

AD-787 399

LONG-RANGE FORECASTING OF SCIENTIFIC-
TECHNOLOGICAL PROGRESS

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Wright-Patterson Air Force Base, Ohio

25 September 1974

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UNCLASSIFIED

AD-787 399

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Foreign Technology Division Air Force Systems Command U. S. Air Force		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	
		2b. GROUP	
3. REPORT TITLE LONG-RANGE FORECASTING OF SCIENTIFIC-TECHNOLOGICAL PROGRESS			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Translation			
5. AUTHOR(S) (First name, middle initial, last name) V. Siforov			
6. REPORT DATE 1971	7a. TOTAL NO. OF PAGES 21	7b. NO. OF REFS 0	
8a. CONTRACT OR GRANT NO.		8b. ORIGINATOR'S REPORT NUMBER(S) FTD-HC-23-2335-74	
b. PROJECT NO		8c. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
c.			
d.			
10. DISTRIBUTION STATEMENT Approved for public release; distribution unlimited.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Foreign Technology Division Wright-Patterson AFB, Ohio	
13. ABSTRACT 05			

Reference Copy
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. Department of Commerce
Springfield, VA 22161

EDITED TRANSLATION

FTD-HC-23-2335-74

25 September 1974

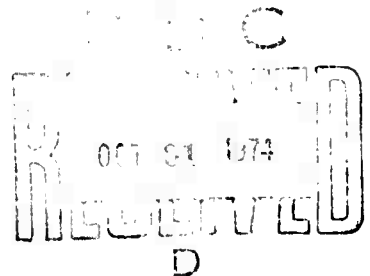
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TECHNOLOGICAL PROGRESS

By: V. Siforov

English pages: 16

Source: Sovet Ekonomicheskoy Vzaimopomoshchi.
Postoyannaya Komissiya Po Koordinatsii
Nauchnykh i Tekhnicheskikh Issledovaniy.
Teoriya i Praktika Prognozirovaniya
Razvitiya Nauki i Tekhniki v Stranakh-
Chlenakh Sev, 1971, pp. 54-63

Country of Origin: USSR
Translated under: F33657-72-D-0854-0005
Requester: FTD/PDTA
Approved for public release;
distribution unlimited.



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PREPARED BY:

TRANSLATION DIVISION
FOREIGN TECHNOLOGY DIVISION
WP-AFB, OHIO.

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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	А а	A, a	Р р	Р р	R, r
Б б	Б б	B, b	С с	С с	S, s
В в	В в	V, v	Т т	Т т	T, t
Г г	Г г	G, g	У у	У у	U, u
Д д	Д д	D, d	Ф ф	Ф ф	F, f
Е е	Е е	Ye, ye; E, e*	Х х	Х х	Kh, kh
Ж ж	Ж ж	Zh, zh	Ц ц	Ц ц	Ts, ts
З з	З з	Z, z	Ч ч	Ч ч	Ch, ch
И и	И и	I, i	Ш ш	Ш ш	Sh, sh
Й й	Й й	Y, y	Щ щ	Щ щ	Shch, shch
К к	К к	K, k	Ъ ъ	Ъ ъ	"
Л л	Л л	L, l	Ы ы	Ы ы	Y, y
М м	М м	M, m	Ь ь	Ь ь	'
Н н	Н н	N, n	Э э	Э э	E, e
О о	О о	O, o	Ю ю	Ю ю	Yu, yu
П п	П п	P, p	Я я	Я я	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
 When written as ë in Russian, transliterate as yë or ë.
 The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

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All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	\sin^{-1}
arc cos	\cos^{-1}
arc tg	\tan^{-1}
arc ctg	\cot^{-1}
arc sec	\sec^{-1}
arc cosec	\csc^{-1}
arc sh	\sinh^{-1}
arc ch	\cosh^{-1}
arc th	\tanh^{-1}
arc cth	\coth^{-1}
arc sch	sech^{-1}
arc csch	csch^{-1}
—	
rot	curl
lg	log

LONG-RANGE FORECASTING OF SCIENTIFIC-TECHNOLOGICAL PROGRESS

V. Siforov (USSR)

The following classification of forecasts is known: forecasts of the first echelon--for 15-20 years ahead; forecasts of the second echelon--for the first decade of the 21st century; and, finally, forecasts of the third echelon--for approximately 100 years ahead. At the present time there is a necessity to speak of a fourth echelon of long-range forecasting for an even longer period of time--for several centuries, and perhaps even longer.

