Latency Information Theory:

Novel Lingerdynamics Ectropies are Revealed as Time Duals of Thermodynamics Entropies

Erlan H. Feria
Department of Engineering Science and Physics, The City University of New York/CSI, USA
E Mail: feria@mail.csi.cuny.edu Web Site: http://feria.csi.cuny.edu

Abstract — Lingerdynamics is thermodynamics' time dual that inherently surfaced from latency information theory (LIT), which is itself a nascent universal guidance theory for efficient system designs. This paper reveals two novel lingerdynamics ectropies that are the time duals of two thermodynamics entropies, one of which is also novel. The classical thermodynamics source-entropy (TSE) of information-sources and the novel thermodynamics retainer-entropy (TRE) of information-retainers are thermodynamics', while the lingerdynamics processor-ectropy (LPE) of information-processors and the lingerdynamics mover-ectropy (LME) of information-movers are lingerdynamics'. An important finding of this paper is the discovery that the 2nd law of thermodynamics must be enhanced to state that the universe's two TSE and TRE entropies, not just the TSE, must continuously increase. Another finding is the 2nd law of lingerdynamics that states that the universe's two LPE and LME ectropies continuously increase. Guided by these results a new lifespan LIT duality theory for both living and non-living systems is revealed and the gravitational and electrical forces shown to be emergent TRE entropic forces. Finally LIT leads us to the theory that the universe's unexplained dark-energy and dark-matter can be explained as a motion-vacuum-energy/retention-black-hole-gravity LIT duality.

Keywords — latency-time certainty, information-space uncertainty, mathematical-intelligence, physical-life, communication-channel, observation-sensor, thermodynamics, lingerdynamics, biochemistry

I. INTRODUCTION

Four confirmed physical dimensions rule the universe, one is temporal and the other three are spatial, where the three space dimensions convey the up, side and front directions. While the three space dimensions are used to describe the location of information-space (IS), in the form of mass and/or energy, the time dimension is used to describe the latency-time (LT) associated with the IS communication through space and/or observation across space. Moreover, while LT has a certainty nature due to the observed 'certainty' of the uniform passing of time, IS has an uncertainty nature due to the 'uncertainty' of the communicated configuration of space (expressed as the Heisenberg uncertainty principle for mass and the wave-particle duality for photons). Thus the space-time physical dimensions of the universe are characterized by a certainty/uncertainty duality. There are also four readily identifiable universal types of systems where their efficient use of IS and LT resources is of interest. They are: 1) physical IS movers (such as photons, racing cars and 100 meter human runners) with the moved physical IS communicated through a limited channel (such as the multi-path running tracks of the 100 meter dash), and of main interest is the life-time, or physical LT in SI second units, used by the mover (such as the 10 seconds spent by exceptional humans to run 100 meters); 2) mathematical IS sources (such as a multimedia compressor) with the sourced mathematical IS communicated through a noisy channel (such as a Gaussian additive one), and of main interest is the intelligence space (intel-space in short), or mathematical IS in *b*inary dig*it* (*bit*) units, used by the source (such as the 4 Megabytes of a synthetic aperture radar (SAR) image); 3) physical IS retainers (such as a thermos for hot tea and the human body for its mass where food is digested daily to compensate for any lost energy) with the retained physical IS observed across a noisy sensor (such as the mouth of an unknown hot tea drinker), and of main interest is the life-space, or physical IS in SI m^3 volume units or m^2 surface units, used by the physical IS retainer (such as the surface area of the volume of hot tea retained in a thermal cup); 4) mathematical IS processors (such as the deterministic plants of linear quadratic control and matched processors control [1], the airborne moving target indicator (AMTI) of an adaptive radar system [2] and the full adder [3]) with the processed mathematical IS observed across a limited sensor (such as a two-path sensor whose two limited LT windows are used to observe the two outputs, sum and carry, of the full-adder), and of main interest is the intelligence time (intel-time in short), or mathematical LT in *b*it operat*or* (*bor*) units used by the mathematical IS processor (such as the two *bor* levels of a full-adder whose OR-AND-Invert 'wired logic' implementation is constrained to the use of 2-input gates). Until recently [4] of the four systems mentioned, only mathematical IS sources have had a 'universal' guiding theory for their efficient designs; namely, information theory which with its lower source-entropy and upper channel capacity performance bounds advances highly effective tools for the universal guidance of information system designs [5]. It is thus expected that the discovery of 'universal' guiding theories for the efficient design of physical IS movers, physical IS retainers and mathematical IS processors will also be highly effective in their applications, particularly if they lead to a cross fertilization with classical information theory and the revelation of fundamental connections among them.

A head start in the development of a universal guidance theory for the efficient design of the three remaining types of universe's systems commenced with the launching in 2009 of latency information theory (LIT) [4]. LIT unified five fundamental theories: namely, 1) the classical information theory [5]-[6]; 2) the LT-certainty motion theories of space-time physics [7]; 3) the IS-uncertainty retention theories of space-time physics [8]; 4) the statistical-physics theories of black-holes, ideal-gases and general mediums [9]; and 5) the structural and physical LT-certainty/IS-uncertainty duality theory discovered by the author in 1978 when studying stochastic control problems that led to his Ph.D. in 1981 [10]. The practical relevance of LIT has already been demonstrated with the solution of real-world problems. These problems are found in engineering (such as source compression, control and radar where a powerful and fast ‘knowledge unaided’ LIT inspired radar scheme was revealed recently [11] that emulated the performance of SAR knowledge aided radar [12]), in physics (such as the discovery of the retention dual for the laws of motion in physics [8] that offers a new duality perspective for retention systems [9]) and in thermodynamics with its four universal laws [13] (such as its revealed time dual, named lingerdynamics with also four laws [14]-[15], and the finding of a new thermodynamics retention-entropy (TRE) for information-retainers that is the retention dual of the ‘classical’ thermodynamics source-entropy (TSE) for information-sources).

In this paper two novel ectropies are revealed that are the time-dual of the thermodynamics’ TSE and TRE: namely, the lingerdynamics processor-ectropy (LPE) of information-processors and the lingerdynamics mover-ectropy (LME) of information-movers. An inherent new LIT duality finding is that the 2nd law of thermodynamics statement that the entropy of the universe (or equivalently its TSE) continuously increases must also include the novel TRE. Another duality discovery is its 2nd law of lingerdynamics time dual stating that the LPE and LME of the universe continuously increase. Guided by these findings a lifespan duality theory is revealed for both non-living and living [16] systems. Also gravitational and electrical forces are found to be ‘emergent TRE entropic’ rather than fundamental in nature [17]. Finally LIT leads us to the theory that the universe’s unexplained dark-energy [18] and dark-matter [19] can be explained as a motion-vacuum-energy/retention-black-hole-gravity LIT duality [20], [8].

