Disruptive Technologies as a Source of Strategic Destabilization

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Abstract

Technology has played a key role in international security throughout human history. However, rapid technological progress and the aggravation of international relations have recently further increased importance of disruptive military technologies for the achievement of strategic objectives. Furthermore, the collapse of the arms control system has made the technological dimension crucial to strategic stability. This paper details specific implementations of disruptive technologies, considers their overall impact, and proposes ways of minimizing their destabilizing effects.

Keywords: disruptive technologies, hypersonic weapons, military space activities, artificial intelligence, cyberweapons, strategic stability.

THE MULTIPLE DIMENSIONS OF TECHNOLOGICAL CONFRONTATION

New and disruptive technologies have played a key role in international security for many decades. In the past, ballistic and cruise missiles were seen as a breakthrough changing "the rules of the game," as were the first satellites, and digital image-processing technologies, and so on. The key distinction today is the speed with which new technologies are being developed and introduced. Militaries are mastering technologies faster, though still delayed by organizational restraints. Decision-makers present technological innovations as priorities for their own militaries' development and as threats if developed by the adversary. Commercial actors and civilian technologies are also of growing importance.

Another distinctive feature of disruptive technologies is the impossibility of defining them as strictly 'stabilizing', or 'destabilizing', i.e., strengthening or undermining strategic security by disincentivizing or incentivizing first strikes, mainly nuclear ones. Much depends upon the specific scenarios for a technology's use and, in any case, almost any action prompts a symmetrical or asymmetrical counteraction. Additionally, the arms race in new technological spheres (which has qualitatively begun and is quantitatively scaling up) is occurring amid renewed great-power competition, and it is accompanied by a collapse of confidence-building and risk-reduction mechanisms in traditional areas and by a rapid increase in the number of actors involved.

TECHNOLOGICAL DEVELOPMENT AND STRATEGIC STABILITY

New and disruptive technologies can be categorized as *support, combat*, and *universal*.

Within the *support* category, of special significance are supercomputing and quantum technologies, which may increase productivity, including in research and design. Amongst other things, they may ultimately assist in:

- Maintaining and modernizing nuclear arsenals given the moratorium (as of 2024) on live tests.
- Similarly, reducing live test requirements for new conventional weapons and equipment, which can be analyzed with qualitatively new simulations and models.
- Global weather and other conditions monitoring and forecasting for the purpose of military operation planning.

Support technologies also include space-based assets (including 'megaconstellations') employed for remote sensing, communication, or spacecraft surveillance; they can also be used to assist the targeting of offensive or defensive strikes against objects on land, in the sea, in the atmosphere, and eventually in orbit.

Combat disruptive technologies include hypersonic ramjet engines (scramjets) and other types of propulsion systems that could become the basis for next-generation missiles, including (ultra-)long-range cruise missiles and anti-ship missiles, and those that could also be used as elements of guided reentry vehicles of ballistic missiles (intercontinental and otherwise).

Universal, fundamentally complex technologies include machine-learning for big data analysis and AI technologies in logistics. This category may also include new (e.g., extreme-temperature-resistant) materials and new types of propellants.

The *impact* of the use of *disruptive technologies* is impressive.

As for support technologies, the development of supercomputers makes it possible to effectively service the nuclear arsenal, reduce the cost of field tests for new and modernized weapons and military equipment, and plan operations detailed to the extent unattainable with existing technologies. Capacity-building in the military-space sphere also increases the effectiveness of combat planning and engagement, both offensive and defensive.

The introduction of combat disruptive technologies, such as weapons using hypersonic technologies (see below), will reduce time-to-kill and make missiles faster and more maneuverable and thus less vulnerable to defenses. Fewer missiles needed to destroy each target may permit the slimming-down of arsenals and, potentially, even lead to new rounds of strategic arms reductions. Autonomous combat systems in all environments (air, sea, ground, space) can reduce combat (and to some extent non-combat) casualties. Smart airborne control systems will increase the capabilities of long-range precision weapons, loitering munitions, and hypersonic weapons.

The employment of effective machine-learning algorithms helps optimize and speed up intelligence data analysis, improve situational awareness and thus decision-making. AI technologies in logistics help maintain weapons and military equipment, cut costs, increase the combat-sustainability and effectiveness of troops. These technologies' development will lead to lethal autonomous weapons and to smart airborne control systems for next-generation strike weapons.

The perceived scale of a threat is crucial for determining its stabilizing or destabilizing consequences. A potential adversary's development of almost any disruptive-technology-based system (especially in the strategic weapons domain) may be considered an attempt to gain unilateral advantage and thereby undermine strategic stability. For instance, the U.S.'s unlimited development and deployment of missile defense systems prompted Russia's development of new nuclear weapon delivery vehicles (Putin, 2018), which was in turn used by the U.S. to justify the development of its own nuclear arsenal (US DoD, 2018). The updated Fundamentals of the State Policy of the Russian Federation in the Area of Nuclear Deterrence identifies various new, purely technological threats, including aerial drones, hypersonic weapons, directed energy weapons, and space-based anti-satellite weapons (Executive Order, 2024).

