On the Theoretical and Experimental Activities Performed by Professor Hermann Oberth in Romania

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ABSTRACT

Finishing studies at Heidelberg University, Hermann Oberth (b. June 25th, 1894 at Sibiu, Romania) returned in Romania and successfully sustained in 1923, at the Cluj University, his thesis: "The Rocket to the Interplanetary Spaces" (published in Munich, also in 1923). Until 1938, Oberth was mathematics and physics professor at a high school in Mediaş, Romania. In this period he developed his first book into the much larger "Ways to Spaceflight" (published in 1929, also in Munich); building and testing solid and liquid fuelled rocket engines, and designing an original launching system. On June 23rd 1930, Oberth tested his first liquid fuelled (gasoline and liquid oxygen) rocket engine in Germany, achieving 70 N thrust and 756 m/s jet speed. After this test, Oberth returned to Mediaş where he tested the principle of electrostatic rocket engine, using the high school's electrical workshop. Also in Mediaş, in the workshops of Romanian Air Force Superior Military School, he built and tested fuel pumps, combustion chambers and nozzles. Oberth received the Romanian Patent No.19516 of March 6th 1931, for „Process and Apparatus for quick combustion". In the same period, he discovered the phenomenon that scientist Esnault-Pelterie will later call: „The Oberth Effect". In 1935, Hermann Oberth performed in Mediaş a real liquid fuelled rocket launching: in a letter to Willy Ley in December 24th 1948, Oberth wrote: "…I really raised my first liquid fuelled rocket in 1935…" Many of his achievements were conceived during the years when he lived and worked in Romania. As he said in an interview: "[...] during that time I was able not only to elaborate the space technique theory, but also made the most significant discoveries and experiments which confirmed that I was on the right way"[1].

KEYWORDS: *spaceflight, theory, liquid, fuel, rocket*

1 FROM DREAMS TO SCIENTIFIC, GROUND-BREAKING THEORY

As a child in Sibiu and also in Sighişoara, Hermann Oberth was always interested in flight and especially in space flight: at the age of fifteen he sketched a spacecraft model propelled by successive explosions of powder, while at sixteen he imagined a rocket model, using as liquid propellants a combination of an alcohol and liquefied oxygen [1]. During his high school studies, Oberth imagined a centrifugal device with a 35m long arm, very much resembling to the centrifuges used today for astronauts training. After 1919, Oberth designed one of his first models of a multistage spacecraft.
In February 1919 he started his studies at the University of Cluj-Napoca, the department of mathematics-physics of the Second Faculty of Philosophy. After the first six months, he continued his studies in München, Göttingen and Heidelberg. In order to obtain his Ph.D. from Heidelberg University, Oberth presented in 1922 a scientific work with the title: "Die Rakete zu den Planetenräumen (The Rocket to the Interplanetary Spaces)" in which he detailed the spaceflight theory: the optimal speed value allowing precise computation of the fuel burning time; the weights ratio; the accelerations and the climbing time; the equation connecting the reactive nozzle and the discharge speed of the jet; the analysis of the free extra-atmospheric flight equations; some selection criteria for optimal fuel in various space missions. In order to assure the spaceship stability and

precise direction control in flight, Oberth imagined the application of a gyroscope; for speed control and regulation of the active part of the trajectory, he elaborated electrical and remotely operated devices. Also he calculated and designed in detail two types of liquid fuelled rockets: the first designed for high-atmospheric research (Model B) and the second for space flight. The paper was rejected with the motivation to have a technical and not astronomical character.
Finally, the paper was printed in 1923 by Oldenbourg Verlag P.H. in München, with the same title (Die Rakete zu den Planetenräumen). In this book (issued again in 1925, 1960 and 1964) Oberth scientifically proves the foundations of modern astronautics, as follows [2], [3]:

- the rocket theory mathematical bases;
- using ethylic alcohol and hydrocarbons with liquid oxygen as liquid fuels for rockets;
- the staged rocket functional principles;
- the fundamentals for some optimal ascent trajectories and for six synergetic curves;
- the use of an orbiting station for spacecraft refuelling;
- the future manned space stations with artificial gravity;
- an astronaut training program and some radiation protection systems;
- the mathematical study of rocket behaviour, both in the atmosphere and in the outer space;
- the Earth artificial satellites and research rockets utilization fields.

