Phaser Telepropulsion Inc. 1888 Century Park East • Suite 10 • Los Angeles, California 90067
(213) 556-2037

February 20, 1990

Charles Kohlhase
Mail Stop 264-443
Jet Propulsion Laboratory
Pasadena, CA 91109

Dear Charlie:

Regarding our telephone conversation on February 2, I wish to retract one of my statements. During that conversation, you took the position that my contribution to space travel represented by the invention and initial development of gravity-assist trajectories was on the same level of scientific achievement and comparable to the contribution made by the person who invented an electronic device that made possible longer distance communication with higher bit rates. Since I did not want to detract from the sceintific contributions of other researchers, nor to appear to be a bragger, I concurred with your position. I was hoping that my humility would be recognized and therefore increase the possibility of getting formal recognition for my invention in the form of a NASA award such as I described in my letter to you of last October 30. I have had some time to reflect upon that conversation and decided that I should have been more forthright, and should have stated my true feelings without regard to any other considerations. Consequently, I have decided to state herein what I believe, and what the historical facts demonstrate.

I believe that my invention of space travel through the Solar System by means of gravitational propulsion -- where the propulsive energy is taken from the orbital energies of passing planets instead of from onboard energy generating systems -- and the research that I conducted in developing this concept during the years 1961 - 1964 at JPL and at UCLA ranks very high on the list of scientific achievements. I was told by more than one physics professor from UCLA as well as from the University of California, Berkeley, that since my work made possible the exploration of the entire Solar System, using very little rocket propulsion, it ranks -- on pure scientific merit -- with the invention and development of the cyclotron by Dr. Ernest O. Lawrence, which made possible the exploration of atomic nuclei.

In order to make a technically correct and unbiased evaluation of my invention and subsequent research, one has to go back to 1961 and view the work as a whole relative to that time period. I began the research on my own initiative, by developing more powerful mathematical techniques to study basic astrodynamic problems in space travel using vector analysis. I did this because of a deep love for mathematics and theoretical physics, and because I saw that astrodynamic analysis using traditional scalar techniques led to very complicated equations that obscured the underlying physical processes. At that time, Celestial Mechanics usually employed traditional mathematical methods from advanced calculus, differential equations, and numerical analysis. (See, for example, the book, Methods of Celestial Mechanics by Brouwer and Clemence, 1961. This book was cited so frequently in JPL papers written during the early

1960s that it was regarded almost as "the Bible" in space trajectory research.)

After developing my vector techniques, I applied them in attacking the "three-body problem" as it relates to space travel. (In astrodynamics, the problem becomes the "restricted three-body problem.") This was a well-known problem in Celestial Mechanics that, except for special cases, had no closed-form solutions. It was considered to be one of the most difficult problems in applied mathematics. Because of the special nature of the situation, this problem is much more difficult in the precise numerical determination of round-trip interplanetary trajectories than in the case of round-trip lunar trajectories (page 55, enclosure 1). This is because in the case of interplanetary trajectories, the hyperbolic encounter trajectory is much more sensitive to errors than in the case of lunar trajectories.

In 1961 it was not possible to accurately numerically determine any interplanetary free-fall round-trip trajectory corresponding to the real situation where the sun and all the planets in the Solar System act continuously and simultaneously to influence the motion of a space vehicle. However, since the differential equations of motion are known for the general N-body problem, an exact numerical solution for determining free-fall round-trip interplanetary trajectories could, in principle, be obtained by determining a sufficiently accurate initial approximation for the hyperbolic encounter trajectory that would converge to the exact solution by applying methods of numerical iteration on numerically integrated trajectories. I recognized that the key to solving the three-body problem involved finding a sufficiently accurate initial approximation for the hyperbolic encounter trajectory that would converge to the exact solution.

Three-dimensional free-fall round-trip trajectories to Mars were first studied in 1959 by Battin ("The Determination of Round-Trip Planetary Reconnaissance Trajectories," Journal of Aero/Space Sciences, Vol. 26, No. 9, Sept. 1959), but his analysis was based upon using the traditional 6 orbital element scalar representation of trajectories and did not incorporate the concept of a "sphere of influence." His analysis was reduced essentially to patching two conic legs together at the center of Mars with the assumption that the perturbation of Mars takes place "instantaneously." The hyperbolic encounter trajectory was, therefore, not completely determined in three-dimensional space, but it was, however, the most important part of the trajectory and essential for the numerical iteration/integration process used in numerically determining the exact encounter trajectory a space vehicle would have to follow for a round-trip trajectory.

One of the major theoretical results of my 1961 research was the development of a practical analytical method for completely determining an accurate initial approximation for the hyperbolic encounter trajectory that could be used to obtain a precise numerical solution to the restricted three-body problem via iteration methods. I wrote up this research in my paper "A Method for Determining Interplanetary Free-Fall Reconnaissance Trajectories", JPL TM 312-130,

Phaser Telepropulsion Inc.

