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SCIENTIFIC INTELLIGENCE REPORT

THE SOVIET SPACE RESEARCH PROGRAM

MONOGRAPH V
PROPULSION SYSTEMS



CIA/SI 17-59

14 May 1959

CENTRAL INTELLIGENCE AGENCY

OFFICE OF SCIENTIFIC INTELLIGENCE

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Scientific Intelligence Report

THE SOVIET SPACE RESEARCH PROGRAM

MONOGRAPH V
PROPULSION SYSTEMS

NOTICE

The conclusions, judgments, and opinions contained in this finished intelligence report are based on extensive scientific intelligence research and represent the final and considered views of the Office of Scientific Intelligence.

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PREFACE

This monograph, one of a special series on the Soviet space program, presents intelligence on current and proposed propulsion systems. The information is based on public statements made by responsible Soviet scientists and officials, published scientific reports on Soviet accomplishments in space vehicle launchings,

The cutoff date for the information contained in this report is April 1959.

The complete series of monographs on the Soviet Space Research Program is listed below. Monographs II through XII in the series are designed to support the conclusions found in Monograph I, which is an overall evaluation of the program and will be published last.

Monographs on the Soviet Space Research Program:

- | | |
|---|---|
| I Estimate 1959-74 | VII Telemetry, Communications, and Reconnaissance Instrumentation |
| II Objectives | VIII Ground Support Facilities |
| III Organization, Planning, and Control | IX Space Medicine |
| IV Space Vehicles | X Space Biology |
| V Propulsion Systems | XI Astronomical Aspects |
| VI Guidance and Control | XII Current Status of Progress |

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THE SOVIET SPACE RESEARCH PROGRAM

MONOGRAPH V PROPULSION SYSTEMS

PROBLEM

To assess Soviet capabilities in space vehicle propulsion systems.

SUMMARY AND CONCLUSIONS

The USSR has liquid-propellant rocket engines with thrusts of 25 and 35 metric tons, probably one with a thrust of 100 metric tons, and possibly a larger one. The 25- and 35-metric-ton thrust engines were designed for liquid oxygen and alcohol propellants; the 100-metric-ton thrust engine was to use liquid oxygen and kerosene. The Soviets may also have a 4-engine cluster available

The 100-metric-ton thrust engine used in cluster, or possibly a single larger engine, is believed to have supplied the primary thrust for the Sputnik and Mechta launchings.

The Soviets are expected to use these basic engines in fulfilling their requirements for the earth launching of space vehicles (required thrusts on the order of 1/2 to 1 million pounds) during the next year or so. These engines would probably use liquid oxygen and kerosene as propellants, but also could possibly use fuel combinations containing unsymmetrical dimethyl hydrazine (UDMH), diethylene triamine (DETA), or other chemicals for specific applications.

The development of liquid-propellant rocket engines with thrusts larger than those presently available is assumed to be in progress,

In the next 2 or 3 years the Soviets will probably develop the greater thrusts necessary for their space program by clustering either improved versions of their existing rocket engines or new engines. The incorporation of improved propellants such as higher energy or storable materials would be beneficial to either approach. By 1961 or 1962, the USSR will probably develop liquid-propellant rocket engines with thrust levels on the order of 1 to 2 million pounds. The new engines could use propellants containing either liquid fluorine and/or liquid oxygen or possibly liquid ozone. The chemical industry of the USSR will be capable of producing adequate amounts of chemicals necessary for proposed liquid-propellant rocket engines, and the metallurgical industry will probably be capable of supplying adequate materials. In addition, the Soviets have a potential for major scientific developments that could advance their present capabilities (as estimated) by several years.

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Statements by responsible Soviet authorities indicate that they do not anticipate the early use of nuclear rockets for interplanetary flights. At the same time, the Soviets also carefully point out that chemically fueled rockets are presently available and feasible for flights to and beyond the moon. The development and efficient use of nuclear rockets by the Soviets during the next 15 years will depend upon their progress in developing suitable high-temperature reactor materials. Lacking these reactor materials, which would permit thrust levels approaching theoretical values, the Soviets will possibly accept reduced performance (thrust) in order to use available materials. The Soviet development and operation of a nuclear propulsion system under these conditions could possibly occur during the next 5 to 10 years. If they succeed in this development, the Soviets will probably use such a nuclear system initially only in outer space because of the radiation hazards and prolonged low-thrust levels.

