Surveillance and Identification (SOSI);
- Orbital manoeuvre detection and analysis;
- Conjunction trend survey, analysis and warning;
- Re-entry monitoring and warning;
- Observation of Near Earth Objects (NEO).

These activities are prerequisites for effective use of space capabilities, as well as enabling the protection

of space assets. In addition, it is sometimes the case that space weather, due to its effects on systems in Space and on the earth, comprises part of SSA, though it is categorized as a capability of its own. SSA is a prime example of how international cooperation enhances capability and strengthens resilience; the more nations that contribute their data about space objects to a shared database, the more accurate and effective operations become. Other than the US, no nation can achieve adequate SSA alone. However, nations can contribute to SSA without necessarily having to possess assets in Space; in some cases, for example, data from ground-based telescopes or radars can comprise nations' contribution to shared SSA. European countries in particular could leverage their geography, e.g. NO for northern areas of the globe and FR and the UK overseas installations for worldwide coverage.

For some nations, having their own SSA capability marks the starting point of a space program. However, with expanding space activities worldwide and their influence on domestic operations – civil, governmental and military, SSA alone does not meet today's space-based information and service requirements; it is far too narrow in scope for operational needs.

Now, NATO is migrating from SSA toward SDA because it recognizes a greater need for information, which is the essential factor in comprehensive situational awareness.

SDA is a much more comprehensive and overarching program for contributing to military objectives than SSA. Effects in the space domain can impact all other domains. Therefore understanding the space domain is essential for planners and decision-makers. SDA allows NATO commanders and their staff to not only monitor objects in orbit, but to have oversight of all facets of the domain which allow them to identify potential operational dependencies. Therefore, SDA, as an all-encompassing approach, is comprised of all six defined space capabilities of NATO.

As explained earlier, NATO does not have the capabilities to execute these tasks; it does not have a SpOC. However, as part of the progression since the recognition of Space as a domain, the establishment of a coordination focal point to ensure interoperability with NATO Operations, the NATO Space Centre was announced in Oct 2020.[11] Additionally, the NCS provides SpSCE as an integral part of the structure though, with a very limited number of SMEs, which are planned to be increased in line with the adaptation of the NCS.

The space capabilities listed in chapter 2.6 are national assets. Nations share DPS with NATO voluntarily based on NATO requirements. Usually, no raw data will be forwarded to NATO due to the fact that NATO does not have the capacity to assess the data to derive actionable intelligence, but more importantly, due to the restrictions imposed by each nation regarding the security of their classified material. Restricting the distribution of classified data between nations is a significant challenge to achieving the level of information sharing that will be required for NATO operations. The objective is not that NATO have access to all data, nor have a complete, 100 percent overview. In fact, relaying all space-related DPS, especially the processing of raw data may overburden NATO's capabilities. However, it is vital to achieving the level of data exchange such that all necessary information is available for each planning and execution phase of NATO operations or missions. Limitations on data and information derived from space resources information may not present problems in limited small operations, such as Non-Article V scenarios. Article V operations, esp. a Major Joint Operation plus (MJO+), represent a significantly greater requirement for information and support services for NATO, so operations without the contribution of information acquired from national space assets would present serious challenges. Even with sharing arrangements in place for large campaigns across a significant area of operations, NATO will not be the only clients requesting space-based services; the contributing nations indeed also have requirements, creating competition for scarce resources.

3.3 Process and Organization

Within most Alliance nations, as well as in NATO itself, the organizations coordinating space-planning

activities are primarily located within the Air Force's organizational structure or at least closely associated with it. This is the result of the Air Forces' historical responsibility for managing all things above the earth – in airspace and Space, and highly comparable technology between both domains. Space and Air Forces share key characteristics in warfare: a three-dimensional area of operations, high velocity and long reach, as well as a strong dependence on sensors, such as radar technology. Within the NATO hierarchy, the Commander of AIRCOM is the primary air and space adviser to the Supreme Allied Commander Europe (SACEUR) and as such is responsible for the coordination and integration of Air and Space effects to maximise Joint Air Power across the Joint Operations Area(s).[12] In recent years, modern air power has become increasingly dependent on the services provided by space assets so much, so that significant interconnectivity exists between the two domains. This does not mean that other domains are not similarly dependent on the benefits of Space; they are indeed and to the same extent. As a consequence of the influence of Space in modern warfare, it has emerged from under the umbrella of the air domain and been emancipated as a domain itself.

IAMD, surveillance and security of national airspace and some operations by tactical flying units are examples of activities within NATO that are highly integrated. Their effective execution calls for standardization, which is formalised in NATO Standardization Agreements (STANAG) to which national forces have agreed to comply. To what extent must NATO standards and agreements apply to the new space domain? This question requires consultation and concurrence among the member nations.

Historically, space systems, their capabilities and products have been treated as sensitive, strategic assets that nations are unwilling to divulge, even among allies. Access to the physical domain of Space can only be achieved by means of Space Launch Vehicles (SLV) and the fully developed infrastructure associated with these launches, such as launch pads. The ability to launch a satellite and operate the payloads in orbit is an expression of national power to the international community, signalling technological advancement, independence and sovereignty. Operating satellites in Space and possessing your own launch capabilities are considered national assets with strategic relevance; NATO has never done its own launches, does not have these capabilities, nor are there intentions for future activities.

NATO as an organization depends upon DPS contributed by its member nations. This is the core requirement for NATO operations with respect to the space domain: the reliable flow of DPS from nations to NATO, as well as within the NCS and is a factor that permeates this paper.

Making national DPS available to NATO on a voluntary basis must be done reliably. From a NATO perspective, it is hardly acceptable that a nation only delivers DPS exclusively within the framework of free capacities and on its own accord. Especially in situations of crisis, emergency or urgency, there is usually a high need from both sides (NATO and national consumers), both are rivals in getting access to these rare capacities.

NATO needs some guarantee from nations that DPS service will be provided when it has committed to respond to situations of crisis and conflict.

The following arrangements need to be secured to fully support NATO with space DPS:

- Guarantees for service at all times and for all missions;
- Contractually regulated backup and reserves;
- Scales of resilience during outages and provision of backup systems or alternatives.

Based on these essential requirements, the procedures and LoC for implementation of national support are of high importance. Currently, only a limited number of agreements are in place between NATO and member nations to secure these levels of support. AJP 3.3 (B) establishes the baseline requirements for the exchange of DPS between NATO and nations/providers (Figure 11 opposite) and presents the entire process for these few standards in detail.[13]

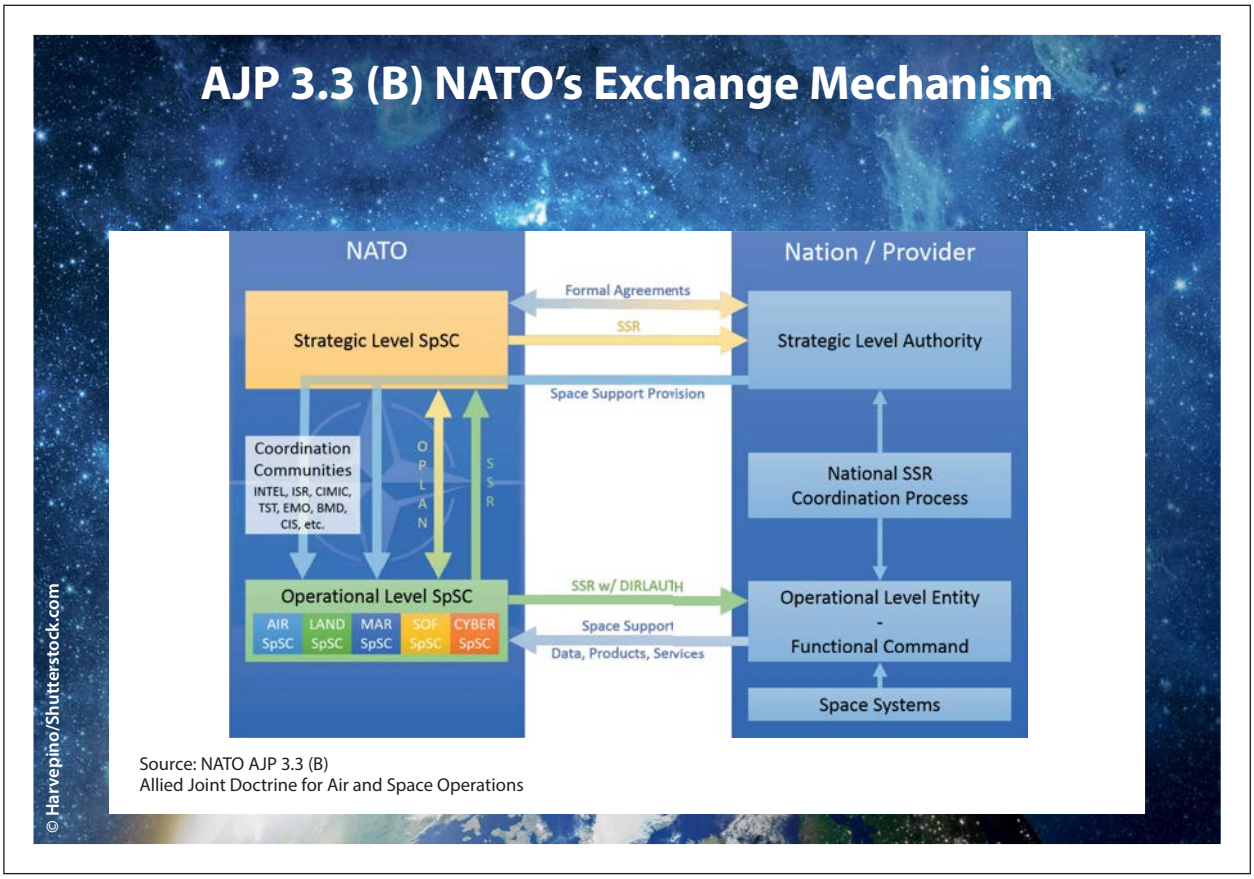


Figure 11: Exchange Mechanism.

During the planning and execution phase of a NATO operation, managing, coordinating and fine-tuning space support is critical. Therefore, a coordination cell for this task is established at each level within NCS, providing input on operational requirements and identifying space support requirements. The details, including the organization and interrelationships within NATO are laid out in a specific annex for Space (Annex DD) of Operational Plans (OPLAN) published by the responsible NATO Operational Commands (e.g. JFC).

Each space-faring nation has its own organization based on their requirements. Their structures vary depending on civilian, military and commercial needs, sometimes there are dual-use capabilities, interconnections, and interdependencies. NATO does not have the authority to impose any specifications or regulations regarding the internal operations of any contributing nation.

If a nation is willing and able to deliver DPS to NATO, formal arrangements will be reached. These agreements may be in the form of MoUs, Service Level Agreements (SLA), Letters of Agreement (LoA), Technical Agreements (TA), or other similar accords.

Regulations governing the provision of services from the nations to NATO must be comprehensive, and so establishing them requires negotiation with the nations. At this time, NATO has concluded agreements in all six functional areas to guarantee the basic delivery of DPS.[14]

These regulations guide the NATO battle staff to arrange for the provision of space capabilities to support operational requirements. It is efficient to have processes already in place, particularly if/when requirements change and further still if the requirements are dynamic and the degree of urgency

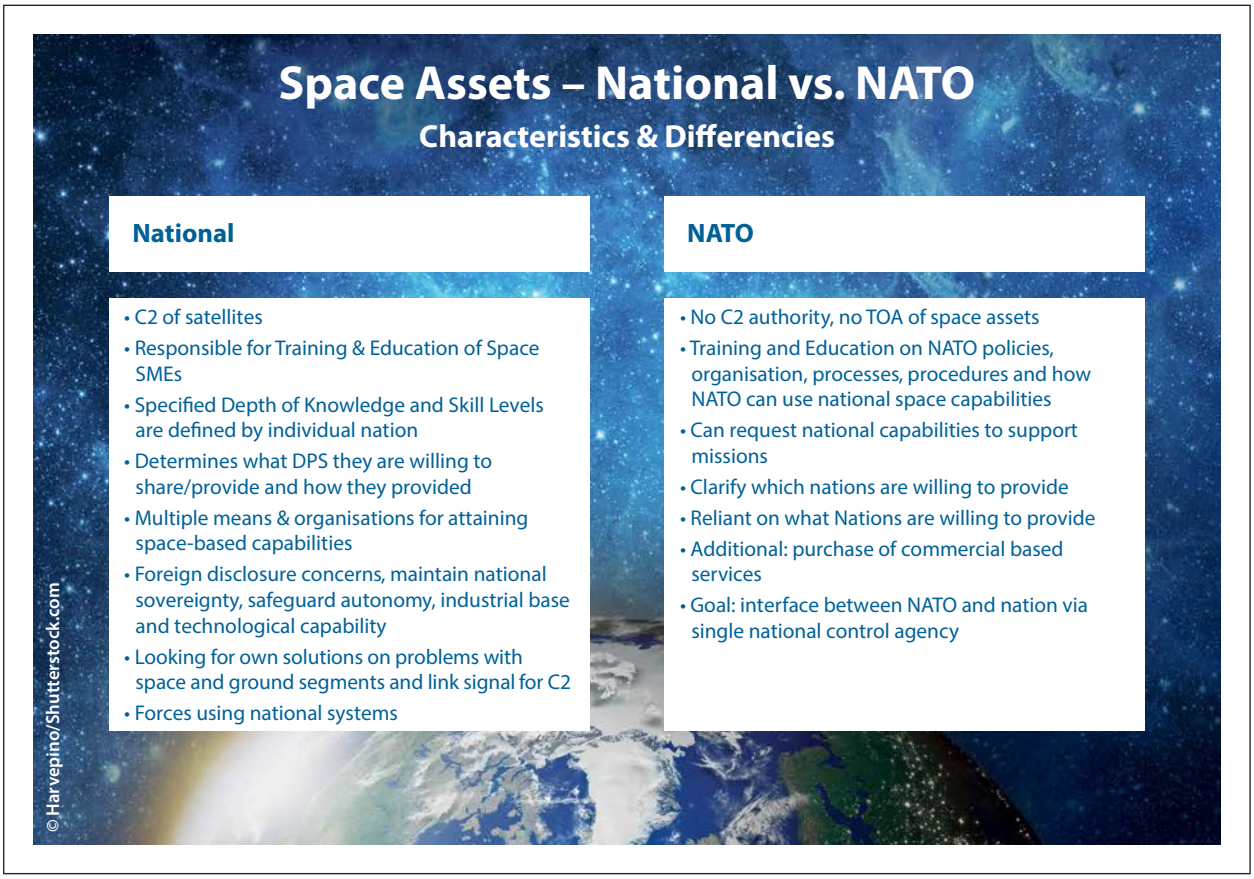


Figure 12: Space Assets – National vs. NATO.

requires rapid decision-making and authorization. Specific processes and procedures are already established, especially within functional areas like the Intelligence (J2) or Communications Community (J6). Additionally, Direct Liaison Authority (DIRLAUTH) has been established at the working level (Figure 11 depicts only the Operational Level), but in some instances, additional DIRLAUTH is permitted at lower levels to facilitate executing the processes in a timely manner. In some cases, DIRLAUTH is made official through bilateral agreements.

Formal agreements, pre-established means of exchange and DIRLAUTH are typical of the numerous established mechanism through which most of NATO's requirements are met!

If certain issues, mission requirements or unforeseen situations cannot be addressed by these arrangements, the Space Support Request (SSR) is yet another mechanism by which space data and services can be requested. The SSR follows a formalised process, by which tactical and/or operational level requirements are submitted through to the respective SpSCE at the strategic level in SHAPE, which is the authority to coordinate directly with the contributing nations to assess whether or not they are willing and able to meet the requirement. Commercial providers may contribute to this effort, if pre-established contracts exist or new contracts can be drawn up within a very short time frame.

The entire SSR process represents a fundamentally regulated exchange, thereby also includes the regulation of procedures for short-term requests in special situations, e.g. in the event of an unforeseen situation.

The establishment of DIRLAUTH allows quick and effective staffing of questions and challenges, especially in situations that require an immediate or rapid response.

Experience from major NATO exercises reveals that there is a lack of understanding of the ways and means for requesting space support for NATO. This lack knowledge is widespread throughout NATO as well as within the nations, e.g. well defined LoC and knowledge of responsibilities. However, there has been a continuous improvement over the years as a result of E&T, as well as the integration of Space into selected NATO exercises.

The new significance of the space domain necessitates integration of Space in NATO's warfare doctrine. This includes considering new organizations, like the Space Centre, as well as building up a group of personnel qualified in space capabilities. Besides these two efforts, other subjects are part of ongoing investigations into their potential for adoption.[15]

As to the exchange of DPS between nations and NATO, as well as the bi- and multinational exchange between Alliance nations, these arrangements are in place and being executed daily. The US, especially, as the most advanced space-faring nation of NATO, has separate agreements on cooperation with NATO and Non-NATO nations as well as other partner nations and organizations worldwide.

Two collaboration efforts in particular are worth mentioning here:

By 2016, the US had signed 13 agreements and arrangements with national governments and international intergovernmental organizations and over 50 with commercial entities regarding sharing of SSA Data.[16] As of 25 April 2019, the number of international data-sharing agreements with the US have reached the milestone of 100.[17] The main purpose of these sharing agreements is to ensure spaceflight safety for all space-faring nations by sharing an accurate accounting of all man-made space objects and assembling their collective knowledge.

The second example of multinational cooperation is the US lead Combined Space Operations Initiative (CSpO). Last to join the initiative in February 2020 was France; now the group is comprised of Australia, Canada, Germany, New Zealand, the United Kingdom, and the US.[18] The purpose of this initiative is to improve combined space operations between the US and all six-partner nations to optimize resources, deepen coordination, strengthen deterrence, enhance mission assurance, increase resilience, and improve mutual security.

Besides these partnerships, other institutionalized exchanges by agreements have formalized and thus improved the cooperation between NATO and its member nations in bi- and multi-lateral exchanges between Alliance members and additionally exchanges between the nations and nations outside of the alliance.

To set the framework for the exchange of DPS between nations and NATO, as well as amongst themselves, two general options are conceivable:

- Firstly, the nations involved could come together and create common rules, which would then be adopted by NATO for exchanges between nations individually and between NATO and the nations.
- Secondly, NATO itself could develop guidelines and set the standards that should be followed by the nations.
- Additionally, certain combinations of the above are also possible.

As a supplement to these sharing arrangements, NATO may contract commercial companies for specific deliveries if/when permitted in accordance with international trade laws.

The optimal and commonly desired solutions for meeting NATO requirements are resilient architectures that are difficult for potential adversaries to disrupt, for example by aggressive action against space assets.[19]

There are also examples of arrangements for the exchange of DPS between organizations other than

NATO and its member nations that have been in place for years. The agreement between the EU and the European Space Agency (ESA) is an example. Unfortunately, an official partnership between NATO and ESA does not exist and no collaboration and data-sharing agreements are forecasted. However, because many European nations are also members of NATO, a type of indirect and unofficial cooperation does occur. One example of this link between NATO, its member nations and the EU is explained in the 'Framework for Space Surveillance and Tracking Support'.[20]

1. BiSCSWG, NATO's Approach to Space, 2-Page Flyer.
2. For a basic introduction on Orbital Mechanics see: JAPCC: Command and Control of a Multinational Space Surveillance and Tracking Network, June 2019, available at https://www.japcc.org/portfolio/command-and-control-of-a-multinational-space-surveillance-and-tracking-network/, [accessed 14 February 2020] or for a deeper insight: The UK military Space Primer, June 2010, available at https://www.gov.uk/government/publications/the-uk-military-space-primer, [accessed 14 February 2020].
3. JAPCC Whitepaper Resiliency in Space as a combined challenge for NATO, published August 2021, available at https://www.japcc.org/portfolio/resiliency-in-space/ [accessed 18 August 2021].
4. JAPCC, Conference Proceedings, Joint Air & Space Power Conference 2019, p. 14, available at https://www.japcc.org/conference-proceedings-2019-conclusion/ [accessed 14 February 2020].
5. Starting with Journal 31, JAPCC will provide a series of articles about Responsive Space.
6. For all terms, definitions and explanations see Annex C with respective sources.
7. For additional info and specific aspects see: NATO C2COE, The Future of the Command Post, Study in two parts, Utrecht 2019, available at https://c2coe.org/download/the-future-of-the-command-post-part-1/ and https://c2coe.org/download/the-future-of-the-command-post-part-2/ [accessed 15 February 2020].
8. AJP 3.3. (B) is under revision, Edition C is foreseen to be published in 2022.
9. See Annex G.
10. https://www.esa.int/Safety_Security/Space_Debris/Space_debris_by_the_numbers [accessed 18 August 2021].
11. NATO Secretary General Jens Stoltenberg announced the establishment of a new NATO Space Centre at Allied Air Command in Ramstein, GE, https://www.nato.int/cps/en/natohq/opinions_178946.htm, [accessed 26 November 2020].
12. Interview with Gen Gorenc, in JAPCC Journal #19, p. 6-10, available from https://www.japcc.org/interview-with-general-gorenc/ [accessed 14 May 2020].
13. Ibid 7.
14. See Annex F Agreements.
15. A recently received GE RfS initiated a JAPCC research about potential future NATO Space Organization; the findings of this work were sent via the requesting nation to the allies.
16. Frank A. Rose, Strengthening International Cooperation in Space Situational Awareness, Advanced Maui Optical and Space Surveillance Technologies Conference, Maui, HI, 22 September 2016, https://2009-2017.state.gov/t/avc/rls/262502.htm [accessed, 20 January 2020].
17. Karen Singer, 100th space sharing agreement signed, Romania Space Agency joins, Air Force Space Command, 26 April 2019, https://www.afspc.af.mil/News/Article-Display/Article/1827412/100th-space-sharing-agreement-signed-romania-space-agency-joins/ [accessed 23 January 2020].
18. France fully embraces the Combined Space Operations (CSpO) initiative, https://www.gouvernement.fr/en/france-fully-embraces-the-combined-space-operations-cspo-initiative [accessed 18 August 2021].
19. JAPCC Whitepaper Resiliency in Space as a combined challenge for NATO, published August 2021, available at https://www.japcc.org/portfolio/resiliency-in-space/ [accessed 18 August 2021].
20. JAPCC Whitepaper Command and Control of a Multinational Space Surveillance and Tracking Network, published June 2019, available at https://www.japcc.org/portfolio/command-and-control-of-a-multinational-space-surveillance-and-tracking-network/ [accessed 13 February 2020].

