"It is necessary to organize the extensive application of cybernetics, electronic computing and control apparatuses to industry, scientific research work, planning-design and construction practice, planning, in the area of accounting, statistics, and control".

(From the Draft Program of the CPSU)

A. I. Berg

Cybernetics at the Service of Communism

Introduction

It has been pointed out in the Draft Program of the CP that a communistic society, in contrast to all pre-existing social-economic structures, is not built up by chance but rather is the result of conscious and purposeful activity of masses of people guided by the Marxist-Leninist Party. Supervision of the entire work of building communism by the Party is based on a knowledge of the laws of development of society, and this gives it an organized, planned and scientifically substantiated character.

These fundamental principles, on which all of Soviet scientific and practical activity is based, are of tremendous importance. They represent the results of study of the entire practice of building socialism in the Soviet Union in the years which have passed. They show us now, after more than 40 years, how much vision V. I. Lenin had in trying to place a scientific foundation under the practical measures of the Soviet regime in the organization, planning and supervision of the control of the national economy of the country, which had just emerged from a bloody and devastating war, since the first days of the Revolution. In March-April 1918 Vladimir Il'ich Lenin published a long article, "The Problems Next in Turn for the Soviet Regime". In this article he said the following:

"We, the Bolshevik Party, have conquered Russia. We have won Russia from the rich for the poor, from the exploiters for the working class. We must now control Russia. All of the distinct-

iveness of the time in which we are living and all of its difficulty lie in understanding the characteristics of transition from the main task of convincing people and military suppression of exploiters to the main task of control" (Works, Fourth Edition, Vol 27, page 214).

The tremendous difficulties of building up the ruins, combatting sabotage by the bourgeoisie and bureaucracy, hunger and need of the most essential in the country, the distraction of all forces for the Civil War and the fight against the interventionists did not prevent V. I. Lenin's returning to this problem in 1920, during his discussion of the role of trade unions.

Finally, in 1923, in his last article, "Better Less but Better" (Pravda, 4 March), V. I. Lenin expressed alarm on account of the imperfection of the governmental apparatus of the young Soviet Republic and emphasized the need for studying the "fundamentals of theory on the subject of our state apparatus" and knowledge of the fundamentals of the science of control (Works, Fourth Edition, Vol 27, page 278).

Subsequent years showed and confirmed the correctness of Lenin's making the problem of control a leading one. With the development of the national economy the difficulties of expedient control of it grew steadily. At the same time, practice confirmed the fact that specifically in socialistic planning all conditions are present for best utilization of the achievements of science and engineering on behalf of all members of society rather than for various competing groups and the privileged minority.

The industrial depression of 1929-1932, which profoundly shook the capitalistic world and depicted its anarchy in a particularly striking manner, did not affect the Soviet Union.

Despite tremendous losses sustained during the Civil War, 1918-1921, the industry of the Soviet Union, developing at rapid tempos, reached the pre-War (1913) level in 1925-1926. The rates of growth and progress of socialistic planning were so great that in 1941 the country was prepared for war on a one-to-one basis with one of the most highly developed countries in the world in an industrial respect, Germany. This undoubtedly was the result of continuous perfection of the planning and control of the national economy.

During the Second World War problems of better organization of work of the defense industry and perfection of control of military operations attracted the most serious attention. New sciences appeared -- the theory of study of operations, the theory of mathematical games, the theory of mass service; mathematical statistics and the theory of probability were developed considerably. The steady and rapid complexification of combat technical equipment and frequent work failures of it attracted attention to the unreliability of complex,

multiunit instruments and apparatuses. Methodical work was begun on the creation of a mathematical theory of reliability and on the study of methods and techniques for maintaining it on a high level.

The rapid development of radioelectronics and instrument construction laid the basis for the first electronic automation facilities and finally, the first electronic computers. Mathematical machines and electronic automation facilities in turn made it possible to pose anew the scientific problem of improving the control of complex processes and operations. In this way a new science of control was born, cybernetics.

In recent years a multitude of books and journal articles on cybernetics have been published in the Soviet and world literature. There have been serious scientific works which can be understood only by persons who are well trained and who work in comparatively narrow specialties. Many good scientific books have been written, designed for readers at large. Despite this, the progressively increasing demand for literature in the field of cybernetics has not been satisfied. This is a phenomenon which is certainly to be expected in the present day. It is explained by the fact that man feels a progressively greater need for improving the efficiency of his labor, that is, for obtaining definite results with the least expenditure of time, labor, materials and energy. The objection may be raised that this striving has always existed. However, it is easy to convince oneself of the fact that this is not really so.

In the past, scientific activity was limited to observations or collection of information, as we now customarily say. The results of observations were remembered, written down and preserved. Large libraries were created, but they contained principally descriptive factual material. Catalogs, classifications and systems were compiled. However, few attempts were made at deeper penetration into the essence and interrelationship of the phenomena observed, chiefly because the mathematical apparatus existing at the disposal of the scientists as well as the technical facilities and equipment were absolutely unsuited to the complexity of the phenomena and processes being studied.

Everyday experience convinced our remote predecessors of their weakness and powerlessness in attempts to conquer the forces of nature. Fear of the all-powerful forces of nature produced by this powerlessness caused man to resign himself to his fate, to passiveness, to superstition. Science developed slowly, because all the forces of man were taken up in a struggle for existence, and no need was felt for establishing cause-effect relations, for explaining facts observed. Only a single facility was expected from "scientists" -- prophecy and prediction. This was the period of astrology in astronomy and of

quackery in medicine. Attempts at independent thinking which did not fit within the legalized canons were considered sacrilege and ended at the stake.

Perhaps all this was very long ago, and nothing is recalled about it now. Unfortunately, the situation delineated above existed until recent centuries, that is, for hundreds of thousands of years -- for the first people appeared on earth a million years ago -- while the first beginnings of civilization, in its most primitive forms, occurred only about 10,000 years ago. The last burnings at the stakes were stopped 135 years ago ... modern science was born in the first works of Leibnitz and Newton on higher mathematics. Only since the time of incorporation of the differential and integral calculus into science can we speak of the birth of the modern natural sciences, because the possibility arose of going from "description" and qualitative characterizations to the establishment of precise mathematical quantitative regularities and therefore not only to noting phenomena and facts but also to attempts at active intervention into the phenomena of the outside world by man.

The success of this intervention called attention to its expediency and gave rise to the need for the development of scientific work leading to the attainment of the specific aims of practical life.

Man began to gain more confidence in his own power and possibilities. Progressively more difficult problems in increasing productivity of physical labor were posed and solved. From the simplest adaptations and mechanisms man went to machines. Skill in making and maintaining fire, acquired 30,000-40,000 years ago, was used about 200 years ago for the creation of the first steam engines, and the era of machine mechanization was begun. At the present time, 99 percent of all the useful work performed on the earth is accomplished by machines under the control of man and only one percent, by unmechanized physical effort. However, this does not at all mean that only one percent of the workers on the earth is engaged in unmechanized physical labor. In the Soviet Union, for example, according to data which are not very accurate, from 40 to 60 percent of the workers are engaged mainly in unmechanized operations, whereby in this group are principally loading-unloading operations. However, a single worker in the Soviet Union operating a lathe or machine does the useful work of more than a hundred workers engaged in simple physical labor. On the average for the earth, considering the low degree of mechanization of the poorly developed countries, the percentage of workers operating machines is much lower than in the USSR and amounts to only several percent. Nevertheless, specifically this small number of qualified workers does the major part (99 percent) of the useful work on earth.

It should be mentioned that about 100 years ago the picture was entirely different: approximately four percent of all the useful work was done by machines and 96 percent was done by physical, manual labor. Mechanization began to spread rapidly only at the end of the past century, after the invention and extensive incorporation of the use of dynamos, of alternating current, channeling of it and the use of electric motors and electric drive. Electrical energy, production of it, distribution and transformation of it into mechanical energy were responsible for the revolution in industry at the end of the 19th Century.

The scientific and industrial application of electricity uncovered new possibilities not only for increasing the provision of labor with energy: instruments and facilities for automation of control began to be utilized extensively. However, this applies to the present century, or, more accurately, to the present time. Let there be no confusion about this -- the age of automation is just beginning.

Automation by means of pneumatic, hydraulic and electromechanical facilities has existed for several decades. However, modern automation began after the appearance of electronic, vacuum and semiconductor devices. Electron tubes began to be used in radioengineering 40 years ago; in industrial electronics and electronic automation facilities, only 10 years ago.

Semiconductor electronic instruments are even younger. They began to find extensive application no more than seven-eight years ago. However, the rate of the incorporation of them into practice is striking even for the present day: at the present time, no less than several hundreds of millions of semiconductor apparatuses are produced per year on the earth.

Soon, the production of them will reach a billion per year, and in many fields they will replace radio tubes.

At the end of the Second World War the first electronic computers were worked out. Several years were needed for improving them. Beginning with 1952, that is, approximately 10 years ago, a new era began in mathematics, electronics, automation, and in all fields of science based on these sciences. Finally, it proved to be possible to pose and solve the problem of considerable increase in the efficiency of mental work. At approximately the same time a new science was born, cybernetics, the science of control.

