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The Impact of Revolution 4.0 on International Law and Arms Regulation (2016-2024).

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ABSTRACT: This research examines the impact of Revolution 4.0 on International Law and arms regulation, particularly in the period 2016-2024, through a critical and socio-legal approach, it analyzes the challenges imposed on International Humanitarian Law (IHL) by new technologies applied to armed conflicts, such as autonomous weapons systems (AWS), artificial intelligence (AI) and cyberwarfare. These innovations have reshaped the modern battlefield, posing serious challenges to the application of fundamental principles such as distinction, proportionality and precaution, the study starts from the recognition of a normative gap that hinders the attribution of state responsibility and meaningful human control, especially in scenarios where war decisions are automated, likewise, the role of states, international organizations and civil society in the construction of effective regulatory frameworks is examined; The methodology used combines normative-dogmatic, comparative-legal and philosophical-legal methods, supported by analysis of recent cases and specialized literature; the project aims not only to identify the normative transformations driven by the technological revolution, but also to propose guidelines to ensure respect for IHL in contexts of digitalized warfare, this research contributes to the reflection on the need to adapt international law to the dizzying changes of the XXI century, reaffirming the imperative of protecting civilian populations in the use of emerging war technologies.

Keywords: Digital ecosystem, audience, social platforms, online education, internet interoperability

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1. Introduction

The irruption of Revolution 4.0 in contemporary armed conflicts has generated a structural transformation in the scenarios of war and has posed unprecedented challenges to International Humanitarian Law (IHL) (Enns et al., 2022) , this revolution, characterized by the development and deployment of emerging technologies such as Autonomous Weapon Systems (AWS), artificial intelligence (AI) applied to the use of force, and the growing militarization of cyberspace, has overflowed the traditional normative categories, straining fundamental principles such as distinction, proportionality and precaution, therefore, a critical and multidimensional review of the current legal scaffolding becomes indispensable, both for its interpretation and for its eventual normative reform.

The research is structured in five sections that allow a progressive and coherent approach to the analyzed phenomenon; first, the adopted methodology combines three complementary approaches (Romero et al... 2024a), dogmatic normative, socio-legal and legal philosophical, 2024a), dogmatic normative, socio-legal and legal philosophical, this methodological triangulation allows us to analyze, from an integral

perspective, both the formal normativity and its application in real contexts (Aponte-García and Sánchez-Arteaga, 2024), as well as the ethical implications that arise when incorporating autonomous technologies in decisions about life and death; the use of recent cases, reports from international organizations and contemporary doctrinal debates allows empirical validation of the challenges posed.
Secondly, the normative gaps in the automation of violence as a description of the research problem that delimits the object of study and highlights the existing normative gap in the face of the vertiginous advance of automated war technologies, based on a critical review of recent literature and empirical cases such as the conflict in Ukraine, it is evident that IHL faces serious limitations in attributing legal responsibilities and protecting civilian populations when lethal decisions are delegated to algorithms.
Thirdly, the state of the art systematizes the main doctrinal contributions around three axes: autonomous weapons, artificial intelligence and cyber warfare, this section reveals not only the lack of academic consensus on the legitimacy of the use of these technologies in combat, but also the inadequacy of international regulatory mechanisms, it also identifies common trends, such as the growing dissociation between technological speed and regulatory capacity, and the emergence of proposals to reconfigure the role of law in digitized wars (Horowitz, 2020) .
The fourth section, development, analyzes in greater depth the disruptive effects of Revolution 4.0 on IHL, focusing on the limits of emerging technologies to comply with humanitarian principles, emblematic cases are examined, such as the use of autonomous drones without direct human supervision (Kunertova, 2023) , the difficulties of attributing state and criminal responsibility, and the opacity of cyber attacks, the analysis highlights the urgent need to establish binding international norms that guarantee meaningful human control over weapon systems and ensure the centrality of ethical judgment in the conduct of hostilities.
Finally, the conclusions summarize the findings of the study, highlighting the urgent need for global legal governance to regulate the use of autonomous warfare technologies, proposing a dual response: the dynamic reinterpretation of IHL and the adoption of new international instruments, the research reaffirms that, in times of digitized warfare, preserving human dignity and protecting people outside the conflict must remain an inalienable imperative of international law.

