On the Contributions of Dr. Irene Sänger-Bredt in the Field of Astronautics

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ABSTRACT

Irene Sänger-Bredt (born in 1911 at Bonn) had remarkable contributions in space science and technology. In 1937, after obtaining a Doctorate in Physics, she became scientific researcher at the German Research Center for Rockets in Trauen, led by Prof. Dr. Eugen Sänger. She became the first assistant of Dr. Sänger, who married her after the war, in 1951. There are three main periods in the development of her career: The first one was as researcher at Trauen (1937–1942) where she was mainly in charge of thermodynamic problems of liquid-fuelled rocket engines and of friction problems related to the rocket-powered launching-sled. The second one was as senior researcher at Ainring (1942–1945) where she was in charge of ramjet performances flight testing and also co-author of the cornerstone technical report "A Rocket Engine for a Long-Range Bomber". The third one was after the war, when she was scientific advisor or director in various civil and military research institutes and universities. Dr. Irene Sänger-Bredt worked together with Prof. Dr. Eugen Sänger to develop important theories, like ramjet thermodynamic theory and photon rocket theory, and also in establishing the International Astronautical Federation (IAF) and the International Academy of Astronautics (IAA). She worked with Prof. Dr. Eugen Sänger so efficiently integrated, that tracing a clear limit between their individual contributions to the ground-breaking achievements they made together remains a difficult endeavour. To this day, many important achievements of space science and technology, like the space plane and its regenerative cooling engine design, are still referred to as "Sänger-Bredt design".

KEYWORDS: *hypersonic, plane, ramjet, photonic, rocket*

1 A SCIENTIFIC EDUCATION

At the beginning of the 20th Century, many books and magazines continued the science fiction visions of Jules Verne regarding space travel. On the other hand, women performances were becoming more and more remarkable in all domains of activity, especially after the First World War, when they made impressive and substantial contributions, in all nations involved.
Irene Reinhild Agnes Elisabeth BREDT, born on April 12th 1911 in Renania, was one of these brilliant women who demonstrated that they can perform in sciences at least as high as men do. She graduated from high school in Köln and studied at the Universities of Köln, Freiburg and Bonn.
Köln was also the place where she could see a piece of real-life rocketry: one of the experimental cars of Fritz von Opel, „Opel-Rak 1" equipped with 12 rockets, which reached a record speed of 100km/h in 8 seconds on April 12th 1928. She looked for a book on this subject, and she only found one about rockets for fireworks, but that was nevertheless a trigger to study rocketry. Another trigger was watching the movie „A woman on the Moon", for which Prof. Hermann OBERTH contributed as scientific adviser of Berlin UFA Studios [1]. However, during studies at the Universities of Köln, Freiburg and Bonn, Irene was focused on another domain: "The Roentgen Spectra of Rare Earths", which will be the subject of her PhD thesis, sustained in 1937. The same year, rocketry came back into her attention when she received a job from the Research Center for Aviation in Trauen, which conducted rocket propulsion researches, although not recognising it officially. Before going there, she had been warned that: "…Possibly, it would be a matter of rockets" but that was, in fact, good news

for her. She was determined to obtain the job and even told the interview commission: "…but I know what you are doing here - rockets!" After examination, she got the job and soon became the best assistant of Dr. Eugen Sänger - the head of the Center [2].

Figure 1: Dr. Irene Bredt and Dr. Eugen Sänger

Her knowledge and skills were more than welcomed in the complex, interdisciplinary domain of rockets, and the way she worked with Dr. Sänger was so efficiently integrated, that tracing a clear limit between their individual contributions to the ground-breaking achievements they made together remains a difficult endeavour, to this day.

