Russian Journal of World Politics and Law of Nations. 2022. 1(1-2). P. 47–86 Research Article
DOI 10.24833/RJWPLN-2022-1-2-47-86

Innovation Mirage: The Role of Technological Uncertainty in Military Instability

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Abstract. This article examines the impact of technological changes on the risks of military clashes between states. Currently, experts express increasing concerns about the destabilizing effect of new weapons (including anti-missile and anti-satellite weapons, hypersonic missiles, autonomous lethal systems, and artificial intelligence). These assessments are rarely based on solid theoretical foundations. The author seeks to fill this gap, arguing that the emergence of new weapons has a negative impact on international stability, and this effect is weakly related to the specific characteristics of underline technologies. The theory of technological uncertainty offers an alternative to the offence-defence balance theory. The latter has been developed since the 1970s, but its validity is questionable. The theory of technological uncertainty attributes the destabilizing effect of weapons to the divergence of states' perceptions of the balance of powers, hyped expectations regarding the ability to compensate quantitative limitations with qualitative superiority, and the alarmistic sense of closing windows of opportunities and growing vulnerabilities. The article tests the theory against the historical record of military clashes in Europe from the end of the 18th to the middle of the 20th centuries, as well as the crises between superpowers during the Cold War. Empirical cases are selected from this period, which is marked by the intensification of qualitative arms races between states. In addition, it is also the period most often used to substantiate the offence-defence balance theory. The history of the last t250 years provides a solid foundation for the theory of technological uncertainty. All instances of large-scale military clashes were preceded by significant technological changes, while peace fell on periods of technological stagnation. The author addresses the policy implications of the theory for the discussions on emerging weapons in the 2010s and 2020s. The study confirms that concerns regarding their destabilizing effect are justified, but for different reasons from those put forward by most analysts. A somewhat optimistic caveat to its conclusions is the fact that currently emerging weapons are at various stages of development. The greatest likelihood of military clashes corresponds to the overlap of several technological uncertainties. Therefore, an increase in the time lag between introduction of various arms can mitigate destabilizing effect.

Keywords: arms, technology, war, balance of power, perception, Revolution in military affairs, window of opportunities, great powers, military force

[1] English translation from the Russian text: Istomin I.A. 2020. Mirazhi innovatsii: «vklad» tekhnologicheskogo progressa v voennuiu nestabil'nost'. *Vestnik MGIMO-Universiteta [MGIMO Review of International Relations]*. 13(6). P. 7-52. DOI: https://doi.org/10.24833/2071-8160-2020-6-75-7-52.

Do advances in technology affect the likelihood of armed clashes between states? In the latter half of the 20th century, many believed that the creation of nuclear weapons, due to their destructive power, sharply reduced (if not eliminated) the risks of political conflicts escalating into military confrontation (Brodie 1946; Waltz 1981; Jervis 1989; Glaser 1990; Karaganov 2010). Nevertheless, the experience of the Cold War showed that even the superpowers continued to fear for their own security. Throughout the mid- to the late-20th century, they sought to achieve military superiority, choosing not to bank on the stability of mutually assured destruction (Green, Long 2017).

Concerns about the possibility of a large-scale collision prompted the Soviet Union and the United States to develop new weapons – missiles with multiple independently targetable re-entry vehicles, anti-submarine defence systems, anti-missile defence systems, etc. (Brooks 1975). Their appearance, in turn, led to even greater fears of a destabilizing arms race. After the end of the Cold War, the risks associated with creating new weapons continued to be of concern to those in the know. Throughout the 2010s, the attention of experts was focused on the possible consequences of the development of anti-missile defence systems, anti-satellite weapons, hypersonic weapons, autonomous combat systems, military applications of artificial intelligence, and weapons based on new physical principles (Burano 2011; Brimley et al. 2013; Yesim 2015; Koko shin, BlueSky, Potato 2015; The Impact of Technology … 2017; Speier 2017; Klara 2018; Arbatov 2018; Sechser, Narang, Talmadge 2019; Johnson 2019; Horowitz 2019). At the same time, most publications were concentrated on the features of individual weapon types.

The present article aims to place such assessments in the context of a theoretical understanding of the impact of technological changes on the likelihood of military clashes between states. At the same time, technologies are understood as a repertoire of knowledge and skills that ensure the production of tools for human activity, as well as artefacts created on the basis of this (Skolnikoff 1994: 13). That is, in this case, various kinds of social and managerial technologies are not considered, as these are modes of behaviour that are not related to the production of physical objects.

We argue that the emergence of new weapons negatively impacts international stability. In the course of doing so, we solve two interrelated problems. First, the study confirms the impact of the dynamics of advances in technology on the possibility of military clashes. Second, it reveals the psychological effects associated with the emergence of new weapons that ensure the current balance of dependencies is maintained. Accordingly, the article's main contribution is the original theory of technological uncertainty, which is designed to explain the logic behind the decisions of countries to launch military operations against another state.

We begin our analysis on the impact of new weapons on the likelihood of military clashes with a review of the debate on the international political significance of the ratio of offensive and defensive capabilities. Experts have used this method since the

1970s to assess the risks of launching military action. At the same time, the assumption that technological innovations have a differentiated effect on the likelihood of aggression and the possibility of organizing effective defence is open to criticism.

In this regard, we offer a never-before-considered explanation for launching military action as a product of technological uncertainty. The destabilizing effect of weapons is attributed to the differences in perceptions of states about the balance of power generated by the emergence of new weapons, overestimated expectations about the ability to compensate for quantitative limitations with qualitative superiority, and alarmism caused by a sense of dwindling opportunities and growing vulnerability.

The article demonstrates the advantages of the theory of technological uncertainty in explaining the experience of military clashes between European states from the late 18th to the middle of the 20th centuries, as well as the relations between the superpowers during the Cold War. The choice of empirical materials for analysis is determined by the fact that the historical period we are looking at was marked by increased arms races between states (Buzan, Lawson 2015). It is also the one most often used to justify alternative explanations for the role of technology in military clashes,

In the conclusion, we discuss the consequences of theoretical developments and historical analysis for discussions about advances in weapons moving into the 2020s. Our research confirms that fears about the destabilizing factor of arms races are justified, but not for the reasons put forward by most observers. It is not the specs of new technologies that is the issue here, but rather the poorly calculated and often misunderstood consequences of advances in weapons. The present article attempts to outline possible ways to reduce the emerging risks.

The subsequent analysis contributes to two areas of international relations research. First, it clarifies notions about the origins of wars between states. The theory of technological uncertainty gives weight to previous hypotheses about the psychological mechanisms that cause political rivalries to turn into military confrontation (for example, Blainey 1973; Jervis 1976; Copeland 2001), revealing the material incentives that trigger them. However, it also takes issues with researchers who focus on the destabilizing potential of individual technologies (Quester 1977; Jervis 1978; Lynn-Jones 1995; Van Evera 1998; 1999; Glaser, Kaufmann 1998), as well as with experts who are more concerned with the ratio of common potentials when explaining armed conflicts (Waltz 1979; Mearsheimer 2001; Lieber 2005).

Additionally, the present paper complements the rapidly expanding literature on the role of technology in international relations in recent years (Ruggie 1975; Skolnikoff 1994; Herrera 2012; Golubev 2015; McCarthy 2017). At the centre of this discussion since the 1990s has been the mutual construction of material and social change. However, any study of the origins of armed conflict is necessarily influenced by technological determinism. The present study demonstrates the applicability of the provisions developed in the course of science and technology studies (STS) to understanding international security issues.

The Impact of Technology on the Offence/Defence Ratio

Studies of international security polemicize about the relationship between the means of armed struggle that dominated in specific historical periods and the likelihood of military clashes. The theory of the offence-defence balance offers an explanation for the risks posed by technological change (Quester 1977; Jervis 1978; Lynn-Jones 1995; Van Evera 1998; 1999; Glaser, Kaufmann 1998). Advocates of this theory point to a change in the intensity of inter-state conflicts due to the emergence of new weapons.[2] The emergence of different technologies affects international security in various ways.

Researchers argue that, in some cases, new weapons, while offering advantages to the defending side, increase the costs of offensive actions. Consequently, aggressive policies are less likely to succeed, and armed conflicts become less effective and last longer. The confrontation turns into a war of attrition, and any victory turns out to be pyrrhic. For example, in the Middle Ages, stone castles allowed petty feudal lords to repel vastly superior forces. By guaranteeing their autonomy, the defences preserved fragmentation in Europe. In the same vein, the expanding opportunities for self-defence in the 19th century played a role in the development of rapid-fire weapons. This made it difficult for the attacking side to overcome the meticulously planned positions of the enemy – a scenario played out in the positional battles of the First World War.

There are, however, cases where other technological advances have made it easier for the aggressor, and far riskier for the defending side. These are technologies that increase the possibility of a swift victory, depriving the enemy of the chance to recover from the initial onslaught, regroup and resume resistance. In such circumstances, armed conflicts are over more quickly, which thus creates prerequisites for expansion.

For example, the development of firearms in the early modern era made it much easier to take castles. This led to the consolidation of sovereign possessions and the emergence of centralized states (Parker 1976; Batchelder, Freudenberger 1983). And the appearance of tanks was a major factor in overcoming the positional battles in the initial stages of the First World War, increasing the possibility of breaking through the defence and carrying out manoeuvres behind enemy lines. Mobile units proved their effectiveness during the Second World War and the conflicts in the later part of the 20th century (Searle 2017).

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[2] In a number of cases, proponents of the offence-defence balance theory call for a broad approach to assessing the ratio of potentials, including such parameters as geographic accessibility, the size of cumulative resources, the level of national unity and the political legitimacy of the government, the presence and strength of alliances, the size of the armed forces, military doctrines, and the organization and deployment of troops. The inclusion of such a large number of parameters complicates the practical use of the theory and makes it virtually unfalsifiable. For an overview of all the variables, see (Lieber 2005: 30–32). When carrying out empirical studies, proponents of the offence-defence balance theory are primarily guided by the nature of the dominant technologies of the time. Our subsequent analysis focuses on the "narrow" version of the offence-defence balance theory.

In international politics, periods when defensive potentials dominate correspond to greater stability, as states face fewer threats of attack and wars become rarer due to the high costs. Even actors with a propensity towards expansion are unable to see their aggressive intentions put into action.[3] The opposite is also true – the spread of technologies that increase offensive potential increases volatility in the international system. The danger of being caught unawares encourages states that maintain the status quo to turn to preventive aggression. Offence thus becomes the best form of defence, and the threat of armed clashes increases.

