1

INTRODUCTION

Aircrew have very heavy workloads when operating modern aircraft. They must prioritise their time. During training, pilots are taught to:

> *"Aviate, navigate, communicate, administrate...in that order!"*

The message is clear. Good navigation and communication is of little consequence if poor "aviating" (flying) causes the aircraft to crash. Avionics systems are designed to help aircrew to do their job and to relieve some of the time pressures placed on them.

Avionics systems are therefore critical elements of modern aircraft. The term "avionics" comes from the concatenation of the first part of aviation and the last part of electronics. Avionics systems therefore include all aircraft systems that require electrical power. Like all complex systems, we must understand and appreciate the entire aircraft system to some extent before turning our attention to the avionics system. This chapter starts by describing the typical functionality and performance required of modern military and civilian aircraft. The chapter then introduces the reader to the many systems that deliver that functionality and performance on board modern aircraft, and the final sections define some of the technical terms for aircraft systems and components.

1.1 AIRCRAFT FUNCTIONALITY

It is worth starting our discussions by focussing on what functionality aircraft must have in order to perform their primary roles. Civilian aircraft are designed and built to transport people and goods from point A to point B in the most efficient manner. Points A and B might be hundreds or thousands of kilometres apart. Military aircraft are designed with specific roles in mind. Strike aircraft are designed to carry weapons from point A and drop them accurately on point B at a predetermined time. In short, strike aircraft aim to achieve "bombs on target, on time". Surveillance aircraft aim to monitor and record information about either the earth or entities on the earth. This information might be photographic (or some other optical recording) but surveillance might also include the surveillance of electronic signals such as radar and communications. This type of surveillance is a part of the broader *electronic warfare* (EW) effort and is called *electronic support* (ES). Fighter aircraft are responsible for the detection, engagement, and destruction of enemy aircraft. Fighter aircraft aim to gain *air superiority* to allow friendly ground and maritime forces to conduct operations without the threat of attack from the air. Military aircraft also conduct support operations in the form of *air lift* which is not dissimilar to the role of civilian cargo aircraft but takes place in a potentially hostile environment.

Regardless of their specific roles, aircraft need to be capable of a range of functions, as described in the following sections.

1.1.1 Situational Awareness

Situational awareness involves aircrew being acutely aware of their aircraft, its systems, and its surroundings. For military aircraft, for example, depending on the specific role of the aircraft, the surroundings might involve a very complex tactical environment full of “sensors” and “shooters”, and might span hundreds of kilometres. Maintaining situational awareness can be difficult in very busy situations such as air combat or arriving at a very congested international airport. Avionics systems aim to relieve some load from the aircrew in this regard and present relevant and timely information to the aircrew.

Being able to sense the environment becomes critical to maintaining situational awareness. Aircraft are normally equipped with both passive and active sensors to sense the aircraft itself, the terrain near the aircraft, the surrounding atmosphere, approaching weather, and potential targets. Active sensors include systems like radar and lasers that rely on the transmission and reception of electromagnetic energy. Passive sensors are designed to receive information only and do not transmit. Passive sensors include air-data sensors, inertial sensors (accelerometers and gyroscopes), and EW receivers.

1.1.2 Control

Control refers to the ability to operate the aircraft safely and control its movements. Traditionally, control of aircraft has come down to the design of very stable and predictable airframes so that the pilot can control the aircraft without having to overcome inherent instability.

More recently, attributes like aircraft agility and stealth have driven unusual aircraft shapes leading to inherent aerodynamic instability. Some aircraft are so unstable that humans are unable to respond quickly enough to dampen the instability. Modern flight-control systems, comprising fast and accurate digital computers coupled with very accurate sensors, are used in these aircraft to provide very fine and rapid adjustments to flight-control surfaces. This process is called *stability augmentation* and provides the pilot with a controllable aircraft.

Auto-pilot systems are also associated with the flight-control systems and relieve the pilot of some of the more mundane flying tasks such as maintaining a constant speed, heading, or altitude.

1.1.3 Navigation

Aircrew must know where their aircraft is and where it is going. This usually involves knowing where they have come from. It also involves an accurate awareness of time. Air navigation is often referred to as a four-dimensional (4D) problem involving latitude, longitude, altitude, and time. 4D navigation is critical whether for a civilian airliner trying to meet schedules in the face of delays and headwinds, or a military aircraft aiming to strike a target at a particular time.

