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A STONE'S THROW INTO THE UNIVERSE: A MEMOIR[+]

F. Zwicky (Switzerland)[++]

Ten days after I first tried to launch a man-made object into interplanetary space with a V-2 rocket from White Sands, New Mexico, E. B. White in The New Yorker of December 27, 1946, reported:

> The year ends on a note of pure experimentation. Dr. Fritz Zwicky last week tried to hurl some metal slugs out into space, free of the Earth's gravitational pull. Dr. Zwicky stood in New Mexico and tossed from there. He was well equipped; he had a rocket that took the slugs for the first forty-mile leg of the journey and then discharged them at high velocity to continue on their own. The desire to toss something in a new way, or to toss it at a greater distance, is fairly steady among men and boys. . .[1]

Author White had guessed correctly. As a boy in the Swiss Alps I had thrown stones across rivers and snowballs up church steeples as far and as high as I could, without having anything particular in my mind, except to be the best. My attempt to throw stones (artificial meteors) away from the Earth, however, was to be just a first step in a more purposeful chain of events. Col. Rivkin asked me at White Sands in December 1946 just what my purpose was, I responded, "First we throw a small slug into space, then a bigger one, then a shipload of instruments, and finally ourselves."[2]

The projects I had in mind for extraterrestrial space research date essentially to 1928, when George Ellery Hale, for whom the entire complex of the observatories of the California Institute of Technology and the Carnegie Institute of Washington is named, obtained a grant of six million dollars for the construction of the 200-inch telescope and the necessary auxiliaries. At that time, Sinclair Smith, John Strong, and myself, all physicists at the California Institute of Technology, shifted our principal scientific activities from physics to astrophysics and observational astronomy, fields that eventually included the use of both optical and radio telescopes. Following Hale's advice to "make no mean plans," we later extended our studies to include many instruments that could be carried aloft by balloons,

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[++]California Institute of Technology and Hale Observatories.

Earth-circling satellites and space ships, including preparations for an observatory on the Moon, possibly in 1975, a proposal supported by the Lunar International Laboratory Committee (LIL) of the International Academy of Astronautics.

Vehicles that could carry instruments to great heights became available as a result of the technical developments of World War II. I participated actively in the war effort as director of research for the Aerojet Engineering Corporation, as a member of the Scientific Advisory Board of the Army Air Forces, and as one of its technical representatives in 1945 and 1946 in Germany and Japan. Thereafter, by a most improbable but fortuitous chain of circumstances and events extending over three decades, I realized a number of divergent projects and goals that I had thought about for a long time. These projects involved problems in basic astronomy, physics, chemistry, engineering, international law, and ways to bridge the ever-widening gap between science, technology, and the general public. In this brief memoir I will only touch upon a few of the high points of my experiences in the fields of astronomy, the development of propulsive power, and man's march into space. A more detailed account of these events will appear in one of my forthcoming books, Operation Lone Wolf.

Specifically, the projects I set for myself involved:

1. A morphological survey of all the results, scientific, technical, and human, that might be achieved in man's MARCH INTO INNER AND OUTER SPACE. Outer Space here stands for extraterrestrial space. Inner Space refers to the depths of the oceans, to the interior of the Earth, as well as to the interior of all the other members of the Solar System, or, for that matter, of any cosmic bodies that might eventually come within man's reach.[+]

[+] I shall not go into any details about the many problems concerning inner spaces, except to mention that we surveyed and discussed all of the potential propulsive power plants and propellants, the possible means of traveling through, communicating and living in, as well as exploring and exploiting inner space. At the Aerojet Engineering corporation in Azusa, California, we studied hydroturbojets[3] in particular, as well as the synthesis of effective hydrofuels, and laid the groundwork for the future mastery of the depths of the oceans. In this connection I should mention that my former teacher in physics, 1916-1920, Professor Auguste Piccard, at the Federal Institute of Technology in Zurich, after he had made the first flight into the stratosphere in 1931, also pioneered the first dives into great depths of the oceans. These efforts reached their climax in the dive of the bathyscaph "Trieste", piloted by his son Jacques Piccard to the greatest oceanic depth of over 11 km in the Challenger Bottom near Guam in the Pacific.

