On the Universe's Cybernetics Duality Behavior

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Abstract. Universal cybernetics is the study of control and communications in living and non-living systems. In this paper the universal cybernetics duality principle (UCDP), first identified in control theory in 1978 and expressing a cybernetic duality behavior for our universe, is reviewed. The review is given on the heels of major prizes given to physicists for their use of mathematical-dualities in solving intractable problems in physics such as those of cosmology's 'dark energy', an area that according to a recent New York Times article has become "a cottage industry in physics today". These dualities are not unlike those of our UCDP, further enhanced with physical-dualities. For instance, in 2008 the UCDP guided us to the derivation of *the laws of retention in physics*, dealing with dark energy physics (which is responsible for the observed volume increase of our Universe as it ages) as the space-penalty dual of the laws of motion in physics. The UCDP has also guided us to the derivation of significant results in other fields such as: 1) in *matched processors quantized control* that has applications in the modeling of the central-nervous-system (CNS) mechanisms that control movements; 2) in radar designs where the discovery of *latency theory*, the time-penalty dual of information-theory, has led us to high-performance radar solutions that evade the use of 'big data' in the form of SAR imagery of the earth; and 3) in the unveiling of biological lifespan bounds where the life-expectancy of an adult organism is sensibly predicted through *lingerdynamics*, the discovered time-penalty dual of thermodynamics, which relates adult lifespan to either: 1) the ratio of body size to nutritional consumption rate (NCR); or 2) the specific heat-capacity of the adult organism; or 3) the ratio of NCR energy to an entropic volume energy, a type of 'dark energy' responsible for the decreased mass density exhibited by an organism as it ages.

Keywords: Dark energy, big data, laws of retention, matched processors, latency theory, lingerdynamics, CNS, radar, lifespan, universe, cybernetics, duality, principle, biophysical chemistry

1. INTRODUCTION

Control and communication issues of living and nonliving systems are studied in cybernetics [1]. Its applications are thus widespread since efficient as well as affordable systems are inherently arrived at via sensible control and communication system designs. A major problem in cybernetics is the identification of basic rules leading to these systems. Among these basic rules one finds the universal cybernetics duality principle (or UCDP), first identified in 1978 [2] in control theory [3], with contributions in: 1) dark energy studies in cosmology [4] via its novel laws of retention in physics [5]; 2) the modeling of the central nervous system (CNS) mechanics [6] via its novel Matched Processors for quantized control [7]; 3) the addressing of big data issues of knowledge aided high-performance radar [8]-[12] via its novel latency-information theory; and 4) the derivation of sensible lifespan bound for adult organisms [13] via its novel linger-thermo theory [14]. In this paper a brief review will be given of the main theoretical as well as practical results derived through the UCDP with references often made to earlier publications. The UCDP in then applied to lifespan bounds for adult organisms where several new results are presented in this paper, including the connection of these lifespan bounds to dark energy studies in physics [15].

The UCDP is simply stated as, "synergistic physical and mathematical dualities naturally arise in efficient system designs." This statement is interestingly consistent with a late 2014 New York Times article [16] which 'prominently' notes, as part of a report on major prizes given to scientists, that the use of *mathematical dualities* has become, *"a cottage industry in physics today."* This is noted to be the case since they allow physicists to study intractable physics problems such as those of the dark energy that drives the expansion of our Universe, *where this dark energy is noted to result in an increase of the volume and thus a decrease in the mass-energy density of the Universe as it ages*. In this paper it will be seen that lifespan bounds for adult organisms can also be expressed v*ia a novel UCDP based thermodynamics entropy study of flexible-phase mediums* (such as liquid water at a temperature of 310 K) [14] in terms of a decrease in their mass density as they age. In this way UCDP entropic

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forces are unveiled as the source of our mass density decrease as we age, *thus establishing them as a dark energy source that naturally extends to cosmological studies of an aging Universe.*

On the other hand, examples of *physical dualities* can be found among the physical entities of motion and retention problems where one notes, for instance, that a vacuum and a black hole form together a physical motion/retention dual in the sense that a vacuum may be viewed as a 'light' medium that exhibits the least resistance to motion, while a black hole may be viewed as a 'dark' medium that exhibits the least resistance to retention. Similarly, certainty and uncertainty space-time assumptions form a motion/retention dual in the sense that a certainty assumption is used in the derivation of the laws of motion started by Newton [17], while an uncertainty assumption, modeled probabilistically, is used in the derivation of the laws of retention [5].

Examples of *mathematical dualities* are also found among the mathematical entities of motion and retention problems where one notes, for instance, that speed and pace form a mathematical motion/retention dual in the sense that in both cases *the ratio* of two physical quantities define them. In the case of speed it is the ratio of a space-dislocation over a time-penalty, while in the case of pace it is the ratio of a time-dislocation (or time duration of some knowledge) over a space-penalty (or storage space).

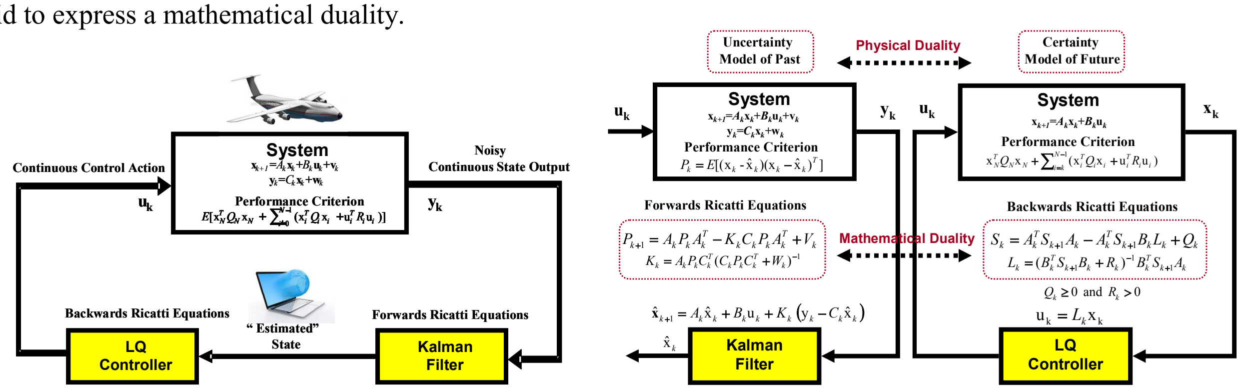
In particular, the UCDP has led us to the discovery of physical and mathematical duals for important scientific theories, such as: 1) *the laws of motion in physics* (used in the study of the space-dislocation of mass-energy, that in turn suffers a *present to future time-penalty* with the efficiency of the motion measured by the mass-energy's speed, with symbol v, and defined as the ratio of space-dislocation with symbol s, in SI meter units, to time-penalty with symbol D, in SI sec units, thus $v=s/D$); 2) *information-theory* [18] (used in the study of *past to present time-dislocations* of information in information-sources and information-retainers, that in turn suffer a space-penalty that is measured by two different *stationary metrics*: namely, the mathematical Shannon's info-source entropy with symbol H, in info-bit units, and a novel [19] physical info-retainer entropy with symbol N, in info-surface-area m^2 units); and 3) *thermodynamics* [20] [21] (used in the study of *past to present time-dislocations* of temperature in thermal-sources and thermal-retainers, that in turn suffer a space-penalty that is measured by two different *dynamic metrics*: namely, the mathematical Boltzmann's thermal-source entropy with symbol $\hat{H}$, in thermo-bit units, and the novel [19] [22] physical thermal-retainer entropy with symbol $\hat{N}$, in thermo-surface-area m^2 units, which is equal to the surface area of a spherical medium given by $\hat{N} = 4\pi r^2$ where r is the radius of the sphere whose mass is modeled as a point-mass M residing at its center). The thermal-sources and thermal-retainers are said to be dynamic in the sense that their $\hat{H}$ and $\hat{N}$ measures, respectively, continuously increase with the passing of time. This notion is supported by two observations. The first is the 2nd law of thermodynamics that states that the Boltzmann entropy S in J/K units continuously increases with time and thus implies the same for $\hat{H}$ since $\hat{H}=S/k\ln 2=\log_2\Omega$ where k is the Boltzmann constant in J/K units and Ω is the total number of possible medium microstates (a microstate is a microscopic configuration of a thermodynamic system that the system may occupy with a certain probability in the course of its thermal fluctuations). The second are cosmological observations like the *cosmic microwave black-body background radiation* that supports the Big Bang theory [23] that our Universe started in a highly dense state and then expanded which is consistent with $\hat{N}$ continuously increasing.

The duality scientific theories that have been discovered through the UCDP for the laws of retention, information theory and thermodynamics are respectively: 1) *the laws of retention in physics* [5] (used in the study of the *past to present time-dislocation of mater-viscidity*, the retention dual of mass-energy in motion, that in turn suffers a space-penalty with the efficiency of the retention measured by the mater-viscidity's pace, with symbol Π, and defined as the ratio of time-dislocation with symbol τ, in SI sec units, to space-penalty with symbol V, in SI m^3 units, thus $\Pi=\tau/V$, where viscidity has *Pa.sec* viscosity units and mater has $kg.m^5/sec^3$ units are the retention duals of energy and mass, respectively); 2) *latency-theory* (used in the study of the space-dislocation of information by latency-processors and latency-movers, that in turn suffer a present to future time-penalty that is measured by two different novel [19] *stationary* metrics: namely, the mathematical latency-processor ectropy with symbol K, in lat-bor units—bor stands for binary operator or gate and the number of them denotes the number of gate delays from input to output of the processor—and the physical latency-mover ectropy with symbol A, in lat-sec units, where ectropy is the time dual of entropy); and 3) *lingerdynamics* (used in the study of the space-dislocation of temperature by linger-processors and linger-movers, that in turn suffer a present to future time-penalty that is measured by two different novel [19], [22] *dynamic* metrics: namely, the mathematical linger-processor ectropy with symbol $\hat{K}$, in linger-bor units, and the physical linger-mover ectropy with symbol $\hat{A}$, in linger-sec units, given by $\hat{A} = \pi r / v$ and denoting half the period of perpetual circular rotation on a spherical medium of r radius where v is the speed of circular motion at a distance r from the center of the sphere whose mass is modeled as a point-mass M residing at its center). The linger-processors and linger-movers are said to be dynamic in the sense that their respective $\hat{K}$ and $\hat{A}$ measures continuously increase with the passing of time. This dynamic behavior is supported by theoretical studies that have revealed basic relationships between $\hat{K}$ and $\hat{H}$, and $\hat{A}$ and $\hat{N}$. The first is the quadratic relationship $\hat{K}^2 = \hat{H}$ which implies that as the thermo-source entropy $\hat{H}$ increases with time so does the linger-processor ectropy $\hat{K}$. The second is $\hat{A}^2 = \pi \hat{N} r / 4GM = 3\pi V / 4GM$ which implies that as the thermo-retainer entropy $\hat{N}$, or equivalently the spherical volume V of the medium, increases with time so does the linger-mover ectropy $\hat{A}$.

