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Role of science and technology in the context of international security and disarmament

Current developments in science and technology and their potential impact on international security and disarmament efforts

Report of the Secretary-General

Contents

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I. Introduction

1. In paragraph 5 of its resolution 74/35 on the role of science and technology in the context of international security and disarmament, the General Assembly requested the Secretary-General to submit to the Assembly at its seventy-fifth session an updated report on current developments in science and technology and their potential impact on international security and disarmament efforts.

2. Throughout history, science and technology have contributed to increasing human well-being and prosperity. They are key enablers in efforts to implement the 2030 Agenda for Sustainable Development. It is important that any efforts to govern new weapon technologies or weapon applications of new technologies do not hamper the economic and technological growth and innovation of any State.

3. There are, however, growing concerns that developments in science and technology of relevance to security and disarmament are outpacing the capacity of normative and governance frameworks to understand and manage the risks. As the Secretary-General laid out in his report entitled "Securing our common future: an agenda for disarmament" in 2018, the international community must remain vigilant in understanding new and emerging weapon technologies that could imperil the security of future generations and that could pose challenges to existing legal, humanitarian and ethical norms; non-proliferation; international stability; and peace and security.

4. The Secretary-General's previous reports on this subject (A/73/177 and A/74/122) provided an overview of recent developments in science and technology of relevance to the means and methods of warfare. The second of those reports, issued in 2019, constituted an update to the initial report and addressed developments in relevant intergovernmental forums.

5. Since 2018, the pace of developments in science and technology relevant to international security and disarmament has continued to accelerate. The present report therefore constitutes a comprehensive update, providing an overview of scientific and technological developments and their potential impact on international security and disarmament efforts.

II. Recent developments in science and technology of relevance to the means and methods of warfare

A. Artificial intelligence and autonomous systems

6. There is no universally agreed definition of artificial intelligence. The term has been applied in contexts in which computer systems imitate thinking or behaviour that people associate with human intelligence, such as learning, problem-solving and decision-making. Modern artificial intelligence comprises a set of sub-disciplines and methods, such as data analysis, visual, speech and text recognition, and robotics. Machine learning is one such sub-discipline. Whereas hand-coded software programs typically contain specific instructions on how to complete a task, machine learning allows a computer system to recognize patterns in large data sets and make predictions. Machine-learning techniques are highly dependent on the quality of their input data.

7. Artificial intelligence has wide-ranging civilian applications, and the majority of artificial intelligence-related research and development occurs in the civilian sphere. Recent advances in artificial intelligence have been fuelled by large commercial investments, faster processors and the availability of ever larger data sets.

Image recognition and image generation have improved significantly in recent years. Speech recognition, language comprehension and vehicle navigation have also seen significant progress. Despite these advances, more generalized artificial intelligence abilities are arguably still not sophisticated enough to be useful for the many weapon applications that could be envisaged.

8. Autonomy refers to the ability of a system, once activated, to execute relatively complex tasks or functions without human input or control. Autonomous systems can be categorized into systems that: (a) require human input at some point during the execution of the task (human in the loop, or semi-autonomous); (b) execute tasks independently but under the supervision of a human who can intervene (human on the loop); and (c) operate independently of human involvement or supervision (human out of the loop, or fully autonomous). The elements of an autonomous system can be integrated into one machine or distributed across multiple networked machines. Recent advances in autonomous systems have been driven by developments in artificial intelligence as well as by developments in various enabling technologies, such as sensors.

Military applications and implications

9. Some States attach increasing importance to artificial intelligence and autonomy in their military capabilities. Some have already tested or fielded a variety of systems applying these technologies. Mobility has been the predominant application of autonomy in military systems. Examples include uncrewed aircraft capable of autonomous carrier-based take-off and landing and aerial refuelling; uncrewed naval vessels capable of autonomous navigation, including in compliance with maritime laws and conventions and interacting with adversaries; autonomous soldier support and ground transport systems; systems that control multiple uncrewed vehicles of various kinds; coordinated mobility and swarming systems; systems that sort and analyse intelligence data, including imagery; defensive and offensive information and communications technology (ICT) systems; decision-making applications; and war-gaming, simulation and training applications.

10. Autonomous weapon systems are generally understood to be weapon systems that employ autonomy in their critical functions relating to carrying out an attack, including target selection and the firing of a weapon. Weapon systems may employ autonomy in other functions, such as navigation, but would not generally be considered autonomous weapon systems if their attack functions are carried out by a human operator. The definition of an autonomous weapon system is the subject of continuing international deliberations (see CCW/GGE.1/2019/3). However, there are weapon systems already deployed that, once activated, are capable of selecting and engaging targets autonomously, without further human intervention, albeit in a limited range of operational environments. Frequently cited examples include certain close-in weapon systems deployed on naval ships, sentry gun turrets deployed along contested borders and certain guided munitions that select a specific target after being fired on the basis of some general or preselected criteria.

11. In commonly cited potential applications of autonomy in weapons, the autonomous functions would carry out tasks that are considered tedious or repetitive or require more endurance, speed, reliability or precision than a human operator. Autonomous systems can potentially perform relatively routine tasks with a high degree of accuracy and reliability, thereby freeing up human resources for other tasks. Those attributes can make such systems attractive to armed forces as well as to non-State armed groups.

Relevant intergovernmental processes, bodies and instruments

12. Pursuant to the Fifth Review Conference in 2016 of the High Contracting Parties to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May Be Deemed to Be Excessively Injurious or to Have Indiscriminate Effects (Convention on Certain Conventional Weapons), the Group of Governmental Experts on Emerging Technologies in the Area of Lethal Autonomous Weapons Systems was established. The Group convened annually in the period from 2017 to 2019. At the 2019 Meeting of the High Contracting Parties, the mandate of the Group was extended for two years. The Group has adopted consensus reports in each of its three years of operation. In its 2019 report, it reached conclusions and identified aspects that might benefit from additional clarification or review under each of its agenda items. The Group also agreed on 11 guiding principles (see CCW/GGE.1/2019/3).

B. Digital technologies

13. "Digital technologies" is an umbrella term for a range of technologies that process information in a binary numerical format. They permeate every facet of contemporary life and drive innovation in all sectors of society. Digital technologies are increasingly integrated, as in, for example, the development of smart cities, industrial control systems and personal objects and devices. The increasing reliance on ever more advanced, complex and interconnected digital technologies has led to new vulnerabilities as well as the development of harmful ICT instruments. These vulnerabilities and instruments can be utilized for a range of purposes, including criminal and terrorist use, as well as the development of military capabilities by States. The present section focuses on developments in the field of digital technologies relevant to international peace and security, namely information and communications technologies, including their convergence with artificial intelligence; the dark web; and quantum computing.