Finishing his studies and preparations, Oberth returned home in Romania and, in order to be appointed school master, presented to the Special Commission for School Masters Examination the paper rejected at Heidelberg. The Chairman of the Commission, Professor Augustin Maior (inventor of a multiplex telephone communications system) appreciated the paper, accepted it and conferred him the title of "Profesor Secundar" (School Master). Thus Oberth was employed at the High School and at the "Bergschule" (The "Hill School") in Sighişoara, until 1924 when he leaved for Mediaş. From 1924 to 1938, Oberth was employed in Mediaş as School Master for Mathematics and Physics at the "Stephen Ludwig Roth" high school. From Sighişoara he wrote letters to K.E. Tziolkovski, Max Valier, Frantz von Hoefft, Walter Hohmann, G.A. Crocco, Guido von Pirquet, Johannes Winkler, Robert Esnault-Pelterie and others.
In 1923, Oberth received from Robert Hutchins Goddard his report "A Method of Reaching Extreme Altitudes" published by Smithsonian Institute and starts a brief correspondence with K.E. Tziolkovski, who will send him his book "Research of Outer Space with Reactive Devices" ('Issledovanie mirovih prostranstvy reaktivnimi priborami" - 1903).

2 EXPERIMENTAL CONFIRMATION OF LIQUID FUEL ROCKET PROJECT

Since 1925 Hermann Oberth looked his paper over and prepared a new one, which will be printed in 1929 by Oldenbourg P.H. with the title "Wege zur Raumschiffahrt (Ways to Spaceflight)" [4]. Oberth presented in this paper some rocket engines he imagined and studied, showing their functioning with the theoretical and practical explanations of reaction principles and thrust generation by the rocket-engines. The publication of calculations and projects for two-stage rockets was very important: a rocket-engine using as fuel liquefied hydrogen was the second stage and an alcohol rocket-engine was the first stage. Figure No.1 shows a drawing from the up mentioned book, illustrating this concept which became classic for modern rockets. Figure No.2 shows the "Model B" rocket, from the same book [5]. The red coloured lines (or gray, in a black/white printing) of the two figures represent elements of the hydrogen-fuelled rocket; the black lines are elements of the alcohol-fuelled rocket.
Both figures use the following notations: **a** – ogive-shaped head of hydrogen (or alcohol) fuelled rocket; **f** – parachute; **I** – equipment compartment; **T** – access to **I**; **e** – hydrogen (or alcohol) tanks; **S** – oxygen tanks; **p** – periscopes; **m, n** – pumps for heating gases; $\mathbf{p_1}$, $\mathbf{p_2}$ – pumping chambers for fuel; $\mathbf{p_3}$, $\mathbf{p_4}$ - pumping chambers for oxygen; **z** – atomizer; **o** – burners; ***l*** – adjusting pins; **t** – nozzles wall; **v** – flow on the nozzles wall and the flow control equipment; **w** – tail planes.
The drawings show original technical ideas, such as the following:

- The ogive-shaped segments, protecting the upper part of the rocket, were equipped (for recovery) with inside air tanks;
- The pressure in the alcohol-water mixture tank (c) was kept constant with pumps assistance;
- The alternation of the (y) valves opening and closing, ensures an uninterrupted flow from the tank (e) to the (p1) and (p2) chambers, while the other chamber pump is introducing the mixture in the (z) atomizer;

- The thermal protection of the rocket skin and combustion chamber is realised by fuel's vaporisation between the thin wall (t) and the skin;
- The rocket was provided with automatic controlled tail planes ensuring flight stability, as well the spacecraft deceleration in the descending flight period;
- The alcohol rocket was to be equipped with electric power source, supersonic stabilisation equipment, accelerometers, pressure gauges, temperature sensors etc;
- The stabilisation and flight control tail planes were operating by deflection of reactive jet, this principle being also used in modern missiles design [5];
- For the Model B, the project provided the use of an alcohol engine booster rocket, having a total weight of 20 kg.

