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Eugen Sänger: Eminent space pioneer

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Abstract

In international literature on astronautics, three main space pioneers are mentioned: Konstantin E. Tsiolkovsky, Robert H. Goddard and Hermann Oberth. There are other two space pioneers that are very rarely mentioned: Robert Esnault-Pelterie and Eugen Sänger. Pelterie is known particularly in Europe, and Sänger is mentioned in the second half of the 20th century normally only in connection with space shuttle flights.

Taking a look at Sänger's work and heritage, it is obvious that he greatly influenced the development of astronautics in terms of purely theoretical dissertations on achievable limits of space research as well as in terms of technical approaches to achieving the short- and long-term goals of astronautics, and in terms of setting tasks for organizing mankind to achieve these goals. Sänger's book "The Technology of Rocket Flight" was the first study based not only on basic research, but also on the applied research that he conducted and the findings of which he published in various papers. Sänger was clearly connected with and influenced the development of two experimental research groups in the US in the 1930s, which resulted in two of the most significant companies in the US in the 1950s that manufactured liquid propellant rocket engines. Basic and applied research in the field of space planes resulted in construction of rocket planes such as the US space shuttle and Soviet Buran shuttle.

Sänger's research on subsonic and supersonic ramjets in combination with a turbojet engine provided a basis for developing this promising propulsion for use in subsequent space planes designed for flights into low Earth orbits. His pioneering work on the photon rocket represents human achievements in reaching almost unimaginable limits of space research.

By striving for a peaceful international approach to space research, Sänger participated in establishing the non-governmental organization IAF (International Astronautical Federation) and realized his idea that space research is a concern for all mankind. He was therefore appointed the first president of the IAF.

The paper presents how Sänger influenced the development of rocket technology and astronautics, which definitely ranks him with the first three space pioneers.

1. Introduction

In general, there are four well-known space pioneers: Konstantin E.Tsiolkovsky, Robert H. Goddard, Hermann Oberth and Robert Esnault-Pelterie. This group should by all means also include Eugen Sänger. Sänger's book Raketenflugtechnik [1], published by Oldenbourg in 1933, was the result of a number of experiments on model rocket engines in the laboratory at the Technical College of Vienna. First, Sänger's book was the primary source for engineers, offering them practical knowledge on the development of rocket engines. Second, the book established a basis for high-speed plane flights, nowadays known as space planes.

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Third, during World War II Sänger began carrying out practical experiments on aircraft and missile propulsion systems—that is, on a subsonic ramjet. Working in France after World War II, he developed a combination of a turbojet engine and a ramjet engine for high supersonic speeds. His efforts resulted in the Griffon-2 aircraft, which flew at a speed of Mach 2. He thus indicated new possibilities for combined propulsion, which are now being intensively developed and will enhance the cost-effectiveness of flights destined to reach initial orbital velocity. Fourth, at the beginning of the 1950s Sänger developed a theory of photon rocket propulsion for interstellar flight, thus showing the greatest possibility for space flights. Fifth, Sänger had always strived for the internationalization of space flights, establishing astronautics as an international concern uniting all the potentials of our planet, particularly for peaceful purposes. He formed this idea after World War II and especially promoted it during the Cold War. With such an attitude towards astronautics, he was one of the most ardent supporters for establishing the International Astronautical Federation (IAF) and he was therefore appointed its first president.

All the facts mentioned above, which will be dealt with in this paper, prove that Eugen Sänger belongs to the first group of space pioneers who established the foundation for astronautics and space flights.

2. Sänger's influence on the development of rocket engines

At the beginning of the 1930s, when Sänger decided to explore the possibilities of space flights, he realized that there was very little relevant literature and practically none offering engineering results and guidelines for designing rocket engines for high-speed aircraft and space shuttles. Therefore he started conducting a series of laboratory experiments on model rocket engines at the Technical College in Vienna in 1931. Through these experiments he was able to define certain elements of rocket propulsion such as thrust, specific impulse or exhaust velocity, combustion chamber pressure, combustion chamber size, the system for injection and dispersion of combustible components, thrust chamber cooling (in particular, regenerative cooling Figs. 1 and 2) and establishing the optimal form of the exhaust nozzle. In addition, Sänger explored a number of propellant and oxidizer types; most of his experiments were carried out on liquid oxygen and gas oil. As a result of these experiments, he published his book Raketenflugtechnik [1] (Rocket Flight Technology) in 1933, his paper "New Results of Rocket Flight Technology" in a special edition of Flight magazine [2] in 1934, and in 1936 another paper entitled "The Rocket Combustion Motor" in the magazine Swiss Construction [3].

