NASA TT F-541

FROM A SCIENTIFIC HERITAGE

By F. A. Tsander

Translation of "Iz Nauchnogo Naslediya"
"Nauka" Press, Moscow, 1967

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – CFSTI price $3.00

TABLE OF CONTENTS

1925

1926

1928

1930-1931

From the Correspondence of F. A. Tsander

Appendix

Foreword

We know Fridrikh Arturovich Tsander as one of the first scientist-engineers who studied the problem of space flight at a time when for most people such flights seemed to be fantasy. /3*

F. A. Tsander, deeply convinced of the feasibility of interplanetary flight, loved his work and dedicated his life to it. The original solutions for a number of problems of interplanetary flight which he suggested are known to our specialists. The materials published in his books and in books about him characterize F. A. Tsander as a penetrating and unique scientist, worthy of deep respect and recognition.

The idea of F. A. Tsander to use the atmosphere in the process of separating the mass of a rocket apparatus from the planet is beginning to attract serious attention of specialists today. This solution will allow not only an improvement of the launch conditions for man in space; tremendous economic gains result with multiple launches, since the first stage of the rocket returns to earth.

The suggestion of F. A. Tsander that the mass of the structures in a rocket apparatus be used as a working fluid for the motor, which has not yet been realized in today's rockets, remains alluring for realization in spacecraft for longer flights.

The purpose of the publication of this collection is not to present a discussion of the technical ideas of F. A. Tsander. The materials of this collection speak of F. A. Tsander as a great propagandist and popularizer of new ideas in space engineering and particularly his own original ideas.

His activity in the area of popularization of the ideas of astronautics was quite broad. He presented lectures and reports in Moscow and other cities, composed organizational plans for clubs, programs of lessons with students, prospects for books in which the technical details for the creation of space motors and apparatus were to be discussed, and attempted to attract /4
the attention of many people to these new problems, educating the ignorant and convincing skeptics.

Several documents from this list testify as to the attempts of F. A. Tsander to receive the support of State organizations and to begin the great practical work on a reliable material and technical basis.

The person responsible for composing this collection -- the daughter of F. A. Tsander -- Astra Fridrikhovna Tsander has included in this collection documents convincing us that the activity of F. A. Tsander in the area of cosmonautics was not limited to scientific investigations alone. He attempted to gather around himself enthusiasts for rocket science, and these attempts bore fruit. Some of those who spoke with him later did a great deal to see

*Numbers in the margin indicate pagination in the foreign text.

that the dreams of F. A. Tsander for the exploration of the cosmos were realized.

We can hope that the readers of F. A. Tsander, rocket engineering history enthusiasts and our youth who dream of the achievement of interplanetary flights will find a great deal of interest in the documents of this collection, reflecting the hopes and dreams of this remarkable man.

Professor A. V. Gvasnikov

FROM THE EDITOR-COMPOSER

The cherished dream of Fridrikh Arturovich Tsander was the dream of practical development of rocket technology, achieving ever higher altitudes and finally leading to space flight. He himself began to study the engineering problems in this new area quite early. /5

However, in order to develop practical work on a broad front and go over to direct construction of rocket apparatus, a production pace and personnel had to be assembled. However, the idea of performance of practical work on rocket technology was not sufficiently recognized at that time. Therefore, one of the most important stimuli to practical development of rocket technology was considered by Tsander to be his popularizing and propagandizing activity, as well as the organization of various clubs, groups and societies -- the predecessors of future "rocket" enterprises. These views of Tsander explain his many lectures and reports on problems of interplanetary voyages made from the early 1920's.

In his appearances, he frequently suggested that various "space" unions be formed. In particular, Tsander suggested the creation of the "Society of investigators and interplanetary voyage enthusiasts." This thought is included in the summary of his report made 20 January 1924 at the theoretical session of the Moscow Society of Astronomy Enthusiasts (MOLA). Soon after this appearance by Tsander, such a union was formed, called the "Society for Study of Interplanetary Voyages" (OIMS), and Tsander was made the chairman of its most important section -- the scientific research section. A number of the materials published in this collection reflect the activity of Tsander in this area. Unfortunately, the Society for the Study of Interplanetary Voyages did not succeed in creating a production base, and after approximately one year it ceased to exist. In his appearances, Tsander usually turned a good deal of attention to presentation of qualitative and numerical results from a /6
number of his own original works, describing them, although not exhaustively, considerably more completely than in his article published in 1924 [1].

This collection has been made up on the basis of materials from the personal archives of F. A. Tsander (in the future we will refer to this as the "archives of F. A. Tsander"), which the author of this article has kept to the present day.

A considerable portion of this collection consists of certain materials from the lectures and reports of Tsander in the area of interplanetary voyages. In some of the published lectures and reports, some portions of sentences are crossed out, marked with the word "read," indicating the point and time of the appearance (corresponding to stipulations made in commentaries on these materials). This means that this lecture or report was not read at the planned time or place. However, as analysis of the archives shows, this crossing out does not exclude the possibility that an appearance was made at a different time or place.

In 1924-25, Tsander read lectures and reports on interplanetary voyages not only in Moscow, but in other cities as well. In particular, on 17 October 1924 he spoke in Kharkov, on 17 November -- in Leningrad, in January of 1925 -- in Saratov, in November in Ryazan, in December in Tula [2]. The archives of F. A. Tsander contain a number of materials related to these speeches, as well as more than 40 notes made by Fridrikh Arturovich during his lectures and reports read in 1924-25 in various cities, including Moscow. As the documents show, including those published in this collection, after 1925 Tsander continued to read lectures and reports.

Desiring to develop practical work on preparations for space flight in addition to theoretical work, Tsander not only read reports and lectures, but also met with organizations and held talks. There is a great deal of material on this problem in the archives of F. A. Tsander, including materials from 1919-1920, and materials published in this collection from 1926-27. A number of documents related to Tsander's correspondence with individuals are of interest, and many are included in this collection. They sometimes include some information on individual stages of Tsander's work, his activity and his relations with others interested in the problem of interplanetary flight. In particular, a letter from Prof. V. P. Vetchinkin to Tsander of 7 June 1926 shows the great interest which this well known specialist in the area of aviation had in the lectures and reports of Tsander.

The many years of activity of Tsander directed toward the creation of special organizations concerned with rocket technology and the development of practical work within these organizations were crowned with success in the beginning of the 1930's. During this period, Tsander showed initiative in the problem of the development of reactive motors in the Moscow Aviation Institute and other organizations, which is reflected to a certain extent in this collection. The most effective support of Tsander's plans came from the Society for the Creation of Weapons and Aviation-Chemical Construction. During the first half of 1932, a group studying reactive engines (GIRD) began working in the central council of the Society for Creation of Weapons and Aviation-Chemical Construction (Osoaviakhim). In GIRD, Tsander was given an opportunity to transmit his knowledge to the young workers by direct contact, and successfully developed intensive activity on the introduction of his works on rocket technology. /7

"Due to his work," the late Academician C. P. Korolev wrote in 1934, "during the past ten years prototypes of the first Soviet rocket motors have been created. F. A. Tsander died in 1933, but was able to create a team of workers, his students and successors" [3].

In addition to the materials on his lectures, reports and correspondence, this book also presents certain materials which he intended for printing after some revision or completion, as well as the manuscripts of Fridrikh Arturovich on the problem of the design of liquid fueled rocket motors.

It should be noted that Tsander's writings sometimes contain inaccuracies as concerns names, dates, etc. For example, in some materials he cites 1915 as the date of the beginning of his work in the area of interplanetary voyages (statement at the Scientific Department of Glavnauka, 8 October 1926) or 1917 (letter to Prof. Chaplygin), although as we know the first ideas and calculations in this area are encountered in the writings of Tsander from 1907-1908. These apparent discrepancies are explained by the fact that Tsander had in mind in these documents not the beginning of his work in the area of interplanetary voyages, but the beginning of his intensive engineering development of this problem, which is evident from a comparison of a number of Tsander's statements on this problem.

These inaccuracies have either been eliminated or left unchanged, but are commented on in the footnotes. The footnotes marked by an asterisk are those of Tsander himself, while the numbered footnotes are those of the editor-composer and chief editor. In preparing the materials for press, some editorial changes were made, although the characteristic expressions which Tsander used were left unchanged.

A. F. Tsander

REFERENCES

1. *Tekhnika i Zhizn'*, No. 13, 1924.
2. Information taken from materials in the archives of F. A. Tsander.
3. Korolev, S. P., *Raketnyy Polet v Stratosfere* [Rocket Flight in the Stratosphere], p. 28, Moscow, 1934.

CUT ALONG THIS LINE

FOLD LINE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
NATIONAL AERONAUTICS & SPACE ADMINISTRATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
CODE USS-T
WASHINGTON, D.C. 20546

NASA TTF No.
541

FOLD LINE

CUT ALONG THIS LINE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL TRANSLATION EVALUATION

Budget Bureau No. 104-R037
Approval Expires: Sept. 30, 1969

O: THE USERS OF THIS TRANSLATION →

NASA TTF NO. 541

AINTAINING THE QUALITY OF NASA TRANSLATIONS REQUIRES A CONTINUOUS EVALUATION PROGRAM. PLEASE OMPLETE AND MAIL THIS FORM TO AID IN THE EVALUATION OF THE USEFULNESS AND QUALITY OF THE RANSLATING SERVICE.

HIS PUBLICATION *(Check one or more)*

- [ ] FURNISHED VALUABLE NEW DATA OR A NEW APPROACH TO RESEARCH.
- [ ] VERIFIED INFORMATION AVAILABLE FROM OTHER SOURCES.
- [ ] FURNISHED INTERESTING BACKGROUND INFORMATION.
- [ ] OTHER *(Explain)*: ____

FOLD LINE — FOLD LINE

TRANSLATION TEXT *(Check one)*

- [ ] IS TECHNICALLY ACCURATE.
- [ ] IS SUFFICIENTLY ACCURATE FOR OUR PURPOSE.
- [ ] IS SATISFACTORY, BUT CONTAINS MINOR ERRORS.
- [ ] IS UNSATISFACTORY BECAUSE OF *(Check one or more)*:
  - [ ] POOR TERMINOLOGY.
  - [ ] NUMERICAL INACCURACIES.
  - [ ] INCOMPLETE TRANSLATION.
  - [ ] ILLEGIBLE SYMBOLS, TABULATIONS, OR CURVES.
  - [ ] OTHER *(Explain)*: ____

FOLD LINE — FOLD LINE

REMARKS

ROM

DATE

OTE: REMOVE THIS SHEET FROM THE PUBLICATION, FOLD AS INDICATED, STAPLE OR TAPE, AND MAIL. NO POSTAGE NECESSARY.

ASA Form 1332 AUG 66 — GPO 915-777

CUT ALONG THIS LINE

CUT ALONG THIS LINE

LECTURES, REPORTS, WORK PLANS AND MANUSCRIPTS

1923

The materials published below are from the period of Tsander's life when he, after being temporarily laid off from Aviation Plant No. 4 (previously "Motor"), was fully occupied by theoretical investigations in the area of interplanetary voyages. However, he did not lose contact with the workers of plant No. 4 and hoped to create there a group which would study the problem of space flight, beginning with the construction of a special reciprocating engine of his design (the most similar to that being made at the plant). /10

We note that the text of the materials presented below contains a number of original ideas and results of calculations made by Tsander, not yet published in the world literature at that time -- the usage of the lifting force of wings as craft are launched into space and the braking effect of the atmosphere upon return from space, numerical data concerning flights to Mars and Venus, etc. Here also we encounter the suggestion that mirror surfaces be used for movement in space (after the force of terrestrial gravity has been overcome).

1. Report of Engineer F. A. Tsander on His Invention: an Airplane for a Flight Beyond the Earth's Atmosphere, for Flights to Other Planets and the Significance of the Development of Aviation in This Direction

Read at the General Plant Meeting of April 1923 at State Aviation Plant No. 4 (Former "Motor")

Comrades!

I've been told by the secretary of your plant committee, Comrade Medvedev, that you have awarded me a gift of one percent of your April wages, to be presented at this general meeting!

Comrades! You yourselves are not living under the best of conditions, and I therefore am even more grateful to you. At the same time, I hope that by my report I can make it possible for you to understand the project on which /11
I am working. I hope also that the money which you have given me will not be in vain, but will make it possible for me to present something of value to your plant, when by our common hopes, experience and equipment produced will manage to make for mankind an airplane and engine of the type which I have invented.

In order to introduce you to the area in which this machine will be used, I should briefly introduce you to the world of the stars. As you probably know, our earth is but one of a number of planets rotating around our central star -- the sun, which is 108 times greater in diameter than our earth. At a distance 1.4 times greater than the distance between the earth and the sun, another planet like our earth rotates about the sun -- this is Mars or the so-called Red Star. It is one half the diameter of the earth and, as recent astronomical investigations have shown, it can be affirmed with almost total certainty that intelligent life exists on Mars. Investigators have seen canals of tremendous length, up to 5,000 verst, extending in straight lines, crossing the entire planet of Mars. Both nearer to the sun than the earth and farther from the sun than Mars there are also other planets; on these planets or their satellites, their moons, we may discover new races of people. Far beyond the limits of our own solar system, there are many other suns. All the stars in the sky are suns; around them, on the planets, we may find other races; the usage of their achievements and inventions would provide for our race tremendous facilitation of labor, yielding for us a happy, peaceful and fruitful life.

This is one aspect of the matter. On the other hand, our modest aviation in the last 10-15 years has achieved successes until recently unknown: an airplane weighing 24,000 kg (i.e., approximately 1470 puds) has flown, and an aircraft weighing 30,000 kg is under construction; the wings of airplanes are beginning to be built shorter, as flying speeds increase; airplanes are being built which can land on water as well as on land. In some other designs, the entire landing gear and wheels are drawn up during flight. (Here are a few pictures of airplanes of this type.) On the other hand, in place of an ordinary engine, Jules Verne has already described in his story "Around the Moon" a rocket, like our ordinary rockets, used as fireworks, but used in his story to change the speed of an aircraft. Furthermore, in place of ordinary shells, military rockets carrying explosives have been used, and in 1903 and later in 1911-1912, our Russian scientist Tsiolkovskiy wrote a great deal concerning rockets and their usage in future interplanetary voyages and gave a /12
review of the phenomena involved in several areas of possible application.

In my independent design of a rocket and its usage in combination with an airplane, and also as I investigated the possibility of using the material of the airplane itself as fuel, with my tremendous interest in flights in the upper layers of the atmosphere and flights beyond the atmosphere and further flights in space, I have discovered something which even Tsiolkovskiy did not predict: first of all, if this combination is used the rocket will have permissible stresses, not the tremendous pressures [1] and dimensions which Tsiolkovskiy calculated, and furthermore, due to the possibility of using almost the entire weight of the airplane as fuel, my device can achieve the required velocities for flights to other planets (show drawings and books. [2] which I have written).

As you see, my apparatus consists of an airplane including an engine of extremely high pressure. The engine is to burn gasoline or ethylene or hydrogen in liquid oxygen, under conditions found to be most suitable by experimentation. The engine will drive propellers, and the aircraft will take off from the earth like an ordinary airplane, gradually increasing its speed with increasing altitude. At an altitude of approximately 26 verst over the earth, due to the great rotation speed of the propellers, they must be stopped and the rocket started. The rocket operates by expelling gases at 1500 kg force, and thus is accelerated in the opposite direction. By placing parts of the airplane and motor into a furnace, in which they are melted, we produce liquid aluminum, which makes an excellent fuel when burned with hydrogen and oxygen. The control surfaces of the apparatus can also be placed in the boiler and melted. The flight speed of the apparatus increases more and more due to the pressure of the rocket, and so does the flight altitude. At an altitude of approximately 85 verst over the earth, the airplane will consist of a very small aircraft with control surfaces and a comparatively thick central portion -- the cockpit for the crew and the portion of the rocket containing the furnace. This remaining portion, according to calculations, will have sufficient speed to leave the earth completely and fly with some slight additional acceleration to other planets. In order for the airplane to rotate about the earth like the moon, an initial speed of 8 km per second must be achieved; in order to leave the /13
earth completely, a speed of 11.3 km per second is required, while in order to reach the planet Mars against the attraction of the sun's gravity, a speed of 14 km per second must be achieved [3]. These speeds can be achieved in a near complete vacuum much more easily than in the strongly braking, dense atmosphere at the surface of the earth. A return is possible if the flight speed is reduced slightly using the rocket until the craft returns to the atmosphere. In the atmosphere, the aircraft can glide to a landing or can return using a small engine.

A flight around the earth would have tremendous significance; flying like the moon, we could use telescopes to observe the other planets much better, and could probably construct a habitation in which living conditions would be much better than on the earth. The same is true of the small planets, the asteroids: if living quarters can be built there, it will be possible within these quarters, regardless of climate, to establish an eternally warm medium, a greenhouse which will follow the natural cycle on earth to provide pure air for respiration and vegetables and grain to eat.

Also, the quantity of work required to support a man will be much less there than on earth, and our senior citizens will find it much easier to maintain health in a medium in which they need not carry their 4-1/2 puds of weight every second. As a result of this, life in these heavenly regions would be, we can say with high probability, longer than on earth, and we would live not 70-80 years but 100-120 or more years. Today, the average man in Russia lives but 33 years, and under the best conditions in Norway and Denmark but 54 years, and these living conditions would be much improved with the almost total absence of weight, with eternal daylight, when bacteria could not infect our organism as on cloudy days and during the night; our reduced demand for food would make it possible for our digestive organs to rest and not become fatigued so quickly as in the strong gravity here on earth.

Concerning the inhabitants of Mars, for example, astronomers have stated the opinion that they will be considerably more advanced in development than our mankind, and in this case their inventions could help us to a great extent /14
to become happy and well off. According to my calculations, a flight to Mars would last 8.5 months, more precisely 256 days maximum. If fuel were not conserved, we could make the flight in two months: The earth makes one half rotation around the sun in one half year, Mars in approximately one year. In our flight we would retain the speed of the earth around the sun and achieve the landing on the other planet not in one year, not in one half year, but in approximately one half the difference, more accurately in 256 days.

I would like to end my brief report by indicating an undoubtable plus which work in this direction would achieve in comparison to the zero which would be achieved if we do not develop this trend in aviation.

Mankind so to speak from its snug childhood home will fly out into the broad world and become acquainted with it, developing its forces and abilities in the limitless world. Astronomy, more than the other sciences, calls upon man to unite for a longer and happier life which, according to the theories of Einstein, theories which I have not yet touched upon, would be slowed down at flight speeds near the speed of light, and could be extended almost indefinitely in combination with visits to the planets of various suns.

2. Summary of Report of Engineer F. A. Tsander on His Invention: an Airplane for a Flight from the Earth's Atmosphere and for Flights to Other Planets [4].

A. Introduction

B. Report

I. Plan of Tsiolkovskiy and some of its defects

II. Essence and Description of my design and method of flying

a) Flight with engine and rocket in airplane

b) Flight with rocket adapted for travel in the atmosphere

c) Uninvestigated case with hollow rods in tension

III. Airplanes available which are similar to my plan in weight, design and operation

1) High weight

2) Wings retract /15

3) Landing gear retract or are jettisoned

4) Rocket adapted for flight in the atmosphere and model of rocket powered airplane

5) Usage of liquid oxygen in aviation during high altitude flights for respiration

IV. Show and explain all my drawings; show my calculations, diagrams in general; show sketches not yet converted to drawings (make a list for myself of all pages on which sketches are to be found and list them; outline them in the report)

V. Systematic review of all my works and detailed calculations (indicating from which page to which page written)

1) High pressure motor

2) Rocket

3) Boiler and fuel tank

4) Assembled airplane:

a) With engine and rocket

b) Model of airplane

c) Initial, with sphere

d) With hollow rods

5) Flight path, fuel expenditure:

a) For engine

b) For rocket

6) Flights exclusively in space

a) Usage of mirrors

b) Usage of rockets

c) Usage of solenoids with electrical current and iron filings

7) Apparatus for respiration:
   a) Carbon dioxide absorption; necessary quantity of oxygen per day, quantity of carbon dioxide exhausted per day; decomposition of carbon dioxide
   b) Greenhouse and results of my experiments with plants
   c) Diving suit with automatic valve

8) Flying time under various conditions:
   a) Minimum fuel expenditures; flight to Mars in 256 days
   b) Parabolic trajectory, flight away from the solar system
   c) Spiral flight using mirrors
   d) With mirrors installed on other heavenly bodies, using transmission of energy over long distances

9) Great benefit from airplane in flight
   a) Benefit to mankind for progress of culture
   b) From new culture of Martians and other races if such are found in the Solar System
   c) From structure of dwellings and easier living conditions, resulting in longer life, riches, larger machines in place of smaller /16
   d) From flights to other solar systems using long-distance energy transmission
   e) For astronomy in the immediate future

10) Cost of apparatus, flight and prize already announced by French Academy of Sciences: several flights can be made for for this price.

C. Conclusion: in order for progress to continue, experiments must go hand in hand with calculations, requiring funds; desirability of forming clubs of those interested. Request for order for oil pump and experiments for engines and model of airplane [5].

3. Report of Engineer F. A. Tsander on His Invention: an Airplane for Flight Outside the Earth's Atmosphere and to Other Planets [6].

Respected meeting!

A. Introduction

I would like today to acquaint you first with an investigation which I am performing in order to find structures and principles for construction of

apparatus making it possible to fly outside the earth's atmosphere and to even make flights into space and to the other planets. As a youth, I was strongly interested both by astronomy and by aviation and their combination; in 1908, when I was 21 years old, I made myself a special notebook for designs of spaceships; although I knew very little then, these designs influenced me, developing a hope for the possibility of flight into space. Since the Earth's atmosphere is the medium in which airplanes operate, I subsequently occupied myself with investigations, not finished to this day, on the graphic prediction of weather using instruments, as well as unfinished investigations into the usage of gyroscopes for stabilization of aircraft, hoping thereby to pave the way for interplanetary flights. In January of 1916 I began experiments on the construction of a greenhouse light enough to be carried in aircraft to be /17
used in interplanetary voyages, based on the material cycle, having in mind conditions under which an apparatus would require almost solely energy to be supplied from without, not materials [7]. I did achieve certain results: I grew peas, some cabbage, giving lovely roots. Since September of 1917, being quite interested in further investigations, I have been independently working on the design of a rocket, airplane, the calculation of flight conditions, design of a motor, etc., and since March 1922 I have been exclusively involved in work on further development of aviation in this area. My project was analyzed to some extent on 10 October 1920, to the extent that I had finished it by that time, by a commission consisting of comrades P. S. Dubenskiy, P. A. Novikov, P. A. Moisheyev, G. N. Mikhaylov, Fedorov and others, and my special engine was analyzed by the governor's conference of inventors on 30 December 1921 [8] and they wished me further success and expressed a desire that I continue my work in this direction.