In the early 1940s I proposed designs for terrajet engines, that is, propulsive power plants intended to move through the solid Earth, that still await construction and application. These engines will be vital not only for terrestrial uses, but in particular for operating underground on the Moon and on other bodies in the Solar System.

2. Develop effective means to reach and occupy all humanly attainable locations in Outer Space and in Inner Space.
3. Revised approaches to Astronomy. In the past, astronomy was entirely a passive science that had to rely solely on observations of the incoming messengers such as light and corpuscular radiations from the extraterrestrial spaces and bodies. But in the 1940s, with the visualization and realistic planning of vehicles capable of traveling through extraterrestrial space, three new major types of activities promised to become possible in the near future, namely:
   a. The direct exploration of extraterrestrial bodies and space.
   b. Experimental Astronomy, in the sense that extraterrestrial bodies, or at least selected parts of them, would be directly investigated to test hypotheses.
   c. Reconstruction of the universe, or at least a very small part of it, that is, for the time being the Solar System.[4]

These goals I had clearly in mind as non-military post-war projects at the time I was working at the Aerojet Engineering Corporation on the invention and construction of various types of propulsive power plants and the many auxiliary devices and weapons that would help bring down the facist regimes led by Hitler, Mussolini, and the Japanese war lords.

EXPERIMENTAL ASTRONOMY

I have long been concerned with subjecting cosmic bodies to direct tests, similar to experiments on terrestrial matter in the laboratory. Concerning my first modest efforts in this direction, J. C. Pecker, Director of the Nice Observatory[5] observed: "The first realistic proposal of experiments of this type was no doubt that of F. Zwicky. Zwicky proposed to produce artificial meteor showers. His first attempts in 1946 were unsuccessful—but later experiments succeeded in 1957—and since then other authors have continued analagous work."

The goals in this field that I had in mind at the end of World War II were:

1. Launching fast particles (artificial meteors) at all heights in the atmosphere for the purpose of exploring its physico-chemical conditions, for instance, winds, shock waves, eddies, desities, electric and magnetic fields as well as local chemical composition. Data on all of these characteristics could be obtained through observations of the tracks and point-for-point spectra of the artificial meteors.[3]
2. Launching artificial meteors from great heights with velocities greater than 11.2 km/sec into interplanetary space, free of the gravitational pull of the Earth.

3. Bombarding the Moon on the dark side of the terminator with ultrafast particles containing reducing metals such as Al, in order to determine the presence of water of crystallization in deeper lying rocks on the Moon's surface. Bound H_2O in the crystals, analogous to that found in granit, could be extracted by the life-sustaining solar furnace that I designed and tested at Aerojet in the 1940s.[3] If no such water of crystallization is found at any reasonable depth, the protons of the solar wind entrapped in the surface grains will have to be used for the production of water, propellants for hybrid propulsive power plants, and foodstuffs on the Moon.[6, 7]

Curiously enough, in the 1940s little or no enthusiasm could be engendered anywhere for these simple projects, and practically no funds could be mustered for their realization. During almost two decades, Mr. J. Cuneo, the former patent attorney at Aerojet, and myself, carried on with our own means, working in our free time whenever we could. Some noteworthy results nevertheless were achieved, since fortuitously, the US Army Ordnance, as well as the US Navy and Air Force, made various of their facilities available to us—for which sincere thanks are due them. Some of the developments have already been described.[3] Additional developments are briefly being touched upon below.

