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GUIDO VON PIRQUET
AUSTRIAN PIONEER OF ASTRONAUTICS[+]

Fritz Sykora (Austria)[++]

INTRODUCTION

If you look under the heading "Rockets" in the Encyclopaedia Britannica, you will find in the History sub-section that a third of the early pioneers of astronautics in the 1920s and 1930s came from Austria-Hungary.[1] Fritz, the director of the former Rocket Museum in Stuttgart, once observed that it seemed then as if Austria-Hungary had a monopoly on rocketry. Heinz Garthmann, a German rocket expert, declared in a lecture that at that time the subject might well have been called Austro-nautics instead of Astronautics.

Let us remember first of all, Hermann Oberth, the founder of modern rocket engineering; he was born at Hermannstadt in Austria-Hungary. Others who ought to be mentioned are: Max Valier, Hans Hoefft, Guido von Pirquet, Hermann Potocnik--who became well-known under the pseudonym Noordung--Friedrich Schmiedl, Eugene Sänger, and last but not least Theodore von Kármán. Franz Abdon Ulinsky should also be mentioned, for, although his projects were to some extent impractical, he was after all the first to suggest electronic propulsion, where the energy needed is derived from solar energy.

BIOGRAPHY OF GUIDO VON PIRQUET

Guido von Pirquet was born on March 30, 1889, at Hirschstetten castle, the son of Peter (Baron) Pirquet von Cesenatico. (Birschstetten, at that time a little village near Vienna, is now part of the city proper.) His brother Clemens von Pirquet is particularly worthy of mention since as a physician and professor at the University of Vienna, he gained a world-wide reputation for his achievements in pediatrics and

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[+] Presented at the Fourth History Symposium of the International Academy of Astronautics, Constance, German Federal Republic, October 1970.

[++] Consultant Engineer, Waagner-Biro AG, Vienna, Austria.

research into allergies and tuberculosis. Guido von Pirquet lived at Hirschstetten castle until 1952, when he moved with his wife Frieda (née Pramer), whom he had married in 1922, to his apartment in Vienna. There he remained for the rest of his life. He died on April 17, 1966. Figure 1 shows Guido von Pirquet at home when he was about 80 years old.