It is important to remember that navigation is a bigger problem for aircraft than for, say, cars on the road. For a start, there are only a finite number of destinations possible in a car on a given road and we always have the option to stop the car and check a map. An aircraft can go pretty much in any direction and the pilot can’t pullover and check a map. Secondly, a car travels fairly slowly so the problem gets worse slowly. By contrast, the aircraft travels very quickly so the problem gets worse very quickly. This prompted test pilot Paul F. Crickmore to say: *"You've never been lost until you've been lost at Mach 3."*

Avionics systems help to ease the navigation problem. A modern aircraft has sensors, computers, and access to external systems that are capable of determining the aircraft's position to within very fine tolerances. Using external systems such as the *Global Positioning System* (GPS), the aircraft also has access to extremely accurate (atomic) clocks. The aircraft systems use a variety of self-contained and external navigation systems to ensure some redundancy in the calculation of position. These navigation systems alone have removed a huge responsibility from the aircrew. It is worth remembering that during World War II (barely 60 years ago), Allied aircraft returning from bombing raids over Europe could become so badly lost that they missed England completely and ended up crashing in the Atlantic when their fuel ran out.

1.1.4 Communication

The need to communicate when operating an aircraft is obvious but we need to understand the types of communication required. Communication suites are part of an aircraft's avionics system and can facilitate voice and data communication. Voice communication is required between the aircrew and this is provided by an *intercommunication system* (ICS), or intercom. Aircrew also need to communicate with people on the ground or in other aircraft and this is achieved using a series of radios operating at HF, VHF, or UHF frequencies. Some aircraft also need to be able to send and receive data as well as voice. For example, modern airliners allow passengers to use the Internet and send and receive email whilst in flight. Military aircraft often send targeting and status data to and from other aircraft and ground forces. In military settings, communication systems may employ encryption to guard against eavesdropping.

1.1.5 Survivability

Survivability refers to the need to build aircraft and aircraft systems that can handle failures and malfunctions during flight. Avionics systems are designed around varying levels of redundancy so that a number of failures can occur during a single flight without the aircraft losing essential functionality. Most aircraft incidents are now caused by human error rather than equipment malfunction. World-wide airworthiness regulations mandate extremely high levels of reliability from modern aircraft. For example, both civilian and military authorities require the probability of failure of safety-critical avionics systems to be much smaller than a million to one.

1.2 AIRCRAFT SYSTEMS

We know that the avionics system is only one system on-board an aircraft. Others include airframes, engines, flight-controls, fuel systems, hydraulic systems, pneumatic systems, environmental control systems, and life-support systems.

1.2.1 Airframes

The aircraft airframe is the physical structure of the aircraft including the fuselage, wings and undercarriage. From an avionics perspective, the airframe is like a skeleton. Airframe design is driven by the role of the aircraft. Some aircraft are designed to be very fast, light, and agile whereas others are built to be very large and capable of lifting heavy loads.

1.2.2 Engines

Engines are the primary source of power in aircraft and provide the aircraft with the propulsion necessary to move the aircraft along the ground and in flight. We refer to the aircraft engines sometimes as the primary power source (or prime mover) to differentiate them from the secondary forms of power such as hydraulics, pneumatics, and electrical systems. The secondary power systems usually convert mechanical power from the primary power source (engines) into hydraulic pressure, pneumatic pressure, and electrical power.

Engines are complex systems in their own right and can have a range of support systems associated with them including engine-control systems, and engine health monitoring systems.

1.2.3 Flight-controls

The term *flight-controls* can refer to the pilot's controls in the cockpit used to manoeuvre the aircraft. The term also applies to the physical structures on the airframe used to control the aircraft and "steer" it as it flies. In the latter context, flight-controls are categorised into two categories; *primary flight-controls*, and *secondary flight-controls*. Primary flight-controls are used to control the aircraft in roll, pitch, and yaw and include the following components:

- *Ailerons* are usually positioned on the outboard, trailing edges of the wings. Ailerons control the roll of the aircraft and are moved by the pilot moving the joystick or control column from side to side.
- *Elevators* are positioned on the trailing edges of the horizontal stabiliser or tail of the aircraft and control the pitch of the aircraft. In some aircraft, the whole horizontal stabiliser may move. The pilot controls the elevators by moving the stick forwards (to pitch down) and backwards (to pitch up).
- The *rudder* is positioned on the trailing edge of the vertical stabiliser (or tail) of the aircraft and is used to yaw the aircraft. Yawing controls the direction in which the aircraft is pointing and is controlled by the pilot's rudder pedals. Yaw control is used in a variety of situations. For example, when changing power settings in a single-engine (propeller) aircraft, the pilot makes adjustments to the rudder to counteract the strong torque produced by the propeller. Rudder adjustments are also made (in conjunction with aircraft roll and pitch) when changing heading during flight to produce balanced turns.