2. Methodology

This article was constructed from the perspective of the interpretative paradigm and under a qualitative methodological approach, in line with the guidelines proposed by Martínez (2010). From this epistemological stance, it is recognized that social reality is constructed by the subjects based on their experiences, meanings and particular contexts. Therefore, the analysis privileges the deep understanding of the phenomena, beyond the search for generalizations, focusing on the meanings that social actors give to their practices, discourses and relationships.
The development of this research is based on a rationalist-idealist epistemological position, which is particularly relevant to address the normative, ethical and conceptual challenges (Romero-Sánchez et al., 2025) posed by the Revolution 4.0 to International Humanitarian Law (IHL). From the gnoseological dimension, we start from the premise that relevant legal knowledge is not limited to the empirical description of norms or facts, but is rationally constructed through processes of theoretical argumentation, systematic interpretation and critical reflection. From the ontological dimension, it is assumed that legal reality, in contexts of digitized war, is not a given fact, but a symbolic and historical construction, mediated by representations, values and meanings attributed by the research subject. In this sense, the rationalist-idealist position allows to problematize how emerging technologies such as autonomous weapons systems, military artificial intelligence and cyberwarfare, reconfigure not only conflict scenarios, but also the frameworks of intelligibility of law, demanding a review of its foundations from a critical, reflective and socio-legal perspective (De Berríos&Briceño de Gómez, 2009).
Consistent with this positioning, an interpretive paradigm is adopted, from which the object of study the impact of the Revolution 4.0 on International Humanitarian Law (IHL) is understood as a complex, multidimensional and sociohistorically constructed reality, such approach privileges the interpretation of meanings, ethical-legal tensions and processes of institutional transformation, rather than the causal

verification or quantification of relationships (Romero-Sánchez et al., 2025; Aponte & Sánchez, 2024).

The approach of this research is qualitative (Romero-Sanchez et al., 2024b; Romero & Aponte, 2024; Romero-Sanchez et al 2025), oriented to the critical understanding (Aponte & Sanchez, 2024) of the challenges that Revolution 4.0 imposes on International Humanitarian Law (IHL), particularly with regard to advances in autonomous weapons, artificial intelligence and cyberwarfare, the approach adopted articulates normative, socio-legal and philosophical-legal elements, consistent with the complex and multidimensional nature of the phenomenon under analysis.

A normative-dogmatic method was used, focused on the study of relevant international treaties, especially the Geneva Conventions and their Additional Protocol I, as well as customary norms and general principles of IHL. This analysis made it possible to identify the current limits of the international legal order to effectively regulate the use of emerging technologies in the military sphere, as noted by authors such as Sedliar et al. (2023) and Tsybulenko&Kajander, (2022) , who point out that instruments such as Article 36 of Additional Protocol I, although useful, are insufficient in the face of the technical and ethical complexity of autonomous weapons systems.

Secondly, a socio-legal approach was adopted, aimed at interpreting how legal norms are applied, challenged or reconfigured in real conflict contexts where advanced technologies are involved, considering recent case studies, such as the conflict between Russia and Ukraine, and reports produced by international organizations such as the UN and the International Committee of the Red Cross, which have warned about the normative gaps in the attribution of responsibility for cyber attacks or automated decisions in combat (Boutin, 2023; Eichensehr, 2022) .

Finally, a philosophical-legal analysis was integrated to problematize the ethical foundations of the participation of autonomous technologies in the use of force, taking up the discussions on meaningful human control, human dignity and moral attribution of responsibility, In this line, authors (Rogers, 2023) have warned that the delegation of lethal decisions to autonomous systems erodes the ethical pillars of IHL, putting at risk essential principles such as the distinction between combatants and non-combatants, and proportionality in attacks.

This methodology seeks not only to describe the impact of emerging technologies on international law, but also to offer a critical perspective on the structural challenges facing legal regulation in scenarios of digitized warfare. Through this approach, the aim is to contribute to the debate on the need to review, adapt or even reconstruct the normative frameworks governing the use of force in the 21st century.

