Chapter 1
Advanced Technologies at NATO: An Overview

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Abstract Understanding and managing the political and practical implications of emerging and disruptive technologies is a priority for NATO and for the Science for Peace and Security (SPS) Programme. To take stock of the Programme's contribution to this field, NATO SPS organized the "SPS Cluster Workshop on Advanced Technologies" on 17 and 18 September 2019, under the auspices of the Katholieke Universiteit Leuven.

1.1 Science for Peace and Security: A History of Scientific Cooperation

Historically, technology was the spark that ignited NATO's interest and commitment to scientific advancement, a little over 60 years ago. Indeed, it was following the 1957 launch of Sputnik, the first artificial Earth satellite, that NATO realized the gap between Soviet and Allied technologies, and saw a need to act. This led to the creation of the NATO Science Committee in 1958, and to decades of NATO-supported practical cooperation in science and technology, through fellowships, research grants, knowledge sharing and capacity building, in the civilian and defence fields.

Science and technology in NATO is today a prominent effort brought forward by a number of programmes and stakeholders, which aims to sustain the technological advantage of the Alliance and its partners as described in the NATO Science & Technology Strategy.[1]

[1] NATO Science & Technology Strategy – Sustaining Technological Advantage. Approved by the North Atlantic Council on 27 July 2018

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Among all programmes, the Science for Peace and Security (SPS) Programme, established in 2006 as the merger of the Science Programme and the Committee on the Challenges of Modern Society (CCMS), is the living proof of NATO's longstanding commitment to science, which over the years brought about many outstanding results in a variety of fields. To mention a few: the project "SILK Afghanistan", which deployed a satellite-based network providing internet access to researchers in Afghanistan and other countries of the Southern Caucasus and Central Asia; the various projects developing real time explosive detection systems for public transportation; the multinational telemedicine system, enabling specialists to share real-time recommendations with first responders in emergency scenes or combat zones; or the establishment of a terahertz imaging laboratory in Algeria, contributing to the detection of explosive devices and other illicit substances – the first capability of this kind installed in North Africa.

Since its creation, SPS has demonstrated a flexible and versatile approach to practical scientific cooperation, and has proved instrumental to promoting knowledge-sharing, building capacity, and projecting stability outside NATO. The priorities addressed by the SPS Programme are aligned with NATO's Strategic Objectives, and aim to tackle emerging security challenges that require dynamic adaptation for the prevention and mitigation of risks. By addressing priorities such as advanced technologies, hybrid threats, and counter-terrorism, the Programme deals with new, contemporary challenges.

The SPS Programme has a unique way to tackle these challenges through partnerships, by engaging a network of scientists both from NATO and partner nations. As the threats it addresses are multidisciplinary in nature and often cross borders, international collaboration is essential to counter them. Bringing together researchers and institutions from Allied and partner nations, SPS helps finding solutions to challenges of mutual concern, at national and regional levels. In doing this, it plays a very important role in building capacity within and outside the Alliance, to deal with challenges affecting Allies and Partners alike.

In order to keep abreast of an ever-changing security landscape, it is in NATO's interest to understand the challenges and opportunities presented by disruptive and emerging technologies. The 1957 Sputnik launch may be considered the first of such challenges for the Alliance, and will not be the last. NATO's continuous adaptation and modernization have been essential to maintain its relevance through the years, which explains why innovation is such a critical element for its future. The future is also tied to advanced technologies, which will certainly have an impact on the security and defence landscape.

1.2 SPS Between Diplomacy and Technology

Science and technology can be a highly effective vehicle for international dialogue, due to their universality and dependence upon international networks. This is the

raison d'être of the SPS Programme, which has been throughout its history a bridge between science, technology and public diplomacy.

In the early years, the Science Programme contributed to building a positive image of NATO as a security provider through engagement with Allied scientific and civilian communities based on the principles of solidarity. Over the years, and particularly at the end of the Cold War, this intra-alliance programme was transformed to reach out to and offer practical cooperation across NATO's partnership frameworks.

Today, the SPS Programme is as vital and necessary as ever before. NATO and Western societies needs to operate in times and environments that are Volatile, Uncertain, Complex and Ambiguous (VUCA), while innovation is following an unprecedented pace, with emerging technologies able to provoke disruption in the economy and societies in very short time and to radically change the security environment.