Oberth was not only a visionary; he always was a scientist, researcher and experimenter. He stated once in a conference: "Sure, to build a great rocket will put tremendous technical difficulties. But I'm dealing with these problems since 17 years ago and I never found anything that would make them impossible or, at least, to put the problem in such a way" [6].

As a scientific counsellor at UFA German film Company for the movie "A woman on the Moon", Oberth succeeded on June 23rd 1930 to test his liquid fuelled combustion chamber: in 1.5 minutes the rocket burned 1 kg of gasoline with 6.6 kg of liquid oxygen, achieving a 70 Newton continuous thrust and reaching a jet speed of 756 m/s. By this achievement, his scientific calculus and technical project on the liquid fuelled rocket engine got a brilliant confirmation.

After performing this successful test in front of the specialists from the "Chemisch Technische Reichanstalt" (Chemical-Technical Institute of the Reich) in Berlin, Oberth returned to his job in Mediaş, the nice and quiet town on the Târnava River, in Romania.

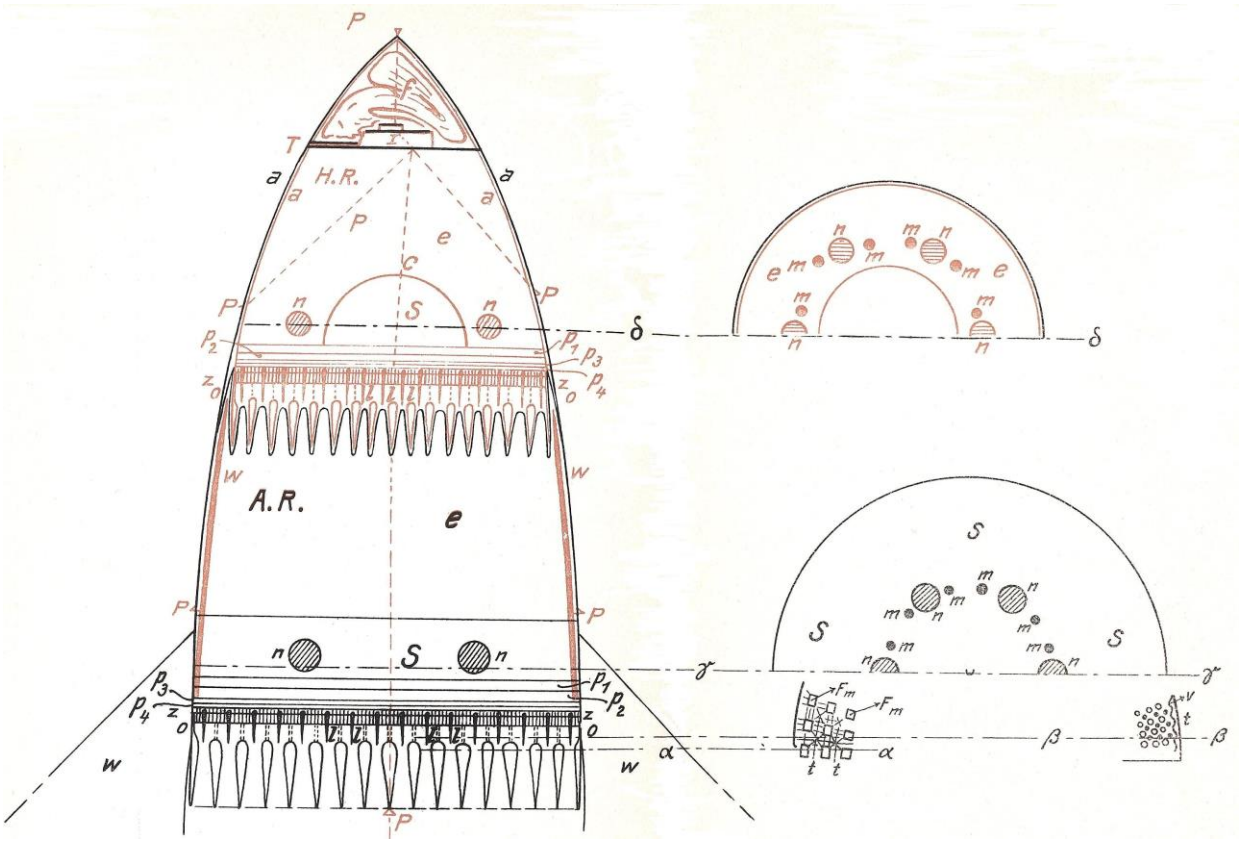

Figure 1: Hydrogen/oxygen (2nd stage) and alcohol/oxygen (1st stage) rockets

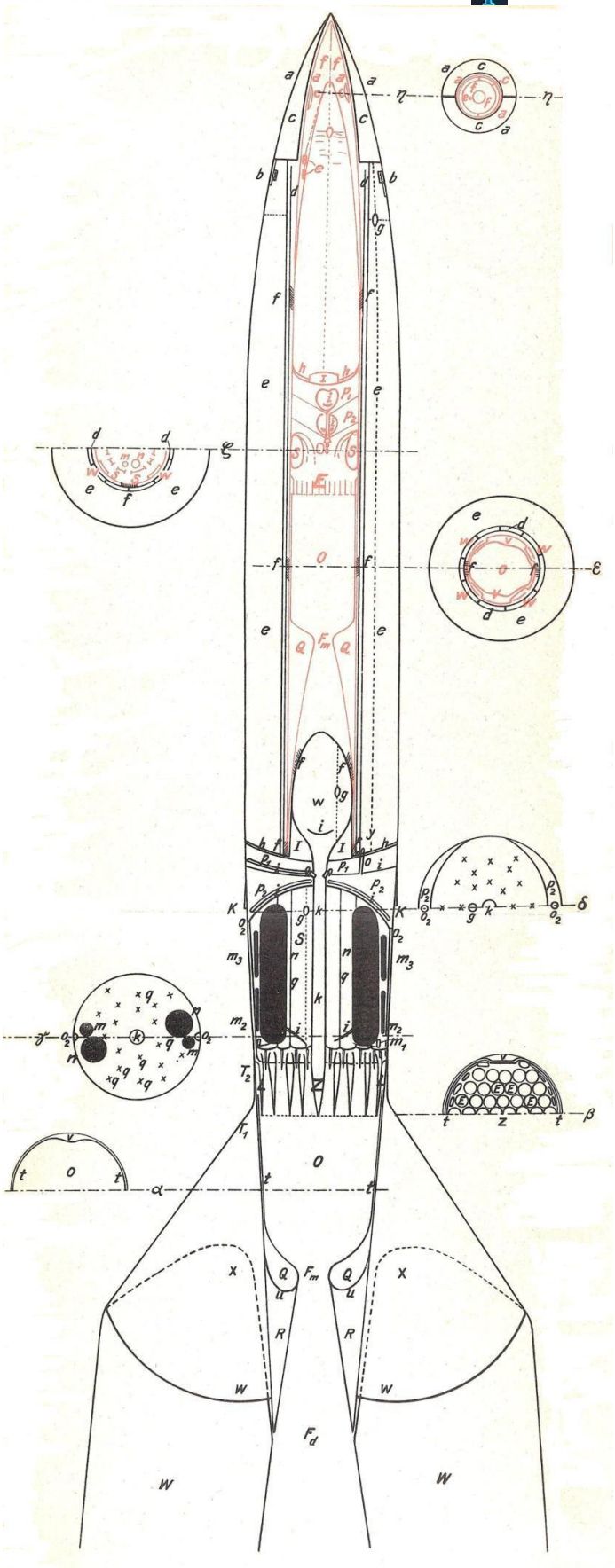

Figure 2: "Model B" rocket design

3 EXPERIMENTS IN MEDIAŞ – ROMANIA

Following a paper presented on a meeting at the Polytechnic School in Bucharest, Oberth returned to his studies on the combustion chamber of the rocket-engine with liquid propergols. For the first stage of the rocket, Oberth observed the necessity to use fuels with high specific weight and low ejection jet speed, different from the case of superior stages. The lack of high temperature resisting materials (as today's super-alloys or Titan alloys) put him very difficult problems in choosing the propergols and the combustion time too. As a device for controlling and regulating the reactive jet's speed, he proposed and tested the employment of a combustible mixture including a substance which doesn't participate in the burning process but through its evaporation absorbs heat. That is the basis of the phenomenon called by Robert Esnault Pelterie "The Oberth Effect".

