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A Concise Formalization of Hyperrealism-Antirealism in Physics Using Neutrosophic Logic

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Abstract. In [6], the relationship between hyperrealism and antirealism in physics is proposed. Hyperrealism-Antirealism describes a spectrum where theories transition from being empirically grounded (realist) to speculative frameworks dominated by untestable assumptions, thereby detaching from observable reality.

This paper presents a concise mathematical formalization of the spectrum of *hyperrealism-antirealism* in theoretical physics and the philosophy of science. We propose a method to quantify the extent to which a theory is "hyperreal" or "antirealist" using a ratio of testable to untestable statements. Additionally, we provide several theorems that outline the conditions under which theories shift into hyperreal or antirealist domains. Finally, we explore how Neutrosophic Logic [38] can capture intermediate degrees between realism and antirealism, offering a nuanced perspective on the spectrum.

Keywords: Hyperrealism, Antirealism, Realism, Neutrosophic Logic

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1. Preliminaries and Definitions

This section provides an introduction to the foundational concepts and definitions required for the discussions in this paper.

1.1. *Physical Theory and Realism*

This subsection provides an explanation of Physical Theory and Realism. Relevant definitions and simple examples are presented below.

Definition 1.1 (Set)**.** [22] A *set* is a collection of distinct objects, known as elements, that are clearly defined, allowing any object to be identified as either belonging to or not belonging to the set. If A is a set and x is an element of A, this membership is denoted by $x \in A$. Sets are typically represented using curly brackets.

Definition 1.2 (Physical Theory)**.** [6] Let $\mathcal{T}$ be a physical theory expressed as a formal system with:

- A set of axioms or postulates $A = \{A_1, A_2, \ldots, A_n\}$.
- A set of theorems or derived statements $S = \{s_1, s_2, \ldots\}$ obtainable from A by rules of inference.

We assume that $\mathcal{T}$ is sufficiently well-defined so that each $s \in S$ has a clear meaning in principle.

Definition 1.3 (Testable vs. Untestable Statements)**.** [6] Partition S into two subsets:

$$S_{\text{test}} = \{\, s \in S : s \text{ is falsifiable or empirically verifiable in principle}\},$$

$$S_{\text{untest}} = \{\, s \in S : s \text{ is not empirically testable in principle or is operationally meaningless}\}.$$

We do not distinguish here whether S_{untest} statements are *in principle* untestable or just untestable given current technology; we treat them uniformly as "not testable."

Example 1.4 (Quantum Field Theory (QFT))**.** (cf. [20, 28, 28]) A *Quantum Field Theory* $\mathcal{T}_{\text{QFT}}$ typically includes:

- Axioms/postulates: Field operators, canonical commutation relations, etc.
- Derived statements: Predictions about particle scattering cross-sections, decay rates, and vacuum fluctuations.

$$S = \{\text{scattering amplitude relations, vacuum state expansions, renormalization group equations, etc.}\}.$$

Many statements here are *testable* via high-energy experiments (e.g. collider data for scattering cross-sections). However, certain assumptions about non-perturbative vacuum structure or extreme energy behaviors could remain *untestable* with current technology.

Example 1.5 (Cosmological Dark Energy Models)**.** Consider a physical theory of *Dark Energy* that posits a particular scalar field or exotic fluid as the driver of accelerated cosmic expansion(cf. [7, 31, 33]). The domain of statements:

$$S = \{\text{Hubble parameter evolution, equation of state parameter,}$$
$$\text{cosmic microwave background constraints, etc.}\}.$$

A subset of these can be tested with astrophysical data (e.g. supernova observations, cosmological distance measurements), thus belonging to S_{test}. More speculative claims (e.g. about the ultimate fate of the universe beyond observable horizons or about higher-dimensional modifications) might be effectively *untestable* with present or near-future technology, placing them in S_{untest}.

Example 1.6 (In the Context of Quantum Gravity)**.** A *Quantum Gravity* framework $\mathcal{T}_{\mathrm{QG}}$ (cf. [15, 18]) might hypothesize:

- S_{test}: Low-energy quantum gravitational effects potentially observable in precise measurements of graviton scattering at extremely high energies (though technologically challenging).
- S_{untest}: Specific features of spacetime foam or Planck-scale discretization that may be inaccessible to direct experimentation.

