From Big Bang to Galactic Civilizations

A BIG HISTORY ANTHOLOGY

VOLUME III

The Ways that Big History Works: Cosmos, Life, Society and our Future

edited by

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Singularity of Evolution and Post-Singular Development

ALEXANDER PANOV

INITIALLY, THIS ESSAY was motivated by questions raised in the SETI project (Search for Extra-Terrestrial Intelligence). If intelligent life is a usual phenomenon in the galaxy and if its rate of technological evolution is at least as advanced as on Earth, then the galaxy must be full of highly developed technological civilizations and we should be able to see them.[1] So why do we not detect them? This question is well-known, being referred to as the 'Fermi paradox' or the 'astrosociological paradox' (ASP). My own research interest concerns the following version of that question: 'Taking intelligent life to be a normal phenomenon in the galaxy, what would their technological civilizations look like, such that they are "invisible" to us now?'

This question has great practical importance. If we would like to find extraterrestrial civilizations, then we should try to understand what we are looking for. The method should depend on the aims. And we need to understand civilizations' potential for technological evolution. It is a difficult problem, but not impossible. The idea is to look at technological development in the light of the general laws of evolution. The question then turns out to have significance for our own possible future as a 'post-singular' civilization and could assist us in overcoming the challenges of a transitional singularity crisis, which our societies on Earth are just now entering.

Let me begin, however, by establishing a definition of 'singularity'. In its most general sense, a singularity is a point when significant change happens.

The word is used in physics, sociology and many other contexts, and has taken on a variety of meanings over the years. There are demographic approaches (Heinz von Foerster, Sergei Kapitza) and technological approaches (Raymond Kurzweil, Vernor Vinge) as well as some lesser-known ones. My own approach to the singularity is based on total planetary evolution, as expressed in phase transitions. The demographic singularity, technological singularity and others are partial expressions of this larger singularity of planetary evolution. My predecessors were systems-theorist Graeme Snooks (who deduced scale-invariant evolution of the biosphere but did not deduce the singularity point from it) and historian Igor Diakonov (who established phase transitions for human history and postulated the singularity point, but could not calculate its position). In brief, my discussion of the singularity is in its largest and most inclusive sense.

Scaling Invariance and the Singularity of Evolution

I begin by constructing a scale of evolutionary rates that is based on a sequence of phase transitions in the biosphere.[2] As an approximation, the biosphere develops as a single system and, since the evolutionary mechanisms of the biosphere and humankind have much in common, I consider their evolution to be a single process. So, for my purposes, the biosphere is understood to include civilization.[3]

The evolution of the biosphere progresses as a sequence of phases with transitions between them. The transitions are the process of overcoming evolutionary crises, which are called *biosphere revolutions* or *civilization revolutions*. By overcoming a crisis, the biosphere takes a step forward towards 'progressive' evolution. This means that, first, the biosphere becomes more complex and, second, the whole system raises the thermodynamic equilibrium to a higher level, i.e. farther from the state of 'heat death'.

Two important mechanisms of evolutionary crises are endo-exogenous and techno-humanitarian. An endo-exogenous crisis results from a habitat change that threatens its stability. A techno-humanitarian crisis occurs when the destructive influence of technology increases without development of adequate compensating controls. These evolutionary crises should not be confused with crises of purely exogenous origin, which are caused by all kinds of natural events, like the fall of an asteroid or a volcanic explosion. Although such exogenous events may influence the course of evolutionary crises, it is the evolutionary crises themselves that are the leading factor in evolution.

A given system serves as a *leader of evolution* in the biosphere at any given time, in the sense that it is the most important forming factor in the biosphere. An evolutionary crisis is a result of the activity of this leader system or is connected directly with it. *Superfluous diversity* plays an important role in overcoming evolutionary crises.[4] This means that there are evolutionary forms that do not play a supporting role in a given phase of biosphere development. However, at the moment of crisis, it is this diversity that permits certain forms to be selected as leaders of evolution at a new phase of biosphere development. *Additivity of evolution* means that as new, more progressive, evolutionary forms appear, the old ones do not totally disappear, but fade into the background and start playing a subordinate role in ecosystems or social systems. In this way, diversity enables evolutionary survival.

The evolutionary crises and their accompanying revolutions include the origin of life, the oxygen revolution, the Cambrian explosion, the revolution of reptiles, mammals and homonoids, as well as the anthropogene revolution–human technological developments, from stone tools and urbanization to nuclear weapons and information technology. Some of these events are graphed in Figures 21.1 and 21.2. There is no one method for selection of an event as a biosphere revolution or phase transition. Of course, many lesser events led to noticeable changes, such as the Chalcolithic period (Copper Age), which lay between the Neolithic and urban revolutions. If we loosen our criteria and account for all such events, we will not find the sequential regularity that we seek. That is why only the deepest reorganizations (revolutions) are considered in our model of phase transitions.[5]

It is not difficult to see that the duration of the evolutionary phases in the biosphere steadily decreases from the past to the present. Furthermore, the sequence of phase transitions has a property of *scale-invariance*. This means that a sequence of transition moments forms a geometric series and that its different parts can be obtained from each other by a simple scale transformation–compression or stretching. In general, the scale-invariant sequence of moments has the formula:

$$t_n = t^* - T/\alpha^n$$

In this equation, the coefficient $\alpha > 1$ is a compression ratio of duration of every subsequent phase of evolution in comparison to the previous one. T is the duration of the entire described period of time, n is the number of a phase transition, t^* is the limit of the sequence of phase-transition moments $\{t_n\}$. Diakonov noticed that such a limit exists.[6] He called it an historical singularity point, but it also can be considered an evolutionary singularity point, because it is the limit of the sequence of phase transitions for the

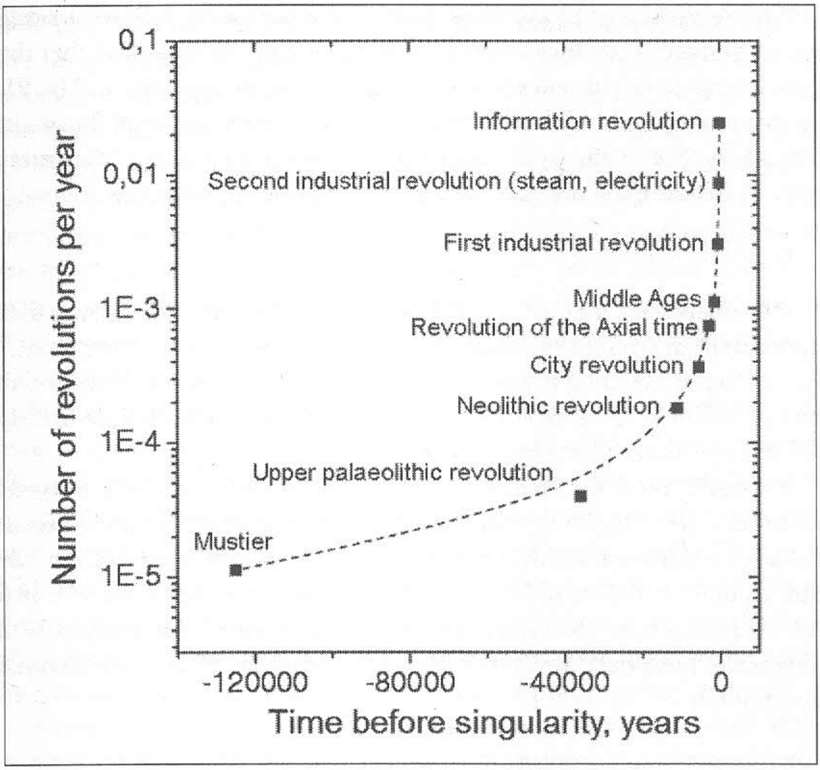

FIGURE 21.1: Number of phase transitions per unit of time as a function of time. The number of phase transitions per unit of time is calculated as the inverse distance between adjacent revolutions. The term, 'Mustier', refers to the Mousterian stone technology of the Early Palaeolithic.

Source: Alexander Panov.

whole biosphere, not just for human history. It is a process that accelerates, and some system parameters tend to infinity in a finite time—a phenomenon well known in synergetics. In this case, it is the number of phase transitions per unit of time that tends to infinity, as seen in Figure 21.1, in the form of a vertical asymptote, at a point of singular time, in the plot of the number of phase transitions per unit of time as a function of time.

The equation contains three independent parameters α, t^*, T that can be estimated by means of the best approximation of the 'experimental' sequence of phase-transition moments by the ideal sequence. To understand if this approximation is good, it is useful to rewrite equation in the form:

$$\lg\,(t^* - t_n) = \lg T - n \lg \alpha$$

It can thus be seen that the time interval between a phase transition and a singularity is close to linear on a logarithmic scale. The result of such analysis is shown in Figure 21.2.