Soviet progress in the research and development aspects of solid- and storable-liquid-

propellant rockets are considered adequate for current space flight needs. Outer space uses for these engines demand simplicity and reliability in operation between extended periods of inactivity during flight. The Soviets will probably be able to continue to improve their capability in order to accomplish their planned space missions. Soviet developments in hybrid rocket engines* and slurries** are probably not now at a stage where they can supplant the existing solid- and liquid-propellant systems.

Soviet scientists have openly expressed a keen interest in futuristic propulsion systems. The need for propulsion systems capable of providing the thrusts and velocities necessary for manned interplanetary travel is clearly recognized by the USSR. The Soviets probably plan to explore the use of free radicals, ions, photons, controlled thermonuclear reactions, and/or energy from sources available in outer space in such futuristic systems. A nuclear reactor power source will probably be required for systems using ions or photons. To date, Soviet efforts in futuristic propulsion systems are probably in the area of pure mathematical research. The USSR probably will not develop a practical full-scale rocket propulsion system utilizing the potential energy from these futuristic systems by 1974.

DISCUSSION

INTRODUCTION

The successful launchings of the world's first artificial satellites by the Soviets may be considered as well-planned steps toward the realization of manned space flight. The vast amount of systematic and well-coordinated scientific and technological work preceding these events probably began in the USSR in 1929 with the formation of a scientific organization known as "GIRD" or "Group for the Investigation of Reactive Motion." In the early thirties, the Soviet government and Stalin recognized the enormous potential of the rocket and established an organized re-

search program. This program soon put into practice some of Tsiolkovskiy's early proposals to use chemicals as a source of propulsive power. As a result, the USSR initiated small-scale testing of chemically-fueled liquid-propellant rocket engines during the early thirties. Capitalizing on these early advances, the Soviets were able to produce a few rocket engines for aircraft application in the early 1940's.

* Hybrid rocket engines — Engines comprising discrete solid- and liquid-propellant phases.

** Slurries — A suspension of metals or solids in a liquid.

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Following World War II, the Soviets, who were familiar with German prewar and wartime achievements in rocket propulsion, began an immediate and systematic exploitation of those German facilities and skills that the Soviets considered essential to their missile programs.

Future objectives of Soviet space research may require initial thrusts in excess of a million pounds for earth launchings. Thrusts of this magnitude could be achieved either by using existing engines in clusters or by the development of considerably larger engines. Concurrent advances in propellant technology would be expected with chemicals such as liquid fluorine, liquid hydrogen, and hydrazine.

Soviet research in rocket propulsion systems using nuclear power is probably under way as a necessary adjunct to their existing systems. Initially, nuclear-powered rockets are expected to be capable only of low thrusts and long duration. Even though the Soviets may make significant progress in the development of nuclear rockets, the combination of low-thrust levels plus the hazards of launch site and atmospheric contamination militate against using this form of propulsion for earth launchings. Similarly, the Soviets are expected to expend vast efforts on the development of futuristic systems. These systems envisage the use of ions, free radicals, photons, and sources of energy available in outer space as a means of obtaining the necessary velocities permitting manned interplanetary flights.

CHEMICAL PROPULSION SYSTEMS AND PROPELLANTS

The Soviet use of chemicals as propellants for rocket engines appears in several distinctive forms varying from those comprised wholly of liquids or solids to hybrids and slurries. Moreover, the chemicals used in these various forms are often categorized as being either conventional or exotic, depending primarily on the performance characteristics obtainable from any particular combination. Advances in the state-of-the-art of rocket-engine design have led to improved engine

efficiencies and performance characteristics. When considering any propellant combination it is well to include specific engine operating conditions, when known and to determine (i) whether or not the propellant can be stored without appreciable losses during extended periods in space, and (ii) the maximum flight velocities attainable with chemical systems.

The USSR has publicly claimed the production and small-scale testing of liquid rocket engines in the early thirties. This milestone was reportedly followed early in the forties by the production and limited use of liquid-propellant rocket engines for use in aircraft.¹ Immediately after World War II, the Soviets began to exploit German facilities and skills. This included the acquisition of German manufacturing equipment and the production of V-2 rocket engines (25-metric-ton thrust) at Plant 456, Khimki. Various reports indicate that between 100 and 300 of these were manufactured in the period 1947-50. These engines were fueled with liquid oxygen and alcohol.^{2,3}

The design of an improved V-2 type rocket engine with a thrust of 35 metric tons was started by German experts at Plant 456, Khimki, in 1947. This engine, incorporating some native design modifications, was being produced in late 1948. Between 100 and 250 of these units are estimated to have been produced during the period 1948-50.^{4,5}

This engine also used liquid oxygen and alcohol as propellants. Minor design and propellant changes since that time could have resulted in an increased thrust level.

