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Introduction

This book is written from the point of view of whole fixed-wing aircraft design. The information herein is primarily of value in the preliminary design phase of an aircraft and in particular to the engineers involved in the design and integration of the electrical and mechanical, or airframe systems. Whether the reader is studying aerospace engineering at undergraduate or postgraduate level, or is an industry practitioner, the book contains valuable guidance and insights.

This volume is intended as a successor to *Aircraft Systems: Mechanical, Electrical and Avionics Subsystems Integration*, Third Edition, which was published in 2008. At that time, the last major airliners to enter into service, the Airbus A350 (2015) and the Boeing 787 (2011), were being designed. These aircraft have been very successful, with the number built approaching 2000 as of 2025. The incorporation of new systems technologies has enabled more electrical systems and improved operating efficiency and maintainability. These more-electric aircraft systems are covered in this book, together with more conventional systems using hydraulics and pneumatics. Although this is not a recent development, the vast majority of aircraft in service feature such systems architectures, notably the Boeing 737 and Airbus A320 series, which will be in production for at least another decade and in service beyond 2050.

There is an ever-increasing focus on the environmental impact of air transport. As such, there are many research and development projects investigating alternative energy carriers to kerosene for the generation of propulsive power. These include so-called sustainable aviation fuels (SAFs) and battery electric, hydrogen and hybrid (battery plus kerosene or SAF or hydrogen) systems as energy carriers. The foreseeable energy density of battery electric systems limits applications for propulsive power to small and short-range aircraft.

Hydrogen in cryogenic liquid form for aerospace use is presently at a very low technology readiness level, and the safety case is yet to be fully established. However, if these significant challenges can be overcome, it would offer a path towards a de-carbonized air transport industry. Hydrogen can be used either in a fuel cell or in a gas turbine–based propulsion system, and the former brings enormous thermal management challenges for a potential gain in efficiency. Such a transformation will have significant implications for the airframe systems, particularly the fuel and aircraft thermal management systems.

Aircraft Systems: A Design and Development Guide, First Edition. Craig Lawson and David Judt.

In contrast to hydrogen, SAF has very similar properties to kerosene, and as such, the impact of its adoption on the aircraft and systems is minimal. Indeed, current in-service aircraft have already been demonstrated to operate with blends of SAF and kerosene with relatively modest aircraft engineering changes. However, SAF has significant off-aircraft challenges associated with its cost-effective production and scalability as a biofuel.

1.1 Which Are the Airframe Systems?

This book covers the major airframe systems. It defines their roles and explains what drives their designs. It is useful to begin by identifying the major airframe systems. These systems can be divided into the following two useful categories:

- Power Generation, Regulation and Distribution Systems
  - Secondary Power Systems
  - Pneumatic Systems
  - Hydraulic Systems
  - Electrical Systems
- Power User Systems
  - Flight Control Actuation Systems
  - Aircraft Ice Protection Systems
  - Aircraft Environmental Control Systems
  - Aircraft Fuel Systems

It should be noted that, in some of these power user systems, the terms are very broad, themselves containing several discrete systems that are best considered individually. However, these definitions are a useful starting point, from which the details should become clearer throughout this book.

1.2 Aircraft Systems Design Processes and Aircraft-Level Considerations

Before embarking on the design of complex, integrated and safety critical systems such as those on aircraft, it is vital to consider the processes that should be followed to achieve a successful design. The analysis of system safety is carried out in parallel with the development of the systems. Industry standards for phases and processes are carried out following the 'v' model (see Chapter 2) including conducting fault and failure analysis and establishing their consequences to aircraft safety.

1.3 Systems Integration

Modern aircraft systems are highly integrated with each other. Multiple functions are often fulfilled by subsystems that cut across traditional systems boundaries. Although each chapter in this textbook is focused on a particular major system, it is worth noting upfront that these interactions are of great importance, and they must be identified and recorded as part of the design process.

Integration may first be viewed at a functional level. For example, a fuel tank may have the primary function to store fuel so that it can be fed to the engines for propulsion. It may have a secondary function to store fuel to control the centre of gravity of the aircraft, typical on wide-bodied airliners where there is often a trim tank in the horizontal tailplane, and on supersonic aircraft that experience large changes in centre of lift during the full flight envelope. The fuel tank may have a tertiary function to act as a heat sink for the hydraulic system, such as on the B737.