2 "SILVER BIRD" - THE GRANDFATHER OF SPACE SHUTTLE

In a 1951 speech, Prof. Dr. Eugen Sänger pointed out the difficulties awaiting space exploration development in the future, if mankind would "stubbornly" use only solutions based on rockets and capsules [3]. Thirty years later, the Space Shuttle brilliantly proved his point and – in spite of two tragic events that marked the programme – led the way to other projects, like "Buran", "Sanger", "Hermes", "HOTOL", all aiming to develop the space planes flotilla of the future.
A contract signed in February 1st 1936 with „Deutsche Versuchanstalt fur Luftfarth – DVL (German Organisation for Aviation Researches)" requested Dr. Sänger to perform two difficult tasks: to design a Research Institute for Rockets Technology, and to elaborate a Research Program for liquid-fuel rocket engines [4]. As a result, a new Research Center for Rockets was built at Trauen, disguised under the public name „Flugzeugprufstelle" (Aircraft Test Center) and subordinated to „Luftfahrtforschungs Anstalt H.G. – LFA" („H.G." Aviation Research Institute). In 1937, Dr. Sänger was very much in need of the best assistants he could get, as the main task of his Research Center at Trauen was tremendous: to design and build a suborbital space plane able to reach the antipodes and also the rocket engine needed for that! He was happy to receive two very capable contributors: Dr. Irene Bredt and Helmut von Zborowski, an experienced engineer coming from Bayerische Motorenwerke Munich. Von Zborowski undertook the responsibility of the Test Rig for big rockets engines with 1,000 kN thrust. [5]
As of Dr. Irene Bredt, she begun by deeply studying Dr. Sänger's work: „Gasknetik sehr grosser Fluggeschwindigkeiten" (Gas kinetics at very high flight speeds) which had been demanded under a contract with the Central Office for Scientific Reports (ZWB). Working together, Dr. E. Sänger and Dr. Irene Bredt delivered in May 1938 this technical report, which showed for the first time the formulae and numeric values of aerodynamic forces acting on a space-plane at altitudes where the atmosphere can no longer be considered a continuous medium. This ground-breaking study was published in English by Dr. H.S. Tsien (May 1950) as NACA Technical Memorandum No 1270: „Super-aerodynamics – Mechanics of Rarefied Gases" [4].
The second task of Dr. Bredt was to solve the theoretic problems of gases thermodynamics associated with building and testing various liquid-fuel rockets, including the one with 1,000 kN thrust

needed for the construction of the semi-ballistic rocket plane. Dr. Bredt's work relayed also on another Dr. Sänger's paper: "On the Construction Principles and Performances of Rocket Planes", published in February 1933 at Deutsch-Österreichische Tages-Zeitung Publishing House. This concept would be later detailed by Dr. Sänger in his book: „Raketenflugtechnik (Rockets Technology)" published in 1933, at R. Oldenbourg Publishing House [6].
Dr. Irene Bredt also received the responsibility of thermodynamic calculus of combustion processes in liquid fuel rocket engines, including the case of weightlessness. Especially, she had to solve the problems of alcohol combustion in liquid oxygen (primed with Zn-diethyl) in various rocket configurations. In October 1938, the Trauen Center already made a steel scale model (1:20) of a supersonic glider. Because of the dome-shaped body and flat bottom of that model, Dr. Sänger assistants (including Dr. Bredt) nicknamed it „the flat-iron". [5].