B. Report

I) If you will look at the plan for the interplanetary spaceship of Professor K. E. Tsiolkovskiy (show drawing) for example, according to Perelman's book "Voyages to Other Planets," of 1919, you will see that it is difficult to perform direct experimentation with his machine since in case the rocket motor should fail the entire apparatus would fall to the earth. Perelman notes another reason for the difficulty of fulfilling this plan on page 56 of his book; he states there: "The primary, and perhaps the only hindrance to immediate manufacture of this reaction powered heavenly dirigible is the unavailability of a sufficiently powerful explosive material. We know of no source at the current state of technology which could develop the force required to move this tremendous rocket."

IIa). The essence of my project is that I, on the one hand, use an extremely high pressure motor, which can also be replaced by an expanded rocket section, adapted for movement in air. The motor is located on the airplane, the central portion of which contains the rocket. Both the motor and the rocket are driven by liquid oxygen and benzene, or acetylene, ethylene, methane, hydrogen or other fuels, whatever type might be found most suitable by experimentation. The rocket is also supplied in part by construction materials. I suggest that the takeoff from the earth be performed in the same manner as with an ordinary airplane. The velocity is to be increased with increasing altitude in order to maintain the most suitable angle of attack of the airplane surface, by increasing the rotating speed and pressure of the motor in approximately inverse proportion to the square root of the density of the atmosphere, so that the lifting force of the airplane will remain approximately constant according to the formula for lift /18

$$P = k \cdot F \cdot \gamma \cdot v^2,$$

where P is the lifting force, F is the surface of the wings, γ is the density of the atmosphere, v is the flight velocity and k is a coefficient which changes as a function of the angle of attack of the surface. If this flight achieves a speed of approximately 400 m/sec at an altitude of approximately 28 km, due to the great rotational velocity of the propellers, the motor will have to be stopped [9]. However, at 400 m/sec the rocket has a sufficient efficiency for usage in subsequent flight sectors; even if the rocket is not adapted to movement in the air, its efficiency is 10-12%. Therefore, at this point we stop the motor and start the rocket. In order to provide sufficient fuel, I decided to take a step which, as far as I know, has not yet been suggested by anyone else, but which solves in a very positive sense the problem of the possibility of achieving the tremendous velocities required: I decided that we must dissemble a portion of the airplane, melt it in a boiler and burn it in the rocket. This step, together with the usage of an airplane to support the rocket, eliminates the obstacle which Perelman noted for the Tsiolkovskiy rocket. A rocket with my combination will have much smaller dimensions than that of Tsiolkovskiy. His rocket is a carrying rocket, while mine powers an airplane [10]. At the present time airplanes fly much more easily than helicopters, which speaks in favor of my plan. If the wings of a small airplane are attached to the cabin and if the motor and all unnecessary parts of the larger airplane, no longer needed with the smaller weight, are used as fuel, according to my calculations the burning of liquid oxygen, hydrogen and duralumin can produce a final velocity of 11.3 km/sec by reducing the weight of the airplane to one-twentieth its initial weight. If the initial weight is 5000 kg, the final weight will be 250 kg; small airplanes of this weight are now being used. If we use gasoline in place of hydrogen, the final velocity with this weight drop will be /19
7-1/2 km/sec, sufficient to achieve an orbit around the Earth like the moon.

IIb). With the second flight method using supplementary cones in the expanded portion of the rocket, adapted to movement in the air in place of a motor, a method which incidentally I have not as yet developed in relation to the dimensions and the effect of the rocket so adapted, flight would be performed in a method similar to the first method. The difference is only that in place of the motor and propellers, we would have to use an expanded rocket section which, depending on the dimensions of this section, would be more or less difficult than in the first case. However, since an engine operating with liquid oxygen rather than atmospheric air can always be used in interplanetary ships, even in combination with a rocket adapted to flights in the atmosphere, and since such a motor can be used to achieve great velocities and altitudes even in the atmosphere, I developed the first method first: flight with both motor and rocket.

IIc). I have begun calculation of yet another, third method of flight, namely: usage of one of the first methods, but with storage of the liquid fuel -- liquid oxygen and other gases in liquid form at low temperatures in the hollow braces, spars and other rods which are subjected to compression. It is possible to select a material which has higher strength at low temperatures. According to the physics course written by Khvolson, in volume 3 page 622, 1919 edition, the following figures are quoted for the strength of wires according to Dewar's experiments.

TABLE 1. DIAMETER OF WIRES 2.49 mm, CROSS SECTION 4.87 mm^2

Material	+15° Rupture force, kg	+15° Stress, kg/cm^2	-182° Rupture force, kg	-182° Stress, kg/cm^2
soft steel	191	3920	318	6530
iron	145	2980	304	6240
copper	91	1870	136	2790
WIRE DIAMETER 5.1 mm, CROSS SECTION 20.5 mm^2				
Wood's metal	64	314	204	1000
zinc	16	78	12	59

We can see from the table that the strength of almost all these materials increases greatly with decreased temperature, so that it will quite probably be possible to find a metal which is light, strong and comparatively easily melted, from which in this case we will be able to make the required airplane parts. The liquid fuel can either be stored without pressure /20 or under high pressure. In this latter case, the rods will be subjected almost exclusively to extension, so that their weight can be comparable to the weight of wires for the corresponding forces. With this type of design, the weight of the metal in the airplane would be decreased to the extent that, first of all, the total cost of construction would be decreased and secondly, at very high altitudes, it would be possible to burn the liquid fuel exclusively, without dismantling the aircraft itself, which would be quite desirable during test flights and, in the third place, due to the great quantity of volatile combustion products in comparison to solid products, the efficiency of the rocket would be increased.

However, I have not yet woven together the threads of my design, since the area of possible designs and the possibility for their combination is so great; it promises to be fruitful in the future.

III_1. Turning to the designs of airplanes available at the present time whose design and characteristics are similar to my airplane, I would like to note that the initial weight of the airplanes in all cases is many times greater than the weight of my airplane. According to Rinin's book *Ekonomika i Tekhnika Aerotransporta* [Economics and Techniques of Aerotransport], these weights are as follows: for a Caproni triplane as was constructed in Italy at the end of 1920, 24,000 kg (see page 24, as well as the map at the end of the book and *Vestnik Vozdushnogo Flota*, No. 8-9, 1921, pp. 33, 49 and Table IV). This apparatus completed a number of successful flights and remained aloft with 114 passengers for 4-1/2 hours. Also, the flying boat Pacific is being constructed in America, to weigh 30,000 kg (see pp. 25-30). In America, a model of the Elston airplane to weigh 51,200 kg has been constructed (see page 30). The Vickers firm has suggested the construction of or is already constructing (it is not precisely known) an airplane designed for 130 passengers (see page 30), and it is heard that the Germans are building an airplane for 500 passengers for flights from Portugal to South America. If we use these airplanes, the final weight of the airplane might be reduced to $50{,}000 \div 20 = 2500$ kg, a rather large airplane still. Using such an airplane, we could easily land on Mars, take off again and return to earth; even using the small 250-kg final weight craft, we could orbit around the earth and return when desired or travel to Mars and not return. According to a journal published by BINT [Bureau of Foreign Science and Technology], No. 3, 1921, page 2, Prof. Junkers is planning an airplane with a total weight of 60,000 kg.

III_2. In addition to the airplanes which are already much higher in weight than that which I plan and which, therefore, could fly with a considerably lower efficiency by burning the material of the airplane, beginning with a weight of 50,000 kg and ending with 250 kg, bringing the efficiency down to 250/50,000 = 1/200 of the initial weight, rather than one-twentieth as I suggest, there are also aircraft which partially retract their wings. In *Vestnik Vozdushnogo Flota*, No. 13, 1922, page 22, the article of Eng. Vegener, a report is made concerning the Levaser-Gostambid aircraft which changes its wing area during flight; according to the same article there are a number of designs in which the designer has achieved the same end. Further, according to *Vestnik Vozdushnogo Flota*, No. 14, 1922 on page 59, the designer Pratt increases the area of the wings by moving the outer sections. Designer Belanje uses a different method -- he changes the width of the wings from 1.2 to 1.5 m, increasing at the same time the angle of attack. This is achieved by moving three sides of a parallelogram; the braces are hinged, and the rear portion of the biplane sections is moved. Also, in *Vestnik Vozdushnogo Flota*, No. 13, 1922, page 58, Capt. Karolin announces the invention of extendable wings. He extends the ailerons on rollers and rails using four tension members, making the maximum flight speed four times the minimum flight speed. /21

REFERENCES

1. By pressure here Tsander means thrust, as we can see in particular from a comparison of this text with his other materials (for example see F. A. Tsander, "The Problem of Flight Using Reaction Motors," *Mezhplanetnyye Polety* [Interplanetary Flights], Moscow, Oborongiz. Press, 1961, p. 444).
2. By the word "book" here as in a number of other places Tsander means manuscripts.
3. The velocity which Tsander indicates (14 km/sec) was produced by adding velocity V_0 necessary to overcome the earth's gravitation (≈ 11 km/sec) and the minimum additional velocity $V_{z\,min}$ which must be given an interplanetary ship after the earth's gravity is overcome in order for it to strike Mars (≈ 3 km/sec). However, these magnitudes cannot be added arithmetically. In order to determine the relationship between velocities, we must use the law of conservation of energy. As a result, the velocity V actually should be $V = \sqrt{V_0^2 + V_{z\,min}^2}$. Tsander soon corrected this error.
4. Although no date was given for this manuscript, a comparison with later published manuscripts shows that it related to an unfinished plan for a report and, consequently, the summary was begun at approximately the same time as the text of the report, i.e., in May of 1923. Later, Tsander decided to make section III of his report the last section, the fifth section, and consequently changed the numeration of the subsequent sections. In this publication, we have left the initial numeration in both the summary and the report.
5. On the basis of this last sentence, we can assume that in the final analysis Tsander decided to use this outline to read his report at plant No. 4 (former "Motor").
6. On the line beneath the words "to other planets" was written "read at Scientific-Technical Committee of the All-Russian Council of National Economy... May 1923." However, Tsander later crossed this sentence out.
7. Speaking of energy, Tsander had in mind luminous energy, by material he meant the material necessary as food.
8. The indication of the end of 1920 as the date of this report found in later materials of Tsander is erroneous.
9. Subsequent practice has shown the unsuitability of propeller driven aircraft with piston motors for the attainment of high altitudes (Tsander suggested 26-28 km). Forther in the text there is a reference to a drawing which is omitted, being on one of the slides (see Figure 2, 1).
10. Tsander called Tsiolkovskiy's rocket a carrier, having in mind that the reactive force of the rocket "supports the weight of the entire interplanetary spaceship during flight and also accelerates it" (Tsander, Flights to Other Planets, *Teknika i Zhizn'* [Technology and Life], No. 13, 1924).

1924

Tsander's first appearance in 1924 was a report at the Theoretical Section of the Moscow Society of Astronomy Enthusiasts (MOLA). The published materials make it evident that in this report he touched primarily on problems which appeared in various of his documents of 1923 (among those presented above), but presented them generally more completely and turned particular attention to his calculations of a liquid fueled rocket motor (Tsander called it a rocket), designed to operate on liquid oxygen and hydrogen. Using his scientific investigations and his primarily engineering calculations, Tsander attempted to prove to the members of the Theoretical Section of MOLA that his dream of space flight was to be realized in the near future, and that engineering development in the area of rocket technology was quite possible and should be begun. At the end of his appearance, he expressed his desire for further investigations of designs and for the organization of a society. The archives of F. A. Tsander do not contain the text of this report, but there is an "outline" and a "summary," written by Tsander, and the scientific memorial museum of N. Ye. Zhukovskiy contains a program of the meeting (Figure 1) where Tsander made his report. A photo of this program, kindly provided by the colleagues of the museum is presented below, together with the other documents mentioned (the program contains a hand written correction made by Prof. V. P. Vetchinkin for his report). According to the recollection of Tsander's widow, as he made his report Tsander used a number of slides showing the results of his calculations. Analysis of the archives shows that in other appearances made in 1924-25 Tsander used this method of illustrating his material quite widely. The archives of F. A. Tsander contain a number of slides. Some of them are published below (Figure 2). The other published materials are primarily related in some way to Tsander's activity in the Society for the Study of Interplanetary Voyages. For example, a sketch of a winged liquid-fueled rocket made by Tsander in stenographic notes taken 20 June 1924 (see Figure 3) corresponds in time and in sense to the sketch which Tsander mentioned in the letter to his wife of 25 June 1924: he wrote that a contest had been begun in the society for the design of a rocket for the study of the upper layers of the atmosphere, stating that he "had already made a drawing of such a rocket," and was preparing to "calculate it." The flying altitude was to be approximately 100 km, as we can see from the final paragraph of Tsander's report "Concerning Interplanetary Voyages," included in this collection. The archives of F. A. Tsander contain, in a similar stenographic inscription, another variant of the winged rocket which was to use atmospheric air. There was considerable interest in the organizational report of Tsander which he made before the Scientific Research Section of the Society for Studying Interplanetary Voyages on 15 July 1924. In this speech, he suggested a plan for concrete practical work on preparation for space flights. The last of the published documents concerns a report by Tsander made during a debate on 1 October 1924 at Moscow State University and repeated there on October 4 and 5. /22

Московское Общество Любителей Астрономии.

ТЕОРЕТИЧЕСКАЯ СЕКЦИЯ.

В воскресенье 20 январ. 1924 г. в 3 ч. дня
аудитории при Обсерватории Центр. Физико-Пед. Инст.
в помещении библиотеки Общества
(быв. Травдина) – 5-Лучевая, 13.
(Моховая Н. Геологический Институт).

состоится

Собрание Теоретической Секции.

ПРЕДМЕТЫ ЗАНЯТИЙ:

1/ Сообщение Ф.А.ЦАНДЕРА - Проект аппарата для межпланетных путешествий.

2/ Сообщение В.П.Ветчинкина - Падение аэролитов в [illegible] переменной плотности.

3/ Выборы Председателя и Секретаря Секции.

Теоретическая Секция.

Figure 1. Program of Meeting of Theoretical Section of Moscow Society of Astronomy Enthusiasts (MOLA)
20 January 1924

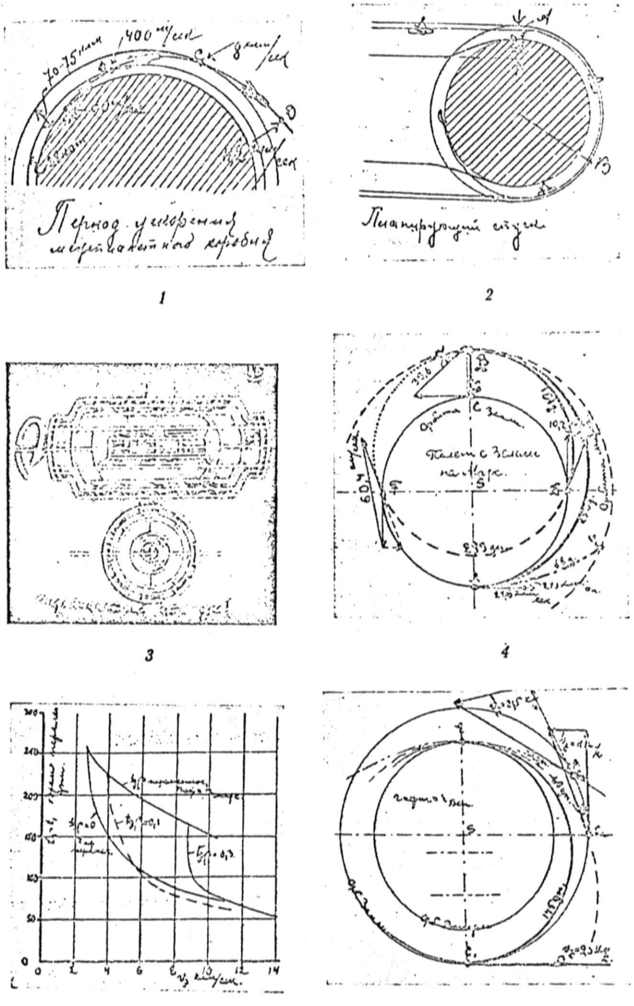
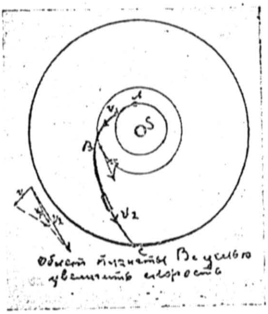
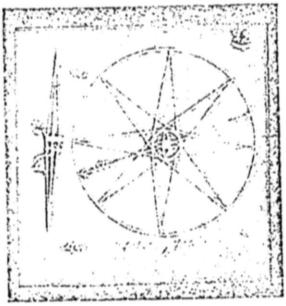


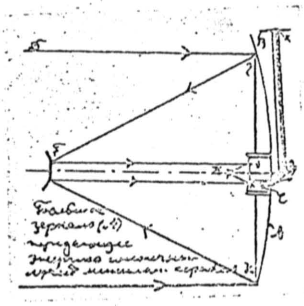
Figure 2. (Continued overleaf)



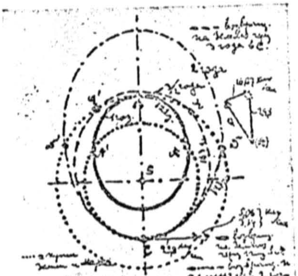
8



9



10



11

Figure 2. Some of F. A. Tsander's slides: 1, Period of acceleration of Tsander's spacecraft; 2, Gliding descent from interplanetary space; 3, Interplanetary station; 4, Curves of flight from earth to Mars; 5, Curves of flight time to Mars as a function of initial velocity; 6, Curves of flight from earth to Venus; 7, Flight around the planet in order to increase speed; 8, Increase in flight speed of spaceship by flying around planet; 9, Spaceship with mirror; 10, Large mirror for transmission of light energy; 11, Flights in outer space with return to earth after one, two and three years

Figure 3. (Continued overleaf)

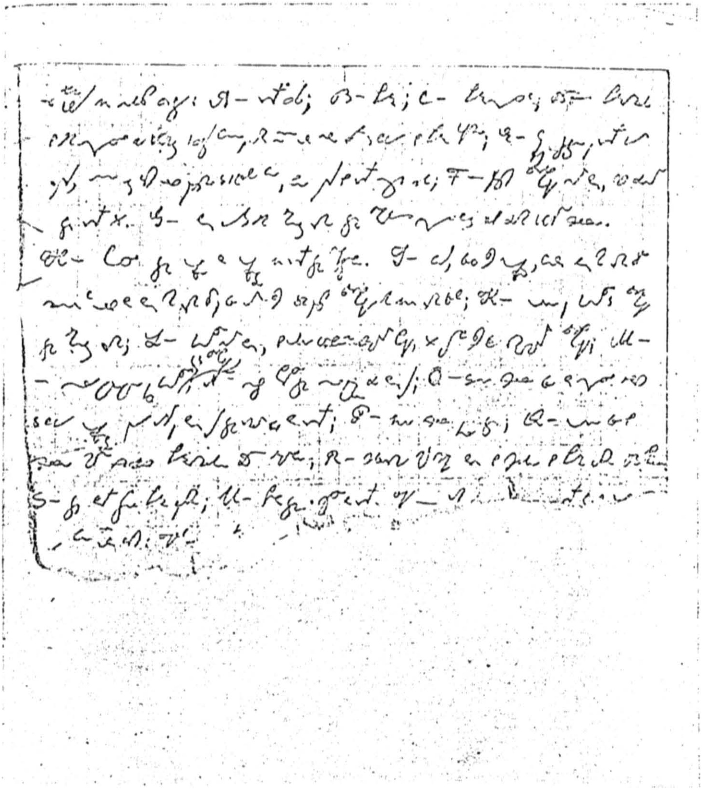


Figure 3. Drawing of Winged Rocket (20 June 1924)

4. Some Materials on the Report Read at the Theoretical Section of MOLA 20 January 1924 /28

4a. Outline of Lecture on My Spaceship Read at Theoretical Section of Moscow Society of Astronomy Enthusiasts [1]

A. Introduction: distribution of material: first primary theses, effect, advantages of my designs, then their calculation

B. Report on my interplanetary spaceship

I. I read article for journal *Samolet* and show drawing.

II. Design of interplanetary space rocket

a) Power of rocket [2]

b) Gas velocity of rocket

c) Efficiency and energy game [3]

d) Determination of cross sections of rockets, velocities, pressures, specific weights and temperatures

e) Calculation of friction on walls of rocket

f) Calculation of heats transmitted through walls and thicknesses of walls

g) Practical example of calculation of quantities from a) to f) and thermal efficiency as a function of altitude /29

III. Calculation of rocket flight and total fuel expenditure

IV. Calculation of flight with motor and motor power [4]

V. Velocities required to reach other planets. Calculation of paths, flight times, curves of least speeds with given flight times

VI. Usages of mirrors and screens in place of rockets in interplanetary space. Calculations and benefits.

VII. List of danger points and list of possible and interesting calculations.

C. Conclusions: comprehensive investigation of constructions is required, and the formation of a society of investigators and interplanetary voyage enthusiasts is desirable.

4b. Summary of Report of F. A. Tsander Concerning Design of His Interplanetary Spaceship and Flights to Other Planets, Read at the Theoretical Section of the Moscow Society of Astronomy Enthusiasts, 20 January 1924

At first F. A. Tsander read an article entitled "Flights to Other Planets," written by him for the journal *Samolet*. In this article, he put forth a number of theses in which he suggested a new method for flight to other planets, namely: the combination of an airplane with a rocket and the usage of the solid construction material of the ship as a fuel for the rocket. He showed and explained a drawing of such an interplanetary spacecraft and showed the benefits produced by using his flying method in comparison with lifting rockets: a decrease in the size of the rocket and stresses on the material, ease of performance of experimental and test flights, lower accelerations in flight, the possibility of gliding descent to land.

Then, he read his calculations of the operation of the rocket, temperatures, pressures, velocities and friction within the rocket, showed diagrams of these quantities and also presented formulas for the efficiency, characterizing the transitions of energy during the flight. It was shown that the ratio of the actual exhaust velocity to the maximum possible velocity is about 0.8 and that the percentage loss from gas friction on the walls of the rocket is low.

Then, going over to a calculation of the velocities, times and altitudes of flight, as well as the influence of friction and the lifting work, he showed a diagram of these quantities as functions of the decrease in weight of /30 the spacecraft; a table of the mean efficiencies during the flight of the rocket was shown, and the area in which investigation of rocket flight would be desirable if oxygen is not carried on board was shown.