While the theory that the likelihood of war is dependent on the nature of the prevailing technologies is widely accepted, it is not without its fervent detractors.[4] The weak point in the argument was how to decide which technologies should be considered offensive and which should be considered defensive (Jervis 1978). Throughout history, uncertainty about this very issue has repeatedly led to destabilization in the international arena.

The experience of both World Wars is a perfect illustration of the inability of states to correctly assess the current balance of offensive and defensive capabilities. In 1914, the European powers, expecting a quick victory, were drawn into a positional confrontation. In 1939, the opposite happened – France and Great Britain underestimated the potential of mobile units and, accordingly, the risks of German aggression (Christensen, Snyder 1990).

Critics argue that the very division of weapons into offensive and defensive is redundant, as it only applies to the tactical level of confrontation. States seeking military expansion adapt all weapons at their disposal to achieve their political goals.[5] Similarly, the defending side is able to adapt offensive weapons to solve its defensive tasks. As a result, the same inventions are used to either pursue an aggressive policy or to protect the status quo, depending on the situation.[6]

For example, in the late 13th century, English ruler Edward I ordered the extensive construction of castles in order to conquer Wales. This led to the formation of a network of strongholds that ensured control over the surrounding territories and the rapid redeployment of royal troops (Brauer, van Tuille 2016: 116–126). Castles were thus not used for their supposed purpose of maintaining fragmentation, acting in this case as an instrument of expansion. The Franco-Prussian War of 1870–1871 also illustrates the creativity of the aggressor, as the German troops took advantage of the

[3] John Mearsheimer pointed out that even expansionist states only tend to start conflicts when they are confident of a swift victory (Mearsheimer 1985).

[4] The popularity of the offence-defence balance theory is proved by the fact that the Google Scholar database contains 28,000 articles on the issue for the 2010s. In particular, it has been widely used to explain the confrontation in cyberspace. See, for example, (Saltzman 2013; Gartzke, Lindsay 2015; Slayton 2017; Garfinkel, Dafoe 2019).

[5] For the most comprehensive critique of this, see (Lieber 2005). See also (Gray 1993; Betts 1999).

[6] For example, Geoffrey Herrera claims that in the wars of the 1850s–1870s, the development of the railways helped the attacking sides more, while the defending sides benefitted most during the First World War (Herrera 2004). Linking directly opposite consequences to the same cause testifies to the logical inconsistency of the reasoning.

increased rate at which small arms could fire, creating barriers behind enemy lines. As a result, the defending French forces had to resort to tactical attacks on fortified positions in order to avoid being encircled. The resulting losses contributed to the success of the German offensive (Lieber 2005: 90–91).

During the Second World War, both the Soviet Union and Germany actively used armoured vehicles in defensive operations, despite the fact that tanks are traditionally associated with offensive operations. Specifically, it was the manoeuvring of mobile units that saved German troops from defeat during the Soviet counteroffensives in 1941–1943. In turn, the Red Army used tank forces to repel attempts to unblock the Stalingrad Cauldron and to hold the defence near Kursk (Izzo 2015; Crow 2015).

It is unsurprising that attempts to link the likelihood of military clashes with the ratio of offensive and defensive weapons runs into numerous issues with consistency. The first half of the 19th century – when the arsenals of states did not change in any significant way – was marked by the Napoleonic Wars and then a long peace under the shelter of the "European Concert."[7] Two large-scale wars took place in the first half of the 20th century, one during the period of the supposed dominance of defensive potentials, and the other during the period of dominance of offensive capabilities.

Thus, in one case, the level of military confrontation changed, despite the fact that the technological conditions remained the same, while in the other case, the level of military confrontation was comparable, despite the advancements in military technology. These examples call the explanatory potential of the theory of offence-defence balance into question. They do not accommodate for the fact that certain technologies generate only stabilizing or destabilizing consequences.

Accordingly, attributing a given functional role to current military innovations (hypersonic carriers, autonomous strike systems, anti-satellite weapons) means underestimating the range of their possible application. It is significant that non-Russian publications see hypersonic weapons mainly as a means of delivering a counterforce strike to disarm an opponent, while Russian politicians and experts choose to see them as a part of guaranteed retribution against an aggressor who has a well-developed missile defence.[8]

Thus, the side that lags behind in the development of weapons positions itself as the aggressor, while the side that has created advanced weapons positions itself as a defensive nation. In actual fact, new weapons have various applications, and they are not all immediately obvious to those who developed them. The uncertainty of what

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7 For an overview of the evolution of international relations during this period, see (Schroeder 1994).

8 For a detailed analysis of the Western view of hypersonic launch vehicles, see (Speier et al. 2017; Klare 2019). Russian views on the same issue can be found in (Karaganov, Suslov 2019: 31). See also: "Putin Announces that US Withdrawal from ABM Treaty Has Forced Russia to Develop Hypersonic Weapons," TASS (September 19, 2020), https://tass.ru/armiya-i-opk/9501307 (accessed on December 9, 2020). For a more nuanced analysis of the significance of hypersonic weapons, see: M. Kofman, "Russia's Avangard Hypersonic Boost-Glide System," *Russia Military Analysis* (January 11, 2019), https://russianmilitaryanalysis.wordpress.com/2019/01/11/russias-avangard-hypersonic-boost-glide-system/ (accessed on December 9, 2020).

technological change could bring is often seen as an obstacle to assessing its impact on the risk of military conflict (Jervis 1978), when it actually determines its impact on international security.

Technological Uncertainty and the Intensity of Armed Conflict

The seriousness of the discussion about the theory of offence-defence balance has polarized the research community. Its proponents fiercely defend the need to distinguish between offensive and defensive potentials and take the relationship between the two into account when assessing the risks of an armed conflict. Meanwhile, critics insist that political considerations should take precedence over technological aspects, arguing that advances in weapons technologies do not influence the likelihood of inter-state clashes.[9]

This polarization creates difficulties when it comes to explaining the link between the aggravation of conflict with the emergence of new weapons without differentiating between different types of technologies. At the same time, both sides of the debate ignore the impact of uneven technological development on human psychology.[10] The evolution of the means of warfare distorts the perception of the current and future alignment of forces. The uncertainty caused by technological development creates risks for international security.

This section aims to describe the oft-neglected relationship between the emergence of new weapons and the start of military conflicts to present an original theory of technological uncertainty. It will also allow us to explain why military clashes occur even when no significant shifts have taken place in the balance of forces. An additional consequence of the dependence described earlier is the conclusion that changes in technology create greater destabilization risks than an increase in the size of armies or organizational and doctrinal innovations.

The impact of new weapons on the likelihood of military clashes is mediated by three psychological effects: differences in the perceptions of states about the balance of power; inflated expectations of one's ability to compensate for quantitative limitations with qualitative superiority; and alarmism caused by a feeling of waning opportunities and growing instability. To explain the logic of our theoretical approach, we will take a

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[9] Keir Lieber offered the theory of technological opportunism as an alternative to the that of offence-defence balance. According to this theory, countries seek to use all available weapons to achieve their (usually offensive) political goals (Lieber 2005: 4–6). However, it is hard to read such statements as part of an independent theory, as they follow from the logic of offensive realism, which attempt to justify the offensive strategies of states. That notwithstanding, there are numerous examples of unjustified technological optimism in history.

[10] Proponents of the offence-defence balance theory point out that the perception of the ratio of offensive and defensive potentials may be even more important for international security than the practical capabilities of the weapons themselves. They also acknowledge that states often incorrectly assess the consequences of technological developments, although they typically put this down to the private preferences of specific interest groups, mainly the military (Van Evera 1999).

deep dive into each of these effects before moving on to a description of the impact of technological advances on international security.

One of the pioneers of international security studies, Geoffrey Blainey, wrote that "wars usually begin when fighting nations *disagree* on their relative strength" (Blainey 1973: 293). Other researchers would also note the unjustified optimism of political leaders in initiating armed conflicts (Lebow 1981; Johnson 2004), while Stephen Van Evera agreed that overconfidence about an easy victory is a basic prerequisite for war (Van Evera 1999: 117). In all these cases, experts linked military action with the distorted perceptions of decision-makers.

Where do these distortions come from? Why do perceptions of the balance of power differ so much? The answer to this question is often linked to differences in the awareness of the warring parties and the inability or unwillingness of one of them to divulge real information to the other.[11] It is even worse when none of the players has complete and reliable information – that is, when the level of uncertainty in the relationship increases.

Technological development acts as a powerful source of uncertainty, making it difficult to agree on relative strength. As Martin van Creveld noted, technology has throughout history had a decisive influence on wars, providing a material basis for them (Van Creveld 1989: 1). Advances in weapons technology are creating a new means of organized violence, although it is difficult to discern in what ways and to what extent.

Physical objects and social relations determine one another. At the same time, technological development and social changes have their own internal drivers – their transformation is not limited to responding to external stimuli (McCarthy 2017: 11–12). Otherwise, the dynamics of mutual construction would lead to a stable equilibrium that does not allow for deviations. Sociotechnical systems that have achieved internal consistency would no longer be able to develop.

The dualism of the mutual influence and partial autonomy of technological and social change means that material artefacts allow for different interpretations – although not any interpretation whatsoever. Designing potential applications for technological advances is a creative process that is difficult to account for. The consequences of innovations are too indeterminate to make informed predictions about their most appropriate applications from the range of hypothetically possible ones.

In this regard, the difficulties faced by military organizations when introducing new weapons are logical (Van Creveld 1989; Rosen 1991; Horowitz 2010). They are integrated with existing developments, adapted into doctrines and organizational structures, and this is viewed with scepticism. Technological innovations themselves rarely give impressive results to begin with, often experiencing "teething troubles."[12] As a re-

[11] For discussions on the possibility of formalizing this thesis within rationalist models, see: (Morrow 1989; Fearon 1995; Fey, Ramsay 2011; Slantchev, Tarar 2011).

[12] The literature on the role of disruptive innovation in business notes a similar paradox (Christensen 1997).

sult, it is not uncommon for a long time to pass between the development of weapons and their eventual use on the battlefield.

While accelerated technological development does not necessarily secure military advantages, it does expand the range of possible hypotheses about the current situation. Difficulties grasping the consequences of deploying new weapons, as well as the differences in the pace of their development and implementation, create room for discrepancies in assessments of the current balance of potentials and the possibility of this balance tipping in the future.