Now, we can return to the beginning of our Introduction. We showed through specific examples that in recent years only the possibility has appeared for conscious formulation of the problem of increasing the efficiency of human labor in all fields of man's activity. Now, we can study phenomena in living nature, industrial processes in industry and operations carried out by people in a human society, by

means of scientific methods and technical facilities which are adequate to the degree of complexity and precision of these phenomena, processes and actions.

Now, however, this study is pursuing practical goals. Now, we are no longer satisfied with the contemplation, observation, measurement and preservation of this information. Study of the world around us and of living nature is necessary to us for utilization of this information in the interests of satisfying the material and spiritual requirements of man, for the facilitation of his labor.

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In the first volume of the collection Cybernetics at the Service of Communism, several articles have been published, the aim of which is to acquaint readers with the opportunities offered by the practical utilization of cybernetic principles. The collection contains, in addition to the Introduction, 19 articles written by authors who worked directly in the corresponding fields. The articles have been grouped into four sections: the first section is the collection, processing and transmission of information; the second section, cybernetics and nature; the third, cybernetics and the humanitarian sciences; and the fourth section, cybernetics in science and engineering.

Below, we shall briefly present the content of each article included within these sections.

"In the age of vigorous development of science the development of philosophical problems of modern natural science on a background of dialectical materialism as the only scientific world-outlook and method of gaining knowledge acquires even greater current importance" (from the draft of the new CPSU Program).

Cybernetics is a new science which is being used progressively more frequently. It aspires to the study of processes of control occurring in nature, industry and human society, that is, to the coverage of practically all of human activity and, for this reason, we rightfully demand that the ideological basis on which this science develops in the Soviet Union be impeccable. As has been pointed out above, since the first days of the Revolution V. I. Lenin was very much absorbed in the science of control. During all the years of existence of the Soviet regime considerable attention has been given to these matters in the USSR. However, cybernetics as a science of control by complex dynamic systems based on a mathematical foundation and on the use of modern electronic instruments was born in the West, and one of its founders is the American mathematician, Norbert Wiener.

In connection with this, the perfectly reasonable and progressive ideas, thoughts and generalizations contained in modern works on cybernetics are sometimes presented to readers from an unclear, controversial and frequently erroneous ideological standpoint, which does considerable harm. The problem of Soviet scientists is the creation of a Soviet school of cybernetics based on dialectical materialism.

In recent years, quite a little has been done in this field. For example, we can refer to the recently published collection, Philosophical Problems of Cybernetics. However, we are far from the idea that the articles of this collection exhaust the entire problem. Therefore, in the present collection we have included the article by I. B. Novik, "Certain Methodological Problems of Cybernetics". In it a discussion is given of the optimization of control, the essence of information, the interrelationship between man and the machine, and the nature of cybernetics as a science. We are sure that the inclusion of this interesting article in our collection will contribute to further reinforcement of the ideological basis of cybernetics.

I. Collection, Processing and Transmission of Information

In the first section, the articles of which present certain information on the collection, processing and transmission of information, Professor B. V. Gnedenko, Academician of the Academy of Sciences UkrSSR, speaks about certain problems of cybernetics and statistics. In 1956, B. V. Gnedenko, N. M. Amosov, Ye. A. Shkabara and their co-workers became interested in problems of medical diagnosis and made one of the first attempts in the world at statistical treatment of clinical material on the basis of which a diagnosis is usually made and used an electronic computing machine for this purpose. This made it possible to obtain more objective evaluation of the various symptom complexes than can be made by the physician. The use of the methods of mathematical statistics, mathematical logic and the theory of probability in making the diagnosis will be of essential aid to physicians in the future.

The author speaks of the significance of utilizing the methods of the mass service theory in the organization of production. From the history of creation of the first telephone stations at the beginning of the present century it is known that the credit for working out the fundamentals of this mathematical science goes to the Danish scientist, A. K. Erlang. In this theory the problems of evaluation of the quality of the "service" of a certain system are analyzed, in which waiting one's turn is inevitable, and the average "service" time is determined. This theory analyzes, for example, the problem of efficient service to

passengers at railroad ticket stations, in stores, in the planning of approaches to plants, mooring ropes, airplane landing fields and others. In this article an interesting case is described of the planning of bins which accumulate reserve articles in constant-flow production, and information is given on some statistical problems of reliability (that is, dependable operation) of control systems consisting of a large number of units each of which is characterized by its inherent probability of good working order.

In a form available to the general reader but, at the same time, in a quite serious form B. V. Gnedenko shows how "pure" mathematics assists in solving present-day practical problems of current importance, the role played thereby by such relatively new fields of mathematics as the theory of optimization, the theory of games, the theory of stochastic processes, and others.

Cybernetics is based on the collection, processing and giving out of information. Information is also the main concept in the general communication theory. Nevertheless, the term "information" in itself has no exact definition. This should not disturb us, because we do not need precise definitions of certain concepts so much for scientific research and practical activity or for the further development of the theory of control. For we do not know what time is; no one can give a definition of this word, but we can excellently measure time with a high degree of accuracy and we make it the basis of all our calculations of efficiency and work productivity; we speak of spending and the need for saving time; the improper utilization of time is punished by law in some cases ... Nor do we know what space is, but we measure it and we use the theorems of geometry, the science of space. We can argue this point, but the generalized concept of space as the continous totality of any homogeneous systems or phenomena, measurement of the distances in which it is made in accordance with some law in infinitely-small steps (Riemann, 1854) can satisfy hardly anyone, with the exception of some philosophers and mathematicians. We can present a multitude of such examples. However, this does not interfere with our scientific or practical activity, which occurs in time and in space ...

Well known are the services of the American scientist and communications engineer, Shannon, and of many other Soviet and foreign scientists who have laid the basis for the general communication theory and the mathematical or, more accurately, probability and statistical theory of information. The applicability of the principles of this theory to problems of transmitting information along inorganic channels is beyond doubt. Attempts to extend it to living organisms have so far failed to give any positive result and, perhaps, in this case it is necessary to use completely different categories. It seems to us

that the collection, The Information Theory in Biology, the translation of which was published in the USSR in 1960 by the Foreign Literature Publishing House, is very interesting in this connection.

The article by R. L. Dobrushin and Ya. I. Khurtin, "Problems of the Information Theory", has been included in our collection. It is of interest to readers in its posing of certain problems, although reading of this article requires some mathematical training. The authors have attempted to formulate and explain some of the problems of optimized information coding and, it seems to us, they have succeeded in doing so. The literature on the information theory is very considerable. The authors list a certain number of works which deserve attention in the light of the problems which they are analyzing. It is interesting to note that in the appendix to the American Radioengineers' Journal on Information Theory, No 2, June 1956, a "Bibliography of Soviet Literature on the Information Theory, Correlation and Noise" has been included, made up in the United States, containing about 150 titles. In the second volume of our collection we intend to publish several articles on information, treated from the standpoint of theoretical cybernetics. Among them are, for example, problems of perceiving and identifying images in living nature. These problems have been attracting progressively greater attention on the part of psychologists and physiologists as well as specialists on electronic machines working in the field of l e a r n i n g and self-adjusting machines. To a certain degree, these problems are touched on in the article by A. V. Napalkov, included in the second section of the present collection.

Because the processing of information underlies control, the article by K. B. Arutyunov and D. V. Svecharnik, "Selection, Initial Processing, Storage, and Transmission of Information on the Course of Industrial Processes" has been printed in the present collection. In it the characteristics of information activity in industry by comparison with living organisms are analyzed. The exceptional expediency of the entire mechanism and arrangement of transmission of information and its preservation in living organisms are noted and explained. The maintenance of a high degree of reliability of these processes is particularly important. In living nature this is assured by the interaction of all structural and functional elements participating in this process. Because of this, over millions of years, by means of natural selection and adaptation to environmental conditions, those species have been preserved in which an exceptionally high degree of reliability is assured by the combined work of a tremendous number of less reliable units. Unfortunately, attempts to increase the reliability of instruments, facilities and systems of collecting, preserving and processing information, which have to be used in industry, have just

begun, and the situation in this field cannot yet be considered very satisfactory.

The problems included in the article mentioned above are of very great current importance. For the second collection, in 1962 we are planning to develop considerably the section of information and, particularly, to include several articles on scientific instrument construction, because the equipping of scientific laboratories with these instruments which does not satisfy the requirements is markedly limiting their possibilities, reducing the effectiveness of research experimental work of Soviet scientists.

The article by K. Ya. Sergeychuk, "Problems of Communication and Cybernetics" has been included in the first section. The author shows the progressively increasing role of science of communications and engineering in the rapidly developing national economy of the Soviet Union. The progressively increasing role of systems with a high degree of capacity is noted, particularly coaxial and radio relay lines. To them now we can add the recently discovered possibilities of sharply focused transmission of a large volume of information on electromagnetic waves in the infrared and optical ranges. Here, truly great possibilities are being uncovered, only part of which has been realized to date. Quantum-mechanical generators and amplifers in this wave range are making it possible to create highly sensitive receivers with a low level of noise, through which radiocommunication will be accomplished at distances of an astronomical scale (several light years). Possibilities are being created of construction of electronic machines with tremendously fast operation. Probably, these new prospects are causing us to overestimate the importance of some of the modern systems of information transmission.