The sequence of phase transitions in the biosphere follows a straight line, as derived from this second equation. It can be suggested that there exists a scale-invariant attractor of evolution (the straight line in Fig. 21.1) and that real evolution follows this attractor with relatively small fluctuations (Fig. 21.2). Since the scale-invariant attractor exists, the parameters α and t^* become meaningful. Analysis leads to their values as follow:

$$\alpha = 2.67 \pm 0.15; \quad t^* = 2004 \pm 15$$

It is interesting that $\alpha \approx e = 2.718$, Euler's Number, a construct that is important in mathematical analysis, probability theory, and other areas.[7] Is there a deeper meaning to this correlation? I have no answer. Note also that since $t^* = 2004$ CE, we live near the endpoint in a cycle of scale-invariant evolution of about four billion years.

Formally, near the singularity point, the evolutionary rate must turn into infinity (see Fig. 21.1), which is obviously impossible as an expression of real life. Hence, it follows that the character of evolution on the Earth must change in the near future, or has already changed. We are at the start of quite a new (*post-singular*) phase of evolution. An analysis of the sequence of biospheric revolutions is not the only way to derive a singularity for evolution.

FIGURE 21.2: Scale invariance of time distribution for biosphere phase transitions. Triangles are for biosphere transitions, squares are for transitions in social history, and the straight line is the scale-invariant attractor of evolution on the Earth. The terms for Early Palaeolithic stone technologies in this figure are translations of terms more often known in English as Chellian, Acheulean and Mousterian technologies.

It has been known for a long time that human population numbers have the property of scale-invariance too and their extrapolation in 1960 predicted a singularity in the year 2026 CE.[8] Details for such a scenario have been elaborated, including the 'technological singularity' proposed in 1993 by Vernor Vinge.[9] This technological singularity is also based on arguments like scale-invariance and is predicted for the first half of the twenty-first century. Such a diversity of sources, each pointing to a similar time for t^*, forces us to consider the singularity of evolution. Of course, the singularity is not a single point–it is an era when evolutionary laws and historical trajectories dramatically change. The Scaling Invariance Law of Evolution can indeed be regarded as a general law.

Furthermore, scaling-invariance and its singularity can be seen as a universal property of evolution on all planets where life achieves complex form and produces intelligent civilization. In view of an extremely short, pre-singular, cosmic-technological period (only a few decades, as seen in our own history), the potential for us to detect such a civilization in the SETI process would be negligible. Our experience shows that few cosmic transmissions are made in this stage. Therefore, it is probable that a potential contact partner would only come from a *post-singular* civilization. The problem that now arises is: what would a post-singular civilization as a potential partner in extraterrestrial contact look like? The other side of this question is: what is our own post-singular future? These two questions are closely connected with each other.

The SETI Problem and the Evolution of Intelligence in the Galaxy

The Search for Extraterrestrial Intelligence (SETI) as a scientific programme began with a paper by physicists Giuseppe Cocconi and Philip Morrison in 1959, in which they analysed the possibility of communication with inhabitants of the nearest stars through radio channels.[10] They proposed looking for artificial signals near the 21-cm. emission wavelength, which is the neutral hydrogen frequency, or 1.420 GHz. In 1960, Frank Drake performed the first SETI experiment, Project Ozma, when he used a radio telescope at Green Bank in West Virginia to examine the stars Tau Ceti and Epsilon Eridani near the hydrogen frequency, but no artificial signals were detected.[11] Two years later, the first SETI conference took place at Green Bank.[12] In 1962, Soviet astrophysicist Joseph Shklovskii wrote the pioneering book of the field–*Universe, Life, Intelligence*, which he expanded with American astronomer Carl Sagan as *Intelligent Life in the Universe*.[13] Altogether, SETI science has existed for more than fifty years.

The main organizations that support and direct SETI searches are the SETI Institute and the SETI League.[14] Both are not-for-profit entities whose mission is to 'explore, understand and explain the origin, nature and prevalence of life in the universe'. There have been numerous attempts to pick up artificial signals from the cosmos since the start of the SETI programme. The most notable of these are SETI@home and SERENDIP.[15]

SETI@home is a popular volunteer-distributed computing project that was launched by the University of California, Berkeley, in May 1999. Any individual can become involved with SETI research by downloading the Berkeley Open Infrastructure for Network Computing (BOINC) software programme, linking to the SETI@home project, and allowing the programme to run as a background process that uses idle computer capacity. The SETI@home programme itself runs signal analysis on data recorded from the central 2.5 MHz wide band of the SERENDIP IV instrument installed on the Arecibo 305 m. telescope in Puerto Rico.

SERENDIP is a series of instruments that have been deployed at a large number of telescopes, including the NRAO 90 m. telescope at Green Bank and the Arecibo telescope. Rather than having its own observation programme, SERENDIP analyses deep-space radio-telescope data that it obtains while other astronomers are using the telescope. SERENDIP observations have been conducted at a wide band of frequencies between 400 MHz and 5 GHz, with most observations near the so-called Cosmic Water Hole (1.42 GHz neutral hydrogen and 1.66 GHz hydroxyl transitions).

The largest special instrument for SETI research is the Allen Telescope Array (ATA) in Hat Creek, California. Regular operations with 42 dishes started in 2007, but the full array, once installed, will consist of 350 or more Gregorian radio dishes, each 6.1 m. in diameter.[16] Despite these and other efforts, no signs of artificial signals have yet been found, except the strange and unique 'WOW!' radio-telescope signal that was detected in 1977 at the Perkins Observatory in Delaware, Ohio.[17] The 'silence of cosmos' and its related astrosociological paradox are still the greatest challenge that we face.

A *communicative civilization* (CC) refers to any civilization in our galaxy from which 'sensible and reasonable' information can be detected, either through actual communication or by some other means, such as by observation of astro-engineering activity. It is also assumed that such civilizations can receive and interpret information sent from Earth. The duration of the communicative phase of a civilization is believed to be of a finite length, which is called the 'lifetime of technical civilization' and is denoted as L. The primary task of SETI is the search for such communicative civilizations.

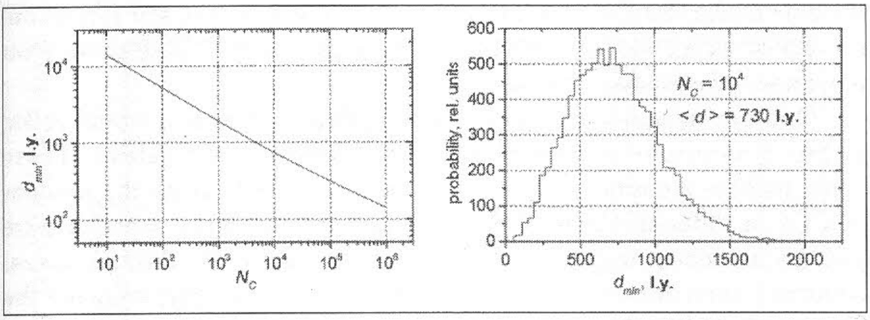

FIGURE 21.3: The expected distance (d_{min}) to the nearest communicative civilization (CC) as a function of the number of CCs in the galaxy N_C (left panel), and the probability distribution of distances to the nearest CC for the case of N_C = 10000 (right panel). The distribution function profile for other values of N_C is similar; only the most probable distance differs.

Source: Alexander Panov.

A crucial question of the SETI enquiry is how far the nearest communicative civilizations are from us. The answer depends on the number of CCs in the galaxy. Figure 21.3 shows how the distance between our Sun and the nearest CC depends on the number of CCs in the galaxy.[18] For the number of CCs in the galaxy (no more than one million), the distance to the nearest civilization is large, so bi-directional contact is virtually impossible. This is due to the fact that the maximum speed of communication is the speed of light, which means that messages will be received only hundreds or thousands of years after being sent. So, contact will be unidirectional. A communicative civilization will send its information into the cosmos and look for information sent by other civilizations in the far past. The best known way to represent the number of CCs is the formula developed by Frank Drake:

$$N_C = R_* f_p n_e f_l f_i f_c L$$

In the Drake equation, R_* represents the star-formation rate in our galaxy, averaged with respect to the time of its existence, f_p stars with planet systems, n_e the average number of planets in systems suitable for life, f_l planets on which life appeared, f_i planets on which life developed into intelligent forms, f_c planets on which life reached the communicative phase, L is the average duration of the communicative phase. It is however necessary to modify this formula, as it only provides the number of CCs in a rough approximation.[19]

The actual number of CCs depends on the current phase of dynamic processes in the CC population, which may be of an essentially non-linear <<character. An estimate of the number of CCs, and even an understanding the character of CCs themselves, depends on an understanding of the nature of these processes. My modification is done in order to allow for

the time it takes for CC development, the variability rate of star formation, non-linear processes, and other factors. I concentrate here mainly on non-linear processes.[20]

One can imagine various non-linear circumstances that would relate to the dynamics of communicative civilizations in the galaxy. These could include the artificial creation of stars so as to increase the number of CCs or different kinds of directed panspermia. But I consider here just the influence of galactic civilizations on each other through actual communication. Moreover, I conclude that such contacts may influence the lifetime (L) of CCs in their communicative phase as well as the efficiency of search for partners and the establishment of communication. I call this a *civilization range*.

