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POSSIBLE SOLUTION TO THE FERMI PARADOX

Abstract – The paper focuses on the problem of the possible existence of extraterrestrial civilizations. It is shown that the abundance of this phenomenon may be low due to the fact that the transition from the stage of civilization to the stage of technological civilization is determined by the aggregate of random and unique factors.

Keywords: extraterrestrial civilization, culture, science, technological revolution

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ВОЗМОЖНОЕ РЕШЕНИЕ ПАРАДОКСА ФЕРМИ

В данной работе рассматривается проблема возможности существования внеземных цивилизаций. Показано, что их наблюдаемое отсутствие может быть объяснено тем, что переход от стадии цивилизации к стадии технологической цивилизации определяется совокупности случайных и уникальных факторов, которые встречаются очень редко.

Ключевые слова: внеземная цивилизация, культура, наука, научно-техническая революция

I. INTRODUKTION

The problem of extraterrestrial intelligence is far from new. It has been discussed at least since the Renaissance, and was expressed in the works of Nicholas of Cusa, Giordano Bruno and other thinkers of the Renaissance and modern times. In the XIX century, this idea exceeded the limits of scientific and philosophical discourses and became the object of description in the literature, e.g. in the novel by HG Wells War of the Worlds. However, since the Renaissance to our time, this problem has not been satisfactorily resolved.

The Fermi paradox was first voiced by Enrico Fermi in his famous question: "Where are they?", in which by "they" he meant representatives of extraterrestrial civilizations. This paradox can be formulated as follows: if we take into account Copernicus' principle (aka mediocrity principle or the principle of ordinariness) that the Earth and the Solar system are not unique in the space (Galaxy), then there should be a sufficient number of technologically advanced civilizations in the Galaxy, the traces of which (in the radio and optical bands in the first place), we should observe. Meanwhile, this is not happening.

In point of fact, the Fermi paradox is a contradiction between the theoretical assumptions about the mediocrity of our cosmic abode (the Earth and the solar system) as the cradle of industrial civilization, as well as mediocrity of this civilization medium - the modern man, and the empirical data, indicating the uniqueness of our technological civilization.

These empirical data can include both the absence of "space miracles" in different ranges of the electromagnetic spectrum and the "silence" in the radio frequency band. This is confirmed by the work of SETI program. Since 1971 it has been scanning the stars in the radio frequency band with the 21 cm wavelength. In this period more than 20,000 stars have been scanned but no signals have been detected.

True, it is a negligibly small part of the stars in the galaxy. Since 1995, SETI has been sponsored by private donations. To increase its effectiveness, in 1999 SETI @ Homeproject was launched through which anyone can provide their computer capacities for processing the results of sky scanning, but this project has not given any results yet (Kaku 2008) [11].

II. DRAKE EQUATION

The Drake equation, as the theoretical basis of the Fermi paradox solution, estimates the number of technogenic civilizations in our Galaxy ready to contact our civilization. This number is the **product of probabilities of presence of factors** necessary for the emergence of a highly developed civilization. Apparently for the "ordinarily distributed" factors the probability ratio will be significantly greater than zero, and for the unique – tend to zero.

It is the product of these probabilities that will define the uniqueness or ordinariness of existence of someone similar to us in our Galaxy.

I.S. Shklovsky [1, p. 613.] cites the Drake equation as follows:

$$N = n \cdot P_1 \cdot P_2 \cdot P_3 \cdot P_4 \cdot t_1 / T \qquad (1)$$

where N – is the number of advanced civilizations in the galaxy now, n – is the total number of stars in the galaxy, P_1 – is the probability that the star has a planetary system, P_2 – is the probability of life on the planet, P_3 – is the probability that in the course of evolution life on the planet will become intelligent, P_4 – is the probability that in the course of its development intelligent life will advance the "technogenic" stage, implying cognition of the objective laws of nature and active transformation of the latter, t_1 – the average duration of technological development era, T – is the Galaxy order of age. t_1/T ratio defines the simultaneity of existence of different technological civilizations. From a present day perspective, this formula should be modified – more factors should be included to characterize the probability that the star has not just a planetary system, but a planet similar to Earth, as well as the probability of transition from the simplest forms of life (unicellular) to complex (multicellular), with their variety of species.