CHAPTER 4

Legal Framework

After the first satellite launches by the USSR and the USA in 1957 and 1958 respectively, the international community reacted quite quickly with the development of a special space law.[1] Basic questions were asked in order to examine how to achieve coordinated and conflict-free use of the newly entered domain. Today, space law must provide legal clarity for all involved parties, ranging from lawful access to the forms of use; this includes the specifications regarding security for private companies' investment as a consequence out of today's trend of commercialization and privatization of Space.

4.1 International Space Law

In 1959, the UN established the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS). According to the basic Space Treaty (1967) and numerous complementary contracts (Space Rescue Agreements (1968), Space Liability Agreements (1972), Space Registration Agreements (1975) and the Lunar Contract (1979)), various Catalogues of Principles have been established, e.g. for Remote Sensing (1986), Nuclear Power Sources (1992) or Space Benefit Resolution (1996). These laws provide

for the peaceful use of Space, the moon and other celestial bodies. However, whether systems such as military intelligence, surveillance and reconnaissance satellites or ballistic missiles (in transit through Space) meet this requirement is a matter of controversy among experts and signatories.

Existing laws and regulations can be described as a framework based on the Cold War era with primary focus on states as actors. The question arises as to what extent space law in its current form is consistent with current developments, with NATO's recognition of Space as an operational domain being only one facet of current worldwide developments. The extent to which existing laws can influence, regulate, or even prevent a potentially new arms race in Space is uncertain. Existing space law does not take these developments into account; it needs to be developed further, and these adaptations are urgently needed due to current dynamics.

Other challenges in the field of New Space include the use of Space by private actors, the extraction of raw materials in Space (asteroid mining), and the avoidance of space debris. These issues have so far only been discussed; legal codification is still largely absent. Space technologies are rapidly evolving, whereas many of the current regulations cited are based on the original 1967 treaty. For example, there is yet no clear delineation between airspace and orbit, nor do laws provide a comprehensive framework for economic exploitation of the universe or a mechanism for the settlement of conflicts. Overall, at the present time, there is rather a lacklustre regulatory framework for Space. The momentum of cooperative progression exemplified in the early years has largely given way to jealousy and selfishness on the part of the nations who invest in Space.

In today's rules-based world, however, codified regulations are essential and much work remains for codification in the international field, such as for a type of space traffic regulation, including evasion rules. There are no fixed rules that determine how satellites draw their orbits, and orbits for some objects are even unknown. Moreover, the lack of a rules-based international order has seen the space domain increasingly threatened by malicious actors, not only on earth, but also in Space.

Historically, the control of the seas, ensuring free and stable trade during peacetime as well as guaranteeing safe transportation of personnel and material in wartime were the main characteristics of the international laws governing freedom of the seas. Is society's dependence on Space similar to our previous dependence on the sea? Could international maritime law be a blueprint for international space law?

Ultimately, it is for legal experts and heads of state and government to determine whether it is essential to renew and/or adapt regulations governing activities in Space. Regulations aimed at preventing an arms race in Space must also be discussed among involved nations.[2] On the other side, an ongoing increase in national space law can be observed to include private actors in many areas of space activities.

4.2 Private Law and Law of Contract

The Law of Contract is a part of Private Law and defines conditions on agreements between individuals, be they actual or artificial persons (e.g. an organization). Aside from Public Law, (which underlies all governmental activities) and the Law of Armed Conflict (for militaries), Contract Law may influence some functions of an OC, depending on their Mode of Operations.

A Nat mil SpOC, which concentrates purely on military missions, does not need expertise in the area of contracts. The legal rights and responsibilities of those working in a military installation as part of the national armed forces are governed by national and international law. The law regarding investment and procurement of specific military equipment is enforced on other levels. SpOC personnel do not need to possess legal expertise.

However, if the SpOC is involved in areas of public administration, or with civilian companies in intergovernmental or private/public partnerships, expertise in

the field of contract design and management is certainly required. If commercial suppliers deliver DPS from private satellites on a regular basis and additional DPS is needed on short notice, knowledgeable legal experts with operational and space-specific skills should be available. Whether it is mandatory to have legal expertise permanently within the SpOC is a decision for each individual nation.

With respect to multinational cooperation, the legal aspects mentioned above are binding. Effective and concrete cooperation between NATO and the nations regarding their SpOCs requires a framework that regulates the corresponding areas of work (contracts) by the parties involved, such as:

- Use of international exchange personnel, including in crisis and war;
- Deployment and cooperation of military and civilian personnel;
- Relationship of personnel subordination and authority to issue directives;
- Payment for provided support, including the mutual exchange of DPS etc.;
- Access to and use of classified data;
- Disclosure of data (classified and unclassified);
- Liability law;
- Regulation of the transfer of costs and also deficit rules or use of profits if applicable;
- Contracts of procurement and usage;
- Other space-specific contracts.

Prior to starting to cooperate, arrangements in any of the above-listed fields must be fully clarified, drafted and ratified through respective national processes and between all the participating nations and organizations, such as in an MoU or TA. The formality is particular to private commercial and personnel law.

Agreements regarding sharing data and services between the nations and NATO, as well as among the nations themselves, must be established for the precise functional areas; a general overarching agreement does not exist and would not be sufficient. In general, NATO does not have binding legal agreements regarding Space. Rather, NATO relies on national and international space laws to formulate arrangements. National space laws, in particular, make reaching exchange agreements difficult. So, for example, not all DPS can be shared with all other NATO members due to legal constraints imposed by some nations. Only DPS explicitly regulated in agreements, based on the law of contract, are permissible for exchange.

4.3 Rules of Engagement

While space security issues, such as regulations on the handling of space debris or CA, require general regulation within the framework of the UN, specific threat assessments and indications of hostile intentions must be evaluated within each nation and more broadly for NATO. Complete assessment requires clarification on whether Article V of the NATO treaty (attack on a NATO member nation) can be declared in the event of an attack on a national space asset. Attacking ground-based space C2-centres are definitely acknowledged to be attacks in this regard. However, whether an attack on a space segment, especially via cyber-attacks, can be classified similarly is less clear and could face some legal challenges.

Also in this argumentation, the geographical boundaries of NATO territory are of interest. Art VI of the North Atlantic Treaty indicates the boundaries within which, if an attack against NATO took place, would initiate a response, is restricted to Europe, Turkey and North America, the Mediterranean Sea and the Atlantic Ocean north of the Tropic of Cancer.[3] However, satellites in orbit cannot be limited to these boundaries; also, their altitude above the Karman Line is beyond the limits of national sovereignties.

It is, therefore, necessary to consider whether, and to what extent, specific Rules of Engagement (RoE) must be established to account for conceivable conflicts affecting resources on orbit, whether during peacetime, crisis or conflict.

Since the 1960s, the development of laws governing activity in Space has not kept pace with advancements

in technology and capability, nor has the UN made the necessary regulatory decisions, nor are they expected in the near future. Therefore, the members of the Alliance must draw up regulations of their own to govern this complex field. This self-regulation may not be the best solution, but it could establish a core set of rules that other nations may decide to adhere to. After all, about 60 % of all satellites worldwide are owned by NATO member nations (Figure 6, page 22).

These questions may be complex, as far as satellites which are dual-use, have both military and other state users. A regulatory framework would be particularly complicated if a satellite is used by both the military and the private sectors. For several reasons, the legal status of a satellite as a military object is of fundamental importance.

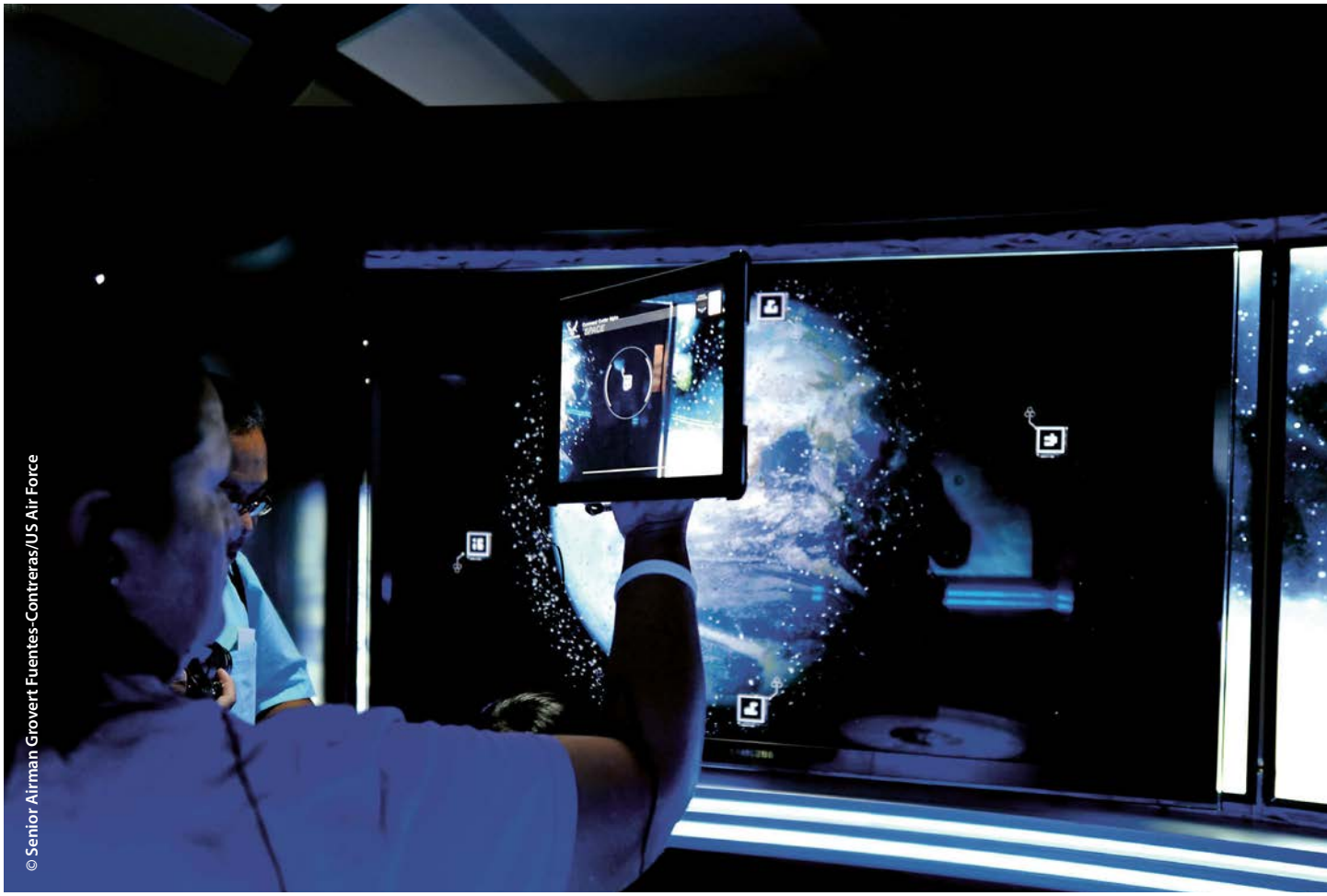
In the first instance, space law is not a uniquely military subject, but it influences the military domain of Space. Questions of security must include how threats from Space are managed lawfully, which includes a clear discrimination of hostile intent or action, space debris and NEO, and the appropriate countermeasures for each threat. This implies nations and, therefore, NATO, must define a threshold and codify norms of acceptable and non-acceptable activities, and declare the specific behaviour that can be interpreted as a hostile act.

Satellite control operators already make decisions within the framework of CA by initiating evasive manoeuvres for individual satellites, but there is no legally binding requirement. Normally, satellite operators clarify among themselves who will cede the right of way if there is a potential risk of collision. However, this unofficial avoidance procedure is executed on a case-by-case basis, not governed by a regulatory framework, nor even with a generally agreed upon code of conduct.

The speed at which events unfold in Space typically means that when the situation demands, quick decision-making on legal issues may be critical to success, so legal experts for a wide variety of space-related aspects should be available on short notice, not necessarily within the organization of a SpOC, but easily accessible.

One of the next challenges on the topic of space law will be Space Traffic Control. Large constellations comprising tens of thousands of satellites that are mainly privately financed will operate in LEO in near future. For this reason, regulations for the central traffic monitoring must be implemented over the next few years. As is the case with air traffic control, regulations will define clear rights and obligations among users. In addition to the implementation of legally binding rules, it must be ensured that these are observed and that sanctions in the case of misconduct are developed and enforced.[4]

1. For basics and additional details about Space Law see: http://www.unoosa.org/oosa/en/ourwork/spacelaw/index.html, http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties.html and http://www.unoosa.org/res/oosadoc/data/documents/2017/stspace/stspace61rev_2_0_html/V1605998-ENGLISH.pdf [accessed 10 February 2020].
2. NATO publication 'Legal Gazette' covers legal aspects of Space in issue 42 (December 2021), available at https://www.act.nato.int/publications.
3. The North Atlantic Treaty, available at https://www.nato.int/cps/en/natohq/official_texts_17120.htm [accessed 12 February 2020].
4. R. Tuellmann et al, On the Implementation of a European Space Traffic Management System I. A White Paper, https://elib.dlr.de/112204/ [accessed 25 June 2020].



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CHAPTER 5

Requirements for a National Military Space Operations Centre

Space is a dynamic area in which many nations see the potential benefits and rewards of investment. With an increasingly unstable world, there are significant risks and challenges, and for this reason, achieving any type of assurances for the security of space-related resources require governmental engagement. Defence of national investment and resources is traditionally the realm of the military and the planning and execution of such defence would be most effective and efficient from a central focal point. A Nat mil SpOC may be one option for the focal point of an overarching effort to ensure the security, safety, sustainability and stability of all activities in, through, and from Space. For these purposes, they have to fulfil – like all OC – all three of the decisive factors of security, resilience and flexibility.

The framework conditions for influencing the design or layout of a Nat mil SpOC were presented above. The details of the specific requirements that must be considered remain to be highlighted. Regardless of how rigorous an examination might be, a complete and a comprehensive collection of national requirements may never be achieved due to the unique political interests of each nation and the fact that the starting points of their individual programmes are too varied. Additionally, the speed and direction of ongoing technological developments can only be estimated.

5.1 General

Space capabilities are typically provided for uniquely military, governmental or public requirements, however some capabilities serve two types of clients and are referred to as 'dual use.' As a consequence of these overlapping responsibilities, it seems logical for limited and high-value assets to consider developing or establishing a shared national SpOC at the earliest possible stage. This type of centralized C2 will enable delineating management of civilian and military functions and synchronization where matters of national security and safety are concerned.

Due to orbital mechanics bound by the laws of physics, assets in Space are not restricted to function only within geographic, terrestrial boundaries, nor within specific theatres of operation. Space assets support many customers in various areas of operation, often simultaneously. Therefore, control of a space asset cannot be given to a single regional commander. Centralized C2 from one focal point will optimize effectiveness and efficiency for the provision of services, maximize the potential of limited resources and minimize fragmentation of capabilities.

The three primary functions defining the scope of a SpOC are:

- Monitoring the whole domain (assessment);
- Applying respective regulation (law, norms, principles, rules);
- Coordination with all relevant actors (working together).

These activities necessitate that personnel possess a high level of knowledge and skills in three areas:

- Education and experience in his/her specific function/position;
- Space-specific knowledge, incl. their integration into operations;
- Competence in working in inter-disciplinary (multi-disciplines) and multinational joint and combined staffs, incl. language skills.

Creating a Common Operating Picture (COP) for the space domain involves more than merely regional awareness, but building a global view. This perspective requires the integration of data from sensors deployed worldwide and therefore, cooperation with those nations that operate these sensors. Other than the US, which possesses resources of all types deployed worldwide, no single nation can create a space COP on its own; international partnerships are necessary.

All relevant Information must be assessed. For example, manoeuvres in Space by a nation's assets could be perceived as normal course corrections in line with a specific task or as an unfriendly action, which may be an indication of the beginning of a conflict. A clear and precise assessment of actions like this (SSA and SOSI) is one of the major tasks and outcomes of a SpOC.

NATO does not have the required capabilities to generate the information, nor provide assessments, as in this example. These activities must be provided by Alliance nations.

Similarly, NATO does not possess standardized templates, nor specify concrete requirements for the creation or structure of these products; these standards are the sole responsibility of the nations. In addition, the restrictions associated with the classification level (such as access rights and procedures for disclosure) as well as data format and size (for the required IT-capacities) are for the most part, not specified. Due to bi- or multi-lateral agreements, only exchanges between NATO and the respective nation(s) are permissible, a transfer to other nations within the Alliance is not normally authorized. First and foremost, the originator of the products determines the structure, scope, content, and conclusions of the report. NATO requirements must be clearly established and presented to the nations for their support.

Finally, one of the general principles of warfare is to ensure the preservation of strategic reserves. Applying this to planning operations in the space domain translates to establishing alternate means of providing

space services in the event the primary means is disrupted. The establishment of a Nat mil SpOC will provide the staff necessary to examine the ability to provide for and anticipated demand for back up and redundant services. Whether one space system in service is a suitable back up for another system, or whether other suitable alternatives are available, must be carefully evaluated. In addition, we must continuously examine how the dependence on space-based DPS can be minimized and to what extent the systems can be protected, secured, hardened and, if necessary, defended. For example, how persistent DPS provision can be ensured via an array of federated systems. The objective is to achieve resilience, meaning, 'further functioning of the overall process without a failed subsystem also through other measures'.[1] To this end, an increase in national resilience measures contributed to a common pool of capabilities orchestrated by NATO is one option towards achieving resilience of space capabilities for Alliance operations and missions.

5.2 Organizational and Financial Aspects

Both the internal organizational aspects of a Nat mil SpOC, as well as the external aspects have to be considered. The latter encompasses the integration within the national organization, especially within the military structure, and within the NATO space community; both require the adoption of strict processes and rigid LoCs. Defining relationships, responsibilities and rules will differ for each individual nation, due to each possessing a unique political structure and security system, as well as differing relationships with academia and industry.

Firstly, the definition of the internal organizational structure as a demanding process must cover aspects such as those listed here in extract.

Internal organization is influenced first and foremost by the differentiation for responsibilities of C2 of the satellite's bus and the payload. To a lesser extent, the organization will depend on who has technical responsibility for space-based and/or ground-based sensors, for external LoC and how they would be integrated with the SpOC's business processes or potentially outsourced to other organizations. A framework for typical arrangements is set out in this paper. However, within the wide range of assets, the breadth of potential structures is even wider, similar to any other military capability in NATO and, therefore, beyond the scope of this paper to describe in full.

The following basic statements must be considered with regard to general organizational factors:

- Determining those national agencies, space functions and their level of integration into the SpOC;
- Establishing the relative position of the SpOC within the national chain of command;
- Maintaining unity of command within the SpOC to avoid fragmented command and leadership breakdown;
- Defining the process for sustainment of operations and of integration with the chain of command;
- Operational lines of communication, both horizontal and vertical;
- Integration and cooperation with non-military actors in government, industry and the technology community;
- Identifying a Back-up or Alternate SpOC capable of a complete or partial transfer of command authority (TOCA);
- Assessing the requirement for a deployable SpOC with reach-back capability;
- Examining the possibility of a static SpOC with forward deployable elements, which may be independent of or integrated with another OC.

Any Nat mil SpOC which has responsibilities beyond those listed above, will require a close liaison to military and civilian research facilities, Think Tanks and the staffs managing Policy and Doctrine related to Tactics, Techniques and Procedures (TTP). It is essential to ensure that all agencies have a common understanding of current and foreseeable requirements, as well as requisite access to applicable documentation on warfare. Experts in analysis, modelling and simulation, as well as consultants and part-time advisors should contribute where permissible by security and

classification regulations. To encourage operational thinking, additional staff with no affiliation with Space, but possessing broad knowledge and experience in traditional warfare and operations, could be integrated within the structure of this organization.

In determining the overall organizational structure, a structure must be found that is sufficiently specialized to accomplish all required tasks (fit for purpose) and sized based on realistic mission requirements. Splitting the totality of tasks and duties among many different sections with self-contained cells can result in small sections that are highly competent in their respective areas, but lose sight of the big picture. Such a structure can lead to the creation of a staff body with too narrow a view, which overemphasizes its own area of responsibility at the expense of the overall responsibility. This organizational barrier could hamper the staff collectively from understanding the overall task and result in delays in delivering what are often, time-critical solutions. The opposite is true as well. Building a staff with an over generalized knowledge base risks diluting the expertise necessary for an OC and the reasons justifying its creation in the first place. A well-balanced mix of technical expertise in specific disciplines, with strategic and operational oversight, should be the structure to which nations aspire.

When determining the structure of a Nat mil SpOC, the provision of military security and defence are not the only components contributing to national security. The numerous roles which civilian agencies and other government departments play in national security calls for a comprehensive analysis that will clearly differentiate each of their roles, responsibilities and means for implementation. A wide range of political and administrative challenges must be clarified. Examples for these (mainly) civilian areas include:

- Governmental services;
- Telecommunication/Information Services;
- Energy services;
- Rescue and emergency services;
- Food and water;
- Health;
- Transportation;
- Finance.

Failures or restrictions in these areas may have far-reaching implications in all parts of daily life, which may extend into and affect national security. Therefore, all these functional areas must be accounted for in a central national space coordination structure. Certainly, space-based DPS for these fields is already processed and implemented in an appropriate agency (state or private), but it is mostly decentralized. Nations are showing a broad variety of solutions. Examining whether it is beneficial and feasible to integrate all governmental entities, dealing with sensitive or highly secure space-based information sources, into one central SpOC to provide greater national security will require a high degree of cooperation between different intergovernmental organizations and/or agencies. A high level of integration is projected to benefit the financial aspects of efforts in Space as well. Nevertheless, a strong centralization implies directly the requirement for an alternative SpOC, to take over without any delay in case of the disruption of services, whether due to maintenance, reinstallation, technical problems or an enemy attack.