Communicative civilizations may be divided into three categories: CCs for which contact is 'harmful' (because it reduces the duration of the communicative phase), neutral CCs, and CCs for which contact is 'useful' (because it prolongs the communicative phase and increases the civilization range). I call the last category *extrovert communicative civilizations* (ECC).[21]

It is important for a positive feedback process to begin. The larger the number of ECCs in the galaxy, the higher is the probability of contact. Contact also increases the lifetime of an ECC and its civilization range, which leads to an increase of the ECC population and raises the contact probability. Such a positive feedback loop can lead to an avalanche-like phase transition in the galaxy, accompanied by a powerful burst in the number of ECCs. As a result, ECCs would prevail in the galaxy, even if the situation was different before such a transition.

In order to study the dynamics of an ECC population in the galaxy during a phase transition, I developed a mathematical model that is a generalization of the Drake equation. This rather complex formulation is built from several related equations. Since it has been elaborated in a previous article, 'Dynamical Generalizations of the Drake Equation: The Linear and Nonlinear Theories' (2007, 2015), I will not go into its details here. Figure 21.4 graphs one of its numerical solutions, and I will describe some of its essential features in order to illustrate how it works.[22]

In order to account for the mutual influence of civilizations through contact, each CC is described by a parameter called 'quality', which is denoted as q. The lifetime and communication range of a CC depends on this parameter q: the greater q, the longer expected lifetime L and the greater communication range r, which is roughly defined as the maximal distance of communication for a given civilization. Receiving information from another civilization increases the quality q of the civilization-recipient. It is important that the increase of quality not be arbitrarily large: There

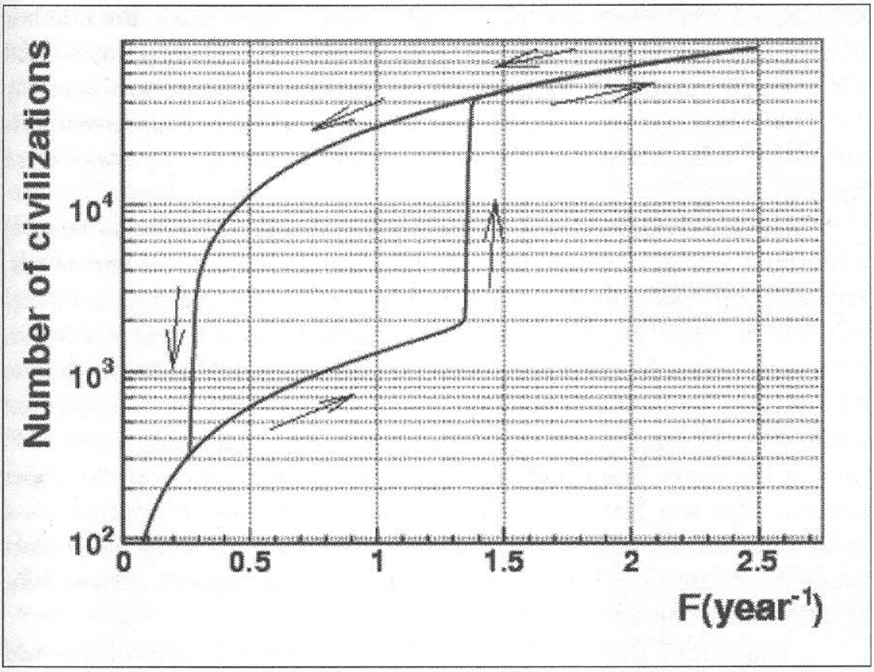

FIGURE 21.4: Model calculation of population dynamics in the Milky Way Galaxy, showing the bistability in an ECC population (see explanation in the text).

Source: Alexander Panov.

is an upper limit of an 'ability to learn' or 'possibility to improve' for any civilization.[23]

At first, there are no civilizations. This models the time just after the formation of the galaxy, when all stars were young and no life existed. After that period, the civilization-origin rate F (number of new communicative civilizations in the galaxy per year) begins to increase slowly, so that a general equilibrium is achieved between the number of ECCs coming into existence and those going out of existence.[24] At this stage, the probability of contact is still small, because the number of civilizations are few. First, a point in the diagram moves along the lower branch of the hysteresis loop from left to right, and the number of civilizations remains small (less than 2000). This is the *silence epoch*, when the probability P to find a contact partner for any civilization is $P \ll 1$, or a very small liklihood.

Due to increasing numbers of civilizations, the probability of contacts increases, while the mutual influence of civilizations increases, and the situation in the galaxy becomes variable. When F achieves a value of about 1.35 civilizations per year and $P \approx 0.05$, then the equilibrium is broken. Due to positive feedback between the numbers of contacts, civilization ranges and lifetimes, the number of civilizations and the probability of their interaction starts to increase rapidly. As this takes place, the number of civilizations increases sharply by about an order of magnitude, and the average number of partners per civilization reaches approximately 10. This phase transition ends, because the 'possibility of improving' is exhausted at large values of the quality q. The *saturation of contacts epoch* starts ($F > 1.4$).

Then the civilization origin rate stops increasing (at $F = 2.5$ years^{-1}) and begins to slow down.[25] First, a point in the diagram moves backwards, repeating the trajectory of F growth. However, when reaching a critical value of $F = 1.35$ per year, the reverse phase transition does not occur. This is prevented by the positive feedback of numbers of contacts, lifetime and range. The contact saturation epoch continues. Here, two different stable states of the civilization population correspond to every value of F: one on the lower branch of the hysteresis loop, the other on the upper branch. This is a bistability phenomenon. Only when P approaches a value of about 0.5 years^{-1}, the positive feedback cannot keep the contact saturation phase from reduction, the number of civilizations sharply falls, and the silence epoch returns.

It is significant that F is much less during reverse transition (downward arrows) than during direct transition (upward arrows), as shown in Figure 21.4. It is also significant that direct transition begins when the probability of contact for a typical civilization in the galaxy is less than one. At this point, on the eve of transition, a majority of civilizations must feel that they are the only inhabitants of the galaxy. After transition, every CC that expends adequate effort on solution of the SETI problem obtains contact partners. The bistability effect can be extremely important for the CC population and the fate of the galaxy. If transition to the contact saturation epoch occurs, then the generated state of the galaxy will be stable–it could be destroyed only by a disastrous fall in the origin rate of new civilizations.[26]

The astrosociological paradox implies a contradiction between the widely held belief in the existence of communicative civilizations and the absence of observable evidence. However, the paradox can be understood when supposing that the main form of contact between CCs is through communication channels with the help of beam emitters and receivers. *Even under the conditions of the contact saturation epoch*, the detection of a CC would be an extremely difficult task.

Suppose that the time of a phase transition has already passed and that the phase of contact saturation is underway in the galaxy. As calculations show, the number of CCs in the galaxy, corresponding to Figure 21.4, would be about 50,000. From Figure 21.3, we find that the expected distance to the nearest communicative civilization would be 500 to 1000 light years.

In order to detect a CC, it would be necessary to *permanently* monitor all likely objects inside a radius of 1000 light years, containing about 10^7 stars, at all reasonable frequencies and channels (radio, optical, etc.) for a sufficient length of time.

Presently, we are dealing–at best–with occasional observations of several tens of stars with just radio waves. Optical channels have not been studied at all. So, why are we astonished that we see nothing? We have made almost no attempt to find anything. A real solution of the SETI problem may be very expensive and require giant instruments and giant efforts. A question is: why do we assume that only beam transmitters and receivers are used for contact?

'Exohumanism' of a Post-Singular Civilization

Let us begin with a remark on the further use of such concepts as 'humanism' and 'ethics'. A human being is devoid of naturally powerful tools of aggression–claws, fangs, etc. This is why, unlike, say a tiger, humans have no biological restriction against aggression on their own kind. When a human first took a stone tool in hand and became owner of the first technology, nothing prevented the crippling or killing of a near relative. This is why populations of especially aggressive hominids did not leave descendants and why less aggressive populations survived. The prohibition against such murder was fixed genetically at first, based on the survivors, and then became culturally restricted.

As technology developed, both the killing power of weapons and the destructive ability of technology increased. Correspondingly, cultural restrictions on aggression against people and nature had to improve. These restrictions were imprinted in ethics, morals, and humanism. Such categories are by no means given to humans a priori but are basic saving-reactions against the destructive action of technologies developed through the process of natural selection. This topic has been well developed by psychologist Akop Nazaretyan as well as by Italian author Umberto Eco and others.[27] However, humanism and ethics are not the only constraints on aggression. There are other mechanisms, such as legislative criminal codes, as well as corresponding penal systems. Therefore, the term, 'humanism', is considered in its wide sense, encompassing both positive and punitive forms, as a cultural restraint on the destructive actions of technology.

It is clear that the survival of a civilization after the evolutionary singularity implies its overcoming a number of the deepest technogenic crises, since the singularity is a period during which these crises are concentrated. In order to overcome these crises successfully, a post-singular civilization must elaborate adaptation mechanisms and use them for homeostasis. *If a civilization does not elaborate such mechanisms, it will not enter the post-singular stage of development*–it degrades or perishes. It is not difficult to imagine at least some of the preserving-reactions that are needed.

First, sufficiently effective mechanisms to deter aggression must be elaborated; otherwise a civilization will destroy itself through internal conflict (related to a decline of natural resources) and the increase in the killing power of weapons. Second, powerful mechanisms of control on material consumption and effective use of resources must be implemented. Third, a civilization must overcome the centrifugal influence of corporate and state egoism inside itself, and elaborate a planetary consciousness. Crises near the singularity have a global scale and can be overcome only by common efforts of continuous compromise. The fourth type of preserving reaction must be an increase in ecological consciousness, up to the point of turning it into an eco-social 'instinct'.