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gines of advanced design. This probably includes engines with higher thrust-to-weight ratios, increased thrust either as clustered units or single engines, and the use of higher energy propellants initially as additives for existing rocket engines and later for newly designed engines. Thus, the USSR today undoubtedly has under development liquid-propellant rocket engines in thrust categories

The availability of the 100-metric-ton engine at its rated thrust or up-rated thrust using conventional propellants is believed to be the backbone of the Soviet ICBM and space programs.^{4 10 11} Although it is believed that this engine has been used in multiple units, the only evidence of clustering of rocket engines relates to the smaller engines that were developed at Plant 456 in 1955. This project began in 1953 in a new experimental engine shop. The single engines of the unit were of modern design and about half the size of a V-2 engine. There is no reliable estimate of the thrust developed by the cluster of four engines.¹²

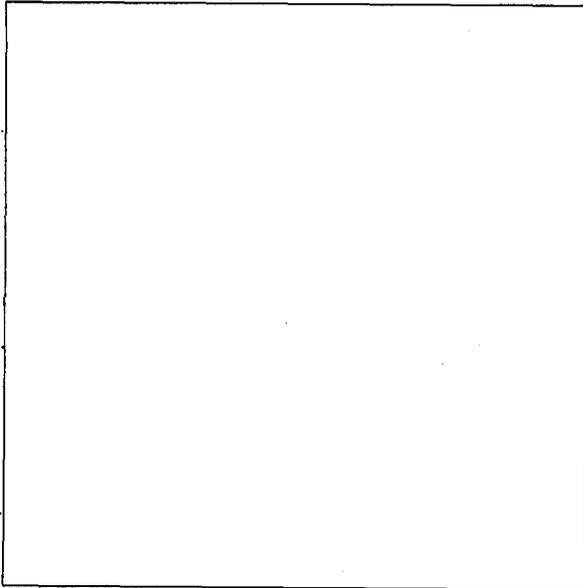
Achievements of the Soviet space program to date have included the three Sputniks and the lunar probe Mechta. R. Ya. Malinovsky, Minister of Defense and Marshal of the Soviet Union, has stated that the ICBM was the basic launching vehicle for these. Assuming this to be the case, calculations indicate that the initial thrust of the launch vehicle was about three-quarters of a million pounds. Thrusts of this magnitude probably could be achieved by using multiple 100-metric-ton engines.

Future objectives of the Soviet space program would require initial thrusts in excess of 1 million pounds. Although these thrusts could be achieved by clustering 100-metric-ton engines that use conventional propellants, the reliability of such clusters would decrease as the number of engines increased. Thus, it is not expected that the Soviets would cluster more than five or six 100-metric-ton engines. Therefore, the Soviets are probably developing large-thrust liquid-propellant rocket engines with total thrusts of about 1 to 2 million pounds. These engines could utilize high-

Nevertheless, it is assumed that the Soviet program includes the development of liquid-propellant rocket en-

energy propellants such as liquid oxygen and/or liquid fluorine as the oxidizer and hydrazine as the fuel. These large-thrust engines would probably be used singly at first and later in clusters in the Soviet space program.¹²⁻¹⁸

Solid-propellant-fuel-rocket engines are important to the Soviet space research program in that they are relatively simple, reliable, and capable of ignition at extremely high altitudes. Such units are well suited for the final stages of satellites, space probes, and space-craft vehicles, especially those for which a later powered phase is envisaged (vernier and retrorockets are also included). In this respect, solid propellants will be competing initially with storable liquid propellants and later with nuclear propulsion, since the present cryogenic propellants may not permit extended periods of storage in outer space.