3. Results and Discussions

3.1 3. Regulatory Gaps in the Automation of Violence

Currently, International Humanitarian Law (IHL) faces one of its greatest challenges since its codification in the 20th century: the irruption of disruptive technologies in armed conflict scenarios; the so-called Revolution 4.0, characterized by the development of autonomous weapons systems (AWS), artificial intelligence (AI) and cyberweapons, has substantially modified the traditional paradigms of warfare (Gaeta, 2024) , generating deep tensions in the application of fundamental principles such as distinction, proportionality and precaution, indeed, the deployment of warfare systems with decisional autonomy poses a break with the model of warfare centered on human judgment, making it difficult to attribute responsibilities and protect civilians in war contexts (Brenneke, 2020; Kwik, 2022) .

The problem is compounded by the increasing difficulty of ensuring meaningful human control over automated lethal decisions, S padaro, (2024) warns that the traditional doctrine of responsibility, based on hierarchical subordination and criminal liability of superiors, is insufficient when it comes to machines operating with increasing levels of autonomy, this normative vacuum questions the effectiveness of IHL and calls into question its ability to respond to new forms of violence promoted by emerging technologies; Aravena Flores, (2024) and Winter, (2021) agree that, although some technological developments in AI promise to improve the accuracy of attacks, current capabilities remain limited to interpret complex contexts and make ethical decisions in accordance with IHL.

Added to this is the difficulty of regulating cyberwarfare, which poses unprecedented problems in terms of attribution of hostile acts, damage assessment and proportionality; as pointed out by Roguski (2021) and Eldem (2021) , cyber attacks lack clear traceability and their effects may be cumulative, invisible or even deferred in time, which complicates their legal treatment within the framework of IHL, the Russian invasion of Ukraine evidenced these limitations, where although cyberattacks were not tactically decisive, they did disrupt civilian infrastructure, sow disinformation and generate considerable psychological effects (Eichensehr, 2022) .

Additionally, the lack of an international consensus on the regulation of autonomous weapons

compounds the problem; while Article 36 of Additional Protocol I requires States to review the legality of new weapons, its application is limited and does not contemplate the technical and ethical complexity of autonomous systems (Tsybulenko&Kajander, 2022) ; similarly, Porcelli (2021) criticizes the idea of a total ban on AWSs and proposes instead the creation of more adaptive ethical and regulatory frameworks that integrate the notion of meaningful human control.

The research problem focuses on how Revolution 4.0 has negatively impacted the interpretation, application and effectiveness of International Humanitarian Law in contemporary contexts of war (RamírezGarcía De León, 2021) , the automation of violence, the legal ambiguity in cyber warfare and the ethical dilemmas raised by the dehumanization of combat require a profound revision of the international normative scaffolding and existing instruments to guarantee the protection of people in times of armed conflict (Khalymon et al., 2021)

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3.2 4. State of the Art: Autonomous Weapons, Artificial Intelligence and Cyberwarfare in the Global Legal Debate.

The analysis of the impact of Revolution 4.0 on International Humanitarian Law (IHL) has given rise to a growing body of scientific literature that recognizes the urgent need to review traditional normative frameworks in the face of the challenges posed by technologies such as autonomous weapons systems (AWS), artificial intelligence (AI) and cyber warfare (CotinoHueso& Gómez De Ágreda, 2024) , these three thematic axes organize the present state of the art, allowing us to understand the tensions between technological development and international legal normativity.

First, autonomous weapons systems have been the subject of criticism from both technical, ethical and legal perspectives. Ananos Meza (2022) highlight that the use of drones in military operations has redefined the notion of distinction between combatants and civilians, while raising doubts about proportionality and precaution in remote attacks, Smith, (2022) points out that drones constitute techno-legal assemblages that combine technology and law to justify state violence, transforming the way in which legitimate use of force is interpreted, authors such as Renic (2019) and Braun,(2022) discuss whether AWSs can operate according to moral criteria such as supererogation or "jus ad vim", while Brenneke (2020) concludes that these weapons cannot, for the time being, comply with the essential principles of IHL without significant human intervention.