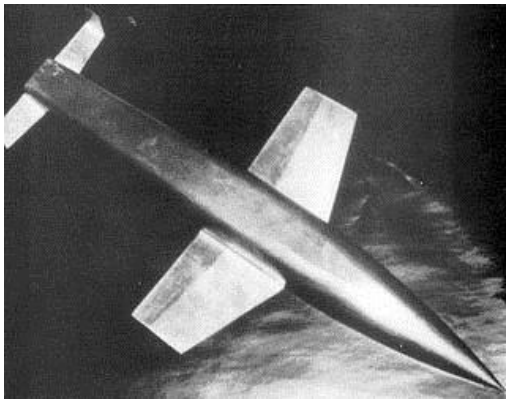

Figure 2: "Silver Bird" steel model at 1:20 scale

Dr. Sänger's concept about this space-plane (named "Silver Bird") was to accelerate it up to a speed of 500m/s before take-off, by means of a rocket-powered launching-sled sliding on a straight horizontal rail, several kilometres long. Such a solution required a careful analysis of the dynamic processes generated by the friction between the sled and the rail, including the large amount of heat to be controlled. Dr. Irene Bredt undertook this task and she understood that, at very high sliding speeds and high negative accelerations during the breaking after launch, it was necessary to ensure the dynamic floating of the sliding surfaces by adequately designing the geometry of the lubrication gap and choosing an adequate lubricant. But for such extreme operating conditions there were no reference data in the scientific literature of that time, and some people even pointed out that it would be impossible to control frictional heat and therefore, the whole concept of the rail catapult was doubtful. [5]