It is entirely valid to raise the question: is it necessary to be concerned with so long-range a forecast; is it necessary in the light of the solution of tasks that stand before us in the contemporary situation?

Long-range forecasts are useful, first of all, because they will fruitfully influence social processes in the more immediate future.

The second reason for the necessity of being occupied with long-range forecasts is related to the psychology of scientific creativity and the dual nature of science. The fact is that science, on the one hand, through technology and production permits us to solve basic socialist tasks, which are established in the program of our party--tasks of more completely satisfying the growing needs of all the members of society. But there is another side, related to the psychology of the people of science, to the psychology of science

collectives; the very pursuit of science for scientists implies the satisfaction of their needs to understand more completely nature, society, and processes occurring in the world. The striving to gaze into the cosmos, into the microcosm--the world of atoms and elemental particles--into the world of viruses and bacteria--this is a characteristic trait of scientific creativity. In the same way it is natural for historians to look into the past of long ago.

From this point of view, to gaze into the farthest future is a completely natural need of scientists.

The history of science persuasively speaks of scientific research of outer space, microcosms, as well as of the remote future, as being only at first unnecessary for the achievement of short-range goals. There is an urgent need for activity in this area, if only from a universal outlook point of view.

This is true also of the second cardinal question: is it possible to look so far into the future? Here there are a variety of points of view. I will present several considerations for and against long-range forecasting.

First of all, science has persuasively demonstrated that there have been and will be in science radical swings, radical changes in the direction of scientific research, great discoveries, which are impossible to predict on the basis of past experience.

Long-range forecasting is difficult also because at the present time the development of science and technology is going very quickly, and the tempo is becoming more accelerated. The doubling of scientific information has occurred on the

Furthermore, new sciences, or new scientific directions, arise as a consequence of the application of methods procured for one science to the research of the objectives of another science; the confirmation of new principles in this manner also has many examples. One of these is radioastronomy. Namely, we were able to penetrate much more deeply into space than would have been possible without its help.

An innovation also emerges by way of the abstract research of analogous characteristics, intrinsic to various types and forms of the motion of matter. Regardless of the total diversity of the various forms and types of the motion of matter, they are also somewhat similar. The discipline of the theory of oscillation may serve as an example of this. It is known that the fundamental principles in the area of the theory of oscillation were discovered by the Soviet scientific school of L. I. Mandel'shtam, N. D. Papaleksi and A. A. Andronov.

The theories of information and cybernetics, having such a fundamental significance for the formation of new sciences, may serve as other examples.

Furthermore, the development of the technique of the scientific experiment, the creation of new scientific methods and the organization of specialized scientific machine construction are powerful levers for the emergence of new scientific discoveries. A typical example is the electron microscope, which has permitted a deeper understanding of such a fundamental secret of the life of nature as the genetic code. Without the electron microscope the accomplishments of contemporary biology, causing a radical turn in biological science, would hardly have been possible.

The development of new branches of production, technology and technological processes as a result of accomplishments in physics and chemistry is also a powerful factor for the emergence of new sciences and scientific directions. Thus, thanks to the application of methods and means of quantum electronics fundamentally new technology has appeared, the application of which will lead to the emergence of new sciences and new scientific directions.

And finally, research on the laws of the development of science itself facilitates the emergence of fundamentally new directions within science itself.

Around 6-7 years ago many people considered that, and this is a far-fetched direction, that the sciences must develop themselves, that complex research into their development is unnecessary, etc. Now nobody has any doubt that together with deep research in the area of every concrete science it is necessary to carry out research on the laws of the development of science itself. The learning of these laws would be very useful for the solution of those problems that the present report is dedicated to.

For a correct forecast it is very important to establish in which directions we may expect major, radical qualitative leaps in scientific-technological progress to go. Here emerges a fundamental question: Is it possible to predict major scientific discoveries?

This question must be answered dialectically: it is both possible and impossible. However, it is necessary, certainly, to expand this short answer, to clarify in which sense it is impossible and in which sense it is possible.