Information and communications technologies

14. Information and communications technologies (ICTs), which can be considered a subcategory of digital technologies, comprise a diverse set of tools and resources used to transmit, store, create, share or exchange information, including through the use of the Internet. Global reliance on ICTs continues to grow through new developments in, among others, network technology, data science, cloud computing and the Internet of things. As the composition of ICT software and hardware is generally becoming more complex and the demand for interoperability and integration of platforms and devices rises, the risk of security vulnerabilities and potential exploitation of ICT products and systems is also growing. There is also a risk that vulnerabilities present in weapons systems may be exploited. States have expressed concern over developments in the global ICT environment, including a dramatic increase in incidents involving the hostile or malicious use of ICTs by State and non-State actors. Incidents of concern include those affecting critical infrastructure and associated information systems of States. The harmful use of ICTs could increase the risk of misperceptions, miscalculation and unintended escalation between States and may jeopardize international peace and security.

15. Harmful activity can be directed at different types of ICT networks and systems and can be channelled through different layers of the Internet,[1] including its physical infrastructure, network and routing functionalities, and applications and content. It

[1] This refers to a simplified version of the Open Systems Interconnection model, in which the Internet is conceived as consisting of seven layers.

can also affect technologies that rely on several of these elements, such as cloud-based services or networked devices. Various means and methods are used to target ICT-enabled systems and to exploit vulnerabilities.[2] Malicious software, or malware, is designed to harm or exploit ICT-enabled devices, services or networks, often through a vulnerability unknown to the product owner or user. Types of malware include viruses, ransomware, trojans, worms, cryptojacking and botnets. Malware is commonly transmitted through social engineering, whereby a user is lured into activating malware under false pretences. Harmful activity targeting the network and routing functionalities of the Internet includes the manipulation of routing protocols and distributed denial of service attacks, whereby a high volume of traffic is directed at a server, often through the use of malware, with the aim of overloading it. Activity that undermines the integrity of the domain name system and other protocols can also have a severe impact, as can interference with physical ICT infrastructure, such as undersea cables and physical network infrastructure.

Information and communications technologies and artificial intelligence

16. Harmful ICT activities increasingly make use of artificial intelligence, including through operations known as autonomous cyber operations. Malware with autonomous functions can move laterally within networks by learning the normal patterns of business operations and security protocols; its malicious activity thereby evades detection. In addition, harmful ICT activity, such as distributed denial of service attacks, can be automated and consequently scaled up. Software that employs algorithms may be used to efficiently scan operating software and security systems to identify vulnerabilities. Algorithms that scan and analyse large data sets, including from social media, can improve the effectiveness of social engineering techniques. Artificial intelligence is also applied to defend against harmful ICT activities.

The dark web

17. The dark web refers to the part of the Internet that is not searchable by traditional search engines and is hidden behind anonymity software. There have been reported misuses of the dark web to facilitate the illicit trade in firearms, ammunition and explosives.[3] Also of concern is the fact that it may be utilized to facilitate the transfer of materials and technologies that could be misused by malicious non-State actors to develop weapons of mass destruction. Undisclosed software vulnerabilities in ICT systems are also known to be traded on the dark web.

Quantum computing

18. Quantum computing is an emerging field that may have both an enabling and a transformative impact. Quantum properties, most notably superposition and entanglement, would potentially allow for exponentially higher computing speeds and an ability to solve problems of higher complexity, as compared with the current generation of computers. Although applied engineering in the field of quantum computing remains at an early stage, research into its military applications currently takes place in areas such as information and communications technologies and intelligence, surveillance and reconnaissance.

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[2] See the survey of threats and vulnerabilities in the ICT environment in Camino Kavanagh, "Stemming the exploitation of ICT threats and vulnerabilities: an overview of current trends, enabling dynamics and private sector responses", United Nations Institute for Disarmament Research, 2019.

[3] See Giacomo Persi Paoli, *The Trade in Small Arms and Light Weapons on the Dark Web: A Study* (New York, Office for Disarmament Affairs (UNODA) Occasional Papers No. 32, 2018).

Relevant intergovernmental processes, bodies and instruments

19. Developments in the field of information and telecommunications in the context of international security have been on the agenda of the General Assembly since 1998.[4] Since 2004, the Assembly has established five groups of governmental experts to study possible cooperative measures to address existing and potential threats in the ICT environment. Three of these groups have agreed on substantive reports with recommendations to address the threats posed by the use of ICTs, including recommendations on norms, rules and principles for the responsible behaviour of States, confidence-building measures, capacity-building and how international law applies to the use of ICTs.[5]

20. In 2018, the General Assembly established an open-ended working group on developments in the field of information and telecommunications in the context of international security (see resolution 73/27), open to all Member States. In 2019, the group held an informal intersessional consultative meeting with interested parties, namely, representatives of business, non-governmental organizations and academia, to share views on issues within the group's mandate.[6] The Assembly in 2018 also mandated the establishment of a new group of governmental experts on advancing responsible State behaviour in cyberspace in the context of international security (see resolution 73/266), which, in addition to its regular sessions, is holding two informal consultative meetings, open to all Member States, as well as a series of regional consultations.[7]

21. Quantum computing and the use of the dark web in the context of international security have not yet been the subject of dedicated intergovernmental deliberations. The dark web may pose a significant risk to effective State control over intangible technology transfers, which may be of relevance to the obligations outlined in Security Council resolution 1540 (2004) and its follow-up resolutions.

C. Biology and chemistry

22. The development, production, stockpiling, acquisition, transfer and use of chemical and biological weapons have long been prohibited under international law. The norms against the hostile uses of chemistry and biology are enshrined in the Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare, the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction (Biological Weapons Convention), and the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction (Chemical Weapons Convention). These norms have been maintained for many years, although the recent use of chemicals as weapons in multiple contexts, combined with advances in chemistry and biology, could undermine these long-held norms.

23. With regard to biological weapons, previous challenges to acquisition associated with either the synthesis of existing agents or the development of novel agents have been overcome by using gene transfer and other biosynthetic engineering approaches.

