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THE SILVER BIRD STORY: A MEMOIR+

Irene Sänger-Bredt (German Federal Republic)++

On March 23, 1935, a self-willed young Viennese engineer wrote in his diary: ". . . Nevertheless, my silver birds will fly!" (Figure 1) He penned these words despite having received two months before notice to quit his post as an assistant at the Technische Hochscule, Vienna, where he had successfully completed two years of tests with new liquid-propellant rocket combustion chambers. Moreover, with debts in the amount of RM 2000 to publish the first textbook on spaceflight technology, he faced ruin.

On January 23, 1964, a tired and weary man in Brussels, just 18 days before his premature death, supported for the last time his favorite project, the space transporter--known today as the space shuttle. Before the assembled delegates of the Europena aerospace industries he observed:

> . . . An efficient, economical system of space transportation will become topical at a time when the problems of rendezvous technique have been solved in Earth orbit; furthermore, when the first successful manned landings on the moon have taken place, the construction of large manned permanent lunar bases has to be started. For undertakings like these, which may be realized, presumably during the next decade--an economic system of space flight becomes an absolute prerequisite . . . .
>
> If such developments are not yet fully underway in the USA and USSR, it is because the total intellectual and material resources of these countries, at present, are occupied with actual pioneering efforts, especially with the race to the moon. As soon as this strain is over, they will devote all their efforts to the next phase of practical spaceflight--the preparatory work of the American aerospace industry shows this already quite clearly.
>
> Hence, there exists for Europe a unique but transient opportunity to become fully active, both intellectually and materially, in a branch of spaceflight where the great powers have not yet gained an unassailable lead; a branch of spaceflight which promises high material profit, and may even make these countries customers of the European aerospace industries.

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

++A physicist who worked with Eugen Sänger on the Antipodal Rocket Aircraft, and later became his wife. Founding member of the International Academy of Astronautics.

Fig. 1
Eugen Sänger (1905-1964) Demonstrating
Skip Flight Trajectories at a Model
Globe of the Earth

Between these two dates mentioned above, and representing nearly 30 years of a man's life work, there took place the story of a technical development project named "Silbervogel" (silver bird) in the dreams of its creator, and known also by several other names--such as "Flugboot" (flying boat), and in Sänger's earliest computations and project notes, simply "Raketenflugzeug" (rocket plane) in the first relevant publication of its advocate in 1933, later on as "Bügeleisen" (flat iron) in the jargon of the technicians at test stands and wind tunnels, thereafter camouflaged as "Raketenbomber" (rocket bomber) during the storms of the second World War, and finally "Raumtransporter" (space transporter) in the dry language of aerospace experts at the beginning of the astronautical age. All these names refer to a manned, recoverable flying machine that operates both in air and space, especially to be used as the first stage of booster rockets, or respectively, to ferry, supply, and furnish rescue equipment for manned space stations. Depending on the region of its flight domain and the type of mission, the craft would be able to follow either ballistic or aerodynamic trajectories, and would combine the properties of a powered booster rocket with those of an aerodynamic glider. The realization of such an aerospace transporter would eliminate a strange gap in astronautical development until now--the historical background of which will be briefly examined first. Of course, it may appear surprising to an unaffected observer that manned spaceflight did not evolve gradually and consistently from aviation within the past 50 years; furthermore, that for ascent into the cosmic regions one should renounce the benefits of an atmosphere delivering oxygen and lift, as well as the benefits of a concept enabling recovery of the hardware. Instead, men have been launched into space with high accelerations tolerable only to a select few, and on projectiles that consume more fuel than is absolutely essential and of which only a small re-entry capsule can be returned--rather inelegantly--to Earth, fit only for display in a museum at last.

Would the first steps into space have been different if the astronautical pioneers, especially Hermann Oberth as the spiritual father of Western Europe spaceflight, been inspired by aerodynamic methods of flight, such as the Icarus legend or Bishop Goodwin's journey, rather than by Jules Verne's novel "De la Terre à la Lune," with the moon traveler setting off in a cannon ball? Was it the war, disastrous promoter of many inventions, that made the ballistic solution (in the form of intercontinental missiles) appear more interesting, and offered it to astronautic purposes as a cheap by-product? Or was the realization of the Silver Bird delayed in fact by the high development costs of aerodynamic carrier vehicles, and by doubts about a sufficiently high operating frequency of reusable boosters?

In his last lecture Sänger expressed his own opinion:

> When a quarter of a century ago, spaceflight first became a technical reality, two fundamentally different avenues of development existed. On the one hand, we could develop the ballistic, missile-like spacecraft, essentially similar to the proposals of Tsiolkovsky, Goddard, Oberth and Esnault-Pelterie; whilst on the other hand lay the further development of aircraft engineering towards space vehicles capable of cosmic flight, the so-called aerodynamic way to space, as advocated by a group of Viennese scientists, including von Hoefft, Valier and Sänger.
>
> More exhaustive work on definite projects very soon showed that, considering the contemporary state-of-the-art, fewer problems would need solving by using the ballistic method, and that the transport of defined payloads would be more economical in the ballistic mode (because the saving of dry weight, enabled by the omission of wings, undercarriages, high bending loads and so on, gave a better payload to gross weight ratio), as long as the operating frequency remained low. The high construction costs of such ballistic and non reusable transporters were overshadowed first by the still higher development costs of reusable transporters. Thus, the benefit of repeated availability of aerospace planes could show no economical effect as long as operating frequencies and consequently mass production rates remained low. Of course, trial flights of individual specimen before their proper application are not possible with ballistic aircraft, because each can be used only once. Nevertheless, a low reliability in flight resulting from this fact seemed acceptable for military and even for unmanned civil missions.
>
> Conclusively, it was the development of ballistic spaceflight which proceeded during the last few decades. This way has led to the well known spectacular first successes in orbit followed by commercial applications of great promise,

such as communication satellites, and will attain its zenith with the first landing of human beings on the surface of neighboring planets. This latter application lies near the limit of technical feasibility, because of the aforementioned restrictions of reliability. This first pioneering phase of experimental space flight is supposed to be finished within the next few years by the landing of men on the moon.

The demand for large, and probably in a rapid manner far more growing, transport-volumes which is to be expected within the near future will result from the following tasks in particular:

- transportation in earth orbit of numerous scientific or commercial satellites and recovering them after their mission is over;
- construction of large manned space stations in earth orbit for scientific or commercial use, and especially qualified as transit stations for the traffic between Earth and the Moon;
- supply of these stations with all the goods necessary for their operation, moreover periodical exchange of the working crew and occasional transportation of visitors;
- transportation of all men and goods needed for the construction and the current management of permanent Moon stations, from Earth to the Moon and back;
- transport missions between mutual space stations in orbit and between such stations and unmanned satellites, for purposes such as supervision, recovering, rescue or repair work, change of orbital elements and so on. . . .

How did Sänger come to advocate so resolutely and so contrary to general opinion, a solution other than a pure ballistic one, more than forty years before the Moon landing? Thirteen days before his death, when he was asked by a radio interviewer of Berlin RIAS, how he had become involved in space research, Sänger answered:

Contact with spaceflight occurred for the first time at grammar school, when my physics teacher whose special favorite I was, gave me as a Christmas present a novel by Kurt Lasswitz, Aufzwei Planeten (On two planets). At that time I was about 16 years old. Naturally I read this novel with glowing cheeks, and thereafter dreamed of doing something like this in my own lifetime. I started to occupy myself seriously with spaceflight when—I think in 1924--the first publication on the subject by Hermann Oberth came into my hands. At that time I was studying at the Technische Hochschule in Vienna. I had to pass my examination on mechanics, and therefore, made a particular study of this and related subjects. Then I also started to check and recalculate in detail everything in the book of Oberth, and I became convinced that here was something that one could take up seriously. From that moment onwards I devoted myself more and more to these things, but there was the added difficulty that at the Technische Hochscule I was studying construction engineering, especially over and underground workings, bridge building, railway construction and so on. Thus I had to change the emphasis of my studies in the direction of aeronautics and the field of science that would favor aeronautic engineering.

Thus, Sänger really was led to his life's work through the influence of Hermann Oberth, as were so many of the second generation spaceflight engineers. However, right from the start he kept himself independent of Oberth's concrete program of realization. Was this because his ideas were formed by his studies of construction techniques (particularly those of the aviation industry) when he began systematically to occupy himself with spaceflight? How far was he influenced by the 'Viennese School' of space research, represented by Valier or von Hoefft? Did Sänger's distinctive inclination towards systematic and complete study, his aversion to discontinuity of thought and unfounded principles of any kind--did these play any part in choosing his way? Maybe even he too was never quite sure about this. Perhaps all three factors motivated his way of project realization. However, there is no doubt that the force of his personal character must have been primarily responsible.

The idea of performing the first step into space using the atmosphere, with the aid of aerodynamically-dependent carrier equipment, is at least as old as the designs that use a purely ballistic method. During the 19th century ballistic rockets received considerable attention as weapons of war, with the experiments of the British Colonel Congreve, and in the publications of the French engineer, Montgéry. At the same time, the French pyrotechnician, Ruggieri, demonstrated with animals the modern techniques of parachute landings from ballistic rockets on the "Champs de Mars," and in 1841 the first patent for an aircraft with hot water rocket propulsion was obtained by the Englishman Golightly.[+] A German project of 1847, in which a rocket plane would be driven by burning nitro-cellulose, is attributed to Werner von Siemens. In 1873 the Russian General Ivanin proposed to power aircraft with war rockets. Toward the end of the 19th century, Ganswindt in Berlin promulgated the idea of a "Weltenfahrzeug" (space-vehicle) driven by dynamite cartridges, after being carried to the upper limit of the atmosphere by a "Spezialflugzeug" (specially-designed aircraft). Further proposals for aircraft with reaction propulsion systems were known by the beginning of the 20th century—for instance those of Christopher Antonovitch in Petersberg (1910), René Lorin in Paris (1911), and Alexander Gorochoff in Moscow (1911). Auguste Picard, the later stratospheric and deep-sea research scientist, started his experiments in 1912 with a rocket-driven model aircraft, because originally he intended to realize his push into the stratosphere by means of rocket propulsion.