The heat productive capabilities of certain metals and the exhaust velocities achieved when they are used as fuel concluded this portion of the report. Then, his own calculation of the minimum and generally attainable velocities required by interplanetary spacecraft after they overcome the attraction of the earth in order to achieve the nearest planets and other planets were shown in brief form. It was proven that this additional energy, necessary for voyages to Mars and Venus, has only a small role to play and that for the other planets it is probable that only a small additional energy expenditure would be required if spacecraft circled Mars and Venus in the upper layers of their atmospheres.

The report included demonstration of formulas and tables by projector.

Near the end, the recently published book of G. Oberth was shown and some numerical values of exhaust velocities for rockets determined in the experiments of Prof. Goddard were cited, which confirmed the calculations made earlier in the report.

3 February 1924 F. A. Tsander

5. Organizational Report of Engineer F. A. Tsander on Proposed Work for Scientific Research Section of Society for Studying Interplanetary Voyages

Read 15 July 1924

Respected visitors!

We are joined together by a single thought: we must study the possibilities in the field of interplanetary voyages!

This is a great and tremendous work, and many people have been inspired to take part in it. The question is: how can we perform our investigations, what should we undertake first and how should we develop our activity?

Our Scientific Research Section apparently occupies the point which will make it possible to penetrate to the very depth of the problem; on the one hand, we will perform theoretical development to penetrate the phenomena, showing their development and in particular will combine our theoretical work with construction; on the other hand, we will perform practical tests, achieving the earliest possible success in flying models and small rockets in order to investigate the upper layers of the atmosphere, experimentally testing the correctness of our theoretical conclusions, quality of our fuels, etc.

Our work will therefore include: /31

1) laboratory work,
2) drawing work [5],
3) theoretical scientific work. Here, all three forms of work will be closely interrelated.

Further in the future, with cooperative combined work we will add, it is foreseen, 4) the construction of large apparatus to lift men into the higher layers of the atmosphere and interplanetary space itself; we hope we will be able to shake hands on other planets.

1. Laboratory and Practical Work

The most important laboratory work will doubtless be:

A. The testing of small rockets, operating with various fuels (after the first few successful tests we may launch rockets to test devices for retention of stability; in this respect, the contest for the production of small rockets for experiments in the higher layers of the atmosphere will advance our work greatly); then, the following tests: 1) investigation of the influence of the initial and final gas pressures; 2) smoothness of walls; 3) investigation of the problem of the transmission of heat through the walls; 4) determination of the propulsive force for all cases; 5) testing of various fuels, including metals; 6) testing of materials for rockets in connection with the problem of wall temperature and internal pressure; 7) testing of various motion stabilizers; 8) testing of an injector rocket operating with atmospheric air; 9) testing of complex joined rockets; 10) investigation of the problem of determining which designs can be used in order to carry along the largest percentage of liquid fuel.

Then should follow:

B. Construction and testing of models of dismountable and nondismountable airplanes of various systems driven by rockets and motors or by rockets alone;

C. Testing of the effects of large accelerations on specially designed centrifugal apparatus;

D. Construction and testing of motors operating with liquid oxygen or solar heat;

E. Testing of diving suits for spacecraft at high altitudes and in space and safety devices for these suits;

F. Testing of apparatus to regenerate exhaled air, etc.;

G. Investigations related to greenhouses of the required lightness; /32

H. Testing of television for rockets;

I. Testing in wind tunnels consisting of two interconnected broad rocket sections of parts of spacecraft at low pressures and high velocities; determination of resistances, lifting force and heating;

K. Investigation of the upper layers of the atmosphere with rockets, balloons and photometric observations of twilight and instrumentation of twilight;

L. Testing of fine sheets for screens;

M. Testing of rings carrying electric current and containing iron powder [6].

6. Report in the Scientific-Popular Section of the Society for the Study of Interplanetary Voyages [7] Concerning the Reaction Motor

Read 31 July 1924

Respected members!

Outline.

A. Introduction.
   I. What is a reaction motor
   II. History of usage of the reaction motor [8]
      1) Van Gu and his 47 rockets
      2) Cyrano de Bergerac "Voyage to the Moon," 1645
      3) Favri (1670); Layolin and Jeaninet (1784)
      4) The pyrotechnics of Roujerie 1806, ram, parachute
      5) Treteskiy (1849)
      6) Ivanin, 1870's
      7) Kibal'chich, 1881
      8) Betty, latter 1890's

B. The reaction motor /33
   I. Tsiolkovskiy
      a) 1896 first works
      b) 1903 and 1911-1912, 1914 three parts of his "investigations."
      c) 1919 "Outside the Earth," 1923 reprinted work of 1903 "The Rocket in Outer Space."

II. Various forms of reaction motors:
  a) Ordinary rocket for fireworks
  b) Continuous operating liquid or solid fuel rocket
  c) Continuous acting powder rocket
  d) Pulsed rocket operating with individual explosions
  e) Reactive steam turbine
  f) Cuttle fish movement

III. Essence of operation of reaction motor
  a) Impulse of force $P\Delta t = w \cdot \Delta M$, pressing forward,

$$P = \frac{\Delta M}{\Delta t} \cdot w = \frac{B}{g} \cdot w,$$

  b) Attainment of velocity w in rocket due to pressure difference

$$(i_1 - i_2) A = \frac{1}{g} \cdot \frac{w^2}{2},$$

$$w = 91{,}5 \cdot \varphi \cdot \sqrt{H}$$

  c) Attainment of velocity greater than speed of sound by bell mouth
  α) Decrease in density during reduction in pressure
  β) Increase in velocity during reduction in pressure
  γ) $B = \gamma \cdot w \cdot f$. Calculation of bell mouth using this formula and diagram
  d) Effect of force P on interplanetary ship in weightless medium:

α) The product of the mass times the acceleration is equal to the force: /34

$$M \cdot \frac{\Delta v}{\Delta t} = P = \frac{\Delta M}{\Delta t} \cdot w$$

or

$$\frac{\Delta M}{M} \cdot w = \Delta v,\ \Delta M —$$ is the decrease in mass;

$$w \cdot \ln \frac{M_0}{M} = v$$

or $$M_0 = M \cdot e^{\frac{v}{w}},\quad e = 2{,}72$$

v	4000	8000	12000	16000
	w	$2w$	$3w$	$4w$
M_0	eM	e^2M	e^3M	e^4M
	$2{,}7M$	$7{,}4M$	. $20M$	$54M$

e) The effect of force P on the interplanetary ship in a medium with gravity.

The rocket is accelerated as before; the Earth attracts it:

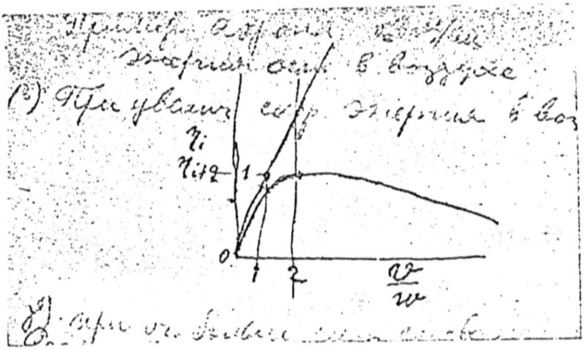
$$v = w \cdot \ln \frac{M_0}{M} — gt;$$

f) The effect of force P ... [9]

g) ... example. Airplane v = 40 m/sec.

$$\eta = \frac{2 \cdot 40}{4000} = \frac{2v}{w} = 0{,}02 = 2\%.$$

A great portion of the energy remains in the air.



β) As velocity v is increased, the energy remaining behind in the air is decreased, and the efficiency is good. /35

γ) At very high velocities, the efficiency decreases once more.

IV. The Melo reaction motor, drawing and operation, benefits

V. Usage of the principle of the reaction motor in the designs and new work in this area

a) Tsiolkovskiy rocket
b) Oberth rocket
c) Goddard rocket
d) Tsander rocket
e) Interplanetary Society rocket

C. Conclusion. The area of the purely reaction rocket is from 400 m/sec to about 20000 m/sec, that of the Melo rocket, adapted for movement in air -- below 400 m/sec.

7. Report of Engineer F. A. Tsander Concerning Interplanetary Voyages [10]

Comrades!

The development of science and technology and the achievements in various areas which would have seemed quite improbable a few years ago have gone hand in hand with the bravery of thinking in the area of travel to other planets. Bravery, as you know, often wins out in the attainment of new areas during a period of advance.

Here, as in other areas, the dream of a better future, of new possibilities, was the first impulse to action.

It has often occurred that poets, novelists, inspired by the annual blooming of life in nature, have first described new phenomena, new combinations, yielding new effects in technology. In particular, in the area of interplanetary voyages, writers first attempted to create designs which they thought had the greatest possibility to be valuable in the future, although the very distant future. As often occurs when estimates are made by eye, they frequently made errors*. The readers of these stories, particularly the young /36 readers, were inspired and developed in their minds new ideas, ideas which sometimes found good soil; mathematicians were found, inventors were found to probe nearer the Earth. On the basis of this, new designs appeared, the general development of technology attained new possibilities and the matter was completed: in one way or another, the dream was converted to reality.

The dream of a better life in the heavens has been developed in many religious cults.

The dream to rise from the earth, to fly higher, to the sun, to the planets, was developed in antiquity. The reaction method of flying in which one portion of the mass of the interplanetary spaceship, namely the burned fuel materials, is ejected with tremendous force in one direction, while the remaining mass, namely the interplanetary spaceship with pilot, is accelerated in the opposite direction according to Newton's third law of motion (equal and opposite reaction to every action) has always seemed the most probable method for interplanetary travel. In this way it is possible to produce an acceleration in totally airless space. However, we can also produce all of the acceleration necessary for a flight to the other planets within the limits of our own atmosphere. To do this, we can give our interplanetary spaceship the form of an airplane moved: in the lower layers of the atmosphere by an ordinary motor and propellers, and at higher velocities by a reaction motor. The oxygen for burning can either be carried on board or (in the lower layers of the atmosphere) can be taken from the atmosphere (Tsander plan).

Let us analyze the history of the development of methods of flying suggested for this purpose [11].

In an ancient Chinese legend written during the time when the Chinese invented gunpowder and rockets, it is said that the mandarin Van Gu fastened two kites together on top of 47 rockets. The experiment was unsuccessful: when the rockets were lit they exploded and the inventor was killed. In Europe, the French novelist Cyrano de Bergerac in his story "Voyage to the Moon" about 1645 described a continuously operating rocket for a flight to the moon as an "air wheel."

Then the Jesuit scientist Fabri about 1670 worked on the construction of a huge machine for flying, moved by compressed air.

Among the later works dedicated to this problem we can point out the general laws of Newton, according to which any action results in an equal and

---

* The scientific method differs from the novelist's writings in that it can be used in many areas to predict phenomena with great accuracy, whereas an evaluation by eye may be erroneous more than 50% of the time.

opposite reaction, then the theoretical development of the problem of the reaction of an exhaust stream by Bernoulli, and further to the attempt by Abbott Layolin and Jeaninet in Paris to use a combination of the lifting force of a balloon and the reaction of a gas stream exhausting from an aperture in the side of the balloon (1784). /37

In 1806 the pyrotechnician Roujerie launched a ram into the air with rockets, and achieved a successful descent by parachute.

In England about 1828, a cartoon was drawn, "From Paris to Peterburg on the high pressure steam machine" (see slide 1). In 1837, the mechanic Rebenstein in Nuremberg decided to use a reaction motor working with water vapor or compressed carbon dioxide for the airplane which he was inventing (see slide II).

In 1849, the military engineer Treteskiy suggested in his work "Methods of Controlling Balloons" that the reactive force of water vapor and alcohol vapor, gases and compressed air be used.

In the sixties, a number of projects appeared, there was a purely reaction rocket, an apparatus with lifting screws on the rocket and the Butler and Edwards airplane, 1867 (slide III) with rocket.

In the seventies, General Ivanin suggested a flying machine operating under the action of powder gases.

On 23 March 1881, the revolutioner Kibal'chich wrote in jail concerning a plan for a lifting reaction flying machine driven by slowly burning powder (see slide IV).

At the end of the nineties in America, Engineer Batey suggested a plan for a dirigible with a rocket propulsion system; the fuel was to be explosive pellets automatically fed to the point of the explosion.

Of the writers, incidentally, Jules Verne, a Frenchman, wrote in his well known work "Around the Moon" a description of a change in the path of a shell achieved by rocket power (see slide V). However, he still thought that the takeoff could be achieved by shooting. Actually, due to the tremendous shock, this cannot be done; the same thing can be said for the return trip, since diving directly into water, as he suggested, cannot be done (see slide VI). The absolute weightlessness of the passengers in the rocket was not established by Verne, although it is shown properly on the picture (see slide VII). Finally, in 1896 the first plan for an interplanetary rocket appeared, drawn up by our countryman K. E. Tsiolkovskiy [12]. He himself speaks in the second portion of his work "Investigation of Universe Space with Reaction Devices," which appeared in *Vestnik Vozdukhoplavaniya* in 1911-1913 (the book can be found in the Leninskaya library or the Bol'shaya Rumyantsevskaya library), that the seeds of his thought for the design of his rocket /38
were implanted as he read Jules Verne's book "Around the Moon."

The first portion of these "Investigations ..." appeared in 1903, the third portion in 1914. In this fundamental work for the lifting rocket (see slide VIII) the author calculates the effect of a rocket during vertical or inclined ascent. Tsiolkovskiy performed experiments in which he dropped extremely fragile objects onto the floor in a liquid filled tank, and the objects did not break. The same thing can be stated for people placed in a bath. Everyone is familiar with the lifting force of water: in water, it is just as easy to hold the arm in a horizontal position as in a vertical position; the same thing will be true in the bath of an interplanetary ship under great accelerations, and the pilot will be able to control the ship while lying down in a tank of water for the 2-4-minute period of acceleration.

You are all familiar with an ordinary rocket: it expels sparks and smoke downward and moves upward. However, these ordinary rockets do not fly very high, because they are inefficiently designed: the pressure at the rear only slightly exceeds the weight of the rocket. If this pressure were equal to the rocket's weight, the rocket would only hover for a time at the same altitude, then fall back to earth. Also, the materials in the rocket burn largely after leaving the rocket. The entire rocket is designed to achieve a beautiful effect, and its form does not correspond to the theory. If we construct the rocket in the form of a funnel, behind a combustion chamber, and use the strongest available fuel, for example hydrogen and oxygen in the compressed state, as Tsiolkovskiy's calculations show (those of you interested in these calculations can read his article "The Rocket in Space"), it is quite possible to achieve tremendous flight altitudes.

Tsiolkovskiy's rocket consists of a vessel similar to a shell, the front portion of which contains the people, the rear containing the rocket itself plus the liquid fuel, which cools the rocket (see drawing VIII).

In 1923, a new and promising work appeared by the German professor of astronomy G. Oberth, entitled: "A Rocket to the Planets." Oberth suggested that two or more imbedded rockets be used (see drawing III): the lower, larger rocket would be fueled with alcohol burning in oxygen, while the upper, smaller rocket would be imbedded in the lower rocket, and at the moment when the larger rocket finished operating, the nose of the larger rocket would fall apart into three pieces, and the smaller rocket would continue its flight, powered by detonating gas: the burning of hydrogen in oxygen. The lower rocket would have rudders which would form a parachute as it falls so that it /39
could be returned safely, with its tanks filled with atmospheric air. It could also be equipped with recording instruments to inform us concerning the temperature, pressure and density of the atmosphere at high altitudes. The second, smaller rocket would be equipped with an ejectable parachute. It might also achieve velocities sufficient for flight to other planets.
Model B developed by Oberth is designed for investigation of the atmosphere without crew. It has initial weight of 544 kg, and at the end of the flight the small rocket would weigh 56.2 kg. Its greatest diameter is 55.6 cm. Also, for better effect it is raised to an altitude of 5500 m by two dirigibles before firing, then reaches an altitude of 56.2 km over the surface of the earth. The small rocket, which flies out from the larger rocket has an

initial weight of 6.9 kg and a final weight of 3.6 kg; its final velocity would be 5.14 km/sec, and it might achieve an altitude of 1960 km over the surface of the earth.

Oberth also drew up a plan for another, larger rocket to be used to launch men into interplanetary space.

Recently, the newspapers and magazines have reported from America that Prof. Goddard in Worcester, Massachusetts, strongly supported by the Government, has performed a number of experiments on rockets, achieving remarkable success so that he, as you can read in Oberth's book, has begun speaking even of sending a rocket to the moon (see drawing). The news that this would be achieved on 4 July 1924 was a bit premature. In his experiments, he first used smokeless powder, then pistol powder, and recently has been using liquid oxygen and liquid fuel. When the powder was being used, a number of explosions were used, as in a machine gun, each one giving the rocket additional speed.

Since my childhood, I have been interested in interplanetary voyages and, beginning in 1915-1917, I began developing designs for an interplanetary spaceship: a combination of an airplane and rocket (see drawing, top, side and rear views). In my design, the rocket pushes the airplane upward at an inclination; in the lower layers of the atmosphere, a propeller motor is used, while the rocket powers the craft beginning at an altitude of about 26 km (see lift diagram). This combination makes it possible to perform experiments with the rocket, starting and stopping it during flight. In case of an accidental failure of the rocket, the craft can glide safely back to earth.

Near the end of the world war, the French constructed an airplane designed for but a single flight, the motors and airplane being constructed as simply as possible. Since the airplane could not carry sufficient liquid fuel for flights to another planet, and following the idea of the Frenchman, I decided that the answer would be to dismantle parts of the wings of the airplane and other parts unnecessary for further flight, melt them in a special boiler (see dismounting diagram). The melted metal is an excellent fuel, and due to the high cost of liquid hydrogen, the usage of the metal will /40
not make the flight much more expensive.

I have even worked on the problem of the possibility of a gliding descent from interplanetary altitudes to the earth, and have produced favorable results (see drawing of plan of descent): in order to achieve this gliding descent, my design includes the wings for a very small airplane attached to the body of the spacecraft (see drawing "Interplanetary Spacecraft by End of Flight"). The rocket can also return to the earth, as Tsiolkovskiy suggested. However, this would require the expenditure of a great deal of fuel, namely: for the ascent, it expends, with initial weight of 20,000 kg, approximately 19/20 that amount of fuel, i.e., 19,000 kg of fuel, only 1,000 kg remaining in space. With gliding descent, no fuel is expended, so that an airplane weighing 1000 kg can be returned. If the rocket is returned, decelerating the tremendous velocities achieved by falling from interplanetary space

(11 km/sec), this requires again approximately 19/20 of the total weight in fuel, i.e., 950 kg, so that only 50 kg could be safely returned to earth. However, since the return of two to three men to earth requires an apparatus of approximately 1000 kg, a rocket returning to earth and decelerating by reaction effect would have to be approximately 20 times greater than in my design, i.e., have a weight of 20 × 20,000 = 400,000 kg. Furthermore, the combination of an airplane with a rocket has the advantage that the pilot can freely control the airplane as he returns, without lying in a bath, since in this design the accelerations are less than in the lifting rocket and interplanetary velocities can be achieved during an acceleration period of 25-40 min, whereas with a lifting rocket the entire velocity must be achieved during 2-4 min.

For flights in interplanetary space, I am working on the idea of flying using tremendous mirrors of very thin sheets, capable of achieving favorable results (see drawing of mirror and dust, and sphere).

In case people might later construct interplanetary stations in interplanetary space which would revolve around the earth like the moon, except closer to the earth, receiving travelers from the earth and sending out large interplanetary spaceships for further travel, equipped with all the comforts, according to my calculations, the following design can be used. The interplanetary ships to be sent to other planets should be equipped with large mirrors almost one square kilometer in area; the interplanetary stations should also have mirrors, but even larger (see drawing). The light is collected by these mirrors and sent to the mirror of the interplanetary space- /41
ship in flight. The low pressure of light over the tremendous distances of travel will result in tremendous flight speeds, thereby shortening flight durations. The greatest time required for flight to the nearest outer planet, to Mars, the so-called Red Star, will be about 256 days; the flight time to the nearest inner planet, Venus, will be about 145 days (flight drawing). There are other sources for the production of the velocities, investigation of which is in progress and will be reported on in our interplanetary Society. If we fly around a planet in space, the planet will attract us, curve our flight trajectory and so to speak pull us after itself, so that our flight speed after passing the planet will be greater than before; in the best case, flight around the earth might yield an increase of 10 km/sec, around Mars -- 4.5 km/sec, around the largest planet of our solar system, Jupiter -- 24 km/sec and around our moon -- 2 km/sec (see diagram). Furthermore, if we approach a planet, then circle around it within its atmosphere, we can achieve high flight speeds: as when a small sphere strikes another large, rapidly moving sphere, the speed of the small sphere can be strongly increased. With this type of flight around the earth, we might receive an increment in flight velocity of about 50 km/sec, which should be quite important in performing various tasks in flights to other planets. However, this question of flying around a planet within its atmosphere requires further development (see drawing of flight in atmosphere).

Let us analyze now the question of the effect of the force of attraction of the earth, planets and sun. We know that the force of attraction of the earth at a height equal to its radius, i.e., 6370 km over the surface, is only one fourth of the force which acts upon us on the surface; if the altitude is two radii, the force is only one ninth that which acts upon us at the surface, etc. Due to this, the work which must be performed in order to fly away from the earth into space is not infinite, but is only a finite quantity. However, if we were to perform infinite work on a stone, it would have the speed of light, i.e., 300,000 km/sec. In order to overcome the entire gravitational attraction of the earth, a speed of 11 km/sec is required. At a lower speed, we will rotate around the earth in an ellipse, at a higher speed we will fly away on a hyperbola to infinity (see drawing).

If we overcome the attraction of the earth, we still retain the speed of the earth around the sun, i.e., approximately 29 km/sec. If, for example, we add 3 km/sec to this velocity for a rocket, we attain very extended flight around the sun, our interplanetary spacecraft will move away from the sun and will reach the planet Mars at the furthest point on its trajectory, Mars being 1.5 times further from the sun than is the earth. If still more additional /42 velocity is given to our ship by a rocket or by light pressure or by circling around Mars, we can reach the other planets.

However, Mars is particularly interesting since the Italian astronomer Schiaparelli first saw the network of canals, some of which are 3-5,000 km in length; it has been assumed that they have been constructed by intelligent beings with a higher level of culture than our own. Although the question of the canals is now a matter of debate, in any case Mars does have polar icecaps which thaw in the summer and increase in size in the winter. The sending of an expedition there would have significance for the entire world. (Incidentally, Mars can be easily seen now, we looked at it yesterday through the large telescope at Lyubyanka 13; the polar cap could be quite easily seen.)