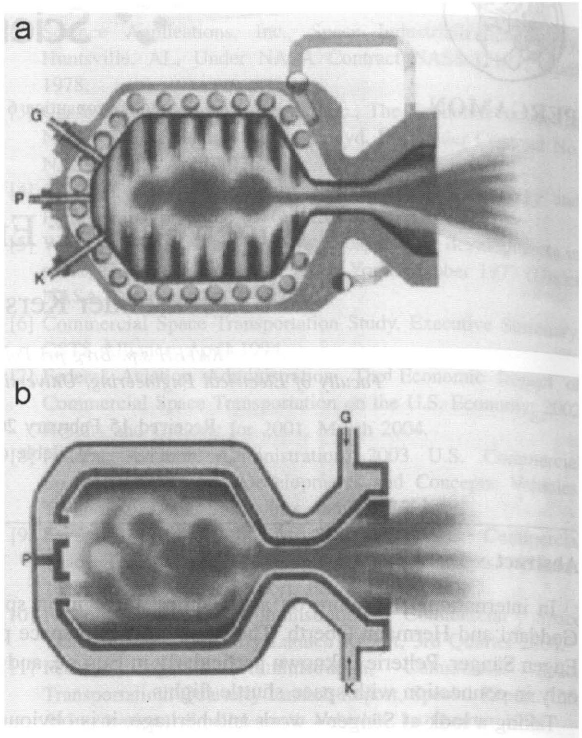

Fig. 1. Regenerative cooling thrust chamber from Sänger Patent (Österreichisches Patentamt Patentschrift No. 144809 5.2.1935).

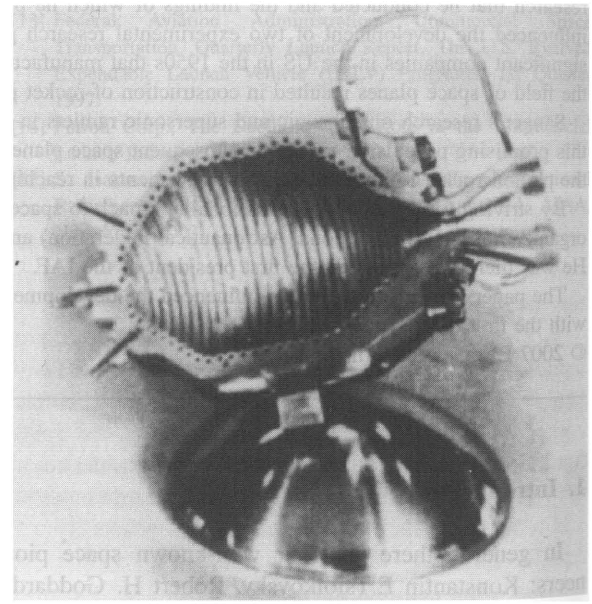

Fig. 2. Cross-section of the model thrust chamber.

The paper presents the findings of his research in detail [4]. All of these publications, especially both papers, directly influenced the development of two groups: one on the US west coast and the other on the US east coast.

At the Guggenheim Aeronautical Laboratory of the California Institute of Technology (GALCIT), Professor Theodore von Kármán, together with his assistants and students, studied various aspects of high-speed aircraft flights. In March 1935, graduate assistant William Bollay summarized and presented Sänger's findings from the 1934 paper in a seminar and presented the features of a rocket-powered aircraft. This was reported by the Los Angeles Times. Two space enthusiasts—John W. Parsons and Edward S. Forman, who wanted to build a liquid propellant rocket engine—asked GALCIT to help them in their lack of funds and technical knowledge. They were directed to Frank J. Malina, who was a graduate assistant at the laboratory. Their effective cooperation led to the establishment of the Jet Propulsion Laboratory [8]. Even earlier, in 1942 the team led by Professor Kármán established Aerojet General Engineering, later renamed Aerojet General, a firm that especially produced JATO (Jet Assistance Take Off) rockets at the beginning. The firm became and remained the second most important enterprise manufacturing engines.

