

TOWARDS SUSTAINABLE FUTURE BY TRANSITION TO THE NEXT LEVEL CIVILISATION*

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Abstract Universal and rigorously derived concept of dynamic complexity shows that any system of interacting components, including society and civilisation, is a process of highly uneven development of its unreduced complexity. Modern civilisation state corresponds to the end of unfolding of a big complexity level. Such exhausted, totally “replete” structure cannot be sustainable in principle and shows instead increased instability, realising its replacement by a new kind of structure with either low or much higher complexity (degrading or progressive development branch respectively). Unrestricted sustainability can emerge only after transition to the next, superior level of civilisation complexity, which implies qualitative and unified changes in all aspects of life, including knowledge, production, social organisation, and infrastructure. These changes are specified by a rigorous analysis of underlying interaction processes. We propose mathematically rigorous description of unreduced civilisation complexity development, including universal criterion of progress. One obtains thus a working basis for the causally complete, objectively exact and reliable development science and futurology.

Keywords: Dynamic redundancy, revolution of complexity, criterion of progress, noosphere

1. Future quest in a high-tech epoch of change

Although permanent change is inherent in a planet, life, and civilisation existence, it has a highly uneven character of “punctuated equilibrium”, where larger periods of relatively smooth and slow evolution are interrupted by short periods of huge and abrupt, “revolutionary” change. Rapidly growing body of evidence shows that today the planetary life and civilisation on Earth are approaching very closely the next “bifurcation point” of development, or “generalised phase transition” [1], which is often referred to as “singularity” (though in terms of

* Report presented at the Symposium “The Future of Life and the Future of Our Civilisation” (Frankfurt am Main, 2–6 May 2005), <http://archive.future25.org/Symposium05/kirilyuk.pdf>

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particular technological aspects) and marks a global change of unprecedented scale (see e.g. [2–6]).

It is not surprising that the eternal humanity quest for its future gains today quickly growing importance and public interest [7] that can be surpassed only by the global change dynamics itself. A large part of this interest is driven by the traditional “fear of the (unknown) future”, essentially amplified now because of the clearly felt huge scale of emerging change and related uncertainty [3, 4]. An important aspect of the present epoch of change and its “future shock” [6] is due to the extraordinary growth of “high”, but *empirically* based technologies that can now, *for the first time in history*, modify the natural system complexity at its *full* depth, in quantum world (high-energy physics), biology (genetics), environment (industrial over-production) and human dimensions (psychology, media, information technologies), while remaining *effectively blind* at the level of genuine *understanding* of those real system dynamics [8–11]. Even the most serious attempts of future studies [7] fail to provide an *objectively* reliable, consistent and *unified* understanding of the emerging change meaning and dynamics, replacing it with empirical *interpolation of separate*, though important aspects of the current development, such as economic and technological tendencies, ecological system evolution, human behaviour, etc.

In this report we present the results of the *causally complete*, rigorous analysis of *unreduced* planet and civilisation dynamics based on the recently developed *universal concept of dynamic complexity* [1, 10–13] and providing the *unified*, many-sided picture, origin, dynamics, and purpose of the beginning *revolutionary* change [1, 14]. We start with an outline of the universal concept of complexity (Sec. 2) emerging from the *unreduced* solution to any *real* interaction problem (Sec. 2.1) and leading to the unified concept of system *development* as manifestation of the universal *symmetry (conservation)* of complexity (Sec. 2.2). In particular, the *sustainability transition* emerges today as inevitable and rather rapid “jump” to the next, *superior level of civilisation complexity* (Sec. 3) prepared by all its previous development and having only one alternative of irreversible destruction (Sec. 3.1). We then analyse various entangled aspects of life at the new complexity level and corresponding transition dynamics, including the qualitatively new kind of knowledge (Sec. 3.2), production (Sec. 3.3), social organisation (Sec. 3.4), and infrastructure (Sec. 3.5). Finally, we pay homage to Carl Sagan and Joseph Shklovsky by showing that discovery of other forms of life and intelligence is related to the new future for our own civilisation by the same universal concept of complexity (Sec. 4). We summarise the obtained results by concluding that the *causally complete* kind of knowledge of the universal science of complexity provides the *unique basis* for the truly scientific, *objectively reliable and intrinsically unified futurology* urgently needed especially at the modern critical point of development.

2. Universal science of complexity

2.1 Unreduced interaction dynamics

Any system dynamics and evolution are determined by the underlying interaction processes. The way of interaction analysis in usual science (including the scholar “science of complexity”) involves rough simplification (reduction) of real interaction within a version of perturbation theory (or “model”) that assumes effective *weakness* of interaction influence upon system configuration, which *kills* any possibility of essential *novelty emergence* from the beginning (with the evident fatal consequences for such approach ability to predict *any* nontrivial future). Subsequent play with analytical or computer models of thus heavily reduced reality, empirically postulated (rather than derived) object properties and arbitrarily adjusted parameters cannot replace the *intrinsic creativity* of unreduced interaction processes. It is no wonder that the *qualitative* knowledge extension to the *causally complete understanding* of real phenomena, provided by the universal science of complexity [1], is simply due to the proposed *non-simplified, truly “exact” analysis of unreduced, real interaction processes*. Its possibilities are confirmed by the obtained *consistent solutions* to various stagnating, “insoluble” problems [1], from those of fundamental physics (causal and unified extensions of quantum mechanics, relativity, cosmology) [9, 15, 16] and unreduced many-body interaction (true quantum chaos, quantum measurement, many-body coherence) [10, 17], to reliable basis for nanobiotechnology [10, 18], genomics [11] and medicine [19], theory of genuine (natural or artificial) intelligence and consciousness [20], the new kind of communication and information systems [21], and realistic sustainability concept [14].

Any real interaction can be represented by *existence equation*, generalising various models and simply fixing the initial system configuration in a “Hamiltonian” form (self-consistently confirmed later) [1, 10–13, 16, 20, 21]:

$$\left\{ \sum_{k=0}^N \left[h_k(q_k) + \sum_{l>k}^N V_{kl}(q_k, q_l) \right] \right\} \Psi(Q) = E\Psi(Q) , \quad (1)$$

where $h_k(q_k)$ is the “generalised Hamiltonian” for the k -th component, q_k is the degree(s) of freedom of the k -th component, $V_{kl}(q_k, q_l)$ is the (arbitrary) interaction potential between the k -th and l -th components, $\Psi(Q)$ is the system state-function, $Q \equiv \{q_0, q_1, \dots, q_N\}$, E is the generalised Hamiltonian eigenvalue, and summations include all (N) system components. It is convenient to represent the same equation in another form by separating certain degree(s) of freedom, e.g. $q_0 \equiv \xi$, that correspond to a naturally selected, usually “system-wide” entity, such as “embedding” configuration (system of coordinates) or

common “transmitting agent”:

$$\left\{ h_0(\xi) + \sum_{k=1}^N \left[h_k(q_k) + V_{0k}(\xi, q_k) + \sum_{l>k}^N V_{kl}(q_k, q_l) \right] \right\} \Psi(\xi, Q) = E\Psi(\xi, Q), \quad (2)$$

where now $Q \equiv \{q_1, \dots, q_N\}$ and $k, l \geq 1$.