Thus, while some approximate predictions about gravitational corrections might be tested indirectly, the deeper structure of spacetime at 10^{-35} meters could remain untestable in practice.

1.2. *Hyperrealism-Antirealism Measure*

This subsection presents the definition of the Hyperrealism-Antirealism Measure. Additionally, we provide several concrete examples of Realist, Hyperrealist, and Antirealist concepts, as discussed in [6].

Definition 1.7 (Hyperrealism-Antirealism Measure)**.** [6] Define the *Hyperrealism-Antirealism Ratio* (HAR) of the theory $\mathcal{T}$ as

$$\mathrm{HAR}(\mathcal{T}) \;=\; \frac{\left|S_{\text{untest}}\right|}{\left|S_{\text{test}}\right|}.$$

We say:

- $\mathcal{T}$ is *realist* or *empirically grounded* if $\mathrm{HAR}(\mathcal{T}) < 1$.
- $\mathcal{T}$ is *hyperrealist* if $\mathrm{HAR}(\mathcal{T}) \geq 1$.
- $\mathcal{T}$ is *antirealist* in the extreme if $\mathrm{HAR}(\mathcal{T}) \to \infty$, i.e., if $\left|S_{\text{test}}\right|$ is finite (or negligible) while $\left|S_{\text{untest}}\right|$ grows arbitrarily large.

Example 1.8 (Solid-State Physics)**.** (cf. [5, 17]) A typical *solid-state* model for semiconductors or superconductors includes statements about electron band structures, doping effects, and transport phenomena. Much of this is directly testable via laboratory measurements of conductivity, critical temperatures, tunneling spectra, and so on. Thus,

$$\mathrm{HAR}(\mathcal{T}_{\text{solid}}) = \frac{|S_{\text{untest}}|}{|S_{\text{test}}|} < 1,$$

since the majority of statements (e.g. doping concentration vs. conductivity) can be empirically verified. This places standard solid-state physics squarely in the *realist* category.

Example 1.9 (Stoichiometric Chemical Bonding)**.** (cf. [34]) Consider a simple *chemical theory* focusing on stoichiometry and bond energy approximations. Most statements, such as predicted yields of reactions under certain conditions, are testable in a basic chemistry lab. Hence

$$\mathrm{HAR}(\mathcal{T}_{\mathrm{chem}}) = \frac{|S_{\mathrm{untest}}|}{|S_{\mathrm{test}}|} \ll 1,$$

reflecting a highly *realist* approach with strong empirical grounding.

Example 1.10 (Electromagnetism as Realist or Mildly Hyperrealist)**.** *Classical electromagnetism* (Maxwell's equations) [16, 23, 36] is also highly testable. Most statements, such as the inverse-square law for electric fields, can be verified. However, some advanced claims (e.g. certain theoretical boundary conditions or idealized continuous distributions) might not be directly testable, so

$$S_{\mathrm{test}} \;>\; S_{\mathrm{untest}},$$

and typically $\mathrm{HAR}(\mathcal{T}_{\mathrm{EM}}) < 1$. Thus it remains primarily *realist*. In specialized theoretical corners (say, extremely idealized boundary conditions or vacuum states), there may be a mild drift toward *hyperreal* statements, but overall the testable component is dominant.

Example 1.11 (String Theory: Hyperrealist Domain)**.** *String Theory* [41] posits that fundamental particles are tiny vibrating strings living in higher-dimensional spaces. Many core aspects, such as the shape of extra dimensions or the existence of a vast "landscape" of possible vacua, remain experimentally unverified or difficult to test.

Thus, while some statements might be in S_{test} (e.g., certain low-energy effective predictions), a large fraction of the theory's claims lie in

$$S_{\mathrm{untest}} = \{\text{existence of extra dimensions, specific compactifications, multi-brane setups, etc.}\}.$$

If the untestable claims outnumber the testable predictions,

$$\mathrm{HAR}(\mathcal{T}_{\mathrm{string}}) = \frac{|S_{\mathrm{untest}}|}{|S_{\mathrm{test}}|} \;\geq 1,$$

placing String Theory in a *hyperrealist* regime. Whether it remains so depends on future experimental possibilities.

