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قواعد النشر

- لغة المجلة هي اللغة العربية والانكليزية على أن يراعى الوضوح وسلامة النص.
- ترحب المجلة بنشر البحوث والدراسات السياسية النظرية والتطبيقية ولا سيما التي تجعل من قضايا المنطقة والعالم محط اهتمامها، ماضياً وحاضراً ومستقبلاً، وعلى وفق الآتي:
 1. أن لا يزيد عدد صفحات البحث أو الدراسة عن (15) صفحة مطبوعة بحجم خط (14) والتباعد (1,15) ونوع الخط Simplified Arabic تقدم عبر المنصة الاليكترونية للمجلة على الرابط :
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 2. أن تتصف البحوث والدراسات بالموضوعية والدقة العلمية.
 3. أن تعتمد الترتيم العشري للعناوين الأساسية والفرعية او التصنيف المعياري العام.
 4. يرفق مع كل بحث او دراسة ملخصين (احدهما باللغة العربية والآخر باللغة الانكليزية/ يتضمن اهداف البحث ، المنهج والمعالجة ، ابرز النتائج واهم الاستنتاجات والمقترحات) مع ضرورة مراعاة ان الملخص مختلف اختلافا جذريا عن المقدمة وليس تكرارا لها .
 5. تخضع جميع البحوث المقبولة للنشر الى نظام الاستلال الالكتروني في كلية العلوم السياسية -جامعة النهرين.
 6. يرفق مع كل بحث ودراسة سيرة ذاتية مختصرة للباحث وتعهده .
- تقوم المجلة بإخطار الباحثين بإجازة بحوثهم أو دراساتهم من عدمها بعد عرضها على محكمين تختارهم على نحو سري من بين أصحاب الاختصاص.

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- يجوز للمجلة أن تطلب إجراء تعديلات شكلية أو شاملة على البحث أو الدراسة قبل إجازتها للنشر بما يتماشى مع أهدافها.
- البحوث المنشورة تعبر عن آراء أصحابها ، ولا تعبر عن رأي المجلة .
- ترحب المجلة بالمناقشات الموضوعية لما ينشر فيها أو في غيرها من الدوريات وبأية ردود فكرية أو تصويب، وكذلك ترحب بنشر التقارير عن المؤتمرات والندوات ذات العلاقة ومراجعات الكتب وملخصات الرسائل الجامعية التي تتم إجازتها على أن تكون من إعداد أصحابها.

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Entropy: An Analytical Framework in Strategic Studies (From Thermodynamic Principles to National Security Applications) [∇]

Professor Dr. Ali Hussein Hameed *

Dr. Safaa Subhi Hamodi**

Abstract:

This study seeks to establish the concept of entropy as an analytical framework in strategic studies and national security, by tracing its intellectual trajectory from its thermodynamic origins to its contemporary applications in analyzing the dynamics of the international system. The study addresses a central problematic: How does the concept of entropy contribute to reformulating contemporary strategic thought, and what are its implications for national security approaches in an international environment characterized by complexity and uncertainty? The study hypothesizes that entropy, as a root metaphor, provides an analytical framework capable of explaining the dynamics of deconstruction and reconstruction in strategic systems beyond the explanatory capacity of traditional theories. The study concludes that the concept of entropy offers advanced analytical tools for understanding structural transformations in the international system, mechanisms of security deterioration, and possibilities for rebuilding order through dissipative structures.

Keywords: Entropy, Strategic Studies, National Security, International System, Thermodynamics, Dissipative Structures.

Introduction:

In the context of the rapid structural transformations characterizing the contemporary international system, and the unprecedented overlap of complexity and increasing structural uncertainty they generate, traditional international relations theories face a growing epistemological and methodological dilemma. This dilemma stems from their limited capacity to explain the dynamics of actual change in an international environment no longer governed by stable patterns or predictable trajectories. The state of turbulence dominating the global landscape does not signify a systemic void as much as it reflects a complex formation of unstable structures, where sources of power intertwine, mechanisms of control disintegrate, and the gaps between prevailing theoretical assumptions and evolving empirical reality widen.

Given that traditional interpretive frameworks were largely formulated within historical contexts characterized by higher degrees of systemic stability and predictability, continued reliance on them as sufficient analytical tools leads to

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interpretive reductions that hinder analysis from grasping the logic of transformation itself. Consequently, there arises a need to expand the conceptual field of strategic studies by drawing upon interpretive models from other knowledge domains, not as mechanical alternatives, but as analytical metaphors capable of rephrasing fundamental questions concerning the nature of the system, the limits of stability, and the logic of decline or disintegration in international political systems. Within this framework, this study proceeds from the assumption that the concept of entropy, despite its physical roots in thermodynamics, possesses high theoretical potential for deployment as a root metaphor, enabling a more dynamic approach to the complexities of international and strategic relations (Schweller 2014).

Entropy, in its scientific origin, is defined as a measure of the disorder, randomness, or dissipation of energy within a closed system. The second law of thermodynamics asserts that any isolated system naturally tends towards an increase in its entropy over time, ultimately reaching a state of final equilibrium where internal differences vanish and the capacity to perform work dissipates. Although this concept may outwardly seem far removed from the realms of politics and conflict, reading it as an analytical metaphor reveals profound explanatory potential for understanding the structural tendency of political and social systems towards erosion and disintegration in the absence of continuous flows of organizational energy, whether political, economic, institutional, or intellectual (Schweller 2014, 12).

From this perspective, states, empires, and institutions can be viewed as complex systems that constantly require inputs of organized energy to maintain their internal cohesion and capacity for action. Just as physical systems arise from an initial concentration of energy, political entities emerge through a foundational moment where purpose, resources, and legitimacy coalesce. However, this foundational energy does not remain constant; rather, it gradually dissipates, institutional structures become rigid, and adaptability declines, unless this tendency is addressed through systematic reform and renewal processes. In this context, Randall L. Schweller articulated a significant analogy between physical entropy and the cycles of rise and decline in organized human action, noting that states, regimes, and institutions exhibit a recurring pattern of emergence driven by latent energy, followed by a gradual erosion of that energy, often culminating in decline or disintegration as the initial momentum that created them is exhausted (Schweller 2014, 13).

Based on this understanding, the rise of great powers or the formation of international systems cannot be comprehended as a permanent state, but rather as a temporary moment of concentrated energy or power and organizational capacity. This is inevitably followed, due to structural necessity, by a trajectory of institutional erosion and strategic stagnation, unless renewed energy is injected into the system through structural reforms, institutional innovation, or leadership

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styles capable of regenerating purpose. In this sense, entropy becomes an analytical indicator for measuring the levels of chaos and randomness that infiltrate the structure of the international system as its capacity for self-regulation declines (Schweller 2014, 13).