A singularity crisis cannot be overcome without a huge jump in the power and depth of mechanisms that constrain the destructive effects of technology. I call this jump the *post-singularity humanization* of civilization. I emphasize that such 'humanization' should not be understood either simplistically or too literally. It can manifest itself as ethical principles accepted by the majority of people, i.e. humanism in the classical sense, or it can be implemented as a system of legal and punitive measures, or as a hybrid system. Such details are secondary to the overarching need for a system of cultural constraints that can overcome the destructiveness of technology, so that civilization can reach the next cosmic-technological stage.

The development of cultural constraints against aggression has increased throughout prehistory and history. Moreover, it has increased such that, despite an increase in the killing power of weapons, the level of *per capita* bloodshed has decreased. Nazaretyan summarized this paradoxical situation in his Law of Techno-Humanitarian Balance.[28] Recent examples of this law at work include the sweeping away of some of the bloodiest regimes in history (Stalin, Hitler, Pol Pot) and their replacement by more sparing methods of control. A sign of the awakening of planetary consciousness and development of ways to overcome corporate/state egoism is the Kyoto Protocol (1997) and the Paris Agreement (2015).

Certainly, the idea that such a developed form of humanism should be typical for highly developed CCs is not new. It was expressed by rocket-scientist Onstantin Tsiolkovsky and palaeontologist Ivan Yefremov in the early twentieth century, as well as more recently by astronomer Lev

Gindilis, and Akop Nazaretyan.[29] It is interesting that this humanization of terrestrial civilization is already being extended towards the cosmos, a process that we term *exohumanism*.

Given lessons from history, it would seem that we humans would think only about our own safety during exploration of the solar system and would disregard any encountered life forms. But to the contrary, all vehicles sent to Mars have been carefully sterilized so as to not harm any possible life that might exist there. Likewise, the space probe *Galileo* was allowed to burn-up in the atmosphere of Jupiter, in 2003, so as not to bring terrestrial microorganisms to its moons, where life is also thought to perhaps exist. And the dispute about the 2005 space experiment, 'Deep Impact', whose aim was to bomb the comet Tempel-1 in order to study its chemical composition, is also indicative of this trend towards exohumanism.

Opinions about the Tempel-1 experiment were varied. A number of professional astronomers and astrophysicists thought that such 'barbarian' methods should not be permitted. Its apotheosis was the lawsuit of a Russian woman, Marina Bai, in the Presnensky Court (Moscow) against the US National Aeronautics and Space Administration (NASA) for moral damages. The formulation was as follows: 'NASA activity encroaches on the system of cultural and vital wealth, and natural life, of the cosmos, which upsets the balance of natural forces in the universe'. The lawsuit was accepted by the court, but the claim was denied.[30]

All this might be considered an amusing incident, if not for the sympathetic attitude of numerous professionals and the fact that such consciousness is becoming more common. Throughout this court case, ethical norms and ecological thoughts about Earth were transferred to the comet, an expression of exohumanism in action. As a result, it is expected that any large-scale astro-engineering activity might result in opposition from at least some sectors of the public.

These examples serve to show that post-singular humanism could hardly exist in a CC 'for internal use only'. These properties must also appear in relation to the cosmos, whatever these relations are: space engineering, contact with unreasonable yet intelligent forms of life on other planets, and other relations. A highly humanistic system cannot be primitively aggressive in its external manifestations. *Exohumanism is a system of planetary cultural constraints designed to curb the destructive manifestations of a technogenic civilization all the way up to the cosmic level.*

It should be emphasized that it is unknown if the process of humanization of *terrestrial* civilization is fast enough and deep enough to overcome the crisis of singularity. Our statement is conditional: *if* post-singular cosmic-technological civilizations exist, *then* their process of humanization in the period of overcoming the singularity must have been sufficiently fast and deep, and that is why they must be exohumanistic.

Cosmic Expansion and Intensive Development

There is a widespread hope by many people that the negative consequences of our technological explosion and exhaustion of Earth's resources can be overcome by cosmic expansion. We have visions of billions of people living in cosmic cities, using resources from other planets, with industrial production set up far away from our habitations. Such visions are in the realm of science fiction, not science. Besides the issues of exohumanism, it would be physically impossible for large-scale settlement of space to take place during the decades of a pre-singularity technological explosion. There is not enough time for it to happen.[31] We could not even establish ecologically safe and cost-effective traffic to near-earth orbit during this short period. Indeed, just the opposite trend is seen.

In actuality, there has been a sharp decrease in space development. Forecasts from the 1970s about the advancement of space technology to the year 2000 turned out to be grossly overestimated, and many of those plans still remain unimplemented. In 1974, rocket engineer Krafft Ehricke announced that an orbital space station for 25 to 100 people would be put into operation sometime after 1985. About the same time, plans also were developed to put a solar power station above the Earth by the year 2000, one having 45 km^2 of solar panels in stationary orbit that would generate 5 million kW.[32] These forecasts had been based on a linear extrapolation of the rate of space development in the mid-twentieth century, a rate that was impossible to maintain.

One way or another, after overcoming the singularity, a civilization must provide for its own stable existence, probably for a long duration and without hope to quickly expand into outer space. This stabilization must be primarily accomplished by our own planetary resources. If large-scale expansion into the cosmos is possible in principle, it cannot be done by continuing the technological explosion of the singularity. And a considerable time in the post-singular phase must pass before sufficient resources are accumulated for such an expansion. Since it is difficult to make forecasts about cosmic expansion in a post-singular phase and the transition to the intensive phase of development is already underway, let us consider the behaviour of a CC in the intensive phase of development.

The features of the long, intensive phase of development predetermine a model of SETI contacts. Since the energy resources of a communicative civilization are rather restricted, signal propagation may be limited to pencil-beam transmitters. For the same reason, pencil-beam receptors will predominate as well, and will be used to monitor separate stars. Simple cost-benefit analyses show that powerful omni-directional, stationary radiators would be excluded from SETI research for reasons of energy cost and conservation. It is also quite probable that they would contradict ethical and ecological imperatives of exohumanism, because of their potential destructive effect on cosmic life.

Information Crisis

The problem of the 'end of science' is a large topic that deserves a paper or even a book all to itself. However, for my purposes, I will briefly relate it to my analysis of exohumanism.[33] To start with, let us define what we mean by the notion of 'science'.

There are several methods of cognition: philosophic, religious, etc. Science is but one of the ways to realize the function of cognition. Scientific truth is not a synonym for truth in general. Science differs from other methods by the fact that its results can be reproduced in quite a definite sense. In science, there are two basic, classical methods with which to verify results: (1) reproducible experiment in the natural sciences and (2) deduction or calculation in mathematics and natural sciences. We call methodology based on reproducible experiment and deduction the 'classical scientific method'.

In the period of technological explosion (prior to the singularity), science and additive characteristics (such as consumption of resources and energy) are in a state of heavy (exponential) growth. The time of doubling of different characteristics–the number of scientists, the number of publications and the number of discoveries–is only about ten to fifteen years.[34] Elementary arithmetic tells us that the current rate in the development of science cannot last infinitely or even for a long time.

In his famous book, *Summa Technologiae*, philosopher Stanislav Lem insisted on the near 'saturation' of the scientific method even in the mid-twentieth century. He was among the first to seriously discuss the possible limitations of science and to state that it would cause a crisis for civilization. Lem called it the 'information crisis'. In 1963, when his book was written, he thought that the exponential growth of science would last thirty to seventy years, i.e. it would end in the period between 1990 and 2030. Lem wrote: 'Thus, if the current rate of scientific growth continues, then every inhabitant of the Earth will be a scientist in some fifty years'. This ironically phrased forecast postulates a date of around 2013 and, as can be seen, greatly overestimates the number of scientists we have now. Indeed, the growth rate in numbers of scientists has significantly fallen already and seems to be on a downward track, despite institutional attempts to try to reverse it.

The problem of the 'end of science' still keeps exciting minds, such as the book of that name by science writer John Horgan (2001) and a paper by chemist Oleg Krylov (1999). Attitudes towards science are especially important in regards to the evolution of civilization, so such an assessment allows us not only to better understand the essence of the crisis but to conceive of possible ways of overcoming it.

The scientific method arose at a particular stage in the development of civilization in order to solve particular problems. Although elements of the scientific method had appeared in the ancient world, they were not a *leading factor* at that stage, i.e. they were merely one form of *superfluous diversity*. (Keep in mind that superfluous diversity is a pool from which new systems are chosen by natural selection for leadership in evolution after a phase transition.) In the ancient world, the leading methods of cognition were philosophy, religion, and art. Later, the scientific method came into its own as a *leader of evolution*: first, to overcome the agrarian crisis of the late Middle Ages, then in the service of the first Industrial Revolution and modern global civilization.