Using the aforementioned duality definitions as background material our review of the UCDP will be presented as follows. In Section 2 the identification of the UCDP in Kalman's Linear Quadratic Gaussian (LQG) for 'continuous' control is presented. In Section 3 the Matched Processors methodology for 'quantized' control is noted. In Section 4 the laws of retention dual for a selection of the laws of motion in physics are reviewed. In Section 5 latency-information theory, including latency theory and information theory, is reviewed which is the basis of a novel high-performance radar scheme named power-centroid radar. This scheme is discussed in [8]-[12] with its development starting with funding from DARPA's 2001-2005 KASSPER program. In Section 6 linger-thermo theory, including lingerdynamics and thermodynamics is applied to the derivation of biological lifespan bounds. Finally in Section 7 a summary is given of the UCDP and conclusions are drawn.

2. LINEAR QUADRATIC GAUSSIAN CONTROL

The UCDP has roots in Kalman's linear quadratic Gaussian (LQG) control [3]. The principle was first identified in 1978 as part of graduate studies in three fields; namely, optimum control [2], cybernetics [1] (where a mathematical model for the CNS mechanisms that control movements was being sought [7]), and digital communications [24]. The global structure of the LQG control scheme is described in Fig. 1(a) with the controlled system receiving a control action u_k from the controller whose magnitude is continuous, and could be applied in either a discrete or continuous time fashion. The output of the system y_k is a noisy state where the state x_k may describe, for instance, the position of an aircraft or some runner. LQG control yields a strictly optimum controller that consists of a Kalman filter followed by a linear quadratic (LQ) controller that receives the estimated state of the system from the Kalman filter and then uses it to generate a control action. In the Kalman filter case a vector gain K_k, where k is the present stage, must be designed using Ricatti equations that are solved forwards in time, while in the case of the LQ controller a vector gain L_k must also be designed using Ricatti equations but that are now solved backwards in time. The similar structures of the backwards/forwards solved Ricatti equations can be said to express a mathematical duality.



(a) (b)

Fig. 1 (a) Stochastic LQG Control System. (b) Separated Uncertainty/Certainty Design.

In Fig. 1(a) the discrete time system case is shown where A_k, B_k, and C_k are deterministic system matrices whose dimensions depend on the state x_k, control u_k and output y_k vector dimensions, and where v_k and w_k are Gaussian white-noise processes with covariances V_k and W_k, respectively. Moreover, a stochastic performance criterion is minimized that is a quadratic function of both the future state and control, see Fig. 1(a) where Q_i and R_i are weighting matrices on the state and control to go, respectively.

The LQG controller design is further characterized by an enabling physical uncertainty/certainty separation property that can be described with the aid of Fig. 1(b). First, it is noted that the Kalman filter can be designed independently of the LQ controller. More specifically this is done by using a stochastic model for the past system behavior, with its future behavior not impacting the result. The performance criterion minimized in this case is the expected quadratic state error $E[(\mathrm{x}_k - \hat{\mathrm{x}}_k)(\mathrm{x}_k - \hat{\mathrm{x}}_k)^T]$ where $\hat{\mathrm{x}}_k$ is the state estimate found through the forwards solution of the Ricatti equations for the gain K_k of the state estimator $\hat{\mathbf{x}}_{k+1} = A_k\hat{\mathrm{x}}_k + B_k\mathrm{u}_k + K_k\left(\mathrm{y}_k - C_k\hat{\mathrm{x}}_k\right)$ shown in Fig. 1(b). Second, it is noted that the LQ controller can be designed independently of the Kalman filter, but now assuming a deterministic future system behavior while ignoring its past behavior. The performance criterion that is now minimized is the deterministic cost to go $\mathrm{x}_N^T Q_N \mathrm{x}_N + \sum_{i=k}^{N-1}(\mathrm{x}_i^T Q_i \mathrm{x}_i + \mathrm{u}_i^T R_i \mathrm{u}_i)$ with the present control u_k found through the backwards solution of the Ricatti equations also shown in Fig. 1(b). This past-uncertainty/future-certainty separation in the controller design can be said to express a *physical uncertainty/certainty duality*, highlighted in Fig. 1(b), that when used in the design process yields an optimum solution only under the LQG assumptions [3]—Fig. 1(b) also highlights the mathematical duality identified earlier in the forwards/backwards Ricatti equations gain solutions. When used in controller design this most convenient uncertainty/certainty design separation is however subject to the caveat that from a strictly mathematical perspective it only yields an optimum result for the LQG case. As a result, in real-world applications where the systems are always nonlinear and the interference and noise are not Gaussian one truly finds a *mathematically intractable problem for the controller design*. This type of intractability is not unlike the mathematically intractable problems encountered by physicists [16] while dealing with either dark-energy (like in a black hole) or light-energy (like in a vacuum) problems.

3. STOCHASTIC MATCHED PROCESSORS CONTROL

In the 1970s when microprocessors first became available for system control [25] and there was also great interest in the derivation of mathematical models for the CNS [26], the identified separations or equivalently the 'physical as well as mathematical' dualities in LQG control were first applied to quantized control [2].

The input to the discrete time controlled system was now a quantized control action, e.g., the on-off values of a relay controller, while the system output was a noisy quantized state. The controller then consisted of a matched filters subsystem for quantized state detections followed by a matched processors subsystem for quantized control decisions. While each matched filter was, for instance, matched to a past sequence of high and low state values, a matched processor was, for instance, matched to a unique sequence of on and off (or zero) values over a finite number of future control decisions or steps.

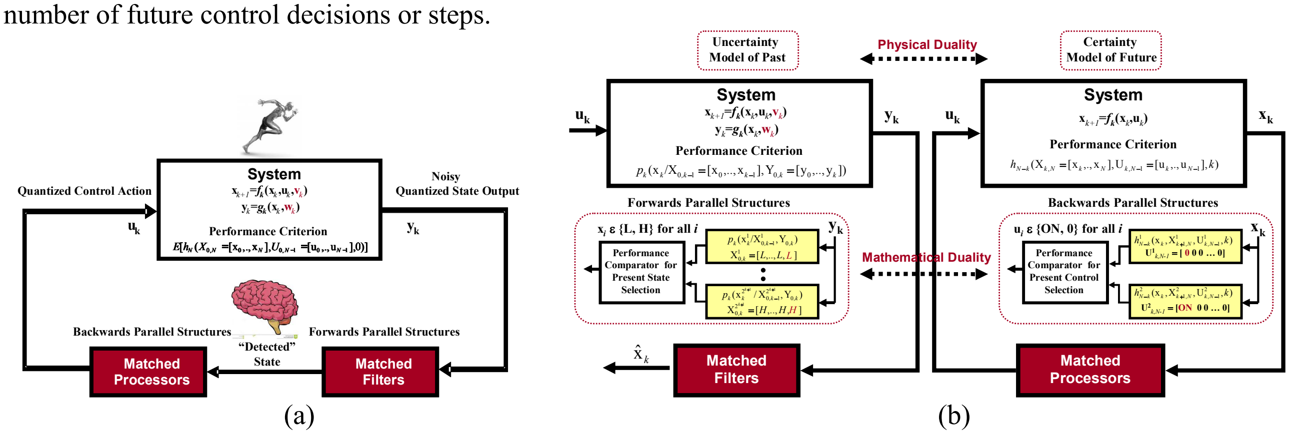


Fig. 2 (a) Stochastic Matched Processors Control System. (b) Separated Uncertainty/Certainty Design.

In Fig. 2(a) a structural description is given of the quantized control system structure that is noted to match that of Fig. 1(a) for LQG control, except that the controlled system input and state are now assumed quantized with the generally nonlinear functions f_k and g_k operating on x_k, u_k, v_k and w_k to give rise to the next state x_{k+1} and output y_k.

To derive the controller for the stochastic quantized control system of Fig. 2(a) a matched filters subsystem for state detections is first derived as part of the past-uncertainty design method as is depicted in Fig. 2(b). The performance criterion used to detect the present state x_k is its conditional probability $p_k(\mathrm{x}_k / \mathrm{X}_{0,k-1}, \mathrm{Y}_{0,k})$ appropriately derived where $X_{0,k}$ and $Y_{0,k}$ are k+1 past and present states and measurements, respectively. Secondly, a matched processors subsystem for control decisions is designed as part of the future-certainty design method (as is also shown in Fig. 2(b)). These matched processors evaluate an appropriately specified performance criterion $h_{N-k}(\mathrm{X}_{k,N}=[\mathrm{x}_k,.,\mathrm{x}_N], \mathrm{U}_{k,N-1}=[\mathrm{u}_k,.,\mathrm{u}_{N-1}], k)$ where each is matched to a feasible future control sequence $U_{k,N\text{-}1}$. Moreover, this matched processors subsystem has a backwards (from future to present) parallel structure that may be viewed as the structural mathematical dual of the forwards (from past to present) parallel structure that is part of the matched filters subsystem. The practical results derived with this parallel processing method have been found to be quite reasonable [27] since only a few matched processor evaluations need to be considered at each control stage regardless of the number of stages to go (illustrated in Fig. 2(b) with just two matched processors). Moreover, the serial/parallel structures encountered in the controller implementations are sensibly suited for CNS modeling. Another remarkable result of matched processors was that unlike Bellman's dynamic programming [28], also used in quantized control, it did not suffer of what Bellman called "the curse of dimensionality" of his dynamic programming when referring to the exponential increase in the computational burden as the process state dimension increased in value.

The main highlight of both the stochastic LQG control scheme and the stochastic matched processors scheme just described is that in their designs a common physical uncertainty/certainty duality anchors structural mathematical dualities. This property was then identified as our UCDP which as noted earlier may be stated as, "synergistic physical and mathematical dualities naturally arise in efficient system designs."