The following questions are also particularly important for interplanetary flight: respiration, food, and safety from the danger represented by puncture of the spacecraft by meteorites.

The first problem can be solved by taking along oxygen for breathing plus materials which absorb carbon dioxide, for example caustic potash. Canned food can be taken along to eat; however, for long-range flights it will be best to use the light weight greenhouse suggested by Tsiolkovskiy. Tsiolkovskiy calculated that permanent food supply for one man could be provided by a single square meter containing the most fruitful plants -- bananas. In this case, the air for breathing could also be restored by plants; they absorb carbon dioxide, using it to construct their tissues, and give off oxygen which we require for respiration (see the figure showing light weight greenhouse).

As concerns penetration of the spacecraft by meteors, according to my calculations this would occur on the average only once every ten years.

For safety in such an event, the spacecraft should be divided into sections separated by air tight doors. The crew should wear diving suits with automatic valves which would close in case the air should leave the cabin through a hole made by a meteorite (see spacesuit drawing).

Reaching other planets would open a new era in the history of man: it is hoped that we might find other forms of life within our own solar system. Many state that the greatly reduced gravity on the smaller planets, making transport easier in the very broadest sense of the word, would balance the difficulties created by the absence of atmosphere, water and plants on these small planets. It is also possible, as Tsiolkovskiy has said, that we could create colonies in interplanetary space between the planets. We could /43
construct eternal springtime in space between the planets; due to the eternal presence of the sun's rays there, tuberculosis would disappear, a tropical temperature could be maintained permanently and, therefore, the fertility of the tropical countries could be attained.

Leaving it to you yourselves to develop further thoughts on life in the weightless medium, I would like to return to new trends and describe for you plans for signaling from Mars and plans for long-distance vision apparatus using radiotelegraphy. In order to show the Martians that intelligent beings exist here on earth, we could plant forests in the form of bands forming regular figures: equilateral triangles, tetrahedrons, the Pythagorean theorem, etc. (see drawing). The width of these bands should be at least 15 km. We can then send a strong beam of light from earth to Mars, but the tremendous quantity of light required will prevent this. Also, it would be possible to attach a camera obscura to a rocket directed to the moon. In recent time, plans have been made up for the transmission of pictures formed on the matte plates of such cameras over long range using apparatus based on the fact that selenium metal changes its electrical resistance strongly when struck by light. If a given point receives no light, the current in the circuit including the selenium will flow very slightly, and vice versa. An analogous current can be created in a receiving electrical circuit using radio transmission. If the receiving circuit contains a small bulb, it will light up if light was present at the corresponding point of the matte plate in the camera obscura of the transmitting station. By covering the entire matte plate with selenium, all images on the plate can be transmitted. If a rocket with such an apparatus approaches the moon, we will be able to see from the earth images in the camera obscura of the rocket approaching the moon. However, these plans require further development.

I would like to end (my report) by stating that we in the recently formed "Society for Studying Interplanetary Voyages" have announced a contest for a high altitude rocket (to fly up to 100 verst altitude). We invite all those desiring to take part in this contest to write to the society. All questions and problems encountered will be worked out from the strictly scientific point of view. We are to publish a journal entitled "Rockets" to report on our work, and we will perform the necessary experiments and do everything to develop science in this direction, which should be of prime significance in the life of man.

8. Flights to Other Planets [13] /44

Engineer F. A. Tsander

Our earth is not the only planet in the space around the sun. At various distances from the sun there are seven other large planets. Of these, one of the closest is Mars, the so-called Red Star, a planet toward which science has recently turned a good deal of attention since this planet, 1.5 times further from the sun than the earth, probably carries life, and quite possibly highly cultured life. To fly there and to seek among the stars a happier life in general is a dream which man has held for a long time.

However, the effect of the engines which will make it possible to fly to other planets, namely rockets, has remained very little studied. This area has remained almost totally uninvestigated from the design standpoint. The first scientific work in this area is that of the Russian scientist K. E. Tsiolkovskiy. He determined by calculation* that in order to give a rocket sufficient velocity that it will not return to the earth, in the best possible instance eight ninths of the entire weight of the rocket must be burned up as fuel, if the fuel used is hydrogen and oxygen, compressed to produce detonating gas. Tsiolkovskiy suggested that a rocket also be used for descent, in order to decelerate the fall. In this ascent and descent together, the rocket would expend at least 57/58 of its entire weight. In practice, however, the ascent would require 19/20 of the weight of the spacecraft, and ascent and descent together approximately 199/200 of the entire weight of the interplanetary rocket. This tremendous expenditure of fuel, together with the great acceleration required, which would force the pilot firmly into his seat, are the primary difficulties involved in fulfillment of his plans. Tsiolkovskiy, in his own words, has not yet developed a definite design to achieve this.

The German astronomer Prof. Oberth** avoided the necessity of expending 19/20 of the weight of the entire rocket as fuel in that he suggested placing a small rocket, 80 times smaller, inside the large rocket. After the fuel of /45
the large rocket was expended, the small rocket would fly out from it and continue on the journey, further increasing the velocity of flight. This allows a smaller quantity of fuel to be used for each rocket, and the rockets can be constructed stronger. According to Oberth, the return descent can be

---

* See K. E. Tsiolkovskiy, *Raketa v Kosmicheskoye Prostranstvo* [The Rocket in Cosmic Space], 1924, reprinted from the 1903 edition. Copies of this book can be obtained from the author or at the kiosk of the Society for Study of Interplanetary Voyages, Moscow, Lyubyanka, No. 13, at the Astronomical Observatory of the Central Physics-Pedagogics Institute.

** See the book by H. Oberth, *Die Rakete zu den Planetenraumen*, 1923. The book is being translated by members of the Society for Studying Interplanetary Voyages into the Russian language. See also articles in the journals *Khochu Vse Znat'*, No. 5, 1924 and *Tekhnika i Zhizn'*, Nos. 12 and 13, 1924.

made by parachute, so that the descent will require the expenditure of no fuel whatsoever.

The American scientist Prof. Goddard, who performed a large number of experiments and hoped to send a rocket to the moon, also suggests that two rockets be used, one placed atop the other.

Being strongly interested in astronomy and aviation, I have also worked a great deal on the problem of interplanetary voyages, particularly since 1917.

In the design which I suggest, the rocket is a part of a large airplane. As calculations have shown, the rocket, and the acceleration which the rocket gives to the interplanetary spacecraft would be many times smaller than in the designs described above. As a result of this, the pilot would be less strongly pressed back into his seat, and could sit in the airplane and control it, whereas in the other designs described above, those of Tsiolkovskiy and Oberth, he would have to lie in a liquid bath during the time of operation of the rocket. In the bath, he would float, even during the strongest acceleration of flight, and would control the rocket while lying down.

The combination of an airplane plus a rocket has the advantage that if the rocket motor should fail the pilot is quite safe: he can glide back to earth, or if he succeeds in starting the rocket motor again, he can continue his flight and achieve the required velocity (8 km/sec) at which he can circle the earth like the moon without falling back to earth.

The parachute which Oberth suggests for the descent will strongly decelerate flight and at high speeds might break, making it impossible for the flight to be continued after the rocket has once stopped.

One difficulty is that in flight an airplane can take along only 40-60% of its weight as liquid fuel. The remaining fuel can be produced by melting parts of the airplane not required for further flight, parts specially simply constructed for this purpose, and using the liquid aluminum or magnesium as a fuel together with hydrogen and oxygen. However, if the large first stage rocket suggested by Oberth fails in the return descent, the flight method which I have suggested will be more suitable, particularly since when the airplane and rocket are combined, the pilot is safe at all times, which cannot be said concerning the lifting rockets of Tsiolkovskiy and Oberth.

When an airplane and rocket are combined, a safe gliding descent from interplanetary space back to earth is possible without expenditure of fuel. /46
The airplane supports the flight only in the atmosphere of course, to about 50-85 km. However, it is possible to take off in such a manner that the velocity required for orbital flight (8 km/sec) will be achieved within the limits of the atmosphere [14].

For flights carrying passengers, the combination of airplane and rocket will therefore greatly facilitate experiments. For scientific flights of rockets without people, it is quite convenient to use Tsiolkovskiy or Oberth type lifting rockets.

Quite recently, our young "Society for the Study of Interplanetary Voyages" in Moscow has announced a contest for rockets to achieve high altitudes. It would be desirable that the greatest number of readers of this article take part in this contest. Incidentally, there is already one sketch, which I have made, which we will be working on together with the Scientific Research Section of the society.

Before the velocity of 8 km/sec is reached, the longest possible continuous operation of the rocket should be achieved. After this velocity has been achieved, a body flying parallel to the surface of the earth will be pulled inward toward the center of the earth by gravity exactly enough to balance the curvature of its trajectory to the curvature of the earth. Therefore, the body can circle around the earth forever as long as it is outside the earth's atmosphere (i.e., at least 400-600 km altitude). Therefore, interplanetary stations will probably be constructed here, and will be able to contain a number of rockets or airplanes with rockets. The pilots or crew members will be able to rest here and perform repairs to their vehicles, since the rockets will not have to continue operating while at the stations*.

Further flights to the moon or other planets should best be performed using interplanetary spacecraft of special design, equipped for long-range flights with all necessary materials: apparatus for respiration, light weight greenhouses, protective devices for meteorites, solar engines, tools for /47
spacecraft repair, rockets for further acceleration of the flight and avoidance of meteor showers which might be encountered on the way, etc.

According to my calculations, the acceleration of these flights in interplanetary space can be performed using the pressure of light falling on thin sheets. If these sheets are made in the form of large circles and rotated, they will hold their flat form due to centrifugal force, in spite of the pressure of the light. Over the tremendous distances between planets, the slight pressure of the light will be sufficient for the acceleration required.

The time of a flight to Mars, if we desire to save fuel, would be 256 days for a rocket. To do this, the rocket would have to take off from the

---

* The interplanetary stations will yield the additional benefit that all objects not required for the return to earth can be left at the stations: devices required only for long-range flight; greenhouses, air regeneration devices for respiration, tools for repair of interplanetary spacecraft, sleeping quarters, most of the crew quarters in general, etc. Without interplanetary stations, it would be necessary to expend tremendous funds to orbit all of this material anew for each flight; thus, the expense for construction of the stations would be rapidly repaid.

earth in the direction of the earth's movement around the sun [15], adding 3 km/sec of additional speed [16] to the 29 km/sec at which the earth rotates around the sun. This would cause the spacecraft to move in an orbit which according to my calculations would take it to the planet Mars. If we decrease the speed of 29 km/sec by 2.5 km/sec, the spacecraft would move on an inward trajectory, somewhat closer to the sun and would reach the planet Venus in 145 days. If more fuel is expended, in order to give the spacecraft additional speed greater than the 3 or 2.5 km/sec, we will reach these planets more rapidly.

The area of rocket design is still very little developed. It would be desirable to continue energetic work in this area, to make it possible for us to enter interplanetary space by orbiting around the earth as described above, then to reach new freedom, new capabilities and new worlds.

11 August 1924 F. A. Tsander

9. Some Materials to the Appearance at the Debate Held at Moscow State University 1, 4 and 5 October 1924 [17]

Outline of the Statement of Engineer F. A. Tsander on His Inter-Planetary Spacecraft

Statements of 1, 4 and 5 October 1924, Made at Debate in Physics Institute of First Moscow University

A. Introduction. Duration and extent of my works: 1906, 1909-11; 1917-1924, number of pages -- over 600; drawings -- 23; experiments of 1915-18 with light weight greenhouse.

B. Report.

I. Description of my interplanetary spacecraft, large and small airplane, propellers and rocket, dismountability of wings and other parts, Melo rocket in place of motor plus rocket. Melting boiler. Experiment with magnesium. Usage of solid fuel. (Slides Nos. 1-9.) /48

II. Ascent and gliding descent of my interplanetary spacecraft, flight safety due to support of airplane throughout entire period of flight, possibility of multiple startup of rocket. Usage of experience of aviation. (Slides Nos. 10, 11.)

III. Dangerous moments during flights of Oberth or Goddard and Tsiolkovskiy rockets.

a) Failure of rocket after liftoff, fall back to earth.

b) Impossibility of restarting rocket which stops during inclined takeoff; strong drag of parachute; danger of conversion to missile.

c) Destruction of parachute during fall after failure of rocket ascending vertically at 5-7 km/sec.

d) Resume: failure of the rocket should not be fatal, takeoff after start and stop of rocket is required, as can be performed with my ship (slides Nos. 12, 13, 14).

IV. Inconveniences of Oberth's plan

a) Necessity of descent in unfortunate location by Oberth parachute; low final weight of Oberth's plan (1/150 at 5 km/sec).

b) Pilot in Oberth's craft must lie in bath, since acceleration is up to 42 g.

c) Tragic results of defects due to rapid change in velocity (flight about 40 sec).

d) Great difficulty of manufacture of huge rocket in comparison to airplane plus smaller rocket.

V. Inconvenience and expense of Tsiolkovskiy rocket used to decelerate descent: initial weight should be 10-20 times greater than that of airplane with rocket.

VI. Ease of performance of experiments with interplanetary ship of my system, starting and stopping it at any speeds. Solid fuel no more expensive than hydrogen. High depreciation with Oberth rocket. Elimination of obstacles pointed out by Perelman -- expenditure of solid fuel.

VII. Interplanetary stations, their location and significance: reception of interplanetary ships from earth, return of ships to earth, launching and reception of interplanetary ships for long-range flights; greenhouses and repair tools, stations for manufacture of oxygen and hydrogen. Cheapness of delivery from the moon.

Their distance: /49

at 1000 km altitude -- 1 hr 23 min around the earth

at 42,000 km altitude = $6\text{-}2/3 \cdot r_e$ -- 24 hr around the earth

at 2.5 lunar distances altitude -- one year around the earth.

Comparative ease of reaching interplanetary stations: 8 km/sec, 90% of fuel, return after 1.5 hr (slide No. 15, 15a) [18].

VIII. Flights to Mars and Venus (slides Nos. 16, 17).

IX. Movement around planets within and beyond atmosphere (slides Nos. 18, 19).

X. With sufficient time available: how should interplanetary spacecraft be driven for long flights?

1) Rockets

2) Mirrors (if: mirrors used to heat soil according to Oberth) (slides Nos. 20, 21, 22)

3) Mirrors transmitting energy from space station to ship (slide No. 23).

4) Ring with electrified iron powder within loop (slide No. 24)

XI. Light weight greenhouse and Melo engine (slides Nos. 25, 26, 27, 28, 29)

XII. Military significance of interplanetary flights
1) Long range of interplanetary rockets
2) Possibility of taking chemically active gases on board
3) Velocity of long-range flight
4) Investigation of country from space stations and effects of mirrors
5) Benefit from investigation of new world with small equipment (slide No. 30)

XIII. Significance of interplanetary flights for astronomy
1) Comparative cheapness achieved by information from other planets and concerning zodiacal light
2) Better observation conditions from space station; possibility of observing disks of other suns, discovery of planets beyond Neptune or within orbit of Mercury and new satellites of planets

XIV. Significance of interplanetary flights for man
1) Decrease in weight and facilitation of all transport operations, lifting of loads and work with various bodies, ease of increasing machines, solar motors
2) Difficulties due to absence of atmosphere, necessity of wearing spacesuits or maintaining completely closed quarters, necessity of regenerating air and carrying greenhouse /50

XV. Society for Studying Interplanetary Voyages
1) Its history: Section of Reaction Motors at Air Force Academy, report of Prof. Vetchinkin, my report at the Astronomical Society. 150 members, three sections: Scientific Research, Scientific-Popular Literature-Propagandistic; Communications Club, library, etc. [19]
2) Its task: study of the upper layers of the atmosphere with rockets, the contest; construction of two-stage and multi-stage rockets, the Melo rocket, the dismountable airplane, the melting boiler, combination of airplane with rocket, motor operating with oxygen and hydrogen, thin mirrors, light weight greenhouses, in the future -- interplanetary spaceship, stations, calculation and investigation of flights to other planets. Affirmed regulations -- show. Read point 2 and part of point 3 of regulations.
3) Work done: many reports read, competition started, communications abroad, letter from Goddard (read), translation of Oberth and Goddard to Russian, articles printed, journal "Rockets" to be published. I am performing scientific work, Prof. Mikhaylov writing scientific book, Tsiolkovskiy has sent articles and is maintaining contact.

XVI. Why perform flights to other planets in the near future.
1) Light rockets with good efficiency are possible.
2) Combination of airplane and rocket will make flights safe for man and allow easy performance of experiments with manned apparatus.

3) With two- or three-stage apparatus, the amount of liquid fuel required for each apparatus is reduced. This combination or melting of parts of the construction material can be used to achieve a speed of 8 km/sec, i.e., the first speed required to reach interplanetary space.

Flight Moscow-New York in two hours. Photography of panoramas from altitude of 700 verst.

Modern German science of radio communications with Mars and other worlds. /51

Fifteen-million-horsepower radio station.

C. Conclusion. Near future.
1) Propaganda between engineers and scientists
2) Experimental plant for long-range and interplanetary rocket
3) Rocket to be constructed by the Society for Study of Interplanetary Voyages
4) Necessity of organizing Society for the Study of Interplanetary Voyages in scientific centers.

REFERENCES

1. Although the original "Outline" did not include the date of the report, a comparison of the outline with the "Summary" makes it quite obvious that it relates to the report made by Tsander on 20 January 1924 at the Theoretical Section of MOLA. The name of section II of the outline, "Design of the interplanetary space rocket" corresponds with the name of an article by Tsander including thermal calculation of a liquid fuel rocket motor and the calculations performed by Fridrikh Arturovich not long before the report (12, 13, 16 and 17 January 1924). However, at the time of the report Tsander had not succeeded in deciphering the problem completely -- his manuscript from the archives in particular does not include the paragraph on "Calculation of the heat transmitted through the walls and wall thickness." The article was published for the first time in 1937 ·the collection "Rocket Engineering," No. 5, under the name "Thermal Calculation of a Liquid Fuel Rocket Motor," together with the paragraph, "Results of Calculations of Heat Passing Through the Walls of a Combustion Chamber," but with no numerical example. As it is shown by this manuscript, in the numerical example Tsander presented the calculation of a hydrogen-oxygen rocket motor with a thrust of 1.5 t using entropy diagrams, the heat capacity being considered variable, depending on the temperature (represented in the form of a polynomial with constants determined experimentally by Pier).

The archives of F. A. Tsander include diagrams showing the magnitudes and dependences mentioned by Tsander in his outline and summary, related to the calculation of the rocket motor mentioned above. Most of these were published by Tsander in 1932 (F. A. Tsander, *Problema Poleta*

pri Pomoshchi Reaktivnykh Apparatakh [The Problem of Flight Using Reaction Motors, Department of Scientific and Technical Information, NKTP USSR, Moscow, State Aviation and Autotractor Press, 1932, pp. 25, 27-29, 33, 34). We note that certain curves involved in the thermal design of a liquid fuel rocket motor, including the entropy diagrams, are contained in the stenographic notes of Tsander from 1918 (record of Acad. Sci. USSR, folio 573, No. 10, book Ve, 1913-1918).

2. Tsander had in mind the thrust of the rocket motor.
3. By the "energy game" Tsander meant the transition of energy from one form to another.
4. Having in mind the reciprocating motor developed by Tsander designed for operation with liquid oxidant.
5. Tsander had in mind design work.
6. Next comes the beginning of the text (several sentences) concerning the following points (2 and 3). Since a continuation was not saved, these sentences have also been omitted in this publication.
7. In the original by Tsander he wrote: "... Research Society ...", not "... Society for the Study of ..." However, it is quite obvious that Tsander had in mind the Society for the Study of Interplanetary Voyages, since there was no other similar society in our country in 1924.
8. It should be kept in mind that Tsander was not a specialist in the area of scientific history and this section, based on information presented in an article by A. A. Rodnykh, "From History of Development of Reaction Powered Flight" (*V Masterskoy Prirody* [In Nature's Shop], No. 3, 1924) contains a number of factual errors and inaccuracies. However, this section is worthy of attention as evidence of the interest which Tsander had in problems of history and development of the ideas of reaction powered flight.
9. The rest of point f), like the beginning of the next point g) could not be deciphered, since the end of the sheet was quite faded and the letters were quite illegible.
10. After the words "Report of Engineer F. A. Tsander on Interplanetary Voyages," follows the word "Read" and a brief stenographic note indicating the year. However, due to the age of the paper, the last number cannot be read. From the note at the end of the report concerning the "recently formed Society for the Study of Interplanetary Voyages," we believe that this report was written in 1924, apparently in July or August.
11. See reference 8 above.
12. In 1896, Tsiolkovskiy began investigations on the possibility of performing space flights using rockets. These calculations were first published in 1903.
13. Approximately in the middle of this manuscript, Tsander names his articles and expresses a desire that the greatest possible number of readers might take part in the competition announced by the Society for the Study of Interplanetary Voyages. This statement gives us reason to believe that the article was written for the journal "Rockets," which was to be published by this society.
14. At the present time there are already well founded variants of the usage of airborne stages of spacecraft achieving speeds of 2-4 km/sec within

the atmosphere.

15. This was followed by a reference to a drawing which we have omitted since more detailed drawings on this theme are contained in Tsander's slides.
16. Tsander here and in the following portions of this manuscript has in mind the additional speed given to the interplanetary spacecraft after it has overcome the gravitational attraction of the earth.
17. The first debate was held on 1 October 1924, then repeated 4 and 5 October due to a large number of people desiring to participate.
18. Next in the original follows the unclear phrase: "winning one. Trenches and reinforcement," which we have omitted.
19. Tsander does not present the history of the creation of the Society for the Study of Interplanetary Voyages in chronological order. In particular, we note that the reaction motor section of the Air Force Academy was created in mid-April 1924, i.e., clearly after Tsander's report read on 20 January 1924 at the Theoretical Section of MOLA.

1925

The first of the documents presented below is included among those materials which reflected Tsander's attempts to develop practical work on reaction equipment and Aviation Plant No. 4 (formerly "Motor"), where he worked for many years. /52

Then, materials are published from the archives of F. A. Tsander for his book "Flights to Other Planets and to the Moon." Although they were not completed, they are still of doubtless interest. They reflect to a certain extent not only the contribution of Tsander to interplanetary voyages (up to August 1925), but also his interest in the history of the reaction method of flying, in fantasy novels concerning flights to other planets, his views on the role of science and its various branches in the life of human society, a few pages from his personal life, beginning with his childhood.

