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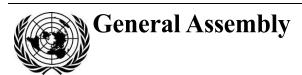
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**Role of science and technology in the context of
international security and disarmament**

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

Report of the Secretary-General

Summary

　　The present report provides an overview of scientific and technological developments of relevance to weapons, means or methods of warfare and their potential impact on international security and disarmament efforts, as well as developments in relevant intergovernmental forums, pursuant to General Assembly resolution 77/43. It covers artificial intelligence, autonomy and uncrewed systems, digital technologies, biology and chemistry, space and aerospace technologies, electromagnetic technologies and materials technologies. In addition, gender considerations are addressed in the report.

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* A/78/150.

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I. Introduction

1.   In paragraph 4 of its resolution 77/43 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-eighth session an updated report on current developments in science and technology and their potential impact on international security and disarmament efforts.

2.   Science and technology contribute to human development and prosperity and are key enablers of efforts to implement the 2030 Agenda for Sustainable Development. As the Secretary-General has noted in his policy brief on A New Agenda for Peace, it is important to ensure that the steps taken to address the perils of weaponizing new and emerging technologies do not restrict access for countries of the global South to the huge benefits promised by such technologies for the advancement of the Sustainable Development Goals.[1]

3.   There are, however, continuing concerns that developments in science and technology of relevance to security and disarmament are outpacing the capacity of normative and governance frameworks to manage the risks. The benefits of new and emerging technologies cannot come at the expense of global security. Governance frameworks should be put into place in order to minimize harm and address the cross-cutting risks posed by converging technologies.[2]

4.   The present report provides an overview of scientific and technological developments of particular relevance to weapons, means or methods of warfare and their potential impact on international security and disarmament efforts, as well as developments in relevant intergovernmental forums.

II. Recent developments in science and technology of relevance to weapons, means or methods of warfare

A. Artificial intelligence and autonomous and uncrewed systems

5.   There is no universally agreed definition of artificial intelligence, but broadly speaking, it relates to machines with the ability to learn, solve problems, make predictions, take decisions and perform tasks that are considered to require human intelligence. Artificial intelligence comprises several subfields, including machine learning, natural language processing and computer vision. Various applications, such as image processing and generative artificial intelligence, stem from these subfields. Both data and design decisions can cause unintended consequences for international peace and security.

6.   Recent advances in machine learning have primarily been fuelled by faster processors and the availability of ever larger data sets. Several qualities make artificial intelligence appealing, including the potential for improvements in efficiency, automation and analytical capabilities.

7.   Uncrewed systems can be piloted remotely, semi-autonomously or autonomously, and they exist in the aerial, ground and maritime domains. Aerial systems remain the most common, although there has been growing development and use of maritime and ground systems. Uncrewed systems comprise a range of technologies, including sensors and onboard and remote computing. While artificial intelligence is not a required function of an uncrewed system, it is increasingly integrated for a variety of

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[1] A/77/CRP.1/Add.8.
[2] Ibid., action 11.

purposes, including piloting, object detection and tracking. While many components of uncrewed systems can be dual-use, systems that are intended for use by the military tend to have higher technical performance characteristics, such as better endurance and payload capacity, than systems used for civilian purposes.[3]

Military applications and implications

8. Military applications of artificial intelligence are broad and include both weapon-related functions, such as targeting and attack, and non-weapon functions, such as operational support and logistics. Some States have already tested or fielded a variety of autonomous systems, including uncrewed systems capable of autonomous navigation; coordinated mobility and swarming systems; systems that sort and analyse intelligence data; defensive and offensive information and communications technology (ICT) systems; and simulation and training applications.

9. The definition of an autonomous weapon system is the subject of continuing international deliberation.[4] Autonomous weapon systems, however, are generally understood to employ autonomy in critical functions during an attack, including target selection and the firing of a weapon. 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 environments.

10. Potential military applications of autonomous systems include the performance of tasks that are tedious, repetitive or require more endurance, speed, reliability or precision than a human operator can provide. These attributes can make such systems attractive to armed forces and non-State actors. States have expressed concerns about the challenges posed by autonomous weapon systems, including ensuring respect for international humanitarian law and other bodies of international law, the maintenance of international peace and security, a lowered threshold for conflict and ethical considerations.

11. The versatility of uncrewed systems and their potential to reduce risk to the life of the operator compared with crewed equivalents makes these systems increasingly attractive to both State and non-State actors. The dual-use nature of the technologies behind uncrewed systems means that both State and non-State actors can access uncrewed systems, or their components, and make use of them to achieve military objectives. In addition, the use of armed uncrewed systems risks lowering the threshold for the use of force. Uncrewed systems are also vulnerable to interference, including hacking.