[4] For more information on intergovernmental deliberations on developments in the field of information and telecommunications in the context of international security, see www.un.org/disarmament/ict-security.

[5] See A/65/201, A/68/98 and A/70/174.

[6] The Chair's letter on the summary report of the informal intersessional consultative meeting is available on the website of the open-ended working group.

[7] The collated summaries of the regional consultations are available on the website of the group of governmental experts.

There are reports that scientists have shown that it is possible to synthesize viruses and bacteria in the laboratory and recreate previously extinct diseases. While this kind of research may be motivated by a desire to better understand such diseases, it raises concerns owing to its dual-use implications. The modification of biological agents can enable or enhance their utility as biological weapons, for example by increasing their pathogenicity, circumventing host immunity, enhancing transmissibility and host range, conveying or improving antimicrobial and drug resistance and boosting their environmental stability. Recent attention has focused on genome editing and techniques such as clustered regularly interspaced short palindromic repeats, which raise ethical and security questions and concerns.[8] Developments in production technologies have simplified and reduced production signatures, meaning that a less advanced skill set and less space and time are needed to develop biological weapon agents, thus narrowing windows for detection and interdiction. Advances in areas such as nanoparticles and the sophisticated modelling of dispersal patterns using aerobiology techniques have also contributed to the increased ease with which biological agents can now be delivered. However, it is important to acknowledge that advances in biological sciences and technology have also contributed to improved means and methods for detection, diagnosis and surveillance, as well as for vaccine production and investigative techniques.

24. With regard to chemical weapons, the remarkable progress made in understanding life processes at the molecular level brings with it a greater ability to manipulate and interfere with such processes through chemical means. Capabilities in these areas are expected to continue to grow in the foreseeable future. Computational tools to design molecules that can target specific cell types (e.g., organs) and highly active pharmaceutical-based chemicals that act on the central nervous system have led to concerns about the possibility of new types of toxic chemical agents.[9] New approaches to synthesis allow for the creation of unforeseen compounds. At the same time, there is also increased risk from more rudimentary and improvised chemical weapons. The availability of knowledge on improvised chemical dispersal devices, including uncrewed aerial vehicles, combined with easy access to commercially available toxic chemicals, presents new challenges to security and disarmament.

25. The continued crossover between the traditional disciplinary boundaries dividing biology and chemistry also requires consideration. Bulk, fine and, in particular, specialty chemicals are increasingly being produced using biologically mediated processes, such as microbial fermentation or the use of enzymes as catalysts. In addition, substantial advances have been made in the chemical synthesis of molecules of biological origin. In industry and academia, multidisciplinary research teams continue to expand beyond biology and chemistry to incorporate ideas and approaches from physics, computing, engineering, materials science and nanotechnology. This scientific convergence provides significant benefits and has been used to develop improved defensive countermeasures against chemical and biological warfare agents. However, these new approaches and processes, combined with developments in drug discovery and delivery, could also be exploited in the development of new toxic chemicals, or reactive mechanisms thereof, that could be used as weapons.

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[8] See, for example, InterAcademy Partnership, “Assessing the security implications of genome editing technology: report of an international workshop” (2017).

[9] It should, however, be noted that recent incidents have involved known chemical warfare agents, such as sulfur mustard, prepared using a method published in the nineteenth century, and organophosphorus nerve agents developed before and during the Cold War.

Relevant intergovernmental processes, bodies and instruments

26. Both the Biological Weapons Convention and the Chemical Weapons Convention have provisions for review conferences every five years, in which the review of relevant scientific and technological developments is a major function.[10]

27. Both treaties also have more regular means of reviewing relevant developments in science and technology. The Chemical Weapons Convention established a Scientific Advisory Board consisting of 25 eminent scientists. The Scientific Advisory Board periodically establishes temporary working groups to explore important and pertinent topics; the most recent temporary working group focused on investigative science and technology.[11]

28. While proposals for a similar advisory body for the Biological Weapons Convention have been made, it has so far not been possible for States parties to agree on such an approach. From 2012 to 2015, a review of developments in the field of science and technology related to the Convention was a standing agenda item considered by States parties on an annual basis. Starting in 2018, States parties have established an annual Meeting of Experts to review developments in the field of science and technology related to the Convention.[12] The Meeting will address specific topics on an ongoing basis until 2020. A previous temporary working group established by the Organisation for the Prohibition of Chemical Weapons (OPCW) considered convergence and interacted with the Biological Weapons Convention community. The importance of the discussions on convergence between the Chemical Weapons Convention and the Biological Weapons Convention has been recognized and the discussions now take place in a biennial forum on the topic.[13]

29. Pursuant to Security Council resolution 1540 (2004), States are required to establish and strengthen controls to prevent the proliferation of biological and chemical weapons and their means of delivery to non-State actors.

D. Aerospace technologies

Missile technologies

30. Missile technology has civilian and military applications. The engines capable of powering intercontinental ballistic missiles and civilian space launch vehicles are largely indistinguishable. Nonetheless, most of the active technology development described below occurs in the military sphere, although some projects are joint endeavours between military and civilian research organizations.[14]

Guidance, accuracy and manoeuvrability

31. The utility of a missile is constrained by its accuracy and the destructive radius of its warhead. Traditionally, missiles have primarily used inertial guidance – onboard

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[10] See Organisation for the Prohibition of Chemical Weapons (OPCW), documents RC-4/DG.1 and RC-4/DG.2.

[11] At the time of writing, the summary report is being finalized and will be available on the website of OPCW in the near future.

[12] For the reports of the 2018 and 2019 Meetings of Experts, see BWC/MSP/2018/MX.2/3 and BWC/MSP/2019/MX.2/2, respectively.

[13] See Spiez CONVERGENCE, reports of workshops, available at https://www.labor-spiez.ch/en/rue/enruesc.htm.

[14] For example, the Hypersonic International Flight Research Experimentation (HIFiRE) scramjet being developed by the National Aeronautics and Space Administration of the United States of America (NASA), the United States Air Force Research Laboratory, the Defence Science and Technology Organisation of Australia and the University of Queensland.

sensors that detect deviations from the preprogrammed flight path and feed corrections to the manoeuvring system. The accuracy of inertial guidance systems degrades over time and over longer distances. States continue to pursue and refine various technological innovations to increase the accuracy of their missiles. These have included flight trajectory tracking by ground-based radar; optical sensors; radar imaging; and navigation and positioning satellites.