Example 1.12 (Quantum Cosmology)**.** *Quantum cosmology* [4] often deals with the wavefunction of the universe, decoherence at Planck epochs, and speculative boundary conditions (e.g. Hartle–Hawking no-boundary proposal). While some broad consequences might be tested indirectly (through cosmic microwave background patterns), many core statements (like the initial wavefunction of the entire universe) may remain effectively untestable. Consequently,

$$\mathrm{HAR}(\mathcal{T}_{\mathrm{qcosmo}}) \geq 1$$

if untestable statements dominate. This places quantum cosmology in a *hyperrealist* regime, at least until novel observations or conceptual breakthroughs reduce S_{untest}.

Example 1.13 (Multiverse Hypotheses). *Multiverse scenarios* (cf. [26]) propose that our universe is one among many, each with potentially different physical constants. While certain anthropic arguments might be testable in a limited sense, many claims (e.g. the existence of infinitely many parallel universes) are *untestable* by definition. Thus

$$|S_{\text{untest}}| \gg |S_{\text{test}}|,$$

and the theory's HAR is typically ≥ 1, indicating a *hyperrealist* orientation.

Example 1.14 (A Fully Untestable Speculative Theory: Antirealist Limit). Consider a hypothetical framework full of *metaphysical claims* (cf. [27]) with no empirical handle:

$$S_{\text{untest}} = \{\text{"Invisible pink unicorns cause time fluctuations," etc.}\}, \quad S_{\text{test}} = \varnothing.$$

Hence,

$$\text{HAR}(\mathcal{T}_{\text{extreme}}) = \frac{|S_{\text{untest}}|}{|S_{\text{test}}|} = \frac{\text{finite or infinite}}{0} \to \infty.$$

Such a theory is *antirealist in the extreme*, offering no measurable or falsifiable predictions.

Example 1.15 ("Simulation Hypothesis" without Empirical Anchors). (cf. [21,35]) A version of the *simulation hypothesis* posits that our entire universe is a computer simulation run by higher beings. If framed in a way that absolutely no test could ever falsify or confirm it (i.e. no predicted anomalies), then

$$S_{\text{test}} = \varnothing, \quad S_{\text{untest}} \neq \varnothing, \quad \text{HAR} \to \infty.$$

This is *antirealist in the extreme*, since no empirical method can, in principle, verify or refute the scenario.

Example 1.16 (Mythical Ether Theory (Unrevisable)). Historically, the *luminiferous ether* [29, 30] was once hypothesized as the medium for light propagation. After experiments (e.g. Michelson–Morley) failed to detect it, a purely ad hoc "ether" with undetectable properties became *unfalsifiable*. If one persists in an ether theory that automatically adjusts postulates to evade every new test, then

$$S_{\text{test}} \to 0, \quad S_{\text{untest}} \text{ grows}.$$

Hence HAR $\to \infty$. This effectively renders the theory *antirealist*, as it ceases to produce meaningful testable claims.

2. **Results of This Paper**

This section outlines the main results of this paper.

2.1. *Properties of Hyperrealism*

In this subsection, we explore the properties of Hyperrealism and related concepts through several theorems. The theorems are presented below.

Theorem 2.1 (Threshold for Hyperrealism). *Let $\mathcal{T}$ be a physical theory with two disjoint sets of statements: S_{test} (testable) and S_{untest} (untestable). Suppose there exists a constant $\alpha \geq 1$ such that*

$$|S_{\text{untest}}| \ \geq \ \alpha \, |S_{\text{test}}|.$$

Then the Hyperrealism–Antirealism Ratio, defined as

$$\text{HAR}(\mathcal{T}) \ = \ \frac{|S_{\text{untest}}|}{|S_{\text{test}}|},$$

satisfies $\text{HAR}(\mathcal{T}) \geq 1$. *In particular, $\mathcal{T}$ lies in the hyperrealist regime.*

Proof. By definition of $\text{HAR}(\mathcal{T})$,

$$\text{HAR}(\mathcal{T}) = \frac{|S_{\text{untest}}|}{|S_{\text{test}}|} \geq \frac{\alpha \, |S_{\text{test}}|}{|S_{\text{test}}|} = \alpha \ \geq \ 1.$$

Hence $\text{HAR}(\mathcal{T}) \geq 1$, placing $\mathcal{T}$ in at least a *hyperrealist* domain. □

Remark 2.2. This result formalizes the intuition that if untestable statements dominate (or at least match) the testable ones by a constant factor $\alpha \geq 1$, the theory departs from a strictly empirical grounding and enters the hyperrealist regime.