In environments characterized by high levels of turbulence, the stable reference frameworks upon which international relations have long relied collapse, and traditional schools of thought lose their explanatory power. This is because the past no longer provides a solid basis for extrapolating the future; instead, the absence of norms becomes the dominant feature of the contemporary international system (Schweller 2014, 17).

In this context, the effectiveness of classical tools for managing the international system—such as alliances, deterrence, and international law—is eroding, as they were designed for environments of lower complexity and entropy. Consequently, decision-makers and analysts find themselves confronting a reality where the validity of inductive reasoning itself is diminishing. Schweller clearly articulated this point when he noted that logic becomes an unreliable guide in environments dominated by chaos (Schweller 2014, 20).

Based on this, the employment of metaphors derived from thermodynamics in international relations theory represents an advanced epistemological endeavor to understand the deep interactions between order and chaos within and among states, and to deconstruct the mechanisms governing the strategies of actors in high-entropy environments. The concept of entropy, as an analytical extension of the second law of thermodynamics, provides a framework for understanding the structural tendency towards disorder, and the energetic and institutional conditions necessary to slow down or contain this trajectory at the international system level.

The theoretical value of this concept is manifested in its ability to transcend its narrow scientific origins to perform what has been described as a radical metaphor, i.e., a metaphor that does not merely explain a specific phenomenon but contributes to reshaping patterns of perception and thought across a wide spectrum of human experiences (Zencey 1986). In this context, the metaphysical nature of entropy gains particular importance, as it enhances its applicability as an explanatory tool in the field of international relations. Eric Zencey observed that the law of entropy is considered one of the most abstract and difficult-to-conceptualize physical laws, and even more problematic cognitively than the first law of thermodynamics—a paradox that makes recourse to it, despite its abstractness, an effective means of imparting a degree of understanding to a reality characterized by ambiguity and structural complexity (Zencey 1986, 253).

This theoretical application is reinforced by the universal nature of entropy as a comprehensive natural law, which has established a conceptual justification for its application to the study of states, political systems, and strategies. In this context, Jeremy Rifkin noted that the law of entropy states that all energy flows

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inevitably transition from states of organization to states of disorganization, and from usability to dissipation, and that any appearance of order produced in one place is achieved at the expense of generating greater disorder in the surrounding environment (Rifkin 1980).

Accordingly, this principle establishes the notion that entropy operates as a non-discriminatory law, applicable to diverse realms of natural and social phenomena alike, across all times and places. This grants it theoretical legitimacy as an analytical framework for understanding the dynamics of decline and sustainability in the contemporary international system (Rifkin 1980, 58).

Research Problem:

The central problem of this study revolves around the following core question: How does the concept of entropy contribute to the reformulation of contemporary strategic thought, and what are its implications for national security approaches in an international environment characterized by complexity and uncertainty?

This central question branches into several sub-questions:

- 1 .What are the epistemological and philosophical foundations that qualify the concept of entropy to be a radical metaphor in strategic studies?
- 2 .How can the concept of entropy be employed in analyzing the dynamics of disintegration and integration within the international system?
- 3 .What are the mechanisms of security deterioration from an entropic perspective, and how can they be countered?
- 4 .What is the analytical value of entropy compared to traditional theories in international relations?

Study Hypothesis:

This study is based on a central hypothesis: entropy, as a radical metaphor derived from thermodynamics, provides an analytical framework capable of explaining the dynamics of disintegration and integration in strategic and national security systems, surpassing the explanatory power of traditional theories in international relations.

Study Methodology:

This study relies on the conceptual analytical approach, which seeks to deconstruct the concept of entropy and trace its trajectory from its original field (physics) to the field of strategic studies and international relations. The study also employs the conceptual metaphor approach to understand the mechanisms of concept transfer between different knowledge domains, and to assess the validity and limitations of such transfer.

Importance of the Study:

This study derives its significance from several considerations:

- 1 .Theoretical Significance: This study attempts to bridge the gap in the Arabic literature regarding the application of the concept of entropy in strategic studies.

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2 .Applied Significance: It offers new analytical tools for understanding transformations within the international system and challenges to national security.

3 .Methodological Significance: It contributes to the development of interdisciplinary approaches that combine natural and social sciences.

Study Structure:

This study is divided into four main sections. The first section addresses the thermodynamic origins of the concept of entropy, from its conceptual foundation in Clausius and Boltzmann to its philosophical underpinnings. The second section examines the transition from information theory to effect-based operations, including the applications of entropy in military and strategic thought. The third section focuses on entropy and transformations in the contemporary international system, through concepts such as Maxwell's demon and dissipative structures. The fourth section concludes by discussing the dialectics of decomposition and synthesis in national security, including complexity theories and mechanisms of security degradation.

Part One: The Thermodynamic Origins of the Concept of Entropy:

First: Conceptual Foundations — From Clausius to Boltzmann:

In the context of classical thermodynamics, entropy is presented as a precise scientific concept reflecting the internal structure of physical systems in terms of their inherent degree of disorder, or the amount of available energy within a closed system that can be converted into actual work. In this sense, entropy is not understood as an emergent or accidental state, but rather as an intrinsic structural property of any isolated system, through which levels of order or disorder within it are measured. An increase in entropy indicates growing disorder and a decline in functional capacity (Schweller 2014, 20).

The central importance of this concept lies in the fact that entropy, within an isolated system that receives no energy inputs from outside, is subject to a strict irreversible logic; it cannot spontaneously decrease, but rather either increases or remains constant. As a result, the system tends over time towards a state of thermodynamic equilibrium where entropy reaches its maximum levels, and energy is distributed uniformly, rendering the accomplishment of any additional work impossible (Schweller 2014, 28).

This governing principle of non-decreasing entropy was clearly summarized in Randall Schweller's formulation, which asserted that isolated systems inherently tend to evolve towards thermal equilibrium, i.e., towards a state of maximum entropy where internal structures and forms of differentiation vanish, and the system effectively devolves into a condition where all its processes are characterized by randomness and an inability to self-organize. This outcome derives its significance not only from its physical dimension but also from its establishment of a new understanding of the trajectories of change and decline in

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complex systems as processes governed by structural constraints that cannot be overcome without external intervention (Schweller 2014, 30).

In the context of the concept's historical development, the earliest roots of entropy theory trace back to the intellectual and scientific milieu of Victorian Britain in the mid-nineteenth century. Academic circles were preoccupied with the profound transformative effects of what was then known as the science of energy. Within this intellectual climate, William Thomson, later known as Lord Kelvin, along with several prominent scientists of his era, including James Clerk Maxwell, engaged in a large-scale epistemic project aimed at elevating the concept of energy from a technical explanatory tool to a comprehensive unifying principle capable of explaining both natural processes and human activities. This endeavor, as Schweller observed, took on a quasi-evangelical character, reflecting the reliance on energy as the theoretical key to understanding the material world and its developmental trajectories (Schweller 2014, 31).