The paper is organized as follows. In Section II the global characteristics of the LIT duality are summarized. In Section III the thermodynamics entropies and lingerdynamics ectropies of LIT are stated and illustrated with simple examples. In Section IV fundamental bridges between the LIT entropies and ectropies are revealed. In Section V three LIT results are established. The paper ends with conclusions.

II. The LIT Revolution

The main global characteristics of LIT are easily described with the aid of its template which is displayed in Fig. 1. This template has been given the name ‘the LIT revolution’ since it is made of four quadrants, each highlighting a different system design guidance methodology. They are: 1) Quadrant I with its ‘physical latency theory’ advancing guidance schemes for the design of life-time efficient movers of space-communicated information through limited life-time channels; 2) Quadrant II with its classical

Mathematical Intelligence Diag. ↘	Ver. ↓ Information Space (IS) Uncertainty Through Time	Ver. ↓ Latency Time (LT) Certainty Across Space
Hor. → Communication Through Channels	II “Mathematical Information Theory” **Guidance Methodologies** **for the** **Design of Efficient** **Intelligence Space (or Intel-Space) in Bit Units** **Sources** Through Noisy Intel-Space Channels	I “Physical Latency Theory” **Guidance Methodologies** **for the** **Design of Efficient** **Life-Time in SI Sec Units** **Movers** Through Limited Life-Time Channels
Hor. → Observation Across Sensors	III “Physical Information Theory” **Guidance Methodologies** **for the** **Design of Efficient** **Life-Space in SI m^2 Units** **Retainers** Across Noisy Life-Space Sensors	IV “Mathematical Latency Theory” **Guidance Methodologies** **for the** **Design of Efficient** **Intelligence Time (or Intel-Time) in Bor Units** **Processors** Across Limited Intel-Time Sensors
Diag. ↗ Physical Life	**Probability Distributions** **Model *Past* IS-Uncertainties of Systems**	**Constrained Structures** **Model *Future* LT-Certainties of Systems**

Fig. 1 The LIT Revolution Global Characteristics

‘mathematical information theory’ [5] advancing guidance schemes for the design of intel-space efficient sources of time-communicated information through noisy intel-space channels; 3) Quadrant III with its novel ‘physical information theory’ advancing guidance schemes for the design of life-space efficient retainers of time-observed information across noisy life-space sensors; and 4) Quadrant IV with its novel ‘mathematical latency theory’ advancing guidance schemes for the design of intel-time efficient processors of space-observed information across limited intel-time sensors.

The movers and retainers of quadrants I and III are said to be physical-life types since their life-time and life-space are specified using physical units, while the sources and processors of quadrants II and IV are said to be mathematical-intelligence types since their intel-space and intel-time are specified using mathematical units. In addition, while the sources and movers of quadrants II and I are said to be communication-channel types since their intel-space and life-time are communicated through channels, the retainers and processors of quadrants III and IV are said to be observation-sensor types since their life-space and intel-time are observed across sensors. Also, while the sources and retainers of quadrants II and III are said to be IS-uncertainty types since their intel-space and life-space are stated with IS-uncertainty units, the movers and processors of quadrants I and IV are said to be LT-certainty types since their life-time and intel-time are stated with LT-certainty units. Moreover, while the designs of quadrants II and III use probability distributions that model the *past IS-uncertainties* of sources and retainers as well as their channels and sensors, the designs of quadrants I and IV use constrained structures that model the *future LT-certainties* of movers and processors as well as their channels and sensors.

Finally the LIT revolution is noted to be characterized by three major dualities, each having two minor ones for a total of six basic dualities. The three major dualities are: namely, 1) the vertical IS-uncertainty/LT-certainty—or (II,III)/(I,IV)—major duality with its two IS-uncertainty II/III and LT-certainty I/IV minor dualities; 2) the horizontal communication-channel/observation-sensor—or (II,I)/(III,IV)—major duality, with its two communication-channel II/I and observation-sensor III/IV minor dualities; and 3) the diagonal mathematical-intelligence/physical-life—or (II,IV)/(III,I) — major duality, with its two mathematical-intelligence II/IV and physical-life III/I minor dualities. In particular, the mathematical-intelligence II/IV minor duality was first identified by the author in 1978 in Linear Quadratic Gaussian (LQG) control [21], which in turn led him to the revelation of Matched Processors for quantized control ([1], [10]) which is the structural and LT-certainty dual of the IS-uncertainty Matched Filters structures for *bit* detection [22].

III. The Design Guiding Entropies and Ectropies

In this section the LIT revolution's guiding entropies and ectropies for system designs are stated with the aid of Fig. 2. Moreover, their corresponding 2nd law of thermodynamics and 2nd law of lingerdynamics are revealed.

A. The Thermodynamics Source-Entropy and its 2nd Law: Consider the information-source of quadrant II of Fig. 2 which has a random variable output G. This information-source is illustrated with one yielding for G the displayed monochrome image with an expected source-rate R_S of 8 *bits/pixel*. The 8 *bits* of R_S denotes the sourced intel-space amount. One then seeks to determine a replacement for the information-source with a source-coder (encoder/decoder) which is lossless when its output $\hat{\mathbf{G}}$ is the same as G and is lossy otherwise. The rate of this source-coder is the source-encoder rate R_{SE} in *bits/pixel* that is less than or equal to that of the information-source R_S, i.e. $R_{SE} \le R_S$. To guide the design of the source-coder classical 'mathematical information theory' [5] provides the source-entropy with symbol H which is defined as the expected source-information of the information-source. The value of H then sets for us a lower bound for a lossless source-coder design which for the image displayed in Fig. 2 is given by 7.44 *bits/pixel*. Also in Fig. 2 the output of the source-coder is shown for two cases. The first is the $R_{SE}=H=7.44$ *bits/pixel* best lossless case yielding the maximum lossless intel-space compression ratio of $R_S/R_{SE}=1.0753$. The second is the lossy $R_{SE}= 0.1036$ *bits/pixel* $< H$ lossy case yielding the significantly higher intel-space compression ratio of $R_S/R_{SE}=77.2147$ and producing a lossy image that can be satisfactory for some applications [23]. The source-entropy H that guides the source-coder design is then defined as the expected source-information