Sänger had heard about some of these attempts in 1924, but at this time it is not known if he was aware of the work of his compatriots Max Valier and Franz Edler von Hoeff, who were born one or two decades before him--even though he seems never to have had any personal contact with Valier.

During his studies at Innsbruk in 1914, Valier had driven a model plane by means of firework rockets—just as Picard did two years before. However, Valier was seriously engaged in problems of spaceflight again only after he had accomplished war service and studies of astronomy. In January 1924 he bought Oberth's book, Die Rakete zu den Planetanrauman. Immediately afterwards he contacted Oberth. This led to an extensive, still extant correspondence between these two pioneers of astronautics--a correspondence

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[+]The Patent of Golightly is unrelated to an early caricature of a man flying a steam-rocket, published in most Western European countries—Ed.

soon joined by von Hoefft and Hohmann. From these letters it is clear that the views of Oberth soon differed with those of Valier and von Hoefft on the most suitable vehicle for the first steps to conquer space.

Oberth insisted upon a purely ballistic, multi-stage, liquid-propellant rocket, as proposed in his book. On the other hand, Valier resolutely supported the idea of an airplane with jet propulsion for the atmospheric phase of flight; however, he mistakenly called it a "rocket plane," not considering the difference between jet propulsion and true rocket propulsion operating too in empty space. He commented in 1925:

> Consider, please, my idea of developing the spaceship from the JUNKERS aircraft. I imagine such aircraft initially provided with Blicharski's wing propeller and completely hermetically sealed, with normal air pressure inside. Then, there would be a way of developing an "intermediate type" between aircraft and spacecraft. Such vehicles would take off like aircraft. Thereafter at an altitude, where propeller engines fail to work, they would boost themselves with a single rocket impulse. Like the projectile of a long-distance cannon they would thereupon follow a very smooth ballistic trajectory over most of the flightpath, where the characteristics of a free flight trajectory are only slightly influenced by the effect of the airfoils. During the descent path, from reentry altitudes of 12,000 to 10,000 m, they would again proceed to the normal gliding flight of the aircraft. Their attainment of half orbital velocity together with the lifting effect of the airfoils would greatly increase their gliding path. Finally they would land just like ordinary aircraft. I cannot depart from the concept of a spaceship with wings, especially not from the "intermediate type," a rocket plane which daily appears to me to have greater chances of realization. A rocket plane using gasoline as fuel and precompressed air as oxidizer could operate with the oxygen of the atmosphere still in altitudes of 15 to 20 km and attain burnout velocities of 1400 to 1500 m/s, in my opinion. In this way one could eliminate the difficulties associated with liquid oxygen carried on board, but had to deal on the whole with technical matters already rather well known.

In the spring of 1927, during a lecture to the "Wissenschaftliche Gesellschaft für Luftfahrt" (WGL) in Berlin, Valier described a program for gradually transforming a three-engined JUNKERS G-23 aircraft into a spacecraft. (Figure 2) He commented on this:

> At first the JUNKERS G-23 will be equipped with two rocket engines in the airfoils. If jet propulsion proves to be successful within the first tests in flight, a true rocket plane with an auxiliary reciprocating engine retained for safety could represent the next transfer stage of development. First there will be four, and later on six rocket engines in the wings. When sufficient experience has been gained, the pure rocket plane, with small wings and pressure cabin suitable for intercontinental flights in the stratosphere, can be built. The final stage is to develop a rocket ship which will ascend vertically from a launching tower, and which will be developed into the spaceship at last.

Dr. Franz von Hoefft's projects were still different from those of Oberth and Valier. He commented on this during a lecture given to the "Verein deutschosterreichischer Ingenieure" in Vienna on 9 February 1928: "I contemplated every possibility, from the exhaust of compressed air to that of ether atoms and electrons accelerated by zero-point energy of ether, or by the energy of nuclear fission, until in 1924, I read Oberth's

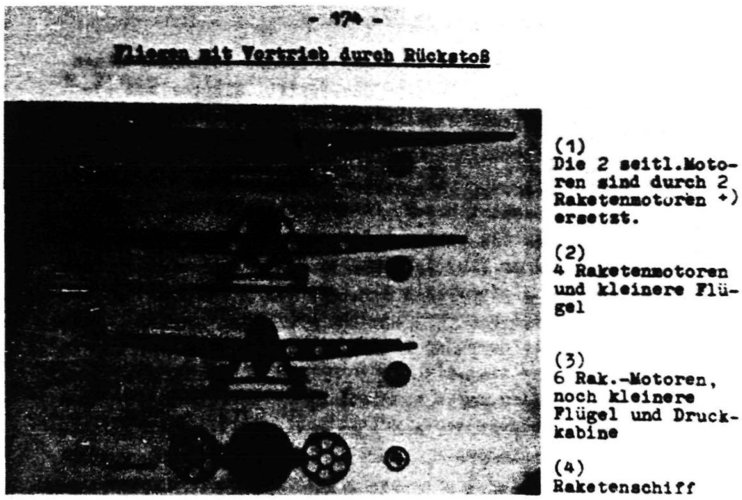

Fig. 2
Valier's Concept of a Space Aircraft developed from a Junkers G-23
(1. The two side engines are replaced by "rocket" motors;
(2. Plane with four "rocket" motors and smaller wing-span;
(3. With six "rocket" motors, even smaller wings and a pressure-cabin;
(4. Definite spaceship.)

book . . . and realized the possibility of achieving the necessary cosmic velocities by using as fuel liquid hydrocarbons presently available."

He then proposed on the staging principle to join jet planes, which were shaped like winged lifting bodies, so that each upper stage became the payload of the lower ones, using a vertical ascent. In this way, with standardized units, he combined different models for different missions. From his designs he first described the RH 3 carrier system, a two-stage combination of three tons gross weight, with which the payload, a camera, should be put into an orbit around the Moon, and after taking photographs of the far side, complete the orbital ellipse and land by parachute on the Earth. A further system (RH 5) (Figure 3) with a gross weight of 30 tons, would take off and land like a hydroplane and was intended as a manned earth-orbiting craft, or as the upper stage of a manned multi-stage spacecraft. But strangely, von Hoefft had apparently overlooked in his space travel plans the establishment of the "orbiting space station," which was claimed by his friend Guido von Pirquet according to his perception of the "cosmonautic paradox."

From present points of view, it seems they had not such bad ideas, all these representatives of the second generation of space pioneers and their predecessors. They overlooked only the fact that they could not proceed in the way of lone wolves with hobby tool and casual work if they wanted to achieve a task that to be realized in a later period demanded a well organized effort involving billions of working hours. Nevertheless,

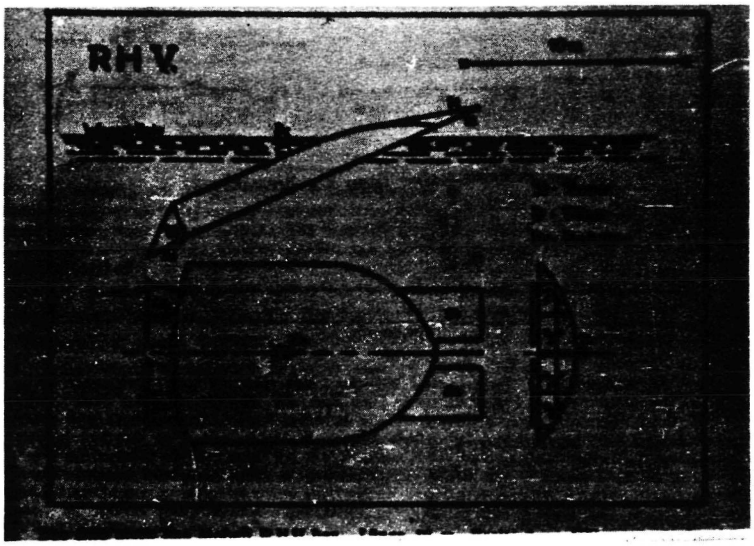

Fig. 3
Franz von Hoefft's scheme for a rocket-powered lifting body of 30 tons weight, capable of taking off and landing like an hydroplane--the upper stage was to have orbital capability.

their creative imagination and their untroubled optimism provided almost all those minute construction elements which only had to be assembled correctly.

One year before , von Hoefft and Sänger made personal contact. Forty years later, von Pirquet wrote about this meeting to Irene Sänger-Bredt:

> In the year 1927 Hoefft had the idea of testing a model rocket in the wind tunnel at the Aerodynamic Institute of the Technische Hochschule in Vienna. This model based on ideas of von Hoefft was designed in detail by me. Of course, the measurements produced satisfactory results, but had no immediate practicable application at that time. However, we heard that a young assistant at the Institute was ardently interested in rocket problems, and so I learned for the first time of Eugen Sänger.

In a letter dated March 24, 1928 and still saved by Guido von Pirquet, Sänger applied for admission to the"Wissenschaftliche Gesellschaft für Höhenforschung" (Scientific Society for High Altitude Research) (von Hoefft was the secretary of this society at that time):

> Honorable Mr. Engineer:
>
> With reference to the detailed consultation with Dr. von Hoefft, I should like to beg the favor of accepting my application as a full member of the Wissenschaftliche Gesellschaft für Höhenforschung and, as far as possible, of informing me of arrangements, lectures, etc. of your society. Especially I shall be at your disposal for the preliminary tests planned at the Aerodynamic Institute, as already discussed with Dr. Hoefft.