32. Research into manoeuvrable re-entry vehicle technology started in the 1990s, and systems with this capability have been deployed since 2010. They have been designed to deliver either conventional or nuclear payloads. In comparison with re-entry vehicles that follow a ballistic trajectory, the main military advantage is that they may be more capable of evading some missile defences. In theory, they can also target moving objects. To be effective, such systems often require advanced targeting support, including the use of positioning data from satellites and ground-based radars.

33. Technologies that increase the accuracy and manoeuvrability of missiles have various implications. Increases in the accuracy of nuclear-armed missiles over time have led to the deployment of strategic systems of warheads equipped with smaller yields.

34. Increases in the accuracy of conventionally armed missile systems have ostensibly enhanced their military utility as tactical or battlefield weapons, as demonstrated by the use in recent years of these systems in various armed conflicts in the Middle East. This has resulted in the development of longer-range artillery rockets, some of which blur the distinction between such systems and ballistic missiles capable of delivering a nuclear weapon. It has also resulted in a greater capacity of some States, and even non-State armed groups, to use ballistic missiles, originally based on designs for nuclear-capable systems, as tactical weapons. The increased tactical utility of these systems can drive proliferation and pose a challenge to regimes designed to curb the proliferation of ballistic missiles capable of delivering nuclear weapons.

Hypersonic glide vehicles

35. Ballistic missiles typically operate at hypersonic speeds[15] during at least the boost and terminal phase of flight. Some States are developing and deploying vehicles with the ability to glide and manoeuvre at hypersonic speeds over long distances within the atmosphere. Like a manoeuvrable re-entry vehicle, a hypersonic glide vehicle would be launched from a ballistic missile. A hypersonic glide vehicle would, however, separate from its booster at a lower altitude, with most of its flight proceeding on a non-ballistic trajectory, and be sustained by aerodynamic lift. Thus, while a manoeuvrable re-entry vehicle may be capable of evading missile defences in the terminal phase of its flight, hypersonic glide vehicles could also be capable of evading mid-course missile defences. This is not only a result of their manoeuvrability but also because they would spend most of their flight at altitudes below the horizon for terminal defence radars.[16]

[15] The term "hypersonic" is generally understood to describe speeds above Mach 5. "Supersonic" refers to speeds between Mach 1 (the speed of sound, 343 metres per second) and Mach 5.

[16] Ballistic missile trajectories can be divided into boost, mid-course and terminal phases. The boost phase is the initial, powered segment of the flight. Mid-course refers to the segment of the flight after the missile's fuel source has burnt out and before atmospheric re-entry. The terminal phase is the final phase of the missile's flight, commencing with re-entry into the atmosphere. Analysts note that, while the trajectory of a hypersonic glide vehicle may make mid-course interception difficult, the relatively slow speed of such vehicles in the terminal phase may render them easier to intercept in that phase.

36. Research into hypersonic glide vehicles began in the 1930s. More recent military interest in such vehicles appears to stem from the possibility that they could have, for example, the ability to carry out a conventional strike at any place on the planet within minutes or hours; the ability to evade strategic and tactical anti-missile systems; the ability to deploy effective strategic weapons with non-nuclear payloads; and the ability to strike moving targets at a long distance, including at sea. The first known hypersonic glide vehicles were deployed in 2019, using an intercontinental-range ballistic missile as a booster. These developments have given rise to concerns about a new strategic arms competition.

Scramjets

37. States are endeavouring to bring scramjet technology to maturity, including as a strategy for achieving the goal of a reusable aircraft capable of sustaining hypersonic speeds. Also called hypersonic cruise missiles, scramjet-powered missiles use engines which, like ramjets, are air-breathing: they use oxygen from the atmosphere rather than oxygen carried on board for fuel combustion. Existing concepts require that such systems first be accelerated by a boost vehicle to a speed of around Mach 3.5.[17]

38. The first successful scramjet flight test was conducted in 2004. Most successful flight tests of scramjets have lasted only seconds. Remaining technical hurdles to sustained scramjet flight include thermal management and the need for on-board guidance and communications systems capable of operating at extremely high temperatures. While the majority of research in this field is conducted in military settings, academic bodies are also involved and there has been some discussion of possible future civilian aviation applications. Experts believe that scramjets may be fielded within a decade.[18]

39. Traditional jet turbine engines cannot exceed speeds of around Mach 2.5. Previous efforts to test scramjets have therefore relied on single-use missile boosters. One relatively new area of research in this field seeks to develop a hybrid system combining turbine, ramjet and scramjet elements, known as a turbine-based combined cycle engine. Such systems remain in development and have not yet been flight-tested.

Anti-missile and terrestrial anti-satellite systems

40. Anti-missile systems have traditionally focused on countering ballistic missiles, which have predictable flight trajectories. Various conceptual approaches have been taken in systems deployed or under development, including surface-to-air or surface-to-space missiles with explosive warheads, high-speed autocannons, lasers and kinetic impactors designed to intercept at high altitudes or outside the atmosphere.

41. Surface-to-air systems that intercept their target within the lower atmosphere are increasingly common and have been extensively used in some armed conflicts as well as other situations. A number of existing surface-to-air systems were developed on the basis of anti-aircraft systems and are designed to counter shorter-range ballistic missiles and rockets in the terminal phase of flight. Generally, such systems have not raised concerns about stability, although their widespread deployment may prompt rivals to develop countermeasures, such as firing missiles in salvos or seeking manoeuvrable systems designed to evade interception. The use of directed energy for

[17] Ramjets, which have existed since the 1940s, slow the air entering the combustion engine to subsonic speeds and operate at speeds of up to Mach 6. In a scramjet, combustion takes place with air moving at supersonic speeds.

[18] See, for example, James M. Acton, *Silver Bullet? Asking the Right Questions About Conventional Prompt Global Strike*, p. 55.

anti-missile applications, including lasers mounted on aircraft, has been explored, although no such system has been deployed. Proponents of the concept argue that such systems could be used for defence against missiles in the boost phase.

42. Anti-missile systems that are designed to strike outside of the atmosphere typically target longer-range missiles that are in either the mid-course or terminal phase of flight. Such systems generally use kinetic impactors rather than explosives. Such interceptors manoeuvre with on-board thrusters, like spacecraft, and require advanced sensors to track their target. More capable systems, defined in terms of the maximum velocity achieved when the booster engine burns out, can strike missiles travelling at higher altitudes and at greater lateral ranges compared with the location of the interceptor's launcher.