When the UCDP is viewed globally one then realizes that it can be applied in three major areas of research. They are: 1) In finding the uncertainty space-penalty dual for the laws of motion in physics, with this dual called the laws of retention; 2) In finding the certainty time-penalty dual for information-theory (applied not only to source but also to retainer information systems), with this dual called latency-theory (applied not only to processor but also to mover latency systems); and 3) In finding the certainty time-penalty dual for thermodynamics (applied not only to source but also to retainer thermo systems), with this dual named lingerdynamics (applied not only to processor but also to mover linger systems). We next review each of these three applications.

4. LAWS OF RETENTION IN PHYSICS

The laws of retention in physics first derived in 2008 in [5] while guided by our duality principle are now reviewed making use of Fig. 3 and Table 1.

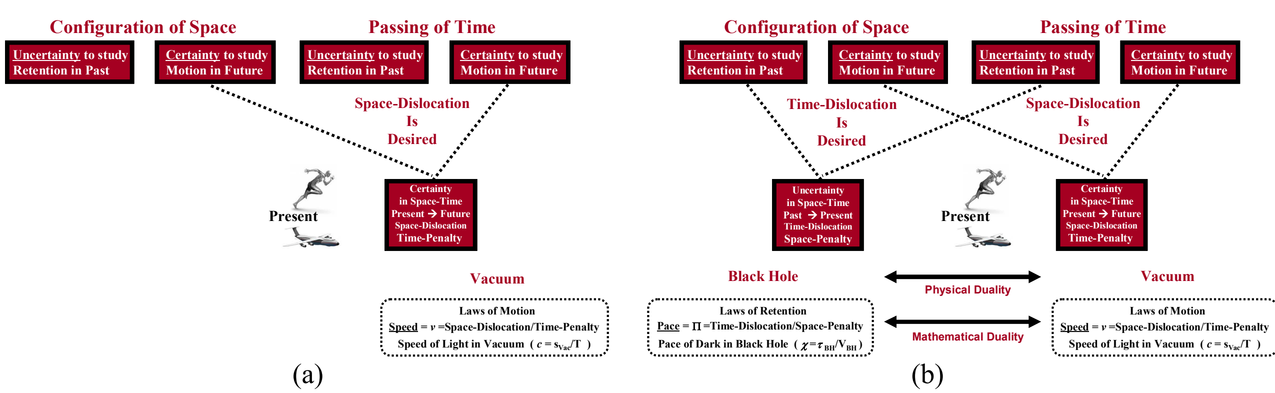


Fig. 3 (a) Motion's space-time certainty. (b) Retention's space-time uncertainty as motion's dual.

In Fig. 3(a) one first notices how in the study of future motions a certainty model for space-time is assumed where our objective is the *space-dislocation of a mass* while subjected to a time-penalty *D*. Moreover it is also seen how the efficiency of this motion is measured by the ratio of the achieved space-dislocation '*s'* to the time-penalty *D*, which is called the speed *v* of the system. One also finds that the medium where the highest speed (or motion efficiency) is achieved is in a vacuum and is the speed of light *c*. Newton in 1687 started the study of the laws of motion [17].

In Fig. 3(b) the retention uncertainty dual of our motion problem has been added to the motion representation of Fig. 3(a). One then notices the following retention/motion dualities that are moreover expressed using our cybernetics duality language.

First one notes that in the study of past retentions an uncertainty model for space-time is assumed where our objective is the *time-dislocation of mater (the retention dual of mass)* while subjected to a volume space-penalty *V*. For instance, the retained mater could be some acquired data (the mater of some event) that we may wish to store 50 years (the desired duration of its retention) while saving it in a storage device (a retainer occupying some volume space) for 50 years. Moreover it is also seen how the efficiency of this retention is measured by the ratio of the achieved time-dislocation τ to the space for storage *V*, which we have named the pace Π of the system [5]. For instance, in a biological application this pace could indicate the number of years that 'healthy' DNA information remains in our bodies (denoting the retention volume) to sustain life as adults, e.g., the pace for an adult individual with a constant volume of 0.07 m^3 would be of 1,143 years/m^3 if his adult lifespan is of 80 years. Moreover, one finds that the medium where the highest pace (or retention efficiency) can be achieved is in a black hole leading to the 'pace of dark in a black hole' (the retention dual of the speed of light in a vacuum) with the assigned symbol χ and whose value is derived in Appendix A.

The revelation in 2006 of this cybernetics retention/motion duality let to [5] where numerous cases of this duality were first published. Among these cybernetic duality results one finds the following three: 1) The listing of the retention duals for the main constants, variables and equations of the laws of motion in physics; 2) The finding of an expression for the pace of dark χ as a function of the three fundamental constants in physics which are the speed of light in a vacuum *c*, the gravitational constant *G*, and the Planck constant *h*; and 3) the derivation of the retention dual of the gravitational constant which has been called gravidness with symbol Φ.

Table 1. Cybernetics Duality Laws in Physics

Laws of Retention	**Laws of Motion**
Π = Pace in *sec/m*^{3} units	v = Speed in *m/sec* units
α = Escalation in *sec/m*^{6} units	a = Acceleration in *m/sec*^{2} units
γ = Press in *Pa* units	f = Force in *N* units
O = Mater of retention in kg_R or $N.m^6/sec$ units	M = Mass of motion in *kg* or $N.sec^2/m$ units
$\upsilon = O\Pi$: Endurance in $Pa.m^3$ or *N.m* units	$p = Mv$: Momentum in *N.sec* units
χ = Pace of dark in black hole in *sec/m*^{3} units	c = Speed of light in vacuum in *m/sec* units
Φ = Gravidness constant in $Pa.sec^{4/3}/kg_R^2$ units	G = Gravitational constant in $N.m^2/kg^2$ units
τ = Time-dislocation in *sec* units	r = Space-dislocation in *m* units
ϖ = Viscidity in *Pa.sec* units	E = Energy in *J* or *N.m* units
$\varpi = O\chi^2$: Mater-viscidity equation *Dark Energy of Retention:* $E_R = \upsilon = O\chi$ *Dark Mass of Retention:* $M_R = \upsilon / c^2$	$E = Mc^2$: Mass-energy equation *Light Viscidity of Motion:* $\varpi_M = \chi M c^2$ *Light Mater of Motion:* $O_M = \varpi_M / \chi^2$
$\gamma_o = \Phi o O / \tau^{4/3}$: Gravidness Press of O on 'o'	$f_m = GmM/r^2$: Gravitational force of M on 'm'
The four cybernetics duality constants Φ, G, χ and c in physics equation: $(\Phi/G)^3 = 4\pi\,\chi^{10}/81c^{12}$	
The pace of dark equation : $\chi = 480c^2 / \hbar G$	
The Planck and gravidness constants inverse equation : $h = 320\pi \sqrt[3]{4\pi\chi^7 / 3c^6} / \Phi$	

In Table I an illustration is given of the laws of retention in physics that were derived as retention duals for key constants, variables and equations of Newton's Principia. These are: 1) Pace Π in sec/m^3 units, the retention dual of speed v in m/sec units; 2) Escalation α in sec/m^6 units, the retention dual of acceleration a in m/sec^2 units; 3) Press γ in Pa units, the retention dual of force f in N units; 4) Retention-mater O in kg_R or $Pa.m^6/sec$ units, the retention dual of mass M in kg or $N.sec^2/m$ units; 5) Endurance $\upsilon=O\Pi$ in 'dark energy' $Pa.m^3$ or $N.m$ units, the retention dual of momentum $p=Mv$ in $N.sec$ units; 6) Pace of dark in a black hole χ, the retention dual of the speed of light in a vacuum c; 7) Gravidness constant Φ in $Pa.s^{4/3}/kg_R^2$ units, the retention dual of the gravitational constant G in $N.m^2/kg^2$ units; 8) The time-dislocation τ in sec units, the retention dual of the space-dislocation r in *meter or m* units; 9) The viscidity (ϖ) in $Pa.sec$ units, the retention dual of the energy (E) in J or $N.m$ units; 10) The mater-viscidity (ϖ) equation $\varpi=O\chi^2$, the retention dual of the mass-energy (E) equation $E=Mc^2$; 11) The gravidness press $\gamma_o=\Phi oO/\tau^{4/3}$ of the point-mater O acting on the point-mater *'o'*, the retention dual of the gravitational force $f_m=GmM/r^2$ of the point-mass M acting on the point-mass *'m'*; 12) The equation $(\Phi/G)^3=4\pi\chi^{10}/81c^{12}$ relates all the four cybernetics duality constants Φ, G, χ and c in physics (derived in Appendix B); 13) The pace of dark in a black hole χ is given by the equation $\chi=480c^2/\hbar G$ (derived in Appendix A); and 14) The equation $h=360\pi\sqrt[3]{4\pi\chi^7/3c^6}/\Phi$ provides an inverse relationship between the Planck constant and the gravidness constant.

Four and last, the following two 'dark-energy' and 'dark-mass or dark-matter' results are highlighted from Table 1. They are; 1) The dark-energy of retention $E_R=O\chi=Press$ *by* V is the retention dual of the light-viscidity of motion $\varpi_M=\chi Mc^2=Pressure$ by D. While the dark-energy E_R *e*nables the space-penalty V paid for the time-dislocation of mater, the light-viscidity ϖ_M enables the time-penalty D paid for the space-dislocation of mass. 2) The dark-mass or matter in retention $M_R=O\chi/c^2$ is the retention dual of the light mater in motion $O_M=Mc^2/\chi$. While dark-mass M_R is the mass of the space-penalty paid for the time-dislocation of mater, light-mater O_M is the mater of the time-penalty paid for the space-dislocation of mass. Moreover, since the units of light-viscidity are those of viscosity our duality perspective suggests the following. Firstly, that the light-viscidity of motion acts in a vacuum *to speed down* the motion of mass-energy, since it induces a time-penalty, leading in turn to c for the maximum speed of light in a vacuum. Secondly, that the dark-energy of retention acts in a black hole *to pace down* the retention of mater-viscidity, since it induces a space-penalty, leading in turn to χ for the maximum pace of dark (the retention dual of light) in a black hole. Many more cybernetics dualities in physics are found in [5] and later publications like [29], [19] and [22]. In particular, in the last page of [19] it was pointed out that dark-energy and dark-matter could be investigated as a cybernetics black-hole/vacuum duality in physics [5], along the lines of how the problem is being approached nowadays by physicists [16].