The Soviets undoubtedly recognize the necessity for developing both solid and storable liquid propellants. On the basis of the high caliber of their work in other areas of propellants and propulsion systems since World War II, the USSR has probably achieved at least as much progress in this field as the United States.^{18 19} It is estimated that the USSR now has available both solid and storable liquid propellants suitable for use in outer-space applications which demand

reliable propellants and simplicity in operation between extended periods of inactivity during flight.^{10 11 14 20}

The development and use of hybrid rocket engines (engines comprising discrete solid- and liquid-propellant phases) and slurries (a suspension of metals or solids in a liquid) has been reported under study in the USSR. To date, the Soviet developments in both of these areas probably do not warrant their supplanting the existing solid and liquid propellant systems.^{2 8 21}

The USSR has published many vague news items about the propellants used in their space vehicle propulsion systems. From published research [redacted] it is apparent that the Soviets are seriously investigating fuels and oxidizers for use as rocket propellants other than the conventional liquid oxygen/alcohol and liquid oxygen/hydrocarbon combinations.

The USSR has been engaged since 1949 in a small boron-fuel program and probably has achieved at least pilot-plant production of several boron compounds that may be used in the production of rocket fuels.²² At a conference early in 1958, Peter V. Dementyev, Chairman of the Council of Ministers of the USSR for Aviation Technology, said that the Soviets had worked with boron fuels experimentally but have not used them operationally.²³ The Soviets have conducted laboratory studies involving the effects of ozone on combustion rates and the ignition of hydrocarbons that could be applicable to propellant research for advanced rocket propulsion systems.²⁴ The Soviets are apparently interested in the production of unsymmetrical dimethyl hydrazine (UDMH). The use of UDMH as a rocket fuel offers several advantages over a conventional chemical system, including high-density impulse values and storability.²⁵ The possibility exists that the Soviets are developing an engine that uses a storable propellant combination of nitrogen tetroxide and hydrazine or UDMH.²⁶

The Soviets recently published an account of the development of a prototype liquid hydrogen plant in order to satisfy the increased demands for liquid hydrogen by scientific re-

search institutes and enterprises. This suggests that Soviet research and development on a high-energy chemical-propellant rocket engine utilizing liquid hydrogen is under way.²⁴

A. A. Blagonravov has stated that the answer to chemical rockets may be found in the fluorochemicals.²⁷ A review of recent USSR open literature has revealed Soviet awareness of and interest in liquid fluorine and oxygen bifluoride.²⁸ Soviet research at the Lebedev Institute of Rubber Research on fluorinated hydrocarbon copolymers could support a high-energy solid-propellant development program.²⁹ L. I. Sedov has stated that the reported specific impulse values of around 260 to 280 seconds achieved for advanced solid propellants is doubtful. From his acceptance of specific impulse values of about 240 to 250 seconds for solid propellants, it appears that the USSR has achieved about the same level.²⁴

The chemical industry of the USSR will probably be capable of producing adequate amounts of these high-energy chemicals necessary for use in any advanced propulsion systems expected to be used by the USSR during the next 15 years. At least for chemical propulsion systems used during the next 15 years, the USSR is expected to be able to produce the necessary chemicals and materials.

Organization, Planning, and Control

The Soviet facilities engaged in the research and development aspects of chemical propellants and the propulsion systems utilizing them fall under the jurisdiction of several State Committees as well as the Academy of Sciences, USSR. Although no particular organization controlling their efforts is known, it is believed that pertinent Soviet research on chemical propulsion systems is carried out for the Ministry of Defense. The adaptation of these systems to space projects is probably coordinated at the Academy of Sciences level, probably under the Interagency Commission on Interplanetary Communications. The general purpose of this permanent commission, which is headed by Academician L. I. Sedov, is to "coordinate and direct all works concerned with solving the problems of mastering cosmic space."³⁰

Manpower

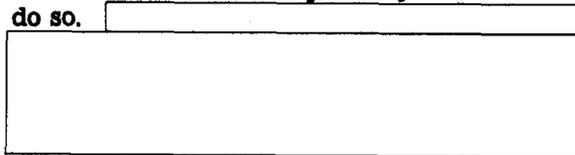
Past Soviet accomplishments in space vehicle launching efforts and the related part of the ballistic missile program provide firm evidence of the quality of the manpower available for their program. Important Soviet scientists associated with the USSR propulsion program include V. P. Glushko, M. Y. Kagan, and Y. A. Pobedonostsev. * 30-32

In 1953, Glushko was made a corresponding member of the Academy of Sciences, USSR, and in June 1958 became an active member. Glushko allegedly was to have received a Stalin Prize for the successful development of the 100-metric-ton engine. There is no available information on 1953 Stalin Prize winners, but Glushko's election to the Academy of Sciences indicates successful development of the engine with the 100-metric-ton thrust and attests indirectly to the quality and effective utilization of scientific manpower.³¹

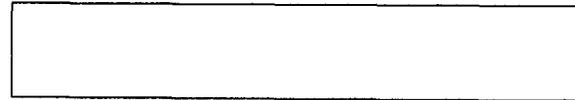
The importance of the Soviet propulsion program is probably of such a nature and priority that the number of competent people involved will probably continue to grow.