The destabilizing effect caused by the uncertainty surrounding the consequences of introducing new technologies increases the tendency to ascribe greater importance to certain phenomena over others.[13] Demonstrating weapons can have a huge psychological effect, creating lasting images in people's minds. In this respect, military parades are frequently used as a form of showing one's power both to external parties and to the general public within the country.[14] Colourful images of the latest weapons are designed to reinforce the idea of the country's military power and technological potential.

Consequently, when new weapons are introduced, this is often accompanied by a wave of inflated expectations regarding alleged qualitative superiority (Fenn, Raskino 2008; Dedehayir, Steinert 2016). Technological changes frequently give rise to speculation about the possibility of a revolution in military science.[15] Unrealistic expectations of new weapons are tempered after they are introduced, but the hype returns when the next round of technological development begins. Thus, along with the diverging views of parties regarding their relative strength, emerging ideas about the magnitude of the consequences of technological advancements also have a negative impact.

Finally, the fact that the advantages provided by new weapons rarely turn out to be long term also increases the likelihood of armed clashes. New weapons do not affect the basic foundations of military power, and rivalries between states encourage other players to try and make up the technological gap by producing their own analogues or developing other counter weapons.[16] The development of weapons creates consequences that are similar in nature to political revolutions, although in the opposite

[13] For more on how the way information is presented affects perception, see: (Tversky, Kahneman 1973; Taylor, Thompson 1982; Bordalo, Gennaioli, Shleifer 2012).

[14] See, for example, the international reaction to the military parade to celebrate the 70th anniversary of the establishment of the People's Republic of China in 2019 (Cao Siqi, "China to Hold Largest Military Parade in Two Decades to Celebrate 70th Anniversary of PRC's Founding," *Global Times* (August 29, 2019), https://www.globaltimes.cn/content/1163004.shtml (accessed on December 9, 2020); A. Fifield, "China Rolls Out its Military Firepower with emphasis on 'Cold War-Style' Nuclear Might," *The Washington Post* (October 1, 2019) https://www.washingtonpost.com/world/asia_pacific/china-rolls-out-its-military-firepower-with-emphasis-on-cold-war-style-nuclear-might/2019/10/01/243d5302-e168-11e9-be7f-4cc85017c36f_story.html (accessed on December 9, 2020); A. Neill, "China Anniversary: Military Parade Brings Out the Big Guns," BBC (September 30, 2019), https://www.bbc.com/news/world-asiachina-49849858 (accessed on December 9, 2020).

[15] See, in particular, the discussions in the 1990s about the revolution in military science brought about the introduction of precision weapons (Krepinevich 1994; Cooper 1994; Metz 1995; Sloan 2002).

[16] For more on the role of imitation in international relations, see (Waltz 1979: 128).

direction. That is, revolutions lead to a short-term weakening of the state, while technological changes lead to an equally transient strengthening.[17]

The fickle nature of the superiority that technological development provides causes many to believe that a limited window of opportunity is created for the side with new weapons, while the side that does not have them is temporarily exposed. The risk that these technologies will be picked up or copied by other states is a reason to take advantage of the supremacy while it is there. Falling behind encourages countries to carry out pre-emptive strikes before their vulnerability becomes apparent.[18] In both cases, states are interested in initiating clashes.

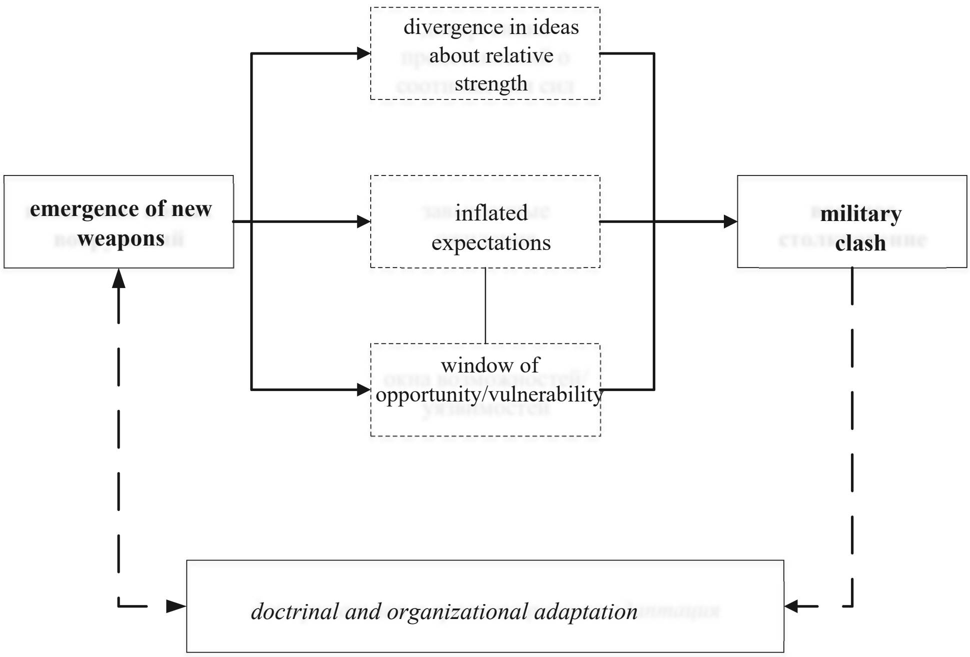

Figure 1. Theory of Technological Uncertainty
Source: compiled by the author.

These logical relationships are presented in diagram form in Fig. 1. Here, the risks of armed clashes are linked with the impact of technological change on how states perceive the international situation. The emergence of new weapons gives rise to differing opinions about the balance of strength, inflated expectations about the ability

[17] See (Walt 1996).

[18] For more on the role of windows of opportunity and vulnerability in conflicts, see: (Van Evera 1999: 73–103). It is important to note that the window metaphor assumes a rise in alarmism at various stages. In the case of a window of opportunity, the incentive to escalate tensions increases the moment the window closes, as states are afraid of losing the advantage they once enjoyed. As for windows of vulnerability, the opposite is true – the incentive is there to pre-empt the window's opening before the state weakens. It often happens that closing a window of opportunity means opening a window of vulnerability.

to compensate for quantitative limitations with qualitative superiority, alarmism due to a feeling of weakening capabilities, and growing vulnerability. These psychological effects can appear separately or at the same time, but they all serve to increase the likelihood of a military clash.

The psychological effects may also make parties less willing to make concessions that would lead to a political settlement. This, in turn, lowers the threshold for the use of violence. In the context of the emergence of new weapons, a state may start to believe that the opposite side is unable to back up its claims with military force. That said, the situation urgently needs to be resolved, as it could very well take a turn for the worse down the road. In such conditions, there is an increasing willingness to exert pressure on the other side or to use extreme measures, including military action.

These relationships are indirectly related to the real balance of potentials, which largely depends not on the emergence of new weapons, but rather on the level of doctrinal and organizational adaptation of troops to their use. The latter typically becomes apparent only in the course of military operations (in fact, combat use itself contributes to a better understanding and mastery of weapons). The gap between perception and the actual situation on the ground explains why aggressors sometimes lose battles.[19]

The theory of technological uncertainty says nothing about the impact of the specific characteristics of new weapons on international security. It does not factor destabilizing consequences into the equation and, as such, it is a criticism of sorts of the offence-defence balance theory. It is based on the assumption that there are potentially a wide range of uses for new technologies. Even if the weapons turn out to be used primarily for defence, their very use increases the risk of the status quo being undermined due to their novelty and the differences in the assessments of their significance.

The provisions of the theory of technological uncertainty have much in common with the conclusions presented in studies on arms races (Wallace 1979; Sample 1997; Gibler, Rider, Hutchison 2005),[20] which argue that competition between states in defence spending increases the likelihood of wars. While the empirical grounds for these conclusions may be reliable, they fall over when it comes to theoretical foundations (Diehl, Crescenzi 1998) – most authors are satisfied with the assumption that arms races undermine trust between states and do not pay attention to the connection between mutual suspicions and the escalation of conflicts to military confrontations. The theory of technological uncertainty gives a detailed explanation of the impact of qualitative changes in the armed forces on international security.[21]

At the same time, studies of arms races mainly refer to gross defence spending, covering investments not only in technology, but also in the quantitative build-up of

[19] Dan Reiter and Allan Stam's analysis of inter-state wars from 1826 to 1982 revealed that the instigators of armed conflicts emerged victorious two times out of three on average (56 to 30). This suggests that aggressors often incorrectly asses the relative strength of the sides (Reiter, Stam 1998).

[20] For a more sceptical assessment of the contribution of arms races to the launch of wars, see (Rider, Findley, Diehl 2011).

[21] Tellingly, Barry Buzan pointed to technological change as one of the three sources of arms races (Buzan 1987: 105–106).

troops. But numerical increases do not generate the same kind of uncertainty as technological development. And building up numbers itself does not produce serious differences in perceptions of the balance of power, meaning that it easier to calibrate expectations in relation to them. Accordingly, their significance is manifested only in combination with the difficulties in assessing the qualitative characteristics of the armed forces.

To sum up this section, the theory of technological uncertainty offers an alternative explanation for the offence-defence balance theory on the destabilizing consequences of advances in weapons. It shares the scepticism regarding the a priori attribution of a functional role to individual technologies, but does not support the absolutization of political considerations. Identifying specific mechanisms that mediate the impact of new weapons on the risks of military clashes opens up possibilities for empirically testing the proposed relationship.

Technological Development and Modern Era Wars

The explanation of the origins of military clashes between states offered in the previous section differs significantly from existing theoretical approaches. The theory of technological uncertainty suggests that an analysis of the purely general structural characteristics of the international system and even the dynamics of their changes (Waltz 1979; Gilpin 1981; Mearsheimer 2001) is not enough to predict when and why a state would transition from political struggle to a military clash. In this regard, rivalries can by their very nature (structure) continue for a long time without developing into armed confrontation, which was the case during the Cold War.

The theory of technological uncertainty also rejects the technological determinism that is characteristic of the offence-defence balance theory, which sets out strictly defined consequences for individual weapons. In addition, the theory emphasizes that the impact of new technologies on the likelihood of conflicts is mediated by three psychological effects (differences in the perceptions of states about the balance of power; inflated expectations of one's ability to compensate for quantitative limitations with qualitative superiority; and alarmism caused by a feeling of waning opportunities and growing vulnerability). In this respect, it builds on prior work in examining the role of the perceptions an misperceptions of states of the international situation (Jervis 1976).