K. Ya. Sergeychuk speaks further about the role and significance of communication facilities in the automation of the national economy, where automatic apparatuses and electronic machines will be the information receivers. In connection with this the term "technological communication" is becoming common; by this is meant a combination of technical communications facilities providing for the control of automated production. We should like to note in passing that these problems are also touched on in the articles by A. I. Kitov and V. A. Il'in included in the third and fourth sections of this collection.

Finally, in this article attention is directed to the increasing importance of further development of problems of information theory and application of electronic machines to processing information. Special and fully deserved attention is given in this article to the increasing significance of reliable operation of automated information transmission facilities.

II. Cybernetics and Living Nature

We are interested chiefly in living nature, the animal and the plant worlds. Most of all we are concerned for man and his health. A communist society should make healthy people. The preservation of health, prevention of disease, early diagnosis of serious diseases, effective methods of treatment in case of disease -- these are the main concerns of Soviet public health organs. Health-improvement of labor in all possible ways, the incorporation of modern safety technique, the provision of technical sanitary conditions which eliminate industrial injury and occupational diseases -- these are the main concerns of the Soviet Party with regard to the Soviet individual, presented in the Draft Program of the CPSU. It is interesting to bring to mind that this concern was manifested even in 1919. In the second Party Program, adopted at the Eighth Congress of the RKP /Russian Communist Party/, the following was mentioned: "In the field of health preservation for the population -- the decisive accomplishment of extensive sanitation measures in the interests of the working class, namely: a) health-improvement in inhabited places (soil, water and air protection)" and others.

Unfortunately, industrialization is accompanied by contamination of our environment. The problems posed more than 40 years ago have not found their solution to the degree necessary. Powerful thermal electric stations constitute the sources of contamination of the atmosphere unless measures are taken to clear the smoke. Modern engineering permits us to do this, and these possibilities should be realized; otherwise, powerful thermal stations will be converted into sources of poisoning of the air and death of vegetation. Is sufficient attention given to this most serious problem? According to information which we have at our disposal, no. Poisoning of the soil and of the water by industrial enterprises continues to be an unsolved problem, because industry is growing and developing more rapidly than preventive and prohibitory measures are being realized.

On all these problems extensive material has been published in the world and Soviet press, but in our opinion these problems have not yet been solved satisfactorily. Here, a radical change is needed. This is specifically required by the following article in the Draft Program:

"Major changes are forthcoming in the development of the entire combination of biological sciences in connection with the requirement for successful resolution of problems of medicine, and the further increase in agriculture. The interests of mankind are con-

fronting these sciences with the main problems of clarification of the nature of the phenomena of life, mastery and control of vital processes, particularly metabolism, and the heredity of organisms. Medical science should concentrate its efforts on discovering means of preventing and curing diseases".

It would appear that concern for the health of the Soviet individual does not apply to the topic of the present collection, but, as a matter of fact, this is not so.

One of the most important documents characterizing this principle is the decree of the CC CPSU and Council of Ministers USSR dated 14 January 1960, "Measures for the Further Improvement of Medical Care and Safeguarding of the Health of the Population of the Country". In accordance with the great possibilities recently created by science and engineering a multitude of measures has been listed in this decree the accomplishment of which will make it possible to utilize achievements in the field of instrument construction and electronics extensively in medical institutions. The decree provides for the considerable expansion of scientific research and development operations for the creation of medical technical articles on the basis of utilization of the current achievements of biology, chemistry, nuclear physics, electronics and cybernetics. Principal attention has been directed to the development of special diagnostic machines and apparatuses for accurate evaluation of the functional and morphological changes in the body on the basis of recent achievements of cybernetics. Diagnosticians will obtain the possibility of establishing the principles and nature of the disease by an analysis of symptoms, which risk remaining unnoticed without electronic machines, and, in this way, assuring that the diagnosis be made at an earlier stage of serious diseases than at the present time.

All these instructions of the Party and Soviet Government are being realized at the present time. Mathematicians, specialists in electronics and biology have been brought in to resolve the difficult tasks associated with these problems. Now scores of groups in Moscow, Leningrad, Kiev, Tbilisi and other cities of the USSR, in the countries of the people's democracy, as well as in the West are working on this problem. A large scientific literature, amounting to no less than 5,000 articles in 1961, has been published on problems of application of mathematics, electronics and cybernetics to biology and medicine. International congresses and meetings have been devoted to this subject. Everywhere measures are being taken for the preparation of specialists in biological electronics, a new variety of physician, engineer, electrician. In 1961, at the Institute of Surgery imeni A. V. Vishnevskiy, a scientific conference was held on the application

of cybernetics to surgery. On the initiative of the director of this Institute, Academician A. A. Vishnevskiy, a laboratory of medical cybernetics was created at the Institute. In it, physicians and engineers, physiologists and mathematicians, roentgenologists and technicians work.

In 1959, in Moscow a scientific conference was held on problems of application of electronics to biology and medicine. At this conference a few score interesting reports were heard, and an original apparatus was demonstrated. The reports at the conference were published in the collection, Electronics in Medicine, Gosenergoizdat, 1960. In 1962 a second conference on the same topics will be convoked.

I should like to permit myself to remind the reader that biological electronics and cybernetics have existed a total of only several years. Everything which has been done to date constitutes only the beginning of a new era in biology, and this is excellently understood by the scientists of the Soviet Union and other countries. There can be no doubt of the fact that even the next few years will open entirely new prospects and possibilities.

In the article, "Cybernetics and Life", published in Ekonomicheskaya Gazeta /Newspaper of Economics/, 12 June 1960, some fields of application of cybernetics to biology have been listed. Among them are the following: study of the various control processes in living nature, the living cell, the behavior of living matter, the evolution of living nature as a whole, diagnosis, control of some physiological processes, study of the phenomena of heredity, and a direct influence on these processes for the purpose of breeding valuable forms of animals, plants and microorganisms, etc.

What is characteristic of this entire new field of science? Specifically for biology, the century-old tendency to accumulate information about living organisms is characteristic. The material accumulated over 5,000-6,000 years is tremendous. But by what methods was it collected, which technical facilities were used for studying the most complex of all the phenomena and processes known in the world? It must be admitted that biologists alone cannot be blamed for the slow progress of biology. Undoubtedly, the technical sciences, which did not give biologists facilities for studying, collecting and analyzing the information, are guilty to the same or an even greater degree. What could engineering put at the disposal of biologists before the 20th Century? Only unsuitable means for the serious study of the very complex rules and regulations of living nature, until electrical engineering and later electronics changed the situation by developing electrocardiographs, microwave radio spectroscopy, electron microscopes, x-rays, encephalographs, and others. Nowhere, in no field of human activity

has such a discrepancy been observed between scientific and engineering facilities and the complexity of the phenomena and processes being studied for thousands of years. The use of mathematical applications in biology, even for treating the results of observations (mathematical statistics), was considered little short of sacrilege until recent decades. This occurred, despite the fact that the founders of Marxism-Leninism and dialectical materialism spoke out in a very definite way on this subject.

In Dialectics of Nature, F. Engels says the following: "Only differential calculus gives natural science the opportunity of representing mathematically not only conditions but also processes: movement" (Gospolitizdat, 1952, page 218).

In his recollections La Farge presents Marx' statement to the effect that "science reaches perfection only when it is able to use mathematics" (P. La Farge, Recollections of Marx, in the collection Recollections of Marx and Engels, Gospolitizdat, Moscow, 1956, page 66).

The very great Soviet scientist, Academician I. P. Pavlov said the following: "... all of life from the Protozoa to the most complicated organisms, finally including man also, represents a long series of environmental equilibriums which are progressively complexified to the highest degree. The time will come -- even though remote -- when mathematical analysis, based on natural scientific analysis will throw light on all these equilibriums with magnificent formulas of equations ..." (Complete Collection of Works, Vol III, Book 1, pages 124-125).

These examples could be continued. If we keep in mind the fact that these statements apply to the early stages of incorporation of mathematics into the natural sciences and biology, that then instrument construction, electrical engineering and computing were on a low level, and that no one could foresee the tremendous possibilities which were to be opened by electronics, particularly by its symbiosis with mathematics, the creation of electronic automation and electronic mathematical machines, and particularly the new science of transmission of information on these machines, cybernetics, we must give what is due to the gift of prophecy of the progressive people of the past in the proper evaluation of the remote prospects of science and particularly of applied mathematics.

We are living in an age of mathematization of all the natural and humanitarian sciences, and mathematization of biology is just one of the aspects of this process.

In the present collection the articles of A. D. Voskresenskiy and A. I. Prokhorov have been included on the application of...

cybernetics to biology and medicine. In them, the considerations presented above have been developed. In the article by Professor S. N. Braynes on neurocybernetics, problems are analyzed which began to be developed in the USSR quite recently. The results of these interesting investigations have been presented in the book on neurocybernetics (S. N. Braynes, A. V. Napalkov, V. B. Svechinskiy, Scientific Records of the Academy of Medical Sciences USSR, Institute of Psychiatry, Problems of Neurocybernetics, Moscow, 1959) (at the end of 1961 a second, enlarged edition of it will come out) and were also analyzed at several international congresses.