PHASE I

As the most convenient means to produce fast particles, in 1945 we decided to use shaped charges of cast and putty explosives, as well as JET-X (that is, liquid nitromethane doped with diethylamine which we developed at Aerojet and which, because of its uniformity, gave the finest ejected particle jets, as shown in one of my previous LIL Symposium articles)[6] As inserts we generally used copper or iron cones with an apex angle of sixty degrees. With these, particle velocities of nearly 10 km/sec were obtained[3, 4] as measured by rotating cameras or rotating hexagonal mirrors plus stationary cameras. With very great difficulty later on we produced conical inserts of titanium because of its ready oxydizability. These ejected particles of Ti, "burning" in the air, produced very luminous tracks, even in tenuous parts of the atmosphere, where poorly oxydizable particles like iron and copper could not be seen, since friction heating did not suffice to make them sufficiently luminous. The problem, however, arose over how to produce self-luminous particles that could be seen even when ejected into a vacuum. This problem I solved through the invention of coruscatives or heat explosives.[3]

Coruscatives are solids that detonate or explode on application of sufficiently strong shearing stresses for instance, but in contradistinction to common explosives, the reaction products at Standard Pressure and Temperature (SPT) are solids. Virtually no gas is generated, or only small amounts of gases are generated. This of course was an imperative condition for our purposes, otherwise we would have ejected a dispersed swarm of particles and gas clouds instead of obtaining well defined particle tracks. I should note that most of the chemists with whom I discussed the matter scoffed at the possibility of coruscatives.

In order to have all of the reacting components distributed in molecular dispersion, it would be ideal to use single crystals of coruscatives. Such crystals exist, but unfortunately, upon transformation they do not release enough energy to heat the reaction products to sufficient incandescence for our purposes. We therefore started experimenting with highly compressed fine powders of powerful reagents. The first obvious mixture to try was thermit, the welding mixture $Fe_2O_3 + 2Al$ which, on reaction, gives iron and aluminum oxide at a temperature of about 4000°C. But we never succeeded in making compressed slugs of thermit explode on application of high shear stresses. Several other compressed powders, however, acted as desired. Finally, we used mostly fine powders of titanium and carbon which, as a compressed conical insert in a shaped charge, can be collapsed fast enough to react itself explosively, resulting in the ejection of TiC droplets at almost 6000°C and speeds of up to 15 km/sec. A telling photograph has already been published.[6] Generally, the speed of the ejected particles can be increased by choosing smaller apex angles for the conical inserts. At the same time, however, the mass of the extruded particles dwindles disastrously, so that they become quickly unobservable.

To photograph the fast luminous particles of artificial meteors we used various types of wide angle cameras. The most powerful one consisted of an 8-inch F/1 transportable Schmidt telescope, which Russel Porter and I, with the help of instrument makers and opticians at the California Institute of Technology, built in 1939. To observe the tracks spectroscopically, single or mosaic objective transparent gratings were mounted over the full apertures of the cameras and telescopes used.[3]

To test the various shaped charges and the efficiency of our cameras, telescopes and objective gratings, over a period of fifteen years J. Cuneo and I undertook many field trips and launched the artificial meteors from the ground in the Chino Hills in Southern California, at White Sands (NM), Edwards Air Force Base (Cal), the Navy test station at Inyokern (Cal), and in the White Mountains of California at elevations above sea level from 500 m to 3500 m. Furthermore, with the help of the Office of Naval Research in Pasadena, we undertook several small expeditions, flying over to St. Nicholas Island on the California coast to launch our artificial meteors there from high-flying balloons. A long series of valuable results were obtained from all of these experiments, which are in part described in my book Morphology of Propulsive Power[3] as well as in reports by the chief scientist in the Office of Naval Research in Pasadena.

PHASE 2

At the end of World War II the US Air Force asked me to go to Germany as their technical representative to learn about various phases of military research accomplished in Germany. My findings were subsequently published in book form.[8] At the same time I and my teammates under the leadership of Col. John A. O'Mara had arranged for much of the German equipment to be sent back to the United States. Of especial interest to me and a few other scientists were a number of V-2 rockets that were brought to the White Sands Proving Grounds to be fired there with various types of scientific devices on board. For my purpose of launching artificial meteors, it was of course important that the firing occur at night. Through the good offices of my friend Theodor von Karman, General Barnes of Army Ordnance arranged for a firing of a V-2 rocket on the night of December 17, 1946.