Relevant intergovernmental processes, bodies and instruments

12. At the 2022 Meeting 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, it was decided to continue the work of the Group of Governmental Experts on Emerging Technologies in the Area of Lethal Autonomous Weapons Systems.[5] It was also decided that the Group should intensify the consideration of proposals and elaborate, by consensus, possible measures, including taking into account the example of existing protocols within the Convention, and other options related to the normative and operational framework on emerging technologies in the area of lethal autonomous weapon systems, building upon the recommendations and conclusions of the Group of Governmental Experts related to emerging technologies in the area of lethal

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[3] United Nations Institute for Disarmament Research (UNIDIR), "Uncrewed aerial, ground, and maritime systems: a compendium" 2023.
[4] See CCW/GGE.1/2019/3.
[5] See CCW/MSP/2022/7.

autonomous weapon systems, and bringing in expertise on legal, military and technological expertise.

13. On 18 July 2023, the Security Council held a high-level briefing on the theme "Artificial intelligence: opportunities and risks for international peace and security", at which the Secretary-General made a statement.[6] In its resolution 51/22, the Human Rights Council requested its Advisory Committee to prepare a study examining the human rights implications of new and emerging technologies in the military domain, taking into account ongoing discussions within the United Nations system, and to present the study to the Council at its sixtieth session.

14. A variety of processes, bodies and instruments make reference to uncrewed systems. These include the Group of Governmental Experts on the continuing operation and relevance of the United Nations Register of Conventional Arms and its further development, which added a distinction for crewed versus uncrewed rotary-wing aerial systems, in line with the existing distinction for fixed-wing systems;[7] the Conference of States Parties to the Arms Trade Treaty; and the Delhi Declaration on countering the use of new and emerging technologies for terrorist purposes.[8]

B. Digital technologies

15. The increasing reliance on ever more advanced, complex and interconnected digital technologies has led to new vulnerabilities and to the development of harmful ICT instruments. Moreover, a number of States are developing ICT capabilities for military purposes.

Information and communications technologies

16. 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, inter alia, network technology, data science, cloud computing and the Internet of things. States have expressed concern over developments in the global ICT environment, including a dramatic increase in incidents involving the malicious use of ICTs by State and non-State actors. Incidents of concern include those affecting critical infrastructure and the infrastructure that underpins the general integrity and functioning of the Internet. The malicious use of ICTs could increase the risk of misperception and unintended escalation and may jeopardize international peace and security.

17. Harmful activity can be directed at different types of ICT networks and systems and can be channelled through different vectors, including technology, processes and people.[9] Various methods are used to target ICT-enabled systems and to exploit vulnerabilities. Malicious software, or malware, is designed to harm or exploit ICT-enabled devices, services or networks, at times through a vulnerability unknown to the product owner or user. Malware is commonly transmitted through social engineering, whereby a user is lured into activating it under false pretences. The proliferation of ransomware and "wiperware" is gaining particular attention. Malicious activity targeting ICT-enabled devices can exploit vulnerabilities in software, hardware or firmware, as well as vulnerabilities found along the supply chain. Undisclosed software vulnerabilities in ICT systems are also known to be traded on the dark web.

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[6] António Guterres, Secretary-General of the United Nations, remarks to the Security Council on artificial intelligence, 18 July 2023.
[7] See A/77/126.
[8] S/2022/998.
[9] UNIDIR, "A taxonomy of malicious ICT incidents", 2022.

Activity targeting network and routing functionalities of the Internet, including manipulation of routing protocols and the domain name system, continues to be a cause of concern. Distributed denial-of-service attacks are also broadly deployed.[10] Moreover, interference with critical infrastructure and critical information infrastructure, such as undersea cables or telemetry data, can have a severe impact.

Information and communications technologies and artificial intelligence

18.   Artificial intelligence can be used to protect ICT systems from malicious intrusion. Artificial intelligence may be used to scan operating software and security systems to identify real time system- and network-level vulnerabilities. Algorithms that scan and analyse large data sets, including from social media and data breaches, can also improve the effectiveness of social engineering techniques. By contrast, malware with autonomous functions can move laterally, without detection, within networks by learning the normal patterns of business operations and security protocols. In addition, harmful ICT activity, such as distributed denial-of-service attacks, can be automated, facilitating a larger number of incidents at quicker speeds. Artificial intelligence tools can pose a variety of threats to international peace and security, including by identifying and exploiting vulnerabilities in systems and networks. Generative artificial intelligence tools, such as language processing models, could be used for the creation of malicious code, not only in peacetime but also during armed conflict. They can also be used to generate so-called deep fakes, extremist propaganda or other destabilizing content, including in the context of armed conflict.

Quantum technologies

19.   The integration of quantum properties into such applications as computation, sensing and imaging, and cryptography can have a considerable enabling and transformative impact, including for international peace and security. For example, quantum computers allow for exponentially higher computing speeds and an ability to solve problems of higher complexity. Quantum sensing and imaging allow for the capture of objects with a resolution beyond what is possible with classical sensor technologies. Quantum cryptography is a method of encryption that is highly secure. In addition to those potential benefits, there remains the possibility that the same advances in quantum technologies could pose risks to international peace and security. Quantum technologies, for instance, are expected to challenge current cryptographic systems, making digital infrastructure, including infrastructure that provides essential services to the public, vulnerable to malicious ICT activities.

