Cambridge University Press
978-0-521-65722-8 - Introduction to Aircraft Design
John P. Fielding
Excerpt
More information

1

Introduction

1.1 Why another aircraft design book?

Aircraft design is a complex and fascinating business and many books have been written about it. The very complexity and dynamic nature of the subject means that no one book can do it justice.

This book, therefore, will primarily act as an introduction to the whole field of aircraft design leading towards the subjects summarized in Fig. 1.1. It will not attempt to duplicate material found in existing design books, but will give information about the whole aircraft design environment together with descriptions of aircraft and component design. It also presents otherwise unpublished data and design methods that are suitable for aircraft conceptual, preliminary and detail design activities.

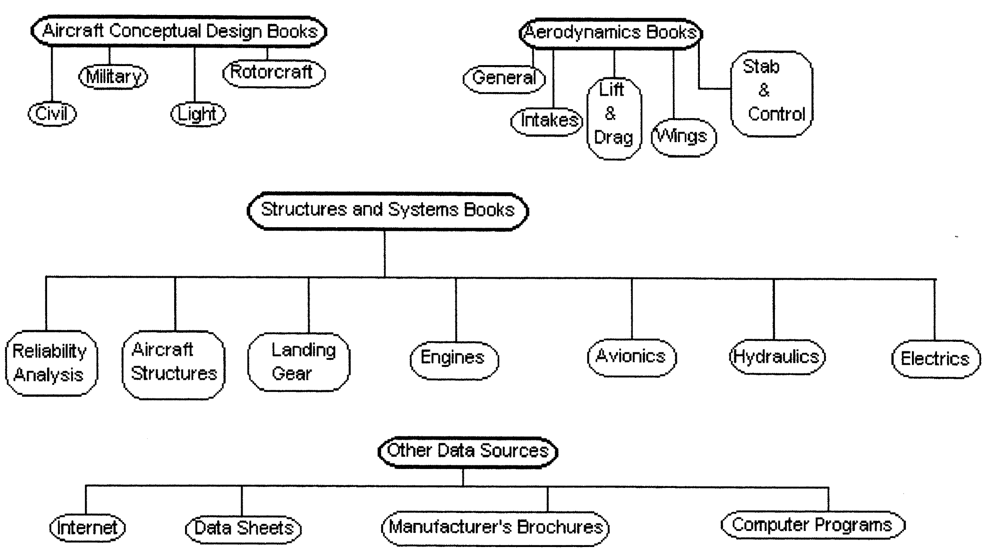

Fig. 1.1 Aircraft design data sources.

1.2 Topics

The following chapters are arranged as a series of questions about aircraft design, the answers to which give largely descriptive overviews of all aspects of aircraft design. This will provide an introduction into the conflicting requirements of aircraft design specialists in a design team, with a view to improving understanding, and the integration of a sound overall design.

The book is divided into chapters which answer a number of significant design questions.

The question 'why design a new aircraft?' is answered in Chapter 2 which shows the derivation of aircraft requirements for civil and military aircraft from market surveys, and gives examples of operator-derived specifications.

Chapters 3 and 4 answer the question 'why is it that shape?' with an initial discussion of aircraft wing and tail shapes, followed by descriptions of the configurations of a wide range of civil and military aircraft types.

The question 'what's under the skin?' is answered in Chapters 5, 6 and 7, which deal with structures and propulsion, airframe systems, avionics, flight controls and weapons, respectively. These chapters describe the interiors of aircraft, ranging from structures to weapon systems via airframe systems, avionic systems and landing gears.

In Chapter 8 the crucial areas of acquisition and operating costs are discussed and some prediction methods are described and the importance of good reliability and maintainability are stressed in order to answer the question, 'why do aircraft cost so much.'

The answer to the question 'what help can I get?' is provided in Chapter 9 which contains a bibliography of the most important current aircraft design books. It is followed by a description of some of the computer design analysis and computer-aided design (CAD) tools that are available. A summary of relevant data sheets is also given.

Chapter 10 draws together the information produced at the end of the conceptual stage and leads on to the preliminary and detail design stages in order to explain 'what happens next'. The question 'what can go wrong' is answered in Chapter 11 in which many unsuccessful or partially successful projects are examined and conclusions drawn from them.

The aircraft designer is bedeviled by lack of design data. Appendix A pulls together information that is not generally available, and includes simple aerodynamic and structural design formulae. It also provides a US/British translation list for aeronautical terms.