In this context, the crystallization of thermodynamics as the science concerned with the ability of heat to produce work and the fate of this ability under dissipative processes contributed to establishing a new analytical language for understanding systemic transformation (Schweller 2014, 32). The first law of thermodynamics established the principle of energy conservation, affirming that energy is neither created nor destroyed but rather transformed from one form to another, which provided a conceptual basis for the continuity of physical processes over time. However, this law, despite its importance, remained neutral regarding the direction of time, merely describing transformations without indicating their trajectory (Schweller 2014, 33).

The second law of thermodynamics, however, carried more radical implications, as it introduced the temporal dimension as a crucial element in explaining natural processes. In 1865, Rudolf Clausius formulated the concept of entropy to express the degree of increasing disorder within a thermodynamic system, defining it as the rate at which usable energy is converted into irrecoverable energy (Schweller 2014, 37). This conception led to a profound reformulation of the understanding of time and change, as time was no longer merely a neutral medium for events, but rather a structural direction governing the trajectory of transformation from order to chaos. In this regard, it is noted that the second law distinguished itself from all other physical laws since Galileo by being the only law that explicitly takes the direction of time into account, while other laws remained theoretically reversible (Schweller 2014, 39).

The introduction of the concept of irreversible processes destabilized the circular worldview that had long dominated Western thought, which assumed the possibility of systems returning to previous states of order. This view was replaced by a linear conception of natural history, expressed by Schweller as the "arrow of time," which indicates a unidirectional movement towards higher levels of disorder. The cosmic implications of this shift culminated in William Thomson's

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1852 proposition of heat death, as the final state the universe reaches when all energetic differences are exhausted, and the extraction of any additional mechanical work becomes impossible (Schweller 2014, 42).

These conceptual foundations of entropy theory emerge from the profound epistemological shifts that accompanied the Industrial Revolution, which reshaped the relationship between time, matter, and organization in understanding complex systems. The nineteenth century witnessed a radical upheaval in fundamental categories of knowledge, as major industrial transformations led to an intermingling of the concepts of time and matter, both in metaphysics through dialectical materialism and in physics through entropy and the second law of thermodynamics (Kremer 2024).

Nevertheless, the genesis of entropy theory cannot be reduced to a purely empirical discovery. Historical analysis reveals that the First and Second Laws of Thermodynamics, despite their precise scientific formulation, acquired a quasi-universal status, leading many thinkers to present them as the fundamental laws governing the entire universe. Despite claims of their basis in observation and experimentation, their generalization to such a broad scope exceeds what the limited empirical evidence available at the time would permit. This suggests the presence of an additional element that contributed to solidifying their position, namely a system of metaphysical and ideological assumptions, including religious belief, which played an implicit role in imbuing these two laws with universality and necessity (Finn 1974).

Second: Philosophical and Theological Foundations of the Concept:

The transition from the physical foundation of the concept of entropy to the deconstruction of its philosophical and theological dimensions represents a necessary analytical extension for understanding the mechanisms by which this concept was formed as an explanatory framework transcending its purely scientific boundaries. The emergence of entropy was not merely an epistemological deviation from classical mechanistic approaches to understanding natural phenomena; rather, it was the product of a complex interaction between precise scientific developments and deep philosophical and theological commitments that contributed to shaping its meanings and interpretations. In this context, the law of conservation of energy can be traced to its roots in Greek philosophy, which posited the eternity of matter and its non-creation from nothing, whereas the second law of thermodynamics, with its inherent linear conception of decay and decline, can be attributed to the traditional Christian worldview that assumes a creative beginning and a finite, directional time (Finn 1974, 35).

These theological underpinnings are clearly evident in the works of Lord Kelvin (William Thomson), one of the most prominent formulators of the Second Law. He not only articulated its physical implications but also imbued it with an explicit religious interpretation when he asserted that all forms of motion, with

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the exception of heat transfer, must eventually cease unless God intervenes with a new creative force that counteracts the inherent dissipation of mechanical effect in natural processes (Finn 1974, 38).

This conception reveals a crucial implicit assumption: that the preservation of order and the prevention of systemic collapse necessitate transcendent external intervention, whether this intervention is understood as a divine act or, in later, more secular formulations, as continuous flows of energy, information, or organization. In this sense, concepts of entropy do not reflect purely thermodynamic constraints but rather entail broader assumptions concerning the impossibility of self-sustaining order and the dependence of systems on external sources to maintain their cohesion (Woodward 2024).

This normative dimension subsequently crystallized in philosophical interpretations of entropy, particularly in contemporary philosophies of technology, which Ashley Woodward refers to as approaches that seek to derive a naturalized value system from the data of thermodynamics, information theory, and related sciences (Woodward 2024, 13).

In these approaches, entropy is not understood as a statistical description of natural processes, but rather is imbued with a negative normative connotation, presented as a structural evil that must be resisted. This value-laden framing is reflected in how systems, including states and international systems, are analyzed, as entropic processes are often interpreted as direct threats to stability and order, instead of being viewed as inherent dynamics that could open the door to transformation and systemic readjustment. This interpretive tendency reveals deeper layers of philosophical and theological assumptions that have become integrated into the historical development of entropy theory. The common methodological descriptions of entropy as chaos, disorganization, dispersion, dissolution, and death, alongside the reading that understands the Second Law as a declaration of the inevitable triumph of entropy over order, organization, creativity, progress, civilization, and life, do not represent purely scientific findings, but rather reflect interpretive choices saturated with pre-existing philosophical perspectives (Woodward 2024, 16). This conception reached its peak since William Thomson deduced the cosmic implications of the Second Law, particularly the idea of the heat death of the universe, whereby entropy was often imbued with negative normative connotations as a genuine force of evil (Finn 1974, 40).

The recognition that entropy has historically been understood as the natural or naturalized equivalent of the theological concept of evil, and that it was condemned and ostracized on this basis, illustrates how philosophical and theological assumptions shaped the scientific and political frameworks subsequently employed in the utilization of the concept of entropy. Consequently, the analysis of systems, whether physical, social, or political, necessitates a rigorous critical examination of the value systems underlying interpretations of

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entropy, in order to avoid transforming these interpretations into normative axioms that restrict theoretical and practical choices in the fields of international governance and institutional development (Woodward 2024, 16).

This normative framework extends its influence to contemporary philosophies of technology, wherein entropy is depicted as an evil to be combated in the name of life, information, or any alternative conception of good. This perspective has contributed to the shaping of technological policies and international institutional designs that prioritize resisting entropy rather than managing or adapting to it. Paradoxically, this approach has led to a reduction in adaptive capacity and undermined the potential for creative responses to new challenges and transformations (Finn 1974, 55).