Of particular importance is the introduction of disruptive technologies, including artificial intelligence (Saltini, 2023) for the in-combat management of nuclear forces (Kania, 2019).

New technologies may be extremely destabilizing given the Biden Administration's determination to preserve Western advantages in all spheres (non-nuclear hypersonic weapons, military capabilities in space and cyberspace, etc.) while minimizing states' nuclear arsenals

(Sullivan, 2023). The Trump administration is likely to continue and intensify this policy, pursuing superiority rather than mere "advantage."

SELECTED DISRUPTIVE TECHNOLOGIES AND THEIR IMPACT

This paper more specifically analyzes hypersonic weapons, artificial intelligence, and military space technologies, as their regular use allows their impact to be observed, and because they are illustrative of various trends.

Hypersonic weapons

One of the most in-demand directions of military technology's development is that of hypersonic technologies (even though they are fundamentally based on previous types of missiles), which can fit within the wider category of high-precision long-range systems. Russia currently leads in their deployment and even their use (specifically, with the Avangard hypersonic glide vehicle, the Zircon hypersonic sea-launched cruise missile, the Kinzhal hypersonic air-launched ballistic missile, and the Oreshnik hypersonic intermediate-range ballistic missile). But work is also underway in the U.S., China, and—to a lesser extent—the UK, France, Japan, India, North Korea, Iran, and others (Brockmann and Stefanovich, 2022). Interestingly, these programs' rationales seem to be significantly a matter of status. For example, after the successful test of a ground-based hypersonic missile, the Indian defense minister emphasized that it "has put India in the group of select nations having capabilities of such critical and advanced military technologies" (India MoD, 2024). Apparently, the status factor is instrumental in declaring certain products tested or used in combat as "hypersonic" as in the case of the DPRK, Iran, and the Hussite movement in Yemen.

In the future, the U.S. may acquire significantly more hypersonic weapons than are possessed by Russia. Yet technological development never stops, and onboard propulsion systems for hypersonic glide vehicles may be the most promising way forward, as they would reduce speed-loss during in-atmosphere flight and might improve maneuvering.

Simultaneously, countries are seeking countermeasures to hypersonic weapons and—despite missile defense's thus far limited success and the general advantage of offensive over defensive weapons—breakthroughs here cannot be ruled out (Bogdanov et al., 2023).

These factors threaten to further destabilize the great powers' strategic relations in the future, although Russia's development of hypersonic weapons has so far had more of a stabilizing effect, and similar effects may be had at the regional level (Chekov and Babkina, 2023). Additionally, non-nuclear hypersonic weapons permit the delay of nuclear weapons' use in an armed conflict (Massicot, 2021).

Maintaining hypersonic parity in the medium term may be one requirement for new arms control agreements. In fact, given hypersonic weapons' declared advantages in delivering nuclear warheads, it might be possible to reduce the total number of those warheads, bilaterally or even multilaterally. (For example, France, too, is considering the hypersonic delivery vehicles for nuclear warheads.) Moreover, given the increased attention to hypersonic weapons, attempts may be made to limit narrow categories of long-range precision weapons (for example, ground-launched hypersonic systems) and subsequently widen these approaches.

Artificial intelligence

The term 'AI' currently refers to a number of (not always connected) advances, primarily in software (but also adaptive computing), that are related to the automation and 'intellectualization' of big data processing and autonomous decision-making. Military AI can be roughly divided into *onboard systems* and *decision-support systems*, although these can overlap, especially in the case of drone swarms.

In the near future, AI may come to play the leading role in logistics. We can expect AI systems to improve and penetrate new areas. Of particular importance is the integration of "civilian" and "military" areas of AI application, which actually may play a positive role. For example, the increasing use of large language models (LLM) and various image and video generative models leads to a better understanding of existing AI technology limitations at this stage.

Over the next decade, AI technologies will be deeply integrated into all spheres of human and government activities, making no exception for defense and security. Of particular importance is the development of technologies used for analyzing the information provided by remote sensing satellites, outer space situational awareness systems, early warning systems, and other radars (including over-the-horizon ones). This will improve situational awareness, counterintelligence, and counter-reconnaissance.

But there are significant ethical complications regarding AI's application to the use of lethal weapons; specifically, connected to the blurring of human responsibility for such decisions. Needless to say, the total abolition of all autonomy in combat systems is unrealistic. Yet some transparency in the decision-making chains between the operator and the combat system itself (e.g., anti-ship missile systems, air and missile defense systems), and in the procedures for using decision-support systems (e.g., within early warning systems), would help international dialogue on these issues. Such transparency could also facilitate the wider employment of specialists, startups, and other nongovernmental actors in the development of AI for national defense.