This letter shows a note handwritten by von Pirquet, and answered on March 28, together with an invitation to the lecture of Dr. von Hoefft on April 4. However, real cooperation between Hoefft, von Pirquet, and Sänger did not occur, as von Pirquet mentioned. Sänger was very much absorbed by his studies and duties as scientific assistant at the college. Moreover, he probably realized quite early that the most difficult stage on the way of realizing spaceflight did not concern the aerodynamics of the airframe, but its propulsion device. Therefore, he devoted most of his life-work to this problem.+

Among the documents left by Sänger were found several notes, written at different times and entitled "Labonsprogramm" (Life program). In these he formulated the aims of each of his diverse interests, and carefully noted points in the program already reached. One of the earliest of these programs probably originated between 1929 and 1931. Beneath the caption "Constructions" he detailed the following developments: "Stratosphere plane--spacecraft--space station--interplanetary spaceship--interstellar spaceship." Below the heading "writings, main works" appears: "Stratosphere flight, cosmic-technique--bio-technique."

From these notes it can clearly be seen how Sanger progressed systematically both as an engineer and a research scientist. He never disregarded the overall interdependence and the final aim, even when he apparently dealt only with detail. From the beginning he understood spaceflight as a manned enterprise. Therefore, he considered the realization of his first project, the stratosphere plane, only as a very first step on the way to realize space flight. Nevertheless, he did not want to omit this stage as in fact it happened during the subsequent development. Among the fragments of the scripts mentioned in Sänger's first "Lebensprogramm" was a draft on "Rocketflight technique." The front page bears the supplementary title: "Dissertation zur Erlangung der Wurde eines Doktors der Technischen, Wissenschaffen, vorgelest der Technischen Hochschunde in Wien in Sommer 1929 von Eugene Sanger."++ (Investigation of energetic problems in connection with high altitude flights with rocket planes.) The draft was divided into four chapters: General considerations; Ascent; Free flight; Descent. In the introduction, Sänger observed:

> The purpose of this work is to give a synopsis of all theoretical and practical knowledge to date in the field of high altitude aviation and cosmonautics. This knowledge will be presented in a practicable way appropriate to technical working and research methods, and will be supplemented by my own investigations.

+However, in this "Silver Bird Story" the report on Sänger's activities and successes in developing liquid rocket engines will be excluded, because they are treated already in other proceedings.

++Dissertation for taking the degree of a doctor of technical sciences, submitted to the Technical Highschool in Vienna by Eugen Sänger, in the summer of 1928.

The investigation consists of a critical, purely theoretical comparison of the different ways of advancing into space; it calculates the most economical and safest method (aerospace transporter - space station - space ship) and supplies a complete theory of this method. As far as possible, the concept has been arranged in a manner that allows an alternate use of chemical or electrical rocket engines; complete, general solutions of problems shall be given first, followed by calculations using specific data . . . The conquest of space with minimum energy display will proceed according to the following principles:

1. Transport to the altitude of a space station by means of the special aerospace-plane; further advances into space will use modified spacecraft.

2. Ascent of the aerospace-plane according to the principle of minimum energy expenditure.

3. Descent of the craft as a glider, without energy expenditure. (Already here, Sänger explicitly provided for the application of Einstein's theory of relativity to the phase of flight in outer space.)

In his last RIAS radio interview, Sänger reported on the fate of this draft for his doctoral dissertation, which he wrote immediately after passing his second state-examination (Staatsprüfung) on June 29, 1929: "I wished to obtain my doctoral degree some years later in the field of spaceflight. But then my good old teacher Katzmayr, with whom I studied aviation, told me: 'It is much more practical to prepare for your doctoral examination in a classical field--the event will then pass silently across the stage. If you try today to take your doctor degree in spaceflight, you will most probably be an old man with a long beard before you have succeeded in obtaining your doctorate.'" So Sänger took his doctor degree on July 5, 1929--not on the "aerospace plane," but with a paper entitled: "Die Statik des Vielholmig-Parallel-stegisen, ganz und halbfreitragemden, Mittelbar und Unmittelbar Belasteten Fachwerk flugels." (On the statistics of multi-spared parallel ridged, total-or-half-cantilever, indirectly or directly loaded panelled wings.)

Sänger mentioned his project for a semi-ballistic rocketplane for flight at very great altitudes in public only at the beginning of February 1933, in an essay "On Construction Principles and Performances of Rocket-Planes." This essay appeared in the Deutschosterreichische Tages-Zeitung.+ Sänger proposed here an aircraft of a relatively conventional construction type (Figure 4), with liquid rocket-propulsion (Petrol + LOX) to reach velocities even up to 10,000 km/h (about Mach 10), and flight altitudes between 60 and 70 km. More than 23 years later, and 28 months before Sänger's death on October 11, 1961, Robert M. White reached a ceiling of 65.9 km in the American rocket research plane NAA X-15, and thus the altitude imagined by Sänger. The realization of the visionary velocity limit of Mach 10 for rocket-planes has not been attained to date. The highest flight velocity was reached by a redesigned and improved X-15 on October 4, 1967 and came to Mach 6.7.

+German-Austrian Daily Paper.

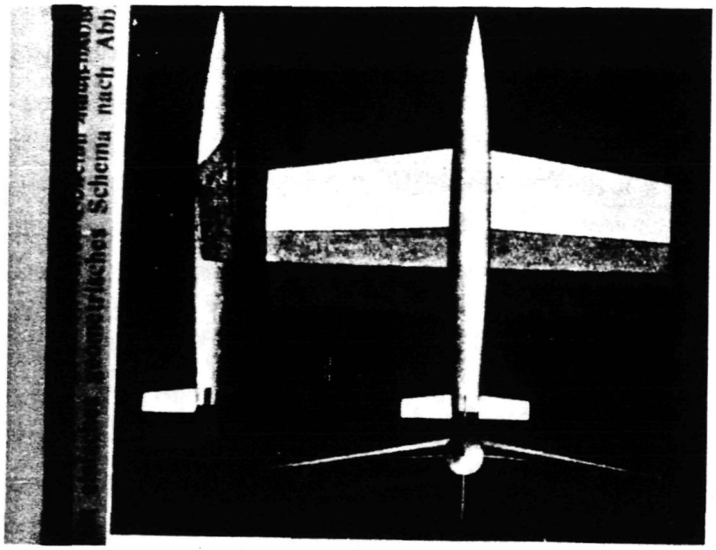

Fig. 4
First Concept of a Space Plane Published
by Eugen Sänger in 1933

In 1933, Sänger wrote in detail about the shape of the airframe of his planned rocket-plane: "One will choose for the body the shape of a projectile, pointed in front and blunt at the back-end to give room for the exhaust velocity. The profile of the wings has to be as thin as possible, with sharp leading edges. The wing span can then be kept low because of the negligible resistance of the wing-edges." Regarding flight performance, he observed: "At first sight their limit is given merely by the possible fuel load. It is this restricted fuel load which prevents these planes from increasing their flight velocity up to the orbital velocity of about 29,000 km per hour when the centrifugal force of the curved trajectory is equal to the weight of the plane; the wings then don't need to provide lift anymore, and the plane circles the Earth continuously, like a moon in a free inertial orbit without needing any driving power."

In the preface to his book Raketenflugtechnik, Sänger discussed his project still more clearly and methodically:

> In a more limited sense the project deals with that of rocket-flight in the upper layers of the stratosphere, with such velocity that the forces of inertia of the orbit contribute to the lifting effect. This kind of rocket flight is the following fundamental step in the phase of development from the troposphere-flight established during the last thirty years. It is the preliminary stage of space flight, the most powerful technical problem of our time. This preliminary stage, and the development to the construction of an orbiting space station of the Earth, is the most noble aim of rocket flight, though its realization still lies in the future."

However, Sänger's Raketenflugtechnik, regarded today as the first real textbook on this subject in the history of rocket flight engineering, was nearly not published at all. In the course of the summer of 1932, eleven publishers, among them Springer, Kroner and VOT edition, rejected the manuscript; a small publishing house in Berlin imposed limited financial conditions. Finally Oldenbourg in Munich; which had also published Oberth's Hohmann's, and Valier's books, agreed to print it if Sänger contributed RM 2000 towards the printing costs and purchased the first 50 copies of the book. In those days, Sänger could raise the money only through great personal sacrifices, and he could only completely pay off his debts in 1936 after he had been engaged by the "Deutsche Versuchsanstalf für Luftfahrt" (DVL, German Research Institute for Aviation) as technical director of their rocket projects.

Still, during the summer of 1933, Sänger outlined the development and testing program of his rocket plane project in the journal Flug. One year later, in a special edition of the same journal, he calculated the possible flight performance and flight trajectories assuming concrete technical data for a fuselage with circular cone-shaped nose, flat, extremely thin wings, a mean lift-drag ratio of 5, and an effective exhaust velocity of 3700 m/s. For a mass ratio G/Go of 0.16, for example, he calculated a burnout velocity of about Mach 13, a steady flight velocity of Mach 3.5 at an altitude of 40 to 60 km, and a flight range of 5000 km. He commented: "Accordingly, the most important task of the constructor has to be the achievement of an adequate range by severe decreases of empty weight, by the most sophisticated aerodynamic shapes, and by the highest possible exhaust velocity of the engine. But even with the not unrealistic assumptions so far used, a rocket plane with a non-stop range of 4000 to 5000 km can be confidently expected."

During the years that followed, however, Sänger was not able to devote much time to his project. He started from the principle of developing first the propulsion system before concerning himself with the construction and testing of the airframe. Experiments which he carried out as assistant at the Technische Hochscule in Vienna up to the end of 1934, on his own responsibility in the so-called "Bauhof" of the Institute für Baustoffkunde (Institute for research into building materials), served exclusively to spur development of a liquid propellant rocket combustion chamber with regenerative cooling. With his model engines he realized exhaust velocities up to 3000 m/s as is well known. The year 1935 passed with laborious and unloved work as a temporary engineer at a Viennese Construction Company, while he applied for employment at rocket research institutes all over the world. On February 1, 1936, Sänger entered a contract with the Deutsch Versuchsanstalt für Luftfahrt (DVL, German Research Establishment for Aviation) in Berlin-Adlershof. This committed him to prepare a design for a Research Institute for rocket techniques and to elaborate a research program for liquid propellant rocket engines. The building of this institute started in February 1937, at Trauen on the Lüneburg Heath.