The article by A. V. Napalkov on automata which learn is very interesting. The author of it participated in a scientific conference on these problems which took place in Karlsruhe (FRG) in April 1961. The main topic of the conference was a discussion of the prospects of studying the principles of operation of the brain and the creation of cybernetic machines of new types on this basis. Theoretical problems of teaching, the brain mechanisms underlying the solution of complex problems of elaborating abstract concepts, learning images, speech and the reading of texts were analyzed. Prospects of utilizing the principles of operation of the brain in the creation of new cybernetic machines were discussed. In the article by A. V. Napalkov work is also described which is being conducted at the Moscow State University.

The automation of control of complex processes and systems does not completely free man but rather places him under new conditions. When man learned to build machines the problem of which is the transformation of one type of energy into another, frequently mechanical, he placed himself in a certain relationship to the machine, the action and operation of which he had to control. The organs of control of the machine or other mechanisms had to be within the limits of availability, and the actions which were to be accomplished by man had to lie within the limits of his physical and psychological capacities. In an age of automation new problems have arisen, because man has turned out to be one of the links in a new chain: machine -- automat controlling it -- man. This chain is complexified when many machines, assembly lines, shops or plants are controlled automatically. There are no operating mechanisms or machines which function continuously with maximum dependability. This principle applies equally to manual organs and even more to automatic control organs. A breakdown, even if temporary, in the work of some link (and in such a chain there are no important and unimportant links) requires immediate intervention into the accomplishment of a series of control operations, frequently in so short a time as to be beyond the physiological and psychological

capacity of man. The problem of reliability arises again with all pointedness. However, even with the "normal" action of a system the role of man remains the decisive one, and such actions must be excluded which go beyond his possibilities.

It must be recognized that far from everywhere and always is this taken into consideration, and there are cases where the planning and designing organizations, constructors and engineers forget about man, believing without any basis that in an age of automation the role of man has become an auxiliary one and that his work is "automatically" facilitated. In the system machine-automat-man every link individually and the entire system as a whole should operate under optimal conditions, and this applies particularly to physical and psychophysiological strain on man. In recent years this principle has begun to win recognition. Considerable attention is being given to the development of a science which has obtained the name of "psychotechnics". Sometimes it is called "engineering psychology".

We should like to recall to the reader that in 1936 a special decree of the TsK VKP (b) [Central Committee of the All-Union Communist Party (Bolshevik)] was promulgated on 4 July, "Pedological Faults in the Narkompros [People's Commissariat of Public Education] System". This decree was directed against the gross ideological and methodological errors which were committed in the study of the mental development and talent of school children. As the result of these errors a progressively larger number of children was included in the category of mentally retarded, "defective" and "difficult". For the purpose of correcting these errors the TsK VKP (b) resolved: 1) to restore pedagogy and teachers to full rights; 2) to eliminate pedologists in the schools, pedological textbooks, and others. By this decision a whole complex of errors committed in pedagogy was eliminated. However, unfortunately, shortly after it turned out that some psychologists understood this decree of the TsK VKP (b) as criticism of all works on labor psychology.

In the theoretical and political journal of the CC CPSU, Kommunist, No 4, 1956, that is, 20 years after the promulgation of the decree mentioned above, a lead article was published under the name "Strengthen the Connection of Psychology with Practice". In confirming fully the inadmissibility of repetition of the old and censured errors in the field of psychology and pedology, the article spoke of the need for studying and developing the scientific basis of development of the human psyche, study of psychological conditions for effective organization of human activity, chiefly of their labor. Mention is made of the tremendous tasks which confront scientists in the matter of extensive, complete study of labor psychology, psychological factors

in increasing work productivity, mastering progressive technique and progressive work methods, to the effect that technical progress increases the importance and effectiveness of application of the data of labor psychology. It was recommended that practical scientific psychological laboratories be organized at the large enterprises, medical institutions, in the system of preparation of labor reserves, for the purpose of assuring the direct connection of psychology with practice.

In this article it is stated in a perfectly clear-cut manner: "Soviet psychology is based on the fact that the human mind is the product of his life in society, that its characteristic features depend on the specific historical conditions of human activity and that, therefore, psychology studies the mind of man as a social individual". Incidentally, these considerations should be kept in mind when the thought capacities of man and some logical operations performed by electronic machines are being compared.

Finally, in this article it is mentioned: "We cannot keep silent about the improper attitude toward foreign psychology. Some of our scientists are giving too little attention even to the most serious works of foreign scientists, not making a deep analysis of them, not considering the good that they bring to psychology, particularly to the method of psychological investigation. The interests of science insistently require the study of the status of psychology of other countries, the ideational struggle with reactionary tendencies, as well as consideration and utilization of the good which exists there: without this, successful development of science is impossible".

Although these lines were written only five years ago everyday practice shows that the interesting ideas and statements contained in this article were thoroughly forgotten or generally unknown by certain administrators in industry.

In the article by Professor D. Yu. Panov and S. A. Oshanin in the present collection mention is made of the causes of origin of engineering psychology, the analysis of human and machine possibilities, the distribution of functions between man and machine, analysis of the operator's activity in complex control systems, the reliability of work of the human operator in the complex control system, problems of training and selection, and problems of an industrial engineering psychology laboratory.

In this article a number of problems are posed anew. The Soviet literature on engineering psychology has so far been limited to a total of several articles. It is to be hoped that this is just the beginning. Neglect of this science has a direct influence upon the labor conditions at the various enterprises. It is very desirable that persons who do not now understand the importance of everything stated

above visit some of the automated Soviet plants -- they would see first-hand how important it is to study human labor conditions in an age of automation.

III. Cybernetics in the Humanitarian Sciences

In 1919, in the second Party Program adopted by the Eighth Congress of the RKP it was stated: "All-possible increase in the industrial power of the country should become the main and the basic, determining the entire economic policy of the Soviet regime". The Fourteenth Congress of the Party (1925) pointed out that in the field of economic construction the Leninist plan of socialistic industrialization of the country will be realized. This was more than 35 years ago.

Now, in 1961, it is mentioned in the Draft Program of the CPSU: "The main economic task of the Party and Soviet people lies in creating the material basis of communism in the period of two decades". In accordance with this, economics is confronted with specific problems of generalizing on new phenomena in the economic life of society and working out national economic problems the solution of which contributes to successful building of communism. "Attention of economists should be directed at seeking out means of the most effective utilization of material and labor resources in the national economy, the best planning methods and methods of organizing industrial and agricultural production, at developing an efficient arrangement of the forces of production and of the technical-economic problems of building communism".

We see that economics is being confronted essentially with the task of increasing its efficiency, that is, with seeking out means and methods for solving the most important problems in the field of economics, in the areas indicated, with the least expenditure of time, labor, material and energy. Speaking at the All-Union Conference of Scientific Workers on 14 June 1961 A. N. Kosygin said the following: "Modern technical facilities -- I have in mind the high-speed computing machines -- make it possible to mechanize many processes of mental work in scientific research, planning and designing, the planning of the national economy, various kinds of accounting and banking operations, statistics, providing information, and even translating a text from one language into another. Experience has been gained in solving many economic problems associated with planning on computing machines. These operations are evidence of the great national economic effectiveness of using mathematical methods and high-speed computing machines. It is essential to expand the scale of application of these methods to practice"; then he said: "In economics and in

economic research we must change over more boldly and extensively to the utilization of modern electronic computing technique and mathematical methods. Economists and mathematicians should together work out the specific recommendations for the use of mathematical methods and modern computing technique, high-speed machines in economic studies, planning and control of production" (Pravda, 15 June 1961).

From these statements it follows that the progress of economics to a considerable degree depends on its mathematization. However, for the purpose of utilizing mathematical methods it is necessary to be disposed of precise information. Existing methods of recording and treatment of initial "paperwork" are designed for quick forward-movement of these papers. There is a discrepancy in methods of accounting even at enterprises which belong to the same branch of industry and are located on the territory of the same administrative region. Mechanization of accounting-computing operations is extremely poor. For approximately a year the Ekonomicheskaya Gazeta has published a number of statements of workers in accounting and statistics in which fundamental problems of bookkeeping, statistics and economic analysis have been involved. However, as was particularly noted (Ekonomicheskaya Gazeta, No 167, 16 July 1961), the organizations and departments which most of all are called on to deal with perfection of methods of bookkeeping and statistics had not drawn the necessary conclusions up to July 1961. We should like to mention that even at the end of 1959 a special decree of the CC CPSU and Council of Ministers USSR was adopted on the mechanization of these operations, and at the beginning of 1960 a special meeting was held in Moscow on improving work efficiency of collection and processing of the initial "paperwork".