At the same time, not only does the theory of technological uncertainty reproduce the provisions of previous theories, it also concretizes and supplements them, taking the achievements of science and technology studies (STS) into account. It establishes possible causes of errors and discrepancies in perceptions, linking them to the uncertainty generated by technological change, and also aims to assess the impact on the only dependent variable – the likelihood of armed conflict – rather than on the broad trends in inter-state rivalry and cooperation. At the same time, the explanation of this dependent variable is of great value in view of the catastrophic consequences of inter-state wars.

Thus, the theory of technological uncertainty makes it possible to more accurately focus analyses than before, helping to concretize a number of previously formulated theoretical positions and refute alternate explanations, including the offence-defence balance theory. In a number of cases, supporters of the offence-defence balance theory also name misperceptions as a cause of armed conflicts. They often mention such distortions in cases where states, in their opinion, incorrectly assess their relative strength (Van Evera 1998; Van Evera 1999).

That said, proponents of the offence-defence balance theory do not give detailed explanations of the causes of these distortions and do not trace their connection with the dynamics of technological advancements. Consequently, their arguments about the impact of errors in perception on destabilization appear to the ad hoc attempts to defend theoretical claims against the numerous empirical anomalies that undermine their validity. The theory of technological uncertainty is intended to provide a simpler, more internally consistent and verifiable explanation of the origins of wars than the offence-defence balance theory.

The rationale for the theoretical provisions is based on an analysis of the experience of changes in the ground forces and military clashes between the leading powers from the end of the 18th to the end of the 20th centuries. This period is most associated with qualitative arms races generated by technological changes (Buzan, Lawson 2015). In addition, it is a significant period for the offence-defence balance theory (Van Evera 1999: 169).

The focus on relations between the leading military powers is explained by the fact that they are the main drivers of technological development in the military field, setting an example for other states to try and imitate. And the further prioritization of land armies is because of the leading role they play in clashes between large states (Mearsheimer 2001). In this regard, the subsequent analysis will demonstrate the greater explanatory power of the theory of technological uncertainty compared to the offence-defence balance theory when it comes to the key threats to international security.

A number of difficulties arise when it comes to analysing the impact of technological advancements on the risk of military clashes. The first relate to the operationalization of the explanatory variable due to the diversity of the changes it describes. How comparable, for example, are such innovations as rifled weapons, railways and armoured forces?[22] The criteria for classifying a given technological innovation as significant, rather than an incremental improvement, remain blurred.

This creates a danger of inconsistencies in the definition of what constitutes a significant technology, or how such a designation can be attributed after the fact – that is, after they have proven their potential. As a result, a study of the impact of technologi-

[22] It is worth noting here that technological change is not the only variable in current research that presents difficulties for operationalization. For more on the challenges in developing concepts in the social sciences, see: (Gerring 1999).

cal changes on international security requires a detailed tracing of the evolution of a wide range of weapons, as well as the impressions that these weapons had on people at the time.[23]

The diversity of technological change prevents statistically significant comparisons. Proponents of the offence-defence balance theory faced similar challenges, which led them to rely on qualitative methods of analysis. The history the evolution of the means of organized violence as documented in fundamental historical works helped in this respect (Howard 1976; McNeill 1982; Van Creveld 1989). Descriptions of how weapons have transformed over time allow us to assess the impact of technological advancements on the risks of armed clashes based on an analysis of the most prominent cases.

Given that the theory of technological uncertainty focuses on the psychological mechanism that mediate the relationship between new weapons and the escalation of conflicts to armed confrontations, an in-depth study of a limited number of cases is even preferable to identifying extensive statistical correlations. It allows us to better trace the micro-foundations of dependence and assess alleged causal mechanisms.[24]

Stephen van Evera singled out four periods between the end of the 18th and the end of the 20th century in which the main military clashes between European powers took place: 1789–1815; 1859–1871; 1890–1918; and 1939–1945.[25] Van Evera explained these dynamics through the prism of the offence-defence balance theory, although he did concede that offensive weapons did not always dominate defensive weapons in these cases. That notwithstanding, van Evera argued that, during these periods, states saw aggressive actions as having a greater chance of success (Van Evera 1999: 179).

Regarding the period from the end of the 1850s, van Evera noted that technological changes favoured defence, but a combination of other circumstances pushed states towards aggressive policies. In addition, he put the periods of peace in Europe (1815–1856, 1871–1890, and 1919–1939) down to changes in the sizes of armies and the diplomatic situation (Van Evera 1999: 170).[26] The introduction of multiple variables to

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[23] In addition, see approaches to describing the relationship between technological change and the emergence of new weapons (Burenok 2010).

[24] On the advantages of qualitative analysis methods, see: H. Eckstein, 1975. "Case Studies and Theory in Political Science," *Handbook of Political Science.* Vol. 7, ed. by F. Greenstein and N. Polsby Reading: Addison-Wesley, 1975), 79–138; (George, Bennett 2005; Gerring 2006; Bennett, Checkel 2015).

[25] These dates require some minor clarification. First, van Evera does not include the Crimean War (1853–1856) in the second period, without providing any compelling reasons for doing so, even though he acknowledges that an increase in offensive capabilities had taken place by the time the war broke out (van Evera 1999: 172). Accordingly, this period should be expanded to 1853–1871. Second, van Evera links the beginning of the third period (1890–1918) with the collapse of the Bismarckian network of alliances and the aggravation of contradictions between the leading military powers, despite the fact that none of them entered into direct military confrontation before 1904 (and even then, it was Japan – a non-European country – that was a participant in the conflict). As such, this period of aggravation of military conflict can be reduced to 1904–1918. Third, van Evera's designation of the period 1939–1945 ignores the Spanish Civil War (1936–1939) and the clashes between the Soviet Union and Japan near Lake Khasan and on the Khalkh River. Plus, the leading military powers were involved in both confrontations. Based on this, the final period of exacerbation should be framed as 1936–1945.

[26] This is a rather broad interpretation of the offence-defence balance theory, which, as we have noted above, is a priori unfalsifiable.

account for historical experience looks like an ad hoc attempt to justify anomalies that run counter to the core tenets of the offence-defence balance theory.

At the same time, the proposed time periods are quite consistent with the provisions of the theory of technological uncertainty. Each period of aggravation in European politics was preceded by a wave of changes in the arming of militaries, which led to differences in the perceptions of states about their relative strengths, inflated expectations of one's ability to compensate for quantitative limitations with qualitative superiority, and alarmism caused by a feeling of waning opportunities and growing vulnerability.

Table 1. Correlation of Technological Changes and European Wars of the late 18th–mid-20th centuries.

Period of military exacerbation	Technological prerequisites	Major military clashes
1789–1815	mobile artillery	War of the First Coalition (1792–1797) War of the Second Coalition (1798–1802) War of the Third Coalition (1805) War of the Fourth Coalition (1806–1807) War of the Fifth Coalition (1809) The French Invasion of Russia / War of the Sixth Coalition (1812–1814) War of the Seventh Coalition (1815)
1853–1871	rifled breech loaders; steel artillery; railways; telegraph	Crimean War (1853–1855) Second Italian War of Independence (1859) Austro-Prussian War (1866) Franco-Prussian War (1870–1871)
1904–1918	automatic firearms; rapid-firing guns; motorized transport; aerial reconnaissance; telecommunications	Russo-Japanese War (1904–1905) First World War (1914–1918)
1936–1945	armoured vehicles; ground-attack aircraft; motorized infantry; radio communications	Spanish Civil War (1936–1939) Japanese–Soviet clashes (1938–1939) Second World War (1939–1945)

Source: compiled by the author.

An overview of the impact of changes in weapons on the risks of military clashes from the late 18th to the middle of the 20th is presented in Table 1. The Cold War is not included here, as it is a difficult case to explain using the theory of technological uncertainty, since the rapid development of weapons during this period was not accompanied by armed clashes between the superpowers. At the same time, further analysis will demonstrate that, in fact, this period does not differ in any serious way from the point of view of the explanation that will be put forward. We will also present an additional systematization of technological changes in the second half of the 20th century and the crises that came with them.

The Use of the Gribeauval System against the Anti-France Coalition

The wars of revolutionary and Napoleonic France were preceded by large-scale socio-political upheavals, which have been written about extensively by historians.[27] A number of technological changes also took place during the same period, mainly with respect to artillery weapons. These innovations receive less attention in works that cover international relations in the late 18th and early 19th centuries, although their impact on international security was less pronounced.

Starting in 1776, sweeping changes were made to artillery weapons in France under the supervision of Lieutenant General Jean-Baptiste Vaquette de Gribeauval.[28] Calibres were standardized, new gun manufacturing technologies were introduced, and gun sights, fuses, carriages and ammunition were improved. These innovations made firearms lighter and easier to use on the battlefield. Technological advancements were complemented by a restructuring of the training of professional soldiers. These reforms led to artillery becoming more reliable, accurate and mobile (McNeill 1982: 170–174; Berkowitz, Dumez 2017).

The *Ancien Régime* failed to take advantage of the Gribeauval System, which was only completed towards the end of the 1780s. Although it was instrumental in the struggle of revolutionary France with the European powers. Tellingly, it was as an artillery officer that the future Emperor Napoleon began his military career, and he later made full use of the superiority of French weapons in his campaigns (Kiley 2004). The innovations of the late 18th century left a lasting legacy – the principles of the Gribeauval System would, with minor adjustments, set the course for the development of artillery until the middle of the 19th century.

While artillery played an impressive role in the wars of France, the period 1789–1815 provides only weak evidence that technological advancements had an impact on the likelihood of military clashes. The formation of anti-French coalitions engendered, first and foremost, a sense of fear among the European elites following the overthrow of the monarchy (Walt 199; Haas 2005). Subsequently, French expansionism fuelled the development of the republican ideology, *levée en masse* and the meritocracy of military command (Herrera, Manken 2003).

Napoleon famously said, “God is on the side with the best artillery.” His confidence in French weaponry affected his perception of the balance of power and his readiness to engage in wars. That notwithstanding, the evidence that is available to us is not enough to assert that advances in weapons played a significant role in the out-

[27] See, for example: (Schroeder 1994).

[28] The French reforms were in many ways a legacy of the innovations introduced by Joseph Wenzel I, Prince of Liechtenstein in Austria in the middle of the 18th century, under whom Gribeauval served. However, unlike the later developments in France, Austria’s attempts to improve artillery did not lead to a profound revision of the principles and forms of warfare (MacLennan 2003).

break of armed clashes in the late 18th and early 19th centuries. Technological change was an ancillary factor to the uncertainty caused by the socio-political and organizational upheavals that were taking place at the time.