We pass now to a “natural” problem expression in terms of free-component solutions for the “functional” degrees of freedom ($k \geq 1$):

$$h_k(q_k) \varphi_{kn_k}(q_k) = \varepsilon_{n_k} \varphi_{kn_k}(q_k), \quad (3)$$

$$\Psi(\xi, Q) = \sum_n \psi_n(\xi) \varphi_{1n_1}(q_1) \varphi_{2n_2}(q_2) \dots \varphi_{Nn_N}(q_N) \equiv \sum_n \psi_n(\xi) \Phi_n(Q), \quad (4)$$

where $\{\varepsilon_{n_k}\}$ are the eigenvalues and $\{\varphi_{kn_k}(q_k)\}$ eigenfunctions of the k -th component Hamiltonian $h_k(q_k)$, $n \equiv \{n_1, \dots, n_N\}$ runs through all eigenstate combinations, and $\Phi_n(Q) \equiv \varphi_{1n_1}(q_1) \varphi_{2n_2}(q_2) \dots \varphi_{Nn_N}(q_N)$ by definition. The system of equations for $\{\psi_n(\xi)\}$, equivalent to the starting existence equation (1)–(2) is obtained in a standard way [1, 10–13, 20, 21]:

$$\begin{aligned} [h_0(\xi) + V_{00}(\xi)] \psi_0(\xi) + \sum_n V_{0n}(\xi) \psi_n(\xi) &= \eta \psi_0(\xi) \\ [h_0(\xi) + V_{nn}(\xi)] \psi_n(\xi) + \sum_{n' \neq n} V_{nn'}(\xi) \psi_{n'}(\xi) &= \eta_n \psi_n(\xi) - V_{n0}(\xi) \psi_0(\xi), \end{aligned} \quad (5)$$

where $n, n' \neq 0$ (also below), $\eta \equiv \eta_0 = E - \varepsilon_0$, $\eta_n = E - \varepsilon_n$, $\varepsilon_n = \sum_k \varepsilon_{n_k}$,

$$V_{nn'}(\xi) = \sum_k \left[V_{k0}^{nn'}(\xi) + \sum_{l>k} V_{kl}^{nn'} \right], \quad (6)$$

$$V_{k0}^{nn'}(\xi) = \int_{\Omega_Q} dQ \Phi_n^*(Q) V_{k0}(q_k, \xi) \Phi_{n'}(Q), \quad (7)$$

$$V_{kl}^{nn'}(\xi) = \int_{\Omega_Q} dQ \Phi_n^*(Q) V_{kl}(q_k, q_l) \Phi_{n'}(Q), \quad (8)$$

and we have separated the equation for $\psi_0(\xi)$ describing the generalised “ground state” of the system elements, i. e. the state with minimum complexity (defined below). The obtained system of equations (5) expresses the same problem as the starting Eq. (2), but now in terms of intrinsic variables. Therefore it can be obtained for various starting models, including time-dependent and formally “nonlinear” ones.

The usual, perturbative approach starts from explicit simplification of the “nonintegrable” system (5) down to a “mean-field” approximation:

$$\left[h_0(\xi) + V_{nn}(\xi) + \tilde{V}_n(\xi) \right] \psi_n(\xi) = \eta_n \psi_n(\xi) , \quad (9)$$

where $|V_0(\xi)| < |\tilde{V}_n(\xi)| < \left| \sum_{n'} V_{nn'}(\xi) \right|$. General problem solution is then obtained as a linear or equivalent *superposition* of eigen-solutions of Eq. (9) similar to Eq. (4). If we want to avoid problem reduction, we can try to “solve” the unsolvable system (5) by expressing $\psi_n(\xi)$ through $\psi_0(\xi)$ from the equations for $\psi_n(\xi)$ using the standard Green function technique and then substituting the result into the equation for $\psi_0(\xi)$ [22, 23]. We are left then with only one, formally “integrable” equation for $\psi_0(\xi)$:

$$h_0(\xi) \psi_0(\xi) + V_{\text{eff}}(\xi; \eta) \psi_0(\xi) = \eta \psi_0(\xi) , \quad (10)$$

where the operator of *effective potential (EP)*, $V_{\text{eff}}(\xi; \eta)$, is obtained as

$$V_{\text{eff}}(\xi; \eta) = V_{00}(\xi) + \hat{V}(\xi; \eta) , \quad \hat{V}(\xi; \eta) \psi_0(\xi) = \int_{\Omega_\xi} d\xi' V(\xi, \xi'; \eta) \psi_0(\xi') , \quad (11)$$

$$V(\xi, \xi'; \eta) = \sum_{n,i} \frac{V_{0n}(\xi) \psi_{ni}^0(\xi) V_{n0}(\xi') \psi_{ni}^{0*}(\xi')}{\eta - \eta_{ni}^0 - \varepsilon_{n0}} , \quad \varepsilon_{n0} \equiv \varepsilon_n - \varepsilon_0 , \quad (12)$$

and $\{\psi_{ni}^0(\xi)\}$, $\{\eta_{ni}^0\}$ are complete sets of eigenfunctions and eigenvalues of a *truncated* system of equations:

$$\left[h_0(\xi) + V_{nn}(\xi) \right] \psi_n(\xi) + \sum_{n' \neq n} V_{nn'}(\xi) \psi_{n'}(\xi) = \eta_n \psi_n(\xi) . \quad (13)$$

The *unreduced*, truly complete *general solution* to a problem emerges now as a *dynamically probabilistic* sum of *redundant system realisations*, each of them equivalent to the whole usual “general solution” [1, 10–13, 17]:

$$\rho(\xi, Q) = \sum_{r=1}^{N_{\mathfrak{R}}} \oplus \rho_r(\xi, Q) , \quad (14)$$

where $\rho(\xi, Q)$ is the observed density, $\rho(\xi, Q) = |\Psi(\xi, Q)|^2$ for “wave-like” complexity levels and $\rho(\xi, Q) = \Psi(\xi, Q)$ for “particle-like” structures, index r enumerates system realisations, $N_{\mathfrak{R}}$ is realisation number (its maximum value is equal to the number of components, $N_{\mathfrak{R}} = N$), and the sign \oplus designates the special, dynamically probabilistic meaning of the sum (see below). The r -th

realisation state-function, $\Psi_r(\xi, Q)$, entering the unreduced general solution, Eq. (14), is obtained as

$$\Psi_r(\xi, Q) = \sum_i c_i^r [\Phi_0(Q) \psi_{0i}^r(\xi) + \sum_{n,i'} \frac{\Phi_n(Q) \psi_{ni'}^0(\xi) \int_{\Omega_\xi} d\xi' \psi_{ni'}^{0*}(\xi') V_{n0}(\xi') \psi_{0i}^r(\xi')}{\eta_i^r - \eta_{ni'}^0 - \varepsilon_{n0}}], \quad (15)$$

where $\{\psi_{0i}^r(\xi), \eta_i^r\}$ are eigen-solutions of the unreduced EP equation (10), and the r -th EP realisation takes the form:

$$V_{\text{eff}}(\xi; \eta_i^r) \psi_{0i}^r(\xi) = V_{00}(\xi) \psi_{0i}^r(\xi) + \sum_{n,i'} \frac{V_{0n}(\xi) \psi_{ni'}^0(\xi) \int_{\Omega_\xi} d\xi' \psi_{ni'}^{0*}(\xi') V_{n0}(\xi') \psi_{0i}^r(\xi')}{\eta_i^r - \eta_{ni'}^0 - \varepsilon_{n0}}. \quad (16)$$