Appendix B presents a parametric study design example which describes the author's parametric study of a 500-seat transport aircraft. Appendix C considers reliability and maintainability targets by discussing targets for civil and military aircraft and describing a method to be used for the prediction of dispatch reliability.

1.3 The design process

There are a number of generally accepted stages in the design, development, manufacture and operation of aircraft, each with associated design methods and data requirements. These are shown schematically in Fig. 1.2, which also shows how the modern practice of concurrent engineering has reduced the overall timescale from conception to service.

Figure 1.3 gives some idea of how a designer's prejudice may affect his or her design to the detriment of others. It is an exaggeration, but not much of an exaggeration!!

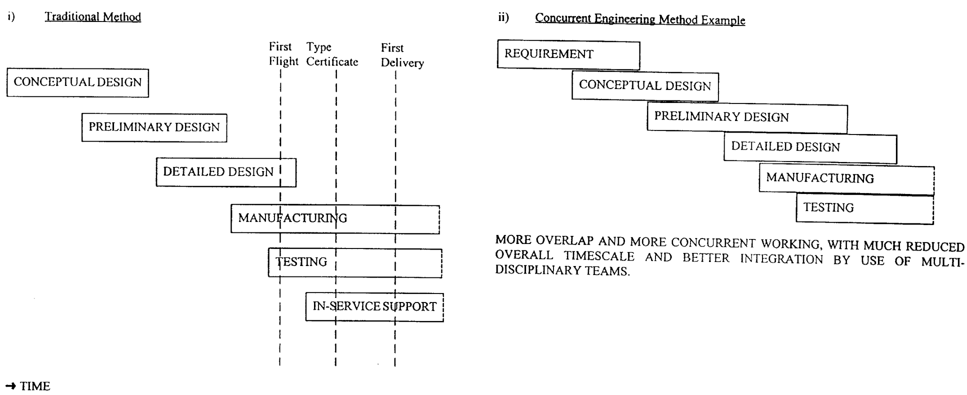

Fig. 1.2 Comparison of traditional and concurrent design approaches.

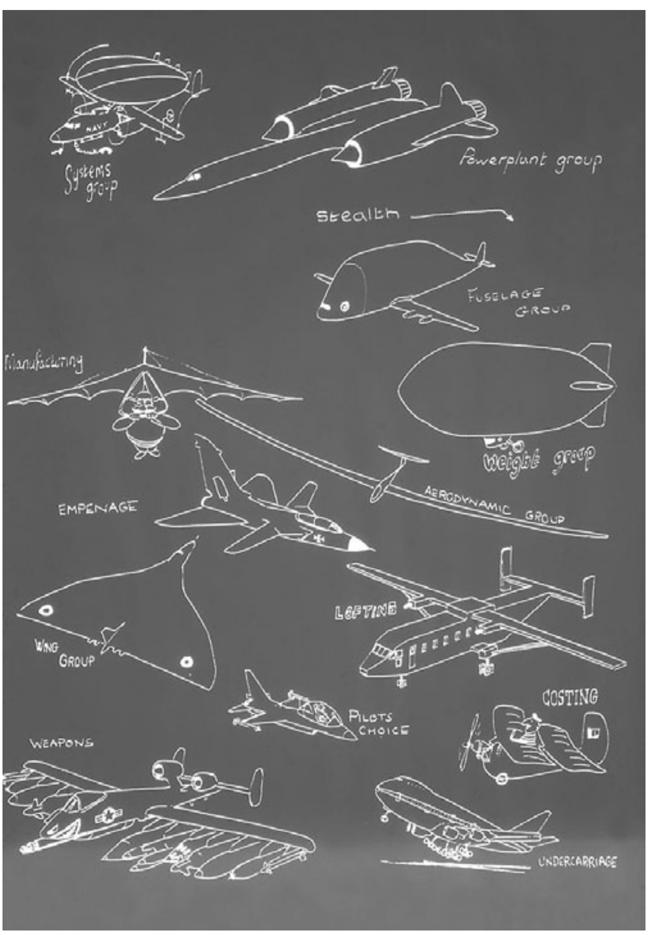

Fig. 1.3 Different specialist's views of an ideal aircraft.