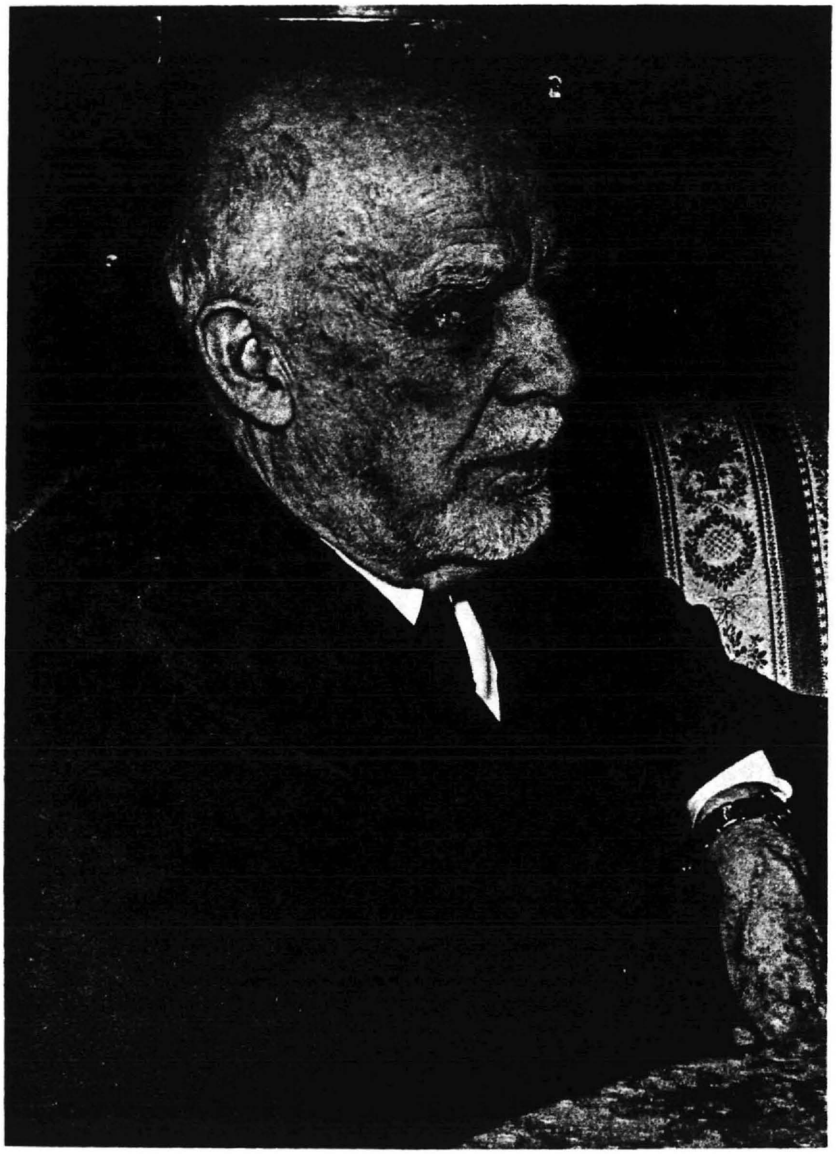


Fig. 1

From 1898 to 1903 Guido von Pirquet studied mechanical engineering at the Technische Hochscule (Technical Institute) in Vienna and Graz. In later life he returned twice to his studies at the University. Between 1931 and 1932 he studied physical chemistry and mathematics at the Technische Hochscule, and, between 1952-1956, pre-history and the history of science at the University of Vienna. This alone shows the breadth of his interests. In fact,his technical works and studies were not confined solely to rocketry and astronautics, they also included new studies in power engineering that dealt with solar and tidal power stations. He made several inventions and served in 1926 as chairman of the Technical Testing Committee of the "Österreichischer Erfinderverband" (Austrian Society of Inventors).[2]

PIRQUET'S EARLY WORKS ON ROCKETRY AND ASTRONAUTICS

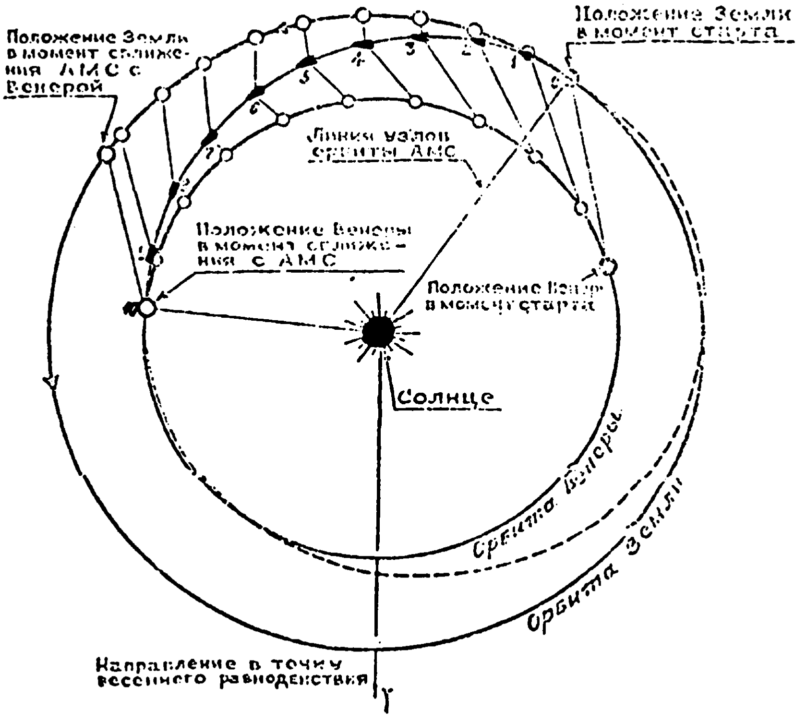
As is generally known, Guido von Pirquet gained a world-wide reputation for his pioneering works on rocketry and astronautics. With specialized knowledge of thermodynamics, ballistics, and, as he said himself, a "great but unsatisfied love for astronomy," in 1926 he joined a committee which founded the "Wissenschaftcliche Gesellschaft für Hönenforschung" (Scientific Society for Exploration of the Atmosphere). He soon became the secretary of this society, and started extensive studies that led Willy Ley to invite him to contribute to his book Die Möglichkeit der Weltraumfahrt (The Possibility of Space Flight)--a book on which most important experts of that time cooperated.[3] Chapters were contributed by Willy Ley, Karl Debus, Hermann Oberth, Franz von Hoefft, Walter Hohmann, Guido von Pirquet and Friedrich Wilhelm Sander.

Pirquet's early reputation was established when his conclusions were mentioned in the chapters written by Oberth, Hoefft and Hohmann. Pirquet himself authored the chapter "Die ungangbaren Wege zur Realisierung der Weltraumschiffahrt" (Ways in which space travel will not be realized) which was, of course, a very thankless task. He provided general view of the state of astronautics at that time and, by means of a simple calculation, demonstrated the advantages of a hyperbolic route which--from the energy point of view--he found preferable to a parabolic one with a subsequent course correction. Then Pirquet described the various impracticable projects: the shot to the moon as described in the book by Jules Verne, the electromagnetic gun, and pneumatic acceleration in a tunnel as devised by Drouet and Ulinsky's project. The idea of electronic rocket propulsion derived from solar energy made its first appearance here. At the end of his chapter, Pirquet developed a research program subdivided into several stages: first, ascent to a height of some hundred or two hundred kilometers, then a ballistic flight over a range of 300 km or more above the Earth's surface; next, a flight to the Moon; and finally, manned interplanetary space travel. Pirquet emphasized that the reason for this detailed description of the impracticable projects thereby separated the scientifically justified efforts from the unjustified ones.