Although the “effective” problem, Eqs. (10)–(16), is formally equivalent to its initial expression, Eqs. (1)–(5), it reveals *emerging interaction links*, in the form of EP dependence on the solutions to be found. It leads to a *new quality* of the *unreduced* solution (as compared to usual reduction of Eq. (9)): the former has *many* equally real, locally “complete” and therefore mutually *incompatible* solutions called (system) *realisations* [1, 10–13, 16, 17, 19–22]. This quality of the unreduced solution is designated as *dynamic multivaluedness (or redundancy)*. Standard theory tries to obtain problem solution in a “closed”, “exact” form and therefore resorts to perturbative reduction of the original EP (see e.g. [23]), thus inevitably *killing* real system multivaluedness, complexity and *creativity*.

Dynamic multivaluedness gives *dynamic, or causal, randomness*: multiple, but incompatible system realisations are forced, by the *same* driving interaction, to *permanently replace each other* in a *truly random* order (thus defined), which leads to the *unreduced* general solution in the form of (dynamically) *probabilistic sum* of Eq. (14). It implies that any quantity is *intrinsically unstable* and its value will *unpredictably* change (together with the system state) to another one, corresponding to the next, *randomly* chosen realisation. We obtain thus a *consistently derived* and *universally valid* property of *novelty emergence*, or intrinsic *creativity* of any real system, absent in any its usual, dynamically single-valued model. We obtain also purely *dynamic* definition of realisation emergence *event* and its *probability*:

$$\alpha_r(N_r) = \frac{N_r}{N_{\mathfrak{R}}} \left(N_r = 1, \dots, N_{\mathfrak{R}}; \sum_r N_r = N_{\mathfrak{R}} \right), \quad \sum_r \alpha_r = 1, \quad (17)$$

where α_r is the probability of r -th actually observed realisation that contains N_r elementary realisations ($N_r = 1$ for each of these).

The obtained picture of real system dynamics can be summarised by the *universal* definition of unreduced *dynamic complexity*, C , as any growing function of realisation number, $N_{\mathfrak{R}}$, or rate of change, equal to zero for the (unrealistic) case of only one realisation: $C = C(N_{\mathfrak{R}})$, $dC/dN_{\mathfrak{R}} > 0$, $C(1) = 0$. Major examples are provided by $C(N_{\mathfrak{R}}) = C_0 \ln N_{\mathfrak{R}}$, generalised energy/mass (temporal rate of realisation change), and momentum (spatial rate of realisation emergence) [1, 10–13, 15, 16, 20, 21]. Since dynamic redundance ($N_{\mathfrak{R}} > 1$) is at the origin of dynamic randomness, our dynamic complexity includes universally defined *chaoticity*. Whereas *all* real systems and processes are dynamically complex and (internally) chaotic ($N_{\mathfrak{R}} > 1$, $C > 0$), their “models” in usual science, including its versions of “complexity” and “chaoticity” (cf. [24, 25]), are invariably produced by artificial (and *biggest* possible) reduction of multivalued dynamics to the unrealistic case of *single* realisation, *zero* complexity, *absence* of *genuine* chaos, *any* real, *intrinsic* change and related *time flow*. This *dynamically single-valued*, or *unitary*, science embracing the whole body of scholar knowledge is a *zero-dimensional (point-like) projection* of multivalued world dynamics, which explains both relative (but never complete!) “success” of unitary science in its *formal* description of the *lowest* complexity levels (\simeq “fundamental physics”) and its explicit failure to understand higher-level dynamics and unreduced complexity features (emergence, time, chaos, etc.) [1, 10–13, 16, 20].

Unreduced dynamic complexity thus defined includes other major features, such as essential (or dynamic) nonlinearity, dynamic entanglement, and probabilistic dynamic fractality. *Essential nonlinearity* designates *dynamically* emerging feedback links, described by EP dependence on the eigenvalues to be found (Eqs. (10)–(12),(16)). It is only incorrectly modelled by usual, mechanistic “nonlinearity” of the unitary theory and appears in interaction problems with a formally linear existence equation (1)–(2), such as quantum chaos [17, 22]. *Dynamic entanglement* is *physically real* mixing of interacting components reflected by the dynamically weighted products of functions depending on different degrees of freedom in Eq. (15). Both essential nonlinearity and dynamic entanglement are amplified due to multi-level realisation branching giving *probabilistic dynamical fractal*. It is obtained by application of the same EP method to solution of higher-level, (ever more) truncated systems of equations, starting from Eqs. (13) [1, 19, 20]. Dynamical fractal is different from usual, dynamically single-valued fractals by its *permanently, chaotically changing realisations* at *each* level of fractal hierarchy, which leads to the important property of *dynamic (autonomous) adaptability* and includes *any* kind of emerging structure.

Quantitative expression of dynamic adaptability takes the form of *huge efficiency growth* of unreduced many-body interaction with respect to its unitary models. The unreduced system efficiency P_{real} is determined by the link combination number in the multivalued fractal hierarchy [10, 11, 18, 20, 21]:

$$P_{\text{real}} \propto N! \simeq \sqrt{2\pi N} (N/e)^N \sim N^N \propto C, \quad (18)$$

where the number of links N is very large itself. Unitary (regular, sequential) dynamic efficiency grows only as $N^\beta \ll P_{\text{real}}$ ($\beta \sim 1$). It is this huge efficiency advantage that explains the such “magic” *qualities* in higher-complexity systems (very large N) as *life, intelligence, consciousness, and sustainability*. Obtained at the expense of *irreducible dynamic randomness*, these *causally derived* properties are *indispensable* for the *correct* analysis of planetary life and civilisation dynamics.