Nine shaped charges were to be fired in groups of three at 36, 48, and 60 kilometers altitude above sea level. The flight of the V-2 rocket to a height of 190 kilometers was a beautiful one. Unfortunately, for reasons not discussed here, none of the shaped charges fired. Our disappointment was enormous. Indeed, the failure of our experiment turned out to be a disaster, because further launchings of this sort were subsequently blocked for a full eleven years. Some so-called experts on (natural) meteors, among them Professor F. L. Whipple of Harvard, reported to the cognizant agencies of the US government that the experiment which I had proposed could not possibly succeed and should not be supported. These agencies not only followed his advice, but officials actually talked about charging me with wasting the tax-payers' money. Fortunately, good friends of ours were informed that I and my collaborators had all paid our own way and had not received any funds from anybody, so we were spared the necessity of having to face a judge.

As mentioned, during the following eleven lean years, Mr. Cuneo and I continued to develop even more powerful shaped charges and better inserts to be ejected from them. We also tried to get funds for launching these larger artificial meteors into interplanetary space from sources other than any of the US governmental or military agencies. Because of their historical interest I will mention two of these attempts.

First I had the idea that, for the sake of keeping records about the beginning of experimental astronomy and man's march into space, it would be of interest to secure moving pictures of all of the important steps that were to be undertaken. By giving the movie industry the right to disseminate the film, that industry might finance our projects. I therefore approached one of the well known Hollywood authors and script writers, my old friend Mr. Michael Blankfort. He went at it enthusiastically, but unfortunately without success, as he relates in the following note which he kindly wrote last year for my use in the present article:

A Note on a Proposal to Finance a Moon Project

> Sometime in the early Fifties (1953-1955), Professor Fritz Zwicky visited my home and during the course of the evening mentioned the problem of financing a project of propelling pellets to the moon via rockets. There was to be a number of special cameras placed strategically around the world to record the launching and landing of the pellets. It was estimated that $100,000 would be sufficient to carry the experiment through. I volunteered to speak to Mr. Darryl F. Zanuck, at that time chief of production of 20th Century-Fox Films. I would offer his company the world film rights to the moon project for that sum. I saw Mr. Zanuck the next day and explained what was proposed and what was being done. He seemed not only interested but enthusiastic, and promised to take the matter up at the next meeting of the Board of Directors of his company. I mentioned that there was an urgency about the passing of time, and he replied that he would not wait but telephone. I saw him about forty-eight hours later. He reported that New York had rejected the proposal as outside their common run of business. His disappointment was almost as great as mine, but neither compared to Dr. Zwicky's.
>
> Michael Blankfort
>
> April 13, 1971

Next, my old friend Sydney Chapman stepped in. He had been in my audience at the University of Oxford in the spring of 1948 when I gave my Halley Lecture on Morphological Astronomy.[4, 9] He had been impressed with the power of the Morphological Approach, and considered organizing all of the projects of the International Geophysical Year (IGY) using this method and, as a special case, include experiments with artificial meteors. As a preliminary he told me that during a stay in Australia he would try to arrange for me to launch my meteors to the moon with rockets from the rocket base at Woomera. He was successful in interesting the cognizant agencies in Australia in my project. As I made preparations to go to Australia, a curious thing happened. On a beautiful Sunday afternoon in Pasadena I was called by the London Times. The reporter said that the Prime Minister of Australia, Mr. Menzies, had called Winston Churchill, inquiring what this crazy project of shooting the Moon from Australia was all about. Mr. Churchill, being quite as uninformed as Mr. Menzies, called the experts of the London Times, who also knew of nothing and who called me. It turned out that neither Sydney Chapman nor the Australian rocket men had ever thought it necessary to talk to the Prime Minister about my simple project. But that is where they had made their fatal mistake. Mr. Menzies became incensed, claimed that my project would give rise to world-wide repercussions, and he ordered the flight cancelled.