THE ROUTE TO VENUS

Though counted at this time among the most famous rocket pioneers, nevertheless, Pirquet's most important and ingenius work was certainly the series of articles, entitled "Fahrtrouten" (routes for space travel) which he published in the journal Die Rakete between May 1923 and April 1929. Hailed as the most noteworthy of the year in astronautics, these articles dealt with the possibility of realizing manned interplanetary space flight.[4] Two results are of special importance: First the route to Venus calculated by Pirquet was in fact followed by the first Russian rocket to Venus, launched on February 2, 1969.

Figure 2 shows the diagram of the route to Venus printed in Pravda (February 26, 1961); Figure 3, which is the diagram by Pirquet himself, contains his proposal of 1928.



Движение автоматической межпланетной станции относительно Солнца (в проекции на плоскость орбиты Земли).

Fig. 2

One can see for himself the close correlation of these trajectories. The outer ellipse in Figure 3 represents the orbit of the Earth, the inner ellipse the orbit of Venus. Point D marks the position of the Earth at the time of the launch, while point O shows the position of Venus at the same moment. The alternate dashes and dots represent the path of the rocket. The corresponding positions of the Earth, Venus and the rocket are marked at intervals of ten days. One can see that after a flight of 97 days the rocket meets Venus at point Z. Also shown are the velocity triangles, the triangle for the start from the orbit of the Earth, as well as the triangle for the arrival in the orbit of Venus. At the start of the journey the velocity of the Earth is 29.8 km/sec, the required velocity of the rocket 26.8 km/sec; the vector of the difference in velocity is 4.2 km/sec. Upon arriving at Venus the velocity of the rocket is 37.4 km/sec and the velocity of Venus 35.1 km/sec. The vector of the difference in velocity--the gravitational field of Venus aside--is 3.6 km/sec. To realize the importance of this graph one must bear in mind the state of rocketry and astronautics at that time.

Considering interplanetary routes, first of all Walter Hohmann's book Die Erreichbarkeit der Himmelskorper (The Possibility of Reaching the Stars), should be mentioned.[5] In this book Hohmann discussed three kinds of interplanetary routes contained in Figure 4, drawn by Pirquet himself. The outer and inner circles represent the orbits of two planets with the Sun as center. Hohmann discussed the