Even these large scale research facilities, however, subordinate to the Luftfahrtforschungsanstalt (Research Institute for Aviation), Hermann Göring (LFA), designed by Sänger and especially built for him, were exclusively determined for research and testing of propulsion engines. Sänger worked here from August 1937 to August 1942. Nevertheless, besides his development work on a 100 ton liquid propellant rocket engine, Sänger still found time for theoretical studies on his aerospace transporter. In May 1938 his paper on the "Gaskinetik Schrgro Ber Fluggeschlindigkelten" (Gas Kinetics of Very High Flight Velocities) appeared as a research report of the "Zentrale für Wissenschaftliches Berichtswesen" (Central Office for Scientific Reports) in Berlin-Adlershof (ZWB). In this study he determined for the first time the formula and numerical values for aerodynamic forces affecting vehicles at altitudes where the atmosphere can no longer be regarded as a continuous medium. At the California Institute of Technology, H.S. Tsien referred to this study already at the end of 1946 in his report "Superaerodynamics, Mechanics of Rarefied Gases" (Journ. Sci. XIII, No. 12, page 653, 1946); Sänger's study had influenced subsequent American work in the field of aerodynamics of rarefied gaseous media. It was translated into English by NACA in May 1950, and published as Technical Memorandum No. 1270. Incidentally, the study "Gaskinetik sehr hoher Fluggeschwindigkeiten" which began in the Autumn of 1937, also signified the start of Sänger's collobaration with Irene Bredt, a collaboration lasting over 26 years, up to Sänger's death.

In October 1938, according to Sänger's outlines, the construction of a steel model (scale 1:20) of a plano-convex supersonic glider plane (Figure 5) was set about. Its optimal lift-drag-ratio with an assumed landing velocity of Mach 0.12, and with a

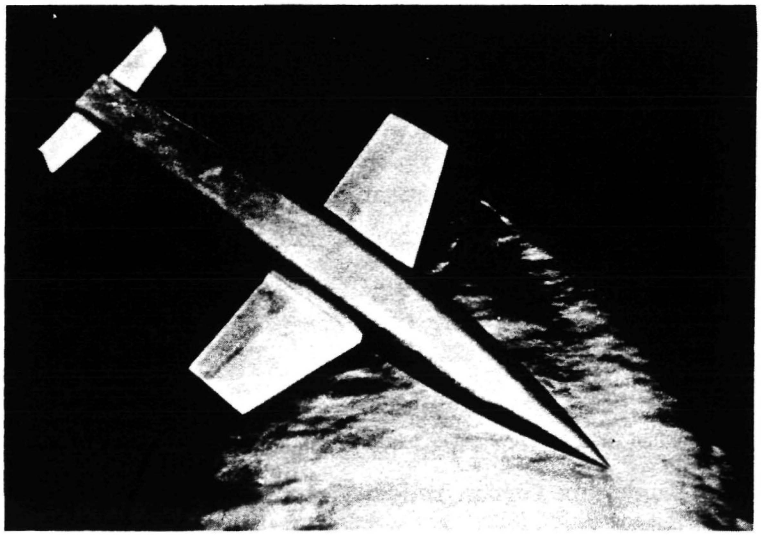

Fig. 5
Wind Tunnel Model of Sänger's Supersonic Glider,
Tested in 1938

5° angle of incidence, was measured as 7.75 in the subsonic wind tunnel. In comparison, the optimal inverse glide ratio of the American glider M-2 was measured as 3.2, with a 12° angle of incidence and a landing velocity of 133 km/h (Mach 0.11). In the supersonic flow region at low flight altitudes the optimal lift-drag ratio was calculated as 6.4 according to Newtons' Theory of Inelastic Collisions. In comparison, the best reciprocal glide ratios realized until now lie between 2 and 3 in the supersonic region, and at 4 in the hypersonic region. To be sure, the reciprocal glide ratios of Sänger's model calculated, assuming free molecule flow (i.e., very great altitudes), proved to be considerably less favorable than those in the region of continuous flow at lower altitudes, but on account of the low absolute values of lift and drag compared with the other forces acting on the craft in this region, they were of no practical importance for computing the flight-path. On the basis of these research results Sänger applied for a patent for his proposed airframe type with half ogival-shaped fuselage, nose, and wedgeshaped wing-profile. Because of its dome-shaped body profile and flat bottom, his assistants nicknamed it "flat-iron." Later on, the German Reichspatent No. 411/42 concerning "Gliding bodies for flight velocities above Mach 5" was granted on June 3, 1942, effective from April 22, 1939.

To save fuel weight, Sänger proposed accelerating his "Silver Bird" before lift-off to a velocity of about 500 m/s by means of a rocket driven launching sled sliding on a straight, horizontal, steel rail several kilometers in length. Thus, it became necessary to obtain knowledge about the amount of dynamical friction between the sliding surface and the upper face of the rail, considering the very high sliding velocities and the subsequent high negative accelerations of braking, for he had to ensure a reliable dynamic floatation of the sliding surfaces by choosing a suitable geometry of the lubricating gap, and a qualified lubricant. For the assumed extreme operating conditions there were no reference data in the literature at that time. Some even feared that it would be impossible to control the frictional heat and consequently the realization of the whole catapult arrangement became questionable. Therefore, Sänger asked his assistant, Irene Bredt, to collect proven values for dynamical friction and lubricating-procedures from qualified experts, and to study adequate research plants everywhere. But even Fottinger and Vogelpohl were not yet engaged in the investigation of sliding velocities of several hundred meters per second, although they worked as professors at the "Institut für Technische Strömungsforschung" (Institute for Technical Flow Research) at the "TH Berlin," at that time the most important German research institution in this specific field. On their test stands, consisting only of rotating elements, the highest sliding velocity obtainable was limited to a fraction of the required values, by the highest tolerable peripheral velocity, i.e., the highest practicable speed of rotation. Again Sänger had a resourceful thought. He suggested a stainless steel bullet("German sS-Geschob") to be fired with a velocity of about 800 m/s, from a military carbine rifle into the spirally curved entrance of a circular, closed, and lubricated steel groove with a U-shaped cross section. During this experiment the bullet would pass through all velocity-ranges down to complete rest (Fig. 6). These high velocity sliding-friction experiments began on June 2, 1939, and demonstrated that the construction of sliding faces for velocities up to 500 m/s was possible on a carefully finished and lubricated rail.

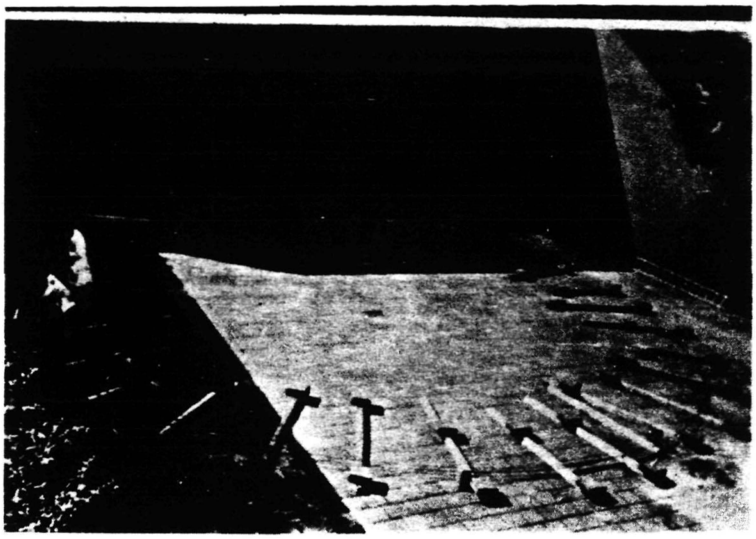

Fig. 6
Dynamical Friction Test Bed at Trauen.
The installation consists of a military carbine and a closed circular sliding track.

A rocket-sled constructed according to Sänger's plan was used 15 years later by the American air medicine officer, Dr. John P. Stapp, in experiments on the effects of short, very high accelerations on the human body. These experiments in the course of which Dr. Stapp endured accelerations up to 25 g, met a basic condition for the feasibility of manned space flight.

World War II burst out a few weeks after the successful sliding-friction experiments on the Trauen test ground. For the small staff of the rocket-research establishment on the quiet Lüneburg Heath, September 1, 1939, meant a sudden awakening from bold, romantic dreams. Sänger, with his own shy charm and his glowing persuasive power, had succeeded in inspiring all his team with great enthusiasm for himself and for his plans--from the head of the testing stand, (a typical representative of the Austrian aristocracy) down to the youngest canteen-helper (a pretty North German peasant girl). This small crew, spending together working hours as well as free time in the remote Oertze valley, and living rather isolated from other people and the general events of Germany at that time, had created their own separate dream world. Recognizing no differences of social origin they spent their free time together walking along the traces of the popular heath through the fen-country in dreaming twilight, listening to wood-pigeons and heath cocks, gathering mushrooms, devouring science fiction stories of Hans Dominik, and tasting red wine in tin cups, if they did not prefer to work voluntary overtime in order to accelerate the development of the silver bird. Everyone was happy to contribute his own personal effort to a work considered the realization of a dream of mankind. Even the driver of our service car earnestly hoped to pass his pilot examination and be able one day to navigate the first spaceship.

Now, suddenly, there existed "priority schedules," mobilization, calling up orders and, soon, a general shortage of material. The continuation of the research work and experiments at the "Flugzeugprufstelle," the camouflage name for the rocket testing stands at Trauen, appeared to be in danger for these projects were unsuitable for immediate military use. To be allowed to continue work at all, the military importance of the current work had to be demonstrated and auxiliary projects had to be worked out--projects that promised military application within a reasonable short time. One such project concerned a fighter plane with ram jet propulsion, that claimed more and more priority during the course of the war. Further, the results of the research work on Sänger's silver bird project, which had just been summarized in a report with the heading "Rocket Spaceplane," had now to appear in a new dress if the project wished to survive. Thus, they had to serve as a rocket bomber project. The good old "Flat Iron" became "Rabo" (anacroynm for Raketenbomber) in the talks and thoughts of the people working on it.