Further development of the universal concept of complexity includes unified classification of all observed dynamic regimes and transitions between them [1, 10, 12, 21]. The limiting regime of *uniform, or global, chaos* is obtained for *comparable* interaction parameters (characteristic frequencies). If they differ essentially, one gets the opposite case of *dynamically multivalued self-organisation, or self-organised criticality (SOC)*, where rigid, low-frequency components *confine* a fractal hierarchy of similar, but *chaotically changing* realisations of high-frequency components. This case *unifies* the *essentially extended*, realistic and multivalued (internally chaotic) versions of usual, dynamically single-valued “self-organisation” (that in reality does *not* describe any *new, explicit structure emergence*), SOC, fractality, “synchronisation”, “chaos control”, and “mode locking”. We obtain also a rigorously derived and universal *criterion* of transition from SOC to the uniform chaos, occurring around the main frequency resonance, which reveals the true meaning of the “well-known” phenomenon of resonance [1, 10, 12, 21]. When the frequency ratio, or “chaoticity parameter”, grows from small values for a quasi-regular SOC regime to unity in the global chaos case, system behaviour follows a gradual (though uneven) change towards ever less ordered patterns, reflecting the observed diversity of dynamical structures.

2.2 Universal symmetry of complexity and evolution law

The major feature of *explicit structure creation* includes emerging elements of *dynamically discrete, or quantized, space* (structure) and *irreversibly flowing time* (event, evolution). Space element, Δx , is given by realisation eigenvalue separation, $\Delta_r \eta_i^r$, for the unreduced EP equation (10): $\Delta x = \Delta_r \eta_i^r$. Time element, Δt , determines the duration of the *event* of space element emergence (or realisation change) and can be estimated as $\Delta t = \Delta x/v_0$, where v_0 is the signal propagation speed in the component structure. A universal *integral* measure of complexity is given by *action*, \mathcal{A} , whose increment is *independently*

proportional to Δx and Δt [1, 10, 13, 20]: $\Delta \mathcal{A} = -E\Delta t + p\Delta x$, where the coefficients E and p are identified as generalised system *energy (mass)* and *momentum*. They represent thus universal *differential* measures of complexity:

$$E = -\left.\frac{\Delta \mathcal{A}}{\Delta t}\right|_{x=\text{const}}, \quad p = \left.\frac{\Delta \mathcal{A}}{\Delta x}\right|_{t=\text{const}}. \quad (19)$$

Due to its irreversible (chaotic) character, any real interaction process can be described as *transformation and conservation (symmetry) of complexity*, where the potential (hidden) form of complexity, or *dynamic information* I , is transformed into the unfolded (explicit) form of *dynamic entropy* S , so that their sum, the *total system complexity* $C = I + S$, remains *unchanged*, $\Delta C = 0$, $\Delta I = -\Delta S$. Although both dynamic information and entropy are expressed in units of action, the latter corresponds rather to dynamic information decreasing during system complexity development:

$$\Delta I = \Delta \mathcal{A} = -\Delta S < 0. \quad (20)$$

Dividing Eq. (20) by $\Delta t|_{x=\text{const}}$, we obtain differential expression of the symmetry (conservation) of complexity and *universal dynamic/evolution equation* in the form of generalised Hamilton-Jacobi equation:

$$\left.\frac{\Delta \mathcal{A}}{\Delta t}\right|_{x=\text{const}} + H\left(x, \left.\frac{\Delta \mathcal{A}}{\Delta x}\right|_{t=\text{const}}, t\right) = 0, \quad (21)$$

where the *Hamiltonian*, $H = H(x, p, t)$, expresses the differential complexity-entropy, $H = (\Delta S/\Delta t)|_{x=\text{const}}$. The *dynamic quantization* procedure relates complexity-action increment to that of the *generalised wavefunction (or distribution function)* Ψ , describing specific, “disentangled” system state *during* its chaotic jumps between realisations, and transforms Eq. (21) to the *universal Schrödinger equation* [1, 10, 13, 20]:

$$\mathcal{A}_0 \frac{\Delta \Psi}{\Delta t} = \hat{H}\left(x, \frac{\Delta}{\Delta x}, t\right) \Psi, \quad (22)$$

where \mathcal{A}_0 is a characteristic action value by modulus (equal to Planck’s constant at the lowest, quantum levels of complexity) and the Hamiltonian operator, $\hat{H}(x, p, t)$, is obtained from the Hamiltonian $H(x, p, t)$ by causal quantization. While the symmetry of complexity unifies and extends *all* (correct) laws and “principles” of the unitary science, the Hamilton-Schrödinger equations, Eqs. (21)–(22), connected by causal quantization, unify and extend all particular (model) dynamic equations [1, 10, 13, 20].

The key implication of the symmetry of complexity is that it provides the *universal meaning, dynamics, and measure of any system existence, evolution, and progress*, in the form of *complexity development* (internal transformation

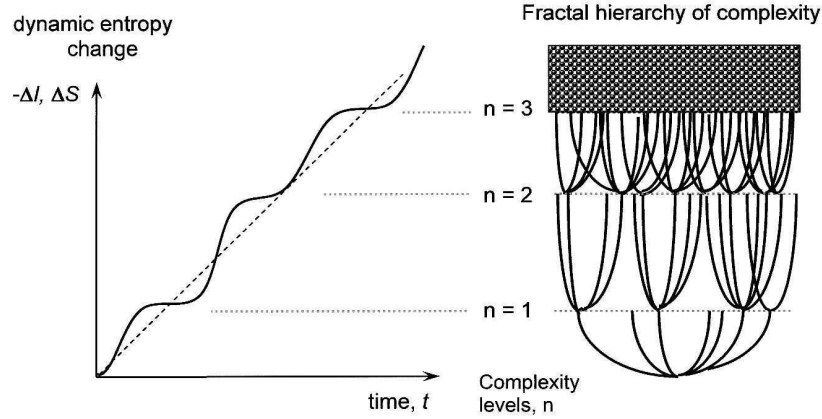


Figure 1. Scheme of universal system development by transformation of its (decreasing) complexity-information (I) into (increasing) complexity-entropy (S).

from dynamic information into dynamic entropy) as a result of its *conservation*, which gives a well-specified solution to such “difficult” and “ambiguous” problems as purpose of history, meaning of life, objective understanding of the future, etc. It is important that due to the internal chaoticity of *any* real (even externally “regular”) system, every structure emergence process corresponds to *growth of complexity-entropy, or chaoticity*, which resolves the long-standing contradiction between the (generalised) entropy growth law and visible order increase in structure creation processes. Another complexity development feature is that due to the *unreduced* interaction dynamics (“everything interacts with everything”) it has a *dynamically discrete*, step-wise character [1]. The hierarchic structure creation and complexity development process is shown schematically in Fig. 1. A sufficiently big step of complexity-entropy growth can be described as *generalised phase transition* to the superior level of complexity with a *qualitatively* different kind of structure and dynamics.

