FLIGHT CONTROL

—an Historical Review: Abstracts from Dr. Draper's Wilbur Wright Lecture

THE significance of the design of the Wright brothers' aircraft in relation to stability and control concepts was emphasized in the paper by Dr. C. S. Draper (of Massachusetts Institute of Technology) due to be presented yesterday, May 19th, before the Royal Aeronautical Society. The occasion was the Society's 43rd Wilbur Wright Memorial Lecture, given at the Royal Institution, London.

Before the Wright brothers demonstrated their powered man-carrying flying machine, Dr. Draper submitted, flight was based on the philosophy of vehicles with high inherent stability, combined with pilots whose only duty was to steer. This combination resulted in low controllability and poor manœuvrability, with a strong response to the disturbances of rough air. The Wright brothers broke away from the high-inherent-stability concept and combined inherently unstable aircraft with three-axis control operation by human pilots, to achieve stable flight systems with good controllability and good manœuvrability. This change from inherently stable to inherently unstable aircraft was the basic contribution made by the Wright brothers in starting the age of flight.

Dealing with aeronautics before the 20th century, the lecturer referred to Leonardo da Vinci, and also to Sir George Cayley who, in 1810, had described the essentials of a flying machine in some detail, including a discussion of stability in flight that correctly accounted for the effects of moments due to gravity acting at the centre of mass, and the centre of pressure as it moved over the wing surface in flight. Cayley had recognized the need for movable tail-surfaces to realize control in flight.

During the century following Cayley's work, the ultimate goal of all the pioneers in aeronautics remained to find a solution for the problem of man-carrying flight. Pénaud, Lanchester, Lilienthal, Pilcher, Chanute, Langley and Manly understood the need for stability in any flying machine, but they all followed the philosophy of making the machine inherently stable so far as possible, leaving the human pilot a job of steering similar to that in a ship. The high degree of inherent stability built into the gliders of Lilienthal, Pilcher and Chanute caused these craft to respond very strongly to gusts and variations in the wind, and also prevented the pilot from exercising enough control to correct effectively for deviations in orientation due to air disturbances.

Complexity of Human Control

The actual process by which the human senses, brain, nervous system and muscles co-operate to move the body in carrying out the required continuous series of corrections in orientation (in a Lilienthal-type glider) was extremely complicated. The pilot could do an acceptable job only after (a) learning to observe required orientational corrections properly, (b) learning to give responses in the proper direction for stability, (c) becoming skilful enough to give these responses rapidly, so that deviations from equilibrium would remain acceptably small, (d) learning to establish desired equilibrium paths, (e) learning to issue internal command signals that caused proper components of the position of his centre of mass with respect to the aircraft to make the actual equilibrium path approach the command equilibrium path.

The success of Wilbur and Orville Wright in producing a practical powered man-carrying aircraft where others had failed was based not on directly visible features of their aeroplane but on a mental attitude that represented a clean break with a universally held dogma in aeronautical thinking. The brothers deliberately made their aeroplane with negative stability and depended on the human pilot to operate movable surface controls so that the flying system (consisting of pilot and machine) would be stable. In effect, the inherent abilities of human beings to observe and evaluate situations and to react swiftly with proper control motions were used to replace built-in aircraft stability. The all-important reward for requiring the pilot to provide essential functions in the stabilizing system was a great increase in manœuvrability and controllability of the aircraft as part of a flying system.

The lecturer went on to quote extensively from the writing of Wilbur Wright concerning the design philosophy behind the construction of the brothers' first powered machine. An early quotation read "The balancing of a gliding or flying machine is very simple in theory. It merely consists in causing the centre of pressure to coincide with the centre of gravity. In actual practice, there seems to be an almost boundless incompatibility of temper, which prevents their remaining peaceably together for a single instant, so that the operator, who in this case acts as a peacemaker, often suffers injury to himself while attempting to bring them together."

After discussing the control problems of the Wright machine, Wilbur described how the brothers had applied their new philosophy: "We would arrange the machine so that it would not tend to right itself. We would make it as inert as possible to the effects of change of direction or speed, and thus reduce the effects of wind gusts to a minimum. We would do this in the fore-and-aft stability by giving the aeroplanes a peculiar shape; and in the lateral balance by arching the surfaces from tip to tip, just the reverse of what our predecessors had done."

The inter-connection of the control surfaces about the roll and yaw axes on the Wright machine, the lecturer continued, made it effectively a two-control aeroplane, although in operation moments were applied about three axes. Since the time of the Wrights, it had become a fact of common experience that human pilots could co-ordinate three-axis controls, provide stability, and also cause their craft to follow accurately flight paths that they might elect to command. In clear weather, trained human pilots and normally unstable aeroplanes formed flying systems that left little to be desired in flight control performance.

When an earth geometrical reference was not available to the eyes of the pilot, however (i.e. when visual contact with the earth was lost because of night or bad weather conditions), one of the primary inputs for the pilot was lost and he became helpless as a sub-system for applying corrective actions for the aeroplane controls. This made it necessary to either provide substitute earth-reference information, or restrict flying to that under clear-weather conditions. The lecturer went on to describe the development in the U.S.A. of blind-flying instruments, from the Sperry rate-of-turn indicator of 1918.

Co-ordinated Control Systems

When the human pilot was a link in the flight-control system, the lecturer continued, he must co-ordinate his three controls when he introduced stabilizing corrections and also when he changed the orientation of his craft in causing it to follow flight commands. It was the necessity of reducing this co-ordination to the level of unconscious acts of skill that dictated the long hours of practice required to produce a qualified pilot, and even qualified pilots found it difficult or impossible to achieve satisfactorily stable flight from certain aeroplanes under some conditions of operation. Control forces might be too heavy, or the inherent instability oscillation might be too fast for the pilot's reflexes and the control-drive system to overcome. In such cases, yaw dampers, pitch dampers, stability augmentators, artificial stability systems or control co-ordinators might be employed—a realization of the pre-Wright Brothers' ideal of complete inherent stability for the aeroplane.

While control co-ordinating systems might reduce the efforts required of the human pilot in giving flight commands by means of his controls, even this duty was undesirable in that it required continuous attention. The remedy was recognized in the early days of flying to lie in the development of automatic piloting devices, to free the pilot from continuous routine operations so that he could devote his mental powers to evaluating situations and formulating decisions in both routine and emergency situations. An outline of American progress in the field of navigational auto-pilots was next given by the lecturer.

Automatic pilots of the present day, Dr. Draper continued, had adequate performance for navigational requirements when the primary objective of all aircraft operations was to land successfully at the intended destination. It was certain, however, that new performance requirements would lead to the development of flight-control equipment with radically new features. In air-to-air fighting, manoeuvres of all kinds must be realized to the ultimate performance limits of fantastically fast and powerful aircraft. It was probable that the distinction between control co-ordinating systems and auto-pilots would disappear, so that an integrated flight-control system would actually become an essential part of a flight system that included the airframe and its propulsion system.

In conclusion, the lecturer presented in graphical form the main trends in the progress of flight-control developments. In this, the variation with time of interest and activity in flight control was shown, for each of the six types of flight-control system considered in the lecture. Other illustrations included functional diagrams showing the forces, signals and other factors involved in various flight-control systems.