5. LATENCY-INFORMATION THEORY

Latency-theory is the time-penalty dual of information-theory. Information-theory designs *through its source coding* [18] a *source-coder* that reduces the space-penalty paid for the storage of an information-source output. For example, for the original Lena image of Fig. 4(b) the space-penalty paid is 8 *info-bits/pixel.*

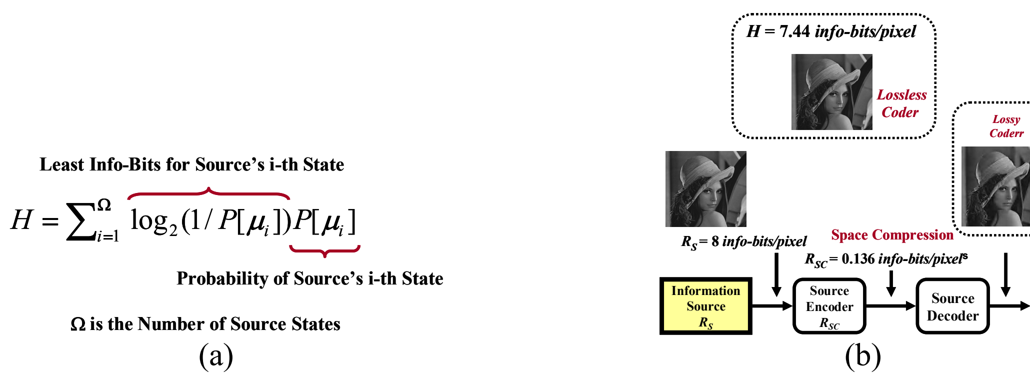


Fig. 4 (a) Information-Source's Entropy H. (b) Source-coder's Lossless and Lossy Illustrations.

On the other hand, latency-theory designs *through its processor coding* a *processor-coder* that reduces the time-penalty paid for the processing of a latency-processor input. For example, for the full adder of Fig. 5(b) the time-penalty paid would be of six gate or bor levels.

In information-theory the Shannon information-source entropy with symbol H is an expectation metric that conveys the minimum amount of space-penalty in 'mathematical' info-bit units to pay for the representation of the source outcomes. The information-source entropy H is defined as

$$H = \sum_{i=1}^{\Omega} \log_2(1/P[\mu_i])P[\mu_i] \tag{1}$$

which is also displayed in Fig. 4(a) for ease of comparison with other metrics, where μ_i denotes the i-th state or outcome of the information-source, Ω is the total number of outcomes, $P[\mu_i]$ is the probability of μ_i and $\log_2(1/P[\mu_i])$ represents the least number of info-bits that may be used to represent the i-th state μ_i. In Fig. 4(b) it is noted that when the original Lena image with 8 info-bits/pixel is the output of the information-source, an evaluation of H reveals it to be 7.44 info-bits/pixel.

On the other hand, in latency-theory the latency-processor entropy with symbol K is a 'minimax' metric that conveys the minimum amount of time-penalty in 'mathematical' lat-bor units to pay for the representation of the processor delay. The latency-processor ectropy K is defined as

$$K = \max\{\log_{C[h_i]} h_i : i = 1,\ldots,\Lambda\} \tag{2}$$

which is also displayed in Fig. 5(a) where h_i denotes the number of info-bits in the i-th info-bits vector $\mathbf{h}_i$ whose processing by the latency-processor gives rise to the i-th element y_i of its vector output $\mathbf{y}$, $C[h_i]$ (the time-penalty dual of the probability $P[\mu_i]$) is the constraint in the number of inputs for the gates processing $\mathbf{h}_i$, and $\log_{C[hi]}h_i$ (the time-penalty dual of $\log_2(1/P[\mu_i])$) is the minimum number of lat-bors that via wired logic [30] implements the sum of minterms Boolean expression relating y_i to the info-bits in $\mathbf{h}_i$. In Fig. 5(b) it is noted that when a full adder (where a_i, b_i and c_{in} are the three added info-bits and s_i and c_{out} are the outputs) with 6 lat-bors/sum is the latency-processor, an evaluation of K reveals it to be K=2 lat-bors/y where the gates are limited to two inputs each, i.e., C=2 for both the outputs y_1=s (or sum) and y_2=c_{out} (or carry out) of the latency-processor.

In information-theory source-coding uses H to guide the design of a source-coder that saves mathematical info-bit space in either a lossless or lossy fashion. For the lossy source-coder case a source-encoder is first designed that determines for the information-source output an energy decomposition, and then only sends to the source-decoder the info-bits linked to the most energetic elements in the decomposition. In Fig. 4(b) the well known lossy Lena image is shown that was encoded with a MMSE-PT source-coder with subbands [31] and yields a source-encoder rate R_{SC} of 0.136 *info-bits/pixel*. It is noted here that the performance of the decoder output is evaluated in terms of the 'multi-pixels' subjective visual result derived from the image output, where the decoder output *is not discarded afterwards*.

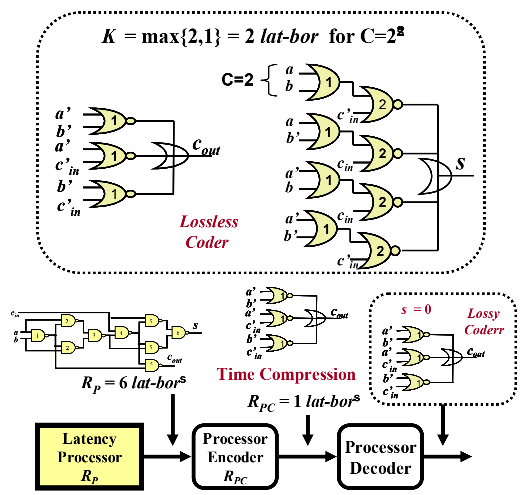
Least Lat-Bors for Processor's i-th Output

$$K = \max\{\log_{C[h_i]} h_i : i = 1,\ldots,\Lambda\}$$

Gate-Constraint of Processor's i-th Output

h_i is the Number of Processor Input Bits Leading to i-th Output
Λ is the Number of Processor Outputs

(a)



(b)

Fig. 5 (a) Latency-Processor's Ectropy *K*. (b) Processor-coder's Lossless and Lossy Illustrations.

In latency-theory processor-coding (the time-penalty dual of source-coding) uses K to guide the design of a processor-coder that saves mathematical lat-bor time in either a lossless or lossy fashion. For the lossy processor-coder case a processor-encoder is first designed that determines for each latency-processor output element the implementation with the least number of processing levels, and then only relays to the processor-decoder the most essential elements for their implementation. In Fig. 5(b) a lossy full adder coder is shown that sets s to zero thus yielding a processor-coder rate R_{PC} of only 1 *lat-bor*. This coder improves by 100 % the processor-coder rate but with the loss of the least significant bit of the two bits full adder output. It is noted here that the performance of the decoder output is evaluated in terms of a practical 'scalar-numerical' result derived from the full adder output, where the decoder output *is discarded afterwards*. In [8], in particular, processor-coding has been used to derive a signal-processor, called power-centroid radar, that obviates the use of prior-knowledge, such as synthetic aperture radar (SAR) imagery of the earth while still yielding high-performance radar, a highly desirable result.

In information-theory H plays another significant role and it is in the *mathematical theory of communication* (MTC) [18]. As expected, this theory also has a time-penalty dual in latency-theory which has been named the *mathematical theory of observation* (MTO) [32]. We now describe in general terms this case via our cybernetics duality language.

While in MTC one seeks a *channel and source integrated* (CSI) coder that achieves the *channel-capacity C* of an uncertainty communication channel, in MTO one seeks a *sensor and processor integrated* (SPI) coder that achieves the *sensor-consciousness F* for a certainty sensor.

The MTC's channel capacity C is given by the ratio:

$$C=(H-\Delta H)/H \tag{3}$$

and describes the most efficient time-communication of the source's H *info-bits* possible by an uncertainty communication channel with ΔH denoting the quantum of operation (QoO) portion of H that cannot be time-communicated because it is an unavoidable penalty due to channel use (e.g., the unavoidable penalty of transmitting error detection/correction parity bits by a CSI coder due to the presence of a noisy channel).

On the other hand, the MTO's sensor consciousness F is:

$$F=(K-\Delta K)/K \tag{4}$$

and describes the most efficient space-observation of the processor's K *lat-bors* possible by a certainty observation sensor with ΔK denoting the QoO portion of K that cannot be space-observed because it is an unavoidable penalty due to the use of a sensor (e.g., the unavoidable penalty of losing one bor of 2 bors needed for processing due to a one-bor limiting sensor, for our full adder a SPI-coder that would satisfy this constraint is the lossy source-coder of Fig. 5(b)).

Physical duals [29] for the mathematical metrics H and K have been identified and are now reviewed. First in Fig. 6(b) an *information-retainer* is shown, illustrated with a cylindrical thermos whose dimensions are the average dimensions of a given set of cylindrical thermos. The information-retainer entropy N is defined as

$$N=\sum_{i=1}^{\Omega}4\pi r_i^2 P[\mu_i]=4\pi r^2 \tag{5}$$

which is also displayed in Fig. 6(a), and is an expectation expression where μ_i denotes the i-th state of the

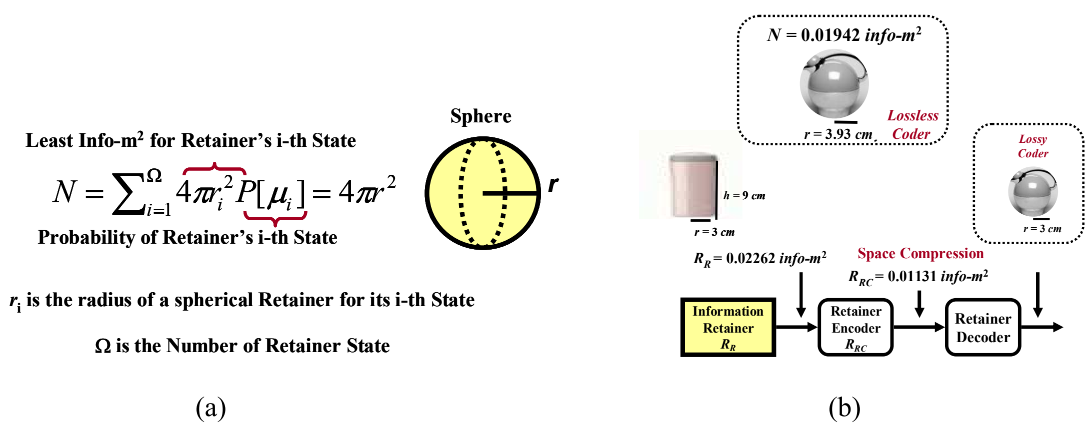


Fig. 6 (a) Information-Retainer's Entropy *N*. (b) Retainer-coder's Lossless and Lossy Illustrations.