Let us consider complexity development stages in more detail, Fig. 2, in view of further application to (modern) *civilisation development*. First of all, we can rigorously define periods of *progress* (accelerated complexity-entropy growth) and *decline* (relative stagnation of complexity development) constituting respectively the steep rise and plateau (saturation) of each discrete step of system complexity development. Whereas entropy S can only grow for both progress and decline, $H = \partial S / \partial t = -\partial A / \partial t = E > 0$, *acceleration* of dynamic entropy growth, or the *power of development*, $W = \partial H / \partial t = \partial^2 S / \partial t^2$, is *positive for progress* (creative development), $W = \partial^2 S / \partial t^2 > 0$, and *negative for decline* (decay, degradation), $W = \partial^2 S / \partial t^2 < 0$. Points of *inflection* of the entropy growth curve, $\partial H / \partial t = \partial^2 S / \partial t^2 = 0$, separate adjacent periods

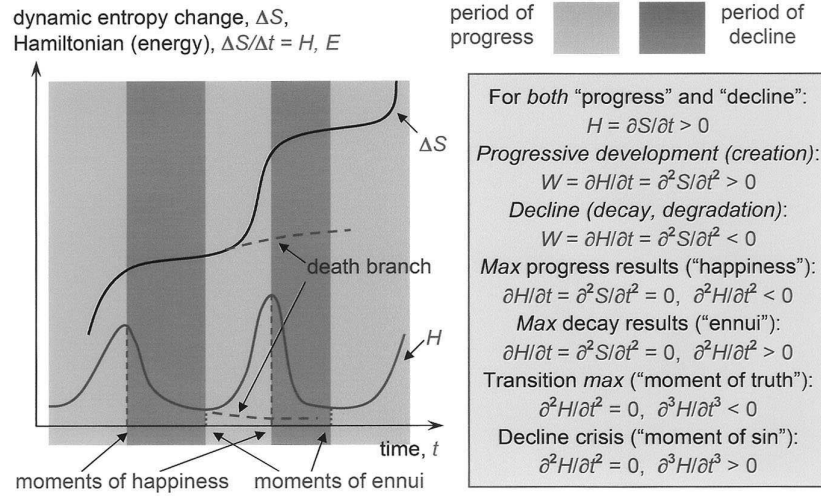


Figure 2. Periods of system progress, decline, and transitions between them rigorously specified in terms of dynamic entropy change $\Delta S = -\Delta A$, generalised Hamiltonian $H = \partial S/\partial t$, or energy $E = -\partial A/\partial t = H$, and higher complexity-entropy/action derivatives.

of progress and decline and correspond, at the same time, to maximum (final) progress results ("point of *happiness*"), $\partial H/\partial t = 0$, $\partial^2 H/\partial t^2 < 0$, and maximum decay ("point of *sadness/ennui*"), $\partial H/\partial t = 0$, $\partial^2 H/\partial t^2 > 0$. One can also define the moment of objective *culmination* of a step-wise complexity jump, progressive transition climax, or the *moment of truth* as the point of inflection of rising $H(t)$ curve, $\partial^2 H/\partial t^2 = 0$, $\partial^3 H/\partial t^3 < 0$, after which progressive complexity-entropy upgrade becomes eminent and irreversible. In a similar way, a critical inflection point within the period of decline, or the *moment of sin*, $\partial^2 H/\partial t^2 = 0$, $\partial^3 H/\partial t^3 < 0$, marks the definite establishment of stagnation and decay. Whereas the points of happiness and sadness separate the periods of progress and decline as such, the moments of truth and sin, situated within (around the middle of) progress and decline periods, separate the intervals of maximum *subjective* perception of their *results* within the system. We can see that such "vague" and "inexact" notions as happiness, sorrow, and "psychological crises" between them are provided with unambiguous and *rigorous* definitions within the *unreduced* science of complexity (one should not forget, of course, the whole underlying *interaction analysis*, Sec. 2.1) [1].

Note that *partial* time derivatives in the above definitions of system evolution stages correspond to *external* observation over system development from a (generalised) *reference (rest) frame*. If now an observer is situated *within* the developing system, he will see similar development stages, but appearing on a different, "internal" time scale and determined by the respective *total* time

derivatives, such as (generalised) *Lagrangian* $L = -dS/dt$ [1, 13]. The difference between those two time flows constitutes the *causal, complex-dynamic* basis of *generalised special relativity* effects emerging at *all* levels of dynamics, from quantum particle motion to civilisation development [1].

Note finally that progressive transition to superior level of complexity can be replaced by another development branch, the “death branch” of purely destructive degradation of existing system structures, without qualitatively new, “progressive” structure emergence (Fig. 2). This scenario becomes real when the stock of complexity-information of the driving interaction process is exhausted or when further complexity development is seriously blocked in a deep impasse (“wrong way”). In the first case one deals with the generalised complex-dynamical system *death*, which is now *rigorously* defined [1] and inevitable (for a closed system) because of the finite quantity of dynamic information, whereas in the second case one has a *bifurcation of development*, where *both* progressive transition to a higher complexity level *and* destructive degradation can happen with certain, dynamically determined *probabilities* (see Eq. (17)).

3. Sustainability transition as the revolution of complexity

3.1 Modern bifurcation of civilisation development: Causal Apocalypse now

We can apply now the unified development theory from the previous section to modern civilisation development, including its recent past and forthcoming future. Observed features analysis shows that modern civilisation, suitably represented by its advanced, “locomotive” parts, is situated in the vicinity of the last “point of sadness (ennui)” (Fig. 2) and maybe already slightly outside of it in the direction of a probable complexity-growth step (but well before its “moment of truth”). That modern world position at the beginning of emerging inflection of $H(t)$ curve after its deep minimum (development saturation) is supported by a variety of clearly observed “ends”, such as End of History, Science, Art, Religion, etc. (e.g. [4, 5, 25, 26]), appearing as a stable absence of true novelty emergence (events) and pronounced degradation of existing structures [1]. In view of the close “death branch” beginning (Fig. 2), we get to the *great bifurcation of development* into the death branch of pure destruction and transition to a superior level of civilisation complexity. Taking into account the huge, *ultimately complete* scale of all “ends” involved, we can say that we deal here with the rigorously substantiated version of Apocalyptic “End of the World”, Doomsday, etc. appearing in reality as that major development bifurcation into two main branches of “(system) death” and “(new) life”, where the latter emerges by transition to a *qualitatively* higher complexity level of the *whole* civilisation dynamics [1, 14]. The latter change can also be designated as *Revolution of Complexity*, or *sustainability transition* (see Secs. 3.2–4).

Particular, *practically important* results of this *rigorously derived* development concept are specified below (Secs. 3.2–3.5). The *causally complete* nature of the underlying interaction analysis (Sec. 2) leaves practically no hope that the observed bifurcational, “Apocalyptic” state of modern civilisation can be avoided by usual, “smooth” amelioration of life conditions, often subjectively privileged by prosperous, “leading” civilisation components (e.g. within standard, “protective” ecological actions, Secs. 3.3–3.5). Dynamic entropy growth *cannot* stop, but the failure to follow the strongly growing, *qualitative* development branch at the *current specific moment* will *inevitably* leave civilisation on the death branch of irreversible destruction. We see that the *causally complete understanding* of *unreduced, unified* civilisation dynamics within the universal science of complexity provides the unique and *vitaly* important basis for the *scientifically exact, rigorous futurology* (Sec. 4).