The American Rocket Society (ARS) was particularly active on the US east coast at that time. In its early stage, the society followed the German Space Travel Society (VFR, Verein für Raumfahrt) in its practical experiments on rocket propulsion systems. The results of the first experiments were similar to the German ones and were rather unpromising because the experiments were carried out by amateurs that did not take a systematic engineering approach and were not based on theoretical research tested through professional experiments. At that time James H. Wyld started working for the ARS; he systematically addressed the rocket engine issue from a professional point of view. He did not find satisfactory answers in the literature available at that time. To Wyld's great satisfaction, Peter van Dresser, editor of the magazine Astronautics, asked him to translate the article published in the Swiss magazine. New knowledge gained from the article led Wyld to opt for regenerative cooling. Based on this concept, he built a demonstration model rocket engine with a thrust of over 400 N and an exhaust velocity of over 2000 m/s [5–7]. The model rocket engine proved successful and was a basis and the reason for establishing Reaction Motor Inc. (RMI), the first corporation manufacturing special-purpose rocket engines. RMI built a number of rocket engines for the US Army, Navy and Air Force. RMI's best-known rocket engine was built in order to power the first supersonic aircraft in the world. It was called the XLR-8-RM-2, later renamed the XLR-11, popularly known as the "Black Betsy". It powered a number of supersonic aircraft such as the X1, the XP-91 and the Douglas Sky Rocket, and furnished propulsion for "lifting body" aircraft until the late 1960s. The engine's upgraded version XLR35-RM-1 served as the engine for the MX-774, which was a precursor to the Atlas ICBM, the first intercontinental ballistic missile.

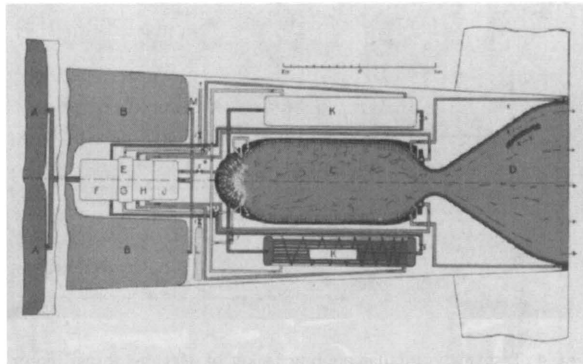

Fig. 3. Rocket motor of the Sänger's antipodal bomber with the characteristics of modern motors like high-pressure combustion (100 atm) tubular cooling jacket and bell-shape nozzle.

In 1936 Sänger was invited to work with the German Luftwaffe because of his great reputation in the use of rocket propulsion for high-speed aircraft. An institute was established for his working team at Trauen; for security reasons, its official name was the Institute of Aircraft Testing. There Sänger developed rocket engines with high thrust and high efficiency for powering aircraft. Used in experiments, these aircraft had a thrust of up to 10,000 N and an exhaust velocity of nearly 3000 m/s (compared to the V2 at 2100 m/s), reached through the classic propulsion combination of liquid oxygen and gas oil (kerosene). Sänger started developing an engine with a thrust of 1,000,000 N for the antipodal bomber project (Fig. 3). He wrote a report [9] on his work, which was translated into French and English. The document was later seized by the Russians and was made public when the West realized the fact.

The third enterprise, Rocketdyne, the biggest enterprise manufacturing rocket engines, was founded at the initiative of Bollay, who conceived and for some time ran the Navaho ICCM (InterContinental Cruise Missile) project at North American Aviation. The missile needed to be equipped with powerful booster rocket engines due to its propulsion and great weight. At that time,

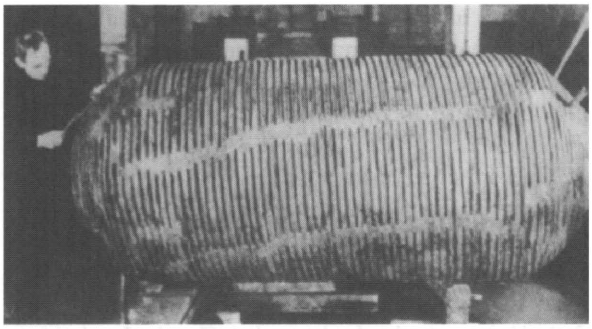

Fig. 4. Test of the tubular cooling jacket of 100 tons thrust motor.