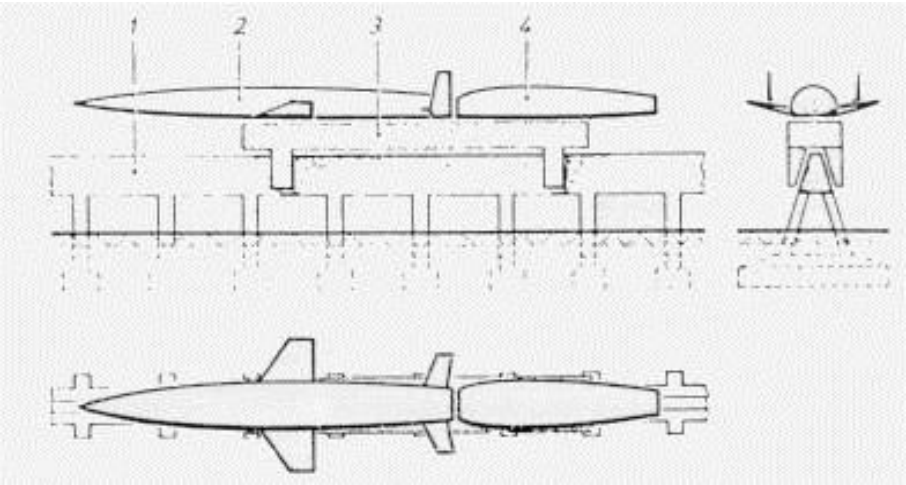

Figure 3: The „Silver Bird" on the launching rail

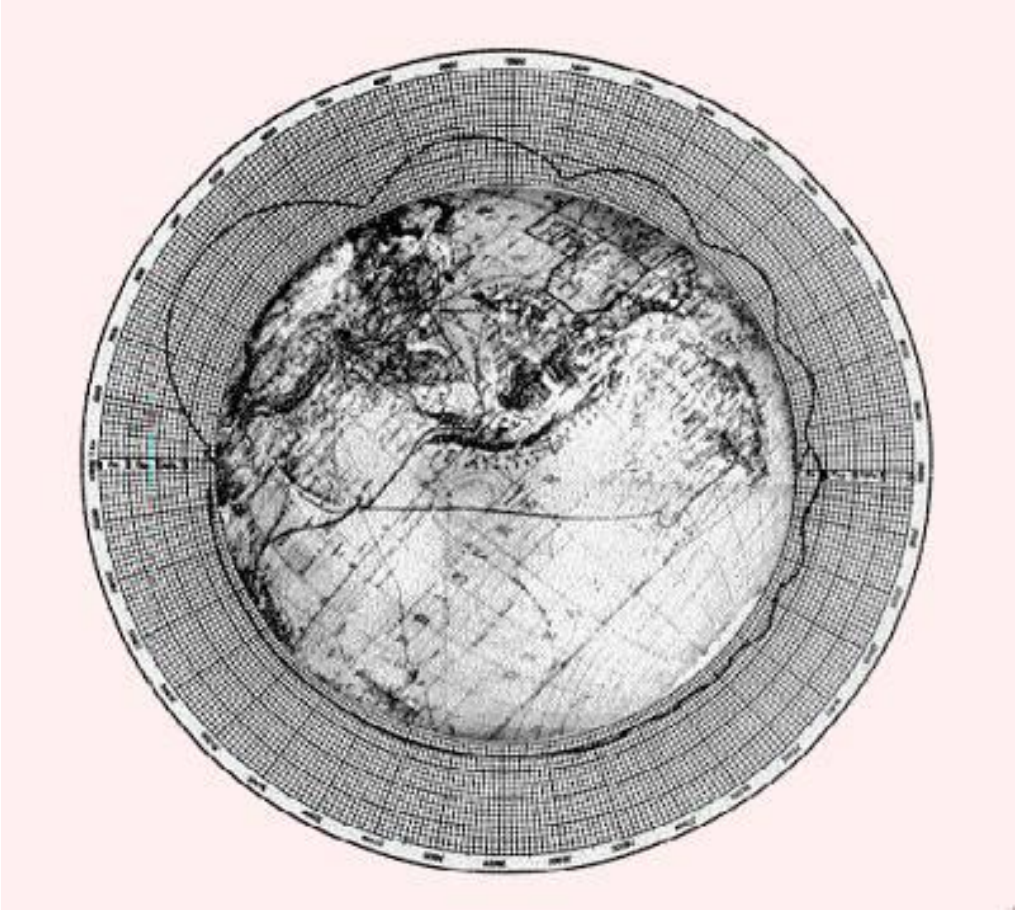

Figure 4: „Silver Bird" multiple ricochets flight path

Initially, Dr. Bredt intended to obtain test data about friction and lubrication processes from the specialists of „Institute für Technische Strömungsforschung" (Institute for Technical Research of Flow Processes) in Berlin; however, the maximum sliding speed obtainable in their test rig was only a fraction of the speed needed at Trauen. Consequently, Dr. Sänger and Dr. Bredt designed a new, spiral-shaped test rig, using as test model a stainless steel bullet fired with initial velocity of 800 m/s. The experiments carried out in 1939 demonstrated the feasibility of the horizontal launching rail allowing a slide speed of 500m/s, provided the rail is carefully finished and well lubricated [5].

By the end of 1939, the Deutsche Luftwaffe had issued a formal order that the entire activity of the Center shall be focused on objectives which could be used in the ongoing war [2]. In this context, the opportunity of working on the complex and futuristic "antipodal bomber" became doubtful. The "Silver Bird" rocket plane study, including analysis and calculus of bombs trajectories, impact ballistics and other combat capabilities, became a Top Secret Technical Report: „Über einen Raketenantriebe für Fernbomber (A Rocket Engine for a Long Range Bomber)" [7]. In 1941, Dr. Sänger and Dr. Bredt submitted this report for approval to the Aviation Ministry, which answered by the autumn of 1942 with an order to stop working on the 1,000 kN thrust rocket engine development. The war requested solutions quickly usable in operations, and the rocket plane, although extremely advanced, was far from becoming operational.

With a 100 tons take-off weight and 100 atm pressure in the combustion chamber, „Silver Bird" was the first project in the class of space vehicles later to be called „Single Stage To Orbit (SSTO)" – a technology which is a huge challenge even today. However, the „Silver Bird" rocket plane delivered important and lasting legacy solutions, like the "regenerative cooling engine" design, in which fuel or oxidizer is circulated around the engines, cooling the engines and pressurizing the fluid. This solution, used today in modern rocket engines, is referred to as the "Sänger-Bredt design" [8]. Another legacy is the sled-launching concept, still envisaged today by some SSTO projects, like "Maglifter" [9].