Relevant intergovernmental processes, bodies and instruments

20.   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.[11] Since 2004, four groups of governmental experts have agreed on substantive reports with recommendations to address the threats posed by the use of ICT, including recommendations on norms, rules and principles for the responsible behaviour of States, confidence-building measures capacity-building, and the ways in which international law applies to the use of ICTs (see A/65/201, A/68/98, A/70/174 and A/76/135).

21.   The open-ended working group on developments in the field of information and telecommunications in the context of international security established by the General

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[10] When a high volume of traffic is directed at a server, often through the use of malware, with the aim of overloading it.

[11] 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.

Assembly pursuant to its resolution 73/27 adopted a report by consensus in March 2021 (A/75/816). The General Assembly endorsed the report and its recommendations in decision 75/564.

22. In 2020, the General Assembly established a new open-ended working group on security of and in the use of information and communications technologies to, inter alia, further develop the rules, norms and principles of responsible behaviour of States; continue to study existing and potential threats in the sphere of information security and how international law applies to the use of ICTs by States; and consider confidence-building measures and capacity-building. The working group adopted its first progress report in July 2022 (A/77/275). That report contains a number of recommended next steps, including, inter alia, the establishment of a global, intergovernmental points of contact directory.

C. Biology and chemistry

23. The norm against the hostile uses of chemistry and biology is long-standing and enshrined in international law through the Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction of 1972 and the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction of 1993. However, recent uses of chemicals as weapons, allegations of the development of biological weapons and advances in chemistry and biology threaten to undermine these legal and normative measures. The coronavirus disease (COVID-19) pandemic has exposed the vulnerability of modern societies to biological agents and could increase the interest of some State and non-State actors in the hostile use of biology.

24. As stated in the Secretary-General's policy brief on A New Agenda for Peace, multiple technologies in the life sciences are advancing and converging to generate considerable potential benefits for society at large. However, the same technologies also raise significant safety and security issues and could facilitate the development of new biological weapons. Trends in a number of broad areas are facilitating advances that should be monitored for any potential security implications. For example, advances in genome editing technologies enable relatively easier and more precise manipulation of the genetic code of life, as a result of which it is now possible to read, write and, increasingly effectively, edit DNA. The convergence of the life sciences with big data and machine learning enables large amounts of data to be collected and analysed for patterns that can address public health challenges more effectively.

25. Research and development in those fields are overwhelmingly undertaken for such peaceful purposes as the development of new vaccines and therapeutics. Along with other technologies, these developments could play a significant role in addressing societal challenges and strengthening the international legal regime against biological weapons. For example, big data and DNA sequencing could aid investigations of non-compliance with the Biological Weapons Convention and facilitate the timely identification and characterization of causative agents, thereby expediting the provision of more effective assistance in the event of a violation. The benefits that such developments bring notwithstanding, several ethical, legal, safety and security concerns exist. These include developments that could feed into new forms of biological weapons, ease access to or production of known biological weapons, or complicate existing means of detecting and responding to disease.

26. For example, improved understanding of immunology could facilitate the development of vaccines and therapeutics. However, the same knowledge could be exploited for hostile purposes in developing new weapons capable of more effectively

overwhelming or avoiding recognition by the immune system and rendering such medical countermeasures as vaccines ineffective. Advances in understanding human genetics and reproductive science could play a role in treating infertility and genetically inherited diseases. Yet such technology has raised ethical and safety concerns that it could be exploited for hostile purposes.

27. With regard to chemical weapons, the remarkable progress made in understanding life processes at the molecular level in recent years has resulted in a greater ability to manipulate and interfere with such processes. Capabilities in those areas are expected to continue to grow. Computational tools to design molecules that can target specific cell types 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 biochemical weapon agents. There is also increased risk from more rudimentary chemical weapons. The availability of knowledge of improvised chemical dispersal devices combined with easy access to commercially available toxic chemicals presents ongoing challenges for security and disarmament.

28. The crossover between the domains of biology and chemistry requires consideration by Member States and other relevant stakeholders, in particular industry, to ensure that existing legal instruments are not undermined. 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. Multidisciplinary research teams continue to expand beyond biology and chemistry to incorporate ideas and approaches from other disciplines, including computing, machine learning, materials science and nanotechnology. This convergence is blurring the boundaries between disciplines and provides significant social and economic benefits, including through improved countermeasures against chemical and biological warfare agents. However, new approaches and processes in drug discovery and delivery could also facilitate the identification, development and delivery of new toxic compounds that could be exploited for use as weapons or in the modification of biological agents on a molecular level to affect the route of infection, transmission or severity of disease.[12]

Relevant intergovernmental processes, bodies and instruments

29. Both the Biological Weapons Convention and the Chemical Weapons Convention have provisions for review conferences every five years, at which relevant scientific and technological developments are reviewed. The Ninth Review Conference of the States Parties to the Biological Weapons Convention was held in November and December 2022, and the fifth Review Conference of the States Parties to the Chemical Weapons Convention was held in May 2023.