Cambridge University Press
978-0-521-65722-8 - Introduction to Aircraft Design
John P. Fielding
Excerpt
More information

The most crucial stage of any design process is to arrive at the correct set of requirements for the aircraft. These are summarized in design specifications for the particular aircraft type. Typical examples of design specifications are shown in Chapter 2. They are augmented by a large number of airworthiness requirements for civil aircraft or Defence Standards for military aircraft. These are distillations of decades of successful (and unsuccessful!) design, manufacturing and operational experience. Fig. 1.4, adapted from Haberland *et al.* [1], shows a very helpful illustration of what may happen after the issue of the design specifications, and illustrates the iterative design process that is not apparent in the simplified illustration in Fig. 1.2.

A converging iterative spiral of design stages, ending in the detail design, and ultimately manufacture and operation of the aircraft can be seen in Fig. 1.4.

It is a truism that 99% of the decisions which affect aircraft success are made on 1% of the facts available during the conceptual design phase. Very coarse methods have to be used which are then refined by progressively more accurate methods as the design evolves. This is true if the spiral is convergent, but there are occasions where the spiral is divergent and the design must be abandoned, and started again, unless significant modifications are made to the design.

Figure 1.5 shows the author's usual design procedure for conceptual design and the start of preliminary design process.

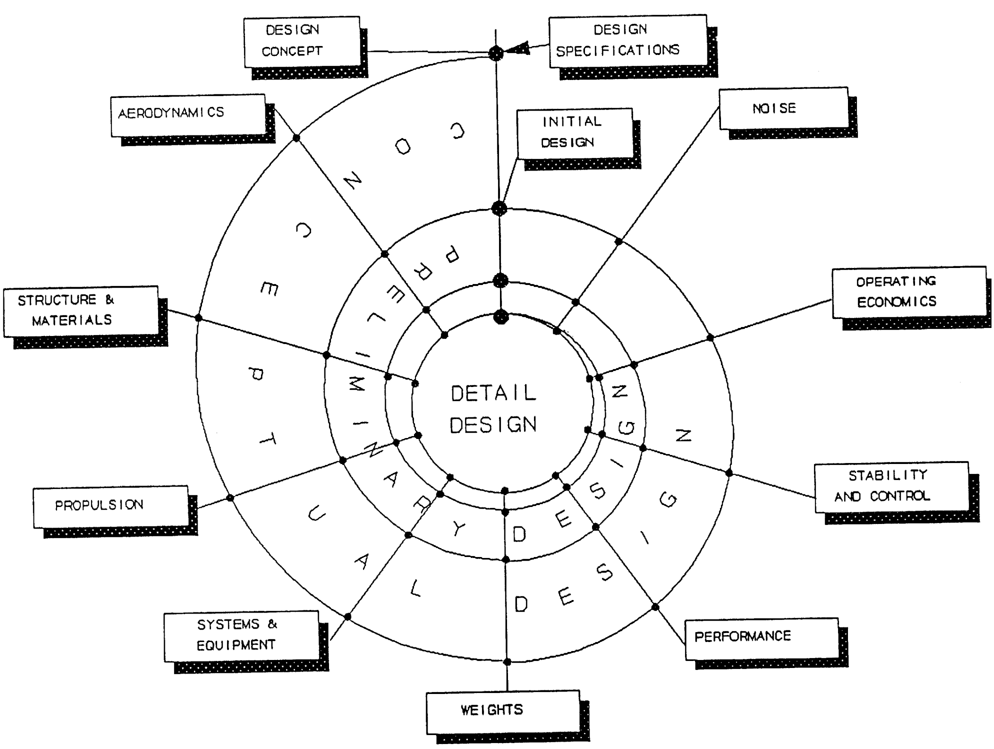

Fig. 1.4 The design spiral.