43. It has been demonstrated that the more capable of these systems have a de facto ability to strike satellites in low Earth orbit.[19] Analysts consider that striking a satellite is easier than striking a ballistic missile, given that satellites travel in predictable paths that can be accurately measured far in advance and generally lack any means of evading threats. Serious concerns have been expressed about strategic anti-missile systems, given their connection with strategic nuclear weapons, their ability to strike satellites, and security concepts based on mutual deterrence.

44. Terrestrial missiles have reportedly been developed specifically to strike satellites in low Earth orbit. The launch of a direct-ascent missile capable of striking a satellite at the altitude of geostationary orbit[20] has been reported. To reach such altitudes, a booster would require the capability of a space-launch vehicle. This is particularly notable given that, up to this point, space-launch vehicles have not been understood as having capabilities suitable for any military mission.

Relevant intergovernmental processes, bodies and instruments

45. The General Assembly established three panels of governmental experts on the issue of missiles in all its aspects between 2001 and 2008.[21] Although the issue of missiles remains on the agenda of the First Committee, there has been no resolution on the topic since 2008.[22]

46. There are two intergovernmental regimes concerned with voluntary measures related to missile technology: the Missile Technology Control Regime and The Hague Code of Conduct. The Missile Technology Control Regime was established in 1987 with the aim of limiting the spread of ballistic missiles and other uncrewed delivery vehicles capable of delivering weapons of mass destruction. It has 35 members. Under The Hague Code of Conduct, which was adopted in 2002, States make politically binding commitments to exercise maximum restraint in developing, testing and deploying ballistic missiles and to uphold transparency measures regarding policies on, and launches of, ballistic missiles and civilian space vehicles. A total of 143 States subscribe to The Hague Code of Conduct.

47. The Advisory Board on Disarmament Matters considered hypersonic weapons in 2016, recommending further study on the topic. To that end, the Office for Disarmament Affairs and the United Nations Institute for Disarmament Research hosted a "track 1.5" meeting on hypersonic weapons in 2018, which was followed by

[19] Low Earth orbit is commonly regarded as extending up to 1,000 km, in comparison with the maximum altitude of approximately 1,200 km of an intercontinental ballistic missile on a standard trajectory.

[20] 35,786 km above Earth.

[21] See A/57/229, A/61/168 and A/63/178.

[22] See General Assembly resolution 63/55.

the publication of a study entitled "Hypersonic weapons: a challenge and opportunity for strategic arms control".

48. It has been reported that the Russian Federation and the United States of America have discussed hypersonic glide vehicles in bilateral arms reduction talks, including in the context of an agreement to succeed the Treaty between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms.

49. The issue of terrestrial anti-satellite weapons has been raised in various United Nations bodies concerned with outer space security, including the Conference on Disarmament, the Disarmament Commission and the First Committee of the General Assembly.

Space-based technologies

50. While military and security interests drove early efforts to access and use space, the use of space today serves a broad range of activities in the civil, commercial, economic and military sectors. Advanced military forces can be heavily dependent on space-based technologies for fundamental tasks, such as early warning systems, navigation, surveillance, targeting and communication. Satellites are particularly vulnerable to various counter-space capabilities, including harmful use of ICTs, radio electromagnetic interference, laser dazzling, spoofing and jamming, and terrestrial anti-satellite hit-to-kill weapons. A number of these capabilities can also target the terrestrial component of space systems. However, the present section focuses on recent developments in space-based technologies with possible anti-satellite applications.

On-orbit servicing and active debris removal

51. Robotic on-orbit servicing capabilities are being developed by national civilian and military entities and commercial companies. Such capabilities rely on a number of component functions, including manoeuvring, close approach, rendezvous, docking and grappling. Certain operations require some of these functions to be performed autonomously. Applications for such capabilities include satellite refuelling, repair and transportation and, potentially, asteroid mining. Systems capable of such activity in both low Earth orbit and geosynchronous orbit are being actively developed and brought into operation. In February 2020, the first commercial satellite servicer successfully docked with the 17-year-old Intelsat 901 satellite.

52. The related concept of active debris removal refers to the use of a third-party system to dispose of space debris, as opposed to an object being designed to remove itself from orbit. Various State and commercial entities are developing and testing such systems through a variety of technological pathways. Most involve rendezvousing with a target, capturing it and modifying its trajectory so that it will burn up in the atmosphere. Strategies being explored include the use of small satellites equipped with robotic arms, nets, harpoons and adhesives. There have also been academic studies on the feasibility of using space-based lasers to destroy relatively small-scale space debris. No such systems have yet reached operational capability, although certain concepts have been tested in space.

53. While automated rendezvous and proximity operations in space have been carried out for decades, on-orbit servicing differs in the sense that it involves interactions between two space objects that were not specifically designed for that purpose. There is concern that satellites capable of performing rendezvous and proximity operations could be used for unwanted, risky, disruptive or hostile acts or that it would be impossible to interpret their purpose directly from their behaviour,

particularly given their ability to approach a satellite without its cooperation and in the absence of norms for the responsible use of such systems.

Space-based lasers

54. Space-based lasers continue to lack the energy to cause harm to other spacecraft or to terrestrial objects owing to the limited energy available in relation to ground-based lasers, which can dazzle sensors or, at high enough power levels, damage sensitive components. Laser-based communication between satellites has been explored and deployed. It is less susceptible to conventional jamming techniques than radio communication. The first laser-based communication system was deployed in November 2016. The further development of such systems could lead to higher-powered space-based lasers. Research is also under way into the use of space-based lasers for deflecting asteroids or other objects posing a risk of impacting Earth.

Relevant intergovernmental processes, bodies and instruments

55. The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies entered into force in 1967 after consideration by the Committee on the Peaceful Uses of Outer Space and by the General Assembly. The Treaty provides the basic framework for international space law, including prohibiting the placement of nuclear weapons or any other weapons of mass destruction in orbit or on celestial bodies or the stationing of such weapons in outer space in any other manner.[23]

56. The prevention of an arms race in outer space has been on the agenda of the Conference on Disarmament since 1985 and has been one of the core issues on its agenda for more than two decades.