30. Both treaties contain provisions relating to more regular means of reviewing relevant developments in science and technology. Pursuant to a mandate from the Conference of the States Parties to the Chemical Weapons Convention, the Director-General of the Organisation for the Prohibition of Chemical Weapons (OPCW) established a Scientific Advisory Board within the Organisation. In 2022, the Board convened its thirty-fourth, thirty-fifth and thirty-sixth sessions, and its temporary working group on the analysis of biotoxins concluded its work after holding its fourth, fifth and sixth meetings. In addition, OPCW has inaugurated its Centre for Chemistry and Technology, which will enable it to carry out research activities to support and

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[12] See, for example, Fabio Urbina, Filippa Lentzos, Cédric Invernizzi and others, "Dual use of artificial-intelligence-powered drug discovery", *Nature Machine Intelligence*, vol. 4, 189–191 (March 2022).

strengthen the verification regime, and to conduct training courses and other capacity-building activities.

31. Several proposals have been submitted in recent years regarding a scientific advisory body or mechanism under the Biological Weapons Convention. Many proposals were discussed during the Ninth Review Conference of the States Parties to the Biological Weapons Convention, which established the Working Group on the strengthening of the Convention and called upon it to further develop such a mechanism and to discuss scientific and technological developments relevant to the Convention. The importance of the discussions on the convergence between the Biological Weapons Convention and the Chemical Weapons Convention has been recognized.

32. Pursuant to Security Council resolution 1540 (2004), Member 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. In November 2022, the Council extended the mandate of the Security Council Committee established pursuant to resolution 1540 (2004) and its Expert Group until 30 November 2032.

D. Space and aerospace technologies

Missile technologies

33. Developments in emerging technologies are enabling new and expanded functions of missile systems, with implications for international peace and security and efforts to ensure the effective regulation of arms, non-proliferation and respect for humanitarian principles.

Increased accuracy in missile technology

34. A growing number of States continue to pursue and refine various technological innovations to increase the accuracy of their ballistic missiles and artillery rockets. Such innovations have incorporated modern avionics into missile systems; flight trajectory tracking, including by ground-based radar, optical sensors, radar imaging, and navigation and positioning satellites; post-boost vehicles that enable a warhead to manoeuvre outside the atmosphere; and the deployment of re-entry vehicles with aerodynamic controls, enabling those weapons to manoeuvre in the atmosphere, including in the coast and terminal phases of flight.

35. Increases in the accuracy of nuclear-capable missiles could enable more States to deploy strategic weapons with smaller nuclear explosive yields, or with conventional warheads. More accurate nuclear weapons with smaller or variable yields can potentially be assigned to an expanded range of roles and military missions, affecting perceptions of "usability".

36. Increases in the accuracy of missile systems have ostensibly enhanced the perception of the military utility of ballistic missiles as tactical or battlefield weapons, as demonstrated by their proliferation and use in recent armed conflicts, including by State and non-State actors.

37. Increases in the accuracy of large-calibre artillery rockets have enabled the development of larger and longer-range systems that blur distinctions between artillery rockets and ballistic missiles capable of delivering a nuclear weapon. That trend poses a challenge to regimes designed to curb the proliferation of ballistic missiles capable of delivering nuclear weapons.

38. Manoeuvrable warheads can be used to avoid anti-missile systems. Such a capability provides incentives to States to improve and develop capabilities and

concepts for missile defence, some of which can exacerbate tensions or potentially contribute to international instability in certain contexts, in the light of different views that remain on the relationship between offensive and defensive weapon systems.

Hypersonic glide vehicles

39. Ballistic missiles typically reach hypersonic speeds[13] during their flight. Some States are developing and deploying vehicles with the ability to glide and manoeuvre at hypersonic speeds over long distances within the atmosphere, sustained by aerodynamic lift. Like a manoeuvrable re-entry vehicle, a hypersonic glide vehicle would be launched from a booster rocket. Thus, hypersonic glide vehicles could be capable of avoiding mid-course missile defences and challenging terminal defences, owing to their manoeuvrability or because they fly below the horizon for terminal defence radars at distances farther from their targets.

40. Research into hypersonic glide vehicles began decades ago. The first known weapon entered into service in 2019 and was a possibly nuclear-armed hypersonic glide vehicle, boosted by an intercontinental-range ballistic missile. Those developments have led to concerns about new strategic arms competition and may be prompting interest in long-range conventional strike capabilities by a growing number of States. Air-launched ballistic missiles characterized as hypersonic weapons have reportedly been used in the armed conflict in Ukraine.

Powered hypersonic vehicles

41. Most existing types of cruise missiles using traditional jet turbine engines are limited to travelling at subsonic speeds. As a means of developing systems that are more capable of evading air defence and anti-missile systems, a number of States are developing and testing cruise missiles that use new engine types, including scramjets, enabling sustained flight at hypersonic speeds. In recent years, a number of States have tested hypersonic cruise missiles powered by scramjet engines, and a variety of such weapon systems are being designed for launch by ground-, sea- and aircraft-based boosters and armed with conventional or possibly nuclear warheads.

Anti-missile and terrestrial anti-satellite systems

42. There has been rapid growth in the capability and proliferation of anti-missile systems in recent decades, certain developments of which may have implications for international peace, security and stability, as well as for disarmament efforts.