Applying the laws of thermodynamics to cosmic and international systems reveals fundamental logical contradictions that expose the philosophical, rather than purely empirical, nature of entropy theory. According to the law of conservation of energy, energy, as the essence of the universe, cannot be created or destroyed, and its total sum remains constant across all transformations. If the universe possesses a specific amount of energy today, it logically follows that it possessed the same amount in the past and will retain it in the future. This leads to the conclusion of the universe's eternality and negates the possibility of creation *ex nihilo*, given that creation presupposes a violation of the conservation principle (Finn 1974, 56).

However, the second law of thermodynamics articulated a different narrative, stating that the universe's energy undergoes a net directional transformation from a past state characterized by maximum availability to a future state characterized by maximum unavailability. The currently observable state of the universe, when interpreted in light of this law, necessitates the assumption that, in a not infinitely distant past, the universe must have existed in a state of absolute minimum entropy, i.e., a state of maximum energy availability. This tension between the two laws revealed a profound philosophical paradox that cannot be resolved by empirical data alone (Finn 1974, 58).

Sir Arthur Eddington addressed this problem by adopting entropic cosmology, despite explicitly acknowledging its philosophical difficulties and describing its assumptions as incredible, without offering a theoretical alternative to overcome this dilemma (Finn 1974, 59). Nevertheless, Eddington elevated the Second Law to the status of the supreme law of nature (Finn 1974, 60), transforming it from a scientific description into a metaphysical doctrine. Although he admitted that conceiving the universe as a unidirectional process or a single cycle was unsatisfactory to reason, he accepted the ultimate outcome of the universe's heat death (Finn 1974, 103).

These issues become more profound when applying entropy theory to biological systems, as fundamental differences emerge between physics and biology, once again revealing the philosophical underpinnings of entropic

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interpretation. Living systems do not necessarily adhere to the same logic that governs closed physical systems, which has direct implications for the analysis of social and international systems that share characteristics of adaptation and self-organization with living organisms. In this context, the Russian biologist A. I. Oparin argued that the second law expresses a general statistical tendency of nature towards disorder and equalization, whereas living organisms not only experience an increase in entropy but also demonstrate potentials for its decrease through system growth and internal organization, as the fundamental law of biology, unlike physics, becomes the enhancement of order rather than its erosion (Finn 1974, 106).

Similarly, a reading of Ludwig Boltzmann's work, often presented as radically opposed to Clausius's interpretation, reveals a greater complexity than commonly assumed. Boltzmann did not deny entropy; rather, he proposed a conception of an entropy-symmetric universe and developed alternative explanations demonstrating that entropic processes might be reversible under certain conditions, instead of inevitably leading to systemic collapse (Finn 1974, 107). These historical disagreements highlight that the development of entropy theory involved fundamental theoretical choices that could not be resolved by empirical evidence alone. This aligns with Thomas Kuhn's observation that methodological rules, by themselves, are insufficient to dictate a single substantive conclusion in many scientific questions, and that the conclusions reached by scientists are often determined by their prior experiences, intellectual formation, and broader epistemic contexts (Tanner 1971, 95).

Part Two: From Information Theory to Effects-Based Operations:

First: Information Entropy and Systems Thinking:

The transition from thermodynamic entropy to informational entropy highlights the central dilemma encountered in attempts to employ this concept in the analysis of human systems, as the problem was not so much technical as it was epistemological. Entropy, in its physical origin, was formulated to analyze closed systems assumed to be completely isolated from their environment, whereas human societies and political systems are inherently open systems, constantly nourished by flows of energy, information, and resources. This disparity initially made it unclear how the concept of entropy could be meaningfully transferred to the realm of human action without falling into simplistic projections or distorting the concept itself. However, this predicament found a path to resolution with the development of information theory, particularly in the works of Norbert Wiener, which redefined entropy as a measure of uncertainty or informational disorder, thereby enabling its application in the analysis of human communication and complex social systems (Tanner 1971, 96).

In this context, the paradox of chaos and communication has become a central organizing principle in contemporary entropic thought. Entropy expresses chaos; however, information itself is measured by the degree of chaos inherent in the

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message, as the greater the amount of information, the higher the level of uncertainty contained within it (Tanner 1971, 98).

On this basis, entropy management is no longer a purely technical matter, but has transformed into a systemic design dilemma concerning how to achieve a delicate balance between probability and comprehensibility. A highly probable message is predictable to the point of banality and conveys little information, whereas a highly improbable message, despite its informational richness, becomes difficult to comprehend and fails to perform its communicative function. This tension reveals a deeper problem related to the limits of regulation and control in complex systems, as neither system nor information can be maximized without risking the loss of meaning or comprehensibility (Hitchins 2007).

This conceptual shift coincided with a broader epistemological transition from the machine age paradigm to the systems age paradigm, a transition that reshaped methods of understanding complexity and holism, and had direct implications for the analysis of international phenomena. As Derek Hitchins points out, the mechanistic approach involves disassembling a phenomenon into its primary elements, analyzing each part in isolation, and then reassembling these parts to explain the whole. This logic aligned with the reductionist approaches that long dominated traditional international relations theories, which assumed that the international system could be understood by analyzing its constituent units, namely states, as independent actors whose behavior could be explained separately. In contrast, the systemic approach necessitates defining an overarching holistic framework within which parts are understood as interacting components within a broader structure, with analysis proceeding from the behavior of the whole before returning to explain the roles of the parts. This distinction embodies a fundamental difference between analysis and synthesis, as analysis aims to uncover how things work, while synthesis seeks to answer why things work the way they do (Hitchins 2007, 33). Hitchins summarized this paradox by noting that analysis produces partial knowledge, while synthesis produces holistic understanding, meaning that the accumulation of knowledge about parts does not automatically lead to an understanding of the system as a whole unless this knowledge is integrated within a synthetic framework that clarifies the logic of internal relationships. This dilemma is likened to attempting to disassemble and reassemble a mechanical watch to understand its mechanism, without grasping the concept of time itself, which demonstrates the limitations of the reductionist approach in dealing with complex systems, including the international system (Hitchins 2007, 37).

The evolution of systems thinking has led to a crucial realization: some phenomena are so complex that examining their individual components does not merely represent a methodological shortcoming, but rather a violation of analytical rationality itself. In this context, a system is defined as an organized or complex assemblage of parts that forms a holistic unit. This definition, despite its

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generality, highlights the internal integration and continuous interaction among components. The central implication of this concept is that a part acquires its meaning only through its relationship with other parts and its constant adaptation to them. Isolating it from the interactive context strips it of its functional significance and deprives the analysis of its explanatory power (Hitchins 2007, 40).

On this basis, systems thinking becomes an essential cognitive prerequisite for understanding how informational entropy operates within human and international systems, as it is a product of holistic interactions that cannot be reduced to the sum of their parts.