Additionally, we have experienced in the past few years a process of democratization of technology: cutting-edge technologies are becoming ubiquitous, affordable and easily accessible for everyone; their development has been more and more driven by commercial and civilian actors rather than the militaries, and as such emerging technologies are intrinsically more difficult to be framed, assessed and governed by institutions.

Today and in the future, emerging and disruptive technologies will not be developed in isolation, but they will be the result of collaborative works, merging ideas and experiences from different fields and contexts. That is why, in this environment, SPS is best placed to tackle these challenges and to bridge the gap between NATO nations and partner nations; academia, industry, end-users and governments; scientists, researchers and diplomats.

Since the SPS Programme's inception, a wide international network of scientist and experts from NATO member and partner countries has been established. More than 20 Nobel Laureates have been associated with the SPS Programme, a testament to the scientific excellence supported by SPS and its important role in innovation and advanced technologies.

1.3 SPS Cluster Workshop on Advanced Technologies

The topic of disruptive and emerging technologies has become more and more important for SPS. To take stock of the Programme's contribution to this field, NATO SPS organized the "SPS Cluster Workshop on Advanced Technologies" on 17 and 18 September 2019, under the auspices of the Katholieke Universiteit Leuven.

The event built upon the experiences from 26 SPS projects supported under the SPS key priority of "Security-related Advanced Technologies",[2] and promoted the exchange of knowledge and scientific know-how between NATO and partner nations. This was an opportunity for researchers to present their activities, to highlight future trends and to provide feedback on how SPS can contribute to scientific and technical development in this field. Additionally, the workshop was an opportunity to appreciate the high scientific value and educational success provided by the SPS Programme: in the context of these activities, prototypes were developed, patent applications prepared, and hundreds of scientific articles were published in high-ranked scientific journals and conference proceedings. Several young students and researchers (MSc and PhD students) were sponsored by SPS and played important roles in the projects.

Presentations and discussions revolved around four thematic areas, which are reflected in the structure of this volume: communication systems, innovative and advanced materials, sensors and detectors, and unmanned and autonomous systems.

In the field of communication systems, seven projects presented advanced technologies to:

- Detect intrusions in the electromagnetic spectrum by means of cooperative and intelligent detections systems;
- Predict and forecast cyber-attack trends through the analysis of big data and geopolitical strategic events;
- Deploy ad-hoc networks in crisis management and counter-terrorism operations;
- Establish a Quantum Key Distribution system over underwater fiber-optic communication networks;
- Develop post-quantum cryptographic algorithms, i.e. algorithms and protocols able to secure communications even in the case of attacks by a quantum computer.

Six SPS projects on innovative and advanced materials focused on the development of new materials (e.g. graphene, silicon carbide, ceramic, titanium, etc.) providing interesting properties for specific security applications. They also developed cutting-edge production and synthetization techniques, contributing to:

- Develop nuclear screening systems to detect illicit trafficking of nuclear materials;
- Develop radiation hardening techniques, i.e. making electronic components resistant to high energy radiation, especially for outer space vehicles and high-altitude flights;
- Develop novel armor concepts based on titanium, providing high strength, micro hardness, bending capabilities, etc.;
- Develop ceramic nanomaterials for infrared transparency.

[2]The list of SPS Key Priorities are reported in Annex II.

Eight SPS projects on sensors and detectors presented their achievements; they developed:

- Multi-static and multi-band radars for border security;
- Noise radar networks for the detection of low altitude Unmanned Aircraft Systems (UAS);
- Compact and portable LIDAR (Light Detection and Ranging) systems to be mounted on UAS for 3D imaging and mapping;
- Sensor fusion technologies to create common operational pictures and provide tactical information to security operators.

Finally, five activities on unmanned and autonomous systems were presented, covering the full domain spectrum (maritime and underwater, ground, air and space).

These projects aim to:

- Develop and deploy an underwater autonomous platform for situational awareness;
- Develop intelligent tyres to guarantee mobility in severe terrain environments;
- Deploy multiple cooperative UAS to monitor large areas;
- Deploy high altitude balloons in the stratosphere, providing high altitude radar coverage;
- Develop and demonstrate countering UAS capabilities, through the release of multiple cooperative drones attacking the enemy drone.

1.4 Outline

This book provides a summary of the projects presented. It is organized in four main Parts, divided according to the themes of the workshop. The full list of projects is reported in Annex I.

Note that the articles do not respect necessarily the opinion of NATO or the editors and are the full contribution of the authors.