The article by the engineer-economist V. Mash, "The Economic Accounting Service in Enterprises of the United States" published in the Ekonomicheskaya Gazeta dated 14 December 1960 is interesting. Although the methods and organizational forms of this service in the United States cannot be recommended for mechanical transference to Soviet enterprises, they are evidence to the effect that in the United States considerable effort is applied to attain a more flexible, more clear-cut and efficient control for purposes of improving efficiency in industrial work and the profitability of production.

By a decree of the Presidium of the Academy of Sciences USSR dated 20 May 1960 the Scientific Council on the Application of Mathematical Methods to Economic Studies and Planning was created under the supervision of Academician V. S. Nemchinov. This Council provides for the coordination of work along two main lines: 1) the application of mathematical methods and the electronic computing machines to economic analysis and planning on a scale of the national

economy of the country and of the separate economic regions; 2) the use of mathematical methods and electronic computers for solving technical-economic problems.

The main organizations on the work of which the Scientific Council bases itself are the Computing Center of the Gosekonomsovet [State Economic Council] of the USSR, the Engineering-Economics Institute, the Leningrad and Moscow universities and the Institute of Mathematics with the computing center of the Siberian Department of the Academy of Sciences USSR, the Institute of Labor and Wages of the Goskomitet [State Committee] on labor and wages, the Laboratory of Mathematical-Economics Methods of the Academy of Sciences USSR.

The science of control of complex processes and operations -- cybernetics -- is finding progressively greater application to economics. The main object of application of cybernetics and electronic machines in the socialistic economy is national economic planning. We have already mentioned above that making up the plan should be based on accurate and timely information which is of adequate volume and content. The purposeful socialistic economy makes it possible to work out the optimum most advantageous plans. This makes it possible to distribute assignments among enterprises so that the maximum total output can be achieved with the observance of set proportions in the production of various goods. Investigations are being made on optimum systems for transportation of mass loads of coal, cement, sand, and others.

The scientific organization and planning of the national economy in the USSR and in the countries of the people's democracy are opening very great possibilities for the application of mathematical methods and means of electronic computing technique. However, this does not mean that the experience and the achievements of the capitalistic world should be neglected in this work.

Interesting material has recently been published on work in the field of mathematical-economic methodology in certain institutes of France (Ekonomicheskaya Gazeta, dated 23 May 1961). There, the "Society of Applied Economics and Mathematics" has existed for about two years; it takes orders from large firms for economic calculations of the most economical manner of accomplishment of different industrial operations. The best variants of transportation which provide for the accomplishment of the program with the minimum total run of the load are determined and studied; efficient combinations of fuel supply to industrial combinations are found in which the total expenditures are reduced to a minimum; the best pipe-line routes are determined, etc. The authors of this article (V. Dadayan, A. Pokrovskiy and Yu. Chernyak) perfectly correctly recommend borrowing this ex-

perience by means of the organization of computing centers in the union republics or sovnarkhozes, with subordination of them to two institutions -- the sovnarkhoz [Council of the national economy] and the republic academies of sciences. In the authors' opinion, this will assure the combination of the solution of practical problems advanced by the needs of industry with the development of the principles of mathematical-economic methodology.

Very interesting are the works being conducted at the Central Scientific Research Laboratory on the application of mathematical statistics and electronic computing technique of the Mosoblsovnarkhoz [Moscow Oblast Sovnarkhoz] under the direction of Professor A. M. Dlin.

In the article, "Mathematical Methods in Industry" (Ekonomicheskaya Gazeta, 21 August 1961, page 18) Professor A. M. Dlin and N. Pokrovskiy tell about the mathematical modelling of various industrial processes which they conducted, the use of linear programming for the determination of the optimum size of the cut of roll iron plates, expansion of the fields of application of mathematical statistics in control and analysis of production, collaboration with the Laboratory on the Application of Mathematical Methods to Economic Research and Planning, directed by Academician V. S. Nemchinov.

In the present collection the article by A. I. Kitov on the application of cybernetics to the control of the national economy has been included. The author's considerations on optimized planning and the use of mathematical methods in planning deserve serious attention.

Special note should be made of the excellent article by Academician S. L. Sobolev, "Solving Economic Problems with Mathematical Accuracy", published in the Ekonomicheskaya Gazeta, 11 June 1961.

The sapid article by V. D. Belkin, Candidate of Economic Sciences, "Cybernetics and Economics" has been published in the present collection. The author emphasizes the fact that under conditions of socialism it is fully possible to create a comprehensive automated system of controlling the country's economy, and this will produce a much greater effect than in capitalistic countries which use automation partially even now in certain areas of economics but which cannot extend this method to include the economics of the entire country.

In the collection, "Problems of Cybernetics", No 5 (Fizmatgiz) edited by A. A. Lyapunov two very important articles have been included on planning. The article by Yu. Ya. Shreyder, "Problem of Dynamic Planning and Automats" represents a generalization and further development of the monograph by R. Bellman on dynamic planning, published in the United States in 1957. Yu. Ya. Shreyder

described ... possible to pose the general problem of dynamic planning, derive the main functional equation and establish the main properties of its solutions. In the article by Ye. G. Golshteyn and D. B. Yudin, "A Single Class of National Economic Planning Problems" the work-up of certain special methods is given for the solution of various important problems of linear programming, permitting an essential reduction of computing operations.

We have dwelled in somewhat greater detail on the situation in economics, because this is particularly important. For in the final analysis the only objective evaluation of all our actions in the field of mechanization, automation, expansion of production and the arrangement of new construction, application of better methods of planning, and of all our attempts to increase the rate of scientific and technical progress is their economic effectiveness. We are not permitting ourselves the luxury of dealing with inadequate accuracy for the field of economics. In the fulfillment of the assignments of the Party, presented in the new Program, we can no longer be satisfied with the inadequate development of the problem of price formation, the basis of all economic calculations.

In his speech to the First All-Union Conference of Scientific Workers at the Kremlin on 14 June 1961 A. N. Kosygin gave very great attention to economic problems. He said: "In the resolutions of the Twenty-First Congress it has been pointed out that in the field of social sciences, particularly economics, there is a problem of creating generalization on the experience of industrial and cultural construction and the study of new problems being advanced by life. Economics is still behind the requirements of life and practice, which has been pointed out by the Central Committee of the Party and personally by Comrade N. S. Khrushchev. Economists are giving little attention to working out the methodology of planning, problems of the effectiveness of capital investments, efficient utilization of the main funds and other matters being advanced by the practice of economic construction" (Pravda, 15 June 1961).

All these problems are to a certain degree touched on in the articles on the utilization of cybernetics in economics, which have been included in the collection, and in the articles to which we are specially directing the attention of the readers.

We love and value the good books of Soviet and world literature. In the Soviet Union recently considerable attention has been given to improvement of the study of foreign languages. Linguistics, the science of language, is one of the oldest sciences and is a descriptive discipline which, it seemed for many years until recently, was very far from engineering and particularly from mathematics. However,

life has caused us to change this traditional viewpoint. In many countries problems of automatic translation from one language to another by means of information machines are being worked out successfully. This has required the creation of a new science, mathematical or structural linguistics.

Such a trend in linguistics has been brought about by the need for better utilization of the tremendous scientific information being published in many languages. Mathematical linguistics is an entirely new science, which has been in existence a total of about 10 years. However, in this short period of time it has been proved that it is practical to use machine translations, that a standard language should be developed, a mediator for the translation of different languages, that it is expedient to "teach" the electronic machine to read written speech and to perceive the combinations of sounds in the human voice. At the present time, work is being done on these problems in the Soviet Union and abroad.

In the article by V. V. Ivanov and S. K. Shaumyan, "Linguistic Problems of Cybernetics and Structural Linguistics" included in the present collection there are very many interesting and new considerations on these subjects. In it mention is made of the role of language in processes of control, of structural linguistics as an abstract language theory, of theoretical and applied significance of applied linguistics.

There is still another new branch of the application of cybernetics to the humanitarian sciences, namely, the field of law. Apparently, putting the question of the use of mathematics, automation and electronics and particularly cybernetics in the science of law has no real basis. However, in the article by N. D. Andreyev and D. A. Kerimov, "The Possibilities of Utilization of Cybernetic Technique in Solving Certain Problems of Law" a number of considerations have been expressed which prove the opposite. This is one of the fields in which the exact sciences have penetrated into the humanitarian sciences.

The problem is posed of accumulation of legal information in logical-information machines, systematization of it and processing and supplying it for practical work of legislation and for improving the efficiency of Soviet legislation. It is recommended that machines be used for carrying out various kinds of laborious auxiliary operations associated with the preparation of codification of law. The utilization of cybernetic machines in the preparation of materials for the generalization on legal practice is promising.

Finally, it is suggested that machines be used for various kinds of examinations of documents.

To be sure, the practical application of these ideas requires

conducting serious preparatory work. However, it is interesting to note that at Leningrad University the first steps have already been taken in this direction.

Making and breaking laws take place in the entire world. For this reason, it is very interesting to study the experience of application of the methods presented above abroad. On this subject there is already a special literature. Sapid reports have been given at the Symposium on Mechanization of Thought Processes at Teddington in November 1958 and at the International Conferences on Machine Languages in September 1959 in the United States.