Each year natural disasters and major catastrophes severely damage critical infrastructure leading to humanitarian crises. Annually there are calls for rapid international intervention for areas without critical services or where there are no local authorities or existing authorities are overwhelmed. International aid from governmental and non-governmental organizations (NGOs) as well as the military must be available on very short notice to respond. A military SpOC would be an ideal entity to include among first responders, as well as for the duration of the period for which humanitarian aid is required. DPS, for example ISR, PNT, SATCOM and Wx, can be made available without any delay. Emergency communications will be necessary to expedite recovery efforts of first responders and to help local businesses return to operation. Therefore, the establishment of a specific cell to coordinate the provision of space capabilities to aid in Disaster Relief (civilian or military) might be highly beneficial.

In general, all organizational structures must be flexible and continuously adapt to evolving tasks and duties in this highly dynamic domain. Furthermore, given that many space resources are dual-use, a broad understanding of military soldiers and civilian employee personnel management as part of running an effective and efficient organization is very important.

Modern militaries have acknowledged the importance of Strategic Communication and Public Relations as significant contributors to achieving mission objectives. Therefore, these functions must be taken into account, either as an integral activity of an internal staff element or segregated as the responsibility of another (likely superior) authority.

Integrating a new Nat mil SpOC even within national (armed) forces is a financial challenge. Though a national SpOC would provide DPS to NATO entities, it is still a national military organization and therefore, not a beneficiary of NATO common funding.

The high cost associated with the military use of Space, due to expensive R & D and purchase prices of existing products in the commercial market, may be financially challenging for smaller nations. On the other hand, new technology in the area of New Space can lead to the production of much more cost-effective and even higher performance solutions.[2] Ongoing research by industry often leads to breakthrough developments which strategic planners must always keep in mind, so much so that a fourth 'C' for Commercial might be postulated as an additional attribute to the better known '3C' of Space: Congested, Contested and Competitive.

The management of public funds for expensive investments paid over the course of one or multiple years requires advanced commitment of the appropriate amount of funds to ensure services are provided to meet immediate and ongoing military requirements. Thus, from a financial point of view, all investments in short- and long-term procurement should be investigated and evaluated.

Another cost-effective alternative would be to create a partnership of nations, each contributing a variety of space assets in various combinations, to create different constellations with differing costs. Options ranging from nations with little to no space expertise working together, up to inexperienced nations cooperating with one or more experienced space-faring nations should be explored.

Partnership solutions between state governments and the private sector may help share the cost burden with the public. This level of collaboration is not unusual for military activities, as it has been proven effective in specific areas, like the outsourcing of logistic support or security services. Even manned space flight has illustrated new opportunities, like e.g. SpaceX' services for NASA.[3]

One new idea is the concept of a Federated Mission Network (FMN) for NATO.[4] This concept is a major contribution to the Connected Forces Initiative (CFI), helping the Alliance as well as partner nations to better communicate, train and operate together in two specific areas:

- Mission–FMN enables a rapid instantiation of mission networks by federating NATO organizations, NATO nations and mission partner capabilities, thereby enhancing interoperability and information sharing.
- Networking–FMN is a governed conceptual framework consisting of people, processes and technology to plan, prepare, establish, use, and terminate mission networks in support of federated operations.

FMN is a capability aiming to support C2 and decision-making in future operations through improved information sharing. It provides the agility, flexibility and scalability needed to manage the emerging requirements of any mission environment in future NATO operations. FMN is based on principles that include cost-effectiveness and maximum reuse of existing standards and capabilities.[5]

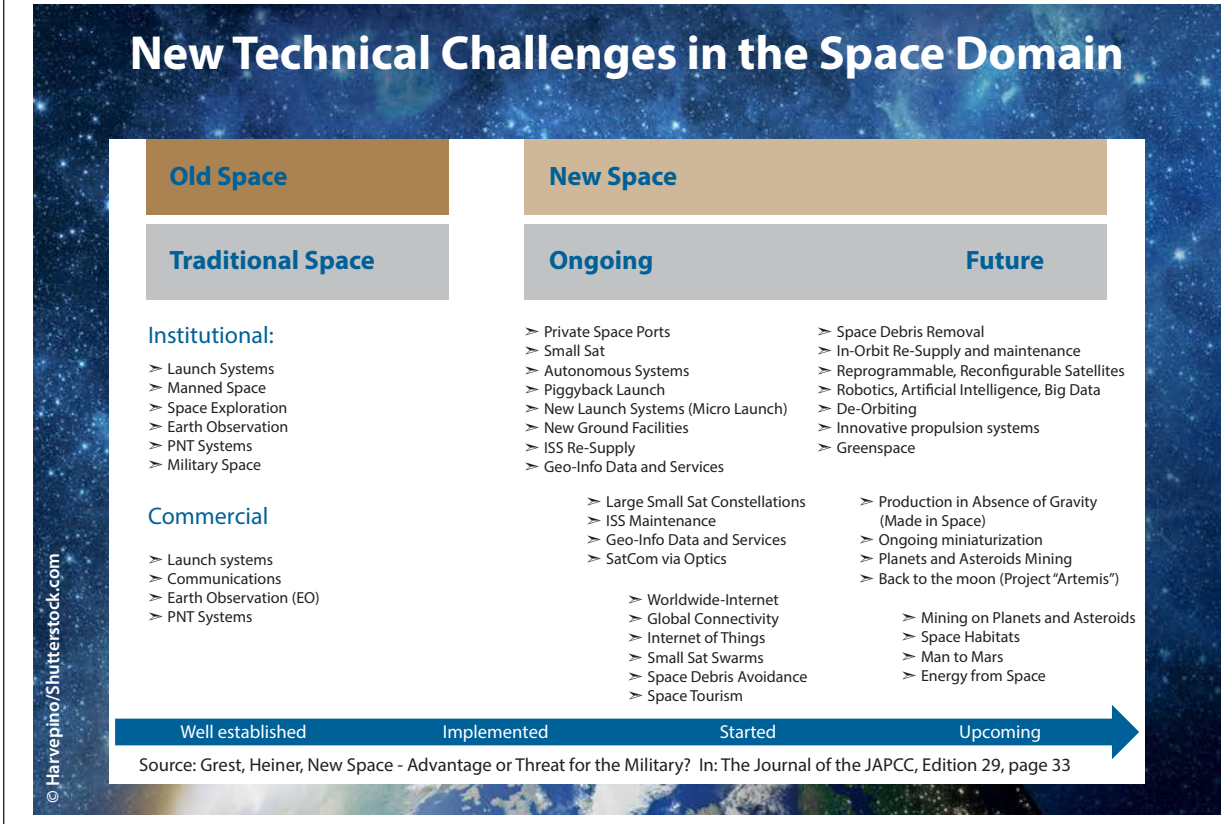


Figure 13: New technical challenges in the space domain.

This NATO initiative may serve as a framework, and further use of this system by nations will save them having to develop their own complex, expensive and lengthy in-house solutions.

Another multinational concept is the Framework Nations Concept (FNC).[6] In this scenario, one single nation provides a military basis or a core competence as a cadre, or framework, in a lead position and nations with fewer capabilities in this area contribute supplementary capacities in the form of manpower and/or materiel. In this way, not all European NATO nations are required to possess all the appropriate capabilities for a functioning organization to emerge. This concept, which has already been initiated in the area of land forces in particular, could also be used as a blueprint for a national or multinational SpOC.

As part of a constant cost-benefit analysis for investment in space assets – but also considering ongoing technological progress – a comparison to conventional, i.e. earth-based or airborne alternatives must take place. Advancements which improve redundancy, resistance, additional capacities, etc. are important and may be decisive factors when having to select between alternative services like terrestrial-based programs or SATCOM.

Continuity of services is of the highest military value, therefore organizational and (if applicable) contractual foundations, inclusive of their funding, must be aligned to this principle objective; this includes short- or longer-term outages, which results from malfunctions, accidents or attacks. Contingency planning at any time and for all situations must be considered for all cases; this may be challenging in some cooperative partnerships.

5.3 Technological Aspects

'War is the Father of All Things' – this popular quote from the ancient philosopher Heraclitus of Ephesus (c. 535–c. 475 BC) is frequently referenced and often with varying interpretations. It is primarily cited to support the theory that it is undeniable that the military has always been a driving force for technological advancement and innovation. The converse can also be argued; that ongoing technical innovation has changed and will continue to change the character of future conflicts.

The military has always been at the forefront with respect to the technological advancements toward the exploitation of Space. This trend seems be changing significantly in the age of New Space.[7] Systems operating in Space must offer a high degree of reliability and possess the ability to operate autonomously in the extreme conditions of a hostile environment (vacuum, heat, cold, radiation) and for a long period of time.

New Emerging and Disruptive Technologies (EDT) are influencing all areas of today's civilian and military spheres and these might impact space operations as well. The number of new and developing technologies that could influence space applications and services, both directly or indirectly, is vast and well beyond the scope of this paper. Figure 13 (opposite) depicts the main challenges, both current and projected, impacting operations in Space.

Space capabilities must support all varieties and types of NATO Military Missions (CD, CM, CS) and at any time. The continual shifts in global security conditions have caused continual changes to geo-political boundaries, whether during war, conflict below the threshold of war, or even (presumed) peacetime and often with little to no notice for the international community to intervene. This complex dynamic between ACTIO and REACTIO, necessitates establishing permanent units, highly skilled forces with the capability to respond on short notice. In the high tech and rapidly advancing field of Space, exploring how to leverage complex, innovative and disruptive technologies, such as Artificial Intelligence (AI) and Robotics, is a must. The rapid cycles from R&D through production, delivery and deployment, the characteristic attributes of modern innovation and technological development require that current procurement programs within NATO and nations be overhauled, because in their present form they are slow and cumbersome processes.

Technological innovations are emerging in ever-shorter cycles and predominantly in the civilian environment. Global innovation cycles and nationally applied procedures to ensure the operational readiness of the armed forces are no longer congruent. Integration of short technological innovation cycles into typical long cycles of procurement of new systems for the armed forces presents an additional challenge. Modern innovation management requires development-oriented testing with the aim of innovation-oriented, planned and continuous renewal on the part of governments, thus continuous cooperation and direct interaction between users and suppliers. Today's situation can be described as the permanent search for faster and more effective solutions.

Massive changes are observable in the today's space business sector. Technological innovation and fast developing program processes arise mainly in the civil sector and not the military anymore. A sophisticated space industry, including innovative research and development, must not be underestimated as an indicator of the overall reputation of a nation for achieving commercial success. Achievements in space activities are a symbol of a powerful, sustainable and progressive nation that presents itself as highly attractive for investors.

Within the context of space technology, the IT subset is a very demanding challenge. The complexity, high tempo of change due to innovation and its interconnectivity to all other aspects of technology as discussed here, are significant and will be examined in the next chapter. One example demonstrating this interdependency very clearly is the development of the newest 5-G mobile network. 5-G will make it possible to enable an almost endless number of digital

applications – such as in the case of the Internet of Things (IoT) – for businesses and thus is the driver of Industry 4.0, with a transfer speed almost in real time. The enormous increase in the rate of transfer is having a huge impact on the economy and society, and this includes the space industry.

The following is a shortlist of the main technical trends for the foreseeable future:

- Emerging and Disruptive Technologies (EDT);
- Ongoing digitalisation and networks;
- Close connection with Cyberspace, Cyberwarfare;
- Cyber security and Cyber resilience;
- Data/Big Data as a strategic resource;
- Robotics and autonomous systems;
- Miniaturization;
- Shorter development period with rapid prototyping.

These trends have huge impacts on Space, and hence the military use of Space.

Advanced technologies that are, or are about to be, introduced in the space industry including small satellites, additive manufacturing (using native material from Space), On-Orbit-Servicing, quantum encryption and autonomous operations are 'mega' trends in advances in space research and development.

Effective and efficient interoperability among digital applications, processes, systems and networks are a prerequisite for achieving the rapid freedom of manoeuvre necessary for success in an intense battle. In other words, when providing program guidance to meet operational requirements, achieving information superiority is a critical principle of war.

Rapid digital change trends toward open architectures of complex systems as well as autonomy, or at least partial automation. When applied to analysis and assessment of the situation, as well as the preparation and decision-making, the next result can mean a requirement for fewer staff.

The production cycle for new systems is getting shorter and shorter. What were new systems not long ago, become legacy systems within a very short period. This not only leads to obsolescence, lower quality and effectiveness, but also has a detrimental psychological impact on operators. Learning, achieving proficiency and mastering the operation and application of new technologies takes a mental toll on operators and even more so when the frequency of replacing technologies increases.

Commercially available products are often relied upon for solutions to military requirements. These products normally lead to lower procurement costs and, therefore, reductions in defence budgets. On the other hand, it could lead to an over-reliance on commercial systems, which may not meet all specific military needs in their entirety. Balancing costs and special military requirements must be done very precisely. However, working closely with the commercial sector enables governments to gain access to cutting-edge solutions, not only with satellites. This applies additionally for systems used within command posts, operation centres and HQs. Using COTS products can enable the military to acquire mission-critical connectivity for C2 on the tactical leading edge in a very short time.

The relationship between the commercial space industry, governments and the military is more important than ever before. The development of proprietary technology is problematic as it is more costly and involves longer lead times, which is more and more intolerable in this time sensitive domain.

C2 is paramount to the decision cycle of the respective supported entities. Integrating as much data as possible, across all aspects of warfare, will assist OCs as they strive to lift the 'Fog of War,' to achieve a reliable foundation for decision-making towards optimum situational awareness: a Vitreous Battlefield.

A primary objective is to achieve a level of C2 that would allow the commander and his staff to prepare and to make the actual decision (e.g. via OODA loop [Observe, Orient, Decide, Act]), whenever possible based on information superiority or dominance. The basic conditions for this purpose are:

- Receipt of information;
- Preparation and interpretation of information;
- Situational presentation;
- Forwarding of information.

A state-of-the-art OC in today's armed forces would be a conglomerate of modern technical products addressing these conditions, a system of systems. Only some of those conditions required for a Nat mil SpOC are listed here. To establish an exhaustive list will require an intensive discussion among experts about the nature and scope of the respective design during the whole planning and build-up process of the SpOC and might include:

- Modern open systems including the potential for ad hoc and modular implementation;
- Flexibility through modularity, modular hardware and interfaces;
- Expandable across system boundaries;
- Robustness and high reliability (a general requirement for all military equipment);
- Plug-and-Play-System with automatic parameter setting;
- Unlimited and open-ended interfaces;
- Defined access to data servers and sharing aspects with NATO and partners;
- COTS products versus specialized military products;
- New products compatible with legacy products;
- Self-restrictions in equipment (e.g. out of political or moral reasons) creates advantages for adversaries;
- Management as well as C2 equipment must be capable of:
  - Integrated situational awareness;
  - Level-oriented situational awareness;
  - Dynamic management and C2 processes;
  - Real-time / near real-time;
  - No delay;
- Interconnectivity with partners and potential partners (national, governmental and private, International, NATO);
- Multi-source data from military, commercial and allied origins;
- Avoid hardware that could deepen/reopen a technology gap within NATO countries;
- Integration of intelligence systems;
- No over-fixation on EDT;
- Redundant communication;
- Communication-based on Internet Protocol (IP);
- Reset-function;
- Easy use of hardware brings advantages in less training, quicker to operate;
- Real-time operation;
- Hardening against electromagnetic pulse;
- Hardening against electronic attacks;
- At least one type of emergency mode;
- Redundancies during outages, returning to service quickly after attacks (also cyberattacks).

In the end, 'we must develop new tools faster than our traditional military processes permit, in order to sustain the speed of relevance'.[8]

The layout of a SpOC must be tailored to operate during the maximum level of threat today, a possible conflict against a peer or near-pear adversary in an Article V environment. This encompasses many implications characteristic of the cold war era. A Nat mil SpOC addressing these conditions would also be effective in all varieties of Non-Article V operations. The utility of forward-deployed elements of a SpOC should also be included in the requirements assessment.

Working together in an Alliance with 30 member nations calls for a high degree of common understanding and the willingness to compromise. From a technical point of view, the main standardization instrument is the STANAG. Normally, if all participants are adhering to agree upon standards, everything should work effectively. However, nations do not always proceed in accordance with ratified STANAGs, at least completely... Many nations do not ratify some agreements due to national restrictions, especially in order to protect national industries. We must keep in mind, that the responsibility for developing new technologies and their relative priority is set by the individual nations and may not necessarily be coordinated with other nations or NATO. This is mainly a result of funding regulations and the individual national assessments of their most likely potential adversaries based on their respective threat potential and the resulting national perceptions and prioritization.

Because technology is developing so rapidly, the innovation cycles are getting much shorter and a collective goal should be to agree to adhere to a requisite number of common standards to ensure interoperability. Hence, NATO nations' research and development in the space domain should be continuously monitored. The space domain (space-based and terrestrial components) is highly technical with significant R&D within the Alliance's nations, therefore, NATO's Science and Technology Organization (STO), must take an active role part in this task. The results and findings of the STO panels involved in this monitoring must be translated and transferred from technical parameters to factors appropriate for inclusion in the development of operational guidance, policy and doctrine in NATO.

In a liberal and democratic nation, researchers must have the freedom to explore new territories and, especially in the military sphere, be able to look at developments where tangible results might only be realized over a longer term. In this way, research can make a decisive contribution to gaining, preserving and expanding the desired sovereignty on strategically important technological issues. It is also crucial that sufficient research funds are assigned to the interests of the national armed forces.

Innovation has no limits. History has many examples where technical progress could not accurately be predicted and how disruptive inventions opened up previously unimaginable opportunities. At all times, the newest technologies have supported a faster and more reliable decision-making process and this will likely continue.

In many cases, when a new system is implemented, the legacy equipment is removed completely and replaced in its entirety. In these cases, it should be verified, whether the original system and/or materiel should be retained as alternative means of service provision, such as during times of maintenance work or as a contingency/emergency in the event of malfunctions, outages, or destruction.

Another alternative may be not to scrap this equipment, but to transfer selected specific materiel to partner nations, which do not own these capabilities at all or use older equipment. This may be an interesting prospect, especially for new actors in the military space domain; however, costs, technical, classification and sharing issues always arise.

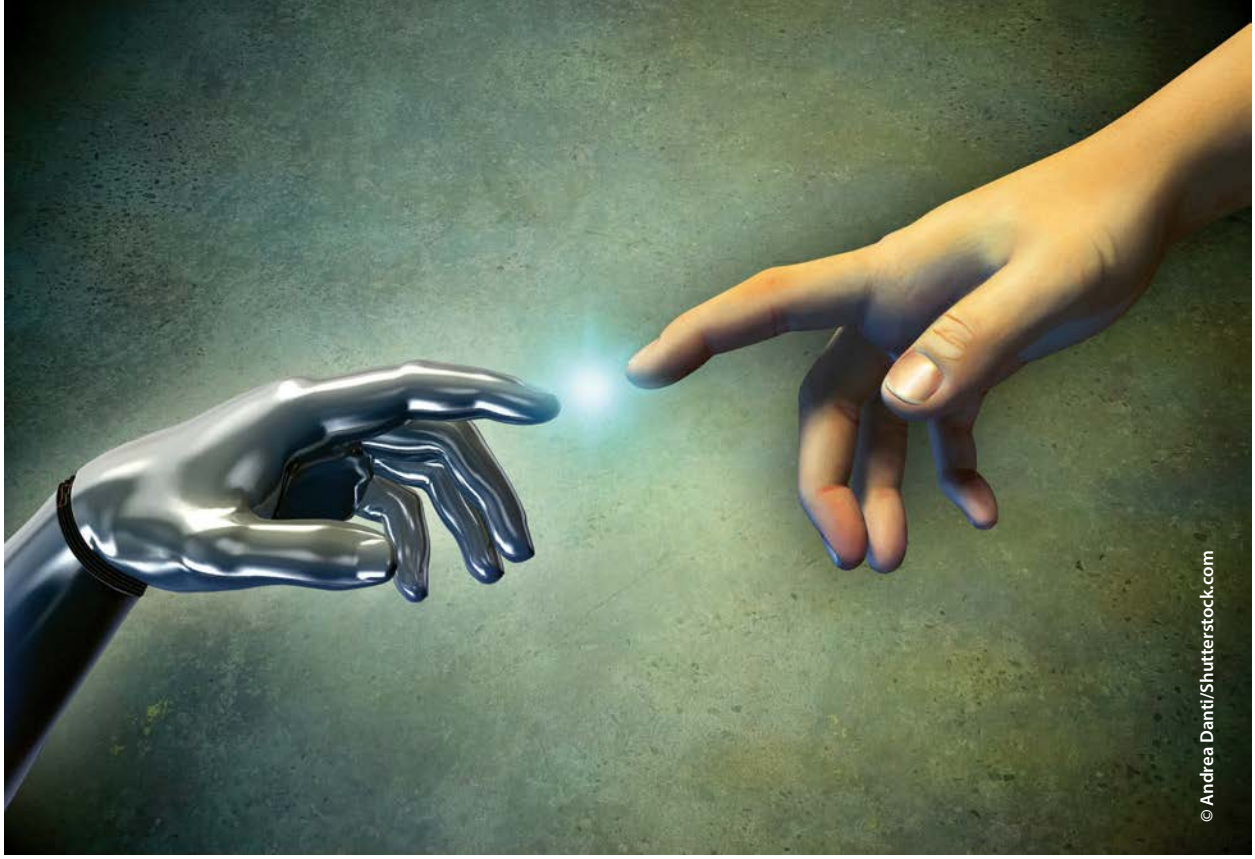
When assessing military requirements, the need to access space provided DPS for all new equipment must be evaluated, especially when it involves civilian research and development, procurement of all new systems or weapons, or even parts of equipment.