information-retainer, P[μ_i] is the probability of μ_i and $4\pi r_i^2$ represents the least surface area (corresponding to a spherical volume) in info-m^2 units that may be used to represent the surface of the volume where the i-th state μ_i is assumed to reside. In this representation r_i denotes the radius of the i-th sphere and r the radius of the average sphere of the set of thermos. In Fig. 6(b) it is noted that an average retention surface value is derived for the set of thermos of 0.02262 *info-*m^2, and N is 0.01942 *info-*m^2 for this case. This new type of entropy in *info-*m^2 units gives rise to a *retainer-enhanced information-theory* that through *retention-coding* has N guiding the design of a retainer-coder. This coder reduces the physical space-penalty for the information-retainer surface area in either a lossless or a lossy fashion. For a lossy retainer-coder case a coder is designed that has a spherical volume with a surface area that is less than that of the lossless retainer-coder. Both the lossy and lossless cases are shown in Fig. 6(b) where the surface area of the lossy coder is 0.01131 *info-*m^2; a 42% improvement over the lossless case but now with less available volume for retention.

Second in Fig. 7(b) a *latency-mover* block diagram is shown, illustrated with the circular motions of a group of runners. The latency-mover ectropy A is defined as

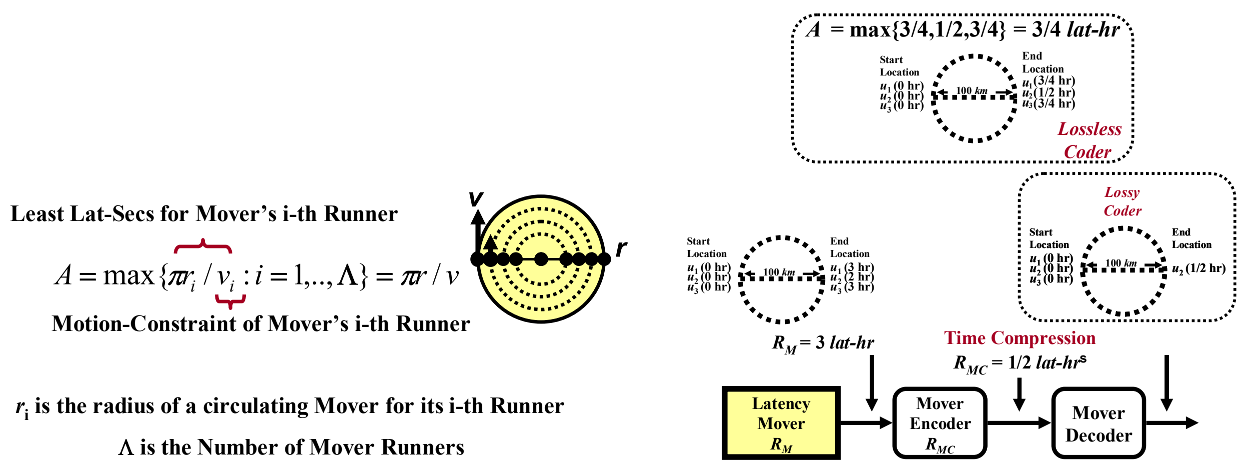
$$A = \max\{\pi r_1 / v_1, .., \pi r_\Lambda / v_\Lambda\} = \pi r / v \qquad (6)$$

which is also displayed in Fig. 7(a), and is a minimax expression where v_i is the i-th runner's average speed constraint, r_i is the radius of circular motion and $\pi r_i/v_i$ represents the least delay in motion from one side to the other side of the circle in *lat-hr* units. In the expression $A=\pi r/v$, r is the largest possible radius and v is the lowest possible speed giving rise to A. In Fig. 7(b) it is further noticed that the minimax delay of 3 hrs is derived for a set of three runners in a circular medium with a 100 km diameter, and a latency-mover ectropy A of ¾ lat-hrs linked to higher average speeds.

This new type of ectropy in *lat-sec* units gives rise a *mover-enhanced latency-theory* that through *motion-coding* has A guiding the design of a mover-coder. This coder is used to save physical *lat-sec* time in either a lossless or a lossy fashion. For a lossy mover-coder case a mover-coder is designed where some of the runners do not reach their destination. Both the lossy and lossless cases are shown in Fig. 7(b) where the duration of the lossy coder is 1/2 *lat-hr*, an improvement by a factor of 3/2 over the lossless case, however with less number of runners in motion.

Physical duals [29] for the mathematical theories of communication and observation are next reviewed. First for the retainer-entropy N the *physical theory of observation* (PTO) applies that seeks a *sensor and retainer integrated* (SRI) coder that achieves the sensor-scope 'I' of an uncertainty sensor (e.g., a random tea drinker mouth). The sensor scope 'I' is given by the ratio

$$I=(N-\Delta N)/N \qquad (7)$$



(a) (b)

Fig. 7 (a) Latency-Mover's Ectropy *A*. (b) Mover-coder's Lossless and Lossy Illustrations.

and describes the most efficient time-observation of the retainer's N square meters of surface area by an uncertainty observation sensor with ΔN denoting the QoO portion of N that is lost because it is an unavoidable penalty suffered by the use of the sensor (e.g., a non-spherical cup, a type of SRI coder, may be necessary for tea drinking).

Second for the mover-ectropy A the *physical theory of communication* (PTC) applies that seeks a *channel and mover integrated* (CMI) coder that achieves the channel-stay T in a certainty channel (e.g., a peddle surface for running). The channel stay T is given by the ratio

$$T=(A-\Delta A)/A \tag{8}$$

and describes the most efficient space-communication of the mover's A seconds of delay via a certainty communication channel with ΔA denoting the QoO portion of A that is lost because it is an unavoidable penalty suffered due to channel (e.g., special shoes, a type of CMI coder, for easy running).

6. LINGER-THERMO THEORY AND ITS BIOLOGICAL LIFESPAN BOUNDS

6.1 Linger-thermo theory

As noted in our introductory section lingerdynamics is the time-penalty dual of thermodynamics. In particular the entropies of thermo systems and the ectropies of linger systems were noted to be related via the following two expressions:

$$\hat{H} = \hat{K}^2 \tag{9}$$

$$\hat{N} = 3\frac{V}{r} = 3\frac{\tau}{r\Pi} = 4\pi\left(\frac{GM}{v^2}\right)^2 = 4\pi\, r^2 = \frac{4v^2}{\pi}\hat{A}^2 \tag{10}$$

where (9) relates the mathematical units entropy $\hat{H}$ of a thermo-source in thermo-bit units and the ectropy of a linger-processor $\hat{K}$ in linger-bor units, and (10) relates the physical units entropy $\hat{N} = 4\pi r^2$ of a thermo-retainer in SI m^2 units and the ectropy $\hat{A} = \pi r / v$ of a linger-mover in SI sec units, with r being the radius of a spherical medium and *v the perpetual rotational speed of a particle on the surface of the sphere* whose mass is modeled as a point-mass M at its center and thus satisfying the gravitational relationship $r = GM / v^2 = 2GM / v_e^2$ *(v_e is the escape speed of a particle from the medium).* In addition in (10) the former gravitational relationship and retention pace relationship $\Pi=\tau/V$ (*τ is defined as the lifespan of thermal-bits of interest, called lifebits*, in our spherical medium of volume $V=4\pi r^3/3$) were used. In particular, the physical units expression (10) can be expressed in quantum of operation (QoO or Δ) form according to:

$$\Delta\hat{N} = 3\frac{\Delta V}{r} = 3\frac{\Delta\tau}{r\Pi} = 4\pi\left(\frac{G\Delta M}{v^2}\right)^2 = 4\pi\,\Delta r^2 = \frac{4v^2}{\pi}\Delta\hat{A}^2 \tag{11}$$

where the following assumptions were made: 1) $\Delta\tau$ is a QoO lifespan of the lifebits of interest, e.g., one day or equivalently 1/356 years; 2) ΔM in *kg* units, e.g., 0.4 *kg*, is a QoO mass contributed by the surroundings of the medium during $\Delta\tau$ in the form of heat energy $\delta Q=\Theta\mu\Delta M$ in joule units where Θ in calories per kg units and μ in joules per calorie units are appropriate conversion factors, e.g., Θ=5,000 kcal/kg and μ=4.18 joules/cal when considering the nutritional consumption rate of an organism, moreover, to maintain M constant in value during $\Delta\tau$ it is assumed here that a similar amount of quantum of radiation (QoR or $\Diamond$) energy $\Diamond Q=\delta Q$ returned to the surrounding by the medium in the form of black body radiation; 3) the pace Π and perpetual rotational speed v are assumed to remain constant during $\Delta\tau$; and 4) the sphere's radius r of the medium is assumed to be much larger than its QoO radius Δr during $\Delta\tau$. Moreover, taking the ratio of (10) to (11) the following QoO ratio of physical quantities results:

$$\frac{\hat{N}}{\Delta\hat{N}} = \frac{V}{\Delta V} = \frac{\tau}{\Delta\tau} = \left(\frac{M}{\Delta M}\right)^2 = \left(\frac{r}{\Delta r}\right)^2 = \left(\frac{\hat{A}}{\Delta\hat{A}}\right)^2. \tag{12}$$

Using (9) and (12) and also making use of the relationship that exists between the thermo-source entropy $\hat{H}$, the Boltzmann entropy S, and the possible number of microstates Ω of the medium given according to:

$$\hat{H} = S / k \ln 2 = \log_2 \boldsymbol{\Omega} \tag{13}$$

the universal linger-thermo equation (ULTE) follows according to:

$$\hat{H} = \frac{S}{k \ln 2} = f_{Med}\left(\frac{\hat{N}}{\Delta \hat{N}} = \frac{V}{\Delta V} = \frac{\tau}{\Delta \tau} = \left(\frac{M}{\Delta M}\right)^2 = \left(\frac{r}{\Delta r}\right)^2 = \left(\frac{\hat{A}}{\Delta \hat{A}}\right)^2 \right) = \hat{K}^2 \tag{14}$$

where f_{Med} is a medium dependent function that relates the mathematical entropies and ectropies of thermal-sources and linger-processors to the physical entropies and ectropies of thermal-retainers and linger-movers.