$$H = E[I_S(g_i)] = \sum_{i=1}^{\Omega} P_S[g_i] I_S(g_i) = \log_2 \hat{\Omega} \ \le \ H_{Max} \tag{1}$$

$$I_S(g_i) = \log_2(1/P_S[g_i]) \tag{2}$$

$$\hat{\Omega} = 2^H \tag{3}$$

where: 1) G $\in \{g_{1,\dots,}g_{\Omega}\}$ is a random variable composed of the Ω outcomes $\{g_{1,\dots,}g_{\Omega}\}$; 2) $P_S[g_i]$ is the source-probability of g_i; 3) $I_S(g_i)$ is the source-information of g_i in mathematical *bit* units; 4) $\hat{\Omega} \le \Omega$ is the number of distinct levels, or effective number of outcomes, that can be specified with the *bits* of the source-entropy H; and 5) $H_{Max}=\log_2\Omega$ is the 'maximum source-entropy' that results when the probabilities of the G outcomes are equally likely.

When used in statistical-physics problems the source-entropy H (1)-(3) will be called the *thermodynamics source-entropy* since it is linked to thermodynamics via the equation

$$H = \log_2 \hat{\Omega} = S/\ln 2k_B \tag{4}$$

where S is the Boltzmann thermodynamics-entropy [24] in SI *J/K* units, k_B is the Boltzmann constant in SI *J/K* units and $\hat{\Omega}$ is the effective number of outcomes or microstates. In statistical-physics a microstate is defined as a particular microscopic configuration of the information-source individual atoms and molecules. In particular, the 2nd law of thermodynamics [13] states that, 'the entropy (or equivalently the H) of a closed system, i.e., a system that does not allow any type of interaction with the outside, is continuously increasing until its thermal energy $E_T=k_BT$, or equivalently the free work energy of Helmholtz and Gibbs [13], is depleted', where E_T is in SI J units and T is the temperature of the closed-system in SI K units. Moreover, since H monotonically increases with $\hat{\Omega}$ it can be said that the closed system (or the *universe* as called in thermodynamics [13]) is continuously evolving from a state of lower to higher number of microstates. Or equivalently, from a state of lower to higher microstate uncertainty since the probability of any microstate (which for our effective model is $P_S[g_i]=1/\hat{\Omega}$ for all i) decreases in value. In this 2nd law scenario H will attain the highest possible value when the microstates are equally likely, i.e., $\hat{\Omega}=\Omega$, and the universe's thermal energy approaches zero, i.e., $E_T \rightarrow 0$, but without quite reaching the zero value because the 3rd law of thermodynamics prevents T from being zero. It should also be noted that the reason why $E_T \rightarrow 0$ is that the 1st law of thermodynamics requires the conservation of the universe's total energy as H increases in value. In this paper the 2nd law of thermodynamics will be renamed the *2nd law of source-thermodynamics* since the closed system or universe is modeled as an information-source, which as noted earlier is one of the four universal types of systems. Moreover, the 2nd law of source-thermodynamics now states that, *"The universe's thermodynamics source-entropy H continuously increases*." Finally the ratio of the H intel-space in *bit* units over the 'time for sourcing' in SI sec units is the information-source's *bit-rate*.

B. The Lingerdynamics Processor-Ectropy and its 2nd Law: Consider the information-processor of quadrant IV of Fig. 2 which has a vector input y and a vector output z. The information-processor is illustrated with a full adder (FA) built with two-input NAND gates that has an input y composed of the added *bits a, b* and the carry-in *bit* c_{in} and generates an output z of two *bits*, i.e., the carry-out *bit* c_{out} and the sum bit s, with a maximum processor-rate R_P of 6 *bors*/[c_{out} s]. The 6 *bors* of R_P denote the processing intel-time levels which is the maximum of the 5 *bors* for c_{out} and the 6 *bors* for s. One then seeks to determine a replacement for the information-processor with a processor-coder which is lossless when its output $\hat{\mathbf{z}}$ is the same as z and is lossy otherwise. The rate of this processor-coder is R_{PC} in *bors*/z units that is less than or equal to that of the information-processor R_P, i.e. $R_{PC} \le R_P$. To guide the design of the processor-coder 'mathematical latency