Advanced Concepts Division
1888 Century Park East • Suite 10 • Los Angeles, California 90067

Aug. 23, 1961. It was tested for convergence using JPL's precision trajectory intergrating program in April 1962 by Gene Bollman after I programmed it myself at UCLA. (Clarke refused to have the paper programmed at JPL because he believed that my ideas and analysis violated the law of conservation of energy. I do not say this with the intention of embarrasing Clarke, or JPL, but rather to state an important historical fact.) My work, therefore, represented the first practical numerical solution to the restricted three-body problem of Celestial Mechanics and, consequently, is of some historical merit in this field. This original work became the basis for my Ph.D. Dissertation in Mathematics at the University of California, Berkeley.

Since the restricted three-body problem was regarded in 1961 as so difficult and inaccessible to detailed investigation, both from the theoretical and numerical points of view (enclosure 1), many Celestial Mechanicians and astrodynamicists believed completely erroneous ideas about the very nature of the problem, and the free-fall trajectories associated with it. One of the most profound widespread misconceptions concerns the orbital energy of a free-fall vehicle moving under the gravitational influence of a primary body before and after passing close to a secondary body and being perturbed by it. A search of the literature of papers published up to and during the beginning of the 1960s indicates that a majority of the leading researchers in this field must have actually believed that the orbital energy remains the same before and after passing a second body. Recalling our phone conversation, you may find this difficult to believe. However, after searching the literature it appears that it was actually true. This can be demonstrated by examining an important theoretical paper by Lagerstrom and Kevorkian (enclosure 2) involving the restricted three-body problem, and a particular application involving free-fall round-trip lunar trajectories. On page 88 of this paper, the authors state: "Each leg will be a Keplerian conic relative to the earth. However, there will be some kind of discontinuity at the position of the moon, similar to a shock wave in fluid flow. The energy relative to the earth will be constant on each leg. Actually, these constants are the same. This follows from the fact that in the exact solution, the total energy, as given by (2.5), is an exact invariant. Hence, in the outer solution the energy relative to the earth is continuous. This implies that the magnitude of the velocity is continuous. However, we expect the attraction of the moon to alter radically the direction of motion or, equivalently, the angular momentum relative to the Earth."

The fact that the authors of this paper were from Caltech, that the paper was published by The Astronomical Journal (which was, at that time, one of the most prestigious journals for papers on Celestial Mechanics), and that the paper was reviewed by qualified professionals, demonstrates how deep, widespread, and institutionalized this constant energy misconception really was at the beginning of the 1960s.

Other examples of this misconception can be cited in the literature. For instance, after Battin obtained numerical evidence indicating that the orbital energy of his round-trip trajectories to Mars would change, he referred to this change as a "curious fact." Quoting directly from page 566 of his above-cited paper, he states: "The variations in the return velocity are much greater and, indeed, we observe the curious fact that the spaceship can return to Earth with a velocity smaller than the one with which it left."

During our telephone conversation of February 2 (and in prior conversations), you cited published astronomical observations made during the previous century that indicated the orbit of a comet can be significantly changed by a close encounter with Jupiter. You assumed that on the basis of those observations, astrodynamicists studying space travel in the early 1960s, must have been aware that orbital energy can be changed by a close planetary encounter. I respectfully submit that your presumption in this matter has been influenced by hindsight generated by the recent NASA gravity-propelled Voyager 2 mission. Although it seems reasonable today to assume that on the basis of those astronomical observations, astrodynamicsts must have known that the orbital energy of a space vehicle could be radically changed by a close planetary encounter, the published papers from that time period show otherwise.

One of the most popular concepts in astronomy involved the assumption that all bodies move around the sun in well-defined, essentially elliptical paths with constant orbital energy. In astrodynamics, gravitational perturbations were generally regarded prior to and during the early 1960s as annoying disturbances that tended to destroy elliptical regularity. The application of the principle of conservation of energy to bodies moving in the Solar System was rarely stated as applying to the collection of all the bodies as a whole.

My most important contribution that resulted from my independent theoretical work on the restricted three-body problem was the recognition that, contrary to popular belief, the orbital energy of a free-fall vehicle can be changed by a close planetary encounter and, that this encounter could therefore be utilized to propel the vehicle to a more distant planet that would ordinarily require more launch energy using a conventional direct-flight Hohmann trajectory. I also recognized that this gravitational propulsion concept could be utilized to propel a free-fall vehicle around the Solar System indefinitely from one planet to another planet with radical trajectory changes visiting an unlimited number of planets without using any rocket propulsion beyond that required to reach the first planet. When I described these ideas to Clarke in 1961, he said essentially that my analysis must be incorrect because it violated the law of conservation of energy. I always believed that Clarke was technically incompetent because of that 1961 conversation. However, Clarke was not the only person who had that misconception. It was evidently held by a majority of the astrodynamicists of that time period. This means that my ideas about space travel and the related research were even more revolutionary than I originally believed.