This "Rabo" report subsequently had a somewhat adventurous fate. "Enriched" with some chapters on the trajectories of bombs, impact ballistics, and offense measures, the elaboration of the original project report could for the time be continued. This project was mainly concerned with an Earth-orbiting, single-stage rocket plane with a launch weight of 100 tons (90 tons of propellant and payload) as well as a propulsion engine for the combustion of highly efficient fuels with liquid oxygen in a combustion chamber at a pressure of 100 atm. and 100 tons thrust (Figure 7). The maximum flight performance of this plane, (with the assumption of semiballistic trajectories and of a specific impulse of 400 sec.) was calculated as follows:

1. flight velocities at the end of the power flight phase of about 8000 m/s, corresponding to the necessary thrust for reaching orbital velocity with a one ton payload;

2. flight altitudes in the ballistic section of the flight path up to 300 km;

3. loading capacities for a transport to the antipodal point of the Earth (20,000 km) up to 8 tons;

4. flight distances up to a single Earth orbit with a payload of 4 tons, or up to two and a half orbits with a one ton payload.

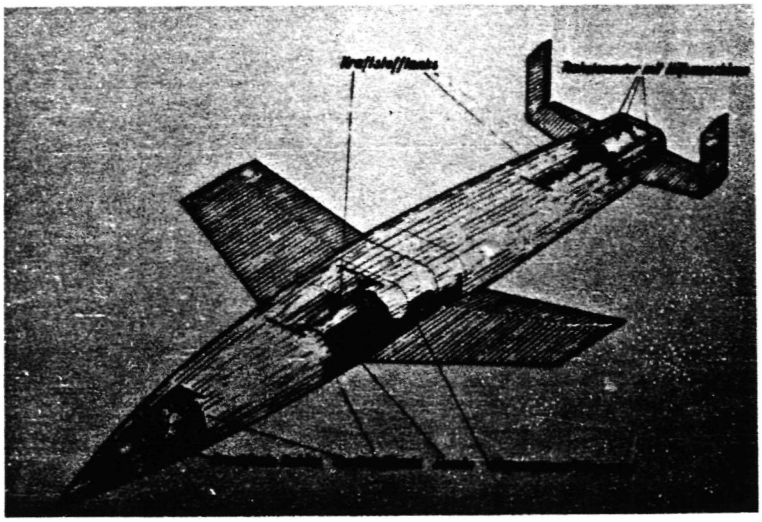

Fig. 7
Concept of Sänger's Orbiting Rocket Plane
with 100 Tons Gross Weight

These flight performance data became possible by the application of a semi-ballistic flight technique proposed by Sanger. This technique was later on known as "Rikoschettier" or "Hupf" (skipping) flight, where the aeroplane ricochetted from the denser layers of the atmosphere like a stone flung at a flat angle across the surface of water. In this way gliding flight paths could be obtained which were several times the range obtained with mere aerodynamic descent (Figure 8).

The manuscript with a new heading: "On a rocket propulsion engine for long distance bombers, "("Ubereinen Raketenantrieb für Fernbomber") was completed in 1941 and submitted for approval on December 3, 1941. But it by no means received the same enthusiastic approval from the authorities in the Reichsluftfahrtministerium (State Ministry for Aviation) as it later received from Eastern and Western countries. On March 17, 1942, the printing of the report was rejected outright by the Luftfahrtforschungsanstalt (Research Institute for Aviation) Hermann Goring (LFA), in the first instance. Sänger, who in his private life was one of the most peace loving of persons, was unprepared for compromise in his technical projects. With that refusal therefore, a period of bitter argument ensued. Because of a fuel shortage, as well as objective and personal differences between Sänger and his immediate superior in the LFA, Sänger and his team had to stop their work on the development of the 100-ton rocket motor in the autumn of 1942. However, Sänger and his closest colleagues were allowed to continue their series of tests on ram jet propulsion that had just started at the Deutsch Forschunsanstalt fur segelflug (German Research Institute for Gliding Flight) (DFS) at Ainring.

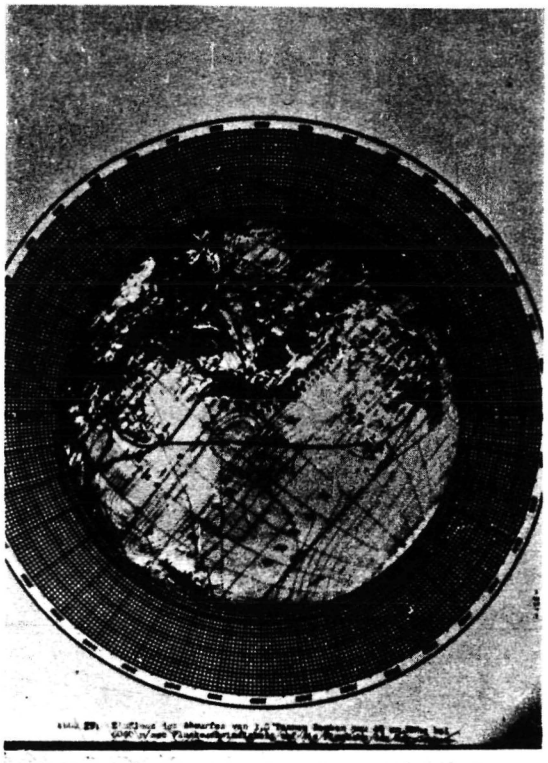

Fig. 8
Skip Flight Trajectory of Sänger's Aerospace Transporter, Assuming 7000 m/s Burnout Velocity, 400 s Specific Impulse and 3.8 Tons Payload

Works on projects adapted to the immediate requirements of war-time, such as the development of a ram jet fighter, an auxiliary ram jet propulsion engine for thrust increase of the ME 262, and related projects, as well as the external conditions of life, became more and more unbearable, and did not allow any detailed engagement with the problems of the space transporter during the last years of the war. However, with the support of Professor Walter Georglii, Sänger succeeded at least in publishing the report on a rocket propulsion engine for long distance bombers--even though shortened to half of its original size--as UM 3538, "secret command report" of German Aviation Research. The official approval for printing reached Sänger on his 39th birthday, September 22, 1944.

Events followed with great rapidity: total war, shifting of the work teams into emergency accommodations in the surrounding villages, collapse of the German Reich, marching in of the Allied Forces, operation "Paperclip," and the emigration of Eugen Sänger and Irene Bredt to Paris as consulting engineers of the Arsenal de l'Aeronautique. Subsequent collaboration with French officials, engineers, and workers Sänger found agreeable in both technical and human relationships: one reason being an early and generous grant of freedom of publishing for Sänger and his collaborators. However, the strenuous reconstruction of the French aviation industry during the first year after the war naturally allowed no scope for far-reaching and expensive projects such as an orbiting aerospace vehicle. Besides, the frequent changes of Government prior to the accession to power of General de Gaulle by no means encouraged continuity of current projects. For example, one evening we would convince Government representatives by a successful experiment of the suitability of a launching rocket with an alcohol-water mixture as fuel, only to be told next morning that a new government had again cancelled all liquid rocket projects.

So the project of the aerospace transporter rested in the refrigerator of world politics. Meantime, there were small encouragements such as the collaboration on the design of the French ram jet research plane GRIFFON, or even the news of the successful first flight of the American rocket research plane BELL-XS-1, that brought new confidence to Sänger after years of frustration. Moreover, with the resumption of international contacts which became feasible again, Sänger was pleasantly surprised to find that his early Viennese work had not been forgotten by the world, and that he had won most of his new friends with the very project that had so far caused him the most annoyance in his home country.

Of course, some of the 70 distributed copies of the secret report on rocket propulsion for long distance bombers had fallen intact into the hands of the Allies, with the conquest of Berlin and Dessau. They had been brought to the notice of rocket research scientists and engineers in the various nations. Some of these experts, like Alexandre Ananoff, Theodore von Kármán, Frank Malina, and Joseph Stemmer, were already in contact with Sänger before the war; others, like Val Cleaver, Arthur Clarke, Fred Durant, Andrew Haley, Leslie Shepherd, and Teofilo Tabanera, were congenial with Sänger and recognized at once in the rocket bomber project the first phase of the realization of spaceflight.

Immediately after the end of the war in most of the highly industrialized countries, private and national societies had been formed for the furtherance of space flight ideas. Some of these national societies met in Paris in the Autumn of 1950, and decided on the foundation of an international organization for the advancement of peaceful space flight. They selected Sänger as chairman of preliminary commission and, in September 1951, in London, as first president of the newly founded International Astronautical Federation (IAF).

Meantime, Sänger had been able to publish some of the chapters which had been deleted from his report, such as, in 1949, the "Kinematics of Spaceflight" in Interavia, and in 1951 a 95 page "Atlas of Selected Trajectories of Rocket Planes to the Spacestation and Back," in the Research Series of the Northwest German Society for Space Research.

On April 19, 1952, Lt. Gen. Walter Dornberger, the former Commander of the Experimental Station for Rocket Weapons at Peenemünde,+ called on Sänger in Paris. He came as a representative of the American Bell Aircraft Company to invite Sänger and his collaborator, who in the meantime had become his wife, to contribute to a rocket plane project for which Bell Aircraft hoped to get an order for development by the American government following Bell's success with the research plane X-1. In spite of the tempting prospects, Sänger and his wife chose not to accept this offer, partly for family reasons, and partly because most Sänger's French friends dissuaded him from his purpose, for they feared that Sänger would not feel happy for long in the rough, impersonal climate of American industries—especially as the receipt of a U.S. government order to Bell was only an indecisive promise in the first instance, something to be decided only after Sänger had joined the firm. Whether Sänger's decision to stay in Europe then was right or wrong, whether moving to the United States of America could have changed anything in the destiny of the space transporter, must remain unanswered. The friendship between Walter Dornberger and Eugen Sänger, however was not tarnished by this refusal. The day in Spring 1961 when Dornberger invited him to the Bell Aerosystems Company at Buffalo to show him proudly the regeneratively cooled liquid hydrogen-oxygen rocket motors with bell-shaped short nozzles (Figure 9) developed according to the Sänger-patents, was certainly for Sänger one of the happiest days of his life.