We hope that the article on the application of cybernetic methods and facilities to law will attract the attention of Soviet lawyers.

IV. Cybernetics in Science and Engineering

In the Draft Program of the CPSU the requirement was advanced that methods of acting on climatic conditions be worked out. This is the oldest dream of mankind and was perfectly impractical in the past. The accomplishment of this task in the immediate future is an exceptionally difficult problem, but the current possibilities of science are already permitting us to put it next on the list.

Apparently, we should begin with perfection of methods of predicting weather. In this respect, in recent decades much has been done. Considerable assistance will be given by better facilities and instruments for the collection and processing of information about the condition and dynamics of the atmosphere. However, the incorporation of scientific mathematical methods and of electronic machines into the weather-predicting service has begun, and this undoubtedly will give a good result.

It is much more difficult to act on factors which determine the weather. This is a typical control problem, that is, action on great energy and material reserves by means of much smaller quantities, but an action on those factors specifically which are responsible for the condition of the system. It is well known by radioengineers how effectively the voltage at the control grid of a tube acts on the energy output of the source of supply of the anode circuit and of the appearance of a much greater voltage in this circuit under conditions of voltage amplification. This is well known in relay effect technique. Essentially all electronics is based on the control of large energy reserves by small potentials and the transformation of this energy into a desirable form.

By utilizing this principle we obtain the possibility of scattering a cloud or fog for the better utilization of solar energy when this is desirable, or, on the other hand, of condensing moisture into

clouds and producing an artificial rain or fog. The solution of these problems at the present time is already possible on a small scale and is being accomplished.

Without doubt it is much more difficult to act on the climate. But are we not even now irrigating deserts and drying bogs on a large scale? Are we not able on a much larger scale and considerably more efficiently to conduct forestry? Shall we and our progeny be satisfied that tremendous spaces of the Soviet Union are covered by "eternal" frost? A tremendous quantity of inexhaustible solar energy falls on the earth and, undoubtedly, the time will come when we will learn how to use it better. Are we not using the force of wind to some degree? All this is a great problem of economic policy and strategy but the solution of which can be begun even now. Here, we include the problem of changing the courses of rivers and directing the water of them to places in which there is a shortage of water.

Certainly, the solution of these problems requires audaciousness, daring and a profound search. However, the Party has not confronted Soviet scientists with easy problems. Therein lies the tremendous advantage of socialist control of the national economy: only it permits seeking and finding optimum solutions for difficult but important tasks and problems.

Electronic mathematics and cybernetics can give great service in the matter of changing the climate but under one condition -- the problems must be posed on a large scale, and the necessary forces should be concentrated for their solution.

In the present collection we have included the article by S. A. Mashkovich, "Cybernetics and Meteorology" in which considerations are developed on the possibility of better weather forecasting, influence on the weather and acting on the climate.

One of the most rapidly developing fields in the Soviet Union is the chemical industry. At the May Plenum of the CC CPSU (1958) special attention was given to this field. In the three years which have elapsed after this, the situation in chemistry has changed radically. More than 60 industrial enterprises have been put into operation and considerable productive power will be introduced in 1961.

Chemical science and industry are being developed at fast tempos throughout the world. At the same time, the use of high pressures and temperatures, great reaction speeds, the harmfulness and prohibitive cost of many technological processes create the acute need of mechanization and automation of production specifically in the chemical industry. The special complexity of many processes affords opportunities for using current methods of cybernetics for control. The main requirements thereby are evidently optimization of the courses

of technical processes and provision of a high degree of reliability of operation of the chemical equipment itself as well as of the electronic (or pneumatic) automation facilities used for controlling them. The use of mathematics or mathematical statistics, the theory of probability, mathematical logic and other branches of mathematics for a strict description of the rules and regulations acting in the chemical industry characterizes one aspect of the matter. Another aspect is information work on chemical literature. The article by G. E. Vleduts, included in this collection, is devoted specifically to this area of work.

The author notes that at the present time the chemical literature makes up approximately one-third of all the scientific literature printed to date. It is impossible to systematize and find the necessary information by the old methods, because this takes up too much time. Therefore, at the present time specialists of all categories are showing exceptional interest in problems of automation of the search for information by means of special logical-information machines.

The problem of creating an information machine language for chemistry, that is, translating the well-known language of structural formulas of chemical compounds into a linear sequence of symbols, is associated with this. This problem can be solved by special machines which process the ordinary chemical language and change it into a convenient machine-chemical language which would be "understood" by the machines. Here, interesting possibilities appear for entrusting the functions of "chemical thinking" to logical-information machines, that is, the solution of the problem of selecting the optimum route of synthesis of some chemical compound which has not yet been described. Such machines in the future will be able to "teach themselves". All this will make the work of scientific workers and investigators in chemistry many times easier.

The article by G. E. Vleduts undoubtedly will expand the scope of the readers who are not engaged in the study of the possibilities of logical-information machines in chemistry.

The degree to which the need has matured for studying problems of the use of mathematics, automatics and cybernetics in chemistry on a much larger scale than is being done at the present time can be judged by the tremendous attention given to these problems abroad. The existence of two trends in the utilization of cybernetics is characteristic specifically of chemistry: an information controlling effect on chemical processes in production with the aim of optimization of them and logical-information activity in the world of chemical literature, scientific, technical, patent and others.

In the Business Club of the Ekonomicheskaya Gazeta an interesting meeting was held on some of these subjects, the materials of

which were published in the Newspaper 4 September 1961.

Along with complex mechanization and automation of industry in recent years a new field of automation has been developed -- teleautomatics. Interesting work in this field is being done in the Soviet Union under the direction of V. A. Il'in. In the article, "Teleautomatics and Cybernetics" the author tells about the development of methods and means of telemechanics for remote control collection of information, signalling, regulation and control as applied to separated systems. Naturally, in such systems a high degree of reliability and dependability of action of all instruments and apparatuses for collection, processing of information and giving commands is required. Already, many power installations in the country have been outfitted with teleautomatic facilities. Apparently, the greatest attention is merited by the work on mass telemechanization of oil fields which has already been done successfully for several years. The complex system of automation and telemechanization in the field of irrigation is also of considerable interest. When the control systems become numerous the need may arise for collection and processing of extensive information as well as control under optimized conditions. Electronic machines can assist in this. Therefore, problems of long-distance automatics are coming closer to the problems solved by cybernetics.

Of considerable interest is the brochure by V. A. Il'in, "Telemechanic Systems for Deconcentrated Objects" (Gosenergoizdat, 1960). According to information obtained from the author, work in the field of telemechanization of the oil wells has advanced to such a degree in the Soviet Union that already more than 20 percent of them are telemechanized.

The great interest shown at the First International Congress on Automatic Control (Moscow, 1960) in matters of remote control collection of information, telemetering, reliability of operation, interference-killing features and efficiency should be noted. "Electrification, which is the backbone of building the economy of a communist society, is playing the leading part in the development of all branches of the national economy, in providing for the entire current technical progress. Therefore, it is necessary to provide a superior rate of electrical energy production". This evaluation was given in the Draft Program of the CPSU for electrification of the country.

More than 40 years ago, in 1920, the first general plan for the development of the national economy of Soviet Russia was worked out, which now maintains tremendous significance as a model of the perspective state of the national economic plan. At the Eighth All-Russian Congress of the Soviets in December 1920, Vladimir Il'ich Lenin characterized the plan for electrification of Russia prepared by

the State Commission for Electrification of Russia (GOELRO) as a second Party Program, a great economic plan indicating the routes for transforming backward Russia into a new economic basis necessary for building communism. "Such a basis", said Vladimir Il'ich, "is electricity only. Communism is the Soviet regime plus electrification of the entire country" (Works, Fourth Edition, Vol 31, page 486).

The boldness of formulation of the problems in the GOELRO plan can be evaluated only if we consider the situation in the country in 1919-1920. While in 1913 about 1,000,900,000-2,000,000,000 kilowatt hours of electrical energy were being produced in Russia, in 1920 four times less were being produced -- about 500,000,000 kilowatt hours. At this time, in the United States $50 \cdot 10^9$ kilowatt hours were being produced, that is, 100 times more. After 40 years the picture has changed markedly. In 1960, in the USSR $292 \cdot 10^9$ kilowatt hours were produced, while in the United States about $900 \cdot 10^9$ kilowatt hours were produced (at the terminals of electric power stations), that is, only three times more. However, if it had not been for the Second World War, which not only stopped but threw back the development of electrification of the USSR and did not do any damage to the United States, the Soviet Union would have produced from 40 to 50 percent of electrical energy production in the United States in 1960.

In accordance with the assignments of the Draft Program of the CPSU in the USSR in 1970 900,000,000,000-1,000,000,000,000 kilowatt hours of electrical energy will be produced; in 1980, 2,780,000,000,000-3,000,000,000,000. This means approximately a tripling in electrical energy production every 10 years. In the United States approximately a doubling has occurred every 10 years, and if we can speak of suppositions (rather than plans) these tempos will be preserved in the United States for the next 20 years (see the journal, Planoye Khozyaystvo [Planning], 1961, No 7, page 84). If this is true, in 1980 approximately the same amount of electrical energy will be produced in the United States and in the USSR.