Theorem 2.3 (Antirealist Limit). *Let $\mathcal{T}$ be a physical theory whose testable statements remain bounded in number, i.e. $|S_{\text{test}}| = T_0 < \infty$, while its untestable statements $|S_{\text{untest}}|$ grow unboundedly over successive reformulations or expansions. Then*

$$\lim_{\textit{expansions}} \text{HAR}(\mathcal{T}) \ = \ \lim_{n \to \infty} \frac{|S_{\text{untest}}|(n)}{T_0} \ = \ \infty.$$

Hence, in the limit, $\mathcal{T}$ becomes antirealist.

Proof. Label each expansion or new version of the theory by an index $n \in \mathbb{N}$, and let $U(n) = |S_{\text{untest}}|(n)$ denote the number of untestable statements at stage n. Assume $U(n) \to \infty$ as $n \to \infty$, while $|S_{\text{test}}| = T_0$ remains fixed (or does not grow comparably). Then

$$\text{HAR}(\mathcal{T})(n) \ = \ \frac{U(n)}{T_0} \ \xrightarrow[n \to \infty]{} \ \infty.$$

Thus, as n increases, the Hyperrealism–Antirealism Ratio diverges, implying $\mathcal{T}$ enters the *antirealist* regime. □

Corollary 2.4 (Surfeit of Speculation Implies Antirealism)**.** *If* $|S_{\text{untest}}|$ *grows without bound, while* $|S_{\text{test}}|$ *stays finite or increases more slowly, then eventually*

$$\mathrm{HAR}(\mathcal{T}) \;\to\; \infty,$$

driving the theory into an antirealist *limit.*

Remark 2.5 (Scope and Limitations)**.** Although these measures (ratio definitions and thresholds) offer a convenient way to quantify how far a theory drifts from empirical verifiability, the distinction between "testable" and "untestable" can be somewhat fluid. Future technological or conceptual breakthroughs may convert currently untestable statements into testable ones. Nevertheless, these theorems underscore a key principle: once untestable content becomes overwhelmingly large, the theory effectively detaches from strict empirical foundations and moves toward hyperrealism or even antirealism.

2.2. *Neutrosophic Realism Index*

The Neutrosophic Realism Index is a concept derived from the application of Neutrosophic Logic to the framework of realism. Neutrosophic Logic [8, 11, 37–40] is widely recognized as a generalization of Fuzzy Logic [42] and Intuitionistic Fuzzy Logic [2, 3]. The principles of Neutrosophic Logic have been applied across various fields, including graph theory [9, 12, 13], topology [19, 32], algebra [24, 25], automata [14], and linguistics [10], demonstrating its versatility and broad utility. Below, we present the definition of the Neutrosophic Realism Index, along with relevant theorems and properties.

Definition 2.6 (Neutrosophic Logic)**.** [38] Neutrosophic Logic extends classical logic by assigning to each proposition a truth value comprising three components:

$$v(A) = (T, I, F),$$

where $T, I, F \in [0, 1]$ represent the degrees of truth, indeterminacy, and falsity, respectively.

Example 2.7 (Real-Life Application of Neutrosophic Logic: Weather Forecast)**.** (cf. [1]) Consider a weather forecast predicting that it will rain tomorrow. Using Neutrosophic Logic, this prediction can be expressed as:

$$v(\text{“It will rain tomorrow”}) = (0.7, 0.2, 0.1),$$

where:

- $T = 0.7$: There is a 70% confidence that the statement is true based on meteorological data.

- $I = 0.2$: There is a 20% level of indeterminacy due to factors such as changing weather conditions or measurement uncertainties.
- $F = 0.1$: There is a 10% chance that the statement is false, possibly due to model inaccuracies or unforeseen events.

This representation highlights the nuanced uncertainties involved in real-world predictions, making Neutrosophic Logic suitable for domains like weather forecasting, decision-making, and risk assessment.