In every major scientific discovery there are always many unanticipated elements. The history of science gives us rich material on the fundamental discoveries in science, such as, for example, the theory of relativity and the quantum theory. Together with fundamental discoveries there were many similar unanticipated discoveries of lesser significance. And, of course, unquestionably, all of these would have been difficult to predict.

But despite this it seems that it is not only possible, but it is even necessary to predict major leaps of a very high rank, the most radical turns in science in general terms and for a very remote period.

What do these leaps of the highest rank consist of? Already in our day they are about to happen in nuclear physics and in power engineering, solid state physics and the chemistry of polymers, radioelectronics and automation, biology and medicine and in many other areas; fundamental discoveries will radically change the character of science, of technology and of production in the relatively near future. They will play a conclusive role in the further development of society.

However, comparing these possible types of scientific discoveries, of revolutionary turns, radically qualitative leaps, in analyzing the conditions of the development of science in the future, it is necessary to promote a hypothesis, the verity of which we deeply believe; the most major, radical, archfundamental leap and turning point in the future developments of science and technology in the life of human society will be the creation by mankind of fundamentally new types and forms of the motion of matter, of which nothing was known before. The hypothesis is disputed by many people, depending

upon their point of view, that to create synethetically new types of motion of matter, of which nothing was known in the past, is fundamentally impossible. We submit that the creation by mankind of new types and forms of motion of matter is not only possible, but that the whole course of the development of science and technology and the process of the further development of human societies is inevitably dependent upon this archfundamental qualitative leap. In the present report we have made an attempt to consider the general direction of science, the development of which may approach the higher archfundamental changes described. It is possible to anticipate these, in particular, for the further development of the sciences dealing with the reality that surrounds us, and above all of research in cosmic space. For example, work may be carried out in the area of scientific forecasts on the existence of extraterrestrial civilizations. Previously this was an area reserved for science fiction novels. In our day it has been transferred into the realm of scientific research. In our country, as well as abroad, special scientific symposia have been created, dedicated to extraterrestrial civilizations.

And so, in the form of long-range forecasting we may anticipate radical changes in science with the discovery of extraterrestrial civilizations and the establishment and development of contacts with them.

The new forms and types of motion that inevitably will be discovered and created in the process of the further development of science and technology will include an internally inherent quality of self-development, and the general direction of this self-development will be determined and directed by man. From this point of view, in order to plan the ways of solving problems; in order to establish what direction it is

necessary to move in, it is necessary to discover and create such new forms of the motion of material; it is necessary to look into the near future.

Above all it is necessary to examine which aspects and directions in science and technology of the present, from among all the numerous aspects and directions, must be recognized as determining, from the point of view of the creation of new forms, the motion of matter in the future. In this relationship the dissertation of D. Bernall, which considers the creation of the computer as the most significant accomplishment of all accomplishments of the twentieth century, is very interesting. Computers signify the entrance of man into a new era, the era of the automation of intellectual labor, which was not long ago denied on the basis of fundamental considerations. It is therefore important, even if only for a proximate time, to foresee the possible directions of development, the possible leaps in the twentieth century and in the first decade of the twenty-first century in the computer area.

In connection with these views, which have been set forth by Academician S.V.M. Glushkov and A.I. Berg, it is possible to consider the following directions:

The first--the increase of the volume of memory banks. In a system of memory banks all the richness accumulated by mankind in science, culture, and in all the diverse aspects of life of people may be stored. The potential possibilities in this connection are practically unlimited.

In the scientific literature that we have, and even in that from abroad, there is work in which the potential possibilities of storing information are researched and tasks, for

example, of how much information may be stored in this or that volume, proceeding from the laws of physics, quantum mechanics, the principle of indefiniteness, etc. are solved. These works are totally real and interesting.

The second direction is microminiaturization. This is related to the development of contemporary radio electronics. For the construction of computers we switched from vacuum tubes to transistors, and in recent years, to solid state systems. The solution of the problem of microminiaturization creates the possibility of building very complex computers containing huge numbers of elements of comparatively limited volume and weight.

There is the topical problem of man-machine communication. In the relatively near future there will be created a global system of machines, a united automatic system of communication, a united system of scientific-technological and other information. For this reason all of these systems will be joined together, to have a complex structure and their own special characteristics. The creation of such a system and the development of its theory is one of the important directions of contemporary science and technology.

