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From Astronomy to Astrodynamics: A Bridge through Astromathematics

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'Astromathematics' was introduced by the speaker on Monday, October 8, 2012, during *the First National Conference on Space Sciences*, as a branch of mathematics focused on geometrical aspects to study orbits from a kinematical perspective, in which the force expressions did not, explicitly, appear — force interactions were expressed as space-time-curvature equivalents. This formulation could deal with accelerated frames, governed by 'geometrodynamics' that are based on general theory of relativity. On March 20, 2014, the speaker delivered Opening Lecture of *the Second Conference on Mathematical Sciences*, "Astromathematics**:** A New Branch of Mathematics". 'Astronomy' is considered as a branch of natural science, which studies celestial objects. Astronomical models are based on geometric ideas, physical concepts, aesthetic notions and basic assumptions. Babylonians, Greeks, Chinese and Muslims all contributed to astronomy, given sophistication by the monumental contributions of Galileo, Kepler, Newton and others. 'Astrodynamics' is a branch of mathematics, which deals with designing orbits to reach a target planet. The term is attributed to Samuel Herrick (1911-1974). In the preface to his book, *An Introduction to the Mathematics and* (*the*) *Methods of Astrodynamics* (Revised Edition), Richard H. Battin remarks, "In the three centuries following Kepler and Newton, the world's greatest mathematicians brought, celestial mechanics to such an elegant state of maturity that, for several decades preceding the USSR's Sputnik in 1957, it all but disappeared from the university curriculum." The speaker studied thoroughly First Edition (1987) of this book. On July 19, 1993, he sent a review to Dr. Battin, who replied on October 25, 1993, "Thank you very much for your letter and your interest in my book. I appreciate your list of corrections and suggestions." When he joined University of Karachi in 1995, he taught Astronomy, Astrodynamics and Space-Flight Dynamics as well as conducted professional training courses at Institute of Space Technology and SUPARCO. The plane-polar coördinates are not the natural choice for setting up two-body problem according to the Strong Noether's Theorem — if one sets up problem close to natural symmetries of the system, one discovers additional constants-of-motion. Planetary orbits were modeled using the elliptic-astrodynamical-coördinate mesh that yielded 3 constants of motion. In addition, two-body problem was set up last year in the hyperbolic-astrodynamical-coördinate mesh. New control laws were devised**:** the extended-cross-product steering, the normal-component-cross-product steering, the dot-product steering, the normal-component-dot-product steering and the ellipse-orientation steering. Cross-range error was incorporated in the Lambert scheme as well as the multistage- and the inverse-Lambert schemes proposed for course-plotting a satellite-launch vehicle. In addition, the multistage and the inverse-Q systems were devised for steering a satellite-launch vehicle. The problems, which are under investigation by my PhD students, are setting up of two-body problem in the parabolic-astrodynamical-coördinate mesh and complete formulation of the extended-Q system.

The last one was proposed in the Richard H. Battin memorial lecture delivered on March 20, 2014 (Battin passed away on February 8, 2014 after a distinguished career). In the extended-Q system, both position and velocity vectors are managed, simultaneously, through extended-cross-product steering to put a satellite in the desired location with the recommended velocity. This lecture is dedicated to the loving memory of the speaker's most-beloved teacher and mentor, **Dr. Mohummed Ishaq Mirza**, Ex-Member, Space Research, SUPARCO, who passed away last year. A self-made person, he was born in Chak Jhumra, near Faisalabad, Punjab. He got his MSc in Physics from University of Karachi, securing First Class First Position and PhD in Space Physics from University of Alaska, United States. He had clear and solid concepts of physics, which he taught to the speaker. He leaves behind his wife and 2 daughters. Space-science and physics community cannot recover for a long time from the great loss, which the absence of **Dr. Mohummed Ishaq Mirza** has created through his departure for his heavenly abode. May *Allah Izz-o-Jal* rest his soul in eternal peace!

*Keywords***:** Dot-product steering • Ellipse-orientation steering • Elliptic- and hyperbolic-astrodynamical-coördinate meshes • Extended-cross-product steering • Multistage-, inverse- and extended-Q systems • Multistage- and inverse-Lambert schemes • Strong Noether's theorem • Two-body problem

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