The general location of the rudders, elevators, and ailerons are shown in Figure 1-1.

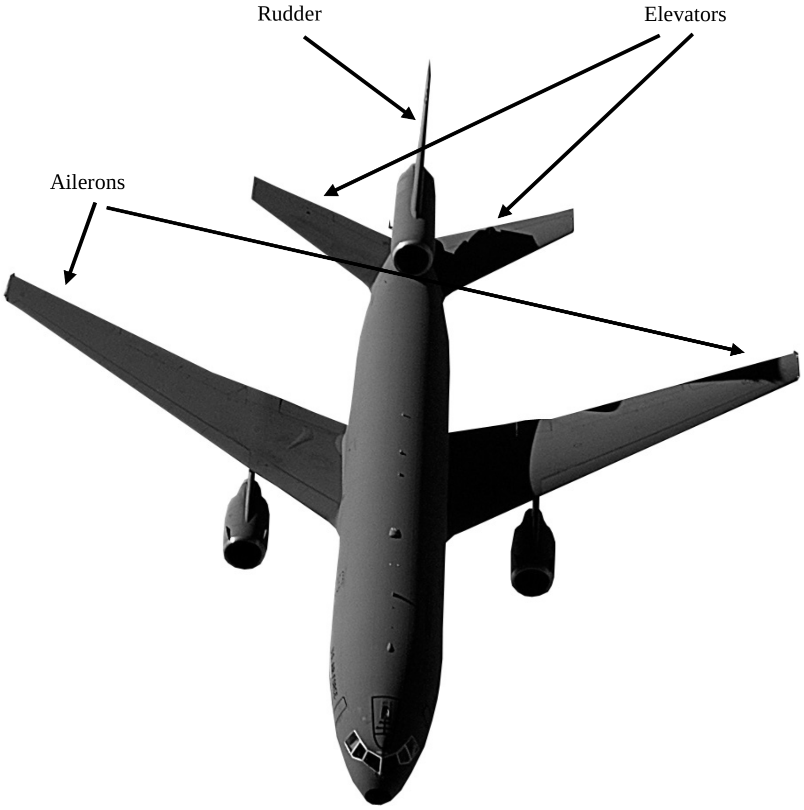

Figure 1-1. KC-10 showing the location of primary flight-controls. (photo courtesy of the United States Air Force).

Secondary flight-controls are used at particular stages of the flight envelope to help the aircraft and aircrew with tasks such as take-off, landing, and low-speed flight. Secondary flight-controls include flaps and slats to alter the aerodynamic performance of the wing, and speed brakes and spoilers to create aerodynamic drag (to slow the aircraft).

The presence and position of secondary flight-controls varies from aircraft to aircraft. The positions of the flaps and spoilers on the Boeing 767 and Airbus A320 aircraft are shown in Figure 1-2.

Sometimes, the role of flight-controls changes with different stages in flight. For example, the F-111 aircraft’s speed brake is also the main undercarriage door. The door is obviously open or closed depending on whether the undercarriage is extended or retracted respectively, but it can also be opened in flight (without extending the main undercarriage) to act as a speed brake.

When talking about primary and secondary flight-controls, we need to be wary of unique approaches taken by each aircraft. For example, the horizontal stabilisers on the F-111 aircraft obviously play the role of horizontal stabilisers but also act as elevators and ailerons. When the aircraft was manufactured, General Dynamics referred to these flight-controls as horizontal stabilators to emphasise their role as flight-controls as shown in Figure 1-3.

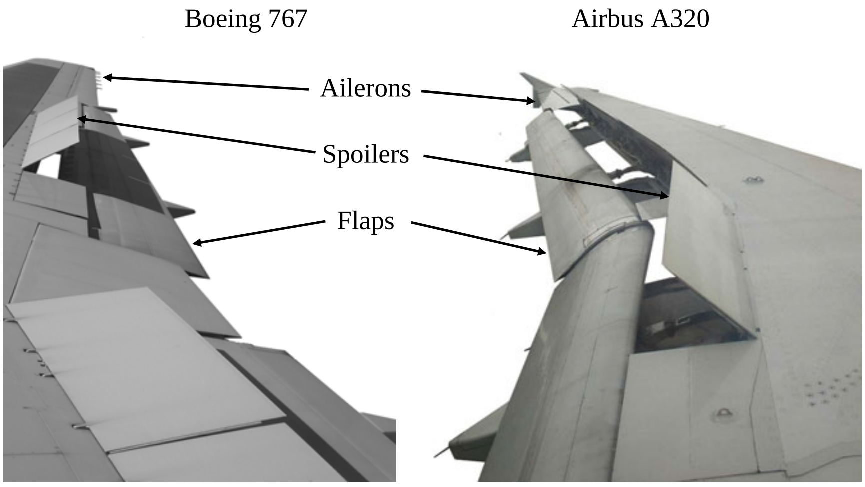

Figure 1-2. B767 and A320 with extended flaps and spoilers. (photos courtesy of Anthony Jackson).