However, sooner or later, any effective evolutionary solution will be exhausted, and the classical scientific method is not an exception. This does not mean that science will disappear. Old evolutionary forms do not vanish when new ones appear; they remain in a reduced form, yielding leadership to more progressive systems by way of the *additivity of evolution*, described above. The 'end of science' is not the end of cognition and moreover not the end of evolution. It merely represents the appearance of new forms of thought or cultural activities that are not 'cognition' in our contemporary meaning. This has already happened in our history, as when the whole primeval view of the world as mythology was replaced by philosophy on nature, religion, etc.

In addition to general evolutionary considerations, it is important to get an idea of concrete causes that could lead to 'saturation' of the scientific method. It will allow us to imagine the dynamics involved and to estimate its timescale. At least three basic groups of causes can be identified.[35]

First, science will encounter limitations on its resources. Such tendencies already exist. It is sufficient to remember the cancellation of the Superconducting Super Collider in the United States (1993), as well as the pared-down space programmes happening today. At best, science expenses could be stabilized at a constant level, taking into account the intensive character of development in a post-singular civilization.[36] This would result in a gradual decrease in the flow of *new* scientific results, because of cost increases (due to an increase in complexity) and despite development of new methods.

It is a rare study that is carried out by one scientist, as it was seventy or eighty years ago. Generally, scientific teams work in large and expensive facilities, and many modern problems can be solved only by international collaboration. Decline in the flow of scientific discoveries could cause declining interest in science, which in turn could lead to decreases in research expropriations and to further decreases in the flow of new discoveries. A feedback loop thus develops. This phenomenon is especially dangerous because many participants have no time to understand what is occurring due to the high and rapid rate of disruption in the scientific fields.[37]

Second, science might encounter ethical limitations, which could relate to post-singular humanization.[38] One can remember the strong opposition to experiments on the cloning of human beings. Other types of aversion might also develop, for example, if hostility to genetically modified products (GMOs) grew into an obstacle to genetic research or resistance to radioactive contamination came to impede development of safe nuclear uses. Under such circumstances, a general distrust of science could become quite widespread.[39]

Third, studies on the complexity of nature could be simply 'exhausted' for scientific cognition.[40] In 1997, astrophysicist Vladimir Lipunov wrote: 'Our Universe is too simple for intelligence'. Certainly, studies in basic physics do not negate the study of phenomena at higher system-levels, but they might reduce the probability of scientific breakthroughs that excite society's interest. The exhaustion of science is not yet a real concern, but certainly public opinion related to it is quite real. Expectation of the end of studies in basic physics (even if hinged on false premises) can cause pessimism which, via feedback loops, could affect the stability of science as a whole. And I have not yet even mentioned the growth of pseudoscience, along with its negative attitudes towards real science.

Thus, there is not one, but a number of interacting effects that can impede the development of science. That is why the information crisis is largely *the system crisis of science*. Sooner or later, a post-singular civilization must deal with this phenomenon. Resource limitations seem to be most important among the causes of the crisis of science, but ethical causes can also grow stronger with time. I do not mean to say that the current state of scientific research forebodes the end of science in the immediate future. The matter of concern is more about an overall fall in the efficiency of the classical scientific method.

At present, terrestrial civilization is in an early phase of the crisis.

However, the processes are so dynamic that it is unlikely that the classical scientific method will be a leader of cognition in future centuries. Indeed, it is a question of the next several decades. This is just the time allocated for solution of the problem, as described by Lem and others. Is the information crisis dangerous for a civilization? A positive answer is most obvious, but some reservation is necessary.

Lipunov believes that if the cognitive function of a society is exhausted, then the end of its civilization is inevitable.[41] However, an information crisis just means that we must implement another form of acquiring knowledge. Though science is now the leading method, it is not the only one. Can a civilization avoid this crisis by developing another method of cognition? Every method mentioned so far is older than science, and was once a leader, but evolution, as the adage goes, 'does not enter the same river twice'. It seems that the information crisis inevitably leads to a general crisis of civilization. The concrete mechanism of this process could refer to the relationship of science and technology, but it is easy to also imagine that it might lead to a general crisis of culture, such as an all-planet 'longing for something new' and the feeling of being in a 'blind alley'.

The crisis could be overcome if a new method is found to replace the classical scientific method as leader of cognition. A new method could be related to modification of ideas about creativity or truth and result in new channels for obtaining information. These new directions should be sought in the pool of superfluous social diversity at our present stage of evolution, as a new leader of evolution has been similarly found in contemporary society at all previously known times of such crisis. It is quite possible that the information crisis is a point of polyfurcation with different possible exits.

It is important to keep in mind that although this crisis of the scientific method in the more or less distant future is inevitable, it does not follow that support of science should be abandoned. On the contrary, science should be supported as much as possible, because scientific knowledge is a basis of overcoming many other crises of the evolution singularity.

I will not assess all the possibilities of overcoming the information crisis (there are many of them), but it is important to note that one of these is related to solution of the SETI problem. This variant will be discussed in detail in the next section, together with other particularities of post-singular civilizations. It is not difficult to see that I am searching for possibilities to overcome the information crisis among the pool of superfluous diversity. Though the work on the SETI problem is one of the forms of cultural activity of humankind, it does not yet play an essential system-forming role.

Off-Planet Communication of Post-Singularity Civilizations

As described above, a civilization in the post-singular phase of development will have to overcome two problems: (1) the challenge of expansion into outer space and (2) an information crisis. Besides blocking a civilization from intensive development, the first problem also can cause serious internal discomfort, because it makes a civilization feel trapped within its own star system or even on its own planet–as within a shell. The second problem can cause a dangerous destabilization of the system. Let us try to imagine the behaviour of a civilization in this situation.

A civilization close to the information crisis understands that in order to preserve homeostasis, let alone develop itself further, it is necessary to acquire new knowledge. Since the classical scientific method will be reaching its saturation point by this stage, new knowledge would need to come from other sources. Extraterrestrial civilizations could be one such origination. The discovery of an extraterrestrial civilization would give powerful moral support for overcoming an information crisis, as it would demonstrate that civilization has the prospect for further progress. Indeed, it would be in our own best interests to try to connect with as many such galactic correspondents as possible.

SETI contact would also solve the problem of the above-mentioned 'shell complex' of feeling isolated, since real expansion into space would be replaced by a virtual, informational one. We should note that such cosmic transmissions would probably contain information about the historical path of other galactic civilizations, which could be used to optimize our own development. This is why SETI contact just by itself could radically increase the stability of our civilization and why the concept of ECCs is so important. The transmission of such signals into the cosmos is an act that should be important for all galactic civilizations. Being exohumanistic, a post-singular civilization would be expected to take actions that are vitally important for other civilizations. This is an example of why an evolutionary mechanism needs to be altruistic and overcome state and corporate egoism.

The understanding of the importance of such transmissions must be usual for post-singular, exohumanistic civilizations. These communications could also provide stability for a post-singular civilization that has experienced an information crisis and receives the transmission. Perhaps it is an answer to the question raised by astronomer Vitayly Shwartsman: since obtaining new knowledge cannot be the purpose of such transmissions (because of the distance and lag-time), this activity does not belong to science. But, then, what would its purpose be?[42]

Civilizations should seek not only to send transmissions into space, but to make them as informative as possible. The simplest way to do that is by a civilization's transmission to not only include its 'own' information, but to relay messages received from other CCs. Indeed, an exohumanistic civilization must think about how to maintain information about vanished civilizations. This reminds one of our modern attitudes about preservation of ancient documents, monuments, and artefacts. In order to keep the culture of vanished civilizations, it is necessary to relay the received information again and again.

Thus, one of the possible behaviours of a post-singular civilization, at the stage of a system crisis and afterwards, is active transmission of its own messages into space and the relaying of everything else that has been received. On the basis of such a model, any civilization that has not found a contact partner yet, and *which is at the stage of the information crisis*, must be ready to apply all its forces to solve the SETI problem, in order to join the process and overcome its own impending crisis.

Obtaining a new source of knowledge is necessary, and there is hope to find it. Only in this circumstance does a civilization become *communicative in the strong sense.* In my opinion, the readiness of a civilization to spend significant resources on the SETI problem should not be expected earlier than when the information crisis becomes evident to the majority of people. Experience shows that important problems with a high price tag are solved only by the principle: 'When the need comes, then we shall do it'. It is evident that Earth's civilization is still far from the communicative phase in the strong sense. Nevertheless, it can come together to resolve the information crisis.

Does this mean that it makes no sense to grapple with the SETI problem now? By no means; at the time when extraterrestrial contact is needed, the theoretical base and methods of searching for CCs and communicating with them must be ready to use. For example, development of a database on exoplanets of a terrestrial type for as many stars as possible is extremely important and is a research agenda that is modestly embraced by space agencies today. All this basic work should be developed now. Work on the SETI problem could be one of the factors of superfluous diversity that might play a key role in overcoming the future information crisis.

The Galactic Cultural Field and the Character of Information in Cosmic Transmissions

A civilization's ability to overcome the information crisis by studying cosmic transmissions means that such efforts will have cumulative, positive effects on other civilizations throughout the galaxy. In other words, a phase transition is possible in the galaxy as a whole, as a result of the positive influence of cosmic contacts. Therefore, the expected properties of post-singular civilizations create the prerequisites for transition of the galaxy as a whole from an epoch of silence to an epoch of contact saturation. In this state, the CC population of the galaxy has rather remarkable properties.