Finally, existing technologies and those under development for the future are to enable a rapid decision-making process, which in turn increases operational tempo. This has an enormous influence on human factors. A combination of rapidly evolving technology contrasted with traditional ways of thinking about warfare may result in conflicts between progressive and conservative thinkers. There is also the question of the need for human control, and whether it is more appropriate to place a human or a machine in the middle of the decision-making process. At this time, it is uncontroversial to keep humans in accountable positions within the decision loop (Human in the Loop).

5.4 Information Technology Aspects

Today, the execution of military operations is almost not technically or geographically limited. The information environment is just as important a factor as the assessment of the entirety of own, adversary and neutral military capabilities or even civilian agencies in the area of operation. This criticality of IT throughout all domains require detailed and strict conformance to the specifications and high standards for the quality of IT equipment and how they are used; this is especially true for sensitive and classified information.

The modern infrastructure of C2 centres and HQs is comprised of a mixture of hardware devices, though an increasingly important element is the software designed for communication, display, storage of data,



management of information, etc. Regardless of their function, the hardware and software are interdependent and one cannot be considered separately from the other.

In addition to some of the technological aspects discussed above, this chapter will examine specific IT, as an element of Cyberspace, to guarantee connectivity. This IT capability is a critical requirement for all operations in which Space plays a major part to establish the end-to-end connectivity for modern military systems.

If information superiority is a prerequisite for superiority in leadership and for creating effects; what does this mean with respect to a SpOC?

The exchange of the space domain's DPS within the Alliance's C2 systems require continuously available, robust, interoperable and secure information and communication technology, which guarantees secured access and freedom of operation. The importance of operational IT/CIS networks within NATO in achieving mission success cannot be overstated.

In general, two aspects of DPS must be taken into consideration: first, as a matter of priority, DPS must be available and usable and secondly, these DPS must be reliable, especially for military matters. Uninterrupted availability of DPS is critical, particularly in times of crises. Planning should factor in the high demand for private-sector services which could result in competition between consumers even in times of crisis and conflict, not to mention the possibility of enemy influence on own LoC.

A significant factor for general technological aspects, the military is using mainly COTS products in the IT sector; design and development of exclusively military IT equipment is rare, and adaptations of COTS products for military products is the standard.[9]

The following three main items are characteristic of the IT realm:

First, IT equipment in a HQ/C2-Centre processes a large volume of data and information from different sources. Systems process information by examining it for relevance, which in turn must be presented in an integrated manner at an appropriate level to provide a complete situational overview within a very short timeframe. Speed, accuracy and reliability are foundational elements for the implementation of military effects. An indispensable prerequisite is a performance-based and resilient data transmission system or

integrated C2 system. In addition to speed, it is also necessary to take into account when planning the design of the HQ/C2-Centre the fact that rapid technological innovations will continue, so systems must be able to incorporate new technologies as they emerge.

Secondly, wireless data transfer carries specific risks. Consequently, wireless means of communication should not be too heavily depended upon and appropriate methods of preventing or minimizing adversaries' intrusions must be put in place. Recognizing that every network is vulnerable to a degree, there is always a chance for adversaries to disrupt NATO networks per se. In time-critical space applications, such as Shared Early Warning and Missile Defence, cyberattacks are unacceptable and establishing very high levels of security is essential. Besides an obvious attack on our own LoC, an unrecognized intrusion into networks reduces the reliability, integrity and authenticity of data, undermines trust in technical systems and most importantly, erodes confidence in human proficiency and military leadership.

Thirdly, massive adversary use of offensive measures within the Electro-Magnetic Spectrum (EMS) can have a major impact, especially on COTS products, particularly at the beginning of a conflict.[10]

This leads to the following questions and challenges with regard to IT standards of a Nat mil SpOC:

- Standardization of LoC between NATO and the nations needs to be managed more intensively;
- Implementation of homogeneous structures and equipment in NATO and national HQ/C2;
- Use of NATO secret systems in all relevant national HQ/C2;
- Need for secure gateways, national/NATO as well as unclassified/classified;
- Capable for Network Oriented Operations;
- Need for synchronisation across all domains (MDO/JADO Concepts);
- IT-based exchange of digital data via different media and integrated networks;
- Consistent establishment of a network to achieve information superiority;
- Redundancies in cases of outages, the operator has to return to service very quickly;
- Very high resilience with the capability for system take-over without delay;
- Protection against unnoticed intrusions into own networks with subsequent exploitation by adversaries (use of Intrusion, Prevention, and Detection Systems (IPS, IDS));
- Emergency operation capabilities and reset functions;
- Exploiting Advantages and resolving disadvantages of platform-centric vs. network-centric warfare and integration of respective technology;
- Smart command networks;
- Software-controlled equipment with easy up-date capability;
- Data transmission: assessment of cable versus wireless communication;
  - tap-proofed;
  - fail-safe;
  - stable signal flow;
  - needed bandwidth;
  - useable at any time;
  - quick maintenance and immediate repair;
  - redundancy;
- Encryption and anti-jamming capabilities on datalinks;
- A balancing act between IT processing and information security;
- 5-G technology; terminals upgradeable for future developments;
- Advantages and disadvantages in integration of COTS products;
- Use of commercial and/or dual-use capabilities;
- Support of Open Source in software development to achieve greater innovation and a larger selection of resources;
- Modern display technologies, e.g. three-dimensional displays;
- Implementation of Virtual Reality (VR) for talking, hearing, showing, grasping and using objects, as well as 3D simulations fostering moving dynamically in a virtual space;
- Modern conference connectivity (voice and video) with adequate bandwidth;
- Integration of multimedia.

Modern OCs with state-of-the-art technology are a prerequisite for a future vitreous battlefield and for taking the lead in information superiority, which must be accomplished early in any conflict in order to stay ahead of the opponent's decision cycle and battle rhythm. It is a priority not only for a SpOC, but in general it is the dominant challenge of the virtual battlefield.

The standardization of formats and procedures for the exchange of space-related DPS between nations and NATO, as well as between individual nations, is a significant challenge.

The Air Command and Control System (ACCS) is the first fully integrated C2 system in NATO, enabling planning, automatic tasking, battlespace management and task execution for all types of air operations.[11] Despite differing assessments of the ability of this established and implemented system, it would be worth considering whether it could provide the basis for at least space SSA integration. With all the experience gained with ACCS, a potential implementation could be faster, cheaper, and more effective than developing and integrating a new system. In addition, an extension beyond air operations could be considered and possibly even integration of other C2 systems to achieve initial multi-domain capabilities. However, this will require extensive research and studies. In any case, the need for full integration of space aspects into NATO operations could be a trigger for such comprehensive reflections.

Modern satellites process and relay enormous amounts of data. These functions require appropriate technology and/or organizational structures to be able to transmit raw data from the satellite via receiving stations to the respective evaluation cells, a process generally regulated by international standards. The section performing the evaluation for conformance to these standards would be fundament to and a fully integrated part of a SpOC; the complex processing and transmission of this type and scope of data for military operations must be ensured.

Automated merging of data of varying formats from different sensors (whether terrestrial or in orbit) in the Electromagnetic Spectrum (EMS) is essential. An equally important role, central to the node, is the evaluation, preparation and recommendation of courses of action with the help of defined assistance systems according to the respective authority. Defining the specific machine–human interfaces, as well as the point where the injection of decisions made by a human are decisive and are critical factors. In particular, time-critical decisions must be carefully evaluated and mapped out.

Research and development toward creating C2 systems capable of such integration will exploit the newest concepts and terms of IT, such as the implementation and use of Big Data and Advanced Analysis (BDAA), Machine Learning (ML), Artificial Intelligence (AI), and Augmented Reality (AR), which are all interrelated disciplines. The huge amount of data, in addition to other factors such as the degradation caused by space weather and electromagnetic interference require evaluation and adaptation in near real time in order to be able to react efficiently, effectively and quickly. In the military decision cycle process, systems employing ML or sophisticated AI support must prepare the digital or 'smooth' battlefield. AI will make access to and use of big and smart data extremely easy – it will prepare a decision-making process for military leaders and ideally, simplify the challenge of reaching a decision as well. This level of support is technically feasible today and will increase exponentially in the future. AI will optimize processes as well as structures, and is able to process data packages of enormous size from modern sensors while enabling structuring and evaluation of this data. AI-based sequencing will lead logically to more efficient information processing, better decision-making, and clearer guidance, as well as support for the military decision-maker, especially in time-critical situations. Adequate use of AI relieves military leaders and their staff from much of the time-intensive evaluation of enormous amounts of data, and allows them to focus on their most important task – assessment of the situation and the critical decision-making. Therefore, implementation of AI is necessary for a state-of-the-art OC; this will

raise the output of a CP enormously.[12] Particular attention should be paid in advance of defining the algorithms; all affected parties must be involved in this process and the final decision must be the responsibility of humans.

The use of AI will improve the autonomy of satellites, which will lessen the amount of contact required with ground-based stations, and additionally will result in much more capable and sensitive on-board sensors as well as the optimization of communications. Within a SpOC, the use of AI could improve the process of analysing orbital data with particular respect to CA and re-entry predictions. In this respect, AI will assist in processing the large quantity of data, the enormous amount of space debris and the dynamics of movement, especially in LEO in line with a high rate of approach. In particular, the risk of collision is not calculated in a standardized manner. There are no technical solutions that allows for a quick and uncomplicated mutual exchange for CA. This technology, based on automated communications and integrated automated machine decisions could automatically initiate change-manoeuvres between directly affected satellites in orbit, if the mechanisms are internally agreed upon in advance.

When considering IT and its use in modern militaries, elements of the cyberspace domain must be factored in, especially cyber-security. The rapid evolution in Cyberspace and its increasing application in warfare by potential adversaries led to the declaration by NATO at the Warsaw Summit of July 2016 stated that Cyberspace is a domain of operations.[13] Prior to this decision, NATO's Cooperative Cyber Defence Centre of Excellence (CCDCOE), established in 2008, had been very active in the assessment of cyber-security, conducting research, training and exercises as well as publishing insightful and thought-provoking information for NATO.[14]

In the design of a Nat mil SpOC, the cooperation between Space and Cyberspace must be ensured by offering a change to bridge an often-existing gap between these domains. Tactical cyber-forces must be implemented for just-in-time actions to ensure the security of our own operations. While NATO is focused on Defensive Cyber Operations (DCO), nations are pursuing their own Offensive Cyber Operations (OCO) capabilities.[15]

A state-of-the-art SpOC could also serve as a testbed for sophisticated technologies, for example, to physically integrate machines and people to enable faster and more efficient warfighting in the future. This degree of interoperability requires the integration of additional structure, development of new technologies, techniques, procedures, and tactics. This also calls for integration and connection to military, governmental and civilian research facilities and – of course – to industry.

5.5 Physical Aspects

Fundamental to the security against current and emerging threats is the requirement for hardening critical infrastructure. Hardening means more than simply placing resources in a bunker. It also includes assessing options for centralization of all parts or decentralization of specific parts, as well as employing deception; ultimately, it requires an assessment of all Force Protection (FP) measures.

It is necessary to decide whether a SpOC is to be established in an already existing OC infrastructure and connecting or integrating it into an existing organization, or to start a new SpOC. Intermediate solutions, such as starting with immediately available/existing infrastructure for an initialization phase and later relocating into a made-for-task, optimized for the mission facility. Resilience, alternate services and backup solutions (in total or part) must also be determined.

An additional factor is the requirement to be able to deploy into an AOO for Article V as well as Non-Article V operations with a complete or merely a partial deployment and to be able to modularize into, for example, a rear (home) and forward (AOO) element.

If there is a need for a mobile version, some additional factors must be accessed:

- Mobile C2-centre with mobility within a nation/NATO territory/worldwide;
- Ability to operate in different/all climate zones;
- Use of standard 20'/40' containers;
- Need for hardening mobile parts;
- COTS technology/need for special military development;
- Need for mobile parts for deployment inside AOO;
- Mobility by truck or train, embarkation via sea-lift or air-lift;
- Need for mobility on short notice;
- Need and reserves for evacuation;
- Need for protection against a Nuclear, Biological or Chemical (NBC) threat;
- Need for protection against electromagnetic pulse and electronic countermeasures;
- FP measures including access control and passive defence;
- Security and Classification requirements.

In addition to solely operational needs, administrative, logistic, support as well as morale and welfare aspects must be taken into account. These factors, however, may be dependent on collocation with other military agencies, whether in the same geographical area or even within the same installation.

Location of a SpOC itself and corresponding additional needed infrastructure for, e.g. communications antenna and sensors in a dedicated military facility should be the standard solution for military purposes. However, a collocation with other objects, e.g. other (civilian) space installations is possible. In all cases, the level of FP should be flexible in accordance with threat assessments and adapted to the security status.

5.6 Aspects of Personnel, Education, Training, Exercises and Evaluation

Integrating space-based DPS in NATO's planning and execution, mitigating vulnerabilities and enhancing the ability to operate in a degraded, disrupted and denied environment are keys to success in this area. Personnel requirements play a very critical role in all aspects.

The human factor is a broad subject for analysis that must be considered with particular care. Technology is indeed very complex and dynamic. However, human factors also represent a very challenging field of study. For example, the process of recruitment, teaching and educating staff and assigning the right person with the appropriate skills to his/her post in a complex structure is a demanding and ongoing cycle that must be carefully orchestrated and closely monitored.

In general, nations are responsible for recruiting, educating and training their military personnel, both individually and collectively, for them to perform effectively within their respective units or HQ. NATO expects to receive personnel fully qualified to perform their specific NATO job when an individual is assigned to a NCS/NFS position. In addition, NATO is responsible for additional E&T unique to a specific post.

A periodic exchange of personnel between NATO positions, but also among national armed forces, is a sound military principles for exchange of best practices that is often practiced. However, this exchange requires a permanent commitment to NATO E&T, including the provision of appropriate resources.

In addition, each national armed force has its own procedures, principles and cultural norms of behaviour. Therefore, not only is interoperability in systems and technology an important factor but also human interoperability is necessary to analyse. Mutual understanding requires more than language skills and comprehension of the technical operation of systems. Cultural interoperability is also a challenge for NATO integration.

A national SpOC must be equipped with an adequate number of appropriately trained staff, which must be provided in sufficient number and with the best possible qualifications. The following main elements must be accessed at the very least:

- If all tasks (in whole or in part) must be carried out at any time (24 / 7), a corresponding number of personnel required must be assigned to the organization. In

this case, the tasks that are not to be carried out continuously, such as administration or logistics, must be defined. However, areas such as ad-hoc maintenance or CIS provision must be assessed critically on the extent to which continuous service provision is required.

- Is it possible to use the respective national language as standard working language within the OC, or is it necessary to use English due to interaction with other nations / NATO and partners? A potential consequence could be the need for an automated translation tool for the national language.
- To what extent training can be accomplished nationally; are nations capable of providing training adequate for candidates to reach qualification and do they have the capacity to train the required number of personnel? Could courses be provided by other nations, and might a nation be interested in training people from other countries? Is it possible to achieve training requirements by purely military courses, or is it possible, even necessary, to use courses at civilian academies, universities (e.g. Space University) or private educational institutions? If so, specific administrative regulations for military personnel, including security aspects, as well as assumption of costs must be arranged. NATO currently offers merely a one-week Basic Course twice a year at NATO School in Oberammergau/GE.[16]
- Since the SpOC staffing is not exclusively military, but also includes experts from other sectors of the state, or from specific private sector institutions, the delineation of responsibilities and decision-making authorities must be defined, as well as all administrative, financial and legal regulations typical for an integrated civil/military organization.
- The degree of integration of a Nat mil SpOC into existing structures, such as for exchanges with NATO and other nations, raises the question of whether liaison personnel are necessary, both internally to the SpOC, from nations, as well deployed to NATO and partner nations. The addition of liaison staff will place increased demand on infrastructure, such as IT / CIS and connectivity via national networks.

Personnel across all national and NATO HQs as well as their military and / or civilian agencies and organizations require an adequate understanding of space-related challenges; this general knowledge must not be limited solely to the Space SME alone, but collectively shared among all staff members. A minimum level of knowledge is necessary in basic space operations as well as an understanding of how they impact specific aspects in their own functions. This includes, at a minimum, a general understanding of the contribution of space assets to the warfighter, as well as knowledge of the appropriate DPS, provided by nations and/or commercial providers and the ways and means to acquire them, all these factors require space E&T.

In addition to individual training, combined training must be addressed. As training and exercises contribute much to NATO's deterrence strength through practice and exploration, they are important for integrating space-specific challenges for the soldier. Exercises in space centric areas, but especially the integration of Space (and, therefore, a Nat mil SpOC) into all areas of warfare and, where required, in security and civilian activities is of immense importance. Furthermore, extensive participation in national exercises, bi- and multinational exercises (e.g. Schriever-Wargame, Kalkar-Sky) and NATO Exercises, (Ramstein Ambition and the TRIDENT Series) are invaluable. Preparation and execution of training and exercises also require a certain amount of personnel, typically in the J-7 staff structure. Depending on the conditions, this staff can be included in the organization of a SpOC, and tasked with adding actual operational aspects and challenges for exercise scenarios. The responsibility for ETEE as well as the professional development of non-space operators on the staff and in the forces in space-specific aspects can also be considered as an organizational responsibility of the SpOC.

In addition, should the ability to conduct experiments become necessary in order to help shape the future in the field of Concept Development and Experimentation (CD&E), this requirement must be depicted in the structure. It should be noted that for complex experiments, especially in the field of Space, an extensive environment is required, particularly from non-military organizations, so that their integration into a

SpOC can only be in a supporting role rather than as a leading functionary.

Training and exercises always require personnel to conduct and evaluate activities, and these activities should be a task for the personnel of a SpOC. In addition, to ensure the exercise meets the training objectives, there is always the benefit that the collective knowledge of all exercise participants is improved. This is true not only for the training audience, but also for members of the evaluation staff who observe and analyse the success of the exercise and receive valuable input to improve their own practices. This is especially true for participation in integrated exercises of the NCS and exercises with multinational partners.

The extent to which smaller agencies with space expertise can be integrated into a military organization, albeit on a lower tactical level, must be taken into account. These space advocates should be available for the commander and his staff for consultation and assistance in the entire decision-making process. Their inclusion must be factored into the requirements for the construction of a Nat mil SpOC. At the moment, the NCS provides SpSCE only at the operational and strategic levels.

If a SpOC is not collocated with other OC or entities, it will be unable to leverage its organizational support staff, so additional personnel will be required for specialist functions such as Admin, Logistics, IT, Communications, and others.

Finally, reserves and augmentation forces may be required and added to the number of personnel that must be educated and trained, in order to maintain their skills at a high level. This group must achieve a requisite level of readiness to be able to mobilize and take action in specific situations such as for exercises, wartime or to assist in situations like disaster management. These personnel could be reservists, civilians from industry, or even qualified student interns from university or academia.

On the NATO side, the adaptation of the NCS as well as the further staffing of the newly established Space Centre[17] also need additional educated, experienced and trained personnel. Therefore, national struggles for flexile personnel management have to include future NATO needs and demands.

5.7 Aspects of Governmental and Industrial Partners

A Nat mil SpOC is a highly dynamic organization. It is neither a small special staff of national subordinated forces, nor a coordination body for purely military matters, nor is it an element that functions for exclusively a single nation's own interests. Rather, the Nat mil SpOC executes broad functions for numerous agencies:

- Coordinates all space functional aspects for the entire national armed forces;
- Institutionalised exchange of DPS with NATO and partner nations;
- Interacts with other national governmental authorities, which are also involved in space-related matters (e.g. economy, transport, research, civil protection);
- Interacts with respective national and international non-military bodies, like NGOs;
- Administers with industrial partners regarding the procurement of equipment, support and maintenance;
- Cooperates with governmental and private educational institutes, academia and universities in the area of E&T;
- Integrates liaison personnel as well as the exchange of personnel with other national SpOCs and NATO.

These diverse functions impact numerous agencies and considering the extensive employment of the dual-uses of many space assets prompts the question as to whether the classic separation between civil and military in the space domain is still meaningful for the future. As a matter of preference, many different variations are possible in individual NATO member nations due to their unique, individual space activities.

When designing a national SpOC the degree to which it would be open to include actors other than the

military must be taken into account. Due to differences between military and civilian regulations, clarity of some requirements and regulations must be established in advance, particularly in matters to do with integration of the military and civilian partners of national space efforts, as well as the corresponding legal and financial requirements.

5.8 Security and Standardization Aspects

Just as the military is subject to myriad restrictions due to the very nature of its national security mandate, so too are space organizations for similar reasons; both areas place a great deal of emphasis on safety and security. For example, key to operating safely and securely includes maintaining well-structured classification regulations for infrastructure, access control, Computer and Information Systems (CIS), storage and dissemination of DPS, as well as employing certified personnel. Therefore, military space capabilities are normally highly classified and, consequently, a Nat mil SpOC must have a very high classification level as well.

In addition to the requirements for high levels of security and classification, certain data from space DPS are sensitive and, therefore, subject to national restrictions, such as being classified for national eyes only. Some DPS cannot be shared beyond a certain number of designated nations in the community; this could be arranged between nations through special mutual agreements. Today, space-based DPS are an integral part of our society and defence operations. However, that close arrangement was not always the case. Space capabilities were developed during the cold war and were limited to only a very few nations with the technology, resources and political will to develop them. In the early days, they were used mainly by the intelligence community and, therefore, were developed and used under a veil of secrecy. This control still has an effect today. Many space DPS are subject to national reservations, and so their use by third parties is the exception, not the rule, certainly not for a large international organization like NATO. It is, therefore, standard practice to negotiate bi- and multinational agreements between individual nations. For some exclusive areas and for specific situations, DPS of individual nations are shared with NATO, but again this is based on respective national contracts (Annex F).