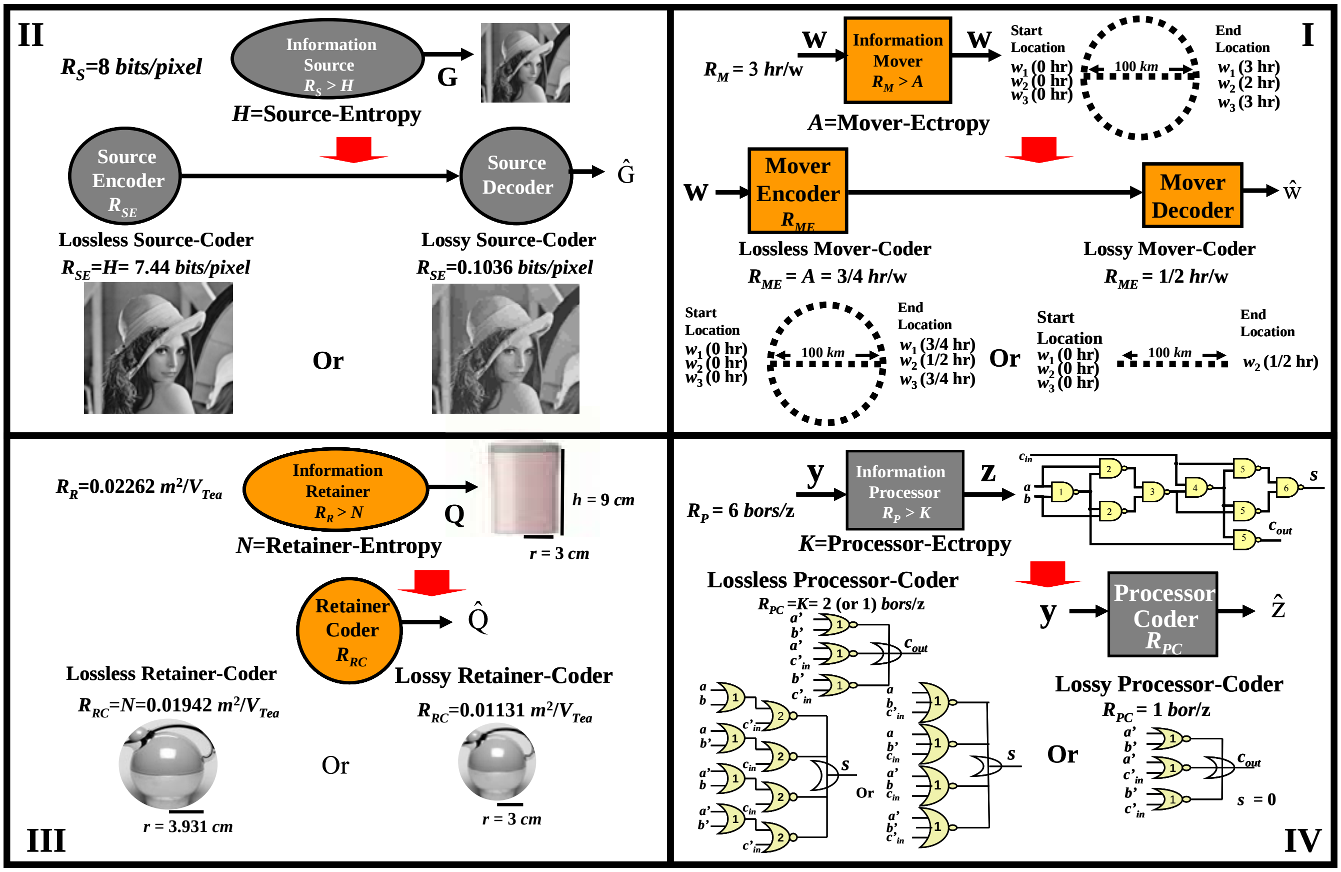

Fig. 2. Illustration of the LIT Revolution's Information Systems and Coders with Simple Examples

theory' provides the processor-ectropy with symbol K which is defined as the minimax processor-latency of the information-processor. The value of K then sets for us a lower bound for a lossless processor-coder design which for the FA displayed in Fig. 2 is given by either 2 or 1 bors/[c_{out} s]. These values were found subject to two different constraints: namely, 1) the FA gates cannot have more than two inputs; and 2) the FA gates can have either 2 or 3 inputs. Three basic assumptions were also made: namely, 1) the Boolean expressions for c_{out} and s are OR-AND-Invert types [3], i.e.,

$$s = \left((a+b+c'_{in})(a+b'+c_{in})(a'+b+c_{in})(a'+b'+c'_{in}) \right)' \quad (5)$$

$$c_{out} = \left((a'+b')(a'+c'_{in})(b'+c'_{in}) \right)'; \quad (6)$$

2) wired logic is used in the implementation of (5)-(6); and 3) the inverted inputs a', b' and c'_{in} are readily available. Also in Fig. 2 the processor-coder is shown for two cases. The first is the R_{PC}=K=2 bors/[c_{out} s] for 2-input gates and R_{PC}=K=1 bor/[$c_{out}s$] for 2 and 3 input gates best lossless cases yielding the maximum lossless intel-time compression ratio of R_P/R_{PC}=3 for 2 input gates and R_P/R_{PC}=6 for 2 and 3 input gates. The second is the R_{PC}=1 bor/[c_{out} s] $\leq K$ lossy case yielding a significantly simpler implementation with an intel-time compression ratio of R_P/R_{PC}=6 and producing a lossy FA that may be satisfactory for some applications. The processor-ectropy K that guides the processor-coder design is then defined as the minimax processor latency

$$K = \max[L_P(z_1),..,L_P(z_n)] = \log_{\hat{C}_P} h(\hat{C}_P) = \sqrt{h(\hat{C}_P)} \;\leq\; K_{Max} \quad (7)$$

$$L_P(z_i) = Ceil[\log_{C_P[z_i]} h(z_i)] \quad (8)$$

$$h(\hat{C}_P) = \hat{C}_P^K = K^2 \quad (9)$$

where: 1) y=[$y_{1,..}y_h$] is the processor input vector composed of the h *bits* {$y_{1,..}y_h$}; 2) z=[$z_{1,..}z_n$] is the processor output vector composed of the n *bits* {$z_{1,..}$ z_n}; 3) the Boolean expressions that relate z to y are OR-AND-Invert types (such as (5) and (6) for a FA) that are implemented using wired logic; 4) $h(z_i) \leq h$ for all i is an integer that denotes the maximum number of literals among the OR factors of the OR-AND-Invert Boolean expression of z_i, e.g., the z_2=c_{out} expression of (6) has $h(z_2 = c_{out}) = 2$ since the maximum number of literals for the OR factors $(a'+b')$, $(a'+c'_{in})$ and $(b'+c'_{in})$ is two, and the z_1= s expression of (5) yields $h(z_1 = s) = h = 3$ using similar arguments; 5) $C_P[z_i]$ for all i is an input-constraint that specifies the maximum number of *bits* that can be operated on (or parallel processed) by a logic gate towards the eventual generation of z_i, e.g., when $C_P[z_i]$=1 only inverters and buffers can be used to generate z_i, while when $C_P[z_i]$ = 3 only gates with 3, 2 and one input can be used; 6) Ceil[*Arg*] is the Matlab function that takes the integer ceiling of the real argument *Arg*; 7) $L_P(z_i)$ is the processor-latency of z_i in mathematical *bor* units (such as the 2 *bors* for s and the 1 *bor* for c_{out} when $C_P[s]$=$C_P[c_{out}]$=2, note from (8) that $L_P(s)$=Ceil[$\log_2 3$]=2 *bors* and $L_P(c_{out})$=Ceil[$\log_2 2$]=1 *bor*); 8)

$h(\hat{C}_P)$ is the 'effective' number of processor input bits and $\hat{C}_P$ is the effective maximum number of gate inputs leading to $h(\hat{C}_P) = \hat{C}_P^K = K^2$ (9) (such as $\hat{C}_P$=2 and $h(2)$=4 when K=2 for the FA of Fig. 2); and 9) K_{Max} is the 'maximum processor-ectropy' that results when the gate input-constraints for all the n *bits* in z are the smallest possible (such the K_{Max}=2 *bors*/[c_{out} *s*] derived when $C_P[s]=C_P[c_{out}]$=2 for the lossless processor-coder of Fig. 2, notice that when $C_P[s]=C_P[c_{out}]$=3 it follows that K=1 *bor*/[c_{out} *s*]<K_{Max}). In particular, when h is large it follows from (7)-(8) that

$$K_{Max} = \lim_{h(z_i)\to h\ \forall i, C_P[z_i]\to C_P\to 1\ \forall i} K|_{h \text{ is large}} = \sqrt{h} \qquad (10)$$

where $h(z_i)$→h for all i (which results when 'product of maxterms' expressions are found for all the outputs [3]) and $C_P[z_i]$→C_P→1 for all i. Moreover, when the number of processor inputs h is the same as the $\boldsymbol{H_{Max}}$ *bits* of an information-source the following bridge is derived from (10)

$$K_{Max} = \sqrt{H_{Max}} \qquad (11)$$

where H_{Max} is a very large number as required by (10).