43. Surface-to-air systems that intercept their target within the lower atmosphere and that are designed to counter shorter-range ballistic missiles and rockets in the terminal phase of flight are increasingly common, and they have been extensively used in some armed conflicts and other situations. Generally, such systems have not raised concerns about stability, although their widespread deployment may prompt rivals to develop countermeasures.

44. The use of directed energy anti-missile systems, 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. In many situations, that would entail the forward deployment of such capabilities near launch sites, possibly leading to concerns about stability. Some anti-missile systems are designed to strike missiles outside of the atmosphere in the mid-course phase of flight. Such systems can use kinetic impactors or explosives. The more capable of those systems have a de facto ability to strike satellites in low Earth orbit. Analysts consider that striking a satellite is easier than striking a ballistic

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[13] Generally understood as greater than five times the speed of sound.

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 designed to counter strategic nuclear weapons, given their ability to strike satellites and the impact of such systems on security concepts based on mutual deterrence.

45. Terrestrial missiles have reportedly been specifically developed to strike satellites in low Earth orbit. The test launch of a direct-ascent missile capable of striking a satellite at the altitude of geostationary orbit has also been reported. To reach such altitudes, a booster would likely require the capability of a medium-lift space-launch vehicle, possibly blurring the lines between space launch vehicles and offensive weapons.

Relevant intergovernmental processes, bodies and instruments

46. The General Assembly established three panels of governmental experts on the issue of missiles in all its aspects between 2001 and 2008 (see A/57/229, A/61/168 and A/63/178). Although the issue of missiles remains on the agenda of the First Committee, there has been no resolution on the topic since 2008 (see General Assembly resolution 63/55).

47. There are two intergovernmental regimes comprised of voluntary measures dedicated to missile technology. 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. The Hague Code of Conduct against Ballistic Missile Proliferation, adopted in 2002, includes politically binding commitments by States 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 space launch vehicles. A total of 143 States subscribe to the Code.

48. It has been reported that hypersonic glide vehicles have been discussed in bilateral strategic arms control-related negotiations.

49. The issue of terrestrial anti-satellite weapons has been raised in various United Nations bodies concerned with outer space security, including most recently in the open-ended working group on reducing space threats through norms, rules and principles of responsible behaviours (see General Assembly resolution 76/231). On 7 December 2022, the General Assembly adopted its resolution 77/41, in which it called upon all States not to conduct destructive, direct-ascent anti-satellite missile testing.

Space-based technologies

50. While military and security interests drove early efforts to access and use outer space, this domain now hosts a broad range of civil, commercial, economic and military activities. Military forces are increasingly dependent on space-based technologies for critical tasks, such as early warning, navigation, surveillance, targeting and communication. Space systems, including the space segment, data link and ground terminals, are particularly vulnerable to various counter-space capabilities, including the harmful use of ICTs, electromagnetic interference, laser dazzling, spoofing and jamming, physical attack by co-orbital systems and terrestrially launched anti-satellite weapons.

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 involve a number

of functions, including manoeuvring, close approach, rendezvous, docking and grappling. Certain operations require some of those functions to be performed autonomously. Applications for such capabilities include satellite refuelling, repair and transportation. Systems capable of such activity in both low Earth orbit and geostationary orbit are being actively developed and brought into operation.

52. The related concept of active debris removal refers to the use of spacecraft to dispose of space debris. Various State and commercial entities are developing and testing systems for active debris removal that use a variety of technological techniques. Most strategies for the use of debris removal systems involve rendezvousing with a target, capturing it and modifying its trajectory so that it will burn up in the atmosphere. Techniques being explored include the use of small satellites equipped with robotic arms, nets, harpoons, magnets 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 been put in regular service, 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 both specifically designed to cooperate with each other. 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 with power as low as 10 watts can potentially dazzle or temporarily blind sensors. Some experts believe 40-watt lasers can damage certain sensitive components. Laser-based communication systems have successfully been developed and deployed in the past decade. Such means of communication are less susceptible to conventional jamming techniques than radio transmission. The further development of such systems could lead to increasing deployment of 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 to Earth.

Relevant intergovernmental processes, bodies and instruments

55. Treaties prohibit the placement and installation 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; the establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military manoeuvres on celestial bodies; any nuclear weapon test explosion, or any other nuclear explosion, in outer space; and any military or any other hostile use of environmental modification techniques in outer space.[14]

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 Transparency and Confidence-building Measures in Outer Space Activities agreed upon a consensus report in 2013

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[14] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, articles IV; Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water, article I; and Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, articles I and II.

(A/68/189). The Disarmament Commission, at its 2018, 2022 and 2023 sessions, considered the agenda item entitled "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 accordance with the recommendations set out in the report of the Group of Governmental Experts on Transparency and Confidence-Building Measures in Outer Space Activities". On the basis of its deliberations, the Disarmament Commission reached agreement on a set of conclusions and recommendations regarding that agenda item (see A/78/42). In 2019, the Committee on the Peaceful Uses of Outer Space adopted its Guidelines for the Long-term Sustainability of Outer Space Activities (see A/74/20, annex II). The Committee also re-established, under a five-year plan commencing in 2021, the Working Group on the Long-term Sustainability of Outer Space Activities of the Scientific and Technical Subcommittee.