Facilities for Research, Development, and Testing

The State Committee for Chemistry and some of its subordinate institutes play important roles in the actual development, synthesis, and testing of particular propellant combinations and will probably continue to do so.

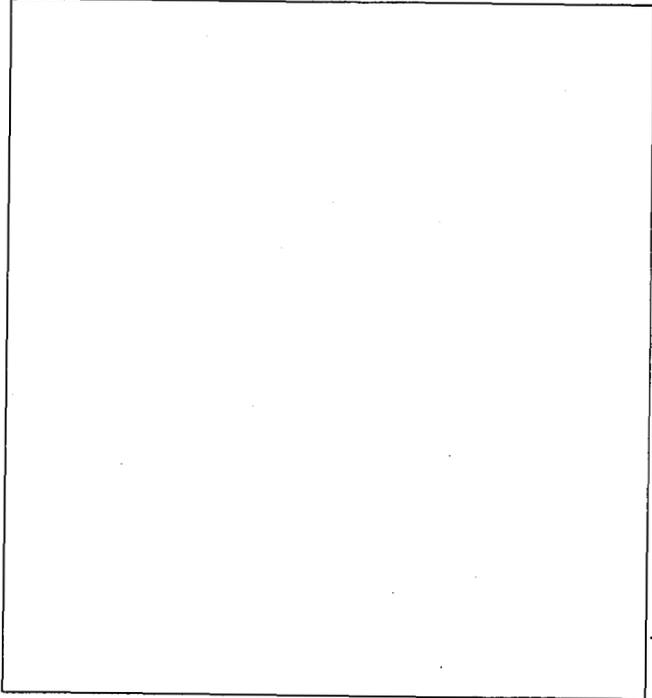
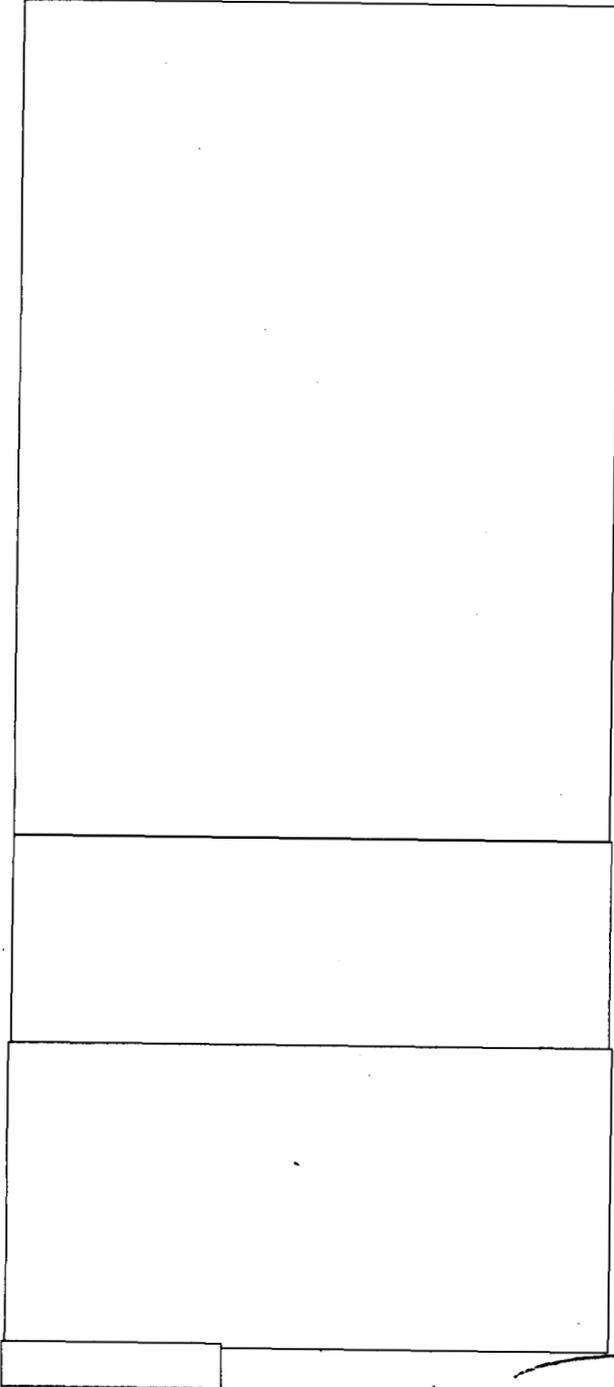