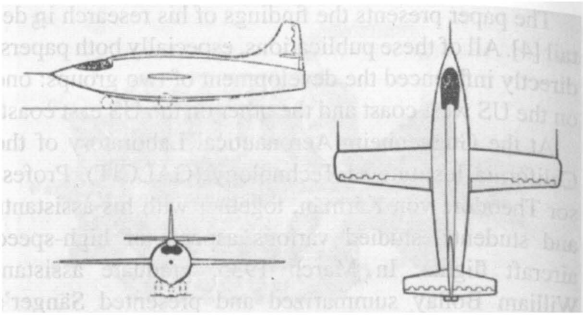

Fig. 5. Sketch of the Sänger antipodal bomber.

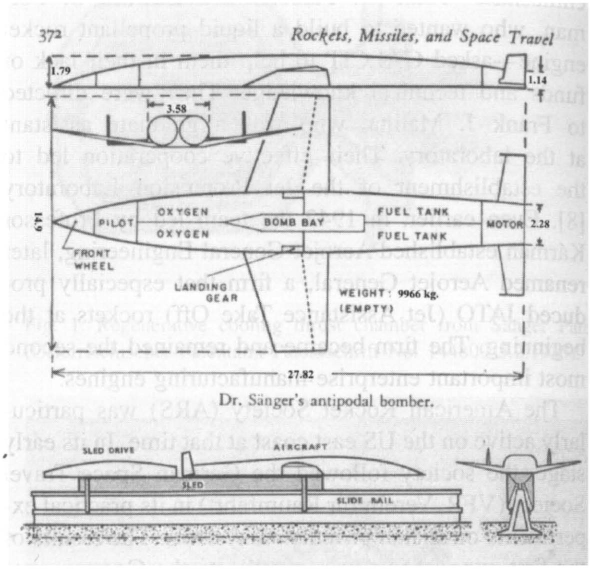

Fig. 6. Bell's X1 rocket plane of the late 1940s.

these engines were extremely high-powered, having a thrust of about 500,000 N, and were based mainly on the engine of the V2 rocket.

Regarding the high thrust of the propulsion system (with a cooling system consisting of special pipes forming the thrust chamber walls) and the propellant combination that Bollay used (liquid oxygen and RP1—in fact, gas oil or kerosene), it can be deduced that the Bollay's decision to build such powerful engines was influenced by Sänger's project to build an antipodal bomber. The bomber was based on a rocket engine with the following features: thrust of 1,000,000 N, a combustion chamber made from pipes arranged to form the combustion chamber walls and nozzles (Fig. 4), and fuel composed of liquid oxygen and gas oil or kerosene (unlike the V2, which was fuelled by lower energy alcohol). It can be concluded that Sänger influenced the development of all rocket engines including the booster engines of the Saturn V, which were the most powerful engines of their type in the world.

3. High-speed aircraft

Unlike other pioneers of rocket technology and astronautics, Sänger did not treat the rocket propulsion system as a ballistic system, but as a high-powered propulsion means for high-speed aircraft including space planes as the final goal. Sänger thus introduced a new field between aeronautics and astronautics—not separating the two sciences, but linking them. Furthermore, regarding rocket flight technology, he made his mark not only on the field of rocket propulsion, but also the fields of high supersonic velocities and, eventually, of hypersonic velocities bordering on escape velocity. He applied the aeroballistics of firearm projectiles in examining high supersonic velocities. The aerodynamics of these high-speed aircraft was a new field of research at the time of the book's publication. Therefore it is not surprising that the airframe of the rocket plane drawn in the book [1] closely resembles firearm projectiles. Sänger's influence on supersonic velocity flight technology can also be seen in this regard. Similarly, the American corporation Bell took a 0.45-in projectile as a model for airframe aerodynamics when it was designing the rocket plane that first broke the sound barrier. Sänger's sketch of a rocket plane (Fig. 5) greatly resembles the outline of the X1 rocket plane (ballistic airframe, flat wings and rocket propulsion); see Fig. 6.

Sänger believed in, and all his life encouraged, the introduction of a space plane as a means of transport to an orbital station. His suggestions were based on his antipodal bomber project from World War II, popularly known as the "Silver Bird" [9]. His endeavours resulted in a number of postwar projects, first military and then in space projects for aerospace planes. Sänger's final aim was believed to be the space shuttle. However, the path to a real space plane and to the final implementation of Sänger's ideas proved distant enough to be a subject of the future. By studying space planes, Sänger introduced entirely new areas of space research that are of scientific interest even now [10]. These are the following:

- Airframe loading and form at high supersonic velocities (up to Mach 30).
- Gas flow with simultaneous chemical conversion of circulating medium.
- Forces in the area of free molecules.
- Research into fuels, especially high-energy light metal supplements and utilization of liquid ozone as a more powerful oxidizer.
- Research into materials suitable for construction of demanding parts such as oxidizer pumps and pumps for high-capacity combustion chambers.
- Construction of steam-powered pumps.
- Construction of rocket-engine ignition systems.
- Construction of combustion chambers for extremely high temperatures and combustion pressure ranging from 50 to 100 atm, with water-cooled walls, internal cooling with steam and a thrust of 1,000,000 N.
- Development of a supersonic rocket catapult for the takeoff of a rocket plane.