In particular, into these global systems of machines will enter to a certain extent both the system of storing and transmitting and of reproducing television programs. In no more than about ten years, and perhaps even earlier, a global system of television will be linked with a system of storage, transmission and processing of information. This will guarantee the most complete satisfaction of the needs of television viewers in the sense that the choice of a desirable program will be conveniently timed for them.

It is thought that in the approaching fifty years the linking of television with contemporary information services will give unimaginable results. Every television viewer, pressing the appropriate buttons, will be able to listen to the particular lecture he is interested in. A question will be fed into the informational service system, and it will be computed automatically. It will be possible to take a tour of every country by television, to closely examine any sort of scientific question, to view any film, to improve foreign language skills, etc. As a result of the joining of television with other services, in particular with an information service, with a computer, and also as a result of the interaction of television with other areas of technology, areas of utilization for television will open up before us that are even now difficult to foresee.

Finally, thanks to electronic machines radical changes in the work of scientists themselves will occur. The machine will accumulate, process, and distribute new information. In this manner, in particular, several new types of codes have been found. For their discovery, it was necessary to sort and compare about a trillion operations. Thanks to the high speed of the computers the new codes were found by the machines themselves, and a man fed into them only requirements and algorithms.

Already in our time the machines carry out not only calculation work: in them the groundwork for new features has been laid down. It is necessary to seriously think of ways to develop these seedlings in the proper topical directions for human society.

Computers will radically change the work of man. They will collect information themselves, process it automatically and give conclusions. The capacity of a computer to improve itself, program itself, and organize itself will have great significance. Thanks to these characteristics the machine will derive the possibility of changing its own structure in definite steps as well as its organization and inner system of interacting elements. A not insignificant role in the development of suitable means will be played by bionics. One of the main directions of bionics is the research on the working of the brain. Unfortunately, we still know very little about its structure. Detailed and deep research of the brain will serve in the future as a starting point for the designing of fundamentally new machines with new characteristics, unusual from the contemporary point of view.

However, in connection with bionics it would be desirable to stress that the development of technology, including such major areas as computers with developed characteristics which were discussed above, although in many instances connected with bionics, would be basically determined by its own specifications, among them social laws.

Even from these general positions it is possible to affirm that in the technology of the future there will appear many specific moments, distinguishing this technology from the life of nature and from man himself. This is demonstrated by the fact that the conditions of development of technology are radically differentiated from the conditions of the development of life on earth, from the conditions of the emergence and development of man.

It seems to me that in the comparatively near future there will be created global heuristic systems for the solution of grandiose tasks. For these creations it will be necessary to join in a common system computers, information and other machines, a global system of communication, and many other components. The beginning of the construction of such a system in the USSR has already been placed on the agenda.

The study of the processes of transmitting information in the visual organs of men and animals permits a still greater understanding not only of the puzzling secrets of human nature, in particular the working of the brain, but will also lead to great qualitative leaps in television technology, to the discovery of fundamentally new technological services, the wide utilization of which will open up to mankind such possibilities as in our day would be an unrealizable fantasy.

Speaking of long-range forecasting, it seems that a section of the scientific forces must be directed to long-range forecasting, in order to research the means for large global systems mentioned earlier and their interactions. This is very important for the task of the near future. In particular, at the present time there are very many insufficiencies which must be eliminated. For example, in the system of scientific-technological information the necessary feedback between the demand of information and the system distributing that information practically does not exist.

The directions of the development of global systems will be conditioned both by social and inner laws of the corresponding sciences. At a definite stage of development there must take place archfundamental qualitative leaps, as was said earlier, in terms of those that will create new types and

forms of motion of matter, with self-development inherently characteristic to them.

The question arises: as a result of the crossing and interaction of which sciences may we anticipate the appearance of such fundamentally new forms of the motion of matter?

On the one hand there is the theory of systems. This area is now intensely developing, while a large role is being played here by mathematical research. We can construct models of systems of greater and greater complexity, all with a more complex organization, and we can discover their properties. In proportion to the growth of the complexity of their organizational structure, we may theoretically anticipate the appearance of qualitative leaps. The task consists in the fact that in order to discover these leaps, it is necessary to find the principles and to utilize them for the construction of fundamentally new machines, systems of machines and global technological systems.