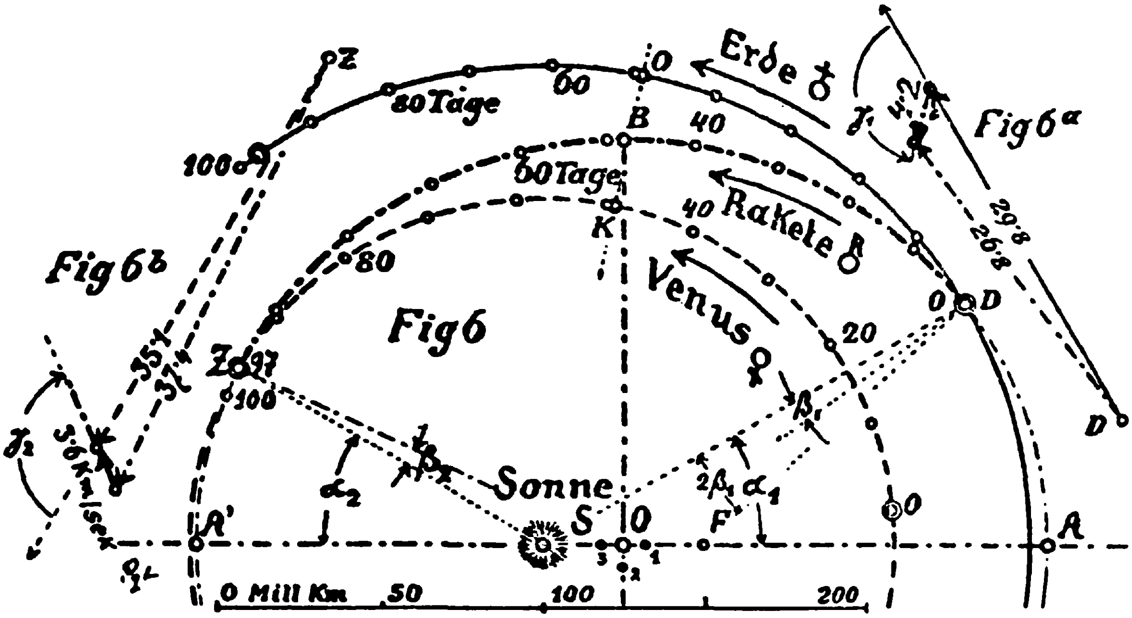


Fig. 3

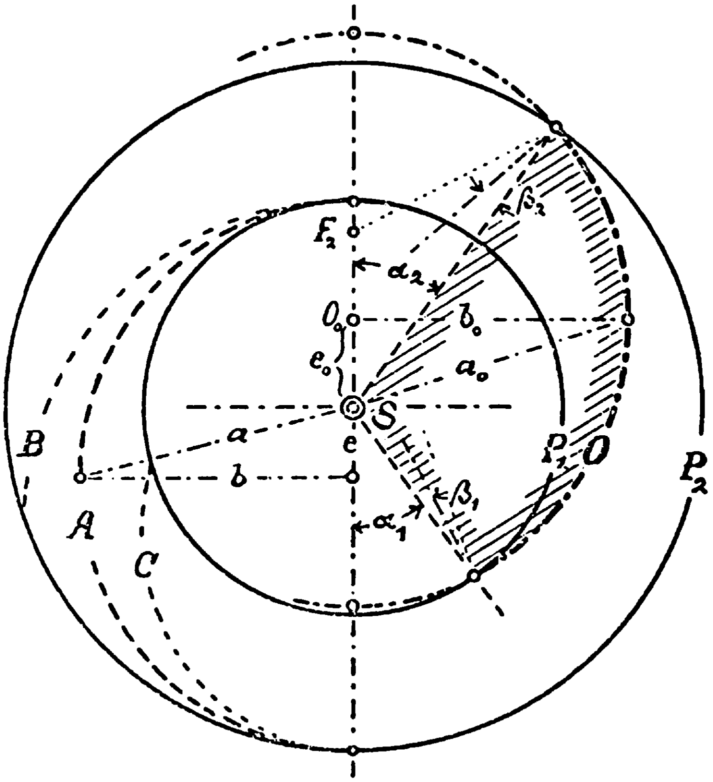


Fig. 4

routes A, B and D: Route A meets both planetary orbits tangentially, route B and C touch only one planetary orbit tangentially and intersect the other. In contrast, Pirquet proposed route O, which is a semi-ellipse with an angle of about 30° cut off on either side with respect to the Sun as focus (O_1 and O_2).

The angle at the center is therefore 120° in contrast to Hohmann's route A of 180°. Therefore route A, which requires a minimum of fuel, takes a much more longer time than needed on route O. Routes B and C require a greater fuel consumption than Pirquet's route 0 despite taking a longer time. In Table 1 the requirements of Hohmann's routes A, B and C, and Pirquet's route are compared: For instance, for a trip to Venus a velocity of 2.4 km/sec is required to switch from the orbit of the Earth into a trajectory to Venus (without taking into consideration the influence of the gravitational field of the Earth), and in order to switch from this trajectory into the orbit of Venus again an additional velocity of 2.6 km/sec (again without taking account of the gravitational field of Venus) is necessary, comprising an additional velocity of 5.0 km/sec, while the duration of the trip is 146 days. For a route of the type B, the corresponding additional velocities are 5.6 and 3.5 km/sec respectively, for a total sum of 9.1 km/sec and a duration of 102 days; for a route of the type C, 3.0 and 6.65 km/sec are required, giving a total of 8.75 km/sec while the trip lasts 109 days.

TABLE I

COMPARISON OF HOHMANN'S ROUTES TO THE PROPOSAL OF PIRQUET

Route (See Figure 4)		A	B	C	O
Velocity Required for Injection Into the Rocket-Trajectory*	km/sec	2.4	5.6	3.0	4.2
Velocity Required For Injection Into the Route Of The Planet*	km/sec	2.6	3.5	5.65	3.6
Sum	km/sec	5.0	9.1	8.65	7.8
Duration	days	146	102	109	97

*without accounting for surmounting the gravitational fields of the Earth and the planet

Pirquet on the other hand, proposed route O, where the additional velocity required for switching from the orbit of the Earth into the trajectory to Venus is 4.2 km/sec, and for switching from that trajectory into the orbit of Venus 3.6 km/sec; the total is therefore 7.8 km/sec while the trip lasts 97 days (Figure 3). We find this route superior to Hohmann's routes B and C mentioned above, for in spite of a shorter duration it also demands less in additional velocities—a total of 7.8 km/sec additional velocity as against 8.65 km/sec and 9.1 km/sec, respectively, for Hohmann's route B and C. Compared with Hohmann's route A, Pirquet's route O admittedly needs additional velocity (7.8 km/sec as against 5/km/sec), but on the other hand it shortens the flight duration considerably: from 146 to 97 days. Although the energy demand needed to overcome the gravitational fields of the planets is not included in the above mentioned velocities, it is, though, essentially equal for all routes. However, if one accounts for the gravitational fields of the Earth and the planets, the ratio of energy demanded for routes O and A is much lower, and one must consider whether perhaps other factors, such as oxygen and food, or other requirements, make the shorter duration preferable. The difference in time needed for a journey to the inner planets involves some months, to the outer planets some years. Possibly a compromise between routes A and O will prove preferable.

