Control Engineering and the Birth of Aviation

Over the last 100 years, control engineering often has been employed as a competitive advantage, with one of the best examples being the birth of aviation by the Wright brothers, who built the very first self-propelled fixed wing controllable airplane. The early aircraft were highly unstable, and it was by control engineering that sustained flight was made possible. A statement by Wilbur Wright to the Associated Press described their intensive flight tests and design modifications up to the end of 1903 as, "…we were determined, before returning home, to know whether the machine possessed *sufficient power* to fly, *sufficient strength* to withstand the shocks of landings, and *sufficient capacity of control* to make flight safe in boisterous winds, as well as in calm air. When these points had been definitely established, we at once packed our goods and returned home, knowing that the age of the flying machine had come at last" [1]. *Control engineering* was one of the three key requirements before powered flight could be realized.

The importance of control was that the initial aircraft designs were highly unstable, and the goal of the feedback control was to ensure that the design was not so unstable that it could not be stabilized reasonably safely by the pilot. The field of "flight control" actually started earlier in 1902, in that Orville and Wilbur Wright prototyped and developed control engineering solutions using gliders before they attempted to move on to powered flight. The Autumn of 1902 was when they implemented an interlinked roll-yaw control system in a glider that, combined with a previously designed control system, gave them control over both the vertical and horizontal components of the flight path. More specifically, the overall control system enabled control of all three axes of motion of the aircraft. These experiments with gliders and mechanical control systems also provided the experimental data that they used to design the minimum power and maximum weight specifications needed for the engine for powered flight, as well as improving the design of the mechanical structures to maintain mechanical integrity.

A keen attention to control systems engineering gave the Wright brothers the advantage over their competitors.

Glider designs with control systems existed before the Wright brothers' famous experiments but used a different control principle. The idea of preaeronautical engineers was to design the control system to shift the center of gravity. Wilbur's opinion, based on watching birds fly, was that a more efficient approach would be for the control system to be based on shifting the center of pressure. This approach was implemented by twisting the outer sections of the wings. This example illustrates one of the most common problems seen in poorly designed controlled systems, which is a poor understanding of the control principles by which a control solution should be formulated and designed. For example, a guiding principle for formulating the design of a control system for a large-scale manufacturing facility is to ensure that any mass recycle loops are handled in an appropriate way; ignoring the recycle loops can lead to snowball effects in which the effects of small disturbances are magnified in the system. A control engineer who ignores key underlying principles important to the control of the physical system can produce very bad control systems designs, even if employing the most advanced control methods.

Many of the ideas used in the 1902 glider were actually first tested by the Wright brothers using kites, demonstrating the value of testing simplified versions of proposed control solutions before application to more complicated systems. The Wright brothers also very tightly coupled the design of the airframe with the design of the controls. They would propose a design based on the best information that they had available, collect experimental data, analyze the experimental results, and design a new system based on those results. This interaction of design and control has been carried out for more than

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100 years, with the Wright brothers providing just one example, but few engineers today are being trained in how to efficiently carry out such integration.

An interesting aspect of the story of flight control is that it was their advances in the understanding of the control issues and their proposed solutions that gave the Wright brothers the key edge on their competitors, who had started working on the problem much earlier. Due to their control advances, by 1908 they could literally "fly in circles" around their competition, whose powered aircraft could only fly in straight lines [2].

The Wright brothers were practicing control engineers.

Readers interested in more information on the control engineering challenges and solutions are encouraged to read a series of articles by Gareth D. Padfield at the University of Liverpool [2]–[5], which also include detailed measurements in modern wind-tunnel experiments and computer simulations of models of several of the Wright brothers' aircraft. The papers also include discussions of how the experimental results relate to the writings of the Wright brothers, who kept meticulous notes on their work that remain available today [1]. One of the papers ends with a list of the factors that contributed to the success of the Wright brothers in founding the field of aviation that are just as relevant today as they were then, which include

- being very focused on the performance objectives while designing the control system
- having a deep understanding of the system that is to be controlled
- considering the design of the *system* as important as the design of the controller when working to meet the performance objectives
- taking a systems approach that considers all of the discrete components as well as their interactions.

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Richard D. Braatz

When Machines Rule

Arthur C. Clark argued that human invention ultimately can only lead to our evolutionary replacement by intelligent machines: "The tool we have invented is our successor…the machine is going to take over." For him, technology was not merely a series of ever more complex gadgets; it was the artificial extension and acceleration of evolution. Indeed, teams of researchers now actively seek not merely faster computers with more memory, but artificial intelligence. One researcher put it this way: "We're getting more and more alienated from these things [nature] that created us. The distance between us and what made us is growing very fast." However, he added, "from an evolutionary point of view, from a rational point of view…it doesn't matter whether the process [life or evolution] is carried on by carbon chemistry or by silicon or by robots…" Indeed, the status of intelligent machines is becoming a legal issue. Would an artificial intelligence deserve the same rights before the law that people have? Would an intelligent machine have the "right" to be eternally plugged in? Might ownership of life forms with artificial intelligence someday seem as heinous as slavery?

—From *Technology Matters, Questions to Live with*,
by David E. Nye, The MIT Press, Cambridge, Massachusetts, pp. 224–225.