In the mutual exchange or in the dissemination of data with NATO, a high degree of standardization is necessary, especially in technology, language and ETEE, but also in using the same taxonomy, templates, and colour codes. In addition, synchronization of battle-rhythms and timing, among many other functions, is required for effective and efficient collaboration. In space-related DPS, NATO is beginning the process toward synchronization. Until now, only some parties within this small community are involved, but to achieve an all-encompassing integration of Space into NATO, a much higher degree of standardization is needed. By whatever method, NATO and thus its member states must determine by consensus how much standardization they would like to establish in this domain. On the one hand, standardization simplifies the exchange, use, and joint actions, as well as provides for cutting investments. On the other hand, it undermines individual new applications and regulates the nations, so that a manifold and wide-ranging offer of different DSP may be not provided anymore.

5.9 Legal Aspects

In general, military activity must be executed in accordance with the international laws of war, the so-called Laws of Armed Conflict (LOAC) as well as national laws. Legal factors regarding operations in Space are mentioned at a basic level above. Therefore, it is imperative that operators within a Nat mil SpOC receive comprehensive training in current space law and the associated Rules of Engagement (RoEs). However, in a day-to-day operation, acute legal questions can surface on short notice and for these specific, time-critical situations; a requisite level of expertise in space law must be available. It is necessary to determine in advance whether legal decisions are required to be made on the spot or whether time will permit

legal expertise to be sought from other areas of the military or state organization, so that legal expertise need not be resident in the unit.

The exchange of DPS with NATO and other nations is based on contracts, which must be developed and agreed upon at the political level of the nations involved; contract negotiations are not part of the daily routine duties of a SpOC. Nevertheless, specific expertise in contract law must be made available at all times, due to the rapid operational tempo that can be experienced in a Nat mil SpOC. To remain up-to-date with the most current technology, quick methods for initiating immediate procurement are recommended e.g. for rapid prototyping in cooperation with industry. Furthermore, if the SpOC is responsible for research activities, or to carry out testing with the science and technology community, a prerequisite knowledge of contract law may be necessary. Normally these activities are not urgent and can be done outside of the SpOC organization, but at the very least, established and functional LoC between the Nat mil SpOC and the legal, R&D and procurement communities are highly recommended.

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CHAPTER 6

Activities of a National Military Space Operations Centre

Following the identification of the essential framework conditions of a Nat mil SpOC, this chapter now lays out the possible implementation.

A SpOC may be compared with an Air Operations Centre (AOC), a proven and established means within national as well as NATO's C2 structure, but focused on space-related challenges and tasks. In short, it is a single hub to fuse all elements of planning and executing space operations including intelligence info, force status, combat planning, execution and battle staff support.

6.1 Existing National SpOCs in NATO Nations

NATO is an Alliance of sovereign nations, almost all of them are conducting space-activities, but not all of them are engaged in military space-activities (Annex E); the boundaries between the two spheres are fluid.

However, even those nations which are active militarily in Space, do not necessarily have a specific SpOC for military space-related operations or parts thereof. The span of duties ranges from covering all elements, as is the case with the US Combined Space Operations Centre (CSpOC)[1], to segments, as with the German Air and Space Operations Centre[2] to more modest initiatives in establishing a small space organization, such as the Dutch efforts.[3]

Additionally, a SpOC may also be a part of a comprehensive and holistic approach to demonstrating national sovereignty. As a part of a nation's efforts to counter adversaries' attempts to negate military and economic advantages in Space through denial, disruption and degradation of their own space systems, a SpOC is a formidable political symbol of national activities and capabilities.

To acquire the current status of space activities among NATO member nations, the JAPCC promulgated a

questionnaire on space relevant topics to each nation. Unfortunately, not all nations responded with feedback to this questionnaire, so the overview assembled in Annex E is incomplete.[4] Where nations did not respond, information was collected from open sources.

Figure 14 depicts the role of a SpOC interconnected within the network of other entities, national as well as international, civil as well as military, governmental as well as private. Due to all these factors, a huge number of external lines of communication must be established and maintained.

6.2 State-of-the-art SpOC

Leadership superiority for western nations relies, among other things, on the use of space-based assets, and the provision and efficient use and management of services by a centralized OC.

Today's Space Support in Operations and tomorrow's OSS, as well as SDA and SDC[5] need to become more efficient, cost-effective, and resilient. Technologies that project satellites and space stations into Space, to assemble, supply, modernize and, finally, dispose of them, must be developed and made suitable for military operation. The use of the space domain is contingent upon very high-tech equipment fulfilling a wide range of requirements in extreme conditions. The military's share of obligations in addressing these challenges must be assessed nationally and mapped accordingly. This also includes a national decision-making element, whereby the question regarding the level of military participation in form of a SpOC must be answered.

As discussed a SpOC is a specific type of Command Post (CP); it serves as a focal point for cooperation and execution and is task-oriented as an organization where a commander, or advisor, and his/her staff, process information as well as DPS from space-based sensors to enhance SA

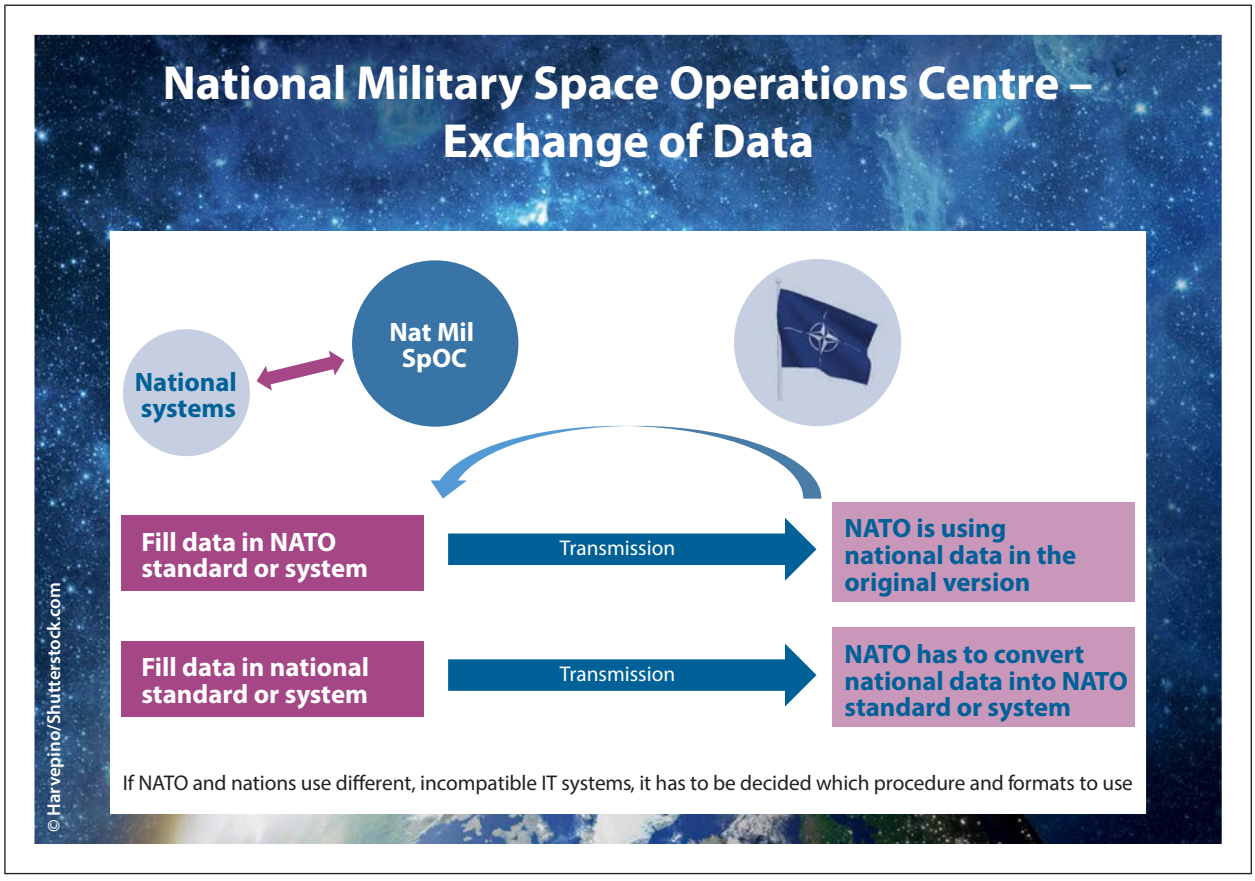


Figure 14: Exchange of data – the technological and procedural part.

and the decision-making process. Basic requirements such as organization, management, administration, support, and transport are not task-specific elements and, therefore, beyond the scope of this paper.

The general requirements of a SpOC elaborated upon in chapter 5, the structure of a SpOC capable of executing the entire range of tasks will be outlined. The limits to the nature and scope of a Nat mil SpOC is a decision for the respective nation to define the span of services the military should be responsible for in Space.

These first two specific tasks are not necessarily military components:

- Space Launch: In most NATO space-faring nations, the launch of a SLV as well as the suspension (deploying a satellite from the SLV) and first use of the satellite are not tasks performed by the military, rather of special governmental organizations or private companies. Due to complex procedures during the whole sequence from start until release of the payload, various steps may be allotted to different OC.
- Manoeuvring of satellites: The follow on control and steering of the satellite can be carried out by an external provider as well as by the military itself. In the latter case, a corresponding cell with personnel would then be required to perform direct control tasks of the satellite, as well as for managing the other critical infrastructure, e.g. data transmission capacity via antennas. In future, this may include maintenance and servicing satellites while in orbit as well as for controlling for de-orbiting or bringing the satellite to a graveyard-orbit at the end of usage; these tasks are primarily the responsibility of Mission Control.
- If a nation performs both activities by a combination of national and military agencies, it may be reasonable to integrate both organizations into this centre. Even if the governmental and military entities are responsible for single steps of the whole process, both organizations may be included in one centre to exploit synergies and prevent duplication of effort and infrastructure.

If a Nat mil SpOC is responsible for this activity, it implies the following tasks:

- Launch and integration;
- Coordination of own space systems;
- Steering of own space systems;
- Monitoring space services.

For purely military objectives the overarching tasks of a SpOC are briefly:

- Understanding the effects that adversaries' space actions have on own functions, systems and operational activities;
- Apprising commanders of existing or potential hostile actions or degradation of own systems;
- Proposing mitigation measures;
- Synchronizing the operational picture with required functions and communities;
- Receiving and processing incoming DPS (own as well as those of allies/partners) and adapting them to the operational environment;
- Disseminating products;
- Maintaining Space Situational Awareness (SSA), Space Domain Awareness (SDA);
- Managing Space Support Requests (SSR) to capability providers.

For most NATO nations, a single Nat mil SpOC must include the elements listed above and execute tasks from the strategic to the tactical levels.

In accordance with NATO's space functional areas (Figure 4, 5 and 10) respective organizational structures should include all capabilities and specific tasks. Therefore the LoC for cooperation and data exchange must be established. However, it bears repeating, the

ISR and SATCOM issues may already be included in established J2 and J6 LoC.

Due to the inherent limitations of each nation's own efforts, a great deal of international cooperation is both required and characteristic for space-related operations. At a minimum, cooperation must be coordinated within a SpOC with the ambition of achieving full integration in the future. This cooperation is required between international partners and organizations, as well as military and governmental entities. The integration of liaison officers with selected stakeholders to establish an official LoC between military and other essential partners is the subject of intense analysis.

Some nations' space-related activities and responsibilities are fragmented and assigned to different ministries, departments or organizations of the government. Due to the different products or applications of space-based services, as well as the development in recent decades, this is an understandable situation. However, close cooperation free from breakage between all involved organizations or parts of them should not be taken for granted, nor should they be based on informal agreements. In addition, the specific tasks regarding the protection and defence of the entire infrastructure (space-, ground-, user- and link segments) must be preassigned to each department. All involved parties must be interconnected and the role, the function and the responsibility for the military in the SpOC must be clearly identified in this relationship. Integration of liaison elements or even separate departments of selected ministries form part of this intergovernmental relationship.

The necessity for mutual integration aside, the benefit of a purely military organization has been reviewed. The military can be prone to fragmenting responsibilities between single organizations (e.g. as in developing and integrating new equipment). Centralization of efforts at the joint level (e.g. strategy, mission

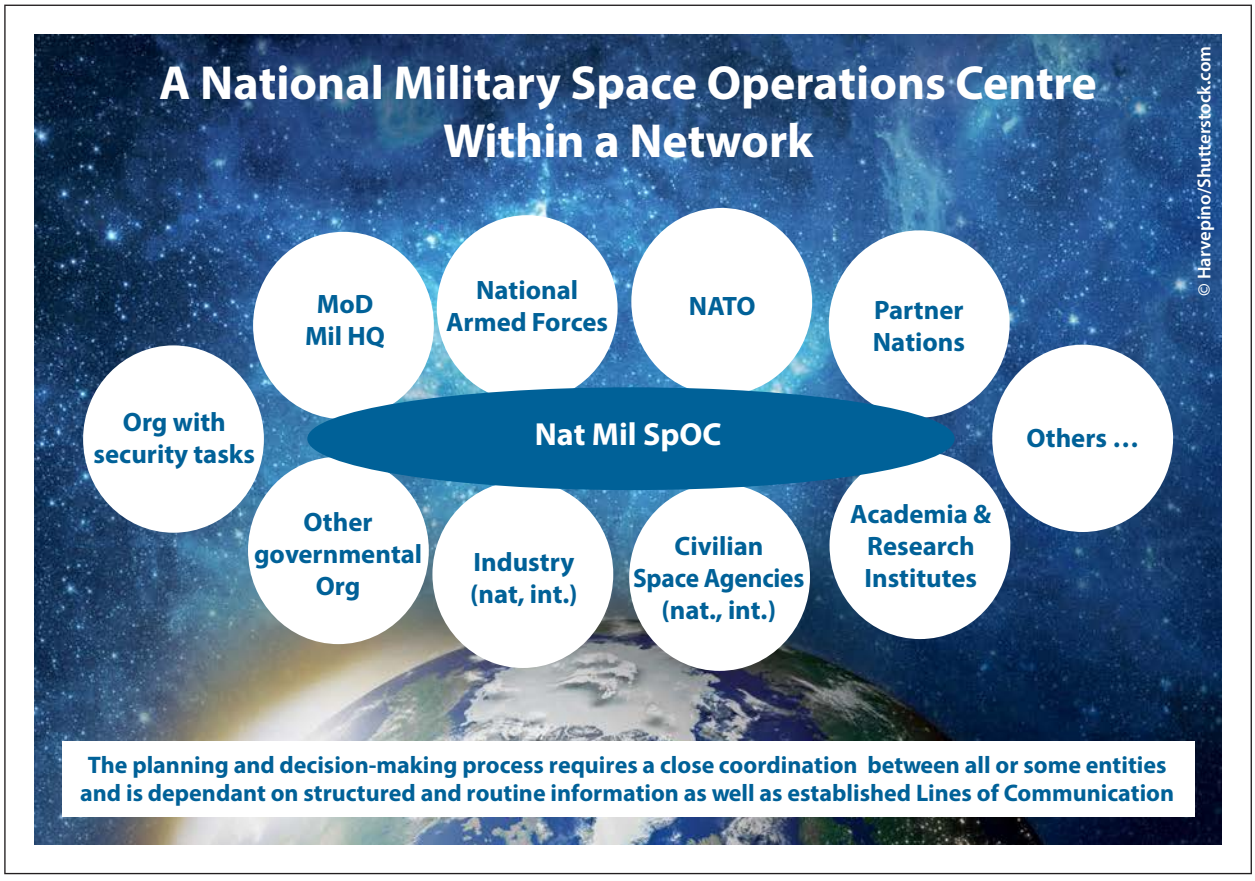


Figure 15: National Military Space Operations Centre within a network.

execution) is a common practice too, in order to make the most of limited resources. Unity of command and minimizing duplicity is not only a path to success, but it is also a more cost-effective way to operate. These considerations will influence the position of a SpOC within the national chain of command and, consequently, the corresponding levels of authority and accountability.

The minimum capability with regard to integration of the space domain into all other warfighting domains is SSA. Situational awareness is a prerequisite for everything – one cannot react to things that are not detected. Therefore, Situational awareness influences organization, battle rhythm as well as C2. SSA's first priority is sensing and presenting what is orbiting the earth (active satellites, space debris, and natural particles). A second aspect of SSA with no less importance is the characterization of the detected object–what is the intent? This assessment requires an INTEL cell capable of conducting an extensive analysis of adversary or enemy Space Order of Battle – this may also be necessary for neutral actors. The situation is very dynamic, therefore, the findings must be evaluated constantly and to assist in the prediction of future problem scenarios. Assessment of natural space threats are an additional part of SSA. For these reasons, SSA is a prerequisite for conducting effective C2, thereby enabling fielded forces to operate effectively in this and all other domains. This would also prevent opposing forces from operating against friendly assets. A much wider view of SSA leads to SDA, which covers all aspects of the domain, including threats and vulnerabilities.

With only rudimentary space laws that date back to the early days of space flight, there is a need for lawyers with expertise in Space to give advice to the commander in very specific situations.

Methods of producing and integration of DPS, as well as disseminating this data, are key functions of the structure. This raises the question of whether a Nat mil SpOC should have its own publications cell in order to perform layout and design for its internal products, as well as being able to distribute them in an organized fashion.

Militaries can be required to defend national critical infrastructure. Today's definitions see critical infrastructure encompassing a wide field of structures; it remains to be determined if and how space-based infrastructure should and could be defended. Space support in operations involving services from Space towards earth is of interest, so too are operations in Space. Protecting and defending space-based equipment is critical, especially with regard to technological feasibility and as it pertains to military escalation in Space, via militarization and weaponization of the physical domain.

6.3 Exchange of Data, Products and Services

NATO, with some minor exceptions, does not possess military forces of its own, and so it does not have its own space capabilities. Nations possess and contribute the required resources for nearly all NATO military activities. The NCS, as a standing organization, is financed by allies and manned by soldiers and civilians of all member nations. The NCS staff plans and executes NATO operations with forces assigned temporarily under the command of NATO HQs and their commanders. Consequently, no national space assets, nor parts thereof will be under the operational control of NATO, merely DPS, which is provided by space-based satellites and processed by Nat mil SpOCs may be available to NATO. The provision of these DPS require preset bi- or multinational agreements on all particular details of the exchange.

Within the NCS for 2020, only a very limited number of space experts are the recipients of these DPS. INTEL and SATCOM services and products are passed in special LoC via J2 and J6.

As part of the NCS, specialized SpSCE are embedded with a small number of experienced space personnel. Since the latest NCS adaptation, these positions are established at HQ ACT, SHAPE, JFC NP, JFC BS, AIRCOM, MARCOM, LANDCOM and the DACCC. As part of the evolution of Space as an operational domain, the terminology, meaning and content of the Space Support Coordination (SSC) functionality will change to Space Domain Coordination (SDC) and the number of SMEs will be reviewed and probably increased to ensure the required number of positions to execute the missions are established.

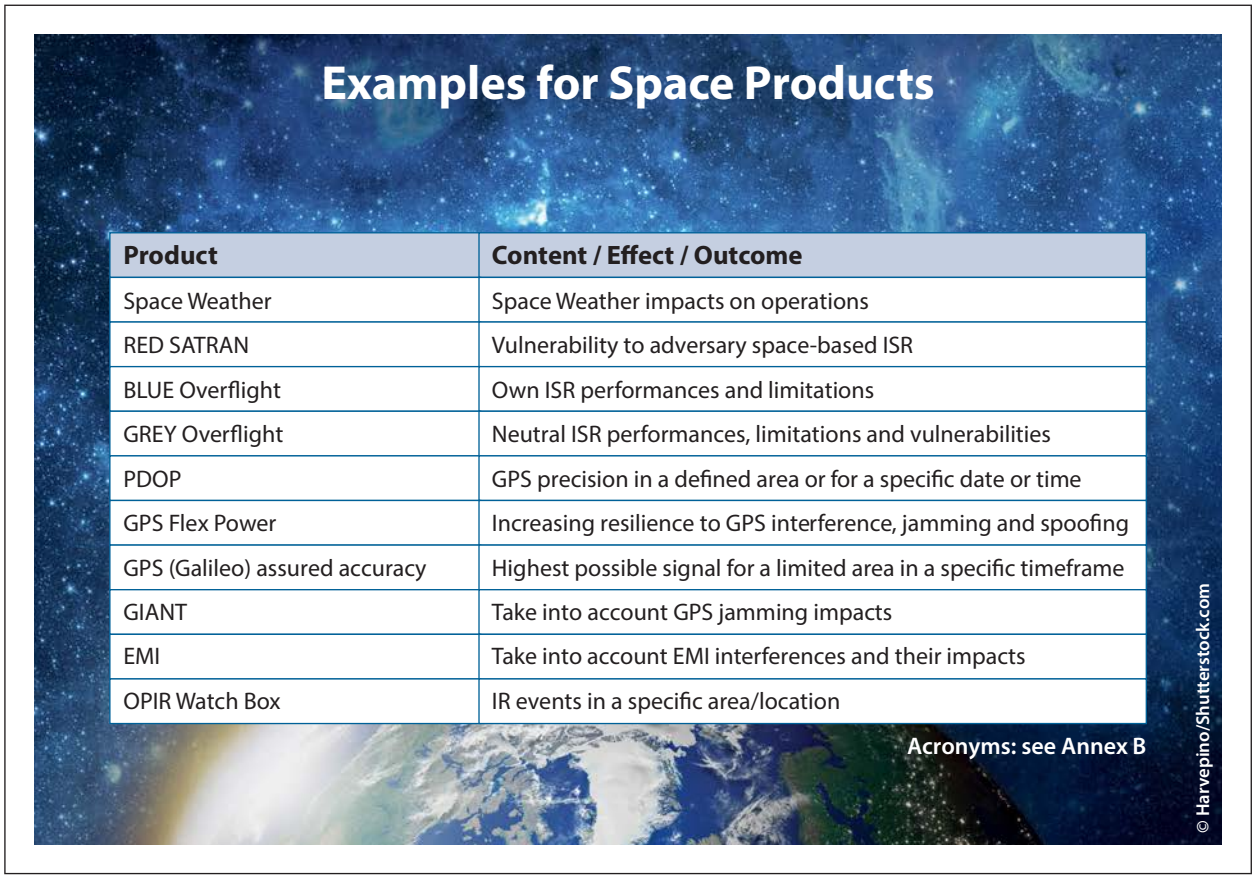
The responsibilities of SpSCE at the strategic and operational levels are laid out in detail in AJP 3.3[6] and can be described as adding the space domain perspective to existing functional areas in all other domains. At the moment this document is the principle NATO publication for the integration of space activities into operations and for setting the standards for the exchange of DPS, as laid out in figure 11. However, this diagram depicts the process in a very abstract way and at a high level. All the detailed work behind it is remains to be specified and a more comprehensive space doctrine has yet to be developed.