+"Versuchsanstalf fur Raketenwaffen".

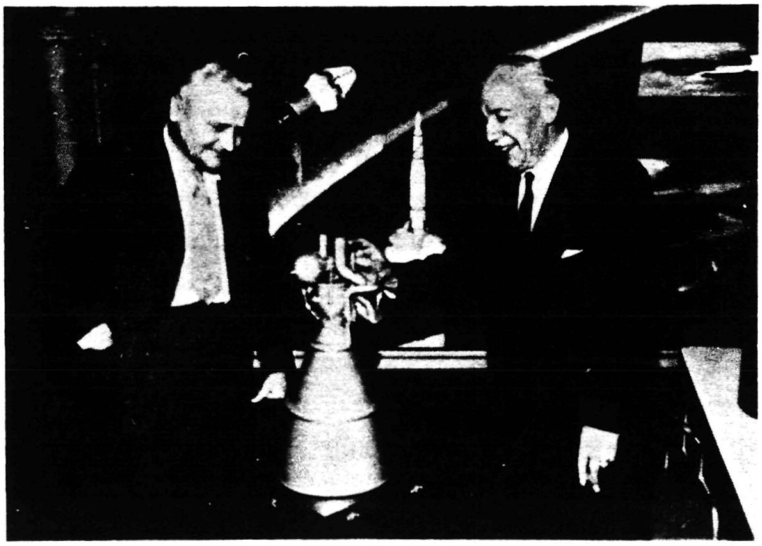

Fig. 9
Eugen Sänger and Walter Dornberger with a Model of LO_2/LH_2 Rocket Engine
Built According to Sänger's Patents by Bell Aerosystems Company

After the war, not only the West but also the East held offers of employment ready for Sänger, even if they appeared to be somewhat more adventurous than the sober offer of American industry. Sänger and his wife heard about this only through French Boulevard papers and discrete warnings by the French Security Service in September 1948, when the whole action was long over. It seems that at least one copy of the captured secret report on rocket propulsion engine for long distance bombers had reached the USSR, and had been submitted to Stalin. This copy gave rise to the following note from the Russian Chief of Government:

> The Council of Ministers of the USSR decrees that a government commission shall be formed for the purpose of directing and coordinating scientific research in the field of aviation problems, with special relation to manned rocket planes and to the Sänger project.
>
> The Commission shall be composed of the following persons:
>
> Colonel General Comrade Serov (Chairman)
> Engineer Lieutenent-Colonel Comrade Tokayev (Deputy head)
> Member of the Academy Comrade Keldisch (Member)
> Professor Comrade Kischkin (Member)
>
> The Commission shall depart immediately for Germany and undertake preparations for work. A complete report of its activities and achievements shall be submitted to the Council of Ministers on August 1, 1947.
>
> Marshal of the Soviet-Union Comrade Sokolovsky is hereby asked to support the Commission in every respect.
>
> Moscow, the Kremlin, April 17, 1947, Stalin.

After having searched for Sänger and Irene Bredt in vain for several months throughout Germany and Austria, Colonel Tokayev and Stalin's son Vassilij, who accompanied Tokayev, learned that both of the wanted persons were in France. However, before attempting to make contact, Tokayev took the opportunity to escape and ask for political assylum in the West in September 1948. He settled in England where he published a book Stalin Means War. From a copy of his book, the Sängers eventually learned the details of this venture. In connection with these events, the fact seems impressive that the Russians obviously adhered faithfully to their original plans in manned space flight and pursued projects which were influenced by the ideas of Valier and Sänger, namely:

- conquest of the Moon and the planets next to Earth by recoverable single stage or at most, two stage space vehicles which started from Earth orbital space stations and returned to them;
- construction and current supply of the orbital space stations by aerospace transporters.

It was obvious that Sänger, who had remained a sensible realist despite his ambitious technical plans, started now to worry about whether his projects, despite their technical feasibility, might after all be realized, considering the existing political-economical situation. He asked himself how large working capacities could be made available in favor of a concrete technical development program in order that its realization was guaranteed as far as scientific and technological aspects allowed. This led, in 1951, to Sänger's study, "What are the costs of Spaceflight?" in which he tried to extrapolate from experience at that time, the probable costs of development of representative spaceflight projects such as those of the first moonshot, an antipodal rocket-plane, a manned space station, or a manned orbital flight around Mars. A diagram from this first investigation (Figure 10), subsequently extended, shows the consumption of working hours for development as a function of the necessary engine exhaust velocity for different missions according to the technical level of development. The diagram shows clearly for the first time that, while the discussed projects were within the capacity of great nations, they surpass by far the capabilities of single smaller nations or even private industries. Six years before the successful launch of a first artificial Earth satellite, Sänger knew that spaceflight, even in the neighborhood of the Earth, belonged to modern large scale techniques, where decisions, because of the high expenditure of development, must move more or less completely from the economic sphere of private

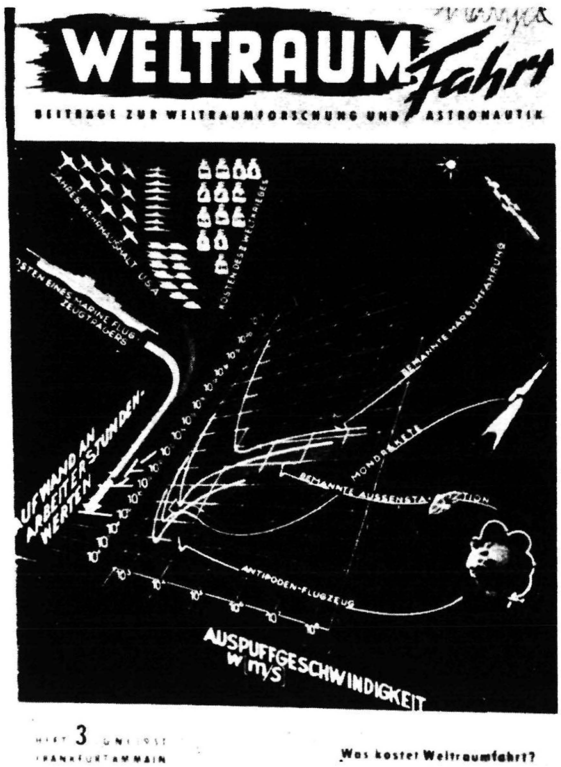

Fig. 10
Estimation of development costs for different space flight projects published by Eugen Sänger. The graph shows the expense in working hours as a function of the effective exhaust velocity attained by the appertaining rocket engines.

enterprise into the region of political power. Subsequently, he tried from that time to interest international societies in the project of the aerospace transporter, and decided to confine his own immediate research work to smaller, separate parts of the general project. He did so because he recognized not only the necessity of international cooperation, but also that the partners in such a community of work would need to contribute, besides money, sufficient technical "knowhow" to effectively participate in the development.

His appointment to Stüttgart from the summer of 1954, with the task of building and directing an Institute for Research in the Boundary Region Between Aeronautics and Spaceflight, allowed Sänger to restart again some modest practical work of his own. He concentrated on preliminary work for the development of suitable auxiliary launching equipment and the main propulsion engines for the aerospace transporter. Thus he began with a project for a ground fixed launching sled propelled by a steam rocket (Figure 11), following this with a liquid rocket engine mixing air in the exhaust jet according to ramjet principles. He also worked on an alternative solution for the first stage of a multiple stage transporter, namely the project of a supersonic ram jet engine. Apart from this he encouraged systematic basic research into different fields which might contribute to further development of the whole project. He commented on this: "Though design, construction, and use of aerospace vehicles in the end will crown all aerospace research, they in themselves represent rather secondary problems within the scientific research

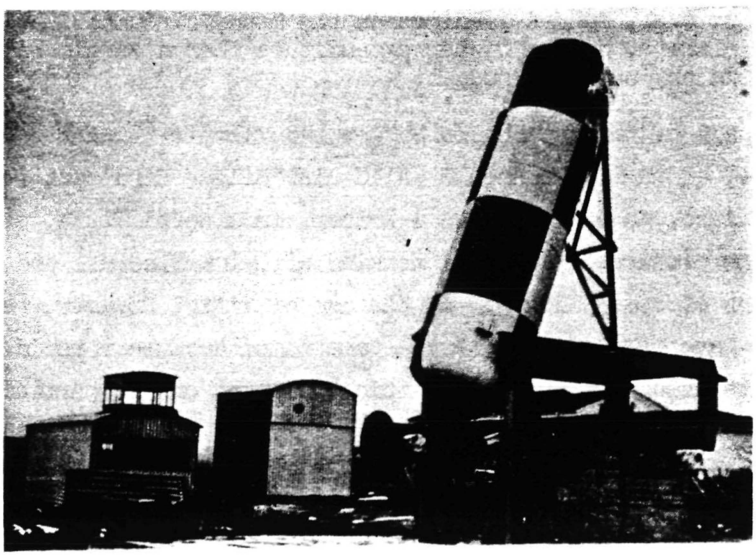

Fig. 11
Steam Rocket Test Stand of the German "Research Institute for the Physics of Jet Propulsion" (FPS) at Echterdingen-Stuttgart

work, since clarification of basic problems must precede these dominant routine engineering tasks."

Sänger also recognized that the necessity for international cooperation in the development of large scale technical projects was not dictated only by economic factors. In a paper published in 1954, "Research work within the field between Aeronautics and Astronautics," he explained:

> The basic idea of the International Astronautical Federation, and its most noble vocation is to let spaceflight become an aim for all mankind.
>
> The innermost motives for this aspiration might be primarily ethical or might be founded in human enthusiasm for a scientific technical problem with the fascinating power of space flight that allows one to forget all insignificant daily worries and oppositions beyond this immense task of mankind. But there are also a number of very sober, objective reasons for spaceflight to be realized only on an international basis.
>
> One compelling reason for international cooperation in spaceflight activities appears clearly in space research, because a single nation may have insufficient intellectual capacity to meet the wide ranging scope of scientific and technical problems involved. . . If we are obliged to internationalize space research in consequence of our limited intellectual capacities, then this argument applies just as much to the field of space technology, because of our limited national resources. It has been pointed out several times that space flight with characteristic flight velocities up to about 13 km/s, such as missions with long-distance rocket planes, ballistic Moon rockets, space stations, and Moon orbiting satellites, still fall into the region of the budget of the greatest nations as to their real expenses. . . .
>
> Further plans, with characteristic flight velocities above 8 km/h, for the whole mission, e.g., manned landings on the Moon, circumnavigation or landings on planets, demand higher expenditure than a single nation can tolerate and are beyond any national budget.