Then the Drake equation becomes:

$$N = n \cdot P_1 \cdot P_2 \cdot P_3 \cdot P_4 \cdot P_5 \cdot P_6 \cdot t_1 / T \qquad (2)$$

where P_1 – is the same as in the previous formula, P_2 – is the probability of presence of a planet similar to Earth, P_3 – is the same as in the previous formula, P_4 – is the probability of transition from simple to complex forms of life, P_5 – is the same as P_3 in the previous formula, a P_6 – is the same as P_4 in the previous formula. The other symbols in the formulas are the same.

The problem of the Drake equation analysis is that, with the exception of the first and second cofactors, the other factors are estimated on the basis of empirical data obtained from just one object familiar to us: the planet Earth, terrestrial life forms, terrestrial intelligence and terrestrial technogenic civilization. It is quite difficult to give a quantitative estimation of the probability of this or other event on this evidence.

However, such estimates are made, but they are only possible under certain conditions or on some assumptions. As an example of such estimation we can cite this work (Forgan 2008) [7]. The author points out that according to various estimates, the value of N ranges from 10^{-5} to 10^{6}. Using the Monte Carlo method, this author defines this value based on three assumptions.

On assumption that life is widespread N equals approximately 38000, on assumption that the Earth is unique as a "cradle of life" N ≈ 361, and on assumption that life is widespread and its intelligent forms are unique N≈31500. Even on the basis of these results, the problematic character of the Drake equation is obvious – it has no unambiguous expression, that is the number of factors was not defined clearly. As science advances and factors, influencing civilization development become more comprehensible, their number and nature are being clarified.

Furthermore, some of the factors are not independent; they are interconnected with each other. Thus, qualitative estimation is preferable to quantitative estimation, especially as modern science is capable of making a qualitative estimation of the probability of events related to the relevant factors in the Drake equation.

By this we mean the estimation of uniqueness of these events, whether they are repeated or occurred only once. If these events are one-time, we can assume that they are absolutely random in character, and in "other worlds", they can not be repeated. Thus their probability tends to zero and consequently the number of highly developed civilizations in our galaxy at present tends to zero too.

If these events are repeatable, they are natural, and therefore can be repeated in other planetary systems, so their probability is nonzero, and therefore they make a significant "contribution" to the possible number of other civilizations. Let's consider the modern research data on each of the factors.

III. MULTIPLERS DRAKE EQUATION

Factor n – total number of stars in our galaxy, according to modern data estimated approximately equal to $2 \cdot 10^{11}$. This is a proven and very high index. P_1 – the probability that the star has a planetary system.

This figure is being intensely specified currently. At the end of November 2014 the catalog The Extrasolar Planets Encyclopaedia [2] indicated 1849 planets outside the solar system, which are grouped in 1160 planetary systems, and 471 of them have more than one planet. Usually monthly, several planets are added to this list.

Such quantitative diversity allows for quantitative estimates of the frequency of planets occurrence (A. Cassan, D. Kubas, J.-P. Beaulieu 2012) [3]. Even taking into account the fact that the observed array of planets with respect to the array of the observed stars is negligible, the total number of planets in the galaxy is estimated at several dozens of billions. According to the authors of this work, "We have come to the conclusion that the stars with planetary orbits are a rule rather than an exception" (A. Cassan, D. Kubas, J.-P. Beaulieu 2012) [3]. In their estimation the value of P_1 equals 0.2 – 0.5.

It is more complicated to estimate the value of P_2. And the problem here is not only the direct observation of such planets, but what kind of planets should be recognized as Earth-like. Obviously, those must be planets similar to the Earth in their weight, size, distance from the parent star, the chemical composition that provides the appropriate temperature regime on its surface, allowing water to exist in the liquid phase.

Current estimates of the occurrence of planets similar to Earth in these parameters give a value of $0{,}34 \pm 0{,}16$ (Traub 2012) [4]. However, we can not identify these values with P_2 to the full. In the context of this issue, the presence of the satellite – the Moon – is a significant factor in the evolution of the Earth, which led to a qualitative diversity of its conditions, and above all the chemical composition of the atmosphere, hydrosphere and lithosphere.

As O.G. Sorokhtin notes the Moon played the role of some "catalyst" in the physical-chemical processes at the early stages of the evolution of the Earth, and in its absence the Earth would not have evolved into its present state, and without the Moon the Earth would be similar to Venus (Sorokhtin 1991) [5].