These institutes and plants have been active in the synthesis and production of a wide variety of industrial and specialty chemicals, some of which are primarily of value for rocket propellants.³⁴⁻³⁵



* See appendix A.
** See appendix B.

pulsion. Numerous academicians have been fulfilling dual responsibilities to the Academy and their individual institutes by serving as consultants in the various State Committees engaged in some phase of the propellants and/or propulsion program.^{46 47} It is expected that these academicians will continue this practice, and their work may well stimulate significant advances in chemical-propulsion technology.



NUCLEAR PROPULSION SYSTEMS

The apparent great advantage of nuclear propulsion over chemical propulsion systems is its tremendous specific impulse, which is many orders of magnitude greater. In principle, at least, extremely high temperatures can be obtained in a nuclear system, but until suitable structural materials are developed that are capable of withstanding such high temperatures, this is of no practical advantage. Other obstacles to the use of nuclear propulsion systems are the extremely low thrust/weight ratios presently attainable, and the hazard of contamination from exhaust products. Moreover, a nuclear propulsion system must be provided with adequate

The Academy of Sciences has at least one institute, the Institute of General and Inorganic Chemistry imeni Kurnakov, engaged in fundamental propellants research that may find application for future space-vehicle pro-

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amounts of a suitable working fluid like hydrogen, ammonia, or methane in outer space. For extended operational periods, other than from the earth's surface, the use of noncryogenic working fluids is indicated. Current concepts envisage operation at lower temperatures and thrust levels than are theoretically obtainable. This type of operation would be compatible with existing materials and would permit extended operation at thrust levels of value principally in outer space.

The intelligence available on Soviet work in nuclear rocket propulsion is limited to information knowingly released by the Soviets. This information, largely from press and radio statements, but also including statements attributed to Soviet scientists who attended international conferences, provides little basis for estimating the probable course of the Soviet nuclear rocket program. Nevertheless, the Soviets do strongly indicate that such a program exists.

One of the most authoritative statements on the existence of a Soviet nuclear rocket program was made recently by L. I. Sedov, who said that Peter Kapitsa is concerned with the application of nuclear energy to rocket propulsion.⁷⁸ Another indication that the USSR has at least carried out feasibility studies of nuclear rockets was provided at an international congress in 1956 where A. P. Vanichev made intelligent comments on a controversial paper entitled, *A New Type of Power for Space Flight*.⁴⁹

Additionally, there are several statements by responsible Soviet authorities which indicate that they do not anticipate the early use of nuclear rockets for interplanetary flights.⁵⁰⁻⁵² These statements describe the potentialities of nuclear rockets in glowing terms, but also carefully point out that flights to the moon and beyond by means of chemical rockets are completely feasible at the present time with existing hardware.

As would be expected, there are no references in the open literature to Soviet attempts to develop the high-temperature reactors required for nuclear rocket engines. Undoubt-

edly, any such efforts would be under the most rigid security restrictions in the USSR, and it is quite possible that even Soviet groups concerned with the design and construction of research and power reactors are not aware of current Soviet developments for rocket applications. It is believed that any significant advance in nuclear rocket propulsion during the next 15 years will depend greatly on Soviet progress in developing suitable high-temperature reactor materials, and there is good evidence that the Soviets are vigorously pursuing this type of research. For example, extensive investigations have been made of metals having extremely high melting points (e.g., tantalum, columbium, and rhenium) alloyed with other metals having favorable properties for use as structural materials in reactors (e.g., zirconium and beryllium). The Soviets also have demonstrated interest in certain ceramic and intermetallic compounds, which are regarded as very promising for nuclear propulsion applications.⁵³

Since a controlled thermonuclear reaction has not yet been achieved in the laboratory, it is indeed premature to consider it as a propulsion medium for space travel during the period covered by this estimate. It is believed that the USSR could achieve a limited capability with a practical fission system of nuclear propulsion by about 1965. At least initially, any capability attained with a nuclear propulsion system will be primarily applicable in outer space rather than from the earth's surface because of the radiation problem and low-thrust levels.