Development of a mathematical theory and calculation of trajectories for long-range rocket aircraft.

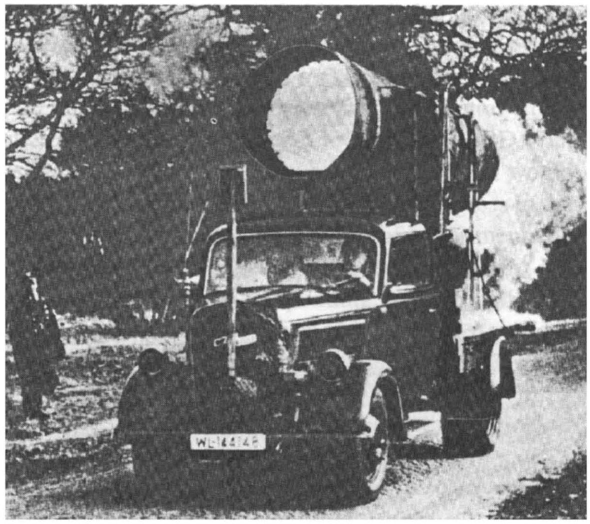

Fig. 7. Testing the ramjet's combustion space on the truck.

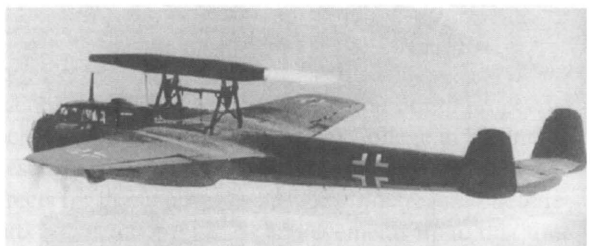

Fig. 8. The Dornier DO17Z with Sänger's ramjet.

4. Ramjet propulsion

While Sänger was developing the antipodal bomber in Trauen, he was also studying ramjet propulsion, which was then known as the "Lorin tube" after its inventor René Lorin, who had been granted a patent for it as early as 1913 [11]. In 1940 the Luftwaffe headquarters personnel sought an efficient propulsion system for a fighter interceptor aircraft to defend German airspace [12,13]. At that time, much hope lay in rocket-powered fighter interceptor aircraft, which resulted in the Me163 fighter interceptor. Sänger surprisingly suggested building a fast fighter interceptor aircraft with subsonic ramjet propulsion that would be capable of reaching an altitude of 12,500 m in two-and-a-half minutes. He carried out preliminary tests on the ramjet in cooperation with Professor Adolf Busemann from the LFA (Luftforschunsganstalt or Aircraft Research Establishment) in Volkenrode. Then he continued his work independently at the Trauen institute, where he defined the ramjet's combustion space through experiments carried out on an old truck (see Fig. 7) and later on aircraft at the local Hörsching airport. When the Trauen institute was closed down in 1942, Sänger turned to the DFS (Deutsche Forschungsanstalt für Segelflug or German Research Institute for Sailplane Flight) aviation institute of Einring, where Professor Walter Georgii made it possible for him to conduct further experiments on ramjets. At that period, he carried out flight tests on very large ramjets 500–1500 mm in diameter and 4–10.6 m in length (see Fig. 8) on Dornier DO17Z aircraft. Although Sänger knew that only supersonic ramjets had a future, he developed subsonic ramjets for practical use for military needs. Those experiments were also the basis for fighter interceptor aircraft such as the SK14 project (see Fig. 9) by the Škoda Corporation. In the last stage of the war Germany faced a great shortage of liquid propellants. Therefore Sänger suggested a ramjet using solid propellant in the form of a charcoal briquettes placed within the ramjet in a special metal framework that enabled controlled combustion. He thus pointed out

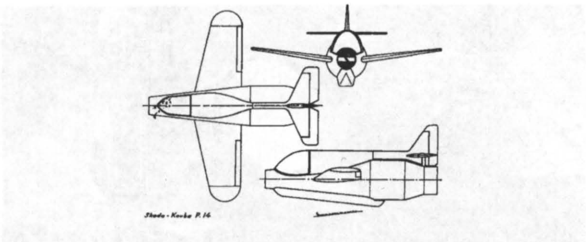

Fig. 9. Sketch of the SK14 fighter interceptor, February 1945.