Definition 2.8 (Neutrosophic Realism Index)**.** [6] Let each statement $s \in S$ have a triple (T_s, I_s, F_s), where $T_s, I_s, F_s \in [0, 1]$ with $T_s + I_s + F_s \leq 3$. Define the *Neutrosophic Realism Index* (NRI) for the theory as an average:

$$\mathrm{NRI}(\mathcal{T}) \;=\; \frac{1}{|S|} \sum_{s \in S} T_s.$$

Example 2.9 (A Highly Realist Theory)**.** Let $\mathcal{T}_1$ have $|S| = 4$ statements: $S = \{s_1, s_2, s_3, s_4\}$. Suppose each statement has (T_s, I_s, F_s) as follows:

$$s_1 : (0.9, 0.05, 0.05), \quad s_2 : (1.0, 0.0, 0.0), \quad s_3 : (0.85, 0.10, 0.05), \quad s_4 : (0.95, 0.02, 0.03).$$

Then the sum of T_s is $(0.9 + 1.0 + 0.85 + 0.95) = 3.70$. Dividing by $|S| = 4$, we get

$$\mathrm{NRI}(\mathcal{T}_1) = \frac{3.70}{4} = 0.925.$$

Since 0.925 is quite high (close to 1), this theory is *strongly realist* by Theorems 2.12 and 2.14.

Example 2.10 (A Partially Realist Theory)**.** Let $\mathcal{T}_2$ have $|S| = 3$ statements with:

$$s_1 : (0.5, 0.4, 0.1), \quad s_2 : (0.6, 0.2, 0.2), \quad s_3 : (0.4, 0.35, 0.25).$$

The sum of T_s is $(0.5 + 0.6 + 0.4) = 1.5$. Hence

$$\mathrm{NRI}(\mathcal{T}_2) = \frac{1.5}{3} = 0.5.$$

If we define $\alpha = 0.3$ and $\beta = 0.8$ as the thresholds, we see 0.5 falls in the intermediate range $\alpha \leq 0.5 < \beta$. So $\mathcal{T}_2$ is *partially realist*, reflecting moderate truth membership but also significant indeterminacy or falsehood.

Example 2.11 (A Low-NRI (Hyperrealist/Antirealist) Theory)**.** Consider $\mathcal{T}_3$ with $|S| = 3$ statements:

$$s_1 : (0.1, 0.5, 0.4), \quad s_2 : (0.0, 0.4, 0.6), \quad s_3 : (0.05, 0.3, 0.65).$$

The sum of T_s is $(0.1 + 0.0 + 0.05) = 0.15$, so

$$\mathrm{NRI}(\mathcal{T}_3) = \frac{0.15}{3} = 0.05.$$

That is very low, indicating most statements are closer to indeterminate or false than to true. By Theorem 2.12, this places $\mathcal{T}_3$ in the strongly antirealist/hyperrealist domain.

Theorem 2.12 (Realism vs. Indeterminacy). *If NRI($\mathcal{T}$) is very low (close to 0), it indicates minimal average truth membership, which implies strong antireal or hyperreal tendencies. If NRI($\mathcal{T}$) is high (close to 1 or beyond), the theory is strongly realist. Intermediate values of NRI reflect partial realism, acknowledging significant uncertainty (large I_s) or partial falsehood (larger F_s).*

Proof. By Definition,

$$\mathrm{NRI}(\mathcal{T}) = \frac{1}{|S|}\sum_{s\in S} T_s.$$

If NRI($\mathcal{T}$) is near 0, that sum of T_s over all statements must be near 0, indicating that most statements have $T_s \approx 0$. Because $T_s + I_s + F_s \leq 3$, such statements must have either I_s or F_s significant. In neutrosophic logic, large I_s or F_s aligns with hyperrealism/antirealism (the statements are either indeterminate or false from a realist standpoint). Conversely, if NRI($\mathcal{T}$) ≈ 1 or larger, then most statements have T_s close to 1, indicating strong agreement with a realist or "true" stance. Intermediate values of T_s imply partial truth or increased indeterminacy. This direct link to the sum of truth degrees proves the theorem. □

Theorem 2.13 (Bounds on NRI). *For any theory $\mathcal{T}$ with statements $\{s_1, \ldots, s_n\}$ assigned triples (T_s, I_s, F_s) in $[0,1]$, we have:*

$$0 \ \leq \ NRI(\mathcal{T}) \ \leq \ 3,$$

where 3 is an absolute maximum only if $T_s = 3$ is allowed; in practice, typical implementations take $T_s + I_s + F_s = 1$, so $0 \leq \mathrm{NRI}(\mathcal{T}) \leq 1$.