I worked on this research by myself for three years (1961-1964) at UCLA and at JPL to demonstrate the validity of my ideas, and to show that these ideas

Phaser Telepropulsion Inc.

Advanced Concepts Division
1888 Century Park East • Suite 10 • Los Angeles, California 90067

could change the history of space travel. They did.

There were a few astrodynamicists prior to 1961 that did recognize that gravitational perturbations could result in a change of orbital energy. These researchers were Kondratyuk (enclosure 3), Tsander (enclosure 4), and Lawden (enclosure 5). However, when considering how gravitational perturbations could be utilized in practical situations to reduce the launch energy required for interplanetary space travel to another planet, these researchers usually viewed the perturbing body as a satellite orbiting the launch planet, or orbiting the target planet. They apparently never recognized that the launch energy required to reach a distant planet could be substantially reduced by sending a vehicle to a much closer planet, and letting the gravitational influence of that planet propel the vehicle to the distant target planet without rocket propulsion. The literature of papers published prior to 1961 is completely devoid of any such concept or proposal. All of the astrodynamicists prior to 1961 viewed Hohmann's co-tangent direct-flight trajectory as the absolute minimum energy trajectory for reaching another planet. See for example, Lawden's book, Optimal Trajectories for Space Navigation, Butterworth and Co., London, 1963. In this book, which is essentially devoted entirely to the determination of minimum energy trajectories, the possible beneficial effects of gravitational perturbations are never mentioned. Tsander's work on gravitational perturbations was directed more at investigating their effect on a space vehicle rather than how perturbations could be utilized to reduce the minimum propulsion requirements of space travel. Tsander (as well as all other astrodynamicists) evidently believed and accepted as self-evident that the basic thrust forces required to accelerate a vehicle on interplanetary voyages to other planets had to be generated "mechanically" either by reaction propulsion (using Newton's third law of motion) or by using giant reflecting surfaces (solar sailing via radiation pressure). In fact, Tsander, who was aware of the fact that the orbital energy of a space vehicle can be changed by gravitational perturbations, actually described Hohmann's minimum energy trajectory as a fundamental "law" of space travel (see page 246 of enclosure 4). These remarks are not intended to detract from the outstanding contributions of these early pioneers of space travel, but rather, to show that the concept of gravity-propelled interplanetary space travel did not originate with them, and to demonstrate the profound impact that my work had on the basic principles of space travel. This contribution was made by an American.

I have taken the time to write you this letter so as to bring to your attention the true circumstances of my research, and its importance relative to the state of the art that existed at the time I conducted the research. I hope you can use it to obtain the award for me.

The fact that I received a NASA award (ESM) for developing the computer program should not preclude my chances for receiving a NASA award for inventing the concept -- which JPL already clearly acknowledges. If you examine the NASA

Phaser Telepropulsion Inc.

Advanced Concepts Division
1888 Century Park East • Suite 10 • Los Angeles, California 90067

award forms you will find blank spaces for listing previous awards.

Charlie, if you feel that JPL will never recommend the award, then you should, as an honorable person, advise me of this situation as soon as possible.

Sincerely,

Michael A. Minovitch

MAM/dk

Dr. Michael A. Minovitch

Enclosures(5):

1. Szebehely, V.G., "Astrodynamics -- State of the Art - 1962", Astronautics, Nov. 1962, pp. 52-55.

2. Lagerstrom, P.A. and J. Kevorkian, "Matched-Conic Approximation to the Two Fixed Force-Center Problem," The Astronomical Journal, Vol. 68, No. 2, March 1963, pp. 84-92.

3. Kondratyuk, Yu. V., "Tem, Kto Budet Chitato, Shtoby Streit" (To Whomsoever Will Read In Order to Build), completed 1917-1919. Paper appears in book Pionery Raketnoy Tekhniki (Pioneers of Rocketry), Moscow, 1964, pp. 533-534, NASA Technical Translation F-9285, Nov. 1965, pp. 45-46.

4. Tsander, A.F., Problema poleta pri pomoshchi reacktivnykh apparatova: Mezhplanetnve polety (Problems of Flight by Jet Propulsion: Interplanetary Flights--NASA Technical Translation F-147, 1964), pp. 221-302.

5. Lawden, D.F., "Perturbation Maneuvers", Journal of the British Interplanetary Society, Vol. 13, No. 6, Nov. 1954, pp. 329-334.