When used in statistical-physics problems the processor-ectropy K (7)-(9) will be called the *lingerdynamics processor-ectropy* where 'lingerdynamics' is the name given to the time dual of thermodynamics [14]-[15]. The *2nd law of processor-lingerdynamics* can now be stated. This law is an MLT property that is the LT-certainty dual of the IS-uncertainty 2nd law of source-thermodynamics that is an MIT property. The 2nd law of processor-lingerdynamics states that, *"The universe's lingerdynamics processor-ectropy K continuously increases*." Finally the ratio of the K intel-time in *bor* units over the 'one-dimensional space for processing' in SI *m* units is the information-processor's *bor-rate*.

C. The Thermodynamics Retainer-Entropy and its 2nd Law: Consider the information-retainer of quadrant III of Fig. 2 with the random variable output Q**.** This information-retainer is illustrated with one yielding for Q the displayed cylindrical hot-tea thermos with volume V_{Tea} =0.0002545 m^3 and an expected retainer-rate R_R of 0.02262 m^2/V_{Tea}. The 0.02262 m^2 of R_R denotes the retention life-space surface area. One then seeks to determine a replacement for the information-retainer with a retainer-coder which is lossless when its output Q̂ is the same as Q and is lossy otherwise. The rate of this retainer-coder is R_{RC} in m^2/V_{Tea} units that is less than or equal to that of the information-retainer R_R, i.e. $R_{RC} \le R_R$. To guide the design of the retainer-coder 'physical information theory' provides the retainer-entropy with symbol N which is defined as the expected retainer-information of the information-retainer. The value of N then sets for us a lower bound for a lossless retainer-coder design which for the hot-tea thermos of Fig. 2 is given by 0.01942 m^2/V_{Tea}. Also in Fig. 2 the retainer-coder is shown for two cases. The first is the R_{RC}=N best lossless case associated with a spherical hot tea thermos and yielding the maximum lossless life-space compression ratio of R_R/R_{RC}=1.1648. The second is the R_{RC}=0.01131 m^2/V_{Tea} < N lossy case yielding the higher life-space compression ratio of R_R/R_{RC}=2 and producing a lossy hot-tea thermos that may be satisfactory in some applications. The retainer-entropy $\boldsymbol{N}$ that guides the retainer-coder design is then defined as

$$N = E[I_R] = \sum_{i=1}^{\Omega} I_R(q_i) P_R[q_i] = 4\pi \hat{r}^2 \ \le\ N_{Max} \qquad (12)$$

$$I_R(q_i) = 4\pi\, r^2(q_i) \qquad (13)$$

$$r(q_i) = 2GM/v_e^2(q_i) \qquad (14)$$

$$\hat{r} = \sqrt{N/4\pi} \qquad (15)$$

where: 1) Q $\in \{q_{1,\dots,}\ q_\Omega\}$ is a random variable composed of Ω microstates $\{q_{1,\dots,}\ q_\Omega\}$; 2) $P_R[q_i]$ is the retainer-probability of q_i; 3) $r(q_i)$ is the radius of the smallest possible sphere that can retain the volume of q_i; 4) $I_R(q_i)$ for all i is the retainer-information of q_i in physical SI m^2 units; 5) $M=E/c^2$ is the retained mass-energy modeled as a 'point mass-energy' located at the center of the $r(q_i)$ sphere; 6) $v_e(q_i)$ is the escape-speed from the $r(q_i)$ sphere with the point mass-energy $M=E/c^2$ at its center that is given next for three mediums: first

$$v_e(q_i) = c \qquad (16)$$

for all i for a black-hole [9], second

$$v_e(q_i) = \sqrt[6]{2^{7/2} e^{5/2} G^3 / 3\pi^{1/2} J^{5/2} \hbar^3}\ \sqrt[4/3]{M}\left(\sqrt[4]{E_T}/2^{I_S(q_i)/6J}\right) \qquad (17)$$

for all i for a monatomic ideal gas [14]-[15] where J is the number of gas molecules, T is the gas temperature, and E_T and $I_S(q_i)$ are the thermal energy and microstate source-information, respectively, defined by

$$E_T = k_B T\,, \qquad (18)$$

$$I_S(q_i) = \log_2(1/P_R[q_i]) \quad \text{for all } i, \qquad (19)$$

and third and final

$$v_e(q_i) = \sqrt[6]{2^7 \pi^3 G^3 / 135 \ln 2 c^3 \hbar^3}\ \sqrt{M}\left(\sqrt{E_T}/\sqrt[6]{I_S(q_i)}\right) \qquad (20)$$

for all i for a black body photon gas [24] where $M=E/c^2$ is the mass-energy of the medium; 7) $\hat{r}$ is the IS-uncertainty radius of the sphere with surface area N; and 8) N_{Max} is the 'maximum retainer-entropy' that occurs when $P_R[q_i] \to P_R$, thus

$$N_{Max} = \lim_{P_R[q_i]\to P_R\ \forall i} N = \lim_{I_S(q_i)\to H_{Max}\ \forall i} N = 4\pi r^2 \qquad (21)$$

$$r = 2GM/v_e^2 \qquad (22)$$

$$v_e = f(M, E_T, H_{Max}) \qquad (23)$$

where: a) the microstates of the universe's information-retainer are equally likely, i.e., $P_R[q_i] = P_R$ for all i, which in turn results in $I_S(q_i)=H_{Max}$ for all i; b) v_e is the escape-speed from the universe that is a function of the retained mass-energy $M=E/c^2$, the thermal energy $E_T=k_BT$ and H_{Max} (as is noted from (17) and (20) where $I_S(q_i)=H_{Max}$ for all i for the two gas mediums), while for the special case of a black-hole it is the speed of light (16); and c) r is the IS-uncertainty radius of the N_{Max}'s sphere that is inversely proportional to the square of v_e (22). From expressions (21)-(23) and the escape-speed of (17) and (20) with $I_S(q_i)=H_{Max}$, it is noted that as H_{Max} increases then E_T → 0, v_e →0 and r (22) increases, thus resulting in an increased N_{Max} value. This result supports a big-bang creation theory for the universe that starts in a dominant black-hole state with a large v_e value (16) and ends in a dominant vacuum state with a small v_e value as E_T → 0 (20).