At present it is very difficult to estimate the abundance of such systems as "Earth – Moon". Theoretically, this can be done by constructing the theory of birth of such a system, which could explain if its origin was incidental or natural. Empirically this can be done increasing the accuracy of observations, when you can observe not only the planet, but its satellite as well.

This is yet to be done, but given the abovementioned values of the abundance of planets similar to the Earth, P_2 factor can still be regarded as a sufficiently large value, significantly different from zero.

It is more difficult to estimate factor P_3. The problem of the emergence of living matter, abiogenesis is one of the most complex and global problems of modern science, and intensive research on it is conducted. It is assumed that abiogenesis went through several stages. At the earliest stages simple organic compounds develop from inorganic matter.

Later on, organic compounds emerge – "biomolecules" including structural units of biopolymers. And then biopolymers develop from them, subsequently creating the structures of living matter. If we select two criteria for distinguishing living matter: the ability to reproduce and the ability to carry out chemical reactions involving enzymes, respectively, then there are two methods of solving the problem of the living matter origin: genobiosis and holobiosis.

There are assumptions that these processes (genobiosis and holobiosis) can be realized not only on the basis of carbon, but also on the basis of silicon, nitrogen and phosphorus, boron and nitrogen.

There are even hypotheses on the possible existence of field forms of life, but neither well developed theoretical models of living matter origin, no empirical data on this topic exist today.

All this adds a certain logical philosophical component to the problem of the origin of life. The notion of life can have several definitions. In the narrow sense - using the chemical carrier (protein), more generally through the physicochemical properties of the living matter, and the most general definition using ontological physical system properties of all that can be called life.

This whole range of problems related to the concept of "life" can not give a qualitative assessment of the factor P_3 and is to be considered uncertain. However, we will revert later to the definition of life on applying its most general properties.

It is also difficult to define factor P_4, but its value is still more certain than P_3. As we all know from the school curriculum: "The fossil record indicates that multicellular organisms appeared in the course of evolution from unicellular eukaryotes independently at least 17 times".

Of the existing metazoan sponges descended from a common ancestor, while all other forms – from some other. In the process of historical development at least 35 types of multicellular organisms appeared on the planet. Of these, there are still 26, being represented by more than 2 million species" [8].

At the moment it seems valid that the process of emergence of multicellular organisms was conditioned by several factors, among which oxygenation of the atmosphere (oxygen catastrophe). These catastrophes stimulated complication in the diversity of life morphology ("Avalon explosion, "about 570 million years ago (Shen B. 2008) [9]").

This suggests that life takes complex shapes provided the conditions are favorable. We can assert that some complex life forms having emerged began to evolve and exist until today, others died, but in general the transition from simple to complex forms of life is a natural phenomenon.

All this allows us to estimate factor P_4 as "quite significant", making a real contribution to the total product of N and not nullifying it.

Factor P_5 probability that in the course of evolution life on the planet will become intelligent, can be estimated in the same way, although the question itself is more complicated than in the previous factor. If the concept of "complex form of life" can be identified with multicellular forms, the concept of "intelligence" is harder to determine.

Without getting into a discussion of this problem, in this case "intelligence" is understood as the ability to think in abstract terms, in the Kantian sense "inference-making ability", i.e. the ability to think and to imagine what is not directly present in the sensory experience.

Capacity for complex communication, for constructive activity of transforming surrounding reality to protect own interests, for creativity and inventions are external features of intelligence.

It follows from the analysis of anthroposociogenesis process (see (Andreyev 1988) [10]) that presence of a sufficiently developed brain, free from walking forelimbs and the ability to manipulate objects, or, put more simply, the presence of fingers are the conditions for the emergence of rational beings.

M. Kaku adds here vision and potential for the development of complex communication, such as speech. (Kaku 2008) [11, p. 201]. The process of evolution has developed in such a way that the totality of these properties was "centered" in our ancestors - apes, but in principle it could have turned out differently, and these qualities would have belonged in its entirety to other developed species, such as reptiles.

Even great apes in the process of anthroposociogenesis evolved "nonlinearly", forming a "dead-end" and "progressive" branches that coexisted and competed with each other.