At the age of thirty, Eugene Sänger had, in his thoughts and diaries, fought the conflict as if he, as engineer, should build his "Silver Bird" and realize the first phase of space flight, or as if he, as a writer, in a novel Thule, should draw for his contemporaries the picture of an ideal mankind with intellectual and cultural maturity equal to his plans of space flight. At the age of fifty, however, he was aware that in fact he ought to have created both at the same time; because a rapid realization of his technical projects assumed moral and political insight on the part of nations and their individual representatives that simply did not exist. Up to that time, he had always believed as a matter of course in the reason of men and their decency. Now, as the desire for the realization of his technical plans forced him to come to terms with just these men, he was mocked because of such naivete and, furthermore, was attacked out of ignorance. For the first time in his life he really began to despair. In the summer of 1957 he suffered his first heart attack. Still in his sick bed, he wrote a paper about the stage of development of missiles, unmanned supersonic flight devices, and space vehicles in the

East and West. The news of the successful development of the American rocket plane X-15, which was to serve for research into manned high-velocity and mesosphere flights, encouraged once more his confidence.

During his recuperation on the Ostersee in Upper-Bavaria, on October 4, 1957, he heard the news of the first successful launch of an artificial Earth satellite orbited by means of a multiple stage ballistic rocket from the USSR. This event brought space flight overnight respectability. The crowd of reporters who flooded the quiet Lauterbacker Mühle, Sänger's refuge, already foreshadowed the fact that from now a preoccupation with space flight would become a political preoccupation too, and attract profiteers among the professionals as light attracts moths. Furthermore, it would become an instrument of the "cold war" between nations thenceforth, and last but not least, a stimulant for the whole industrial technological development on Earth, and thus represent a considerable factor in economy and power.

In many smaller countries, especially in Europe, there suddenly appeared the prospect of national budget funds for space research. The time had dawned when spaceflight became an object of state subsidies--including all its advantages and disadvantages. Silent disregard of all astronautical endeavors practised by the official representatives of science, technology, and government until then was now replaced by a keen struggle for the best starting places for collaboration, and it was not by chance that the center of gravity in projects immediately shifted from astronautics technology towards general space research, where more people felt themselves competent. Already in 1958 the International Council of Scientific Unions (ICSU), in which the national Academies of the Sciences of about 40 countries were united, founded a special committee for questions of space research, COSPAR (Committee for Space Research). An "ad hoc" committee for furthering the peaceful use of space was likewise formed in 1958 by a resolution of the U.N. plenary session. On December 11, 1959, this was converted into a standing U.N. Committee with at first 24 member states.

In the Western European sphere the "Groupe d'Etudes European pour les Recherches Spatiales," active after June 1960, developed into the European Space Research Organization ESRO, the foundation of which was signed in Paris in 1962. Parallel to these activities, nearly all civilized states formed national Space Authorities or agencies. However, all these newly-formed organizations limited their range of work to new possibilities for space research and space exploitation opened up by satellites and space probes. In the technological field they engaged only in the development of scientific instruments and containers like probes or satellites, i.e., the so-called "payloads." They cared little about the technical feasibilities of launching equipment or men in space. Especially, they were unconcerned about the development of carrier-rockets and manned space vehicles.

The political doubtfulness of such an attitude was not difficult to recognize. So, following recommendation of the British government, on September 2, 1960, Australia, Belgium, the Federal Republic of Germany, France, Great Britain, Italy, and the Netherlands, joined in the task to develop a European satellite transporter. A European Launcher Development Organization (ELDO) began work in Paris on September 15, 1962; the agreement was signed successfully by the member states and at last ratified on May 5, 1964--three months after Sänger's death. Although the first successes with the trials of the American X-15 rocketplane were obvious from 1959, and although it was known with reasonable certainty that in the USSR work on the development of recoverable aero-ballistic carrier equipment was proceeding--especially theoretical and experimental studies concerning skip flight--the work of ELDO concentrated only on the development of a 3-stage ballistic rocket of classical construction. Its single parts were separately developed in the different member countries or modified there from existing hardware in order to adapt them to their use within the total project.

Sänger (who attended the preliminary discussions for the foundation of ELDO in January 1961 as a German delegate at the first expert conference in London) early had recognized two essential weaknesses of this organization:

1. When the project began it was already technically surpassed. Therefore, the ballistic carrier rocket EUROPA could only be of some use in case that new qualified working teams had to be established after a long period of technical abstinence and, nevertheless, should be brought to effective cooperation with optimal efficiency in large-scale technical projects.

2. An international body of the character of ELDO, where political interests claim priority over technical necessities, where the different interests of the member states have to be reconciled by conference partners with no real authority, and where no long-term commitments can be concluded, where besides all this technical decisions are made by political functionaries, where each decision is preceded by time-consuming bureaucratic measures, and where the real experts of the technical developments at best, are only briefly heard. . . such an apparatus cannot conceivably effect the realization of true technical progress, especially if there exist competitors in its neighborhood with less heavy organizations.

The subsequent fate of ELSO unfortunately confirmed Sänger's gloomy prognosis.

He tried in the following period to act according to his perception--on the one hand by public education work, on the other hand by attracting to those organizations others who seemed to be suitable to carry on the developments. In this way he had, so to speak, to struggle on two fronts; first for his project of an aeroballistic space transporter serving as a ferryboat between Earth and space stations, and second, against the chronic aversion to manned spaceflight, especially by the Federal German officials.

So in 1962 and 1963 he wrote the following publications: "Which Gaps in the Spaceflight Technology can be Filled by Europe?" "Space flight--Yesterday, Today, and Tomorrow," "From Ballistic to Aerodynamic Spaceflight," "Now or Never--Eleventh Hour for

European Spaceflight," and last, a 21-page Memorandum dedicated to the President of the German Federal Republic in which Sanger--following an introduction on the consequences of space flight and the necessary expenditure for its realization--drew up a detailed program of basic research in astronautics and of the best ways to organize space flight in the German Federal Republic.

He indicated again the propositions presented by him concerning the formation of centers of main effort in the European aerospace industry:

(1) Small satellite carriers and Earth satellites on the basis of the existing English Blue Streak and French Veronique rockets, in the framework of the European Satellite Program - mainly for the introduction of the European industry and research institutions into the technique of space flight.

(2) Manned aerodynamic Earth-Orbit-Earth-ferryboats in order to supplement the corresponding U.S. developments, which worked only with limited resources, and to produce economical and reliable supersonic planes for the fastest possible air travel as well as conveyor vehicles to reach Earth satellites and Earth space stations.

(3) Fast manned interplanetary space vehicles based on the development of nuclear energy rocket engines of high thrust, and of high specific impulse.

Propositions (2) and (3) made in 1961 by Sanger, correspond exactly to the latest U.S. official general conception with the following key elements: "Space-station," "Space-shuttle," and "Nuclear Propulsion" (Project Rover), as made known by President Nixon in September 1969. About a possible starting date for such a development, Sänger wrote in 1959 in a contribution, "The Future of Space Flight," to the collective report of the Select Committee on Astronautics and Space Exploration, on The Next Ten Years in Space, 1959-1969, for the American Congress: "With the beginning of the first interplanetary phase of manned spaceflight--probably around 1970--mankind will step into its cosmic age. The proper spacecraft will presumably never enter the atmosphere of the Earth or of other planets, but will only move in empty cosmic space between the space stations of the planets."

The time-table for the successive phases of development, namely research, development, testing, production, and actual use between 1960 and 2000, was described by Sänger in a graph (Figure 12) for the following spaceflight-projects: Pioneer landing on the Moon, Installation of a near-Earth space service-system (aerospace transporter), Construction of permanent Earth-orbital space stations and moon stations, High efficiency nuclear propulsion engines, Installation of a fast interplanetary transport system, Pioneer flights in interstellar space.

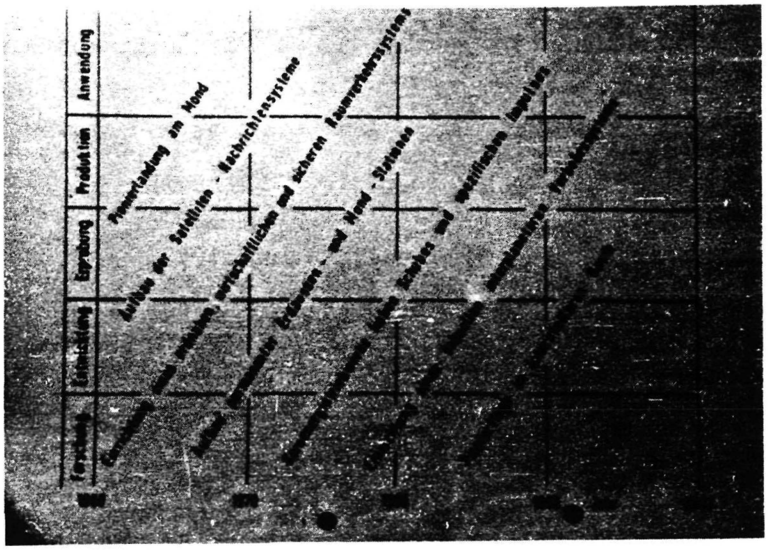

Fig. 12
Estimated Development of Space Flight According
To A Sänger Study in 1959

Sänger explained his ideas about the future progess of the development of space flight in more detail during an address on the occasion of his appointment to the newly-created chair for Space Flight Technique at the Technical University Berlin, early in 1963:

> The first pioneer phase of practical space flight will probably be terminated during the next few years with the landing of men on the Moon. With this event practical space flight in the neighborhood of the Earth will enter into its next phase, that of big, regular transportation problems such as the organization of a hypersonic air traffic over long distances on Earth, of building manned space stations circling the Earth, and furthermore of the construction of permanent habitable stations on the Moon.
>
> The demands for large and presumably rapidly growing transportation volumes in space, expected within the next few years, arises with a number of tasks:
>
> (i) Establishment of a hypersonic air traffic system between different points on the surface of the Earth over distances from 800 km to 20,000 km, with flight times below two hours, that is, with the highest physically possible velocities within the Earth's atmosphere;
>
> (ii) Launch of numerous scientific and commercial satellites into Earth orbit, and returning them after they have concluded their mission;
>
> (iii) Building of large, manned, space stations in Earth orbit for scientific and economic purposes, and especially as transit stations for space transport between Earth and the Moon;
>
> (iv) Provision of these manned space stations with the materials necessary for their maintenance, change of crews, and transport of visitors;

(v) Transport of the necessary equipment and men to the Moon and back to Earth, required for the building and continuous management of permanent Moon stations;

(vi) Transport between different Earth orbiting space stations, and between these and unmanned satellites for the purpose of control, salvage, rescue work, repairs, change of orbiting planes, etc.;

(vii) Military political services.