When used in statistical-physics problems the retainer-entropy N will be called the *thermodynamics retainer-*

entropy. The 2nd law of retainer-thermodynamics can now be stated. This law is a PIT property that is the observation-sensor dual of the communication-channel 2nd law of source-thermodynamics that is a MIT property. The 2nd law of retainer-thermodynamics states that, "*The universe's thermodynamics retainer-entropy N continuously increases*." The ratio of the 'time for retention' in SI *sec* units over the volume life-space in SI m^3 units is the information-retainer's *pace*. Finally, the ratio of the time for retention over the *N* life-space in SI m^2 units is the information-retainer's *surface-pace*.

D. The Lingerdynamics Mover-Ectropy and its 2nd Law: Consider the information-mover of quadrant I of Fig. 2 which has w as both its vector input and output. The information-mover is illustrated with 'human powered' unicycles that move from one side of a given circular terrain to its other side either along its circumference or diameter. There are three moved individuals represented by the w elements w_1, w_2 and w_3, with a maximum mover-rate R_M of 3 *hrs*/[w_1 w_2 w_3]. The 3 *hrs* of R_M denotes the motion life-time duration which is the maximum of the 3 *hrs* for w_1 and w_3 and the 2 *hrs* for w_2. One then seeks to determine a replacement for the information-mover with a mover-coder (encoder/decoder) which is lossless when its output $\hat{w}$ is the same as w and lossy otherwise. The rate of this mover-coder is the mover-encoder rate R_{ME} in *secs*/w units that is less than or equal to that of the information-mover R_M, i.e. $R_{ME} \le R_M$ To guide the design of the mover-coder 'physical latency theory' provides the mover-ectropy with symbol *A* which is defined as the minimax mover-latency of the information-mover. The value of *A* then sets for us a lower bound for a lossless mover-coder design which for the example displayed in Fig. 2 is given by 3/4 *hrs*/[w_1 w_2 w_3]. This value was found subject to the constraint that the movers are unicycles, thus having the least number of wheels. Also two basic assumptions were made: namely, 1) the movers are either motorized or externally driven in an efficient manner; and 2) from start to finish the translational speed of each mover is kept constant. Also in Fig. 2 the mover-coder is shown for two cases. The first is the R_{ME}=*A* best lossless case yielding the maximum lossless life-time compression ratio of R_M/R_{ME}=4. The second is the R_{ME}=1/2 *hrs*/[w_1 w_2 w_3] < *A* lossy case yielding the higher life-time compression ratio of R_M/R_{ME}=6 and producing the movement of just one individual that may be satisfactory in some applications. The mover-ectropy *A* that guides the mover-coder design is then defined as the minimax mover latency

$$A = \max[L_M(w_1),..,L_M(w_N)] = \pi r/\hat{v}_t \quad \le A_{Max} \tag{24}$$

$$L_M(w_i) = d(w_i)/v(w_i) = \pi\, r / v_t(w_i) \tag{25}$$

$$v_t(w_i) = \sqrt{G\,M/r(w_i)} \tag{26}$$

$$\hat{v}_t = \pi r/A \tag{27}$$

$$M = r\, \hat{v}_t^2/G \tag{28}$$

where: 1) w=[$w_{1,..,}w_n$] is a vector composed of *n* elements {$w_{1,..,}w_n$}; 2) $L_M(w_i)$ for all *i* is the mover latency of w_i in physical SI *sec* units (such as the mover latencies of $L_M(w_1)$=$L_M(w_3)$=¾ *hrs* and $L_M(w_2)$=½ *hr* of Fig. 2 leading to *A*=3/4 *hr*); 3) $d(w_i)$ for all *i* denotes the distance traveled by w_i (such as the distances $d(w_1)$=$d(w_3)$=50π *km* and $d(w_2)$=100 *km* of Fig. 2); 4) $v(w_i)$ for all *i* denotes the constant speed of w_i (such as the mover speeds $v(w_1)$=$v(w_3)$=50π/(3/4)=200π/3 *km/hr* and $v(w_2)$= 100/(1/2)=200 *km/hr* for Fig. 2).

The other variables in (24)-(28) relate to statistical-physics applications where a point mass-energy $M=E/c^2$ is at the center of a sphere of radius *r* (such as *r* =50 *km* when the circle of Fig. 2 is part of this sphere), exerting a gravitational pull on w_i, inclusive of its mover, for all *i*. In particular: 1) w_i is at the pseudo radial distance $r(w_i) \le r$ in perpetual, i.e. no energy used, circular motion since moving at the tangential speed of $v_t(w_i)$ (26); 2) π *r* is one half of the sphere circumference; 3) $v_t(w_i)$ is found from (25) with $v_t(w_1)$=$v_t(w_3)$=200π/3 *km/hr* and $v_t(w_2)$=100π *km/hr* for the Fig. 2 case; 4) $\hat{v}_t$ is the v_t value on the sphere-surface and is 200π/3 *km/hr* for the Fig. 2 case; 5) *M* is 2.54 x 10^{15} *kg* for the Fig. 2 case; 6) $r(w_i)$ for all *i* is found from (26) and yields $r(w_1)$=$r(w_3)$=50 *km* and $r(w_2)$=22.22 *km* for the Fig. 2 case; and 7) A_{Max} is the 'maximum mover-ectropy' that results when $r(w_i)$=*r* for all *i* and gives rise to the square root bridge

$$A_{Max} = \pi\, r/v_t = \sqrt{\pi N_{Max}/4v_t^2} \tag{29}$$

$$v_t = v_e/\sqrt{2} = \sqrt{GM/r} \tag{30}$$

$$v_e = \sqrt{2G\,M/r} \tag{31}$$

where: a) N_{Max} is defined by (21); b) v_e is the escape-speed from a sphere of radius *r*; and c) v_t is the tangential speed of any of the objects in w that are now in perpetual circular motion on the surface of the sphere since $r(w_i)$=*r* for all *i*.