Currently, about 12 species of hominids are known and one existing species - Homo sapiens. At the early stages of development, he did not exist alone, but competed with 5 more species [12].

It can be assumed that not all hominids, who coexisted with Homo sapiens, have been discovered up to now, but those discovered let us suggest that the emergence of intelligence in the process of evolution is a natural event, and factor P_5 has a "normal value" in the sense that it does not "nullify" N and makes a positive contribution to its overall value.

IV. THE PROBLEM OF APPEARANCE OF INDUSTRIAL CIVILIZATION

The last factor in the Drake equation is factor P_6 – the probability that in the process of its development intelligent life will reach the "technological" stage, involving the cognition of the objective laws of nature and its active transformation.

However, in this case, the situation with the estimation of this factor value is somewhat different from the previous cases. First, on the assumption of formal arguments. The term "civilization" comes from the Latin "civilis" – a civilian government.

Without going into details of various theories of civilizations which indicate the diversity of their features, it may be noted that one of them is the presence of state institutions in society. In a broader sense, civilization can be understood as a specific human culture in which state institutions are functioning.

It is difficult to give an unambiguous definition to the term "technogenic civilization", since the man has been using a wide range of technical tools and devices since he appeared.

But taking into consideration the fact that one of the most basic human needs is the need for food, an advanced, "completed" technogenic civilization can be understood as a civilization in which food production is not based on manual labor (or animal labor), but on the use of mechanisms and machinery.

This enables people to accumulate a considerable surplus of food and material resources in general, directing them for other purposes, such as the development of technical means of communication, manufacturing, researching and colonization of space.

Different researchers in retrospect allocate a different number of civilizations. In particular, Toynbee speaks about 21 civilizations (Toynbee 1991) [13]. But, despite the fact that civilizations arise virtually in any place where there are favorable conditions (according to Toynbee, the emergence and development of civilization is a "response" reaction to the "challenge" that nature offers to the human community, or – other community), it can be stated as a fact, that only one civilization of all known from the history – the European civilization – became technogeneous, and by historical standards not long ago – 1.5 – 1 century ago.

This suggests that factor P_6 is really very small, much smaller than P_1, P_2, P_3, P_4 and the transition from civilization to a technogeneous civilization is a unique, "one-time" event and can be quite random. We will discuss later what are the mechanisms of this randomness.

The emergence and development of the technogeneous civilization is closely related to the emergence and development of scientific and technical progress. We can talk about the transition of civilization into a technological civilization when science and technology are integrated into a single unit in terms of institutions and content.

Therefore, the emergence of science is a necessary but insufficient condition for the emergence of the technogeneous civilization. And if technical activity is characteristic of all civilizations, the phenomenon of science occurs in only one – the ancient civilization of Greece.

Then it spreads to the ancient Greco-Roman civilization, from there it moves to the civilization of Byzantium and the medieval Islamic civilization, and then again returns to Europe and there science makes a breakthrough, merging with technology and achieving scientific and technical progress.

The problem of determining what science is, as well as the time of its emergence is also quite complex. Without going into other points of view, in this paper we assume that science is primarily a special way of thinking, which can be called theoretical thinking.

Specificity of this way of thinking lies in the fact that it operates with abstract, idealized objects the existence of which is ultimately not inferred directly from empirical experience, but is an indirect axiomatic statement.

We can say that theory is a representation of reality described with a special language. This language differs from the language which reflects normal everyday reality, but it also claims to be describing reality. This description occurs at a higher level of abstraction and "reveals" "secret mechanisms" of reality "functioning”.

A particularly clear understanding of theory is reflected in the age of the first academies of sciences, such as the Lincean Academy (Accademia dei Lincei), "Invisible College" and others.

This form of thinking appears in ancient Greece as philosophy, but we can speak about the emergence of theoretical science in the true sense only with the advent of logic, developed by Aristotle. Aristotle managed to create an ontological system, which proves the possibility of scientific theoretical thinking interconnected with empirical experience.

The emergence of logic as a methodological framework of any theory, and on its basis development of such theoretical scientific disciplines as physics, biology, and cosmology has become the consequence of Aristotle's ontology. More details about the origin of theoretical science, the impact of Aristotle’s ontological system on this process and ontological basis of scientific knowledge in the form of two paradigms of ontological basis of science can be found in (Tararoyev 2011) [14].