Figure 1-3. Horizontal stabilators on the F-111. (© Royal Australian Air Force).

1.2.4 Fuel System

Most aircraft carry fuel internally but some (especially military aircraft) extend their range with external tanks. Sometimes, these tanks are called drop tanks as they can be jettisoned from the aircraft when the fuel has been used. Fuel is of critical importance to all aircraft as evidenced by the common aviation expression: “*The only time you have too much fuel is when you’re on fire.”*.

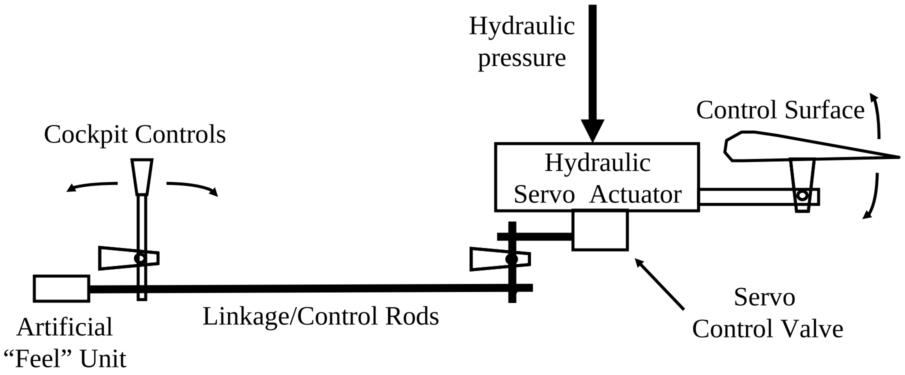

Figure 1-4. Hydraulically assisted flight-control system.

The design of aircraft fuel systems requires careful consideration with respect to pressurisation and ventilation in order to guarantee fuel supply even under severe aerodynamic forces. Fuel also weighs a considerable amount and designers and aircrew need to be careful of the impact fuel has on aircraft weight and centre of gravity (CofG). Accordingly, large aircraft usually have a series of tanks distributed around the aircraft and also have an ability to transfer fuel between tanks to maintain aircraft CofG within normal limits. Some aircraft also have the ability to dump fuel in an emergency.

1.2.5 Hydraulic System

Most moderate to large aircraft have hydraulic systems to power flight controls and undercarriages. In simple terms, once a flight-control surface starts getting reasonably large and the aircraft flies at reasonable speeds, a human no longer has the physical strength to move that surface. Consequently, hydraulic systems are used to provide the additional power to move the surfaces. In this arrangement, the pilot commands a flight-control surface movement by controlling a hydraulic actuator via a control valve. It is the hydraulic system that then moves the surface in accordance with the pilot command.

Figure 1-4 illustrates the likely arrangement in which we can see that the pilot is now isolated from the control surface and therefore loses the "feel" of the aircraft. To compensate, an artificial "feel" unit is often added to the control column so the pilot feels some force against the stick similar to the expected aerodynamic force.

A typical hydraulic system consists of pumps, reservoirs, valves, accumulators, and hydraulic lines.

1.2.6 Environmental Control System

There are many systems onboard aircraft that need to be kept within certain temperatures and humidity ranges. Examples include the human aircrew but also include some airborne computers, communication equipment, and sensors. Although the outside temperature at high altitudes is well below freezing, avionics equipment can generate hundreds of watts of heat and require cooling to prevent overheating. It is also worth remembering that ground temperatures as aircraft land, taxi, and takeoff can be very high indeed. Environmental control systems (ECS) can be thought of as airborne air conditioners responsible for keeping the sensitive aircraft equipment and crew comfortable.

ECS can use a combination of air and liquid cooling to perform the control role. Air cooling can be provided by directing and ducting ram air (air from the outside environment) into given locations within the aircraft or by extracting bleed air from the aircraft engines, passing it through a heat exchanger and then into the required locations. Liquid cooling can also be used via super-cooled liquid such as nitrogen. This type of cooling is often associated with sensitive sensors such as infrared detection systems.