The cessation of armed conflicts in the following decades against the background of a relative stagnation in the development of weapons is a far more compelling argument in favour of a testable theory on the impact of technological change on the likelihood of armed clashes. Despite the rivalry between Austria and Prussia in Germany, the trade competition between Great Britain and France that intensified starting in the 1830s, and the disagreements between liberal and conservative powers, peace was nevertheless maintained in Europe for almost four decades following the Napoleonic Wars.

This period was marked by a serious imbalance, with Russia holding an overwhelming superiority over other powers in terms of the size of its army. The military advancements that did take place in the years following the Napoleonic Wars were mostly incremental in nature.[29] The lack of technological leaps helped maintain predictability in the balance of power, stave off alarmist feelings that one's country may be falling behind in terms of arms development, and, similarly, reined in expectations of qualitative superiority. That is, the absence of significant changes in armaments was a factor in maintaining stability.

Railroads, Rifles, Telegraph Communications and the Wars of 1853–1871

By the early 1850s, the spread of new means of transport and communications, coupled with the development of small arms and artillery weapons, made the possibility of a clash breaking out between European powers increasingly real (Showalter 1975; Herrera 2004). Advancements on a large scale brought previously stable notions about the balance of power into question, resulting in a series of wars. This period in history supports the assumptions of the theory of technological uncertainty and contradicts the provisions of the offence–defence balance theory.

The development of modern railways began in Great Britain in the 1810s, but rail transport was not used for military purposes until the 1840s in Prussia. Berlin started to finance the construction of commercial railways in strategically important areas. Other powers would soon do the same (Showalter 1975; Herrera 2012). Railways were used to deliver troops to the front for the first time during the Second Italian War of Independence in 1859. In 1866, the advantages that a developed transport network provided in terms of getting a large number of troops to the front quickly factored into Prussia's calculations when it was pondering launching a war against Austria.[30]

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[29] For example, in 1827, the French artillery switched from the Gribeauval System to the Valée system, with other European powers following suit in the 1830s. The changes were intended to further increase the mobility of artillery, but did not include the kind of game-changing transformations that had taken place in the latter half of the 18th century.

[30] See, in particular, the *Rationale for the Campaign against Austria* of April 20, 1866 by Chief of the Prussian General Staff Helmuth von Moltke (Moltke 1992).

In subsequent years, Paris invested heavily in increasing the density of its rail network. This formed the core of its plans in the period leading up to the Franco-Prussian War of 1870–1871. France expected to defeat the larger German forces before the foe had been able to fully deploy its troops (Howard 1961; Wawro 2005). That is, Paris also hoped to compensate for the mismatch in size with superior mobility. The decision was precipitated by concerns that Berlin might close the gap in this area.

The expanded use of the railways was accompanied by a similar increase in the firepower of troops. In the late 1840s, French inventor Claude-Etienne Minié proposed an expanding bullet that would increase the rate of fire from muzzle-loading rifles. The advantages of rifles in terms of range and accuracy had long been known, but issues with loading prevented them from becoming widespread. The so-called Minié ball solved this problem, and their extensive use during the Crimean War proved the devastating effect of the invention (Showalter 1975: 93; Shah 2017).

It was also in the 1840s that Prussia started experimenting with a breech-loading needle gun developed by Johann von Dreyse. The gun was far superior to the usual muzzle-loading weapons in terms of the rate of fire, while also enjoying the advantages of a rifled barrel. However, there were doubts about the reliability of the Dresye gun, which meant that the Prussian army was slow to adopt it. In fact, it was not until 1858 that it became an official weapon of Prussian soldiers (Showalter 1975: 99).

The new weapon proved its effectiveness in the war of 1866, prompting Prussia's rivals to switch to breech-loading small arms as well. Influenced by the successes of Berlin, Paris adopted the Chassepot rifle, which had a range twice that of the German gun. This, along with the appearance of the mitrailleuse (a forerunner of the machine gun), convinced French leaders that the country was ready to go to war with Prussia in 1870. The density of the French rail network, and its superiority in terms of small arms fuelled optimism in Paris that it could defeat the German states against which had declared war.

At the same time the revolution in small arms was taking place, advancements were also being made in terms of artillery. From the late 1840s, states started to introduce rifles, which provided a greater range of fire. They also replaced solid metal ball ammunition with explosive projectiles. France demonstrated the advantages of the new guns in the war of 1859. Around the same time, German industrialist Alfred Krupp developed a steel breech-loading gun. It differed from previous bronze models in its greater range and durability. Berlin hastened to get the new guns into use, while Paris underestimates Krupp's innovation. These differing assessments played a role in the calculation of the parties on the eve of the war in 1870–1871. As the conflict unfolded, Prussia's steel guns proved superior to the weapons the French side was using (Showalter 1988).

A less prominent innovation of the middle of the 19th century was the telegraph, which expanded the possibilities of command and control. The development of communications helped speed up the process of mobilizing troops and improve the coordination of military operations in conditions where the sizes of armies were constantly growing (Herrera 2004). Telegraph communication was first used during the Crimean War, and subsequently played a significant role in the Franco-Prussian War. That said, there is no evidence in the available sources and literature to suggest that the development of communications had a serious impact on the calculations of states. On the contrary, the Chief of the Prussian General Staff, Helmuth von Moltke, feared that these developments would lead to excessive centralization of command and control, which in cause would cause commanders to be less decisive on the battlefield. It was not until the Franco-Prussian War was in full swing that he changed his opinion on the matter.

On the whole, the period 1850–1870 was marked by the emergence of numerous technological innovations in European armies. The significance of these innovations was assessed differently by individual powers, reflecting the difference in how they perceived the balance of power and in their ideas about an imminent revolution in military affairs. The wars that took place between 1853 and 1871 confirmed time and again the impact that technological advancements had on military clashes. During this period, states repeatedly entered into armed confrontations with opponents who clearly had a numerical superiority, counting on their own technological supremacy.[31] They often pinned high hopes on the inventions they introduced, attributing revolutionary consequences to new technological capabilities.[32]

Finally, they sought to take advantage of the closing window of opportunity before others could catch up. A prime example of this was France's decision to declare war on Prussia in 1870: Paris believed that investment in railway construction would allow it to deploy an army before the enemy, which had greater numbers of trained reservists, had a chance to fully mobilize. It was also confident in the advantages that the latest Chassepot and mitrailleuse rifles would give it. At the same time, Paris was concerned that Berlin would be able to quickly close the gap, and therefore sought to force matters. However, all these calculations turned out to be wrong.

Thus, the development of events in the middle of the 19th century fully corresponds to the assumptions of the theory of technological uncertainty. The wars of this period provide compelling evidence to support this theory, as many of the innovations that appeared during this time would come to be associated with improved defensive capabilities. That said, the growth of uncertainty in the 1850s–1860s caused by the appearance of these new technologies stimulated an aggressive policy based on military power.

[31] Examples of this include the actions of London and Paris during the Crimean War, Berlin during the Austro-Prussian War, and Paris during the Franco-Prussian War.

[32] See, for example, Helmuth von Moltke's comments on how improvements in firearms influenced his tactics (Moltke 1992).

Rapid Fire Artillery, Automatic Weapons, Aviation and the First World War

After the end of the Franco-Prussian War, peace was established in Europe for four decades. The fact that the continent remained conflict-free for so long is often attributed to the diplomatic genius of Otto von Bismarck, who managed to get states to cooperate by developing a network of mutual obligations (McDonald, Rosecrance 1985; Schroeder 2004; Alexandroff 2014). But the fact remains that even after his removal from office in 1890, the European powers did not enter into any armed confrontations with each other for almost a quarter of a century. This long period of peace can be put down to the relative predictability of the balance of power at the time.

The main change in European armies after the Franco-Prussian War was the replacement of single-shot rifles with multi-shot rifles, which further increased the rate of fire. States started to introduce them into service on a large scale in the mid-1880s (Stevenson 1996: 17). These developments coincided almost perfectly with the invention of smokeless powder, which had a greater explosive power than the previous gunpowder used. However, its usability in terms of increasing the range of fire was hampered by problems with stabilizing the guns.

On the whole, by the late 19th century, the pace of development of land weapons had slowed down compared to the middle of the century.[33] This situation was partly responsible for the closeness of views among states of their relative military potentials, their tempered expectations, and the reduction of alarmist statements about loosing opportunities and growing vulnerability. In the event of a crisis, states preferred to negotiate, rather than rely on military force.[34]

The pace of technological change picked up once again at the beginning of the 20th century. Just like in the middle of the 19th century, innovations in various areas appeared simultaneously, leading to an increase in firepower and the scale of operations and to the emergence of a fundamentally new space for confrontation. The developments again created an imbalance in the capabilities of states, and this became a factor in the outbreak of the First World War.

The most significant changes in terms of building up military potential occurred in artillery. In 1897, a field gun equipped with a recoil mechanism appeared in France. It provided a significant increase in speed, accuracy and range compared to its predecessors.[35] Before this, the recoil after firing meant that guns had to be constantly repositioned and aimed. Recoilless guns made it possible to ad-

[33] However, rapid changes were taking place in the technological equipment of naval fleets. For an overview of the evolution of naval forces, see (Van Creveld 1989).

[34] For example, during the "war scare" of 1875, the escalation of the situation caused by the Russo-Turkish War of 1877–1878, and the Fashoda Incident of 1898. For an overview of the political history of this period, see (Taylor 1955).

[35] Recoilless guns had previously been used in naval artillery. In 1877, the V.S. Baranovsky quick-shooter was developed in Russia, although it was never put into wide production.

just fire and shoot from closed positions based on information from fire spotters (Herrmann 1997: 17–18).

The French kept their new invention secret for several years, although this did not bring Paris any dividends. The hit in prestige suffered by the army as a result of the Dreyfus affair prevented France from pursuing an aggressive policy. Other countries started to adopt guns with recoil mechanisms in 1902. Large-calibre recoilless howitzers appeared the following decade. By the beginning of the First World War, Germany had become a leader in the development of artillery.[36]

Another important innovation was the appearance of machine guns. Back in 1884, the American inventor Hiram Maxim proposed a promising system of automatic fire, but the European powers were sceptical. The experience of colonial conflicts and the Russo-Japanese War of 1904–1905 gradually dispelled these doubts. The European armies feverishly stocked their armies with machine guns in the decade preceding the outbreak of the First World War (Herrmann 1997: 19–20).