As an illustration a partial version of a spherical, uncharged, and non-rotating black hole (BH) ULTE expression is given according to:

$$\hat{H}_{BH} = \frac{S_{BH}}{k \ln 2} = \frac{1}{\ln 2} \frac{\chi c}{1920} \hat{N}_{BH} = \frac{1}{\ln 2} \frac{\chi c}{1920} 4\pi r_{BH}^2 = \frac{\tau_{BH}}{\Delta \tau_{BH}} = \left(\frac{M}{\Delta M_{BH}}\right)^2 \tag{15}$$

$$\chi = 6.1203 \text{ x } 10^{63} \; s/m^3 \tag{16}$$

$$\Delta \tau_{BH} = 640 \ln 2 \, r_{BH} / c \tag{17}$$

$$\Delta M_{BH} = 5.1152 \;\text{ x } 10^{-9} kg \tag{18}$$

$$\lozenge E_{\Delta \tau_{BH}}^{LB=1} = \lozenge M_{\Delta \tau_{BH}}^{LB=1} c^2 = \left(1 - \sqrt[3]{1 - \Delta M_{BH}^2 / M^2}\right) M c^2 \tag{19}$$

where c is the speed of light in a vacuum, χ is the pace of dark in a black hole, $\Delta \tau_{BH}$ is the QoO lifespan in a black hole, ΔM_{BH} is the constant QoO mass in a black hole during $\Delta \tau_{BH}$, $\lozenge E_{\Delta \tau_{BH}}^{LB=1} = \lozenge M_{\Delta \tau_{BH}}^{LB=1} c^2$ is the QoR mass-energy of a single life-bit equation when the lifebit is emitted from a black hole of mass M, r_{BH} is the black hole radius, and S_{BH} is the Bekenstein-Hawking entropy given by [33]:

$$S_{BH} = (kc^3 / 4\hbar G) 4\pi r_{BH}^2 \, . \tag{20}$$

6.2 Linger-thermo theory and its biological lifespan bounds

There are macro and micro expressions that may be used to find the adult lifespan τ of an organism. The macro expression depends on the nutritional consumption rate (NCR) of an organism and can be determined from the QoO ratio of physical quantities given by (12) where one derives the *macro NCR adult lifespan upper bound equation* of:

$$\tau = \Delta \tau \left(\frac{M}{\Delta M}\right)^2 \tag{21}$$

where M is the body size of an individual and $\Delta M = \delta Q / \Theta \mu$ is his NCR, with δQ denoting the input heat energy in joules and Φ=5,000 *kcal/kg* and μ=4.18 *J/cal* are unit conversion factors. For instance, (21) yields an adult lifespan of 84 years (or a total lifespan of 102 years when 18 years of childhood are added) when the body size of the individual is of 70 kg and his NCR is of 0.4 kg/day which corresponds to 2,000 kcal/day. This result is a sensible upper bound prediction for a healthy individual since, for instance, the life expectancy of the US population is of 79 years, including all types of deaths.

On the other hand, when the ULTE of (14) is solved for a flexible-phase medium, like liquid water at a temperature of 310 K, micro expressions can be found for the adult lifespan of an individual (whose medium is at a temperature of 310 K and more than 98 % of his molecules are of liquid water) in terms of his specific heat-capacity in *J/kg.K* units or equivalently from his molecule's dimensionless degrees of freedom (DoF) heat-capacity. The derivation of a micro approach to adult lifespan investigations is highly desirable due to both its theoretical as well as practical implications since some, like specific heat capacity, may be more readily available.

The ULTE for a flexible-phase (FP) medium was first advanced in [14] and given by the expressions:

$$\hat{H} = \frac{S}{k \ln 2} = J \log_2 \left(\frac{e^{c_V(\eta)+1} q(\eta)}{J^{\alpha \eta}} = \frac{\tau}{\Delta \tau} = \left(\frac{M}{\Delta M}\right)^2 \right) \tag{22}$$

$$e_T = c_V(\eta)kT \tag{23}$$

$$m_T = c_V(\eta)kT / c^2 \tag{24}$$

$$J = E / e_T = Mc^2 / e_T \tag{25}$$

$$q(\eta) = q^e q^t (q^R q^v)^{(c_V(\eta)-3/2)/2} \tag{26}$$

$$0 \le \eta = \frac{c_V(\eta) - 3/2}{c_{V,Max} - 3/2} \le 1 \tag{27}$$

$$q^e = g_0 \tag{28}$$

$$q^t = V\,\hat{q}^t \tag{29}$$

$$\hat{q}^t = \left(\frac{mkT}{2\pi\,\hbar^2}\right)^{3/2} \tag{30}$$

$$q^R = \frac{2kT\,I}{\hbar^2\,\sigma} \tag{31}$$

$$q^v = \frac{kT}{2\pi\,\hbar\;v} \tag{32}$$

$$PV = kTJ \tag{33}$$

$$S = kJ\ln\left(e^{c_V(\eta)+1} q(\eta) / J^{\alpha\eta}\right) \tag{33}$$

where: 1) S is the entropy of our linger-thermo flexible-phase medium which is similar in form to that of an idea gas (IG) which is given by the expression $S_{IG} = kJ_{IG}\ln\left(e^{c_V+1} q / J_{IG}\right)$ (with $J_{IG}=U/c_VkT$ being the number of gas molecules given by the ratio of the IG's internal energy U, denoting the kinetic plus potential energy of non-interacting molecules, to the product of the thermal energy kT and the constant volume heat capacity c_V of the gas, and $q=q^eq^tq^Rq^\upsilon$ being the molecular partition function with q^e, q^t, q^R, q^υ denoting the electronic, translational, rotational and vibrational partition factors of a molecule given by (28)-(32) where m is the molecular mass, g_0 is the degeneracy of the ground energy state, 'I' is the average moment of inertia of a molecule, σ is its symmetry number and υ is the average vibrational frequency); 2) $PV=kTJ$ is the flexible-phase law, with P and V being the pressure and volume of the linger-thermo flexible-phase medium, which is similar in form to that of an ideal gas which is given by $P_{IG}V=kTJ_{IG}$ with P_{IG} and V being the pressure and volume of the ideal gas); 3) The $c_V(\eta)$ is the constant volume heat-capacity of the medium that is equal to the DoF of the molecules of the medium over two, with $c_{V,Max}$ being the maximum value that this heat-capacity may have; 4) η is a coupling factor conveying the generally non-equilibrium thermal state of the medium whose value is one when $c_V(\eta)=c_{V,Max}$; 5) $e_T=m_Tc^2$ denotes the mass-energy of a thermote particle that is defined for a flexible-phase medium; 6) J is the number of thermotes in the medium whose value changes as the temperature and heat-capacity of the medium changes; 7) α is a normalizing constant for our linger-thermo flexible-phase medium; and 8) E is the internal energy of our linger-thermo flexible-phase medium which is in fact the total energy of the medium and thus includes all molecular interactions.

Making use of expressions (22)-(33) the following QoO FP-ULTE expressions follow when the Classius input heat $\delta Q=TdS$ is added to the flexible-phase medium:

$$\delta Q = T\,dS = kT\,dJ\ln\left(F(\alpha\eta)\frac{e^{c_V(\eta)+1}q(\eta)}{J^{\alpha\eta}} = F(\alpha\eta)\frac{\tau}{\Delta\tau} = F(\alpha\eta)\left(\frac{M}{\Delta M}\right)^2\right) \tag{34}$$

$$F(\alpha\eta) = 1\Big/\left(1+\frac{dJ}{J}\right)^{\alpha\eta\left(1+\frac{J}{dJ}\right)} = 1\Big/\left(1+\frac{dV}{V}\right)^{\alpha\eta\left(1+\frac{V}{dV}\right)} \tag{35}$$

$$PV = kTJ \tag{36}$$

$$d(PV) = kTdJ \tag{37}$$

$$E = e_T J = c_V(\eta)kTJ \tag{38}$$

$$\delta E = e_T dJ = c_V(\eta)kTdJ \tag{39}$$

$$\delta\overline{H} = \delta E + d(PV) = c_V(\eta)kTdJ + kTdJ \tag{40}$$

$$\delta G = \delta\overline{H} - TdS = -kTdJ\ln\left(F(\alpha\eta)q(\eta)/J^{\alpha\eta}\right) \tag{41}$$

where: 1) dS is the QoO Clausius entropy added to the medium; 2) dJ is the QoO thermote number added to the medium; 3) δQ is the heat energy added to the medium 4) δE is the part of δQ contributed to the internal-energy of the medium; 5) $\delta\overline{H}$ is the enthalpy energy part of δQ that encompasses both δE and the 'dark energy' $d(PV)=kTdJ$ necessary to provide space for δE; 6) δG is the Gibbs energy part of δQ that is available to the medium to do non-mechanical work; and 7) $F(\alpha\eta)$ is the QoO FP-ULTE factor.

From our QoO FP-ULTE (34) with $E=Mc^2$ and $V=M/1000$ (assuming the mass density of liquid water for an organism) two micro adult lifespan expressions surface as alternatives to (21). They are:

$$\tau = \Delta\tau\frac{e^{c_V(\eta)+1}q(\eta)}{J^{\alpha\eta}} = \Delta\tau\frac{g_0}{1000}\left(\frac{m}{2}\right)^{1.5}\left(\frac{I}{\sigma\,v}\right)^{\frac{c_V(\eta)-1.5}{2}}\frac{e^{c_V(\eta)+1}(kT)^{c_V(\eta)}}{\pi^{\frac{c_V(\eta)+1.5}{2}}\hbar^{\frac{3c_V(\eta)+1.5}{2}}}\frac{M}{(Mc^2/kTc_V(\eta))^{\alpha\frac{c_V(\eta)-1.5}{c_{V,Max}-1.5}}} \tag{42}$$

$$\tau = \Delta\tau\frac{e^{\frac{\delta Q}{d(PV)}}}{F(\alpha\eta)} = \Delta\tau\frac{e^{\frac{\Theta\mu\Delta M}{kT\,dJ}}}{F(\alpha\eta)} = \Delta\tau\frac{e^{\frac{\Theta\mu}{kT}dm}}{F(\alpha\eta)} = \Delta\tau\frac{e^{\frac{\lozenge Q}{\lozenge E^{LB}_{\Delta\tau}}}}{F(\alpha\eta)} \tag{43}$$

where: 1) equation (42) is a *micro DoF adult lifespan upper bound equation* since it depends on the value of the heat-capacity $c_V(\eta)$; and 2) equation (43) is a *mixed macro-micro adult lifespan upper bound equation* since it depends on the ratio of the *macro NCR energy* $\delta Q=\Theta\mu\Delta M=\lozenge Q$ over the *micro volume energy* (or dark energy) $d(PV)=kTdJ=\lozenge E^{LB}_{\Delta\tau}$ with $\lozenge E^{LB}_{\Delta\tau}$ denoting the 'dark energy' lifebits portion of the Clausius heat energy $\lozenge Q$ transmitted to the surroundings in the form of black body radiation.