1.2.7 Life-support Systems

Life-support systems are often required on aircraft to provide assistance to aircrew and allow them to operate at their peak. High-performance aircraft may manoeuvre so quickly as to render human occupants unconscious due to the sudden onset of g-force. Rapid changes in direction can cause the blood to drain from aircrew’s heads resulting in a condition called “g-induced lack of consciousness” or *gloc*. In aircraft where this might be a problem, a life-support system may provide a connection for an anti-g suit which is worn by the aircrew. The anti-g suit inflates around the aircrew legs and stomach in an attempt to keep as much blood as possible in the upper torso and head as the aircraft pulls more g-force. As the g-force eases, the suit deflates providing more comfort to the pilot.

Another life-support system is the oxygen system. Oxygen is provided either into the cockpit or through aircrew masks worn during flight. Normally, the oxygen is set to flow in conjunction with normal aircrew breathing but, in emergencies, the oxygen can be set to flow more aggressively and provide a forced supply to aircrew.

Military aircraft have long used ejection systems as a last-ditch life-support system. Ejection systems allow the aircrew to get out of the aircraft extremely quickly as shown in Figure 1-5 where a pilot ejects from his F-16 a fraction of a second before the aircraft crashes.

Ejection systems in particular are very dangerous systems that need to be managed carefully when the aircraft is on the ground or in the air. Aircraft with ejection systems are normally marked like the A-10 Thunderbolt in Figure 1-6 to highlight the danger to people approaching the aircraft.

Other systems that fall under the banner of life support include aircrew restraints and cockpit pressurisation systems.

1.3 AVIONICS HISTORY AND DIRECTION

The history of avionics as we know it today can be traced back to the early 1900s when airborne communications equipment first came into service [1]. The use of barometers to determine altitude started to become common around 1910 (although strictly speaking these instruments were not avionics devices as they did not rely on electrical power). Similarly, from about 1914 onwards gyroscopes were used to provide artificial horizons for aircrew in conjunction with rudimentary flight-control systems. In the 1930s and into World War II, analogue auto-pilots emerged as a way of relieving aircrew fatigue on long flights.

Figure 1-5. A pilot ejects from an F-16 (photo courtesy of the United States Air Force).

Figure 1-6. Ejection system warning markings on an A-10 Thunderbolt (photo courtesy of the United States Air Force).

World War II drove a number of important advances in the avionics field including radio-based navigation aids, airborne radar, and electronic warfare equipment. Ground-controlled approaches (GCA) were also developed during the latter stages of World War II leading to the development of instrument landing systems (ILS) in the 1950s. The 1960s saw the emergence of strap-down inertial sensors including gyroscopes and accelerometers used as the basis for attitude/heading reference systems (A/HRS) and dead-reckoning navigation. During the same period, digital computers started to emerge as a technology that would have far-reaching impacts on the aviation industry. The 1970s were dominated by an explosion in airborne computer technology and the emergence of digital data buses used for transporting computer data from one part of the aircraft to another. Now avionics systems started to resemble a flying local area network (LAN). Full authority digital fly-by-wire (FBW) flight control systems were also pioneered during this era, as were digital auto-pilot systems. Display technologies like helmet-mounted displays (HMDs) and sights and liquid-crystal displays (LCDs) started to become available during the 1980s. The 1990s saw further developments in on-board computers and data networks and aircraft like the F-22 Raptor pioneered a revised avionics architecture known as “integrated architectures”. Further advances in integrated avionics systems continue to this day in aircraft such as the Joint Strike Fighter (JSF).

It is guess-work to suppose what the 21st century will hold for avionics systems, but fully autonomous uninhabited aerial vehicles (UAVs) are being talked about a great deal at the time of writing. Wireless networks building on 1990s data link technology like Link 16 are emerging that are capable of networking hundreds of aircraft together in a virtual flying wide area network (WAN). These WANs are capable of extremely high bandwidths meaning that video and other forms of data can be transmitted securely from one aircraft to another or from one aircraft to many others in real-time. This is forcing a change in the way people think about things like warfare and air traffic management. For example, in the 1980s and 1990s, the focus was very much platform-centric, but a common phrase heard in the late 1990s leading into the 21st century was that we need to become *network-centric* in our thinking.

One thing is for sure, though. Avionics systems will continue to push the performance and capability of aircraft whilst at the same time reducing aircraft acquisition and through-life support costs.