This increase in missions and in transport-volume which requires a regular transportation system within the near space, introduces a whole range of new and greater demands on the spacecraft. In the first place, the average of only 50% reliability of the ballistic space vehicles of today is much too low for these tasks, especially in view of the fact that the spacecraft in this second phase of practical space flight have to carry not only crews, but also passengers.

At the end of May 1961, a few days before the constitution of a pooling agreement among aviation firms, namely the "Association Internationale des Constructeurs de Material Aerospatial" (AICMA), industrial managers met at Konstanz for one of the Drielander-Congresses of the Federal German, Austrian, and Swiss Space Flight Societies organized by Sanger under the Motto "Space Flight and Europe." Sänger was searching for a suitable European Society to support his Space Transporter Project; the European space flight industrialists on their part were looking for promising projects toward which to orientate their common work and aims. Thus both partners consulted together.

On September 21, 1961, an association of 86 European firms for common industrial development in the field of the spaceflight techniques, called EUROSPACE, was founded in Paris as a sub-organization of the AICMA. On October 4, 1961, Sänger and his wife were nominated associate members of EUROSPACE by the executive committee of the newly-founded association, and on April 30, 1963, the management of the EUROSPACE project group "Aerospace transporter" was assigned to Sänger.

On July 1, 1961, Sänger had already concluded an agreement with JUNKERS about "consultation on the selection of and work on spaceflight developments." Following his advice, all activities were concentrated on preliminary studies for a smaller, manned space transporter (Figure 13) for antipodal flights or transport missions in a 300 km Earth orbit; the assumptions of these studies were: 180 tons launching weight; 2.5 tons payload in orbit; horizontal catapult launching by means of hot water rocket-propulsion; also, for the first phase of development, a two-stage device, each stage with liquid hydrogen-oxygen rocket propulsion of known characteristics (I_{sp} = 430s). Following development Phase One, a single stage with increased specific impulse (up to 540s) was specified.

Sänger's endeavors met with approval in the German Federal Republic. The Commission for "Space Flight Technique" responsible for aerospace project planning since July 1961 recommended for the first time in their 1963 Research program for German

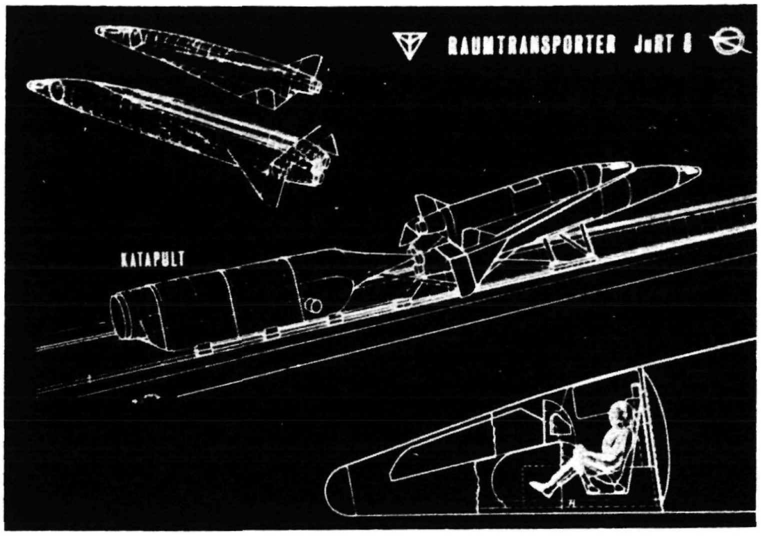

Fig. 13
Two-stage aerospace transporter studied by Junkers Flugzeug- und Motorenwerke (now part of Messerschmitt-Boelkow-Blohm) in the early 1960's. Eugen Sänger was consultant on this project which incorporated many of his original ideas.

industry a "Study Project 623" for the determination of the design parameters for a space transporter. For this project a yearly budget of 6.6 mill. D.M. was recommended as well as work in collaboration with EUROSPACE.

Sänger summarized his experience and knowledge in the field of recoverable space transporters since August 1961 in a comprehensive House Report of JUNKERS, "Preliminary Proposals for the Development of a European Space Vehicle." (He supplemented this report up to date and completed its Chapter 32 in the morning of February 10, 1964--only a few hours before his sudden death from another heart attack.) That report, in which Sänger dealt with the scientific, technical, economical, and political aspects of the project, also contained a summary of the possible variations and alternatives of the following space transporter and space glider projects, which were known at that time:

(1) X-15, a research plane for manned hypersonic flight, launching from a carrier airplane (North American Aviation Inc./USA);

(2) X-20 (Dyna-Soar I), a research soaring plane for re-entry tests, launching vertically by ballistic carrier rockets (Boeing Comp./USA);

(3) ASTRO-A2, a 2-stage aerospace transporter, launching vertically (Douglas Aircraft Comp./USA);

(4) M-2, a manned soaring space plane with auxiliary propulsion device by solid rockets, launching from a carrier airplane (NASA/USA);

(5) ASP (Aerospace Plane), aerospace glider for preliminary studies in view of manned aerospace transporter with liquid-hydrogen-ramjet propulsion for operation in lower flight altitudes and devices for liquefaction of air to extract oxygen from the atmosphere for operation in upper flight altitudes (USAF-Aeronautical Systems Division/USA);

(6) T-4A, an unmanned, 3-stage antipodal airplane with horizontal launching by catapult (manufacturer unknown/USSR);

(7) Orbital Fighter; manned, 2-stage aerospace transporter with ramjet propulsion during the first stage (Royal Aircraft Establishment/GB);

(8) MUSTARD, a 3-stage aerospace transporter with parallel-arranged cluster, vertical launching (British Aircraft Comp./GB);

(9) Lane Project, preliminary design in view of a 3-stage aerospace transporter with horizontal launching, airbreathing first stage, and rocket propulsion during the following stages (Bristol Siddeley Ltd./GB);

(10) EUROSPACE space glider model, a reduced variation of X-20 (Nord-Aviation/EUROPE).

After critically balancing all these projects Sänger drew the following conclusions from his investigation: "It is my firm opinion, that for civil use of the aerospace transporter the catapult start by means of steam rockets and the main propulsion by liquid-hydrogen liquid-oxygen high pressure rocket engines, is the best initial approach. Later on the main stage may be powered by thermal nuclear fission rocket engines. The total launching weight should initially be chosen between 100 and 1000 tons, and the use of single stage vehicles may be justified if catapults are applied for launching." In opposition to the trend towards a vertical takeoff with a modest lift-to-drag ratio between 2 and 3 in the hypersonic flight range — a technique which needs less development effort in the beginning — Sänger always insisted upon developing aircraft with high reciprocal gliding ratios and the application of horizontal launching devices.

Only a few weeks after Sänger's death an American newspaper article confirmed Sänger's daring expectations, always somewhat doubted in Western Europe. It is reported there:

> According to studies of the United Aircraft Corporation which were carried out for a commission of NASA, outward and return flights to the Moon with a single stage space transporter system lie in the region of feasibility. The firm is now working on studies for a one stage space transporter which shall be equipped with a gaseous core nuclear rocket propulsion device. Such nuclear propulsion engines would make feasible loading capacities up to 30% of the launching weight and would also offer the economical advantages of a recoverable aerospace transporter system. . . .

In 1965, the "Deutsche Gesellschaft fur Raketentechnik und Raumfahrt" (German Society for Rocket Technology and Astronautics) founded a "Eugen Sänger Medal for special merits in the field of recoverable space vehicles" in honour of Sänger who acted as a president of this society during 8 years before his death. On October 6, 1966, this medal was awarded to Dr. Walter Dornberger for his working on the project of A-10 in Peenemünde; on December 5, 1968, the medal was awarded to John V. Becker leading project engineer of the X-15 team.+

Eugen Sänger did not live long enough to see the realization of his dream of the "Silver Bird". However, 3 years before his death, on April 12,1961, he learned that the Russian Yuri Gagarin had first succeeded in a manned orbital flight around the Earth. More than 5 years after his death, on July 21, 1969, the American Neil Armstrong, was the first man to set foot on the surface of the Moon.

With this event began the "interplanetary phase of manned space flight" predicted by Sänger in 1959 for some time in the early 1970s. With the development of the American "Space Shuttle" a first step has been made towards the realization of Sänger's aerospace transporter. May the defiant motto of Eugen Sänger's youth become true: "Nevertheless, my Silver Birds will fly!"

+It was awarded on October 8, 1970 to George S. Mueller, leading project engineer of the Space Shuttle development. In 1970, the International Astronomical Union approved Sänger's contributions to rocketry and space flight by giving his name to one of the newly discovered craters on the Moon.

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