THE ASTRONAUTICAL PARADOX (SIGNIFICANCE OF THE SPACE STATION)

The second and most important point brought out by Pirquet's series of articles involved the so-called astronautical paradox, where a trip from Earth to a space station requires more energy than a trip from the space station to the planets, even though the distance of the space station from the Earth's surface is only a few hundred or thousand kilometers, while the planets are millions of kilometers away. Here Pirquet thoroughly analyzed the technical details of manned interplanetary flight, a part of rocket technology that is yet to be realized. In his analysis he compared three alternatives:

liftoff from Earth,
liftoff from a space station,
liftoff from the Moon.

As far as a liftoff from the Moon is concerned, Pirquet made it quite clear that he included it for comparison's sake only, and that mode should most decidedly be forborne since for the time of liftoff for an interplanetary trip the relative positions of the Earth and the planet in question are significant, while a liftoff from the Moon only made sense at a moment when the Moon's velocity happened to add itself to that of the Earth. The combination of a favorable position of the Moon with respect to the Earth and of a favorable position between the Earth and the target planet would be a rare coincidence indeed. In computing his interplanetary routes, Pirquet used a graphic method of maximum clarity. In a diagram with a logarithmic-scale ordinate, the relationship between velocity and mass of a rocket according to the equation

$$m_o/m = c^{v/c}$$

appears to be represented by a straight line (AB in Figure 5). If, for instance, the entire rocket has an initial mass m_o of 130 metric tons (point A), an exhaust velocity c of 4 km/sec will give it, after consumption of 90 metric tons of fuel, a mass of 40 metric tons and a proper velocity v of 4.71 km/sec (point B). If the empty mass of the first stage, assumed to be 10 metric tons, is shed at this point, 30 metric tons remain for the other stages (point C). If the ratio of payload-to empty mass-to fuel is the same for the second stage as for the first--an assumption made in approximation, but impossible to realize exactly—the second stage will attain twice the

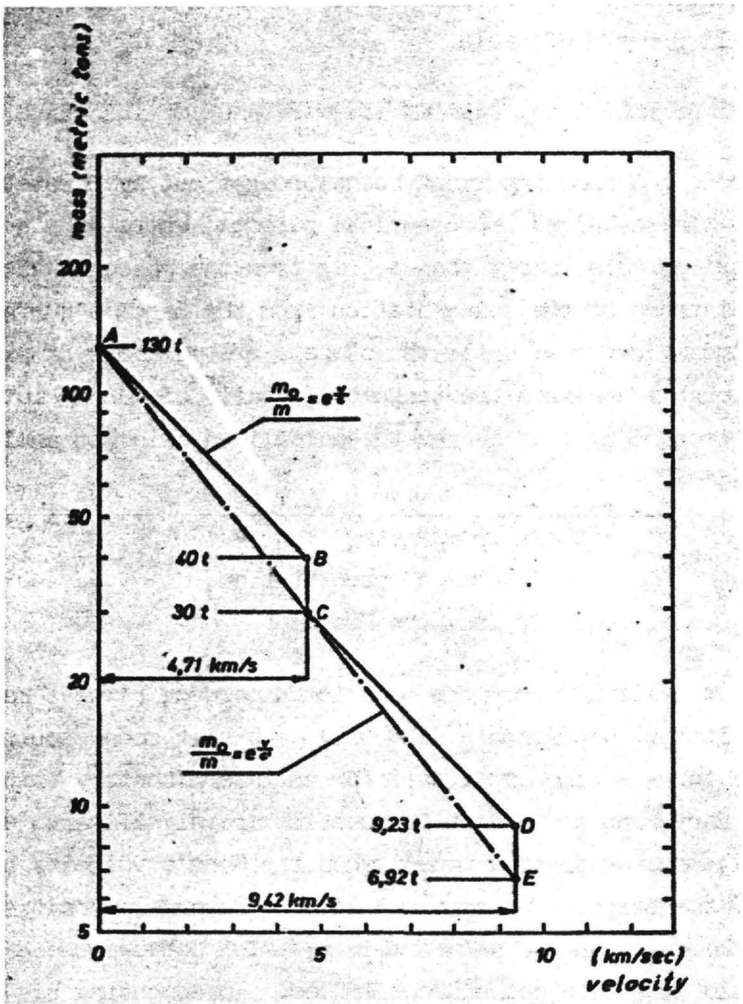


Diagram for simplified graphical calculrtion of the mass ratio of staged rockets

Fig. 5

previous velocity, i.e. 9.42 km/sec. At "brennschluss" its mass will be $30 \times \frac{40}{130} =$ 9.23 metric tons, reduced after shedding the empty second stage to $30 \times \frac{30}{130} =$ 6.92 metric tons at point E. It then becomes possible to connect points A, C and E by a straight line (dash-dotted in Figure 5) which, for purposes of computation we may apply the same formula for the single-stage rocket (with the difference that a fictitious exhaust velocity c' whose value is 3.21 km/sec in our case, must be used for computation). Thus, it is possible to use the single-stage rocket formula, in the form

$$m_o/m = e^{v/c'}$$

at least as an approximation for the multi-stage-rocket. This method appears particularly well suited for rough initial calculations. It requires certain assumptions concerning the ratio of payload to total rocket mass and the empty mass of the individual stages, depending on the final velocity to be reached and the number of stages.