Second: Entropy in Military and Strategic Thought:

The application of entropy in contemporary military and strategic thought has demonstrated a clear transition from being a descriptive concept derived from physics or information theory to an analytical framework for understanding the structural transformations brought about by the digital revolution in the communicative and organizational foundations of the international system. The development of the concept of political entropy, particularly as crystallized in Russian political theory, has contributed to the formation of an understanding that the information-communication surge, coupled with the emergence of the digital society, has generated new patterns of political disorder that transcend the traditional boundaries of the state and sovereignty, operating across transnational spaces not easily amenable to classical control mechanisms (Yavlinsky 2021). In this context, international communication is no longer governed by stable diplomatic and institutional channels but is instead shaped by high-speed and high-impact digital networks. New-generation information and communication technologies, associated with the expansion of the internet and big data processing, have led to unprecedented levels of communicative entropy that undermine the ability of traditional institutions to control the flows of meaning and influence (Yavlinsky 2021, 16).

Given that communication constitutes one of the structural pillars of any international system, the escalation of informational entropy quickly acquired a direct military dimension, manifested in what has become known as the weaponization of information. The concept of the information weapon revealed the potential to induce profound changes in the consciousness of individuals and groups, by compelling them to a distorted perception of reality or by reshaping their frames of reference, thereby leading them to inhabit alternative cognitive worlds. In this sense, informational occupation transcended the logic of traditional warfare, establishing a permanent pattern of communicative disruption and cognitive disintegration, which creates ongoing dilemmas in international coordination and collective decision-making (Information Warfare 2018, 45).

Extending this logic, the concept of entropy-based warfare has articulated a new understanding of the nature of conflict, not merely as a direct targeting of the

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adversary's material capabilities, but as an attack directed at the organizational and communicative structures underpinning the cohesion of political units. Recent conflicts have demonstrated that military operations are no longer confined to destroying infrastructure or depleting human resources; rather, they now aim to disrupt coordination mechanisms, erode trust, and dismantle command and control systems, thereby increasing the adversary's level of chaos while simultaneously striving to maintain internal cohesion. This shift has established a break with traditional military analysis, as the temporal dimension, particularly the manipulation of operational rhythm and timing, is now viewed as the most promising area in concepts of the revolution in military affairs, and the least amenable to measurement by classical attrition metrics. On this basis, the essence of these wars no longer lies in abstract informational content, but in managing the dynamics of timing and coordination mechanisms, a notion reinforced by the development of precision weapons linked to advanced sensory and informational structures (Herman 1997).

Amidst this discussion, there has been a growing realization that entropy does not necessarily signify apparent chaos, homogeneity, or smoothness. Rather, in its essence, it refers to the number of possible configurations of a system. Systems may transition from homogeneity to heterogeneity, and then back to homogeneity, without negating the general trend of increasing entropy. Thus, entropy is not measured solely by the degree of instantaneous disorder, but by the structural system's tendency towards an expanding space of possibilities and the erosion of the capacity for stable control (Styer 2019).

Randall Schweller significantly contributed to a paradigm shift in the study of international politics by introducing the concept of entropy as an explanatory tool for the trajectory of the international system's evolution. Schweller posited that the random and indeterminate nature of the unipolar world reflects an increasing state of entropy, explaining that international systems, by virtue of their structure, tend towards greater disorder unless substantial amounts of energy are expended to maintain their structural cohesion (Schweller 2010).

From this perspective, entropy has been defined as the tendency of matter and energy to evolve towards a state of inert homogeneity, a principle that explains, in the field of international relations, the reason for the need for massive material resources and high political will to maintain any form of international order (Schweller 2010, 146).

This entropic logic extends to the analysis of the strategic behavior of international actors. Schweller noted that the world is no longer governed by a single superpower or a group of major powers capable of imposing order; instead, it is moving towards a competitive environment with multiple actors. These include states, multinational corporations, ideological movements, transnational crime and terrorist networks, alongside rising regional powers, all of which

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contribute to increasing the levels of complexity and entropy in the international system (Schweller 2014b).

Within this framework, the concept of entropy has garnered particular attention in Russian strategic thought as a tool for understanding post-Soviet dynamics. The "threat of entropy" has been framed as a threat to the very identity of Russian society, revealing that entropy has not merely been employed as an analytical metaphor, but rather as a security framework through which existential threats are perceived (Morozov 2002). Similarly, Ukrainian researchers have utilized the concept to understand their strategic environment, considering that processes of identity re-formation within Ukrainian society exhibit entropic tendencies that directly impact the state's position within international system interactions (Ishchenko 2021).

Paul Goncharoff added another interpretive dimension by linking the second law of thermodynamics, as a law dictating the inevitable increase of entropy in closed systems over the long term, to the limitations of attempts to impose order in complex strategic environments. Drawing on Rudolf Clausius's analogy, Goncharoff explained that the energy expended to create an organizing effect can paradoxically lead to an amplification of entropy on a broader scale, similar to a billiard ball transferring the cue's energy to the other balls, thereby creating a more widespread disturbance that exceeds the instantaneous energy expended. This analogy established a profound logic governing strategic interactions, as attempts at control do not always lead to enhanced order but may instead accelerate its disintegration (Goncharoff 2023).

In its structural dimension, entropy also points to a tendency towards homogeneity through chaos, as the acceleration of globalization and the transformation of the international system into a semi-closed space lead to the weakening of biological, cultural, political, and economic diversity. This tendency makes the disintegration of large entities or the collapse of international alliances a recurring trajectory in modern history, as occurred with the British Empire, the Soviet Union, and the Warsaw Pact. In the contemporary context, the features of growing political and economic entropy are evident in structures such as NATO and the European Union, as well as in the dollar-centric global financial system, where these dynamics are exacerbated by sanctions and trade restrictions. Even major powers that have undergone radical transformations, such as Russia after 1989 or China after 1949, do not appear immune to these trajectories in the long run (Goncharoff 2023).

Based on this, the effect of entropy on patterns of political polarization among actors reveals pathways of systemic evolution that traditional linear models cannot capture. This confirms that entropy is not merely a metaphor for chaos but represents a qualitative framework for analyzing the transformations of complex strategic systems. From a critical perspective, it has been noted that some prevalent concepts, such as multipolarity in Russian discourse, remain essentially

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selective aggregations of general observations and data. This reflects the limitations of traditional theoretical frameworks in comprehending the increasing entropic nature of contemporary international relations (Mantzaris 2023).

Part Three: Entropy and Transformations in the Contemporary International System:

The invocation of Maxwell's hypothetical demon in the analysis of contemporary transformations within the international system represents a conceptual turning point in understanding the relationship between entropy and the potential for order production. The thought experiment proposed by James Clerk Maxwell in 1867 posed a direct challenge to the classical interpretation of the second law of thermodynamics. He hypothesized the existence of a being capable of sorting molecules according to their speed, thereby allowing for the creation of temperature differences without apparent work being done. This appeared to violate the principle of the inevitable increase in entropy (Schweller 2010, 148).