In addition, the following expression follows:

$$\lozenge N^{LB}_{\Delta\tau} = \lozenge E^{LB}_{\Delta\tau}/\lozenge E^{LB=1}_{\Delta\tau_{BH}} \tag{44}$$

which denotes the number of lifebits emitted to the surroundings during $\Delta\tau$ in terms of $\lozenge E^{LB=1}_{\Delta\tau_{BH}}$ bit energy units, where $\lozenge E^{LB=1}_{\Delta\tau_{BH}}$ (19) is the dark energy used to emit a single lifebit by a black hole of similar mass as that of our flexible-phase medium.

In order to use our two new adult lifespan equations (42) and (43) in our studies, all that remains for us to do is to find sensible expressions from which values for α and $c_{V,Max}$ can be derived. Three such expressions have been derived and are given by:

$$\tau_{Avg} = \Delta\tau\frac{g_0}{1{,}000}\left(\frac{m}{2}\right)^{1.5}\left(\frac{I}{\sigma\,v}\right)^{\frac{c_{V,Avg}-1.5}{2}}\frac{e^{c_{V,Avg}+1}(kT)^{c_{V,Avg}}}{\pi^{\frac{c_{V,Avg}+1.5}{2}}\hbar^{\frac{3c_{V,Avg}+1.5}{2}}}\frac{M}{(Mc^2/kTc_{V,Avg})^{\alpha\frac{c_{V,Avg}-1.5}{c_{V,Max}-1.5}}} \tag{45}$$

$$\frac{1}{(1+kTc_{V,Max}dJ_{Max}/Mc^2)^{\alpha(1+Mc^2/kTc_{V,Max}dJ_{Max})}}g_0\left(\frac{m}{2}\right)^{1.5}\left(\frac{I}{\sigma\,v}\right)^{\frac{c_{V,Max}-1.5}{2}}\frac{(kT)^{c_{V,Max}}}{\pi^{\frac{c_{V,Max}+1.5}{2}}\hbar^{\frac{3c_{V,Max}+1.5}{2}}}\frac{M/1000}{(Mc^2/kTc_{V,Max})^{\alpha}} = 1 \tag{46}$$

$$\frac{1}{e^{c_{V,Max}+1}(1+kTc_{V,Max}dJ_{Max}/Mc^2)^{\alpha(1+Mc^2/kTc_{V,Max}dJ_{Max})}}\left(\frac{\Theta\mu M}{kTdJ_{Max}(c_{V,Max}+1)}\right)^2 = 1 \tag{47}$$

where: 1) equation (45) follows from (42) with the average adult lifespan τ_{Avg}, say 62 yrs, and average heat-capacity $c_{V,Avg}$, say 2.49 (or 3,469 *J/kg.K*), of a population are used for τ and $c_V(\eta)$, respectively; 2) equation (46) surfaces from setting the Gibbs energy δG (41) equal to zero which yields the condition $F(\alpha\eta\ )q(\eta\ )/J^{\alpha\eta}\Big|_{c_V(\eta)=c_{V,Max}} = F(\alpha)q(\eta=1\ )/(Mc^2/kTc_{V,Max})^{\alpha}=1$ from which (46) surfaces; and 3) equation (47) which surfaces from the conditions $\left(e^{c_V(\eta)+1} = F(\alpha\eta)(M/\Delta M)^2\right)\Big|_{c_V(\eta)=c_{V,Max}}$ and $\left(\Theta\mu\,\Delta M/kT\ dJ = c_V(\eta)+1\right)\Big|_{c_V(\eta)=c_{V,Max}}$.

6.3 Study of human adult lifespan bounds

In Table 2 a summary is given of the biophysical parameter values assumed during the adult lifespan of an individual whose internal temperature is assumed to be 310 *K* and whose medium is modeled as liquid water where the mass of a water molecule is 3 x 10^{-26} *kg*. Moreover, from Table 2 it is noted that for some population it is assumed that its average constant volume heat-capacity is 2.49 or 3.469 *J/kg.K* and average adult lifespan is 62 years (similar to that of the US).

Then in Tables 3, 4 and 5 simulation results are given for three different body sizes (50 kg, 70 kg and 100 kg) and three adult lifespans (102 years, 62 years and 42 years). The following results are then highlighted from these three tables:

1) From the top and leftmost cells of these three tables it is noted that the values of α do not vary by more than 0.06 % from 0.8465 and the values of $c_{V,Max}$ by more than 0.04 % from 2.578 (or 3,591 J/kgK) as the body size is varied from 50 to 100 kg.
2) The highest adult lifespan of 102 years is achieved with the least metabolic stress as noted from the tabulated $\Delta M/\delta Q$ values.
3) The most efficient use of the inputted heat energy δQ occurs when the adult lifespan τ is the largest, as measured by the Gibbs energy which is the largest percent of δQ, i.e., 64 %, when $\tau = 102$ years.
4) The best lifespan of 102 years is achieved when: a) the ratio of body size to NCR $M/\Delta M$ is the largest, i.e. of around 193; b) the heat capacity $c_V(\eta)$ is the smallest, i.e., around 2.4822 (3,458 *J/kgK*); and c) the ratio of ΔM to δJ or dm is the largest, i.e., around 1.9976 x 10^{-27} *kg*. This value of dm is noted to be greater than the mass of a hydrogen ion or proton which is 1.6667 x 10^{-27} *kg*. In connection with this observation it is further noticed that according to Harman's mitochondrial aging theory, the greater the number of high energy electrons producing protons for metabolism's ATP creation (the biological energy molecule) the more the number of free radicals created and thus the shorter lifespan due to more mitochondrial DNA mutations. A larger value for dm for the best adult lifespan of 102 years may thus be interpreted as indicating that a lesser number of protons are being created during the metabolism process.

Table 2. Biophysical Parameter Values for an Individual

***T*:** Temperature	310 *K*
***m*:** Mass of H_2O molecule	3 x 10^{-26} *kg*
$\Delta\tau$: QoO Lifespan	1 day = 1/365 *yrs*
Θ: Kilocalories per kilogram conversion factor	5,000 *kcal/kg*
μ: Joules per calorie conversion factor.	4.18 *J/cal*
g_0: Degeneracy of ground energy state	1
***I*:** Average moment of inertia of H_2O molecule	2 x 10^{-47} $kg.m^2$
***v*:** Average vibrational frequency of H_2O molecule	1.5 x 10^9 *Hz*
σ: Symmetry number of H_2O molecule	2
$c_{V,Avg}$: Average heat-capacity (Dimensionless/Specific)	2.49 / 3,469 *J/kg.K*
τ_{avg}: Average adult lifespan	62 yrs

Table 3. Adult Lifespan Bounds for 50 kg Body Size Individual

α= 0.845976 $c_{V,Max}$ = 2.57862	τ = 102 *years*	τ = 62 *years*	τ = 42 *years*
J	4.2298x10^{38}	4.2166x10^{38}	4.2063x10^{38}
dJ	1.2972x10^{26}	1.7547x10^{26}	2.2270x10^{26}
$\Delta M/\delta Q$ *in kg/kcal*	0.2591 (1,296)	0.3324 (1,662)	0.4038 (2,019)
$-\delta G$ *in % of* δQ	64	62	61
$F(\alpha\eta)$	0.4624	0.4601	0.4579
$M/\Delta M$	192.976	150.421	123.824
$c_V(\eta)$	2.4822 (3,458 *J/kg.K*)	2.49 (3,469 *J/kg.K*)	2.4961 (3,477 *J/kg.K*)
dm in kg	1.9976x10^{-27}	1.8944x10^{-27}	1.8133x10^{-27}

Table 4. Adult Lifespan Bounds for 70 kg Body Size Individual

α = 0.846525, $c_{V,Max}$ = 2.57821	τ = 102 *years*	τ = 62 *years*	τ = 42 *years*
J	5.9218x10^{38}	5.9032x10^{38}	5.8888x10^{38}
dJ	1.8163x10^{26}	2.4566x10^{26}	3.1175x10^{26}
$\Delta M/\delta Q$ *in kg/kcal*	0.3628 (1,814)	0.4653 (2,327)	0.5654 (2,827)
$-\delta G$ *in % of* δQ	64	62	61
$F(\alpha\eta)$	0.4624	0.4596	0.4575
$M/\Delta M$	192.944	150.441	123.806
$c_V(\eta)$	2.4822 (3,458 *J/kg.K*)	2.49 (3,469 *J/kg.K*)	2.4961 (3,477 *J/kg.K*)
dm in kg	1.9974x10^{-27}	1.8942x10^{-27}	1.8135x10^{-27}

Table 5. Adult Lifespan Bounds for 100 kg Body Size Individual

α= 0.847095 $c_{V,Max}$ = 2.577648	τ = 102 *years*	τ = 62 *years*	τ = 42 *years*
J	8.4596x10^{38}	8.4331x10^{38}	8.4125x10^{38}
dJ	2.5947x10^{26}	3.5094x10^{26}	4.4536x10^{26}
$\Delta M/\delta Q$ *in kg/kcal*	0.5183 (2,591)	0.6647 (3,324)	0.8077 (4,038)
$-\delta G$ *in % of* δQ	64	62	61
$F(\alpha\eta)$	0.4624	0.4593	0.4571
$M/\Delta M$	192.940	150.444	123.808
$c_V(\eta)$	2.4822 (3,458 *J/kg.K*)	2.49 (3,469 *J/kg.K*)	2.4961 (3,477 *J/kg.K*)
dm in kg	1.9972x10^{-27}	1.8942x10^{-27}	1.8133x10^{-27}