The increase in rate of fire made troops more dependent on supplies, which, in turn, prompted the expansion of the use of motorized transport to deliver goods from railway hubs. With the growth of armies, the military also became interested in new means of communication, primarily telephone communication, since radio station remained too complicated, inconvenient and expensive. Nevertheless, during the First World War, officers continued in many cases to rely on messengers to transmit information to the battlefield, and weapons were mostly delivered on horseback.

The early 1900s saw the field of battle move to the air. Before this, attempts had been made to use balloons for military purposes, but controlling vehicles in flight proved to be difficult before the advent of internal combustion engines (Ziegler 1994). From 1906, European armies experimented with the use of airship, and after 1908, they began to study the possibilities of the recently invented airplane (Herrmann 1997: 75, 138). France initially took the lead in this area, but Russia and Germany had caught up by 1914. The limited carrying capacity of planes made aerial bombardment pointless, but they did expand the ability to monitor the movement of troops. Aviation was also used to artillery spotting.

The increase in firepower made it difficult to capture the prepared positions of an entrenched enemy, meaning that serious changes in tactics and operational art were needed. The wall of fire produced by machine guns forced attackers to lie down on the ground, where they would be taken unawares by mounted artillery shelling. Carrying out offensive operations in such conditions required the development of tactics that were inaccessible to European armies at the time.[37] That notwithstanding, states continued to consider offensive manoeuvres as the best option for military action, trying

[36] Among other things, Germany acquired twelve 305-mm calibre siege mortars and five 420-mm calibre guns; no other country could boast weapons of this kind (Herrmann 1997: 201).

[37] The implications of increased firepower for military tactics back then are detailed in (Biddle 2004).

to adapt new technical means to it (Van Evera 1984). The lack of experience in using such technology in live conditions made it difficult for the armed forces to adapt, both strategically and organizationally.

At the same time, the armed forces of Russia and France were traditionally superior to those of Germany and Hungary in terms of total strength. Despite this, up until the mid-1910s, Berlin remained convinced it would be victorious in any potential class due to the speed at which it could mobilize troops, its better organization, and the fact that its army possessed a greater abundance of advanced weapons. Germany's strategy was based on balancing out quantitative disparity with qualitative superiority. By 1914, Germany had caught up with France in those areas where it had previously lagged behind (the widespread provision of machine guns, field guns and aircraft to troops), while maintaining its superiority in heavy guns.

At the same time, Berlin was concerned by Russia's resurgence, which consisted in a bigger army, improved training methods, the provision of advanced weapons, and increased mobilization speed. Germany's Minister of War Josias von Heeringen admitted in April 1913: "Russia had enough men and money and a willing parliament. Already today it had 400,000 more men than in 1912."[38] Germany came to the conclusion that the strengthening of Russia in the coming years would ensure the superiority of the Entente. The gap in size of the armies threatened to increase even more, while Berlin's technological superiority was in danger of fading, which would increase its vulnerability. Meanwhile, St. Petersburg and Paris were confident that their joint capabilities in 1914 were enough to ensure victory (especially with the participation of Great Britain). Although they acknowledged that their prospects would be less rosy if they were to lose their Balkan allies (Clark 2012).

In the period leading up to the First World War, states paid great attention to the number of bayonets they had at their disposal. Both Germany and France changed their conscription rules in order to have a larger pool of reservists and build up a permanent contingent. However, the size of the armies themselves said very little about the actual balance of power. Their battle-worthiness was in large part linked to their mastery of weapons, many of which had yet to be tested in real combat conditions. At the same time, the increase in firepower created unjustified expectations that a military confrontation would take the form of a short, extremely intense engagement in which the speed of initial mobilization would play a decisive role. As usually happens when new technology appears, these expectations fell far short, but the belief in the superiority of the first strike made the stakes that much higher.

The events of the early 20th century confirm the destabilizing effect of technological change, in combination with other factors, including the growth in the size of armies, the quality of military training, and the dynamics of relations in coalitions. Rapid changes in armaments made it difficult to assess the international situation, el-

[38] Quoted by (Herrmann 1997: 183).

evating the risk of a military clash even more. The major European powers differed in their ideas about the balance of power, taking both qualitative and quantitative characteristics into account. Berlin and Vienna in particular relied heavily on their ability to compensate for their numerical disadvantage with technological and organizational superiority. All the warring parties, especially Germany and Austria–Hungary, were concerned about their increasing vulnerability in the face of the modernization of their opponents' armies. In this case, the explanatory power of the theory of technological uncertainty is noticeably greater than that of the offence-defence balance theory, since the weapons that appeared did not enhance offensive operations, but rather distorted the perception of the balance of power.

The Technological Foundations of Blitzkrieg and the Second World War

The prerequisites for the next wave of technological development were laid as early as during the First World War. The mechanization of the armed forces, coupled with the development of aviation and the emergence of new means of communication again complicated the perception of the balance of power in the 1930s. As a result, the next clash of European powers took place only two decades after the previous large-scale conflict.

Any discussion of the origins of the Second World War cannot ignore the aggressive aspirations of Nazi Germany, which sought to master the "living space" and achieve European hegemony (Kamenetsky 1961; Koch 1983). However, until 1939, Berlin acted cautiously, hiding its ambitions and potential, only moving to open expansion when it was sufficiently confident in the capabilities of the German armed forces (Mihalka 1980). At the same time, just like in 1914, Germany was counting on its qualitative superiority as a counterbalance to its quantitative limitations.

The most important technological innovation in the final battles of the First World War was the appearance of tanks. Tracked armoured fighting vehicles helped to overcome zones of intense enemy fire, punch holes in barbed wire barriers, and suppress machine gun emplacements. However, early tanks were slow, poorly protected and unreliable. Moreover, the armed forces could not figure out the best ways to use them back in 1918.[39]

In the interwar period, European powers actively experimented with various designs of armoured vehicles. By the end of the 1930s, the thickness of the armour, calibre of the guns, and speed of the vehicles had increased, and exotic designs with several turrets were gradually abandoned. In the middle of the decade, light tanks made up the core of the arsenals of the European powers, which provided protection against

[39] Alaric Searle, who wrote the most comprehensive history of the armed forces, claims that tanks made an important contribution to the victory in the First World War (Searle 2017: 33), although most historians do not share his enthusiasm (Rosen 1991; Childs 1999; Biddle 2004: 34–35).

bullets only (for example, the German Panzer I and II, and the Soviet T-26). In many cases, they were equipped with machine guns, rather than canons.

By the start of the Second World War, new medium and even heavy tanks had started to play a leading role (examples include the Panzer III and IV, the T-34 and the KV-1 and KV-2). At the same time, until 1940, most countries continued to see tanks primarily as a means of reinforcing infantry, rather than the basis of offensive power. Armies were unable to adapt to the new technological capabilities (Murray 1996; Searle 2017).[40]

It was only when planning its campaign against France in the winter of 1940 that the German military developed the concept of using mobile formations to encircle the enemy, which would later be termed *blitzkrieg* (Mearsheimer 1985; Posen 1984). Carrying out such operations required both a new approach to the use of tanks, and an increase in the mobility of the accompanying infantry. This led to an increase in the use of light armoured vehicles to transport troops close to the battlefield.

Managing mobile units increased the requirements for communication technologies. This was not as important during the positional battles of the First World War, but organizing offensives of large groupings of troops increased the need for communication several times over. From the mid-1930s, the German armed forces started to purchase radio equipment in far greater volumes than their potential adversaries, using it to coordinate actions at the tactical level (Citino 2004).

Another manifestation of technological advancement was the improvement of aircraft. At the same time, states followed different paths in the development of their respective air forces. Great Britain was more focused on creating a material base for strategic bombing of the rear, which would require increasing the payload of aircraft. It was also interested in developing its air defence capabilities, launching a radar network by the beginning of the 1940s (Meilinger 1996; Overy 2010: 27–28).

Germany, the Soviet Union and France were more interested in aircraft that would provide support for ground force operations. Accordingly, they focused on developing attack aircraft. German Junkers Ju 87 dive bombers, first tested during the Spanish Civil War, proved effective with the support of mobile formations. At the same time, Germany lagged behind in the development of heavy aircraft, which became evident during the Battle of Britain in 1940 (Young 1974; Corum 1996; Muller 1996; Overy 2010: 27–28).

Technological uncertainty played a significant role in the launch of military clashes in Europe. By 1939, Great Britain and France had an edge over Germany in terms of the number of tanks and aircraft, although Germany did have more weapons. At the time of the invasion of Poland, Berlin had not yet adapted to the new technological possibilities in terms of its military doctrine. While this did not prevent Germany

[40] The Soviet Union differed in this respect, as it embraced the idea of using mobile formations to break through defences and carry out actions in depth more than any other state (see Mints 2010).

from defeating an obviously weak opponent, it did not guarantee victory in a war with major powers.

Great Britain and France underestimated the importance of new weapons, counting on a repetition of the experience of the struggle of attrition of 1914–1918. In the 1930s, Paris invested in an advanced fortification system, pinning its security on the advantages of a defensive strategy. Meanwhile, London was determined to exhaust the enemy with strategic bombing, taking advantage of its supremacy in heavy aircraft (Posen 1984). As a result, having declared war on German, the Western allies could not turn their qualitative superiority into victory.

By 1940, the German leadership had developed a new approach to the offensive built around armoured forces, which it used against France. One of the major factors in the decision to attack France was the technological superiority of German weapons and, most importantly, the fact that German troops knew how to use them. Given the technological innovations at its disposal, Berlin expected to encircle and defeat the sizeable Franco–British forces. And the results exceeded Germany's wildest expectations (Jackson 2004; Frieser 2005).

In turn, Germany's invasion of the Soviet Union stemmed not only from Hitler's ideological programme, but also from the desire to deprive Great Britain of potential allies to continue the struggle. Germany's lack of resources for a long campaign, coupled with its desire to end the war in the west paradoxically pushed it to aggressive actions in the east. Hitler's primary foal in the war with Moscow was not so much to capture territory as it was to destroy the Soviet Union's military and industrial potential (Stahel 2009: 38, 54, 61, 71).