Specifications for the formats of DPS do not yet exist. Each nation delivering its contribution to NATO accomplishes it according to their national procedures. Therefore, these products are often not comparable to each other, so NATO operators must work with different formats, possibly including varying focus points, scales, or codes that may lead to greater time required for evaluation. Eventually, these different protocols may lead to a failure to meet NATO requirements for collaboration and integration.

Although the respective agreements are in place, there is no guarantee that nations will conform to the standards of exchange necessary to accomplish the delivery of information. National requirements may have a higher priority, and in some cases, create potentially negative impacts on NATO.

Standardization could be reached in the form of an SSR. This specialized form is a type of RFI, that if widely adopted, could serve as a method to identify required protocols for specific requirements for the exchange of data. However, this format is not yet published in NATO doctrine AJP 3.3 and is distributed solely in space-specific LoCs.

Further to the evolution of Space as an operational domain, a new phase of implementation within the NCS has recently begun. The structures, personnel



Product	Content / Effect / Outcome
Space Weather	Space Weather impacts on operations
RED SATRAN	Vulnerability to adversary space-based ISR
BLUE Overflight	Own ISR performances and limitations
GREY Overflight	Neutral ISR performances, limitations and vulnerabilities
PDOP	GPS precision in a defined area or for a specific date or time
GPS Flex Power	Increasing resilience to GPS interference, jamming and spoofing
GPS (Galileo) assured accuracy	Highest possible signal for a limited area in a specific timeframe
GIANT	Take into account GPS jamming impacts
EMI	Take into account EMI interferences and their impacts
OPIR Watch Box	IR events in a specific area/location

Figure 16: Examples for Space Products.

requirements as well as project timelines following NATO's recognition of Space as an operational domain have just started. In support of this development, JAPCC published a paper on possible NATO space structures, means, procedures, and arrangements.[7]

In general, the regulations on how NATO receives DPS from the Alliance's member nations could be managed in two different ways. One possibility could be the definition of official minimum requirements by NATO itself; using this method, all nations must agree, or at least not disagree. This approach may result in a consensus on a very low level due to individual nations' high priority of space-related assets as national key assets. Therefore, the overall output may not be sufficient for all NATO needs. The alternative would be to arrange a contract with each nation individually to contribute on a voluntary basis. In this way, NATO may be able to gain more benefits in each area of space services, because of the high capability and capacity of the willing nations. However, there could be a risk of no nation wanting to support any particular area.

6.4 International SpOC and Cooperation

In addition to a purely national organization, bi- or multinational centres could be a solution to fulfil requirements in this domain. This is already practiced in other areas of the military with some success.

On the international side, besides NATO, the EU intensified their space efforts and in the 2019 Commission, created a new Director General Defence and Space within the European Commission for Internal Market and Services, led by a French commissioner.[8] However, this is a political forum, a high-level organization to foster developing technology jointly among the EU member nations, and does not aim to staff its own space assets.

European members of the Alliance must bundle their forces, relieve the US of some of its overall commitments and act more independently, and the emerging domain of Space may be a perfect area for doing so. This requirement is especially true if the political postulation that European allies will have to do much more for their own security and defence is to be realized. If Europe is achieving to retain a broad vision in the long term, closer cooperation in military space aspects are appropriate, not only to deal with purely military issues, but also to be able to contribute meaningfully on the geopolitical stage.

Unless nations agree on full integration within in a common SpOC that works on all their respective national military space aspects, only partial integration or some forms of cooperation in individual areas is achievable.

SSA is one of these areas where some European nations work together to create a multinational catalogue of space objects based on data from their own sensors. Five NATO member nations (FR, GE, IT, SP, and the UK) established the European Space Surveillance and Tracking Network (EU SST), which is open for new members to join. Although this initiative is mainly a civilian programme, the military is involved and benefits from having access to a more detailed picture on space objects.[9] However, a direct and official partnership between NATO and EUSST to share or cooperate does not yet exist. Since all five nations involved are members of both organizations, there is thus an indirect benefit for NATO.

Although this is a very specific activity involving only a few European space-faring nations, this may be an entry-point for other nations as well as a mechanism for cooperation between military and civilian partners. NATO should also monitor the ongoing developments of this network.

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CHAPTER 7

Future Development and Vision

Looking from today's perspective into the future, there are a number of possibilities for new capabilities in Space, each with varying probabilities; all are subject to a degree of uncertainty.

As space technology progresses, the military will be one of the main benefactors. In particular, the four areas of digitization, automation, robotics and miniaturization will influence the military in general, and Space more specifically. From a military point of view, NATO's Strategic Foresight Analysis[1] and Framework for Future Alliance Operations[2] provide a very good starting point for the vision of the future, which will be marked by significant social, economic and environmental changes, occurring within increasingly shorter time periods.

Within this complex scenario, the nature of modern warfare will change rapidly and dramatically. NATO has clearly recognized this change as the NATO Defence Minister defined in October 2019 seven S&T areas as strategic disrupters over the next 20 years:[3]

1. Data
2. Artificial Intelligence
3. Autonomy
4. Space
5. Hypersonics
6. Quantum
7. Biotechnology
8. Materials (added later)

Consequently, Space has a prominent role within NATO's effort in S&T and, vice versa, other technological areas have an enormous impact on space capabilities; some aspects of future EDT with special regard to space-related topics may be discussed here.

Long development and procurement cycles are, in general, typical for military equipment. However, this does not apply to the cyberspace domain, nor for the most part, to the space domain, due to the dual-use capability of many systems. Products of the New Space era are evolving rapidly based on short-term solutions and modern planning and implementation cycles. The military will benefit from these advances. Therefore, especially the procurement process must be adapted to a shorter timetable, something already being successfully practiced in the cyberspace domain.

In the past, satellites were tailored to one specific mission; today and into the future, the satellite will be designed as a platform with parallel equipment or software applications capable of serving different missions. Additional satellites with specific capabilities will be available on demand and could be launched within a short period of time, due to the involvement of more private launch companies and additional launch sites.

Space systems will be made more and more autonomous, communicating between each other and with ground stations.

Today satellites in the GEO belt are mainly used for communications. Actual research and trends for the near future will see communication satellites stationed in MEO and LEO, as well as part of large constellations or swarms of small satellites, e.g. Starlink.[4] They will provide a higher capacity of dataflow, a kind of virtual fibre[5] in Space, from almost anywhere worldwide and with fewer limitations than today. In addition, optical LoC will be available and serviceable in the near future. This may create new opportunities such as Link 16 from Space.

Weaponising Space is an upcoming and controversial discussion, resulting from actual developments in Space, like national space forces and the declaration of Space as a domain. Although these were discussed in the past, like the flightpath of surface-to-surface missiles through Space and military ISR Sat, the use of Space today has dramatically changed the strategic environment and Space will soon become a battlefield of its own. However, the recognition of Space as an operational domain does not mean NATO is starting to weaponize Space; rather, it recognizes the significance of Space for NATO to today's mission.

NATO's area of operations is changing. Out-of-Area Operations (Non-Article V) have specific requirements with respect to space support. The re-establishment of Collective Defence tasks (Article V) requires additional and varied solutions. For future scenarios, additional investments in space capabilities must be considered.

Melting of the arctic ice as a consequence of climate change and the use of that region for shipping and mining will increase the economic activities and may result in this area becoming a territory of competition and, therefore, of increasing strategic importance. These northern latitudes have already seen an increase in Russian activity and influence and, for that reason, have become a region of rising interest for NATO, at least with regard to improving situational awareness.

These efforts may require changes in specific space capabilities, for example, with respect to orbits. Normal LEO are not optimal for extreme northern lines of latitude; additional resources would be needed for full coverage. Furthermore, the polar region is an area that also poses a number of challenges to SATCOM in particular. Today, SATCOM satellites are located in GEO above the equator and from high latitudes are only visible at low angles, which could cause some limitations. Optimal use of space services in this realm needs new solutions, either via advances in technology or in leveraging or changing other satellite constellations. New developments can be observed in the business models of New Space, like the megaconstellations of a new generation of standardized small satellites in low orbits covering the whole world, including the polar regions.

Due to a rapidly increasing number of mega-cities worldwide, Urban Operations will very likely form part of Article V as well as in Non-Article V operations. A high degree of space support for these very specific and highly dynamic operations will be necessary along with the appropriate applications, especially PNT, SatCom or ISR.

LEO is the most extensively used orbit for the majority of all applications. Furthermore, this area is also highly polluted with space debris, and the resulting congestion means that the probability of it accommodating additional use is unlikely. Without the LEO as an option for further deployment, other orbits must be used for capabilities that normally would not use these orbits. In addition, the realization of highly specific activity, like the re-entry of re-usable rockets, lunar orbits, mars expedition, and star-ships as platforms for outer-space exploration, in the not too distance future, must all be considered in long term military planning today.

Stratospheric platforms can also host some of the applications that have been previously on-board LEO satellites. Therefore, the gap that exists today in the area above the flight ceiling of an aircraft and below the minimum orbit of a satellite must be included in planning considerations (Near Space Operations).

On-orbit servicing (OOS) – characterized as maintenance performed on the system while in orbit – is generally very reliable and may extend the limited lifespan of satellites. Apart from repairing damage (for example from collision with smaller space debris or from radiation) and providing additional fuel to what is generally a limited reservoir, components can be replaced by integrating more powerful and modern modules to improve performance and extend the lifespan. The funds invested to increase utility and lengthen the term of deployment is a cost-effective alternative to exchanging the system completely. When considering C2 of operations in Space, SA of OOS activity will be of fundamental importance for a SpOC. Given a situation of two converging satellites, on the one hand, an approach of one satellite towards another could simply be an OOS operation (service, inspection or maintenance). On the other hand, it could be a threat, such as an accidental collision, or a hostile act to destroy, exploit, jam, monitor or hijack the satellite. Thus, SSA is of enormous importance for analysing situations such as this one and the exchange of information and data among all satellite-operating nations and organizations is one of the critical functions of a SpOC in the exchange of DPS.

Today, in the field of SSA/SDA, especially for CA, there are no regulations dictating the proper procedures for managing converging satellites and avoiding collisions. The evasion scheme is clear when it comes to dealing with an active satellite encountering space debris; nevertheless, there are no rules in place for CA of two active satellites. Therefore, both responsible parties must coordinate how to prevent collision. However, this presupposes that lines of communication and some rules of engagement can be established between those two parties and these exchanges are not usually regulated or institutionalized. Capabilities will progress rapidly from the current state of affairs where the methods for calculating collision risks are not standardised, to a future when decisions are made automatically based on machine learning, and executed within the satellites themselves. In the near future, within some mega-constellations of small satellites in LEO, manual processing will no longer be possible.[6]

Advances in technology will continually affect the organization and structure of Nat mil SpOCs. This advancement must be factored into the design of an OC to ensure it is easily adaptable and always at the forefront of technological progress.

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CHAPTER 8

Conclusion and Outlook

Is NATO prepared to respond to an aggressor that denies the Alliance and member states access to Space or even physically strikes segments or the entire system? Does an actual contingency plan exist for such a situation? Are sufficient scenarios prepared and realistic exercises conducted at all appropriate levels? Are the lessons learned from the lessons correctly identified, and are they transformed into something tangible? Are there current and realistic RoEs for space-specific challenges?

Looking at these few selected questions with respect to Space there is 'a need for speed,' mainly for three reasons: firstly, the speed of objects in Space (approx. 16,000 km/h of LEO objects) and the associated consequences such as short fly-over times and fast revisit-times as well as the transmission of data at the speed of light. Secondly, the high rate of new technological developments in this field with short innovation cycles and lengthening life spans. Third, decisions must be made rapidly, due to a growing number of threats, from the resurrection of known adversaries to the appearance of new competitors. All of these demands for rapid action require appropriate organizational and mental adaptation to this rapid pace and is the central challenge of today. The recognition of Space as an operational domain was only a starting point for NATO and especially member nations. The amount of work required to adapt procedures, develop personnel with expertise, and establish technological prerequisites is a wake-up call for taking an active role in thinking about and shaping this domain.

All these aspects clearly highlight the need for a Nat mil SpOC!

On the other hand, NATO owns no space assets, as has been mentioned several times in this paper. Additionally, NATO does not conduct space operations, in terms of flying or tasking satellites. Therefore, to the untrained eye, the requirement for a NATO SpOC is not readily apparent. Much of the planning and management of space-based activities fall directly within the responsibility of functioning staffs. The J2, for example, addresses ISR issues including space–based ISR and the J6 deals with communication systems, including SATCOM. In addition, Shared Early Warning is part of Integrated Air and Missile Defence, a subject area assigned to J3 and/or J5. Only space weather remains an unassigned area which is under discussion; some experts consider space weather as one part of the meteorological discipline; others as part of the space area. At present, space weather is a responsibility assigned to the METOC community. However, the functional area in which it will be based more permanently is a subject for discussion within an ad hoc NATO Space Weather Working Group. Ultimately, only SSA and PNT are the responsibility of the Space SME. However, this assignment may also be subject to change due to the establishment of Space Domain Awareness (SDA) as a common understanding of the space domain.[1]

Space-related issues must be included in NATO's operational planning cycle – at least the use of DPS provided by the allies, as well as the processes of exchange have to be part of NATO's efforts in ETEE.

Working together with partners in one area also helps to strengthen cooperation in other areas. This robust cooperation is a cornerstone of NATO's foundation. Integration, Interoperability, Jointness, Coordination and Unity of Command are the most important aspects of this partnership and, therefore, are guiding principles for an effective solution to achieve objectives in the space domain. Strengthening NATO's deterrence via Space requires access to the most advanced space capabilities, technology and applications. NATO's strength also depends upon full integration into NATO C3, the availability of a common NATO space domain situational awareness capability and miscellaneous capabilities for operations are all sustained by comprehensive training. Additionally, counter-space facilities and activities to deny adversaries space capabilities form part of the whole network and must be considered in the near future to be included in all respective regulations.

Consequently, the spider in the tactical and operational net is an OC. This whitepaper adopts the general term SpOC for an entity responsible for the execution of space-specific national tasks. A further integration of conceptual and doctrinal tasks may be a subject for future discussions.

This kind of a SpOC is not a requirement for NATO today. NATO is already receiving DPS, coordinating and integrating these into their efforts without a dedicated SpOC. Therefore, some kind of Space Coordination Element or Space Cell is required at a focal point within the NCS; the term NATO SpOC would be misleading. NATO decided to name its focal hub as the Space Centre[2], collocated with AIRCOM at Ramstein/GE and this term seems to be appropriate without being fixed to specific tasks by including all and excluding nothing.

A Nat mil SpOC must be very flexible with respect to its organizational structure, disposition and expertise of its personnel, how it is equipped, and especially with regard to its operating procedures. The requirement for this broad degree of flexibility is due to the constant rate of change from rising numbers of actors and satellites in Space, the increase in the crowding of orbits, more competition for frequencies, and greater amounts of space debris, as well as a broader military use of Space by more competitors. Tracking satellites, discriminating threats from non-threats, predicting close approaches of satellites, and preventing collisions are all growing challenges and the associated data related to these activities is of great value for NATO.

A vision for the next ten years and beyond will provide insight into other challenges anticipated for the military, such as creating a Common Space Picture and executing Space Traffic Management. The civilian

environment also faces enormously ambitious and complex endeavours regarding Moon Orbits, Moon Bases, On-Orbit Services, Asteroid-mining, and Space Stations beyond GEO, which will have significant impacts on international security. These future and maybe even futuristic aspects should be taken into account for today's structure and potential future incorporation. Aside from the technological factors that will influence R&D of these projects, changes in political agendas, demographics and climatic may also play a significant part and, therefore, influence permanently the structure and organization of a Nat mil SpOC.

In recent years, the main obstacles to achieving better and closer cooperation within NATO and among its members could be attributed to legal constraints, political factors, organizational and technological issues, as well as financial and even cultural considerations. However, the nature and degree of influence of these characteristics vary according to the countries involved.

Due to rapid advancements in space technology, the changes in the global security situation and the corresponding impacts on the Alliance, the value of space assets for international security and hence, the military must not be underestimated. Participating in military Space and being an active partner inside NATO, including in the space domain, will strengthen the efforts of the Alliance in deterrence and defence of the Euro-Atlantic area.

A one-size-fits-all solution for a Nat mil SpOC does not exist because national conditions are too different. Therefore, relationships and LoCs, both internal and external to each nation, must be analysed comprehensively.

The findings in this study underline the need for Nat mil SpOCs with a flexible architecture to accommodate future developments, which will be very dynamic, not only due to new discoveries in Space, but also the supporting technological fields such as computers, cyberspace, artificial intelligence and communications. Changes should also be expected regarding law and, of course, in the geopolitical landscape which will influence willingness to achieve higher levels of international cooperation and integration.

Installation of a Nat mil SpOC now would be a well-timed decision and in lock step with the establishment of the appropriate space structures within NATO. Mutual consultation, sharing of experiences among established space-faring nations, integration of new nations, and pursuing common solutions for NATO in a complex domain can lead to significant developments and progress for the benefit of NATO and member nations. National contributions to NATO, such as capabilities, personnel and DPS, will merge in NATO's newly established space structures and achieve a higher degree of synergy and interoperability. Ultimately, this collaboration will raise the participants' collective knowledge and understanding of the domain and increase their ability to generate effects.

Other than a purely national SpOC, a bi-, multinational, or a European cooperation model, like the previously discussed EU SST[3] could provide another option. Whether a common military OC of European members of the Alliance or some other similar combination is developed, either would still bring many benefits. This European approach offers a number of advantages on the military as well as the political side. Finally, it could be a kind of entry point for space newcomers. Whatever the final solution, overall, it would reduce the dependency on the US and strengthen, not only European space activities and respective industries, but could also lead to further European integration.

Besides the clear benefit to national militaries for establishing a Nat mil SpOC, this OC would be advantageous through enhancing the nations' overall capability to operate in Space, strengthening NATO's cohesion and ability to deter aggression, and foster further cooperation of European and North-American nations with worldwide partners in the space domain.

1. BiSCSWG, NATO's Approach to Space, 2-Page Flyer.
2. NATO Allied Air Command (2020) NATO agrees new Space Centre at Allied Air Command., available from: https://ac.nato.int/archive/2020/NATO_Space_Centre_at_AIRCOM [accessed 17 November 2020].
3. see Chapter 6.4.

ANNEX A

Main Outcome and Recommendations

A national military Space Operation Centre (Nat mil SpOC) will first and foremost serve its own national requirements, but also support NATO's needs for some specific aspects which should be taken into consideration. This will enable the Alliance to safeguard the exchange process within both the nations and the whole of NATO to guarantee freedom and security of its members through political and military means. In this vein, the main objective of NATO is to ensure space data, products and services (DPS) are available if and when they are needed.

The recommendations within this annex are based on three major principles:

1. NATO does not have its own space capabilities, nor does it operate satellites; additionally, NATO is not planning to develop its own space capabilities in the future.

2. Alliance Nations are the owners of the space capabilities and retain sovereignty over those capabilities.

3. Alliance Nations are the main providers of space-related DPS, with commercial entities serving as additional providers for NATO's needs.

In the following pages, the respective recommendations are listed structured in different capabilities.

Capabilities are defined in NATO as a complex combination of Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities, and Interoperability (DOTMLPF-I), which provides the framework for a holistic approach. Requirements for exchange mechanisms, as well as specifications for DPS from single NATO member nations to NATO or between member nations require certain specifics in all eight elements of the DOTMLPF-I model and may help with the identification of the required actions.

Doctrine

NATO and its member nations should use the current momentum of interest and the absence of a major crisis in Space to start or strengthen their activities in pursuing doctrinal concept work. No external stress or urgency is currently influencing this work, but this does not mean there is no requirement to do so.

- A military theory of space power, like classical Air power theory, as the basic principle for all domain military activities is indispensable.
- Political and military leaders need a better understanding of the uniqueness of operating in the space domain. A high-level body at NATO HQ is needed to coordinate all ongoing activities for a coherent NATO implementation, especially the evaluation of political implications of a military confrontation in Space.
- NATO needs to define what exactly space-based capabilities can contribute to NATO's missions.
- Space-related aspects have to be included in respective NATO documents, starting at the political level (Strategic Concept), doctrinal work (Allied Joint Publications), down to the operational (Operations Plan, Standing Operating Procedures), and tactical levels.
- Establish a NATO forum for consultations between allies on space-related issues regarding overall concepts.
- Develop a NATO Space Concept of Operations (CONOPS).
- Sufficient elements of doctrine have to be published and discussed in public to avoid confusion and rampant speculation concerning NATO's intent.
- Develop standardized definitions (Space Lexicon) for the clarification and specification of generally accepted technical and common operational space language.
- Agreements for exchange mechanisms of space derived DPS are in-place, however, information sharing is filtered through restrictions and national caveats. Reconsider, review and, if possible, reduce national

security classification guidelines and political restrictions for space derived DPS to allow increased and improved sharing within the alliance.
- The current Alliance doctrinal body does not present a comprehensive and fully joint approach. It is only AJP 3.3. (B) 'Air and Space Operations' which includes Space, however with a close connection to the Air related aspects. This does not cover all aspects of Land and Maritime operations. The publication of a space focused Allied Joint Publication will better define the considerations and approach of operations in and through this newest operational domain.
- NATO and its member nations have to examine whether the current sharing agreements are sufficient for all current requirements or if additional formal agreements are necessary.
- Practical solutions have to be discussed, developed, and implemented to guarantee data exchange keeps pace with the requirements. NATO should foster the discussion for harmonization by setting a framework and looking for flexible ways of achieving and maintaining agreements.
- A first consensus may be found in an agreement for exchanging some Meta-Data for SSA in an open architecture, which will allow NATO to interpret the data. This will demonstrate good will from the allies as well as internal cohesion of the Alliance.
- NATO needs to produce an operational overview of requested space derived DPS from across all space capability areas. A recommended approach would be either top-down (NATO guidance to nations) or bottom-up (national standards accepted by NATO).
- A list of space-based capabilities which the nations voluntarily share with the Alliance should be developed, focusing on the shared DPS provided to NATO.
- NATO has to increase resilience by looking for alternatives and reserves to the space derived DPS it receives from across the Alliance.
- C2 technology and architecture efforts are often pursued independently within the nations. More effort is necessary to create an effective joint and coalition interconnected C2 structure. Therefore, NATO must develop technologies, strategies, and procedures to connect the numerous C2 systems utilized by the Alliance.
- Other legal frameworks, particularly regarding Space Traffic Management (STM), rules of engagement, and private engagement have to be further developed in close cooperation with the UN.
- Nations should consider all pertinent NATO documents when establishing a national SpOC to enable free exchange of space derived DPS across the Alliance.