Secondly, the application of artificial intelligence in the military domain generates serious difficulties in attributing responsibility and ensuring meaningful human control; Boutin, (2023) and Juarez Guraieb, (2022) agree that the autonomy and complexity of these systems make it difficult to comply with IHL standards, especially with regard to target identification and civilian risk assessment; Pacholska, (2023) proposes considering autonomous systems as extensions of the States that employ them, thus facilitating legal imputation; this approach makes it possible to treat the failures of these systems as violations attributable to States under international law, which reinforces the need to establish technical and legal review mechanisms prior to their operational use.

Third, the study of cyberwarfare reveals new normative challenges. Eichensehr, (2022) warns that low-level cyberattacks, although not decisive at the immediate war level, have a significant cumulative effect that escapes the traditional frameworks of IHL; Eldem (2021) and Roguski (2021) emphasize the difficulty of establishing mechanisms for verification and attribution of responsibility for cyberattacks, which generates an environment of impunity and legal ambiguity; King (2024) argues that certain cyberattacks could reach the threshold of a crime of aggression, particularly when they affect critical infrastructures, which calls for a reinterpretation of the use of force in international law.

As a transversal trend, several studies underline that the speed of development of these technologies exceeds the response capacity of law, CotinoHueso& Gómez De Ágreda (2024) argue that the digitization of the battlefield has transformed the very structure of conflicts, which requires not only normative adjustments, but also a reconceptualization of the role of law in contexts of technified warfare (Aponte &Sánchez, 2024). Schmitt (2022) warns that the automation of violence poses unsolvable problems from the ethical point of view, such as the loss of moral judgment in lethal decisions.

3.3 5. Disruptive effects of the 4.0 Revolution on IHL.

The proliferation of autonomous and artificial intelligence technologies, emblematic of the so-called Revolution 4.0, is reshaping the paradigms of armed conflict (Kwik, 2022) ; advanced drones, Autonomous Weapon Systems (AWS) and cyber incursions enable greater automation and remote warfare, but have raised profound concerns about the ability of International Humanitarian Law (IHL) to adequately govern their employment (Brenneke, 2020) ; as these technologies proliferate, the need to re-

evaluate the existing legal framework intensifies (Leghari et al., 2020) .

One of the pillars of IHL, the principle of distinction, faces serious doubts when faced with the use of autonomous AI-powered weapons (Aravena Flores, 2024; Juarez Guraieb, 2022) ; recent studies argue that AWS are not yet capable of reliably distinguishing military targets from people or civilian objects in complex environments (Korac, 2023) ; Aravena Flores (2024) concludes that these systems are not able to strictly comply with the basic principles of IHL, mainly that of distinction, precaution and proportionality, a contemporary example being the use of autonomous drones in Libya: according to a UN report, in 2020 a STM Kargu-2 drone acted autonomously, attacking without connectivity with the human operator, evidencing an unsupervised lethal capability (Eichensehr, 2022) .

Likewise, the principles of proportionality and precaution present formidable challenges with autonomous weaponry (Llano and Aponte, 2024), the principle of proportionality prohibits attacks that cause excessive incidental damage relative to the anticipated military advantage, an assessment that typically requires ethical and contextual judgments that an algorithm can hardly reproduce (Brenneke, 2020; Winter, 2021) ; similarly, attack precaution, understood as an obligation to verify the target and take measures to minimize damage, is limited by the technical characteristics of AWSs, whose autonomy depends on non-interpretable neural networks (Boutin, 2023a) .

Brenneke (2020) warns that for now, autonomous lethal weapons cannot function fully independently without violating these essential IHL principles..., even with recent advances in AI, evidence suggests that current capabilities remain insufficient to ensure the compatibility of these systems with IHL requirements (Winter, 2021) ; in the face of these uncertainties, numerous experts and humanitarian actors advocate ensuring "meaningful human control" over autonomous weapon systems at all times (Tsybulenko&Kajander, 2022) , this concept implies that lethal decisions are never fully delegated to the machine, while preserving a sufficient level of human judgment and oversight (Spadaro, 2024) ; the International Committee of the Red Cross (ICRC) has urged States to adopt legally binding rules guaranteeing this control (Boutin, 2023) .