Looking at the latent capabilities of the Soviet Union, Berlin once again relied on qualitative superiority, counting on the rapid defeat of the Red Army. The German leadership's underestimation of the Soviet enemy was based, among other things, on notions about the inferiority of Slavic peoples and the consequences of Stalin's purges of the command personnel. Berlin's calculations were also heavily influenced by the confidence in the superiority of German weapons.

Chief of the General Staff of the German Army High Command Franz Halfer, who planned the invasion, noted in his diaries that the Red Army aviation was archaic, its artillery was based on obsolete models, and its tanks were noticeably inferior to Panzer IIIs. At a meeting on December 23, 1940, German intelligence emphasized the shortcomings of the armoured vehicles of potential enemies in terms of security, speed, communications and targeting devices (Stahel 2009: 63, 70). Based on these assessments, we can conclude that it was not the possible resistance of the Red Army that caused Berlin concern, but rather the likelihood of its retreat deep into Soviet territory and the subsequent prolongation of the campaign.

Just like in the period before the First World War, technological uncertainty (in combination with other factors) influenced the decision to initiate a conflict in the late 1930s. The years running up to the war saw the widespread introduction of new weapons. As a result, states differed significantly in their doctrinal and organizational adaptation to the use of new technologies. Paris underestimated the capabilities of armoured forces, prompting it to declare a war it was not ready for, and then passively accept a German invasion. And Germany's reassessment of the successes of the French campaign created inflated expectations among the country's leadership regarding its technological superiority over the Soviet Union.

In both cases, the ideas of these countries about the balance of power turned out to be incorrect. Berlin's decisions were also influenced by the thought that the window of opportunity for an attack was closing, given the greater industrial potential of its adversaries and its own limited resources. Meanwhile, Paris and London proceeded from the fact that their window of opportunity for resisting German expansion was largely closed, and therefore did not take any pre-emptive actions, despite their numerical superiority. Finally, Moscow sought to delay its entry into the war, hoping that its vulnerability would decrease as the Red Army completed its modernization.

The period 1936–1945 provides limited opportunities for comparing the theory of technological uncertainty with the offence-defence balance theory, which, for its proponents, is associated with the growth of the offensive potential of states and, accordingly, the likelihood of conflicts escalating to the stage of military confrontation. Under these conditions, it is difficult to assess which of the two hypotheses better explains the outbreak of the Second World War. At the same time, the theory of technological uncertainty is supported by the fact that the states had distorted ideas about the balance of power, and did not unanimously prefer offensive actions, as one may expect from the nature of their weapons. In addition, both high expectations associated with technological innovations and alarmism about the likelihood of a rapid change in the situation were present during this period,

Technological Changes during the Cold War

It would appear that it is rather difficult to apply the theory of technological uncertainty to the Cold War period. While it is marked by the intensive development of weapons, there was no direct military clash between the Soviet Union and the United States. This could lead us to the conclusion that there is no relationship between technological change and the risk of military confrontation. At the same time, proponents of the offence-defence balance theory explain the period of peace in the latter half of the 20th century by the appearance of nuclear weapons, which ensured the dominance of defence (Van Evera 1999).

The purpose of this section is to prove that the historical period of the Cold War does not contradict the provisions of the theory of technological uncertainty. It allows us to explain both the absence of a direct military clash, and instances of intensified rivalry between the Soviet Union and the United States. In this respect, it has greater explanatory power compared to the offence-defence balance theory. In addition, the experience of the second half of the 20th century highlights the differences in uncertainty generated by single and multiple technological advancements.

While several new types of weapons appeared during the Cold War, they were introduced over the course of a long historical period. The risks created by technological change did not overlap, but instead spread out over several decades. This is where the second half of the 20th century differs from the middle of the 19th century, and the periods leading up to the outbreak of the two world wars. This difference was caused, on the one hand, by fact that technological uncertainty was not as pronounced at specific points in time, and, on the other hand, by the fact that this uncertainty came in several bursts.

As new weapons appeared, the superpowers experienced periods of heightened mutual fears, but ideas about the balance of power did not differ enough to bring about actual armed hostilities. However, they did provoke a number of crises that brought the sides to the brink of aggression. Thus, the Cold War period for the most part does not contain any anomalies in terms of a testable theory, although it does require clarification regarding the difference between cases of single and numerous technological breakthroughs.

Table 2 summarizes the technological changes that took place in the second half of the 20th century and the accompanying crises that threatened to escalate into military clashes.[41]

There were four waves of the introduction of new weapons during this period: the emergence of nuclear weapons; the development of missile technology; missile defence and carriers with multiple warheads; and the creation of high-precision conventional arms. Three of the four waves were accompanied by an intensification in the Soviet–US rivalry, bringing the superpowers to the verge of an armed collision.

Table 2. Correlation between the Dynamics of Technological Change and the Crises of the Cold War

Period of military exacerbation	**Technological prerequisites**	**Crises that could potentially have escalated to a direct military clash of the superpowers**
late 1940s – early 1950s	nuclear and thermonuclear weapons	Korean War (1950–1953)
late 1950s – early 1960s	rocket technologies	Second Berlin Crisis (1958–1961); The U-2 Incident (1960); The Cuban Missile Crisis (1962)
late 1960s – early 1970s	missile defence; multiple independently targetable re-entry vehicles	
1980s	precision weapons; intermediate-range missiles; the Strategic Defense Initiative	West – 1981 Downing of a Boeing plane in 1983; Able Archer – 1983

Source: compiled by the author.

[41] The table does not cover a number of asymmetric conflicts (such as the Vietnam War and the War in Afghanistan), as well as the clashes between Soviet and US satellites (for example, in the Middle East), since the risks of direct confrontation remained low in these cases.

The appearance of the atomic bomb was announced by the American bombings of Hiroshima and Nagasaki at the final stage of the Second World War. The United States had a monopoly in these weapons for a short time. The Soviet Union did not test its first nuclear weapons until 1949, and the progress Moscow had made took many in Washington by surprise. This notwithstanding, the United States continued to have more nuclear warheads for many years to come. In the early 1950s, both superpowers tested thermonuclear weapons. The potential damage that such weapons could cause was many times greater than anything that had been seen before.[42]

The unprecedented power of this new type of weapon was immediately obvious, but the most promising methods of its application and, accordingly, its impact on the balance of power remained a topic of discussion (Rosenberg 1983). The United States saw its nuclear arsenal as a means of compensating for the superiority of the Soviet Union in conventional weapons. At the same time, in the early years of the Cold War, it was extremely limited in terms of both the number of nuclear bombs it possessed and in their means of delivery.

In this respect, during the Berlin Blockade of 1948–1949, the sides did not actually consider options for escalating conflicts to the point of an armed confrontation (Betts 1987). The United States would subsequently increase the potential for the combat use of nuclear weapons, building up arsenals and creating the necessary infrastructure. The Americans considered using these weapons on several occasions during the Korean War. In particular, China became the target of planned nuclear bombing when peace negotiations stagnated in 1953. In the first half of the 1950s, the US leadership, concerned about the growing Soviet arsenal, seriously considered the possibility of a pre-emptive strike against Moscow (Trachtenberg 1988).

The uncertainty caused by the appearance of nuclear weapons did not result in a clash of superpowers, although it did complicate assessments of the balance of power. The new weapon created a surge in expectations of revolutionary consequences, and the temporary nature of US dominance created the temptation to take advantage of the closing window of opportunity. At the same time, the United States did not expect its monopoly to be so short-lived. In addition, the emergence of nuclear weapons, in a sense, created less uncertainty than the development of weapons in the previous periods we have looked at, as its destructive effect was patently obvious from the onset. This may explain the willingness of the Soviet Union to make unilateral concessions during the crises in the early days of the Cold War. Technological advancements did not lead to any direct clashes between the superpowers in the 1950s, but they did increase the risks of destabilization.

The next stage of exacerbation came as a consequence of the development of rocket technology. This period was preceded by a limited détente in US–Soviet relations,

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[42] The power of the bomb used in Hiroshima was estimated at the equivalent of around 15 kilotons of TNT. The power of the first detonated thermonuclear charge exceeded 10 megatons.

which was made possible by the stabilization of the balance of power. In 1956, the superpowers even demonstrated their ability to work together when they opposed the "triple aggression" of Great Britain, France and Israel against Egypt.   But the competition heated up again towards the end of the 1950s.

The successes of the Soviet Union in the Space Race gave rise to fears in the United States about the risks of a "missile lag." Intercontinental ballistic missiles, which both superpowers put into service in 1959, put US territory within reach of the Soviet nuclear forces. Moreover, Moscow often exaggerated its successes in the production of new weapons, which only served to heighten US fears (Roman 1995).

The increased capabilities gave the Soviet Union leadership a swagger to their step, which was manifested in its disputes over Berlin and the expansion of Moscow's activity expansion into the Third World.[43] Tension was also caused by the incident with the U-2 reconnaissance aircraft that was shot down by newly developed anti-aircraft missiles over Soviet territory in 1960. The reason for these was Washington's desire to get some kind of confirmation of Moscow's achievements in military construction. That is, they came about due to a lack of information about the balance of power. The provocative nature of this foray, as well as the likelihood of US military personnel being killed or captured, raised the stakes of the confrontation (Geelhoed 2020: 167).

The most striking case of destabilization during this period was the Cuban Missile Crisis, caused by the deployment of Soviet missiles in Cuba in 1962. The appearance of cutting-edge weapons near US territory provoked a sharp reaction from Washington. The United States considered a strike on Soviet installations in response, a move that would have put the world on the verge of a military clash between superpowers. At the same time, Moscow's reasoning for deploying missiles in Cuba was that it was concerned about the United States doing the same in Turkey (Betts 1987).

Once again, the emergence of new weapons heightened the risks of a military clash between the superpowers. The development of rocket technology raised doubts among the superpowers about the current balance of power. In particular, it was accompanied by inflated expectations of possible shifts in favour of the Soviet Union following the emergence of new types of nuclear weapons carriers. The United States was particularly concerned about its growing vulnerability in the near future, associating missile technologies with the risks of losing their advantages. Against the background of growing technological uncertainty, the superpowers against came closer to a direct confrontation, but they did not cross the line.

The next stage in the arms race between the Soviet Union and the United States unfolded in the late 1960s and early 1970s as a consequence of the development of missile defence systems, as well as the emergence of new weapons. A distinguishing feature of this stage was that technological uncertainty did not lead to an acute crisis. Quite the opposite, it was during this period that the confrontation between the superpowers stabilized and international tensions cooled.

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43 For more on the risks of nuclear escalation during the Soviet blockade of Berlin, see (Betts 1987).