As such, the fuel system in this case is intrinsically linked with the hydraulic system for thermal management and flight management systems for centre-of-gravity control.

The hardware available to provide functions and their interactions with each other can be considered early in the systems design process, when the overall aircraft and systems concept is being established. An example of such an aircraft-level architecture is shown in Figure 1.1, where interrelations through different mediums, such as electrical power and heat, are shown. With subsystems models, an optimisation can be performed to suggest the most efficient overall systems architecture for best aircraft performance.

Once the architecture is established, a formal approach to design safe systems is followed using SAE ARP 4754B and SAE 4761A in tandem (see Chapter 2). This leads to a certifiable arrangement of system power provision consistent with the required loads. Figure 1.2 illustrates a preliminary design aircraft-level layout for a more-electric twin-engine airliner. Various sources of electrical power and major loads are shown.

The physical integration of the systems within the airframe should also be investigated at this relatively early stage. The volume available and the accounting of systems in the aircraft mass and centre-of-gravity analysis will thus be achieved. The value of a computer-aided design (CAD) model to highlight interference issues cannot be overstated. An example of the system sizing and integration after the preliminary design phase is illustrated in Figure 1.3. In this aircraft design, the fuel tanks are kept inboard of where the wing folds to achieve a high aspect ratio while still fitting at a single-aisle airliner airport gate. This look at physical integration is an essential enabler to zonal safety assessment.

As aircraft become more complex and more highly integrated, synergies can be sought to achieve better aircraft-level performance. An example of this is integrated thermal management, where heat is transported from where it needs to be rejected to where it needs to be supplied, cutting across traditional system boundaries. Additionally, disparate systems that require cooling,

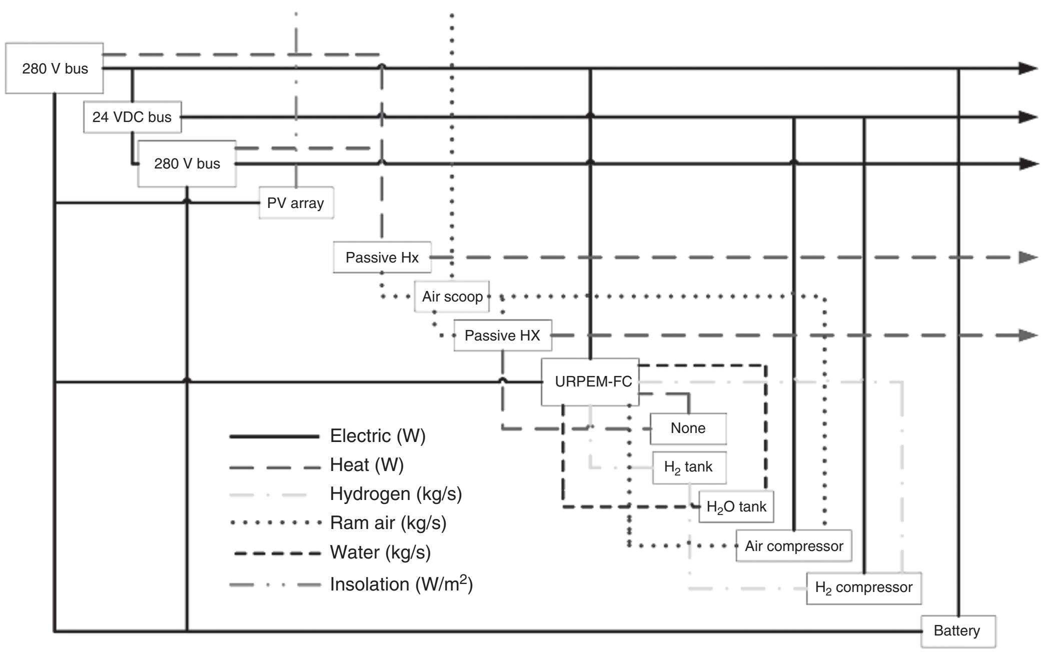

Figure 1.1 Aircraft systems concept showing technologies and interactions HX: heat exchanger, PV: photovoltaic, URPEM-FC: unitised regenerative proton electron membrane fuel cell