However, the U.S.'s attempts to impose its own views on the need for "meaningful human control" of AI, primarily in nuclear combat-control systems—though supported to some extent by China (MFA China, 2024)—ignore the extreme sensitivity of this sphere, and appear rather cynical given the U.S.'s own stated interest in AI's use in the nuclear sphere[1] (Hadley, 2024) and its employment of private companies to implement it. For example, Anduril's Lattice software will be used for the autonomous exchange and processing of data from military satellites (including in the early warning systems) (Erwin, 2024).

Over time, AI's growing use will gradually lead to some improvement in understanding of its limitations.

[1] There are numerous examples of humans' approval of decisions suggested by AI-assisted systems, e.g., the use of Lavender software by Israel to designate targets in Gaza.

Outer space

Many new and disruptive technologies are spreading into outer space:

- Intelligence, surveillance, and reconnaissance (ISR) capabilities, using mega-constellations of satellites and AI for data analysis.
- Increasingly mobile spacecraft, capable of in-orbit maintenance and engagement.
- Directed-energy and electronic-warfare systems for use against missiles and satellites.
- Cyber and electronic-warfare capabilities that can disrupt satellites' links to ground control stations.
- Nuclear-powered spacecraft.

The pursuit by some countries of superiority in outer space will tend to generate conflicts. The U.S. Space Force openly speaks of the need for capabilities that can strike enemy spacecraft (Hitchens, 2024).

Space military technologies can be categorized as either destructive (targets are destroyed by e.g. kinetic interceptors) or nondestructive (targets' sensors or communications are temporarily disabled by electromagnetic pulses, cyber weapons or directed energy weapons).

Given the current deterioration of international relations and the ever-growing great-power rivalry, we are in a most dangerous situation However, since the competing great powers are themselves the most dependent upon space infrastructure (despite attempts to create alternatives), they might be able to reach agreement to not attack certain elements of space infrastructure except, perhaps, in the event of direct conflict. (In which case, space would be far from the main concern.) Although the use of third parties' commercial space infrastructure during a conflict (Romashkina, 2024) is also an important matter, its treatment would require a separate article.

The overlapping of space security and cybersecurity is also important, especially in relation to nuclear capabilities. The greatest threat is posed by possible strikes on nuclear forces' combat-control systems (NC3) on the ground and in space (Acton, 2018). Naturally, these are well-protected, including against cyber threats, but historically they were developed in the absence of any space infrastructure.

The maintenance of communications and restoration of space-based assets architecture is seemingly being ensured by rapid on-demand space launches (known as "Tactically Responsive Space" in the U.S.) and by a shift from fairly large spacecraft to constellations of small satellites. New Space capabilities play a special role here (Stefanovich and Yermakov, 2024).

Cyberattacks on space infrastructure (including its ground-based assets) can be effective in temporarily or permanently depriving the enemy of intelligence, communications, target-designation, and other assets. Crucially, malicious software may be easily-accessible to non-state actors, a fact that may be exploited by any state actor.

Thus, space and related ground infrastructure is becoming one of the key areas of intelligence and information operations.

POSSIBLE STABILIZING ACTIONS

Technological progress in the military sphere is making non-nuclear weapons increasingly lethal: they are approaching nuclear weapons not in destructive power, but in their ability to perform strategic military tasks, and they are rapidly proliferating (Horowitz and Schwartz, 2020). Hence Russia's current pursuit of an arms-control regime that covers all strategic weapons—nuclear and non-nuclear, offensive and defensive—with an emphasis on disincentivizing a first strike (Ryabkov, 2020). Yet the focus of the traditional "narrow" understanding of strategic stability, upon avoiding a first strike, does not prevent combat below that threshold, a phase where disruptive technologies offer increasing possibilities (Bogdanov, 2023).

There are several steps that could be helpful here. Given the difficulty of establishing universally-accepted rules governing new technology, countries may unilaterally state what they consider to be acceptable in certain circumstances, and what is always unacceptable and will lead to rapid escalation. Examples include Russia's and separate countries' bilateral commitments to the no-first-placement of weapons to space, and the U.S. initiative on the responsible military use of AI. While these solutions are far from ideal, they may be good enough as first steps.

Strategic planning documents may help to deepen understanding of new and disruptive technologies.

In the absence of constructive interstate dialogue on specific problems, the creation of a conceptual framework, a glossary of relevant topics ('artificial intelligence,' 'hypersonic technologies,' 'directed energy weapons'), might facilitate Track II dialogue. This will certainly not solve all the problems and could become a problem in itself. Yet there are recent successful examples of such efforts, such as the Lexicon for Outer Space Security prepared by the UN Institute for Disarmament Research (Ortega and Samson, 2023).

Efforts at the official, academic, and expert levels should focus on understanding actors' perceptions of the threats posed by disruptive military technologies. These efforts should be made in good faith, trying to understand actors' motivations, without dismissing threats or concerns as non-existent.

Disruptive technologies could lead to a nuclear apocalypse but could also help avoid it. Thus, the scientific and expert community should carefully analyze the technologies' consequences and promote the proper training of future operators and decisionmakers, in order to avoid the most negative scenarios.

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