In the present collection chiefly the problems and tasks of control of complex systems are being analyzed. We have presented the figures for the increase in production of electrical energy in order to show what difficult tasks have to be solved in the field of the most advantageous optimized control of the tremendous energy supplies of the future.

In recent years, great attention has been given to problems of automation of control of separate electrical power stations, and considerable results have been achieved. Problems of automatic control of separate, larger or smaller power systems have been solved and are continuing to be solved successfully. We are coming close to

solving the very important problem of unified dispatcher control with a standardized energy system in the European part of the USSR. In the near future, we shall begin to solve the problem of a standardized energy system for all of the Soviet Union, and in accordance with this also the problem of optimized control of it. Finally, a study is already being made of the problem of unification of the national power systems of the countries of the people's democracy and of the USSR into a single power system. Naturally, the problem will rise of optimized and reliable control of such complex systems, and this is a typical problem of cybernetics, and preparations for the scientific solution of it should be made even now.

In May 1960, in Kiev a technical scientific conference was held on the application of computing technique in the planning and designing and operation of power systems. The conference adopted a detailed resolution which noted that for the purpose of scientific research and engineering practice in the field of planning and designing and operation of power systems the extensive application of comparatively complex mathematical methods which bring in the theory of probability, qualitative theory and numerical methods of solving linear and nonlinear differential equations, higher algebra, and others are essential. The conference noted that these problems can be solved only by means of the facilities of modern computing technique, for the application of which to energetics the following main trends have been determined: A. Prospective and concurrent planning, processing of corresponding statistical and information material. B. The planning and designing of electrical power stations, electrical circuits, long-distance electrical transmission, and automatic apparatuses; scientific research work. C. Calculations of operational routines (planning and operational), an analysis of accident-control system and equipment routines, the recording and initial processing of the information. D. Automatic control of the operating conditions of power systems, electrical power stations and other power installations.

Finally, we should like to mention that at the First Congress of the International Federation on Automatic Control (IFAK), which was held in 1960 in Moscow, representatives of the USSR, the United States, England, Italy, Poland, Czechoslovakia, Hungary and other countries gave interesting reports on problems of automation of the control of power systems and on the application of electrical computing apparatuses for these purposes.

All these considerations underlay the interesting article "Cybernetics and Power Systems" by Professor V. A. Venikov, laureate of the Lenin Prize.

In the Draft Program it is mentioned: "Growth of the

national economy requires accelerated development of all types of transportation. The most important problems in the field of transportation are the following: the expansion of transport highway construction and the provision of complete satisfaction of the needs of the national economy and of the population for all types of transport; further technical reequipping of railroad and other types of transport; considerable increase in speeds on railroads, sea and river lanes; coordinated development of all types of transportation as the constituents of a standardized transportation system. The importance of pipe-line transport will increase".

If we take into consideration the size of the territory of the USSR, the rapid development of industry and agriculture in the entire country, the reclaiming of new areas for the mining of useful ores, the need for accelerating transport and providing them with safety and economic expediency, it is easy to understand that the transport problem cannot be solved by the old methods.

In this collection the article by I. Ya. Aksenov has been included, "Transport Problems of Cybernetics"; the author of this article says that transportation more than many other branches of the national economy needs the promptest and most rapid incorporation of cybernetics both by virtue of its characteristic features, conditioned by the very nature of transportation, as well as in view of those great technical-economic results which can be assured for transportation and the Government as a whole by cybernetics. This is also mentioned in the article of the Minister of Communications of the USSR, B. Beshchev, in Pravda dated 6 August 1961 as applied to railroad transportation, "Control of the Movement of Trains and All Processes of Activation and Inactivation of Trains at Stations will be Carried Out with the Application of Cybernetic Apparatus".

We have already mentioned that cybernetics studies complex dynamic systems and the processes which occur in them. Transportation is a characteristic example of a gigantic, very complicated dynamic system the control of which for the purpose of achieving a maximum effect with minimal expenditure is a most difficult task.

At the same time, technical facilities for collecting and processing information for the purpose of solving this problem have practically just begun their existence.

The initiative of residents of Kiev should be noted; they in 1961 and 1962 held a correspondence seminar, "Cybernetics in Transportation". The organizers of the seminar note that the matter of making technical progress in transportation advances a number of problems on the automation of control of the movement of transport facilities, the incorporation of cybernetic instruments and automatic electronic com-

puting machines into the practice of transport production. Because transportation is a branch of the national economy with a centralized control and because the same methods for finding optimized solutions are used in it, it may be expected that the utilization of special control machines, mathematical methods of solving problems with many variants and systems of automatic control will produce a great economic effect.

Of considerable interest is the work of Soviet institutes of railroad transportation in the development of a special computing center; this work is being conducted under the direction of Professor A. P. Petrov, Corresponding Member of the Academy of Sciences USSR. The work of B. Del Rio, N. A. Samarin and L. V. Safris on the utilization of electronic digital computers for making up a parallel graphic train time-table deserves serious attention; this has been done at the Institute of Railroad Engineers at Rostov-na-Donu.

V. Some Results

We have told about the process of mathematization of many sciences characteristic of the present time: biology, medicine, economics, linguistics, meteorology, chemistry and others. In all cases a transition is occurring from description, from general qualitative evaluation to the establishment of precise mathematical rules and regulations. The aim of this evolution of natural and humanitarian sciences, consciously directed by man, is a deeper penetration into the nature of phenomena of the world surrounding us, of living nature and particularly of our bodies. The main task of this activity is the utilization of rules and regulations learned for the satisfaction of human needs. We cannot change the elementary laws of nature, but we can, by knowing them, learn how to control them.

This is how, by responding to a need which was realized, the new science of control arose, cybernetics. We are speaking about a "new" science of control, because this science is not applied to control of ordinary simple processes. In the tremendous majority of cases in practice it deals with reliable cause-effect relations and simple interactions, where control amounts to elementary commands, the result of which is reliably known beforehand. In these, most ordinary conditions of practice and everyday life, cybernetics is absolutely unnecessary. The need for developing a new science of control arises in those complex cases where the old methods, being applied to simple cases, have ceased to act. Cybernetics is uncovering the possibility of controlling complex systems, complex operations made by groups of people, complex industrial processes, infinitely complex processes

occurring in living nature.

Cybernetics studies complex structures, the states of a multitude of interrelated structural elements organized into a single system. The constituent elements carry out the functions characteristic of them.

The condition of a system is determined by the values of the parameters, variables or coordinates of the constituent elements of the system and their derivatives. The values of the variables can change in time and space. Then, the system also changes its condition and becomes dynamic. If the derivatives of the variables are equal to zero the dynamic system goes into a state of rest and becomes static. By acting on the variables of a dynamic system or on their derivatives it is changed from one condition to another, a new condition. The transition of the system from one state to another is customarily called a process. The transformation of the system into a new state by means of acting on its variables is also controlled.

Therefore, cybernetics studies processes occurring in complex dynamic systems when they are under control. If the control is accomplished by man or by mechanisms as well as by automata working according to a program set by man, it is purposeful. The aim of control in this case is that of changing the system to a new state designated beforehand. Cybernetics also studies processes of control occurring in nature around us as well as the very complex processes of control in living organisms. Finally, cybernetics studies the social processes and operations carried out by groups of people.

The complex process of control is divided into separate control operations which are accomplished in a certain sequence or in a certain combination. For example, industrial operations are of this type. However, in a human society various people or organized groups of people accomplish various purposeful actions or operations subordinate to a certain plan. A multitude of such operations or actions can be named: credit, transport, insurance, military operations and others. They may be simple or complex, independent of one another or interrelated.

From the standpoint of cybernetics complex dynamic systems in living nature, in industry, and in human society are control systems. Therefore, before beginning control it is necessary to make a thorough study or, as they say in modern scientific language, to collect information characterizing the system which is subject to control, study this information and demonstrate the characteristics which must be known for the realization of control: the structure, organization, interconnections and related functions of the elements. The results of this study should be expressed in a mathematical and a mathematic-

al-logical language.

Therefore, if the system to be controlled has been studied mathematically, it is necessary to create a controlling system, in accordance with the purposes and problems posed for the purpose of acting on the variables of the system to be controlled. In principle, it is absolutely immaterial whether control occurs automatically or by means of feeding a certain combination of commands. It is customarily considered that all cybernetic apparatuses act automatically with the utilization of feedback principles. In many cases this is true. However, there are also cases where lags, introduced intentionally, occur between the separate steps or stages. Thus, for example, the process of collecting information may even be separated by long intervals of time from the process of realization of this information for the purpose of control.