1.4 AVIONICS DRIVERS

There are a number of issues that continue to drive the design and development of avionics systems. A key driver is to relieve aircrew of as much workload as possible. In a civilian context, this allows airlines to operate aircraft with fewer aircrew and reduce costs accordingly. In a military environment, this relieves the pilot of mundane pilotage tasks and releases their attention to more operational imperatives. In short, it allows pilots to spend less time flying the aircraft and more time using it to fight. Another factor that continues to push the design and development of avionics equipment is the increase in the amount of information being generated by systems like sensor systems. This information needs to be processed, stored, displayed, and possibly transmitted; all placing load on the avionics system.

Avionics systems are also part of a bigger picture involving all of the other aircraft systems. From an aircraft perspective, qualities like weight, safety and reliability are key elements in aircraft operations. As electronics technologies develop and mature, we generally see reductions in weight and power consumption but improvements in reliability. Avionics systems should take advantage of these advances and pass the improvements onto the aircraft as a whole. By reducing the weight of our avionics, we create an effective knock-on effect. We reduce the all-up weight of the aircraft via the reduction in avionics weight. This reduces the amount of fuel that needs to be carried which further reduces the weight. Power consumption is another interesting issue. By reducing the amount of power consumed by the avionics, we can reduce the amount of heat generated and therefore the requirement for cooling air (and cooling systems). We also reduce the requirement for electrical power and can then reduce the size and weight of the electrical generation and distribution equipment. Clearly, pushing avionics systems towards lighter and more power-efficient systems produces compounding advantages.

Cost (both of acquisition and through-life support) is also a major driver as commercial and military organisations strive to reduce operating costs. Some “facts and figures” associated with avionics costs illustrate the problem very clearly [2] and are summarised in Figure 1-7.

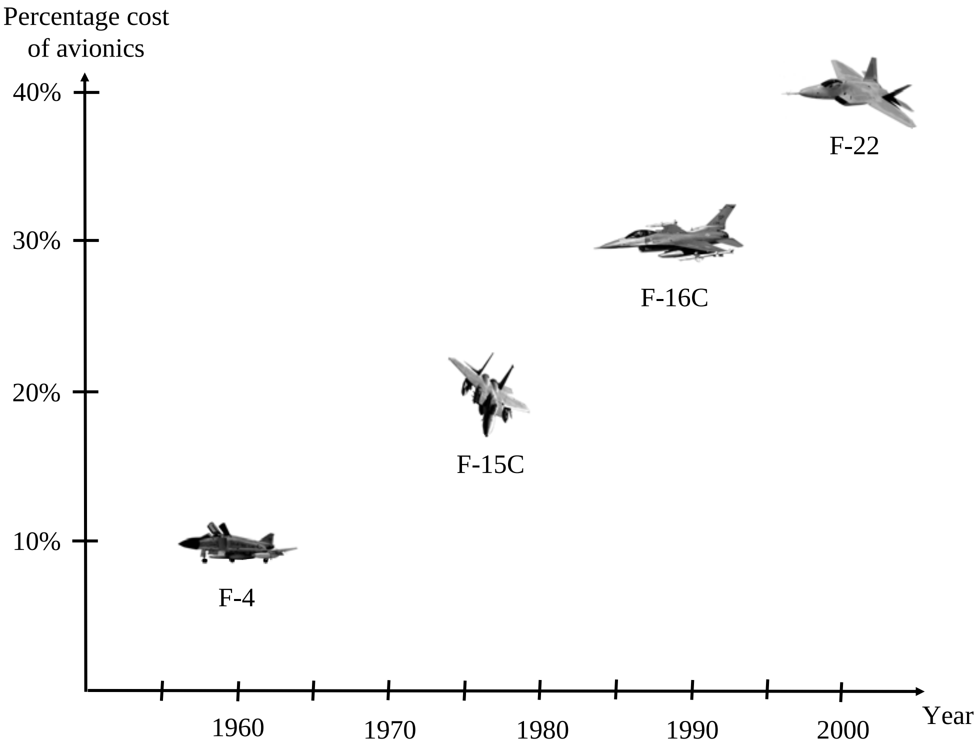

Figure 1-7. Increasing avionics cost as a percentage of fly-away cost of aircraft (photos courtesy of the United States Air Force).

These costs do not include the substantial research, development, test and evaluation (RDT&E) costs of the avionics systems. Up to 50% of the total RDT&E budget for a new aircraft may be spent on avionics hardware and software.

Up until recently, therefore, the costs associated with avionics systems have been spiralling upward. Recently customers of new aircraft have been pushing designers to use more and more commercial-off-the-shelf (COTS) hardware and software in an attempt to strike economies of scale and reduce the overall cost of the aircraft. This effort is sure to continue into the future and is driving the design of the next-generation avionics architectures called *advanced integrated avionics* or *fourth-generation architectures*. First-, second-, and third-generation avionics architectures (as well as fourth-generation architectures) are described and discussed in Chapter 10.