3.2 The last scientific revolution

It is convenient to start our more detailed analysis of sustainability transition and the resulting superior complexity level with the description of respective changes in the *system of knowledge*, the more so that the new level of complexity is characterised by a much greater, *decisive* role of a *new kind* of ordered, “scientific” knowledge in the whole civilisation development.

Unitary, dynamically single-valued science approach dominating today (and including *zero-complexity imitations* of “complexity” and “chaoticity”) is unable to provide consistent understanding of *any* real, *dynamically multivalued* system behaviour (Sec. 2.1), which becomes especially evident for higher-complexity cases (strong interaction, living organisms, intelligent behaviour, social, ecological systems, etc.). At the same time, the *purely empirical*, technological civilisation power has attained today, *for the first time in history*, the critical threshold of the *full depth* of *any* real system complexity, from quantum world (elementary particles and fields) to the structure of life (genome and related cell processes, ecosystems, brain processes). This *effectively blind* but quantitatively powerful, “stupid” technology uses the conventional trial-and-error empiricism to *strongly modify* systems whose real dynamic complexity exceeds by far the possibilities of zero-dimensional “models” of unitary science (they are still shamelessly promoted for “simulation” of ultimately complex behaviour of economic, social, and ecological systems!). The resulting contradiction creates *real and unprecedented dangers* at *all* complexity levels, from particle physics to genetics and ecology, which are *not* due to the “risk of science/technology” in general (cf. [4]), but due to the *specific, artificial limitation* of the *unitary* science paradigm and results [1].

Transition to another, *causally complete* kind of knowledge is therefore *urgently needed* today and the failure to perform it will *inevitably* lead to de-

structive consequences, as the probability of successful empirical “guess” or unitary “simulation” of the huge power of real system complexity (see Eq. (18)) is very close to zero. It is clear that the new, *practically efficient* knowledge can only be based on the detailed understanding of the *unreduced* interaction process underlying any real system dynamics, which leads directly to the dynamic multivaluedness paradigm [17, 22] and universal science of complexity (Sec. 2) [1]. Being thus indispensable for real problem solution already at the existing level of development, the unreduced science of complexity becomes *unified and unique basis* for realisation of sustainability transition and resulting superior level of civilisation complexity. It is this, ultimately complete and realistic kind of knowledge that can form a practical basis for the “*society based on knowledge*” at the superior complexity level. It is clear also that imitations of the unitary “science of complexity” can only be harmful because of their *biggest possible*, dynamically single-valued simplification of real system dynamics. Practical *organisation of science* should follow the corresponding *qualitative* change towards a much more liberal, decentralised and adaptable system with *emergent* structure [1, 8, 10].

The essential extension of science content, role, and organisation constitutes thus a major part of the forthcoming Revolution of Complexity. The latter can be considered, in this sense, as the *last* “scientific revolution” of the kind described by Thomas Kuhn [27], since the unreduced science of complexity realises the *intrinsically complete, permanently creative* kind of knowledge, devoid of *antagonistic* fight between “paradigms” and people (which originates, as it becomes clear now, from the *specific, strongly imitative* nature of the *unitary, “positivistic”* science, rather than scientific knowledge in general).

3.3 Complexity-increasing production: Growth without destruction and the universal criterion of progress

Modern industrial production leads to evident and rapid degradation of environment and life quality, and therefore *cannot* provide *long-term progress*. As such progress is a *necessary* condition for planetary civilisation *existence*, one is brought to the idea of *sustainable development*. However, the self-protective approach of the current system tends to the tacit assumption that sustainability can be attained by gradual “purification” of production methods, without major, qualitative change of the dominating industrial mode as such [3, 28–30].

The unreduced interaction analysis of the universal science of complexity rigorously shows, first of all, that the latter hope is totally vain and sustainability *cannot* be attained within the current way of production, irrespective of the details, simply because it is invariably reduced to *destruction* of complexity, i.e. transformation of higher-complexity structures into lower-complexity ones [1, 14]. We also use here the rigorous and universal *definition and criterion*

of progress as optimal growth of complexity-entropy according to the system development curve (Figs. 1, 2). At the modern moment of maximum/ending stagnation (Sec. 3.1) civilisation progress can only proceed by self-amplifying complexity-entropy growth towards its superior level, without which the system will inevitably follow the death branch of catastrophic destruction.

This criterion of progress can be provided with exact formulation by recalling that transition to superior complexity level acquires a well-defined character after the “moment of truth”, or Hamiltonian/Lagrangian inflexion point, where the second time derivative of Hamiltonian/Lagrangian changes sign from plus to minus (Fig. 2). The ensuing criterion of progress (in its “internal” version expressed by total time derivatives) is

$$\frac{d^3 S}{dt^3} < 0, \text{ or } \frac{d^2 L}{dt^2} > 0, \quad (23)$$

where $L = -dS/dt$ is the system Lagrangian (Sec. 2.2) [1, 13]. Note that progressive *development* thus defined overlaps with both *periods* of progress and decline defined before (Sec. 2.2) and includes their “best” parts of *essential*, self-amplifying growth of complexity-entropy (even though its *rate*, dS/dt , decreases within the beginning period of decline). A *narrow* understanding of “definite” progress would include only progressive development part *within* the period progress, $d^2 L/dt^2 > 0$, $dL/dt < 0$, while the *whole* progressive development can also be designated by the condition $dS/dt \gg (dS/dt)_{\text{death}}$, where $(dS/dt)_{\text{death}}$ is the maximum entropy growth rate for the death branch (or its minimum value for the decline period).

Impossibility of sustainable development at the current complexity level follows from the generalised entropy growth law: any, even “ecologically correct” production of the current, industrial way can at best only minimise the inherent complexity destruction (entropy growth), but can never reduce this high enough minimum to values around zero. But the *same* entropy growth law underlies *genuine sustainability* at the *superior* complexity level, after the key transition to *complexity-increasing production* methods and technologies. That’s why it is called *sustainability transition* (Sec. 3.1). Indeed, in this case the inevitable complexity-entropy growth takes the form of intrinsically *progressive* creation of *ever more complex* structures (“period of progress” in Fig. 2), as opposed to a “period of decline” where entropy growth is dominated by destruction of previously created structures. It means that the criterion of progressive development, Eq. (23), remains practically *always valid* after the sustainability transition, and very short periods of formal “decline” are determined by decreasing, but *high* rate of entropy growth, $d^2 S/dt^2 < 0$, $dS/dt \gg (dS/dt)_{\text{death}}$, *within* progressive development, $d^3 S/dt^3 < 0$.

Realistic basis for production sustainability is due to *complexity creation* and *complexity-based* kind of technology, where the unreduced complexity-

entropy of *all* production results should be *essentially greater*, than that of the initial system configuration. An important example is provided by *irreducibly complex dynamics* of *realistic* sources of pure energy from *nuclear fusion reactions* (in its both “hot”, less sustainable and “cold”, more prospective versions), demonstrating the *unified, multi-level* structure of the Complexity Revolution.

