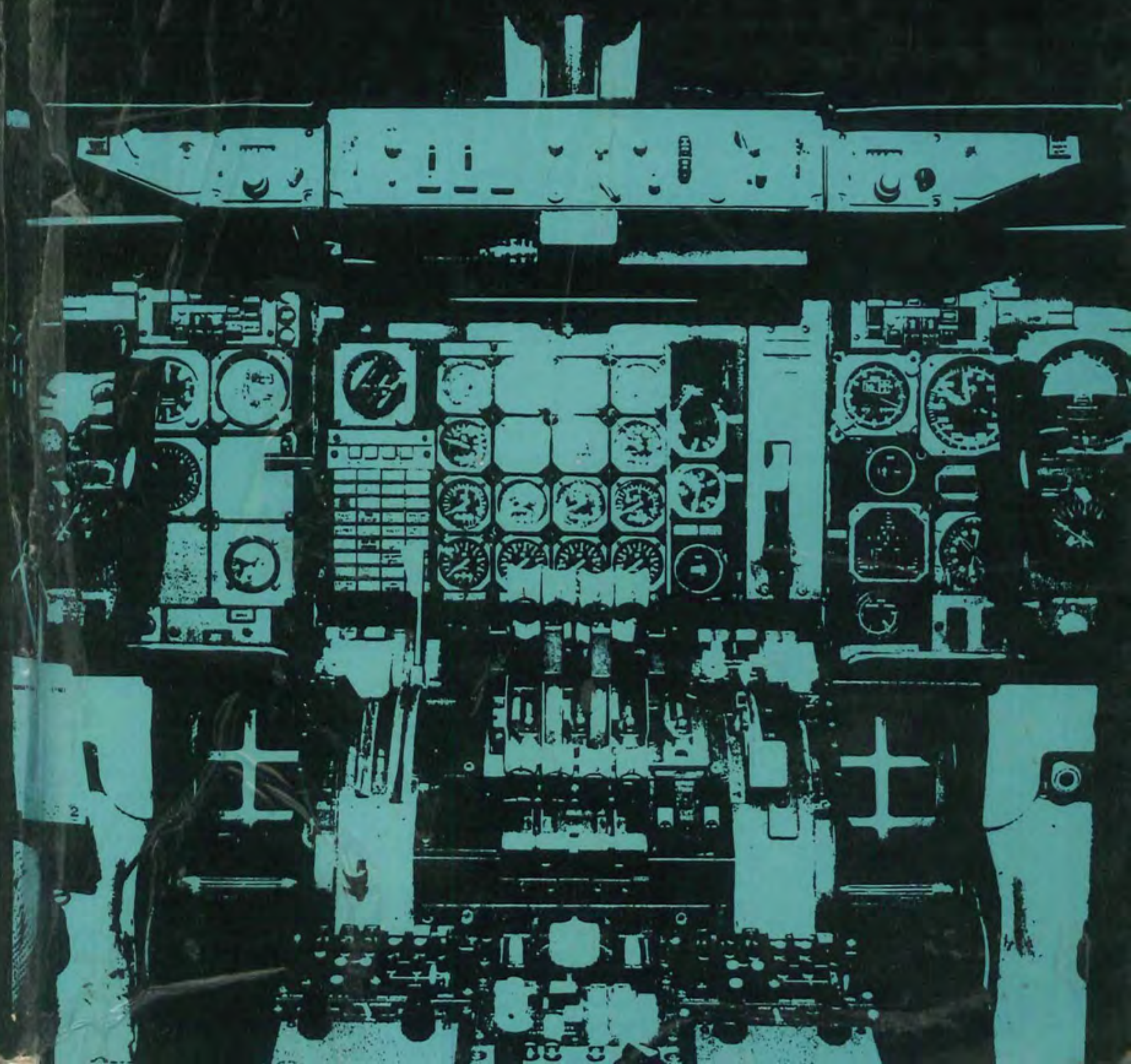
E. H. J. PALLETT

AUTOMATIC FLIGHT CONTROL



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Preface

At the present time there is hardly an aircraft in either civil or military operation without some form of automatic flight control system comprising part of its standard operational equipment. The systems available are as diverse as the aircraft themselves, varying from a simple roll stabiliser or 'wing-leveller' in a single-engined private aircraft, to the sophisticated flight-guidance systems capable of automatically controlling the flight paths of large transport aircraft from take-off to touchdown and roll-out. It is then a little difficult perhaps to realise that the development of such systems has arisen from foundations laid years before man himself took to the air to become the controller of his own 'flight path destiny'.

The early inventors of 'heavier-than-air flying machines' were, of course, faced with many problems, the most prominant of which was the one associated with the attainment of stabilised flight. Although there was an awareness that stability should be inherent in the basic design of a machine, little was known of the separation of stability into dynamic and static elements in relation to the various degrees of freedom possessed by a machine. As a result, and as recorded history indicates, efforts were directed more towards keeping a machine straight and level and free from the effects of external disturbances, and to derive the requisite stability by applying some form of artificial stabilising device.