However, subsequent developments in physics and information theory have shown that the sorting process itself is not energetically neutral, as it requires the acquisition and processing of information. These cognitive processes, in turn, generate entropy that compensates for any localized decrease in disorder, thereby keeping the second law active at the level of the overall system. In this sense, the law is not abrogated but rather reinterpreted in light of the dialectical relationship between information and energy (Schweller 2010, 148).

When this model is applied to international relations, it becomes possible to liken certain international actors or institutional blocs to Maxwell's demons, capable of creating local pockets of order through the selective control of information and resource flows. However, this localized organization is not achieved in a vacuum; rather, it necessitates the export of entropy to other parts of the international system. This explains how attempts to impose stability in one region may, due to structural reverberations, lead to destabilization in other regions. On this basis, the production of order is not understood as the antithesis of chaos, but rather as a process of entropy redistribution across the international system (Schweller 2010, 150).

This understanding is reinforced by Ilya Prigogine's crucial contribution to explaining the emergence of order from chaos through the concept of "dissipative structures." Prigogine demonstrated that systems far from thermodynamic equilibrium do not necessarily descend into disintegration; rather, under a continuous flow of energy, they can spontaneously develop organized and complex structures (Schweller 2010, 150). These structures are characterized by maintaining their internal regularity by exporting entropy to their surroundings, in a process known as order through fluctuations. Consequently, order becomes a product of managed instability, not a result of static equilibrium (Prigogine 1978).

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When this framework is applied to the international system, states and international institutions can be understood as dissipative structures that maintain their coherence by importing material and informational resources and exporting entropy to their external environments. However, this model simultaneously reveals an inherent structural fragility, as any disruption in energy or information flows, or an excessive accumulation of entropy within the system, could push it to a critical tipping point leading to a sudden collapse instead of a gradual decline. Thus, international stability becomes a temporary state conditioned by the continuity of organizational flows, rather than an inherent characteristic of the system (Prigogine and Stengers 1984, 189).

In the broader context of contemporary transformations, the traditional international framework is disintegrating, to be replaced by what Robert Harkavy aptly described as an era of unaligned alignment or juxtaposition, as the classificatory structure of the nation-state erodes, and the international system transforms into a fragmented mosaic of fragile states, semi-sovereign entities, and regions of ambiguous character (Harkavy 1997, 585).

This shift reflects the inherent paradox of entropy in the contemporary international system, as the integration of the global village, driven by technology and economic interdependence, is accompanied by increasing structural fragmentation. The thermodynamic cost of maintaining high levels of integration may exceed the system's capacity to generate the necessary organizational energy, leading to an escalation of disorder instead of the consolidation of order (Harkavy 1997).

Harkavy coined the concept of multiple structures to describe this complex situation, as global politics is not subject to a single hierarchy but is distributed across coexisting layers with different logics. The upper military layer is characterized by unipolar features, while the middle economic layer takes on a tripolar character, and the layer of transnational interdependence is characterized by the diffusion and dispersion of power (Harkavy 1997, 587). This superposition produces a highly complex dissipative system, in which each layer requires distinct energetic inputs and produces different entropic patterns, thereby increasing the difficulty of comprehensive control and deepening tensions between the system's levels (Harkavy 1997, 588).

These dynamics are clearly evident in Parag Khanna's analysis of globalization-related transformations, where he argues that the international system is experiencing a gradual erosion of the structures established after World War II, replaced by dynamics based on competitive connectivity. In this context, supply networks, cross-border infrastructure, and megacities emerge as central nodes of power, at the expense of traditional borders and sovereignty. These transformations do not merely represent a redistribution of power, but a qualitative change in the energetic characteristics of the international system, as classical mechanisms for maintaining order become incapable of keeping pace with the

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accelerating production of entropy. Khanna further highlights the role of megacities as entropy sinks or swamps, where human, informational, and economic energy is concentrated, but which, in turn, generate immense flows of pollution, social pressure, and organizational chaos (Khanna 2024).

This coincides with the rise of non-state actors and the proliferation of governance mechanisms, leading to the fragmentation and competition of sources of authority, and complicating coordination and control processes. In this context, legitimacy transforms from being a product of formal authority to a result of performance and problem-solving capability, precisely reflecting a state of legitimacy entropy (Khanna 2024).

This analysis integrates with complexity and chaos theories in international relations, particularly the concepts advanced by Philip Cerny and Alex Prichard within the framework of "new chaos." According to this perspective, globalization does not lead to a more integrated system; rather, it simultaneously generates forces for homogenization through standardization and forces for differentiation by destabilizing local arrangements and producing new conflicts (Cerny 2017). Here, scale-dependent entropic effects emerge, as disorder may decrease at one level only to increase at other levels, making concepts such as glocalization dual mechanisms that combine homogenization and differentiation. Conversely, the dismantling of sovereignty leads to the production of sovereign entropy resulting from the dispersion of authority across overlapping levels, thereby complicating coordination and governance processes (Cerny 2017, 381).

The emergence of transnational networks possessing "small-world" characteristics expands the possible avenues of interaction, yet simultaneously increases the system's vulnerability to cascading failures. On this basis, globalization reveals a dual entropic logic: it creates integrated markets but undermines political institutions, and it opens new channels of communication but weakens the traditional legitimacy of states (Cerny 2017, 383).

Within this framework, Randall Schweller established a central analysis of the entropy of power and influence, demonstrating that the transformations of globalization not only reshape the structure of the international system but are also subject to thermodynamic constraints that limit the ability of states, including hegemonic powers, to convert capabilities into sustainable influence (Schweller 2010). Structural constraints operate through performance-based selection mechanisms that penalize policies inconsistent with the logic of the system, rendering certain choices more costly and less efficient through what is known as entropy gradients (Schweller 2010, 177).

In this context, Schweller observed that despite its unipolar superiority, the United States possesses less influence than it did under bipolarity, a paradox that embodied "the entropy of influence." This is because the concentration of power can undermine the ability to attract and retain allies (Schweller 2010, 178). Furthermore, the relationship between capabilities and influence is not linear, as

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minor shifts can lead to radical changes in system behavior. Accordingly, entropic pressures in unipolarity produce two potential paths: a gradual path beginning with the erosion of legitimacy, or a shocking path characterized by sudden collapse. Both reflect the fragility of concentrated structures and their inherent tendency towards disintegration (Schweller 2010, 180).

Marina Lebedeva complements this perspective through the concept of the "perfect storm," resulting from simultaneous transformations at three interconnected levels (the Westphalian system, the international relations system, and domestic political systems) (Lebedeva 2016). According to her conception, these levels function as a global political pyramid, where changes at any one level lead to ripple effects at the other levels, generating a state of entropic amplification that reflects the loss of the restraining mechanisms that previously prevented limited disturbances from escalating into comprehensive collapses. Lebedeva described the current situation as historically unprecedented, given that all three levels are undergoing simultaneous radical transformations. The erosion of the Westphalian system produces "border entropy" that blurs the distinctions between internal and external, while the coexistence of different state models reveals "normative entropy" that increases the difficulty of building stable international consensus (Lebedeva 2016, 128).