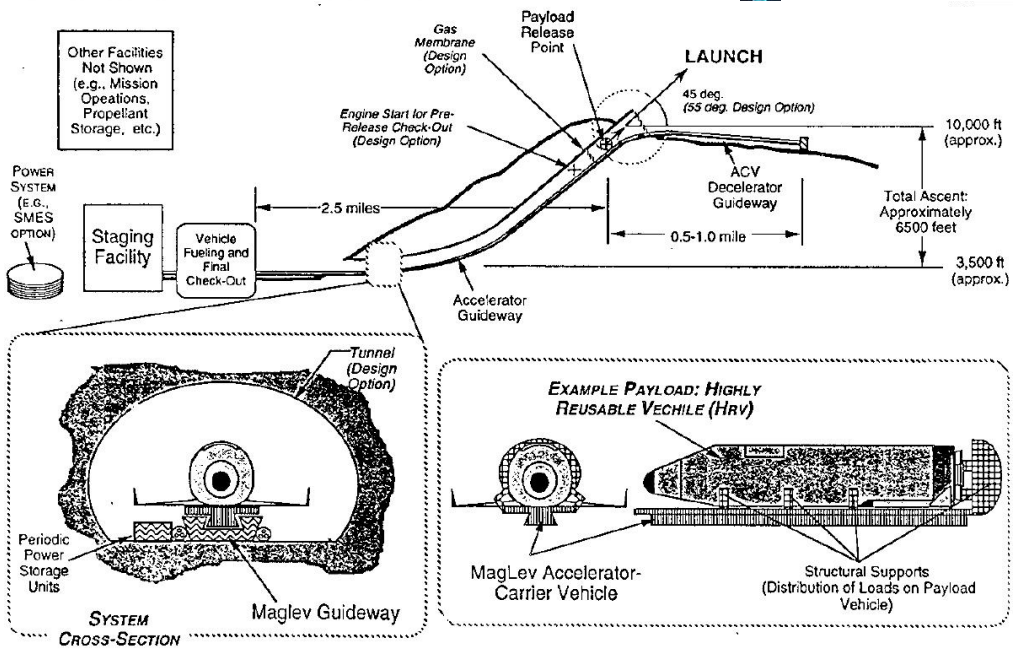

Figure 5: „Maglifter" sled-launching concept

As for Dr. Sänger and his team, they were allowed to continue their scientific work only in the field of ramjet propulsion, under the leadership of the German Research Institute for Gliding Flight (Deutsche Forschungsanstalt fur Segelflug – DFS) of Ainring, in the Upper Bavaria.

3 RAMJET PROPULSION PROJECTS AND FIRST FLIGHT TESTS

Looking back to the visit made by Wermacht General Staff at Trauen in 1940, they obviously wanted to define ways to achieve superiority for Germany in the ongoing air war. At that time, Dr. Sänger proposed to equip German fighters with ramjet engines. This suggestion being accepted, Dr. Sänger begun very fast the Ramjet Project, built a prototype and installed it on a flying test bed – an old Do-17 bomber, obtained by pilot Capt. Paul Spremberg. Weighing 12 tons, having installed on its back the ramjet tube (6m length and 1,5m diameter) the old Do-17 took off with Capt. Spremberg and Dr. Sänger at the controls, becoming the first aircraft to fly with a ramjet engine. This half-hour first flight was reported to Berlin and rewarded with a…punishment, because the Research Office of the Aviation Ministry had not approved such a flight. [5]

Figure 6: Ramjet test flight on Do-17

Dr. Sänger and Dr. Bredt as his first assistant were transferred at Ainring to continue their work under the direct supervision of Prof. Walter Georgli, director of DFS. Dr. Irene Bredt was promoted Senior Researcher at the Special Propulsion Center of the Ainring Institute, being in charge with the development of ramjet engine performances. However, Dr. Bredt will later uncover the real motivation of the punishment order which referred only at Dr. Sänger and herself: "… the difference of opinions between Dr. Sänger and his chief in LFA, obliged him to stop his work on the 100 tons rocket engine for the antipodal bomber" [4].
At the Ainring Institute, Dr. Sänger and Dr. Bredt convinced Prof. Georgli to print, in September 22nd 1944, a very short variant – a secret excerpt – of their technical report, under the title „Raketenantriebe für Fernbomber" (A Rocket Engine for a Long Range Bomber). Their tenacious preoccupation for this report was motivated by the scientific value of setting the foundation principles