When used in statistical-physics problems the mover-ectropy *A* will be called the *lingerdynamics mover-ectropy*. The 2nd law of mover-lingerdynamics can now be stated. This law is a PLT property that is the LT-certainty dual of the IS-uncertainty 2nd law of retainer-thermodynamics that is a PIT property. The 2nd law of mover-lingerdynamics states that, *"The universe's lingerdynamics mover-ectropy A continuously increases*". Finally the ratio of the 'space for motion' in SI *m* units over the *A* life-time in SI *sec* units is the information-mover's speed.

IV. The Entropy and Ectropy Bridges

In this section bridges between entropies and ectropies are stated for general, black-hole and ideal-gas mediums.

A. General Bridges: The general mathematical-intelligence bridge (11) and the physical-life bridge (29) are next given in quadratic form. They are: 1) the mathematical-intelligence

$$H_{Max} = K_{Max}^2 \tag{32}$$

quadratic bridge from K_{Max} to H_{Max}; and 2) the physical-life

$$N_{Max} = 4v_t^2 A_{Max}^2/\pi \tag{33}$$

quadratic bridge from A_{Max} to N_{Max} with v_t given by (30).

B. Black-Hole Bridges: The thermodynamics-entropy for a 'spherical' uncharged nonrotating black-hole (*BH*) is [9]

$$S_{BH} = k_B c^3 Y_{BH}/4\hbar G \tag{34}$$

where $Y_{BH} = N_{Max}^{BH}$ is its surface area (or retainer-entropy) and $\hbar$ is the reduced Plank constant. Making use of $v_t = v_e/\sqrt{2} = c/\sqrt{2}$, (4) and (32)-(34) it follows that

$$H_{Max}^{BH} = N_{Max}^{BH}/N_{Max}^{Bit} = \tau_{BH}/\tau_{BH}^{Bit} \tag{35}$$
$$= (M_{BH}/M_{BH}^{Bor})^2 = (A_{Max}^{BH}/A_{Max}^{Bor})^2 = (K_{Max}^{BH})^2$$

$$N_{Max}^{BH} = 4\pi\, r_{BH}^2 = 4\pi\left(2GM_{BH}/c^2\right)^2 \tag{36}$$

$$N_{Max}^{Bit} = 4\pi(r_{BH}^{Bit})^2 = 4\pi\left(2GM_{BH}^{Bit}/c^2\right)^2 = 1920\ln 2/c\chi \tag{37}$$

$$A_{Max}^{BH} = \sqrt{\pi N_{Max}^{BH}/2c^2} \tag{38}$$

$$A_{Max}^{Bor} = \sqrt{\pi N_{Max}^{Bit}/2c^2} \tag{39}$$

$$\tau_{BH} = \chi V_{BH} = \chi N_{Max}^{BH} r_{BH}/3 \tag{40}$$

$$\tau_{BH}^{Bit} = \chi \Delta V_{BH} = \chi N_{Max}^{Bit} r_{BH}/3 = 640\ln 2 r_{BH}/c \tag{41}$$

$$\chi = 480c^2/\hbar G = 6.1123 \text{ x } 10^{63} \quad \sec/m^3 \tag{42}$$

where: 1) equation (35) is the BH bridge; 2) r_{BH}, V_{BH} and M_{BH} are the radius, volume and point mass-energy of the spherical BH; 3) χ is the pace of dark of the uncharged nonrotating BH [8] that is the space dual of the speed of light in a vacuum c; 4) N_{Max}^{BH}, A_{Max}^{BH} and τ_{BH} are the BH's N_{Max}, A_{Max} and lifespan; 5) N_{Max}^{Bit}, A_{Max}^{Bor} and τ_{BH}^{Bit} are the N_{Max}, A_{Max} and lifespan of activity (or motion) of the bit BH point mass-energy M_{BH}^{Bit}; 6) r_{BH}^{Bit} is the radius of the bit N_{Max}^{Bit}'s sphere; and 7) ΔV_{BH} is the incremental BH volume released from retention for M_{BH}^{Bit} activity during τ_{BH}^{Bit}.

C. Ideal-Gas Bridges: The thermodynamics-entropy for an ideal-gas (IG) is given by [14]-[15]

$$S_{BH} = k_B J\left(\ln(V_{IG}T^{c_V}/JB) + c_P\right), \tag{43}$$

$$B = T^{3/2}X^3/g, \tag{44}$$

$$X = \hbar/\sqrt{mk_BT/2\pi} \tag{45}$$

where c_V and c_P are the dimensionless volume and pressure heat capacity constants, respectively, J is the number of gas molecules, $\boldsymbol{V_{IG}}$ is the gas volume, T is the gas temperature, B is an undetermined gas constant with the SI units of $V_{IG}T^{c_V}$, $\hbar$ is the reduced Plank constant, X is the thermal de Broglie wavelength, and g is the microstate degeneracy of appropriate SI units, with g=1 for a monatomic gas. Making use of $v_t = v_e/\sqrt{2}$, (4), (32), (33) and (43)-(45) it follows that

$$H_{Max}^{IG} = J\log_2\left(N_{Max}^{IG}/\Delta N_{Max} = \tau_{IG}/\Delta\tau_{IG}\right. \tag{46}$$
$$= (M_{IG}/\Delta M_{IG})^2 = (A_{Max}^{IG}/\Delta A_{Max})^2\big) = (K_{Max}^{IG})^2$$

$$N_{Max}^{IG} = 4\pi\, r_{IG}^2 = 4\pi\left(2GM_{IG}/v_e^2\right)^2 \tag{47}$$

$$\Delta N_{Max} = 4\pi\Delta\, r_{IG}^2 = 4\pi\left(2G\Delta M_{IG}/v_e^2\right)^2 = 3\alpha/v_e\Pi \tag{48}$$

$$A_{Max}^{IG} = \sqrt{\pi N_{Max}^{IG}/2v_e^2} \tag{49}$$

$$\Delta A_{Max} = \sqrt{\pi\Delta N_{Max}/2v_e^2} \tag{50}$$

$$\tau_{IG} = \Pi V_{IG} \tag{51}$$

$$\Delta\tau_{IG} = \Pi\Delta V_{IG} = \Pi\Delta N_{Max} r_{IG}/3 = \alpha\, r_{IG}/v_e \tag{52}$$

$$v_e = \sqrt{2GM_{IG}/r_{IG}} \tag{53}$$

$$\Delta M_{IG} = \sqrt{3\pi^{3/2}\hbar^3/16\pi G^3\sigma(eM_{IG}/J)^{5/2}E_T^{3/2}}\; v_e^3 \tag{54}$$