Figure 6 is an original draft by Pirquet, with Diagram III representing

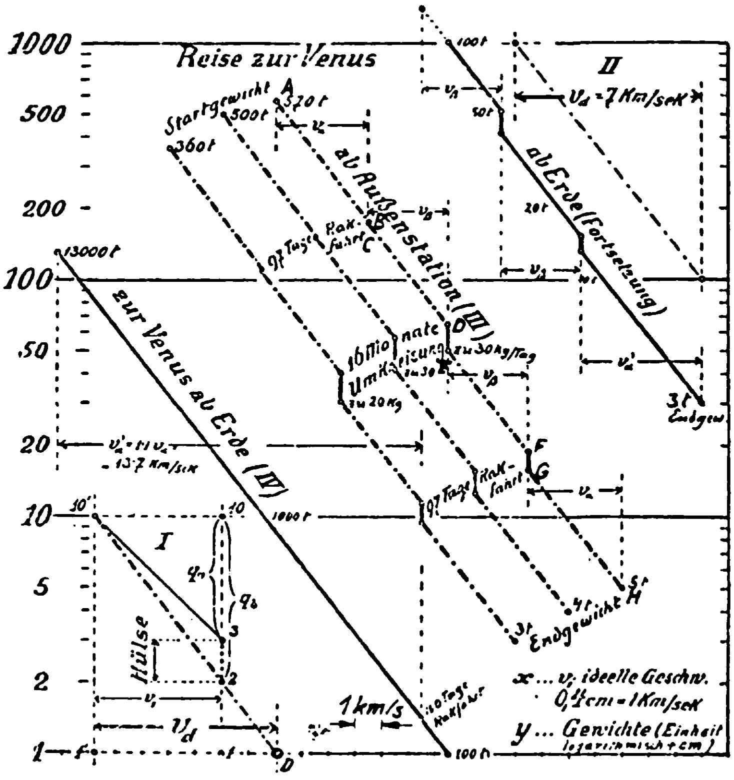


Fig. 6

a trip to Venus from a space station and back. Pirquet chose 10% of the total weight of the rocket as the empty weight of the first stage, and 20% of the total weight of the rocket as payload, or weight of all succeeding stages. He made proportional assumptions for the second and succeeding stages. The 10% assumed for the empty weight of the first stage has already been undercut in our day, with less than 5% used in the Apollo project; but at the time such a value would have been considered presumptuous. Pirquet contrasted three variants with final masses of 3, 4 and 5 metric tons respectively, corresponding to initial masses of 360, 500 and 570 metric tons.

Initial and final masses fail to be in proportion because Pirquet made different assumptions for oxygen and food for the various alternatives, viz. a reduction of mass of 20 kg per day in the 3-ton project and of 30 kg per day in the other projects. The dash-dotted lines represent the relationship between rocket mass and velocity, with staging already taken into account as discussed in the description of Figure 5. Changes of mass at constant velocity are therefore not caused by staging but by the reduction of mass due to the crew's oxygen and food consumption. The effective exhaust velocity c was assumed to be 4 km/sec; a value not yet attained for large rockets. Pirquet adds a 10% safety margin for course corrections, etc. to his rocket speeds, and took the gravitational fields of the Earth and Venus into account in the above example. Choosing an orbit for his space station, Pirquet worked according to the philosophy of maximum universal usefulness for interplanetary trips, coming to the conclusion that the radius of the space station's orbit should be three times the radius of the Earth. In Figure 6 the change of rocket velocity in km/sec is plotted on the abscissa and the mass in metric tons on the ordinate.

In order to attain a Venus-bound route from this space station orbit, Earth's gravity and the proper speed of the space station require an additional velocity of v = 3.14 km/sec, with 10% safety margin added for course corrections. This calls for a reduction of the initial mass from 570 metric tons to approximately 182 metric tons (point B). Ninety-seven days of free flight follow, with an assumed mass reduction of approximately 3 metric tons due to consumption by the crew (point C). This reduction in mass is barely significant for a rocket mass of 179 metric tons, and can hardly be represented in the diagram. Injection into Venus orbit requires a change of velocity of v = 2.76 km/sec with due consideration of the gravitational field and the orbital velocity. Again, considering a 10% safety margin for course corrections, the rocket mass is reduced to approximately 66 metric tons (point D).