If we adhere to the accepted terminology and if we make it clearer for technicians, particularly for radiospecialists, the system being controlled is the "load" for the controlling system. Programmed and coded control commands are fed to the input of the controlling system (for example, an electronic control mechanism). These commands are "understood" by the controlling apparatus or system. However, this does not mean that they are "understood" by the system under control. They must be processed appropriately so that the control commands coming from the controlling system be carried out correctly by the system under control. A good example may be a system of dial telephone communication. In placing a call to a person by means of dialing his telephone number a control command is sent to the central telephone station. There, this command is processed and a search is made for the number of the person being called. If the line is open, and the person's telephone line is not busy, the call is placed and the line is connected to his telephone. The fact that the station, subscriber or line is busy is indicated by a hooter -- these are feedback information signals. In this way, the regional dial telephone station together with the communications lines and the telephone subscribers represent a good example of a complex dynamic system controlled by many simpler controlling apparatuses or systems. As in the case of any complex dynamic system it has its own characteristics. One of its characteristic features is the interreplaceability of the points at which the information is received and from which the information comes, that is, the subjects and objects of control.

Long distance control systems can serve as another example. Here, the functions of the controlling and the controlled systems are distributed in a perfectly clear-cut and standardized manner. The points at which the control commands are elaborated and given and

the points at which the controlled systems are located may be separated by great distances. The intermediate medium can be most different: the atmosphere of the earth, space or a water medium. Feedback information communication can exist and act automatically, or it may be absent if the cause-effect relations are accurately and reliably known and if there is no doubt of the execution of the commands. Usually, automatic feedback information communication is used, but this is not the only possible system.

Long distance control by power systems can serve as another example of the separateness of controlling and controlled systems.

We have concentrated on these examples and terminology, because in the majority of cases in cybernetic literature the term "controlling" system is used in a somewhat different sense: by this we mean the totality of apparatuses which give and process the commands and the systems receiving them. This is based on the fact that sometimes it is hard to separate the controlling system from the control system according to our terminology. In this case living organisms can constitute an example. The source of the original information is frequently constituted by various processes occurring in the environment. If the organism has at its disposal receivers for this original information -- receptors -- it reacts to them. The stimulus signal is transmitted along many nervous system channels (whereby the organism selects the most advantageous and most reliable routes) and is processed repeatedly en route to the brain. After a very complex processing of the information which arrives here response signals are elaborated which are then transmitted to the effector organs, which in the final analysis carry out the body's reaction to the external stimulus. Here, the functions of commands or control signals for processing them and carrying them out continuously and repeatedly are tied together, whereby every successive command signal is determined by information received along feedback channels. All these processes are far more complicated than those in engineering and social life. Study of them has just begun but is being developed successfully in the Soviet Union and in many other countries. This study is an inexhaustible source for the enrichment of our knowledge and for imitation in simpler cases of control. However, every elementary act of this complex process is included under our terminology. As far as the control mechanisms, machines, apparatuses and operations of groups of people are concerned, it seems to us that in this case our terminology is fully applicable.

In the present collection there are no articles on electronic mathematical machines. There is an extensive scientific and popular scientific literature on this subject. From the standpoint of cybernetics

electronic machines are modern technical cybernetic facilities. With regard to electronic machines, problems of their further development, particularly reduction in their size, miniaturization of the structural elements and chiefly problems of improving their operational reliability and increasing their speed of action will be touched on in the second volume of the collection.

We shall not discuss problems of reliability in this collection either. This topic will be thoroughly analyzed in the second volume of the collection. We consider this topic one of the most important. It should be recognized that the situation in this field is definitely unfavorable. The reliability of electronic automatics facilities satisfies no one. We can speak about extensive incorporation of these facilities into the national economy only in the event of satisfactory solution of the problem of reliability. Here, there should be no illusions. However, at the same time, it should be admitted that the problem of increasing the reliability of electronic automatics facilities and cybernetic facilities cannot be solved by the efforts of electronic specialists alone. For the solution of it wider use should be made of mathematicians, constructors and technologists. The opinion that the reliability of the primary instruments and sensing devices is sufficiently great is perfectly unsound. Equally incorrect is the opinion of the great reliability of the effector mechanisms. This applies chiefly to the chemical industry.

Attempts to "swing away" from the solution of the reliability problem as a problem which has been thought up and which, as it were, does not exist do not stand up to any criticism. People should be held strictly responsible for slurring over these problems and for lack of attention to them. This is beginning to be understood by the majority of progressive persons responsible for scientific and technical progress. However, it should be kept in mind that the reliability problem, even if satisfactorily solved for today (which it certainly is not) will arise anew tomorrow and will never be eliminated until new technology and new instruments are developed and incorporated into practice. This is an "eternal" problem, and it will never be solved by episodic measures.

VI. Conclusion

In the Soviet Union for a long time people have been accustomed to count solidly on the aid of the Party in all difficult matters. We know very well that science develops only as the result of persistent, purposeful creative work of various scientists and in laboratories which are well organized and equipped with modern scientific instruments and outfits.

Beginning with the first few days of the Soviet regime V.I. Lenin, that ingenious learned man and excellent organizer, assisted in the development of young Soviet science and directed it toward the solution of the most important national economic problems. Not everyone remembers that on the initiative of V. I. Lenin the following was included in the Party Program adopted at the Eighth Congress in 1919: "The Soviet regime has already taken a whole series of measures directed at the development of science and toward bringing it closer to production: the creation of a whole system of new applied science institutes, laboratories, testing stations, experimental factories for the checking of new technical methods, improvements and inventions, the registration and organization of all scientific personnel and facilities, etc. The RKP, supporting all these measures is striving to develop them further and create the most favorable conditions for scientific work in its conjunction with the increase in the productive power of the country" (CPSU in Resolutions, Part 1, Seventh Edition, 1953, pages 423-424). Has any other country had to experience the difficulties which fell to the lot of Soviet science during the years of siege, starvation and intervention? Have any other countries had to evacuate not only a large number of industrial enterprises but almost all the scientific institutions, as had to be done in Leningrad and in many other cities subjected to Fascist invasion during the Second World War? Scientists of other countries have never experienced this. Nevertheless, several years after the end of the War the first atomic power station began to operate in the Soviet Union and shortly after this the first satellites were launched, and at the present time the first cosmonauts in the history of mankind are flying around the earth.

This progress is particularly noteworthy because it was made in spite of the greatest difficulties very recently experienced in a country which 30-40 years ago was considered backward.

It is interesting to note that according to the data of UNESCO in the past 50 years the average annual increase in the number of scientific workers on the earth has reached seven percent in the presence of a much lower population increment (about 1.7 percent per year). This means that the number of scientific workers in the world is doubling every 10 years, whereas the population of the earth is doubling every 40 years. For the purpose of solving the problems which have been set before Soviet science for the next 20 years it is essential to prepare a tremendous number of young scientific workers, to expand considerably the scientific research basis, to bring in colleges for research work on a much larger scale than is being done at the present time, to distinguish the most important trends of research and to concentrate the main efforts on them. Outfitting of colleges, laboratories

of institutes and plants should be coordinated with the complexity of the solution of the new scientific problems. Special attention should be given to the development of instrument construction, particularly scientific instrument construction and equipment necessary for doing experimental work.

All these problems were the subject of discussion at the All-Union Conference of Scientific Workers and at the conference of workers of the higher school, which took place in the Kremlin in the summer of 1961. The soundness of proposing topics and making demands for scientific equipment of research and scientific laboratories depends on scientific workers and teachers in colleges.

Special attention should be paid to the development of the theory and principles of creation of new machines, automatic and telemechanic systems, the active development of radioelectronics, the development of the theoretical basis and technical perfection of computing, controlling and information machines, as has been indicated in the Draft Program of the CPSU.

Specifically these trends constitute the content of the new science of optimal control by complex systems, which has been given the name of cybernetics. As has been shown above and as has been stated in greater detail in the articles of the present collection, the main aim of cybernetics is the elaboration of such new methods and utilization of such new scientific and technical facilities for the control of the national economy, industrial processes and scientific research which would lead to the goal with the least expenditure of time, labor, materiel and energy. Such control conditions are customarily called optimized.

Speaking at the First All-Union Conference of Scientific Workers on 12 June 1961, Academician M. V. Keldysh, President of the Academy of Sciences USSR, stated the following: "To date we do not have an adequate work front in the field of cybernetics, the science of control processes which at the present time is of first practical and theoretical importance. Research in this field should be activated and integrated at an appropriate institute or special coordination council". We are completely in agreement with this statement.

The group of authors of the present collection, the editorial staff and the State Power Engineering Publishing House would like their work to contribute to the solution of problems entrusted to Soviet cybernetics. We consider it our main aim to place this new science at the service of the most rapid construction of a communistic society in the Soviet Union. The second and third volumes of the present collection, which we plan to publish in 1962 and 1963 will serve this aim.

Scientific workers of the Soviet Union are undoubtedly doing

everything possible to justify the faith of the Party and the tremendous assistance which it is giving to science in the Soviet Union. In their everyday labor activity they will be guided by the excellent thoughts presented in the Draft Program:

"The progress of science and engineering under conditions of a socialistic system of economy makes it possible most effectively to utilize the resources and power of nature in the interests of the people, to discover new types of energy, create new materials, work out methods of acting on climatic conditions, mastering cosmic space. The use of science becomes the decisive factor in the powerful growth of the productive forces of society. The development of science and the incorporation of its achievements into the national economy will in the future be the subject of special concern of the Party".