10. Report of Engineer F. A. Tsander at Meeting of Workers and Peasants Party Cell Bureau of State Aviation Plant No. 4 Imeni Frunze (Formerly "Motor") of 27 April 1925 [1]

Concerning the Work Which He Suggested to Be Performed in the Name of the Cell of the Society of Friends of the Air Force (ODVF) at This Plant in the Area of Aviation and High Altitude Rockets in Order to Help Cultural and Military Affairs and Make Preparation for Interplanetary Voyages

I propose to you:

1) The construction of an aviation motor operating on the principle of the diesel engine using petroleum, kerosene or gasoline and liquid oxygen under pressures of up to 200 atm, double action, with rocking cylinder, of 20 h.p.; the cylinder pressure, volumetric efficiency and rotating speed must be adjustable, making it possible to increase the motor power (for rapid lift, flight onto another airplane or away from another airplane, in order to reduce the takeoff run speed when taking off from the earth and the landing speed when returning to the earth); the motor will operate independently of the /53 atmospheric air pressure, will provide for normal or even temporarily increased power at high altitudes and can therefore be used for flights at high altitude and for the establishment of altitude records; the motor can be used as part of an interplanetary spacecraft-airplane, lifting the spacecraft according to my plan to altitudes at which the rocket engine can take over: the motor can perform rapid flights at high altitude and achieve flight altitude records due to its low weight per horsepower;

2) Construction of a rocket to burn liquid fuel and oxygen for flights in the upper layers of the atmosphere and dispersal of literature.

11. Materials for the Book "Flights to Other Planets and the Moon" [2]

11a. Flights to Other Planets and to the Moon

F. A. Tsander, Engineer-Technologist

A scientific-popular review of all the work in this area, including the work by the author, partially still unpublished, indicating the new and grandiose possibilities.

Table of Contents

Safety devices in case of collision between spacecraft and meteor.
Interplanetary stations; their structure, purpose and advantages.
Life on other planets or on the moon.
Difficulties and advantages: necessity of living in pneumatically sealed homes and suits, air regeneration, covered greenhouses; facilitation of transport and work with large masses and large machines, free solar energy.
Lectures on flights to other planets.

VI. Moscow Society for the Study of Interplanetary Voyages.
VII. Melo rocket, adapted to flight in air.
VIII. Interplanetary signaling.
IX. Usage of high velocities in military affairs: long-range cannons, long-range rockets, electrical cannons.
X. Benefits to astronomy from flights to other planets.
XI. Probable course of development of practice of interplanetary travel. /55
XII. Reaching other solar systems by atomic energy or special energy from decomposition of radium.
XIII. Slowing of life and possibility of returning to earth alive after millions of years, by flying at velocity near the speed of light, according to Einstein's theory of relativity.
Possibility of flying through all of interstellar space.
XIV. Approximate cost of flight to another planet.
XV. General summary of state of affairs in the area of interplanetary flight at this moment.

Conclusion: invitation to scientific and experimental work in this area.

Foreword

The idea of printing a popular scientific book on flights to other planets occurred to me when I, following the invitation of the Artistic-Lectors Bureau of the Leningrad military district political administration, began to read lectures in the form of debates on the theme of flight to other worlds. In the autumn of 1924, I read a public lecture in the physics institute of the First Moscow State University, which was repeated twice due to the great crowds which came to the auditorium and was clearly approved by the majority of those present, indicating the interest generally felt in this problem. At each lecture, I was given approximately 40 notes with various questions. Those present included members of our Government. No serious disputations of my ideas were presented. At one of these lectures, the chairman of the Ryazansk State Department of Literature and the press invited me to write a book on this theme. Later, in the winter of 1924-1925, I read more lectures in Leningrad, Kharkov and Saratov, also with success. In the autumn of 1925, the State Council of the Party school in Moscow invited me to read lectures in nine large cities in the RSFSR.

The main purpose of this book is:

1) To familiarize a broad range of readers with the theoretical and practical achievements made to this moment, indicating the great probability

of the achievement of interplanetary voyages in the near future;

2) Light training of scientific workers, presenting for them in review form some of the results of my calculations; the scientific works themselves will be printed by me somewhat later.

I would like to say the following concerning my life.

22(?) August 1887, a tremendous meteor shower fell, and I was born
23/11 August of that same year [3]. I do not know whether my mother was /56
frightened by this meteor shower, or whether I was told about it, but this phenomenon in any case left a deep impression on my mind. From childhood, I loved to stand at the window and look at the stars in the dark winter nights. On the other hand, my father, a doctor by profession, was a natural science enthusiast, and worked actively for a number of years in the museum, where he showed us stuffed birds and animals of all types, as well as the remains and parts of fossilized extinct animals and meteoric rocks which had fallen from the sky. In 1894, when I was seven years old, he traveled from the city of Riga (on Riga Bay) to Baku and Uzenada beyond the Caspian area and brought back all types of crabs, lizards, monitors, turtles, serpents, etc. Of course, we children were highly impressed by all of this. At the same time, he told us the nature of the stars, the moon and the planets, and added that we might some day find there completely new and different animals, many more marvelous forms. Often, children hear only half that which they are told, and so I later became very sad and even cried when they told me that it was as yet impossible to fly to the other planets.

The stories about the flights of G. Lillienthal in Germany and the kites which my father flew tempted me early to think of the possibility of flying to other planets. This thought has never left me. At an early age, I began picking out constellations on star maps and memorizing their outlines [4].

During the last year of the school, before the winter holidays, our cosmography teacher read us an article [5] written by K. E. Tsiolkovskiy in 1903 entitled "Investigation of Universe Space Using Reaction Devices."
(The affirmation [6] of the highly respected K. E. Tsiolkovskiy that his work /57
was hidden for 20 years was therefore not quite accurate.)

After graduating from the technical high school in 1905, I studied at the higher technical school in Danzig for 1-1/2 years, then studied at the Riga Polytechnical Institute. All this time, my reading of books on astronomy and stories concerning travels to other planets did not allow me to forget my dream of working in this area. In 1908, I received an astronomical telescope with an objective diameter of four inches and a magnification of 60 to 300 power, and used it with great enthusiasm to observe the lunar landscape and Mars during its great opposition in 1909. I told the other students about my plans and we organized a students' society of flight and aviation in 1908-09. It seems to me that perhaps the approach of Mars to the earth to a particularly close position and the articles which appeared in connection with this not only inspired us, but in general were one of the factors giving men the courage to work in the area preparing for flights to the stars. This is indicated also by the fact that some flying fields are called "Mars fields."

We did not at that time get farther than the construction of a glider, except that I performed several calculations in 1909-1911, concerning: 1) the work required to reach high altitudes, and 2) the weight of a cable which would be suspended in space between the moon and the earth, touching both, and 3) a reaction motor. In the library of the Polytechnical Institute, I subsequently read a work by Tsiolkovskiy [7]. Only my energetic preparation for exams at the institute (I wanted to be as well prepared as possible for future work in the area of interplanetary voyages) held me back.

In 1914, I graduated from the Mechanics Department of Riga Polytechnical Institute, and went to work at a large plant in the rubber industry, thinking I would study the quality of rubber which would be very important in the manufacture of air tight clothing, etc., necessary for interplanetary voyages.

From 1915 to 1917, I performed experiments on a light weight greenhouse, as time permitted, and after 1917 worked energetically on the theoretical and design development of the problem of flight to other planets. In February of 1919 I was transferred to a plant constructing aviation motors (State Aviation /58 Plant No. 4, "Motor" in Moscow) in which both the administration and the workers met me quite well. I was also interested in the Aviation Department of the All-Russian Council of the National Economy, but did not as yet have time to develop my plans sufficiently to present it. From the summer of 1922 to the summer of 1923 I continued working independently, sitting home and working on my project. I was forced to sell my astronomical telescope. It was purchased by the club department of the All-Union Central Executive Committee in the Kremlin, which was interested in it. Since that time, I have been working at the aviation plant again and preparing drawings for experiments to be performed at this plant. In 1924, the increase in interest due to the experiments of Goddard made it possible for me to organize in Moscow the Society for the Study of Interplanetary Voyages. The shortage of time which I had free and the comparatively small number of scientific workers in the presidium is the reason why the last person, after the society had been approved by a number of others, did not affirm it; however, I am quite confident that after a number of experiments and experimental constructive projects have been completed, we will succeed in revitalizing the society, particularly after several scientific works are printed here and abroad.

In all, I have approximately 650 large rough draft pages, plus various scientific and technical calculations in this area, all written in shorthand, increasing the volume by 4-5 times. As yet, only a portion has been transcribed. Also, there are 27 drawings with an average size of about 50 × 70 cm, on which I have drawn the designs required for experiments, motor parts and the interplanetary spaceship aircraft. However, everything is not yet completed. I still must perform energetic work, the performance of which will require time, which is in very short supply since I must continue to earn my living.

A model of the interplanetary spaceship is half finished.

In describing the work of other authors, I have used books and articles as listed in the following bibliography. The chapter on the history of the development of interplanetary voyages I shortened somewhat, since the history of the problem of reaction flying has been well described in the journal *V Masterskoy Prirody*, No. 3, 1924. I turned most attention to the possibilities which have resulted from scientific investigations; I hope that the thoughts which I have stated will attract new investigators and engineers to work in this area. This area is, so to speak, a tremendous, rich country which man has hardly touched with his culture (his scientific investigations and technically well developed designs).

List of Books, Journals and Articles Concerning the Problem of Inter-Planetary Flight /59

1. Scientific and Scientific-Popular Works and Articles

Kibal'chich (1881).

K. E. Tsiolkovskiy, "Investigation of Universe Space with Reaction Device," in 3 parts, one part published in 1903 in *Nauchnoye Obozreniye*, book 5, May, republished in 1924 in Kaluga as a separate brochure under the title *Raketa v Kosmicheskoye Prostranstvo* [The Rocket in Cosmic Space]; the second part was published in 1911-1912 in the journal *Vestnik Vozdukhoplavaniya*; the third part was published as a separate brochure in 1914 in the scientific-popular book *Vne Zemli* [Outside the Earth].

Prof. H. Oberth, *Die Rakete zu den Planetenraumen*, Munich and Berlin, R. Oldenbourg Press, 1923.

Ya. I. Perelman, *Mezhplanetnyye Puteshestviya* [Interplanetary Voyages], fourth edition, 1923, Petrograd, Academic Press and fifth edition 1924.

Prof. R. Goddard, *A Method of Reaching Extreme Altitudes*, Washington, Smithsonian Institution Press, 1919.

Engineer F. A. Tsander, "Flights to Other Planets," an article in the journal *Tekhnika i Zhizn'*, No. 13, 1924.

A. A. Rodnykh, "The History of the Development of Reaction Flying" (article in the journal *V Masterskoy Prirody*, No. 3, 1924).

Vegener, "The Immediate Future of Aviation," *Vestnik Vozdushnogo Flota*, No. 13, 1922.

Lapirov-Skoblo, "Interplanetary Voyages," article in the journal *Molodaya Gvardiya*, Vol. V, 1924.

Introduction

1. Historical Development. Interplanetary Voyages in Novels, Stories and Plans. Lists of Methods Suggested for Flight to Other Planets

The development of science and technology, particularly achievements in the area of aviation, radiotechnology, Einstein's theory of relativity and the splitting of atoms of the elements which would have seemed quite improbable a few years ago, have gone hand in hand with the bravery of thought and the bravery of design of devices in the area of voyages to other planets. During the period of advance in the war, bravery decided the outcome of battles on many occasions.

The dream of a better future, of new possibilities for man, of new freedom of action has been and continues to be the prime impulse to action: people have hoped that out there among the stars we may be able to find a /60 more peaceful and happier life; astronomers have pointed out that most planets rotating around star-suns should carry highly cultured life and that the difference in development may reach millions of years. Of course, the contact between our mankind and such cultures will bring us into a golden age.

In many areas the novelists and poets have written descriptions, frequently described by the annual blossoming of life, and the spring storms, of new combinations, new phenomena giving new effects in technology; so it is in the area of interplanetary voyages that writers have attempted to create designs which in their opinion would have the greatest probability of being achieved in the future, even in the very distant future. As always occurs when ideas spring from fantasy, they have frequently made errors (the scientific method assures the investigator that in many areas phenomena can be predicted with great accuracy, whereas these fantasy estimates will be in error at least 50% of the time). Readers of these stories, particularly the young readers, have been inspired and new ideas have sprung up in their minds; mathematicians and inventors have been found who have probed the soil more carefully; on the basis of this, new designs have appeared, and the general development of technology has received new capabilities and as a final result the dreams have been converted in some way to reality.

IIb. Detailed Outline for Book "Flights to Other Planets and to the Moon"

Part 1. Historical Development. Interplanetary voyages in novels, stories and plans.

List of methods suggested for flight to other planets. Kibal'chich.

List of novels and stories concerning flights to other planets and life on other planets.

Author	Name of book and year of first publication	Main hero	Flight method and specific features of idea	Defects
Jules Verne	"From a Cannon to the Moon" and "Around the Moon"	Maston	shot from cannon	Tremendous acceleration would destroy crew.
Zhulavskiy	"On the Silver Sphere"	an old man		
Kryzhanovskaya	"In Another World", "On a Neighboring Planet"		plants produced by higher mankind, harmony of rays. Magic. Transplantation of soul of Matthew.	nonscientific flight method
Meister	Reisen u. Abenteuer der "Sternschnuppe"(in the yearbook "Das Neue Universum", ... year)			/61
Flamerion	"In the Skies of Uranus, the Multitude of Inhabited Worlds"		tale of the spirit of a deceased friend. Interesting description of life on other planets.	
Aleksey Tolstoy	"Aelita"	Eng. Los'	rocket	
Bruno Byurgel'(?)	"Rocket to the Moon"(?)	Baumgarten	rocket with explosive material of tremendous force (uzambaranite)	
Tsiolkovskiy	"Outside the Earth"		Tsiolkovskiy rocket. Interesting description of life in	pressure in greenhouse too low (slight defect)

Author	Name of book and year of first publication	Main hero	Flight method and specific features of idea	Defects
			inter-planetary colonies	
Mukhanov	"Flaming Abyss" (in the journal Mir Priklyu-cheniy, 3" years)			
Goncharov	"The Psychomachine" and "Interplanetary Guide-book"		psycho-energy	method not quite powerful enough
Welles	"War of the Worlds" and "Invasion of the Mar-tians"		cavarite, a material impermeable for the force of gravity	low probability of finding cavarite and property of action
Welles	"The Time Machine"		flight in time to remote area while remaining in same place	flight possible only into the future, most probably, not back using the same method
	"Unter Marsmenschen" (in the annual "Das Neue Universum")	Lormier	decomposi-tion of man in a machine to atoms and assembly after radi-ation to another planet	reception insufficiently scientifically probable
Berrouz	"The Martians"		spirit transport	nonscientific approach
K. Lasvitz	"To Two Planets"(?)		(?)	
Edgar Poe(?)		Edmun Rosh-en	balloon(?)	
	(in the journal "Mir Priklyucheniy")	Thomas Fer-vertam	airplane to planet nearer than the moon	no air for airplane and propellers, method impossible
Cyrano de Berjerac	"Voyage to the Moon" 1645		continuously operating rocket	

LIST OF EXPERIMENTS AND PLANS PREPARING FOR INTERPLANETARY VOYAGES OR RELATING TO THEM /62

Name of investigator performing experiment or suggesting plan	Subject of experiment or plan	Year	Result
Van Gu (Chinese)	ascent of man with kites and 47 rockets	ancient China	unsuccessful
scientist Jesuit Fabri	effect of compressed air	1670	
Layolin and Jeaninet	sphere	1784	
the pyrotechnician Roujerie	ascent by rocket, descent by parachute	1806	successful
Eng. Treteskiy	water and alcohol vapors, compressed air	1849	
Ivanin	powder	1870's	
Kibal'chich	rocket powered by powder lifting man on platform	1881	plan
Capt. (?) Batey	dirigible driven by rockets operating with explosive balls	end of 1890's	plan

REFERENCES

1. In the original the words: "Report of Engineer F. Tsander at the session of the Workers and Peasants Party cell bureau of State Aviation Plant No. 4 imeni Frunze (formerly "Motor") of 27 April 1925" were crossed out.
2. In Tsander's manuscripts from the field, the dates of work performed are systematically entered throughout. All these dates were in the first half of August 1925 and have been omitted.
3. In the fraction, the first number corresponds to the new style, the second to the old. In Tsander's text he erroneously placed the date 19/8, which he later decided to correct, indicated by the question mark which follows it in the manuscript.
4. We note that in connection with the idea Tsander had of flying himself to other planets, he not only became familiar with constellations, as is noted in the text, but also went over on 12 January 1904 to independent astronomical observations and theoretical exercises (in the archives of F. A. Tsander there is a notebook of these exercises). These were the first steps of Fridrikh Arturovich as a future scientist. Later, he performed a number of investigations requiring special knowledge in the area of astronomy (trajectories of flights to other planets, etc.). We can consider that by January-February 1904, Tsander was a full-fledged enthusiast in the area of interplanetary flights. He himself frequently mentioned that he was interested in interplanetary voyages since his childhood, and in one of his letters to K. E. Tsiolkovskiy (17 September 1932) he wrote: "The same enthusiasm which I feel when I read your books has filled me since my childhood ..."

5. Tsander completed the technical high school in 1905 and, consequently, the date of his first information on the work of K. E. Tsiolkovskiy must be the end of 1904 -- beginning of 1905.
6. Tsander has in mind the affirmation of Tsiolkovskiy in the foreword to this brochure "The Rocket in Cosmic Space," published in Kaluga in 1924.
7. We can see from certain other autobiographic material of Tsander that he was interested in a broad range of literature on the question of space flight. For example, in an autobiography dated 15 January 1926, he writes: "I continually borrowed scientific books from the library, and constantly thought of the usage of that which I had learned for flights to other planets. During my nine years in the higher educational institution I read books from the area of aviation, meteorology, astronomy, mathematics, etc. so as to prepare myself more or less systematically for work in the area of interplanetary voyages."

1926

The "calendar plan ..." published below is one of the documents indicating that long before the creation of the group for the study of reaction movement (GIRD), Tsander was thinking of the development in Osoaviakhim of practical work on reaction technology. The manuscript "The Design of a Hydrogen-Oxygen Rocket" contains elements of thermal design of liquid fuel rocket motors not to be found in his works published to the present time. /63

12. Calendar Plan for Work of Interplanetary Subsection of Sport-Aviation Section of Mosaviakhim (January-April 1926)

January-February

1. Development and presentation to Aviation Section for confirmation of statements on: a) Interplanetary Subsection for Sport-Aviation Section of Mosaviakhim; b) Regional and Traveling Subsections.

2. Calling of general meeting of Interplanetary Subsection for selection of officers and determination of plan for work.

3. Development and presentation to Sport-Aviation Section of plan for work of Interplanetary Subsection for analysis and approval.

4. Analysis, approval and presentation for affirmation in Sport-Aviation Section of budget for plan of work of Interplanetary Subsection.

5. Composition of approximate plan of work for Regional and Traveling Interplanetary Subsections and organization of sections with indication of literature available on this question.

6. Support an expansion of communications with institutes interested in this area.

March

1. Continuation of organization of Interplanetary Subsection.

2. Reading of published lectures in Moscow, its regions and on trips on the theme of the flight of rockets and interplanetary voyages.

3. Publication in various journals (in particular in the journal "Samolet") of articles on flights to other planets, in which the designs of /64 rockets and models of airplanes with rockets according to ideas of F. Tsander will be presented.

4. Preparation in technical bureau of drawings for rockets, determination of possibility of construction of rockets using various systems similar to rockets of Prof. Goddard or Oberth.

5. Launching of purchased rocket to high altitude, composition of collections of rockets for museum and participation in sports competitions in the area of aviation.

April

1. Leadership of workers in technical bureau in the area of preparation of drawings of rockets.

2. Search for place for manufacture of rockets from drawings.

3. Participation with extra-high altitude rockets in model competitions.

4. Reading of lectures on interplanetary problems.

13. The Design of Hydrogen-Oxygen Rockets [1]

The determination of pressure (p), density (γ), temperature (t), degree of dissociation (χ), heat content (i), entropy (S) for water vapor at high temperatures, as well as the heat (Q) liberated upon burning of hydrogen in oxygen, the affinity (A) and dissociation constant (K) [2].

Suppose we represent*:

$\nu_1, \nu_2, \nu_3 \ldots$ -- the least number of molecules which are formed or decomposed simultaneously;

$h_1, h_2, h_3 \ldots$ -- the relative quantities of molecules (or kilogram-molecules) of gases [3],

$n_1, n_2, n_3 \ldots$ -- the quantity of available kilogram-molecules of gases; /65

$N = \Sigma n_i$ is the total quantity of kilogram-molecules of gas;

L is the work of dissociation;

H = 845 is the gas constant per kg/mol of any material;

τ is the absolute temperature of the gases;

$p, p_1, p_2, p_3 \ldots$ is the pressure of the mixture of gases and of individual gases;

A = 1/427 is the thermal equivalent of a unit of work;

v is the specific volume of the mixture of gases;

---

* See the book by Prof. Khvol'son, *Kurs Fiziki* [A Course on Physics], Vol. 3, 1899, pp. 411-417.

$v_1, v_2, v_3 \ldots$ are the individual gas volumes;

S is the entropy of the mixture of gases;

$S_1, S_2, S_3 \ldots$ are the entropies of the gases;

Φ is the thermodynamic potential;

$U, U_1, U_2, U_3 \ldots$ is the internal energy of the mixture and the individual gases;

$c, c_1, c_2, c_3 \ldots$ is the thermal capacity of gases at constant volume;

$w_1, w_2, w_3 \ldots$ are the molecular weights of the gases;

$\gamma, \gamma_1, \gamma_2, \gamma_3 \ldots$ is the specific weight of the mixture and of the individual gases;

$R_1, R_2, R_3 \ldots$ are the gas constants per kg of gas.