58. By its resolution 77/250, the General Assembly decided to re-establish the Group of Governmental Experts on Further Practical Measures for the Prevention of an Arms Race in Outer Space, which will meet in 2023 and 2024. The first Group, which had convened in 2018 and 2019, had discussed a number of emerging issues, including possible measures related to rendezvous and proximity operations, as well as active debris removal (see A/74/77).

59. The open-ended working group on reducing space threats through norms, rules and principles of responsible behaviours, which was established pursuant to General Assembly resolution 76/231, is scheduled to conclude its work in 2023. The open-ended working group's mandate is to, inter alia, make recommendations on possible norms, rules and principles of responsible behaviours relating to threats by States to space systems, including, as appropriate, how they would contribute to the negotiation of legally binding instruments, including on the prevention of an arms race in outer space.

E. Electromagnetic technologies

60. A variety of weapon technologies exist or are under development that use electromagnetic energy to achieve their primary effect or as a means of propelling a projectile. These weapons can be divided into three general categories: (a) electronic warfare capabilities, which deny, impede or destroy an adversary's ability to access the electromagnetic spectrum; (b) directed-energy weapons, which use electromagnetic energy to cause damage or destruction; and (c) electromagnetically propelled weapons, such as rail or coil guns, that use electromagnetic energy to accelerate a solid projectile to a high velocity.

61. Modern military systems frequently rely on sensors, guidance systems and communications that use electromagnetic signals. Electronic warfare systems exploit that reliance through jamming, disrupting or spoofing those signals. The term also encompasses systems for countering such attacks. Electronic warfare systems can be human-portable, fixed or mounted on ground vehicles, crewed and uncrewed aircraft, ships and missiles. They can be deployed under the sea or in outer space. Several States are developing ground-based electronic warfare capabilities to disrupt space-based services. Such capabilities have already been used to disrupt space-based services, including broadcast media and position, navigation and timing. Electronic warfare systems have the potential for the large-scale disruption or disabling of digital connectivity, for example, by jamming Internet satellites and their ground stations. The use of such systems can fall within a grey area that some States may regard as being below the threshold of the use of force or armed attack. Nonetheless, the potential use of such capabilities to target critical military infrastructure, such as early warning satellites, has raised concerns in recent years.

62. Directed-energy weapons include lasers, high-power microwaves, millimetre waves and particle beams. Of those, terrestrial-based and naval high-energy lasers may have the most immediate potential for destructive and disruptive applications. Terrestrial-based lasers have also reportedly been used by States to blind or dazzle the optical sensors of surveillance satellites. Research is ongoing regarding very small fibre lasers in arrays, free-electron lasers as directed-energy weapons and electromagnetic pulses as anti-satellite weapons. Directed energy systems for deployment in outer space are under development in several States. These could be used to blind, dazzle or confuse other satellites.

63. Electromagnetically propelled weapons, such as rail or coil guns, could have ranges up to 200 km and could be capable of launching projectiles to greater speeds than chemical propellants. While advances have aided the development of prototypes, technical barriers remain, including the requirement for a large power supply and sufficiently robust components. Such weapons are primarily considered for anti-access/area denial and naval defence roles. Railguns have been test-fired, and such weapons are expected to be deployed before the end of the 2020s.

Relevant intergovernmental processes, bodies and instruments

64. Electronic warfare capabilities and directed energy weapons 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). The current views of Member States can be found in recent reports of the Secretary-General on the disarmament aspects outer space, including documents A/76/77 and A/77/80. The open-ended working group on reducing space threats through norms, rules and principles of responsible behaviours has discussed issues related to electronic warfare in the context of its mandate.

F. Materials technologies

65. Additive manufacturing is revolutionizing manufacturing processes by enabling the decentralized production of an increasing number of parts and components, creating new challenges for the governance and monitoring of supply chains and for export controls. The improvements in both industrial- and commercial-grade printers, the ability to print in an increasing number of materials, even with the same device, and the wealth of open-source knowledge have further lowered the barriers for State and non-State actors to build complex components for a wide range of applications in conventional and unconventional weapon systems. Additive manufacturing has also increased the significance of intangible transfers of technology and software-based designs in the context of arms control.

66. Advances in material sciences, which also benefited from the rise of artificial intelligence, are playing a key role in enabling innovation across multiple domains relevant to peace and security. For example, novel materials have enabled significant progress in miniaturization, weight reduction, energy efficiency, enhanced protection and physical resistance and increased stealth capabilities. These properties have been key enabling factors in the development of modern conventional platforms, including uncrewed systems, as well as weapons systems, their parts and components.

67. Developments in nanotechnology have made it easier to produce and transport chemical and biological agents, potentially hindering non-proliferation efforts. Nanotechnology can also enhance the means of delivery for lethal biological and chemical agents by enabling new and improved processes of encapsulation and aerosolization. When coupled with synthetic biology and chemistry, the technology could also aid in the development of novel agents with enhanced lethality and

resilience. The development of sensors employing nanotechnology is ongoing. Such sensors could be used to detect very small amounts of gases and vapours; those developments could have benefits for disarmament verification efforts.