Concerning the problem of propergols, at 9th March, 1931 Oberth presented and obtained from the Romanian Patent Office, the Patent No. 19510, entitled: "Process and Apparatus for quick Combustion"; here he claimed priority for a fast burning of fuels not containing oxygen (as do the explosive materials) a process characterized by injection of fuel in liquid oxygen or, vice versa, by injection of oxygen in liquid fuel [7], [8].

It is interesting to look at some of the great scientist's ideas, written in the patent request: "In different situations, especially in generating propulsion gases for rockets, it's important to realize the quick burning of big quantities of fuel in a restricted space. If the combustion is requested to be as fast as an explosion, then the explosive materials have great disadvantages, because they are dangerous and the speed of their combustion might not be calculated. It's more favourable to use fuels for which the necessary oxygen is delivered in the moment of combustion. This idea is already known, but it was not applied in such a way that a high combustion speed could be achieved or even to reach the nature of an explosion. This is realized by the present invention..." Further, Oberth is writing: "...That regards essentially the fact that the two materials involved in combustion, the oxygen and the fuel are mixed by spraying in such a way that the liquid oxygen particles are penetrating in liquid fuel, or fuel particles are penetrating in oxygen. The author established by experiment that the combustion taking place in these conditions has the speed of an explosion; he also established that in these conditions a preliminary chemical combination of oxygen and fuel is no more necessary, as it happens with a common explosive material. Also, it is not even necessary a reciprocal absorption capacity through dissolution or similar" [7].

In an article published in the Romanian scientific review *Natura* on the 15th December 1932, under the title "Zborul rachetelor şi zborul în vid (Rocket flight and flight in vacuum)" Professor Oberth stated: "We are not willing to accept the limits of the Earth atmosphere as the limits of our existence!" In this article Oberth wrote:

"…My researches show that the rocket capacity could be larger by employing liquid fuels such gasoline, alcohol or cryogenic liquefied gases. Liquefied air has the power to increase enormously the combustion. If, for instance, for the combustion in my rocket, gasoline and liquefied air are mixed in an established proportion, it results a fire powerful enough to lift by reaction at considerable altitudes a sufficiently big rocket. […] The speed of such rockets might grow to 1 km/s or even more than the bullet speed; the rocket might be equipped with sensitive instruments, because that velocity would not be reached suddenly. Such a rocket might land by parachute and will never fail. Usual rockets are climbing vertically, but this might be so arranged that the rocket should not climb too high and instead would fly on some determined curves, for flying over established zones… These rockets could be equipped with photographic cameras; in comparison with a reconnaissance plane, they would have the advantage of an easier and cheaper construction. For example, all the raw materials for my little test rocket which I'm building in Medias, are now produced in the country. My targets are some rockets flying very high and extremely far […] These rockets may be automatically controlled […] Such a device for controlling meteorological rockets is ready. It was tested on the stand for some time (in Mediaş, a.n.) and if it will resist, we may rely on a precision of 1/10,000 of the trajectory [...] If such a vehicle will reach the velocity of 8 – 10 km/s, it will happen something amazing, it will... never land after the consumption of the fuel, it will continue to fly on an elliptical trajectory which would remove it from the Earth [...] Landing of the rocket transformed in a spaceship, could take place only tangential to the planets owing an atmosphere; in that case, the spaceship will cover a long way in the atmosphere and it would be braked, avoiding burning like a meteorite, by flying the suitable trajectory [...] and landing tangential to the Earth..." [5].