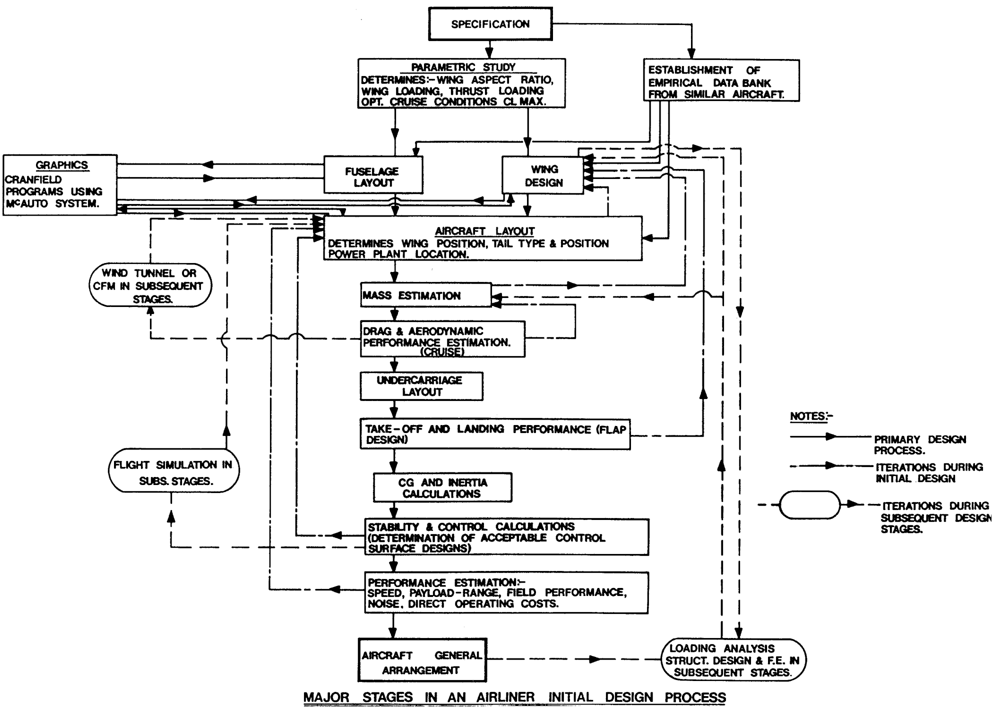

Fig. 1.5 Major stages in an airliner initial design process.

Cambridge University Press
978-0-521-65722-8 - Introduction to Aircraft Design
John P. Fielding
Excerpt
More information

2

Why should we design a new aircraft?

The world has accepted that flying is an extremely efficient means of quickly transporting people, cargo or equipment, and performing a wide range of other activities. All operators need to increase efficiency, cost-effectiveness, environmental compatibility and safety. It is often possible to do this by modifying either the design or operation of existing aircraft. This is limited, however, by the inherent capabilities of the original design and the cost-effectiveness of modifications. Under these circumstances, it is necessary to consider the initiation of the design of a new aircraft. Aircraft manufacturers are usually in the business of making profit out of building aircraft. They may do this by means of building their own existing designs, modifying their designs or licence-building the designs of other companies. Another reason for the initiation of new designs is to retain or enhance their design capabilities.

Requirements and aircraft specifications come from a number of different sources, but they must all consider the needs of the aircraft operators, whether they are airlines or air forces. A certain path to disaster is to produce an aircraft that no one will buy!

Descriptions will be given of the two main means of deriving a requirement specification, namely the results of market surveys and individual aircraft operators' specifications.

2.1 Market surveys

The major aircraft manufacturers employ marketing departments which produce annual reports [2]. Historical data are analysed and extrapolated in such areas as world economic indicators. Figure 2.1 shows gross domestic product (GDP) and highlights the recent recessions. Figure 2.2 shows the close correlation between GDP and the world air travel growth in revenue passenger miles (RPM).

Further work led to predictions of world capacity requirements in terms of available seat miles (ASM) (Fig. 2.3) and numbers of passenger seats in various aircraft size categories (Fig. 2.4). Table 2.1 shows the results of the author's summary of the market surveys which led to the specification for the aircraft design described [5]. (Appendix B shows the initial stages of the design process of the aircraft.)

Having determined the projected market for aircraft, the next stage was to examine existing and proposed competitors in that market. Figure 2.5 shows a very simple but effective illustration of current and projected jet transport competitors. More details of these aircraft are gathered and analysed to show strengths and weaknesses. Some useful means of

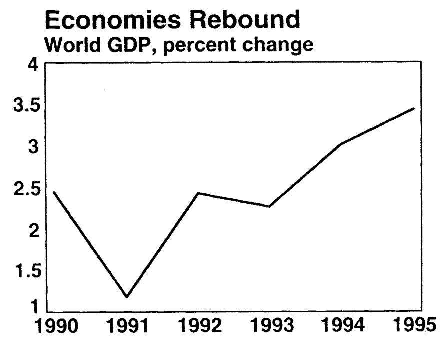

Fig. 2.1 Recent changes in world gross domestic product (GDP), 1996.