68. Trends in small arms and light weapons manufacture and design have continued to raise concerns regarding the durability of weapons marking and, by extension, the ability of States to keep accurate records and undertake effective tracing. Modular weapons are composed of multiple components that can be reconfigured. Such modularity presents particular challenges to the requirement in the International Tracing Instrument to Enable States to Identify and Trace, in a Timely and Reliable Manner, Illicit Small Arms and Light Weapons that a unique marking be included on an essential or structural component of a weapon. In addition, the use of polymer plastics in weapons manufacture has raised concerns, given that markings on such material are more vulnerable to erasure and alteration than on more traditional materials, such as steel.

Relevant intergovernmental processes, bodies and instruments

69. The Security Council, through its resolution 2325 (2016), expressed its commitment to consider the use by non-State actors of rapid advances in science, technology and international commerce for proliferation purposes in the context of the implementation of resolution 1540 (2004). The Council also encouraged States to control access to intangible technology transfers and to information that could be used for developing weapons of mass destruction and their means of delivery.

70. At the Eighth Biennial Meeting of States to Consider 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, States considered the implications of new technologies and recommended that the fourth 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 discuss the establishment of an open-ended technical expert group to develop recommendations to ensure the implementation of the International Tracing Instrument and the Programme of Action in the light of recent developments in small arms and light weapons manufacturing, technology and design (see A/CONF.192/BMS/2022/1, annex). In parallel, the General Assembly encouraged States to take into account recent developments in small arms and light weapons manufacturing, technology and design, in particular polymer and modular weapons, and requested the Secretariat to develop proposals for an open-ended technical expert group (see Assembly resolution 77/71).

III. Gender considerations

71. Developments in science and technology affect men, women, girls and boys differently. The integration of increasingly advanced technologies into the military domain could be used to reinforce, intentionally or not, gender and other social inequalities. The Commission on the Status of Women has called for "targeted measures to identify and eliminate all forms of discrimination against women and girls, including those exacerbated by the use of new and emerging technologies" (see E/2023/27, agreed conclusions, para. 86 (c)).

72. New technologies can also have beneficial effects, including contributing to preventing gender-based and sexual violence.

Artificial intelligence and autonomous and uncrewed systems

73.   Artificial intelligence can have potential benefits for gender equality if and when regulated by laws and policies that ensure gender-responsive technology design, development and deployment. In its Recommendation on the Ethics of Artificial Intelligence, the General Conference of the United Nations Educational, Scientific and Cultural Organization called on member States to ensure that artificial intelligence is utilized in a way as to contribute to achieving gender equality and to avoid violating the fundamental freedoms of girls and women.[15]

74.   Several States have expressed concern regarding unintended bias in artificial intelligence and have called for steps to be taken to reduce such bias,[16] which is generally understood to include gender bias. One potential cause of discrimination, including gender-based discrimination, is the use of imbalanced and non-representative data. The lack of equal participation of women in the conceptualization, development and use of new technologies, such as artificial intelligence and digital technologies, also poses concerns. The Commission on the Status of Women recognized that the use of artificial intelligence has the potential to transform the delivery of public services, societies, economic sectors and the world of work and to contribute to the achievement of gender equality and the empowerment of all women and girls, as well as their human rights and sustainable development. It also recognized that the use of artificial intelligence can contribute to setbacks in these areas and have far-reaching implications and cause disproportionate negative impacts on women and girls, especially through new evolving technologies that create new forms of violence, such as deepfakes.[17]

75.   Within the framework of the Convention on Certain Conventional Weapons, the Group of Governmental Experts on Emerging Technologies in the Area of Lethal Autonomous Weapons Systems considered that weapons systems based on emerging technologies in the area of lethal autonomous weapons systems rely on data sets that can perpetuate or amplify unintentional social bias, including gender and racial bias, and that can thus have implications for compliance with international law.[18] Proposals submitted by States addressed the question of algorithmic bias, including gender bias. In 2021, the United Nations Institute for Disarmament Research recommended a gender-based review of the military applications of artificial intelligence to highlight how such systems represented and responded to gender, as well as to explore past cases in which harmful effects related to bias had been mitigated.[19]

Digital technologies

76.   A number of Member States have recognized the importance of applying a gender lens to discussions on the question of information and telecommunication security. One particular focus of intergovernmental discussions has been narrowing the "gender digital divide." In its first annual progress report, the open-ended working group on security of and in the use of information and communications technologies 2021–2025 underscored the importance of narrowing the "gender digital divide" and

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[15] United Nations Educational, Scientific and Cultural Organization, *Records of the General Conference, Forty-first Session, Paris, 9–24 November 2021*, vol. 1, *Resolutions*, annex VII.

[16] Responsible Artificial Intelligence in the Military Domain, "REAIM call to action", document prepared during the Responsible Artificial Intelligence in the Military Domain Summit, The Hague, February 2023. Available at www.government.nl/documents/publications/2023/02/16/reaim-2023-call-to-action.

[17] See E/2023/27, agreed conclusions, para. 45.