Even if a certain degree of human control is guaranteed, complex challenges of attribution of responsibility arise when autonomy intervenes, the doctrine of command responsibility, which allows charging war crimes to a commander for not controlling his subordinates, shows limits in the face of a "subordinate" who is a machine (Spadaro, 2024) ; some jurists explore ways to fill this gap through figures such as improper omission, although concerns persist that the current criminal mechanisms are insufficient (Gaeta, 2024).

Regarding State responsibility, the majority position states that acts committed by an AWS employed by a State are legally attributed to that State (Pinheiro et al., 2020) , according to Pacholska (2023) , even unintentional actions of an AWS should be considered acts of the State, this reinforces the need for a robust regulatory framework to ensure compliance with IHL from the design and employment of these systems (Boutin, 2023) .

The militarization of cyberspace represents another critical front, most states have affirmed that IHL applies to cyber operations in contexts of armed conflict, including the principles of necessity, humanity, distinction and proportionality (Eichensehr, 2022; Khalymon et al., 2021; Roguski, 2021) ; however, its practical application faces obstacles such as the difficulty of attribution, dual uses of infrastructures and the uncontrollable spread of digital tools (Maskun et al., 2020).

In the face of these phenomena, the international response has been uneven. Although guiding principles were agreed upon in the framework of the Convention on Certain Conventional Weapons (CCW), military powers have blocked a binding agreement (UNGA, 2023), in response, 152 countries passed a resolution at the UN General Assembly in 2023 recognizing the dangers of autonomous weapons systems and the urgent need for regulation (Danielsson&Ljungkvist, 2023) ; organizations such as the ICRC and the Stop Killer Robots campaign have been instrumental in making visible the ethical risks of delegating life and death decisions to algorithms, the UN Secretary General, has called killer robots politically unacceptable and morally repugnant, advocating for their legal prohibition .

The impact of Revolution 4.0 on IHL is profound and challenging, technological innovations have exposed legal and ethical gaps that require urgent regulatory and political solutions, the 2016-2024 period shows

a growing consensus on the need to preserve the centrality of the human in war, reinforcing the fundamental principle of IHL: to protect those who do not directly participate in hostilities.

4. Conclusions

Revolution 4.0 has reconfigured the dynamics of armed conflict through the accelerated incorporation of technologies such as autonomous weapons systems, artificial intelligence and cyberwarfare. These innovations, while representing advances from the operational and strategic point of view, have challenged the applicability and effectiveness of International Humanitarian Law (IHL), especially with regard to the principles of distinction, proportionality and precaution.

The analysis shows that the current capabilities of autonomous systems are limited to meet the humanitarian standards required by IHL. Difficulties in correctly identifying targets, assessing complex contexts and applying moral and ethical judgment in war situations are evidence of a worrisome normative gap; moreover, the absence of meaningful human control compromises not only the legality of attacks, but also the real possibility of establishing legal responsibility for the consequences of their use.

In the case of cyberwarfare, regulatory gaps are exacerbated by the diffuse and asymmetric nature of digital attacks, which hinders the effective application of existing rules of warfare, attribution of liability, assessment of damage to civilian assets and traceability of cyber aggressions remain unresolved challenges.

Although the international community has made progress in recognizing these challenges, there is still no binding instrument that comprehensively regulates the use of these technologies; the UN General Assembly resolution in 2023 represents a significant step, but is insufficient in the face of the urgency of global governance of smart weapons systems.

Consequently, it is concluded that it is indispensable to strengthen the existing normative framework through a twofold approach: the adoption of new international norms that specifically regulate autonomous and IA weapons in war contexts, and the dynamic reinterpretation of IHL to respond to contemporary realities; this effort must be guided by the principles of humanity, dignity and responsibility, avoiding the dehumanization of the conflict and guaranteeing the protection of people in times of war.

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