In the epoch of contact saturation, messages sent by a civilization into space during the communicative phase will be received and relayed by at least one other civilization with a probability P of about 1. That is why information about civilizations that have completed the communicative phase can be circulated in the galaxy for a long time via transmission from one civilization to another. Upon reaching contact saturation, the amount of information available to all in the galaxy significantly increases, and it turns the CCs in the galaxy into a single cultural field. I emphasize that the existence of the cultural field does not mean two-way communication between civilizations, due to the time-lapse in such communications over such vast distances. What occurs, instead, is the sharing of information.

This development of a single galactic civilization results from the process of communication itself. As information in the cultural field accumulates, every civilization, proceeding from the imperative of exohumanism, will process and relay greater and greater quantities of it. At some point, the information flow will become so saturated that it will be impossible to relay all the information. CCs will start selecting data that is the most valuable, from their point of view, which will initiate a process of selection of information in the cultural field. Changes of the information content will have a backward linkage on the constitution and properties of civilizations in the galaxy. In this way, the cultural field will turn into a unified galactic civilization, evolving according to its own laws.[43]

This consideration of a galactic cultural field is similar to the 'big correction' developed by mathematical psychologist Vladimir Lefebvre. His study refers to the coordinated activity of many intelligent 'cosmic subjects' for improvement of conditions for the development of life and intelligence in the universe. He pondered the situation by which cosmic residents would not have the ability to agree directly with one another upon fulfilment of their work, so they would have to act on the basis of the moral imperative, in the hopes that the others would act in the same altruistic manner.[44] My scenario about post-singular civilizations closely corresponds to his ideas.

The model of a cultural field suggests that a typical cosmic transmission of one CC would need to contain relayed information of many–maybe millions–of civilizations. A transmission of this kind would have to be a complicated and branched information system. The term 'transmission' turns out to be inadequate. One might formulate, for example, the concept of *an exobank of data.* Transmission of such a huge amount of information, with the help of a modulated laser beam or a wide-band but narrow-beam radio signal, is not an unsolvable problem for a civilization whose energy resources do not exceed planetary capacity, as would be expected for an exohumanistic, post-singular civilization.

It is easy to imagine the possible character of information in exobanks of knowledge. It would be meant primarily for post-singular civilizations that face an information crisis (since only such CCs are communicative in the strong sense and can find a contact partner). That is why basic sciences like physics, mathematics and astronomy would not be the ones most interested in exobanks of knowledge: post-singular civilizations that are close to the exhaustion of the scientific method must have an approximately equivalent knowledge in these fields. Certainly, some specific information about the fundamental nature of the universe would be of interest, for instance, parallaxes of quasars and distant galaxies, as were pointed out by astrophysicist Vladimir Lebedev.[45]

Basic scientific knowledge will play an auxiliary role, serving to help decode exobank data, it having been transmitted through different languages, experiences, and cognitions. The data that is unique for each civilization (biology, history, sociology, literature, art, and religion) will be the most interesting and important. I call a cosmo-technological civilization that has stabilized its existence by processing information of a predominantly humanitarian character an *exohumanitarian civilization.* My conclusions are close to the idea expressed by Philip Morrison at the Byurakan SETI conference in 1971:

> In my opinion, the most part of this rather complicated signal will mainly refer to what I would call art and history, but not natural sciences and mathematics. For me this is clear from combinatoric considerations, because our society or any other long-living society will solve many natural-scientific and mathematical problems by easier ways than by studying records of interstellar messages.[46]

Vitayly Shwartsman stated similar ideas: 'An opinion generally accepted among physicists that extra-terrestrial intelligence must pass fragments of its scientific knowledge to "younger brothers" seems to be very disputable'. He noted that information related to art and games can turn out to be much more important.[47] This opinion is grounded in two aspects. First, scientific information forms a single logical construction. If a part of it is lost, the whole is lost as well: scientific information is difficult to decode and understand.[48] In contrast, information contained in art is much more resistant to the loss of fragments–the parts have a definite integrity and value. Rules for games of logic are simple and compact, and they can be transmitted easily. But, at the same time, they contain huge amounts of information about an unimaginable number of possible sets. Second, art and games say much more about the intellect that created them than impersonal, scientific information or even data of neurophysiology.

It should be noted that although my thinking leads to similar conclusions as those of Morrison and Shwartsman, it does differ. They believe that the motive for 'humanization' of interstellar messages is that it would be too difficult to understand communications of a scientific nature. My conclusion is that interstellar messages will be accessible (or the urgent need to study them will appear) only after most of the problems are solved by the classical scientific method. Morrison's and Shwartsman's consideration that it is difficult to extract information from an interstellar message is also important.

For me, the major importance lies with organizing and decoding exobanks of knowledge. Certainly, it is difficult to pose such a problem, and only some general considerations about it can be expressed at this time. It should be expected that an exobank will contain one or several root messages with a signal for attracting attention and instructions for further search for information. This part of an exobank must be decoded easily (for instance, on the basis of reduction to natural-scientific or mathematical concepts). But difficulties are certain to be faced in advancement to the humanitarian parts of an exobank.

Here, the papers of astronomer Boris Panovkin about the difficulties of understanding between different cosmic civilizations should be remembered. Panovkin considered the setting up correspondence between systems of ideas (thesauri) of these civilizations. He showed that this problem is not solvable algorithmically, even for two-way contact.[49] However, in my opinion, such a conclusion does not mean that understanding is impossible; it only means that the process of understanding must be of a substantially non-algorithmic nature. It is a human being who is able to make an illogical (but correct) guess, an ability that is impossible for a computer.

At the initial stage of studying materials from an exobank, there would be no correspondence between thesauri of different CCs (except for a narrow field of simple mathematical or natural-scientific concepts). This 'translation' would need to be built up gradually through the developing of a conceptual model and then making a test. Models of understanding some fragments of an exobank would be suggested and would then be tested on other materials of the same exobank. If the model stood the test, it would be accepted and used for construction of finer models, otherwise it would be rejected. A non-algorithmic element of this process would be the suggestion of new models. Here it would be impossible to do without guesswork. The understanding achieved in this way would never be final, but it would always be of a model-building nature.

It is easily noticed that this cyclic process is very similar to the classical scientific method of hypothesis and experiment. That is why the process of understanding an exobank can be called *exoscience*. Thus, after the information crisis, leadership in methods of cognition can pass from science to exoscience. Exoscience is not simply a new kind of science, which can be seen through its purely formal features.

First of all, this distinctiveness concerns the criteria of truth or reproducibility. In exoscience the notion of truth turns out to be of two-levels: (1) how adequate are the models of interpretation of information and (2) how true is the interpreted information itself? If it is still possible to achieve something resembling reproducibility of results at the first level, then in many cases it will be unachievable in principle at the second. The element of belief becomes inevitable through the obtained knowledge. Besides, the obtained knowledge refers not to nature directly but to artificially generated information, or to nature but indirectly through artificial information.

Let me emphasize that the possibility of a long process of obtaining knowledge through exoscience is possible, but the obtained knowledge makes such an endeavour worthwhile. The process of exoscientific cognition could drag on for thousands of years, but this is just what might be necessary to support the homeostasis of civilization at the intensive post-singularity phase of development. It is hard to tell how and when this process of exoscientific cognition will be exhausted (since this must eventually happen).

Conclusion

I propose post-singular, evolutionary civilization as a model for the intensive phase of global society's development. Such a civilization will be communicative in a strong sense. It is not overstating the case to say that, when we establish contact with such an extraterrestrial civilization, we are also put in contact with other communicative civilizations and become part of a larger cosmic field consisting of many such entities. Thus, a post-singular civilization is exo-humanitarian.

I would like to emphasize that quantitative estimates show that it is very difficult to find a first partner for interstellar communication if pencil-beam channels are the primary form of communication. This is true even at the epoch of contact saturation for the galaxy. Therefore, the astrosociological paradox (silence of the cosmos) may easily coexist with a galactic cultural field. Great efforts from each civilization are needed to establish contact with the galactic cultural field. We cannot see a lot of civilizations out there because they are in the intensive, post-singular exo-humanistic stage, a time when the energy resources of their civilizations are not large and they can use only pencil-beam channels for interstellar communication. This is a possible answer to the main question proposed at the beginning of this paper as to why contact is so difficult.

Although I try to avoid arbitrary hypotheses, my analysis uses a scenario approach, which could turn out to be plausible or wrong. The crisis in science could be less than assumed, but it could also be greater–amplified by other crises not taken into account. The strategy of overcoming a general crisis based on solution of the SETI problem could also be combined with the strategy of creation of artificial intelligence or some other global mechanisms. Perhaps different strategies used by galactic civilizations would be incompatible and a problem for communication, so they would need to be classified into several types, according to their ways of overcoming the information crisis: cybernetic, communicative, etc. Even if the suggested scenario is correct in general, rare but strong deviations from it are possible.