This is followed by orbiting Venus for 16 months, with a reduction of mass of approximately 15 metric tons due to the crews biological needs (point E). The rocket mass is now approximately 51 metric tons. Injection into the return-to-Earth route follows at v - 2.76 km/sec, with the rocket mass dropping to approximately 18.7 metric tons (point F). During the free return flight to Earth, again claiming 97 days, the rocket mass diminishes by approximately 3 metric tons to approximately 15.7 metric tons (point G). It can be clearly seen that the astronauts' food consumption plays a far more important role now than on the outward trip, where the rocket was still considerably heavier, with food consumption the same. Finally, insertion into the space station's orbit requires another change of velocity v = 14 km/sec, and leads to a reduction of mass down to 5 metric tons. This simple method is seen to afford a surprisingly rapid overview of the conditions of an interplanetary trip. It seems, however, that the final mass of 5 metric tons appears somewhat too low for an interplanetary trip, so that an increase in this respect seems indicated.

Table 2 tabulates the results of Pirquet's calculations for interplanetary trips to Venus and Mars. His assumptions are again the same as in the previous example, with the exception of an increase in the fictitious exhaust velocity mentioned above by 1.4%. Explaining the reasons for this assumption would exceed the scope of this paper. Pirquet contrasted the conditions for liftoff from Earth, from a space station, and from the Moon. On the return to the Earth, he assumed a reduction of velocity by rocket thrust before atmospheric reentry of 4 or 4.5 km/sec for the Venus and Mars trips respectively. A trip to Venus required 3,200 metric tons of Earth-liftoff weight for every metric ton of final weight, while the figure is only 90 metric tons for liftoff from a space station. For Mars the figures are 7,400 metric tons from Earth, but only 235 tons from the space station. With progress in light construction and by braking the total reentry velocity in the atmosphere, the mass ratio may be made much more favorable than Pirquet computed at the time. Even so, the exhaust speed of 4 km/sec assumed by him has not been attained yet, so that the mass ratio becomes less favorable again.

Based on the above numerical results, Pirquet concluded that a manned interplanetary liftoff from Earth is impossible, since the spacecraft would become so heavy that the total cross section of thrust jets would be far too large to be accommodated structurally in even the largest imaginable base area of a spacecraft. But at the same time Pirquet, by computing the situation for liftoff from a space station, proved the feasibility of interplanetary flight. These two conclusions are the core of his work and show the importance of a space station as a necessity for manned interplanetary flight. We should mention in this context that a space station orbiting the Moon has already been realized in the lunar flights of Apollo. Requirements for a lunar landing have been essentially reduced by this method.

Pirquet in his time summarized his results as follows: "Thus the whole problem is reduced to theoretical feasibility, to the question whether construction of the space station is structurally feasible . . . ." Therefore: "In order to realize space flight, it will suffice to realize the space station." Even today the magnitude of a rocket needed for liftoff from Earth to neighboring planets with manned spacecraft presents a problem, whereas rockets required for building a space station and for a flight from the latter to the planets already exist. Pirquet pioneered the space station, and he kept making interesting proposals in this connection, proposals that were often so progressive that even experts opposed him. He intended to publish a paper on an unmanned orbiting observatory for the International Astronautical Congress in Rome, but was dissuaded from doing so; it was this very project that he tackled before his death.

TABLE II

VELOCITIES REQUIRED FOR A MANNED SPACE-FLIGHT TO VENUS AND MARS CALCULATED BY PIRQUET 1928[4]

		TRIP TO VENUS			TRIP TO MARS		
Liftoff		From Earth	From The Moon 2)	From a Space Station	From Earth	From The Moon 3)	From a Space Station
Velocity Required For Launching	km/sec	12.2	4.4	3.14	12.8	6.8	3.73
Injection Into the Planet's Orbit	"	2.76	2.76	2.76	3	3	3
Velocity Required For Injection Into The Earthward Route	"	2.76	2.76	2.76	3	3	3
Velocity Required For Landing	"	4.0	4.4	3.14	4.5	6.8	3.73
Sum + 10% Safety Margin	"	23.9	15.7	13.0	25.6	21.6	14.8
Total Mass Ratio 1)	"	3200	210	90	7400	3000	235

1) Accounting also for food consumption of the crew

2) When the Moon's velocity happens to add itself to that of the Earth

3) When the Moon's velocity is in opposition to the velocity of the Earth

INTERSTELLAR SPACE-FLIGHT

Pirquet's publication in the Journal of the British Interplanetary Society in 1950[6] provides an interesting parallel to his paper of 1928. In it he stressed the dangers threatening a rocket that might attempt to reach even the nearest fixed star. Such an attempt would obviously require very high velocities in order to conclude the trips during a human lifetime. If the distribution of cosmic dust is assumed to correspond to Clarke's model as published in the same journal,[7] such a fast spacecraft would have to cross clouds of cosmic dust. Cosmic dust may be compared to raindrops whipping into a motorcyclist's face; the faster he drives the harder he feels them. Applying this to rocket flight, Pirquet concluded that these dust clouds represent no risk to interplanetary rockets with their velocities of several dozen kilometers per second, but for interstellar rockets to the stars with required velocities of a magnitude of 100,000 km/sec they constituted an insurmountable obstacle; even if they failed to penetrate the rocket wall, the small particles would produce enough frictional heat to make the spacecraft red hot. Pirquet demonstrated the possibilities open to man in his 1928 paper; similarly, he pointed out just as clearly in 1950 that there are limits that nature has set to man's efforts.