Organization

Organization refers to the area of governmental and military bureaucracy, which is widely known as very static and inflexible. In particular, bi-, multi- or international organizations, like NATO can include barriers to information exchange. The barriers can take the form of differing military and economic priorities, legal rules, administrative regulations, workflow processes, and political willingness.

- The organization must be adequate in response to the demand for rapid exchange and ensure, as far as possible, real-time decisions. Additionally, 'Unity of Command' is a major prerequisite for all military planning and execution of operations and other activities within national armed forces as well as in NATO.
- This requires, on the national side, a concentration of all space-related efforts to be represented in one single service, not spread across various services. This might include partners outside the military, like governmental and commercial entities.
- The organization must be adaptable and open-minded in order to be able to react flexibly to ongoing slight or dramatic changes, like technological trends or innovations, and hence ultimately prove future viability.
- Establish a unique Space Task Group at NATO HQ Level, separate and distinct from the current BiSC-SWG, to concentrate on political-strategic work and to show the importance of the new domain within NATO.
- Analyse and establish all lines of communication from Nat mil SpOC to Space Cells and/or Space Coordination Elements within national forces.

- Establish direct lines of communication from Nat mil SpOC to the new NATO Space Centre at Ramstein AB, Germany, to guarantee a holistic approach to NATO operations and analyse the need for a specific additional requirements to other NATO entities.
- Need for integration of space derived DPS in planning and execution cycles, as appropriate, along pre-defined lines of communication.

Training

Space is integrated into some national and NATO ETEE in a limited manner, however national courses are mainly for their own personnel, and are not generally open for the Alliances' personnel. A more inclusive approach between space-faring nations to provide training across the Alliance is an urgent requirement.

- There is currently no need for NATO space-specific exercises because NATO does not operate any space-based assets and therefore does not execute space operations. For the time being, the focus should be on the broader integration of space derived DPS and promoting understanding of the processes that enable those exchanges in existing NATO exercises.[1]
- More integration of space-based capabilities into national exercises, as appropriate at various (all) levels, as well as in bi- and multinational exercises.
- Use of various exercises within NATO to integrate space aspects; joint exercises as well as domain-specific exercises.Participation of NATO elements in the Schriever-Wargame Series for observing compatible procedures related to the planning and conduct of national military space operations.
- Specific E&T lectures have to be included in courses, workshops, and seminars for those entities which need to integrate space-related DPS into their daily work to ensure a broader distribution of space-related knowledge.
- All applicable E&T should consider the appropriate space aspects into account and focus on those aspects which will affect the warfighter.
- A basic level of space knowledge has to be embedded in all staff functions, just as Space SMEs have to consider other staff functions in their planning. This requires a cross-functional E&T approach within NATO staff organizations.
- NSO offers one space basic course, with a second about to be introduced. NATO needs to define the requirements for additional courses, as appropriate, whether generic or courses in specific functional areas, in-line with the potential growing number of Space SMEs in the NCS. These requirements could be aligned with national requirements as well as national capabilities open to NATO personnel and may even include the potential need for additional education facilities.
- Full implementation of Space into the lessons learned process (LI, LL, best practises) and establishing links to Joint Analysis and Lessons Learned Centre (JALLC) and national war centres.
- Develop an exchange of designated SpOC personnel for inaugural training at other established Alliance SpOCs.
- Establish relationships with scientific organizations and universities to stay current with regards to ongoing technological developments.
- Outside of the specific scope of this paper are two basic recommendations:
  - Language is the most obvious barrier to common working and exchange practices; this also includes military traditions, different acronyms, and technical vocabulary. This raises the need for a broader education plan, esp. in language skills along with common training, personnel exchange and combined exercises.
  - A basic digital capability will be more and more important to establish or expand the needed digital mind-set.

Materiel

The majority of military equipment procured today is based on modern technology, to achieve greater and decisive effects of all forces across the full range of military activity, ultimately to maintain superiority in any confrontation. Constant progress in these highly technical fields is one of the main drivers of change and adaptation in the armed forces. New military materiel to be fielded must be modern, operational,

robust, and durable, but most importantly, it must ensure interoperability among allies.

In particular, the space sector is based on sophisticated technologies that must meet the extraordinary requirements to function in the extreme conditions of Space. In addition, the use of their specific products requires correspondingly high-quality equipment.

Additionally, the pace of innovation in space-related technologies and the use of new disruptive technologies accelerates from year to year. Building a SpOC could be seen as a primary driver for innovation, not only in national military space challenges but also in general for the national military. A new entity, oriented at modern organizational and technological state-of-the-art solutions could test and benchmark new approaches. Successful implementation of such a highly advanced space facility could serve as an example and blueprint to promote the procurement of other advanced techniques in the armed forces or even in the national government. In addition, the high costs of space-related developments can be compensated to some extent by 'dual-use' applications used in terrestrial applications.

- Standardization and specifications for national efforts in the military space domain, by using technical documentation like STANAGs.
- Modern material is normally cost-intensive, sharing or pooling resources can help to mitigate the expense. Multinational integration of capabilities (like AWACS, AGS) may be a model for the pursuit of some space-related capabilities.
- Future developments of new military systems, regardless of the domain, should take into consideration dependencies on space-based capabilities. Forces must be equipped (and trained) to integrate and use space capabilities.
- National SpOCs need a network-centric approach and full integration into sophisticated C2-systems and avoiding platform-centric solutions.
- Include EDT, to be complimentary for allies and competitive to adversaries.
- Incorporate the use of AI to support decision-making processes.
- Testing of new technologies in a real environment with the involvement of the user in the development phase, thereby reducing the time required for the introduction of new technologies.
- Modernization in a short timeframe, i.e. all users get new equipment or updates at nearly the same time, not stretched on the timeline. Possible disadvantages of a short period of reallocation of new equipment (possibly higher costs, non-availability of the system in the roll-out phase) are offset by the advantages of using a common system configuration by all users, as well as harmonization of logistical and technical support.
- Protection of national space capabilities is a national responsibility. However, if NATO defines minimum requirements, collective effort could guarantee service and strengthen the coherence of the alliance.
- NATO should promote the development of technology demonstrators in a multinational approach to show the benefits of integration and interoperability. This could be particularly beneficial for smaller nations who, with the support of a framework nation, could eventually establish their own military space capabilities.
- Integration of space technology aspects and materiel within respective armament groups at NATO HQ level.
- A robust sharing of DPS by technical means could mitigate the lack of trained and experienced space professionals within NCS and nations and may open an efficient way for further cooperation.

Leadership

The role of today's leadership is changing. With new concepts like MDO/JADO and the rising influence of Space and Cyberspace as critical enablers, and the responsibility of the military leader for operations within single domains is shifting to a responsibility for effects-based operations across multiple domains. This includes a specific level of digital leadership.

- SpOCs leadership must be truly joint and combined, not possessing stove-piped thinking focused within one domain, but intentionally

prepared, experienced, and tested for mission command across multiple domains
- All leadership has to include aspects of 'What can be achieved with space-related capabilities" as well as "What cannot be achieved with space-related capabilities' into their decision-making process.

Personnel

The 'warfighter' is the focal point of all activities. In the past, space operators played a role in 'support to the warfighter', giving them a level of support, which is needed to optimize their individual tasks. This is still true today, however the quality and quantity of this support is continuously increasing. At the same time, the role of the space operator is changing to that of a space warfighter; they are not only executing a supporting role, but increasingly performing a warfighting mission of their own–a clear change of mind-set for many.

- NATO positions require personnel with skills and experience developed within their nations, with the eventual addition of skills developed through their NATO assignments. NATO has to define their own requirements related to Space for all personnel and these should guide national E&T specifications. A close correlation between both ensures their effectiveness.
- Mutual exchange of personnel between various Nat mil SpOCs, as well as respective NATO staffs should be intensified; they are key to multinational cooperation and coordination as well as execution. This dialogue may also lower cultural barriers, bring different positions and perspectives together, and enhance mutual trust.
- A broad liaison network among all or selected Nat mil SpOC and NATO space entities should be established to foster a better understanding of tactics, techniques, and procedures, facilitate the integration and synchronization of operations, and play a dominant role in the transfer of vital information. Not only during their liaison-duty but also after returning to their home country, liaison personnel will yield a return on new knowledge, experiences and skills for the benefit of their national armed forces.
- Definition, selection, training and maintenance of a space cadre, as it already started in some nations as well as NATO.

Facilities

A Nat mil SpOC needs specific facilities to fulfil their tasks. This could be integrated into existing operations centres or built completely anew.

- As with all military facilities a Nat mil SpOC needs to be constructed due to threat assessment of potential adversaries (maximum peer-to-peer threat).
- Evaluation of the necessity for a stationary mode of operation or for deployability and mobility needs.
- Analyse an additional need for specific training facilities for national as well as NATO requirements with the ability to grow/expand as NATO develops more space personnel and possibly takes a more active role in space operations in the future.
- Improve the cooperation with universities, academia and industry to be at the top level of todays and tomorrows challenges, developments and techniques.

Interoperability

NATO's DOTMLPF-I process is based on the US-national DOTMLPF process, with the addition of the 'I' for Interoperability. Today's national security of NATO's member nations is guaranteed by the strength of the Alliance, with their key attributes being cooperation and partnership. For this reason, multinationalism is the nucleus of NATO's character and descended from this, interoperability is one, if not the main focal point for NATO to achieve high standards in defence planning and execution of military operations in all 15 mission types. Interoperability is in line with the integration and standardization, therefore, it includes connectivity and helps NATO to operate coherently, effectively, and efficiently among the member states, but also with external partners in line with appropriate agreements, like Partnership for Peace (PfP),

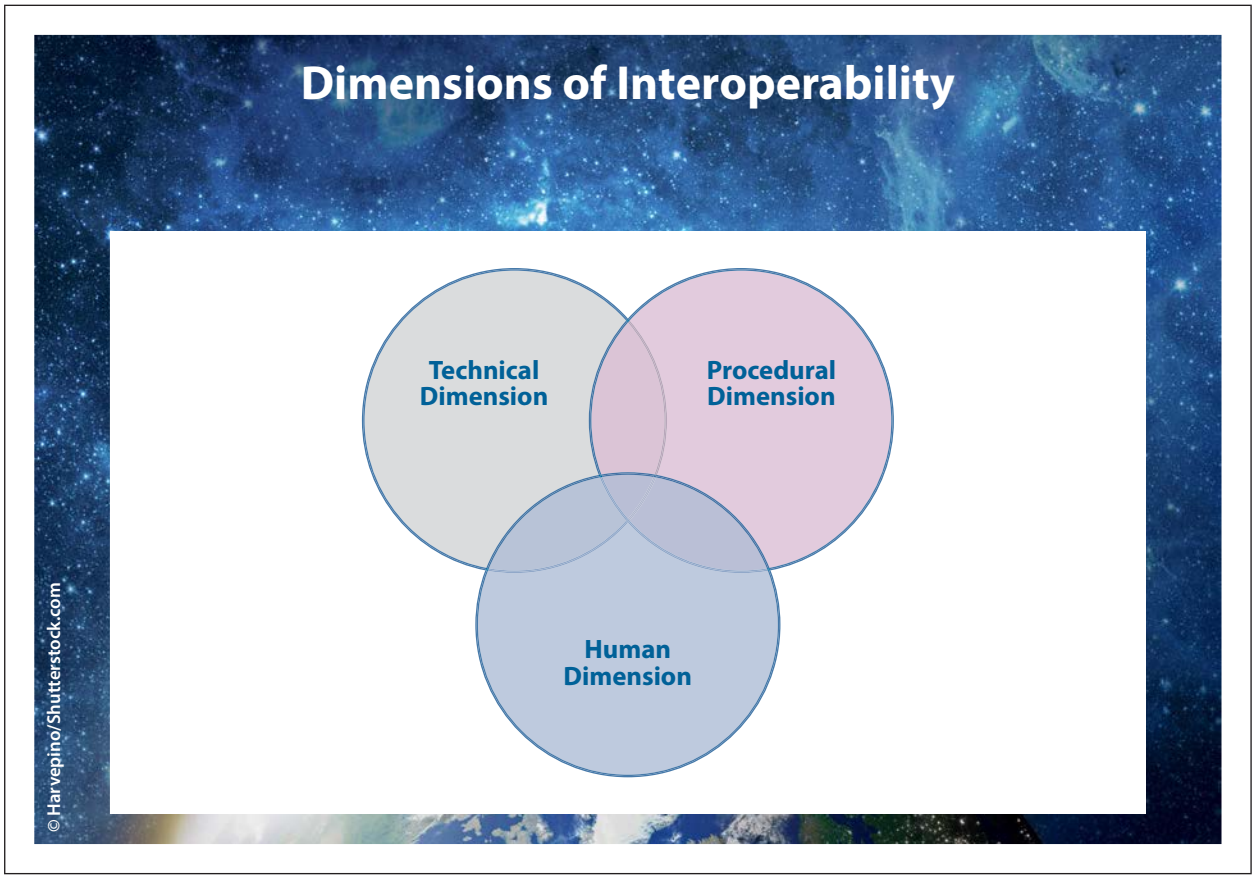

Figure 17: Dimensions of Interoperability.

Mediterranean Dialogue (MD) etc. Interoperability must be seen as a broad approach, which includes aspects such as technological, procedural, and human dimensions.

All details listed in this annex can be assigned to one of these dimensions (see Figure 17 above):

Facilities (7), Material (4)
-> Technical Dimension

Doctrine (1), Organization (2)
-> Procedural Dimension

Training (3), Leadership (5), Personnel (6)
-> Human Dimension

Additional overarching recommendations related to Interoperability are listed here:

- Space-based capabilities have to be more extensively included in the NATO Defence Planning Process (NDPP), which was already initiated for the new planning cycle 2022-26. This guarantees a continuous synchronization and harmonization of national defence planning with NATO's needs as well as the chance for nations to establish capabilities in a common approach and focus on shared priorities. Space is already included in the Political Guidance (PG).
- Formalize the inter-Alliance partnership for space aspects maintaining a greater cohesion within the alliance by highly visible symposia or panels of experts. This includes political aspects of Space to explain NATO's activities within the new domain to the public, as well as confidential meetings on the expert level for specific military details.
- NATO needs an ongoing gap analysis which includes the space domain in the Lessons-Learned process. Recognized requirements have to be well defined and should be a determining factor for future

decision in the technical, human and procedural dimensions.

- Establish NATO relationships with regard to space topics with EU, ESA, and others for mutual exchanges, best practices and to avoid duplication.
- Space-faring allies as well as NATO should strive to place at least a liaison in the Combined Space Operations (CSpO) initiative.[2]
- NATO should fuse national Space Domain Awareness capabilities into one comprehensive picture and make it available across the Alliance.
- Nations which struggle to develop alternatives and redundancies should look for cooperation opportunities with other nations, which in turn supports NATO through diversification of their providers. Increased providers of DPS for NATO achieves additional redundancy and resiliency, while avoiding duplication, if not absolutely necessary. Informing of partners should be done in the very early stages of development.
- Nations should use various models of collaboration and cooperation like Smart Defence, Pooling and Sharing, and the Framework Nations Concept.

Conclusion

NATO is a coalition of 30 independent nations, which has made great efforts in internal cooperation during its 70 years of existence. Synchronization of all allies to act as one is the key to success. This organization does have the power to integrate national contributions for a common goal and vice versa to set the standards for national developments. Therefore, NATO itself needs more efforts to ensure the integration of space capabilities of their member nations; it could actively adopt the role of a space integrator, aimed at using Space as a utility for all their efforts in a supporting role. However, NATO can only be as strong as the nations want it to be; they must set the pace!

In this realm, we also have to ask if it is sufficient for NATO to rely on the capabilities of only a few allies or would it be better to also include member nations with little or no space capabilities for military use for as well as a solidarity measure. At the same time, these nations have to assess this situation to determine if they want to be reliant on others or to step into space activities themselves.

A Nat mil SpOC could be the focal point of national military space activities as well as NATO's need for support. Therefore, nations and NATO must come together to demonstrate their willingness to cooperate by promoting standardization, interoperability, and connectivity for their specific requirements in the space domain.

Allies and the Alliance could demonstrate unity in implementing Space as its newest operational domain through truly joint coordination and harmonization in the unity of command via sophisticated political and military leadership. This seems all the more important given that some of today's challenges within the alliance appear to stem from a greater focus on national priorities in security matters. In contrast, the collective issues of NATO are partially sidestepped, while at the same time, new security challenges for the Alliance are emerging. Political, legal, organizational, technological, budgeting, cultural, and other barriers for collaboration could be obstacles on the way forward.

1. An example of this kind of exercise is 'Coalition Warrior Interoperability eXploration, eXperimentation, eXamination eXercise' (CWIX), a multinational Exercise of NATO and the allies. Due to the Corona Pandemic, this exercise is decentralized as a remote Exercise and, therefore, a brilliant opportunity for testing interoperability in all facets, not only in Communications and IT https://www.act.nato.int/cwix, accessed 1 July 2020.
2. This Five-Eyes Community consist of AUSTRALIA, CANADA, NEW ZEALAND, the UNITED KINGDOM and the UNITED STATES OF AMERICA (as of 2019).

ANNEX B

List of Acronyms and Abbreviations

ACCS	Air Command and Control System
ACO	Allied Command Operations
ACT	Allied Command Transformation
AGS	Allied Ground Surveillance
AI	Artificial Intelligence
AJP	Allied Joint Publication
AOC	Air Operations Centre
AOO	Area of Operations
AOR	Area of Responsibility
AR	Augmented Reality
ASAT	Anti Satellite (Weapons)
ATC	Air Traffic Control
AWACS	Airborne Warning and Control Systems
BACO	Baseline Activities in Current Operations
BDAA	Big Data and Advanced Analysis
BFT	Blue Force Tracking
BLOS	Beyond Line of Sight
C2	Command and Control
C3	Consultation, Command and Control
CA	Collision Avoidance
CD	Collective Defence
CD&E	Concept Development and Experimentation
CFI	Connected Forces Initiative
CIS	Communication and Information System
CM	Crisis Management
COP	Common Operating Picture
CONOPS	Concept of Operations
COTM	Communications-On-The-Move
COTS	Commercial-off-the-Shelf
CP	Command Post
CS	Cooperative Security
CSpOC	Combined Space Operations Centre (US)
DCS	Defensive Counter Space
DCO	Defensive Cyber Operations
DIRLAUTH	Direct Liaison Authority
DOTMLPF-I	Doctrine, Organization, Training, Material, Leadership, Personnel, Facilities and Interoperability
DPS	Data, Products, Services
E&T	Education and Training

EDA	European Defence Agency
EDT	Emerging and Disruptive Technologies
EMI	Electro Magnetic Interference
EMS	Electro-Magnetic Spectrum
EO	Earth Observation
ESA	European Space Agency
ETEE	Education, Training, Exercises and Evaluation
EU SST	European Union Space Surveillance and Tracking Project
EW	Electronic Warfare
FMN	Federated Mission Networking
FNC	Framework Nations Concept
FP	Force Protection
GEO	Geostationary Orbit (36,000 km directly above the equator)
GIANT	GPS Interference and Navigation-Analysis Tool
GPG	Global Public Good
GSSAC	German Space Situational Awareness Centre
HQ	Headquarters
I&W	Indications and Warning
IAMD	Integrated Air and Missile Defence
ICAO	International Civil Aviation Organization
IDS	Intrusion Detection System
INTEL	Intelligence
IoT	Internet of Things
IP	Internet Protocol
IPS	Intrusion Preventing System
ISAF	International Security Assistance Force (Security mission in Afghanistan)
ISR	Intelligence, Surveillance and Reconnaissance
IT	Information Technology
JADO	Joint All Domain Operations
JALLC	Joint Analysis and Lessons Learned Centre
JAP	Joint Air Power
JFC	Joint Forces Command
JOA	Joint Operations Area
LEO	Low Earth Orbit (usual definition 200 to 2,000 km)
LOA	Letter of Agreement
LoC	Line(s) of Communication
MD	Missile Defence
MDO	Multi-Domain Operations
MEO	Medium Earth Orbit (usual definition 2000 up to 36,000 km)
METOC	Meteorology and Oceanography

MJO+	Major Joint Operation plus
ML	Machine Learning
MLE	Maximum Level of Effort
MoU	Memorandum of Understanding
NATINAMDS	NATO Integrated Air and Missile Defence System
NAVWAR	Navigation Warfare
NBC	Nuclear, Biological, Chemical
NCIA	NATO Communications and Information Agency
NCS	NATO Command Structure
NDPP	NATO Defence Planning Process
NEO	Near Earth Orbits
NFS	NATO Force Structure
NGO	Non-Governmental Organization
NIFC	NATO Intelligence Fusion Centre
NR	NATO Restricted
NSA	NATO Standardization Agency (1951–2014)
NSO	NATO Standardization Office
OC	Operations Centre
OCO	Offensive Cyber Operation
OCS	Offensive Counter Space
OODA	Observe, Orient, Decide, Act
OOS	On-Orbit Servicing
OPIR	Overhead Persistent Infra Red
OPLAN	Operational Plan
OPP	Operational Planning Process
OSP	Overarching Space Policy
OSS	Operational Space Support
PDOP	Position Dilution of Precision
PE	Peacetime Establishment
PG	Political Guidance
PGM	Precision Guided Munition
PNT	Positioning, Navigation and Timing
PoC	Point of Contact
PoW	Programme of Work
PPP	Public-private Partnership
R&D	Research and Development
RAP	Recognized Air Picture
RFI	Request for Information
RfS	Request for Support
RoE	Rules of Engagement
RS	Resolute Support (Training, advisory, and assistance mission in Afghanistan)
RSP	Recognized Space Picture
SAGE	SACEUR's Annual Guidance for Education, Training, Exercises and Evaluation
SATCOM	Satellite Communication

S&T	Science and Technology
SATRAN	Satellite Transit Advanced Notification
SDA	Space Domain Awareness
SEW	Shared Early Warning
SLA	Service Level Agreement
SLV	Space Launch Vehicle
SME	Subject Matter Expert
SOSI	Space Object Surveillance and Identification
SpOC	Space Operations Centre
SpSCC	Space Support Coordination Cell
SpSCE	Space Support Coordination Element
SSA	Space Situational Awareness
SSR	Space Support Request
STANAG	Standardization Agreement
STM	Space Traffic Management
STO	Science and Technology Organization
TA	Technical Agreement
TOCA	Transfer of Command Authority
TTP	Tactics, Techniques and Procedures
UAS	Unmanned Aerial System
UN	United Nations
UNCOPUOS	United Nations Committee on the Peaceful Uses of Outer Space
USSF	United States Space Force
VR	Virtual Reality

ANNEX C

Terms, Definitions and Explanations

Air C2 System: Essential to deliver the full spectrum of air and space capabilities to support joint efforts.