These dynamics are partly explained by the fact that the United States was still reeling from its defeat in Vietnam, the Soviet Union had become concerned about the growth of China, and both sides recognized their strategic parity. At the same time, the easing of tensions was only possible after the Soviet Union and the United States realized that it was technically impossible to protect their respective territories from a missile attack. Throughout the 1960s, the sides developed programmes in this area, but in the end, they limited themselves to the deployment of warning systems and the missile defence of specific areas. Thus, arms control could only be established after the uncertainty associated with the development of defensive means of countering the enemy's strategic nuclear forces (an ultimately fruitless endeavour) had subsided (Cameron 2017).

The consequences of the appearance of intercontinental ballistic missiles with multiple independently targetable re-entry vehicle (MIRV ICBMs) raises more questions. The United States was the first to test such weapons in 1969, putting them into service the following year (Green, Long 2017). Despite the widespread recognition that this technology would likely not prevent a retaliation in the event of an attack, its creation did not impede the de-escalation process. The introduction of such weapons reflected the attempts of the parties to achieve strategic superiority, but they did not lead to a significant divergence in their views on the balance of power ¬– the appearance of MIRVs shook, but did not undermine, the idea of the relative stability of mutual vulnerability. Nor did it cause a rise in alarmism associated with increased expectations from the new technology that was appearing.

This anomaly is a repeat of the situation with the introduction of multi-shot weapons in the 1880s we talked about earlier. In both cases, a technological breakthrough in one area did not undermine international stability in any significant way. At the same time, the appearance of MIRVs does not fit into the explanation offered by the offence-defence balance theory, since this technology, just like missile defence, is typically given an offensive significance. Even so, these technological advancements did not bring about an escalation in the rivalry between the two states, despite the specific characteristics of the weapons themselves.

Finally, another wave of technological change appeared at the turn of the 1980s in connection with the development of space tracking, guidance and positioning, as well as the development of cruise missiles. The combination of these technologies resulted in the emergence of high-precision weapons, which provided conventional forces with the ability to create a threat comparable to the use of nuclear charges. These weapons were integrated into updated doctrinal approaches and organizational models.[44] The technological advancements made in the late 1970s and early 1980s represented the most serious revision of previous approaches to confrontation in a key European theatre of potential conflict (Mearsheimer 1985; Posen 1991).

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[44] For more on the correlation between technological, doctrinal and organizational innovations during this period, see (Palmer 2014).

In parallel with this, towards the end of the 1970s, the Soviet Union and the United States started to adopt and deploy a new generation of medium-range missiles equipped with nuclear warheads that combined wide coverage of targets in the European theatre with a short approach time. Additionally, discussions on missile defence systems resumed in the early 1980s, including systems deployed in space and those equipped with laser weapons (Duric 2003). These projects resulted in Ronald Reagan's Strategic Defense Initiative, which was never put into operation.

Thus, a wide range of new types of weapons were developed in parallel from the late 1970s to the early 1980s. Throughout the entire Cold War, this period was characterized by the densest overlap of several sources of technological uncertainty. Consequently, in the early 1980s, the superpowers came closer than they ever had before to the threshold of a conflict escalating into a full-scale military confrontation in the most significant region of adversarial engagement – Europe.

The emerging superiority of the United States in a number of technological areas exacerbated the sense of vulnerability in Moscow. In particular, the articles published by the Chief of the General Staff of the Armed Forces of the USSR Nikolai Ogarkov noted the concerns of the Soviet leadership regarding the impact of new weapons on the balance of power (Ogarkov 1982; Ogarkov 1985). What is more, Soviet military thought attached even greater importance to the prospects for qualitative changes in the conventional forces than American experts, who were the first to formulate the thesis of a "scientific and technological revolution in the military sphere."

The growing uncertainty surrounding the stability of the balance of power led to even greater military tensions (Fischer 1997; Miles 2020). Growing fears about possible Western military aggression prompted Moscow to systematically collect information on the possibility of a nuclear strike based on a system of indicators that had been developed. The confrontation reached its peak in the autumn of 1983, when a Soviet fighter jet shot down a South Korean airliner that had entered Soviet airspace and did not respond to requests, causing a rather intense crisis. Immediately after this incident, NATO conducted large-scale exercises involving the use of nuclear weapons, which many saw as a potentially destabilizing factor.

Despite the fact that the ideological tenets of the Reagan administration also served to increase tension in the early 1980s, it is difficult to ignore the influence that the growing uncertainty of the sides regarding the balance of power caused by the introduction of qualitatively new types of weapons and the expectations of a revolution in military affairs had on the development of events. First, the Soviet side was concerned about the window of vulnerability that was opening up as a result of the country's lagging behind in the field of informatization and the introduction of new conventional means of warfare. With limited access to archival sources, it is difficult to assess how close the parties came to a military conflict during this period.

In general, the experience of the Cold War does not refute the theory of technological uncertainty as such, but it does require a slight modification to the previous arguments. The greatest risks are fraught with the implementation of several innovations in parallel within a short period. Individual advancements in arms development are less dangerous, although they also increase the likelihood of exacerbation. This much is confirmed by the experience of previous periods (for example, the spread of multi-shot rifles in the 1880s).

Throughout the Cold War, almost every wave of new weapons brought the superpowers to the brink of direct military clashes. What is more, they were all associated with an increase in fears about possible aggression. Even nuclear weapons, sometimes described as predominantly defensive, created incentives for offensive action. This effect goes against the provisions of the offence-defence balance theory, but this is to be expected based on the theory of technological uncertainty.

The analysis given above was intended to prove the theory of technological uncertainty by establishing the dependence of risks of military clashes on the emergence of new weapons, and identifying the psychological effects that mediate such influence. The validity of the explanation we have presented here was tested on vast and varied empirical material, more so than the offence-defence balance theory that has been widely recognized up until now.

Examples from history provide solid support for the theory of technological uncertainty. Advancements in arms technologies affect the perceptions of states, creating risks of military confrontation. The emergence of such technologies, as well as the differences in doctrinal and organizational adaptation to the new military capabilities, lead to differing ideas about the balance of power. These changes bring with them inflated expectations about one's ability to compensate for quantitative deficiencies with technological superiority. Finally, alarmism caused by dwindling opportunities and growing vulnerability, push sides to preventive action. All this generates powerful incentives for military escalation.

The most compelling argument in favour of the theory of technological uncertainty is the experience of the middle of the 19th century and the beginning of the 20th century. In both cases, the expectations associated with it clearly diverge from the assessment of the ratio of offensive and defensive capabilities. The manner in which events unfolded demonstrated the greater explanatory power of the theory of technological uncertainty compared to the offence-defence balance theory.

Conversely, the period of the end of the 18th century predictably provides the weakest evidence in support of our theory. While years were marked by an intensification of technological change, the long period of peace that follows is telling, and it cannot be explained by a change in the ratio of offensive and defensive capabilities.

In the case of the middle of the 20th century, the predictions of the theory of technological uncertainty and the offence-defence balance theory coincide, which makes it difficult to determine which is correct. Both connect the outbreak of the Second World War with the emergence of new weapons. That said, the theory of technological uncertainty appears to better explain the discrepancies in the assessments of technological change by individual states.

Finally, the second half of the 20^{th} century proves to be the most difficult period in terms of corroborating the theory of technological uncertainty, as changes in weaponry did not lead to direct military clashes between the superpowers. That said, the Cold War is less of an anomaly if we take its duration, as well as the fact that new weapons were constantly emerging, into account. At the same time, technological uncertainty explains the escalation during the Cold War better than changes in the ratio of offensive and defensive weapons.

The causes of military clashes, as well as the preconditions for peace, serve as important pieces of evidence in support of the theory of technological uncertainty. In this regard, our historical survey confirms that periods of stability correspond to a comparative stagnation in the development of weapons. As such, the study cannot be accused of cherry-picking cases for analysis based on the variable under analysis (King, Keohane, Verba 1994), which lends further credence to the conclusion about the impact of technological uncertainty on international security.

It is worth noting that our analysis does not suggest that advances in weaponry are a necessary or sufficient condition for military clashes. They are typically accompanied by other conditions – growing armies, socio-political upheavals, changing coalition dynamics, etc. And we cannot rule out the possibility that states at times have distorted perception of the balance of power, even in the absence of technological innovations. Nevertheless, the experience of the last two and a half centuries shows that such changes were observed before every single large-scale military clash.

What are the practical implications of our analysis for contemporary international relations? The theory of technological uncertainty is extremely relevant today. Discussions at the turn of the 2020s have centred on the introduction of a number of new weapons, including hypersonic launch vehicles, autonomous combat systems, military applications of artificial intelligence and quantum computing, and a new generation of anti-missile and anti-satellite systems.

Expectations are already being formed in connection with these developments regarding revolutionary changes in the methods of conducting a war. Many states hope to use them to make up for their numerical disadvantages in terms of army sizes, the availability of traditional weapons for troops, and military budgets. They are also thinking in terms of likely windows of vulnerability in the near future.

All this raises serious concerns about the prospects for a military clash. To the extent that historical experience and the theory of technological uncertainty can guide forecasts, the risks of large-scale collisions increase. Under these conditions, there are no guarantees that states will be able to control the course of events, since their perception of the balance of power and the prospects of armed confrontation are distorted.

The fact that potential innovations are currently at various stages of development add a modicum of optimism to our conclusions. In the case of hypersonic, anti-missile and anti-satellite weapons, prototypes and even practical examples are ready. As for autonomous combat systems and the military applications of artificial intelligence and quantum computing, developments in these areas still require some time.

Given that the greatest threat of military clashes is observed in the case of overlapping sources of technological uncertainty, an increase in the time lag between emerging innovations can play a stabilizing role. It is unrealistic to expect states to stop developing new weapons altogether, but if they were to postpone the introduction of some of them, then this would help maintain international security.

Additionally, players who expect to gain advantages through the development of advanced technologies should bear in mind that qualitative superiority is often not enough to win a military clash. Historical experience urges caution when it comes to assessing the possibility of securing one's own interests by initiating a military clash.

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Conflicts of interest.

The author declares the absence of any conflicts of interests.

Acknowledgments:

This research is funded by the Ministry of Science and Higher Education of the Russian Federation (Grant Agreement Number 14.641.31.0002). The author expresses gratitude to Alexander Chekov, Ivan Danilin, Mikhail Mironyuk, and Elena Nechaeva for their valuable comments on preliminary drafts of the article.

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