Organization, Planning, and Control

Statements by Soviet authorities have made it clear that they envision space missions rather than military missions for nuclear powered rockets.^{54 55} For this reason, the overall planning of the program would probably be a function of an organization at the level of the Academy of Sciences, possibly the Soviet Interagency Commission on Interplanetary Communications. Kapitsa, a member of this commission, has probably been concerned with the application of nuclear power to rocket propulsion.

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There is no information available as to the magnitude of the Soviet effort in a nuclear rocket propulsion program. If Kapitsa is directing their program as has been implied, the USSR should have the benefit of capable leadership. Any Soviet efforts to develop a nuclear-rocket engine would require the services of competent reactor engineers, physicists, and metallurgists. That such competent individuals are available and considering the many problems involved is plainly evident. Among them are K. Stanyukovich, Vanichev, and G. Babat.

Facilities for Research, Development, and Testing

There are many locations and facilities within the USSR where the design, development, and testing of nuclear propulsion systems could take place. The institutes and plants working on chemical propulsion systems possibly would be concerned with certain aspects of a nuclear program. Reactor design and development probably would be associated in some manner with the Ministry of Medium Machine Building with the assistance of Academy of Sciences personnel and facilities, including the Institute of Atomic Energy in Moscow. The construction of engine-test facilities would probably be accomplished by the Construction Directorate of the Ministry of Medium Machine Building.

Although present launching facilities are considered adequate in size to accommodate nuclear propulsion systems, it is considered unlikely that the Soviets will conduct early research and development testing there. The USSR is considered capable of utilizing existing facilities and constructing additional installations that may be required to support sizable feasibility studies, research, development, experimental tests, and possibly early flight tests.

FUTURISTIC PROPULSION SYSTEMS

In space technology, the propulsion systems most feasible under gravity conditions at the earth's surface are not necessarily the most efficient under conditions of

little or no gravity in outer space. Such futuristic systems are especially marked by their utilization of nuclear or solar energy or by the possession of very low thrusts created by the acceleration of ions or photons. Some of these proposed systems will depend upon the existence of electric and magnetic fields of force in interstellar space for their drive, while other proposals contemplate the use of dust and gas particles present in outer space to serve as a propellant. The Soviets evidently are making an extensive collection of published Western data on futuristic propulsion systems.

The Soviets are conducting upper atmosphere studies at various astrophysical institutes and observatories, and their research work on airglow and reflection is well known.^{56 57} Sputnik III was designed in large part for the study of particles in space.⁵⁸ Soviet interest in the chemistry of the upper atmosphere and space propulsion using interstellar gas was clearly demonstrated by L. I. Sedov at a recent international conference.⁵⁹ This activity indicates that the Soviets have more than a casual interest in developing a source of power that would use the gas and dust particles in outer space.

The Soviets have also shown interest in anti-gravity problems.⁶⁰ Stanyukovich has asserted that some means other than rockets could be devised to overcome the earth's gravity.⁶¹ The Soviets have published pure research works involving electric and magnetic propulsion schemes.⁶² Research on the generation and storage of extremely powerful magnetic fields has been associated with Kapitsa.⁶³

There have been several Soviet references to the use of ion propulsion in space flights.^{64 65} The Science Secretary of the Interagency Commission on Interplanetary Communications, A. Karpenko, proposes ionic propulsion powered by nuclear energy as a means of space ship travel to Mars and Venus in the next 15 to 20 years.⁶⁶ G. I. Pokrovsky proposes as a Soviet goal an ion system that is not based on nuclear energy and the concomitant high-temperature and lethal-radiation problems.⁶⁷ The Soviets participated in

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a recent international conference on ionization phenomena in gases and included one of their experts on ion and electric propulsion systems as a delegate to the Ninth Annual Congress of the International Astronautical Federation.⁶⁸ Most proposed systems of ionic or photon propulsion envisage the use of a nuclear reactor for the energy source.⁶⁹

According to a lecturer at the Air Institute in Moscow, the Soviets have already made preliminary calculations for a photon rocket theoretically capable of a round trip to Mars in 4 to 5 days, as compared with approximately 3 years required for existing rockets.⁶⁹ Photon drive, according to the well-known Soviet astronautics writer K. A. Gil'zin, is one of the awe-inspiring scientific problems facing the Soviets in their first steps toward the conquest of space.⁷⁰ Another Soviet account indicates that the creation of the photon rocket will be considerably accelerated by Soviet achievements in science and technology.⁷¹ Such advances contemplate the conversion of matter into radiant energy as a prerequisite to photon propulsion.⁷⁰

The many and varied problems that ultimately must be overcome in order to achieve any marked degree of success in futuristic propulsion systems also indicate that their present thinking and progress are at best only in an embryonic state. Although the need for propulsion systems capable of providing the thrusts and velocities necessary for humanly feasible interplanetary travel are clearly recognized by the Soviets, they are not expected to achieve any useful system embodying the foregoing proposals by 1974.