[18] See CCW/GGE.1/2021/3, para. 39.

[19] UNIDIR, "Does military AI have gender? Understanding bias and promoting ethical approaches in military applications of AI", 2021.

welcomed the prominence of gender perspectives in its discussions.[20] The issue was also addressed by the General Assembly in its resolutions 77/37 and 73/218. Concern has been expressed regarding inherent gender bias of digital services and products, as well as regarding potential gendered impacts of ICT incidents. The Secretary-General has recognized that, while there is growing attention to the issue of violence against women and girls in digital contexts, more needs to be done to effectively prevent and respond to new and escalating forms of online violence (see A/77/302). The Human Rights Council has recognized the risks of gender-based violence and abuses of women's rights online.[21]

77.   During discussions of the open-ended working group on security of and in the use of information and communications technologies 2019–2021, the need to strengthen linkages between security of and in the use of information and communications technologies and the women and peace and security agenda was emphasized.[22] Some national action plans on women and peace and security address new and emerging technologies. Looking to the future, the open-ended working group on security of and in the use of information and communications technologies 2021–2025 has recommended that States engage in discussions at the fourth and fifth sessions of the open-ended working group that are focused on, inter alia, the gender dimensions of security in the use of ICTs (see A/77/275).

Space and aerospace technologies

78.   In its resolution 75/36, the General Assembly recognized for the first time the need to assess the possible differentiated impacts of space threats on women and men. On the other hand, space technology could cause harm and provide benefits. For example, it has been noted that geolocation could be an important element in eliminating gender-based violence.[23]

79.   In her report on the use of armed drones for targeted killings (A/HRC/44/38), the Special Rapporteur on extrajudicial, summary or arbitrary executions noted that exposure to constant anticipation of an attack causes significant psychological harm, including post-traumatic stress disorder, cripples daily activities of civilians and creates largely unaccounted for socioeconomic burdens, particularly on women.

Equal participation of women and men

80.   Women remain underrepresented in sectors dealing with new technologies, including ICTs, the aerospace sector and artificial intelligence. Intergovernmental forums, Member States and the Secretary-General have called for the full, equal and meaningful participation and leadership of women in these sectors.

81.   Since 2010, the General Assembly has adopted a number of resolutions on women, disarmament, non-proliferation and arms control. The most recent of those is resolution 77/55, in which the Assembly acknowledged "that the success of efforts to achieve sustainable development and disarmament depends on the full and effective inclusion of women in all aspects of these efforts". Specific calls have been made for gender balance or the effective and meaningful participation of women in disarmament and international security-related processes addressing new technologies, including ICTs, lethal autonomous weapons systems and outer space security.

82.   However, in meetings held in connection with international security, women often represent about one third of delegates. In the Group of Governmental Experts

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[20] See A/77/275, para. 6.
[21] See, for example, Human Rights Council resolution 53/29, preambular paragraph 17.
[22] See A/75/816, para. 37.
[23] See A/77/CRP.1/Add.6, figure VII.

on lethal autonomous weapons systems, the proportion of women delegates has varied between 34 per cent and 37 per cent.

83. The sessions of the open-ended working groups on security of and in the use of information and communications technologies saw a high level of participation of women, something that was recognized by both the 2019–2021 and the 2021–2025 open-ended working groups. In 2023, a total of 47 per cent of statements in the open-ended working group were delivered by women. This can be attributed at least in part to the efforts of such organizations as the Women in International Security and Cyberspace Fellowship.

84. In his disarmament agenda, Securing our Common Future: An Agenda for Disarmament, the Secretary-General committed to achieving parity on all panels, boards, expert groups and other bodies established under his auspices in the field of disarmament. The efforts made in that regard have had a noticeable effect. Women comprised 40 per cent of the experts on the 2019 Group of Governmental Experts on developments in the field of information and telecommunications in the context of international security, compared with 20 per cent for 2016 Group on the same topic. While this increase in women's representation is a significant improvement, more needs to be done to achieve parity.

IV. Conclusions and recommendations

85. 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, human rights, humanitarian norms and principles, or other purposes and objectives of the Organization. It is recommended that Member States identify multilateral forums to discuss synergies across the technologies considered in the present report.

86. It is recommended that United Nations bodies and entities continue to encourage multi-stakeholder and geographically equitable engagement, including by academia, industry and other private sector actors, through formal and informal platforms.

87. Member States are encouraged to continue to seek ways of integrating reviews of developments in science and technology in their work, including through processes to review the operation of disarmament treaties and within all relevant United Nations disarmament bodies.

88. Member States are encouraged to review the recommendations in my policy brief on A New Agenda for Peace in relation to emerging technologies and their impact on peace and security in order to devise concrete actions in the lead-up to the Summit of the Future.

89. Member States are encouraged to mainstream capacity-building initiatives and conduct efforts to promote gender-responsive capacity-building efforts on science and technology in the context of international peace and security.

90. It is recommended that the General Assembly continue to request reports containing updates to the information in the present report on an annual basis, as a contribution to maintaining awareness of developments in science and technology and their potential impact on international security and disarmament efforts.

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