CONCLUSION

Guido von Pirquet was recognized as a pioneer of rocketry in his own day, and received honors and distinctions in his old age. The key importance of his work is still recognized, with Wernher von Braun, among others, giving him repeated credit.[8] We have attempted to comment briefly on Pirquet's major works and to contrast them with the present state of the art. Some of his projects have already been partially realized, e.g. the Venus route, while work is still in progress on other parts. The validity of Pirquet's statements remaining unchallenged. Of particular topical interest is the space station, a valuable construction Pirquet demonstrated, and one that will likely be realized in the very near future.

APPENDIX A

HONORS AND DECORATIONS AWARDED GUIDO VON PIRQUET

1948	Honorary member of the "Deutsche Gesellschaft für Raketentechnik und Raumfahrtforschung" (German Society of Rocketry and Research into Space Flight).
1949	Honorary member of the British Interplanetary Society.
1951	Honorary President of the "Österreichisches Ehrenkreuz für Wissenschaft und Kunst Erster Klasse (Austrian Cross of Honor of Science and Arts, 1st Class).
1956	Awarded the 6th Hermann Oberth Medal for exceptional merits in space flight.
1960	Awarded the Österreichisches Ehrenkreuz für Wissenschaft und Kunst Erster Klasse (Austrian Cross of Honor of Science and Arts, 1st Class).
1965	Awarded the Prechtl Medal of the Institute of Technology in Vienna.
1965	Honorary member of the International Academy of Astronautics.

APPENDIX B

PUBLICATIONS OF GUIDO VON PIRQUET

"Die ungangvaren Wege zur Realisierung der Weltraumschiffahrt" ("The Impossible Ways Towards Realization of Space Flight") in *Die Möglichkeit der Weltraumfahrt* (The Possibility of Space Flight), edited by W. Ley, published by Hachmeister & Thal, Leipzig, 1928.

"Interplanetare Fahrtrouten" (Interplanetary Travel Routes") a series of articles in the journal *Die Rakete* (The Rocket), May 1928 through April 1929.

"Thermodynamik der Rakete" ("Thermodynamics of the Rocket"), *Der Maschinenkonstrukteur* (The Technical Designer), No. 8, 1929.

"Beweis der Übereinstimmung der vorliegenden Raketentheorie mit dem Energiegesetz" ("Demonstration of the Compatibility of the Current Theory of Rockets With the Law of Energy"), *Der Maschinenkonstrukteur* (The Mechanical Designer), No. 14, 1929.

Report on Pirquet's paper on the occasion of the reforming of the "Österreichische Gesellschaft für Raketentechnik" (Austrian Society of Rocketry) *Der Flug* (The Flight), No. 4, 1931.

"Über den Wirkungsgrad des Raketenantriebes" ("On the Efficiency of Rocket Propulsion"), *Raketenflug* (Rocket Flight), No. 6/7, 1932.

Autobiography and report on his own works on rocketry in *Männer der Rakete* (Rocket-Men), edited by Werner Brügel, published by Hachmeister & Thal, Leipzig, 1933.

Five papers in *Das neue Fahrzeug* (The New Vehicle), journal of the "Verein für fortschrittliche Verkehrstechnik," (Society for Progressive Technics in Transport), Berlin, 1934-1936.

Paper in *Weltraum* (Space), journal of the "Gesellschaft für Weltraumforschung" (Society for Space Research), Cologne, No. 3/4, 1939.

"Die Aussenstation, das Sprungbrett ins Weltall" (The Orbital Station, Spring-Board into Space, in *Weltraum—Utopie?* (Space Travel—Utopia?), published by Natur und Technik, Vienna, 1949.

"Meteors and Space-Travel" (*Journal of the British Interplanetary Society*), No. 4, 1950.

"Die Gründung der Aussenstation" (The Foundation of the Orbital Station), read by Prof. Dr. Hecht at the Second International Congress of Astronautics in London, 1951, published in *Zeitschrift fur Natur und Technik* (*Journal of Nature and Engineering*), Vienna, No. 2, 1952.

Pirquet also published many popular papers in various journals and newspapers.

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3. W. Ley, ed., Die Möglichkeit der Weltraumfahrt (The Possibility of Space Flight), Verlag Hachmeister & Thal, Leipzig, 1928.

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5. W. Hohmann, Die Erreichbarkeit der Himmelskörper (The Possibility of Reaching the Stars), Verlag R. Oldenburg, Munchen, 1925.

6. G. von Pirquet, "Meteors and Space-Travel," Journal of the British Interplanetary Society, No. 4, 1949.

7. A.C. Clarke, "Meteors as a Danger to Space-Flight," Journal of the British Interplanetary Society, No. 4, 1949.

8. W. von Braun, Letter to Prof. E. Dolezal, Vienna, Dec. 1963.