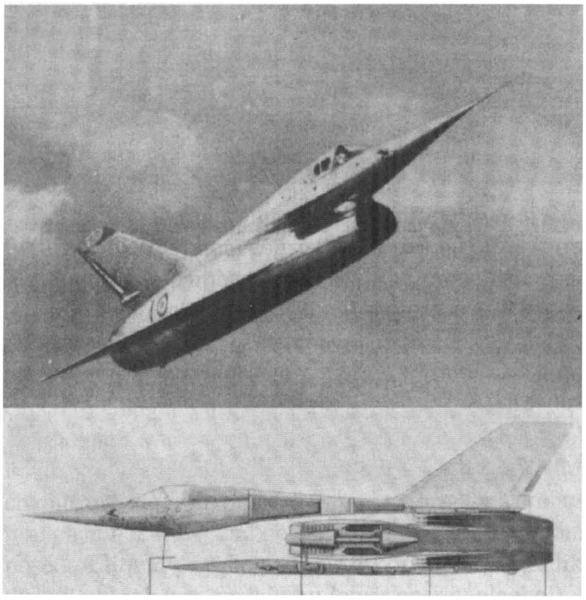

Fig. 10. The Griffon 2 cutaway, a turbojet engine in the middle.

another aspect of ramjet propulsion that remains of great interest even today.

After the war Sänger and Irene Bredt—his assistant at the time and later his wife—continued his work on ramjets in France, but on the more promising supersonic ramjets known in France thanks to René Leduc [11], who carried out experiments on them at approximately the same time. At that very period Sänger took a further step by integrating turbojet and ramjet propulsion, and thus initiated the further development of combined propulsions for high supersonic and hypersonic velocities. His research directly influenced the development of the Griffon 2 fighter interceptor [14] (see Fig. 10) with combined ramjet–turbojet propulsion destined for the velocity range of Mach 2. Nowadays, combined propulsion is popular with aerospace plane projects such as the Sänger 2 project [15] (see Fig. 11), which, unfortunately, has been suspended. Nevertheless, the development of combined propulsion systems for space planes

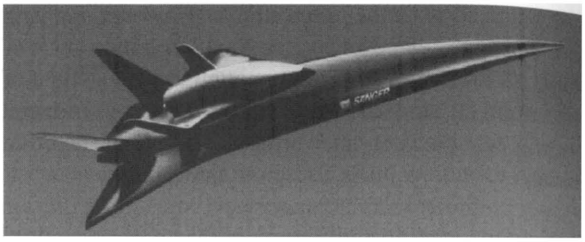

Fig. 11. The Sänger 2 space plane; the first stage using a turboramjet engine, the second stage an LOX + LH2 engine.

is going on in all countries developing transport facilities destined for space flights (the US, Japan, China, France, Germany and Great Britain). In the future, intensive further development of ramjet combined with other propulsions is expected because only combined propulsion makes possible economical utilization of transport means to travel between Earth and an orbital station.

5. Photon rocket propulsion

The area of interstellar flights that Eugen Sänger studied in his later years proves that he really was a space pioneer. After he examined orbital space through the engineering method of feasibility, he established the scientific basis for interstellar flights through research into photon rocket propulsion. He proved conclusively that there were real possibilities to design space propulsion capable of reaching flight velocities and ranges approaching the very limit of human scientific knowledge. In 1952, Leslie R. Shepherd published his paper on interstellar flight possibilities in the Journal of the British Interplanetary Society (JBIS) [16]. The paper tackled some basic problems concerning interstellar flights by means of modern physics, especially Einstein's theory of relativity. The key problem with interstellar flights is long distances and this can only be solved through high velocities, which are strongly affected by exhaust velocity. Theoretically speaking, the highest exhaust velocity is the speed of light reached by photons. Only a year later Sänger showed that interstellar flights are possible through photon propulsion. As in the case of the flights, his statement was based on the knowledge of modern physics as well as on the latest technical advances [17]. Sänger suggested a photon rocket that would use antimatter as fuel. A positron (the only known antimatter at the time) would be annihilated with an electron, which would result in the production of high-energy gamma rays to direct it. Later on he tackled the basic problems of photon propulsion from an engineering point of view and pointed to the solutions to be found in a source of photon radiation and in beam collimation. He provided basic physical equations in which he made use of advances in modern physics, particularly quantum mechanics. In addition, he examined the impact of photon propulsion on the environment, considering negative side effects. Through his theoretical contribution, Sänger established the basis for more in-depth research in the field.