On the other hand, there is miniaturization. The primary elements, the primary bricks, of which we will construct computers and other machines, apparatus and systems, are becoming smaller and smaller. Science and the area of technology that deal with miniaturization have an important significance from the point of view of long-range forecasting, because for the construction of a system with a very complex structure it is necessary to master the means and technological preparation of these elements, and to find technological means of joining them together, etc.

It seems to me that such self-organizing complex systems will be gradually developed, and in them will take place leaps

of every rank and finally the arch-large-scale leap will take place; and a new form of the motion of matter will be created.

Gradually, of course, there will be many great discoveries. At some stage there will be theoretically predicted the ideally new forms and types of motion of matter which have not existed before on our planet and which by the efforts of scientists and engineers will be placed into actual operation. This hypothesis, from our point of view, is very progressive, and if it is adhered to, it will exert a beneficial influence on the development of science in the very near future.

In the order of a distant goal it is possible to strive for the creation of a number of fundamentally new systems, in order to put into those systems those characteristics that are needed by man.

It is of course difficult to speak of the time of the approach of such radical qualitative leaps in detail. It is possible only to forecast the processes in general terms, but even in this general view the forecast is totally suitable for the near future.

From the positions described I would like to express several ideas relating to the technological sciences. The possibilities of science and technology in the future are practically unlimited. All that is lacking are those forecasts which will contradict the laws of the development of nature, society and thought. From this point of view such forecasts as the creation of synthetic "mind," the changing of the planets, the extraction of useful minerals from the sea, the control of weather, the designing of liners with speeds significantly higher than the speed of sound, the total elimination

of hunger on our planet, the distillation of sea water, and many others, will be accomplished. The realization of several of these forecasts is possible prior to the year 2000; the others, later.

Considering the questions of forecasting technology, it is necessary to differentiate potentially achievable possibilities and possibilities which will actually be realized in practice, because in human society in the process of its further development by way of social progress, corresponding demands will not emerge. For example, in society, which in its development is substantially moving forward on the course of social development, it is doubtful that the demand will arise for the automatic interception of thought. It is doubtful, also, for the same reason, that there will occur in the future all the other numerous events in science and technology that have been published by foreign writers, whose forecasts have been discussed. In this, in particular, the activity of social laws shows up--the laws of the development of human society.

Speaking of long-range forecast, it is necessary to refer to the second leap, related to the change of man himself.

The question arises, is intellectual matter in its present form the final stage of development? Of course not.

The study of the working and the structure of the brain, a deep understanding of it, will lead to intellectual matter's becoming active and transforming not only the world around it, but itself, and at some stage this feedback will lead to a radical qualitative leap--the appearance of a new form of the motion of matter, with specific laws of development intrinsic to it.

For the planning of the development of science, scientific research must be thoughtfully combined, directed both towards the near future and also towards the more remote and most distant future. Some part of the scientific forces and agents must be contributed to long-range planning, although, of course, it is not a major determining factor in the contemporary conditions of the development of the society.

At the very same time, it is necessary for the planning of the development science to keep in mind that insufficient attention to prospective fundamental scientific research will lead to an arrest of the development of science and in the utilization of the achievements in the near future.

Pausing again on several aspects stressed in the present report, there are the hypotheses of the creation of new forms of the motion of matter in the future. One of these is related to the question: do not these new forms of the motion of matter present a danger for human society? In the literature there are many points of view on this question.

For the purpose of giving a correct answer to the proposed question, it is necessary to proceed from social laws. Contemporary technology, and in particular nuclear technology, has achieved such a level that already in our day the careless or criminal application of it presents an extremely serious danger for mankind. However, by force of the activity of social laws, the progressive forces of the world will not permit such a criminal use of it.

In the future, thanks to the same social laws, technology as a result of its evolutionary and revolutionary development will inevitably be transformed in the self-arranging new form

of the motion of matter, the general directions of the development of which will be determined by people. This is inevitably going to occur because such a technology will be extremely useful and suitable for human society, because it in the fullest measure will facilitate the totally progressive material and cultural demands of all the members of the society.