The thermodynamic potential is expressed by the formula

$$\Phi = U - S \cdot \tau + A \cdot p \cdot v \tag{1}$$

for individual gases, as well as for the mixture. According to the equation of state for one mole, we have

$$p \cdot v = H \cdot \tau. \tag{2}$$

From this, for the mixture of gases

$$\Phi = \Sigma n_i (U_i - \tau \cdot S_i + A \cdot H \cdot \tau). \tag{1a}$$

On the other hand, we can write

$$dS_i = \frac{dQ_i}{\tau} = \frac{dU_i + Ap_i\, dv_i}{\tau}, \tag{3}$$

or

$$dS_i = c_i \frac{d\tau}{\tau} + \frac{A \cdot p_i\, dv_i}{\tau}, \tag{3a}$$

since

$$dU = c_i \, d\tau. \tag{4}$$

According to Dalton's rule, we have

$$p_i = p \cdot h_i.$$

Ho $v_i = \frac{H \cdot \tau}{p_i} = \frac{H \cdot \tau}{p \cdot h_i}$, from which $\frac{p_i \, dv_i}{\tau} = H \cdot d \ln \frac{H \cdot \tau}{p \cdot h_i} = H \cdot d \ln \frac{\tau}{p} -$ (5)

$-H \cdot d \ln h_i + H \, d \ln H$; substituting this in equation (3a) and integrating, we produce /66

$$S_i = c_i \ln \tau + A \cdot H \cdot \ln \frac{\tau}{p} - AH \ln h_i + A \cdot k_i \tag{6}$$

and

$$S = \Sigma n_i \left(c_i \ln \tau + A \cdot H \cdot \ln \frac{\tau}{p \cdot h_i} + A \cdot k_i \right). \tag{6a}$$

If we consider the heat capacity c_i constant and write

$$U_i = c_i \cdot \tau + a_i, \tag{7}$$

then substitute (6) and (7) into (1a), we produce

$$\begin{aligned} \Phi = \Sigma n_i \Big(c_i\tau + a_i - \tau \cdot c_i \ln \tau - \tau \cdot A \cdot H \cdot \ln \frac{\tau}{p \cdot h_i} - \\ - A \cdot \tau \cdot k_i + A \cdot H \cdot \tau \Big) = \Sigma n_i \Big[c_i\tau (1 - \ln \tau) + \\ + a_i - A \cdot H \cdot \tau \cdot \ln \frac{\tau}{p} - A \cdot \tau \cdot k_i + AH\tau \Big] + AH\tau \cdot \Sigma n_i \ln h_i. \end{aligned} \tag{8}$$

If τ and p are constant quantities, while n_i or the degree of dissociation change, the equilibrium in the mixture of gases is established under the condition: $d\Phi = 0$. Representing the expression in parentheses in the first term of equation (8) as B_i, we produce

$$\Delta\Phi = \Sigma B_i \Delta n_i + A \cdot H \cdot \tau \cdot \Sigma(\ln h_i + 1) \cdot \Delta n_i = 0. \tag{9}$$

Here we have considered that B_i does not depend on n_i and, furthermore,

$$\frac{\partial(n_i \ln h_i)}{\partial n_i} = \ln h_i + \frac{n_i}{h_i}\frac{\partial h_i}{\partial n_i} = \ln h_i + \frac{n_i}{h_i N} = \ln h_i + 1,$$

since $h_i = n_i/N$, and therefore $\partial h_i/\partial n_i = 1/N$, while N is a constant number near the equilibrium position.

But the values of Δn_i are proportional to ν_i. Therefore, introducing the symbol $\nu = \Sigma\nu_i$, we produce

$$\tau(1 - \ln\tau) \cdot \Sigma c_i\nu_i + \Sigma a_i\nu_i - A \cdot \tau\Sigma k_i\nu_i + 2AH\tau \cdot \nu - \\ - AH\tau \cdot \nu \ln\frac{\tau}{p} + AH\tau \cdot \Sigma\nu_i \ln h_i = 0. \tag{10}$$

According to Jules Core's law, the approximate euqality $\Sigma c_i\nu_i = 0$ obtains; if we introduce also the new quantities k, a and B according to the formulas

$$\Sigma k_i\nu_i = H \cdot \ln k; \quad \Sigma \nu_i a_i = -H \cdot \ln a; \quad 2\nu = \ln\frac{k}{B},$$

after dividing equation (10) by $A \cdot H \cdot \tau$, we produce /67

$$\Sigma\nu_i \ln h_i = \ln k - \ln\frac{k}{B} + \nu\ln\frac{\tau}{p} + \frac{1}{A\tau}\ln a. \tag{10a}$$

When there is no external work, the heat of dissociation produced by dissociation of new kg-molecules of matter is

$$L = \Delta \Sigma U_i = \Sigma \Delta U_i = \Sigma (c_i \tau + a_i) \nu_i = \tau \cdot \Sigma c_i \nu_i + \Sigma a_i \nu_i. \quad (11)$$

If we assume once more $\Sigma c_i \nu_i = 0$, we produce

$$L = \Sigma a_i \nu_i = -H \ln a, \quad (11a)$$

and formula (10a) takes on the form

$$h_1^{\nu_1} \cdot h_2^{\nu_2} \cdot h_3^{\nu_3} \ldots = B \cdot a^{\frac{1}{A\tau}} \cdot \left(\frac{\tau}{p}\right)^{\nu}. \quad (11b)$$

This is the Gibbs formula. We can also write

$$h_1^{\nu_1} \cdot h_2^{\nu_2} \cdot h_3^{\nu_3} \ldots = B \cdot e^{-\frac{L}{AH\tau}} \cdot \left(\frac{\tau}{p}\right)^{\nu}. \quad (11c)$$

For Water Vapor We Have, If

subscript 1 relates to H_2O;
subscript 2 relates to H_2;
subscript 3 relates to O_2;
so that according to the formula $2H_2O = 2H_2 + O_2$ we have

$$\nu_1 = -2; \quad \nu_2 = +2; \quad \nu_3 = +1 \text{ and } \nu = \Sigma \nu_i = -2 + 2 + 1 = +1$$

and, if we introduce the degree of dissociation χ, equal to the ratio of the quantity of gram-molecules of free hydrogen to the sum of gram-molecules of hydrogen and water vapor, i.e.,

$$\chi = \frac{h_2}{h_1 + h_2} = \frac{p_2}{p_1 + p_2} \quad (12)$$

[see formula (5)], if the mixture is made up without an excess of hydrogen or oxygen

$$h_2 = 2h_3$$

or

$$p_2 = 2p_3. \tag{13}$$

Further, according to Dalton's law,

$$p = p_1 + p_2 + p_3. \tag{14}$$

With (12) and (13) we produce /68

$$p_1 = p_2 \cdot \frac{1-\chi}{\chi}; \quad p = p_2 \frac{1-\chi}{\chi} + p_2 + 0{,}5p_2 = p_2 \cdot \frac{1+0{,}5\chi}{\chi}$$

or

$$p_2 = \frac{\chi}{1+0{,}5\chi} \cdot p, \tag{14a}$$

$$p_1 = \frac{1-\chi}{1+0{,}5\chi} \cdot p, \tag{14b}$$

$$p_3 = \frac{0{,}5\chi}{1+0{,}5\chi} \cdot p. \tag{14c}$$

Equation (11c) is converted to

$$\left(\frac{p_1}{p}\right)^{-2} \cdot \left(\frac{p_2}{p}\right)^2 \cdot \left(\frac{p_3}{p}\right)^1 = B \cdot e^{-\frac{L}{AH\tau}} \cdot \left(\frac{\tau}{p}\right)$$

or

$$\left(\frac{1-\chi}{1+0{,}5\chi}\right)^{-2}\cdot\left(\frac{\chi}{1+0{,}5\chi}\right)^{2}\cdot\frac{0{,}5\chi}{1+0{,}5\chi}=$$

$$=\frac{\chi^3\cdot 0{,}5}{(1-\chi)^2\cdot(1+0{,}5\chi)}=B\cdot e^{-\frac{L}{AH\tau}}\cdot\frac{\tau}{P},$$

or

$$\frac{p\cdot\chi^3}{(1-\chi)^2(1+0{,}5\chi)}=2Be^{-\frac{L}{AH\tau}}\cdot\tau. \quad (11d)$$

For the specific weight (γ) of the mixture of gases we can write

$$\gamma=\gamma_1+\gamma_2+\gamma_3;$$

but we still have

$$\left.\begin{aligned} p_1\cdot v_1 &= R_1\cdot\tau=\frac{H}{w_1}\cdot\tau\\ p_2\cdot v_2 &= R_2\cdot\tau=\frac{H}{w_2}\cdot\tau\\ p_3\cdot v_3 &= R_3\cdot\tau=\frac{H}{w_3}\cdot\tau \end{aligned}\right\} \quad (15)$$

and since $\gamma_i = 1/v_i$, we produce

$$\gamma=\frac{p_1w_1}{H\cdot\tau}+\frac{p_2w}{H\cdot\tau}+\frac{p_3w_3}{H\cdot\tau}=\frac{1}{H\cdot\tau}(p_1w_1+p_2w_2+p_3w_3)=$$

/69

$$=\frac{p}{H\cdot\tau\cdot(1+0{,}5\chi)}\cdot\left[(1-\chi)w_1+\chi\left(w_2+\frac{w_3}{2}\right)\right],$$

but from the formulas $H_2O = H_2 + O$, it follows that $w_1 = w_2 + w_3/2$, so that the expression in the parentheses will be

$$(1-\chi)\,\omega_1+\chi\omega_1=\omega_1$$

and therefore

$$\gamma=\frac{p\omega_1}{H\cdot\tau\cdot(1+0{,}5\chi)}=\frac{p}{R_1\cdot\tau\cdot(1+0{,}5\chi)}. \tag{16}$$

If the gas is completely dissociated (χ = 1), we produce

$$\gamma=\frac{p}{R_1\cdot\tau\cdot 1{,}5},$$

i.e., the density will be 1.5 times less than the density of the nondissociated gas of the same temperature and pressure.

Using formula (11b), we can still write

$$\gamma=\frac{2B\cdot\omega_1}{H}\cdot e^{-\frac{L}{AH\tau}}\cdot\frac{(1-\chi^2)}{\chi^3}. \tag{16a}$$

In the general case it may occur that $\Sigma c_i \nu_i \neq 0$; then, from equation (10) it follows, if we write here

$$L=-H\ln a=\tau\cdot\Sigma\, c_i\nu_i+\Sigma\, a_i\nu_i \text{ и } L_0=\Sigma\, a_i\nu_i;$$

$$h_1^{\nu_1}h_2^{\nu_2}h_3^{\nu_3}\ldots=B\cdot\left(\frac{\tau}{p}\right)^{\nu}\cdot e^{-\frac{L}{AH\tau}}\cdot\tau^{\frac{\Sigma c_i\nu_i}{AH}}= \tag{11e}$$

$$=B\cdot\left(\frac{\tau}{p}\right)^{\nu}\cdot e^{-\frac{L_0}{AH\tau}}\cdot\left(\frac{\tau}{e}\right)^{\frac{\Sigma c_i\nu_i}{AH}}$$

REFERENCES

1. This is an incompleted manuscript by Tsander in which he clearly shows the beginning of the path to the modern thermodynamic design of liquid fuel rocket motors.
2. In this manuscript, Tsander used only one reaction $2H_2O \rightarrow 2H_2 + O_2$. In the manuscript "Tables of Constant Quantities Important for the Calculation and Design of Reaction Motors," he included the following reactions, together with their equilibrium constants as a function of temperature: $H_2 \rightarrow 2H$; $2H_2O \rightarrow 2H_2 + O_2$; $2CO_2 \rightarrow 2CO + O_2$; $H_2 + CO_2 \rightarrow CO + H_2O$; $N_2 + 2H_2O \rightarrow 2NO + 2H_2$; $H_2 + O_2 \rightarrow H_2O_2$. At the end of the second page of Tsander's rough manuscript, he began approximate calculation of the chemical equilibriums according to Nernst. The presentation is interrupted in midsentence at the bottom of the page, indicating that a continuation existed or exists somewhere. The date is not given on the page, but judging from the statement that the information is taken "from the latest sources," and that the latest date in the bibliography is 1923, we can assume that he wrote this in the mid-twenties.
3. In the rough draft here and in the two following cases, as well as in one place further on, "gram-molecules" is actually written in the manuscript. However, this is apparently a misprint, since the gas constant is taken in units including the kg/mole.

1928

Reports by Tsander are mentioned in the two papers presented below. The text of these reports are not to be found in the archives of F. A. Tsander, although certain direct and indirect information concerning their content is available, and is presented in the commentaries thereto. /70

14. Agenda for Meeting of Commission on Scientific Aeronautics at Moscow Aerological Observatory 15/3/1928

Notice to Fridrikh Arturovich Tsander

On Thursday, 15 March 1928 at 19:30 in the Meteorological Observatory building of the First Moscow State University (Krasnaya Plesna, Bol'shevistskiy Pereulok, Dom 13) will be held the seventh session of the Commission on Scientific Aeronautics.

Agenda

1. Report of F. A. Tsander, "Possibility of Achieving High Altitudes on the Basis of the Principles of Astronautics."

a) History of the problem of flight in cosmic space.

b) Principles of theory of astronautics.

c) Usage of the principles of this theory as applicable to investigation of the upper layers of the atmosphere [1].

2. Current business

Chairman of Commission M. Kanishchev

15. Agenda of Session of Commission on Scientific Aeronautics at Moscow Aerological Observatory 30/11/1928 [2] /71

Agenda to Tsander Fridrikh Arturovich, Bol'shaya Simenovskaya, Medovyy Pereulok, Dom 12/14, Kvartira 15

On Friday, 30 November 1928 at 19:10 in the building of the Meteorological Observatory of the First Moscow State University (Krasnaya Plesna, Bol'shevistskiy Pereulok 13) will be held the fifteenth session of the Commission on Scientific Aeronautics at Moscow Aerological Observatory.

Agenda

1) Report of Engineer P. P. Polozov, "Modern Methods of Determining Gas Permeability of Aerostat Materials."

2) Report of Engineer F. A. Tsander, "Preliminary Work on the Construction of a Reaction Apparatus."

3) Current business

Chairman of Commission M. Kanishchev

REFERENCES

1. Here Tsander clearly has in mind problems related to a meteorological rocket. The archives of F. A. Tsander contain a drawing of such a rocket, begun the day before the report, i.e., 14/3/1928, as follows from a number of dates on the drawing. In the inventory of the works of Tsander made up at the archives of the Academy of Sciences USSR we find his article "The Design of High Altitude Rockets for Investigation of the Upper Layers of the Atmosphere," with dates of 27/3/1928-22/5/1928. Apparently, Tsander spoke at some length on his thoughts which, in turn, stimulated him to further work (see also letter of Tsander to Lutsenko below).
2. Some information on the content of this report can be found in the letter of Tsander to Lutsenko published in this book. In particular, Tsander wrote that in the autumn of 1928 he "prepared a number of alloys of light metals containing magnesium, as well as several pulverizing devices for these alloys, having in mind the usage of these alloys in the future as a partial fuel in a reaction motor," and that he reported on his experiments on metal fuel at the Commission on Scientific Aeronautics.

   In 1947, M. K. Tikhonravov, in the foreword to a collection of works of Tsander, wrote that the manuscript "On Experiments on the Manufacture of Alloys Suitable for the Production of High Altitude and Interplanetary Rockets" is an outline of a report read by Tsander at the Commission on Scientific Aeronautics at the Aerological Observatory of the First Moscow State University on 29 November 1928 (F. A. Tsander, *Problema Poleta pri Pomoshchi Raketnykh Apparata* [The Problem of Flight Using Reaction Apparatus], Oborongiz. Press, Moscow, 1947, p. 17). Tikhonravov errs in the date by one day. Also, he stated the assumption that a number of other manuscripts by Tsander related to 1928 were related to the preparation for the report at the Commission on Scientific Aeronautics.

1930-1931

In 1930-1931, Tsander was quite involved with his activity at MAI (Moscow Aviation Institute). F. A. Tsander set himself two purposes: the preparation of personnel and the creation at MAI of a production base for subsequent development of practical work in reaction equipment. This was reflected in materials published below, from which we also see that during this time Tsander had completed work on liquid fuel rocket motors, using liquid air as an oxidizer and gasoline as a fuel, designed for installation on aircraft and there was also a "plan for the Tsander flying rocket." Tsander presented the design of a petroleum-oxygen rocket and started a project on an alcohol rocket. /72

Tsander did not forget other organizations, in particular the Moscow Society of Astronomy Enthusiasts (MOLA). In a questionnaire sent to MOLA on 17 February 1930, in part 10, he wrote, "I consider it quite desirable that the purposes of the society include work on interplanetary voyages" (a copy of this document with Tsander's signature is stored in the archives of F. A. Tsander). On 22 April 1931 he read a lecture at this society, the list of illustrations of which is published. This lecture is included in the list in the archives of F. A. Tsander of organizational problems (for example, see the letter of N. K. Frederenkov to Tsander of 12/5/31 published in this collection). We also present below a photograph (Figure 4) of the beginning of an outline for his report "Testing Wing Profiles ...", which is of interest from the point of view of Tsander's plans for usage of aerodynamic devices in experimental investigations on reaction technology. This last document is included in the plans of works of Tsander on liquid fuel rocket motors installed in aircraft.

16. Some Materials Related to the Activity of F. A. Tsander in Moscow Aviation Institute (1930-1931)

16a. Program of Work of Section of "Rocket Men", Students of the Aviation Institute from 20/9/30 to 20/12/30

Meetings are held once each ten days. The following are included at the meetings. Reading of reports concerning theories of the effects of ordinary and complex rockets, operating with liquid or partially solid fuel, as well as air reaction motors. The main works of the activists in rocket construction; discussion of their designs and experiments. Discussion of certain plans for rockets suggested for construction by the club: experimental, test rockets on /73
test stands or moving along the ground, on snow, ice, water, flying, attached to ... airplanes [1], aviettes, etc. Further. Production of designs and working drawings for experimental designs to be used. Search for laboratories for performance of experiments, shop and means for manufacture of instruments. Improvement of available experimental devices and performance of experiments. Secondly. Theory of movement of rockets outside the atmosphere,

flights to other planets. Other methods for movement in interplanetary space, etc. Influence of gravity and atmospheric resistance on rocket movement. Operation of reactive cannon. Subscription to and partial translation of foreign literature to Russian.

Moscow, 19/9/1930

16b. Application to Educational Section, Moscow Aviation Institute

To Educational Section, Moscow Aviation Institute

Application
from Engineer Tsander, F. A., leader of Rocket Section, Aviation Scientific-Technical Society

I attach herewith a list of the lectures which I read between 26/10/30 and 9/6/31 at your institute on reaction motors and interplanetary voyages, requesting hereby that you pay me the fees due, keeping in mind that I was not a graduate student of anyone, but conducted the courses independently, including in part my own conclusions, as yet unpublished.

The money which you pay me will aid the cause of rocket building.

Moscow, 20/6/31 Signature

16c. Budget of Rocket Section of AKNYeZh, MAI, 1/11/30 to 1/11/31

Income

I. Subsidy	1,000
II. Income from publication of brochure	1,000
Total	2,000

Expenditures

/74

I. Library:	
1) Purchase of books	150
2) Subscription to journals	20
3) Binding	30
Total	200
II. Publication of brochure:	
1) Publication	500
2) Author's honorarium	200
Total	700

III. Experiments with rockets:

1) manufacture of experimental rocket with liquid or partially metal fuel	
a) materials	50
b) labor	200
c) fuel	50
Total	300
2) manufacture of experimental rocket operating with powder or chemical materials	
a) materials	20
b) labor	80
c) fuel	50
Total	150
3) manufacture of models of airplanes, both nondissemblable and partially dissemblable, moved by rockets operating with liquid, metal or general chemical fuel and oxygen	
a) materials	20
b) labor	30
c) fuel	40
d) Vessel for liquid oxygen	20
Total	110
4) measuring instruments for experiments	
a) thermometers, mercury or toluene	10
b) thermometers and pyrometers, electrical	50
c) manometers	30
d) force meters	30
3) foot pump and bellows	30
f) weights, commercial and apothecary, with balance weights	50
g) devices for measurement of air velocity and flow	
a) materials	10
b) labor	50
h) tools and unforeseen devices	30
Total	290
IV. Drawing room and office supplies:	
1) drawing paper, India ink, writing paper, ink, pencils, etc.	20
2) postage for notifications	15
Total	35
V. Equipments (cabinets, shelves)	80
VI. Special clothing, aprons	30
VII. Trips by members of club	20
VIII. Cleaning of area	20
IX. Various expenditures	65
Total	2,000

16d. Program on Reaction Motors and Interplanetary Voyages in Rocket Section of ANTO, MAI, 1931 /75

work with leader: 92 hr + 6 hr
homework: 92 hr + 6 hr

	w/leader	home
1. Subject and program of lessons. Methods suggested to reach outer space and high flight velocities. Familiarization with literature available on this question.	2 hr	2 hr
2. Main formula for determination of force of reaction of rocket. Effect of 2 spheres repelling each other. Velocities of particles ever more finely ground.	2 hr	2 hr
3. History of development of reaction flight from ancient time to Kibal'chich, 1881 (illustration).	2 hr	2 hr
4. Conclusion of formulas for determination of acceleration of force of gravity at any distance from the earth; work necessary to overcome force of gravity to rise to any altitude. Initial velocities for flight to infinite distance, considering only attraction of the earth. Velocity necessary to circle the earth. Expenditure of fuel and rocket flight speed achieved in medium without gravity according to Tsiolkovskiy.	2 hr	2 hr
5. History of development of reaction flying (continued) from Kibal'chich to experiments of Loren (1911) (illustrations).	2 hr	2 hr
6. Conclusion of formulas for determination of acceleration and secondary stoppage of rocket in medium without gravity, expenditure of fuel for this case.	2 hr	2 hr
7. Determination of exhaust velocity of gases from rocket nozzle. Theoretical indicator diagram of compression in jet pump.	2 hr	2 hr
8. New work on rocket building. Experiments performed with rockets (illustrations).	2 hr	2 hr
9. Plan for Tsander flying rocket. Determination of combustion temperature for petroleum-oxygen rocket, design task for alcohol-oxygen rocket.	2 hr	2 hr
10. Design of rocket nozzle: temperatures, pressures, specific weights, velocities and reaction force for various rocket nozzle cross sections.	2 hr	2 hr
11. Friction on walls. Example: our rocket.	2 hr	2 hr
12. Passage of heat through walls of nozzle and combustion space of rocket. Cooling of walls of our rocket.	2 hr	2 hr
13. Determination of the stresses in walls from temperature difference at individual points and gas pressures. Various types of tanks for fuel and oxygen. Determination of thickness of parts of our rocket.	2 hr	2 hr
13a. History of development of rockets (illustrations).	2 hr	2 hr

13b. Rockets for firework purposes, their system and methods of manufacture (illustrations).	2 hr	2 hr
13c. Continuation. Classification of rockets in general (illustrations).	2 hr	2 hr
14. Gyroscope calculations. Example.	2 hr	2 hr
15. Vertical takeoff of rocket in medium with gravity. Altitude of atmosphere and its resistance.	2 hr	2 hr
16. Inclined takeoff in medium with gravity and with atmosphere.	2 hr	2 hr
17. Work of Oberth: determination of most favorable flight speed.	2 hr	2 hr

16e. Assignments to Students (May-June 1931) /76
Moscow Aviation Institute, Scientific-Technical Society,
Principles of Reaction Movement, Reaction Motors

Lesson No. 1

Time. Lecture 10 hr, consultation 10 hr. Independent work 20 hr.

Theme: The reaction motor for the aircraft.