Contrary to popular ideas about industrial production, its complexity-killing features are *not* due to *massive* use of man-made *machines* as such, but due to a certain, “unitary” way of using certain kind of machinery. Those particular, complexity-reducing tools and methods are closely related to *specific organisation* of usual industrial production characterised by explicitly *reduced dynamic complexity* (tendencies of unification, regularity, etc.). Correspondingly, the new, intrinsically sustainable production at the superior complexity level should be organised in a qualitatively different way dominated by the permanently developing, hierarchic, distributed “ecosystem” of *dynamically* connected, generally small units of *individually* structured production (they certainly can form *loose, dynamic* associations at higher ecosystem levels that will replace modern inefficient and decadent corporate monsters). It becomes evident that such complexity-increasing production organisation and content is inseparable from the accompanying *personal progress* of human complexity, i.e. the level of *consciousness* [20] (see also Secs. 3.4–4).

3.4 From unitary to harmonical social structure: Emerging order without government

Due to *holistic* dynamics of unreduced interaction [1], sustainability transition involves a qualitative change of *social structure and dynamics*. In order to specify this change, we show first that social structure of the current complexity level, including *all* known (modern and ancient) social and political regimes, constitutes a single kind of order called *Unitary System* [8, 14]. The term “unitary” (behaviour) has a *mathematically exact* interpretation in the universal science of complexity (Sec. 2.1) of “dynamically single-valued” and therefore *qualitatively uniform*, regular, zero-complexity, “effectively one-dimensional”, sequential (dynamics, evolution, etc.). Although any social system cannot be strictly unitary in this rigorous sense, the Unitary System of social structure is close to it because it is a rigid, centralised system of *preferably* regular (controlled) dynamics that can change essentially (usually just to its another *version*) only by way of *destructive* “revolution”. Such unitary social order includes *all* previously known social systems (usually considered to be very different), such as any totalitarian, democratic, or meritocratic political structure. Correspondingly, social structure resulting from sustainability transition should differ *qualitatively* from *any* of these, including allegedly the “best possible system” of modern democracy (as well as any meritocracy).

We call the social organisation type of that qualitatively superior, higher-complexity level *Harmonical System* [8, 14]. Contrary to any version of Unitary System, the Harmonical System has the *emergent*, intrinsically *creative*, permanently developing kind of social order whose origin resembles that of the free market *economical* structure, but encompasses now the whole civilisation structure. It is dominated by a system of interacting, independent units similar to those of the complexity-increasing production structure (Sec. 3.3), but including *all* spheres of activity. *Global* system dynamics is monitored by the *same* kind of *independent*, interactive units, very different from any unitary “government” (or even “non-government organisations”, NGO) in that they are *forced* to produce *explicitly useful* services, *compete* with each other and bear *individual, well-specified responsibility* for their results (similar to *small enterprises* within market economy). Any loose associations of such units, as well as “high councils”, may exist, but only as far as they are needed and without any formal power *exceeding* that of *emergent* actions of independent enterprises (including various “forces of order”).

Note that some seeds of such emergent social order may exist within modern “developed” version of unitary democracy, but any its most “liberal” version or component (like NGO) is severely limited by the *imposed* rigid, formal (“obligatory”), centralised power ensuring the status of unrealistic dream for any true liberty (= unreduced, natural, progressive development). The Harmonical System of *emergent order* realises what is considered as impossible by the conventional, unitary democracy, a *qualitatively higher* kind of liberty and “democratic” order obtained *without* any “majority vote” (always manipulated by “minority games”). This “miracle” becomes possible only at the described superior level of civilisation complexity realised by unreduced interaction of independent units pervading *all* spheres of activity (Secs. 3.2–3.5).

The harmonical social order has *intrinsically progressive*, or *sustainable* structure due to *permanent*, non-antagonistic and *essential* complexity development in the sense of our rigorously defined progress (Sec. 3.3). The very character of civilisation development changes *forever* after sustainability transition, from painful alternation of “stagnation” and “revolution” periods to the *permanent unreduced creativity* (that could also be described as “distributed complexity revolution”). By contrast, the modern “developed” unitary democracy, apparently repeating respective periods of ancient civilisation development, represents not the “best possible” social system (according to its own praise, thoroughly maintained by self-privileged “powers that be”), but rather the *definite end*, generalised complex-dynamical *death-equilibrium* [1] of the Unitary System as such, in *any* its version, followed inevitably by either sustainability transition to a superior complexity level of Harmonical System, or irreversibly destructive death branch (Sec. 3.1, Fig. 2). In fact, this “final”, decadent, *equilibrium* character of unitary democracy, clearly seen today, does result

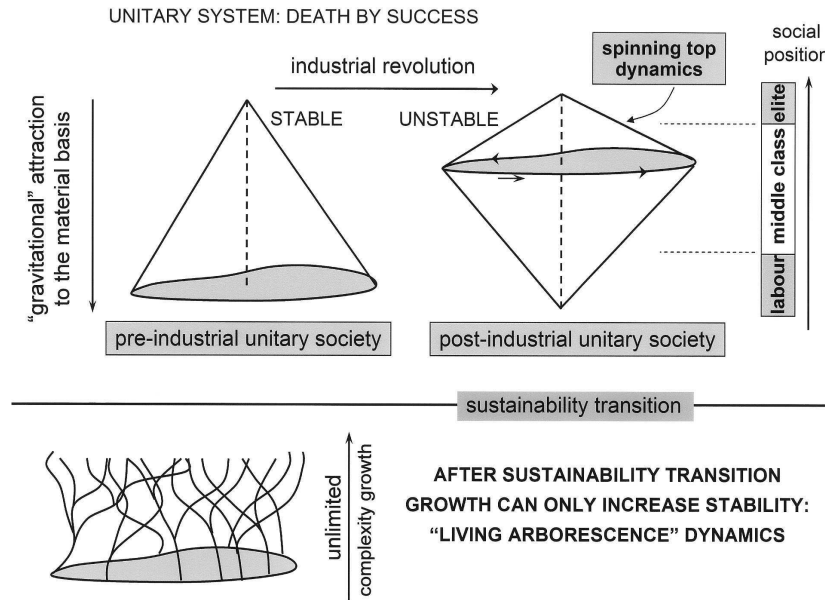


Figure 3. Schematic representation of the critical instability of the developed (modern) Unitary System followed by globally stable structure of the Harmonical System.

from its *highest possible* development of the *unitary* kind of social structure that does not need to be, however, its *only* possible kind and actually represents the *simplest*, basically “tribal” (imposed, compulsion-based) kind of social order. The latter becomes insufficient today just *due to* the ultimately high development of the industrial Unitary System creating self-amplifying, and therefore *insurmountable*, dynamic barriers to its own progress.