Part Four: Mechanisms for Containing Entropy and Managing Complexity in National Security:

The exploration of mechanisms for entropy containment and complexity management within the field of national security falls within a broader endeavor to answer a pivotal question: how can political and strategic systems coexist with increasing levels of structural disorder without succumbing to total collapse? In this context, Johan Galtung provided an early foundational framework for linking entropy to peace theory, seeking to transfer the principles of thermodynamics from describing physical decay to analyzing the conditions of stability and conflict in international systems. Galtung distinguished between actor entropy, which reflects how powers, identities, and resources are distributed among the system's units, and interaction entropy, which focuses on the nature of connections and patterns of exchange between these units (Galtung 1967).

The escalation of both dimensions leads to the formation of cross-cutting cleavages and complex interaction networks, which weaken the system's ability to align into rigid conflict blocs. Conversely, this grants the system a greater capacity to absorb and locally manage conflicts before they accumulate into comprehensive confrontations (Galtung 1967, 174). Based on this understanding, integrative policies that expand interconnected ties and dependencies become more effective at dismantling conflict energy and distributing it throughout the system, whereas divisive policies lead to the concentration of tensions along sharp, highly volatile fault lines (Galtung 1967, 175).

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This logic is embodied in Galtung's distinction between homogeneous, low-entropy systems, where identities and loyalties align with political boundaries, thereby increasing the likelihood of conflict mobilization, and heterogeneous systems, where affiliations are distributed across multiple units, raising what he termed the "entropy of loyalties" and weakening the potential for the formation of absolute conflictual identities. Thus, the rise in entropy here is not understood as a mere factor of chaos, but rather as a structural mechanism for restricting large-scale violence (Galtung 1967, 180).

This understanding deepens when considering security deterioration as an entropic process within political systems. Systems analysis demonstrates that entropy levels are not solely determined by external pressures but are critically shaped by the dynamics of internal support. Jung Hyun Byeon noted that the relative balance between adaptability and the level of political support determines the entropy of the political system as a whole (Byeon 2005). From this perspective, Byeon distinguished between external entropic change, which is related to the system's ability to cope with environmental disturbances and depends on the efficient use of knowledge and information, the flexibility of institutional structures, and timely boundary control (Byeon 2005, 225), and internal entropic change, which is measured by the strength of spontaneous political support, as reflected in indicators of legitimacy and stability at multiple levels of the political system (Byeon 2005, 226).

This distinction reveals a fundamental difference between political systems and closed thermodynamic systems. While the latter inevitably tend towards maximum entropy, political systems operate as open systems capable, in principle, of reducing entropy through effective interaction with the environment and efficient information processing (Byeon 2005, 227).

In this context, Byeon drew upon the work of Ilya Prigogine and Isabelle Stengers on dissipative structures to assert that energy flows from the environment can lead to a decrease in entropy that outweighs the internally generated increase, thereby allowing political systems to be understood as both dissipative and negentropic structures, capable of maintaining relative stability despite escalating structural pressures (Byeon 2005, 227).

The issue of boundary regulation is considered one of the pivotal mechanisms in this context. Byeon argues that system boundaries are not fixed between openness and closure, but rather are managed selectively to achieve a delicate balance between excessive diversity and excessive uniformity. This balance gains particular importance in light of Ross Ashby's Law of Requisite Variety, which states that effective control requires the variety of the control system to be equal to or greater than the variety of disturbances it faces. When this principle is applied to international relations, it becomes clear that international institutions and security systems need to develop sufficient levels of internal complexity and functional diversity to be able to absorb increasing challenges without

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succumbing to organizational paralysis or entropic disintegration (Byeon 2005, 228).

The concept of autopoiesis complements this perspective by highlighting the self-producing nature of systems within political institutions. Autopoietic systems do not merely interact with their environments; rather, they actively seek to reshape them by modifying their structures and selectively adjusting their boundaries. Byeon likens this process to living cells that permit the passage of beneficial elements and integrate them into their structure, while excluding harmful elements to maintain continuity. Consequently, these systems are not passive entities that merely respond to pressures, but active agents that strive to direct their environments in ways that serve their survival (Byeon 2005, 229). In this context, political support acquires crucial importance, as it is defined as the set of attitudes and behaviors that ensure the continuity of the system, and its decline leads to an increase in entropy. David Easton's analytical framework underscores the multidimensional nature of this support, in terms of its connection to the community, the regime, and authority, and the different implications each level has for the dynamics of entropy (Byeon 2005, 231).

Historical experience has clearly demonstrated that the failure to manage entropy can undermine attempts to build international order. In his analysis of the Versailles system, Srdja Trifkovic showed that the Paris Peace Conference of 1919, despite its magnitude, resulted in a treaty that carried within it the seeds of an even more destructive war a generation later (Trifkovic 2019).

One of the fundamental shortcomings was the exclusion of key European powers from the system-building process, particularly Germany and Russia. This constituted a failure to regulate boundaries in a systemic sense and contributed to the accumulation of systemic entropy instead of its containment. Furthermore, the contradiction between imposing harsh sanctions on Germany and the need to preserve its economic capacity to ensure system stability revealed how the very mechanisms of construction generated internal entropy that ultimately led to the system's collapse (Trifkovic 2019).

This analysis integrates with informational entropy approaches to uncertainty management, as presented by Mark Matthews in his study of governance and uncertainty. Matthews defined entropy, based on Shannon's theory, as the statistical potential for surprise inherent in a signal, i.e., the amount of uncertainty associated with information or an event (Matthews 2012). Matthews highlighted the concept of asymmetric uncertainty, which posits that understanding the near past is less entropic than understanding the distant future, placing the decision-maker before a U-shaped curve in dealing with time and uncertainty. In this sense, entropy in international relations does not arise solely from structural randomness but also manifests in diagnostic errors accompanying decision-making processes (Matthews 2012, 40).

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The concept of the confusion matrix, derived from signal processing theory, helped to deconstruct this problem. It allowed for the analysis of failures in distinguishing between correct and incorrect signals, and the resulting accumulation of confusion that becomes difficult to contain over time (Matthews 2012, 43).

From this perspective, Matthews proposed the low-entropy governance framework as an approach that integrates appraisal, evaluation, and risk management through advanced information processing capabilities. This proposition demonstrated that excessive caution or rigid compliance can increase entropy instead of reducing it, transforming institutions into sources of instability rather than tools of stability. This necessitates the development of more scientific approaches to future foresight, incorporating strategic foresight as a category of outcomes rather than merely a predictive exercise (Matthews 2012, 47).

Accordingly, the structural anarchy of the international system emerges as a permanent incubator for entropy, as William Wohlforth elucidated in his analysis of the absence of a higher authority. The international system, based on the interaction of sovereign powers in the absence of a binding center, differs fundamentally from any hierarchical system. It reproduces what Kenneth Waltz described as a self-help world, where every actor is compelled to secure its own safety with its own resources (Wohlforth 2018).