In the context of this problem it is necessary to point out that scientific and technical progress took place in two stages. The first was associated with the emergence and development of science itself, and the second was associated with the process of integrating science and technology.

This integration implied methodological "convergence" of science and technology, in which technology was theorized and science became more empirical.

It is difficult to determine the beginning of the second stage, but we can clock the time of its institutionalization. First institutional integration of science and technology takes place in the most scientifically and technically developed country – Germany.

In 1887 Imperial Institute of Physics and Technology was opened in Berlin, and solution of the problems of theorizing technology and comprehensive practical application of science was among its tasks. By the beginning of World War 1 along with it Imperial Institute of Chemical Technology and several other institutions: biology, chemistry, coal mining, experimental medicine, physiology of labor and physical chemistry have already been functioning in Germany, unified into the Kaiser Wilhelm Society. (Walker 2003) [6].

Coming back to the main issue of this work, we can say that the small value of P_6 can be explained by two factors:

1. By the uniqueness of development of theoretical thinking basis, and therefore uniqueness of the existence of science as a theory, as a specific form of thinking. Indeed, this foundation is formed on the basis of Aristotle’s ontological system, which in its turn arises as revision and criticism of Plato's ideas, which in its turn arises from Socrates’ "anthropological turn", reflective not of the properties of the surrounding world, but of a human ability to think in terms of concepts.

Theory ontology formed by Aristotle, presents it as strict and systemic logical thinking, not isolated and opposed to the empirical experience, but based on it. All pre-Aristotelian ontological concepts had one important drawback preventing them from becoming the basis of scientific knowledge – inequality of the ideal and empirical, subordination of the former to the latter.

In the modern era the empirical component of science is developed further, leading to the unity of scientific and technical knowledge. However, we can assume that the origins of this – highly developed culture of ancient Greece in general, where a pleiad of thinkers Socrates – Plato – Aristotle emerged and developed logic as a separate discipline, which functions as methodological framework of theoretical knowledge.

This culture that gave rise to rational knowledge was unique and inimitable owing to several reasons (see for example (Childe 1942) [15]). One of the most important reasons is its geographical location. Natural conditions of its habitat (the sea and mountains) provided peculiar isolation from external enemies, allowing it not to allocate significant resources to the military and state-building, saving them for development and "mild", "trade colonization".

2.A relative poverty of the society was another feature of ancient Greece which distinguished it from the societies of the ancient East. This eliminated significant stratification, in economic terms. The society was more homogenous and "fair", as it possessed less total social wealth, than the societies of the ancient East.

The wealth of ancient Greece did not arouse such interest of neighbors, as it was in the Ancient East. Its social organization was consistent. The society was less militarized and theologized, social groups of the military and clergy played a much smaller role there than it was in the "old world" of the Ancient East.

Similarly, powers were also distributed equitably. Ancient Greek city-states used other forms of government, different from the Ancient East – democracy, where power was not concentrated in a small group of persons who held enormous wealth, but was distributed among the members of the society, which was one of the obstacles to the creation of an authoritarian centralized state.

At the same time, navigation and trade promoted active contacts with all developed societies of the ancient Mediterranean and geographically close to them. In these contacts, Greek culture has accumulated all the most important and successful achievements of other cultures. These achievements needed systematization, and Greek philosophy, within the scope of which logic developed, was called upon for that putpose.

Thus, we can assume that the major "social order", the main function of logic and theory along with it was to systematize the variety of intellectual knowledge of Greek. At least Plato’s theory and Aristotle’s metaphysics aspire to this function. Of course, this assumption is a hypothesis, and the task of validating the systematizing function of theory and logic requires a more serious study and research.

Transition to the second stage of scientific and technical progress can also be unique and inimitable. This transition is not natural and can also be random in nature. Prerequisites of this transition are socio-cultural in nature; they create motivation and need for inventive activity and complex technical solutions. Motivation of transition to this activity can be attributed to the crisis of medieval society.

This activity does not "take place" immediately, significant technical achievements were made several centuries after the motives emerged. The objective of this work is not a detailed analysis of the socio-cultural backgrounds of the crisis of medieval society; it is possible to mention only some of them, which are to a certain extent accidental:

1. Gradual urban growth in the IX – XIII th centuries and later. The development of urban lifestyle necessitates the development of science as well as technology. Science and technology at a particular level of development became an essential element of urban life, the first universities were opened at that time in Europe, which met the needs of the city; much later, in the era of the first industrial revolutions cities became a place of concentration and development of industry.