of the new aerodynamics of rarefied gases, where the forces acting on a space plane are entirely different, and also their priority in conceiving a new method of de-orbiting a space plane, using a semi-ballistic flight path later to be known as "Rikoschettier flight (ricochet flight)" when the space plane is ricocheting on the denser layers of air, like a flat stone thrown at small angle on water surface. In this way, the flight path will be much longer than what can be obtained by using a simple aerodynamic descent [5]. In her memories [4] Dr. Bredt writes that "approximately 70 copies of that secret report had fallen into the hands of the Allies". These have certainly been useful for the researches developed in USA, which ultimately led to the Space Shuttle. The Russians were also interested in the space-plane concept, and even planned to bring Sänger and Bredt to the Soviet Union. That didn't happen, but Russian scientist Mstislav Keldysh developed a project in 1947 for a version of the Sänger-Bredt antipodal bomber, without the launch sled and the ricochet trajectory, and using two big ramjets. [10]. Even if that variant of space-plane was not built, this line of research was useful for the development of other Russian space projects [11].

Dr. Bredt helped Dr. Sänger to develop the correct and complete thermodynamic theory of ramjet engine. She was permanently in charge with flights schedule and the performances obtained with the flying test bed aircraft (initially Do-17, later an improved variant Do-217) equipped with a functional ramjet, with which the pilot Paul Spremberg performed the flights from Hörsching Airfield. Taking advantage of the ramjet operation time of 10 to 30 min, the daring pilot performed rapid climbing to 7,000m altitude and reached 720 km/h in a dive from 4,000m to 1,500m (performances obtained not with a fighter plane, but with an old bomber!). The pilot Fritz Stammer (who was the first man to ever fly a rocket powered aircraft) representing Prof. Georgli at the test flights, was completely astonished [5].

In 1944, a Technical Report sent by Dr. Sänger and Dr. Bredt to the Aviation Ministry in Berlin stated that the ramjet tests results have demonstrated the possibility of supersonic flight. Some official high-ranking person from Berlin was so surprised, that he wrote a resolution on this report: „What kind of imbeciles! At such speed it will not be possible to fly or to aim a target [2]." It was not for the first time in the history of science and technology, that this type of reactions appeared; and if one thinks of the difficulties experienced in controlling the fighter planes of that time (like the Focke-Wulf 190 or the P-38 Lightning) in fast dive manoeuvres, that reaction becomes more understandable. However, solutions were not so far away, if we think at the swept wing fighter designs like Willy Messerschmitt's "Me-262" and "Škoda-Kauba Sk P.14" project [12] equipped with Dr. Eugen Sänger's ramjet or if we consider the widely spread use of hydraulic controls today.

Figure 7: "Škoda-Kauba Sk P.14" fighter project [13] with Dr. Eugen Sänger's ramjet

4 THE CONCEPTS OF SCRAMJET AND PHOTONIC ROCKETS

After the war, as residents of the part of Germany administrated by France, Dr. Sänger and Dr. Bredt were selected and invited in 1946 by the French Aviation Ministry to work as scientific researchers at the Aeronautical Arsenal of France, at Paris-Chatillon, which became later SFECMAS under the leadership of Société Nationale des Constructions Aéronautiques (SNCA) du Nord. Until 1954, Dr. Irene Sänger-Bredt (she had married Dr. Eugen Sänger in 1951) was also consulting engineer at the French Rocket Company MATRA in Paris-Billancourt division. [5]

Together with her husband, Dr. Irene Sänger-Bredt proposed the rocket combustion chambers with cooling channels; they also imagined pressurized mixer systems for combustion gases, and a system for precise measurement of speed and temperature of combustion gases, based on the Doppler

Effect. They also developed the theory of corrugated propelling nozzles, the theory of luminescence in burning processes, the theory of solid bodies' explosion, and they studied the reactions of burning nuclei.

