In Memoriam

Theodore N. Edelbaum

TED Edelbaum was a young man—vigorous and creative both in his profession and in his avocations. He was competitive and highly competent at the chess table with many trophies to attest his skills. He played an aggressive game of handball and was a virtual walking encyclopedia of information on ornithology. He made many important analytic and numeric contributions to the art of trajectory optimization which plays such a major role in the development and understanding of space-flight mission planning. He was a loving husband and companion to Donna and a caring father to Laura. He was my colleague and my friend. His passing was sudden—without pain and without anxiety to himself but not without a great sense of loss to those of us who had the good fortune to know him well.

Ted began his career at Rensselaer Polytechnic Institute, where he received the Bachelor of Aeronautical Engineering degree in 1953. He then became a research assistant in its Department of Rational and Technical Mechanics, exploring the phenomena of wave propagation in incompressible solid cylinders.

He then joined the Research Department of the United Aircraft Corportation where he was involved in the performance analysis of aircraft, missiles, and spacecraft. He participated in high-energy fuel studies for aircraft, missiles, and spacecraft and evaluated the mission performance of various advanced propulsion systems, including electric propulsion systems, solid and gas core nuclear rockets, solar sails, and hybrids of these. This work contributed to United Aircraft Corporation's prominence in the research and development of hydrogen-oxygen rockets, ion thrustors, nuclear electric power supplies, and gas core nuclear rockets.

Ted's research on trajectory optimization began in 1954, and he became one of the pioneering contributors to his rapidly growing field. He received the Master of Science degree from RPI in 1958 and taught space trajectory optimization at the RPI Hartford Graduate Center in 1964.

In 1965 Ted founded and managed the Boston office of Analytical Mechanics Associates to support the work of the NASA Electronics Research Center until its closing in 1970. During this period he extended his work in trajectory optimization to the consideration of optimal guidance strategies.

In 1970 he joined the MIT Instrumentation Laboratory, later to become the Charles Stark Draper Laboratory, Inc. In addition to trajectory optimization, he broadened his interests to include control of large optical systems and of fusion reactors such as Tokamaks.

He held the post of lecturer in the MIT Department of Aeronautics and Astronautics where he supervised the theses of both Master and Doctoral candidates and also served as a thesis reader for Princeton University and for Canterbury University in New Zealand.

Ted was an active member of the AIAA, beginning as an officer of the Institute of the Aerospace Sciences (IAS) Student Section at Rensselaer Polytechnic Institute. He was an officer and director of the Hartford Section and a member of both the IAS Flight Mechanics Committee and the American Rocket Society (ARS) Astrodynamics Committee at the time that the two Societies merged. He chaired the AIAA Astrodynamics Committee, served on the AIAA Publications Committee and the AIAA Electric Propulsion Committee and was an extensive contributor to and conscientious reviewer for the *AIAA Journal,* the *Journal of Spacecraft and Rockets,* the *Journal of Aircraft, Jet Propulsion,* the *ARS Journal,* and *Astronautics & Aeronautics.* He was active on program committees as session chairman, as author, as discusser, and as general chairman for various IAS, ARS, and AIAA meetings.

He was an Associate Editor of the *Journal of Optimization Theory and Applications* and a member of the editorial board of *Celestial Mechanics* since the founding of these journals. He also was a member and secretary of the Theory Committee of the American Automatic Control Council.

Ted had the unique honor of being the first recipient of the American Astronomical Society (AAS) Dirk Brouwer award in 1973 for his excellent work in space trajectory optimization. Further honors and awards would certainly have been his except for his untimely passing.

Richard H. Battin

A Selection of Theodore N. Edelbaum's Publications

"Minimum Impulse Transfers in the Near Vicinity of a Circular Orbit" *Journal of Astronautical Sciences,* Vol. 14, April 1967, pp. 66-73. An analytic solution for the optimum impulsive transfer between nearby low eccentricity orbits is derived. It is shown that two impulses are sufficient, unlike the corresponding fixed time rendezvous where six may be required. This solution was independently derived by J.P. Marec in France at the same time.

"How Many Impulses?," *Astronautics & Aeronautics,* Vol. 5, Nov. 1967, pp. 64-69. A survey article on optimum impulsive transfer.

"Energy Climbs, Energy Turns and Asympotic Expansion" (with H.J. Kelley), *Journal of Aircraft,* Vol. 7, Jan-Feb 1970, pp. 93-95. This is the first paper on the energy height solution to the optimal turning flight of supersonic aircraft.

"Four Body Trajectory Optimization" (with C.L. Pu), *AIAA Journal,* Vol. 13, March 1975, pp. 333-336. An innovative and efficient method of calculating optimum multi-body multi-impulse trajectories is developed. As an example a calculation of optimum trajectories to the interior earth-sun libration point via a lunar swingby is made.

"Effect of Attitude Constraints on Solar-Electric Geocentric Transfers" (with L.L. Sackett) *Journal of Spacecraft and Rockets,* Vol. 13, March 1976, pp. 174-179. One of a series of papers on the development of a sophisticated computer program to calculate optimal geocentric trajectories by a numerical averaging technique. The program optimizes the initial injection orbit and includes the effects of attitude constraints, oblateness, shadowing, and Van Allen radiation. It is currently being adapted to solar sail escape and capture trajectories.

Ted Edelbaum published almost forty papers in the last twenty years, the majority of these being for the AIAA. He also recorded an AIAA tape cassette on "Problems in Orbit Transfer" and held a patent on "Compound Propulsion System" jointly with Edward Pinsley of United Technology Corporation. Among his more significiant publications are the following:

"Some Extensions of the Hohmann Transfer Maneuver," *ARS Journal,* Vol. 29, Nov. 1959, pp. 864-865. This paper contains the first description of the optimum transfer from a high circular orbit to hyperbolic energies (three impulses).

"Propulsion Requirements for Controllable Satellites," *ARS Journal,* Vol. 31, Aug. 1961, pp. 1079-1089. Here are derived the optimum high thrust and the optimum low thrust maneuvers for a variety of modifications of circular orbits, for both small and large changes. The most notable result is an analytical solution for the optimum low thrust transfer between inclined circular orbits.

"Applications of Ion Propulsion to NASA Missions" (with H.S. London, W.R. Fimple, and F.W. Gobetz), ARS Preprint 2223-61. Presented at ARS Space Flight Report to the Nation, 1961. This is the first of a long series of papers on mission applications of ion propulsion.

"The Use of High- and Low-Thrust Propulsion in Combination for Space Missions," *Journal of the Astronautical Sciences,* Vol. 9, Summer 1962, pp. 49-60. This appears to be the first paper to point out and analyze the advantages of using high and low thrust systems in combination.

"Theory of Maxima and Minima," *Optimization Techniques,* edited by G. Leitmann, Academic Press, New York, 1962, Chap. 1, pp. 19-30. This is the first chapter of a pioneering and influential book on modern optimization theory.

"Optimum Power-Limited Orbit Transfer in Strong Gravity Fields," *AIAA Journal,* Vol. 3, May 1965, pp. 921-925. Krylov-Bogoliubov averaging is used to obtain analytic solutions to the optimum power-limited tranfers between arbitrary coplanar ellipses and between arbitrary coaxial ellipses—one of the earliest and most instructive examples of the occurance of conjugate points on optimum trajectories.

"Application of a Finite-Difference Newton-Raphson Algorithm to Problems of Low-Thrust Trjaectory Optimization" (with C.P. Van Dive and W.R. Fimple), AIAA Paper 65-698, 1965. A new and very efficient method of numerically calculating optimum trajectories is developed.