The origin of modern, *inevitably* emerging *critical instability* of the *developed*, industrial Unitary System can be conveniently demonstrated with the help of schematic presentation of its social structure dynamics, Fig. 3. Pre-industrial, “traditional” Unitary System can be presented by a pyramidal structure stably resting on its large base of labour classes due to the “gravitational attraction” towards material production/consumption. In the post-industrial society, the same unitary pyramid acquires a strongly deformed, “inverse” (upside-down) configuration due to huge productivity growth as a result of technological revolutions. But since the material “gravity” force preserves the same downward orientation, that monstrous construction with now *quantitatively* dominating non-productive “elitary layers” becomes critically unstable and can preserve its normal, “vertical” position only due to the high-speed spinning motion of production-consumption cycles (similar to spinning top stability). However, this *artificially* maintained, *relative* stability has its limits, especially due to

basically *dissipative*, chaotic dynamics of any social system, which means that the unitary “whipping top” *will* fall in a destructive manner within a reasonably small time period (like few tens of years). By contrast, the harmonical social structure, shown at the bottom of Fig. 3 as a distributed arborescence, does not possess any global, destructive instability: instead, its *local, creative* instability provides sustainable progress.

Harmonical System represents thus the *unique* way of *any* further progress, and in order to realise it one should have a *realistic* sustainability transition. Such realistic transformation takes the form of generalised “phase transition” of *higher order*, where the *qualitatively big* structure change occurs not in the whole system volume simultaneously (as in “first-order transitions”), but starts with *small, growing* “seeds” of the “new phase”, which strongly facilitates the transition process. The dynamics of both sustainability transition and resulting Harmonical System can be properly understood and monitored only with the help of the *causally complete* understanding of the unreduced science of complexity (Sec. 3.2), which emphasises once more the high role of this *new kind of knowledge* in the forthcoming development stages.

3.5 New settlement and infrastructure

It is not surprising that civilisation infrastructure at the unitary level of development, including the dynamical structure of settlements, production and communications, reflects major features of the Unitary System, such as high centralisation, rigidity, development rather by destruction, pronounced tendency towards mechanistic simplification, and the resulting urban decadence in the phase of “developed” unitarity. Indeed, there is the evident degradation to over-simplified, “squared” and “smooth” configurations and operation modes in modern infrastructures, despite *much greater* practical possibilities for their diversity in the developed industrial technology. Whereas this effective complexity destruction is a part of the emerging “death” tendency of the ending level of development (Sec. 3.1), it is equally evident that the forthcoming harmonical level of complexity should be based on a *qualitatively different* type of settlement with a distributed, decentralised, and *progressively developing* structure (see Sec. 3.3 for the universal progress definition).

This another kind of settlement can only be realised as a man-made structure intrinsically and strongly *submerged* into the “natural environment” and *constructively* interacting with it, so as to *increase* complexity-entropy of the whole system. Such sustainable civilisation structure can be described as omnipresent, man-controlled, progressively evolving *forest*, or “natural park”, with submerged, *distributed* settlement, production and transport infrastructure, which excludes anything closely resembling modern cities, towns, and villages, with their *centralised* structure tendency. Transport networks in such

“living” infrastructure will be well hidden among other, more “natural” and complexity-bearing elements, contrary to their domination in the unitary infrastructure. The omnipresent and intense *creation* of “natural”, i.e. *complex-dynamic* environment, rather than its unitary “protection” (inevitably failing), constitutes the essence of complexity-increasing settlement and infrastructure dynamics. The latter correlates directly with the complexity-increasing production mode (Sec. 3.3) because it can be considered as a specific sphere of production with strong involvement of “human dimensions”.

Progressively growing dynamic complexity of this new kind of “natural” but totally man-controlled environment and infrastructure has a positive reverse influence upon dynamic complexity of man’s consciousness and life style. This positive feedback loop in the man-environment system leads to a dynamic complexity boost that can be described as *Supernature* at the level of “environment” structure and as (*realistically* specified) *Noosphere* at the level of human consciousness (including its individual and “social” aspects). Supernature can have the same or even *much greater* dynamic complexity than the “wild” nature (contrary to any “protected” environment of the unitary ecology), while Noosphere emerges as inseparable, fractally structured, and progressively evolving *dynamic entanglement* (Sec. 2.1) of (superior) consciousness and Supernature. In this sense one can say that nature, in its new form of Supernature, should become again man’s home, at this superior, harmonical (complexity-increasing) level of their interaction.

4. Cosmic intelligence, future, and complexity: Concluding remarks

Summarising the universal science of complexity [1, 8–22] (Sec. 2) and its application to the problems of modern civilisation development (Sec. 3), one should emphasize *intrinsic unification* of *causally specified* meaning and purpose of life, future, progress, nature, cosmos, and our destiny within the *universal symmetry of complexity* (Sec. 2.2), thus constituting the *practical guiding principle for civilisation development*.

Application of the unreduced science of complexity to the problem of cosmic life and extraterrestrial civilisations shows that life realisations in cosmos should be *multiple and diverse*, while unique civilisation existence is highly improbable: it follows already from the basic property of *dynamic multivaluedness* (Sec. 2.1). The *complexity correspondence principle* following directly from the universal symmetry of complexity [1, 10] provides a *rigorous* basis for the statement that real, constructive contact between different civilisations is possible if they have similar levels of unreduced complexity (consciousness) that should certainly be high enough for the contact at a cosmic scale. Therefore the complexity/consciousness upgrade of a particular civilisation of the planet

Earth, which is necessary for its own development (Sec. 3), can be a much more efficient way of establishing contact with extraterrestrial intelligence than usually applied technical means (“find an alien within yourself”).

There is no other way to a sustainable, non-destructive future than essential growth of civilisation complexity taking the form of *Revolution of Complexity* in all fields of human activity (Sec. 3.1). But since the latter is determined by the level of consciousness that can be causally understood itself as a high enough level of complex interaction dynamics [1, 20], it becomes evident that modern *bifurcation of development* is centred around that *critical consciousness upgrade*, which constitutes today the main factor of *civilisation survival*: real Future comes as a superior level of individual consciousness. It shows the emerging predominant role of *individually* specified results of *global interaction* processes, as opposed to conventional “mass consciousness” effects of the unitary society at previous development stages. In fact, only consciousness complexity development provides the basically *unlimited progress perspective* after the objective end of the unitary history of “hot” events (cf. [26]).

As *every* future becomes *uncertain* at a qualitative transition point of modern Apocalyptic scale (Sec. 3.1), one should understand now *all* possible futures within a *unified* vision, by contrast to innumerable “scenarios” and one-dimensional unitary interpolation “threads” for *separate* aspects of development that become totally inefficient and misleading just at such critical point of “generalised phase transition” [1] (cf. [2–7]). Providing a unique possibility of such unified, causally complete vision of multiple interaction processes determining civilisation development, the *universal science of complexity* constitutes the *truly scientific* basis for *consistent, provably reliable futurology* and its critically important applications to modern development problems [1, 14].

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