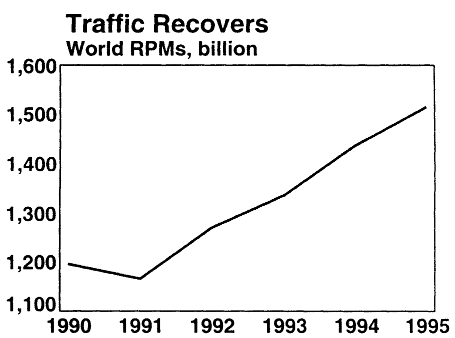

Fig. 2.2 Recent changes in world revenue passenger miles (RPM), 1996.

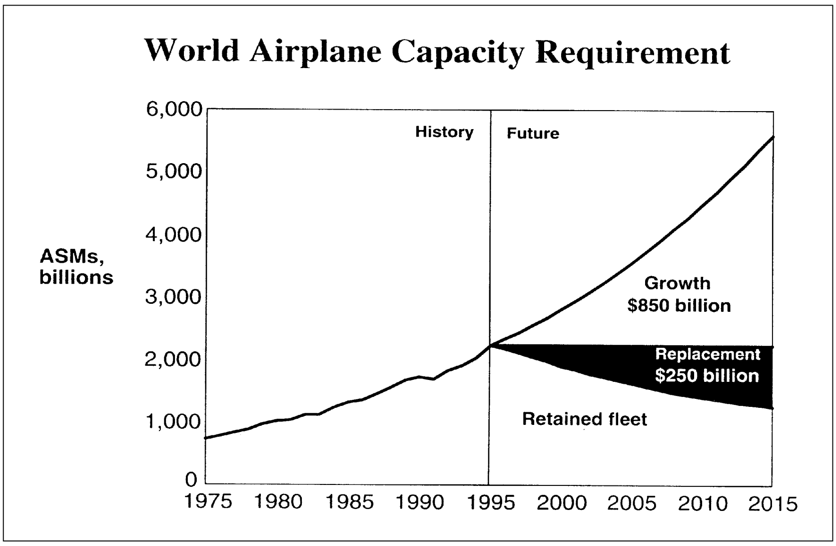

Fig. 2.3 Commercial aircraft capacity requirement in available seat miles (ASM), 1996. Values of growth and replacement in 1995 US dollars.

Table 2.1 *Summary of future requirements for airliners*

Parameter	Boeing [2]	Airbus (1) [3]	Airbus (2) [4]
Projected date	2005	2008	2005
Projected fleet	9935	11136	7840
Percentage of 240–350 passengers	14	28	–
Percentage of 250 + passengers	39	45	54
Long range 240 + passengers	25%	–	14%
Percentage of < 130 Seats	8%	14%	–

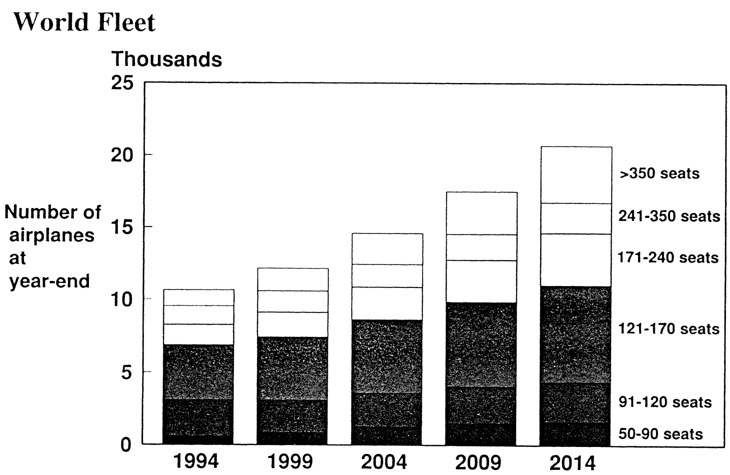

Fig. 2.4 Projected world fleet, 1996. (Excludes Confederation of Independent States and Baltic republics.)