57. The Group of Governmental Experts on further practical measures for the prevention of an arms race in outer space, established pursuant to General Assembly resolution 72/250, met in two sessions in 2018 and 2019. It discussed a number of emerging issues, including possible measures related to rendezvous and proximity operations as well as active debris removal. The Group was ultimately unable to reach consensus on a final substantive report (see A/74/77).

58. The Group of Governmental Experts on Transparency and Confidence-building Measures in Outer Space Activities met in 2012 and 2013 and agreed upon a report by consensus (A/68/189). In 2018, the Disarmament Commission agreed to add to its agenda for the 2018–2020 cycle the following item: “In accordance with the recommendations contained in the report of the Group of Governmental Experts on Transparency and Confidence-building Measures in Outer Space Activities (A/68/189), preparation of recommendations to promote the practical implementation of transparency and confidence-building measures in outer space activities with the goal of preventing an arms race in outer space”. In 2019, the Committee on the Peaceful Uses of Outer Space adopted the preamble and 21 guidelines for the long-term sustainability of outer space activities. The Committee decided to re-establish the Working Group on the Long-term Sustainability of Outer Space Activities with a five-year plan, commencing in 2020.

[23] The other United Nations treaties on outer space are the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space; the Convention on International Liability for Damage Caused by Space Objects; the Convention on Registration of Objects Launched into Outer Space; and the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies.

E. Electromagnetic technologies

59. A variety of weapon types under development or recently deployed use electromagnetic energy to produce their primary destructive effects. They can be broadly divided into systems that: (a) deny, impede or destroy an adversary's ability to access the electromagnetic spectrum, in a practice that is commonly termed electromagnetic warfare (also referred to as electronic warfare); and (b) destroy a target by causing physical damage. Railguns, which employ electromagnetic energy to propel a projectile, fall into the latter category. Different types of directed-energy weapons may fall into either or both categories.

60. Many modern weapon systems, in particular aircraft and missiles, employ sensors, guidance systems and communications that rely on the electromagnetic spectrum for their operation. Electromagnetic warfare seeks to exploit that reliance through jamming, disturbing, spoofing or hacking, and can employ various means, ranging from radiofrequency weapons to, hypothetically, nuclear electromagnetic pulses. Systems with these capabilities have been in place since at least the 1970s. In general, they are much less expensive to use than comparable countermeasures, such as air defence systems. Electromagnetic warfare systems can be mounted on ground vehicles, crewed and uncrewed aircraft and ships. In theory, they can also be placed under the sea or in outer space. Militaries use electromagnetic systems to prevent electromagnetic attacks on their systems. Advances in electronics are driving innovations in this area, which include systems that can jam multiple frequencies simultaneously, can target with greater precision and are more difficult to attribute to a given actor. Electromagnetic weapons have the potential to disrupt or disable digital connectivity on a large scale, although attempts are being made to better defend certain critical infrastructure against such attacks.

61. Directed-energy weapons are a specific subset of electromagnetic warfare systems that, in some cases, could also be employed to have a destructive physical effect. Technological avenues are being pursued in that regard, including high-energy lasers, high-power microwaves, millimetre waves and particle beams. High-energy lasers appear to have the most immediate potential for destructive and disruptive applications. Laser weapons are attractive to militaries, in particular for air and missile defence applications, owing to their precision, speed and low cost per "munition". Terrestrial lasers have reportedly been used by States to blind or dazzle the optical sensors of surveillance satellites passing over their territory. In recent decades, advances in solid-state laser technology have at least partially addressed size and weight concerns. In this connection, research is under way on the possible use of very small fibre lasers in arrays. Militaries are also examining the use of free-electron lasers as directed-energy weapons. Several high-energy laser weapons with kinetic effects are known to be deployed, and many others are known to be undergoing development and testing. Lasers are widely used in civilian sectors.

62. Railguns use electromagnetic energy to fire solid projectiles. Such weapons, which would have ranges of around 200 km or less, could theoretically be capable of launching projectiles at greater speeds than rockets or missiles with engines that use chemical propellants. They would therefore be capable of destroying targets with their kinetic energy alone. The projectiles employed by railgun systems would be much lighter and less costly than missiles with comparable ranges. Technical barriers to the fielding of railguns include their requirements for a large power supply and for extremely robust components in the launcher and projectiles. Advances in energy storage and the miniaturization of robust electronic circuits have aided the development of viable prototypes. It has been reported that railguns are being developed for anti-access/area denial and naval defence roles and that a first such weapon has been tested. Such weapons are expected to be deployed within 5 to 10 years.

Relevant intergovernmental processes, bodies and instruments

63. Weapons covered in the present section that have been addressed in recent intergovernmental deliberations are those used in electromagnetic warfare and directed-energy weapons, which were discussed by the Group of Governmental Experts on further practical measures for the prevention of an arms race in outer space (see A/74/77 and also section D of the present report).

F. Materials technologies

64. The present section addresses developments in materials technologies as they apply to weapons and related concerns.

65. Developments enabling the modular design and manufacture of small arms and light weapons, as well as the increasing use of polymers in their construction, could undermine the long-term viability of weapons marking and the ability of national authorities to keep accurate records and undertake tracing.

66. Modular weapons are composed of multiple components that can be reconfigured either by the manufacturer, at an armoury workshop, or in the field by a user. Such reconfiguration may or may not require the use of specific tools, resulting in a variable configuration that poses a potential challenge to ensuring that a unique marking is preserved for the weapon as a whole. The International Instrument to Enable States to Identify and Trace, in a Timely and Reliable Manner, Illicit Small Arms and Light Weapons (International Tracing Instrument) requires a unique marking on the essential or structural component of the weapon, such as the frame and/or receiver.

67. While the majority of small arms and light weapons are made using traditional materials such as steel, wood and Bakelite, the increasing use of polymers in manufacturing techniques could undermine the long-term viability of markings. Weapons markings on polymers are relatively easy to alter or remove in comparison with marks on weapons made of more traditional materials such as steel. Polymer plastics were originally used for production only of non-structural weapons components, such as grips. However, such materials have subsequently been integrated into the manufacture of other parts of weapons, including the frame. The increased use of these materials is likely due, in part, to their cheaper cost and lesser weight; it is therefore important not to lose sight of the security implications associated with shortcuts in weapon designs.

68. Additive manufacturing, also known as three-dimensional printing, is a family of production technologies that fabricate objects by adding successive layers according to a digital design. Compared with traditional production techniques, it is cheaper at scale, can build more complex structures and does not rely on skilled human operators. Additive manufacturing techniques were first developed in the 1980s, but their use for military applications is relatively recent.