1.5 MAJOR AVIONICS COMPONENTS

We have discussed the need for flight-control systems, navigation systems, and communication systems; these are all critical parts of avionics systems. This section lists and introduces additional avionics components critical to modern avionics systems.

1.5.1 Electrical Systems

Electrical systems are responsible for converting mechanical power (usually provided by the aircraft engines via a gearbox) to electrical power for consumption by the avionics systems. Electrical systems are also responsible for distributing the power around the aircraft in an efficient manner. Other major functions carried out by aircraft electrical systems include conditioning the power so that it is within strict electrical tolerances (for voltage levels and frequencies) and protecting the connected equipment from sudden and unexpected changes or disruptions to the power supply.

Most aircraft have electrical loads that require AC voltages and DC voltages at different levels, so electrical systems need to be able to support these requirements. Aircraft electrical systems consist of equipment such as AC or DC generators, transformers, rectifiers, and inverters to support the electrical requirements of the avionics system

Given the importance of aircraft electrical systems, some standardisation has occurred to provide clarity and consistency across different aircraft types and different manufacturers. Standards of interest for aircraft electrical systems include MIL-STD-704F (Aircraft Electrical Power Characteristics) and RTCA/DO-160 (Environmental Conditions and Test Procedures for Airborne Equipment). These standards dictate voltage levels, frequencies, and test procedures applicable to aircraft electrical systems and the avionics connected to them.

1.5.2 Identification Systems

A part-radar/part-communication system called *secondary surveillance radar* (SSR) is onboard most aircraft flying today. SSR is generally associated with *air traffic control* (ATC) and is used by the controllers to identify aircraft and determine additional information such as altitude. Some aircraft are also fitted with an ability to interrogate other aircraft using SSR to obtain the same information. SSR is the technology upon which the well known military *identification friend or foe* (IFF) is built but, it is currently developing into a much more sophisticated airborne communication and air traffic management tool.

1.5.3 Sensor Systems

Sensors capable of sensing aspects of aircraft operations and environment are critical to the provision of accurate and timely information to aircrew.

The most basic form of data sensed by aircraft is called *air data* and consists of the measurement of different types of atmospheric pressures and temperature. From these basic measurements, knowledge of the earth’s atmosphere and knowledge of basic gas laws of physics, *air-data systems* can calculate a surprising array of information such as altitude, airspeed, rate of climb/descent, outside temperature, and the local speed of sound. Many avionics systems like navigation systems, flight-control systems, and engine-management systems rely on this information for their operation. Aircrew also rely on this information as air data provides inputs to many instruments located in the cockpit.

Aircraft often carry sensors capable of measuring linear accelerations and angular rotation about the aircraft axes. These sensors are called *accelerometers* (linear acceleration) and *gyroscopes* (angular rotation rates and displacements). From acceleration we can derive velocity, and from velocity (and time) we can calculate displacement. It is not surprising, therefore, that these sensors (collectively called *inertial sensors*) are critical to aircraft requiring self-contained, global navigation in all weather conditions. Inertial sensors also provide inputs into systems such as *attitude/heading reference systems* (A/HRS) that allow pilots to fly the aircraft at night or in conditions of very poor visibility.

Air data and inertial sensors are examples of *passive* sensors as they do not transmit energy. Another type of passive sensor often employed on military aircraft are *infrared* (IR) sensors, which are sensitive to contrast between hot and cold areas. These sensors can track targets like exhaust pipes for the purposes of surveillance, tracking, and engagement.

Radar is a popular *active* sensor on aircraft. Radar is an example of an active sensor as it transmits and receives energy to perform its job. Most large aircraft will have at least two types of radar onboard: weather radar and radar altimeters. Miliary aircraft usually have additional radars capable of searching volumes of space for contacts, tracking targets, and supporting weapons systems to engage those targets. Reconnaissance aircraft may also have extremely high-resolution radars called *synthetic aperture radars* (SAR) onboard to build very accurate pictures of their targets. Laser range finders and laser designators are other examples of active sensors normally associated with military aircraft.

1.5.4 Human Machine Interfaces

The human operator is a critical element of aircraft operations. Information and control inputs come from the human into the aircraft, and feedback and additional information flows from the aircraft to the human. The interface between the human and the machine (called the *human machine interface* or HMI) is of critical importance to the efficient flow of information and commands.