It is of interest to note that possibly the first machine to use such a device was an unmanned glider designed by the Frenchman Charles Renard in 1873. The device consisted of a transverse pendulum coupled to two 'steering wings', the idea being that if the machine turned from its intended flight path, the pendulum would raise one wing and lower the other, and thereby straighten the machine's path. The first flight test indicated that such a device could work, but that lateral instability would have to be much less than that exhibited by

Renard's machine to be really successful! Apart from the pendulum, the stabilising properties of a gyroscope were also considered, and a noteworthy 'first' in this connection was the stabiliser patented in 1891 by Sir Hiram Maxim and installed in his steam-powered machine. The design concept was somewhat ahead of its time in that it also comprised a servo control loop and other features which are basic to today's automatic flight control systems. Maxim's flying machine unfortunately, came to an untimely end before the stabiliser could be tested under 'live' conditions.

When later pioneers took up the challenge of designing machines in which they themselves ventured to fly, the possibility of manoeuvring their machines away from straight and level flight was realised. However, this was to present another problem; namely, how to cater for the changes in stability which would result when control for initiating a manoeuvre was applied. Thus, 'controllability' was to become an important feature of flying machine design, and one which the Wright brothers were to incorporate in the machine which gained for them the distinction of making that historic flight in 1903. The Wrights' approach to aerodynamic and in-flight problems was more advanced than that of their predecessors, and although the machines built and flown by them were not completely stable, the incorporation of the controllability feature permitted a number of successful flights to be made without artificial stabilisation.

The introduction of control systems by the Wright brothers and subsequent pioneers in their aeroplanes (as they were becoming known) was to establish an additional role for stabilisation devices to play because, if a device could be coupled to the controls, then it alone could correct any departure from a stabilised condition. This was not to go unchallenged of course, and the first practical demonstration of a coupled gyroscopic two-axis control device was given by Lawrence Sperry during his historic flight in Paris in 1914. Thus, it can be said that the foundation for automatically-controlled flight was laid in the early years of this century. By the mid-twenties and in the 'thirties', the development of systems in the United States, the United Kingdom and Europe, became a separate field of engineering technology, and a number of 'automatic pilots' and 'gyropilots' demonstrated their capabilities in commercial and military aircraft operations, and in several historic long-distance record flights. As the technology has continued to develop, system designs have been influenced not only by the advances made in aerodynamics and aircraft controllability characteristics, but also by the advances taking place in other technological fields. For example, the changeover from pneumatic operation of gyroscopes to electrical operation; the processing of control signals by electron tubes and magnetic amplifiers; the introduction of the semi-conductor, and perhaps the greatest influence of all at this moment in time, the vast potential of digital processing technology.

The diversity of present-day automatic flight control systems arises principally because they need tailoring to suit the aerodynamic and flight handling characteristics of individual types of aircraft. It is possible to compromise, and by virtue of this, many of the systems installed in aircraft designed for operation in the general aviation sector are, in fact, highly versatile in their applications; however, there are limitations particularly where the more complex types of transport aircraft are concerned. Thus, any attempts at describing the range of systems and their operating fundamentals would be a mammoth task involving the writing of several volumes. However, any one automatic flight control system may be considered as being composed of four principal elements, which although differing in design and construction, perform functions common to all other control systems. The element functions concerned are progressively: attitude sensing, error signal sensing, signal processing, and conversion of processed signals into powered control, and they set a convenient pattern for a general study of control fundamentals. The material for this book has, therefore, been structured accordingly, and it is hoped that the selected examples of devices performing such functions, will usefully illustrate how relevant principles are applied.

A basic understanding of the principles of flight and aircraft stability, and of servomechanisms, is a pre-requisite to a study of the main subject and they are therefore covered in the opening chapters. With the development of flight director systems and of the concept of integrating basic attitude and navigational data, it became logical to share data and servomechanism links such that a director system could provide guidance commands to an automatic flight control system. Thus, manufacturers develop and make available a wide range of complementary systems, the basic principles of which have also been included in this book. The concluding chapter deals with what may be termed the ultimate in automatic flight control evolution, namely automatic landing.

In preparing the material on systems, I have been greatly assisted by data and illustrations supplied by manufacturers, and would in particular, like to express grateful thanks to Collins Radio Company of England Ltd, Smith's Industries, Marconi Avionics Ltd, and Sperry Rand Ltd, for their permission to use certain of the data, and to have photographs reproduced. My thanks are also extended to friends and colleagues for useful suggestions, comments and assistance in proof reading, and finally to the publisher's editoral staff for their patience.

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