Organization, Planning, and Control

Information concerning the planning and control of Soviet research in the field of futuristic propulsion systems is lacking. Likewise, information concerning organization of the Soviet program is lacking. Frequent and substantive statements emanating from well-known members of the Interagency Commission for Interplanetary Communications, imply that this body is eminently concerned with possible futuristic propulsion systems.

The avowed general purpose of this commission is to coordinate and direct all work concerned with solving the problems of mastering cosmic space.⁷⁰ Specific duties and functions are probably manifold and involve the initiation, organization, coordination, and popularization of the problems of space flight. Official interest at the level of the Academy of Sciences is also indicated by the establishment in September 1954 of the K. E. Tsiolkovskiy Gold Medal to be awarded every 3 years beginning in 1957 for outstanding work in interplanetary communication.⁷²

Manpower

Some of the USSR's most competent scientists probably are engaged in research efforts pointing toward achievement of futuristic propulsion systems. Well-known spokesmen on the overall aspects of Soviet astronautics include some of the world's best scientists, for example, N. N. Bogolyubov, V. A. Ambartsumyan, A. A. Blagonravov, and Yu. A. Pobedonostsev.⁸⁰ Many of the unnamed Soviet scientific personnel now working in the field of rocketry and cosmic flight formerly were in the aviation industry.⁷⁰ The Soviets probably now have an adequate number of scientists conducting research in unconventional propulsion systems and will be capable of diverting any additional assets as their program may require.

Facilities for Research, Development, and Testing

Soviet efforts in the field of futuristic propulsion systems are more in the area of preliminary research, mathematical calculations, and similar theoretical investigations, rather than in the area of the development and testing of actual systems. Therefore, the various aspects of such basic research would probably be done in the numerous Soviet universities and in organizations affiliated with the Academy of Sciences. Scientists at the Crimean Astrophysical Observatory are studying dust clouds of outer space by means of their polarization of transmitted starlight.⁶⁴ In 1955, the Bauman Institute published a collection

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of papers on theoretical mechanics, several of which could have application to problems in space flight.³⁰ Associated and necessary nuclear energy power sources will probably be investigated by the Institute of Atomic Energy in Moscow. Since these various futuristic propulsion systems that have been proposed to date probably will not find any application involving an earth launch by 1974, the Soviets probably will not construct any

sizable facilities for testing futuristic systems between now and 1974. It is believed that the Soviets now possess extensive and completely adequate facilities for investigating some of the concepts that have been advanced in recent years. The next 10 to 15 years will probably see an increased tempo of the Soviet efforts in this area, and they are considered capable of developing and expanding the necessary facilities.

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APPENDIX A

SOVIET SCIENTISTS WHO ARE ACTIVE IN SPACE RESEARCH IN THE USSR

The following Soviet scientists are active in the space research program in the USSR:

V. A. Ambartsumyan
G. Babat
A. A. Blagonravov
N. N. Bogolyubov
K. A. Gil'zin
V. P. Glushko

[Redacted]

P. Kapitsa
A. Karpenko
Yu. V. Kondratyuk
Y. A. Pobedonostsev
G. I. Pokrovskiy
K. Stanyukovich
A. P. Vanichev

APPENDIX B

SOVIET ORGANIZATIONS AND INSTITUTES INVOLVED IN RESEARCH AND DEVELOPMENT RELATED TO ROCKET PROPULSION SYSTEMS

The following organizations and institutes are involved in the Soviet guided missiles research and development program:

Bauman Institute, Moscow

[Redacted]

Kapustin Yar Missile Test Range

[Redacted]

Plant 94, Moscow

[Redacted]

Plant 456, Khimki

State Institute of Applied Chemistry, Leningrad

Scientific Research Institute 4, Bolshevo

Scientific Research Institute 88, Kaliningrad

Tyura Tam Missile Test Range

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