Of course, the HMI in aviation is called the cockpit and an example of a modern civilian cockpit is shown in Figure 1-8.

The physiology of the human eye and ear are major drivers in designing cockpits as are the statistical sizes of different parts of the human body that impact on reach and so on. The cockpit is dominated by knobs, dials, instruments, flashing lights, and warning tones, making cockpits appear very complex arrangements. But none of these have a random design. The shapes, sizes and locations of knobs and controls, the colours of the lights, the rate at which the lights flash, the volume and frequency of tones and even the accent used in voice-like warnings are all carefully considered based on human physiology and psychology. For example, the yellow and black colour combination used on the cover of this book is reserved for emergency or extremely critical systems [3] in a cockpit such as ejection systems.

Incorrect design can lead to ineffective information and command transfer at best, and incorrect response and mistakes at worst.

1.5.5 Avionics Architectures and Data Buses

When avionics systems started to appear in the early twentieth century, there was little sharing of data or information between individual systems. Each system was self-contained and relied on the pilot to *fuse* (combine) data from different sources. For example, an aircraft may have a communication system, a navigation system, and a flight-control system but all three systems would operate independently.

Figure 1-8. The “front office” in a Boeing 767 (photo courtesy of Anthony Jackson seated here in the right hand seat).

In fact, these early arrangements are called *independent avionics architectures* for this reason. During the 1970s, data buses emerged as a method for transferring data from one computer to another over some distance. This technology found its way into universities, laboratories, and offices. It also found its way into aircraft where different avionics systems could communicate and share data along a common connection or bus. This freed the onboard computers to concentrate on their own tasks without a need to replicate the functions of other on-board systems. These arrangements are called *federated avionics architectures* and still dominate a large number of aircraft today. The power of computers and the speeds of networks have continued to grow to an extent where a single avionics computer can perform a number of avionics functions concurrently. This has allowed the number of computers on-board aircraft to be reduced and for many avionics functions to be integrated into a small number of high-speed computers. The architectural options resulting from this approach are called *integrated avionics architectures*. The push for integration continues in an attempt to save cost, weight, and power consumption and promote commonality across different aircraft systems. The latest avionics architectures are building on the lessons learnt with integrated avionics architectures and are called *advanced integrated avionics architectures*.

The heart of an avionics system, regardless of architecture, often comprises one or more avionics buses. The most popular avionics bus standard in military aircraft is MIL-STD-1553B, and in civilian aircraft is ARINC 429. Many other bus standards exist or are emerging including MIL-STD-1773, STANAG3910, and ARINC 629. Commercial data bus standards like Ethernet and Firewire are also starting to be considered and used in some of the latest avionics designs.

1.5.6 Avionics Software Considerations

Avionics systems are a good example of a *real-time* system. In this context, real-time means time-constrained rather than instantaneous. For avionics functions to be performed properly, the responses must be numerically correct but also available at the right time. For example, there is little point in a weapons systems determining a firing solution for a missile five seconds after that missile should have been fired. Similar examples exist for flight-control systems, diagnostics, auto-pilots, stability augmentation systems, and navigation. A great deal of avionics functionality is now performed by software running on resource-limited computer hardware. This forces designers to think about the concepts of task scheduling and prioritisation, CPU utilisation, and background processing to ensure the avionics system operates correctly.

1.6 SUMMARY

In this chapter, we have looked at the aircraft as a whole and investigated the wide range of functionality required of modern aircraft. We investigated most of the major systems onboard aircraft so that we could place avionics systems in context. We then looked at a brief history of avionics systems dating from the early 1900s to today before looking at current design drivers and trends. We then completed the chapter by discussing the major components of an avionics system.

The following chapters look at each of these major components individually and describe them in more detail.

1.7 REVISION QUESTIONS

1. List and describe the major systems onboard a modern aircraft.
2. Explain the functionality required from a modern military aircraft.
3. List and describe the major avionics subsystems discussed in this chapter.
4. Explain the trend in avionics costs that is being addressed with current and future avionics developments.
5. List and explain the main design drivers associated with modern avionics systems.

ENDNOTES

1 "A Century of Powered Flight 1903–2003", *IEEE Aerospace and Electronic Systems Magazine*, July 2003, Vol. 18, No. 7.

2 *"Avionics Architecture Definition Appendices Version 1.0"*, Joint Advanced Strike Technology Program, United States Department of Defense, 9 August 1994.

3 MIL-STD-1472F, *Department of Defense Design Criteria Standard—Human Engineering*, United States Department of Defense, Washington, 1999.