This structure, therefore, naturally tends towards the erosion of cooperative arrangements as circumstances and interests change, as formal commitments become weak constraints against the logic of competition. This tendency parallels, from a thermodynamic perspective, the transformation of organized energy of cooperation into disorganized energy of competitive behavior, thereby solidifying entropy as an inherent structural characteristic of the contemporary international system (Wohlforth 2018, 88).

Conclusion:

An analytical tracing of the concept of entropy, from its thermodynamic roots to its applications in contemporary strategic thought, leads to a series of structural conclusions regarding the nature of transformation in the international system and the limitations of traditional conceptual tools in comprehending this transformation. This research has demonstrated that entropy cannot be reduced to merely a physical metaphor arbitrarily projected onto international politics. Instead, it represents a complex analytical framework that allows for understanding the dialectical interaction between disintegration and integration, and between order and disorder, in international environments characterized by increasing complexity and deep structural uncertainty.

One central finding highlighted by this analysis is the absence of what could be termed a creative destruction mechanism, which historically served to structurally readjust the international system through major wars. In previous contexts, total wars, though violent, decisively contributed to the removal of obsolete structures

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and institutions, and to the reshaping of the system according to new power balances. In the current context, however, nuclear deterrence, coupled with unprecedented levels of economic entanglement and interdependence, has disabled this mechanism. This has resulted in what Schweller describes as an age of entropy, where institutions and arrangements accumulate without the effective dismantling of those that have lost their function, thereby multiplying complexity and increasing the system's fragility instead of its stability (Schweller 2011). This situation recalls Hegel's observation that prolonged, unrenewed peace carries within itself the elements of its own decay, much like a stagnant sea corrupted by its stillness (Schweller 2011, 289).

In the absence of decisive structural dismantling mechanisms, entropy in the current era assumes more complex forms, most notably those associated with the digital revolution. The intense and unregulated flow of information has provided unprecedented opportunities for new actors—from ordinary individuals and social movements to extremist groups and criminal networks—to influence the international arena. However, these opportunities are characterized by fundamental asymmetry, as they enhance the capacity for disruption and the production of chaos without being accompanied by a parallel capacity to build stable alternative systems or institutions capable of containing disorder. Thus, the digital revolution does not function as a source of order as much as it contributes to accelerating the production of entropy at both the structural and epistemic levels (Schweller 2011, 290).

Herein lies the great paradox of the age of entropy, as articulated by Schweller: the international system finds itself trapped between the impossibility of total war as a tool for restructuring and the impossibility of stasis as a sustainable condition. In the past, major wars would effect a *Tabula Rasa* or a systemic reset, allowing for the construction of new arrangements. Today, however, the structural constraints that render total war practically inconceivable simultaneously lead to increasing stasis, wherein structures and institutions accumulate without the capacity for radical renewal. In this context, Schweller emphasized that the enduring historical challenge for human action has always been, and continues to be, the creation of order from the heart of disorder. Nevertheless, managing this challenge in the current era necessitates new strategies capable of addressing the non-linear and discontinuous changes imposed by technology and economic transformations, while acknowledging that any success in this domain remains contingent upon high degrees of uncertainty (Schweller 2014b).

This predicament is not limited to the structural level of the international system but extends to the epistemic level, as the abundance of information itself leads to the production of escalating epistemic entropy. The surplus of data, instead of enhancing shared understanding, contributes to the erosion of meaning and the disintegration of common reference frameworks, thereby transforming international interaction into a space where conflicting subjective truths compete,

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making them difficult to verify or reconcile (Schweller 2014b). As Matthews clarified, diagnostic errors in policy assessment are not necessarily corrected by the accumulation of information; rather, they too can accumulate, raising the level of entropy within the decision-making process itself (Matthews 2012, 50). In this sense, structural entropy and epistemic entropy intertwine to produce a state of continuous attrition, which Schweller described with the concept of a permanent entropic interstice (Schweller 2014b).

This reality necessitates a more radical theoretical reconceptualization of the dynamics of order and chaos in international relations, one that transcends traditional dichotomies between stability and instability. The theoretical work presented by Ilya Prigogine and Isabelle Stengers contributed to establishing an alternative understanding of how order emerges from chaos, by analyzing systems far from equilibrium as capable of generating new organizational forms through nonlinear, irreversible processes and the amplification of fluctuations. The realization that the second law of thermodynamics introduced irreversibility at the macroscopic level, and that its implications can also be understood at the microscopic level, leads to a re-evaluation of the capacity of limited political interventions to reverse trajectories of structural change in the international system (Prigogine and Stengers 1984, 291).

Within this framework, the distinction between reversible and irreversible processes acquires crucial analytical importance. Some international interactions, such as simple bilateral relations or automatic balance-of-power dynamics, may exhibit reversible characteristics that can be analyzed with traditional tools. However, complex multilateral institutional development, profound cultural transformations, and the emergence of new patterns of global governance are inherently irreversible processes, requiring theoretical approaches centered on history, path-dependent evolution, and entropic accumulation. The central challenge for international relations theory, therefore, lies in constructing frameworks capable of distinguishing between these different types of processes and applying diverse analytical tools according to their nature, rather than striving for a unified theory that disregards this structural multiplicity (Prigogine and Stengers 1984, 292).

In light of these findings, an entropic approach to national security emerges, transcending traditional perspectives that confine threats to the hard military dimension. Entropy, as an analytical framework, reveals that contemporary threats encompass informational, cognitive, and structural dimensions that dismantle the internal cohesion of states as much as they target their material capabilities. Furthermore, the concept of dissipative structures has shown that stability is not achieved through maintaining a static equilibrium, but rather through continuous adaptation and the management of flows of energy, information, and legitimacy.

Controlling borders, in their functional and regulatory sense, and managing these flows, becomes a crucial element in containing entropy, thereby

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necessitating a rethinking of the concepts of sovereignty and borders in the context of globalization. Furthermore, acknowledging the non-linear and irreversible nature of many international processes calls for the adoption of more flexible national security strategies, capable of operating amidst uncertainty and surprise instead of striving for comprehensive control.

Nevertheless, it is imperative to acknowledge the limitations of this approach. Social and political systems fundamentally differ from physical systems in their capacity for learning, conscious decision-making, and the redefinition of their objectives. Furthermore, the transfer of concepts between epistemic fields always entails the risks of oversimplification or unwarranted generalization. However, entropy, as a root metaphor in the sense defined by Stephen Pepper, remains a highly fertile conceptual framework for understanding contemporary transformations in the international system, and for analyzing the dialectical relationship between chaos and order, and between disintegration and integration. This opens promising research avenues for developing more profound and realistic approaches in strategic planning and the formulation of national security strategies in the twenty-first century.

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