Contact could be established sooner if there was a relatively small distance between two galactic civilizations–not at the post-singular phase, when strong communication is achieved, but much earlier. It could more easily take place within a star cluster. In this case, the problem of cosmic transport could become important and the self-preservation mechanism of foregoing expansion into outer space would be unnecessary. Such civilizations could develop super-civilizations with large-scale, astro-engineering activity.[50] Perhaps the galactic cultural field created by exo-humanitarian civilizations is only one kind of 'incubator' for super-civilizations and this scenario would only be a phase in the development of intelligence. This means that both a search for beam signals typical for the cultural field and a search for 'cosmic marvels' of such super-civilizations should be implemented simultaneously.

If the potential for overcoming the information crisis is possible, then, in accordance with the principle of *superfluous diversity*, a solution to the problem should already exist in a rudimentary form. Perhaps these new sprouts in the culture of humanity are already here, and we only need to look more closely to see them.

1. As mentioned before, science is not the only method of knowing. There are other, more ancient but still alive methods that reflect human conditions–such as mythology, art, religion, and philosophy. Maybe one of these traditional forms can take on the role of a new leader in shaping the direction human development. This is highly unlikely though–evolution does not swim in the same river twice, and all these forms of knowledge

have already been used. If this scenario occurred, it would be an unequivocal sign of degradation rather than progressive evolution.

2. One can imagine a synthesis of scientific knowledge with a traditional method of cognition. A 'return to roots', while maintaining science, could lead to a line of thought known as *metascience*. But this would not provide a solution to our problem. If reproducible scientific knowledge is crossed with a traditional form of knowledge that is irreproducible, then little that is accurate or useful would result. The motion of the planets around the Sun is described by the laws of Kepler and belongs to science–it is reproducible. The assertion that God exists belongs to religion and is not reproducible. A synthesis might be that God wants the world to obey the laws of Kepler, but the value of such a statement is not clear–it is irreproducible to the same extent as the assertion of the existence of God.
3. Could Artificial Intelligence (AI) provide an alternative to science? This is one of the proposals associated with cybernetics.[51] Computer numerical simulation and proofs of theorems imply reproducibility and scientific rigor, but–in truth–a computer is just a tool. If AI separates from the tool and the researcher becomes a partner, we could speak about a qualitative change in the scientific method and the birth of a new method of learning. However, there is no indication that this could happen in the foreseeable future. The fundamental ideas exist, but they do not hang on the ends of logical chains.[52] Our computers are finite automata (in the sense of computer scientist Alan Turing) and are only able to walk along chains of logic, so creative ideas are unattainable. The problem of creative AI has not been solved, not so much because it is so complex, but because we do not know how to properly state the questions, let alone the answers.[53] Often in general literature (but not in scientific monographs), one can find arguments that begin with: 'When AI will surpass the power of man . . .'. The authors do not really understand what they are saying. Computers have long surpassed many human parameters, such as speed, reliability and memory, but development of computers' creativity is exactly zero. What's more, the path of development in this direction cannot be found, or, at least, there is no accepted opinion where this road goes. But zero is zero, and has existed as zero for six decades of computer science. Therefore there is no reason to expect miracles from AI, since it is not yet creative.
4. Another possibility, also related to cybernetics, lies in the virtual computer world. In this scenario, science (in the usual sense) would be unnecessary. The prototypes of this application are modern computer games and virtual reality.[54] Such development is possible but unlikely to provide progressive advancement if based in classical computers, even those orders of magnitude more powerful than now. Virtual reality is poorer than actual reality for a fundamental reason: Reality is described by NP-complete problems, which are beyond the power of classical computers.[55] Reality on a classical computer cannot be modelled. Many if not all such

problems might be resolved by quantum computers, but these exist only in theory and it is unclear if they can be made into reality.[56]

5. Humanity's knowledge of nature is almost completely converted into application. Our focus has shifted from the acquisition of pure knowledge of science to 'kreatike' or creative efforts. This is apparent in the developments of science and engineering, which form a large part of human cognitive activity. The biggest question for this strategy is linked to sustainability. Without a constant influx of knowledge about fundamental nature, development and technology cannot persist.

Our predicament is really quite serious. In order to avoid decline and overcome civilizational crisis, something extraordinary needs to happen. Science needs to be shifted by some new type of cognitive activity or another vector of civilization must be radically changed. What could it be?

Notes

1. In only its first four months after deployment in 2009, the Kepler space mission discovered 68 planets of approximate Earth-size, 54 of which had a habitable zone temperature range. This is only a small portion of the results, because long-period planets (a one year orbit or more) had not yet been considered, etc. William Borucki et al., 'Characteristics of Planetary Candidates Observed by Kepler, II: Analysis of the First Four Months of Data', *The Astrophysical Journal*, vol. 736, no. 1, 20 July 2011.
2. I use an evolutionary model derived from Graeme Snooks, *The Dynamic Society: Exploring the Sources of Global Change*, London: Routledge, 1996; Akop Nazaretyan, *Civilization Crises in a Universal History Context: Self-Organization, Psychology and Forecasting*, Moscow: Mir, 2004; Erik Galimov, *Phenomenon of Life: Between Equilibrium and Nonlinearity; Origins and Principles of Evolution*, Moscow: URSS, 2001; Edward Kolchinsky, *Neocatastrophism and Selectonism: Eternal Dilemma or Possibility for a Synthesis?* St. Petersburg: Nauka, 2002; Igor Diakonov, *Paths of History: From the Most Ancient Humans to the Present*, Moscow: Oriental Literature, 1994 (Russian publications).
3. Scholars who have addressed commonalities between biological and social systems of evolution include Snooks, *The Dynamic Society*; Nazaretyan, *Civilization Crises*; Leonid Grinin, Alexander Markov and Andrey Korotayev, *Macroevolution in Wildlife and Society*, Moscow: LKI, 2008 (Russian publication).
4. Nazaretyan, *Civilization Crises.*
5. My list of revolutions and transitions was derived from the models of evolution mentioned in endnotes 2 and 3. Life events were chosen from literature on bacterial and classical palaeontology (discussed later), while those for human history correspond to the eight-phase transitions suggested by Diakonov in *Paths of History* and sequences derived by interdisciplinary scientist Sergey

Kapitsa in 'The Phenomenological Theory of World Population Growth', *Physics: Uspekhi, Advances in Physical Sciences*, vol. 39, no. 1, January 1996. Much of my periodization for human social revolution is derived from Diakonov and Nazaretyan. Dates are approximate, since they vary from scholar to scholar, and the phase transitions often had no exact beginning or end. This does not present a problem, because my analysis does not demand high precision. Our basic conclusions will not change if a moment is shifted to about 30 per cent of its absolute value.

6. Diakonov, *Paths of History*.
7. There are two famous numbers in mathematics: $\pi = 3.14159265$ (the ratio of a circle's circumference to its diameter) and $e = 2.71828182840$ (or Euler's Number). Euler's Number is the base of the natural logarithm $\ln(x)=\log_e(x)$ and the exponential function $\exp(x) = e^x$. It is exceptionally important in mathematical analysis, probability theory, theory of analytical functions (complex analysis) and other areas, because the number e has many famous properties, for example the derivative of e^x is equal again to e^x.
8. Heinz von Foerster, Patricia Mora and Lawrence Amiot, 'Doomsday: Friday, 13 November, AD 2026: At this Date Human Population will Approach Infinity if it Grows as it has Grown in the Last Two Millennia', *Science*, vol. 132, no. 3436, 4 November 1960.
9. Vernor Vinge, 'The Coming Technological Singularity: How to Survive in the Post-Human Era', <http://www-rohan.sdsu.edu/faculty/vinge/misc/singularity.html>; a version of this essay is also in this volume of our anthology. Kapitza, 'The Phenomenological Theory'. Also, for an overview of this subject, see Wikipedia, 'Technological Singularity', <http://en.wikipedia.org/wiki/Technological_singularity>.
10. Giuseppe Cocconi and Philip Morrison, 'Searching for Interstellar Communications', *Nature*, vol. 184, no. 4690, 19 September 1959.
11. SETI Institute, 'Early SETI: Project Ozma and Arecibo Message', <http://www.seti.org/seti-institute/project/details/early-seti-project-ozma-arecibo-message>.
12. Lee Billings, 'The Alien-Life Summit', *Slate*, 27 September 2013, <http://www.slate.com/articles/technology/future_tense/2013/09/green_bank_conference_seti_frank_drake_s_equation_for_estimating_the_extraterrestrial.html>.
13. Joseph Shklovskii, *Universe, Life, Intelligence*, Moscow: Academy of Sciences of the USSR, 1962 (Russian publication); Joseph Shklovskii and Carl Sagan, *Intelligent Life in the Universe*, San Francisco: Holden-Day, 1966.
14. SETI Institute, <http://www.seti.org/>; SETI League, <http://www.setileague.org/>.
15. SETI@home, <http://setiathome.ssl.berkeley.edu/>; Wikipedia, 'SETI@home', <http://en.wikipedia.org/wiki/SETI@home>; University of California, Berkeley, Berkeley SETI Research Center, 'Serendip', <https://seti.berkeley.edu/serendip>; Wikipedia, 'SERENDIP', <http://en.wikipedia.org/wiki/SERENDIP>.
16. The Allen Telescope Array is named after a project benefactor, Paul Allen. Formerly, it had been called the One Hectare Telescope (1hT).