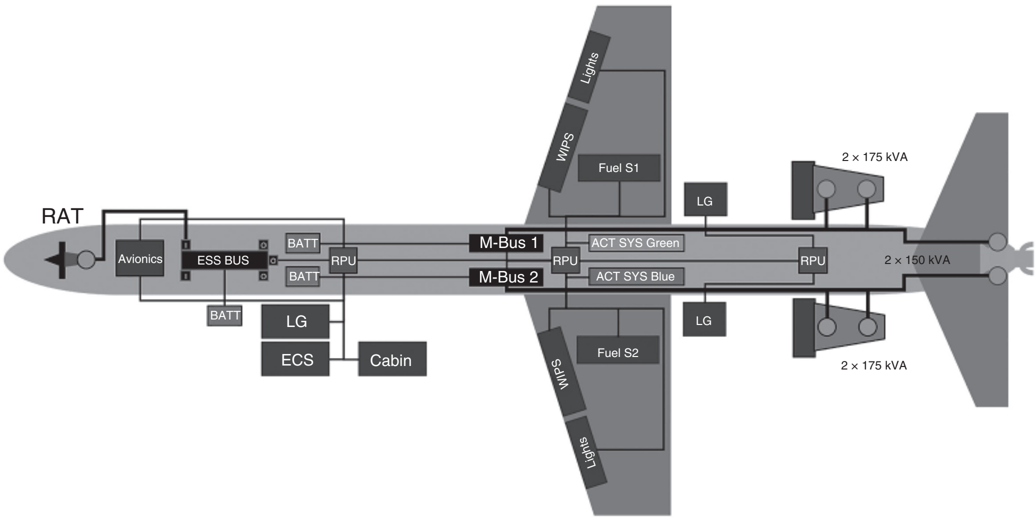

Figure 1.2 More-electric secondary power systems aircraft overall preliminary architecture showing generation distribution and major loads ACT SYS: actuation system, ECS: environmental control system, ESS: essential, LG: landing gear, RPU: remote power unit, WIPS: wing ice protection system

Figure 1.3 Cranfield University A-17 Zephyr semi-wide-body, high-aspect-ratio-wing airliner

such as power electronics and the galleys, can be integrated into a single cooling system. An aircraft-level heat load analysis, such as that depicted in Figure 1.4, is a good starting point for such considerations.

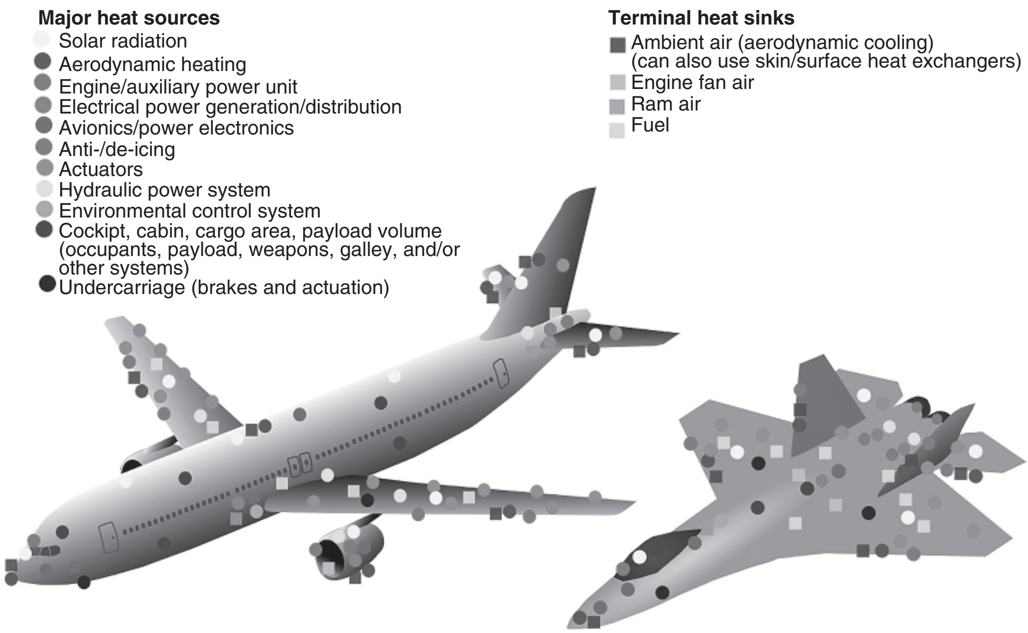

Figure 1.4 Locations of the main aircraft heat sources and sinks

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