7. SUMMARY AND CONCLUSIONS

On the heels of major prizes given to physics for the use of mathematical dualities in addressing intractable problems in physics such as those in dark energy studies, this paper has reviewed the universal cybernetics duality principle or UCDP first identified in control theory in 1978. To help in remembering the UCDP timeline of development Fig. 8 is also advanced. The UCDP was not only found to offer mathematical dualities but also physical dualities such as those originating in retention/motion problems which led in 2008 to the discovery of the laws of retention in physics as the space-penalty dual of the laws of motion in physics. Moreover, it was noted that the dualities of the UCDP not only led to addressing intractable problems in physics but also those found in CNS modeling, high-performance radar and biological lifespan bounds. While solving these problems novel scientific methodologies have been derived such as: 1) *matched processor for quantized control* started in 1978 and leading to sensible parallel/series structures for CNS modeling use; 2) *latency-information theory* started in 2005 for the derivation of high-performance radar designs that obviate the use of prior-knowledge in radar detection, such as synthetic aperture radar (SAR) imagery of the earth while still yielding high-performance radar; 3) *linger-thermo theory* started in 2008 for the derivation of sensible biological lifespan bounds where it is predicted, for instance, that the lifespan of individuals with a body size of 70 kg and a nutritional consumption rate of 1,814 kcal/day have an upper adult lifespan bound of 102 years. Moreover, three possible sensible methods were found to determine adult lifespan. One was based on the ratio of body size to nutritional consumption rate. The second was based on the specific heat-capacity of the individual. Finally, the third type was based on the ratio of the individual's daily input heat energy to the portion of this energy that produces a volume increase, a kind of dark energy, for a constant body size, or decreased mass density as the individual ages. All of the sensible results reviewed in this paper compel the view that the UCDP will find broad use in future theoretical and practical studies.

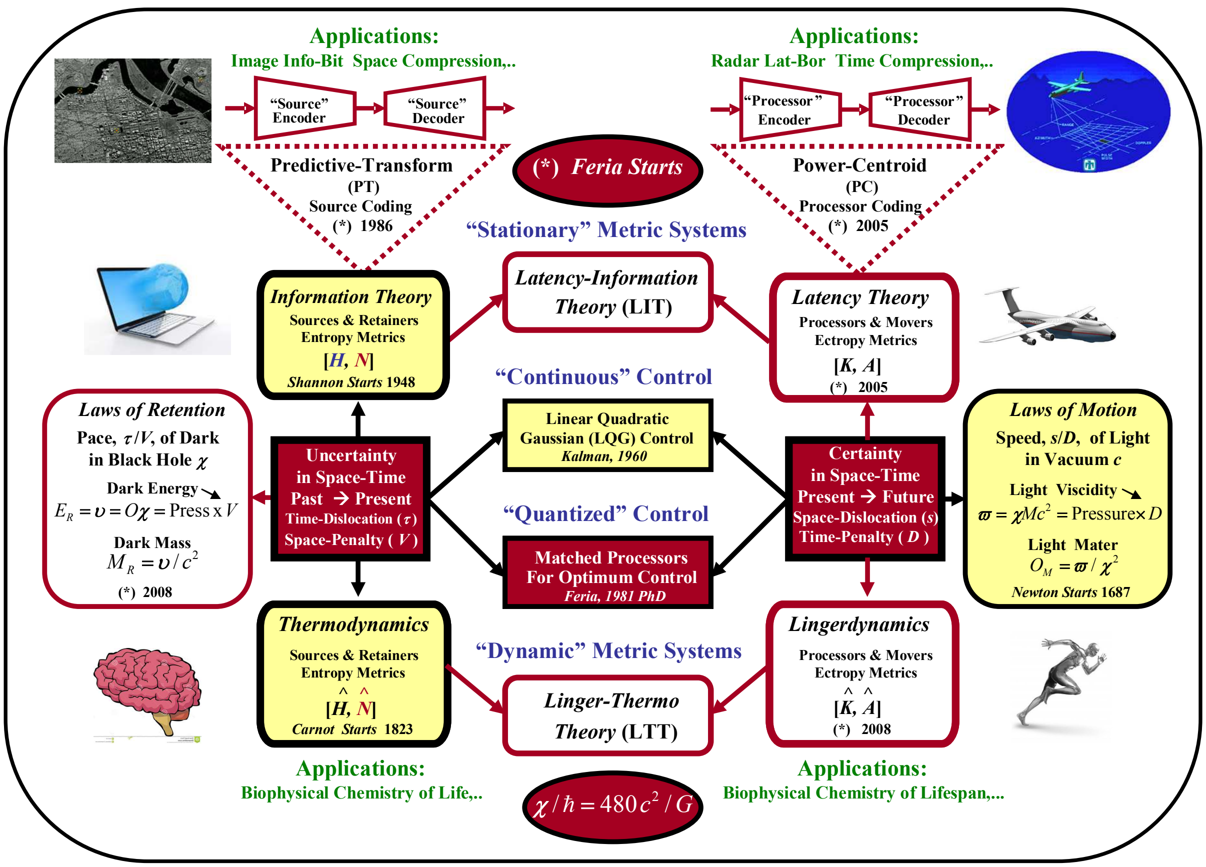


Fig. 8 Universal Cybernetics Duality Principle's Timeline

APPENDIX A
PACE OF DARK IN A BLACK-HOLE

In this appendix we derive the pace of dark in a black hole (spherical in shape, uncharged, and non-rotating) with symbol χ expression [5]:

$$\Pi = \frac{\tau}{V} = \chi = \frac{480c^2}{\hbar\, G} = 6.1203 \text{ x } 10^{63} \sec / m^3 \tag{48}$$

where c is the speed of light in a vacuum, $\hbar$ is the reduced Planck constant, G is the gravitational constant, τ is the retention-time (or time-dislocation) of the spherical volume V=$4\pi r^3/3$ of radius r of the black hole, and $\Pi = \chi$ is its pace of dark.

The derivation starts with the assumption that the black hole satisfies the black body luminance (dE/dt) expression [33] according to:

$$-\frac{dE}{dt} = \frac{\pi^2}{60\hbar^3 c^2}(4\pi r^2)(kT)^4 \tag{49}$$

where k is the Boltzmann constant, T is temperature, kT is thermal energy, and E=Mc^2 is the mass-energy of the black-hole.

Next the Schwarzschild radius expression for the event horizon of a black hole is noted to be given by:

$$r = 2GM / c^2 = 2GE / c^4 \tag{50}$$

Next the Bekenstein-Hawking entropy (S) for our spherical black hole [33] is:

$$S = \frac{kc^3}{4\hbar G} 4\pi r^2 = \frac{kc^3}{4\hbar G} 4\pi \left(\frac{2GE}{c^4} \right)^2 \tag{51}$$

where the expression (50) has been used for r. Next the following thermal-energy expression is derived via (51):

$$kT = \left(\partial S / \partial E\right)^{-1} = \frac{\hbar c^5}{8\pi GE} \tag{52}$$

Next making use of (52) in (49) one obtains the luminance non-linear differential equation:

$$-\frac{dE}{dt} = \frac{\hbar c^{10}}{15360\pi G^2 E^2} \tag{53}$$

Solving (53) one then finds the following result for the energy of the black hole at time t:

$$E^3(t) = E^3(t)\Big|_{t=0} - \frac{\hbar c^{10}}{5120\pi G^2} t = E^3 - \frac{\hbar c^{10}}{5120\pi G^2} t \tag{54}$$

Next the retention-time (τ) or time-dislocation of the black hole is found by setting $E(t)$ equal to zero to yield:

$$t\Big|_{E(t)=0} = \tau = \frac{5120\pi G^2}{\hbar c^{10}} E^3 \tag{55}$$

Finally using (50) and V=$4\pi r^3/3$ in (55) the desired result (48) is obtained.

APPENDIX B
GRAVIDNESS CONSTANT DERIVATION

In this appendix we derive the gravidness constant (Φ) expression given by [5]:

$$\Phi = \sqrt[3]{4\pi\chi^{10}/81c^{12}}\ G = 1.8619 \text{ x } 10^{168}\ \ Pa.\sec^{4/3}/(N.m^6/\sec)^2 \tag{56}$$

where G is the gravitational constant, c is the speed of light in a vacuum and χ is the pace of dark in a black hole.

The derivation starts with the gravitational force (f_m) from the point mass M_R (viewed as a retention dark matter) at the center of a spherical black hole of radius r that acts on another point mass m_R (also viewed as a retention dark matter) at a radial distance r according to:

$$f_m = \frac{Gm_R M_R}{r^2} \tag{57}$$

Next a retention press γ_o (or pressure), see Table I, that acts on the retention mater (o) (a function of m_R as will be seen) is found by dividing (57) by the surface area of the sphere of radius r to yield:

$$\gamma_o = \frac{f_m}{4\pi r^2} = \frac{Gm_R M_R}{4\pi r^2 r^2} = \frac{Gm_R M_R}{(4\pi r^3/3)(3r)} = \frac{Gm_R M_R}{V \times 3r} \tag{58}$$

Next using $\chi = \tau/V$ in (58) one obtains:

$$\gamma_o = \frac{Gm_R M_R}{V \times 3r} = \frac{Gm_R M_R}{(\tau/\chi) \times \sqrt[3]{81\tau/4\pi\chi}} \tag{59}$$

Next simplifying (59) one finds:

$$\gamma_o = \sqrt[3]{4\pi\chi^4/81}\ G\frac{m_R M_R}{\tau^{4/3}} \tag{60}$$

Next substituting in the endurance equation $\upsilon = O\Pi$ the dark energy of retention $E_R = M_R c^2$ for the endurance υ and the pace of dark χ for the pace Π one finds:

$$\upsilon = O\Pi = E_R = M_R c^2 = O\chi \tag{61}$$

Using (61), including $m_R c^2 = o\chi$ in (60) one derives:

$$\gamma_o = \frac{\left(\sqrt[3]{4\pi\chi^{10}/81c^{12}}\ G\right)oO}{\tau^{4/3}} = \frac{\Phi oO}{\tau^{4/3}} \tag{62}$$

which implies (56) as desired.

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