Purpose: Assignment of theme: study of reaction motor operating with liquid fuel using liquid oxygen as oxidizer.

Plan of Work

1) Overall plan of calculation.
2) Body and rocket nozzle.
3) Pump for gasoline.
4) Pump for liquid oxygen.
5) Pressure difference regulator.
6) Heater and liquid air evaporator.
7) Ignition diagram.

Bibliography

To section 1.

1) Manuscripts of lectures of Engineer Tsander of 9/6/1930.

2) Book "Paths to Space Flight," by Oberth (pp. 261-263 of original in German). Book being translated to Russian and will be published in 1932 by State Scientific and Technical Press.

To section 2.

1) Manuscripts of lectures of Engineer Tsander of 6, 17, 18, 23 and 28/11/1930; 5, 10, 28/12/1930. Furthermore 8, 13/1/1931, 23, 27/3/1931, 2 and 6/4/1931, 19 and 29/5/1931.

2) *Tekhnicheskaya Termodinamika* [Technical Thermodynamics], Mart'yanov, 1924 edition, pp. 119-140.

3) *Tekhnicheskaya Termodinamika* [Technical Thermodynamics], Pio-Ul'skiy, 1930 edition, Gosizdat. Press.

4) *Termodinamika* [Thermodynamics], Planck, 1925 edition, Gosizdat. Press.

5) *Termodinamika* [Thermodynamics], Schule.

6) *Termodinamika* [Thermodynamics], part 1, Yapyk, 1923 edition, Leningrad.

7) *Teploperedacha* [Heat Transfer], Ten-Bosh, 1930 edition, Petroleum Press.

8) *Introduction to Theory of Heat Transfer*, Greber, 1929 edition, Gostekhizdat. Press.

17. List of Slides and Pictures for Lecture "Problems of Interplanetary Voyages," Read on 22 April 1931 by Engineer F. A. Tsander at MOLA

No.	Slide	Picture, book	Page	Drawing
1	+			part of Milky Way
2	+			Milky Way
3	+			Solar System
4	+			comparison of earth, Mars, Mercury and moon
5	+			the planet Mars
6	+			Jupiter
7	+			Saturn
8	+			electric cannon
9	+			principle of rocket flight
10	+			flight of rocket at 100 km /77
11	+			the fate of a cannon ball
12	+			shot around the world
13	+			flight from earth to Mars
14	+			flight from earth to Venus
15	+			Tsiolkovskiy rocket
16	+			first model of Goddard rocket
17	+			model B of Oberth

No.	Slide	Picture, book	Page	Drawing	
18	+				Oberth's large rocket
19		Oberth	5	3	model A of Oberth
20		Oberth	16	14	model D of Oberth
21		Oberth	21	22	model D of Oberth
22	+				experiments with melted metal
23	+				melting points and values of metals
24	+				complex Tsander rocket
25	+				Tsander's lateral rocket
26	+				Tsander's lateral vessel
27	+				period of acceleration of interplanetary ship
28	+				Tsander's airplane
29	+				Melo system motor
30	+				installation of Melo motor on airplane
31	+				gliding descent
32	+				meteorite
33	+				increase in flight speed by flying around planet
34	+				flight around planet in order to increase speed
35	+				parachute descent
36	+				solar mirror
37	+				pressure of light
38	+				interplanetary ship with mirror
39	+				ring with iron dust
40	+				interplanetary greenhouse
41	+				interior of interplanetary ship
42	+				crew in interplanetary ship
43		Rinin	65	90	Loren motor
45		"	64	84-85	Loren motor
46		"	65	86	Loren motor
47		"	66	88	Gorokhov's reaction aircraft
48		"	82	104	reaction cars
49		"	84	106	OS No. 1 reaction motor vehicle
50		"	"	107	detail of OS No. 1 reaction motor vehicle
		"	85	108	diagram of Volkhart and Vollier reaction motor vehicle
51		"	86	110	OS No. 2 reaction motor vehicle
52		"	88	115	OS No. 3 motor vehicle

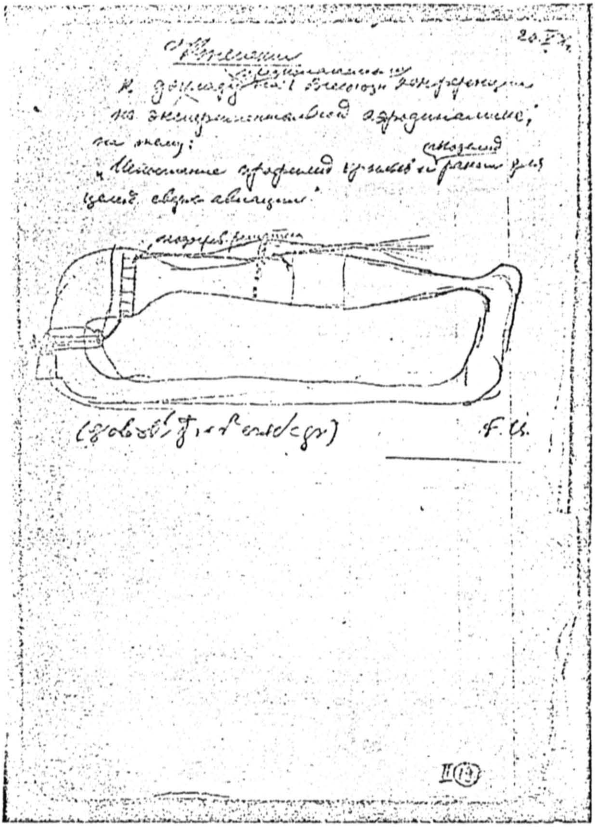


Figure 4. Beginning of Outline of Report "Testing of Wing Profiles and Models of Rockets for Superaviation Purposes," to Be Read at First All-Union Conference on Experimental Aerodynamics (20 May 1931)

18. General Plan of Design of Reaction Motor Operating with Liquid Fuel and Liquid Oxygen Designed for Installation on Airplane /79

1) Selection of fuel, oxidizer and reaction motor system.

2) Selection of airplane system: production or planned airplane.

3) For production airplane: obtaining principal data and drawings of airplane.

4) Determination of required axial pressure of reaction motor jet based on power of motor installed on aircraft and flight speed.

5) Determination of combustion temperature.

6) Determination of jet exhaust velocity, required combustion products flow rate, consumption of fuel and oxidizer per unit time. Temperature of combustion products at exit from nozzle. Cross section of nozzle at exit. Critical velocity of combustion products. Specific weight of combustion products at critical cross section. Area and diameter of critical cross section.

7) Dimensions of combustion chamber; diameter and length of combustion tube.

8) Laying out body and nozzle.

9) Calculation of heat transfer from combustion products to cooling air and determination of gap between shell and combustion tube. Air velocity in this gap.

10) Diameter of fuel jets; selection of fuel overpressure.

11) Planning of pump for gasoline, determination of size.

12) Planning of oxygen pump. Selection of oxygen excess pressure. Diameter of oxygen jets.

13) Design of oxygen heater, velocity in heating tubes, friction in these tubes; heat, required to perform heating, air or water heating. Initial and final water temperatures. Calculation and planning of water cooling system (in case of air cooling, design of ribs for heating).

14) Calculation and planning of pressure difference regulator. Diameter of piston; spring pressure force; rotation angle of regulating valves.

15) Selection of electrical spark source. Required spark size. Other ignition methods.

16) Preparation of general form of device.

17) Construction of installation of device on airplane.

18) Aerodynamic calculation of airplane.

19) Testing of calculations of airplane.

Moscow, 28/10/1931 Composed by F. Tsander

REFERENCES

1. The points indicate three illegible letters followed by a period, looks like "mod" (apparently model).

FROM THE CORRESPONDENCE OF F. A. TSANDER /80

1. Some Materials from Correspondence with Glavnauka [Main Administration for Scientific, Museum and Scientific-Artistic Institutions]

1a. Application to Scientific Department of Glavnauka of 8/10/1926 [1]

To the Scientific-Technical Committee of the All-Russian Council of the National Economy

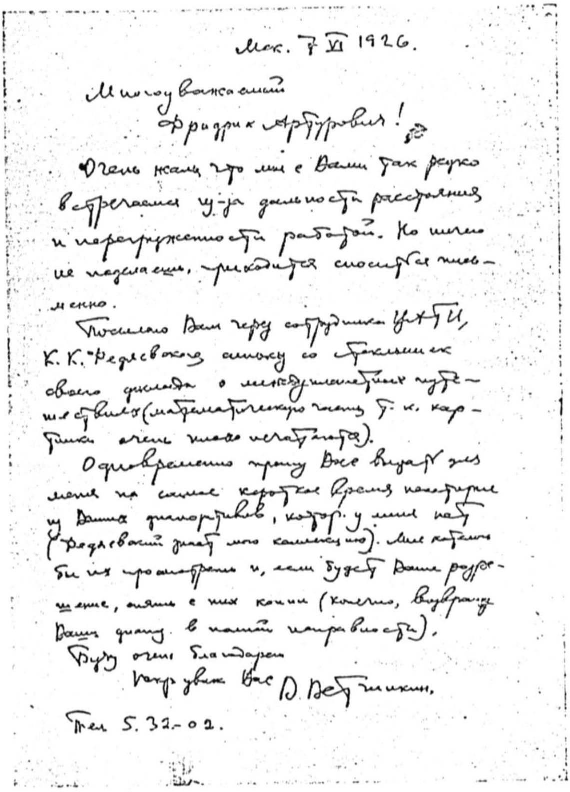
From Tsander, Fridrikh Arturovich,
Engineer-Technologist, age 39,
working at State Aviation Plant No. 4
("Motor")

Application

I enclose herewith several of my scientific and technical works in the area of interplanetary voyages, as well as a description of my planned interplanetary ship, and request that you allocate funds for me to continue this work and prepare scientific material for printing.

Ever since my childhood, I have been interested in this problem; in 1914, I graduated with honor from Riga Polytechnical Institute in its Mechanics Department, and since 1915 have been studying work in the area of interplanetary voyages, while working simultaneously at the plant [2]. Since the beginning of 1919, I have been working at State Aviation Plant No. 4 "Motor," imeni /82
Comrade Frunze in the Technical Bureau, from mid-1922 until mid-1923 I worked at home exclusively on interplanetary voyages, working on a plan for a motor, the spacecraft itself, and on purely scientific problems. Only after expending all of my funds was I forced to return to the plant. I have read public lectures on the theme of interplanetary voyages and on my own works in this area three times in Moscow at the First Moscow State University, in Leningrad, where a debate was held under the chairmanship of Prof. Glazenap, in Kharkov, Saratov, Tula and Ryazan. The first seven lectures were organized by the political administration of the Leningrad military district (PULVO), the last by the Earth Construction Technical School in Moscow, and all were conducted quite successfully. I read one lecture at the Theoretical Section of Moscow Society of Astronomy Enthusiasts (MOLA); the lectures were read in the winter and spring of 1924-1925.

My work was greatly slowed by the fact that, since I did not have sufficient funds to occupy myself exclusively with scientific work, I was forced to work at the plant, and therefore I request that you not turn me down in allocating funds for successful development of this work.



Моск. 7 VI 1926.

Многоуважаемый
Фридрих Артурович!

Очень жаль что мы с Вами так редко встречаемся из-за дальности расстояния и перегруженности работой. Ко многим [illegible], приходится сноситься письменно.

Посылаю Вам через сотрудника ЦАГИ, К. К. Федяевского, оттиск со стенограммы своего доклада о межпланетных путешествиях (математическую часть т. к. картинки очень плохо печатаются).

Одновременно прошу Вас выдать мне на самое короткое время некоторые из Ваших диапозитивов, котор. у меня нет (Федяевский знает мою коллекцию). Мне хотелось бы их просмотреть и, если будет Ваше разрешение, снять с них копии (конечно, [illegible] Ваш [illegible] в нашей [illegible]).

Буду очень благодарен
Искр. уваж. Вас В. Ветчинкин.

Тел. 5.32-02.

Figure 5. Letter of Prof. V. P. Vetchinkin to
F. A. Tsander of 7 June 1926

I have a great quantity of work in the area of interplanetary voyages in rough draft form.

I attach hereto:

1) A review concerning the interplanetary spaceship which I invented, written on 17/7/1922 by the chief of the Production Section of the plant P. Moisheyev and chief engineer of Aviation Plant No. 4 N. Okromeshko.

2) A testimonial of the fact that I worked on my invention, written 15/7/1922 by the Association of Inventors of AIZ [Association of Inventors].

3) Fifty-four sheets of calculations and descriptions in the area of interplanetary voyages written by me, namely:

a) An article: "Flights to Other Planets" -- 10 single pages
b) A report on my new work in the area of interplanetary voyages, 1 double page
c) A description of work and designs, 4 double pages
d) Outline for lectures, 2 single pages /83
e) Calculation of flight of an interplanetary spacecraft in the atmosphere, 14 pages
f) The deflection of meteors by the effects of an electrostatic electricity, 3 double pages
g) The suitability of the acceleration of a rocket flight at the moment when velocity is greatest, 2 double pages
h) Calculation of an interplanetary space rocket (not completed), 9 single pages
i) Determination of the time required for exhaust of combustion products, 8 double pages
k) Beginning of calculations for 20-h.p. motor, 1 single page

Total: 54 pages

4. Seventeen copies with slides.

5. One drawing of the F. Tsander interplanetary spacecraft in three projections.

Moscow, 8 October 1926 F. A. Tsander, Engineer-Technologist

In rough form I also have the following [3]:

1) An article: "Determination of Flight Paths to Other Planets, Required Additional Accelerations and Time Required for Flights."

2) Mutual position of planets during takeoff and arrival; when it is possible to arrive at another planet easily, when it is difficult (not completed).

3) Adjustment of flight trajectory upon approach to planets to assure safe descent at desired location.

4) Change in flight path around the sun due to the influence of the planets. Kinetic energy increment resulting from flight past a planet. Flight past the moon for maximum increase or decrease of flight velocity.

5) The pressure of light on combined mirrors; the production of light pressure directed toward the light source.

6) The usage of fine sheets for flights through interplanetary space.

7) A numerical example of gliding descent from interplanetary space to the earth (not completed).

8) Freefall, gliding descent along simple curves, the zone into which a landing can be made with gliding descent, flight at constant altitude due to kinetic energy during descent from interplanetary space to the earth. /84

9) The temperature of an interplanetary spacecraft resulting from gliding descent to the earth.

10) Altitude of the earth's atmosphere; density, pressure and temperature, chemical composition at various altitudes.

11) Calculation of the flight of an interplanetary airplane in the atmosphere, ascent.

12) Determination of variations of the cost of interplanetary spacecraft with variations in the quantity of solid combustion products.

13) The operation of rockets which exhaust volatile and solid combustion products simultaneously.

14) Calculation of the flight of long-range rockets.

15) Flights to other planets using spheres repelled by the charge of the earth.

16) One lecture from a cycle of 15 lectures to be read.

17) The expenditure of fuel material if oxygen can be taken from the atmosphere.

18) Translation into German of an article by Tsiolkovskiy "Investigation of Universe Space Using Reaction Devices," part II.

19) Translation to Russian from book by Prof. Centnerschwer "The Dissociation of Gases" from German.

20) Abbreviated Russian translation of formulas from book of Prof. Oberth.

Also, I have the following in shorthand in rough form:

1) A great number of calculations for an interplanetary motor with liquid oxygen and petroleum injection, a small 20-100-h.p. model; general and detailed drawings.

2) A large quantity of calculations for an interplanetary airplane.

3) Calculation of flight through interplanetary space using solenoid rings through which electric current flows (movement of the spacecraft occurs due to the effect of solar rays on the iron filings held inside the ring by the current).

4) Calculation of flights through interplanetary space with return to the earth after trips around the planets [4].

8 October [19]26 Tsander

1b. Letter of Scientific Department of Glavnauka to V. P. Vetchinkin, 15/10/1926 /85

The Scientific Department of Glavnauka sends to you with this letter the following materials of comrade Tsander on the problem of interplanetary voyages:

1) Certificate of the Association of Inventors No. 272 of 15/8/1922,

2) Report of P. Moisheyev [5],

3) Ten drawings,

4) Outline of lectures on interplanetary voyages on two sheets,

5) Application of comrade Tsander on two sheets,

6) "The Deflection of Meteors and Deceleration of Meteors by Electrostatic Electric Action Emitted by Interplanetary Ship" on three sheets,

7) "The Suitability of Acceleration of Rocket Flight at Moments When the Flight Speed of the Rocket Is Great" on two sheets,

8) "Determination of the Time of Exhaust of Combustion Products from a Motor Cylinder with Variable Initial and Constant Final Pressures" on nine sheets,

9) "Design of a Rocket for an Interplanetary Spacecraft" on nine sheets,

10) "Flights to Other Planets" on ten sheets,

11) "Description of work on design of motor and rockets" on four sheets,

12) "Report on New Works by Comrade Tsander in the Area of Interplanetary Voyages" on one sheet,

13) "Calculation of the Flight of an Interplanetary Ship in the Atmosphere" on fourteen sheets.

You are requested to make a report on these materials, and return the materials to the Scientific Department of Glavnauka.

Head of Scientific Department: V. Kostytsyn
Head of Secretariat (signature illegible)

1c. Report of V. P. Vetchinkin on Works of F. A. Tsander of 8/2/1927

To the Scientific Department of Glavnauka

The works of F. A. Tsander on the calculation of interplanetary voyages and the plan for an interplanetary spacecraft are doubtless among the finest in the world on this problem.

K. E. Tsiolkovskiy over 24 years ago indicated the only possible method of reaching altitudes beyond the atmosphere -- flight with rockets. He also /86 proved the possibility of achieving cosmic speeds -- over 11 km/sec -- in this way, and the possibility of penetrating the atmosphere using only existing fuels. However, he gave no design solution to the problem of construction of a rocket, and the lift method which he suggested -- overcoming the force of gravity with the force of the rocket -- is not completely rational.

Tsiolkovskiy's footsteps were followed by foreign scientists -- Espo-peltri, Goddard, Oberth and Val'ye, who repeated the works of Tsiolkovskiy and moved them forward both theoretically (Oberth) and experimentally (Goddard).

An essentially new facet was contributed to this difficult problem by F. A. Tsander by his three suggestions:

1) that the rocket be equipped with wings for flight in the atmosphere and for gliding descent, allowing the rocket to be made much less strong, using low accelerations ($j < g/2$) in place of the high accelerations of Tsiolkovskiy ($j > 3$ g), and providing a considerable fuel economy, decelerating the rocket only to 8 km/sec, not to zero;

2) in the lower layers of the atmosphere, where the efficiency of the rocket is very low, that motors be used, although not ordinary motors, but rather special light motors capable of operating for one half hour, only until the rarefied layers of the air are reached, in which time flight is powered by the rocket;

3) that solid fuels be burned in the rockets in addition to the ordinary fuel in order to increase the combustion temperature, using parts of the rocket itself no longer required as solid fuel.

In addition to this, he performed calculations of flight and descent and design solutions of the main problems of construction of the rocket, for example a calculation of nozzles and nozzle cooling, which is apparently the primary obstacle to rocket flight.

Unfortunately, F. A. Tsander only read reports on his works, and did not print them. Incidentally, W. Hohman in 1925 printed a work in which he also suggests winged flight and gliding descent. It is possible that this work was influenced by rumors of the reports of F. A. Tsander performed in the winter of 1924-25.

Thus, due to the impossibility of printing his work, we are gradually losing our priority even in those cases when the USSR doubtless has priority.

On this basis, I consider it quite necessary that F. A. Tsander be given the right to prepare and print his work, individual chapters of which have been presented to Glavnauka, as soon as possible.

8 February 1927 V. Vetchinkin

1d. Application of F. A. Tsander to the Scientific Department of Glavnauka of 7/3/1927 /87

Copy

To the Scientific Department of Glavnauka

From Tsander, Fridrikh Arturovich,
Engineer-Technologist, Designer of
Experimental Motor Department of
Aviation Trust

Application

I refer to your memorandum of 15/10/1926 No. 141930, sent by Prof. V. P. Vetchinkin concerning a report on my works in the area of interplanetary voyages, which I return, on the request of Prof. Vetchinkin, along with samples of my works together with Prof. Vetchinkin's report concerning them.

I also present, on the advice of Prof. Vetchinkin, an outline of a book which I propose for publication on the problem of interplanetary voyages, on ten sheets [6].

My request for support of my work in this area foresees two possibilities: either

1. I request that you send me a memorandum for the Administration of the Air Force (UVVS) suggesting that I be allowed to work at TsAGI or the aviation trust exclusively in the area of interplanetary voyages, special high altitude aircraft, motors and rockets for them; or

2. I request that you make it possible for me to prepare my book on interplanetary voyages of approximately 500 pages for print, with the stipulation that I report regularly on the course of my work to those persons whom Glavnauka shall suggest.

The following work has been completed on my book: almost all necessary formulas have been concluded. Calculations have been performed for some of the numerical examples, many calculations and constructions have been completed. The main rough draft has been written in shorthand, and makes up approximately 1,000 large pages.

Transcribed calculations: approximately 150 pages -- 12 printer's sheets.

Still to be transcribed: approximately 150-200 pages -- 12-16 printer's sheets.

Remaining to be calculated, numerical examples: approximately 120 pages -- 10 printer's sheets.

Theoretical calculations still not written: 50 pages -- 4 printer's sheets.

The book in all will contain: approximately 470-520 pages or 40-44 printed sheets.

I hope to complete my book in approximately one year if I will be given the possibility to work exclusively on the book.

Approximately 5,000-6,000 men are working in the area of aviation in the USSR. If even one man can be given the possibility to work exclusively in the area of special high altitude and high-speed flights and flights to other planets, this research work will occupy only one five-thousandth the volume of the work in the area of ordinary aviation, which can be considered quite permissible. /88

Moscow, 7/3/1927 With greatest respect F. A. Tsander

Attachments.

1) Report of Prof. V. P. Vetchinkin of 8/2/this year on my work on one page.

2) Outline of my book which I propose to print under the title "Flights to Other Planets; the First Step into Limitless Universe Space, the Theory of Interplanetary Voyages ..," on ten pages.

3) Affirmation of Association of Inventors No. 272 of 15/7/1922.

4) Report of P. A. Moisheyev concerning my invention of 17/7/1922.

5) Eleven drawings.

6) Outline for lectures on interplanetary voyages, on two pages.

7) My application on two pages, of 8/10/1926.

8) "The Deflection of Meteors and Deceleration of Meteors by the Effects of Electrostatic Electricity Emitted by an Interplanetary Spaceship," on three pages.

9) "The Suitability of the Acceleration of Rocket Flight at Moments When the Speed of the Rocket Is High," on two pages.