Proof. By definition, $T_s \in [0,1]$ for each statement. If we allow the extended sum $T_s+I_s+F_s \leq 3$, then the maximum T_s for a single statement can be 3. However, in many neutrosophic logic formulations, one confines $T_s + I_s + F_s = 1$. Under that typical constraint, $T_s \leq 1$. Summing n such values and dividing by n yields a maximum of 1 for NRI($\mathcal{T}$). The minimum is clearly 0, achieved if $T_s = 0$ for all s. □

Theorem 2.14 (Thresholds for Classification). *Fix two constants $0 < \alpha < \beta \leq 1$. We may define realism categories based on NRI($\mathcal{T}$):*

- *If NRI($\mathcal{T}$) $< \alpha$, the theory is* antirealist-leaning *or* hyperrealist-leaning.
- *If $\alpha \leq$ NRI($\mathcal{T}$) $< \beta$, the theory is* partially realist *(significant uncertainty or partial falsehood).*
- *If NRI($\mathcal{T}$) $\geq \beta$, the theory is* strongly realist.

Proof. This follows from Theorem 2.12 and the observation that NRI($\mathcal{T}$) can be partitioned into different ranges. Such threshold-based classification is common in fuzzy or neutrosophic logic frameworks, where intervals represent distinct qualitative categories. □

Theorem 2.15 (NRI and Global Consistency)**.** *Assume each statement in S must satisfy $T_s + I_s + F_s = 1$ (a common simplification in neutrosophic frameworks). Then:*

$$NRI(\mathcal{T}) + \frac{1}{|S|}\sum_{s\in S}(I_s + F_s) = 1.$$

Hence

$$NRI(\mathcal{T}) = 1 - \frac{1}{|S|}\sum_{s\in S}(I_s + F_s).$$

Proof. If $T_s + I_s + F_s = 1$ for each s, summing this over all $s \in S$ gives:

$$\sum_{s\in S} T_s + \sum_{s\in S} I_s + \sum_{s\in S} F_s = |S|.$$

Divide both sides by $|S|$:

$$\frac{1}{|S|}\sum_{s\in S} T_s + \frac{1}{|S|}\sum_{s\in S} I_s + \frac{1}{|S|}\sum_{s\in S} F_s = 1.$$

The left term is precisely NRI($\mathcal{T}$), and the other two terms sum to the average $(I_s + F_s)$. So the statement follows. □

Corollary 2.16 (Trade-off of Realism, Indeterminacy, and Falsehood)**.** *Under the same assumption, if NRI($\mathcal{T}$) is high, then $\frac{1}{|S|}\sum_{s\in S}(I_s + F_s)$ must be low, meaning the theory does not rely heavily on indeterminacy or falsehood. Conversely, if NRI($\mathcal{T}$) is low, then $I_s + F_s$ must be high on average, implying an antirealist or hyperrealist stance.*

Proof. Immediate from Theorem 2.15: NRI($\mathcal{T}$) $= 1 - \frac{1}{|S|}\sum_{s\in S}(I_s + F_s)$. If one term is large, the other is correspondingly small. □

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Data Availability

This research is purely theoretical, involving no data collection or analysis. We encourage future researchers to pursue empirical investigations to further develop and validate the concepts introduced here.

Ethical Approval

As this research is entirely theoretical in nature and does not involve human participants or animal subjects, no ethical approval is required.

Conflicts of Interest

The authors confirm that there are no conflicts of interest related to the research or its publication.

Disclaimer

This work presents theoretical concepts that have not yet undergone practical testing or validation. Future researchers are encouraged to apply and assess these ideas in empirical contexts. While every effort has been made to ensure accuracy and appropriate referencing, unintentional errors or omissions may still exist. Readers are advised to verify referenced materials on their own. The views and conclusions expressed here are the authors' own and do not necessarily reflect those of their affiliated organizations.

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