THE FIRST SHOT INTO THE UNIVERSE

I still had many far-sighted friends in the US Air Force. I had come to know these men after my tour in Germany as their technical representative, and after serving for many years on the Air Force Scientific Advisory Board under Generals Arnold, Spaatz, and Vandenberg. In particular, Dr. Knox Milsaps, Chief Scientist at the Alamogordo Air Force Base, and Dr. Maurice Dubin promised to watch for any space available in one of the research sounding rockets that might allow us to install our shaped charges. In August 1957 these two gentlemen informed me that an Aerobee rocket would be fired in October, and that about one cubic foot of space would be available for us in the instrument head. Mr. Cuneo and I therefore feverishly went to work on our shaped charges and the construction of timers that could be set to ignite the charges at the proper moment of the rocket flight.

All of our devices were ground tested at Alamogordo on the night of October 15, 1957. Next day some trouble arose, because another group of scientists had cosmic ray recorders installed in the rocket. They feared that our exploding charges would destroy their instruments. How we resolved this very difficult problem has been described elsewhere.[3, 10] In any case, the charges were ignited properly as we had planned at a height of 85 kilometers, exactly 91 seconds after the rocket had left the ground.

One very luminous pellet consisting mostly of TiC and some Al_2O_3 was ejected with a velocity of 15 km/sec, considerably in the excess of the escape velocity of the Earth. This pellet became the first man-made object to be shot into interplanetary space, and thus the first tiny artificial satellite of the Sun. Its luminous trajectory on the way out was photographed by many cameras, including the Palomar 48-inch Schmidt telescope located over 1000 kilometers to the West. The velocity of the pellet was determined by the Superschmidt telescope on Sacramento Peak in New Mexico, by means of interrupting the photographed trajectory with a propeller shutter.

PHASE 3

Unfortunately, both the scientific community and the world at large did not hear about our success until a few months later, because the Air Force would not release any data until they had made sure of all of the facts. Furthermore, everybody was excited because the Soviets already had successfully launched Sputnik 1 twelve days before. During the subsequent rush, when the United States tried to catch up with the Soviets, artificial meteor projects were forgotten and all of my plans to shoot chemically reducing projectiles into the Moon came to naught. Thus, to this very day we have no answer yet to the vital question of whether or not deeper lying moon rocks might contain water of crystallization that would make possible the installation of simple life-sustaining devices (solar furnaces, plus magnetohydrodynamic generators, plus electrolytic cells for the production of various elements), such as I had proposed and partly constructed twenty years ago.[3, 6, 7]

RECONSTRUCTION OF THE PLANETARY SYSTEM

With the launch of Sputnik 1, some modest phases of the plan,[+] that I had first outlined in my Halley Lectore[4] at Oxford in 1948, appeared within practical grasp. To prevent the various governments and their respective agencies from blundering into outer space and bungling things, as has been done throughout history with all large-scale new developments on Earth, some far-sighted men (and in particular the lawyers, physicians, pure scientists and engineers of the International Academy of Astronautics [IAA]) emphasized the necessity of international agreements to precede any practical constructive or destructive actions on extraterrestrial bodies and in outer space. These efforts led to the formulation of a preliminary Treaty for Outer Space which was signed by some eighty nations in 1968.

Many details still remain to be clarified and the members of the IAA and of the International Institute of Space Law are hard at work to analyse and formulate them. Once the basic aspects of the March into Outer Space have been isolated, analysed, and evaluated, some international organization such as the UN will have to decide which of the following three generic types of enterprises should be allowed and undertaken:

1. Scientific exploration and construction of research stations in space and on the various bodies of the solar system.
2. Exploitation of some of the extraterrestrial resources for use in pure and applied science, basic technology and medicine.
3. Exploration on a moderate, or large, scale for commercial and technical uses, including the establishment of general human settlements on the various bodies of a suitably reconstructed planetary system.[4]

[+]Zwicky's plan called for modifying the physical conditions of some of the presently uninhabitabitable bodies in the solar system; e.g., First, constructing subsurface installations on the Moon and the planetoids; second, making them habitable by changing surface conditions of the Moon to provide a breathable atmosphere of molecules heavy enough not to escape; third, reconstructing various large bodies of the solar system by moving them to other locations—Ed.