It is very important that cities were emerging and growing at this time everywhere in Europe both in Eastern and Western Europe, from the Atlantic to the Volga. In Western Europe south of the Danube and west of the Rhine, ie in the territories that were part of the Roman Empire, old (Roman times) cities were revived and new cities were built. On the territory to the north of the Danube and east of the Rhine, including the territory of Kievan Rus, only new cities emerged as these areas were beyond the direct influence of the ancient world and the urban way of life was not common there.

No unambiguous explanation of this global synchrony has been found, so we can assume that warming was one of the causes of this process and subsequently led to the production of agricultural surpluses necessary for the urban lifestyle.

2. Climate change, known as the "Little Ice Age" in the XIV – XIX th centuries. Obviously, this was a very serious challenge to human society, which led to a number of serious consequences, such as crop failure, epidemics, etc.; and increasingly widespread use of technology necessary to maintain the urban lifestyle, developed earlier, when a more favorable climate persisted was one of ways to meet this challenge.

3. Plague in middle of the XIV century. This event had disastrous consequences. According to various estimates from 30 to 60% of the population in Europe died from plague.

In economic terms, it was a terrible loss of human resources, which led to a crisis in the economic system based on manual labor, and consequently to the transition to work based on mechanisms and machines. Moreover, plague significantly undermined the authority of religion and the church, as they had nothing to contrapose against the "black death" and at the same time raised the authority of science (especially medicine) as something that can deal with such disasters.

To the reasons mentioned above, which formed prerequisites of gradual transition to the integration of science and technology, we can add some others, in particular the "common scientific and educational space" (wider – cultural), inherited from the Roman Empire, the territory in which Latin was spread as the language of culture.

Actively formed in the rationalized society of the Roman Empire, Latin contributes to the perception of the ancient science achievements to the maximum extent. In general, the formation of a scientific way of thinking took place within the context of Greek and Latin.

The specificity of these languages, their advantages for developing science in particular were noted by G. Childe (see (Childe 1926) [16]). However, it should be noted as a fact that the transition to the second stage of development of scientific and technical progress occurred at the time when the language of science "split" into national languages. The importance of the language problem in this transition is a topic of another researchwork.

V. CONCLUSIONS

Returning to the Drake's equation it should be noted that in addition to the values mentioned above, it includes two more values: t_1 – the average age of technological development and T - the order of the age of the Galaxy. The first is uncertain, because at the moment we know only one technological civilization – our civilization that has existed for 200 – 100 years, and it is not correct to give any qualitative and quantitative estimation on the basis of such small empirical data.

We can only indicate that it is interconnected with P_6. The second value is set precisely enough and is $1{,}32 \cdot 10^{10}$ years.

Thus, the analysis of all the factors of the Drake equation gives us ground to state that some of them can already be quantified, and their quantitative assessment gives them a large enough value, some parts - high quality, and some often uncertain.

The first group includes n – the total number of stars in the galaxy, P_1 – the probability that the star has a planetary syste, P_2 – the probability that the star has a planet similar to Earth, and T - the order of the age of the Galaxy.

Among uncertain factors P_3 – the probability of life on the planet and - the average age of technological development. And of those that can be evaluated qualitatively, factors P_4 – the probability of transition from simple to complex forms of life, and P_5 – the likelihood that in the course of evolution life on the planet will become intelligent are "quite significant", they make a real contribution to the overall product of N and do not nullify it.

Qualitative evaluation of factor P_6 – the probability that in the process of its development intelligent life will reach the technological stage, shows that it can be very small, in fact tends to zero and significantly understate the value of N.

Then factor P_6, given more precise definition of all the other factors, and if they are large enough, can resolve the Fermi paradox, on the assumption that the emergence of a technologically advanced civilization in the history of the universe is quite a rare event.

It happened on the Earth, but will not occur on other planets inhabited by sentient beings. This, in particular, means that the phenomenon of "progress", including scientific and technical, economic and civilizational is not deterministic and accidental, but depends on many different factors. Understanding the nature of these factors is very important for the progressive solution of the problems that modern society is facing today.

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