Anti-Satellite Weapons (No official NATO definition): For general understanding: Weapons and other means designed to incapacitate or destroy satellites in orbit for military purposes.

Artificial Intelligence: The ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings.[1]

C4ISR Systems: Modern military operations are based on satellite-supported systems (command, control, communications, computers, Intelligence, surveillance and reconnaissance). These systems guarantee unrestricted reconnaissance, leadership, navigation and positioning as well as uninterrupted communication and they are an essential component for the control of unmanned systems and autonomous weapons of precision.

Collision Avoidance: Processes and/or technical systems minimizing colliding of orbiting spacecraft inadvertently with other orbiting objects, inclusive space debris.

Command: The authority vested in an individual of the Armed Forces for the direction, coordination, and control of military forces.[2]

Command Post: In operations or exercises, a location from which command is exercised.[3]

Control (1): The authority exercised by a commander over part of the activities of subordinate organizations, or other organizations not normally under his command that encompasses the responsibility for implementing orders or directives.[4]

Control (2): To exert influence over an entity, process, object or area to establish, maintain or prevent a specific situation or event.[5]

Cooperation: (as used in social sciences) Process of groups of organisms working or acting together for common, mutual, or some underlying benefit, as opposed to working in competition for selfish benefit.[6]

Counterspace: Mission, like counter-air, which integrates offensive and defensive operations to attain and maintain the desired control and protection in and through Space. These operations may be conducted across the tactical, operational, and strategic levels in all domains (air, space, land, maritime, and cyberspace), and are dependent on robust space situational awareness (SSA) and timely command and control (C2). Counterspace operations include both offensive counterspace (OCS) and defensive counterspace (DCS) operations.[7]

Critical Infrastructure: Organizational and physical structures and facilities of such vital importance to a nation's society and economy that their failure or degradation would result in sustained supply shortages, significant disruption of public safety and security, or other dramatic consequences.[8]

Data: Representations/indications of facts and procedures that exist in the form of certain characters/symbols on certain data carriers (raw data). As accessed data they become 'information'.

Domain: not defined in NATO.[9]

Effect: (Not defined in NATO): Operational result of specific means out of the military toolkit.

Force Enabler: Something or someone that makes it possible for a particular thing to happen or be done.[10]

Force Multiplier: Something that increases the effect of a force.[11]

Global Common: Term typically used to describe international, supranational, and global resource

domains in which common-pool resources are found. Global commons include the earth's shared natural resources, such as the high oceans, the atmosphere and outer space and the Antarctic in particular. Cyberspace may also meet the definition of a global commons.[12] Global Common Goods are not limited to national borders, but are available worldwide for use.

Information: A variety of different definitions of information exists, mainly due to their different purpose. In this study information is used as: Task-specific assessment (human as well as machine-made) of raw data or the purpose-specific knowledge needed to act on set goals.

Interoperability: The ability to act together coherently, effectively and efficiently to achieve Allied tactical, operational and strategic objectives.[13]

Joint: Adjective used to describe activities, operations and organizations in which elements of at least two services participate.[14]

Joint Air Power: Capturing the collective capabilities and capacity of air, land, maritime and special operations forces, Joint Air Power is the ability to coordinate, control, and exploit the air domain in the pursuit of Alliance objectives.[15]

Karman-Line: The definition of a boundary between earth's atmosphere and outer space. The Fédération Aéronautique Internationale (FAI), an international standard-setting and record-keeping body for aeronautics and astronautics, defines the Kármán line as the altitude of 100 kilometres (62 miles; 330,000 feet) above Earth's mean sea level, where aerodynamic flight ends and centrifugal force prevails.[16] Other organizations do not use this definition. For instance, the US Air Force and NASA define the limit to be 50 miles (80 km) above sea level. There is no international law defining the edge of Space, and, therefore, the limit of national airspace; however, the 100 km line is internationally recognized.[17]

Kessler Syndrome: A growing density of objects increases the likelihood of collisions, the resulting new debris leads to further collisions, generating in turn more debris. This chain reaction permanently increases the number of objects in each orbit and partially beyond, which ultimately makes a safe usage of Space impossible (cascade effect).[18]

NATO Defence Planning Process: The aim of the NDPP is to provide a framework within which national and Alliance defence planning activities can be harmonized to enable Allies to provide the required forces and capabilities in the most effective way. It should facilitate the timely identification, development and delivery of the necessary range of forces that are interoperable and adequately prepared, equipped, trained and supported, as well as the associated military and non-military capabilities, to undertake the Alliance's full spectrum of missions.[19]

NATO Missions:

1. Article V Collective Defence (CD)
2. Non-Article V crisis response operations (NA5CRO) / Crisis Management (CM)
3. Consultation and cooperation / Cooperative Security (CS)[20]

NATO Standardization: The development and implementation of procedures, designs and terminology to the level necessary for the interoperability required by Allies, or to recommend useful practices in multinational cooperation.[21]

NAVWAR: Military actions and/or technical measures to assure positioning, navigation, and timing superiority.[22]

Near Space Operations: Operations below Karman line and above maximum height of today's aircraft.

Offensive Counter Space: (not defined yet, in analogy to Offensive Counter Air[23]): An operation mounted to destroy, disrupt or limit enemy space power as close to its source as possible.

Operational Domain: distinct realms with unique considerations for the planning and execution of military activity.[24]

Operations Plan: A plan for a single or series of connected operations to be carried out simultaneously or in succession. It is usually based upon stated assumptions and is the form of directive employed by higher authority to permit subordinate commanders to prepare supporting plans and orders. The designation `plan' is usually used instead of 'order' in preparing for operations well in advance. An operation plan may be put into effect at a prescribed time, or on signal, and then becomes the operation order.[25]

Operations Planning: Planning of military operations at the strategic, operational or tactical levels. [26]

Operational Space Support: Provision of space data, products and services in support of NATO activities, missions and operations, procured from nations, governmental, commercial, and relevant multinational and international organizations.[27]

Overarching Space Policy: NATO classified document published on 24 June 2019. This document defines for the first time NATO's role in Space.

Request for Information (Not defined in NATO): usually: one party needs critical information to proceed or make a decision. The NATO intelligence community formalized the process for their needs.

Rules of Engagement: Directives to military forces, including individuals, that define the circumstances, conditions, degree, and manner in which force, or actions which might be construed as provocative, may be applied.[28]

Small Satellites: Satellites that are less than 500 kg in mass.

This can be further divided into subcategories:

Mini Satellites	100–180 kg
Micro Satellites	10–100 kg
Nano Satellites	1–10 kg
Pico Satellites	0,01–1 kg
Femto Satellites	0,001–0,001 kg

Special categories of modular small satellites are Cube Satellites with a standard size of 10 x 10 x 10 cm.[29]

Space Capabilities: Summary of unique abilities in space relevant areas to a common functional area. All space capabilities are normally subdivided in single capabilities:

- Positioning, Navigation and Timing (PNT)
- Intelligence, Surveillance and Reconnaissance (ISR)
- Meteorological and Space Weather (METOC)
- Space Situational Awareness (SSA)
- Satellite Communication (SATCOM)
- Shared Early Warning (SEW)
- Space Security[30]

Space Data: All information acquired, produced or provided by space systems or related to or through space systems, necessary for the provision of space products and services.

Space Debris are all man-made objects, including fragments and elements thereof in earth orbit or re-entering the atmosphere, that are not functional.[31]

Space Domain: In 2022 NATO will publish a document for Space Taxonomy and Definitions, which will provide a definition..

Space Domain Awareness (1) (US): The effective identification, characterization, and understanding of any factor, passive or active, associated with the space domain that could affect space operations and thereby impact the security, safety, economy, or environment of our nation.[32]

Space Domain Awareness (2) (NATO): Common understanding, comprehension, and perception of all aspects associated with the space domain, to include threats and vulnerabilities, which could impact NATO and the Allies' safety, security, economy, and environment.[33]

Space Domain Coordination: Coordination of actions for all domains which provides or manages space effects across the full-spectrum operating environment.[34]

Space Effect: The operational result of space products/services used in support of an operation. From this perspective, a space effects is what the commander expects from a space product/serve.[35]

Space Power: No NATO definition; examples for national definitions:

– **United Kingdom:** Exerting influence in, from, or through, Space.[36]
– **United States of America:** The use or denial of the use of the space medium for military value.[37]

Space Products: The result of processed and analysed data originated by space-based sensors. Space products include but are not limited to space imagery and weather maps.[38]

Space Services: Utility provided by space systems to users (e.g. PNT, SATCOM).

Space Security: A new seventh NATO space functional area (capability) concentrating on Non-NATO space threats.

Space Support Coordination Element: The SpSCE serves as the primary advisor for commanders and their staff on space support in NATO Operations and conduct all respective functions and tasks.[39]

Space Support to Operations: includes all activities that provide capabilities through Space in order to support NATO Operations.[40]

Space Support Request (Not defined in NATO): A specific request for space-related needs, similar to a Request for Information (RfI).

Space System: A complete system consisting of four segments, the space-, ground-, user- and link- segment.

Standardization Agreement: A NATO standardization document that specifies the agreement of member nations to implement a standard, in whole or in part, with or without reservation, in order to meet an interoperability requirement. Note: A NATO standardization agreement is distinct from the standard(s) it covers.[41]

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27. BiSCSWG, NATO's Approach to Space, 2-Page Flyer.
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ANNEX D

List of Figures

ANNEX E

JAPCC's Questionnaire for National Contribution

The JAPCC's Space SME initiated and developed a questionnaire to collect basic information about the nation's needs and view for further analysis and use in two JAPCC studies. The answers were taken into consideration and integrated into this study as well as for the project 'Resiliency in Space as a Combined Challenge for NATO'. The questionnaire was sent to all NATO member nations; 16 nations sent an official response.

The questions, their intended aims as well as respective national answers are laid down in this annex:

1. **Does your nation operate a national Space Operations Centre (SpOC)? If yes, please give some details to structure / tasks / workflow / further development.**
   Aim is to find criteria for military Space-faring nations. Aim is to identify nations that operate a SpOC.

2. **What Space products and Space support services to potential operations does your nation produce?**
   Aim is to find Space support that can be used for NATO.

3. **Do you share these products / services or parts of it with NATO or are you willing to do so in the future?**
   Aim is to find potential limiting factors.

4. **Are official agreements / contracts / MoUs established between your nation and NATO in effect? Please list them in detail.**
   Aim is to get an overview about already existing cooperation.

5. **From your point of view, is there a need for additional agreements / contracts / MoUs between NATO and your nations, as well as organizations and commercial entities?**
   Aim is to get recommendations from the nations for further development.

6. **From the NATO point of view: are there existing and desired redundancies in Space support data, products and services; do we need these?**
   Aim is get an overview about nation's understanding of NATO Space support.

7. **Do you cooperate with other nations (bilateral, multilateral), if yes in which areas?**
   Aim is to get an overview out existing cooperation.

8. **What are the requirements to guarantee the provision of Space support data, products and services? Please list detailed NATO's requirements for information for Space support in operations.**
   Aim is get an understanding of nation's needs.

9. **Please provide recommendations for the possible future role of NATO to improve Space resiliency.**
   Aim is to collect further ideas by the nations.

10. **Do you know NATO requirements for special products and services? Please list them and explain the procedures for their implementation.**
    Aim is to get an overview about nation's knowledge of NATO Space support.

11. **What are the requirements for a mutual support arrangement between national SpOCs and NATO HQ with regard to information flow and exchange?**
    Aim is to collect further ideas by the nations.

12. **Do you have some recommendations for a potential structure of a typical national SpOC for a support arrangement with NATO?**
    Aim is to collect ideas by the nations in respect to national needs.

13. **What do you think is the best way / the realistic way of exchanging data and services?**
    Aim is to collect certain ideas by the nations.

14. **Highlight technical and security restrictions / issues and special legal aspects regarding support from your national SpOCs to NATO.**
    Aim is to find limiting factors for potential future developments.

15. **Do you have technical comments for a potential data transferring systems for Space support in operations data and Space products?**
    Aim is to collect ideas from the nations.

16. **Does your nation use Space support services in operations in training, exercises or national operations? If yes which ones?**
    Aim is to get an overview about the nation's current status.

17. **For potential requests for Space support, what national entities in your country (civilian as well as military) are responsible for that?**
    Aim is to understand the nation's structure.

18. **What kind of Education and Training (E&T) for the military personal responsible for Space support are mandatory in your nation? Do you offer courses in your nation and are these open for other NATO members? Do you use E&T support from other nations?**
    Aim is to understand and analyze the national training and education structure as well as finding potential courses for NATO training and education.

19. **Are there potential Space training support requirements in your nation?**
    Aim is to understand then national needs.

The nation's responses to the questionnaire are listed in the table below. The table contains only the NATO member nations which have responded the questionnaire. A given answer which was usable for analyzing the topic and got integrated in the study is marked ('X') or if it is in experimental or development status ('(X)'). Only question number 1 marks an existing SpOC as 'X'.

HU and RO responded to the questionnaire, but stated that they do not have any involvement in Space Support in Operations yet, but are interested to follow the development of that topic.

	BE	CA	CZ	GE	DK	FR	UK	GR	HU	IT	NE	NO	PL	PO	RO	TU
1 nation operates a SpOC		X		X		X	X			(X)						X
2 offer products / services	X	X		X	(X)	X	X	X		X	X		X			X
3 sharing of stated in 2		X		X	X	X	X			X	X					X
4 MoUs agreements to NATO	X	X		X		X				X						
5 need for additional MoU			X	X	X	X	X			X				X		X
6 existing redundancies in NATO	X				X	X	X						X			
7 bi- / multilateral cooperation	X	X		X	X	X	X	X		X	X	X	X	X		
8 requirements for Space support		X			X	X	X			X	X	X				X
9 future role of NATO to improve Space resiliency	X	X		X	X	X	X			X	X	X	X			X
10 requirements for special Space products						X				X		X				
	BE	CA	CZ	GE	DK	FR	UK	GR	HU	IT	NE	NO	PL	PO	RO	TU

	BE	CA	CZ	GE	DK	FR	UK	GR	HU	IT	NE	NO	PL	PO	RO	TU
11 arrangements between national SpOC and NATO HQ					X	X	X									X
12 potential structure of a SpOC				X			X					X				X
13 way of data exchange	X	X		X	X	X	X				X	X	X			X
14 restrictions between SpOC and NATO	X	X		X		X	X	X								X
15 technical comments on data transfer	X			X	X	X							X			X
16 national use of Space products/ services in exercises	X	X		X	X	X	X			X	X	X		X		X
17 POC for Space support	X	X		X	X	X	X	X		X		X	X	X		X
18 Education and training options	X	X		X	X	X	X	X		X	X		X			X
19 Space training support require-ments		X	X	X		X	X				X		X			X
	BE	CA	CZ	GE	DK	FR	UK	GR	HU	IT	NE	NO	PL	PO	RO	TU

ANNEX F

List of Agreements Between Nations and NATO

This overview lists some agreements of exchange of DPS between nations and NATO; however, it is not exhaustive. The primary sources for this list are non-classified NATO documents, like the Space Handbook[1] as well as open sources:

PNT

Policy on Satellite Navigation Services for NATO Military Operations (Jun 2016)

MC NATO Secure Positioning, Navigation and Timing Directive (Jun 2017)

NAVSTAR GPS Memorandum of Understanding IV between individual nations and the USA for the secure military service.

Info:

- Public free US GPS System open for all NATO nations.
- The European Union system 'GALILEO' offers an Open Service and an encrypted Public Regulated Services and is designed to be interoperable.

NATO ISR

NATO Intelligence Fusion Centre (NIFC) provides products based on data delivered by nations to NIFC as part of the Intelligence System (2006 Intel Fusion Concept).

METOC

No formal agreements for space weather

SSA

NATO does not have agreements for receiving SSA Data

Bi-national agreements of individual nations with the USA

SATCOM

NATO SATCOM Post 2000 (NSP2K) from 2005 until 2019 with three nations (FR, IT, UK)

Capability Package 9A0130 (2019–2034) for protected SATCOM capabilities with an investment for procurement of 1.5 billion Euro

SEW

NATO does not have agreements for receiving SSA Data. Some Bi-national agreements of individual nations with the US.

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ANNEX G

Literature

Used Literature and Additional Reading Recommendations

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Operational Documents

Details on Space-specific operational issues are laid down in documents of various HQ of the NATO Command Structure (NCS), such as:

Operational Plan (OPLAN), Annex DD, Space Operations

Standard Operating Procedures (SOP) 223 Space Support in Operations

Standard Operating Instructions (SOI) 223 Space Operations

Additional Useful Internet Sources

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Heiner Grest
Lieutenant Colonel (GE AF),
Branch Head Space

ANNEX H

About the Author

Lieutenant Colonel Heiner Grest, German Air Force

Lieutenant Colonel Grest began his military career in July 1982 as a conscript in the German Air Forces' NIKE-HERCULES Air Defence System.

After his appointment as an officer and an initial assignment as a Tactical Control Officer on the PATRIOT system, he subsequently served in various command and staff positions in ground-based air and missile defence.

During this tour of duty, he was deployed to ISAF Headquarters in Kabul in 2003 as a Military Assistant to DCOM AIR as part of the NATO mission in Afghanistan.

From 2006 to 2012, he served in the 4th Air Division as Staff Officer A3A; in this position, he was responsible for training and organization, as well as doctrine and policy evaluation and implementation. This included planning and monitoring the deployment of 4th AirDiv units to missions such as ISAF, NRF, and EUBG.

From 2012 to 2014, he served with the Rapid Medical Reaction Forces Command as a planning staff officer, responsible for deployments of medical services in stabilization operations.

Since January 2015, Lieutenant Colonel Heiner Grest has served as a Space SME at the JAPCC, currently as Acting Branch Head of the Space Branch, established in 2020.

Lieutenant Colonel Grest holds a diploma in business administration from the Bundeswehr University Hamburg.

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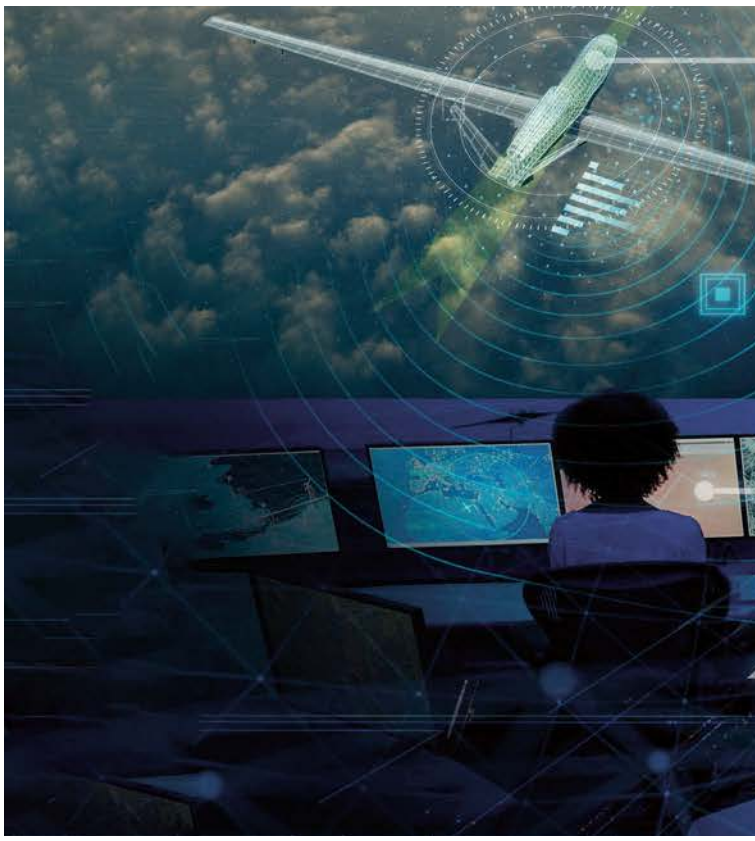

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