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A VARIANT OF THE KÁRMÁN LINE THEORY FACILITATING THE IDENTIFICATION OF A PRECISE ALTITUDE BOUNDARY

Abstract

The concept of Kármán line was first proposed by Andrew G. Haley in a 1957 IAC space law paper, based on Kármán's idea to rely on flight mechanics considerations to identify a boundary between atmospheric flight and spaceflight. The physical phenomenon highlighted by Kármán, and illustrated by Masson & Gazley's "corridor of flight" diagram, is the fact that, starting from a certain altitude domain, a near-orbital velocity is required to meet equilibrium glide conditions, while weight is nearly completely compensated by centrifugal force and lift becomes negligible. The Kármán line altitude was eventually set by FAI (Fédération Aéronautique Internationale) to 100 km in 1960 for the purpose of separating aeronautics and astronautics records. Although we know that this altitude was set in accordance with Kármán's idea, it is partly an arbitrary choice, as Kármán's guidelines alone are insufficient to define a very precise altitude. Indeed, in a conference he presented in 1961 (i.e. one year after he contributed to FAI's choice), Kármán confirms that his proposal for the boundary of space is based on the Masson & Gazley diagram and the phenomenon of centrifugal force being "dominant" (consistently with Haley's and FAI's explanations) but he only points the approximate altitude range where this phenomenon becomes visible on this diagram (300,000-400,000 ft, or 91-122 km), instead of recommending a very precise altitude. In this paper, we propose a variant of the Kármán line theory based on the fact, apparently never mentioned before in Kármán line literature, that the equilibrium velocity actually goes through a maximum when altitude increases. The altitude where this occurs conveniently separates an "atmospheric flight domain", where lifting flight behaviour prevails, and a "spaceflight domain", where orbital flight behaviour prevails. We demonstrate, both numerically and analytically, that this altitude boundary is relatively stable with regards to the vehicle's lift performance, and that it necessarily implies a near-orbital velocity, in accordance with Kármán's idea. Numerically, this variant of the Kármán line theory yields an altitude boundary around 110 km, which is relatively close to FAI's choice. The advantage of this variant is that it is compatible with Kármán's original theory, but does not rely on an arbitrary setting to define the conditions at which lift is considered negligible. Legal aspects of the boundary of space definition(s) are outside the scope of this paper, which focuses only on flight mechanics/astrodynamics aspects.