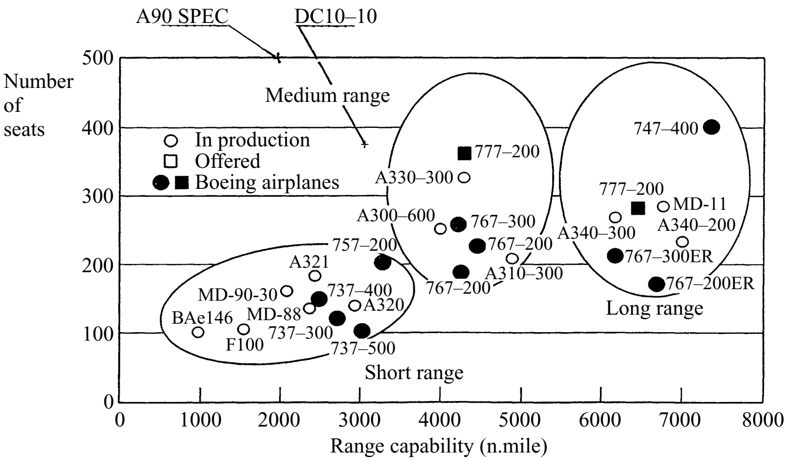

Fig. 2.5 Airliner seat/range capabilities, 1996.

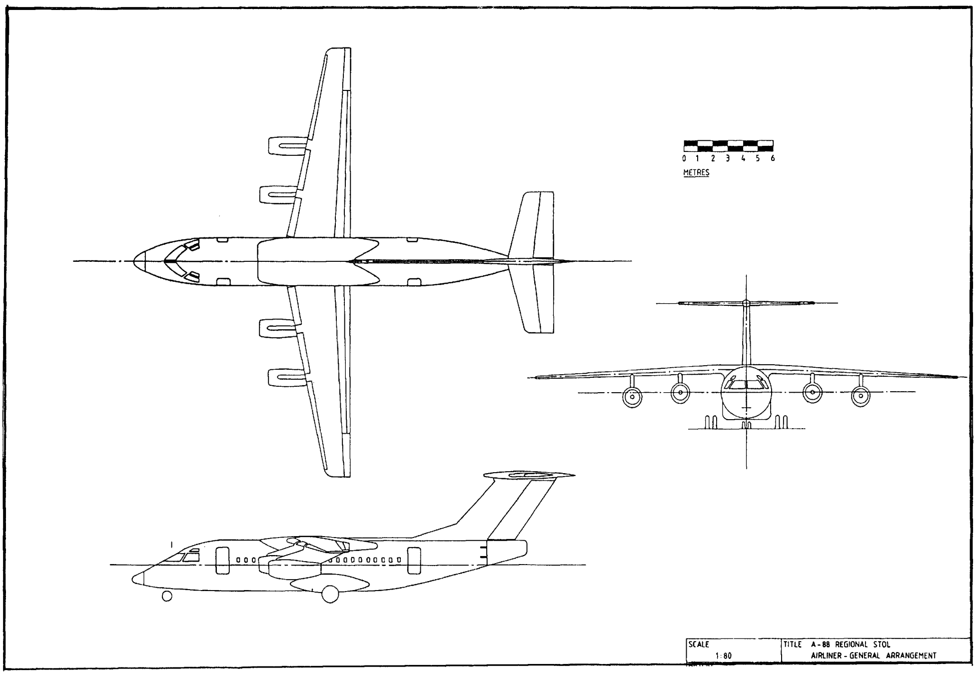

Fig. 2.6 Cranfield regional jet general arrangement drawing, 1988.

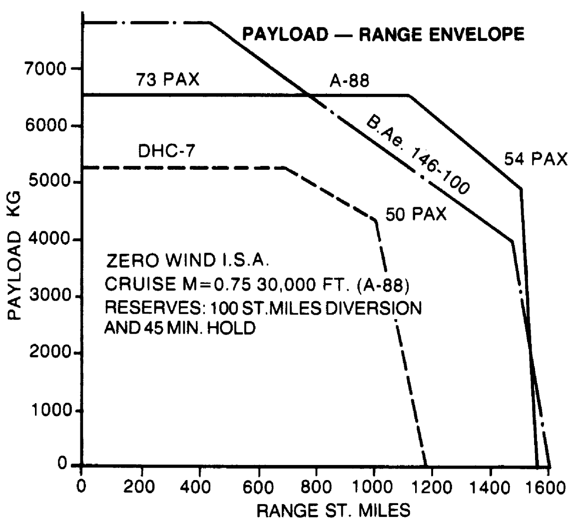

Fig. 2.7 Regional aircraft payload–range envelopes.

comparison are the tables of aircraft major characteristics, as shown in Appendix A, as part of what might be the rather grandly named 'empirical database'. This sort of data is an obvious candidate for computerization. An annual publication is the major source of the information required for such tables [6], but it may be augmented by information from