SOME MODEST AUXILIARY RESEARCHES FOR THOSE WHO FOLLOW

For the past several decades funds for research have been rather overabundant, not always to the benefit of fundamental research. These funds have now become scarce, and it is useful to remind the young scientist in particular that very important research still can be done simply and cheaply. By way of illustration, here are a few proposals and investigations that, in part, existed even before the later rapid developments in space research.

First, I would mention a class of extraterrestrial bodies with which we can actually experiment because they come to us: meteors and meteorites. Although a considerable number of spectra of meteors have been observed, far more could be done through the systematic use of powerful Schmidt telescopes equipped with prisms and full size objective transmission gratings, some of which have now been successfully built to sizes of 45 cm x 45 cm, either as mosaics or ruled full size by myself, R. W. Wood, and John Strong and associates.[3, 11, 12]

More important, perhaps, many meteors actually come crashing down to the Earth's surface to lodge with us as meteorites. Since they have been traveling in interplanetary space for many millions, and probably even billions of years, they have been subjected to all sorts of extraterrestrial interactions and events. Therefore, in some respects, they may be considered as substitutes for artificial test bodies which we might otherwise launch intentionally into outer space. During their travel they have been exposed to cosmic rays, to the solar wind and electromagnetic radiations covering the whole wave length range from radio waves to Gamma rays, leaving the meteorites with the following tell-tale signs to be searched for:

a. Excitation of long duration pseudostable states that are analogous in character to the latent photographic images caused by sufficiently energetic quanta of light in heteropolar crystals, for instance. The energy thus stored in the solid meteorites can be determined by baking them out, as was done extensively by F. G. Houtermans and his collaborators at the University of Berne.

b. Protons from the solar wind will be imbedded to a depth of a few hundred Angstoms in the meteors, as they have been found in lunar rocks recently. Whether or not these proton layers in meteors survive the dive through the atmosphere and have ever been found in meteorites is not known to me.

c. Heavy nucleons of the cosmic rays leave permanent tracks in certain crystals and should therefore also be found in meteorites.

d. Finally, we know that fast solid particles ejected from solid inserts in shaped charges at velocities of up to 15 km/sec[3] can penetrate solid blocks, of steel for instance, to depths of one meter. There is a good chance that during their long travel large meteors will have been hit by small ones traveling at velocies even higher than 15 km/sec and should therefore occasionally exhibit straight long thin channel holes. Searching through various museums, I think that I may have spotted such holes, but the respective museum directors were reluctant to let me cut up their beautiful large specimens in order to test my expectation. Continuation of this type of inquiry might, however, some day be rewarding.[+]

e. Finally, the faint suspicion remains that the missing planet between Mars and Jupiter may have been blown apart by a nuclear fusion reaction, initiated for instance through the impact on it by a very fast body of "local origin," such as a nuclear goblin ejected from the sun or some interstellar ultrafast missile.[13] We shall be able to draw more definite conclusions once we have investigated whether or not some craters on the Moon have been caused by impacts capable of igniting nuclear fusion reactions and by actual experiments of our own with ultrafast particles.

Second, the results of some experimentation with extraterrestrial bodies can be observed from the Earth, inasmuch as nature itself provides the means. For instance, the Sun "experiments" with the Moon by illuminating it in various phases. The resulting successive heating and cooling of various parts of the Moon's surface could thus be observed and its heat conductive properties be derived. Sunlight falling on the Earth is partly scattered and can be observed illuminating the dark part of the Moon which faces us. Proper measurement would allow us thus to determine the Albedo of both the Moon and the Earth, the latter varying because of different cloud cover.

Third, direct measurements of the Albedo of the Moon were made in the 1940s by sending radar signals to it and observing the echoes, while recently the same was accomplished with Laser beams. These various attempts actually represent modest examples of passive experimental astronomy.

APPENDIX

FRITZ ZWICKY, A SELECT BIBLIOGRAPHY

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[+]I have also long considered the problem, during a concentrated meteor shower, of intercepting some of the fast incoming missiles by placing convenient targets in the stratosphere or ionosphere in order to test the meteors penetrating power. Since this will, however, soon be done more conveniently on the Moon, I have abandoned wracking my brains further on the matter.

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