6. Sänger's establishment of astronautics in the international context

In its pioneering period, astronautics stimulated the development of rocket technology, which became a powerful new weapon in World War II. After the war, the idea of space flights came to life again; supporters of the development of astronautics were inspired by the weapons created during the war that provided them with the proof, technical experience and knowledge to build rocket transport systems destined for space flights. Just after the beginning of the Cold War at the end of the 1940s, some national astronautical and rocket societies brought forward ideas to join efforts to develop and implement space flights. Eugen Sänger was the most prominent of all the supporters that promoted this idea at the beginning of the 1950s and encouraged national societies to unite at the international level through various articles and personal initiatives. Sänger wrote letters to national societies to summon them to organize debates and consider volunteer international integration. Based on Sänger's initiative, the first international astronautical congress was held in Paris in 1950 [18]. The congress resulted in the establishment of the IAF and Eugen Sänger was elected its first president. Whereas the first congress in Paris covered the IAF's organization and development in particular, the second one in London in 1951 was more work-oriented and included a number of papers on specialist subjects delivered at organized congress sections. President Sänger considered problems in astronautic research in his paper [19] and gave some guidelines for the development of the IAF.

7. Conclusion

The facts highlighted in this paper show that Eugen Sänger was a real space pioneer because he significantly influenced the development of astronautics in its period of early development: he produced ideas and then implemented them, and thus pointed the way to solving the key initial problem of space flights—that is, rocket propulsion—by applying an engineering approach. Tsiolkovsky developed Sänger's idea and also proved to a certain extent the theoretical possibilities of space flights through theoretical design of rocket propulsion. He had some influence on practical work in the Central Committee for the Study of Rocket Propulsion (GIRD), but this did not produce technical achievements that would establish the foundation for considerable progress in the field. Goddard carried out a number of experiments on rocket engines in the US and published the results, but he did not publish the corresponding methods and technical solutions. This is confirmed by several American pioneers from the JPL group that contacted Goddard but did not receive any technical or engineering information from him. Oberth conducted some practical experiments based on his theoretical work. The results showed only that such propulsion was possible; Oberth did not take any further steps to indicate the direction of development in that area. Esnault-Pelterie also conducted some experiments, but his results did not significantly affect the development of rocket technology in France or elsewhere in the world.

Eugen Sänger defined the technical elements of a liquid propellant rocket engine through a methodical scientific approach to experiments on liquid propellant rocket propulsion at the Technical College in Vienna. In these experiments he achieved very high efficiency and effects for liquid propellant rocket propulsion. These results outperformed all the achievements up to that time in the area of liquid propellant rocket propulsion. The first part of this paper demonstrates Sänger's indirect and direct influence on the development of liquid propellant rocket engines.

Essentially, Sänger revealed his view of the development of astronautics through his concept of a rocket serving as a propulsion engine for high-speed aircraft. In Sänger's view, this development was to be a follow-up to the development of aeronautics into astronautics. He thus opened a new broad and demanding area of research between these two sciences, which is being intensively investigated as part of the development of transatmospheric vehicles. At the same time, he conceived the idea of a reusable space plane that led to the development of the shuttle system and other projects to follow in the future.

The development of the idea of high-speed aircraft also had some influence in the area of aircraft propulsion, which was covered only theoretically at that time. Sänger carried out a number of experiments on subsonic ramjets, considering the circumstances that encouraged this, and planned a supersonic ramjet system that he implemented in France after World War II. This opened a new area of combined propulsion that is very demanding to implement from the technological point of view but vital for the future because of its cost-effectiveness.

By designing the concept of a photon rocket, Eugen Sänger hit upon the path towards the most extreme limits of space flight—that is, interstellar flight. He therefore started the very long development process of humanity's future exploration of space.

Sänger completed his pioneering space studies by striving for the internationalization of the institute of international space research. This may well be his greatest achievement in humanity's endeavours to conquer space.

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