

One hundred years of Flight Dynamics equations

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ABSTRACT

During the 19th Century many scientific disciplines bloomed. Some of them, particularly Fluid Mechanics, Thermodynamics, Electricity, Strength of Materials, etc, were required for the success of powered flight, once gliding flights had been proved by numerous visionaries such as Cayley, Henson, Stringfellow, Phillips, du Temple, Maxim, Ader or Lilienthal.

Everything was ready at the turn of century and thence, if the Wright brothers had not performed the first successful flight in December 1903, an airplane would have flown sooner or later. As a matter of fact, many designs appeared independently in the first decade of 20th Century: Santos-Dumont, Curtiss, Bleriot, Latham, Farman ... However, the pioneers faced considerable control troubles since the flying qualities of the aircraft at that time were absolutely unsatisfactory. Therefore, understanding the modes of motion was extremely importance for the success and safety of aviation. However, the equations governing the airplane motion are so complex that Flight Dynamics requires concepts and tools from Mathematics, Mechanics, Aerodynamics, instrumentation, simulation, pilot handling, etc.

The paper will present an overview of the pioneer stability theories, devoting special attention to those published by Zhukowsky, Lanchester and Painlevé. Their models were very important for subsequent developments, but were incomplete or included errors, although Lanchester achieved great recognition thanks to the term “phugoid”, soon accepted and widely known. But the full set of equations was developed, independently, by Bothezat and Bryan, in 1911. Except for minor notation aspects, these equations have remained unchanged. The core of the paper will be, therefore, devoted to Bothezat and Bryan contributions.

Georges de Bothezat was a young Russian engineer who performed his Doctorate in Paris under the guidance of Paul Painlevé. He returned to Russia, but fled to the United States after the Revolution and worked on propellers and helicopters. Bothezat’s Thesis was based on Painlevé’s early works, but extended them to a full six degrees of freedom motion model. His longitudinal stability findings are very complete and contradictory to previous hypotheses and results. For example, Bothezat stated that the airplane longitudinal stability needed not any particular hypothesis on the centre of pressure location, and it was enough to set the horizontal tail incidence at a smaller angle than that of the wing.

Professor George Bryan was an eminent applied mathematician, highly interested in Physics, who discovered manned gliders thanks to his friend Percy Pilcher, one of Lilienthal’s disciples. The tragic death of his friend, Pilcher, three years after that of his German mentor, prompted Bryan into the study of flight stability and safety. According to Bryan, the motion of an aircraft and its stability and control could be determined completely by dynamical principles. His formulation was based on two key assumptions: first, the aerodynamic forces and moments depend only on instantaneous values of the motion variables; and, second, the aerodynamic forces and moments could be linearized with respect to the motion variables. Following the rigid body dynamics, he studied the airplane motion through six equations, corresponding to the six degrees of freedom: three linear coordinates, plus three angular coordinates. With the additional assumption of airplane and disturbance symmetry, the lateral asymmetric motion (lateral-directional) can be separated from the longitudinal motion.

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