$$\sigma = ge^{c_P-5/2}T^{c_V-3/2} \tag{55}$$

$$\alpha = 4\pi\left(2G\Delta M_{IG}\right)^2\Pi/3v_e^3 \tag{56}$$

where: 1) equation (46) is the IG bridge; 2) r_{IG}, V_{IG} and M_{IG} are the radius, volume and point mass-energy of a spherical IG; 3) Π is the IG pace and v_e is the escape speed from the IG; 4) N_{Max}^{IG}, A_{Max}^{IG} and τ_{IG} are the IG's N_{Max}, A_{Max} and lifespan; 5) ΔN_{Max}, ΔA_{Max} and $\Delta\tau_{IG}$ are the N_{Max}, A_{Max} and lifespan of activity of the incremental IG point mass-energy ΔM_{IG}; 6) $\Delta\tau_{IG}$ is the radius of the incremental ΔN_{Max}'s sphere; 7) ΔV_{IG} is the incremental IG volume released from retention for ΔM_{IG} activity during $\Delta\tau_{IG}$; 8) E_T=k_BT is the thermal energy of the gas; and 9) σ and α are dimensionless constants.

D. Further General Bridges. A comparison of the black-hole bridge (35) and the ideal-gas bridge (46) reveals the following

$$N_{Max}/\Delta N_{Max} = \tau/\Delta\tau = (M/\Delta M)^2 = (A_{Max}/\Delta A_{Max})^2 \tag{57}$$

physical-life bridge that appears to apply to general mediums.

V. Three LIT Duality Applications

A. On lifespan duality theories. In [14] and [15] some of the previously discussed physical-life LIT bridges have been successfully applied to lifespan studies [16]. In particular,

$$\tau/\Delta\tau = (M/\Delta M)^2 \tag{58}$$

can be used to make lifespan predictions for humans where τ is the average *future* healthy life-time of an 18 year old human whose growth has just ended, M is the human's mass, and ΔM is the mass of the digested food during the time duration $\Delta\tau$ (such as the 86,400 seconds for a single day). For instance, when M=70 *kgs* and ΔM=0.4 *kgs* (or 2,000 *kcal/day*) an average future healthy life-time of τ=83.9 years is predicted, for a lifespan for the 18 years old of 101.9 years, which is reasonable since the maximum lifespan for humans is over 120 years [14]. Another physical-life bridge of interest is

$$A_{Max}/\Delta A_{Max} = \sqrt{\tau/\Delta\tau} \tag{59}$$

that relates the square root of the human age τ per *sensed* $\Delta\tau$ to the processing mover-ectropy ratio $A_{Max}/\Delta A_{Max}$, which may lead to a satisfactory explanation as to why any sensed $\Delta\tau$ appears to pass faster as we age, i.e., as τ increases [25].

B. On the origin of gravity and other forces. Recently it has been prominently reported that the origin of the gravitational force is emergent entropic [17], thus its previous 'fundamental in nature' status has been seriously challenged. This entropic origin is inherently supported by LIT via an IS-uncertainty TRE (or $\boldsymbol{N}$) based derivation, which can be further extended to other forces previously identified as being fundamental in nature. In this $\boldsymbol{N}$-based derivation it is first noted that for both the Newton gravitational force

$$F_G^{LTC} = GM_1M_2/r_{LTC}^2 \tag{60}$$

and the Coulomb electrical force

$$F_E^{LTC} = k_EQ_1Q_2/r_{LTC}^2 \tag{61}$$

where M_1 and M_2 are two different point mass-energies, k_E is the Coulomb constant, and Q_1 and Q_2 are two different point charges, the space distance r_{LTC} between the mass-energies and the charges is non-emergent LT-certainty (*LTC*) rather than emergent IS-uncertainty (*ISU*) as a space variable should be. Second and last, the ***N***-emergent IS-uncertainty $\hat{r}$ of (15) substitutes r_{LTC} in (60)-(61) to yield the gravitational and electrical emergent entropic forces given by

$$F_G^{ISU} = 4\pi G M_1 M_2 / N \quad (62)$$

$$F_E^{ISU} = 4\pi k_E Q_1 Q_2 / N\,. \quad (63)$$

These results further suggest that entropic definitions can also be derived for the electromagnetic, weak and strong forces.

C. On the creation and evolution of the universe. The LIT revolution presents vacuums and black-holes as dual mediums that offer the least resistance to the motion and the retention of mass-energy, respectively, with the maximum speed of light *c* found in a vacuum and the maximum pace of dark χ in a black-hole [8]. Moreover, while in the theoretical side retention-black-hole space-evolutions were revealed in [8] as the space dual of motion-vacuum time-evolutions (or dynamics), in the practical side supermassive black-holes have been observed to have a significant gravitational impact on the space-time evolution of the galaxies [20]. It is thus possible that the dark-matter in physics that enables the universe's galaxies to be tightly bound (or retained) and whose hypothesized particles remain undetected [19], may just be a *retention-black-hole-gravity effect*, while the dark-energy in physics that enables the universe's expansion (or motion), inclusive of its big bang, may just be a *motion-vacuum-energy effect* as noted in [18]. Consequently, the theory is advanced that a motion-vacuum-energy/retention-black-hole-gravity LIT duality is the catalyst and glue of the universe's creation and evolution through time and across space.

VI. Conclusions

In this paper latency-information theory or LIT guided us to the discovery of the processor-ectropy and mover-ectropy of lingerdynamics that are the time duals of the source-entropy and retainer-entropy, also novel, of thermodynamics. The classical 2nd law of thermodynamics was further enhanced and now states that the universe's two entropies, rather than just one, continuously increase. Moreover, its time dual, i.e., the 2nd law of lingerdynamics, has been revealed and states that the universe's two ectropies also continuously increase. In addition, discovered ectropy-entropy bridges for different physical mediums led us to the discovery of a lifespan duality theory that when applied to humans predict a lifespan that is reasonable. Also, IS-uncertainty retainer-entropy based gravitational and electrical force derivations were advanced that presented these forces as emergent entropic rather than fundamental in nature. These results further suggest that entropic definitions can also be derived for the electromagnetic, weak and strong forces. LIT also led us to the theory that the universe's unexplained dark-energy and dark-matter can be explained as a motion-vacuum-energy/retention-black-hole-gravity LIT duality. A final note is that LIT has unveiled a powerful duality language for the efficient communication and observation of scientific ideas, whose strength resides in its roots being firmly anchored on information theory, statistical-physics and the structural and physical LT-certainty/IS-uncertainty dualities of space-time.

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