Professor Oberth designed in Romania, in Mediaş, two of the rockets he described in the article from *Natura* review and in the speech at Radio Bucharest. The first rocket was designed as a liquid propergol rocket carrying 3.5 tons over a distance of 1,000 km and having a weight of 100 tons and a length of 24 m at launch. The second rocket, also with liquid propergols, was radio guided and designed as a ballistic missile or an AA missile. The start of this rocket would be assisted by solid fuel rockets. Concerning this solid fuel, it probably resembled to the "black powder" including ammonium nitrate, potassium nitrate, charcoal and water. Oberth will try to re-evaluate this project in 1943 at the Research Center in Wittenberg on Elbe. But he really finished this study in the period 1950-1955, when he worked for the Italian Navy in the La Spezia Laboratories. The Diesel Medal, which was awarded to Oberth in 1954, was also related to the construction of the ammonium nitrate rocket. This idea germinated in the brain of this great scientist when he was still in Mediaş, in the period 1930-1935. During that period, professor Oberth was also in charge of students' workshop training at "Stephan Ludwig Roth" High School. This way, he got the possibility to realise mechanical and electrical parts, necessary for his experiments, during the locksmith and electro-technology training – including testing the electrostatic rocket engine principle in the electro-technology workshop.
In 1932 Hermann Oberth sustained several conferences at the Polytechnic Society in Bucharest; as a result he got the Government's approval to work in the workshops of the Air Force Superior Technical School in Mediaş.
Between the experiments made at the Air Force Superior Technical School, we notice the test of several liquid fuel pumps for rocket engines; the pumps were drive by a gas turbine and introduced the fuel in the combustion chamber. Oberth suggested that the turbine might be driven by the same fuel in order to avoid building supplementary fuel tanks in the rocket; he assembled his combustion chamber under the microscope. For his combustion experiments with the new assembly – combustion chamber and nozzle – Oberth transported liquefied air from Braşov City [9].
In 1935, in Mediaş - Romania, Oberth tested a liquid fuelled rocket, test regarded by different sources and by himself as a real launching.
A clear proof that one of professor Oberth liquid fuelled engine was built and tested in Mediaş, is the letter written from Feucht to Willy Ley, on December 24th 1948: "...After our separation (1930) I started to deeply learn the job of a locksmith, to get those dexterities which I missed; because I think that Ford was right when he said that nobody should invent something he isn't able to build himself. It seems that I was talented for this profession because since 1933, I took the responsibility of leading a didactic mechanical workshop, complementary to my job of School Master of mathematics and physics, which I practice again since 1931. Nearby I made experiments with rockets and in 1935 I really raised my first liquid fuelled rocket..." [9, vol.1, pg.151] This success is also mentioned in professor Oberth's technical report edited in Switzerland, 1948. Knowing that Oberth launched also several solid fuel rockets in Mediaş, this town in Romania can be regarded as one of the first places in the world which were witness of rocket launching, after Roswell (New Mexico, USA) Dessau and Berlin (Germany), Moscow (USSR).
Interesting technical details about the construction of the liquid fuelled rocket can be found in a previous letter, dated April 16th 1933, which Oberth sent from Mediaş to dipl.eng. Otto Wiemer in Essen [9]: "...Presently, I have at my disposal an experimental model, half finished, 1,400 mm long and with a maximum diameter of 142 mm. For liquefied air removal from the tank to the combustion chamber, I used gasoline and at least (one – a.n.) liquefied carbon dioxide capsule. This (the capsule, a.n.) has an ignition fuse protected with Cellon varnish against gasoline action. At starting the ignition was electrical, the fuse was burning and the access of gasoline to the oxygen tank was free. Gasoline was sprayed over a piece of calcium oxide (quicklime), soaked with liquefied air and burned, combustion being ignited electrically with an electric device... This rocket combustion chamber is brass canned and plated inside with Stemak kit; because of that, the combustion chamber is extremely heavy, though the stock left was totally rasp down. It has to be searched a company able to can the chamber with a light alloy..." In the same letter, Oberth informed about his new intentions: "Following this model, a 14-15 m long and 250 mm diameter rocket will be built; before the construction of the 15 m rocket, it's necessary to answer the following questions:

- Obtaining the pressure in the pumps; the experimental models worked without pumps;
- At the 15 m long rocket the fuel tank will be placed in the superior part and the oxygen tank, 10-12 m long, in the lower part; the oxygen pumps are also in the lower part. Because finally it will attain 10g, they must reach 10 atm in order to lift the oxygen at least in the ascent pipes;

- In order to preserve the gasoline pressure, I used the burning of ammonium nitrate powder in the tank; that's not a nice solution because of the impurity generation, but for the gasoline pump I would be pleased to introduce something else, let's say liquefied air, which I would spray in the burning fuel;
- Not circular, but spherical pumps will be necessary; I don't know if there will be any problems; in two-three months I may be able to send you projects for the pumps;
- I don't have any satisfactory metallic thermometer, but I would be interested to know how hot the combustion gases are, before exhausting from the engine;
- I would need some accessories very difficult to obtain here, as for instance, ignition conductors: I need insulators with a maximum external diameter of 1 mm. At the tested model I introduced (don't laugh) the wire through dried straw... I would need also a good material for welding of "Elektrometall", and so on;
- Definitive construction and testing of acceleration sensors and control devices." [9]

The letters he wrote to his scientist friends [6], [10] are relevant for Professor Oberth's prolific activity developed in Romania, and also for his well-known modesty. On February 21st 1933, Oberth wrote from Mediaş, also to Wiemer: "...Answering your letter of 15th current month, I let you know that I am continuing my experiments here, although (because of) the natural facilities absence, they are very much delayed... I will not work anymore in Germany. If you are going to realize in Essen an experiment facility, I am pleased to be at your disposal with my experiments already performed. It is easier to realize that because, in fact, I'm working only for the interest of the problem; the income interests me only for higher efficiency. Generally the building of a liquid fuel rocket must be easier the bigger the rocket is. For the moment, I'm not interested in a too big publicity. Maybe, at the end of this year, I will publish some of my experimental results. The early publicity doesn't help, it's more detrimental. The Spaceflight Association will not send my apparatus to the exhibition. I don't like to present after four years some devices built in the first half year of my practical activity". [9]
Oberth's essential contribution to the first rocket gliders development is clearly shown in a letter he sent to Guido von Pirquet: "...I let (Max) Valier to assume alone the inventor position of the rocket airplane, although we worked together at the development of this idea... Because he was not a specialist, I elaborated at his request the rocket-plane theory and showed him a calculation example..." [9] In spite of his modesty, these words clearly indicate that Professor Oberth anticipated the modern technologies of rockets and missiles.

4 A PRECIOUS LEGACY

Wernher Von Braun, who was a young (18 years) student when he begun experimental works with the professor, said about him:
"Hermann Oberth was the first, who when thinking about the possibility of spaceships grabbed a slide-rule and presented mathematically analysed concepts and designs [...] I, myself, owe to him not only the guiding-star of my life, but also my first contact with the theoretical and practical aspects of rocketry and space travel. A place of honour should be reserved in the history of science and technology for his ground-breaking contributions in the field of astronautics." [11]
Many of these contributions were conceived by Hermann Oberth during the years when he lived and worked in Romania. He was well aware of this fact and, during a 1982 Symposium, confirmed the remarks on this subject, made by Romanian astronaut Dumitru Prunariu [12].
Professor Hermann Oberth was kindly available to meet Romanian scientists and researchers, encouraging them to persevere in their work, as shown in a photo taken at the 34th International Astronautical Federation Congress in Budapest, in 1983, together with Romanian astronaut Dumitru Prunariu and the first author of this paper.

Figure 3: Prof. Hermann Oberth (3rd from left) with Romanian astronaut Dumitru Prunariu (4th from left) and prof. Florin Zăgănescu (1st from left)

One of the best certifications of Professor Hermann Oberth's activity in Romania was his own opinion, expressed in an interview offered to the Romanian Television (in 1977, for a biographical film):
"My friend and biographer Hans Barth declared that during the years spent here I realized already most of that what brought me a later celebrity. I have to admit that's just so; it's true that during that time I was able not only to elaborate the space technique theory, but also made the most significant discoveries and experiments which confirmed that I was on the right way" [1].

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