10) "Determination of the Time of Exhaust of Combustion Products from the Cylinder of a Motor with Variable Initial and Constant Final Pressures," on nine pages.

11) "Design of an Interplanetary Spaceship Rocket," on nine pages.

12) "Flights to Other Planets," on ten pages.

13) "Description of Work on the Design of a Motor and Rocket," on four pages.

14) A report on my new works in the area of interplanetary voyages, one page.

15) Calculation of the flight of an interplanetary spacecraft in the atmosphere on fourteen pages.

1e. Letter from Scientific Department of Glavnauka to F. A. Tsander of 7/7/1927 /89

As the result of your applications to the Scientific Department of the People's Comissiariat for Education of 8/10/1926 [7], of 7/3/1927 and the third application undated, Glavnauka hereby sends to you for information the report of the Scientific Department on the content of your works [8].

Glavnauka advises you that it will not be possible to satisfy your request for cooperation in the printing of your work on problems of interplanetary voyages. As concerns your desire that we send a reference to UVVS, if you would obtain from UVVS a request that you be given a position and allowed to work in one of the institutions which you indicate in your application of 7/3/1927, Glavnauka would support such a request, considering that you are a specialist -- a theoretician on problems of rocket flights.

Enclosures: materials on 69 sheets and drawings.

Head of Scientific Department: V. T....
Secretary of Administration: Lushe...

2. Letter of F. A. Tsander to K. Ye. Voroshilov of 9/6/1927

Dear comrade Voroshilov!

Desiring to improve the arms of the Red Air Force, I hereby request you to allow me to perform work at the plant or at TsAGI in the area of interplanetary voyages, which should now be of tremendous aid to military affairs, namely by allowing me to work on a special (oxygen-petroleum) motor for high altitude, high-speed airplanes and on long-distance rockets.

Moscow, 9/6/27

F. A. Tsander,
Engineer of Aviation Trust

3. Application of F. A. Tsander to Prof. S. A. Chaplygin of 10/9/1927 /90

Copy in State Scientific Council
Chairman of TsAGI College, Prof. Chaplygin

From Engineer Tsander, Fridrikh Arturovich, designer of Central Design Bureau, Experimental-Motor Department, Central Design Bureau, OMO Aviation Trust

Application

Having worked since 1917, i.e., for ten years, in the area of interplanetary voyages [9], I hereby request that you include me, if possible, as a colleague of TsAGI and assign me to work in the area of preparation for interplanetary voyages. I have written approximately 2,000 pages of shorthand on this area in rough draft and have transcribed a portion of this work. Furthermore, I have 70% completed drawings and design calculations for a petroleum-oxygen motor of a special system and have made a number of drawings and calculations concerning an airplane equipped with this motor and a rocket for flights in the higher layers of the atmosphere and beyond.

I have applied to Glavnauka with a request for support for my work, sending along several of my works. Prof. V. P. Vetchinkin, to whom Glavnauka sent my works for evaluation, gave a favorable answer; Glavnauka also gave me its evaluation, saying at the same time that it could support me if I applied to TsAGI requesting that I be made a colleague for work on interplanetary problems.

I also sent a letter to Glavvoyenmor, comrade Voroshilov, in which I, desiring to increase the strength of the Red Air Force, due to the great importance which the first work in the area of interplanetary voyages should have for military affairs, requested that I be allowed to work at TsAGI or in the aviation trust exclusively in this area. In answer to this letter, I was called by comrade S. S. Kamenev, comrade Voroshilov's deputy, who questioned me concerning my work, both completed and proposed, in a half-hour telephone conversation.

I am certain that in case of a favorable reply by TsAGI to this question the military department will probably provide the funds necessary for one year, approximately 3,000 rubles for my salary and approximately 7,000 rubles for experiments relating to the petroleum-oxygen motor and to rockets, or a total of 10,000 rubles (ten thousand rubles).

Glavnauka has requested that it receive a copy of this application, after which it will contact TsAGI; I am sending another copy to the military department to comrade S. S. Kamenev with a request also for his own conclusion. /91

Awaiting your favorable answer, which would move scientific work in the finest area of human knowledge forward, increasing at the same time the military might of our country, I remain yours truly

Moscow, 10/9/1927 F. Tsander, Engineer

Copies to Glavnauka and military department

4. Application of F. A. Tsander to A. V. Lunacharskiy of 14/9/1927

People's Commissiariat for Education, Anatoliy Vasil'yevich Lunacharskiy

From Engineer Tsander, Fridrikh Arturovich, Central Design Bureau of Experimental-Motor Department of Aviation Trust, attached to State Aviation Plant No. 4 "Motor"

Application [10]

I have sent in an application to the Board of TsAGI with a request to make me a colleague of TsAGI and allow me to work in the area of preparation for interplanetary voyages. The State Scientific Council, to which I sent several of my scientific works in this area for evaluation, has answered me that it might be able to help me if I sent an application to TsAGI with a request that I be made a colleague. I also sent comrade Voroshilov a letter requesting that he support my work in this area, due to their importance for military affairs. In response to this letter, I was called in to see his deputy, comrade S. S. Kamenev, who promised after a half-hour discussion to report to comrade Voroshilov concerning my work. The military department will probably allocate 10,000 rubles which I have requested for work during the first year. I have sent Glavnauka a copy of my application to TsAGI, and I hereby request your cooperation in the form of a favorable memorandum concerning work in the area of preparation for interplanetary voyages.

Moscow, 14/9/27 F. A. Tsander

5. Letter of F. A. Tsander to Ye. V. Lutsenko of 4/12/1929 /92

Dear Ye. V. Lutsenko!

In answer to your letter of 25 October of this year I would like hereby to inform you what has happened recently in my life [11].

The side requests have changed, and I have been given the possibility to perform experiments on reaction motors; autumn of last year, I prepared a number of alloys of light metals containing magnesium, as well as several pulverizers for these alloys, having in mind the future utilization of these alloys as partial fuel in a reaction motor. These experiments have not yet been completed. According to the idea which I first published in 1924, rockets must be constructed of these light alloys and during flight parts made of these light alloys must be used as partial fuel, since it is impossible to take a sufficient quantity of liquid fuel to provide for flights into interplanetary space.

The Commission on Scientific Aeronautics of the First Moscow State University, where I read a report concerning these experiments, has expressed the desire that I construct a rocket for meteorological purposes, to fly to a height of 20-40 km; it has been decided that the rocket will be equipped with a parachute to be folded to take up a space the size of a man's fist, plus meteorological instruments placed in a cylinder approximately 10 cm in diameter and 20 cm high. The total weight of the parachute will be about 100 g, the instruments -- about 300-400 g. The rocket is to replace the pilot balloons which are now used to investigate the upper layers of the atmosphere.

Due to this work, in which I was strongly interested, I became over-fatigued, working at every free moment at home. I became quite ill with a /93 sore throat and had the misfortune to lose my three-year-old son due to complications from scarletina; then I myself became ill with scarletina and almost died also. After this, I was some time in recuperation.

At the present time I am back at work, constructing an experimental reaction motor in which the initial construction is a gasoline soldering torch; I intend to use it to study extremely important temperature conditions in a rocket, then a rocket operating partially with metallic fuel, and a rocket capable of flying in the air by drawing in outside air [12]. It will probably be tested on a sled or a boat, or on a three-wheeled motorcycle.

Due to all of this work and misfortune, my works on the publication of my book on interplanetary affairs, as well as my lectures, for which I could not fully prepare myself, have lain dormant.

I prepared a campaign to attract the attention of Osoaviakhim to astronautics at Mososoaviakhim approximately two years ago, thinking to give an article to the journal *Samolet*, which was being published at that time in Moscow. I thought also to turn in the design of a high altitude rocket which could be easily constructed so that the departments of Osoaviakhim could use it as an additional design; however, due to insufficient free time and the factors mentioned above, I have not yet done this; however, I would be glad if you would take upon yourself this task in the publication of your aviation collection. For the manufacture of experimental high altitude rockets, you may also use the book of Prof. Rinin: "Interplanetary Voyages" -- "Rockets" and announce competition for:

1) the highest flying rocket;

2) the longest range rocket;

3) flights of model airplanes using rocket motors, etc.

I am convinced that mankind will gain greatly from an extension of his knowledge in the area of rocket construction, and can only welcome your initiative. For a start you might, for example, cover but a single city, carefully observing fire safety measures, giving our experimental comrades all necessary help in avoiding fires. The tremendous uplift which would be connected with a flight in interplanetary space and the unknown world of the other planets will then carry the matter.

I have straightened everything out with AIIZ. It seems that the organ- /94
izers of the exhibition fell in debt to the housing trust and folded.

I enclose a photograph of myself as requested in your letter.

Respectfully,

F. A. Tsander

Moscow 23, Medovyy Pereulok
Dom 12, Kvartira 15
4 December 1929

6. Letter of N. K. Fedorenkov to F. A. Tsander

6a. Letter Written December 1930 [13]

Dear Fridrikh Arturovich!

If you would like to become chairman of the Society for the Study of Interplanetary Voyages, attempt to form such a society, attracting those whom you know to be interested in this problem to work in the society, since the interest among the population of Moscow is great, as indicated by the letters which I have received in connection with my announcement in *Vechernyaya Moskva* of 12/10/11 this year. The interest of the masses must be attracted into the society, which will construct the first interplanetary spaceship in the immediate future.

If not, answer immediately.

My address is: Moscow 26, Varshavskoye Shosse, Vtoroy Zelenogorskiy Pereulok, Dom 6, Kvartira 1

(Signed) With comradely greetings,
N. K. Fedorenkov

6b. Letter of 12/5/1931

Dear Fridrikh Arturovich!

On 10 May I visited the administration of MOLA, where the question was raised of the creation of a section in MOLA. In the discussion which developed, in which more than half of the administration participated, the fact became quite clear that the administration of the society did not want to create a section, since they could not provide the required control of the section from the technical standpoint. However, they considered the creation of such a section expedient and will send their opinion to the Central Council of Osoaviakhim. This lack of enthusiasm by the administration of MOLA is explained by an improper attitude to your report, which was not understood by most of those present at the MOLA meeting of 22 April.

Due to all the above, I suggest that you contact MAI and VAI and invite them to join with you in creating a society similar to that which existed in 1924. On the other hand, we should first get in contact with Osoaviakhim. The position which has arisen requires great effort and energy for the creation of the Society for Study of Interplanetary Voyages with centers in Moscow and in Leningrad, and with departments throughout the Soviet Union.

Long live the Society for the Study of Interplanetary Voyages!

Long live the rocket -- the apparatus which will allow us to conquer the universe!

Long live the advance guard of man -- those such as K. E. Tsiolkovskiy and others who have shown us the way to the unknown reaches!

12/5/31 Moscow

With comradely greeting,

N. Federenkov

REFERENCES

1. The text of the application which the author of these lines has at her disposal is addressed to the Scientific-Technical Committee of the VSNKh. However, analysis of a number of materials from the archives shows that a similar text was sent to the Scientific Department of Glavnauka, as we can see from the fact that its contents are presented in a review of Prof. V. I. Yakovlev contained in the archives of F. A. Tsander.

All materials of Tsander were first sent to Prof. V. P. Vetchinkin, who on 8 February 1927 wrote a positive response (the text of the review and its manuscript were first published in 1961 in Tsander's book "*Problema Poleta* ... on pp. 37-40). However the materials of Tsander were then sent for a second appraisal to another reviewer -- Prof. V. I. Yakovlev, who, bypassing almost all the problems touched upon in Vetchinkin's review and turning particular attention to Tsander's suggestion for the usage of solar energy, calling it "completely fantastic," responded with the following conclusion:

"1. In Engineer Tsander we doubtless have a man deeply interested in the problem of interplanetary voyages and a man who has spent a great deal of labor in the theoretical development of various problems in this area."

"2. Many of Tsander's works have no scientific significance."

"3. If Engineer Tsander will approach the administration of the Air Force (UVVS) with a request that he be given a job and allowed to continue his work at TsAGI [Central Aerohydrodynamic Institute imeni N. Ye. Zhukovskiy] or the aviation trust, Glavnauka could support such a request, i.e., the work of Engineer Tsander as a specialist in the area of the theory of rocket flights might be useful to TsAGI or the aviation trust."

"4. There is no foundation for cooperating with Engineer Tsander in printing his large monograph of up to 44 printer's sheets, which will doubtless consist primarily of pseudoscientific material."

"5. It should be suggested to Engineer Tsander that he reduce the volume of the book which he proposes to print to approximately 6-8 sheets in order to outline the contemporary state of the problem of interplanetary voyages."

"6. If Engineer Tsander will present a manuscript of this work, it could be printed, but only under the editorship of some well known specialist in the area of physics or astronomy."

2. Concerning the date of the beginning of Tsander's work in the area of interplanetary voyages, see the article "From the Editor-Compositor" (beginning of this book).
3. This portion was later copied by Tsander's wife from the manuscript of an application sent by Tsander to Glavnauka, and checked by Tsander personally, which is indicated by his corrections.
4. Prof. Yakovlev confirmed in his review that Tsander listed 20 works in this application, three of which were translated works in rough draft and four of which were at that time in shorthand.
5. The original has a slightly different name, "Mansheyev," but analysis of the materials of the archives shows that this is simply a misreading of the name "Moisheyev."

6. This outline was printed in the collection of Tsander's work of 1961 (F. A. Tsander, *Problema Poleta ...*, pp. 444-455).
7. In the original, the date 8/10/1927 is erroneously given. Since the stamp shows a date of 7 July 1927, the application could not have been made after this date.
8. Having in mind the report of Prof. V. I. Yakovlev.
9. See [2] above.
10. Printed from a copy made by Tsander's widow. Another copy was given to GIRD in 1933, as number 55.
11. In this letter to Tsander of 25 October 1929, the secretary of the Aviation Section of Zakosoaviakhim, Ye. V. Lutsenko, reported to Tsander concerning his propaganda activity in the area of rocket technology and the preparation for publication in the Georgian language of an aviation collection, in which it was intended that problems relating to space flights would also be discussed. After reading in Tsander's autobiography published in 1929 by Rinin that Tsander was preparing a book of approximately 500 pages, which would contain his calculations in the area of interplanetary voyages, and that he planned to read lectures on interplanetary voyages at the Academy of the Air Force, Lutsenko became interested and in his letter to Tsander requested that information on his unpublished works be supplied for publication in the aviation collection. Furthermore, he requested that Tsander send a photographic portrait. At the same time, he expressed his desire to acquire an album of the International Exhibition on Interplanetary Voyages organized in 1927 by members of AIIZ, and also discussed with Tsander the problem of the timeliness of a campaign to attract the attention of Osoaviakhim to astronautics -- the organization of a special subsection, development of rocket modeling, etc.
12. Tsander had in mind here the OR-1 motor. The material wealth of Tsander was so modest that he did not have construction material for the construction of reaction apparatus. In seeking such materials, he found a construction most similar to be used in the construction of a reaction motor. This construction (a soldering torch) contained the greatest number of elements which could be used under the conditions.
13. The precise date of this letter is unknown, since it was not placed on the letter and the envelope was not saved. It can only be affirmed that it was written in December of 1930, after 12/10/11, since the announcement mentioned in the letter was published 12/12/1930

APPENDIX /95

Bibliography of Printed Works of F. A. Tsander [1]

1. "Flights to Other Planets (One Variant)," *Tekhnika i Zhizn'*, No. 13, p. 15, 1924; *Problema Poleta pri Pomoshchi Raketnykh Apparatov* [The Problem of Flight Using Rocket Apparatus], 0. 20, Moscow, Oborongiz. Press, 1947; "The Problem of Flight Using Reaction Apparatus," *Mezhplanetnyye Polety* [Interplanetary Flights], p. 267, Moscow, Oborongiz. Press, 1961; *Pionery Raketnoy Tekhniki* [Pioneers of Rocket Technology], p. 259, Moscow, Nauka Press, 1964. Manuscript, 7-11/12/1923.

2. "Table of Numbers of Teeth of Gear Drive Distributor Mechanism with Internal Mesh for Radial Engines," [2], *Tekhnika Vozdushnogo Flota*, No. 5, 1930.
3. "Reaction Motors and Their Combination with Ordinary Internal Combustion Motors," *Samolet*, No. 1, 1932; *Problema* ..., p. 21, 1947; *Problema* ..., p. 156, 1961 (in these latter two books, the article was republished under the title "Reaction Motors").
4. *Problema Poleta pri Pomoshchi Reaktivnykh Apparatov*, ONTI NKTP USSR, Moscow, State Aviation and Motor Vehicle Press, 1932; *Problema* ..., p. 30, 1947; *Problema* ..., p. 76, 1961; *Pionery* ..., p. 404, 1964.
5. "Thermal Calculation of Rocket Motor Using Liquid Fuel," *Raketnaya Tekhnika*No. 1, 1936; *Problema* ..., p. 126, 1947; *Problema* ..., p. 161, 1961; *Pionery* ..., p. 360, 1964.
6. "Reaction Motors Operating with Materials Producing Not Only Volatile, But Also Solid Combustion Products," *Raketnaya Tekhnika*, No. 1, 1936; *Problema* ..., p. 174, 1947; *Problema* ..., p. 223, 1961; *Pionery* ..., p. 482, 1964.

In the first three sources, this work was published under the title "Usage of Metallic Fuel in Rocket Motors." On the first page of the manuscript in the archives of F. A. Tsander of the article "Design of Rockets Ejecting Volatile and Solid Combustion Products from Their Nozzles Simultaneously, or Materials in General" there are two dates: 7/5/1928 and 27/9/1924, the latter of which precedes the short inscription in shorthand. /96

7. "Description of the F. A. Tsander Interplanetary Spacecraft," *Raketnaya Tekhnika*, No. 5, 1937; *Problema* ..., p. 24, 1947; *Problema* ..., p. 280, 1961; *Pionery* ..., p. 271, 1964.

In the first two publications, this work was published under the title "Design of a Long-range Rocket," while in the collection *Raketnaya Tekhnika* it was included by the editor in the article "Problems of Construction of a Rocket Using Metal Fuel." A variant of this work with a patent formula by Tsander was sent as an application to the Committee for Inventions in 1924.

8. "Thermal Calculation of a Liquid Fuel Rocket Motor," (article 2), *Raketnaya Tekhnika*, No. 5, 1937; *Problema* ..., p. 155, 1947; *Problema* ..., p. 188, 1961; *Pionery* ..., p. 387, 1964; manuscript 12/1-17/1/1924.

See [1] to "Outline of Lecture on My Interplanetary Spacecraft," read at the Theoretical Section of MOLA."

9. "Problems of the Design of a Rocket Using Metallic Fuel," *Raketnaya Tekhnika*, No. 5, 1937; *Problema* ..., p. 195, 1947; *Problema* ..., p. 242, 1961.

M. K. Tikhonravov has indicated that this article in preparation for press was made up of several manuscripts of Tsander, most of which were written in 1928 (*Problema* ..., p. 47, 1947).

10. "Comparison of Fuel Expenditure for the Case When Oxygen Is Taken from the Atmosphere and for the Case When It Is Stored in a Rocket," *Raketnaya Tekhnika*, No. 5, 1937; *Problema* ..., p. 216, 1947; *Problema* ..., p. 261, 1961.
11. "The Problems of Superaviation and Tasks in Preparation for Interplanetary Voyages," *Problema* ..., p. 115, 1947; *Problema* ..., p. 436, 1961.
12. "Flights to Other Planets," (article 2), *Problema* ..., p. 222, 1947; *Problema* ..., p. 271, 1961; *Pionery* ..., p. 263, 1964.

This work is one variant of an article published in 1924. In one of his lists of works, Tsander lists this article as the first article, rather than the second.

13. "Flights to Other Planets (The Theory of Interplanetary Voyages)," *Problema* ..., pp. 285-360, 1961; *Pionery* ..., pp. 277-359, 1964.

In this large work, Tsander combined several of his works first published in various earlier years.

The first work published was "The Suitability of Acceleration of the Flight of an Interplanetary Spacecraft by the Operation of a Rocket at Times When the Flight Velocity Is High." (*Problema* ..., p. 231, 1947; *Problema* ..., p. 348, 1961; *Pionery* ..., p. 345, 1964). The archives of F. A. Tsander contain a manuscript of this article. Its first part, carrying dates in 1925, was first published in 1947; the second part, carrying dates in 1929, was first published in 1964. Most of the works combined under these titles were first published in 1961. (*Problema Poleta* ..., p. 285, sections 1-7, 9, 1961), while some were published for the first time in 1964. (*Pionery* ..., pp. 311, 312, 328, 1964). The manuscripts of these works in the archives of F. A. Tsander bear dates primarily in March-April 1924; the manuscripts corresponding to sections 1 and 9 in the 1961 edition carry dates in 1925. In the 1961 publication the titles were changed by the editor, while in the 1964 edition they were left in the original form as written by Tsander.

14. "Design of the OR-1 Experimental Rocket Motor," *Problema* ..., p. 206, 1961.
15. "The Usage of the Pressure of Light for Flights in Interplanetary Space," *Problema* ..., p. 361, 1961.
16. "Calculation of the Flight of Interplanetary Spacecraft in the Earth's Atmosphere (Descent)," *Problema* ..., p. 382, 1961; manuscript, 14 pages with dates of 30/1/1924-27/2/1924 and six pages with dates in 1925. /97
17. "Calculation of the Flight of Interplanetary Spacecraft in the Atmosphere (Ascent)," *Problema* ..., p. 415, 1961.
18. "The Temperature of an Interplanetary Spacecraft During Gliding Descent to the Earth," *Problema* ..., p. 424, 1961.
19. "The Deflection of Meteors and Deceleration Meteors by the Effects of Electrostatic Electricity Emitted by an Interplanetary Spacecraft," *Problema* ..., p. 429, 1961. Manuscript 26/6-9/7/1925.

Compiled by A. F. Tsander

REFERENCES

1. In this bibliography, the works are arranged in chronological order of their publication. In those cases when the archives of F. A. Tsander contain manuscript copies of published works, this is indicated with the date of the manuscript. It should be noted that Tsander ordinarily wrote his works in shorthand, then transcribed them later. Therefore, as a rule, the dates of completion of work should be considered earlier than those noted on the manuscripts. Some headings in the articles of Tsander in preceding publications have been changed by the editors. In the case of sharp differences, we will note these differences.
2. In an appendix to an accounting card of 18/2/1930, Tsander also mentions the article "Determination of Cutting Angle for a Cutting Mill with Inset Teeth," *Zavodskoy Byulleten'*, No. 4.

Translated for the National Aeronautics and Space Administration under Contract No. NASw-1695 by Techtran Corporation, P.O. Box 729, Glen Burnie, Md. 21061

NASA-Langley, 1969 —— 34 F-541