69. Additive manufacturing can create new challenges for controlling the proliferation of weapons and related items. Digital design files in particular can be transferred or widely disseminated with ease. Additive manufacturing is already being used in the aerospace and defence industries for the production of aircraft and missile components, including engines. States are also studying the use of additive manufacturing to create novel warhead structures. The quality of both the material and the manufacturing technique remains a concern.

70. Nanotechnology refers to the manipulation of objects at a scale of between 1 and 100 nanometres. It is a very broad field with numerous potential civilian and

military applications. Engineered nanomaterials can have a range of attractive characteristics, including increased electrical conductivity, hardness and strength, and reduced weight. Possible applications for such materials have been explored for at least a decade. In addition to applications such as cloaking, camouflage and smart armour, military forces have examined the use of nanomaterials to increase the energy released by explosives. Concern has been expressed about the potential for nanotechnology to enhance the delivery of chemical and biological weapons.

Relevant intergovernmental processes, bodies and instruments

71. Since 2011, States have consistently considered developments in small arms and light weapons manufacturing, technology and design in meetings on the Programme of Action to Prevent, Combat and Eradicate the Illicit Trade in Small Arms and Light Weapons in All Its Aspects and the International Tracing Instrument (see A/CONF.192/2018/RC/3, sects. II.A.4 and III.F).

72. During the third United Nations Conference to Review Progress Made in the Implementation of the Programme of Action to Prevent, Combat and Eradicate the Illicit Trade in Small Arms and Light Weapons in All Its Aspects, held in 2018, States committed, in particular, to take into account the challenges related to modular design and the use of polymers, notably the difficulties encountered in marking and tracing. States reiterated that small arms and light weapons must be durably marked in line with the International Tracing Instrument and noted that unique markings on the essential or structural component of a modular weapon were fundamental to traceability.

73. As requested by the participants in the Conference, the Secretary-General sought the views of Member States on recent developments in the manufacturing, technology and design of small arms and light weapons, in particular polymer and modular weapons, including associated opportunities and challenges, as well as on the impact of those developments on the effective implementation of the International Tracing Instrument, and made recommendations on ways of addressing them. The Secretary-General's consolidated report on the illicit trade in small arms and light weapons in all its aspects and assistance to States for curbing the illicit traffic in small arms and light weapons and collecting them (A/74/187) includes a non-exhaustive list of elements relating to modular weapons and polymer design for a possible supplementary annex to the International Tracing Instrument.

74. During consultations on the 2016 comprehensive review of the status of implementation of Security Council resolution 1540 (2004), States discussed the proliferation-enabling aspects of additive manufacturing. The final document on the review noted that the threat of the proliferation of weapons of mass destruction by non-State actors was complicated by rapid advances in science, technology and international commerce (S/2016/1038, para. 34).

75. Additive manufacturing will have implications for various export control regimes, including the Missile Technology Control Regime, the Nuclear Suppliers Group and the Wassenaar Arrangement. Additive manufacturing has been discussed within the Missile Technology Control Regime for several years and was formally added to its agenda in 2017.

76. Since the Third Review Conference of the States Parties of the Chemical Weapons Convention in 2013, the OPCW Scientific Advisory Board has recommended keeping advances in nanotechnology under review and included a review of the field in its recent report to the Fourth Review Conference.[24]

[24] See OPCW, document RC-4/DG.1.

III. Broader impacts on security and disarmament

77. The present section describes common and interconnected concerns associated with new means and methods of warfare in relation to the potential challenges they pose to the maintenance of peace and security at the global and regional levels as well as to disarmament.

78. A number of new weapon technologies have the potential to contribute to arms competition, including at the strategic level. As international arms control efforts continue to be strained, technological developments in weapons systems such as anti-missile systems and hypersonic weapons are accelerating. Research into military applications of artificial intelligence and autonomy, including in nuclear weapon systems and harmful ICT operations, has been intensified. Finally, technological advancements may lead to new threats to early warning and surveillance infrastructure, potentially contributing to new interest by many States in developing counter-space capabilities.

79. Some new weapons technologies may have the potential of lowering thresholds for the use of force. New weapons technologies could also strain existing legal frameworks, including by facilitating the use of force through non-traditional means, such as electromagnetic jamming, and also in ways that are difficult to understand in the light of traditional thresholds for exercising the right of self-defence. Likewise, the increased use of remotely piloted and autonomous systems arguably facilitates the employment of force in contexts in which the applicable legal framework is unclear. Increased autonomy and remote operation, as well as the pursuit of military operations in the ICT environment and outer space, could, moreover, create perceptions of casualty-free warfare. Finally, some military doctrines specify that attacks against critical infrastructure could warrant consideration of the employment of nuclear weapons.

80. Many new weapon technologies effectively reduce the decision-making time for opposing forces to respond. This is particularly the case for weapons that travel at high speeds or that are designed to be undetectable. Weapons that combine these characteristics may be especially problematic, particularly if they involve systems that can be deployed with either nuclear or conventional munitions. Such technologies can have several undesirable consequences, such as misunderstandings and unintended or inadvertent escalation. Such consequences could be further exacerbated by increased autonomy in weapon systems. Moreover, the increasing reliance of modern military forces on ICTs and space-based technologies, as well as the difficulty of defending against attacks in these spheres, could be destabilizing.

81. Concerns have been raised regarding complications for attribution associated with many of these developments. The harmful use of ICT instruments and remotely controlled technologies has already posed challenges in this regard. For example, there have been instances of civilian uncrewed aircraft being shot down where the identity of the operator was unclear. Harmful ICT activity can be conducted using proxies, which can make the technical attribution of such activity more challenging. Artificial intelligence-enabled ICT and artificial intelligence-enabled kinetic attacks will likely pose additional challenges regarding attribution.

82. Finally, many share concerns that these technologies could easily be acquired or used as tools of proliferation by malicious non-State actors. The combination of additive manufacturing and encrypted or dark web-based communications increases the risk of proliferation. Information on otherwise undisclosed vulnerabilities in ICT systems can also be obtained by non-State actors, including through the dark web. The increasing digitization of information can allow proliferation-sensitive information to be passed electronically from country to country, thereby

circumventing export and import controls that are applied to tangible items. Malicious actors could seek to exploit unique weaknesses in artificial intelligence-enabled systems, drawing, for example, on research into strategies that are able to fool otherwise well-performing machine vision and speech recognition systems through very simple manipulations. Much cutting-edge research in fields such as synthetic biology and artificial intelligence is conducted by academic and private industry researchers who publish their findings. Remotely piloted aerial vehicles are readily available commercially, and more sophisticated models already incorporate autonomy or are otherwise programmable in their basic functions, such as navigation.