17. Wikipedia, 'WOW! Signal', <http://en.wikipedia.org/wiki/Wow!_signal>.
18. The calculation for the distance to the nearest civilization in the galaxy, against the number of communicative civilizations, was derived from computational algorithms of the Monte Carlo method, along with a model for the distribution of stars and the location of the Sun in our galaxy (8.5 kpc from its centre).
19. According to the Drake formula, N_C does not depend on time. This is a flaw, as, for example, it is obvious that there were no CCs in our galaxy at first. Then there was a transition period, when their numbers increased. So, N_C could not be a single number. The Drake formula describes only a stable situation, which can be very remote from the facts. Also, the Drake formula is essentially linear in the sense that it ignores possible influences of CCs on each other or on the galactic media, as well as other related feedbacks.
20. I have presented a more detailed explanation of my modification of the Drake equation elsewhere. Alexander Panov, 'Dynamic Generalizations of Drake's Equation: Linear and Nonlinear Theories', *Bulletin of the Special Astrophysical Observatory*, vols. 60–1, 2007 (in Russian); idem, 'Dynamical Generalizations of the Drake Equation: The Linear and Nonlinear Theories', *Third IAA Symposium on Searching for Life Signature, St. Petersburg, Russia, June 27–30, 2011*, ed. Stephane Dumas and Alexander Panov, Paris: International Academy of Astronautics, 2015.
21. In the following discussion, the supposition is that ECCs exist and I consider only the dynamics of the sub-population of extrovert civilizations.
22. Similar models also allow us to study other effects, like variation in star-formation rate. Panov, 'Dynamic Generalizations of Drake's Equation'; idem, 'Dynamical Generalizations of the Drake Equation'.
23. Ibid.
24. This equilibrium also means that the characteristic time of change in the population of ECCs is longer than the mean lifetime of an ECC. The equilibrium in this context is similar to the concept of equilibrium for thermodynamic, quasi-stationary processes like an ideal Carno cycle, etc. In other words, the F(T) changes very slowly.
25. The decrease of the civilization-formation rate F may relate to the decrease of the start-formation rate R that is taking place at the present time and will hold in future.
26. The galactic community in principle will be able to prevent such a disastrous fall by resorting to directed panspermia or by other ways that may look fantastic now. But all such possibilities are not considered in our model.
27. Akop Nazaretyan, 'Technology, Psychology and Catastrophes: On the Evolution of Non-Violence in Human History', *Social Evolution and History*, vol. 9, no. 2, September 2009; idem, *Civilization Crises*; Umberto Eco, *When the Other Comes onto the Stage: Five Essays on Ethics*, St. Petersburg: Symposium, 2002.
28. Nazaretyan, *Civilization Crises*; idem, 'Technology, Psychology and Catastrophes'.

29. Konstantin Tsiolkovsky, *Dreams of Earth and Heaven*, St. Petersburg: Khudogestvennaya Literatura, 1895; repr. 1995; Ivan Yefremov, *Andromeda: A Space-Age Tale*, Amsterdam: Fredonia Books, 2004; Lev Gindilis, 'Extraterrestrial Civilizations: The Twentieth Century', *Social Studies and the Present*, vol. 1, 2001; idem, 'Search for Extraterristrial Civilizations', *Culture and Time*, vol. 2, 2003; Nazaretyan, *Civilization Crises.*
30. Lenta.ru, 'Presnensky Court Astrologer Saves NASA from Attacks', 8 November 2005, <http://www.lenta.ru/news/2005/11/08/bai/> (Russian publication).
31. Gindilis, 'Extraterrestrial Civilizations'.
32. The mass of the conceptualized orbiting solar power station was to be 9,570 tons and it was to have a lifetime of thirty years. Vladimir Levantovsky, *Cosmic Transport Systems*, Moscow: Knowledge Publishing, 1976, p. 37 (Russian publication).
33. A detailed analysis of the end of science is presented in Alexander Panov, 'Science as a Phenomenon of Evolution', in *Evolution: Cosmic, Biological, Social*, ed. Leonid Grinin et al., Moscow: Librokom, 2009 (Russian publication).
34. Stanislaw Lem, *Summa Technologiae*, Moscow: Terra Fantastica, 2002; Gregory Idlis, 'Regularities of Development of Cosmic Civilizations', in *Problems of the Search for Extraterrestrial Civilizations*, ed. Vsevolod Troitsky and Nikolai Kardashev, Moscow: Nauka, 1981 (Russian publications).
35. Special caution should be taken into account when considering the distant future. Since we are extrapolating a scale-invariant, pre-singular stage to a post-singular stage, the evolutionary character of that future time will be significantly different from its points of origin. Likewise, such extrapolation uses inductive reasoning, so it should be clearly understood that while induction can be a valid method of constructing hypotheses, it does not provide proof of anything.
36. It would not be so under the conditions of the extensive growth of a civilization at the expense of cosmic expansion.
37. I constructed a mathematical model for this scenario of a scientific collapse. Panov, 'Science as a Phenomenon of Evolution'.
38. We should keep in mind that a prohibition on some kinds of scientific activity could also serve as an overall stabilizing function.
39. The phrase, 'science is evil', is found by Google approximately 72,000 times, and, in many cases, it appears in the title of papers. The phrase is used in a great variety of contexts, of course, but the popularity of the issue is obvious.
40. John Horgan, *The End of Science: Facing the Limits of Science in the Twilight of the Scientific Age*, New York: Broadway Books, 1996; Leonid Leskov, *Cosmic Civilizations: Problems of Evolution*, Moscow: Knowledge Publishing, 1985 (Russian publication). Lipunov wrote about the decline of science in relation to the SETI problem. Vladimir Lipunov, 'On the Problem of Super Reason in Astrophysics', *Astrophysics and Space Science*, vol. 252, no. 1, March 1997.

41. Lipunov, 'On the Problem of Super Reason in Astrophysics'.
42. Vitayly Shwartsman, 'Search for Extraterrestrial Civilizations: A Problem of Astrophysics, or Culture in General?', in *Problems of the Search for Life in the Universe*, ed. Victor Ambartsumian, Moscow: Nauka, 1986 (Russian publication).
43. I am dealing with a qualitatively higher level of the organization of matter, following the social one, and, as such, the galactic cultural field has many interesting properties that have been discussed in detail in one of my earlier works. Alexander Panov, 'Intelligence as an Intermediate Link in the Evolution of Matter and the SETI Programme', *Philosophical Sciences*, September 2003 (Russian publication).
44. Vladimir Lefevre, *The Cosmic Subject*, Moscow: Institute of Psychology, Russian Academy of Sciences, 1996 (Russian publication).
45. Vladimir Lebedev, 'Civilization: From Cradle to Grave', *Bulletin of the Special Astrophysical Observatory*, vols. 60–1, 2007 (Russian publication).
46. Philip Morrison, in *The SETI Problem (Communication with Extraterrestrial Civilizations)*, ed. Samuel Kaplan, Moscow: Mir, 1975.
47. Shwartsman, 'Search for Extraterrestrial Civilizations'.
48. I do not agree with this reasoning. Vice versa, the knowledge in mathematics, physics, chemistry and astronomy (cosmology) are common to all and should be easy to decrypt.
49. Boris Panovkin, 'Information Exchange between Various Highly Organized Systems', in *Problems in the Search for Extraterrestrial Civilizations*, Moscow: Nauka, 1981 (Russian publication).
50. This scenario of cosmic expansion is assumed by astrophysicist Nikolai Kardashev and astronomer Samuel Kaplan, for example. Samuel Kaplan and Nikolai Kardashev, 'Astro-Engineering Activities and Possibilities of their Detection', in *Problems in the Search for Extraterrestrial Civilizations*, Moscow: Nauka, 1981 (Russian publication).
51. Stanislaw Lem considers such a cybernetic solution in his book, *Summa Technologiae*.
52. This conundrum of existing concepts but lack of coherence is aptly written about by science-fiction writers Arkady and Boris Strugatsky in their story, Беспокойство (Disquiet). Editors' Note: Originally composed in 1965, *Disquiet* was released in various versions before coming out in 1990 and then online in 1995. Its accessibility was brief and limited, and its similarity to the 2009 film, *Avatar*, has been noted. A report about it in English may be read online at Wikipedia, 'Disquiet (Strugatsky novel)', <https://en.wikipedia.org/wiki/Disquiet_(Strugatsky_novel>.
53. This group of AI questions is discussed in detail in Roger Penrose, *The Emperor's New Mind: Concerning Computers, Minds and The Laws of Physics*, Oxford: Oxford University Press, 1989; idem, *Shadows of the Mind: A Search for the Missing Science of Consciousness*, Oxford: Oxford University Press, 1994. Detailed discussion of connecting state machines with the world around them (a common counterargument by AI enthusiasts) does not fundamentally change anything.

54. Again, Stanislaw Lem considers the virtual realities of areas related to cybernetics in his book, *Summa Technologiae*.
55. This includes all cases where it is important to accurately take into account the behaviour of several quantum particles.
56. Existing demonstration samples containing only a few quantum cells do not count, as their main base is not implemented—so called quantum correction calculations, without which a universal quantum computer will not work.