Dr. Irene Sänger-Bredt helped her husband to develop the concept of Aerospace Transporter „SCRAMJET" (Supersonic Combustion RAMJET) which they considered to represent the future of air transport. Dr. Eugen Sänger vision on future of air transport was that it will be integrating the technologies of aviation and astronautics, and he also demonstrated that this solution could only be achieved by international cooperation. With the help of his wife, he also discovered the principles which allow the gradual increase of aircraft speeds, up to those of future spacecraft [14]. Working together, they wrote many studies and scientific papers, like [5]:

- Gemischauf bereitung on Stationaren Feuerungen (Mixer for Stationary Combustion Chambers), Paris, 1948;
- Ionisation und Lumineszenz in Flammen (Ionization and Luminescence of Flames), Paris, 1949;
- Thermodynamik der Überschall-Gerät stoss diffusors (Thermodynamic of Supersonic Nozzles with Right Shockwaves), Berlin, 1954;
- Stationare kernverbrenung in Raketen (Stationary Nuclei in Combustion Processes inside Rocket Engines), Viena, 1955.

As Dr. Eugen Sänger was tasked to lead the new German Institute for Physics and Jet Propulsion in Stuttgart-Pfaffenwald, the Sänger family returned to Germany in 1952. From 1954 to 1962, Dr. Irene Sänger-Bredt was Scientific Director of the Pfaffenwald Institute, contributed to its reconstruction and elaborated its Research Program. From 1963 to 1972, she was external consultant engineer at the Junkers Inc. Company (later integrated into MBB). From 1951 to 1958, she was also professor examiner at the Faculty of Aerodynamics of the Chromepey-Madras Institute of Technology, in India. In all these periods, she wrote and published numerous scientific books and papers [14], [15], [16].

The common work of Dr. Eugen Sänger and Dr. Irene Sänger-Bredt stands also the foundations of the photonic rocket engine concept. Following the essay „Zur Strahlungs Physik der Photonenstrahlantriebe (On the Physics of Radiations of Photons Emission Propulsion Systems)" which they published together in Munchen in 1957, Dr. Eugen Sänger published in 1959 his fundamental work „Zur Richtprobleme der Photonenstrahlantriebe (On the Principle of Propulsion by Photons Emission)" [5]. Their vision was that mankind should make the effort to build and use the photonic rocket engine – the ultimate version of space propulsion system.

5 CONCLUSIONS

Dr. Irene Sänger-Bredt has many important contributions to space science and technology, most of them achieved working together (as they always did) with her husband Dr. Eugen Sänger:

- Creating the bases of the new aerodynamics of very high altitudes, where the distances between air molecules are comparable with the dimensions of the space planes;
- Concept and design of the stratospheric jet bomber and pioneering the technology known today as „Single Stage To Orbit (SSTO)" [17];
- Concept of the new method of de-orbiting a space plane by ricochets on the denser layers of the upper atmosphere [18];
- The "Sänger-Bredt design" of regenerative cooling liquid fuel rocket engine [15];
- Development of corrugated propelling nozzles theory;
- Creation of the ramjet engine theory;
- Demonstration of the possibility to build SCRAMJET (Supersonic Combustion RAMJET) propulsion systems;
- Creation of the photonic rocket engine theory.

Dr. Irene Sänger-Bredt was a founding member of the International Academy of Astronautics, and she constantly promoted the ideal of international cooperation in space exploration. By a series of letters kindly sent to Prof. Dr. Nicolae Florin ZĂGĂNESCU between 1973 and 1978, she helped him presenting to Romanian readers the ground-breaking space science developments achieved by Dr. Eugen Sänger and herself.

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