IV. Implications for efforts to limit the humanitarian consequences of armed conflict

83. New weapons technologies have implications for the international community's efforts to limit the impact of armed conflict on civilians. They also give rise to concerns over the interpretation of and respect for international humanitarian law.

84. While new weapons technologies may help limit the impact of armed conflict, such as through increased precision and accuracy, they also pose novel threats to civilians and civilian objects. Several reported ICT incidents in recent years have severely hampered the functioning of civilian infrastructure, including government services, banking systems, nuclear facilities, power grids, industrial systems and health services. The risk of exposure to harmful ICT activities may also increase owing to the widespread personal and industrial use of connected devices. Finally, ICT incidents that affect the physical infrastructure of the Internet and hamper connectivity could have a widespread impact on entire populations.

85. A major source of concern about the possible use of weapons in outer space and the intentional destruction of space objects relates to the persistent and unpredictable nature of the space debris that would consequently be generated and that can create a hazard to all objects operating at a similar altitude. This could in turn result in the destruction of other space objects that provide essential civilian services or that support disaster prevention and mitigation and humanitarian activities. The loss of such services could have significant humanitarian consequences.

86. The increasing introduction of artificial intelligence and autonomy into the critical functions of weapon systems has given rise to humanitarian and other concerns. It has yet to be demonstrated that any algorithm can reliably make sufficiently human-like decisions and judgments required to comply with international humanitarian law, including the principles of distinction, proportionality and precaution. Many States have argued that no weapon system can ever be capable of performing such judgments in conformity with international humanitarian law. The complexity of an artificial intelligence system may render it unpredictable or unexplainable, which could lead to situations in which the system fails in unforeseen ways or ways in which a human operator would not. In addition, some actors may not possess the same capacity, interest or understanding necessary to design artificial intelligence-enabled weapons in a manner sufficient to comply with humanitarian and human rights principles as others, leading to perceptions that such actors are unduly benefiting from these technologies and possibly prompting others to lower their own standards to avoid disadvantages. Finally, the use of autonomy in the targeting process of a weapon system may hamper its ability to identify a legitimate target in cluttered dynamic environments, including populated areas.

87. Uncertainty regarding how international humanitarian law applies in new domains can complicate multilateral efforts for regulation and control. Some governmental experts have argued that recognition of the applicability of

international humanitarian law could normalize the conduct of hostilities in new domains or the use of new weapon technologies with unknown or possibly dangerous and destabilizing consequences. It has also been noted that international humanitarian law neither encourages militarization nor legitimizes any form of warfare or renders its use lawful. This uncertainty can pose a number of challenges, given that States may maintain widely divergent views on how international humanitarian law applies or pursue capabilities to offset the perceived advantages of adversaries that might not necessarily respect their international obligations.

88. Certain new weapon technologies also have increasing implications for ensuring respect for human rights. Some weapons, like armed uncrewed aircraft, can enable the use of force in situations outside armed conflicts. Certain uses of enabling technologies by armed forces, such as big data and artificial intelligence in the identification and selection of targets, may raise further concerns in the areas of ethics, data protection and privacy.

V. Processes for responding to general developments in science and technology with implications for security and disarmament

89. While there is a tendency for United Nations disarmament instruments and bodies to address issues related to a single type or category of weapon or domain at a time, various disarmament-related processes and bodies have recently addressed in a more general manner developments in science and technology with implications for security and disarmament.

90. Article 36 of the Protocol additional to the Geneva Conventions of 12 August 1949, and relating to the protection of victims of international armed conflicts, obliges States parties to determine, in the study, development, acquisition or adoption of a new weapon, means or method of warfare, whether its employment would, in some or all circumstances, be prohibited by applicable international law. Developments in science and technology have driven increasing interest in the sharing of information on national processes for carrying out such reviews, which could help to build confidence in how States fulfil this responsibility, ensuring predictability with respect to the potential introduction of destabilizing new technologies and promoting common understanding regarding international law, in particular international humanitarian law.

91. The Convention on Certain Conventional Weapons is a framework that has served to address developments in science and technology of relevance to its purpose.

92. In 2018, the Conference on Disarmament established five subsidiary bodies to start a gradual process encompassing all substantive agenda items, as well as emerging and other issues relevant to the substantive work of the Conference in accordance with decision CD/2119. The fifth subsidiary body addressed, inter alia, developments in science and technology, information and communications technologies, and the weaponization of artificial intelligence (see CD/2141).

93. The Advisory Board on Disarmament Matters has in recent years considered and made recommendations on a number of scientific and technological developments with possible implications for security and disarmament.

94. In its resolution 2325 (2016), the Security Council called upon States to take into account developments on the evolving nature of risk of proliferation and rapid advances in science and technology in their implementation of resolution 1540 (2004).

VI. Conclusions and recommendations

95. Many of the developments addressed in the present report are either the subject of recent or active multilateral deliberations within the United Nations or have been addressed as a part of active processes. United Nations entities will continue to support and facilitate existing and potential new processes to address emerging challenges before they can pose a danger to peace and security, humanitarian principles or other purposes and objectives of the Organization.

96. Various actions relating to emerging technology set out in the Secretary-General's report entitled "Securing our common future: an agenda for disarmament" recognize the importance of multi-stakeholder engagement and commit to facilitating it in various contexts. The activities carried out so far have underscored the high level of interest among actors in industry and the private sector in engaging in intergovernmental processes and having an opportunity to share their views. Many States also have demonstrated their wish to practise inclusiveness and transparency with their own private sectors. It is recommended that United Nations bodies and entities continue to encourage multi-stakeholder and geographically equitable engagement, including by industry and the private sector, through formal and informal platforms.

97. Moving forward, Member States are encouraged to continue to seek ways of integrating reviews of developments in science and technology into their work, including through processes to review the operation of treaties and within the primary United Nations disarmament organs.

98. As a contribution to maintaining awareness of developments in science and technology and their potential impact on international security and disarmament efforts, it is recommended that reports containing updates to the information in the present report should continue to be submitted on an annual basis.